Please check our wiki for help on navigating the form.

Horizon 2020

Call: H2020-IBA-SPACE-CHE2-2019

(Copernicus evolution – Research activities in support of a European operational monitoring support capacity for fossil CO2 emissions)

Topic: IBA-SPACE-CHE2-2019

Type of action: CSA

Proposal number: 958927

Proposal acronym: CoCO2

Deadline Id: H2020-IBA-SPACE-CHE2-2019

Table of contents

How to fill in the forms

The administrative forms must be filled in for each proposal using the templates available in the submission system. Some data fields in the administrative forms are pre-filled based on the steps in the submission wizard.

1 - General information

Topic	IBA-SPACE-CHE2-2019	Type of Action	CSA
Call Identifier	H2020-IBA-SPACE-CHE2-2019	Deadline Id	H2020-IBA-SPACE-CHE2-2019

Acronym	CoCO2
Proposal title	Prototype system for a Copernicus CO2 service

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months	*36*
Free keywords	*capacity building, anthropogenic emissions monitoring system*

Abstract

To support EU countries in assessing their progress for reaching their targets agreed in the Paris Agreement, the European Commission has clearly stated that a way to monitor anthropogenic CO2 emissions is needed. Such a capacity would deliver consistent and reliable information to support policy- and decision-making processes. To maintain Europe's independence in this domain, it is imperative that the EU establishes an observation-based operational anthropogenic CO2 emissions Monitoring and Verification Support (MVS) capacity as part of its Copernicus programme.
The CoCO2 Coordination and Support Action is intended as a continuation of the CO2 Human Emissions (CHE) project, led by ECMWF. In the Work Programme, ECMWF is identified as the predefined beneficiary tasked to further develop the prototype system for the foreseen MVS capacity together with partners principally based on the CHE consortium. In addition, ECMWF will continue some of the work initiated in the VERIFY project as well.
The main objective of CoCO2 is to perform R&D activities identified as a need in the CHE project and strongly recommended by the European Commission's CO2 monitoring Task Force. The activities shall sustain the development of a European capacity for monitoring anthropogenic CO2 emissions. The activities will address all components of the system, such as atmospheric transport models, re-analysis, data assimilation techniques, bottom-up estimation, in-situ networks and ancillary measurements needed to address the attribution of CO2 emissions. The aim is to have prototype systems at the required spatial scales ready by the end of the project as input for the foreseen Copernicus CO2 service element.

Remaining characters 293

Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under Horizon 2020 or any other EU programme(s)? ○ Yes ◉ No

Please give the proposal reference or contract number.	
xxxxxx-x	

Declarations

1) The coordinator declares to have the explicit consent of all applicants on their participation and on the content of this proposal.	☒
2) The information contained in this proposal is correct and complete.	☒
3) This proposal complies with ethical principles (including the highest standards of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity — and including, in particular, avoiding fabrication, falsification, plagiarism or other research misconduct).	☒

4) The coordinator confirms:

- to have carried out the self-check of the financial capacity of the organisation on http://ec.europa.eu/research/participants/portal/desktop/en/organisations/lfv.html or to be covered by a financial viability check in an EU project for the last closed financial year. Where the result was "weak" or "insufficient", the coordinator confirms being aware of the measures that may be imposed in accordance with the H2020 Grants Manual (Chapter on Financial capacity check); or	○
- is exempt from the financial capacity check being a public body including international organisations, higher or secondary education establishment or a legal entity, whose viability is guaranteed by a Member State or associated country, as defined in the H2020 Grants Manual (Chapter on Financial capacity check); or	◉
- as sole participant in the proposal is exempt from the financial capacity check.	○

5) The coordinator hereby declares that each applicant has confirmed:

- they are fully eligible in accordance with the criteria set out in the specific call for proposals; and	☒
- they have the financial and operational capacity to carry out the proposed action.	☒
The coordinator is only responsible for the correctness of the information relating to his/her own organisation. Each applicant remains responsible for the correctness of the information related to him and declared above. Where the proposal to be retained for EU funding, the coordinator and each beneficiary applicant will be required to present a formal declaration in this respect.	

According to Article 131 of the Financial Regulation of 25 October 2012 on the financial rules applicable to the general budget of the Union (Official Journal L 298 of 26.10.2012, p. 1) and Article 145 of its Rules of Application (Official Journal L 362, 31.12.2012, p.1) applicants found guilty of misrepresentation may be subject to administrative and financial penalties under certain conditions.

Personal data protection

The assessment of your grant application will involve the collection and processing of personal data (such as your name, address and CV), which will be performed pursuant to Regulation (EC) No 45/2001 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data. Unless indicated otherwise, your replies to the questions in this form and any personal data requested are required to assess your grant application in accordance with the specifications of the call for proposals and will be processed solely for that purpose. Details concerning the purposes and means of the processing of your personal data as well as information on how to exercise your rights are available in the privacy statement. Applicants may lodge a complaint about the processing of their personal data with the European Data Protection Supervisor at any time.

Your personal data may be registered in the Early Detection and Exclusion system of the European Commission (EDES), the new system established by the Commission to reinforce the protection of the Union's financial interests and to ensure sound financial management, in accordance with the provisions of articles 105a and 108 of the revised EU Financial Regulation (FR) (Regulation (EU, EURATOM) 2015/1929 of the European Parliament and of the Council of 28 October 2015 amending Regulation (EU, EURATOM) No 966/2012) and articles 143 - 144 of the corresponding Rules of Application (RAP) (COMMISSION DELEGATED REGULATION (EU) 2015/2462 of 30 October 2015 amending Delegated Regulation (EU) No 1268/2012) for more information see the Privacy statement for the EDES Database.

2 - Participants & contacts

#	Participant Legal Name	Country	Action
1	EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS	UK	
2	EIDGENOSSISCHE MATERIALPRUFUNGS- UND FORSCHUNGSANSTALT	CH	
3	INTEGRATED CARBON OBSERVATION SYSTEM EUROPEAN RESEARCH INFRASTRUCTURECONSORTIUM	FI	
4	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	BE	
5	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	FR	
6	MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV	DE	
7	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	NL	
8	LUNDS UNIVERSITET	SE	
9	STICHTING VU	NL	
10	WAGENINGEN UNIVERSITY	NL	
11	AKADEMIA GORNICZO-HUTNICZA IM. STANISLAWA STASZICA W KRAKOWIE	PL	
12	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	ES	
13	CICERO SENTER KLIMAFORSKNING STIFTELSE	NO	
14	FONDAZIONE CENTRO EURO-MEDITERRANEOSUI CAMBIAMENTI CLIMATICI	IT	
15	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR	
16	DEUTSCHER WETTERDIENST	DE	
17	ECOLE NATIONALE DES PONTS ET CHAUSSEES	FR	
18	ILMATIETEEN LAITOS	FI	
19	IDRYMA TECHNOLOGIAS KAI EREVNAS	EL	
20	KAMINSKI THOMAS HERBERT	DE	
21	MERCATOR OCEAN	FR	

22	METEO-FRANCE	FR	
23	THE UNIVERSITY OF EDINBURGH	United Kingdom	
24	FCIENCIAS.ID - ASSOCIACAO PARA A INVESTIGACAO E DESENVOLVIMENTO DE CIENCIAS	PT	
25	THE CYPRUS INSTITUTE	CY	

2 - Administrative data of participating organisations

PIC	***Legal name***
999916741	*EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS*

Short name: ECMWF

Address of the organisation

Street SHINFIELD PARK

Town READING

Postcode RG2 9AX

Country United Kingdom

Webpage www.ecmwf.int

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....yes

International organisation of European interest .....yes

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Copernicus Services ☐ not applicable

☒ Same as proposing organisation's address

Street: SHINFIELD PARK

Town: READING

Postcode: RG2 9AX

Country: United Kingdom

Department 2

Department name: Research Department ☐ not applicable

☒ Same as proposing organisation's address

Street: SHINFIELD PARK

Town: READING

Postcode: RG2 9AX

Country: United Kingdom

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Richard** Last name: **Engelen**

E-Mail: **richard.engelen@ecmwf.int**

Position in org.: Deputy Director CAMS

Department: Copernicus Services ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: SHINFIELD PARK

Town: READING Post code: RG2 9AX

Country: United Kingdom

Website: www.ecmwf.int

Phone: +44 118 949 9606 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Daniel	THIEMERT	daniel.thiemert@ecmwf.int	+xxx xxxxxxxxx
Gianpaolo	Balsamo	gianpaolo.balsamo@ecmwf.int	+xxx xxxxxxxxx
Ben	Brown	ben.brown@ecmwf.int	+xxx xxxxxxxxx

PIC	***Legal name***
999907138	*EIDGENOSSISCHE MATERIALPRUFUNGS- UND FORSCHUNGSANSTALT*

Short name: EMPA

Address of the organisation

Street UEBERLANDSTRASSE 129

Town DUBENDORF

Postcode 8600

Country Switzerland

Webpage www.empa.ch

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....01/01/1900 - no

SME self-assessment .....01/01/1900 - no

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Laboratory for Air Pollution / Environmental Technology ☐ not applicable

☒ Same as proposing organisation's address

Street: UEBERLANDSTRASSE 129

Town: DUBENDORF

Postcode: 8600

Country: Switzerland

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Dominik** Last name: **Brunner**

E-Mail: **dominik.brunner@empa.ch**

Position in org.: Group leader

Department: Laboratory for Air Pollution/Environmental Technology ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: UEBERLANDSTRASSE 129

Town: DUBENDORF Post code: 8600

Country: Switzerland

Website: https://www.empa.ch/web/s503/modelling-remote-sensing

Phone: +41 58 765 49 44 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Nikola	Tatalovic	nikola.tatalovic@empa.ch	+xxx xxxxxxxxx

PIC	***Legal name***
922983713	*INTEGRATED CARBON OBSERVATION SYSTEM EUROPEAN RESEARCH INFRASTRUCTURECO*

Short name: ICOS ERIC

Address of the organisation

Street ERIK PALMENIN AUKIO 1

Town HELSINKI

Postcode 00560

Country Finland

Webpage www.icos-ri.eu

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: HEAD OFFICE ☐ not applicable

☒ Same as proposing organisation's address

Street: ERIK PALMENIN AUKIO 1

Town: HELSINKI

Postcode: 00560

Country: Finland

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Werner** Last name: **Kutsch**

E-Mail: **werner.kutsch@icos-ri.eu**

Position in org.: DIRECTOR GENERAL

Department: HEAD OFFICE ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: ERIK PALMENIN AUKIO 1

Town: HELSINKI Post code: 00560

Country: Finland

Website: https://icos-ri.eu

Phone: +358504484598 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
LEYSAN	KARIMOVA	leysan.karimova@icos-ri.eu	+xxx xxxxxxxxx
ANNE	MALM	anne.malm@icos-ri.eu	+xxx xxxxxxxxx

PIC	***Legal name***
999992304	*JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION*

Short name: JRC

Address of the organisation

Street Rue de la Loi 200

Town BRUSSELS

Postcode 1049

Country Belgium

Webpage https://ec.europa.eu/jrc

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....21/08/2008 - no

SME self-assessment ..... unknown

SME validation sme.....21/08/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Directorate of Sustainable Resources ☐ not applicable

☒ Same as proposing organisation's address

Street: Rue de la Loi 200

Town: BRUSSELS

Postcode: 1049

Country: Belgium

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: ○ Male ◉ Female

First name: **Greet** Last name: **Janssens-Maenhout**

E-Mail: **greet.maenhout@ec.europa.eu**

Position in org.: Deputy Head of Unit, Scientific Officer

Department: irectorate of Sustainable Resources, Unit for Knowledge Management of Sus ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Via Enrico Fermi 2749, TP 123

Town: ISPRA Post code: 21027

Country: Italy

Website: ec.europa.eu/jrc/en/science-area/environment-and-climate-change

Phone: +39 0332 78 5831 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Vincent	Van Rompaye	vincent.van-rompaye@ec.europa.eu	+xxx xxxxxxxxx

PIC	***Legal name***
999992401	*COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES*

Short name: CEA

Address of the organisation

Street RUE LEBLANC 25

Town PARIS 15

Postcode 75015

Country France

Webpage www.cea.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....17/05/2019 - no

SME self-assessment ..... unknown

SME validation sme.....01/10/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: LSCE ☐ not applicable

☐ Same as proposing organisation's address

Street: L'Orme des Merisiers, Bat 714, Point cou

Town: Gif-sur-Yvette

Postcode: 91191

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Frédéric** Last name: **Chevallier**

E-Mail: **frederic.chevallier@lsce.ipsl.fr**

Position in org.: team leader

Department: LSCE ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: L'Orme des Merisiers, Bat 714, Point courier 129

Town: Gif-sur-Yvette Post code: 91191

Country: France

Website: https://www.lsce.ipsl.fr/Pisp/frederic.chevallier/

Phone: +33 1 69 08 77 29 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Isabelle	Rault	isabelle.rault@cea.fr	+xxx xxxxxxxxx

PIC	***Legal name***
999990267	*MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV*

Short name: MPG

Address of the organisation

Street HOFGARTENSTRASSE 8

Town MUENCHEN

Postcode 80539

Country Germany

Webpage www.mpg.de

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....05/04/2016 - no

SME self-assessment .....05/04/2016 - no

SME validation sme.....31/10/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Max Planck Institute for Biogeochemistry ☐ not applicable

☐ Same as proposing organisation's address

Street: Hans-Knöll-Str. 10

Town: Jena

Postcode: 07745

Country: Germany

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: ○ Male ◉ Female

First name: **Julia** Last name: **Marshall**

E-Mail: **marshall@bgc-jena.mpg.de**

Position in org.: group leader

Department: Biogeochemical Signals ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Hans-Knöll-Str. 10

Town: Jena Post code: 07745

Country: Germany

Website: bgc-jena.mpg.de

Phone: +49 3641 576383 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Katharina	Witt	kwitt@bgc-jena.mpg.de	+xxx xxxxxxxxx

PIC	***Legal name***
999988909	*NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK*

Short name: TNO

Address of the organisation

Street ANNA VAN BUERENPLEIN 1

Town DEN HAAG

Postcode 2595 DA

Country Netherlands

Webpage www.tno.nl

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....30/09/2008 - no

SME self-assessment ..... unknown

SME validation sme.....30/09/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Climate Air & Sustainability ☐ not applicable

☐ Same as proposing organisation's address

Street: Princetonlaan 6

Town: Utrecht

Postcode: 3484CB

Country: Netherlands

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Hugo** Last name: **Denier van der Gon**

E-Mail: **hugo.deniervandergon@tno.nl**

Position in org.: Senior scientist

Department: Climate Air & Sustainability ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Princetonlaan 6

Town: Utrecht Post code: 3484CB

Country: Netherlands

Website: www.tno.nl

Phone: +xxx xxxxxxxxx Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Dick	Heslinga	dick.heslinga@tno.nl	+xxx xxxxxxxxx

PIC	***Legal name***
999901318	*LUNDS UNIVERSITET*

Short name: ULUND

Address of the organisation

Street Paradisgatan 5c

Town LUND

Postcode 22100

Country Sweden

Webpage www.lu.se

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Department of Physical Geography and Ecosystem Science ☐ not applicable

☐ Same as proposing organisation's address

Street: Sölvegatan 12

Town: Lund

Postcode: 22362

Country: Sweden

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Marko** Last name: **Scholze**

E-Mail: **marko.scholze@nateko.lu.se**

Position in org.: Senior Lecturer

Department: Department of Physical Geography and Ecosystem Science ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Sölvegatan 12

Town: Lund Post code: 22362

Country: Sweden

Website: http://www.nateko.lu.se/?lang=2

Phone: +46 46 222 4082 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Irma	Habermann	irma.habermann@cgbkansli.lu.se	+xxx xxxxxxxxx

PIC	***Legal name***
954530344	*STICHTING VU*

Short name: VUA

Address of the organisation

Street DE BOELELAAN 1105

Town AMSTERDAM

Postcode 1081 HV

Country Netherlands

Webpage www.vu.nl

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....03/03/2016 - no

SME self-assessment ..... unknown

SME validation sme.....31/12/2011 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Department of Earth Sciences ☐ not applicable

☐ Same as proposing organisation's address

Street: De Boelelaan 1085

Town: Amsterdam

Postcode: 1081 HV

Country: Netherlands

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Sander** Last name: **Houweling**

E-Mail: **s.houweling@vu.nl**

Position in org.: professor

Department: Department of Earth Sciences ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: De Boelelaan 1085

Town: Amsterdam Post code: 1081 HV

Country: Netherlands

Website: https://research.vu.nl/en/persons/sander-houweling

Phone: +31205983687 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Paul	Bijlsma	p.j.bijlsma@vu.nl	+xxx xxxxxxxxx
Han	Dolman	han.dolman@vu.nl	+xxx xxxxxxxxx

PIC	***Legal name***
999981634	*WAGENINGEN UNIVERSITY*

Short name: WU

Address of the organisation

Street DROEVENDAALSESTEEG 4

Town WAGENINGEN

Postcode 6708 PB

Country Netherlands

Webpage http://www.wur.nl/

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....no

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....12/04/2016 - no

SME self-assessment .....12/04/2016 - no

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Environmental Sciences Group, Dept of Meteorology and Air Quality ☐ not applicable

☐ Same as proposing organisation's address

Street: Droevendaalsesteeg 3

Town: Wageningen

Postcode: 6708-PB

Country: Netherlands

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Wouter** Last name: **Peters**

E-Mail: **wouter.peters@wur.nl**

Position in org.: Personal Professor Carbon Cycle and Atmospheric Composition

Department: Environmental Sciences Group, Dept of Meteorology and Air Quality ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Droevendaalsesteeg 3

Town: Wageningen Post code: 6708PB

Country: Netherlands

Website: https://www.wur.nl/en/Research-Results/Chair-groups/Environmental

Phone: +31 317 486654 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Marina	Kuiper-Agadjanian	marine.kuiper-agadjanian@wur.nl	+xxx xxxxxxxxx

PIC	***Legal name***
999844573	*AKADEMIA GORNICZO-HUTNICZA IM. STANISLAWA STASZICA W KRAKOWIE*

Short name: AGH

Address of the organisation

Street AL ADAMA MICKIEWICZA 30

Town KRAKOW

Postcode 30-059

Country Poland

Webpage http://www.agh.edu.pl/en

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....15/12/1975 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Environmental Physics Group ☐ not applicable

☒ Same as proposing organisation's address

Street: AL ADAMA MICKIEWICZA 30

Town: KRAKOW

Postcode: 30-059

Country: Poland

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Miroslaw** Last name: **Zimnoch**

E-Mail: **zimnoch@agh.edu.pl**

Position in org.: Associate Professor

Department: Environmental Physics Group / Department of Applied Nuclear Physics / Fac ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: AL ADAMA MICKIEWICZA 30

Town: KRAKOW Post code: 30-059

Country: Poland

Website: aurora.fis.agh.edu.pl/~zimnoch

Phone: +48126173046 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Monika	Zdybał-Michalik	zdybal-michalik@fis.agh.edu.pl	+xxx xxxxxxxxx

PIC	***Legal name***
999655520	*BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION*

Short name: BSC

Address of the organisation

Street Calle Jordi Girona 31

Town BARCELONA

Postcode 08034

Country Spain

Webpage www.bsc.es

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....01/03/2005 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Earth Science department ☐ not applicable

☐ Same as proposing organisation's address

Street: NEXUS II building, Jordi Girona 29

Town: Barcelona

Postcode: 08034

Country: Spain

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Marc** Last name: **Guevara Viladrell**

E-Mail: **marc.guevara@bsc.es**

Position in org.: Postdoctoral Researcher

Department: Earth Science department ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: NEXUS II building, Jordi Girona 29

Town: Barcelona Post code: 08034

Country: Spain

Website: https://orcid.org/0000-0001-9727-8583

Phone: +34 934137612 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Mar	Rodríguez Rodrigo	mar.rodriguez@bsc.es	*+34934137566*

PIC	***Legal name***
998157161	*CICERO SENTER KLIMAFORSKNING STIFTELSE*

Short name: CICERO

Address of the organisation

Street Gaustadallèen 21

Town Oslo

Postcode 0349

Country Norway

Webpage www.cicero.oslo.no

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....29/05/2009 - no

SME self-assessment ..... unknown

SME validation sme.....29/05/2009 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: CICERO Center for International Climate Research ☐ not applicable

☒ Same as proposing organisation's address

Street: Gaustadallèen 21

Town: Oslo

Postcode: 0349

Country: Norway

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Glen** Last name: **Peters**

E-Mail: **glen.peters@cicero.oslo.no**

Position in org.: Research Director

Department: Climate Mitigation Group ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: Gaustadallèen 21

Town: Oslo Post code: 0349

Country: Norway

Website: http://www.cicero.uio.no/en/employee/30/glen-peters

Phone: +47 22 00 47 00 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Elise	Prytz Hafskjold	elise.hafskjold@cicero.oslo.no	+xxx xxxxxxxxx
Sgirid	Rian Song	sigrid.rian.song@cicero.oslo.no	+xxx xxxxxxxxx

PIC	***Legal name***
999419422	*FONDAZIONE CENTRO EURO-MEDITERRANEOSUI CAMBIAMENTI CLIMATICI*

Short name: CMCC

Address of the organisation

Street VIA A IMPERATORE 16

Town LECCE

Postcode 73100

Country Italy

Webpage www.cmcc.it

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....11/05/2005 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: IAFES - Impacts on Agriculture, Forests and Ecosystem Services ☐ not applicable

☐ Same as proposing organisation's address

Street: Viale Trieste 127

Town: Viterbo

Postcode: 01100

Country: Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: ○ Male ◉ Female

First name: **Lucia** Last name: **Perugini**

E-Mail: **lucia.perugini@cmcc.it**

Position in org.: Senior researcher

Department: IAFES - Impacts on Agriculture, Forests and Ecosystem Services ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Viale Trieste 127

Town: Viterbo Post code: 01100

Country: Italy

Website: https://www.cmcc.it/it/people/perugini-lucia

Phone: +39 0761 309587 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Giulia	Galluccio	giulia.galluccio@cmcc.it	*+390283623433*

PIC	***Legal name***
999997930	*CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS*

Short name: CNRS

Address of the organisation

Street RUE MICHEL ANGE 3

Town PARIS

Postcode 75794

Country France

Webpage www.cnrs.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....18/11/2008 - no

SME self-assessment ..... unknown

SME validation sme.....18/11/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Laboratoire d'Aérologie ☐ not applicable

☐ Same as proposing organisation's address

Street: 14 Avenue Edouard Belin

Town: Toulouse

Postcode: 31400

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title Dr. Sex ○ Male ◉ Female

First name **Claire** Last name **Granier**

E-Mail **claire.granier@aero.obs-mip.fr**

Position in org. Directrice de Recherche (Senior Scientist)

Department Laboratoire d'Aérologie ☐ Same as organisation name

☐ Same as proposing organisation's address

Street 14 Avenue Edouard Belin

Town Toulouse Post code 31400

Country France

Website http://www3.obs-mip.fr/la

Phone +33 5 61 33 27 10 Phone 2 +xxx xxxxxxxxx Fax +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Christophe	GIRAUD	fp7@dr14.cnrs.fr	+xxx xxxxxxxxx

PIC	***Legal name***
998059094	*DEUTSCHER WETTERDIENST*

Short name: DWD

Address of the organisation

Street FRANKFURTER STRASSE 135

Town OFFENBACH AM MAIN

Postcode 63067

Country Germany

Webpage http://www.dwd.de

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....no

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....18/02/2009 - no

SME self-assessment ..... unknown

SME validation sme.....18/02/2009 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Greenhouse Gas Emission Verification ☐ not applicable

☒ Same as proposing organisation's address

Street: FRANKFURTER STRASSE 135

Town: OFFENBACH AM MAIN

Postcode: 63067

Country: Germany

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: ○ Male ◉ Female

First name: **Andrea** Last name: **Kaiser-Weiss**

E-Mail: **andrea.kaiser-weiss@dwd.de**

Position in org.: Head of department

Department: Greenhouse Gas Emission Verification ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: FRANKFURTER STRASSE 135

Town: OFFENBACH AM MAIN Post code: 63067

Country: Germany

Website: https://www.dwd.de/EN/climate_environment/climateenvironment_node

Phone: +49 69 8062 - 2426 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Nicole	Riß	nicole.riss@dwd.de	+xxx xxxxxxxxx

PIC	***Legal name***
997637629	*ECOLE NATIONALE DES PONTS ET CHAUSSEES*

Short name: ENPC

Address of the organisation

Street AVENUE BLAISE PASCAL-CITE DESCARTES

Town MARNE LA VALLEE CEDEX 2

Postcode 77455

Country France

Webpage http://www.enpc.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....unknown

International organisation of European interest .....unknown

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: CEREA ☐ not applicable

☐ Same as proposing organisation's address

Street: 6-8 avenue Blaise Pascal – Cité Descarte

Town: Marne-La-Vallée

Postcode: 77455

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Marc** Last name: **Bocquet**

E-Mail: **marc.bocquet@enpc.fr**

Position in org.: Senior researcher/Deputy director of CEREA

Department: CEREA ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: 6-8 avenue Blaise Pascal – Cité Descarte – Champs-sur-Marne

Town: Marne-La-Vallée Post code: 77455

Country: France

Website: http://cerea.enpc.fr/HomePages/bocquet/

Phone: +33 1 64 15 21 51 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Charlotte	Huber	charlotte.huber@enpc.fr	*+33 1 64 15 38 65*

PIC	***Legal name***
999591306	*ILMATIETEEN LAITOS*

Short name: FMI

Address of the organisation

Street Erik Palmenin aukio 1

Town HELSINKI

Postcode 00560

Country Finland

Webpage www.fmi.fi

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status..... unknown

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Earth Observation Research, Climate System Research ☐ not applicable

☒ Same as proposing organisation's address

Street: Erik Palmenin aukio 1

Town: HELSINKI

Postcode: 00560

Country: Finland

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof.

Sex: ○ Male ◉ Female

First name: **Johanna** Last name: **Tamminen**

E-Mail: **johanna.tamminen@fmi.fi**

Position in org.: Head of Earth Observation Research Unit

Department: Earth Observation Research, Space and Earth Observation Centre ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: Erik Palmenin aukio 1

Town: HELSINKI Post code: 00560

Country: Finland

Website: www.fmi.fi

Phone: +358 40 737 8733 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Kirsi	Virolainen	kirsi.virolainen@fmi.fi	+xxx xxxxxxxxx

PIC	***Legal name***
999995893	*IDRYMA TECHNOLOGIAS KAI EREVNAS*

Short name: FORTH

Address of the organisation

Street N PLASTIRA STR 100

Town IRAKLEIO

Postcode 70013

Country Greece

Webpage www.forth.gr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....11/05/2016 - no

SME self-assessment ..... unknown

SME validation sme.....25/09/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Institute of Applied and Computational Mathematics ☐ not applicable

☒ Same as proposing organisation's address

Street: N PLASTIRA STR 100

Town: IRAKLEIO

Postcode: 70013

Country: Greece

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: (•) Male ( ) Female

First name: **Nektarios** Last name: **Chrysoulakis**

E-Mail: **zedd2@iacm.forth.gr**

Position in org.: Director of Research

Department: Institute of Applied and Computational Mathematics ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: N PLASTIRA STR 100

Town: IRAKLEIO Post code: 70013

Country: Greece

Website: http://rslab.gr

Phone: +306932929775 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Antonia	Mpikaki	mpikakh@admin.forth.gr	+xxx xxxxxxxxx
Stavros	Stagakis	sstagaki@iacm.forth.gr	+xxx xxxxxxxxx
Zina	Mitraka	mitraka@iacm.forth.gr	+xxx xxxxxxxxx

PIC	***Legal name***
924150332	*KAMINSKI THOMAS HERBERT*

Short name: iLab

Address of the organisation

Street MARTINISTRASSE 21

Town HAMBURG

Postcode 20251

Country Germany

Webpage

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....no

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....no

Legal person .....no

Industry (private for profit).....yes

Enterprise Data

SME self-declared status.....05/01/2015 - yes

SME self-assessment .....05/01/2015 - yes

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

No department involved

Department name: *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street: *Please enter street name and number.*

Town: *Please enter the name of the town.*

Postcode: *Area code.*

Country: *Please select a country*

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Thomas**

Last name: **Kaminski**

E-Mail: **thomas.kaminski@inversion-lab.com**

Position in org.: sole Owner/Director

Department: KAMINSKI THOMAS HERBERT ☒ Same as organisation name

☐ Same as proposing organisation's address

Street: Tewessteg 4

Town: Hamburg

Post code: 20249

Country: Germany

Website: http://Inversion-Lab.EU

Phone: +49 40 46773651

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

PIC	***Legal name***
974300496	*MERCATOR OCEAN*

Short name: MOi

Address of the organisation

Street RUE HERMES 8-10 PARC TECHNOLOGIQUE

Town RAMONVILLE SAINT AGNE

Postcode 31520

Country France

Webpage www.mercator-ocean.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....04/06/2010 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Operational Oceanography Department ☐ not applicable

☒ Same as proposing organisation's address

Street: RUE HERMES 8-10 PARC TECHNOLOGIQUE DU CA

Town: RAMONVILLE SAINT AGNE

Postcode: 31520

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: ○ Male ◉ Female

First name: **Coralie** Last name: **Perruche**

E-Mail: **coralie.perruche@mercator-ocean.fr**

Position in org.: Research engineer

Department: Operational Oceanography Department ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: RUE HERMES 8-10 PARC TECHNOLOGIQUE DU CANAL

Town: RAMONVILLE SAINT AGNE Post code: 31520

Country: France

Website: http://www.mercator-ocean.fr

Phone: +33 5 61 39 38 72 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Laura	Cherdel	laura.cherdel@mercator-ocean.fr	+xxx xxxxxxxxx

PIC	***Legal name***
999578890	*METEO-FRANCE*

Short name: MF

Address of the organisation

Street AVENUE DE PARIS 73

Town SAINT MANDE CEDEX

Postcode 94165

Country France

Webpage www.meteo.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....18/06/1993 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: CNRM, GMME ☐ not applicable

☐ Same as proposing organisation's address

Street: avenue Gaspard Coriolis

Town: Toulouse

Postcode: 31057

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Jean-Christophe** Last name: **Calvet**

E-Mail: **jean-christophe.calvet@meteo.fr**

Position in org.: researcher

Department: CNRM, GMME ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: avenue Gaspard Coriolis

Town: Toulouse Post code: 31057

Country: France

Website: https://www.umr-cnrm.fr/

Phone: +33 561079341 Phone 2: *+xxx xxxxxxxxx* Fax: *+xxx xxxxxxxxx*

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Elisabeth	Gérard	ppr@meteo.fr	*+33 5 61079838*

PIC	***Legal name***
999974941	*THE UNIVERSITY OF EDINBURGH*

Short name: UEDIN

Address of the organisation

Street OLD COLLEGE, SOUTH BRIDGE

Town EDINBURGH

Postcode EH8 9YL

Country United Kingdom

Webpage www.ed.ac.uk

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....yes

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....12/12/2008 - no

SME self-assessment ..... unknown

SME validation sme.....12/12/2008 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: School of GeoSciences ☐ not applicable

☐ Same as proposing organisation's address

Street: Alexander Crum Brown Road

Town: Edinburgh

Postcode: EH9 3FF

Country: United Kingdom

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Paul** Last name: **Palmer**

E-Mail: **paul.palmer@ed.ac.uk**

Position in org.: Professor

Department: School of GeoSciences ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Alexander Crum Brown Road

Town: Edinburgh Post code: EH9 3FF

Country: United Kingdom

Website: http://www.palmergroup.org/

Phone: 0044 131 650 7724 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Europe	ERO	europe@eri.ed.ac.uk	+xxx xxxxxxxxx

PIC	***Legal name***
915056194	*FCIENCIAS.ID - ASSOCIACAO PARA A INVESTIGACAO E DESENVOLVIMENTO DE CIENCIAS*

Short name: FC.ID

Address of the organisation

Street CAMPO GRANDE, EDIFICIO C1, PISO 3

Town LISBON

Postcode 1749 016

Country Portugal

Webpage http://www.fciencias-id.pt

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....no

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....10/01/2017 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: Instituto Dom Luiz ☐ not applicable

☐ Same as proposing organisation's address

Street: Campo Grande Edifício C1, Piso 1

Town: Lisbon

Postcode: 1749-016

Country: Portugal

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Emanuel**

Last name: **Dutra**

E-Mail: **endutra@fc.ul.pt**

Position in org.: Researcher

Department: Instituto Dom Luiz ☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Campo Grande Edifício C8, Piso 2

Town: Lisbon Post code: 1749-016

Country: Portugal

Website: http://idl.campus.ciencias.ulisboa.pt/idlmember/emanuel-dutra/

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Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Carla	Marques	ccmarques@fciencias-id.pt	*+351 217500448*

PIC	***Legal name***
965934440	*THE CYPRUS INSTITUTE*

Short name: CyI

Address of the organisation

Street CONSTANTINOU KAVAFI 20

Town NICOSIA

Postcode 2121

Country Cyprus

Webpage www.cyi.ac.cy

Legal Status of your organisation

Research and Innovation legal statuses

Public body .....no

Non-profit .....yes

International organisation .....no

International organisation of European interest .....no

Secondary or Higher education establishment .....yes

Research organisation .....yes

Legal person .....yes

Industry (private for profit).....no

Enterprise Data

SME self-declared status.....12/10/2005 - no

SME self-assessment ..... unknown

SME validation sme..... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Department(s) carrying out the proposed work

Department 1

Department name: CARE-C ☐ not applicable

☒ Same as proposing organisation's address

Street: CONSTANTINOU KAVAFI 20

Town: NICOSIA

Postcode: 2121

Country: Cyprus

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

The name and e-mail of contact persons are read-only in the administrative form, only additional details can be edited here. To give access rights and basic contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Prof. Sex: (•) Male ( ) Female

First name: **Jean** Last name: **Sciare**

E-Mail: **j.sciare@cyi.ac.cy**

Position in org.: Professor; Director of CARE-C

Department: CARE-C Environmental Observations Department ☐ Same as organisation name

☒ Same as proposing organisation's address

Street: CONSTANTINOU KAVAFI 20

Town: NICOSIA Post code: 2121

Country: Cyprus

Website: www.cyi.ac.cy

Phone: +357 22 208675 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Sotia	Nicolaou	s.nicolaou@cyi.ac.cy	+357-22 397552

3 - Budget

No	Participant	Country	(A) Direct personnel costs/€	(B) Other direct costs/€	(C) Direct costs of sub-contracting/€	(D) Direct costs of providing financial support to third parties/€	(E) Costs of inkind contributions not used on the beneficiary's premises/€	(F) Indirect Costs / € (=0.25(A+B-E))	(G) Special unit costs covering direct & indirect costs / €	(H) Total estimated eligible costs / € (=A+B+C+D+F+G)	(I) Reimburse-ment rate (%)	(J) Max.EU Contribution / € (=H*I)	(K) Requested EU Contribution/ €
1	European Centre For Medium-range	UK	1901775	222000	15000	0	0	530943,75	0	2669718,75	100	2669718,75	2669718,75
2	Eidgenossische Materialprufun	CH	294000	10000	0	0	0	76000,00	0	380000,00	100	380000,00	380000,00
3	Integrated Carbon Observation	FI	284000	20000	0	0	0	76000,00	0	380000,00	100	380000,00	380000,00
4	Jrc -Joint Research Centre-	BE	81000	3000	0	0	0	21000,00	0	105000,00	100	105000,00	105000,00
5	Commissariat A L Energie Atomique Et	FR	456000	16000	0	0	0	118000,00	0	590000,00	100	590000,00	590000,00
6	Max-planck-gesellschaft Zur Forderung	DE	302000	10000	0	0	0	78000,00	0	390000,00	100	390000,00	390000,00
7	Nederlandse Organisatie Voor	NL	294000	10000	0	0	0	76000,00	0	380000,00	100	380000,00	380000,00
8	Lunds Universitet	SE	270000	10000	0	0	0	70000,00	0	350000,00	100	350000,00	350000,00
9	Stichting Vu	NL	326000	10000	0	0	0	84000,00	0	420000,00	100	420000,00	420000,00
10	Wageningen University	NL	310000	10000	0	0	0	80000,00	0	400000,00	100	400000,00	400000,00

11	Akademia Gorniczo-hutnicza Im.	PL	77500	62500	0	0	0	35000,00	0	175000,00	100	175000,00	175000,00
12	Barcelona Supercomputing Center -	ES	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
13	Cicero Senter Klimaforskning Stiftelse	NO	160500	7500	0	0	0	42000,00	0	210000,00	100	210000,00	210000,00
14	Fondazione Centro Euro-mediterraneos	IT	160500	7500	0	0	0	42000,00	0	210000,00	100	210000,00	210000,00
15	Centre National De La Recherche	FR	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
16	Deutscher Wetterdienst	DE	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
17	Ecole Nationale Des Ponts Et	FR	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
18	Ilmatieteen Laitos	FI	160500	7500	0	0	0	42000,00	0	210000,00	100	210000,00	210000,00
19	Idryma Technologias Kai Erevnas	EL	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
20	Kaminski Thomas Herbert	DE	168500	7500	0	0	0	44000,00	0	220000,00	100	220000,00	220000,00
21	Mercator Ocean	FR	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
22	Meteo-france	FR	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
23	The University Of Edinburgh	UK	150500	17500	0	0	0	42000,00	0	210000,00	100	210000,00	210000,00
24	Fciencias.id - Associacao Para A	PT	152500	7500	0	0	0	40000,00	0	200000,00	100	200000,00	200000,00
25	The Cyprus Institute	CY	72500	7500	0	0	0	20000,00	0	100000,00	100	100000,00	100000,00

	Total	6689275	498500	15000	0	0	1796943,75	0	8999718,75		8999718,75	8999718,75

4 - Ethics

1. HUMAN EMBRYOS/FOETUSES		Page
Does your research involve Human Embryonic Stem Cells (hESCs)?	○ Yes ◉ No	
Does your research involve the use of human embryos?	○ Yes ◉ No	
Does your research involve the use of human foetal tissues / cells?	○ Yes ◉ No	
2. HUMANS		**Page**
Does your research involve human participants?	○ Yes ◉ No	
Does your research involve physical interventions on the study participants?	○ Yes ◉ No	
3. HUMAN CELLS / TISSUES		**Page**
Does your research involve human cells or tissues (other than from Human Embryos/ Foetuses, i.e. section 1)?	○ Yes ◉ No	
4. PERSONAL DATA		**Page**
Does your research involve personal data collection and/or processing?	○ Yes ◉ No	
Does your research involve further processing of previously collected personal data (secondary use)?	○ Yes ◉ No	
5. ANIMALS		**Page**
Does your research involve animals?	○ Yes ◉ No	
6. THIRD COUNTRIES		**Page**
In case non-EU countries are involved, do the research related activities undertaken in these countries raise potential ethics issues?	○ Yes ◉ No	
Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	○ Yes ◉ No	
Do you plan to import any material - including personal data - from non-EU countries into the EU?	○ Yes ◉ No	
Do you plan to export any material - including personal data - from the EU to non-EU countries?	○ Yes ◉ No	
In case your research involves low and/or lower middle income countries, are any benefits-sharing actions planned?	○ Yes ◉ No	
Could the situation in the country put the individuals taking part in the research at risk?	○ Yes ◉ No	

7. ENVIRONMENT & HEALTH and SAFETY		Page
Does your research involve the use of elements that may cause harm to the environment, to animals or plants?	○ Yes ◉ No	
Does your research deal with endangered fauna and/or flora and/or protected areas?	○ Yes ◉ No	
Does your research involve the use of elements that may cause harm to humans, including research staff?	○ Yes ◉ No	
8. DUAL USE		**Page**
Does your research involve dual-use items in the sense of Regulation 428/2009, or other items for which an authorisation is required?	○ Yes ◉ No	
9. EXCLUSIVE FOCUS ON CIVIL APPLICATIONS		**Page**
Could your research raise concerns regarding the exclusive focus on civil applications?	○ Yes ◉ No	
10. MISUSE		**Page**
Does your research have the potential for misuse of research results?	○ Yes ◉ No	
11. OTHER ETHICS ISSUES		**Page**
Are there any other ethics issues that should be taken into consideration? Please specify	○ Yes ◉ No	

I confirm that I have taken into account all ethics issues described above and that, if any ethics issues apply, I will complete the ethics self-assessment and attach the required documents. ☒

How to Complete your Ethics Self-Assessment

5 - Call-specific questions

Extended Open Research Data Pilot in Horizon 2020

If selected, applicants will by default participate in the Pilot on Open Research Data in Horizon 2020[1] , which aims to improve and maximise access to and re-use of research data generated by actions.

However, participation in the Pilot is flexible in the sense that it does not mean that all research data needs to be open. After the action has started, participants will formulate a Data Management Plan (DMP), which should address the relevant aspects of making data FAIR – findable, accessible, interoperable and re-usable, including what data the project will generate, whether and how it will be made accessible for verification and re-use, and how it will be curated and preserved. Through this DMP projects can define certain datasets to remain closed according to the principle "as open as possible, as closed as necessary". A Data Management Plan does not have to be submitted at the proposal stage.

Furthermore, applicants also have the possibility to opt out of this Pilot completely at any stage (before or after the grant signature). In this case, applicants must indicate a reason for this choice (see options below).

Please note that participation in this Pilot does not constitute part of the evaluation process. Proposals will not be penalised for opting out.

We wish to opt out of the Pilot on Open Research Data in Horizon 2020.	○ Yes	◉ No

Further guidance on open access and research data management is available on the participant portal: http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/open-access-dissemination_en.htm and in general annex L of the Work Programme.

[1] *According to article 43.2 of Regulation (EU) No 1290/2013 of the European Parliament and of the Council, of 11 December 2013, laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" and repealing Regulation (EC) No 1906/2006.*

Prototype system for a Copernicus CO_2 service

List of participants

Part. No. *	Participant organisation name	Short Name	Country
1 (Coord)	EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS	ECMWF	INT
2	EIDGENOSSISCHE MATERIALPRUFUNGS- UND FORSCHUNGSANSTALT	EMPA	CH
3	INTEGRATED CARBON OBSERVATION SYSTEM EUROPEAN RESEARCH INFRASTRUCTURECONSORTIUM	ICOS ERIC	INT
4	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	JRC	INT
5	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	FR
6	MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV	MPG	DE
7	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST ATUURWETENSCHAPPELIJK ONDERZOEK TNO	TNO	NL
8	LUNDS UNIVERSITET	ULUND	SV
9	STICHTING VU	VUA	NL
10	WAGENINGEN UNIVERSITY	WU	NL
11	AKADEMIA GORNICZO-HUTNICZA IM. STANISLAWA STASZICA W KRAKOWIE	AGH	PL
12	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	BSC	ES
13	CICERO SENTER KLIMAFORSKNING STIFTELSE	CICERO	NO
14	FONDAZIONE CENTRO EURO-MEDITERRANEOSUI CAMBIAMENTI CLIMATICI	CMCC	IT
15	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	CNRS-LA	FR
16	DEUTSCHER WETTERDIENST	DWD	DE
17	ECOLE NATIONALE DES PONTS ET CHAUSSEES	ENPC	FR
18	ILMATIETEEN LAITOS	FMI	FI
19	IDRYMA TECHNOLOGIAS KAI EREVNAS	Forth	HE
20	KAMINSKI THOMAS HERBERT	iLab	DE
21	MERCATOR OCEAN	MOi	FR
22	METEO-FRANCE	MF	FR
23	THE UNIVERSITY OF EDINBURGH	UEDIN	GB
24	FCIENCIAS.ID - ASSOCIACAO PARA A INVESTIGACAO E DESENVOLVIMENTO DE CIENCIAS	FC.ID	PO
25	THE CYPRUS INSTITUTE	CyI	CY

Coordinator: Dr Richard Engelen (ECMWF)
Richard.engelen@ecmwf.int

Contents

1 Excellence

1.1 Objectives

The "Prototype system for a **Co**pernicus **CO_2** service" (**CoCO2**) project will deliver the prototype systems for a new European anthropogenic CO_2 emissions monitoring and verification support capacity that can be implemented within the Copernicus programme as a (pre-)operational service element.

The Paris Agreement, a pivotal milestone of the United Nations Framework Convention on Climate Change to combat climate change and adapt to its effects, entered into force on the 4th of November 2016. Currently, 197 Parties have signed the Agreement committing to reducing global emissions of greenhouse gases, of which 187 have completed the ratification in 2020. Specifically, the Agreement requests each country to outline and communicate their post-2020 climate actions, known as the Nationally Determined Contributions (NDCs).

To enable the European Union (EU) to move towards a low-carbon economy and implement its commitments under the Paris Agreement a binding target to cut emissions in the EU by at least 40% below 1990 levels by 2030 was set and European Commission (EC) President von der Leyen recently committed to deepen this target to at least 55% reduction by 2030. This has now been further consolidated with the release of the Commission's European Green Deal on the 11th of December 2019, setting the targets for the European environment, economy and society to reach zero net emissions of greenhouse gases in 2050, outlining all needed technological and societal transformations that are aiming at combining prosperity and sustainability.

To independently assess the progress of countries towards their targets, an objective way to monitor anthropogenic CO_2 emissions and their evolution over time is needed. Such a capacity would deliver consistent and reliable information to support informed policy- and decision-making processes, both at national and European level. To maintain independence in this domain, it is seen as critical that the EU establishes observation-based operational anthropogenic CO_2 emissions Monitoring and Verification Support capacity (CO2MVS) as part of its Copernicus programme.

In advance of the Paris Agreement in 2015, the European Commission (EC) already anticipated these needs and tasked an international group of experts to assess the state-of-the-art for the monitoring of anthropogenic CO_2

emissions. This dedicated Task Force, with support from the institutional partners ESA (European Space Agency), ECMWF (European Centre for Medium-Range Weather Forecasts) and EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) is providing advice for the design of the overall systems, including space-based and ground-based components of the infrastructure. So far, this has resulted in a report outlining the CO2MVS architecture (Ciais et al., 2015), which was then further elaborated in Pinty et al. (2017). More recently, a peer-reviewed paper was published outlining the ideas and recommendations from the CO_2 Task Force (Janssens-Maenhout et al., 2020). In addition, very similar approaches appear in the Integrated Global GHG Information System (IG3IS) of the World Meteorological Organization (WMO) (DeCola and Tarasova, 2019) and the White Paper of the Community of Earth Observation Satellites (CEOS) (Crisp et al., 2018). Furthermore, some heritage already exists, for instance through the Global Carbon Project (GCP, e.g., Friedlingstein et al., 2019; Saunois et al., 2019), which was formed to work with the international science community to establish a common and mutually agreed knowledge base to support policy debate and action to slow down and ultimately stop the increase of greenhouse gases in the atmosphere.

The proposed observation-based CO2MVS will be driven by a new generation of highly accurate and precise CO_2 imaging satellites as part of the Copernicus Sentinel programme. ESA, in collaboration with EUMETSAT and supported by a dedicated Mission Advisory Group, is designing and building this new CO_2 Monitoring mission, which will significantly increase the capabilities of satellite-based sensors. Integral to this new mission is the implementation of a constellation of low Earth orbiting satellites that provide a better than 3-day revisit time at mid-latitudes, at 4 km^2 sampling and a precision better than 0.7 ppm in XCO_2 (the ratio of the total dry-air column of CO_2 to that of dry air). In order to limit the systematic error, the inclusion of a multi-angle polarimeter is foreseen, enabling the CO_2 retrieval process to better account for cloud and aerosol scattering effects. In addition, the inclusion of coincident measurements of NO_2, a proxy for the plumes of freshly emitted anthropogenic CO_2 from power plants and cities, could significantly increase the accuracy of the inferred CO_2 emission estimates. In parallel, the CO_2 Task Force has produced a report detailing the requirements for the in situ[1] component of the CO2MVS (Pinty et al., 2019). The report clearly documented the critical importance of the in situ component and made recommendations regarding the requirements, sustainability and governance.

As illustrated in Figure 1, the CO2MVS capacity will combine information from these satellites and in situ observations with detailed computer simulations of the atmosphere and biosphere to estimate anthropogenic emissions of CO2. This combination of observations and modelling will provide the added value to what we already know in terms of emissions from human activities, monitoring CO_2 emissions in much more detail, both in space and time.

To support the Commission and the CO_2 Task Force with designing and ultimately building the CO2MVS, the CO_2 Human Emissions (CHE) project was funded through the H2020 programme. The project started in October 2017, bringing together a consortium of 22 European partners and lasting for over three years. The project, coordinated by ECMWF, has so far carried out various scientific studies supporting the design of the CO2MVS, resulting in clear recommendations described in a set of reports. In parallel, the Commission has been funding through H2020 the VERIFY project, which runs from February 2018 until January 2022. VERIFY, coordinated by the Laboratoire des Sciences du Climat et de l'Environnement (LSCE), is developing a system to estimate greenhouse gas emissions in European countries to support countries' emission reporting to the UN Climate Change Convention Secretariat. The emissions are estimated based on existing land, ocean and atmospheric observations. VERIFY focuses on the three major greenhouse gases responsible for global warming: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Both projects are closely coordinated by having shared General Assembly meetings, overlapping consortia, and regular meetings between the projects' coordination teams, to ensure complementarity and avoid duplication of work.

[1] In the current Copernicus Regulation, in situ observations are defined as follows: 'Copernicus in situ data' means measurements collected by groundborne, seaborne or airborne sensors, as well as reference and auxiliary data licensed or provided for use in Copernicus.

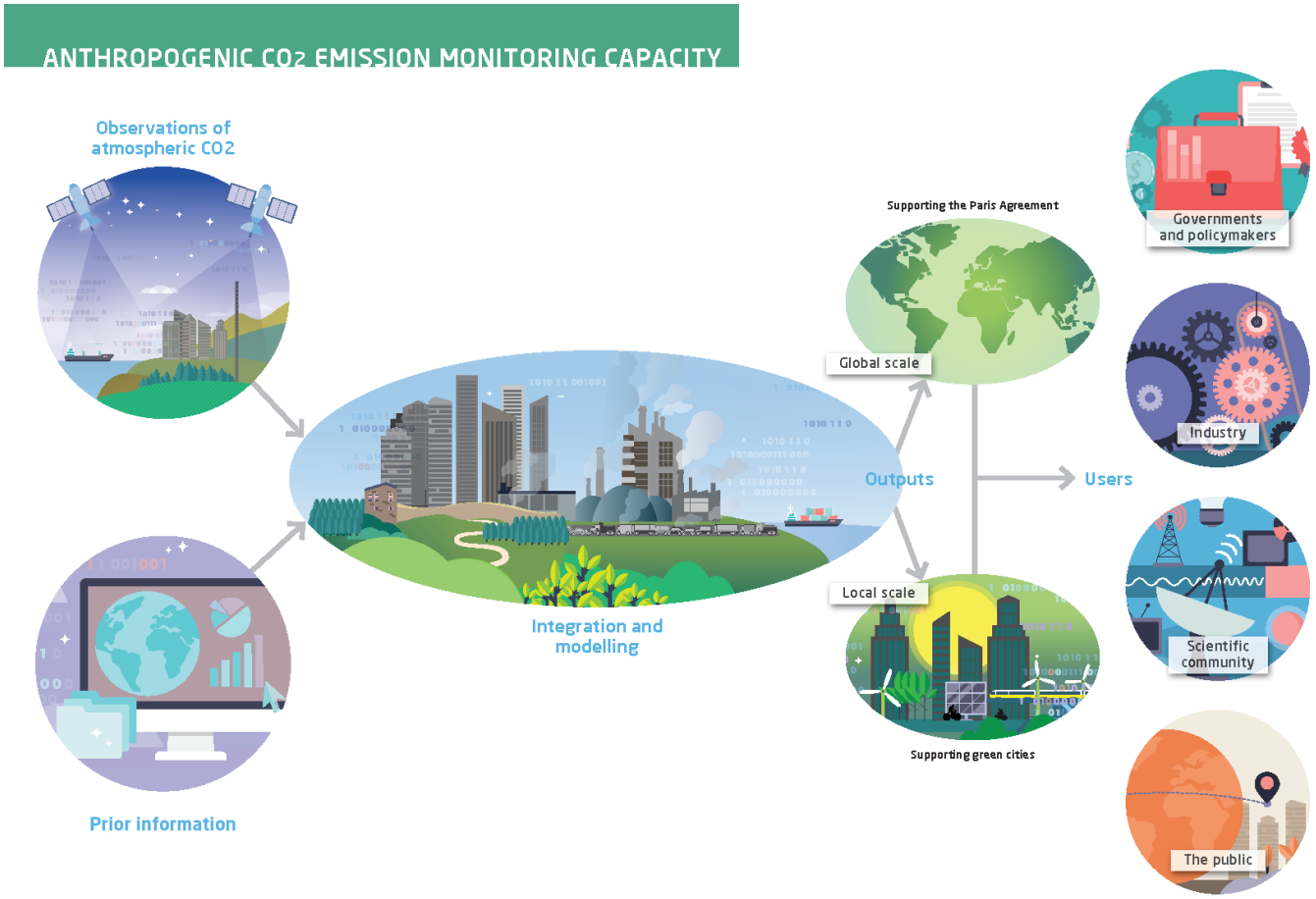


Figure 1: Illustration of the components of the planned anthropogenic CO_2 emissions Monitoring and Verification Support (MVS) capacity

The 'Prototype system for a **Co**pernicus **CO_2** service' (CoCO2) project will build on the recommendations from the CO_2 Task Force and the developments and recommendations from the CHE and VERIFY projects to deliver further research activities (where needed) and prototype systems for the CO2MVS that can be implemented by the Copernicus programme as a pre-operational service by the end of the project. In doing so, CoCO2 will also link to as much of the existing Copernicus infrastructure as possible. More specifically, it will connect with services and service developments in the Copernicus Atmosphere Monitoring Service (CAMS) for the atmosphere, the Copernicus Marine Environment Monitoring Service (CMEMS) for the ocean, the Copernicus Land Monitoring Service (CLMS) for the land, and the Copernicus Climate Change Service (C3S) for climate aspects. CoCO2 will also work closely with ESA and EUMETSAT to ensure a good interface with the CO2MVS space segment.

The objectives of CoCO2 are set around the high-level data flow diagram, presented in Figure 2. This diagram, developed by the CO_2 Task Force, shows the main building blocks and data flows of the CO2MVS. To deliver policy-relevant information (red box), observations (orange box) and prior knowledge (green box) are combined using state-of-the-art Earth system models and data assimilation techniques at various scales (blue box) to provide consolidated data sets with uncertainty estimates (yellow box). CoCO2 will advance on all components individually, but also address the links between the 5 components.

For the observation building block CoCO2 will, in addition to the interaction with ESA and EUMETSAT, ensure the required stream of data from in situ observations towards the envisaged CO2MVS. It will support the definition of observational standards, the identification of data providers and exploring new measurements techniques and instruments. The work will take the recommendations from the CO_2 Task Force Green Report into account and further elaborate these. CoCO2 will also closely interact with international frameworks, most notably ICOS, Total Carbon Column Observing Network (TCCON), CEOS and IG3IS.

Within the prior information building block, CoCO2 will provide global high-resolution bottom-up anthropogenic fossil fuel emission estimates of CO_2 and co-emitted tracers per sector, including estimates for human and animal respiration and combustion of biofuels. Land and ocean fluxes from the biosphere as well as the impact of land use change on the CO2 exchange between the land surface and the atmosphere will be produced. A specific

development topic will consist of addressing the emission variability in space and time for seven identified human-activity sectors and their uncertainties, supporting modelling and data assimilation work. This will also address the potential modelling of emission variability as a function of other variables (e.g., temperature). This activity will be closely coordinated with similar activities in the Copernicus Atmosphere Monitoring Service (CAMS).

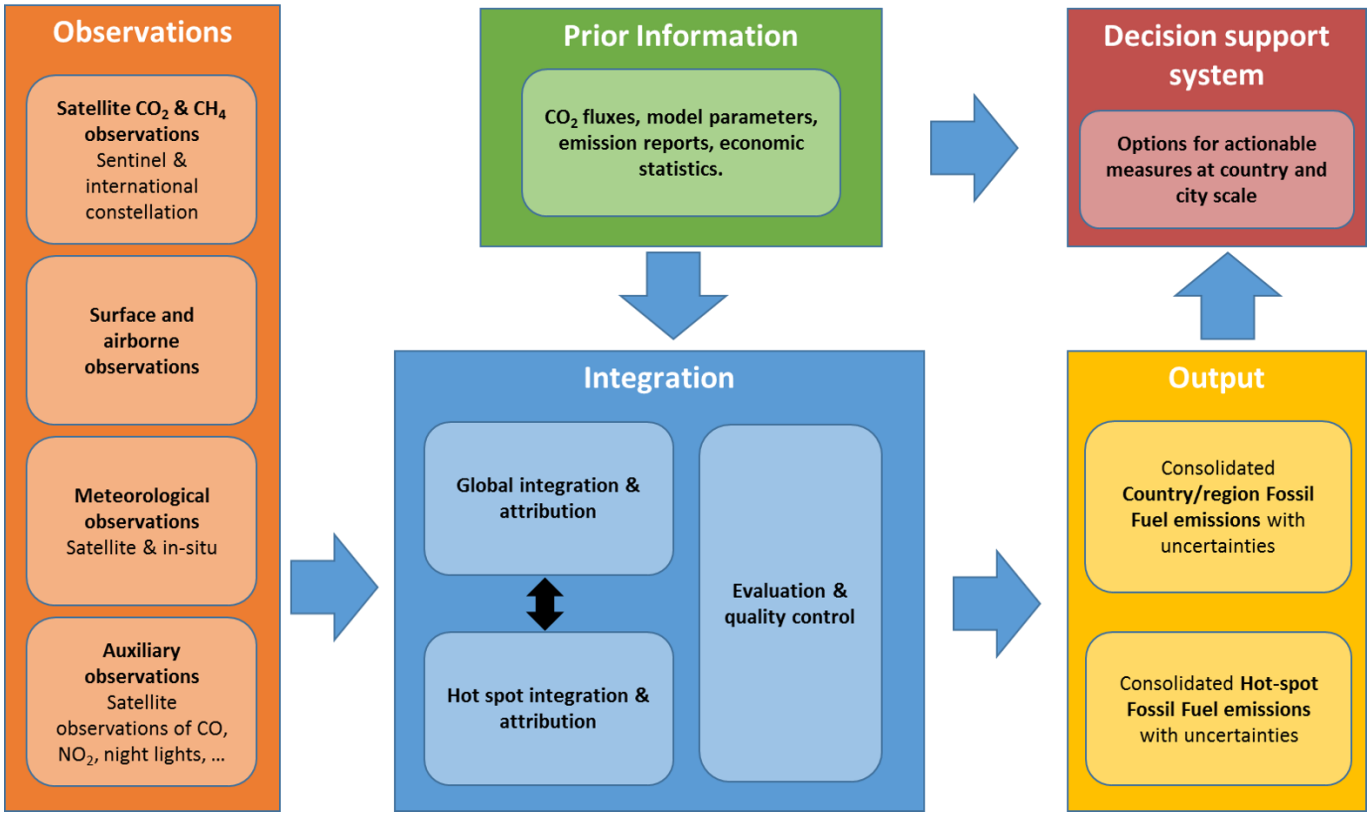


Figure 2: High-level data flow of the CO2MVS

The Integration building block is central for the conversion of satellite and in situ observations to actual emission estimates. Existing modelling capabilities available at the various CoCO2 partners will be further developed to meet the very demanding requirements of the CO2MVS. Transport modelling, land surface modelling and emission modelling will be improved, both at global and local scales. In parallel, advanced data assimilation techniques, as already explored in the CHE project, will be further developed to ensure the prototype systems can accurately process observational information at the scale of individual plumes with very high detail as well as process the enormous amount of observational information at the global scale in an efficient and accurate way. The transfer of information between the global and local systems will also be addressed, again using novel modelling and data assimilation techniques. An equally important part of the Integration building block is the evaluation and quality control (EQC). CoCO2 will address the estimation of uncertainties in all aspects of the CO2MVS and deliver recommendations for an operational EQC framework (e.g., Bastos et al., 2020, and references therein).

Finally, the generation of consolidated data sets in the Output building block and especially the transfer of this information into user-friendly information as part of the Decision support building block will receive ample attention in CoCO2. This part of the data flow is critical for the success of the future Copernicus service element. CoCO2 will therefore closely interact with representatives from the United Nations Framework Convention on Climate Change (UNFCCC), the European Commission and the national entities in charge of managing NDCs and reporting of several European countries to co-design this critical part of the CO2MVS. In addition, CoCO2 will use the recommendations and tools from the CHE and VERIFY projects as well as the expertise from existing Copernicus services into account to support this process.

Summarising the above, CoCO2 has set the following key objectives:

1. Deliver prototype anthropogenic CO_2 emission estimation systems at global, regional and local scales;
2. Engage with user communities to co-design a service portfolio that ensures fitness-for-purpose of the prototype systems;
3. Develop methodologies to assess the propagation of uncertainties within the system as well as of the outputs resulting in an Evaluation and Quality Control framework;

4. Provide first inputs to the global stocktake process in time for the 1st global stocktake in 2023;
5. Provide recommendations for the operational implementation of the CO2MVS within the Copernicus programme.

1.2 Relation to the work programme

The CoCO2 proposal is responding to the Space 2018-2020 Work Programme 'Other' Action 13: "Copernicus evolution – Research activities in support of a European operational monitoring support capacity for fossil CO_2 emissions. of the Horizon 2020 Earth observation (EO) programme" (H2020-IBA-SPACE-CHE2-2019). This grant will be awarded without call for proposals in line with Article 190(1)(e) of the Rules of applications of Regulation (EU, Euratom) 966/2012, Regulation No 1268/2012 and Article 11(2) of the Rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)", Regulation (EU) No 1290/2013. The requested Coordination and Support Action is intended as a continuation of the CO_2 Human Emissions (CHE) project, led by the European Centre for Medium-Range Weather Forecasts (ECMWF). In line with Regulation EU 377/2014, which identifies ECMWF as one of the entities to be involved in the implementation of the Copernicus service component and article 190(1) (d), (e) and (f) of the Financial Regulation, this action shall be awarded to ECMWF, as the body responsible for the implementation of the Copernicus climate service, its high degree of specialisation and its administrative power, together with additional partners principally based on the CHE consortium. With this proposal, ECMWF and the proposed project partners are responding to the above Action.

In October 2015, a European Commission expert report ("Towards a European Operational Observing System to Monitor Fossil CO_2 Emissions", the so-called Blue report) outlined an implementation strategy for a European initiative on monitoring anthropogenic CO_2 emissions with full operational capabilities. The report recommended a step-wise approach to implement a requirement-driven integration of remote-sensing, in-situ and modelling capabilities for an operational end-to-end system with the aim of having an operational system as part of the Copernicus services from 2030 onwards. Using the recommendations of this initial report, the Commission set up two expert Task Forces addressing separate but interconnected tasks: Task Force A, co-convened by ESA and the Commission, dealt with the Space Component; Task Force B, convened by the Commission, addressed the end-to-end infrastructure of an operational emission monitoring system. The discussions within the two Task Forces resulted in the publication of the Mission Requirements Document (MRD) for the CO_2 Monitoring (CO2M) Mission and a second report on the end-to-end infrastructure ("An operational anthropogenic CO_2 emissions Monitoring & Verification Support Capacity - Baseline requirements, model components and functional architecture", the so-called Red report). Since then, these two expert groups have been converted to a Mission Advisory Group (MAG) to advise ESA on the CO_2 Monitoring (CO2M) mission and a CO_2 Monitoring Task Force to advise the Commission on the various aspects of the CO2MVS capacity. On the 26th of September 2019, the CO_2 Task Force published an additional report focusing on the in-situ requirements for the CO2MVS capacity ("An operational anthropogenic CO_2 emissions Monitoring & Verification Support Capacity - Needs and high-level requirements for in situ measurements", the so-called Green report).

Consistently with the needs highlighted in the various reports and in support of the European Commission and its Task Force, Call H2020-IBA-SPACE-CHE2-2019 asks for a continuation of the CO_2 Human Emissions (CHE) project using existing European competencies relevant to the CO_2 emissions topic, and to sustain the development of a European capacity for fossil fuel CO_2 emissions. These activities should address all components of the system, such as atmospheric transport models, re-analysis, data assimilation techniques, bottom-up estimation, in-situ networks and ancillary measurements needed to address the attribution of CO_2 emissions. CoCO2 has these ambitions at its core and brings together a comprehensive consortium of key European players that will provide answers to the critical topics defined in the Call, provide expert advice to the CO_2 Task Force, and put together the building blocks of a future CO2MVS in the form of a prototype system. In addition to the expertise of its partners, CoCO2 will engage with renowned European and international experts through an External Expert Group as well as through the organisation of dedicated workshops to interact with key user communities of the planned Copernicus CO2MVS, such as the UNFCCC, the European Commission, and EU member states. The latter is critical for an effective co-design of the CO2MVS portfolio with these key user communities. A more detailed response on the requirements from the Work Programme is provided in Table 1.

Table 1 Requirements from the Work Programme

Work Programme requirements	CoCO2 response
Perform R&D activities identified as a need in the CHE project and strongly recommended by the CO_2 monitoring Task Force. These R&D activities will sustain the operational support capacity in a seamless and consistent way through all partners contributing to the CHE project.	The COCO2 workplan described in this proposal has used the recommendations from the CO_2 Task Force and the CHE outcomes so far, especially the reports from CHE work package 5, as guidance for the proposed R&D activities. The CoCO2 consortium also has a large overlap with the CHE consortium to ensure continuity of the on-going development work. In addition, the CoCO2 consortium has taken on board partners from the VERIFY consortium, where appropriate, as well as some new partners to extend the expertise.
These activities should therefore address all components of the system, such as atmospheric transport models, re-analysis, data assimilation techniques, bottom-up estimation, in-situ networks and ancillary measurements needed to address the attribution of CO2 emissions.	As is described in sections 1.3 and 3.1, CoCO2 will address all components of the system using the proposed system architecture diagram from the CO_2 Task Force as guidance (see also Figure 4).
The activities shall in particular support an open standard integrated system test bed for the components above, which will be gradually replaced by pre-operational components as they become available. Such a test bed shall in particular help to understand expected end-to-end performances for different scenarios for space-borne and in-situ observations, different implementation options of the above components, as well as to reply to evolving policy-driven future questions.	CoCO2 will build prototype systems at different scales. For the global prototype, the system will expand current operational Copernicus capabilities in CAMS and C3S by using the ECMWF Integrated Forecasting System (IFS) data assimilation system. Other existing global carbon cycle data assimilation systems, most notably CarbonTracker-Europe and the LMDZ system that is also providing some CAMS services, will be used to benchmark the required IFS developments. The IFS itself is based on intense developments from many groups in ECMWF and EU member states and is therefore already the result of collective European expertise. For the local component of the CO2MVS, CoCO2 will employ several existing modelling systems that will be further developed to meet the requirements of the CO2MVS capacity. All systems will be involved during the development phase to test the end-to-end performance and to assess the various implementation options.
As it is already expected that the spatial resolution and the accuracy of the atmospheric transport models have to be significantly increased in order, for instance, to match the km scale resolution of the CO_2 measurements from space, the Observing System Simulation Experiments have to be set-up to help in defining the in-situ component resulting from an optimised configuration given the future CO_2 satellite constellation.	CoCO2 will use various kinds of sensitivity studies to assess the requirements for the various components of the overall system. As explained in the Methodology section 1.3.2, CoCO2 sees the use of Observing System Simulation Experiments (OSSEs), which have a very strict definition, as one of the sensitivity tests. The proposal therefore does not directly refer to the term OSSE. However, the requirements for the in situ component will be addressed in specific sensitivity studies through a collaboration between WP3 and WP6.
Research activities are also required to better evaluate the contribution to fossil fuel emissions and thus address the attribution issue, as well as to strengthen the capacity for bottom-up estimation. This target will require the development of new measurement techniques and instruments to fill existing gaps.	As part of work package 6, which is entirely focused on the in situ and ancillary observation component, a specific Task is set to look at new measurement techniques. The study will be focused on Krakow, Poland, but results will be documented to provide more general recommendations.

The overall performance of the system when reaching its full capability has to be assessed in particular with respect to the time and space requirements suggested by end users. By the same token, the potential and essential functionalities of a decision support system have to be established.	Work package 7 is entirely focused to engage with the various user communities. The aim of CoCO2 is to involve users in a co-design approach of the future service portfolio and user interface, including a decision support system. This will ensure the developments of the system will lead to a fit-for-purpose end result.
More generally, this action should support the design of an integrated support capacity, enabling European experts to collectively share their knowledge and join forces on the multiple fronts required to develop such a system with operational capabilities.	CoCO2 is based on a large consortium with significant expertise in all relevant areas. The design of the CO2MVS capacity is such that it fits the governance of Copernicus, i.e., future services will be based on collective expertise and joined forces. The different components of the system will be developed by the groups who have most expertise in those areas.

1.3 Concept and methodology; quality of the measures

1.3.1 Overall concept

The CoCO2 proposal will build the prototype systems for a European Monitoring and Verification Support capacity for anthropogenic CO_2 emissions (CO2MVS) by bringing together expertise, existing capacities and innovative ideas from a wide range of European and international players. A mature and credible monitoring system for anthropogenic CO_2 emissions requires the integration of all available information streams, which is a complex undertaking and requires careful consideration of all components and interfaces. Within the precursor CHE project, the high-level data flow, as illustrated earlier in Figure 2, was further developed into a service architecture diagram that was then adopted by the CO_2 Task Force. This architecture, shown in Figure 3, will be used to structure the CO2MVS and therefore underpins the overall concept of the CoCO2 proposal.

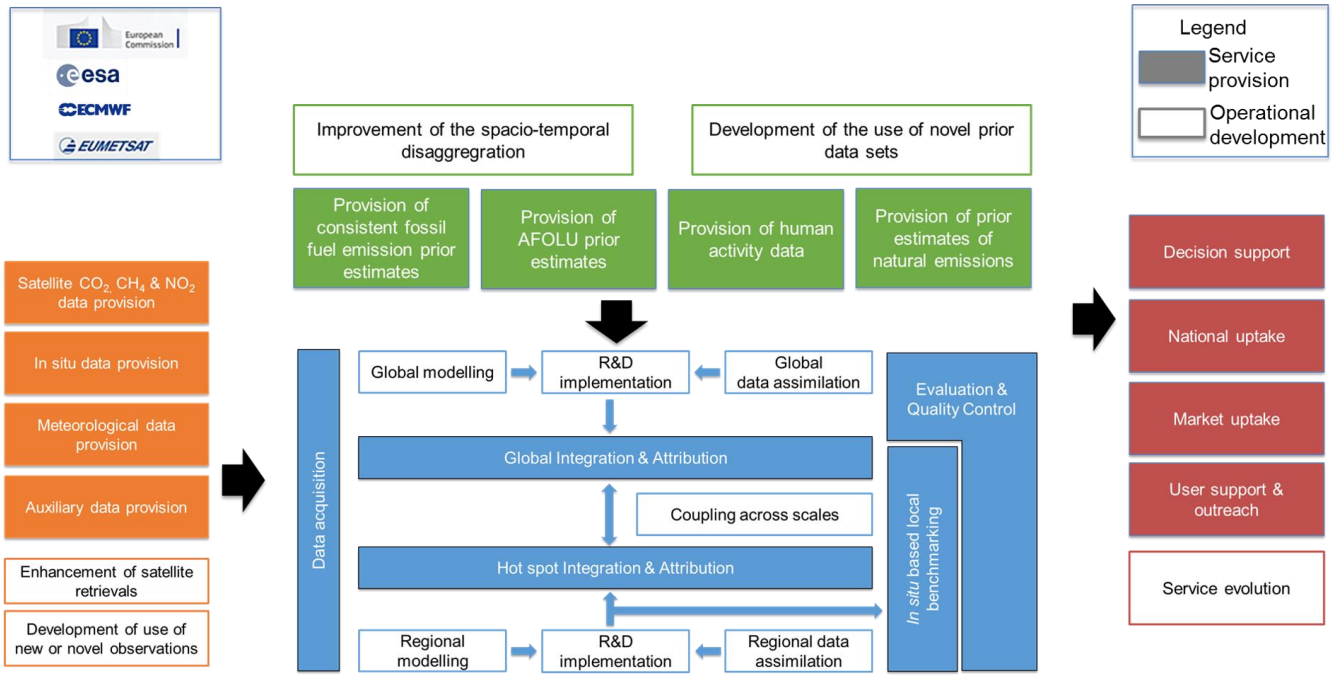


Figure 3: Schematic of the anthropogenic CO_2 emissions Monitoring and Verification Support (CO2MVS) capacity as developed in the CHE project and adopted by the CO_2 Task Force. The foreseen service provision elements are depicted by the coloured boxes, while the required continuous development of the operational services is depicted by the white boxes.

This overall concept of the CO2MVS combines the information from various observational data sets and information from prior knowledge (e.g., actual, estimated or projected emission inventories) with detailed computer models of the Earth system that represent in particular the sources, sinks and transport of CO_2 in the atmosphere in a Bayesian estimation framework, i.e., by minimising a cost function in a mathematically rigorous approach to correctly account for the uncertainties in observations, priors and models to estimate the required outputs, in this case anthropogenic CO_2 emissions at various scales. This will bring the same level of mathematical rigour to the CO2MVS

system that has proven critically important in other application areas, such as Numerical Weather Prediction and air quality forecasting.

Being an observation-based system, data from both satellite and in situ instrumentation, observing various parts of the Earth system (atmosphere, land surface, ocean), are the main input of the CO2MVS. The satellite data comes from existing or new Copernicus Sentinel satellites and from various other sensors from national and international space agencies. These satellite instruments can provide information on atmospheric CO_2, currently the most direct proxy for CO_2 emissions, but also on Solar Induced Fluorescence (SIF), a measure of photosynthetic activity. They also provide information on atmospheric temperature and wind speed, which are needed to model the transport of CO_2 from one place to another. The in-situ data is provided by various ground-based networks, coordinated through national, European or international efforts (e.g., NOAA, ICOS and WMO). While the interface with satellite data providers is mostly well-established, this is not always the case for in situ data. Sustainability, data policy, and timeliness are aspects that need to be addressed as part of setting up an operational CO2MVS.

The first main challenge of the CO2MVS is that the observations do not directly measure the variables we are interested in, i.e., the anthropogenic emissions. The observations provide information on atmospheric CO_2 and co-emitted species, which are a result of the anthropogenic emissions. In addition, observations can provide information on some of the processes that cause an exchange between the Earth's surface and the atmosphere (e.g., photosynthesis or human activity). We therefore need tools to translate the observations mentioned above to actual estimates of emissions at global and local scales. The second main challenge is that the signal of anthropogenic emissions in the variables we can observe (e.g., atmospheric CO_2) is very small relative to the signal of natural fluxes between the land and ocean surfaces and the atmosphere, especially on time scales of less than a year. In addition, the variability of atmospheric CO_2 concentrations due to human activity is small compared to the average background concentrations and the large-scale variability. To face these challenges the CO2MVS foresees state-of-the-art computer models of the Earth system that can simulate the variables that are observed based on prescribed or modelled emissions and fluxes. Advanced data assimilation methods can then make adjustments to the emissions and fluxes that are consistent with the information from the observations and constrained with physical knowledge encapsulated in the models. The models need to be comprehensive and detailed to capture all relevant processes that determine the value of the observed variables. The foreseen CO2MVS will include models at three different scales: i) a global integration & attribution system to provide world-wide coverage integrating all available observations, ii) hot-spot integration & attribution systems to directly assess the underlying emissions of individual plumes as observed especially by the CO2M satellite mission, and iii) regional in situ based benchmark systems that can focus on specific areas with a very dense observation infrastructure around them to provide a benchmark for the global system. In addition, the CO2MVS will contain mechanisms to transfer information from global to regional to local scales (e.g., through boundary conditions for the specific domains) and vice versa (e.g., using the detailed information from the local estimates in the global system). In addition, the data assimilation systems at all three scales will be able to make use of observations of co-emitted species (e.g., NO_2 and CO), either for better detection of individual plumes or for exploiting the correlations between atmospheric concentrations of these additional species and CO_2.

As described above, the models need to be as realistic as possible to make best use of the observations in the data assimilation framework. An important input to these systems consists therefore of the information we already have before we integrate the observations, the so-called prior information. In Figure 3, this is focused on the emissions and natural fluxes of CO_2, although other aspects of the Earth system can be included as well. Emission information based on national inventories, information about the AFOLU (Agriculture, Forestry and Other Land Use) sector, information about human activities and prior knowledge of fluxes between the land and ocean surfaces and the atmosphere are all part of the prior knowledge. One has to note that the use of data sets, such as nationally reported inventories or energy statistics, will inhibit the CO2MVS from being fully independent from these inputs to the UNFCCC. However, the CO_2 Task Force recommends in its reports to follow this approach, keeping in mind that nationally reported emissions are generally two years old, due to the time required to process all the statistics, and that the distribution of emissions within a country is neither required by UNFCCC nor prescribed by the guidelines from the Intergovernmental Panel on Climate Change (IPCC), resulting in emission grids varying country by country. CoCO2 will develop the necessary metrics to be able to assess the impact of the observations on the output data relative to the prior information.

The fourth element of the CO2MVS is the translation of the generated data into user-friendly services. For some user sectors, this could mean providing the raw output data, for other user sectors specific tools need to be developed and put in place. The aim of the CO2MVS is to serve the policy sector at European, national and local

scales, to support countries with developing their own specific emission monitoring capabilities, and to stimulate business uptake as part of a green economy. In addition, the output data is seen as a key contribution to the scientific community. Based on experience in the Copernicus programme it is essential to have a dedicated user support and user engagement component as well. CoCO2's aim is to interactively address all these elements, especially with the key user communities, resulting in a co-designed portfolio and user interface.

1.3.2 Methodology

The CoCO2 concept will be implemented through specific scientific and technical activities, which will structure the work breakdown, and an overall coordination approach. CoCO2 will use a multitude of existing tools and data sets using the heritage of the precursor CHE and VERIFY projects. While these tools and data sets form the basis for the work in CoCO2, they will be further developed as part of the overall methodology to meet the specified requirements for the overall CO2MVS capacity. This is especially important to remove current barriers and inconsistencies between methods and systems to move forward to a comprehensive and internally consistent CO2MVS capacity.

In **WP1 (Prior and ancillary information)** state-of-the-art emission and emission uncertainty data will be generated as input for the modelling and data assimilation activities in WP2 (globally) and WP3 (locally). WP1 will also develop new methodologies to improve the emission and emission uncertainty data. In addition, spatially explicit uncertainty information will support the design of an observational network in WP4. The main limitation of the current emission inventories is that they are based on nationally reported data that become available with a lag of at least 2 years. Also, the way emissions are distributed within a country varies from country to country. Therefore, the ultimate way forward is to model emissions using other sources of information that are available in near-real-time (e.g., temperature, wind, and (potentially) human activity data), which is one of the focus points of WP1. In addition, the uncertainty quantification of emissions is still under development. Methods have to be developed to provide the uncertainty information with the required level of detail, for example describing (currently unknown) error correlations between co-emitted species or source sectors.

WP2 (Global Modelling and data assimilation) will focus on the development of the CO2MVS at global scale building on the existing capacity developed in CHE, VERIFY, CAMS, CMEMS, CEMS (Copernicus Emergency Management Service), and C3S. The WP will deliver a system that can provide information of CO_2 emissions and other surface exchange in near-real time, as well as in a longer-term re-processing mode to provide the most accurate annual estimates as possible and to evaluate trends in support of the Global Stocktake (GST) process. The core of this system is the Integrated Forecasting System (IFS) at ECMWF, augmented with a number of new capacities as detailed below, and following the recommendations made by the series of CHE Interim Reports, as well as the EU's CO_2 Red Report from 2017. Using the IFS for the global Earth system maximises the exploitation of synergies with existing Copernicus services and their development (CAMS and C3S) as well as with Numerical Weather Prediction (NWP) services and development. WP2 will focus on further developing the data assimilation capacity, disentangling anthropogenic emissions from natural carbon exchange, and the use of multi-species constraints for improved attribution of CO_2 signals to individual processes (e.g., land-use change) or sectors (e.g., shipping or power plants).

WP3 (Local and regional modelling and data assimilation) involves the development and application of high-resolution atmospheric transport and inversion systems covering limited geographical areas and addressing scales from mesoscale weather phenomena to individual plumes as they are resolved by CO2M. Monitoring emissions critically depends on addressing the local and national scales. The analysis and developments in this WP will rely on state-of-the-art transport models and inversion approaches. However, these systems require improvements in their efficiency and robustness to ensure that they can be applied operationally. These systems will be fed with inventories of anthropogenic emissions and simulations of the Net Ecosystem Exchange from WP1 (at high-resolution over Europe), with boundary conditions from global systems in WP2, and with the corresponding uncertainty estimates from WP1, WP2 and WP4. National data products (inventories, observations) will also be considered for a subset of national inversions to demonstrate the benefit of detailed country-specific information. Guidance provided by WP4 for specifying modelling uncertainties and connecting the different scales should be used to increase the consistency within or between the local and regional inversions. WP3 will link to the global prototype through WP4 and WP5. It will provide benchmarking test cases and guidance on the design and selection of methods for inclusion within the CO2MVS. It will also provide local and regional estimates in the form of ensembles characterizing their uncertainties, to be assimilated in the global prototype to exchange information between the various scales and to ensure consistency between the scales. Suitable systems from WP3 could

participate to the submission of estimates for the 1st GST in WP5. Systems developed here and specific data assimilation sensitivity experiments with existing networks and CO2M data will support network design in WP4 and WP6.

WP4 (Connecting scales and uncertainties) is a critical work package developing methods and mechanisms to transfer information among and between the different scales and to ensure consistency between the various scales. Within the CO2MVS, emission estimates will be generated by inversion systems operating at different scales, from global to regional to local. Such data assimilation systems should be mutually consistent in the sense that their posterior flux estimates should agree within their respective uncertainties. Inconsistencies between such estimates can help diagnose system components that require further improvements or potential issues with the uncertainty estimation. Moreover, regional limited-area models require boundary conditions, which are usually provided by global model simulations. In such nested configurations error propagation from the global to the regional domains need to be properly accounted for in order to provide realistic posterior uncertainty estimates for the regional flux products. Reciprocally, global models can benefit from regional models running at higher spatial resolution that can exploit plume-resolving observations. WP4 will address this transfer of information using innovative methods, wherein heterogeneous posterior emission products, from regional and local scales, are assimilated as observations into the global CO2MVS prototype. This approach would facilitate the integration of many posterior inversion products into a global CO2MVS product by minimising methodological constraints (no model coupling). In addition, WP4 will, in continuation of the work done in CHE and VERIFY, continue to work on coordinated efforts on uncertainty estimation. In particular, WP4 will provide a toolbox based on direct flux observations for evaluating terrestrial ecosystem models and facilitating customised improvement of the description of the biogenic prior uncertainties in transport inversions. It will also assess the impact of transport model uncertainties, additional design options for the prototype (assimilation window, prior specification, online vs offline simulations) as well as correlated uncertainty in the satellite observation on posterior estimates and their uncertainty. This work package investigates ways to evaluate posterior estimates and their uncertainties by means of model inter-comparisons (both for CO_2 and CH_4) as well as the development of dedicated bench-marking metrics. For some of this work, CoCO2 will use the Community Inversion Framework (CIF), which has been developed in the VERIFY project. This work on addressing uncertainties of the various CO2MVS components is placed in WP4 to ensure a coordinated effort with all modelling groups involved.

WP5 (Integration, testing, application and initial validation of prototype systems) will bring together the activities from work packages 1 to 4, both on the short and long term. On the short term, it will already provide appropriate CO_2 anthropogenic emission products for the 1st Global Stocktake (GST), at a spatial scale consistent with GST requirements. This will be especially challenging given the short time frame and in the absence of the imaging power of the future CO2M satellite mission, which will be launched after the end of the project. Therefore, improvements of existing inversion systems with proven performance and accuracy will be prioritised, as well as the development and integration of inversion methods that leverage co-emitted species observations (NO_2, CO) to provide additional constraints on the CO_2 source attribution problem. In addition, CoCO2 will collaborate with the VERIFY project to extend the CO_2 and CH_4 syntheses for the year 2021. These syntheses are focused on the European domain only but will benefit from the developments in the VERIFY project. For the longer term, WP5 will channel the research developments of WP 1 to 4 into building a comprehensive multi-scale prototype that will serve as the basis for the pre-operational Copernicus CO_2 service. In particular, this prototype shall fully exploit current and future observations from the Sentinel missions to deliver CO_2 emission estimates on time for the 2nd GST with the best possible accuracy. This activity will also include the design of data assimilation sensitivity studies using simulated observations as well as observation-based validation methods to provide a rigorous benchmarking mechanism to advise on which relevant elements from WPs 1-4 should be selected for implementation in the prototype. The combination of sensitivity studies with simulated observations and observation-based validation will serve as a proof-of-concept framework to demonstrate the performance of the final pre-operational system. WP5 will also support the design and implementation of an Evaluation and Quality Control (EQC) tool for the CO2MVS, building on existing approaches in the CAMS and C3S operational services and on the experience acquired for the 1st GST with real data. This EQC framework will address the service components at all scales.

As identified in the CO_2 Task Force Green Report on situ requirements, it is very clear that ground-based and ancillary measurements are irreplaceable in the context of the CO2MVS. They are required for calibrating and validating the space component, assimilation into models, validating and further improving process models, and evaluating the output generated by the CO2MVS capacity. **WP6 (Observations)** will on the one hand support the activities in other work packages and on the other hand further elaborate on the content of the Green Report to

provide more detailed information on the in-situ requirement of the CO2MVS versus current capabilities. WP6 will i) collect and document the in situ observation and ancillary data requirements of the CO2MVS, taking into account the required precision, uncertainty, and timeliness of the data, ii) identify and contact providers of the required data streams, and document the current capacity of these data providers to meet the described needs, and iii) identify and describe the gaps in the currently available in situ observations and ancillary data, providing guidance with respect to the optimal future expansion of the current in situ capacity. It is important to note that CoCO2 aims to collaborate with other stakeholders related to in situ observations, such as ICOS, TCCON, WMO and the European Commission. In addition, WP6 will come with recommendations for the technical requirements for a data pipeline to connect the relevant data streams with the operational data assimilation system and implement a prototype. Finally, WP6 will investigate the potential of new measurement techniques and instruments to fill current gaps. This will especially be focused on the urban area and also address the potential of radiocarbon measurements in collaboration with WP4.

The main purpose of **WP7** (User engagement) is to engage with the various user communities to co-design a fit-for-purpose CO2MVS service portfolio and develop mechanisms and tools to provide diverse, but targeted information to these user communities. This will be achieved by several user consultation meetings and workshops, but also by using existing international communication and planning mechanisms. At local scale, city networks like C40 or Covenant of Mayors will help disseminating the results. CoCO2 has enlisted ICLEI (Local Governments for Sustainability) to help organising these contacts. Closer links with the IPCC working groups and inventory agencies and other data providers will be established as well as the relevant working groups of DG-CLIMA. A workshop will be held in the first year to engage both UNFCCC, IPCC, Global Emissions InitiAtive (GEIA), and city (or other local) stakeholders. In this process we will involve NGOs, and organisations like the United Nations Environment Programme (UNEP), WMO and the Group on Earth Observations (GEO). In addition, CoCO2 will continue the discussion framework between national reporting agencies and the CoCO2 scientific partners, as established in the VERIFY project, with the aim to align the development of the CO2MVS capacity with the diverse requirements from these national reporting agencies. Ultimately, the Copernicus CO2MVS should be embedded in the national processes providing information that is currently missing or difficult to generate at national scale. For this purpose, CoCO2 has included several of these national agencies as 3rd-party members to the Consortium to facilitate open discussions on how the future CO2MVS can support Member States' activities relevant for the Paris Agreement. As part of this user engagement process, and in response to the Call and in support of discussion within the CO_2 Task Force on this topic, WP7 will develop a blueprint for a Decision Support System (DSS). The exact definition and content of the DSS will develop over time to address the user requirements coming out of the user engagement activities. While the development of such a final all-encompassing DSS will likely take many years, and requires extensive consultation and feedback from stakeholders, we aim to set the first steps here by developing a blueprint for a DSS that would be part of the Copernicus CO_2 service.

WP8 (Coordination, Dissemination, Exploitation and International Liaison) will ensure the CoCO2 project is coordinated and project-managed in a timely and effective manner. It covers the administrative and financial support and will apply established quality management methods. WP8will also look after communication and dissemination of the project outcomes from WP1-7. WP8 will also maintain the liaison with the European Commission, ESA, the CO_2 Task Force, ESA's CO2M Mission Advisory Group, EUMETSAT and other stakeholders, such as the Copernicus services, Global Climate Observing System (GCOS), Global Atmospheric Watch (GAW), IG3IS, CEOS/CGMS, GEO, WIGOS, and UNFCCC.

As mentioned above, CoCO2 will use several existing tools and data sets providing a representative cross-section of the available methodologies. These tools and data sets form the basis for the various developments in CoCO2, implementing specific innovations as part of the overall methodology. This is especially important to remove current barriers and inconsistencies between methods and systems to move forward to a comprehensive and internally consistent CO2MVS capacity. A brief description of the data sets and modelling and data assimilation tools is given below.

Modelling systems

To develop the prototype systems needed for estimating emissions globally as well as for specific hotspots (e.g., power plants, cities) CoCO2 will employ a range of different CO_2 modelling systems at different scales. This also takes into account the needs for regional benchmark systems that are defined as part of the Evaluation and Quality Control in section 1.3.1. The modelling systems range from comprehensive Earth System models to atmospheric dispersion models in order to address the development of the various components of the CO2MVS and to address specific research questions within the project. The variety of models (as well as data assimilation methodologies;

see next part) allows studying and testing specific trade-offs between methodologies before they are built in to the prototype systems. This ensures the prototype systems benefit as much as possible from existing expertise and capabilities. Most of the models will simulate not only CO_2 but also other trace gases such as radiocarbon, NO_2 and other relevant atmospheric composition species that may help discriminate between anthropogenic and biospheric contributions. To support the investigation of the influence of aerosols on satellite CO_2 retrievals, as is done within specific ESA- and EUMETSAT-funded activities, and to allow the assessment of simultaneous NO_2 observations, a subset of models will account for atmospheric chemistry, which requires many species and chemical reactions to be simulated. This will also involve the use of CAMS global forecasting capabilities. Some of the atmospheric transport models are applied only in forward simulations (e.g. in WP2), while others are integrated into an inverse modelling/data assimilation framework (in WPs 1, 3 and 4) as described in more detail in the next section.

Forward simulations will be conducted at the highest resolution that is computationally affordable in order to represent the true state of the atmosphere as closely as possible ("nature runs") and at a level of detail that is compatible with the expected resolution of future satellite missions.

CoCO2 models will be applied at the global, continental (Europe), regional, and local point source scale at increasing resolution. The smaller-scale models will use the output of the larger-scale simulations as initial and boundary conditions as much as possible, in order to produce a consistent set of simulations across a hierarchy of scales. The setup of the individual simulations will be closely coordinated in terms of input datasets, model domains, time periods, and output formats, to build model ensembles whenever feasible. A brief overview of the model systems is given in the CoCO2 model table (Table 2).

Table 2: CoCO2 Model Systems

Model	Institute/ Consortium	Domain	Archived resolution			Meteorology Boundary Conditions
			horizontal	**vertical**	**temporal**	
IFS	ECMWF	Global	9 km	137 levels	hourly	N/A
TM5+OpenIFS	WU	Global	25 km	60 levels	hourly	ECMWF operational/reanalysis
TM5	WU/SRON	Global	3 x 2 degrees	60 levels	hourly	ECMWF operational/reanalysis
		Zoom	1 x 1 degree	60 levels	hourly	
LMDZ	CEA	Global	3.75 x 1.9 deg^2	39 layers	30 min.	ECMWF operational/reanalysis
GEOS-Chem	University of Edinburgh	Global	2 x 2.5 degrees	47 levels	hourly	GEOS-FP/MERRA-2
		Zoom	0.25x0.3125			
CCFFDAS	Lund University, iLab	Global	0.1 degree		weekly	ECMWF operational/reanalysis
		Local	2 km		hourly	WRF
CHIMERE	CEA	Regional	1-2 km	20 layers	hourly	ECMWF operational/reanalysis
COSMO-GHG	EMPA	Europe	5 km	60 levels	hourly	ECMWF operational/reanalysis
		Regional	1 km	60 levels	hourly	
LOTOS-EUROS	TNO	Europe	5 km	20 levels	hourly	ECMWF operational/reanalysis

		Regional	1 km	20 levels	hourly	COSMO or WRF
ICON-ART	DWD/MPI-M/KIT-IMK	Europe	6.5 km	60 levels	hourly	global ICON and ECMWF
		Regional	2.5 km	65 levels	30 min.	regional ICON and ECMWF
MICRO-HH	WU	Local	1 - 100 m			Global or regional model

Data assimilation systems

The term data assimilation system is used here to describe all schemes that combine information of a prior state with current observations to estimate surface fluxes and emissions. CoCO2 will employ a range of different data assimilation systems from the global to the local scale to address the requirements of the CO2MVS within the project. The variety of data assimilation methodologies allows studying and testing specific trade-offs between methodologies before they are built in to the prototype systems. This ensures the prototype systems benefit as much as possible from existing expertise and capabilities. The data assimilation systems are based on the models listed in Table 2 with their specific spatial domain and resolution. They also differ in how they constrain the fluxes and emissions. Most traditional top-down inversion systems solve for the spatial and temporal distribution of net fluxes at the surface, taking into account the uncertainties of the observations, the prior estimates of the natural fluxes and emissions, and the transport model that links the fluxes to the observed atmospheric concentrations. This can typically be done at different spatial and temporal scales.

Another approach, which has recently been gaining momentum, is to optimise a surface flux model (CCDAS - Carbon Cycle Data Assimilation System) or emission model (FFDAS - Fossil Fuel Data Assimilation System) with parameters that can be constrained by observations. This approach potentially reduces the number of unknowns, but adds more dependence on the complexity, structure, and potential non-linear formulations of the underlying models. However, it allows for better use of prior knowledge of the physics of the system or the typical drivers of emissions. CoCO2 will exploit both approaches in various forms to search for an optimal configuration of a future monitoring system with the right balance between the complexities of the models and making best use of the observations and prior information to constrain all aspects of the system (emissions, biospheric fluxes, meteorology, and supporting atmospheric tracers).

In addition, CoCO2 will address the challenge of transferring the information from one scale to another. For modelling activities, there is already long heritage of providing boundary conditions from for instance global models to regional models or embedding zoom facilities in larger-scale models. For data assimilation systems, this is more complex and especially the use of information from the local/regional-scale systems in the global system will be targeted in CoCO2.

Observations

The future CO2MVS capacity will be an observation-based estimation system for anthropogenic CO_2 emissions. Using satellite and in situ observations to provide additional information on emissions and their trends is the main innovative value of the foreseen capacity. CoCO2 will therefore use multiple datasets from both satellites and ground-based networks to achieve its aims. For the satellite observations, CoCO2 will directly link with existing frameworks, such as Copernicus and the ESA CCI datasets, to obtain quality retrievals of CO_2 from the Japanese GOSAT and American Orbiting Carbon Observatory 2 (OCO-2) instruments. CoCO2 will also use observations of CH_4, NO_2 and CO from the Copernicus Sentinel-5p satellite for specific studies and showcases. Sentinel-5p currently provides retrievals with a spatial resolution of 3.5 by 5 km^2, which is reasonably close to the expected resolution from the CO2M mission. In addition, ECMWF has already established links with the American OCO-3 science team and the GHGSat team to facilitate the use of dedicated CO_2 and CH_4 observations over specific domains using the target mode of these instruments over the duration of the project. CoCO2 will also work with ESA and EUMETSAT to enable the generation of simulated CO2M observations based on the CoCO2 nature runs. Ground-based measurements will consist of observations from the current European in-situ networks of atmospheric mixing ratios of CO_2, and CO, as well as radiocarbon and APO. Close links with ICOS are guaranteed through the involvement of ICOS ERIC in the CoCO2 consortium. In addition, the ground-based Total Carbon Column Observing Network (TCCON) is an important source of observations for model-data comparison and model-data fusion, as are the routine aircraft measurements, to be provided by the IAGOS (In-service Aircraft for a Global

Observing System) European Research Infrastructure. Moreover, CoCO2 work package 6 is dedicated to facilitating the evolution of in situ data over the coming years to meet the requirements of the future CO2MVS.

Priors

The needs for prior estimates of CO_2 emissions and their uncertainties involve the preparation and harmonisation of gridded data sets that can support the global and regional modelling and data assimilation activities. This also involve land use data sets and the prescription of anthropogenic and natural fluxes that are not yet integral part of the online modelling systems, such as ocean CO_2 fluxes. For anthropogenic CO_2 emissions, the fluxes aggregated in opportune sectoral clusters will be complemented by land-use and urban maps that can support the integrated Earth system modelling and data assimilation, improving the match of model simulation with in-situ observations that will support the benchmarks activities.

The generation of consistent prior and ancillary data depends on processing nationally reported inventories and large volumes of EO data. This requires extensive efforts and the focus in CoCO2 will therefore be on the years 2016 and 2021. The year 2021 is chosen to support the 1st Global Stocktake in 2023, which is reporting on 2021 emissions. The year 2016 is chosen to provide emissions 5 years previous to the 2021 emissions allowing the assessment of a detectable trend signal over a standard 5-year Stocktake period.

Sensitivity studies

Putting together the building blocks of the CO2MVS requires extensive testing of all the components as well as the integrated end result. CoCO2 will therefore use various forms of sensitivity studies to test and illustrate the impact of specific configurations on the estimated emissions. In the Work programme text, specific reference was made to the use of Observation System Simulation Experiments (OSSEs). OSSEs are defined as follows: *An OSSE uses computer models to test different designs of new satellite systems before their instruments are actually built or deployed, and to compare the performance of the new satellites against current observing platforms. The results can help to guide the design of new instruments and to determine if a new satellite platform will be cost-effective*. OSSEs can be computationally expensive and only address part of the overall system. CoCO2 therefore uses a variety of sensitivity study set-ups that not only address the requirements for the observation component of the CO2MVS, but also the requirements for some of the other components. In the remainder of this proposal all these studies will be described as sensitivity studies.

1.3.3 Overall quality of coordination and support

The Action to which this proposal responds is described in the Work Programme as a Coordination and Support Action. While the text states that "the main objective is to perform R&D activities identified as a need in the CHE project and strongly recommended by the CO_2 monitoring Task Force", it also clearly states that "this action should support the design of an integrated support capacity, enabling European experts to collectively share their knowledge and join forces on the multiple fronts required to develop such a system with operational capabilities." Or in other words, the CoCO2 proposal shall build on the community established within the CHE project to ensure the developed prototype systems are embedded in or linked to existing European and international frameworks. The CoCO2 proposal has been designed with exactly this in mind. The CoCO2 consortium is largely based on the CHE consortium, but has been extended to strengthen specific aspects. It consists of a significant group of partner organisations chosen because of their expertise in the various topics required to perform the work in the proposed work packages. This ensures all the required expertise is included and that partners can actively work together to create a strong community to support the development of the future CO_2 emission monitoring system.

CoCO2 also draws on a wide array of former and current research projects (see Table 3). Many of the CoCO2 partners have been or are involved in these projects, in some cases coordinating them, ensuring the required transfer of information and expertise into the CoCO2 project itself.

Table 3: CoCO2-related research & development projects

Acronym or name	Full title	Website
CHE	CO2 Human Emissions	https://www.che-project.eu/
VERIFY	Verifying greenhouse gas emissions	https://verify.lsce.ipsl.fr
CAMS	Copernicus Atmosphere Monitoring Service	https://atmosphere.copercius.eu

GCP	Global Carbon Project	http://www.globalcarbonproject.org
EUROCOM	Development of regional ecosystem-atmosphere models assimilating the ICOS data for a European-scale intercomparison of net CO2 fluxes	
TRANSCOM	Atmospheric Tracer Transport Model Intercomparison Project	http://transcom.project.asu.edu/
ICOS-INWIRE	ICOS improved sensors, network and interoperability for GMES	http://www.copernicus.eu/projects/icos-inwire
SmartCArb	Use of Satellite Measurements of Auxiliary Reactive Trace gases for fossil fuel CARBon dioxide emission estimation	
URBANFLUXES	URBan ANthropogenic heat FLUX from Earth observation Satellites	http://urbanfluxes.eu
URGE	URban Greenhouse gas Emissions assessment through inverse modelling	
URBISPHERE	Coupling dynamic cities and climate	

In addition, CoCO2 will continue to reach out to the global community. To counterbalance the fact that the CoCO2 consortium cannot be all-inclusive, an External Expert Group (EEG) will be formed that includes experts from within and outside Europe. To reach out as much as possible, the EEG will include a relatively large number of members, who will be informed about the progress of CoCO2 and will be invited to the CoCO2 General Assemblies and workshops (see also section 3.2.1).

CoCO2 will interact closely with the European Commission's CO_2 Task Force, which is seen as the main Advisory Board for the project. CoCO2 will inform the Task Force about its progress, advise them of possible development options, and take their feedback into account, where appropriate. The development of a future Copernicus CO_2 service is a grand challenge and the CoCO2 partnership is fully aware of the interest of many stakeholders in the development process. A good working relationship with the Task Force, and therefore the European Commission and its member states, is very important. CoCO2 will also report to and interact with the CO_2 Monitoring Mission Advisory Group that supports ESA with the development of the future CO_2 Monitoring Mission. Currently, the following CO_2 Task Force members are participating in the CoCO2 proposal: Richard Engelen (ECMWF), Gianpaolo Balsamo (ECMWF), Greet Janssens-Maenhout (JRC), Hugo Denier van der Gon (TNO), Han Dolman (VUA), Marko Scholze (ULUND), Philippe Peylin (LSCE), Philippe Ciais (LSCE) and Paul Palmer (UEDIN). The following CO2M MAG members are also part of the CoCO2 consortium: Richard Engelen (ECMWF), Greet Janssens-Maenhout (JRC), Hannakaisa Lindqvist (FMI) and Sander Houweling (VUA).

Finally, a very important part of the CoCO2 proposal is work package 7, which will address the gathering and assessment of user requirements from as many user communities as possible. Specific workshops will be set up to discuss the CoCO2 progress and to align the progress with user requirements. These workshops will connect with representatives from the national inventory agencies, DG-CLIMA, IPCC, UNFCCC, GEIA, and city or local stakeholders. In this process CoCO2 will also involve organisations such as UNEP, WMO (I3GIS) and GEO in order to better align our activities.

2 Impact

2.1 Expected impacts

2.1.1 Impacts listed in the work programme

As clearly stated in the H2020 Work Programme 2018-2020, this Action shall sustain the development of a European operational monitoring support capacity for fossil fuel CO_2 emissions. The proposal shall enable European experts to collectively share their knowledge and join forces on the multiple fronts required to develop such a system with operational capabilities. The main impact of CoCO2 will come though the delivery of the prototype systems that

can be implemented as a Copernicus pre-operational service element at the end of the project (2023). By 2026, this observation-based Copernicus Monitoring and Verification Support capacity is expected to operationally deliver consistent and reliable information to support policy- and decision-making processes as part of Europe's commitment to the Paris Agreement. Being the first to provide this kind of comprehensive and operational service will allow Europe to support developments of similar nature within intergovernmental frameworks, such as UNFCCC or WMO.

To deliver the prototype systems, CoCO2 will strongly collaborate with the European Commission and its CO_2 Task Force, ESA and its CO2M Mission Advisory Group, EUMETSAT, the CO_2 science community, and the Copernicus Services. CoCO2 will also align as much as possible with development plans that have been defined within the WMO/IG3IS, CEOS, GCOS and GEO frameworks. To ensure the prototype systems are fit-for-purpose and therefore can maximise the impact, CoCO2 will engage with the relevant user communities. The European Commission, EU member states, UNFCCC, cities and regions, science, industry and finance are among these user communities. This interaction is especially important to support the European Commission with the definition of an adequate service portfolio that not only addresses the needs for the 5-year Global Stocktake process but tries to support as many climate mitigation and adaptation efforts as possible. ECMWF, as Entrusted Entity for the existing CAMS and C3S Copernicus services, has a well-documented track record of organizing policy workshops and User Days, maintaining User Requirement Data Bases, and co-designing products and service interfaces with users at national level.

CoCO2 also very much aligns with the European Commission's Green Deal, a very ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition. As stated by the Commission: "Supported by investments in green technologies, sustainable solutions and new businesses, the Green Deal can be a new EU growth strategy. Involvement and commitment of the public and of all stakeholders is crucial to its success." CoCO2's impact and the impact of its successor Copernicus service element will materialize though the support of this transition.

CoCO2 will bring innovation by developing and connecting the various building blocks (observations, emission inventories, modelling and inversion systems) that will form the future monitoring system and exploit synergies and strengths of the various (inverse) modelling methodologies that are already available. However, CoCO2 is not starting from scratch. The proposal is designed to combine and further develop existing capabilities. It will extend the service framework of the Copernicus Atmosphere Monitoring Service, benefit from and link with relevant elements from the Copernicus Climate Change Service, Copernicus Marine Environment Service, Copernicus Land Monitoring Service, and use the developments from existing H2020 projects, most notably CHE and VERIFY. In addition, CoCO2 will closely work with the Integrated Carbon Observation System (ICOS) and the Global Carbon Project (GCP). This liaison is assured by having key CoCO2 partners being deeply involved in ICOS and GCP.

Specific focus points listed in the Work Programme are and the response from the CoCO2 proposal are shown in Table 4.

Table 4: Impacts listed in the work programme

Work Programme Text	Response of the CoCO2 project
The activities should fulfil the technological and scientific needs for the integration of this European end-to-end operational capacity, in particular:	
Contribute to solving scientific issues that are critical to ensure a successful development of the operational system;	In parallel with the development of the core prototype systems, CoCO2 will address various scientific questions, such as CO_2 emissions characterisations (e.g. point emissions, injection height, inventories gridding), global inversion capabilities, and uncertainty representations.
Improve the performance and resolution of regional scale atmospheric transport models;	CoCO2 will employ modelling systems at different scales, from global to local. An important element is to improve the performance of these modelling systems in terms of numerics, transport, and boundary conditions.
Make a significant contribution to helping countries evaluate the effectiveness of their CO_2 emission reduction strategies such as	The main goal of CoCO2 is to build and test the prototype systems, which will deliver the expected contributions from 2026 onwards. CoCO2 will, however, interact with key

those associated with the impact of the Nationally Determined Contributions;	stakeholders at European and national levels to ensure user requirements are well understood and to co-design a portfolio of products and services.
Support the optimal planning of networks of in-situ measurements in coordination with the WMO Integrated Global Observing System (WIGOS) programme, and contribute to develop and validate techniques enabling the quantification of fossil fuel CO_2 emissions;	Using the CO_2 Task Force Green Report on in situ data requirements as a starting point, CoCO2 Work Package 6 will further elaborate these requirements as well as identify the potential data providers to meet the needs of the CoCO2 Integration & attribution systems. Work Package 6 will also explore new measurements techniques and instruments with a particular focus on urban areas and the attribution of anthropogenic emissions to the total observed CO_2 signal. The standardisation of CO_2 observations will interface with the WMO WIGOS via the IG3IS.
Identify the functionalities of a decision support system for monitoring anthropogenic emissions and address the expected capacities suggested by the CO_2 monitoring Task Force;	CoCO2 Work Package 7 will link with local, national and international stakeholders defining the user requirements at all scales in a policy-oriented framework and to co-design a portfolio of products and services. Experience from the VERIFY project in this area will be used to further develop the concept of a decision support system. With the CO_2 Task Force in the role of Advisory Board, this development process will be properly aligned with discussions in the Task Force itself.
Ensure the 'fit for purpose' of the entire system with regard to the expected capabilities;	The fitness-for-purpose of the prototype systems will be continually monitored during the development process. While Work Package 1 - 4 cover the build of this development, Work Package 5 will provide intermediate (showcase) results already for the 1st Global Stocktake in 2023, while Work Package 7 will maintain the discussion gathering user feedback collected in user consultation workshops to enable checks of the fit-for-purpose aspects of the information portfolio. The External Expert Group (see also section 3.2.1) will further advise the consortium on these aspects.

2.1.2 Barriers and Obstacles to overcome

As outlined above, the challenges that CoCO2 is facing are complex. Accurately estimating anthropogenic CO_2 emissions from global to local scales using Earth observation data is a very significant scientific challenge in itself. In addition, the full integration of a consistent emission monitoring system will require the combination of CO_2 data analysis approaches that were developed for different objectives. This implies the need for adaptation to fully exploit the available methodologies. CoCO2 has gathered a consortium that is confident it can support this challenging design phase and will bridge across communities by involving key representatives of all relevant areas in a dialogue that aims at building these connections and synergies through focused innovation.

However, for the specific project's aims there are no barriers and obstacles foreseen, because all the required inputs for the described methodology is readily available. Also, all the computing capacity needed for the fulfilment of CoCO2's objectives has been secured. In addition, because CoCO2 is involving national entities in charge of emission reporting to the UNFCCC to co-design the future portfolio and user interface, there is no immediate barrier in terms of user uptake of the outcomes of the project. The adaption by the European Parliament of the Space Regulation will be decisive for setting up the operational Copernicus CO_2 service element, but this does not directly affect the work described in this proposal.

2.2 Measures to maximise impact

2.2.1 Dissemination and exploitation of results

Dissemination activities are designed around providing/disseminating information to the scientific communities and relevant stakeholders in three areas:

1. Scientific and technical results through
    a. Scientific Publications
    b. Conference Talks
    c. Organised Workshops, providing updates on the project results
    d. Reports to and feedback from Committees and Boards
2. Products through dissemination of
    a. Datasets and accompanying material (e.g. descriptions, meta data)
    b. Algorithms/ Specifications
    c. Graphics and animations
3. Progress information through provision of
    a. Newsletters (digital and print)
    b. Public Deliverables
    c. Dissemination Materials (brochures, posters, flyers)
    d. Website and social media

2.2.1.1 Dissemination of scientific and technical results

Both the scientific and technical achievements and findings within the CoCO2 project will be advertised and disseminated through the project website and portal, which will contain all reports and technical documentation, publications in the peer-reviewed scientific literature, publications in conference proceedings and links to the relevant data portals.

Strong engagement with the academic sector will promote the work performed in CoCO2 and at the same time follow the scientific developments taking place outside the consortium. This exchange of information and knowledge will be realised through attendance of scientific conferences, organisation of sessions devoted to CoCO2 and related topics at relevant scientific conferences (e.g., EGU, Transcom, IG3IS, IWGGMS), and by the general process of CoCO2 scientists attending and presenting seminars and engaging in discussion at universities and research institutes. Scientific results from CoCO2 will also be conveyed to international programmes and bodies such as the Global Climate Observing System (GCOS), Committee on Earth Observation Satellites (CEOS), the World Climate Research Programme (WCRP) and the WMO-IG3IS programme. In this regard, there is also a key role envisaged for the CoCO2 External Expert Group which consists of many European and international experts. Apart from providing feedback on the CoCO2 developments, these experts will also establish the link with many other international initiatives related to the future monitoring of CO_2 emissions. Finally, progress and results will be directly shared with the European Commission and its CO_2 Task Force that supports the Commission with planning the development of a future CO_2 emission monitoring system. The CO_2 Task Force will act at the External Advisory Board for CoCO2. This will directly and indirectly ensure that the advice resulting from the CoCO2 project will inform policy makers in Europe and beyond. The close interaction with the Task Force will also ensure that any guidance coming from it can be taken into account during the CoCO2 project.

2.2.1.2 Dissemination of products

The products of CoCO2 will comprise reports, graphical displays, datasets and improved methods, algorithms and code. All these elements have their own important role. Reports are mostly targeted at informing the Commission and its Task Force on assessments, innovation progress and future directions. Graphical displays, where applicable, are targeted at all users as supportive information for the various model runs, method comparisons, and input datasets. The datasets will also target a wide user community to support them with parallel or alternative studies. Finally, improved methods, algorithms and code are meant to form the basis for follow-on development after the CoCO2 project has finished.

Reports will be openly available from the public pages of the central CoCO2 website. To increase its visibility, the CoCO2 website will be linked on the websites of ECMWF, CAMS, C3S, and other partners.

All mature data products of CoCO2 will be made publicly available to maximize the uptake by the scientific community. It is envisaged to make use of three parallel data portals to ensure full visibility of the datasets. These data portals will be based on the ICOS Carbon portal, the Global Carbon Atlas and the Copernicus Atmosphere Data Store, which is currently being implemented by the Copernicus Atmosphere Monitoring Service (CAMS). The steps

undertaken by CoCO2 towards building a European Platform for Monitoring CO_2 anthropogenic emissions contribute directly to this operational requirement.

2.2.1.3 Dissemination of information on the progress of the project

The CoCO2 website will provide access to information on the progress of the project. All deliverables that are published in the form of reports will be hosted on the website. A news slot on the website will draw attention to highlights such as new data deliveries and reports, eye-catching developments, and so forth. Important information of general interest will be published on the CoCO2 website, including the project status on milestones and deliverables.

2.2.1.4 Exploitation of the products of CoCO2

CoCO2 will use existing modelling and inversion infrastructure (after further improvement where needed) to develop a future emission monitoring system. The important outputs of CoCO2 are therefore the various detailed designs and prototype components. Although various developments within CoCO2 will be based on pre-existing technology and will be realised through developing integrated technology, these developments will be shared publicly through proper documentation, either through public project documents (e.g., the Functional Requirements Specification Documents (FRSDs) in WP5) or through articles in the peer-reviewed literature. Sharing this information publicly will support the implementation of the future Copernicus CO_2 emission monitoring service element, which is normally done through competitive Invitations To Tender. In addition, some data sets will be created, and these will be provided on data servers without any restrictions, as described above. Therefore, the wider science community as well as the policy makers will be exploitation targets. Science communities include those related to CO_2 monitoring, atmospheric monitoring, as well as the wider weather and climate modelling communities. Policy makers include those on regional, national as well as European level. This is especially relevant for any parallel or future studies related to the development of the future CO_2 emission monitoring system as initiated by the European Commission and/or the European Space Agency. There may in addition be some exploitation of CoCO2 products in the other activities undertaken by partners in the consortium operating CoCO2, in particular at the national level.

2.2.1.5 Management of intellectual property rights

Intellectual property rights will be managed according to the Grant Agreement with the European Commission and the Consortium Agreement covering CoCO2. As noted above, all rights related to CoCO2's data products will follow the Copernicus data policy. Software rights will require careful definition due to the extensive pre-existing know-how (the “background” in H2020 terminology) contained in the major model and data assimilation elements on which CoCO2 is based. These software elements are already subject to multiple ownership rights in several instances, so experience exists within the consortium to resolve any issues that might arise.

2.2.2 Communication activities

Communicating effectively and efficiently is an important factor in realising the impact of the CoCO2 project. It will help the project to reach the right (wider) audience with the right message.

CoCO2 communication activities will address the interaction with current stakeholders and promote the project to potential new stakeholders and the general public. The CoCO2 website and data portals will be the main repositories for the project documentation and related news.

Project description, news items, listing of main events, description of results and products will all be covered through the CoCO2 website. The website will be maintained by ECMWF with input from the consortium partners.

Defining the target audience is important to produce the impact outside CoCO2 and tailor the information provided accordingly. The target audiences identified for CoCO2 include the European Commission (also outside DG-DEFIS), EU Member States, the CO_2 Task Force, industry, satellite agencies and technology providers, science community outside the consortium, climate community, amongst others.

CoCO2 will also align its communication activities with the general communication around the future Copernicus CO_2 service element, as things develop. This involves the European Commission, ECMWF, ESA and EUMETSAT. Key results from CoCO2 can in particular be disseminated through ECMWF Copernicus communication efforts, resulting in very substantial additional reach in press, media and social media.

CoCO2 will utilise expert communicators through the ECMWF communications section with support from external contractors on the communication, including graphic design, as well as dissemination aspects to ensure a high visibility of the project in the community and wider audience, promoting the added value of this European

collaboration. Professional communication support will also help to clearly convey the sometimes-complex findings of CoCO2 to a wider audience.

Target audience	Communication/ Dissemination Means	Responsibility
European Commission, CO_2 Task Force, EU Member States (incl. policy makers)	▪ Dissemination: – Workshops and resulting reports – Policy briefs ▪ Communication: – Project news/ Newsletters – Tailored updates on the results – CoCO2 website	ECMWF with support from all partners
Scientific community	▪ Dissemination: – Peer-reviewed scientific papers – CoCO2 data portal – Workshops – Conferences ▪ Communication – Newsletters	All partners
Satellite agencies, technology providers	▪ Dissemination – CoCO2 data portal ▪ Communication – Targeted publication material – Link with relevant H2020 and other initiatives – Representation at relevant conferences and fairs – Newsletters	All partners
General public	▪ Communication – General Information Material – CoCO2 website – Project news/ Newsletters – Dissemination Material – Press releases	ECMWF with support from all partners and in close collaboration with the European Commission (REA and DG-DEFIS).

3 Implementation

3.1 Work plan – Work packages and deliverables

3.1.1 Overall Work Plan

CoCO2 has been designed to support the development of a prototype system for the Copernicus CO2MVS capacity taking into account the guidance from the European Commission and its CO_2 Task Force. The proposed work plan therefore reflects the further development of all the building blocks of the future system, as they were identified in the various reports of the CO_2 Task Force and developed by the CO_2 Human Emission project (CHE 2017-2020). Figure 4 shows a version of the schematic that includes the main building blocks of the Copernicus CO2MVS with the additional component of the Decision Support system, recommended by the CO_2 Task Force 2019 action. The mapping into the CoCO2 work packages is shown within the Figure.

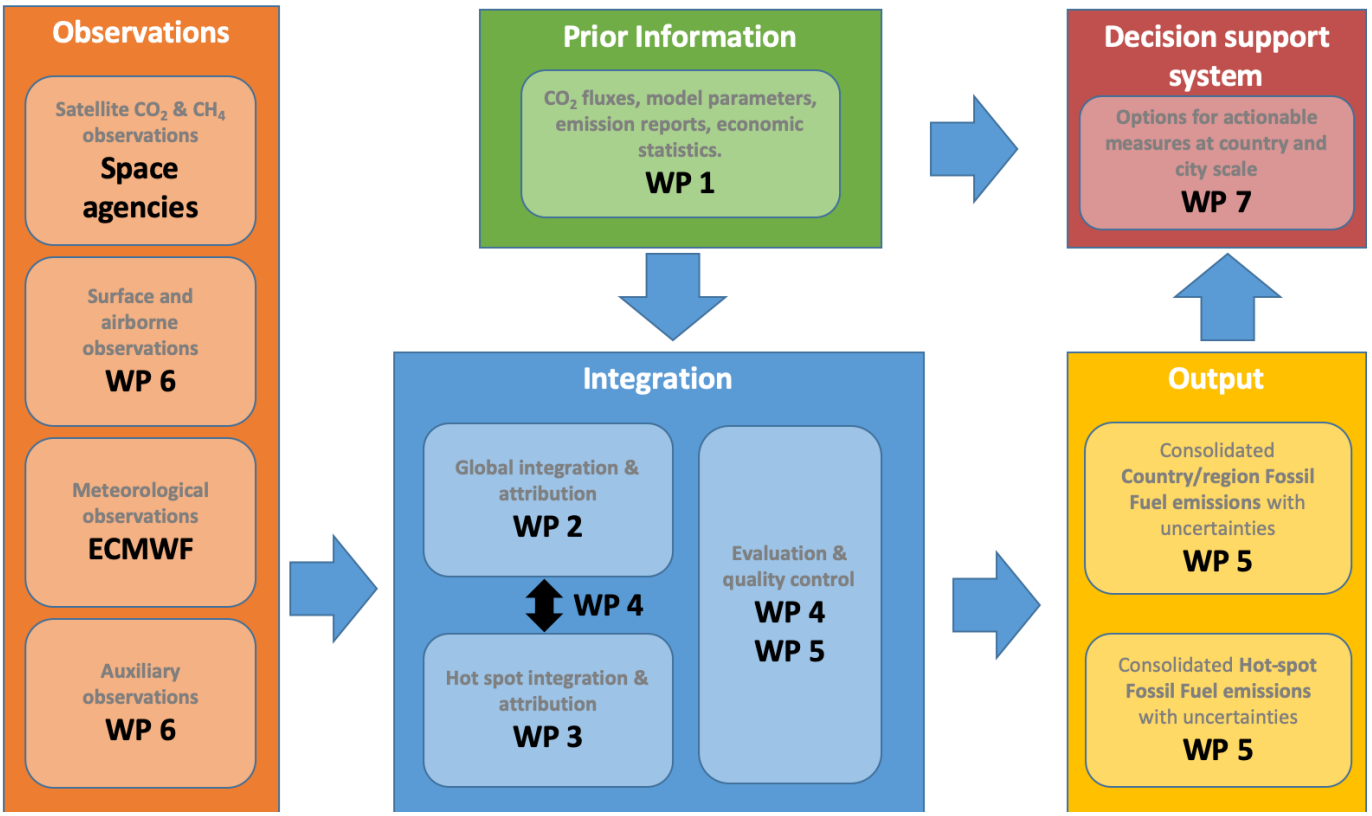
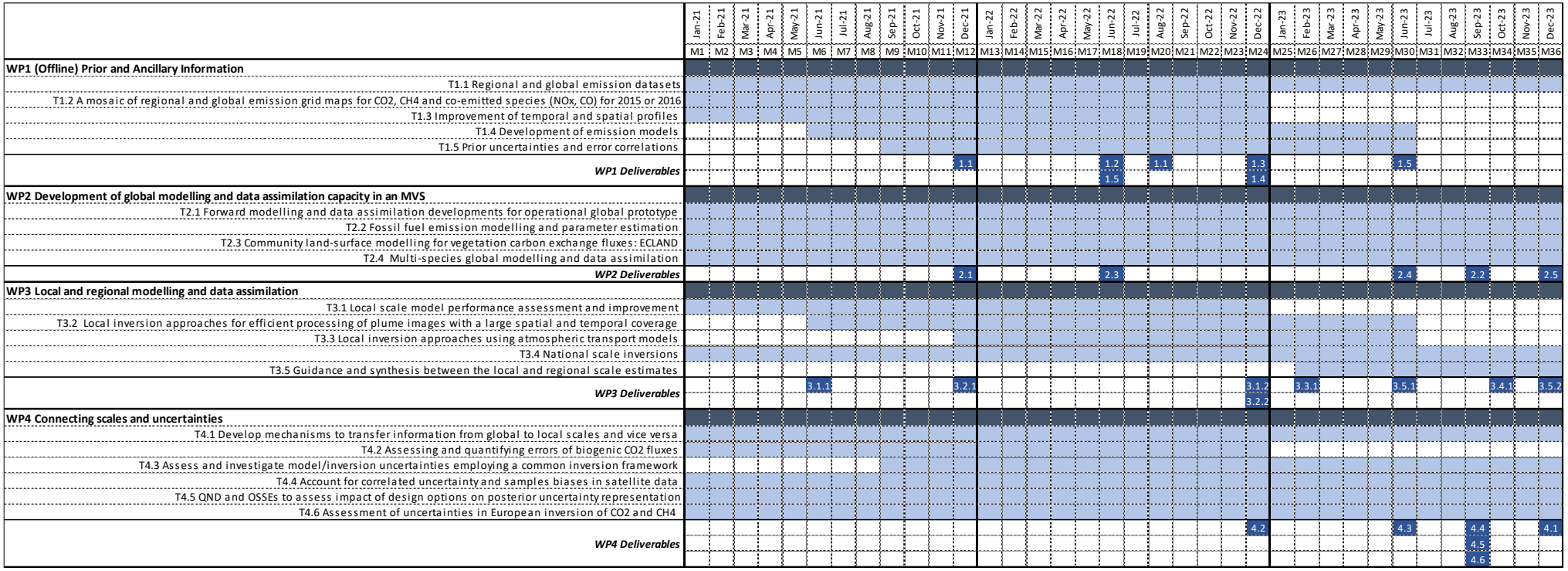
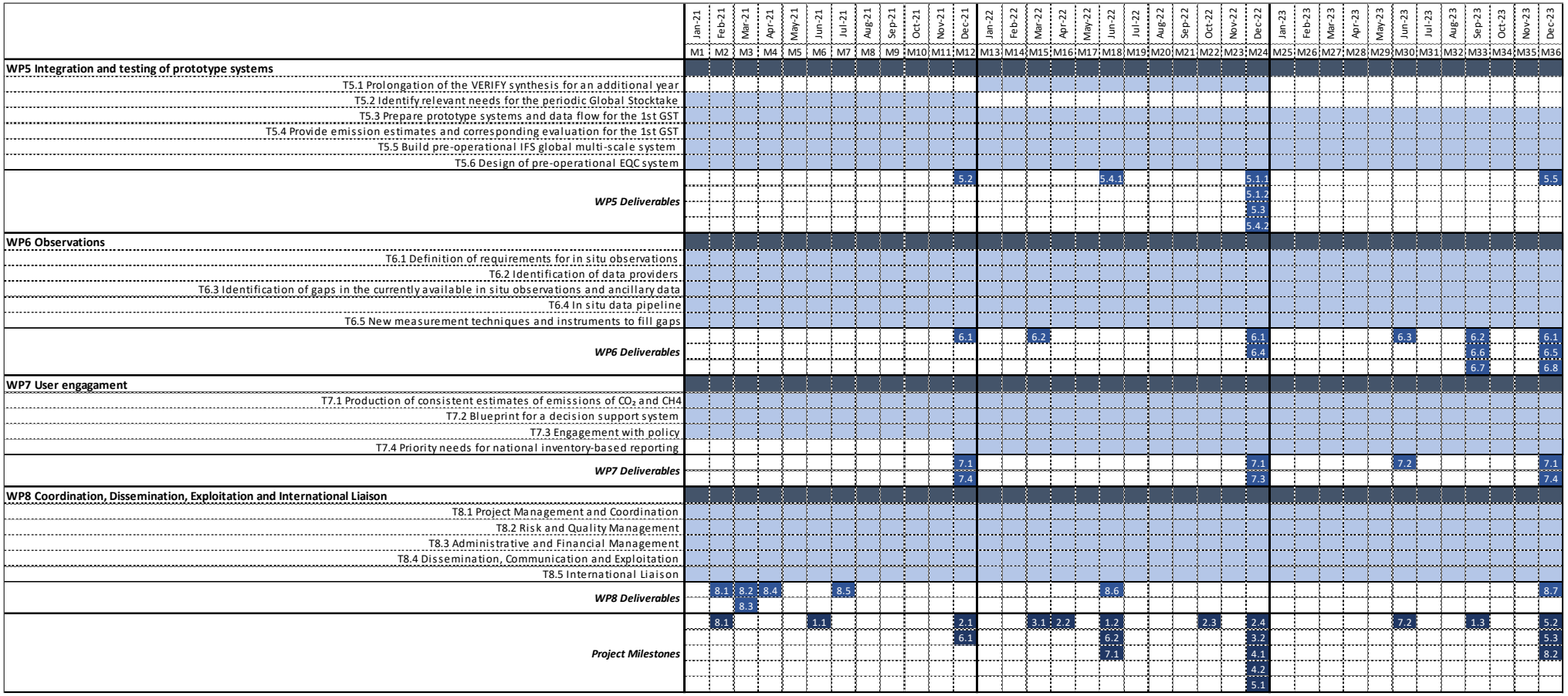


Figure 4: CoCO2 WP mapping

The work package breakdown structure reflects the priorities of the research and development activities that were identified in Other Action 13 of the Horizon 2020 Work Programme 2018-2020 and it is articulated in eight work packages. These work packages were already summarized in Section 1.3.2 on Methodology and full details are provided hereafter in the form of detailed work package tables. While the work package tables are very helpful to illustrate the extent and timing of the work performed in those work packages, they are sometimes less insightful in terms of showing the interactions between the work packages. However, from the diagram in Figure 4 it is clear that the blue arrows are key to the functioning of the overall CO2MVS capacity and they are therefore considered critical in the workplan for CoCO2 as well. The CoCO2 coordination team, in collaboration with the Work package leaders, will therefore monitor these interactions very closely for the duration of the project.

3.1.2 Timing of work packages





3.1.3 Table 3.1 a: Work package description

Work package number	1			Lead beneficiary					TNO				
Work package title	(Offline) Prior and Ancillary Information												
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	12	0	0	13	10	6	20.5	9	0	0	0	27.5	4
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	Cyl	TOTAL
Person months/ participant:	0	23	0	0	0	0	4	24	0	0	0	13	166
Start month	1				End month				36				

Objectives

- Deliver global high-resolution bottom-up anthropogenic fossil fuel emission estimates of CO_2 and co-emitted tracers per sector up to yr-1, with updates at a two/three-year interval. Focus years will be 2016 for first-set of emissions and 2021 for the second-set.
- Provide a biogenic fluxes dataset (ocean, biosphere) for the years 2016 and 2021
- Provide the space-time distribution of fossil CO_2 and anthropogenic bioCO_2 fluxes including quantification of the CO_2 released by human and animal respiration and combustion of biofuels.
- Demonstrate new methods to describe spatial and temporal emission variations in more detail using novel datasets including the land use changes
- Develop a fossil fuel emission and uncertainty model and harmonize the description of the emission datasets for implementation in a data assimilation system
- Evaluate uncertainties in the emission inventories/models, including error correlations, and develop a prototype tool to translate this into covariance matrices for data assimilation studies

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP1 is led by Hugo Denier van der Gon (TNO) and Greet Janssens-Maenhout (JRC).

The overall aim of WP1 is to provide state-of-the-art emission and uncertainty data as input for WP2 (globally) and WP3 (locally) and the CO2MVS in general and to develop new methodologies to improve the emission and uncertainty data. Data assimilation efforts in WP2 and WP3 require prior information on emissions and a quantification of the uncertainty in these emissions. Moreover, spatially explicit uncertainty information supports the design of an observational network in WP4. The main limitation of the current emission inventories is that they are based on data that comes available with a lag of at least 2 years. Therefore, the ultimate way forward is to model emissions using other sources of data that are available in near real-time, which is one of the focus points of WP1. In addition, the uncertainty quantification of emissions is still under development. Methods have to be developed to provide the uncertainty information with the required level of detail, for example describing (currently unknown) error correlations between co-emitted species or source sectors. The initial focus on 2016 ensures the connection with H2020-CHE, is the 5-years step to the first inventory year of the Global Stocktake and enables us to use the previously realised work to assess innovative representation of the emissions.

T1.1 Regional and global emission datasets (M1-36) (TNO, BSC, Cyl, CNRS-LA, MPG, MOi, ECMWF, CEA, CICERO)

T1.1.a European and global (fossil fuel and anthropogenic bio) emission datasets up to yr-1

A regional and global emission dataset is made that covers all relevant species and sectors, except the land-use, land-use change and forestry sector (covered in T1.1.b). Our first target year is 2016 based upon available

products but expanding the global CO_2 grids with co-emitted species. Next, we will start preparation for a 2021 dataset. The emission dataset will be based on a consistent bottom-up approach at regional or global scale to ensure consistency and transparency e.g. as is done in Emission Database for Global Atmospheric Research (EDGAR), TNO-GHGco (H2020-CHE / H2020-VERIFY). Sub-tasks are:

- Description and analysis of the close to present year (year-1) datasets (EDGAR, GCP, BP (British Petrol), etc.), add co-emitted species in a practical (budget-constrained) manner and in a later stage using the emission modelling of T1.4; including harmonization with CAMS-GLOB (CAMS Global Emissions) for selected sources like international shipping
- Updated high-resolution European datasets in cooperation with CAMS81. [resolution 0.1 x 0.05, point sources at exact location] A regional zoom version at 1 x1 km for north-west EU will be made for use in WP3 (Task 3.4); a bottom-up test case for Cyprus by producing a detailed statistical first-guess spatially disaggregated dataset for CO_2 emissions on a sector-based analysis. Existing and new CO_2 observational data over the island and inverse modelling to provide the first validated estimates of optimised emissions for the country (which will be delivered to T5.1).
- Estimate the anthropogenic bioCO_2 emission component for uptake in the atmospheric inversions. This includes the source term when crop products are used by humans and livestock and wood is burned for energy or decays in product pools and the sink term when biomass is grown and harvested for the purpose of feeding animals and humans or for delivering biofuels. This will be done by combining activity data of biofuel use and burning and gridded land use datasets on forest plantations and crop yields.
- Addressing the issue of potential double counting between WP1 products and products from e.g. GFAS and CAMS-81 which partly include anthropogenic bioCO_2 emissions such as agricultural waste burning (harmonize / analyse the vegetation maps used in both projects for attribution of emissions).

T1.1.b Regional and global biosphere and ocean fluxes

In this task, the focus is on providing CO_2 emissions from land-use, land-use change and forestry (LULUCF), from the biosphere and from the oceans. The LULUCF sector has become highly relevant to obtain carbon neutrality. National carbon stock changes have to be reported based on geospatial data (such as Copernicus). For Europe, this carbon stock change and corresponding emissions are calculated under the VERIFY Project using different methods. Moreover, the IFS model of ECMWF needs both anthropogenic and natural emissions and sinks. While the interest goes for the anthropogenic part, the natural emissions provide the largest variation of the CO_2 profile in the atmosphere and should therefore be included in data assimilation studies. Here, the temporal and spatial distribution are inherent part of the dataset itself. Sub-tasks are:

- Create biospheric fluxes (MPG) for 2016 and 2021 (based on CHE WP3). European based on VPRM at 1 x1 km resolution; Global scale: provision of FLUXCOM product (data-driven biogenic CO2 fluxes)
- Create prior ocean fluxes (Mercator-Ocean) for 2016 and 2021. The objective of this sub-task is to improve the sea-air CO2 fluxes derived from the global assimilative ocean model of the Copernicus Marine Service (CMEMS), by assimilating pCO2 (partial pressure of CO_2 in the ocean) maps and BGC Argo data. As the number of Argo floats that carry the full suite of BGC sensors is limited, the purpose is to use data sets that are BGC Argo profile data reconstructed through neural network with T, S and O2 Argo data only. Error statistics corresponding to the ocean CO2 flux will be also provided. We will also assess our ocean fluxes with CMEMS observation-based products. A dataset of sea-air CO2 flux is already available for 2016. We will provide improved dataset for 2016 and 2021 with assimilation of pCO2 maps and BGC-Argo observations
- Explore the quantification of CO_2 fluxes / emissions due to land-use change. Here we will explore the use of the products of the Copernicus Global Land Service (CGLS), which has developed a global land cover component for 2015 (global land cover dataset at 100m resolution which is also foreseen for 2016-2019). Based on this, the product will be extended with land cover change percentage in the next round of land cover maps (for 2016, 2017, 2018 and 2019) using the very same methodology. The backward reconstruction of land use/cover changes will be done using the HILDA+ data set, based on the Copernicus Climate Change Service (C3S) dataset as reprocessed by the ESA Climate Change Initiative (ESA-CCI) back to 1990 (with annual steps). Quantification of fluxes from the Agriculture, Forestry and Land use (AFOLU) sector is too big a task for WP1, but we will invest in adding CO_2 fluxes to the Land use change indices produced by CGLS to learn and make progress.

- Estimate error variances and spatio-temporal correlations in the estimated biospheric fluxes (in cooperation with WP2 and WP4).

T1.2 A mosaic of regional and global emission grid maps for CO_2, CH_4 and co-emitted species (NOx, CO) for 2015 or 2016 (M1-24) (JRC, BSC, CNRS-LA, TNO)

Gridded emission inventories are available for different regions, at different resolutions, and using different methodologies. Parallel and in cooperation with Task 1.1 we will develop a mosaic inventory to cover the entire globe for CO_2 and co-emitted species. This approach nests regional inventories (high-quality, high-resolution, limited coverage) in a base inventory (more generic, global coverage), that was used in the preceding project CHE for 2015. Regional inventories are embedded using their own spatial distribution and emission calculation, because they often use more detailed spatial disaggregation and country-specific emission information. This is a compromise between quality and transparency. This dataset will encompass primarily official and/or widely used regional emission grid maps, it can be used as a global baseline emission inventory, which is regionally accepted as a reference. To create support and buy-in from various partners we intend to lead / start an international working group of the Global Emissions InitiAtive (GEIA) for this endeavour making it a community effort. WP1 will facilitate the construction of the mosaic through the High-Elective Resolution Modelling Emissions System (HERMES) allowing the combination of regional emission inventories in a transparent and flexible way. The year 2015 or 2016 will be decided upon data availability with a preference for 2016. The dataset will be supplied to WP2 T2.1a for targeted sensitivity runs. Sub-tasks are:

- Formatting and pre-processing of the selected inventories following the HERMES input requirements
- Creation of configuration files to run the model and addressing the masking in country border cells
- Coordination of tasks and production with CAMS-81 and GEIA including timeline for international exchange
- Extensive analysis of the combined dataset to prevent double-counting or missing sources, which also provides information for the uncertainty analysis in Task 1.5.

CCDAS and FFDAS (see WP4) will be used to derive more recent years for the mosaic inventory needed by other WPs and aligning with the 7 sectorial emissions identified in Choulga et al. (2020).

T1.3 Improvement of temporal and spatial profiles (M1-24) (BSC, TNO, CyI)

Main focus will be on CO2 and co-emitted species (NOx, CO), where/when possible we will also address CH_4.

T1.3.a Temporal profiles Current temporal profiles delivered with emission inventories are often generic and based on long-term average activity data for a limited domain without accounting for inter-annual variation and/or climate dependencies. Temporal variation is also important for the point sources and directly coupled to the activity of the plant (e.g. the power level variation over time for the power plants). Also, for line sources, the temporal variation is significant, but entangled with the distribution along the network of lines. Several industrial facilities in the middle-east will be used as case studies to provide temporal profiles of the point source data based on modelling results and the availability of continuous or campaign-based concentration measurements by the Cyprus Institute (CyI). With this task, we aim to improve the temporal profiles of key sectors using activity data or proxies with high temporal resolution (hourly to daily) and assess, where possible, differences between regions and/or species. For diffusive sources, such as residential heating, the temporal and spatial distribution cannot be disentangled. The use of meteorological data (e.g. heating degree days) is desired for distributing the residential heating emissions in space and time. We attempt to create a globally consistent set of temporal profiles and, where needed/possible, provide regional updates for EU28. The updated temporal profiles will be part of the final submission under Task 1.1 and Task 1.4.

T1.3.b *Improvement of spatial representation* A correct representation of the spatial distribution of emissions is important for data assimilation efforts, because this strongly affects the simulated concentrations at (sub)urban measurement sites and the simulation of plumes at industrial facilities detected by satellites. The major improvement beyond the current 0.1° x 0.1° resolution of e.g. EDGAR and CAMS-GLOB will come from inclusion of point sources at their exact location. This will make the point source emissions resolution independent, regardless of the resolution of the atmospheric (inversion) model. Moreover, it allows for adding emission height and time profiles if we keep a point source identifier in the gridded data (as is done in CAMS-REG (CAMS Regional Emissions)). In this task, we will start the construction of a global point source database giving priority from high to low total emission. We will combine different approaches working on the one hand from what is currently publicly available, and on the other hand from novel techniques like image recognition

and deep learning to derive new datasets from sentinel 2 data. These updates will be part of the final submission under Task 1.1 and Task 1.4. Sub-tasks for task 1.3.a and 1.3.b are:

- Gather temporal profiles (also from the Copernicus CAMS products) and assess the periodicity for deriving generic near real time setup. Test various approaches including the use of modelling the temporal profiles inside the atmospheric models (links to T1.4)
- Assess the use of gridded data to describe the spatial distribution of emissions and options to connect temporal profiles on a GIS basis – e.g. using elevation or climate zones.
- Update the spatial gridding of the base inventory
- Develop a methodology to recognize point sources using satellite imagery, cross-check and update the known point source locations. Validate the new additional point sources locations (with WP3).
- A case study for both the temporal profiles and completeness/validation of the point source data will be done for the Middle east (Egypt, Lebanon, ...).
- Analysis of the usefulness of emission clumps, responsible for aggregated emission plumes (Y. Wang et al., 2019)

T1.4 Development of emission models (M6-M30) (ULUND, ilab, TNO)

T1.4.a Develop global fossil fuel emission model for data assimilation purposes (ULUND, iLab, TNO…)

This task aims at developing a global fossil fuel emission model based on a simple equation and generally available parameters. A gridded emission map is built from a wide range of data sources and is in fact a simple mathematical model. Normally, the product (i.e. a gridded emission map) is optimized with a data assimilation system. However, there is interest in optimizing the emission model parameters for few sectors, which requires a careful description and harmonization of this model in a way that can be used in the data assimilation framework. An example is the Kaya identity, which can be used to determine country-level CO_2 emissions based on population, Gross Domestic Product (GDP) and energy consumption. In this task, a similar approach is used to calculate country-level emissions using generic data, where possible updated with country-specific data. Whereas the Kaya identity is unable to explain year-to-year variations due to e.g. variable weather conditions, in this task temperature dependencies are taken into account. Sub-tasks are:

- Sensitivity analysis of the non-point source variation on the result of the global dynamic emissions model CCFFDAS (Carbon Cycle and Fossil Fuel Data Assimilation System).
- Prioritisation of emission sources for a global dynamic emission model
- Gather global data
- Create an equation to calculate country-level emissions globally, using few parameters that can be optimized in a global data assimilation system
- Develop a methodology to take into account temperature dependencies
- Develop and distribute the adjoint of the emission model for use in variational inversion systems such as the global IFS 4DVar prototype.

This task will provide a simple emission model, which is tested in a global data assimilation system (WP2). The development of an emission model is also favourable for validation purposes as it provides a prior independent from the inventories and will further support modelling data assimilation tests (WP2, WP3, WP4).

T1.4.b Develop regional fossil fuel emission model for data assimilation purposes

This task aims at developing a regional fossil fuel emission model. In contrast to task 1.4.a, this emission model is intended to use local, detailed data to reach better quality and is therefore developed for a selected region (*one country) as input for WP4 (T4.5)*. Where possible near real-time data will be used, such as traffic counts, which provide information about emissions at a high spatial and temporal resolution. Eventually, we would like to use such activity data directly to predict emissions in near real-time (i.e. a dynamic emission model). This requires establishing clear relationships between the activity and the emissions, which is very challenging. Moreover, local calculations are not always consistent with the national inventory. Nevertheless, such dynamic model is a promising addition to the 'static' emission map for local regional studies and this task will provide a first step towards a dynamic emission model. Sub-tasks are:

- Gather regional data, preferably at high spatial and temporal resolution with special attention to point sources and determine the relationship between the activity data and yearly, country-level emissions *(this is the non-dynamic approach)*
- Develop equations to describe the relationship between the activity data and emissions at high temporal resolution (*dynamic approach)* for few important sectors
- Develop and distribute the adjoint of the emission model for use in variational inversion systems.

This task in combination with T4.5 will provide a detailed, high-resolution (possibly dynamic) emission model, which is tested in a local data assimilation system (WP3).

T1.5 Prior uncertainties and error correlations (M9-M30) (JRC, ECMWF, TNO, Lund)

In addition to the emissions, their uncertainties are required as prior information for data assimilation studies. Efforts have been made in CHE to quantify these uncertainties and in this task, we will elaborate on this. The focus will be on describing error correlations between sub-sectors and/or species, but also on describing spatial and temporal correlations or correlation length scales. Sub-tasks are:

- Create a globally consistent set of uncertainties in the underlying data used to build the emission database (based on an update of dataset of CHE.WP3 for 2015 of Choulga et al. (2020 in draft) to 2016)
- Create a more detailed set of uncertainties for EU27+UK and for Europe's neighbourhood (Middle East) using country-specific data and including emission factor ratios of co-emitted species NO_2/CO_2, CO/CO_2, as well as space borne and in-situ atmospheric measurements.
- Update uncertainties in the newly developed spatial proxies and temporal profiles
- Assess error correlations between sub-sectors and species
- Assess spatial and temporal correlation length scales for key sectors and species and provide a spatially explicit uncertainty assessment as input for WP2 and WP4
- Use emission models developed in 1.4 to provide emission error covariance statistics based on Monte-Carlo simulation with relevant parameter perturbations. Those statistics will be used to define prior information in direct emission inversion systems.
- Build a prototype tool to translate the database with uncertainties and correlations into a covariance matrix for WP2 and WP3 (starting from the deliverable D3.3.2 in CHE)

Consistency is ensured by focusing on the 2016 data set initially to characterise error correlations (WP4) and to update the results for enhancing the quality and validity of the uncertainty for use with the 2021 emission inventory in preparation for the GST (WP5).

Deliverables (brief description and month of delivery)

D1.1 Prior Emission Dataset (PED) 2016 and 2021 (Lead: TNO; M12 (2016), M20 (2021); D, R; PU) – PART I: ANTHROPOGENIC: Global and regional prior emission datasets of ffCO2 and bioCO2 and co-emitted species for 2016 and 2021. Resolution Global 0.1° x 0.1°; European 0.1° x 0.05°; point sources at exact location. A regional zoom version for NW Europe (1/60° x 1/120°) for WP3 (Task 3.4). This is accompanied by a Documentation Report including analysis of changes 2021-2016, datasets of NO_2/CO_2 (and CO/CO_2) ratios; PART II: BIOGENIC: Global and regional prior emission datasets for biogenic fluxes (VPRM Europe 1x1 km; Global at least 0.5° x 0.5° and hourly; M20 product aims for 0.05°x 0.05°and hourly); Ocean fluxes (0.25° x 0.25°, daily/monthly mean); LULUCF (0.1° x 0.1°). The Biogenic dataset is accompanied by a Documentation Report describing the prior biogenic emission dataset for 2016 and 2021.

D1.2 Global mosaic PED 2015 or 2016 (Lead: JRC; M18; D, R; PU) - Global mosaic of ffCO2 and NO_2 emission datasets at 0.1° x 0.1° resolution for the year 2015 or 2016, based on regional datasets provided by international partners of GEIA, accompanied by a report documenting the global mosaic prior emission datasets of ffCO2, based on regional datasets provided by international partners of GEIA.

D1.3 Documentation of new temporal and spatial profiles including a global point source database (Lead: BSC; M24; D, R; PU) - Improved temporal profiles that enable to disaggregate prior emissions and an emission height profile by sector for point sources accompanied by a documentation report including further research needs

D1.4 Emission model for Data Assimilation (DA) (Lead: TNO/ULUND, M24, C/OTHER, PU) - Global ffCO2 emission model with focus 2020-2021 using fast-track approach and modelling. Regional FFDAS for a specified country using high-resolution activity data and modelling.

D1.5 PED uncertainty 2016 and 2021 and uncertainties based on Monte Carlo simulation using the emission model from D1.4 (Lead: ECMWF/JRC; M18, M30; D, R; PU) - Global emission uncertainties for 2016, 2021 respectively using updated uncertainty characterisation for ffCO2 and bioCO2 global emission gridmaps, accompanied by a report documenting the uncertainties of ffCO2 and bioCO2 emission gridmaps with special focus on the spatial distribution sensitivity, respecting sector-specific constraints.

Partner Roles	
TNO	• TNO will co-lead WP1 and lead task 1.1. It will develop the regional inventory (under T1.1.a) and contribute to the global inventory development. It will contribute to T1.2 and its synthesis. • Based on its T1.1.a product it will contribute to T1.2 and its synthesis. In T1.3b it will initiate the development of a global point source data base together with T1.3 partners. • It will contribute to lead task 1.4b (regional FFDAS) and under T1.5 expand the uncertainty and error correlations for the regional domain selected in WP3 for CO_2, NO_x and CO.
BSC	• Contribute to the emission datasets developed under Task 1.1. • Contribute to the combination of regional emission inventories and the development of a mosaic of fossil emission datasets under task 1.2 by using the its in-house HERMES emission modelling tool. Parallel, BSC will also contribute to the emission datasets developed under Task 1.1. • Moreover, BSC will lead the task 1.3.a on improving emission temporal profiles using activity and meteorological data in cooperation with CAMS81 and will also provide expert knowledge and methodology for the improvement of the spatial proxies for mapping emissions (task 1.3.b).
JRC	• co-lead WP1 and link with WP4 (for the uncertainties, based on the work in CHE.WP3) and with WP7 (to tailor CoCO2 products to the policy needs of DG CLIMA) as co-chair of the CO2 Monitoring Task Force, and JRC representative in DG CLIMA's Climate Change Committee Working Group I (with the National Inventory Agencies). • contribute to Task 1.2 the global mosaic by reaching out via a special working group of the Global Emissions Initiative (GEIA) on Greenhouse Gas Monitoring and Verification to the international community and bridging inventory compilers and satellite experts. • contribute to Task 1.5, based on experience on uncertainties trade-off for fossil emissions of the CHE project (WP3, Task 3.2), assessing spatio-temporal representativeness of provided profiles
ECMWF	• contribute to Task 1.4 and guide the emissions model, such that it is suitable for integration in the data assimilation tools of ECMWF • contribute to Task 1.5 and guide the uncertainty and covariance matrix such that it is suitable for ECMWF's IFS model
CNRS-LA	• Provide support on development of global anthropogenic inventories based on their CAMS-GLOB-ANT product and the data available in ECCAD and Copernicus CLMS. • Establish links with the international AMIGO (Analysis of eMIssions usinG Observations) project of the International Global Atmospheric Chemistry (IGAC) project where uncertainties on emissions are quantified and evaluated, using satellite and ground-based observations.
iLab/ ULUND	• Implement and test models for sectorial fossil fuel emissions based on the CCFFDAS approach, in close collaboration with TNO and JRC (T1.4).
MOi	Will contribute to Task 1.1: • Assess/review the quality of CMEMS model derived air/sea CO2 fluxes and sensitivity to physics and bio (satellite ocean colour/Chl-a from S3 and other sensors) data assimilation incl. the comparison with CMEMS observation (and others) based products (T0 - T0+ 6months) • The development of a new data assimilation system for Argo BGC (and other in-situ data / SOCAT/GLODAP) and satellite Chl-a data focused on a better reconstruction of air/sea CO2 fluxes (pCO2) and their errors (T0 - T0 + 18 months). • Synthesis of results and recommendations/roadmap for the provision & use of CMEMS air/sea CO2 fluxes in the Copernicus CO2 monitoring service (T0+18 months - T0+24 months)

	• Quantify errors associated to simulated ocean fluxes
MPG	• Will lead the activities on biospheric fluxes described in T1.1.b and provide a full update of the global biospheric fluxes deliverable of the CHE (WP3, Task 3.1) project, with spatio-temporal disaggregation and uncertainties. • Also, hourly fluxes at 1-km resolution for the European domain will be provided for the years 2016 and 2021 with the VPRM model.
CICERO	• Contribute to activities in Task 1.1, in particular, on updates to yr-1 and consistency with datasets in other projects (VERIFY, Global Carbon Budget). Furthermore, based on these data CICERO will help with the development of monthly (or better) profiles of ffCO2.
CyI	• Contribute to Task 1.1 with a test case over Cyprus. For this task, we will use existing and new CO2 observational data over the island and inverse modelling techniques to provide the first validated estimates of optimised emissions for the country. • Contribute to Task 1.3, using several industrial facilities as case studies to provide temporal profiles of the point source data, based on modelling results and the availability of continuous or campaign-based concentration measurements (in Cairo 2020 and Beirut 2014 and the Arabian Basin shipping campaign 2017 (https://usrl.cyi.ac.cy/?page_id=2048), planned measurement campaigns in the Gulf region around oil facilities (META-Sat ESA PECS project).
CEA	• Lead the activities on biofuel inventory described in T1.1.a

Work package number	2		**Lead beneficiary**						10 WU				
Work package title	Development of global modelling and data assimilation capacity in an MVS												
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	45	1	1	0	4	2	0	7	0	24	0	6.5	0
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	**TOTAL**
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	CyI	
Person months/ participant:	0	0	0	5.5	0	10	3	0	17	4	27	0	**156**
Start month	1				**End month**					36			

Objectives

- Provide research and development support for implementation of the prototype global CO_2 monitoring system based on the IFS.
- Develop and evaluate different global modelling approaches for anthropogenic and biogenic CO_2, improve global transport, incorporate consistent uncertainty estimates.
- Develop fossil fuel emission and biogenic flux process modelling within a community model framework where all the model developments can be transferred to the global CO2MVS prototype and tested in global nature run.
- Move towards process- and regional- specific attribution capacity through multi-tracer data assimilation
- Focus will be on 2016 for the first-set of simulations and 2021 for the second-set in line with GST period.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP2 is led by Wouter Peters (Wageningen University) and Anna Agustí-Panareda (ECMWF).

The Paris Agreement requires a global effort based on transparency and consistency in the reporting of the CO_2 emissions at national scale. The focus of this work package is to support the development of the CO2MVS at global scale building on the existing capacity developed in CHE, VERIFY, CAMS, CMEMS and CEMS. The WP will

deliver a system that can provide information of CO_2 surface exchange on a near-real time basis, as well as in a longer-term (re-analysis) mode for the evaluation trends to support the Global Stocktake (GST). The core of this system is the global Integrated Forecast System (IFS) at ECMWF, augmented with a number of new capacities as detailed below, and following the recommendations made by the series of CHE Interim Reports, as well as the EU's CO_2 Red Report from 2017.

Tasks will focus on data assimilation capacity (Task 2.1), disentangling anthropogenic emissions (Task 2.2) from natural carbon exchange (T2.3), and the use of multi-species constraints (T2.4) for improved attribution of CO_2 signals to individual processes (e.g., land-use change), sectors (e.g., shipping), or actors (e.g. power plants). Each task is connected to activities in the other Work Packages as follows:

- Task 2.1 provides model boundary conditions for regional and national CO2MVS systems in WP3, model-sampled CO2M columns for uncertainty assessments in WP4. This activity also provides data assimilation research and development support to build the pre-operational CO2MVS prototype in WP5 and contributes to the provision of products for the first Global Stocktake in WP5.
- Task 2.2 implements fossil fuel product developments achieved under WP1 in the global prototype CO2MVS, and enables the use of local observation networks designed in WP6
- Task 2.3 leads to a community land-surface modelling system for global, regional, and national CO2MVS applications developed under WP3, and takes advantage of the land-surface flux benchmarking capacity developed under WP4
- Task 2.4 integrates with the local plume modelling and chemical conversions of trace gases investigated in WP3, it leverages emission ratio data developed under WP1, and builds on uncertainty assessment of satellite products done under WP4

We furthermore note that all Deliverables in Work Package 2 are aimed to directly support the development of the global IFS prototype system, to be ready for the 2023 GST.

T2.1 Forward modelling and data assimilation developments for operational global prototype (Lead: ECMWF, M1-M36)

The development of the CO2MVS relies on the integration of the prior information (WP1) and the observations with a transport model into a Data Assimilation (DA) system. The CO2MVS will be embedded in the Integrated Forecasting System (IFS) at ECMWF, but will rely on research, development and benchmarking based on other models and DA systems. There are still technical aspects that need to be developed, implemented and tested both in transport and data assimilation (see subtasks below) using in situ and ancillary observations provided by WP6. A demonstration of the integration of the new developments in the transport model (T2.1b) and prior fluxes (T2.2, T2.3) will be performed with nature runs at 9km resolution (e.g., Agusti-Panareda et al., 2019) and an ensemble of simulations at 25km resolution (e.g., McNorton et al., 2020). The implementation of the CO2MVS will be tested using satellite observations of CH_4, CO and NO_2 for 2016 and 2021 in accordance with an evaluation protocol defined in WP5 (T5.5).

T2.1a Production of nature runs and benchmarking of new modelling capacity in the global prototype
This task will test the integration of the improvements in anthropogenic emissions and prior biogenic fluxes (provided by WP1, T2.2, T2.3) with their respective uncertainties together with the improvements in the forward transport model (T2.1b). The resulting simulations will be a follow on from the CHE nature runs, focusing on 2016 and extending to 2021. Benchmark simulations will be performed at low horizontal resolution (25km) for 2016 and 2021 with the purpose of informing the best choice for anthropogenic emissions and ocean fluxes. An ensemble of simulations will provide further uncertainty estimates in the atmospheric concentrations. The best datasets and performing modelling approaches will be used to produce high resolution nature runs for the GST reference years of 2016 and 2021. A few months will be selected to perform high resolution simulations with full chemistry. The nature runs will provide boundary conditions for regional models in WP3 and support the simulation of CO2M observations for data assimilation sensitivity studies in collaboration with ESA. In particular, the following products will be made available:

- Global high-resolution nature run for 2016 (ECMWF, M24). An extension of the CHE nature run for 2016 will be made available an interim product for boundary conditions.
- Ensemble and benchmark runs for 2016 including a sensitivity test with the WP1 Mosaic inventory (D1.2) (ECMWF, M24)

- Global high-resolution nature run for 2021 (ECMWF, M24)
- Ensemble and benchmark runs for 2021 (ECMWF, M33)

Partners: ECMWF, MPG, ICOS ERIC, FORTH

T2.1b Transport model development

Atmospheric tracer transport is a key component in the inversion capability to estimate emissions from atmospheric composition observations. Systematic errors in the atmospheric transport can lead to biases in the estimated emissions of the CO2MVS. It is therefore paramount to assess and improve the accuracy of the numerical representation of atmospheric transport in the global CO2MVS, when simultaneously (online) simulating weather, emissions, transport and mixing, as well as chemistry and deposition. This task will test different numerical representations of resolved atmospheric transport in the prototype using a variety of tracers and horizontal resolutions. In particular, new formulations that explore the quality of alternative spatial discretisations (finite-volume, discontinuous Galerkin) and the role of specific transport features, such as (upwind-based, 2nd or higher order, 3D or split 2D/1D) flux-form Eulerian, monotone positive-definite advection transport algorithms (MPDATA), or local refinement (p-adaptive semi-Lagrangian). These are compared with locally conserving corrections (COMAD) applied as part of the standard semi-Lagrangian transport algorithm to improve the continuity and the conservation property of the transport trajectories. The benchmarking of different resolutions can be used to inform the global CO2MVS on the potential representation error associated with the assimilation of CO2M data.

The work will be organised in three main subtasks:

- Implementation in IFS of tracer advection schemes with improved mass conservation that are more suitable for modelling the transport of plumes emitted from local sources than the current scheme. These advection schemes will be assessed, and the best solution will be used in nature runs of T2.1a.
- Evaluate capability of plume transport from global models at different resolutions compared to satellite observations and regional simulations, closely connected with Task 2.4c, as well as Task 3.1 and Task 4.3 (ECMWF, EMPA). Activities will include simulations on various horizontal resolutions, and use tagged- and/or idealized tracers in IFS. Specific cases will be selected for further study, both here and in the closely connected Task 2.4c, and in coordination with Task 3.1.
- Estimate representativeness error globally based on sensitivity tests at different resolutions and explore parameterizations for those errors that can be fed into the global prototype.

Partners: ECMWF, EMPA

T2.1c Data Assimilation development

The development of the pre-operational global IFS prototype in WP5 will rely on research activities focusing on key aspects of the system design: inversion methodology, modelling of the error covariance statistics, and computational requirements. Each of these aspects can be best investigated using existing state-of-the-art offline inversion systems or simplified configurations (toy models) that provide reliable yet flexible testbed environments for method evaluations before integration in a pre-operational system. In this task, the following work will be carried out in support of the global IFS prototype development:

- Hybrid ensemble-variational approach (ECMWF, ENPC): the new hybrid ensemble-variational algorithm, the development of which was started in the CHE project, will be implemented in the Object-Oriented Prediction System (OOPS) and tested using a Quasi-Geostrophic (QG) model including tracer transport. In particular, innovative 4D localisation approaches will be developed and tested in this simplified framework.
- Impact of DA window length (ECMWF, CEA, WU): both the CTE (EnKS) and LMDz (variational) systems will be used to evaluate the impact of different window lengths on the inversion performance.
- Scalability of new parallel DA algorithms (ECMWF, CEA): new stochastic highly parallelizable optimization algorithms will be implemented in CIF to improve the scalability of adjoint-based inversions, which in turn should enable long-window optimization of anthropogenic CO_2 fluxes at higher resolution. These algorithms will be tested using an offline IFS-driven long-window (1-2 years) inversion based on LMDz. The saving in wall-clock computing time will be invested into an increase of the inversion spatial resolution. Experiments will be performed using available C_2 observations (e.g., OCO-2, in situ measurements) to assess the convergence property of the algorithm. Moreover, the quality of the approximation of key information content diagnostics, such as the posterior error covariance and model resolution matrices, will be compared

to previous (lower rank) approximation methods such as Monte-Carlo estimates or iterative Hessian-based approaches.

- Prior error covariance modelling and tuning (ECMWF): a model for the prior error covariance matrix associated with both the anthropogenic and biogenic fluxes will be developed and integrated in the global IFS prototype (T5.5). The modelling of the spatial error correlation component will follow a 2D-wavelet formulation currently used in the IFS. Realistic error correlations between co-emitted species are also critical for successful joint inversion of CO_2 and its co-emitters (e.g., NO_2, CO). Bottom-up and process-based model estimations of error covariance statistics will be used to provide a first guess that will be further optimised based on a top-down approach using atmospheric observations (see, e.g., Bousserez, 2019). The optimisation of the parameterised **B** matrix (i.e., spatial correlation lengths, cross species correlations) will be performed using satellite column observations of CO_2 (OCO-2), CO and NO_2 (TROPOMI) together with available in situ data.
- Control vector design for combined anthropogenic and biogenic fluxes: The operational CO2MVS will require a control vector that holds (a combination of) NWP variables, atmospheric mole fractions of multiple species, their emissions and uptake at the surface, and possibly parameters that control this exchange. The CHE report on data assimilation recommends various configurations to be tested in the prototype, including the direct estimation of gridded surface CO_2 fluxes using priors generated and benchmarked in Task 2.2 and 2.3, as well as a parameter-based CC/FF-DAS approach that will be tested based on work performed in T2.2.

Partners: ECMWF, ENPC, CEA, WU

T2.2 Fossil fuel emission modelling and parameter estimation (Lead: ECMWF, M1-M36)

The first step of this task is the implementation of models and profiles provided by WP1 that can improve the representation of the variability of fossil fuel emissions in space and time using observations, proxies and activity data. Testing of WP1 emissions and emission model developments will be performed as part of the nature runs and ensemble simulations (requires uncertainty representation) for 2016 and 2021 (T2.1), further testing of the FFDAS model and ancillary data will be done as part of this task. The emission model development is split into two separate components, the integrated residential heating module, which is NWP dependent, as part of the global online IFS and the parallel development of FFDAS, with consideration for a final implementation within the online global system. This will include model and profile parameter optimisation for each component.

T2.2a Anthropogenic emission modelling at global scales

- This task will involve numerical implementation and region-specific testing of weekly/diurnal temporal profiles for specific CO_2 sectors inside the IFS prototype. These are provided by WP1 but have not yet been implemented in the current IFS model structure and this task will make the needed changes to the prototype to include this sector-specific information in a fully consistent way, needed for attribution and multi-species approaches (T2.4).
- We will implement and test the existing empirical anthropogenic emission model for energy and other sectors for which we have proxies available (FFDAS) in the global system (iLab, TNO/WU, ECMWF, ULUND). This will mainly focus on FFDAS developments as part of WP1, which are not dependent on well constrained NWP variables (e.g. GDP, population density, energy consumption, traffic). This can be extended to incorporating elements of the FFDAS system within the global system, which can then be benchmarked.
- The developments in T2.2a will lead to a benchmarking activity through the IFS simulations in T2.1 in which we can assess combinations of developed capacity, and also quantify the sensitivity across the full global space/time domain represented in the IFS prototype. Additionally, results will be used to inform the inventories generated as part of WP1.

Partners: ECMWF, TNO, WU, FORTH, iLab, ULUND

T2.2b Parameterizing anthropogenic impacts on land-surface exchange and CO_2 emissions in urban tiles of the global CO2MVS prototype

- Numerical weather prediction variables are directly computed as part of the online global system. These will be used online to generate urban emissions using a residential flux model. This will integrate work done offline as part of WP1 (BSC) and merge it within the online global system (ECMWF). This will be done in conjunction with the development of an urban representation within the NWP system, which will complement the requirements for detailed spatiotemporally resolved urban flux estimates.

- Observations will be used to benchmark developments, with consideration for spatial scaling to account for model-observation representation errors.

Partners: BSC, TNO, ECMWF, FORTH

T2.3 Community land-surface modelling for vegetation carbon exchange fluxes: ECLAND (Lead: ECMWF/ULUND, M1-M36)

The aim of this task is to substantially improve global simulations of biogenic fluxes and to integrate land-surface remote sensing observations and ancillary data related to vegetation carbon exchange in the IFS prototype. The development of the ECLAND land-surface model for IFS will be based on a community framework approach that allows CoCO2 partners to support the IFS development to benefit from the expertise in other land surface modelling activities. The first focus of this task is to test the high-resolution Copernicus products of land use cover provided by WP1. Its impact on the biogenic fluxes, the water and energy fluxes and the atmospheric parameters will be assessed in an incremental manner and benchmarked using independent analysis products. The land surface model will also be improved with interactive Leaf Area Index (LAI) module to support the assimilation of LAI in NRT provided by CLMS. Observation operators will be developed for Vegetation Optical Depth (VOD) and SIF with the aim of integrating them in the IFS prototype.

The ECLAND model development will be coordinated across work packages and tested against direct flux observations. The offline land-surface simulations will span the period 2015-2021 at low resolution (~25km). High resolution (9km) simulations will be performed for 2016 and 2021. The tests with the online IFS will be focusing on specific months in 2016 (e.g. January and July). All the model developments that show improvement in the representation of the biogenic fluxes will be used in the nature run (T2.1). The specific model developments that will be integrated directly into ECLAND will also be tested/benchmarked in the ISBA model. Similarly, for the data assimilation integration into the prototype, both Land Data Assimilation Systems (LDAS) at ECMWF and Meteo-France will be used. The SIF observation operator will be developed for the SDBM3 and ORCHIDEE models with the aim of transferring the operator to the IFS+ECLAND, as this is a complex operator and its integration with in the prototype requires further research.

T2.3a Land-surface mapping improvements and modelling improvements

This subtask explores the role of high-resolution land cover and land cover change products on biogenic fluxes in ECLAND. The experiments will be based on the offline ECLAND and the ISBA model with the same configuration to transfer modelling capabilities to ECLAND. In particular it focuses on:

- Updating the vegetation classification and land cover based on Copernicus products (FC.ID, Meteo-France, ECMWF)
- Update vegetation description to create quasi-prognostic LAI in IFS, prepare the integration of process description with remote-sensing data (Meteo-France, FC.ID, ECMWF)
- Test impact of high-resolution annual land use description updates in IFS on biogenic fluxes (FC.ID, Meteo-France), and benchmarking against data-driven biogenic CO_2 flux products (FLUXCOM, WP1) (MPG).
- Benchmarking with near-surface parameters derived from the operational IFS system, scoring specifically on NWP forecast metrics (ECMWF, FC.ID, Meteo-France).

Partners: FC.ID, Meteo-France, ECMWF, MPG

T2.3b Land-surface data assimilation of remote sensing products

This subtask develops a series of observation operators, provide recommendations on their use as well as demonstrate their use in ECLAND and the IFS prototype. The focus lies on data assimilation of remote sensing observations of VOD, LAI, and SIF.

- Provision of observation operator for VOD and demonstration tests on its impact on Gross Primary Production (GPP) and surface meteorological parameters. (Meteo-France, ECMWF)
- Assimilation of VOD to analyse LAI in offline LDAS and online coupled land-atmosphere assimilation in the IFS. (Meteo-France, ECMWF)
- Provision of biospheric GPP datasets (0.5°, 2016-2021) based on process-based assimilation of OCO-2 SIF into the SDBM3 / ORCHIDEE models and exploration of future integration in the IFS with prototype (including tests of CTESSEL parameter optimisation with SIF observations). (ULUND, iLab, CEA)

- Intercomparison of GPP products from LAI, VOD, and SIF and evaluation against data-driven biogenic CO2 flux products (FLUXCOM, WP1) and in-situ measured CO2 fluxes using the uncertainty analysis toolbox from WP4 (Meteo-France, ULUND/iLab, CEA, ECMWF, MPG).

Partners: Meteo-France, ULUND/iLab, CEA, ECMWF, MPG

T2.4 Multi-species global modelling and data assimilation (Lead: WU, M1-M36)

In the estimation of fossil CO2 emissions in a global operational data-assimilation system, additional information can be obtained from other chemical species. Highly industrialised centres around the world are observable from space using NO_2 sensors. Likewise, large biomass burning plumes are easily observed by tracking CO plumes from space. Combining estimated emissions of NO_x (=NO+NO_2) and CO from these locations with CO_2/NO_x and CO_2/CO emission ratios will obviously inform about CO_2 emissions, but emission ratios are known to be variable in space and time and to depend on the burning process and technology implemented.

Nevertheless, there are good reasons to develop a multi-species framework. While the observational capacity from space-borne sensors for CO_2 is still limited, current sensors on e.g. TROPOMI produce good quality CO and NO2 products from space. These observations can help the development of an operational system based on the current IFS and CAMS efforts. These efforts will be supported by several mature inversion systems that assimilate satellite CO products to infer CO emissions. Issues that need to be addressed include the chemistry, the required inversion window length in the proposed combined 4DVAR-ensemble approach (T2.1c), and CO sources from atmospheric oxidation of methane and non-methane hydrocarbons. The operational system will assimilate the CO products from TROPOMI, Infrared Atmospheric Sounding Interferometer (IASI), and Measurement of Pollution in the Troposphere (MOPITT) (based on current CAMS efforts) to estimate global CO emissions and will be benchmarked by similar inversions in off-line systems.

The chemical lifetime of NO_2 (< day) is much shorter than that of CO (order of months). As a result, small-scale variations and atmospheric chemistry become more important. In order to exploit the information brought by space-borne NO_2 sensors, the effects of horizontal and vertical model resolution will be studied. This will be done in close collaboration with WP3, in which suitable parameterizations for the NO_2 decay of large emitters will be developed. These parameterizations will be implemented and tested in the prototype system, which will be operated in various resolutions, and with either full chemistry or parameterized chemistry.

In an additional step, all information will be combined in an off-line multi-species (CO, NO_2, CO_2, and possibly O2) data-assimilation system to explore the effects of resolution, assimilation-window length, and the sensitivity to the error settings. Such an off-line system will also be used to explore the possibilities for multi-species CCDAS and FFDAS approaches, in which gridded state vectors are replaced by parameters of the carbon-cycle and fossil fuel emission routines. In such a system, emission ratios can be added to the state vector to link the emission of various species to specific activities.

T2.4a Scale dependency of multi-tracer emission estimates

- Investigate the horizontal and vertical scale-dependency of multi-tracer modelling. Investigate plumes at small scales (WP3) to intermediate scales (T2.1) and larger scales (T2.4). Based on results, define specific sectors and geographic regions suitable for optimization in the IFS prototype.

T2.4b Parameterizing multi-tracer chemistry for global DA

- Explore impact of simplification of NO_x chemistry or fast surrogate modelling and CO with linear chemistry. A case study of a plume from an emission hotspot will be performed using the IFS with different configurations building on the transport model development in Task 2.1b: full chemistry at 9km, 25km and 50km resolution, and surrogate chemistry (linearized NO_x and/or parameterised lifetimes) at the same resolutions. The results will be compared with TROPOMI observations and other available observations and with WP3 simulations at very high resolution and with a more comprehensive description of atmospheric chemistry.

T2.4c Development of multi-tracer capability for CO_2, CO, and NO_2 inversions

- Implementation of a DA system for three tracers, including capacity to optimize emissions from fossil fuel and land-use change (biomass burning). The fast-track development on coarser resolution within an existing DA system (CTE) supports the transfer of capacity to the IFS prototype in the second stage of CoCO2. Nature runs spanning 1-2 months from T2.1 will be used to build testing capacity with simulated observations, and use of real satellite data (IASI, TROPOMI, MOPITT, OCO-2, GOSAT-2) is planned too.

Partners: ECMWF, WU, UEDIN

Deliverables (brief description and month of delivery)

D2.1 Progress on developing the global transport model, data assimilation, and preliminary demonstration of CO2MVS capacity (Lead: ECMWF, M12 R, PU)

This Deliverable report outlines the development cycle for the global transport capacity of IFS, and its data assimilation. The development cycle includes tests of the advection improvements, state vector, assimilation windows, covariance treatment, implementation of the tangent-linear and adjoint models, and observations. It will also include a timeline for the operational implementation of the new emission inversion capacity in the IFS prototype, and a list of research priorities and development tasks to be considered under the umbrella of Copernicus.

D2.2 Recommendations on anthropogenic CO_2 emission modelling, evaluation, and optimization (Lead: ECMWF, M33, R, PU)

This Deliverable report outlines the development cycle for global fossil fuel emissions as either spatial, or FFDAS-based fluxes, to be the basis for an CO2MVS to estimate anthropogenic emissions. The report will recommend the optimal setup to estimate anthropogenic fluxes of CO_2, with respect to the newly developed urban tile, the state vector, assimilation windows, covariance treatment, implementation of the tangent-linear adjoint, and observations. It will also include a timeline for the operational implementation of this capacity in the IFS prototype, and a list of research priorities and development tasks to be considered under the umbrella of Copernicus.

D2.3: Validation of online global vegetation carbon fluxes in ECLAND for prototype modelling developments (Lead: FC.ID, M18, R, PU).

This Deliverable will provide an assessment of the modelling developments (land use cover, classification and interactive LAI) and their impact on the carbon/energy/water fluxes, as well as NWP scores. The results of this evaluation will be the basis for the estimation of the temporal and spatial structure of the biogenic flux error that will be used in the error covariance matrix. The report will include full documentation of the technical setup of this system and provide feedback to WP1 from the perspective of the operational IFS system.

D2.4 Demonstrator systems for using remote sensing data (LAI, VOD, SIF) in online global prior fluxes for the CO2MVS prototype (Lead: Meteo-France, M30, DEM, PU).

This Deliverable consists of a demonstrator system, which will ingest satellite observation of LAI, VOD, and SIF to constrain biogenic carbon uptake. The result will be a dataset covering at least five years of biospheric primary productivity (GPP or Net Primary Production (NPP)) for all major biomes in the world, with each biome either directly constrained via LAI, VOD, or SIF and (non)linear observation operators, or indirectly by having these products as a proxy for phenological development and/or canopy integrated photosynthetic capacity. The demonstrator will include full documentation of the technical setup of this system and each component will be described specifically connecting it to the community land-surface scheme of the IFS CO2MVS prototype, such that the design of the demonstrator can be translated easily into the operational system.

D2.5 Demonstration of multi-tracer capability for 2021 (Lead: WU, M36, DEM, PU)

This Deliverable consists of demonstrator systems, which will simultaneously ingest satellite observation of CO_2, NOx, and CO to constrain both anthropogenic and biogenic emissions, as well as land-use. The result will be a dataset covering at least one year of such fluxes, together with full documentation of the technical setup of the systems. Each component will be described specifically connecting it to the IFS CO2MVS prototype, such that the design of the demonstrators can be translated easily into the operational system.

Partner Roles	
ULUND, iLab	Contribute to the task on fossil fuel emissions modelling (T2.2) and terrestrial carbon cycle modelling (T2.3), especially on the exploration of SIF observations to optimise model parameters. We propose to contribute by developing a process-based SIF observation operator and provide GPP estimates from assimilation of SIF into the Simple Diagnostic Biosphere Model (SBDM3) model. iLab and ULUND will also support the integration of the fossil fuel emissions model in the global prototype system.

WU	Support the development of a global MVS prototype by co-leading this WP. Based on CarbonTracker Europe, WU will fast-track the development of Fossil Fuel data assimilation (FFDAS) capacity in Task 2.2. WU will additionally lead the task on multi-species data assimilation, by building a prototype system focusing on CO_2, CO, and NO_x.
ECMWF	Work on the implementation and testing of the different components in the prototype global MVS. For this reason, ECMWF is involved in all tasks of WP2 to: • Perform high resolution nature runs (including CO_2, CH_4, linear CO and idealised NO_x) in 2016 and 2021 with latest model cycle and emissions with their temporal profiles, as well as the ensemble simulation. A few months will be selected to perform high resolution simulations with full chemistry based on the CAMS forecasting system including NOx and all the relevant tracers. This will be provided to WP3 as boundary conditions or to do data assimilation sensitivity experiments. It will also be used to test the capability of IFS to simulate plumes by comparing the high-resolution simulations with TROPOMI. • Evaluate the improvements and enhancements in the Semi-Lagrangian (SL) advection scheme and the development of a new scheme by the Numerical Aspects team at ECMWF. The tangent linear and adjoint of the improved SL schemes will also be developed. These schemes will be tested with a variety of tracers including CO_2. • Extend the IFS with the hybrid variational-ensemble approach to extend the DA window and include chemical mechanisms in the minimization (in collaboration with ENPC), work on scalability of new parallel DA algorithms (with CEA), and definition of control vector for CO2 and co-emitters for inversions. Aggregation of sectors will be considered and made consistent across emitted species. This work will build on the design of sectorial emissions carried out under the CHE project and CAMS and will be completed or revised based on available literature. The prior error covariance modelling work will benefit from the support of other tasks in WP1 and WP2 that will provide prior statistics and further top-down constraints on the error covariance matrix. • Implement the anthropogenic emission models developed in WP1 to support the FF-DAS approach in the context of the urban model development in the IFS. The possibility to model the energy sector and transport sector will also explored based on the FFDAS models used in CHE. The immediate priority will be to implement weekly and diurnal profiles for the different sectors. • Run the offline land surface model with the new CAMS developments from 2016 to 2021 (Farquhar formulation and CH_4 wetland model) and estimate the uncertainty associated with the modelled biogenic fluxes. The BFAS bias correction will be tuned with new emissions and references (based on other NEE/GPP products, e.g. FLUXCOM data from WP1 as well as the CAMS and CT-Europe inversion products). • Test new ocean flux products provided by WP1. • Explore impact of simplification of NOx chemistry or fast surrogate modelling and CO with linear chemistry. A case study of a plume from an emission hotspot will be performed using the IFS with different configurations: full chemistry at 9km, 25km and 50km resolution, and simplified chemistry at the same resolutions. The results will be compared with TROPOMI observations and other available observations.
FC.ID	Contribute to land surface model and data assimilation developments in IFS
CEA	Work on task 2.3 (carbon cycle modelling to inform priors): We can make a strong link with Copernicus projects (CAMS41) to further develop the carbon cycle in CHTESSEL and prepare for DA with the provision of observation operators to assimilate i) SIF data (simpler version of Scope model as in Bacour et al., 2019 (doi: 10.1029/2019JG005040)) and possibly ii) atmospheric Carbonyl Sulfide (COS) observations using a process-based operator to compute COS uptake following the Farquhar photosynthesis model (both SIF and COS operators could be combined). Note that we could also

	envisage together with CAMS projects to perform offline parameter optimisation of CHTESSEL using multiple-data streams (FluxNet, SIF, CO2/COS). Finally, we could also provide expertise (for the land use mapping activity, T2.3.2) on how to best use the ESA-CCI+ high / medium resolution land cover data sets to derive Plant Functional Types (suitable for CHTESSEL) from the initial ESA mapping. CEA will also contribute to T2.1c "Data Assimilation development" with the CO2 inversion system that it has been developing for CAMS73.
EMPA	Links with WP3
ENPC	Provide guidance to the methodological developments of the hybrid ensemble-variational system based on the IFS and assist with the initial testing of the prototype by performing idealized experiments.
FORTH	Leading "T2.3.1 Anthropogenic emission model developed in WP1 (e.g. residential heating) within the context of the urban tile". This task will be in close co-operation with WP1, where FORTH will potentially be involved in the development of the regional inventories for urban areas. Contribute to "T2.1 Testing emissions and uncertainty estimates", by providing local scale Eddy Covariance measurements and source area modelling of urban CO_2 fluxes for the evaluation of the high-resolution bottom-up models (developed in WP1) in selected cities. The test cases could be Heraklion, Greece, where FORTH operates two urban Eddy Covariance stations the last three years and Basel, Switzerland, where a long time series of Eddy Covariance measurements is available.
MF	Contribute to WP2 (2.3.3 on Biospheric carbon exchance), we are planning to provide global offline reanalysis of the Land Surface Conditions. To that end we will use LDAS-Monde system [1,2] where satellite derived surface soil Moisture and LAI are jointly assimilated in the ISBA Land Surface Model. Different "carbon-related" option of ISBA could be tested with great interest as well as trying to link observed SIF to modelled/analysed GPP.We have already tried to assimilate FAPAR but to date did not see any added value w.r.t. assimilating LAI. However, assimilating other variables linked to vegetation like Vegetation Optical Depth (microwave-based product) seems very promising. At global scale, we would force our system by ERA5, resulting in 0.25x0.25 spatial resolution reanalysis, we can also force LDAS-Monde by the IFS, providing regional reanalysis at 0.1x0.1 spatial resolution.
UEDIN	• Explore model and observed CO_2:CO:NO_2:CH_4 correlations in satellite column space and explore how these atmospheric constraints can be used to separate combustion and non-combustion sources of CO_2 • Understand how Monte Carlo uncertainty analysis of fossil fuel inventories from WP2 can be integrated with atmospheric data analysis.
BSC	Links with WP1. Advisory role in task 2**.3.1.**
TNO	Links with WP1. Advisory role in task 2**.3.1.**
JRC	Links with WP1. Advisory role in tasks 2.1 and 2.3.1
MPG	Contribute to benchmarking the nature runs through comparisons to the FLUXCOM biosphere fluxes and atmospheric measurements, in Tasks 2.1a, 2.3a and 2.3b.
ICOS ERIC	Supports WP 2 in an advisory role on the use of observations in the evaluation of global nature runs and inversion products of WP2

Work package number	3		Lead beneficiary			EMPA						
Work package title	Local and regional modelling and data assimilation											
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	12	25	0	0	23	9	11	9	10	12	10	0	0
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	TOTAL
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	CyI	
Person months/ participant:	0	0	20.5	20	10	0	6	0	0	19	0	0	196.5
Start month	1				End month				36				

Objectives

This work package develops methods and systems to monitor the anthropogenic CO_2 emissions at national to facility / city scale. It demonstrates the capabilities of the systems and provides guidance for benchmarking. This monitoring will rely on satellite imagery from CO2M and complementary instruments (OCO-2, TROPOMI NO_2/CO) as well as on ground-based observations. This work package will help identify optimal strategies for local scale inversions of emissions from hot spots such as cities and power plants and for potential integration into the global multi-scale integrated prototype of the future operational CO2MVS system developed in WP5. It will also demonstrate the capabilities of the future operational system for monitoring national to subnational budgets based on the application of regional modelling systems. It will estimate national emissions using observations from ground-based networks as well as using existing satellite measurement of CO_2 and co-emitted species, demonstrate the added value of future CO2M observations, and provide these estimates as benchmarks for the multi-scale prototype developed in WP5. Finally, this work package will build the connections between the multi-scale prototype and independently developed national systems and assess their complementarity. The optimal methods and practices identified in this work package will feed local to national scale systems whose estimates will be assimilated by the multi-scale prototype.

The focus years for local and national simulations and inversions will be 2016 and 2021 to be aligned with the Global Stocktake process and to maximize the synergies with the other work packages providing input to or using the output from WP3.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP3 is led by Dominik Brunner (EMPA) and Gregoire Broquet (CEA).

This work package relies on the development and application of high-resolution atmospheric transport and inversion systems covering limited geographical areas and addressing scales from mesoscale weather phenomena to individual plumes as they are resolved by CO2M. While addressing local and national scales is critical when monitoring emissions, there is still a need to improve such systems and their efficiency and robustness to ensure they can be applied operationally. The analysis and developments in this WP will rely on state-of-the-art transport models and inversion approaches.

These systems will be fed with inventories of anthropogenic emissions and simulations of the net ecosystem exchange from WP1 (at high resolution over Europe), with boundary conditions from global systems in WP2, and with the corresponding uncertainty estimates from WP1, WP2 and WP4. National data products (inventories, observations) will also be considered for a subset of national inversions to demonstrate the benefit of detailed country-specific information. Guidance provided by WP4 for specifying modelling uncertainties and connecting the different scales should be used to increase the consistency within or between the local and regional inversions. WP3 will link to the multi-scale prototype and to WP5 in multiple ways. It will provide benchmarking test cases and guidance on the design and selection of methods for inclusion within the multi-scale prototype. It will also provide local and regional estimates in the form of ensembles characterizing their uncertainties, to be assimilated in the multi-scale prototype in T4.1 of WP4. Some of the suitable systems from WP3 will participate

to the submission of estimates for the 1st GST in WP5. Systems developed here and first experiments with existing networks and simulated CO2M data will support network design in T4.5 of WP4 and WP6. Finally, WP7 will ensure the use of the standard tools, expertise and complementarities with the future operational global CO2MVS system by promoting them and the development of local- to national-scale systems towards territorial and national agencies and European member states.

WP3 is divided into the following 5 tasks:

T3.1 Local scale model performance assessment and improvement (Lead: EMPA, M1-M24)

Partners: EMPA, CEA, WU, VUA, MPG, FMI, TNO, DWD, ENPC, ECMWF.

The future CO2M satellites will be able to image the plumes of strong point sources and clusters of sources (e.g. cities, industrial complexes) with a horizontal resolution of 2 km x 2 km. In order to use this information in atmospheric inversion systems, the underlying atmospheric transport models should be able to resolve the plumes and reproduce their basic properties. Currently, large uncertainties exist regarding the ability of atmospheric transport models to describe individual observed plumes, and the sensitivity to different model settings such as resolution, boundary layer and advection schemes, and the sensitivity to the representation of the source such as its temporal variability and injection height in the case of stack emissions. This task will assess the performance of current high-resolution transport models, identify critical elements affecting the simulations, and develop recommendations for the optimal simulation of the plumes. In addition, this task will develop a library of plumes for use in tasks T3.2 and T3.3 for method development and benchmarking.

Subtask 3.1.1 will develop a library of plumes from isolated sources and complex source clusters using simulations at very high resolutions from a few metres to 1 km. Simulations will cover the densely populated Randstad region in the Netherlands, the cities of Berlin and Paris, and a selection of power plants. Simulations will represent a wide range of conditions in terms of plume dispersion (stability, roughness, entrainment, presence of clouds), terrain (near land-sea gradients, near orography) and source types (stack emissions, isolated city, cluster of cities). The simulations will include CO_2 and co-emitted species NO_2 and CO, which will be simulated with full or simplified linear chemistry. Simulations will focus on the year 2016 except for a few cases used in Task 3.2.2 for model evaluation. The production of synthetic CO2M observations from the simulations is not part of this activity but will be coordinated with ESA.

Subtask 3.1.2 will assess and optimize model performance. Multiple models including coarser (few km) resolution models will simulate a subset of cases from Task 3.1.1 following a well-defined protocol. The cases will cover at least: Randstad region (selected periods in 2016), Berlin (Apr 2016), and the power plants Jänschwalde or Belchatow (May/Jun 2018), for which extensive observation data sets (in situ, remote sensing, airborne, satellite) are available for model evaluation. At least 3 different models are required to provide output per case. Model evaluation will focus on plume dispersion characteristics (e.g. peak concentrations and plume width as function of distance, horizontal versus vertical dispersion) and test the influence of different assumptions (e.g. temporal variability of source, injection height of emissions). Models with online meteorology will also test different model settings such as boundary layer or advection schemes. In addition to CO_2, co-emitted species NO_2 and CO will be simulated with full or simplified chemistry. Idealized tracers will provide additional insights to diagnose model differences.

Models will be compared with each other (with local nature runs from T3.1.1 serving as reference) and evaluated extensively against observations (in situ and remote sensing from ground-based and airborne platforms and from satellites). Finally, ensembles of simulations with identical emission inputs will be used to assess transport model uncertainties. The main outcome of this task is a set of requirements for plume-resolving models to be suitable for plume-scale inversions and for integration into the future operational CO2MVS framework.

T3.2 Local inversion approaches for efficient processing of plume images with a large spatial and temporal coverage (Lead: FMI, M6-M30)

Partners: FMI, CEA, EMPA.

This task will develop and benchmark light and fully automated approaches for quantifying CO_2 emissions from point sources and cities directly from images collected by the future CO2M mission using plume detection and direct flux computation or light atmospheric inversion methods. These methods will not require any expensive high-resolution model simulations and will be applicable globally at low computational cost. The potential use of co-emitted species (notably NO_2) to support the detection of the plumes or to estimate CO_2 emissions directly (relying on the observed NO_2/CO_2 ratios) will also be investigated. The final goal is to develop a pre-operational

method that can be applied to the whole globe and the full year 2021 to provide estimates that can be assimilated into the multi-scale prototype or upscaled to support the contribution of WP5 to the first GST.

This task will start by building an inventory of existing methods such as Gaussian plume matching, plume slicing and divergence methods and document their advantages and disadvantages. Methods will have to cope with the challenges of clouds, low signal-to-noise ratios, and incomplete images due to the limited swath width. Selected methods will be benchmarked against the library of plumes from Task 3.1 (with known emissions) and will be tested on real satellite images of CO_2, CO, NO_2, or CH_4 (e.g. from TROPOMI and OCO-3) to invert the emission of CO_2 or of the corresponding species. These tests will help further refine the methods with the goal to develop fully automated and efficient algorithms.

Finally, an ensemble of inversion estimates will be generated for a selection of cases from the plume library with synthetically generated satellite observations perturbed according to their error statistics. This will be used as an estimate of the likelihood function associated with the inverted emissions for assimilation of the local emission products as observations into the global IFS prototype.

T3.3 Local inversion approaches using atmospheric transport models (Lead: ENPC, M12-M30)

Partners: ENPC, CEA, iLab, WU, UEDIN, FMI, VUA, AGH.

The light approaches developed in T3.2 will be suitable for well-defined, isolated plumes but may hardly cover situations with complex plume structures or large variability in background concentrations. Such conditions may arise, for example, due to the complex morphology of a city or a cluster of sources producing complex and overlapping plumes, local wind systems shaped by topography and land-sea breezes, or strong variability in background concentrations due to biospheric activity. Approaches relying on the type of high-resolution transport models assessed in T3.1 could overcome such challenges. They could also provide insights into the spatial and sectoral distribution of the emissions within an urban area as opposed to approaches in T3.2. However, they should solve for the limitations of the transport models to simulate the spread, shape and location of the plumes, which plays a key role in the detection and interpretation of plumes from noisy satellite images. Monitoring systems dedicated to specific urban or industrial areas could be based on such approaches. These approaches could also be applied directly within the future multi-scale integrated system. A subset of local posterior emission products obtained from these approaches will be used for assimilation in the global multi-scale prototype (T4.1). Those experiments will be carried out by the end of the project, although an operational implementation is considered as a longer-term perspective (typically for the second GST).

This task will develop and explore the potential of such inversion systems with high-resolution models. Subtask 3.3.1 will test new inversion methods to overcome uncertainties in the plume chemistry-transport modelling. Subtask 3.3.2 will provide insights on the optimal configuration of the control vector for city inversions and test the ability to distinguish between biogenic fluxes and anthropogenic emissions from different sectors or areas within a city.

In both subtasks, the analysis will be based, first, on inversions of CO_2 emissions from cities using synthetic truths from the libraries of simulations in T3.1, and simulations of CO2M data. Second, they will be based on the processing of real satellite data (e.g. from TROPOMI and OCO-3). The use of ancillary data (like co-registered NO_2 images) to strengthen the plume detection and matching, and demonstrations of the plume inversion capabilities with real data using species other than CO_2 will also be considered in both subtasks. Methods will either mix or separate in two steps the detection and actual inversion of the plumes. Ensembles characterizing the uncertainties in the inverted emissions and transport will be provided to test the assimilation of the estimates from these tasks in the multi-scale integration prototype in WP5.

In subtask 3.3.1, an advanced scheme (with non-local evaluation metrics and potentially machine/deep learning) will be developed, tested with low dimensional problems and then applied to a full transport model over a few test cases with synthetic and real images over one or two cities, including Paris. Results will be compared with those from the methods of T3.2. In subtask 3.3.2, several different approaches will be compared: A local scale CCFFDAS system controlling activity parameters underlying the biogenic fluxes and emissions for different sectors of activity will be applied to Berlin. An ensemble Kalman Filter approach will be applied to the Randstad region in the Netherlands including the cities of Amsterdam and Rotterdam, to test the sensitivity to model resolution and the sectorial definition of the state vector. An analytical inversion system will be applied to Kraków testing potential benefits of grouping specific anthropogenic emission-sectors as well as the capability to capture urban biospheric fluxes (using data gathered in the scope of WP6, task 6.5). Finally, observed CO_2:CO and CO_2:NO_2 ratios over cities across Europe, taking advantage of OCO-2/GOSAT-2 and TROPOMI data, will be analyzed to

understand how they can be used to quantify combustion sources of CO_2 within a multi-tracer local-scale inversion framework.

T3.4 National scale inversions (Lead: MPG, UEDIN, M1-M36)

Partners: MPG, UEDIN, TNO, DWD, EMPA, CEA, ENPC, VUA, FMI, ULUND, ECMWF, AGH.

This task will support the development of national scale systems and evaluate their potential to monitor national to regional (in the administrative sense) budgets of CO_2 anthropogenic emissions. For this, it will investigate the respective advantages and complementarities between two types of national scale inversions: (i) standard configurations using the same products (inventories, observation datasets, natural flux estimates, global simulations for the boundaries) from WP1 and WP2 that are consistent with the global prototype, and (ii) national configurations using country-specific information. It will also test the sensitivity of inversions to the type of observation network: using the existing in situ surface networks (of CO_2 and fossil fuel tracers like co-emitted species) or a combination with existing spaceborne observations of co-emitted tracers (like CO and NO_2 from TROPOMI), or using a combination with synthetic data from CO2M. This task will use experiments with synthetic data for 2016 on timescales from 1 month to 1 year and use real data that will be collected in 2021. CH_4 inversions will be considered to demonstrate the potential of national scale inversions since the CH_4 observational coverage is currently more developed than that for the monitoring of anthropogenic CO_2, thanks to the availability of TROPOMI measurements.

A series of national scale inversions will be conducted over different countries. While some of these inversions will rely on pre-existing systems from national efforts, others will be developed over the course of the project. The use of the Community Inversion Framework (CIF) as a standard platform for such developments will be encouraged and supported via training and assistance. These systems should rely on mesoscale transport models with spatial resolution ranging from 0.25° to a few km and include some treatment of chemistry when assimilating co-emitted species.

More than three inversion systems in parallel to the multi-scale integration prototype will be used over four countries in Western Europe: Germany, France, the Netherlands and the UK. These countries have been chosen because efforts are currently underway to develop national systems and because the surface network is relatively dense and country-specific information is available. Inversions of the emissions from Poland, the USA and Scandinavia will also be conducted. These test cases can be used to benchmark the different inversion options since the national and annual emissions budgets are relatively well known in these countries. The fact that most of the test cases are in the EU supports WP7 activities by promoting the use of national scale inversions by member states. The optimal inversion configurations should be used to support the contribution of WP5 to reports on the national emissions. Ensembles characterizing uncertainties in the inverted emissions for some of the national inversions will be provided to test the assimilation of such regional scale estimates in the multi-scale integrated prototype of WP5.

T3.5 Guidance and synthesis between the local and regional scale estimates (Lead: CEA, M26-M36)

Partners: all partners of previous tasks + relevant partners from WP4

This task aims at synthesizing the analysis of the whole WP by confronting results and conclusions from local scale and national scale inversions. An attempt will be made to reconcile results from both approaches using test cases with local areas and periods covered by both types of inversions in tasks 3.2-3.4. As a first step, comparisons between local scale inversions from T3.2 and T3.3, fed with conclusions from T3.1, should provide some perspective on the use of high-resolution models for local scale inversions: about its relevance, requirements, potential and capacity to be operationalized.

As a second step, analysis of comparisons between estimates of instantaneous city and plant emissions from local inversions in T3.2 and T3.3 and corresponding estimates from the gridded national scale inversions of T3.4 should provide indications for the reconciliation between these two approaches. Such a reconciliation should help upscale the results from local scale inversions to feed the estimates of city and industrial emissions at the national and annual scale in WP5 and help refine the configuration of national scale inversions. In this perspective, the task will explore how to improve the spatial attribution of the emissions in national scale inversions, propose suitable configurations for the prior uncertainty covariance matrices in the national scale inversions, and propose methods for the temporal extrapolation of estimates from plume inversions. Nesting techniques studied in T4.1 of WP4 may also be considered for this task. Test cases could include the comparison

of estimates for Paris, Berlin, and a Dutch city from tasks 3.2 and 3.3 vs. gridded inversions for France, Germany and Netherlands from task 3.4.

Finally, a synthesis of the results from both local scale and national scale inversions will identify benchmarking tests cases and criteria (primarily used in WP5), and support guidance on the tools, good practices and potential for the local to regional scale systems. In conjunction with results from T4.1 in WP4, it will support the development of local, regional or nested systems that can be operated by national agencies or included into the overall framework of the multi-scale integration prototype in the long run.

Deliverables (brief description and month of delivery)

D3.1.1 Definition of simulation cases and model systems for building a library of plumes (Lead: WU; M6, R) – Documentation of planned plume simulations, the participating model systems, and the simulation protocols.

D3.1.2 Assessment of plume model performance (Lead: EMPA; M24, R) – Report on model performance for different plume types, and on plume-scale transport model errors. The report will also provide recommendations for the optimal setup of plume-resolving simulations for a future operational system.

D3.2.1 Documentation of plume detection and quantification methods (Lead: EMPA, M12, R) - Documentation of existing methods and of their advantages and disadvantages. Identification of most suitable approaches and of gaps and needs for further development.

D3.2.2 Benchmarking of plume detection and quantification methods (Lead: FMI, M24, R, PU) - Benchmarking of methods for library of plumes (benchmarking against known emissions) and testing on real satellite observations. Evaluation of methods using co-emitted species.

D3.3.1 Perspectives on the use of atmospheric transport models for local scale inversions (Lead: ENPC/CEA, M26, R, PU) – Report on local scale inverse modelling approaches with an evaluation of new methods to overcome transport modelling uncertainties and of optimal control vector configurations.

D3.4.1 Inter-comparisons of national scale inversions (Lead: MPG, M34, R, PU) – Report on the analysis of the national to regional scale emissions estimates: evaluating configurations and methods and potential complementarities between standard and country-specific systems based on inter-comparisons and sets of experiments.

D3.5.1 Ensemble of estimates for assimilation into prototype (Lead: UEDIN, M30, DEM, PU) - Ensemble of local and national emission and transport estimates for assimilation as observations into the multi-scale prototype.

D3.5.2 Synthesis and recommendations (Lead: CEA, M36, R, PU) – Synthesis report on the short to longer term perspectives for local to national scale inversion methods and to support the reconciliation between local scale and national scales estimates.

Partner Roles	
EMPA	• WP co-leader • Task 3.1: coordination, selection of case studies, modelling protocol, collection of data for model evaluation, simulations with COSMO-GHG, statistical analysis of model performance, definition of metrics, recommendations for representation of plumes from cities and power plants • Task 3.2: application of plume detection algorithm to synthetic and real satellite images of CO2 and NO2 and quantification of emissions by plume slicing • Task 3.4: CH_4 and CO_2 inversions for Germany using COSMO-GHG (or possibly ICON-ART) and using the CIF or CTDAS. Several inversion experiments with and without satellite observations
CEA	• WP co-leader • Task 3.1: support modelling protocol and statistical analysis of model performance, simulations with CHIMERE (forced by ECMWF analysis) and possibly with WRF-CHEM • Task 3.2: development of a light automatic plume detection and inversion system, application to the common case studies (synthetic CO2M CO2 and NO2 images and real OCO-3 and TROPOMI images), participation to the analysis of the results from the different methods and partners

	• Task 3.3: co-development with ENPC of a plume inversion system based on a full 4D meteorological transport model: generation of the simulation database underlying the method, tests with synthetic CO2M and real OCO-3/TROPOMI images, comparisons with lighter methods from T3.2 • Task 3.4: sets of CO2 and CH4 inversions for France with the CIF and CHIMERE assimilating in situ and satellite CH4, CO2, NO2 and CO data, using standard vs. country-specific configurations; lead of the inter-comparisons over France. Training to the CIF and support to users. • Task 3.5: coordination, lead of the synthesis
ENPC	• Task 3.1: support to the analysis • Task 3.3: coordination, co-development with CEA of a plume inversion system based on an advanced scheme and a full 4D meteo-transport model: theoretical developments, numerical implementation, tests with low dimensional problems, comparisons with methods from T3.2 • Task 3.4: support to CEA, providing methods to refine the statistical description of the uncertainties in the inversion framework
iLab	• Task 3.3: Application of a local CCFFDAS to monitor the emissions from Berlin.
ULUND	• Task3.4: Experiments with high-resolution LUMIA over western European countries (Germany/France) as well as Scandinavia, and with a high-resolution atmospheric transport inversion system based on WRF over the USA.
WU	• Task 3.1: CO_2 / NO_2 plume-resolving simulations with DNS code of MicroHH (build-in chemical reactivity, scales of 1m - 1 km), • sensitivity tests (stability, roughness, entrainment, clouds…) for locations in various terrain (urban, near land-sea gradients, orography…) • Task 3.3: use MicroHH to set up a library of plume dispersion characteristics, and/or plume transport errors, to build synthetic truth for inversions over a set of large anthropogenic emission sources in Europe or in the Netherlands, covering the tracers NO_2, CO_2, CH_4, and CO.
TNO	• Task 3.1: simulations with full chemistry, provision of parameterized chemistry and/or chemical loss rates • Task 3.4: inversions of the CO2 emissions of UK, France, Germany and the Netherlands using a standard configuration, the CIF and a 5 to 1 km resolution transport model, assimilating CO2, CO and NO2 data; contribution to the analysis of the intercomparisons over the four countries.
FMI	• Task 3.1: participation to the definition of the simulated cases for the plume library • Task 3.2: coordination, development and benchmarking of the computationally light approaches for quantifying local CO_2 emissions • Task 3.3: support to the comparison with methods and estimates from T3.2 • Task 3.4: inverse modelling in Finland/Scandinavia • Task 3.5: guidance on estimates from T3.2
VUA	• Task 3.1: high resolution simulation of CO_2 over a ~100x100 km2 domain in The Netherlands at 100x100m resolution using the Dutch Atmospheric LES model (DALES). The domains cover the densely populated Randstad region along the North Sea shore line. • Task 3.3: use of the VUA WRF-CHEM EnKF (interface to CTDAS for optimization) to invert the CO2 emissions from a city of the Randstad region. • Task 3.4: inversion of national emissions for the Benelux region using the VUA WRF-CHEM EnKF, in situ surface measurements (ICOS, Ruisdael) and TROPOMI data. Integration of WRF-CHEM into the CIF framework.

MPG	• Task 3.1: contribution to the library plume simulations • Task 3.4: co-coordination with UEDIN, national-scale inversions of the CO_2 and CH_4 emissions from Germany and the Netherlands using mesoscale simulations with the WRF-GHG model.
UEDIN	• Task 3.3: explore model and observed CO2:CO:NO2 correlations in satellite column space and how these atmospheric constraints can be used to separate combustion and non-combustion sources of CO_2 • Task 3.4: co-coordination with MPG, inversion of CO2 emission across a European domain, with a focus on the UK, using the nested GEOS-Chem model and the corresponding EnKF, in situ data, NO_2 (or CO) data from TROPOMI and CO2 from a selection of available satellite instruments
DWD	• Task 3.1: ICON-ART simulations at different scales (2.5-6.5 km resolution) with variation of sensitive model parameters, characterizing the ICON limited area model forward modelling uncertainties at ICOS observation locations • Task 3.4: regional CH_4 and CO_2 inversions with an EnKF, using ICOS observations. Focus area is Germany, with possible extension to France and Benelux for comparison and evaluation. Collaboration with national initiatives: promoting CoCO2 results and options for applications. • Task 3.5: contribution to comparisons and evaluation exercises.
AGH	• Task 3.3: using WRF-Chem with an analytical inversion system to invert emissions from Kraków. Assimilation of regular Unmanned Aerial Vehicle (UAV) CO2 and event-based 14C observations. High-resolution simulations to produce synthetic satellite observations as input to test the new inversion methods. • Task 3.4: national CO2 (and possibly CH4) inversions for Poland using WRF-Chem coupled to an analytical inversion system based on WRF tagged tracer simulations (the state space consisting of IPCC sector emissions divided geographically over administrative regions in Poland).
ECMWF	• Task 3.1: participation to the model comparisons • Task 3.2 to 3.4: guidance on the production of ensemble-based statistics for assimilation of the local/regional products into the global multi-scale IFS prototype • Task 3.4: provision of national scale estimates for the inter-comparisons

Work package number	4		**Lead beneficiary**				ULUND					
Work package title	Connecting scales and uncertainties											
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	22	3	5	0	10	17	6	16	14	1	0	0	0
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	**TOTAL**
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	Cyl	
Person months/ participant:	4	0	0	0	13	0	8.5	0	8	0	0	0	**127.5**
Start month	1				**End month**			36					

Objectives

The objective of this WP is to improve the representation of uncertainties in inversions, which are important not only for the uncertainty of the generated flux estimates, but also to determine the weight that different elements of information that are used should receive.

The following aspects of uncertainty will receive specific attention:

- The uncertainty of boundary conditions, and how to combine information from separate inversions addressing different but complementary spatio-temporal scales.
- The quantification of uncertainty arising from sampling biases and atmospheric transport models.
- The impact of several design options (assimilation window, prior specification, online vs offline simulations) on posterior estimates and their uncertainty.
- Best practice on evaluating/benchmarking atmospheric transport models and terrestrial ecosystem models for providing prior error covariances.

To address these aspects, experiments will be conducted using real data as well as synthetic data in the form of data assimilation sensitivity experiments and Quantitative Network Design (QND) experiments. These experiments will be performed for the most recent periods covering at least the year 2016.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP4 is led by Marko Scholze (Lund) and Sander Houweling (VUA).

Brief description of work package

This work package develops methods and mechanisms to transfer information among and connecting the different scales from 'Global Modelling and data assimilation' (WP2) and 'Local and regional modelling and data assimilation' (WP3). It will, based on the work done in CHE and VERIFY, continue to work on coordinating efforts on uncertainty trade-off for fossil fuel emissions. In particular, WP4 will provide a toolbox based on direct flux observations for evaluating terrestrial ecosystem models and facilitating customised improvement of the description of the biogenic prior uncertainties in transport inversions based on flux observations. It will also assess the impact of transport model uncertainties, additional design options for the prototype (assimilation window, prior specification, online vs offline simulations) as well as correlated uncertainty in the satellite observation on posterior estimates and their uncertainty.

This work package investigates ways to evaluate posterior estimates and their uncertainties by means of model inter-comparisons (both for CO_2 and CH_4) as well as the development of dedicated benchmarking metrics.

WP4 links to work done in WP1 concerning prior information and WPs 2 and 3 providing boundary conditions from global systems as well as input on local scales for use in global systems. The work done here requires input from WP6 on observations and their uncertainties but also provides output to WP6 on the needs of observation type and network structure.

T4.1 Develop mechanisms to transfer information from global to local scales and vice versa (Lead: ECMWF, contributing CEA, VUA, ULUND; M1-M36)

Flux estimates are generated by inversion systems operating at different scales, from global to regional to local. Although targeting different spatial and temporal resolutions, such inverse systems should be mutually consistent in the sense that their posterior flux estimates should agree within their respective uncertainties. Inconsistencies between such estimates can help diagnose system components that require further improvements. Moreover, regional limited-area models require boundary conditions, which are usually provided by global model simulations. In such nested configurations error propagation from the global to the regional domains need to be properly accounted for in order to provide realistic posterior uncertainty estimates for the regional flux products.

This task will investigate the sensitivity of regional inversions to uncertainties in boundary conditions using an ensemble of global IFS CO2 simulations. Reciprocally, global models can benefit from regional models running at higher spatial resolution that can exploit plume-resolving observations. One approach is a two-way nested inversion, wherein the high-resolution regional model outputs are used as inputs to the global model, which in turn provides improved boundary conditions. Albeit theoretically robust, this approach presents several limitations in an operational context such as the one envisioned for the prototype, including its computational cost and the maintenance associated with running two inversion systems in parallel. Therefore, in this task an alternative method will be investigated, wherein heterogeneous posterior emission products, from global to regional to local, are assimilated as observations into the global IFS CO2 prototype built in WP5 [see Bousserez, 2019]. This approach would facilitate the integration of many posterior inversion products into a unified CO2MVS product by minimising methodological constraints (no model coupling) and providing a computationally tractable framework wherein a small ensemble of posterior local/regional emission outputs would be rapidly processed

to improve the global IFS CO2 simulation. The regional inversion error statistics required for assimilation into the global prototype will be readily obtained through an ensemble of simulations performed in WP 3. The core activities of this task are the following:

- Sensitivity studies will be performed to assess errors arising from transferring information between inversion systems using boundary conditions.
- This assessment includes the benefit of weak constraint approaches trying to account for uncertainties in boundary conditions by co-optimising selected aspects of it.
- The consistency between global and regional inversions using real data will be investigated in the light of these theoretical uncertainties.
- Inversion simulations will be performed to generate samples of the likelihood functions (i.e., approximation of the averaging kernel matrices) associated with the regional inversions.
- Regional products will be assimilated as observations into the global IFS prototype based on the approximated likelihood functions.

T4.2 Assessing and quantifying errors of biogenic CO2 fluxes (Lead: MPG, contributing CEA, ECMWF, ICOS ERIC, iLab, ULUND, WU, CMCC; M1-M24)

The objective of this task is to facilitate an assessment of uncertainty and error of estimated biogenic CO2 fluxes to support global modelling and data assimilation in WP2: a) allowing for establishing best-possible error covariance parametrizations for the assimilation of biogenic priors, and b) supporting land surface model developments by benchmarking with observations. The task will build upon a data base of globally distributed and quality controlled in-situ eddy covariance measurements of CO2 fluxes (WP6) and complement it with required model forcing data and other necessary ancillary data in a standardized format. This data base will be complemented with a toolbox to read data, apply quality flags, perform various statistical analysis and visualizations of model-data mismatches, and to merge new model simulations into the data base. The toolkit will be easily extensible to customized analyses and shall become a living repository that is shared within the project. The core activities of this task are:

- Collection of requirements and simulation protocol: The requirements on model forcing data (e.g. variables and resolutions) and the functionality of the toolbox will be gathered. Experimental designs for simulation benchmarking to optimally support model development and data assimilation will be discussed and defined. A simulation protocol which includes the definition of experimental setups, output formats, variables, and units will be developed.
- Enhance flux measurement data-base: The data base of globally distributed and quality controlled in-situ eddy covariance measurements of biogenic CO2 fluxes (WP6) will be extended by required model forcing data, processing tools and specific formats, providing data access customized for modelling experiments. The data base includes in-situ measured meteorological variables to allow for forcing models with observed weather conditions and to study the impact of meteorological forcing data uncertainty. Remotely sensed vegetation indices from MODIS as required by some of the participating models will also be provided. All provided variables will be gap filled and be complemented with comprehensive quality flags and additional information needed for the use in modelling activities.
- Perform site level simulations: Participating modelling teams will perform site-level simulations (VPRM, C-TESSEL, SDBM3, ORCHIDEE, ISBA) according to the protocol and using the prepared forcing data. The data-driven FLUXCOM modelling approach will also participate which allows for assessing a potential added value of using FLUXCOM as prior and investigating the potential of using FLUXCOM instead of site-level observations for estimating (aspects of) the error structure of simulated biogenic CO2 flux priors. The latter could alleviate the strong representation bias in the in-situ observation network.
- Establish analysis toolbox: A toolbox to read, pre-process, and analyse observation-simulation mismatches will be developed according to the defined requirements. The toolbox will be designed to facilitate customized extensions of functionality such as enabling modelling groups to investigate non-isotropic spatial and temporal error covariance structure to go beyond current state of the art.

T4.3 Assess and investigate model/inversion uncertainties employing a common inversion framework (Lead: CEA, contributing ECMWF, EMPA, FMI, MPG, TNO, VUA; M9-M36)

Transport errors represent one of the largest source of uncertainties in atmospheric inversions. They impair our ability to compare observations with simulations in a consistent and relevant way. Yet, their quantification proved very challenging in the past because research groups performing inverse modelling experiments can usually only afford to employ one specific transport model in their inversion system. We propose to take full advantage of a new common tool, the Community Inversion Framework (CIF) to rigorously assess transport errors in the present task. The CIF was developed during the H2020 project VERIFY as an open-source flexible research suite for inversion studies. The main purpose behind this new numerical system was to rationalize development efforts within the inversion community by bringing existing systems together within a unified standardized system. The CIF was applied on test cases at the regional scale in Europe in the project VERIFY with a variety of models. We plan to leverage past efforts by applying the CIF on similar configurations to avoid duplicating efforts in generating inversion inputs. We will choose a short period of time (one to several months) to be able to carry out uncertainty quantification using different models (in particular, a set of Eulerian and Lagrangian models, and regional and global models) in different inversion set-up, including different definition of the control vector and of the underlying data assimilation method (variational and ensemble methods). This will allow us to assess the sensitivity to transport model uncertainty in various inversion contexts

The test case will focus on the European scale for CO_2. Two sets of inversions based on two different observation types will be done: one based on in-situ observations and another with CO2-M data. A comparison with CH_4 inversions will also be carried out in order to differentiate the impact of transport errors in one case dominated by ecosystem fluxes (CO_2), and another by anthropogenic emissions (CH_4). A set of at least six transport models (CHIMERE, LMDZ, TM5, FLEXPART, WRF-CHEM, LOTOS-EUROS) will be used in the CIF with all non-transport related parameters remaining the same. For the models which can be easily constrained by ECMWF meteorological data, an ensemble of inversions based on a set of 50 perturbed meteorological forcings (as derived from the EDA-IFS ensemble of simulations) will be carried out to assess the transport error attributable to uncertainties in underlying meteorological fields. This will allow us to quantify transport uncertainties at the meso-scale. It will give guidance for the analyses and set-up of inversions at scales from the continental to the national and fine scales. We will propose a new way of integrating information from several transport models in inversions. This task will support the work carried out in task T4.6 at the continental scale, in task T3.4 at the national scale and in task T3.3 for finer scales.

T4.4 Account for correlated uncertainty and samples biases in satellite data (Lead: VUA, contributing: MPG, CEA; M1-M36)

The aim of this task is to investigate the representation of satellite retrieval uncertainty in inversions. Satellite data are difficult to represent in a statistically consistent manner, not only because the uncertainties of individual satellite retrievals are not statistically independent - but also because the number of available data requires some degree of averaging for which assumptions on the statistics are required. In addition, the data coverage is not even, since the sampling is limited to clear sky conditions and the local overpass time of the satellite. The task makes use of the global and regional nature runs delivered in CHE (CHE D2.6; D2.4) as well as estimated retrieval uncertainties (CHE D2.5) to test inversion performance using CO2-M data relative to the use of OCO-2 data in the VUA, MPG and CEA regional inversion systems.

Activities are as follows:

- Regional inversion simulations using the setup of T3.4, varying the treatment of the CO2M data uncertainty, and the method to aggregate individual retrievals into super-observations. Data are generated from the CHE nature runs using the random and systematic CO2M retrieval uncertainties delivered from CHE. Alternatively, the CO2M end-to-end processor at EUMETSAT could provide orbits and uncertainties. At the start of the project we will decide which dataset is best suited for this task. The CO2M performance is compared to that achieved using OCO-2 (using actual orbits and uncertainties from the OCO-2 data archive used to sample the available nature runs).
- Sensitivity studies with simulated observations focusing on the impact of sampling biases, comparing results of the T3.4 reference setup to alternative tests in which the same number of data is either sampled purely randomly, or data thinning is applied to distribute the measurement constraint more evenly in space and time. Inversions are performed with and without the use of the surface network to investigate its potentially mediating effect. The same tests are performed using an OCO-2 setup to assess whether the impact of uneven sampling gets worse (stronger data constraint) or better (improved coverage) when more satellite data are available.

The task will deliver recommendations for the global system on how to make most efficient use of CO2M data, and a protocol for testing its performance.

T4.5 QND and data assimilation sensitivity studies to assess impact of design options on posterior uncertainty representation (Lead: iLab, contributing ULUND, FMI, MPG, CEA, TNO; M1-M36)

This task will perform data assimilation sensitivity studies and (computationally more efficient) QND experiments to investigate (where possible in a 'light' and flexible DA system) the impact of different design aspects of the inverse modelling / data assimilation approach on accuracy of the fossil fuel emissions (both best estimate and its uncertainty range). The design aspects include:

- in-situ network (i.e. type and coverage of observations)
- inclusion of C14 observations
- length of assimilation window
- prior error description
- set up of the control vector
- direct flux estimation by transport inversion versus parameter estimation by data assimilation (online versus offline)
- evaluation of approaches to posterior uncertainty approximations, including the use of low-dimensional subspaces of the control space

The DA systems applied in this task include the global CCFFDAS, the local CCFFDAS set up around Berlin, CTE-CH4, Jena-CarboScope, and inverse modelling systems around CHIMERE and LOTOS-EUROS. TNO will also advise on emissions data sets including their uncertainties. This task can also respond (within limits) to additional design questions and evaluation assignments from the Mission Task Force.

T4.6 Assessment of uncertainties in European inversion of CO_2 and CH_4 (Lead: ULUND, contributing CEA, ECMWF, FMI, ICOS ERIC, MPG, VUA; M1-M36)

Multi-model inter-comparisons provide valuable (but also often sobering) information about the performance of inversions and the range of uncertainties involved as demonstrated for biogenic fluxes by the Transcom experiments (e.g. Peylin et al. 2013) and more recently the Eurocom experiment (Monteil et al., 2019). From these inter-comparison activities two questions arise:

1. Is the uncertainty range expected given the information on uncertainties that this WP as well as WPs 1-3 provide?
2. What kind of validation measurements and benchmarking metrics would help to quantify the performance of different inversions - which is critical to being able to identify directions for improvement?

The aim of this task is to perform sensitivity experiments to quantify the expected uncertainty range and evaluate the results of the Eurocom (CO_2) and planned IG3IS (CH_4) inversion inter-comparisons. The activities are as follows:

- The ensemble of inversion results already available from the Eurocom CO_2 and upcoming from the IG3IS CH_4 inter-comparisons will be analysed with respect to their uncertainty overall ranges and their consistency with the information on uncertainty components from WPs 1 to 4.
- The analysis of the CH_4 inversion inter-comparison will investigate the readiness of the inversion systems for the potential use of CO2M (which also provides XCH4 observations) in refining CH_4 emissions reporting.

Within this setup, the potential added value of additional measurements (such as profiles from aircrafts, radon concentrations and emission maps) will be assessed for benchmarking inversion performance. Both the evaluation of the inter-comparisons and the benchmarking activities will be closely linked to activities in WP6 concerning the availability of required observations and their uncertainties. The development of benchmarking methodologies (such as performance metrics) and best-practice are done in connection with activities in WPs 2 and 3 and overall benchmarking guidance and criteria including recommendation on the appropriate indices and scores will be detailed.

Deliverables (brief description and month of delivery)

D4.1 Proof-of-concept for multi-scale global IFS prototype (Lead: ECMWF; M36, DEM, PU) – Multi-scale IFS global posterior emission maps for years 2016 & 2021. For each year two months (January and June) will be considered.

D4.2 Toolbox to derive customized model forcing data and for assessing errors of simulated terrestrial CO2 fluxes from data base of biogenic CO_2 flux measurements (Lead: MPG, M24, OTHER, PU)

D4.3 Quantification of transport errors and database of optimized fluxes and simulations for an ensemble of models and inversion set-up (Lead: CEA; M30, R, PU) – Simulated equivalent to in situ observations and satellites, as well as optimized fluxes will be made available in support to T4.6.

D4.4 The representation of CO2M satellite retrieval uncertainty in inverse modelling (Lead: VUA; M33, R, PU) – Report summarising the main findings of T4.4, the consequences for the use of CO2M data, and recommendations for their implementation in inversions.

D4.5 Impact of System Design on Emission Estimates (Lead: iLab; M33, R, PU) – Report summarising the findings on the impact of different design aspects of the inverse modelling / data assimilation approach on accuracy of the fossil fuel emissions (both best estimate and its uncertainty range).

D4.6 Quantification of uncertainty ranges from European multi-model inversions and ways to benchmark inversion systems (Lead: ULUND; M33, R, PU) – Report summarising the robustness of the uncertainty ranges arising from multi-model inter-comparisons for CO_2 and CH_4 as well as potential developments for reducing these ranges including recommendations on benchmarking inversion systems.

Partner Roles	
ECMWF	Participation in T4.1 Task lead, assimilation of regional product ensembles into IFS T4.2 Provision of the offline CTESSEL GPP and Net Ecosystem Exchange (NEE) fluxes T4.3 Provision of IFS-EDA meteorological data
FMI	Participation in T4.3 CIF development, especially for the ensemble system and provision of European CO_2 and CH_4 flux and atmospheric concentration estimates and their uncertainties using CIF and the CTE-CH4 model. T4.5 Evaluate uncertainties of posterior fluxes and improve their temporal consistency by assessing the impact of in-situ network, length of assimilation window, prior error description for CH_4 using the CTE-CH4 model. T4.6 Contribute to evaluation of atmospheric CO_2 and CH_4 concentration estimates and their uncertainties using data from surface in situ network, aircraft, AirCore, TCCON and satellites.
iLab	Participation in T4.1 Providing regional CCFFDAS simulations for use in global prototype system T4.2 Optimisation of SDBM3 against Fluxnet data T4.5 Leading T4.5 and performing QND experiments with CCFFDAS
ULUND	WP4 co-lead, and participation in T4.1 LUMIA experiments on boundary conditions as well as ensemble simulations with WRF-CHEM T4.2 Application of SDBM3 for more realistic biogenic prior error covariances T4.5 Performing QND experiments with CCFFDAS T4.6 Task lead, contributing to the analysis of intercomparison results and their evaluation/benchmarking
TNO	Participation in T4.1 Connecting global CH_4 inversions (as produced in CAMS-73) with regional inversions (with LOTOS-EUROS) and testing with iterative coupling of global and regional scale, passing updated information during each iteration: does it converge to a single solution?

	T4.3 Implementation of LOTOS-EUROS in CIF T4.5: For one country compare the use of the regular emission inventory as prior (as in WP3) with the use of the emission model developed in WP1.4. How Performing sensitivity studies on the impact of priori uncertainty definition on the inversion results on both global and regional scale
VU	WP4 co-lead, and participation in T4.1 Investigate the treatment of boundary conditions in CO_2 inversions using nested domain versions of WRF-CHEM (VUA CTDAS EnKF version). T4.4 Task lead, investigate the impact of the varying spatial coverage of satellite data on the results of CO_2 inversions, including fair whether biases, fixed overpass times etc. T4.6 Joint effort with IG3IS to assess combined uncertainties (transport model, inversion method, etc.) in inverse modelling of national CH_4 emissions. Additional funding is available from IG3IS for coordination of such an experiment. This is to make sure that the results are used in the context of the CoCO2 uncertainty assessment.
ICOS ERIC	Participation in T4.2 and T4.6 Support the development and host the database of extended site level products for terrestrial ecosystem model (T4.2) and atmospheric transport model (T4.6) benchmarking, help design and build the assessment toolbox using existing experience within the Carbon Portal. Host the toolbox software under version control, and implement FAIR access to the code, functionality, and results of this task.
MPG	Participation in T4.2 Task lead, coordination and provision of quality-controlled model input and in-situ CO2 flux observations at FLUXNET sites and providing FLUXCOM results as well as a toolbox for assessment of model outputs against flux observations T4.3 Adaptation of WRF-GHG for use with CIF for EnKF inversions. T4.4 Contribution to sensitivity studies looking at sampling biases and developing guidelines on optimal production of super-observations. T4.5 Following on developments in CHE WP4, looking at in-situ and radiocarbon network design questions for Europe using existing mesoscale modelling system. T4.6 Participation in the intercomparison exercise based on EUROCOM and CH_4/IG3IS results.
CEA	Participation in T4.2 Contribution with some ORCHIDEE simulations to the analysis of the Flux error correlation (in space within and between ecosystems and in time between seasons). T4.3 Task lead, application of the CIF to analyse the transport model differences and their impact on the inversion uncertainties T4.4 Performing inversions and applying outcome in WP3 T4.5 Participation to the data assimilation sensitivity studies based on the system developed in CHE T4.6 Participation to the inter-comparison exercises: EUROCOM and CH_4 (IG3IS/VERIFY)
EMPA	Participation in T4.3 Adaptation of CIF to input from COSMO-GHG model and forward simulations with COSMO-GHG within the CIF framework
WU	Participation in T4.1 Provide ensembles of boundary conditions from CT Europe inversions done in Task 2.4 (multi-species) to regional systems for data assimilation sensitivity studies. Support VUA in their regional inversions with the CTDAS (CarbonTracker) system with WRF-CHEM.
MF	Participation in

	T4.2 Performing site-level simulations using the ISBA model (with and without sequentially integrating EO data) and linking WP4 to WP2 by transferring in WP2 the best validation practices collectively implemented in WP4 across scales.
CMCC	Participation in T4.2 Support the development of the tools to derive extended site level products for terrestrial ecosystem model and application of the processing.

Work package number	5		**Lead beneficiary**			05 CEA						
Work package title	Integration, testing, application and initial validation of prototype systems												
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	46	1.5	1	0	40	3	1	1	2	3	0	0	1
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	Cyl	**TOTAL**
Person months/ participant:	12	0	0	0	1.5	0	0.5	0	0	1	2.5	2.5	**119.5**
Start month	1				**End month**					36			

Objectives

- Extend the CO_2 and CH_4 syntheses of the H2020 VERIFY project to year 2021
- Identify relevant needs for the periodic Global Stocktake that can be addressed by CoCO2 prototype systems
- Prepare the prototype systems and data flow for the first Global Stocktake
- Provide proof of concept for the first Global Stocktake
- Prepare prototype systems for the second Global Stocktake by integrating building block innovations from WP1-WP4

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP5 is led by Frederic Chevallier (CEA) and Nicolas Bousserez (ECMWF).

Brief description of work package

The timeframe of CoCO2 corresponds to that of the first Global Stocktake (GST), that will be delivered at the end of 2023. The second GST will be initiated in 2026 soon after the project has ended. CoCO2 aims at contributing to this important mechanism of the Paris Agreement by providing accurate information about spatially-aggregated anthropogenic emissions of the Parties with a series of prototype systems that have been prepared in CHE, VERIFY or by the Task Forces, and that, for some of them, are being further developed in WPs 1-4. These prototype systems will assimilate real atmospheric observations from space or from the surface in order to constrain globally the anthropogenic CO_2 budget and provide a Monitoring and Verification Support (MVS) capacity to all parties of the Paris Agreement. Distinction between some emission sectors will be aimed at, but will depend on the information content of available observations. The main objective of WP5 is threefold:

1) Extend the CO_2 and CH_4 syntheses of the H2020 VERIFY project to year 2021.

2) Provide appropriate CO_2 anthropogenic emission products for the 1st GST, at a spatial scale consistent with GST requirements.

3) Coordinate WP 1-4 activities and channel research developments into building a comprehensive global multi-scale integrated prototype that will serve as the basis for the pre-operational Copernicus CO_2 service. In

particular, this prototype shall fully exploit current and future observations from the Sentinel mission to deliver CO_2 emission estimates on time for the 2nd GST with the best accuracy.

These three objectives will be carried out in parallel. Objective 2) will be especially challenging given the short time frame and in the absence of the imaging power of CO2M, which will be launched after the end of the project. Therefore, improvements of existing inversion systems with proven performance and accuracy will be prioritized in this task, as well as the development and integration of inversion methods that leverage co-emitted species observations (NO2, CO) to provide additional constraints on the CO2 source attribution problem.

Objective 3) will contribute to the longer-term objective of building the pre-operational Copernicus CO2MVS, and will integrate as many relevant developments from WPs 1-4 as possible. This activity will include the design and implementation of an EQC tool for the future MVS. This observation-based validation tool will serve as a proof-of-concept framework to demonstrate the performance of the final pre-operational system.

For both objectives 2) and 3), an extensive documentation will be prepared in order to make the process that leads to the emission estimates transparent and as useful as possible for the 1st GST.

Resources permitting, WP5 will also consider contributing to the preparation of the first Biennial Transparency Reports (BTRs) of the Paris Agreement, that are due by the end of 2024. This contribution could take the form of guidelines for the use of the prototype systems at national level for inventory verification purposes or for data generation for the inventory itself.

T5.1 Prolongation of the VERIFY synthesis for an additional year (lead: CEA, M13-24)

The four-year H2020 project VERIFY produces each year an observation-based synthesis of CO_2 (fossil fuel and LULUCF sectors) and CH_4 fluxes, at the European-country scale, gathering numerous high-resolution model simulations and atmospheric inversions (based, e.g., on the Community Inversion Framework). The flux synthesis is further confronted to the national inventory estimates that are provided to the UNFCCC. The production of VERIFY synthesis products for year N begins in Q1 of year N+1 with the collection/update of model forcing datasets, continuing through Q2 and Q3 with launching high resolution simulations (bottom up and top down), and finishing with output synthesis before the annual UNFCCC Conference of Parties meeting in Q4. However, the project officially ends on January 31, 2022, which means that VERIFY will not produce synthesis products for 2021, a year critical to the 1st GST. Task 5.1 will thus prolong and fund the VERIFY activities most critical to the creation of European carbon cycle synthesis products for this key year, relying on a methodology developed and consolidated during the four years of VERIFY. These include : preparation of input data for the year 2021 ; bottom-up and top-down CO_2 fossil fuel flux estimates ; bottom-up and top-down CO2 flux estimates for the LULUCF sector ; bottom-up and top-down CH_4 flux estimates ; output data processing and update of the synthesis plots comparing observation based estimates (VERIFY methodology) and UNFCCC inventories ; updates of country summary factsheets and website ; synthesis analysis and article writing ; promotion of the synthesis at the (Conference of the Parties (COP) and Subsidiary Body for Scientific and Technological Advice (SBSTA) meetings of the UNFCCC (together with WP7); and organisation of dedicated meetings between the climate science community and inventory experts. Task 5.1 serves to cement the legacy of the VERIFY project within international climate policies by targeting the next major UNFCCC data collection activity.

T5.2 Identify relevant needs for the periodic Global Stocktake (lead: CMCC, M1-12)

This task will update the User Requirement Document of VERIFY given the needs of the periodic GST process that should be based on best available science, taking advantage from observation-based emission monitoring systems. It is the starting point to define the prototype functionalities for a timely support of the GST, according to the process and concepts defined in the decision 19/CMA.1, further refined on the basis of the guiding questions to be established in 2021 by the Chairs of the UNFCCC Subsidiary Bodies. It is primarily designed to best channel the design of the prototype systems within this WP and will be coordinated with WP7 that has a broader scope.

T5.3 Prepare prototype systems and data flow for the 1st GST (lead: ECMWF, M1-36)

This task will prepare the codes of, and the input data to, the prototypes in a coordinated way. It will integrate relevant results that will have been obtained in WP 1-4 early enough to be used for the 1st GST. It will document them in dedicated Functional Requirements Specification Documents (FRSDs) that explain what the codes do and how they do it. It will harmonize their outputs as much as possible in order to facilitate their post-processing. It will compare the results with the corresponding ones from the VERIFY legacy (T5.1). At least two prototypes are expected to contribute: the global IFS and a local plume inversion system developed at CEA (also contributing to

WP3). In the latter case, some statistical link will have to be made between the ensemble of analysed local emission clusters and emission totals at the country or global scale. Depending on their respective maturity by mid-2022 after the various developments brought in WPs 1-4, some inversion systems for anthropogenic CO2 emissions developed by other partners of the WP will join the data production. This will allow a larger expert group to intercompare and interpret the results.

T5.4 Provide emission estimates and corresponding evaluation for the 1st GST (lead: CEA, M1-36)

This task will run the codes to assimilate real observations acquired for year 2021 on time for the 1st GST. It will provide a first layer of monitoring statistics and visual results of the outputs before WP7 synthesizes them for the EC and the member states. In collaboration with WP4, it will bring the results at the space-time scales that are relevant for the GST. The performance of the prototypes with respect to the user requirements will be documented in Fitness for Purpose Documents (FPDs). The performance demonstration will be based on as much evidence as reasonably possible, from a quantitative point of view (uncertainty of the delivered variables) and from a qualitative point of view (realism of the space-time variations of the delivered variables). The three documents, URD, FRSD and FPD form a logical chain that starts from the GST as the focus user and ends to it. Other uses of the data may also be addressed, like the preparation of the BTSs: this will be also documented in the FPDs.

T5.5 Build pre-operational IFS global multi-scale system (lead: ECMWF, M1-36)

This task will integrate the system elements developed in WP 1-4 into the pre-operational IFS hybrid ensemble-variational prototype. The main objective is to build a pre-operational infrastructure for the future Copernicus CO2 service and to prepare the delivery of the first CO2 emission product on time for the 2nd GST. The system elements required for integration include: the control vector definition (sectors, parameters) (WP 2), the prior error covariance matrix estimation and modelling (WP 1-2), the model transport errors estimation and modelling (WP 2), the observational operators for Sentinel data (WP 2), the development of the ensemble-variational assimilation layer in OOPS (WP 2), the integration of multi-scale, multi-model emission products into the global IFS prototype (WP 3-4). Selection of those system components, tested in WP 1-4, will be achieved through a rigorous performance evaluation process designed and implemented in WP 1 and WP 4 (T1.5, T4.5-4.6). The relevant system elements will then be assembled into the global prototype by interfacing them with the OOPS data assimilation software developed at ECMWF.

T5.6 Design of pre-operational EQC system (lead: CEA, ECMWF, M1-36)

This task focuses on the design and implementation of an Evaluation and Quality Control (EQC) tool for the MVS, building on existing approaches in the CAMS and C3S operational services and on the experience acquired for the 1st GST with real data (T5.4). Benchmarking tools will be developed in the form of data assimilation sensitive experiments following recommendations and inputs provided by WP 2-4. The proposed evaluation methodologies shall accommodate the heterogeneous nature of the posterior emission products considered for the CO2MVS (global, regional, direct mass-balance or Bayesian transport model inversions). Therefore, both global (WP 2, T2.1a) and regional/local (WP 3, T3.1.1-2) reference nature runs will be considered in the EQC. Additionally, observation-based validation methods targeting the different scales of the CO2MVS products will be developed and requirements for their implementation in a pre-operational infrastructure at ECMWF (software, data flow, computational resources) will be evaluated.

Deliverables (brief description and month of delivery)

D5.1.1 Fact sheets with national observation-based carbon budgets from T5.1 for year 2021 (lead: CEA; Month 24, R, PU) – similar to what has been done annually for VERIFY

D5.1.2 Scientific review article on carbon budgets for year 2021 (lead: VUA; Month 24, R, PU) – similar to what has been done annually for VERIFY

D5.2 User Requirement Document (lead: CMCC; Month 12, R, PU) – Define requirements for an observation-based emission monitoring system in the periodic Global Stocktake process.

D5.3 Functional Requirements Specification Documents (lead: ECMWF; Month 24, R, PU) – Code description. Define how the user requirements are addressed by each prototype delivered for the 1st GST from a technical point of view.

D5.4.1 Emission estimates for year 2021 (lead: CEA; Month 18, R, PU) – Emission estimates from each CoCO2 prototype, including the IFS, in an appropriate harmonized format.

D5.4.2 Fitness for Purpose Documents (lead: CEA; Month 24, R, PU) – Describe how the user requirements have been addressed by each prototype for the 1st GST from a scientific point of view.

D5.5 Report on the proposed EQC tool (lead: CEA, ECMWF, Month 36) – The report will address both observation-based statistical validation methods and data assimilation sensitivity methods using simulated observations.

Partner Roles	
ECMWF	WP co-leader T5.5: ECMWF implements the global IFS-driven prototype by assembling system elements developed in WP 1-4 into a pre-operational data assimilation infrastructure. T5.6: ECMWF participates to the development the EQC framework for the future Copernicus CO2 service.
CEA	WP co-leader T5.1: CEA prepares the input data to run the bottom up models for CO_2 and CH_4 fluxes, provides top-down gridded natural CO_2 and CH_4 fluxes and bottom-up gridded natural CO_2 fluxes for all ecosystems, processes all data streams to prepare the synthetic plots and updates the data portal to promote the GHG synthesis. T5.3: CEA coordinates the data production for the 1st GST. T5.4, T5.6: CEA coordinates the data production for the 1st GST and the writing of the code evaluation reports for the first two GSTs. It directly participates to the data production by using its VERIFY-type systems and by adapting and running its own plume analysis system, which is part of WP3.
Cyl	T5.2: Cyl brings together the involved parties in order to assess the reporting process and identify needs towards improved user requirements of CoCO2 for a timely and robust support to GST.
CMCC	T5.1: CMCC contributes to update and analyse the country-scale factsheets of the GHG budget synthesis. T5.2: CMCC leads the task providing linkages with the UNFCCC process and inventory community to improve the user requirement document that was produced in VERIFY in relation to the GST and in close collaboration with WP7 (T4.7 and T4.6).
VUA	T5.1: Contributes to the extension of the VERIFY CO_2 and CH_4 syntheses to year 2021 by producing the annual update on the CO_2 and CH_4 budgets in the form of a synthesis paper. Also contributes to identifying products for stakeholders to be developed.
TNO	T5.1: TNO provides high resolution bottom-up estimates of CO_2 / CH_4 fluxes over Europe.
UEDIN	T5.1: UEDIN provides top-down gridded anthropogenic CO_2 fluxes.
MPG	T5.1: MPG provides i) top-down gridded natural CO_2 fluxes and ii) bottom-up gridded natural CO_2 fluxes (FluxCom data-driven model).
WU	T5.1: WU provides i) top-down gridded natural and anthropogenic CO_2 fluxes and ii) bottom up gridded CO_2 fluxes for the forest sector (using the EFISCEN model).
FMI	T5.1: FMI provides bottom-up gridded wetland CH_4 fluxes over Europe.
EMPA	T5.1: EMPA provides top-down gridded CH_4 fluxes.
ICOS ERIC	T5.1: ICOS ERIC contributes to the analysis and promotion of the country-scale synthetic factsheets (towards COP and SBSTA).
CICERO	T5.1: CICERO produces a synthesis of various anthropogenic CO_2 flux estimates.
FC.ID	T5.5: FC.ID brings the developments about the land surface made in WP2 (model and data) into the pre-operational system (testing/merging code/scripts).
ULUND, ILab	T5.3, T5.4, T5.6: ULUND and iLab contribute to the data production if their CCFFDAS system is mature enough for the GST.

Work package number	6		Lead beneficiary							ICOS ERIC			
Work package title	Observations												
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	6	0	30	0	1	5	0	1	0	0	15	0	0
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	TOTAL
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	Cyl	
Person months/ participant:	5	0	0	0	1	15.5	0.5	0	0	0	0	0	80
Start month	1				End month					36			

Objectives

- Collect and document the in-situ observation and ancillary data requirements of the MVS, taking into account the required precision, uncertainty, and timeliness of the data
- Identify and contact providers of the required data streams, and document the current capacity of these data providers to meet the described needs
- Identify and describe the gaps in the currently available in situ observations and ancillary data, providing guidance with respect to the optimal future expansion of the current in situ capacity
- Determine the technical requirements for a data pipeline to connect the relevant data streams with the operational data assimilation system, and implement a prototype
- Develop new measurement techniques and instruments to fill current gaps

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP6 is led by Werner Kutsch (ICOS ERIC) and co-led by Julia Marshall (MPG)

While it is clear that the Copernicus CO2 Monitoring and Verification Support (MVS) capacity will be heavily dependent on satellite measurements, it is equally clear that ground-based and ancillary measurements are irreplaceable in this context. They are required for calibrating and validating the space component, assimilation into models, validating and further improving process models, and evaluating the output generated by the CO2MVS capacity. These needs are documented extensively in the "Green Report" of the CO_2 Monitoring Task Force (Pinty et al., 2019, hereafter referred to as GR).

Broadly speaking, these needs can be grouped into the following six categories:

1. In situ atmosphere observations and eddy covariance sites to observe biospheric fluxes, LULUCF, in-situ detection of extreme events and their impact (e.g. GR 3.1, 3.2)
2. Radiocarbon as a tracer to directly measure anthropogenic signals (e.g. GR 2.2.1, 3.3, 3.6.2)
3. Additional species and ancillary information (e.g. traffic information, air quality sensors, GR 2.1.2) also from satellite observations (e.g. nightlights (GR3.5), SIF (GR 4.2.4), land cover)
4. Urban networks (GR 3.4)
5. In-situ observations, including ground-based remote sensing measurements, to support satellite retrievals (e.g. GR 4.3)
6. Observations for transport model evaluation, such as radon and profile measurements (GR 3.2, 5.2; link to CoCO2 Task 2.1b)

These categories provide a framework for the tasks below, each of which corresponds to one of the objectives listed above.

T6.1 Definition of requirements for in situ observations (Lead: MPG, Participants: Forth, ICOS ERIC, ULUND, M1-M36)

This task will collect and document the in situ and ancillary data requirements from tasks across WPs 1 through 5. The documentation of these data needs is critical in order to move the work from a scientific exercise to an operational capacity. It is key that all data requirements are documented, and not only those data streams that are currently provided by e.g. ICOS. Thus, the data dependencies of the infrastructure will become transparent, and potential weak links in the provision of timely GST estimates can be identified.

Together with the respective task leaders the data standards (e.g. methodologies, accuracy) and data specifications (e.g. spatial-temporal resolution) for data provision and auxiliary information will be collected. This includes input data for model parameter estimation for process models and data-driven approaches. Implicit within this are the in-situ data requirements of an Evaluation and Quality Control (EQC) system, which is being developed elsewhere in CoCO2. Note that the timeliness requirement for data used for EQC purposes may well be more relaxed than that of measurements that are assimilated directly into the MVS.

The outcome of the task will be a ***living book of requirements*** containing a compilation of variables, methods, network densities and measurement frequencies for the in situ component. This book of requirements will be updated annually over the course of the project as the prototype evolves (D6.1) and will provide guidance for programmatic decisions regarding in situ measurement networks.

This task links extensively with other WPs, including:

- WP1: in situ measurements as input for ocean and land biosphere CO_2 flux products in Task 1.1; surface measurements to improve anthropogenic emission time profiles in Task 1.3; ancillary data for CCFFDAS approach in Task 1.4
- WP2: use of observations to assess e.g. advection scheme in Task 2.1; FFDAS ancillary inputs and urban flux tower measurements for validation in Task 2.2; carbon isotope measurements, flux tower data, and ancillary retrievals (e.g. SIF) in Task 2.3
- WP3: in situ data for use in national-scale inversions in Task 3.4
- WP4: eddy covariance measurements of CO_2 fluxes along with required model forcing data for assessing errors in modelled biogenic CO_2 fluxes in Task 4.2; quantitative network design and data assimilation sensitivity experiments addressing the in-situ network, including radiocarbon in Task 4.5; validation measurements and benchmarking metrics for quantifying the performance of different inversions in Task 4.6
- WP5: observation-based statistical validation tools in Task 5.5

T6.2 Identification of data providers (Lead: ICOS ERIC, Participants: MPG, Forth M1-M36)

Based on the requirements defined in T6.1, data providers will be identified and contacted. Many of the European data providers are already linked to ICOS, but certainly not all. For international coordination, links will be made to the relevant WMO GAW programmes, specifically regional-scale initiatives in IG3IS. To involve input from the broader community in this activity, ICOS ERIC will organize a workshop to discuss the metadata, data quality, and timeliness requirements of additional observations, following and setting community standards in the framework of WMO IG3IS. This workshop is tentatively scheduled as Milestone 6.2 in M18 but may be shifted to allow colocation with relevant international meetings.

For each of the data requirements defined in T6.1, the currently available spatial and temporal coverage of the variable will be compared to the identified needs. Conditions for data provision (precision, uncertainties, timeliness) as well as the organisational sustainability of the observations will be compiled. This latter issue is critical, as many data providers are precariously funded and cannot guarantee the continued provision of the data upon which the Copernicus CO2MVS capacity will depend.

The documentation of the data providers follows directly the structure and content of the compiled data needs described in D6.1. It is proposed to document the current state of in situ data provision at M15 of the project (D6.2) with an update at M33.

T6.3 Identification of gaps in the currently available in situ observations and ancillary data (Lead: ICOS ERIC, Participants: MPG, ULUND, Forth, CEA)

In confronting the data needs documented in Task 6.1 with the currently available data streams documented in Task 6.2, it is expected that a mismatch will be apparent. This discrepancy may take the form of insufficient

measurement coverage, or insufficient timeliness and/or quality control of the required measurements for use in an operational context. Entirely missing data streams, representing scales and variables that are currently not observed, may be identified. These gaps will be documented for each data stream for which they occur. Taking into account the extensive experience of ICOS partners in the development of operational measurement provision, recommendations for improvement will be given concerning organisational, administrative and financial aspects. This task will also address the identification and reporting of current methodology-technology gaps (e.g. standardized methods for analysing/upscaling urban eddy covariance measurements). The documentation of these gaps will also feed into Task 6.5, providing guidance on the work to be carried out there.

In the case of insufficient measurement coverage, the gaps will be addressed with a ***design study for a future comprehensive in-situ network***. This will link directly with Task 4.5, which aims to perform quantitative network design studies addressing the in-situ network (i.e. type and coverage of observations) and the inclusion of radiocarbon observations. Thus, the outcome of this task is not only the documentation of the gaps themselves (in D6.3) but will also lead to recommendations for how to cost-effectively close these gaps for the in-situ network and radiocarbon measurements (to be documented in D4.5). This action links to the proposed extension of the European radiocarbon network, as documented in section 3.6.2. of the CO_2 Green Report. A close link to Task 4.5 is provided through the involvement of ULUND, MPG, ICOS ERIC, and CEA in both tasks.

T6.4 In situ data pipeline (Lead: ICOS ERIC, Participants: ULUND, MPG, M1-M36)

In order for the Copernicus CO2MVS capacity to be able to use the in-situ measurements in an operational capacity, the various data streams need to be provided to the operational data assimilation system in a reliable and timely manner. This task is building on the current capacity of ICOS as provider of high quality greenhouse gas observations using a robust, FAIR, and transparent data processing pipeline and repository, but this capacity needs to be extended to ingest and process many new data streams from ancillary tracers, city observations, and mobile sensors. This task will determine and document the technical requirements for creating such a data pipeline and implement the basic functionality to digest and process the additional data streams including near real time and final quality-controlled data publication to the pipeline of CAMS (D6.5).

T6.5 New measurement techniques and instruments to fill gaps (Lead: AGH, Participants: CMCC, ICOS ERIC, Forth, ULUND, M1-M36)

This task will focus on investigation of potential of combining different in-situ observation systems with dynamic datasets and high-resolution modelling systems to capture the spatiotemporal variability in CO_2 concentrations and flux distributions in urban environment and thus better discriminate between anthropogenic and biogenic CO_2 fluxes. The observation systems will include urban flux towers, meteorological observations, boundary layer profiling using airborne platforms based on Unmanned Aerial Vehicles (UAVs), low cost sensors, as well as the application of a high-temporal-resolution radiocarbon tracer experiment on a campaign basis aimed at the characterization of the diurnal variability of anthropogenic emissions in cities. The dynamic datasets will originate from remote sensing (e.g. land cover monitoring, vegetation dynamics, urban morphology), while population density and other citizen data, such traffic data, will be involved. The potential added value of integrating networks of IoT (Internet of Things) sensors delivering meteorological, atmospheric composition and traffic data with comparatively lower quality but higher density will be explored.

The radiocarbon and UAV profile measurements will be carried out by AGH and will focus on the city of Krakow, Poland. Measurements will begin already in the target year of 2021 to ensure that the datasets collected can be exploited by the modelling work in Task 3.3. The work by FORTH focusing on urban flux tower measurements and related urban-scale emission monitoring will focus on Basel, Switzerland and Heraklion, Greece. Here, also, the measurements will cover at least the full year of 2021, one of the target years of the CoCO2 project. Synergies between the methodology of the urbisphere project (ERC -Synergy, GA No 855005) and the work in CoCO2 will be exploited.

Deliverables (brief description and month of delivery)

D6.1 Book of in-situ requirements (Lead: MPG; M12, M24, M36, R, PU) – The book of requirements will contain a compilation of variables, methods, network densities and measurement frequencies for the in situ component of the envisaged monitoring and verification support system. As a living document, it will be updated as the project progresses. A first version will be provided by M12, a second updated version by M24, and a final version for M36.

D6.2 Report on data providers and long-term data availability (Lead: ICOS ERIC, M15, M33, R, PU) - For each of the data requirements identified in D6.1, the current spatial and temporal coverage, uncertainty, and timeliness of the available measurements with a link to the data providers will be documented. A first version will be provided by M15, a second updated version by months 33.

D6.3 Gap analysis report of the current in situ measurement capacity (Lead: ICOS ERIC, M30, R, PU) - This report will document the mismatch between the data requirements and the currently available measurements. Suggestions on how to fill these gaps, including organisational, administrative and financial recommendations, will be included.

D6.4 Requirements for data streams from additional tracers and new instrumentation (Lead: ICOS ERIC, M24, R, PU) - This report that describes the requirements for all the new in situ observational data streams beyond the current level 2 and near real time data products at the ICOS data portal including the detailed instrument, quality control and provenance metadata.

D6.5 Demonstrator of the updated data pipeline (Lead: ICOS ERIC, M36, D, PU) - The updated data and metadata streams following the specifications of D6.4 will be implemented at the ICOS data portal and the FAIR open data pipe line towards CAMS and all other potential users is open for access.

D6.6 Dataset of atmospheric observations from Krakow, Poland (Lead: AGH, M33, D, PU) – Data set of one year long observations performed during 2021 in Krakow, Poland including regular observations of meteorology, radiation balance, air quality data and a set of campaigns dedicated to the characterization of the diurnal variation of vertical CO_2 profiles within the urban boundary layer and the anthropogenic CO_2 contribution to the total emissions.

D6.7 New measurement and modelling methodologies for high resolution monitoring of urban anthropogenic and biogenic CO_2 fluxes (Lead: FORTH, M33, D) - A data set of long-term urban flux tower measurements and remote sensing, meteorological, population and traffic data will be used in a novel approach for capturing the spatiotemporal CO_2 flux profiles of the urban environment in fine scales. Moreover, a new urban ecosystem model for the quantification of the biogenic CO_2 flux (i.e. photosynthesis and respiration of urban soils and urban vegetation) will be demonstrated. The test cases will be the city of Basel, Switzerland and Heraklion, Greece and will cover at least the full year of 2021.

D6.8 Analysis of the potential of IoT measurements (Lead: CMCC, M36, R, PU) - The document on the performance and information that can be obtained using a dense network of cheap sensors (IoT) in urban environments, describing the limits and potentialities. This will be based on specific tests on past and new data collections.

Partner Roles	
ICOS ERIC	ICOS ERIC co-coordinates the work package, participates in all tasks and is responsible for deliverables 6.2, 6.3, 6.4, and 6.5. It has to be remarked that ICOS ERIC represents the full competence of ICOS as a distributed research infrastructure, namely the Head Office, the ICOS Carbon Portal (hosted by University of Lund), the ICOS Ecosystem Thematic Centre (hosted by CMCC), ICOS Atmosphere Thematic Centre (hosted by CEA) and the ICOS Central Radiocarbon Laboratory (hosted by University of Heidelberg, currently not partner in CoCO2). University of Lund as host of the ICOS Carbon Portal, CMCC as host of the ICOS ETC have already dedicated resources to ICOS-related tasks. Further resources are distributed to ICOS ERIC. It will be taken care that the highest competence within ICOS ERIC will be available for all tasks. This will be managed between the ICOS-related partners through potential amendments during the runtime of the project, re-distributing resources based on detailed work planning. ICOS Carbon Portal and Thematic Centres will provide established competence of the ICOS data life cycle that is connected through the running cluster project ENVRI-FAIR to the services of the European Open Science Cloud to the Task 6.4.
MPG	Co-lead this work package and lead the compilation of the living book of documents developed in Task 6.1 and constituting Deliverable 6.1. Also contributing to Tasks 6.2, 6.3, and 6.4.
CMCC	Test and evaluate network of sensors (IoT) in urban environment to analyse performances, limits and potentialities.

Forth	Provide the necessary links to WP2, and specifically the benchmarking activity of the fossil fuel modelling (T2.2), to define the in-situ data types and requirements for such task. FORTH will also support the development of D6.1, D6.2 and D6.3, focusing on the requirements, specifications, availability, providers and the gap analysis of the city observations. FORTH will lead the deliverable D6.7 based on the dedicated activities on new measurement and modelling methodologies for high resolution monitoring of urban anthropogenic and biogenic CO2 fluxes that will take place in the framework of T6.5. Finally, FORTH will develop synergies between the methodology of urbisphere project (ERC -Synergy, GA No 855005) and CoCo2.
AGH	Performing city observations in Krakow, Poland, delivering observation data for modelling tasks, coordination of T6.5
CEA	Support T6.3 (together with T4.5) with the regional inversion system that it has developed within CHE WP4.
iLab	Connect T6.3 with the regional inversion system that it has developed within CHE WP4.
ULUND	Support the definition of observation requirements for assimilation with QND experiments (T6.1 and T6.3) and for benchmarking with analysis of inversion intercomparison results (T6.1). ICOS: Implement the support for the ingestion of processed and quality-controlled data (by ATC and other providers) of additional tracers, instrumentation and mobile sensors and data publication in the pipeline to CAMS
FMI	Support the vertical profiling in Task 6.5.

Work package number	7		**Lead beneficiary**						VUA				
Work package title	User engagement												
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	9	0	2	1	2	0	0	0	20	0	0	0	12
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	**TOTAL**
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	Cyl	
Person months/ participant:	2	0	0	0	0	0	0	0	0	0	0	2.5	**50.5**
Start month	1				**End month**				36				

Objectives

- Identify User Community and User Needs to serve UNFCCC national submissions, in a policy-oriented framework.
- Design a set of information products that can meet user needs and provide an outline for a Decision Support System.
- Produce a synthesis of CO_2 (and CH_4) observation-based emission estimates.
- Focus years will be 2016 for first-set of information products and 2021 for the second-set using the differences for assessing progress 5-year apart.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP7 is led by Han Dolman (VUA) and Glen Peters (CICERO).

Brief description of work package

Observation based estimates of emissions are required by multiple stakeholders and at multiple scales to verify bottom up emission estimates. These estimates are performed at different scales for a variety of applications: the continental scale for science purposes, country scale for reporting to the UNFCCC, sub-country scale for urban planning, and for point sources like large power plants (e.g. CO_2 Green report). The main purpose of this work package is to develop a mechanism and the tools to provide diverse, but targeted, information to the relevant stakeholders. This will be achieved by several user consultation meetings and workshops, but also by using existing international communication and planning mechanisms.

The reporting requirements and the implementation of the Paris Agreement require countries to annually report their GHG emissions. While the Global Stocktake (GST) occurs every five years, every two years countries will submit their GHG emission estimates for scrutiny (Biennial Transparency Report). This multilateral facilitated data exchange and review processes holds for all countries. We will support this effort by evaluating and weighing consistent evaluations of the UNFCCC reported estimates against the observational based evidence produced primarily in WP2-4 and aggregated in WP5. For this reason, we plan to interact intensively with WP5.

At a local scale, some cities and regional councils implement plans for CO2 emission reductions and they also need to track progress. We will directly aim and involve these groups to disseminate the results via well-known city initiatives (e.g. Covenant of Mayors, C40, ICLEI). We will further draw in other relevant stakeholders, such as industry (e.g. via FMI) and NGOs (e.g. WWF).

The work package will also improve the usefulness of the observation-based estimates by developing a blueprint for a Decision Support System (DSS) for a range of governments and NGO's. While the development of such a final all-encompassing DSS will likely take many years and requires extensive consultation and feedback from stakeholders, we aim to set the first steps here by developing a blueprint for a DSS that would be part of the Copernicus CO2 service. This will also involve outlining a strategy for the uptake of novel information and graphical material to serve a wider set and range of stakeholders and policy makers beyond those of the national inventory agencies UNFCCC by liaising closely with Global Emission InitiAtive (GEIA).

T7.1 Production of consistent estimates of emissions of CO_2 and CH_4 (Lead: VUA, M1-M36) Detailed estimates will be produced for the top 10 emitters (i.e. US, China, India, Brazil, ...) and countries within the EU-27. Identification and quantification of the divergence between UNFCCC (and other inventory) estimates and observation-based estimates taking into account uncertainties provided by WP1-4 and WP5. These will take the form of 5yr and 2yr averages together with the annual estimates as they become available. Of special interest here is also the representativeness of the 5yr period, particularly with respect to climate sensitive emissions in the AFOLU sectors. These estimates and their analysis will be produced every year when new data and model analysis becomes available. VUA will be responsible for the AFOLU estimates of CO_2 and CH_4 and the development and streamlining of the workflow in CoCO2 to produce the relevant data, while CICERO will be responsible for the fossil fuel emission estimates. We will also establish contacts through GEIA to obtain whenever possible relevant non-CoCO2 estimates from monitoring networks deployed from the US (OCO2) China (TANSAT) and Japan (GOSAT) to compare with the estimates of CoCO2. This effort will be closely aligned with RECCAP2, the regional budget project of the Global Carbon Project.

T7.2 Blueprint for a decision support system (Lead: CICERO, M1-M36) Traditionally, emissions that are reported to the UNFCCC are provided in a multitude of detailed tables and provide little directly actionable information. One of the envisaged future tools of the Copernicus CO2MVS is a decision support system that would provide information on which policy makers and stakeholders can act. This would capitalize on the rich detail in inventory reports but provided in a format that helps policy makers and stakeholders to make use of the wealth of data that is produced in the CO_2MVS. Different reporting formats will be explored, with tools put in place to automate the development of a range of quality outputs. This task will provide the blueprint for such a system. The ideas will be presented and discussed in user consultation meetings, where we will pay special attention on how the data is presented and how we specify possible further actions. This will allow key user communities and stakeholders to provide their input to this development as well.

T7.3 Engagement with policy (Lead: JRC, M1-36) At local scale, city networks like C40 or Covenant of Mayors will help disseminating the results. We have enlisted ICLEI (Local Governments for Sustainability) to help organising these contacts. Closer links with the IPCC working groups and inventory agencies and other data providers will be established. A workshop will be held in the first year to engage both UNFCCC, IPCC, GEIA, and city (or other local) stakeholders. In this process we will involve NGOs, and organisations like UNEP, WMO and GEO. We will

provide a catalogue of published studies on hot spot detection of emissions for CO_2 (cities, powerplants) and CH_4 (gas leaks etc). The final result will be an implementation plan for adequate communication to societies seen as an educational link to fighting climate change. In the final year we will organize a workshop aimed at a wider range of policy makers such as European and national MPs, civil servants active in the climate negotiations, local and regional stakeholders, and the wider public. In this process, we will involve organisation such as UNEP, WMO (I3GIS) and GEO. The result will be an implementation plan for adequate communication.

T7.4 Priority needs for national inventory-based reporting (Lead: ECMWF, M12-36) This task will provide the needed link and dialogue to address the policies and GST process from the Paris Agreement for CO_2 and CH_4 between national inventory agencies and research groups participating in the project. The Task will continue the discussion framework established in the VERIFY project with the aim to align the development of the CO2MVS capacity with the specific requirements from these national reporting agencies. The areas where observation-based emission estimates can contribute most effectively will be identified and further developed through three dedicated workshops.

Deliverables (brief description and month of delivery)

D7.1 Budget Estimates for CO_2 and CH_4 (Lead: VUA; M12,24,36 R, PU) – annual, bi-annual and five-year budget estimates using inventory data, observation-based estimates, indicating uncertainties involved

D7.2 Decision Support Blue Print (Lead: CICERO, M30, OTHER, PU) - Blueprint for a decision Support System specifically for UNFCCC Member States and policy makers that indicate trends, budgets, and uncertainties and hot spot detection.

D7.3 Catalogue of Studies (Lead: VUA, M24, OTHER PU) - Catalogue of published studies on hot spot detection (city estimates, gas leaks etc).

D7.4 Engagement and Implementation Plan (Lead: JRC, M12,36, R, PU)- Engagement plan (M12) and implementation plan (M36)

Partner Roles	
VUA	Leads WP and responsible for annual updates on budgets (7.1) and engagement with policy (with JRC, 7.3) and be involved in and 7.4. Will also be responsible for organising stakeholder and user meetings and contacts with local government organisations such as ICLEI.
CICERO	Co-leads WP, delivers fossil fuel estimates to T7.1, and leads T7.2 to develop an outline for a decision support system
ECMWF	Leads Task 7.4
CMCC	Contributes to task 7.5
CEA	Contributes to task T7.1 and to the link with WP5, where data production is done.
CyI	The Cyprus Institute will contribute in Task 7.4 by communicating with two ministries (Ministry of Agriculture, Rural Development and Environment and Ministry of Labour, Welfare and Social Insurance) for the improvement of the national reporting process in the East Mediterranean region.
JRC	JRC will take care of Task 7.3 and 1. reach out to DG CLIMA and link to the EU27 Member states + UK via the Climate Change Committee Working Group 1 2. link to the urban initiatives, such as the Global Covenant of Mayors 3. reach out to UN organisations, which can engage with the UN Parties for their buy in (e.g. WMO for the observations) or which can multiply the uptake of the system's results (e.g. UNEP for the use of the system by UN Parties for reporting on SDG)
ICOS ERIC	ICOS ERIC is international observing organisation at UNFCCC and connects the project to and presents it at COPs. Furthermore, ICOS ERIC has a well-established cooperation with WMO through GAW and IG3IS.

Work package number	8	**Lead beneficiary**	1 ECMWF

Work package title	Coordination, Dissemination, Exploitation and International Liaison												
Participant number	1	2	3	4	5	6	7	8	9	10	11	12	13
Short name of participant	ECMWF	EMPA	ICOS ERIC	JRC	CEA	MPG	TNO	ULUND	VUA	WU	AGH	BSC	CICERO
Person months/ participant:	24	0	0	0	0	0	0	0	0	0	0	0	0
Participant number	14	15	16	17	18	19	20	21	22	23	24	25	TOTAL
Short name of participant	CMCC	CNRS-LA	DWD	ENPC	FMI	FORTH	iLab	MOi	MF	UEDIN	FC.ID	Cyl	
Person months/ participant:	0	0	0	0	0	0	0	0	0	0	0	0	24
Start month	1				End month				36				

Objectives

- Coordination and project management
- Administrative and financial support
- Quality management
- Risk management
- Communication, Dissemination & Exploitation
- Liaison

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

WP8 is led by Daniel Thiemert (ECMWF, Project Manager) and co-led by Richard Engelen (ECMWF, Project Coordinator).

T8.1 Project Management and Coordination (Lead: ECMWF, M1-M36)

Task 8.1 will provide the project management and coordination for the CoCO2 project. The work will comprise project initiation, including setting up the management structure such as project board, WP leader board, project office etc. The necessary communication channels including mailing lists, and document management system will be implemented to support the project work.

The task will also be responsible for the organisation of project meetings including kick-off meeting and annual project board meetings.

In addition, progress monitoring will occur through regular WP leaders meetings (online, monthly) as well as quarterly progress reports from partners and work packages which will also aid the risk and quality management (see task 8.2).

Finally, T8.1 will also serve the scientific coordination of the project, ensuring that all partners and work packages are aligned and working towards the goal of the project.

T8.2 Risk and Quality Management (Lead: ECMWF, M1-M36)

Based on the initial risk table already identified in Table 3.2b, this task will maintain a risk register (part of D8.1) that is regularly updated (through quarterly progress reports described in T8.1) or on an ad-hoc basis, as required. The task will thus actively monitor existing and emerging risks and identify mitigation measures.

Task 7.2 will also perform the quality management. A quality manual (also part of D8.1) will detail the Key Performance Indicators and will provide target measures for these. The manual will also provide the quality review process for each deliverable of the project, through a rigorous internal review process (at least two reviewers for each deliverable). The quality manual will also contain templates for the project, including deliverables, presentations, posters, etc.

T8.3 Administrative and Financial Management (Lead: ECMWF, M1-M36)

Task 8.3 provides the administrative and financial management for the CHE project. This includes management of potential amendments to Grant Agreement and Consortium Agreement, periodic reporting, management of the project finances (distribution of funds, financial claims, etc.) as well as organisation of periodic reviews. The task will also ensure liaison and communication with the European Commission.

T8.4 Dissemination, Communication and Exploitation (Lead: ECMWF, M1-M36)

T8.4 will act in collaboration with WP6 (which focuses on community liaison and coordination). T8.4 thus provides the dissemination, communication and exploitation activities. In a first step, a dissemination and exploitation plan (D8.3) will be developed, outlining the dissemination activities as well as identifying the potential for exploitation and their routes. In addition, a dedicated Media and Communication Plan will be developed, outlining communication objectives, channels (including social media channels such as Twitter), audiences and approach and providing scripts and templates for communication (D8.4). The task will also develop and maintain the project website as the main portal for project dissemination (D8.2). The task will also develop and maintain the Data Management Plan according to the Open Research Data Pilot of H2020 (D8.5).

In a second stage, the task will be responsible for implementing the dissemination and exploitation plan, e.g. through organisation of scientific publications, newsletters, as well as maintenance of an Intellectual Property Rights (IPR) register. Exploitation will focus on the uptake of the various reports and data sets in the scientific communities and by policy makers.

The task will report at mid-term (D8.6) and at the end of the project (D8.7) on the activities in dissemination and exploitation, including updates to the plan.

T8.5 International Liaison (Lead: ECMWF, M1-M36)

Task 8.5 consists of liaising with the European Commission, ESA, EUMETSAT and the CO2 Task Force as well as the CO2 Monitoring Mission Advisory Group to ensure the project is addressing the relevant questions for which the Task Force needs support. Several members of the CoCO2 consortium are currently a member of the Task Force, which ensures a direct interaction on the relevant topics. Representatives of the Commission, ESA and EUMETSAT also participate in the Task Force. In addition, CoCO2 will liaise within existing coordination activities (e.g., CEOS, GEO, GCOS, WMO, UNEP, and UNFCC) as well as activities at Member state level. T8.5 will also be responsible for the coordination with the CoCO2 External Expert Group, which will provide feedback and guidance on the work performed. Finally, CoCO2 will seek to identify and develop synergies with other relevant H2020 projects.

Deliverables (brief description and month of delivery)

D8.1 Risk and Quality Management Plan (Lead: ECMWF; M2, R, CO) - contains the risk register and quality manual

D8.2 Project Website (Lead: ECMWF; M3, DEC, PU) - Web Portal of the Project

D8.3 Dissemination and Exploitation Plan (Lead: ECMWF, M3, R, PU)- Outline of the dissemination and exploitation activities

D8.4 Media and Communication Plan (Lead: ECMWF, M4, R, PU) - Outline of the communication approach for the CoCO2 Project.

D8.5 Data Management Plan (Lead: ECMWF, M6, R PU) - Outline of the Data Management Principles of the CoCO2 Project

D8.6 Mid-Term Dissemination and Exploitation Report (Lead: ECMWF; M18, R, PU) - reporting on the activities in the first 18 months and providing an update to the dissemination and exploitation plan

D8.7 Final Dissemination and Exploitation Report (Lead: ECMWF; M36, R, PU) - reporting on the activities in the second 18 months and providing an outlook of activities after the end of the project

Partner Roles	
ECMWF	leader of the work package, project management, liaison, dissemination, communication and exploitation
WP leaders	Contribute to management through their specific WP activity efforts

All Partners	Contribute to dissemination and communication through their specific WP activity efforts

Table 3.1 b: List of work packages

Work package No	Work Package Title	Lead Participant No	Lead Participant Short Name	Person-Months	Start Month	End month
WP1	(Offline) Prior and Ancillary Information	07	TNO	166	1	36
WP2	Development of global modelling and data assimilation capacity in an MVS	10	WU	156	1	36
WP3	Local and regional modelling and data assimilation	02	EMPA	196.5	1	36
WP4	Connecting scales and uncertainties	08	ULUND	127.5	1	36
WP5	Integration, testing, application and initial validation of prototype systems	05	CEA	119.5	1	36
WP6	Observations	03	ICOS ERIC	80	1	36
WP7	User engagement	09	VUA	50.5	1	36
WP8	Coordination, Dissemination, Exploitation and International Liaison	01	ECMWF	24	1	36
			Total PMs	920		

Table 3.1 c: List of Deliverables

Deliverable (number)	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
D1.1	Prior Emission Dataset (PED) 2016 and 2021	WP1	TNO	D,R	PU	M12/20
D1.2	Global mosaic PED 2015 or 2016	WP1	JRC	D,R	PU	M18
D1.3	Documentation of new temporal and spatial profiles including a global point source database	WP1	BSC	D,R	PU	M24
D1.4	Emission model for Data Assimilation (DA)	WP1	TNO/ULUND	OTHER	PU	M24
D1.5	PED uncertainty 2016 and 20212021 and uncertainties based on Monte Carlo simulation using the emission model from D1.4	WP1	ECMWF/JRC	D,R	PU	M18/30
D2.1	Progress on developing the global transport model, data assimilation, and preliminary demonstration of CO2MVS capacity	WP2	ECMWF	R	PU	M12
D2.2	Recommendations on anthropogenic CO_2 emission modelling, evaluation, and optimization	WP2	ECMWF	R	PU	M33
D2.3	Validation of online global vegetation carbon fluxes in ECLAND for prototype modelling developments	WP2	FC.ID	R	PU	M18
D2.4	Demonstrator systems for using remote sensing data (LAI, VOD, SIF) in online global prior fluxes for the CO2MVS prototype	WP2	MF	DEM	PU	M30
D2.5	Demonstration of multi-tracer capability for 2021	WP2	WU	DEM	PU	M36

D3.1.1	Definition of simulation cases and model systems for building a library of plumes	WP3	WU	R	PU	M6
D3.1.2	Assessment of plume model performance	WP3	EMPA	R	PU	M24
D3.2.1	Documentation of plume detection and quantification methods	WP3	EMPA	R	PU	M12
D3.2.2	Benchmarking of plume detection and quantification methods	WP3	FMI	R	PU	M24
D3.3.1	Perspectives on the use of atmospheric transport models for local scale inversions	WP3	ENPC	R	PU	M26
D3.4.1	Inter-comparisons of national scale inversions	WP3	MPG	R	PU	M34
D3.5.1	Ensemble of estimates for assimilation into prototype	WP3	UEDIN	DEC	PU	M30
D3.5.2	Synthesis and recommendations	WP3	CEA	R	PU	M36
D4.1	Proof-of-concept for multi-scale global IFS prototype	WP4	ECMWF	DEM	PU	M36
D4.2	Toolbox to derive customized model forcing data and for assessing errors of simulated terrestrial CO_2 fluxes from data base of biogenic CO_2 flux measurements	WP4	MPG	OTHER	PU	M24
D4.3	Quantification of transport errors and database of optimized fluxes and simulations for an ensemble of models and inversion set-up	WP4	CEA	R	PU	M30
D4.4	The representation of CO2M satellite retrieval uncertainty in inverse modelling	WP4	VUA	R	PU	M33
D4.5	Impact of System Design on Emission Estimates	WP4	iLab	R	PU	M33
D4.6	Quantification of uncertainty ranges from European multi-model inversions and ways to benchmark inversion systems	WP4	ULUND	R	PU	M33
D5.1.1	Fact sheets with national observation-based carbon budgets from T5.1 for year 2021	WP5	CEA	R	PU	M24
D5.1.2	Scientific review article on carbon budgets for year 2021	WP5	VUA	R	PU	M24
D5.2	User Requirement Document	WP5	CMCC	R	PU	M12
D5.3	Functional Requirements Specification Documents	WP5	ECMWF	R	PU	M24
D5.4.1	Emission estimates for year 2021	WP5	CEA	D	PU	M18
D5.4.2	Fitness for Purpose Documents	WP5	CEA	R	PU	M24
D5.5	Report on the proposed EQC tool	WP5	CEA/ECMWF	R	PU	M36
D6.1	Book of in-situ requirements	WP6	MPG	R	PU	M12/24/36
D6.2	Report on data providers and long-term data availability	WP6	ICOS ERIC	R	PU	M15/33
D6.3	Gap analysis report of the current in situ measurement capacity	WP6	ICOS ERIC	R	PU	M30
D6.4	Requirements for data streams from additional tracers and new instrumentation	WP6	ICOS ERIC	R	PU	M24
D6.5	Demonstrator of the updated data pipeline	WP6	ICOS ERIC	DEM	PU	M36

D6.6	Dataset of atmospheric observations from Krakow, Poland	WP6	AGH	DEM	PU	M33
D6.7	New measurement and modelling methodologies for high resolution monitoring of urban anthropogenic and biogenic CO_2 fluxes	WP6	FORTH	DEM	PU	M33
D6.8	Analysis of the potential of IoT measurements	WP6	CMCC	R	PU	M36
D7.1	Budget Estimates for CO_2 and CH_4	WP7	VUA	R	PU	M12/24/36
D7.2	Decision Support Blue Print	WP7	CICERO	OTHER	PU	M30
D7.3	Catalogue of Studies	WP7	VUA	OTHER	PU	M24
D7.4	Engagement and Implementation Plan	WP7	VUA	R	PU	M12/36
D8.1	Risk and Quality Management Plan	WP8	ECMWF	R	CO	M2
D8.2	Project Website	WP8	ECMWF	DEC	PU	M3
D8.3	Dissemination and Exploitation Plan	WP8	ECMWF	R	PU	M3
D8.4	Media and Communication Plan	WP8	ECMWF	R	PU	M4
D8.5	Data Management Plan	WP8	ECMWF	R	PU	M6
D8.6	Mid-Term Dissemination and Exploitation Report	WP8	ECMWF	R	PU	M18
D8.7	Final Dissemination and Exploitation Report	WP8	ECMWF	R	PU	M36

3.2 Management structure and procedures

3.2.1 Project Organisation

The efficiency of the project management and coordination will be ensured using a sound organisational structure, clearly assigning responsibilities to the different participants of the project. This organisational structure will be supported by project management methods relying on the latest communication and collaboration technologies. ECMWF has a proven track record of successfully managing large CSA and will build upon this experience. Project Management and Coordination will be provided by ECMWF, responsible for:

- Leadership of the management work package and of the whole project;
- Organisation of the necessary General Assembly meetings and provision of agendas and minutes;
- Liaison between the Consortium and the European Commission;
- Financial Administration.

Figure 5 reports the adopted management structure. The planned structures and roles are described in detail below.

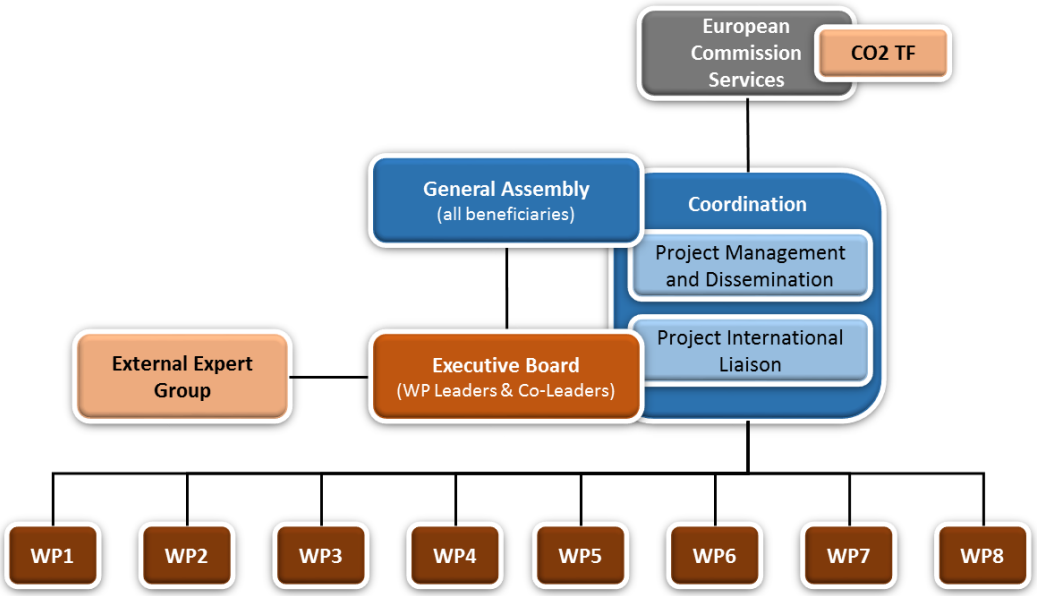


Figure 5: Project Management Structure

The **General Assembly** is chaired by the coordinator and consists of one representative from each partner. It will meet once a year (or in case of need, more often) by arrangement at venues to be agreed by Consortium partners (or through online means). At least once a year, physical meetings are planned, including the project initiation meeting. The General Assembly will be responsible for:

- Monitoring of project progress and costs. Detailed procedures will be agreed at the first meeting of the General Assembly;
- Preparation of any contractual changes; where necessary, revision of the project plan in response to unforeseen problems;
- Conflict resolution;
- Contribution to the resolution of disagreements between participants and assistance in the drafting of the plan for the use and dissemination of foreground;
- Definition and refinement of the exploitation and dissemination strategy.

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- Definition and refinement of the exploitation and dissemination strategy.

The **Executive Board (EB)** will be the supervisory body ensuring successful execution of the project, and will be accountable to the GA. The board will be chaired by the Project Coordinator. The EB is the coordination body and its members will be the WP leaders and Co-Leaders. The EB will convene monthly through online and/or physical meetings. EB meetings will be chaired by the Project Coordinator. Responsibilities of the EB include:

- Monitoring of the effective and efficient implementation of the project,
- Preparation of meetings, proposal of decisions and preparation of the agenda for GA meetings,
- Assurance that the project is compliant with the CA and, if required, proposal of modifications of the CA (for approval by the GA),
- Provision of advice to the GA on rearrangement of tasks and budget, if applicable.

The role of **External Advisory Board (EAB)** will be assigned to the European Commission's CO_2 Task Force.

The **External Expert Group (EEG)** will consist of 15 - 20 international experts, who will follow the CoCO2 project and who will be invited to participate in the CoCO2 meetings. The aim of the EEG is to link to various related initiatives around the world to ensure the CoCO2 community building reaches out to as many groups as possible. Through these links, CoCO2 will also follow and aim to engage with these research groups to ensure that the CoCO2 objectives benefit as much as possible from worldwide expertise and ideas. The following experts have already agreed to be member of the EEG: Peter Rayner (Chair, U MELBOURNE, AU), Kevin Gurney (ARIZONA SU, US), Kevin Bowman (NASA JPL, US), Saroja Polavarapu (ECCC, Canada), Chris O'Dell (CSU, US), Shamil Maksyutov (CGER/NIES, Japan), Heather Graven (IMPERIAL, UK), Ning Zeng (U Maryland), David Crisp (NASA JPL, US), Yasjka Meijer (ESA, EU), Oksana Tarasova (WMO). Some additional members will be confirmed before the anticipated start of the project.

The Coordination team consists of the Project Coordinator, the Deputy Project Leader, and the Project Manager.

The **Project Coordinator** is responsible for the:

- Evaluation of project progress, results and information to be protected;
- Day-by-day legal, contractual, ethical, financial and administrative management of the project;
- Coordination of knowledge and information flows;
- Relations with EU officers;
- Management of the partnership;
- Co-ordination, monitoring and supervision of the overall technical work;
- Supervision of the development of the Reference System Architecture;
- Resolution of technical issues;
- Avoiding internal risks.

The CoCO2 Project Coordinator will be Dr Richard Engelen (ECMWF).

The **Deputy Project Leader** will assist with the general management of the project and deputise for the Project Coordinator, when required.

The CoCO2 Deputy Project Leader will be Dr Gianpaolo Balsamo (ECMWF).

The **Project Manager** is responsible for the efficient administration of the project and works together with the Project Coordinator, Work package leaders and the representatives of each beneficiary. The main tasks are to:

- Establish the necessary infrastructure for the project administration;
- Handle project administration in terms of project progress monitoring and reporting;
- Provide support to the project meetings.

The Project Manager will be Dr Daniel Thiemert (ECMWF).

The Coordination Team will also be responsible for the international liaison and interaction of the CoCO2 project with relevant stakeholders, Task Force, and communities and will thus ensure that the relevant feedback is taken up by the project.

Work package leaders are responsible for:

- Technical co-ordination and supervision of the work related to their assigned work package, including the organisation of work by some or all of the participants in the work package;
- Reviewing the results of the work carried out in each WP, confirming the suitability of the next stages in the project plan and identifying possible problems;
- Ensuring the timely delivery of agreed work package deliverables to high standards.
- Reporting to the EB
- Participating in the project's review meetings and assembling the WP's contributions to the periodic and final reports.

The WP leaders are as follows:

Table 5: CoCO2 WP Leaders

WP	Leader	Co-Leader
WP1	Hugo Denier van der Gon (TNO)	Greet Janssens-Maenhout (JRC)

WP2	Wouter Peters (Wageningen University)	Anna Agusti-Panareda (ECMWF)
WP3	Dominik Brunner (EMPA)	Gregoire Broquet (CEA)
WP4	Marko Scholze (ULUND) and	Sander Houweling (VUA)
WP5	Frederic Chevallier (CEA)	Nicolas Bousserez (ECMWF)
WP6	Werner Kutsch (ICOS ERIC)	Julia Marshall (MPG)
WP7	Han Dolman (VUA)	Glen Peters (CICERO)
WP8	Daniel Thiemert (ECMWF)	Richard Engelen (ECMWF)

The **Task leaders** are the managers in charge of each Task and their responsibilities are:

- Scientific co-ordination and supervision of the work related to their assigned Task as per the project Work Breakdown Structure, including the organisation of work by some or all of the participants in the Task;
- Reviewing the results of the work carried out in each Task, confirming the suitability of the next stages in the project plan and identifying possible problems;
- Ensuring the timely delivery of agreed deliverables to high standards.

The Task leaders have already been appointed and are clearly stated in the WP tables.

Table 3.2 a: List of milestones

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
MS1.1	Prior data 2016 document	WP1	M6	Note describing all gridded global prior (anthropogenic and biogenic) emissions datasets with characteristics and steps towards a full data sets (D1.1, M12) including full uncertainty for 2016 (D1.3 M18) that is necessary in WP2-WP3-WP4-WP5 (incl. assessment using the global mosaic dataset) To also include an emission height profile by sector for point sources
MS1.2	Emission model	WP1	M18	spatio-temporal profiles and emission model for the extending the ECMWF modelling suite
MS1.3	Prior data 2021	WP1	M33	reviewed / improved final global and regional prior emission datasets of ffCO2 and bioCO2 for 2018 and 2021 with reviewed uncertainty
M2.1	Workshop on ECLAND model and planned developments	WP2	M12	This milestone in the form of a meeting will bring together the CoCO2 partners working on the land surface component of the IFS (ECLAND) to discuss the future developments of ECLAND within the community modelling framework. The plan is to organize the meeting as a workshop early on in the project at ECMWF. This will also allow to link the planned developments in CoCO2 with the NWP developments at ECMWF.
MS2.2	First results for data assimilation of CO_2 and co-emitted species	WP2	M16	This milestone documents the first results from a multi-species satellite-based data assimilation

				run, focusing on the TropOMI CO and NO_2 column products.
MS2.3	Evaluation of fossil fuel emissions provided by WP1	WP2	M22	This milestone documents the results from the benchmarking tests to assess the impact of new anthropogenic emission and ocean flux data sets and temporal profiles from WP1. The focus of the report is to provide feedback to WP1.
MS2.4	Completion of first global nature runs and global ensemble runs for data assimilation sensitivity studies	WP2	M24	This milestone documents the production of the first 9km global nature runs based on 2016 consolidated emissions and 2021 fast track emissions from WP1, as well as the corresponding ensemble simulations at 25km resolution. A shorter 9km nature run will be provided for selected months with full chemistry. The nature runs will benefit from the latest transport developments delivered by T2.1 and the integration of temporal/vertical profiles provided by WP1. The nature run data set will be used by WP3 and by ESA for the production of simulated CO2M observations.
MS3.1	Library of plume simulations	WP3	M15	Data set of plume simulations for isolated sources and cities for a wide range of conditions. The data set will serve as nature runs for development and benchmarking of methods in Task T3.2 and T3.3.
MS3.2	Ensembles of local emission estimates for assimilation into prototype	WP3	M24	First set of local estimates for the first tests of assimilation of results from other inversions into the multi-scale prototype.
MS4.1	Database of optimised regional fluxes based on ensemble of IFS-driven boundary conditions	WP4	M24	Availability of database of optimized regional fluxes.
MS4.2	Best-practice on benchmarking atmospheric transport inversions	WP4	M24	A collection of atmospheric datasets hosted at the ICOS-CP together with best practice guidelines for evaluating atmospheric transport inversions.
MS5.1	Global long-window ensemble-variational IFS CO2/CO/NOx emission inversion for years 2016 & 2021	WP5	M24	This system will allow one to extend the assimilation window to several weeks for CO2 emission optimization (i.e., Kalman smoother configuration).
MS5.2	Global multi-scale long-window ensemble-variational IFS CO2/CO/NOx emission inversion for years 2016 & 2021	WP5	M36	This system will allow one to extend the IFS inversion system capabilities to the assimilation of external, multi-scale posterior emission products as observations.
MS5.3	Pre-operational testing of the EQC tool	WP5	M36	Testing of the EQC tool using prototype results from 2016 & 2021 inversions.

MS6.1	First compilation of in-situ data requirements	WP6	M12	Availability of the first version of the Book on in situ requirements, which will be used as input for the other tasks in WP6.
MS6.2	Workshop on data requirements	WP6	M18	Workshop to discuss the metadata, data quality, and timeliness requirements of additional observations following and setting community standards in the framework of WMO IG3IS. The outcome of this workshop will be documented as part of D6.4.
MS7.1	Presentation of first ideas for decision support system at user engagement workshop	WP6	M18	The ideas for a future decision support system will be presented and discussed at user consultation meetings with national inventory agencies. This will allow this key user community to provide their feedback and input to this development for a proper co-design of the functionality.
MS7.2	User consultation workshop	WP7	M30	Organisation of a workshop aimed at a wider range of policy makers such as European and national MPs, civil servants active in the climate negotiations, local and regional stakeholders, and the wider public.
MS8.1	Project initiated	WP8	M2	Communication channels established
MS8.2	Project completed	WP8	M36	All deliverables and reports submitted

3.2.2 Project management procedures

Project management activities will be based on the following procedures, which will be agreed among project partners and detailed in the Project Quality Plan, according to ISO-9001:2000 directives.

- Detailed project planning;
- Project monitoring and control process;
- Project deliverables reviews and validation;
- Risk and problem management;
- Communication management.

3.2.2.1 Project monitoring and control

Project monitoring and control processes allow for the planning, tracing and monitoring of work progress and other events that impact the project.

The main formal occasions for project control will be:

- Project Progress Meetings, scheduled both regularly and for special purposes. Regular internal Progress Meetings will be held by each project team. Output from meetings will be Work Progress Reports and Risk/Problem Management Reports that will be collected by the Project Manager in order to produce corresponding documents that will be discussed during Progress Meetings at project level.
- General Assembly meetings will normally be planned to correspond with project milestones or on request of either the Project Coordinator or project partners.

The following project meetings are planned: Kick-off (M1), General Assembly (Q4/5), Review Meeting (Q6/7), General Assembly (Q8/9), Final Review Q12).

3.2.2.2 Risk Management

Risk management aims to minimise factors that can be detrimental to project objectives. Risk management will be performed at all project levels and will adopt a uniform and systematic approach across project teams to:

- Identify and evaluate risks;

- Define and plan proactive and efficient actions for risk reduction;
- Start, perform and control planned mitigation activities;
- Document progress of risk management activities and evaluating their results with continuity in order to bring needed corrections.

The duty of risk management will be shared by Project Teams and Project Coordinator with support of the Project Manager, according to their responsibility level. They will trace identified risks in the Risk Management report, which describe risk probability, seriousness in terms of impacts and costs, mitigation strategy, risk monitoring activities and plan of mitigation activities.

A specific procedure will be defined for risk escalation from project team level up to General Assembly level.

Table 3.2b: Critical risks for implementation

Description of risk (indicate level of likelihood: Low/Medium/High)	WP(s) involved	Proposed risk-mitigation measures
Personnel involved or recruited not able to fulfil tasks (low)	all	Monitoring by the PO, and implementing adjustments within each organisation through GA
Partner leaving the consortium (low)	all	some of the competencies are partially overlapping, introduction of new partner
Underperforming partners (medium)	WP8	Close contact between WP Leaders and Project Leader, short feedback loops and personal contact
Late delivery of Global/Regional emission dataset T1.1 (low)	WP1	This risk is relevant for the quality of WP2 global and WP3 regional CO_2 simulations. The risk is mitigated structurally within the CoCO2 project by having only two focus years 2016 and 2021. The provision of 2016 emissions dataset (and 2015 available from CHE project) will allow to test and study fast-track options for 2021 (using 2020 information).
Late delivery of Global Nature run dataset T2.1 (medium)	WP2	The global nature runs are functional to WP2-3-4-5 and dependent on WP1 emissions. In order to mitigate the risk of late delivery a first version of the 2016 global nature runs has been realised within the CHE project as extended deliverable item in order to cover 2016 (low risk). The risk remains medium for the 2021 nature runs.
Prior uncertainties and error correlation T1.5 not usable in T2.1 (medium)	WP1, WP2, WP5	The use of prior uncertainty and correlation assumptions developed within the CHE project can mitigate this risk. The quality of data assimilation depends on well-calibrated error statistics and would in that case deteriorate somewhat.
Systematic differences between local, regional and global CO_2 emissions and concentrations (medium)	WP3, WP4, WP5	Differences are expected due to scale-dependent capacity in describing CO_2 emissions, transport, and observations availability. A multi-source multi-stream data assimilation approach and the established benchmarking are both mitigating measures to enable detecting inconsistencies due to errors or misrepresentation (outliers) and scale-dependent diversity (useful signal) to integrate in the CO2MVS.
Difficulty in benchmarking multiple inversions due to sparsity of ground-truthing observations (low)	WP4, WP6	Observational data are key to the benchmarking activities. However, ground-truthing remains a risk in case of differences in observationally sparse areas. This risk is mitigated by explicitly accounting for uncertainty estimation and flow-

		dependent error characterisation. Inter-scale differences and consensus estimates are also among the mitigation measures that will be outlined in the WP4 benchmarking best-practice.
Delay in getting input from WP 1 - 4 for the global prototype contributions for 1st GST (medium)	WP5	The key to mitigate this risk is to work closely with WP-leaders in promptly detecting delays and deviation so that integration work can proceed. The experience within the CHE project in organising dedicated small workshops between integration team and the WP leaders has proven an efficient mitigation measure.
Degradation of CoCO2 assembled prototype performance following integration (low)	WP5	The incremental approach adopted in WP2 shall reduce the risk of unforeseen deterioration in the assembled prototype. A further step of Evaluation and Quality Control within WP5 is introduced to further mitigate this risk.
In-situ data accessibility (medium)	WP6, WP2	Effective and timely data access to in situ data will be key to the CO2MVS capacity. Addressing these critical requirements is a longer-term development in WP6, in collaboration with other stakeholders, but there is also a risk within CoCO2 itself related to the planned benchmarking and quality assurance activities
Difficulties in compiling consensus estimates for emission in T7.1 (medium)	WP7, WP5, WP4	Inconsistencies in the production of emission estimates for reporting activities are expected. The characterisation of uncertainties within WP4, the Evaluation and Quality Control in WP5 and expert judgement within WP7 and CoCO2 consortium are mitigation measures to ensure consistent messages for policy makers and stakeholders.
Extended travelling difficulties due to epidemic outburst or other unforeseen events affecting consortium meetings and onsite working patterns (low)	WP8, all	To mitigate the risk of unforeseen circumstances preventing physical access to facilities will be mitigated by use of digital repositories for the internal communication and prompt access to all deliverables of public access. Streaming facilities for the main gatherings such as general assemblies and workshops will contribute to mitigate this risk.

3.2.2.3 Problem resolution

The aim of problem resolution is to guarantee project objectives against impacts of negative events on quality of project results, planned times and project budget.

Problems may occur during all project phases and activities. They will be analysed and managed inside the related project team; in the case that they cannot be resolved or entail risks for the whole project, they are referred to the Project Coordinator and the General Assembly.

All problems will be included in the Problem Management reports at both Team Leader and Project Manager level. The report will include problem description and classification, problem status, problem resolution activities and their costs and results.

3.2.2.4 Innovation management approach

Traditionally, innovation management revolves around market/user needs, science and technology development, and market realisation. However, as CoCO2 is focused on Capacity Building and Coordination, this approach only partially applies, e.g. to some results of CoCO2 contributing to future CO_2 missions, system designs, etc.

Thus the innovation management in CoCO2 will focus on the sustainability of the CoCO2 results and ensuring that follow-on activities can build upon the momentum created by CoCO2. This, therefore, means that the innovation management will include actions to collaborate with the Task Force (as e.g. in WP8), collaboration with member

states to communicate the results and findings, and thus mobilise efforts (e.g. through workshops) for a future continuation of the CoCO2 activities leading to a European Platform for Monitoring CO_2 anthropogenic emissions.

3.3 Consortium as a whole

The CoCO2 Consortium (Figure 6) is comprised of 25 partners from 14 European countries (Germany, Netherlands, France, Switzerland, Italy, United Kingdom, Sweden, Norway, Portugal, Poland, Cyprus, Spain, Greece, Finland). Through ECMWF, the reach is extended beyond these countries due to the member and cooperating states of this international organisation. This extended reach will be further enhanced by ensuring that institutes from member states outside the consortium are invited to the workshops organised by the CoCO2 project, thus ensuring that this initiative will be truly European and relevant capacity is built in all regions of Europe.

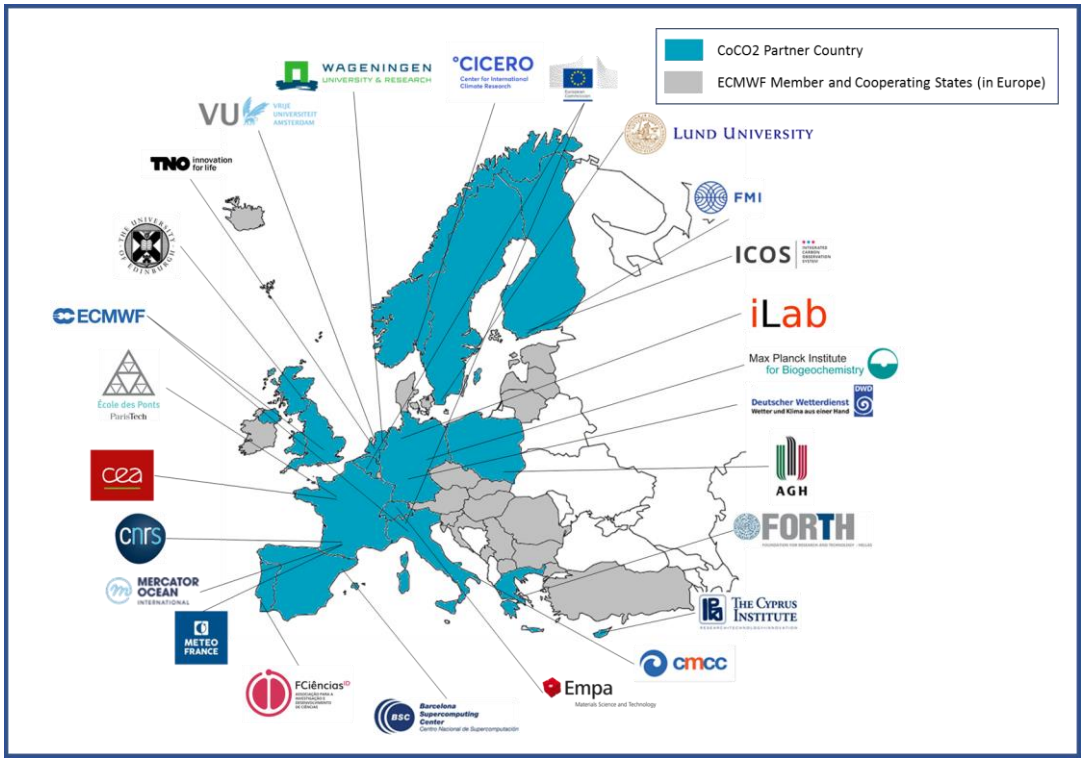

Figure 6: CoCO2 Consortium

The partnership presents a well-balanced mixture of research organisations (EMPA, JRC, CEA, MPG, TNO, ULUND, VUA, WU, AGH, BSC, CICERO, CMCC, CNRS-LA, ENPC, FORTH, UEDIN, FC.ID, CyI), a very active SME (iLab), International Organisations (ECMWF, ICOS) as well as operational centres (ECMWF, ICOS ERIC, DWD, FMI, MOi, MF). All partners have experience in collaborative research on a European level and have previously been engaged in FP projects.

3.4 Resources to be committed

The overall budget is outlined in the table below. In total, 920 Person Months (PM) will be deployed during the 3 years project time, averaging 25.55 persons per project month. The budget of €8,999,718.75 requested EC contribution is within the budget expectations indicated by the European Commission in the Call text. The Consortium considers this appropriate due to the complexity of the project and the uniqueness of its offerings requiring the involvement of a variety of partners.

	Participant	Country	(A) Direct Personnel costs, €	(B) Other Direct costs, €	(C) Direct costs of subcontracting, €	(D) Direct costs of providing financial support to third parties, €	(E) Costs of inkind contributions not used on the beneficiary's premises, €	(F) Indirect costs, € (= 0.25*(A+B-E))	(G) Special unit costs covering direct & indirect costs	(H) Total estimated eligible costs (= A+B+C+D+F+G)	(I) Reimbursement rate	(J) Max grant, € (=H*I)	(K) Requested grant, €
P1	ECMWF	INT	1,901,775.00	222,000.00	15,000.00	-	-	530,943.75	-	2,669,718.75	100%	2,669,718.75	2,669,718.75
P2	EMPA	CH	294,000.00	10,000.00	-	-	-	76,000.00	-	380,000.00	100%	380,000.00	380,000.00
P3	ICOS ERIC	INT	284,000.00	20,000.00	-	-	-	76,000.00	-	380,000.00	100%	380,000.00	380,000.00
P4	JRC	INT	81,000.00	3,000.00	-	-	-	21,000.00	-	105,000.00	100%	105,000.00	105,000.00
P5	CEA	FR	456,000.00	16,000.00	-	-	-	118,000.00	-	590,000.00	100%	590,000.00	590,000.00
P6	MPG	DE	302,000.00	10,000.00	-	-	-	78,000.00	-	390,000.00	100%	390,000.00	390,000.00
P7	TNO	NL	294,000.00	10,000.00	-	-	-	76,000.00	-	380,000.00	100%	380,000.00	380,000.00
P8	ULUND	SE	270,000.00	10,000.00	-	-	-	70,000.00	-	350,000.00	100%	350,000.00	350,000.00
P9	VUA	NL	326,000.00	10,000.00	-	-	-	84,000.00	-	420,000.00	100%	420,000.00	420,000.00
P10	WU	NL	310,000.00	10,000.00	-	-	-	80,000.00	-	400,000.00	100%	400,000.00	400,000.00
P11	AGH	PL	77,500.00	62,500.00	-	-	-	35,000.00	-	175,000.00	100%	175,000.00	175,000.00
P12	BSC	ES	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P13	CICERO	NO	160,500.00	7,500.00	-	-	-	42,000.00	-	210,000.00	100%	210,000.00	210,000.00
P14	CMCC	IT	160,500.00	7,500.00	-	-	-	42,000.00	-	210,000.00	100%	210,000.00	210,000.00
P15	CNRS-LA	FR	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P16	DWD	DE	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P17	ENPC	FR	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P18	FMI	FI	160,500.00	7,500.00	-	-	-	42,000.00	-	210,000.00	100%	210,000.00	210,000.00
P19	FORTH	GR	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P20	iLab	DE	168,500.00	7,500.00	-	-	-	44,000.00	-	220,000.00	100%	220,000.00	220,000.00
P21	MOi	FR	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P22	MF	FR	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P23	UEDIN	UK	150,500.00	17,500.00	-	-	-	42,000.00	-	210,000.00	100%	210,000.00	210,000.00
P24	FC.ID	PO	152,500.00	7,500.00	-	-	-	40,000.00	-	200,000.00	100%	200,000.00	200,000.00
P25	Cyl	CY	72,500.00	7,500.00	-	-	-	20,000.00	-	100,000.00	100%	100,000.00	100,000.00
Total			**6,689,275.00**	**498,500.00**	**15,000.00**	**-**	**-**	**1,796,943.75**	**-**	**8,999,718.75**	**25.00**	**8,999,718.75**	**8,999,718.75**

Tables 3.4a and 3.4b outline the efforts allocated to each partner and WP as well as the breakdown of "Other Direct Cost" for partners whose Other Direct Cost exceed 15% of the Personnel Cost.

Table 3.4a: Summary of staff effort

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	Total PMs
01 ECMWF	12	45	12	22	46	6	9	**24**	176
02 EMPA	0	1	**25**	3	1.5	0	0	0	30.5
03 ICOS ERIC	0	1	0	5	1	**30**	2	0	39
04 JRC	13	0	0	0	0	0	1	0	14
05 CEA	10	4	23	10	**40**	1	2	0	90
06 MPG	6	2	9	17	3	5	0	0	42
07 TNO	**20.5**	0	11	6	1	0	0	0	38.5
08 ULUND	9	7	9	**16**	1	1	0	0	43
09 VUA	0	0	10	14	2	0	**20**	0	46
10 WU	0	**24**	12	1	3	0	0	0	40
11 AGH	0	0	10	0	0	15	0	0	25
12 BSC	27.5	6.5	0	0	0	0	0	0	34
13 CICERO	4	0	0	0	1	0	12	0	17
14 CMCC	0	0	0	4	12	5	2	0	23
15 CNRS-LA	23	0	0	0	0	0	0	0	23
16 DWD	0	0	20.5	0	0	0	0	0	20.5
17 ENPC	0	5.5	20	0	0	0	0	0	25.5
18 FMI	0	0	10	13	1.5	1	0	0	25.5
19 FORTH	0	10	0	0	0	15.5	0	0	25.5
20 iLAB	4	3	6	8.5	0.5	0.5	0	0	22.5
21 MOi	24	0	0	0	0	0	0	0	24
22 MF	0	17	0	8	0	0	0	0	25
23 UEDIN	0	3	19	0	1	0	0	0	23
24 FC.ID	0	27	0	0	2.5	0	0	0	29.5
25 Cyl	13	0	0	0	2.5	0	2.5	0	18
Total PMs	166	156	196.5	127.5	119.5	80	50.5	24	920

Table 3.4 b 'Other direct cost' items (travel, equipment, infrastructure, goods and services, large research infrastructure)

11 AGH	Cost (€)	Justification
Travel	7,500	Travel to consortium meetings
Equipment	7,000	second drone system for sharing flight load/backup in case of technical problems
Other goods and services	48,000	3,000 - Maintenance & parts (replacement batteries & electronics) 5,000 - components for AirCore system and Low-Cost sensors tested in the frame of task 6.5 5,000 - Minor update of sampler electronic controls, valves, etc. 5,000 - maintenance (replacement tubing chemical reagents & other consumables) 30,000 - AMS analysis of 14C samples (75-90 samples) collected in the Krakow plume; measurements)
Total	62,500	

Figure 7 shows that research partners make up 64% of the effort which shows the scientific baseline of the CoCO2 proposal. Nevertheless, industry represent 2% of the effort, while International Organisations are responsible for 34%. 8% has been attributed to Project Management, Dissemination and Outreach, which will ensure that the project will successfully integrate the various stakeholders in the consortium, while 79% focus on development and 13% on integration.

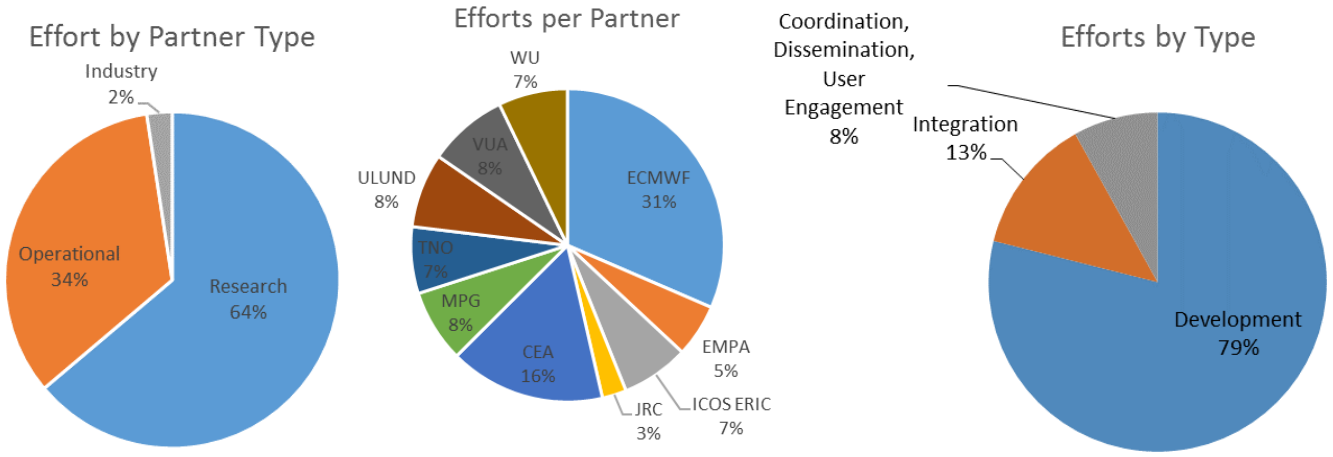

Figure 7: CoCO2 Effort Distributions

Prototype system for a Copernicus CO2 service

Section 4 - 7

Contents

4 Members of the consortium

4.1 Participants

4.1.1 ECMWF

01 - European Centre for Medium-range Weather Forecasts

About the Organisation

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an international organization supported by 34 States: 22 Members (Austria, Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom) and 12 Co-operating Members (Bulgaria, Czech Republic, Estonia, the former Yugoslav Republic of Macedonia, Hungary, Israel, Latvia, Lithuania, Montenegro, Morocco, Romania and Slovakia). ECMWF's principal objectives are the preparation, on a regular basis, of medium-range and long-range weather forecasts for distribution to the meteorological services of the Member States, the development of scientific and technical research directed to the improvement of these forecasts, and the collection and storage of appropriate meteorological data ECMWF's strategy includes the principal goals to provide reliable forecasts of severe weather across the medium-range and high-quality, near-surface forecast products focusing on areas such as precipitation, wind and temperature. ECMWF's computer facility includes supercomputers, archiving systems and networks.

ECMWF is the entrusted entity for the Copernicus Climate Change Service and the Copernicus Atmosphere Monitoring Service. The Copernicus Climate Change Service responds to environmental and societal challenges associated with human-induced climate change. The service will give access to information for monitoring and predicting climate change and will, therefore, help to support adaptation and mitigation. It benefits from a sustained network of in situ and satellite-based observations, re-analysis of the Earth climate and modelling scenarios, based on a variety of climate projections. The service will provide access to several climate indicators and climate indices for both the identified climate drivers and the expected climate impacts. The Copernicus Atmosphere Monitoring Service provides continuous data and information on atmospheric composition. The service consists of daily global forecasts of atmospheric composition, daily forecasts of European air quality, global and regional reanalyses, as well as services on solar radiation, greenhouse gases and emissions.

Role in this Project

ECMWF coordinates the CoCO2 project, leads work package 8 and co-leads work packages 2 and 5). The

coordination role covers the international liaisons of the CoCO2 project and the project management activities within the consortium. The links between CoCO2 and the international CO2 community for both the science and programmatic levels is an essential part of capacity-building effort.

Expertise with Relevance to this Project and Role

ECMWF led the research projects (e.g. GEMS, MACC/-II/-III) preparing the operational elements of the Copernicus Atmospheric Monitoring Services (CAMS) and the Copernicus Climate Change Services (C3S), integrating research across Europe and world-wide. Those projects have supported the transfer from research to operational monitoring and forecasting activities. The atmospheric and surface data assimilations components, continuously developed to take up new Earth Observations from satellites and ground-based platforms, already include the carbon cycle affecting CO2 concentrations and provide a global ensemble-based high-resolution framework that can estimate and characterise uncertainties. ECMWF also is the coordinator of the CoCO2 predecessor CHE.

Key Persons

Dr Richard Engelen (male), a native of the Netherlands, is Deputy Director of the Copernicus Atmosphere Monitoring Service and an expert in remote sensing and data assimilation of atmospheric composition. He obtained his PhD at Utrecht University before working for six years at Colorado State University. Since 2002, he has worked at ECMWF on various projects related to atmospheric composition modelling and data assimilation. As such, he has been part of the development and implementation of the Copernicus Atmosphere Monitoring Service from the beginning. He is an internationally respected scientist on global atmospheric composition issues and has around 50 international peer reviewed publications to his credit. He is a member of several international scientific and advisory committees, including for the European Commission and the European Space Agency.

Dr Gianpaolo Balsamo (male) is a team-leader and senior scientist at ECMWF coordinating a group working on Earth system coupled processes, and responsible for the development of the Earth surface modelling. His education background includes a degree in Physics, a doctorate in Meteorology (PhD) and a professorial accreditation (HDR/Habilitation). His research activities include surface modelling and data assimilation, for weather and environmental monitoring and prediction. His expertise is documented in over 120 publications in international peer-reviewed journal, book chapters and environmental encyclopaedia. His external recognition include membership in the Scientific Steering Groups of the Global Energy and Water Exchanges (GEWEX) panel of the WMO World Climate Research Programme and the Global Cryosphere Watch panels. He has been leading the surface reanalysis ERA-Interim/Land and contributed to several European projects as work-package leaders within large consortium efforts (e.g. EartH2Observe, GEOLAND). He is the coordinator of the CoCO2 predecessor CHE.

Dr Anna Agusti-Panareda (female) is a scientist at ECMWF responsible for the activities on modelling of long-lived greenhouse gases in the Integrated Forecasting System for atmospheric Composition (C-IFS) used in the Copernicus Atmosphere Monitoring Service (CAMS). Her expertise is in the field of meteorology, atmospheric transport and land surface modelling. She obtained a BSc and MSc from the University of Edinburgh in computational physics and meteorology, and a PhD in meteorology from the University of Reading. She has worked in several EU-funded research projects on climate change in remote mountain lakes (MOLAR), the African Monsoon Multidisciplinary Analysis (AMMA), the Monitoring of Atmospheric Composition and Climate (MACC), as well as the NERC-funded Polluted Troposphere Thematic programme. She has over 50 international peer-reviewed publications.

Dr Daniel Thiemert (male) joined ECMWF in 2015 as Project Manager in the Research Department. Before joining ECMWF, he was working for the University of Reading as Senior Researcher and Project Manager, being responsible for the management and coordinator of large scale European and national projects in the area of intelligent systems. He obtained his masters in computer science from the Anhalt University of Applied Sciences, Germany, and his PhD in Computer Science from the University of Reading, UK. At ECMWF he is responsible for the project management of the EU-funded FET-HPC project ESCAPE, ESCAPE-2, CHE, as well as for managing externally funded project acquisition.

Relevant Publications (up to 5)

1. BAUDOUIN RAOULT, CÉDRIC BERGERON, ANGEL LÓPEZ ALÓS, JEAN□NOËL THÉPAUT, DICK DEE, Climate service develops user-friendly data store, ECMWF Newsletter no. 151, doi:10.21957/p3c285
2. Copernicus Atmosphere Monitoring service, https://atmosphere.copernicus.eu
3. McNorton, J., Bousserez, N., Agustí-Panareda, A., Balsamo, G., Choulga, M., Dawson, A., Engelen, R.,

Kiping, Z., and Lang, S.: Representing Model Uncertainty for Global Atmospheric CO2 Flux Inversions Using ECMWF-IFS-46R1, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-314

4. Ciais, P, D. Crisp, H. Denier van der Gon, R. Engelen, G. Janssens-Maenhout, M. Heimann, P. Rayner, and M. Scholze: Towards a Euroepan Operational Observing system to monitor Fossil CO2 Emissions. Final report from the expert group, European Commission, doi:10.2788/350433

5. Ciais, P., Dolman, A. J., Bombelli, A., Duren, R., Peregon, A., Rayner, P. J., Miller, C., Gobron, N., Kinderman, G., Marland, G., Gruber, N., Chevallier, F., Andres, R. J., Balsamo, G., Bopp, L., Bréon, F.-M., Broquet, G., Dargaville, R., Battin, T. J., Borges, A., Bovensmann, H., Buchwitz, M., Butler, J., Canadell, J. G., Cook, R. B., DeFries, R., Engelen, R., Gurney, K. R., Heinze, C., Heimann, M., Held, A., Henry, M., Law, B., Luyssaert, S., Miller, J., Moriyama, T., Moulin, C., Myneni, R. B., Nussli, C., Obersteiner, M., Ojima, D., Pan, Y., Paris, J.-D., Piao, S. L., Poulter, B., Plummer, S., Quegan, S., Raymond, P., Reichstein, M., Rivier, L., Sabine, C., Schimel, D., Tarasova, O., Valentini, R., van der Werf, G., Wickland, D., Williams, M., and Zehner, C.: Current systematic carbon cycle observations and needs for implementing a policy-relevant carbon observing system, Biogeosciences, 11, 3547-3602, doi:10.5194/bg-11-3547-2014, 2014

Recent Projects (up to 5)

- CO2 Human Emissions (CHE) (2017 - 2019)
- Global and regional Earth-system monitoring using satellite and in-situ data (GEMS) project (2005 - 2009)
- Monitoring Atmospheric Composition and Climate (MACC) project (2009 - 2015)
- Copernicus Atmosphere Monitoring Service (2015 -)
- Copernicus Climate Change Service (2015 -)

Major Hardware/ Infrastructure available

ECMWF maintains a multi-petaflops supercomputer facility which is designed for operational resiliency featuring two Cray XC40 systems and independent Cray Sonexion storage systems. Each subsystem consists of 20 Cray XC40 cabinets equipped with Intel Broadwell processors and around 3,600 dual-socket compute nodes per system, a number of Cray Development and Login nodes and around 10 petabytes of Lustre storage with the ability to cross mount the Lustre file systems between the halls.

4.1.2 EMPA

02 - Eidgenössische Materialprüfungs- und Forschungsanstalt

Empa
Materials Science and Technology

About the Organisation

EMPA is a Swiss Federal research institute within the ETH domain with ~1000 employees including ~150 PhD students. The Laboratory for Air Pollution/Environmental Technology has a long and outstanding record in air pollution and greenhouse gas (GHG) monitoring and atmospheric modelling. It operates the Swiss National Air Pollution Monitoring Network (NABEL), the World Calibration Center (GAW-WCC) for CO_2 and other gases on behalf of WMO, and is responsible for the Swiss monitoring activities in several international programs. It is a world-leading developer of Laser absorption spectrometers for high precision measurements of atmospheric trace gases and isotopes. The laboratory has consistently advanced emission estimation and source attribution of air pollutants and GHG by successfully linking field measurements with model approaches. It has (co-) developed several advanced atmospheric modelling systems (FLEXPART-COSMO, COSMO-GHG, GRAMM/GRAL, COSMO-BEP-Tree) and is a founding member of the Center for Climate Systems Modeling C2SM at ETH. It has extensive expertise in atmospheric transport and inverse modelling with a focus on regional to urban scales.

Role in this Project

Co-lead WP3; high-resolution atmospheric transport modelling; plume detection; inverse methods

Expertise with Relevance to this Project and Role

- Advanced users and developers of Eulerian and Lagrangian transport models
- High resolution CO_2 modelling with COSMO-GHG in support of future CO_2 satellite mission (Brunner et al. 2019; Kuhlmann et al. 2019; Liu et al. 2017)
- Inverse emission estimation using Bayesian methods and Kalman Filters: Evaluation of Switzerland's GHG inventory of CH_4, N_2O and synthetic GHGs (Henne et al. 2016; Annex of Swiss National Inventory Reports).

Estimation of European halocarbon emissions (Brunner et al. 2017)

- Plume detection and quantification methods (Kuhlmann et al. 2019; Kuhlmann et al. 2020 in prep.)
- Modelling of urban climate (Mussetti et al. 2019a,b) and urban air pollution (Berchet et al. 2017a,b)
- Air pollution modelling with COSMO-ART: Contributed to eight publications in framework of COST Action EuMetChem and Air Quality Model Evaluation International Initiative AQMEII-2.
- Evaluation of atmospheric chemistry transport models (Brunner et al. 2003, 2005, 2015).

Key Persons

Prof. Dr. Dominik Brunner (male) is the head of the modeling and remote sensing group with currently 3 PhD students and 8 postdocs/senior scientists. He is also adjunct professor and lecturer for atmospheric chemistry at ETH Zurich. His group is applying and developing atmospheric models from the city to the regional scale to study the sources, distribution and impacts of air pollutants and greenhouse gases. He was PI of the Swiss project CarboCount-CH, which established an observation and inverse modeling system for CO_2 and CH_4 for Switzerland. He is PI of the project Carbosense4D, which combines a dense network of ~250 CO_2 sensors with data science methods and atmospheric modeling. His group is tasked by the Swiss Federal Office for the Environment to provide annual top-down estimates of Switzerland's GHG emissions as a contribution to the annual reporting to UNFCCC. D. Brunner is also active in satellite and airborne remote sensing with a focus on NO_2. He has been a member of the CarbonSat Mission Advisory Group and the CO_2 Monitoring Task Force of ESA. He is a member of the Commission on Remote Sensing of the Swiss Academy of Sciences, the Center for Climate Systems Modelling, and the Swiss Space Center. He acted as main supervisor of 8 PhD students at ETH and Empa. He authored or co-authored >110 peer-reviewed publications (h-index 38).

Relevant Publications (up to 5)

6. Brunner, D., Kuhlmann, G., Marshall, J., Clément, V., Fuhrer, O., Broquet, G., Löscher, A., and Meijer, Y. (2019): Accounting for the vertical distribution of emissions in atmospheric CO_2 simulations, Atmos. Chem. Phys., 19, 4541-4559, https://doi.org/10.5194/acp-19-4541-2019, 2019.
7. Kuhlmann, G., Broquet, G., Marshall, J., Clément, V., Löscher, A., Meijer, Y., and Brunner, D.: Detectability of CO_2 emission plumes of cities and power plants with the Copernicus Anthropogenic CO_2 Monitoring (CO2M) mission, Atmos. Meas. Tech., 12, 6695–6719, https://doi.org/10.5194/amt-12-6695-2019, 2019.
8. Brunner, D., Arnold, T., Henne, S., Manning, A., Thompson, R. L., Maione, M., O'Doherty, S., and Reimann, S. (2017): Comparison of four inverse modelling systems applied to the estimation of HFC-125, HFC-134a, and SF_6 emissions over Europe, Atmos. Chem. Phys., 17, 10651-10674, doi:10.5194/acp-17-10651-2017.
9. Liu, Y., Gruber, N., & Brunner, D.: Spatiotemporal patterns of the fossil-fuel CO_2 signal in central Europe: results from a high-resolution atmospheric transport model, Atmos. Chem. Phys., 17, 14145-14169, doi: 10.5194/acp-17-14145-2017, 2017.
10. Henne, S., Brunner, D., Oney, B., Leuenberger, M., Eugster, W., Bamberger, I., Meinhardt, F., Steinbacher, M., and Emmenegger, L. (2016): Validation of the Swiss methane emission inventory by atmospheric observations and inverse modelling, Atmos. Chem. Phys., 16, 3683-3710, doi:10.5194/acp-16-3683-2016.

Recent Projects (up to 5)

- VERIFY – 776810 – Observation-based system for monitoring and verification of greenhouse gases.
- CHE – 776186 – Explores the development of a European system to monitor human activity related carbon dioxide (CO_2) emissions across the world.
- MEMO2 – 722479 – Identify and evaluate methane emissions and support mitigation measures using mobile observations from cars and drones of methane and its stable isotopes.
- CLIMGAS-CH – NN – Swiss project to monitor atmospheric concentrations and quantify Switzerland's emissions of CH_4, N_2O and synthetic greenhouse gases.
- Carbosense – NN – Swiss project, which established a dense network of ~250 CO_2 sensor sites to better understand Switzerland's CO_2 budget.

Major Hardware/ Infrastructure available

- Center for Climate Systems Modeling (C2SM): IT experts supporting code maintenance and development.

- Direct access to archives of operational model products of ECMWF and MeteoSwiss
- Piz Daint, Europe's fastest supercomputer at Swiss Supercomputing Centre CSCS (fixed allocation plus additional resources through proposals)
- Swiss GHG measurement network: 7 sites with Picarro instruments, 2 sites with GC-MS for synthetic GHGs, 240 sites with low-cost and 15 sites with medium-cost CO_2 sensors

4.1.3 ICOS ERIC

03 - Integrated Carbon Observation System - European Research Infrastructure Consortium (ICOS ERIC)

About the Organisation

The Integrated Carbon Observation System (ICOS) is a distributed European Research Infrastructure (RI) operating standardized, high-precision, and long-term observations on greenhouse gases (GHG) budgets and their perturbations. The observations provided by ICOS RI are required to understand the present state and predict future behaviour of the global carbon cycle and GHG emissions. The operations of ICOS RI are coordinated by the legal entity ICOS ERIC, based in Helsinki, Finland. ICOS RI facilitates research, provides necessary information on greenhouse gases which supports policy- and decision-making to combat climate change and its impacts and promotes technological developments and implementations by the linking of research, education and innovation.

The backbones of ICOS RI are the national measurement stations such as ICOS atmospheric, ecosystem and ocean stations. Together they form national measurement networks. Each of the ICOS station has a responsible Principle Investigator (PI) and together PIs form a Monitoring Station Assembly (MSA). MSAs are established for atmospheric, ecosystem and ocean networks to monitor, develop and improve the scientific and technical basis (e.g. station networks) of ICOS RI. ICOS Central Facilities (CFs), such as Atmospheric Thematic Centre (ATC), Ecosystem Thematic Centre (ETC), Ocean Thematic Centre (OTC), Central Analytical Laboratories (CAL), Carbon Portal (CP) and Head Office (HO) are the European level ICOS RI Centres, which have the specific tasks in collecting and processing the data and samples received from the national measurement networks.

ICOS aims to become the European pillar of a global observation system on carbon and GHGs and wants to cooperate with other regional observation systems. In this endeavour ICOS aims to support African countries to build related, however adapted observations systems. ICOS is an admitted observer organization of the United Nations Framework Convention of Climate Change (UNFCCC) and a participating organization in the Group on Earth Observation (GEO) and. ICOS has supported the GEO initiative on carbon and GHGs (GEO-C). Furthermore, ICOS is involved in the development of the Integrated Global Greenhouse Gas Information System (IG3IS) of the World Meteorological Organisation (WMO).

Role in this Project

Beneficiary, Leader WP6

Expertise with Relevance to this Project and Role

Managing carbon and GHG observations is the core activity of ICOS. Through involvement of PIs of national networks it has contacts to all the elements of in situ observation communities in Europe and globally. It has experience of providing data to modelling community via its Carbon portal.

Key Persons

Dr. habil. Werner Leo Kutsch (male) is Director General of ICOS-ERIC. He has a strong scientific background in ecosystem science. He has authored or co-authored more than 100 scientific publications (incl. peer-reviewed book chapters, more than 10 000 citations, actual H-Index (google scholar): 50). He got his first experiences in organizing research cooperation from 1995 - 1999 as Theme coordinator for 'ecosystem matter exchange' in the nationally founded Ecosystem Research Center at the University of Kiel (overall budget 48 Mio €). After a research stay in South Africa (2003/2004) he changed to the Max-Planck-Institute for Biogeochemistry, Jena, Germany in 2004. From 2004 to 2010 he contributed to the FP6 projects CarboEurope IP (cluster of observational sites and data integration for all agricultural sites) and CarboAfrica (member of the Steering Committee; work package leader). 2003-2007 he was chair of the ESF-Program “The role of soils in the terrestrial carbon balance”. Since October 2009 he coordinated the national implementation of ICOS in Germany (ICOS-D) at the Thuenen Institute

in Braunschweig, Germany. This work has comprised the development of a national concept with 13 research institutions, coordination of the financial planning, of the formulation of two official proposals and concept papers, negotiations with the respective ministries and between the involved research institutions. The overall budget of the ICOS-D proposals was 15 Mio €. In parallel to the national implementation, he contributed to development of ICOS at the European level (Focal Point for Germany). Since March 2014 he is Director General of ICOS RI and has successfully steered the procedure towards becoming an ERIC which was finalized at 23. November 2015. In this position he managed the final internal integration of ICOS. In this work he focused on legal work on contracting the distributed central facilities, on optimizing the internal data workflow between the different observational programs of ICOS, on developing the data platform of ICOS ('Carbon Portal') which will also serve as an interface to COPERNICUS and GEOSS, and on deepening the cooperation with other RIs. While ICOS has achieved full operation during its first five-year phase (2015 – 2019), he has successfully steered the transition to the second five-year period by updating the strategy for the next decade, renewing the financial commitments of the participating countries and compiling an action plan. From May 2015 to July 2019 he was coordinator of the H2020 project ENVRIplus that clustered 21 environmental research infrastructures (total budget 15 Mio €) and he is currently coordinator of the H2020 project RINGO (total budget 4,7 Mio €).

Ir. Alex T. Vermeulen (male) is Director of the ICOS Carbon Portal. He has a strong background in (micro)meteorology, air quality modelling, observation techniques and data acquisition and ecosystem science. He has authored or co-authored more than 60 peer-reviewed scientific publications (current H-index 28). He has been involved as PI or coordinator in international cooperation projects since 1994.

He started as junior scientist on a project on ammonia deposition and acidification research at ECN (energy research Center of the Netherlands). Since 1990 he worked in climate research in the field of greenhouse gas emission and concentration measurements and transport modelling. He is project leader since 1994 and has been assistant group leader (~20 people) from 2005-2012. Since June 2014 he is Director of the Carbon Portal, leading a group of 12 scientists and technicians at Lund and Wageningen University.

As ECN project leader he participated in European projects like European Methane (FP4), AEROCARB, RECAB (FP5), CarboEurope-IP, IMECC, GEOMON, EuroHydros, GHG-Europe, and ACTRIS (FP7). He coordinated the CHIOTTO (FP5, RTD, 5 M€, 10 partners) and the InGOS (FP7, IA, 12 M€, 38 partners) project. Currently he is involved as PI and work package leader in the H2020 projects RINGO and ENVRIFAIR. He is chair of the WMO GAW Greenhouse Gas Scientific Advisory Board.

Besides the activities on climate change research he worked in the fields of local air pollution, specifically measurement and modelling of highway dispersion; dry deposition flux measurements and high resolution modelling of deposition loads. Worked as scientist and PI in other related EU projects like GRAMINAE (FP5), ACTRIS NitroEurope-IP (FP6).

He coordinated the ECN greenhouse gas and aerosol observations at Cabauw tall tower from 2000-2014. At ECN he was project leader for several big national projects on climate change in the field of greenhouse gas exchange and coordinator of the Dutch network on greenhouse gas observation in the national ME-2 project. Focal point for ICOS-nl from 2011-2014.

Dr. Elena Saltikoff (female), PhD (Meteorology) is the Head of OPERATIONS at ICOS ERIC since September 2019. She moved to ICOS from position of research scientist at Meteorological Research unit of FMI. She started her career at FMI as a weather forecaster. Since 1996 she has worked with research and development related to weather radars. In addition to her career at FMI she has worked two 2-year periods for the weather radar industry. Since 2013 her main duty has been programme manager of EIG EUMETNET radar project OPERA. She was the science officer and a WP leader in S2020 project PNOWWA (Probabilistic Nowcasting of Winter Weather for Airports) 2016-2018.

During her scientific career she has authored or co-authored more than 20 articles in peer-reviewed scientific journals and several congress proceedings, abstracts or scientific reports. She has been a supervisor or a co-supervisor for 3 MSc thesis and one PhD thesis.

Relevant Publications (up to 5)

1. Kutsch W.L, Kolari P (2015) Data quality and the role of nutrients in forest carbon-use efficiency. NATURE Climate Change 5: 959-960
2. Vermeulen, A.T. et al., (2011) Greenhouse gas observations from Cabauw Tall Tower (1992–2010).

Atmospheric Measurement Techniques, 4(3), pp.617–644.

3. Bergamaschi, P., Karstens, U., Manning, A. J., Saunois, M., Tsuruta, A., Berchet, A., … Dlugokencky, E. (2018). Inverse modelling of European CH4 emissions during 2006–2012 using different inverse models and reassessed atmospheric observations. Atmospheric Chemistry and Physics, 18(2), 901–920. https://doi.org/10.5194/acp-18-901-2018
4. Agustí-Panareda, A., Diamantakis, M., Massart, S., Chevallier, F., Muñoz-Sabater, J., Barré, J., … Wunch, D. (2019). Modelling CO2 weather – why horizontal resolution matters. Atmospheric Chemistry and Physics, 19(11), 7347–7376. https://doi.org/10.5194/acp-19-7347-2019
5. Saltikoff, E., Friedrich, K., Soderholm, J., Lengfeld, K., Nelson, B., Becker, A., Hollmann, R., Urban, B., Heistermann, M. and Tassone, C., (2019). An overview of using weather radar for climatological studies: Successes, challenges and potential. *Bulletin of the American Meteorological Society*.

Recent Projects (up to 5)

1. VERIFY; Grant Agreement ID: 776810; RIA
2. ENVRIplus (H2020) Grant agreement ID: 654182; RIA
3. RINGO (H2020) Grant agreement ID: 730944; CSA
4. ENVRI FAIR (H2020) Grant Agreement 824068 ; RIA
5. 8. E-SHAPE (H2020) Grant Agreement ID: 820852; IA

Major Hardware/ Infrastructure available

ICOS Atmosphere Thematic Center

ICOS ERIC Carbon Portal

ICOS National Networks for Atmosphere, Ocean and Ecosystem

4.1.4 JRC

04 - Joint Research Centre

About the Organisation

The Joint Research Centre (JRC) is the European Commission's science and knowledge service which employs about 3000 scientists to carry out research in order to provide independent scientific advice and support to EU policy. We create, manage and make sense of knowledge and develop innovative tools and make them available to policy makers. JRC's scientific work supports a whole host of EU policies in a variety of areas, including climate mitigation and environment in the directorates for climate, energy and transport as well as for sustainable resources. JRC provides scientific evidence throughout the whole policy cycle and contributes in the climate field to mitigation and adaptation under the Paris Agreement, including GHG monitoring, reporting and measuring. JRC provides observation-based evidence for verifying anthropogenic (fossil and biogenic) GHG emissions from all sectors (energy-related as well as agriculture, forestry and other landuse).

Role in this Project:

JRC is co-lead for workpackage 1, taking the responsibility of task 1.2 on the global mosaic (reaching out in the international GEIA network for state-of-the-art regional emission inventories with high spatio-temporal resolution, covering all world countries) and task 1.5 on the uncertainty assessment (building further on the emission uncertainties and covariance matrix of the preceding project CHE, WP3).

JRC guarantees the link to the CO2 Monitoring Task Force under EC's Copernicus Programme (as chair of the Task Force), and the link to the national inventory agencies in DG CLIMA's climate change committee, working group 1 (as participant in the working group).

Expertise with Relevance to this Project and Role

JRC supports DG DEFIS under EU's Copernicus Programme with the preparation of a European capacity to monitor CO_2 anthropogenic emissions. JRC chairs the CO2 Monitoring Task Force (since 2015), participates in ESA's

Mission Advisory Board for the CO2 Monitoring Sentinel (since 2016), and participates in DG CLIMA's Climate Change Committee Working Group 1 with national inventory agencies. JRC scientists were selected to coauthor review and co-edit the 2019 Refinement of the IPCC (2006) guidelines for national GHG inventories and is responsible for the reporting and review of EU's inventory of the AFOLU (agriculture, forestry and other land-use) sector.

Key Persons

Greet Janssens-Maenhout (F) – is deputy head of the unit Knowledge management for sustainable development and food security at the Sustainable resources directorate of the JRC. She focuses on the Copernicus programme, more in particular on the Global Land Service, the Climate service and the Atmosphere monitoring service. In support of DG DEFIS, she contributes to the establishment of a new European operational capacity for the monitoring and verification of anthropogenic GHG emissions and co-chairs the CO2 monitoring task force. She also participates at the CO2 Monitoring Mission Advisory Group, at discussions of national inventory agencies under the IPCC Task Force Inventories (for the 2019 Refinement) and at meetings of the DG CLIMA climate change committee WG1. She has been 10 years leading JRC's Emissions Database for Global Atmospheric Research.

Relevant Publications (up to 5)

1. Janssens-Maenhout, G., Pinty, B., Dowell, M., Zunker, H., Andersson, E., Balsamo, G., Bézy, J.-L., Brunhes, T., Bösch, H., Bojkov, B., Brunner, D., Buchwitz, M., Crisp, D., Ciais, P., Counet, P., Dee, D., Denier van der Gon, H., Dolman, H., Drinkwater, M., Dubovik, O., Engelen, R., Fehr, T., Fernandez, V., Heimann, M., Holmlund, K., Houweling, S., Husband, R., Juvyns, O., Kentarchos, A., Landgraf, J., Lang, R., Löscher, A., Marshall, J., Meijer, Y., Nakajima, M., Palmer, P., Peylin, P., Rayner, P., Scholze, M., Sierk, B., Veefkind, P., Towards an operational anthropogenic CO2 emissions monitoring and verification support capacity, accepted for publication in BAMS, doi:10.1175/BAMS-D-19-0017.1, 2020 forthcoming
2. Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Dentener, F., Bergamaschi, P., Pagliari, V., Olivier, J. G. J., Peters, J. A. H. W., van Aardenne, J. A., Monni, S., Doering, U., Petrescu, A. M. R., Solazzo, E., and Oreggioni, G. D.: EDGAR v4.3.2 Global Atlas of the three major greenhouse gas emissions for the period 1970–2012, Earth Syst. Sci. Data, 11, 959–1002, https://doi.org/10.5194/essd-11-959-2019, 2019
3. Petrescu, A. M. R., Peters, G. P., Janssens-Maenhout, G., Ciais. P., Tubiello, F. N., Grassi, G., Nabuurs, G-J., Leip, A., Carmona-Garcia, G., Winiwarter, W., Höglund-Isaksson, L., Günther, D., Solazzo, E., Kiesow, A., Bastos, A., Pongratz, J., Nabel, J.E.M.S., Conchedda, G., Pilli, R., Andrew, R. M., Schelhaas, M-J. and Dolman, A. J.: European anthropogenic AFOLU greenhouse gas emissions: a review and benchmark data, Earth Syst. Sci. Data Discuss., essd-2019-199, in review, 2020.

Recent Projects (up to 5) of EU's Horizon 2020 research and innovation programme

- Coordination and Support Action H2020-EO-3-2017 with project *CHE* (CO_2 Human Emissions) - grant agreement No 776186 (JRC is workpackage leader and contributes with prior emissions and uncertainties)
- Research and Innovation Action H2020-SC5-4-2017 with project *VERIFY* (Observation-based monitoring and verification of greenhouse gases) - grant agreement No 776810. (JRC is workpackage leader and contributes to the policymakers' decision support tool, to prior emissions of CH4 and N2O and to the biogenic emissions of the AFOLU sector).

Major Hardware/ Infrastructure available

Mainly database work is done for the project, but also high0performance computing infrastructure is available.

4.1.5 CEA

05 - Commissariat à l'énergie atomique et aux énergies alternatives

About the Organisation

The French Alternative Energies and Atomic Energy Commission (French: Commissariat à l'énergie atomique et

aux énergies alternatives, CEA) is the legal entity that represents the Laboratory of Climate and Environmental Sciences (French: Laboratoire des Sciences du Climat et de l'Environnement, LSCE) within CoCO2.

The LSCE, created in 1998, is both an institution and joint research unit (UMR 8212) of CEA, of the French National Centre for Scientific Research (French: Centre national de la recherche scientifique, CNRS), and of the University of Versailles Saint-Quentin (UVSQ). The LSCE aims to understand past and future climate evolution and to predict the changes our planet will have to face in the next decades and centuries due to the global increase in greenhouse gases.

Role in this Project

The LSCE co-coordinates WP3 and WP5 of CoCO2. It also directly participates to the design of advanced inverse modelling prototypes for the quantification of CO2 anthropogenic emissions based on observations of appropriate atmospheric tracers, made in situ or from space, and of the associated uncertainties. For this purpose, it shares some of its expertise and tools gained in VERIFY (e.g., the Community Inversion Framework), a project that it has been coordinating.

Expertise with Relevance to this Project and Role

The LSCE has coordinated many national and international projects related to environmental Research Infrastructures, including the preparation phase of the Integrated Carbon Observation System (ICOS) infrastructure, the FP6 Geomon and IMECC projects and the FP7 ICOS-INWIRE project. It was the scientific leader of the FP7 CARBONES project dedicated to a 30-year re-analysis of carbon fluxes and pools over the globe and now leads the H2020 VERIFY project about the monitoring of greenhouse gases (GHGs). The LSCE is a partner in the current H2020 CHE project about a future satellite-based carbon service, and of the ENVRIplus and COOP+ RI-clustering projects. LSCE hosts the ICOS Atmospheric Thematic Centre and operates one of the largest networks of GHG measurement stations in the world. LSCE has also participated to the science teams of several GHG space missions (NASA: OCO-2, ESA: Carbonsat, A-SCOPE and CO2M, Eumetsat: IASI-NG, CNES-DLR: MERLIN, CNES-UKSA: Microcarb).

Key Persons

Frédéric Chevallier (M) obtained his Master degree in Physics at the University of Rennes (France) in 1993. His PhD work on radiation modelling in the atmosphere took place at the Laboratoire de Météorologie Dynamique (LMD, France). He joined ECMWF in 1998 to work in the Physical Aspects and Satellite sections. His involvement in data assimilation increased over the years, in particular to initiate the assimilation of cloud-affected and rain-affected satellite radiances. Appointed permanent research scientist at the LSCE in December 2003, he has developed a variational system for the atmospheric inversion of surface fluxes of atmospheric compounds from in situ measurements and satellite retrievals, that has played a pioneer role for the scientific exploitation of several satellite missions dedicated to the observation of the atmospheric composition. He has been coordinating the inversion activities of the Copernicus Atmosphere Monitoring Service both in its pre-operational (since 2009) and operational (since 2015) phases. He is the author or co-author of about 180 peer-reviewed publications and of 1 patent.

Grégoire Broquet (M) has a 16-year expertise in the development and application of data assimilation systems for ocean modeling and for the atmospheric inverse modeling of greenhouse gas (GHG) fluxes. Since 2009, he supervises at LSCE a wide range of activities for the monitoring of natural and anthropogenic GHG fluxes from the continental to the city / industrial site scales, based on the assimilation of in situ and satellite data. In the recent years, he has been coordinating the activities on the satellite monitoring of GHG fluxes of the industrial projects (« chaires ») BridGES and ANR TRACE (co-funded by Thales Alenia Space), the EUROCOM project (involving eight European partners), and the GeoCARB-Fr CNES project. He has been strongly involved in the VERIFY and CHE H2020 projects and in ESA projects for the preparation of the CO2M mission.

Philippe Peylin (M) is a research scientist working on the Carbon Cycle with a 20-year strong expertise in the development of terrestrial ecosystem models and the application of data assimilation techniques to improve the simulations of carbon, water and energy balances. He is the coordinator of the H2020 VERIFY project (https://verify.lsce.ipsl.fr/) that is currently paving the road for the development of future greenhouse gas Monitoring and Verification Support systems as well as of the Copernicus Atmospheric Monitoring Service component CAMS41, dedicated to the development of greenhouse gas aspects of the Integrated Forecasting System (IFS) of ECMWF. He also coordinated an FP7 project, CARBONES, dedicated to a 30-year reanalysis of the carbon cycle. He is responsible for the development of the global land surface model, ORCHIDEE

(http://labex.ipsl.fr/orchidee/), the land surface component of the IPSL Earth System Model, involving a community of more than 50 scientists. He published around 130 per-reviewed papers and has an h-index of 50. P.P. will be primarily involved in WP4-5 of CoCO2 project, ensuring a direct link with the VERIFY project.

Philippe Ciais (M) is researcher at CEA and professor at UVSQ and is the author of > 500 peer- reviewed publications, cited 29000 times (H-index= 79; ISI-Web of Science). PC is among the top-1% most-cited scientists in both Geosciences and Ecology, author of more than 60 publications in Nature, Science and other high impact factor journals, PC co-chaired the Global Carbon Project (GCP), coordinated the Carbon Strategy of the Group on Earth Observation, and acted as Convening Lead Author in the 5th IPCC Assessment Report. European experience. PC has proven experience in European consortia coordination. He coordinated the AEROCARB and TACOS projects in FP-5, CARBOEUROPE (FP-6) and GHG-EUROPE (FP-7) atmospheric components, and the GEOMON (FP-7) project. PC is a co-laureate of an ERC-synergy grant on the phosphorus interactions in the Earth system. Working with the private sector. PC has a record of working with industry partners. At UVSQ, he founded the Industrial partnership BridGES in 2012. He was involved in the team preparing the Climate KIC proposition to the European Institute of Technology (EIT), and co- chaired the Climate KIC GHG Platform involving 10 private institutions.

Thomas Lauvaux (M) has been actively involved in the development of inversion systems applied to large metropolitan areas as co-lead of the Indianapolis Flux Experiment since 2010. Based on advanced meteorological modeling systems, TL has combined atmospheric greenhouse gas measurements collected on the ground and from space with fossil fuel emission products to improve the quantification of GHG emissions. A significant part of his research was dedicated to the characterization of uncertainties, an essential component of the system to achieve standardization of these approaches. After a decade working in North America, TL is now working in France, at LSCE, developing new approaches to monitor GHG emissions at city-scale in combination with air quality measurements.

Antoine Berchet (M) obtained his PhD degree in data assimilation applied to the quantification of greenhouse gas fluxes to the atmosphere in 2014 at LSCE. During his PhD he designed novel data assimilation techniques to optimize how information is used in inversion systems. In 2014, he joined Empa, Switzerland, to develop a system simulating greenhouse gas and atmospheric pollutant concentrations at very high resolution (a few meters) in city landscapes in support to observation networks. Since December 2017, he holds a permanent researcher position at LSCE. He designed the Community Inversion Framework within the H2020 VERIFY project as a generic tool for atmospheric **inversion studies. He is author and co-author of 13 peer-reviewed publications.**

Relevant Publications (up to 5)

1. Wang, Y., Broquet, G., Bréon, F.-M., Lespinas, F., Buchwitz, M., Reuter, M., Meijer, Y., Loescher, A., Janssens-Maenhout, G., Zheng, B., and Ciais, P.: PMIF v1.0: an inversion system to estimate the potential of satellite observations to monitor fossil fuel CO2 emissions over the globe, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-326, in review, 2020.
2. Lian, J., Bréon, F.-M., Broquet, G., Zaccheo, T. S., Dobler, J., Ramonet, M., Staufer, J., Santaren, D., Xueref-Remy, I., and Ciais, P.: Analysis of temporal and spatial variability of atmospheric CO2 concentration within Paris from the GreenLITE™ laser imaging experiment, Atmos. Chem. Phys., 19, 13809–13825, https://doi.org/10.5194/acp-19-13809-2019, 2019.
3. Broquet, G., F.-M. Bréon, E. Renault, M. Buchwitz, M. Reuter, H. Bovensmann, F. Chevallier, L. Wu, and P. Ciais, 2018: The potential of satellite spectro-imagery for monitoring CO2 emissions from large cities, Atmos. Meas. Tech., 11, 681-708, doi:10.5194/amt-11-681-2018.
4. Staufer, J., G. Broquet, F.-M. Bréon V. Puygrenier, F. Chevallier, I. Xueref-Rémy, E. Dieudonné, M. Lopez, M. Schmidt, M. Ramonet, O. Perrussel, C. Lac, L. Wu, and P. Ciais, 2016: A first year-long estimate of the Paris region fossil fuel CO2 emissions based on atmospheric inversion, Atmos. Chem. Phys., 16, 14703-14726, doi:10.5194/acp-16-14703-2016.
5. Ciais, P., D. Crisp, H. Denier Van Der Gon, R. Engelen, M. Heimann, G. Janssens-Maenhout, P. J. Rayner and M. Scholze (2015) Towards a European operational observing system to monitor fossil CO_2 emissions, doi:10.2788/350433, European Commission Joint Research Centre – ISBN 978-92-79-53482-9.

Recent Projects (up to 5)

- CHE – GA 776186 – CHE explores the development of a European system to monitor human activity related carbon dioxide (CO2) emissions across the world.

- VERIFY – GA 776810 – VERIFY quantifies more accurately carbon stocks and the fluxes of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) across the EU based on independent observations in support of inventories that rely only on statistical data.
- CAMS41 – Copernicus – CAMS41 supports the development of greenhouse gas aspects of the Integrated Forecasting System (IFS) of ECMWF.
- CAMS73 – Copernicus – CAMS73 maintains, further develops and operates processing chains that deliver time series of surface flux fields over the last decades from the analysis of atmospheric mole fraction measurements and satellite retrievals.
- EMME-CARE – GA 763699 – EMME-CARE establishes a world-class research and innovation Centre focused on environmental challenges, via the upgrade of an existing regional Centre of excellence and through a combination of research, innovation and education.

Major Hardware/ Infrastructure available

The LSCE maintains its own local cluster of about 1000 cores. It has also access to the French national High Performance Computing resources (GENCI, www.genci.fr).

4.1.6 MPG

06 – Max Planck Institute for Biogeochemistry

About the Organisation

The Max Planck Institute for Biogeochemistry (MPI-BGC) is a research institute of the German Max-Planck Society (MPG). The research mission of the Max Planck Institute for Biogeochemistry is the investigation of the global biogeochemical cycles and their interaction with the climate system. The institute combines strong observational and process-based studies (soil carbon, plant community and growth, vegetation-atmosphere fluxes) with global scale modelling (e.g. vegetation dynamics, global carbon cycle, aerosol). MPI-BGC is one of the pivotal European research institutions in its field, and as such was co-ordinating the CARBOEUROPE-IP project (FP6) and the FP7 projects CarboSchools, CARBO-Extreme and IGAS, and is currently leading the project BACI as well as the ERC grants QUINCY and 14Constraint (Horizon 2020) and two MSCA projects. Moreover, the institute is strongly involved in more than ten collaborative EU projects, around 30 projects from other international (e.g. ESA) and national sources, and co-leads international collaborative efforts such as FLUXNET and the global TRY database on plant traits. Not only does the institute have an outstanding international reputation for its research success but it has a strong commitment to higher education and scientific training, housing around 60 Ph.D. students from more than 25 countries and operating the International Max Planck Research School for global Biogeochemical Cycles in cooperation with the Friedrich Schiller University Jena. The institute successfully maintains numerous scientific collaborations in a wide range of geographical locations and scientific disciplines, including long-term observation sites in the Arctic, and manages two large observational towers in Siberia and the Amazon.

Role in this Project

MPG will be involved in $CoCO_2$ through the generation of data-driven biospheric CO_2 flux products and the uncertainty characterisation of biospheric priors. Atmospheric inversions will also be carried out, focussing on the regional/national level (in WP3). Furthermore, Julia Marshall is co-leading WP6, coordinating the use of in situ measurements.

Expertise with Relevance to this Project and Role

The expertise of MPG is in both bottom-up and top-down modelling of surface-atmosphere gas exchange, as well as with simple and complex carbon-cycle data assimilation systems. In this context strong expertise exists in terms of interpreting eddy covariance data, land surface remote sensing, atmospheric flask and satellite-based atmospheric composition measurements as well as carbon cycle modelling from local to global scale.

Key Persons

Name (Gender) – brief CV

Dr Martin Jung (male) – group leader “Global Diagnostic Modelling” at MPI-BGC, Department of Biogeochemical

Integration, PI of FLUXCOM initiative (www.fluxcom.org), highly-cited researcher (top 1%) in the field of geoscience in the years 2018 and 2019.

Dr Sophia Walther (female) – PostDoc at MPI-BGC ("Global Diagnostic Modelling" group), co-lead of FLUXCOM2.0 initiative, expert in vegetation remote sensing and sun-induced fluorescence, dissertation (Free University Berlin and GFZ) in 2018 with distinction ("summa cum laude"), Ernst-Reuter-Award for dissertation in 2019.

Dr Julia Marshall (female) – group leader "Satellite-based Remote Sensing of Greenhouse Gases", Department of Biogeochmical Signals. Focussing on the use of satellite (and other) measurements of carbon dioxide and methane to constrain surface fluxes. Currently involved in projects CHE (H2020), GHG-CCI+, Methane+Carbon (both ESA) in addition to national-level projects. She is a member of the Scientific Advisory Group of the active methane satellite mission MERLIN and the EDF-funded MethaneSAT.

Relevant Publications (up to 5)

1. Jung et al. (2017): Compensatory water effects link yearly global land CO2 sink changes to temperature. Nature.
2. Jung et al. (2020): Scaling carbon fluxes from eddy covariance sites to globe: Synthesis and evaluation of the FLUXCOM approach.BG.
3. Bodesheim, Jung et al. (2018): Upscaled diurnal cycles of land-atmosphere fluxes: a new global half-hourly data product. ESSD.
4. Tramontana, Jung et al (2016): Predicting carbon dioxide and energy fluxes across global FLUXNET sites with regression algorithms.

Recent Projects (up to 5)

- CHE (CO_2 Human Emissions) – GA Nr 776186 (H2020) – Coordinating efforts towards developing a European monitoring and verification support capacity for anthropogenic CO_2 emissions.
- VERIFY – GA Nr 776810 (H2020) – VERIFY is working to develop a system to estimate greenhouse gas emissions to support countries' emission reporting to the UN Climate Change Convention Secretariat.
- GHG-CCI+ (Greenhouse Gases – Climate Change Initiative +) - Contract Nr 4000126450/19/I-NB (ESA) - Produce, validate, analyse, and deliver consistent time series of demonstration satellite greenhouse gas data products for climate science.
- BACI (Towards a Biosphere Atmosphere Change Index) - GA Nr 640176 (H2020) – Develop novel downstream data products, not directly observable from space, towards the generation of "Essential Ecosystem Variables"
- Methane+ - (ESA) – Assess if combining SWIR and TIR satellite measurements of methane can better differentiate between sinks and sources on the regional and global scale.

Major Hardware/ Infrastructure available

For all research, the in-house high-performance Linux Cluster and the super-computing centre DKRZ will be available.

4.1.7 TNO

07 - Netherlands Organisation for Applied Scientific Research

About the Organisation

TNO is the Netherlands Organisation for Applied Scientific Research. TNO is the largest fully independent Research, Development and Consultancy organisation in the Netherlands with a staff of about 3,000 and a total annual turnover of more than 500 million Euros. It derives a significant portion of its contract R&D from foreign private sector, governments and international organisations. TNO's primary tasks are to support and assist trade and industry including SME's, governments and others in technological innovation and in solving problems by rendering services and transferring knowledge and expertise. TNO participates in many EU programmes aiming at

technological development. TNO has conducted co-operation agreements with many foreign research institutes and companies in Western, Central and Eastern Europe, USA, Canada, Japan and India. The expertise group Climate, Air and Sustainability (CAS) is an expert centre and contract research unit for industry and government in the field of sustainable development and environmentally oriented process innovation. The expertise group investigates the processing of anthropogenic pollutants in the atmosphere and their influence on the environment and climate change. TNO has multiple decades of experience in quantifying emissions from various technologies and their characteristics, constructing emission inventories using all this input, and the impacts of legislation on the emission characteristics. TNO also has decades experience in translating emissions into air pollution concentrations at local, national and European scale as well as impact assessments using various modelling tools, including local and regional scale air quality models at European level. TNO has ample experience with the use of observed air pollutant concentrations in ambient air, amongst others in comparison to modelled values.

Role in this Project

TNO will co-lead WP1 and will be actively involved in WP3 and WP4. The core of TNO's role is its expertise in preparing bottom-up model-ready emissions data. In WP1 TNO is the main provider of regional emissions data including associated uncertainties and it will coordinate the delivery of associated products. Moreover, TNO will work on a global point source data base and the development of a fossil fuel emission model (FFDAS). In WP3 it will focus on the national scale using the TNO's LOTOS-EUROS model and its data assimilation routines to make inversions over NW Europe. Focus will be on CO2 and the co-emitted species CO and NOx, if feasible data on CH4 will also be provided. As part of WP4 TNO will incorporate the CIF in its LOTOS-EUROS model (for use in WP3) and it will for 1 country compare the use of the regular emission inventory as prior (as in WP3) with the use of the emission model developed in WP1.4 to determine how sensitive the inversion result is for a priori uncertainty definition.

Expertise with Relevance to this Project and Role

The emission expertise of the TNO-CAS is built up in research projects (many funded by FP7/H2020 e.g. ENERGEO, MEGAPOLI, EUCAARI, MACC, CHE, VERIFY) where amongst others high resolution gridded emission data on the European scale were prepared for air pollutants and GHGs as input for air quality or climate modellers. Furthermore, since 1974 TNO has been strongly involved in the annual compilation of the Dutch emission inventory, including the National Inventory Reports on greenhouse gases to UNFCCC. Translating emissions into air pollution concentrations at local, national and European scale as well as impact assessments using various modelling tools such as the regional air quality model LOTOS-EUROS is another key strength of TNO. LOTOS-EUROS is TNO's regional chemical transport model designed to simulate air quality over regional and sub-regional scales. It includes data-assimilation (satellite data and ground measurements). TNO cooperates closely with developers of satellite retrievals to improve its emission inventories e.g., for SO_2 and CH_4.

Key Persons

Name (Gender) – brief CV

Dr Hugo Denier van der Gon (M) is Senior Scientist and Emission Inventory Expert at TNO. He has over 20-year experience in measuring and estimating emissions from anthropogenic sources. He coordinates a team at TNO that provides emission inventories to modelling groups and / or policy advising bodies such as the UNECE-EMEP, various EU-IPs and H2020 projects (e.g., CHE, VERIFY, MACC, EUCAARI), German Umwelt Bundesambt (UBA) and Dutch Institutes (RIVM, PBL). He is in charge of providing high resolution European emission inventories to EU IP MACC-I,II,III and the Copernicus Atmospheric Monitoring Service (CAMS). He coordinates 2 GHG observation stations around Rotterdam and investigates the use of in-situ and space based data to verify /improve emissions inventories with a current specific interest in CH_4 and CO_2.

Dr. Arjo Segers (M) is a leading expert on data assimilation in atmospheric chemistry modelling. He has nearly 20 years of experience as a research scientist in the field of atmospheric chemistry and transport, contributing to projects related to air quality, stratospheric ozone, and greenhouse gasses. Due to this he has experience with atmospheric transport models on both regional scale (LOTOS-EUROS and EMEP models) and global scale (TM5 model), and with their associated data-assimilation systems based on ensemble or variational approaches. He is currently contributing to projects under the Copernicus Atmospheric Monitoring Services related to the regional air quality ensemble and global greenhouse gas emission inversions.

Dr. Ingrid Super (F) obtained a PhD in urban fossil fuel emission quantification at Wageningen University (2019). Her work involves different methods related to emission verification, including the use of in-situ observations and

atmospheric modelling. She has been involved in the development of an urban dynamic emission model for CO_2 and improving the timing of fossil fuel emissions. She has also developed a data assimilation system to optimize the emission model parameters, including source sector attribution using co-emitted species. Currently, she works on describing uncertainties and error correlations in the prior emission data to support data assimilation studies at different scales.

Stijn Dellaert, MSC (M) is a an environmental research scientist with experience in emission modelling and accounting, energy systems modelling and life cycle assessment. He did his MSc in Sustainable Development in Energy and Resources. Furthermore, he worked as an intern at Quintel Intelligence, developing educational tools around energy transition and working on an extensive model of the Dutch energy system. Having started at TNO in February 2015, Mr. Dellaert has since contributed to the Dutch emissions inventory and reporting obligations (e.g. NIR, IIR, IED/LCP directive). Furthermore, he has participated in many European projects, where his activities include developing large emission databases (CAMS 81, VERIFY, CHE) and developing tools to help companies reduce energy use and greenhouse gas emissions (ClimateKIC: Waste MITI2 & BEST Energy CheckUp). In 2019, Mr. Dellaert was involved in the NECD review as technical expert for the energy sector.

Relevant Publications (up to 5)

1. Super, I., Dellaert, S. N. C., Visschedijk, A. J. H., and Denier van der Gon, H. A. C.: Uncertainty analysis of a European high-resolution emission inventory of CO2 and CO to support inverse modelling and network design, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-696, in press, 2020.
2. Timmermans, R., Segers, A., Curier, L., Abida, R., Attié, J.-L., El Amraoui, L., Eskes, H., de Haan, J., Kujanpää, J., Lahoz, W., Oude Nijhuis, A., Quesada-Ruiz, S., Ricaud, P., Veefkind, P., and Schaap, M.: Impact of synthetic space-borne NO2 observations from the Sentinel-4 and Sentinel-5P missions on tropospheric NO2 analyses , Atmos. Chem. Phys., 19, 12811–12833, https://doi.org/10.5194/acp-19-12811-2019, 2019.
3. Super, I., Denier van der Gon, H. A. C., van der Molen, M. K., Sterk, H. A. M., Hensen, A., and Peters, W.: A multi-model approach to monitor emissions of CO2 and CO from an urban–industrial complex, Atmos. Chem. Phys., 17, 13297-13316, https://doi.org/10.5194/acp-17-13297-2017, 2017.
4. Alexe, M., Bergamaschi, P., Segers, A., Detmers, R., Butz, A., Hasekamp, O., Guerlet, S., Parker, R., Boesch, H., Frankenberg, C., Scheepmaker, R. A., Dlugokencky, E., Sweeney, C., Wofsy, S. C., and Kort, E. A.: Inverse modelling of CH4 emissions for 2010–2011 using different satellite retrieval products from GOSAT and SCIAMACHY, Atmos. Chem. Phys., 15, 113–133, https://doi.org/10.5194/acp-15-113-2015, 2015.
5. Kuenen, J. J. P., Visschedijk, A. J. H., Jozwicka, M., and Denier van der Gon, H. A. C. (2014): TNO-MACC_II emission inventory; a multi-year (2003–2009) consistent high-resolution European emission inventory for air quality modelling, Atmos. Chem. Phys., 14, 10963-10976, doi:10.5194/acp-14-10963-2014.

Recent Projects (up to 5)

H2020 project CHE (CO2 Human Emissions) GA No 776186, is coordinating efforts towards developing the European monitoring and verification support capacity for anthropogenic CO2 emissions. CHE uses existing capabilities to provide supportive datasets and assessments of the current state of affairs, while at the same time bringing innovation to the various components with an eye on overall integration in a fully comprehensive system. These include reconciling bottom-up and top-down approaches and handling systematic errors of satellite observations. Earth observations from satellites will be combined with in situ CO2 observations and information from co-emitters or isotopes to support the attribution of fossil fuel emissions and uncertainty reduction. In addition, CHE will identify the operational aspects of all the components to ensure a realistic architecture.

H2020 project VERIFY (GA 776810) develops a system to estimate greenhouse gas emissions to support countries' emission reporting to the UN Climate Change Convention Secretariat. The emissions are estimated based on land, ocean and atmospheric observations. The project focuses on the three major greenhouse gases responsible for global warming: carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O).

H2020 project AQ-WATCH Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health (GA870301): AQ-WATCH will develop a supply chain leading to the generation of seven downstream products and services that are innovative for improving air quality forecasts and attribution. These prototypes will be based on existing space and in situ observations of air quality and tailored to the identified needs of

international users.

COPERNICUS service CAMS-81 Global and Regional Emissions: the goal of this service is to provide gridded distributions of European and global anthropogenic emissions, as well as global natural emissions for the CAMS (Copernicus Atmosphere Monitoring Service) regional and global production chains.

COPERNICUS service CAMS-50 Within the Copernicus Atmospheric Monitoring Service project, operational regional air quality forecasts and analyses are produced for Europe. TNO in cooperation with KNMI participates with the LOTOS-EUROS model to the ensemble of regional models. TNO is mostly involved in the developments of the model and together with KNMI is responsible for the operational forecasts and analyses.

Major Hardware/ Infrastructure available

TNO has access to a high performance cluster (HPC) on which all model calculations are performed

4.1.8 ULUND

08 – Lund University

About the Organisation

Lund University is one of the largest research organisations in Northern Europe and has a strong profile in the environmental sciences and global change studies. It was ranked 29 in 2019 in the world for geography in the QS World University Rankings. The Department of Physical Geography and Ecosystem Science (INES) enjoys an international reputation as a centre for multi-disciplinary studies of ecosystem-atmosphere interactions, based both on empirical approaches and modelling. The department's research is focusing on issues relating to the development of a predictive understanding of the impacts of changes in climate and atmospheric composition on terrestrial ecosystems and the feedback mechanisms on climate that may arise from these ecosystem processes. It hosts or contributes to the leadership of a number of excellence centres and research networks within Earth system science, including the Swedish node of the Integrated Carbon Observation System (ICOS) and the ICOS Carbon Portal.

Role in this Project

Carbon Cycle/Fossil Fuel Data Assimilation, intercomparison studies, OSSEs; details to be defined

Expertise with Relevance to this Project and Role

Data Assimilation / Inverse Modelling, Global Carbon Cycle, Terrestrial Biosphere and Fossil Fuel Emissions Modelling, Member of the CO2M Task Force

Key Persons

Name (Gender) – brief CV

Assoc Prof Marko Scholze (male)
M. Scholze is a physicist by training and is working in the field of Earth system science since 1997. He is one of the main developers of the Carbon Cycle Data Assimilation System (CCDAS), the first inverse modelling tool using, among others, atmospheric CO_2 observations to calibrate terrestrial ecosystem model process parameters. He is/was the PI of the UK's NCEO Data Assimilation theme, the EU FP6/FP7/H2020 projects IMECC, CARBOCHANGE, GEOCARBON, VERIFY and CHE, the VR Eurocom, the FORMAS 14C-FFDAS, and the ESA Carbonflux, SMOSNEE, SMOS-Veg+ and CCFFDAS projects. He coordinated the ISSI Working Group 'Carbon Cycle Data Assimilation: How to consistently assimilate multiple data streams'. Scholze's current research focuses on the development and application of data assimilation methodologies to improve the quantification of the global carbon cycle with a focus on ecosystem-atmosphere interactions. He has been a member of the ESA ASCOPE Mission Advisory Group and is a current member of the European Commission CO_2 Monitoring Task Force. He is also a member of the AIMES (Analysis, Integration and Modelling of the Earth System, a core Future Earth global research project) scientific steering committee and a member of the ICOS-Sweden steering board. His research output encompasses 51 peer-reviewed publications (h-index of 23`).

Dr. Guillaume Monteil (male)
G. Monteil is a climate scientist, specialized in atmospheric chemistry and transport processes. During his PhD and

post-doc at Utrecht University (2008-2014), he focused on deriving top-down constraints on the methane emission budgets, using inverse methods and various types of observational constraints. He worked in particular on the assimilation of satellite observations (GOSAT, SCHIAMACHY), and of measurements of the isotopic composition of atmospheric methane, on monthly to centennial time scales. In March 2015, he started to work as at Lund University, as part of the EUROCOM project (funded by VR). In the framework of EUROCOM, he developed a new regional inverse modelling setup (LUMIA), adapted to the assimilation of observations from the ICOS network, and he led the redaction of the first collective assessment of the European land carbon sink from the EUROCOM project. His long-term research objective is to work towards bridging the resolution gap between top-down and bottom-up estimates of the surface carbon exchanges.

Dr. Hans Chen (male)

H. W. Chen is an atmospheric and climate scientist. His main areas of expertise include atmospheric dynamics, numerical weather prediction, statistical and machine learning techniques, and data assimilation. During his PhD at Penn State University he extended a regional atmospheric data assimilation system based on the ensemble Kalman Filter to assimilate CO_2 observations to constrain CO_2 surface fluxes. He used this modelling system to investigate the effects of atmospheric transport errors on modelled CO_2 concentrations, and also has experience with using aircraft measurements to evaluate modelling results. In September 2018, he started a postdoc position at Lund University to work on the CO_2 Human Emissions (CHE) project. As part of CHE WP3 his main task involves evaluating the potential improvements from enhanced spaceborne and in-situ observations to constrain fossil fuel emissions, with a focus on using additional tracers such as radiocarbon.

Relevant Publications (up to 5)

1. Rayner, P.J., M. Scholze, W. Knorr, T. Kaminksi and R. Giering, 2005. Two decades of terrestrial Carbon fluxes from a Carbon Cycle Data Assimilation System (CCDAS). Global Biogeochemical Cycles, 19, doi:10.1029/2004GB002254.
2. Scholze, M., T. Kaminski, P. Rayner, W. Knorr and R. Giering, 2007. Propagating uncertainty through prognostic CCDAS simulations. Journal of Geophysical Research, 112, doi:10.1029/2007JD008642.
3. Kaminski, T., M. Scholze, P. Rayner et al., 2020. Atmospheric CO2 observations from space can support national inventories. Nature Communications, in revision.
4. Chen, H. W., F. Zhang, T. Lauvaux, et al., 2019. Characterization of regional-scale CO2 transport uncertainties in an ensemble with flow-dependent transport errors. Geophysical Research Letters, 46, 4049–58, doi:10.1029/2018GL081341.
5. Monteil, G., Broquet, G., Scholze, et al., 2019. The regional EUROpean atmospheric transport inversion COMparison, EUROCOM: first results on European wide terrestrial carbon fluxes for the period 2006–2015, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-1008, in review.

Recent Projects (up to 5)

- CCFFDAS, European Space Agency: Contributed to the assimilation of three EO products (XCO2, soil moisture and FAPAR) into CCDAS-BETHY.
- EUROCOM, VR: Development of regional ecosystem-atmosphere models assimilating the ICOS data for a European-scale intercomparison of net CO_2 fluxes
- 14C-FFDAS, FORMAS: Quantifying fossil fuel emissions based on atmospheric radiocarbon within a Fossil Fuel Data Assimilation System
- VERIFY, EC H2020: Developing a system to estimate greenhouse gas emissions to support countries' emission reporting to the UN Climate Change Convention Secretariat
- CHE, EC H2020: Exploring the development of a European system to monitor human activity related carbon dioxide (CO2) emissions across the world based on satellite observations.

Major Hardware/ Infrastructure available

- The department has access to the ULUND's central HPC facility, which is part of the Swedish National Infrastructure for Computing providing resources and user support for large-scale computation and data storage
- The department hosts several relevant modelling systems among them the LPJ-GUESS dynamic global

vegetation model, the Carbon Cycle Data Assimilation System (CCDAS), the Fossil Fuel Data Assimilation System (FFDAS) and also coupled together, the atmospheric transport inversion system LUMIA (based on coupled Eulerian/Lagrangian transport models TM5/FLEXPART) as well as an EnKF WRF-based inversion system.

- The department is coordinating the national ICOS-Sweden monitoring network and is hosting the ICOS Carbon Portal central facility
- The department has a long-standing experience with a range of GHG flux and concentration measurement systems.

4.1.9 VUA

09 – Vrije Universiteit Amsterdam

About the Organisation

The Vrije Universiteit Amsterdam (VUA) was established in 1880. Since then, the university has expanded and presently consists of fifteen faculties employing 300 professors and 3,300 academic and non-academic staff. About 14,000 use the teaching facilities offered by the university.

Environmental research is carried out at the Faculty of Sciences. The Faculty is offering education and conducts research on a wide range of issues in the fields of earth sciences, biology, environmental sciences, geo-archaeology, biomedical sciences and public health. The environmental research includes research on physical processes related to the impact of land use change on our climate, water resources, ecological systems, geomorphology, biodiversity, carbon and nutrient cycling, as well as research on the social and economic issues and drivers leading to such land use change. Because of the wide range of disciplines covered, the Faculty is excellently placed to approach environmental issues such as climate change and carbon cycling in an integrated manner.

The Department of Earth Sciences of the Faculty is involved in several studies on carbon cycling and Global Change. Within the the Department of Earth Science the Cluster Earth and Climate studies past climate changes, modern climate processes and future perspectives of the Climate System. We combine experimental knowledge of terrestrial, oceanic, atmospheric, and biogeochemical processes with modelling of System Earth. Within the Earth and Climate cluster, the Carbon Cycle group studies the changes and evolution of terrestrial, coastal and ocean environments and its key biogeochemical cycles (N, C) and water. We study the internal dynamics and the response of these systems to natural and anthropogenic forcings.

Since 2002, the Carbon cycle research group has invested in research in carbon emissions from a variety of ecosystems, including peatland, tropical forests and permafrost tundra. The group has been active in setting up the ICOS Integrated Carbon Observing system, one of the first ESSFRI infrastructures to become an independent European Research Infrastructure (ICOS-RI). We were also involved in a number of EU funded projects such as GHG-Europe that aimed to determine the full Greenhouse Gas balance of Europe. ICOS and ICOS-INWIRE that aimed to set up a European Infrastructure for GHG monitoring, GEOCARBON a global analysis and monitoring system for carbon, and H2020 project VERIFY preparing for pre-operational monitoring of greenhouse gas emissions. Our group contributes to the development of the Copernicus Atmospheric Monitoring Service (CAMS) on global CH4. Within The Dutch Ruisdael Observatory program we develop tools for quantifying and monitoring of the greenhouse gas budget of The Netherlands. Group members participate in ESA funded projects to advance the use of current and future satellite missions to support the quantification of regional greenhouse gas budgets.

Role in this Project

WP3

- High resolution simulation of urban CO2 emissions, and the development of simplified methods to quantify emissions from CO2 imaging satellites.
- Development of inverse modelling tools for the quantification of national scale emissions of carbon dioxide, focusing on The Netherlands, using surface and satellite measurements.

WP4

- Development of methods for quantifying the uncertainty of inverse modelling derived emissions

- Development of methods to transfer information and uncertainty between scales

WP7

- Workpackage leader
- Production of consistent estimates of emissions of CO_2 and CH4
- Engagement with policy

Expertise with Relevance to this Project and Role

A.J. (Han) Dolman, His work is a combination of modelling and experimental work. One of the first to develop inverse modelling techniques to regional carbon balances and derived the full GHG balance of Russia. Much of the research in WP7 focusses on improved quantification of regional carbon balances with a view to reconcile and compare different estimates of countries from the atmosphere (top down) with UNFCCC estimates and other bottom up estimates. This expertise has been building up in the GCP RECAP and EU VERIFY projects.

S. Houweling: Quantification of greenhouse gas fluxes (CO2 and CH4) from atmospheric measurements using inverse modelling at global to local scales. Much of his research focuses on the development of methods to make efficient use of data from Earth orbiting satellites. This expertise will be used in WP3 and WP4 for developing the tools needed to make use of high resolution information provided by CO2-M and how to transfer that information across scales.

A.M.R. Petrescu: environmental researcher specialised on emissions of greenhouse gases. She has expertise in both bottom-up modelling and emission inventory calculation and verification methodologies. Current research in the VERIFY H2020 project focuses on reconciliation and assessment of observation-based estimates of GHG fluxes from bottom-up, top-down and global emissions databases with official country level UNFCCC emission inventories. Her expertise will be used in WP7, focusing on improved quantification of regional carbon balances, synthesising and reconciling UNFCCC national GHG inventories with bottom-up and top-down country based estimates.

Key Persons

Prof. dr. H. Dolman (Male) – brief CV

A.J. (Han) Dolman (Male). Professor of Ecohydrology. PhD University of Groningen, Natural Sciences, 15 June 1987. Since 2001 Professor of Ecohydrology. His research interests are the interaction of the terrestrial biosphere with the carbon and hydrological cycle and the atmosphere and the carbon cycle, both biospheric and anthropogenic emissions. His work is a combination of modelling and experimental work. He was one of the first to develop inverse modelling techniques to estimate regional carbon balances and derived the full GHG balance from a variety of model products and observations of Russia. He was one of the founders of the Integrated Carbon Observing System (ICOS-RI). He was involved in the GEO Carbon strategy report and briefly led the GEO Carbon task (until it was dissolved in 2019). He is a member of the GCOS Steering committee and the Task Force for CO2 MRV of the European Commission and has extensive experience with deriving country specific estimates of GHGs (a task also executed in VERIFY).

Prof. dr. ir. S. Houweling (Male) – Expert in the quantification of greenhouse gas emissions from atmospheric data on scales ranging from global to local. He obtained a Ph.D. in atmospheric chemistry at Utrecht University (2000) on global modeling of sources and sinks of atmospheric CH_4. After that, he worked as a post-doctoral researcher at the Max-Planck-Institut für Biogeochemie in Jena, Germany, and as a senior scientist at SRON Netherlands Institute for Space Research in Utrecht, The Netherlands. Presently, he is a professor at Vrije Universiteit Amsterdam, Department of Earth Sciences, in atmosphere, greenhouse gases, and climate. The research focuses on the use of satellite measurements to improve inverse modeling-derived source and sink estimates of the long-lived greenhouse gases CO_2 and CH_4. Sander Houweling is currently involved in several (inter)national projects, including H2020 VERIFY, H2020 SCARBO, H2020 CHE, ESA METHANE+, GO-NWO BETTER, STW GALES, CAMS, and the Dutch Ruisdael Obserrvatory. He is a member of the scientific advisory group of the WMO-GAW CO_2 experts, IG^{3}IS steering committee, the scientific advisory group of the German-French CH_4 lidar MERLIN. Currently, he is supervising PhD students studying the use of data from TROPOMI for estimating local emissions of air pollutants, and PostDoctoral scientists on atmospheric inverse modeling of CO2 and CH4 using TROPOMI, CO2M, NanoCarb, and CO2-M.

Dr. A. M. R. Petrescu (Female)

Environmental researcher with expertise in bottom-up GHG modelling and emission inventory calculation and verification. She has a Ph.D. in environmental sciences/hydrology obtained at Vrije Universiteit Amsterdam (2010)

on modelling CH_4 emissions from natural wetlands. She has more than 10 years of environmental research experience related to data analysis of greenhouse gas emissions (CO_2, CH_4 and partly N_2O). She has great experience working with emission databases as previously part of the JRC EDGAR database operational team. She was in charge of developing new methodologies for the inclusion of C stocks from the LULUCF sector and performing updates (biomass burning), data management, gridding procedures and data inter-comparisons. Her current work is dealing with reconciliation and assessment of different models and tools leading to verification of GHG inventories (VERIFY WP5) by synthesising observation-based estimates of GHG fluxes and carbon stocks from bottom-up, top-down and global emissions databases (e.g. EDGAR, FAOSTAT) to deliver products for comparison purposes and reconciliation with official country level UNFCCC national GHG inventories. She is, as well, leading the GCP-RECCAP2 regional (European) GHG budget synthesis.

Relevant Publications (up to 5)

1. Janssens-Maenhout, G. , B. Pinty, et al. (including H. Dolman and S. Houweling), 2020, Towards an operational anthropogenic CO2 emissions monitoring and verification support capacity, accepted for publication in BAMS.
2. Pandey, S., Gautam, R., Houweling, S., Van Der Gon, H. D., Sadavarte, P., Borsdorff, T., … Aben, I. (2019). Satellite observations reveal extreme methane leakage from a natural gas well blowout. Proceedings of the National Academy of Sciences of the United States of America, 116(52), 26376–26381. https://doi.org/10.1073/pnas.1908712116.
3. Dolman, A.J., 2019. Biogeochemical cycles and climate. Oxford, UK, Oxford. Univ. Press, 272 pp.
4. Dean, J. F., Middelburg, J. J., Röckmann, T., Aerts, R., Blauw, L. G., Egger, M., et al., Dolman, A.J. (2018). Methane feedbacks to the global climate system in a warmer world. Reviews of Geophysics, 56, 207–250. https://doi.org/10.1002/2017RG000559
5. Petrescu, A. M. R., Lohila, A., Tuovinen, J. P., Baldocchi, D. D., Desai, A. R., Roulet, N. T., Vesala, T., Dolman, A. J., Oechel, W. C., Marcolla, B., Friborg, T., Rinne, J., Matthes, J. H., Merbold, L., Meijide, A., Kiely, G., Sottocornola, M., Sachs, T., Zona, D., Varlagin, A. & 7 others, 2015, The uncertain climate footprint of wetlands under human pressure, In : Proceedings of the National Academy of Sciences of the United States of America. 112, 15, p. 4594-4599

Recent Projects (up to 5)

- H2020 CHE – 776186 – 'Development of a European monitoring capacity for anthropogenic CO2 emissions'
- H2020 VERIFY – SC5-04-2017 – 'To advance the development of accurate and robust observation-based methods for quantifying GHG emissions and sinks, as well as deliver knowledge and products that are of practical use for policy and societal stakeholders'
- H2020 SCARBO – 769032 – 'Preparation for a European capacity to monitor CO2 anthropogenic emissions'
- METHANE+ - ESA AO/1-9602/19/I-DT - Infer global sources and sinks of CH4 from inverse modelling of 2 years of TROPOMI and IASI (and/or CrIS) data, investigating the added value of the combined use of SWIR and TIR
- GEOCARBON

Major Hardware/ Infrastructure available

n/a

4.1.10 WU

10 - Wageningen University

About the Organisation

Wageningen University is a university dedicated to education and knowledge generation in the field of life science and natural resources. As an international center of learning and research it receives students from over a hundred countries. Over 200 PhD students graduate annually from the university. WUR participates in more than

200 EU projects and has received the ECTS label from European Union.

Role in this Project

Work Package Leader for WP1, contributor to WP1 and WP2

Expertise with Relevance to this Project and Role

Within Wageningen Universities' department of Environmental Sciences, the Meteorology and Air Quality Group has a large expertise on boundary layer dynamics, data assimilation, and the carbon cycle. Experience with numerical modeling of in-situ and satellite remotely sensed trace gases is reflected in an extensive publication record. This includes radiocarbon, CO_2, CO, and NOx. WU contributes the CarbonTracker data assimilation system for CO_2 to the Global Carbon Project as well as to the ICOS Carbon Portal where it is a key partner. WU personnel developed the open-source MicroHH CFD code.

Key Persons

Prof Dr. W. (Wouter) Peters (male) is full professor holding a personal chair in Carbon Cycle and Atmospheric Composition. His research focuses on the carbon cycle and atmospheric mole fraction observations of CO_2 and its isotopes. Part of this work entails the semi-operational CarbonTracker system, which diagnoses recent global exchange of CO_2 using an ensemble data assimilation system. Since 2015 he conducts an ERC Consolidator program aiming to measure stable isotopes from aircraft samples collected over the Brazilian Amazon. WP is member of the core-team of the Global Carbon Project.

Prof Dr. M. (Maarten) Krol (male) obtained his PhD in theoretical chemistry. Since 2005 he is professor Air Quality and Atmospheric Chemistry at Wageningen University and Research Centre. About 10 PhD students work under his supervision in fields ranging from aerosol modeling to the source inversion from CO satellite data. In 2017, he was awarded an ERC Advanced Grant to study carbonyl sulfide in the atmosphere.

Dr I.T. (Ingrid) Luijkx (female) is Assistant Professor at Wageningen Univ since 2018, working on a prestigious national talent grant (VENI program). She is an expert on the carbon cycle, and specifically on modeling and measurements of O_2 in the atmosphere. Dr Luijkx has extensive experience with the CarbonTracker system and has developed a specific tropically-oriented version of our system. She co-leads the RECCAP2 global flux synthesis effort and contributes the GCP annual syntheses.

Dr L. (Liesbeth) Florentie (female) is Postdoc at Wageningen University working on the CHE project since 2018. She had developed extensive expertise on carbon cycle data assimilation and built the numerical capacity to ingest XCO2 satellite data from NASA and Bremen products. She is also the architect of the long-window-short-window dual approach for data assimilation in CarbonTracker.

Dr C. (Chiel) van Heerwaarden (male) is Assistant Professor at Wageningen Univ since 2016, working on a prestigious national talent grant (VIDI program). He is an expert on turbulent modeling and atmospheric dynamics, and the architect of the highly versatile CFD/LES model MicroHH. His research focuses on drought impacts on evaporation, and 3D cloud-radiation interactions over heterogeneous terrain.

Dr B. (Bart) van Stratum (male) is PostDoc at Wageningen University since 2019, and responsible for the development of both the DALES large-eddy simulation code and the microHH CFD model. He is an expert on numerical methods, coding in C/C++ and CUDA, and on turbulent interactions at the interface of land and atmosphere.

Relevant Publications (up to 5)

1. Peters, W. et al. (2018). "Increased Water-Use Efficiency and Reduced CO2 Uptake by Plants During Droughts at a Continental Scale." Nature Geoscience, August. Springer US, 1–6. doi:10.1038/s41561-018-0212-7.
2. van der Laan-Luijkx, I. T. et al. (2015) "Response of the Amazon carbon balance to the 2010 drought derived with CarbonTracker South America". *Global Biogeochem Cy*., 29, doi:10.1002/2014GB005082
3. Van Heerwaarden, C. C., Van Stratum, B. J. H.,et al, (2017), "MicroHH 1.0: A computational fluid dynamics code for direct numerical simulation and large-eddy simulation of atmospheric boundary layer flows" *Geoscientific Model Development*, 10, 8, p. 3145-3165

4. Peters, W. et al. (2007) “An atmospheric perspective on North American carbon dioxide exchange: CarbonTracker”. *Proceedings of the National Academy of Sciences* 104, 18925–18930.
5. van Stratum, B. J. H., et al, (2014) “Subcloud-Layer Feedbacks Driven by the Mass Flux of Shallow Cumulus Convection over Land”, *Journal of the Atmospheric Sciences.* 71, 3, p. 881-895

Recent Projects (up to 5)

- ASICA, 649087, ASICA aims to collect new measurements of stable isotopes of CO_2 from the atmosphere over the Amazon, to estimate the carbon uptake and drought sensitivity of the rain forest.
- QA4ECV, 607405, QA4ECV generated multi-decadal climate data records for 3 atmospheric Essential Climate Variable precursors (nitrogen dioxide, formaldehyde, and carbon monoxide) and 3 land ECVs (albedo, leaf area index and absorbed photosynthetically active radiation), with full uncertainty metrics for each and every satellite measurement.
- RINGO, 730944, RINGO aims to ensure the readiness of the European ESFRI ICOS for integrated Global Observations needed to support carbon exchange estimates and verification
- COSOCS aims to understand the role of carbonyl sulfide in the climate system, as a precursor for sulfate aerosol formation and as a tracer for photosynthetic activity of vegetation. It includes components of measurements, stable isotope analyses, and numerical modeling including data assimilation.
- CHE stands for Carbon Human Emissions, and is a H2020 project that laid the groundwork

Major Hardware/ Infrastructure available

- CarbonTracker data assimilation system
- MicroHH CFD code
- Supercomputing facilities (national)
- Ruisdael national GHG infrastructure for hi-res modeling and monitoring

4.1.11 AGH

11 – AGH University of Science and Technology
(Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie)

About the Organisation

AGH University of Science and Technology is a modern technical university that takes active part in building a society based on knowledge while taking advantage of technologies for the purpose of economic growth and development. The university was established in 1913, but was only opened in 1919 due to the outbreak of First World War. The Environmental Physics Group (EPG), working as part of Department of Applied Nuclear Physics at the Faculty of Physics and Applied Computer Science, has long-term experience in the area of atmospheric sciences and hydrology, with main focus on the application of natural isotope tracers (both stable and radioactive) in hydrological and atmospheric studies. The atmospheric part of the group is active in the area of greenhouse gases monitoring and budgeting both in the remote as well as urban areas. The experimental activity is also supported by atmospheric modelling, using mesoscale atmospheric models (WRF, WRF-GHG, Aladin), as well as lagrangian dispersion models (Hysplit,, STILT). EPG is running remote greenhouse gas observatory at Kasprowy Wierch (Tatra Mountains) monitoring CO_2 and CH_4 concentration since 1994. The mixing ration measurements are supplemented by the analysis of isotopic composition of CO_2 (^{13}C, ^{14}C). Apart from regional analyses based on measurements carried out at the remote, EPG is also conducting tasks aiming at the characterisation of the local carbon cycling in the Kraków agglomeration, a typical Central-European city influenced by a strong anthropogenic emissions.

Role in this Project

EPG will contribute to WP6 task by delivering historical and ongoing radiocarbon in CO_2 (^{14}C-CO_2) data from two possible locations: Kasprowy Wierch (KAS) remote mountain station and Kraków (KRK) urban environment. For mountain site, the data will consist of CO_2 and CH_4 mixing ratio, radiocarbon content in atmospheric CO_2. For urban site, radiocarbon data will be delivered. Depending on project needs and budget constraints, the partnership can be extended by additional measurements of CO_2 and CH_4 fluxes in Krakow using Relaxed Eddy Accumulation method, mobile measurement campaigns aimed at characterisation of spatial (both horizontal by cars or vertical up to 200 m a.g.l. by drones) and temporal variability of mixing ratios in selected regions.

Expertise with Relevance to this Project and Role

Since 1994 EPG is maintaining remote mountain GHG station at Kasprowy Wierch. The quality of measurements is continuously monitored in the frame of several European projects delivering consistent high quality CO_2 and CH_4 mixing ratio observations. Apart of long term historical mixing ratio record representing Central Europe, radiocarbon content in atmospheric CO_2 is simultaneously monitored since 2000, with collection of monthly mean samples. Both historical dataset and ongoing measurements performed at Kasprowy Wierch station will contribute to the project as a potential input data for the state-of-the-art modelling systems. Apart of regional datasets, additional radiocarbon dataset representing urban environment can be delivered. Radiocarbon (^{14}C-CO_2) content monitoring in atmospheric CO_2 in Krakow is running since 1984. This activity is still ongoing delivering valuable long term data for analysis of variability in urban environment stimulated by different socioeconomical and climatic changes (like industrial transformation in Eastern Europe in 1990, or implications of solid fuel burning ban regulations introduced in Krakow in 2019).

Key Persons

Miroslaw Zimnoch (M) – holds a PhD in Physics (AGH University of Science and Technology, 1997) and habilitation in environmental engineering (Warsaw University of Technology 2017). Researcher with almost 30 year experience in isotopic composition measurements of greenhouse gases (CO_2, CH_4), atmospheric modelling and flux measurements. In 1997 enrolled as Assistant Professor and in 2019 as Associate Professor in Environmental Physics Group at the Faculty of Physics and Applied Computer Science AGH University of Science and Technology in Krakow. During his scientific career he managed and participated in several national and European grants (eg. Escoba, Carboeurope-IP, MethMoniteur, IMECC, Eurohydros, INGOS). He is the author of 22 scientific publications indexed in Web of Science having 470 citations and H-index equal to 11 and several communications to International conferences.. Currently he is also involved in air quality studies, application of drones for atmospheric boundary layer studies and development of measurement systems dedicated for mobile platforms (cars, drones). He is supervisor of 4 PhD (three still ongoing), 40 MSc and 31 BSc thesis.

Michal Galkowski (M) – Holder of a PhD in Physics (AGH University of Science and Technology, 2015). A postdoc researcher with almost 10 year experience in greenhouse gas measurements and modelling. Started by analysing isotopic composition of atmospheric carbon dioxide, then became a PhD student in 2010 and researched nitrous oxide emissions and loads over the region of south Poland, also as a project head of a NCN (National Science Centre) grant for a project: “Temporal and spatial variability of nitrous oxide in the southern Poland region: an estimation of loads and fluxes.”. Currently finishing his 3 year postdoc contract at Max Planck Institute for Biogeochemistry in Jena in the scope of AIRSPACE project, where he is responsible for airborne in-situ measurements measurements of CO_2 and CH_4 on board HALO aircraft during 2018 CoMet mission, as well as subsequent data analysis and regional modelling of greenhouse gases using WRF-Chem. his research he uses high-resolution modelling with modern measurement data streams in order to understand emissions and transport of pollutants at regional to local spatial scales. Currently he is also involved in development of atmospheric measurement network in Poland. He has co-authored 8 papers in international scientific journals and co-supervised 3 bachelor and master students.

Relevant Publications (up to 5)

1. Zimnoch M., Necki J., Chmura L., Jasek A., Jelen D., Galkowski M., Kuc T., Gorczyca Z., Bartyzel J. and Rozanski K. 2019, Quantification of carbon dioxide and methane emissions in urban areas: source apportionment based on atmospheric observations, Mitig Adapt Strateg Glob Change 24:1051–1071 https://doi.org/10.1007/s11027-018-9821-0
2. Jasek A., Zimnoch M., Gorczyca Z., Smula E., Rozanski K., 2014, Seasonal variability of soil CO2 flux and its carbon isotope composition in Krakow urban area, Southern Poland, ISOTOPES IN ENVIRONMENTAL AND HEALTH STUDIES, Vol50(2), pp.143-155, DOI:10.1080/10256016.2014.868455
3. Zimnoch, M., Jelen, D., Galkowski, M., Kuc, T., Necki, J., Chmura, L., Gorczyca, Z., Jasek, A., Rozanski, K.,

2012, Partitioning of atmospheric carbon dioxide over Central Europe: insights from combined measurements of CO2 mixing ratios and their carbon isotope composition, ISOTOPES IN ENVIRONMENTAL AND HEALTH STUDIES Vol.48(3), pp.421-433, DOI:10.1080/10256016.2012.663368

4. Zimnoch, M., Godlowska, J., Necki, J. M., Rozanski, K., 2010, Assessing surface fluxes of CO2 and CH4 in urban environment: a reconnaissance study in Krakow, Southern Poland, TELLUS SERIES B-CHEMICAL AND PHYSICAL METEOROLOGY, Vol.62(5), pp.573-580, DOI:10.1111/j.1600-0889.2010.00489.x
5. Kuc, T., Rozanski, K., Zimnoch, M., Necki, J., Chmura, L., Jelen, D., 2007, Two decades of regular observations of (CO2)-C-14 and (CO2)-C-13 content in atmospheric carbon dioxide in central Europe: Long-term changes of regional anthropogenic fossil CO2 emissions, RADIOCARBON, Vol.49(2), pp.807-816

Recent Projects (up to 5)

- AIRSPACE project. BMBF (German Federal Ministry of Education and Research) project: FK 390 01LK1701C (2017-still ongoing) Responsible for JAS instrument (Jena Air Sampler) for in situ sampling of atmospheric air aboard HALO (High Altitude Long Range Research Aircrafts) during CoMet 1.0 campaign. Responsible for regional modelling of transport and emissions of CO_2 and CH_4 using WRF-Chem.
- "Changes of microRNA expressions of human blood monocytes under PM2.5 stress in-vitro – potential connections between air pollution and atherosclerosis". NCN (National Science Centre) grant no. 2016/21/B/NZ7/01747 (2018-2020). Project performed in cooperation between AGH University and Collegium Medicum of Jagiellonian University. Role: collection, elemental, chemical and isotopic analysis of PM2.5 particulate matter fraction from Krakow, numerical analysis of atmospheric transport of pollution.
- INGOS (Integrated Network for non-CO2 GHG observations) 7th Framework Programme project. Contribution: measurements and data analysis of CH_4 and N_2O for the purpose of the network. Development and implementation of QA/QC procedures.
- Assessment of carbon dioxide exchange flux between atmosphere, terrestrial and aquatic ecosystems on the urban area of Krakow, SiBAE COST Action and supported national grant no 817/N-COST/2010/0 (2011-2013). Role: project coordinator. Contribution: Assessment of CO2 biogenic flux and its isotopic signature for the urban area of Krakow.
- IMECC project "Infrastructure for Measurement of the European Carbon Cycle" VI Framework Programme, Contract number: 026188 (2007-2011). Role: PI responsible for Kasprowy Wierch GHG monitoring station.

Major Hardware/ Infrastructure available

1. Remote mountain station at Kasprowy Wierch, Tatra Mountains (49°14'N 19°59'E 1989masl) equipped with Picarro G2101-I analyser, system for CO_2 sampling for radiocarbon analysis, flask sampling system.
2. Urban monitoring station located close to the Krakow city centre equipped with 20m tower installed at the roof of Faculty building (top at 40m a.g.l.) full meteorology, 3D anemometer, radiation balance, Eddy accumulation system for CO_2 and CH_4 flux measurements, system for CO_2 sampling for radiocarbon analysis, flask sampling system.
3. Access to supercomputing cluster Prometheus (53604 cores, 282TB RAM, 10 PB HDD, 2403 TFlops) for WRF/WRF-Chem simulations
4. Unmanned Aerial Vehicle platform equipped for carrying light measurement devices, e.g. for meteorological sensors. One of the contributors is a licensed UAV operator (VLOS).

4.1.12 BSC

12 - Barcelona Supercomputing Center – Centro Nacional de Supercomputación

About the Organisation

Barcelona Supercomputing Center (BSC), formed in 2005, has a mission to research, develop and manage

information technology in order to facilitate scientific progress. At the BSC, more than 500 people from 40 different countries perform and facilitate research into Computer Sciences, Life Sciences, Earth Sciences and Computational Applications in Science and Engineering. The BSC is one of the four hosting members of the European PRACE Research Infrastructure as well as one of the first eight Spanish "Severo Ochoa Centre of Excellence" awarded by the Spanish Government.

The Earth Sciences Department of the BSC (ES-BSC) was established with the objective of carrying out research in Earth system modelling, and focuses its activity on emissions, air quality, mineral dust and global and regional climate modelling and prediction. ES-BSC is organized around four closely interacting groups (Atmospheric Composition, Climate Prediction, Computational Earth Sciences, and Earth System Services) comprising ~100 employees, including scientific, technical, and support staff. The department is an active member of the EC-Earth consortium, whose Earth System Model is widely used at ES-BSC for research and teaching purposes. During last 5 years (2014-2019), BSC-ES was granted 23 EU H2020 projects, 6 H2020 MSC personal grants, 14 EU Copernicus projects, 10 national projects, 2 projects funded by the European Space Agency, 1 project funded by the French Ministry of Sciences, 1 project funded by the Flanders Research Foundation, 1 project from ERA-NET, 3 from ERA4CS and 1 ERC Consolidator Grant. During that same period, BSC-ES also participated in 21 RES and 4 PRACE projects. BSC-CNS has been awarded with the Severo Ochoa's Centre of Excellence project of the Spanish government since its first call (2011). The BSC-ES international activity includes the coordination of the two World Meteorological Organisation (WMO) regional centres specialized in sand and dust warning and forecasting, as well as the participation in climate services initiatives like the Climate Services Partnership (CSP). Members of the BSC-ES participate in committees of the World Climate Research Programme (WCRP), such as the CLIVAR Scientific Steering Group or the Working Group on Seasonal to Interannual Prediction (WGSIP).

The Atmospheric Composition (AC) Group aims at better understanding and predicting the spatiotemporal variations of atmospheric pollutants along with their effects upon air quality, weather and climate, and will be the group directly involved in CoCO2. The group has a wide experience in running operational atmospheric forecasting systems and delivering timely and quality forecasts, observations, information and knowledge to users. The group currently hosts the CALIOPE air quality forecast system (http://www.bsc.es/caliope), the Barcelona Dust Forecast Center (http://dust.aemet.es/) and the WMO Regional Center Northen Africa-Middle East-Europe for the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) (http://sds-was.aemet.es/). The AC group is a reference in dust modelling at different scales, and, as such, hosts a long-term AXA Chair on Sand and Dust Storms, and has been recently awarded with the ERC Consolidator Grant FRAGMENT, held by Dr. Carlos Pérez García-Pando.

Role in this Project

BSC contribution to the CoCO2 project will be mostly focussed on WP1 (Prior information) to support the development of state-of-the-art emission data for other WPs. More specifically, BSC will contribute to the combination of regional emission inventories and the development of global fossil emission datasets by using the in-house HERMES emission modelling tool. Moreover, BSC will lead the task on improving emission temporal profiles for key sectors (e.g. road transport, point sources, residential heating), and will also provide expert knowledge and methodology for the improvement of the spatial proxies for mapping emissions. Additionally, BSC will have an advisory role in WP2 (Global Modelling and data assimilation) for the implementation in the IFS system of the temporal profiles and emission parametrizations developed in WP1.

Expertise with Relevance to this Project and Role

The ES-BSC has developed multiscale and dynamic anthropogenic emission models (i.e HERMES, HERMES-Mex) in collaboration with the Spanish Ministry for Environment and the Mexico City's Secretariat of the Environment. The resulting models constitute the emission core of operational air quality forecast systems (e.g. CALIOPE) and are also used to perform emission scenario analysis for the evaluation of air quality management strategies. The group has a strong experience in the combination of bottom-up and top-down emission estimation approaches, as well as in the development of spatial, temporal and speciation profiles for creating atmospheric chemistry transport model-ready emissions. The ES-BSC has performed emission intercomparison exercises using MACC products (i.e. TNO_MACC emission inventories) and is currently developing a new set of emission temporal profiles under the CAMS_81 Copernicus Service. The spatial and temporal adaptation of emission datasets to evaluate the performance of air quality models at the global and regional scales (e.g. EURODELTA III exercise) is another strength of the group. The ES-BSC has also developed global dust and sea salt emission schemes under research projects financed by the Spanish Commission of Science and Technology.

Key Persons

Marc Guevara (Male) – holds a PhD in Environmental Engineering (Polytechnic University of Catalonia, Spain, December 2014). He is a postdoc researcher with 9 years' experience in the areas of emission and air quality modelling. In 2010, he was enrolled as support engineer at the Earth Sciences Department of the Barcelona Supercomputing Center (BSC), and in 2014 he moved to the emission working group coordinator position at BSC. His main expertise includes high resolution atmospheric emission modelling, air quality modelling, geographic information systems and environmental impact assessment. He coordinates the development of the in-house HERMES emission model, which is the emission core of the Spanish CALIOPE operational air quality system. He is co-chair of the Emissions Working Group of the Forum for Air quality Modelling (FAIRMODE) community and member of the Emissions and Deposition Working Group of the MUlti-Scale Infrastructure for Chemistry and Aerosols (MUSICA) community. He has coordinated the development and implementation of an air quality forecast system for the Mexico City's Environment Secretary. He coordinates the Service Evolution work package of the Copernicus CAMS_81 – Global and Regional emissions service and participates in the Copernicus CAMS_50 – Regional production. He has participated in the Spanish air quality-related CALIOPE-And project and the PAISA national project (CGL2016-75725-R). He has co-authored 19 papers in international scientific journals (Scopus 12h-index and 311 Citations), 4 book-chapter and several communications to International conferences. He is currently co-directing 1 PhD thesis.

Carles Tena (Male) - Bachelor on computer science by the Autonomous University of Barcelona (Spain) and currently finalizing a master on computational mathematics (Rovira i Virgili University, Spain). His main expertise includes objected oriented programming language Python and the development of earth science models and workflows for the execution of operational atmospheric composition forecast systems. In 20, he was enrolled as part of the Computational Earth Science group of the BSC, with the objective of developing an optimized framework to use more efficiently the high performance computation (HPC) resources. He currently coordinates the technical development and maintenance of the HERMESv3 emission system and the Mexico City air quality forecasting system. He is also responsible of supervising the operational runs of the CALIOPE Air Quality System in the HPC infrastructures of the BSC. His work has produced tree papers on scientists publications and the supervision of one master student final thesis

Relevant Publications (up to 5)

1. Guevara, M., Tena, C., Porquet, M., Jorba, O., and Pérez García-Pando, C., 2019. HERMESv3, a stand-alone multi-scale atmospheric emission modelling framework – Part 1: global and regional module, Geosci. Model Dev., 12, 1885-1907.
2. Benavides, J., Snyder, M., Guevara, M., Soret, A., Pérez García-Pando, C., Amato, F., Querol, X., and Jorba, O., 2019. CALIOPE-Urban v1.0: coupling R-LINE with a mesoscale air quality modelling system for urban air quality forecasts over Barcelona city (Spain), Geosci. Model Dev., 12, 2811-2835.
3. Trombetti, M., P. Thunis, B. Bessagnet, A. Clappier, F. Couvidant, M. Guevara, J. Kuenen and S. Lopez-Aparicio, 2018. Spatial inter-comparison of top-down emission inventories in European urban areas. Atmospheric Environment, 173, 142-156.
4. Guevara, M., C. Tena, A. Soret, K. Serradell, D. Guzmán, A. Retama, P. Camacho, M. Jaimes-Palomera and A. Mediavilla, 2017. An emission processing system for air quality modelling in the Mexico City metropolitan area: Evaluation and comparison of the MOBILE6.2-Mexico and MOVES-Mexico traffic emissions. Science of The Total Environment, 584-585, 882-900
5. Guevara, M., Pay, M.T., Martínez, F., Soret, A., Denier van der Gon, H.A.C., Baldasano, J.M., 2014. Inter-comparison between HERMESv2.0 and TNO-MACC-II emission data using the CALIOPE air quality system (Spain), Atmospheric Environment, 98, 134-145

Complete list of publications of the ES-BSC: https://earth.bsc.es/wiki/doku.php?id=publications:publications

Recent Projects (up to 5)

- H2020 project *AQ-WATCH Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health* (GA870301): AQ-WATCH will develop a supply chain leading to the generation of seven downstream products and services that are innovative for improving air quality forecasts and attribution. These prototypes will be based on existing space and in situ observations of air quality and tailored to the

identified needs of international users.

- COPERNICUS service *CAMS-81 Global and Regional Emissions*: the goal of this service is to provide gridded distributions of European and global anthropogenic emissions, as well as global natural emissions for the CAMS (Copernicus Atmosphere Monitoring Service) regional and global production chains.
- COPERNICUS service *CAMS-50 Regional production*: The purpose of the Service will remain to produce numerical data and mapping products providing information on air quality and atmospheric composition on the European scale, with the aim of making it freely and easily accessible to the various user communities.
- ERC project FRAGMENT (GA 773051) The goal is to understand and constrain the global mineralogical composition of dust along with its effects upon climate. It will contribute new fundamental understanding of the size resolved mineralogy of dust at emission and its relationship with the parent soil, based on an unprecedented ensemble of measurement campaigns that have been designed to thoroughly test our theoretical hypotheses.
- H2020 *project ACTRIS-PPP Aerosols, Clouds and Trace gases Preparatory Phase Project* (GA 739530) The main objectives of ACTRIS PPP are to develop the organizational, operational and strategic frameworks of the RI. The work includes legal, governance, financial, technical, strategic, and administrative aspects carried out in 9 work packages. The main outcomes of PPP are signature-ready documents for establishment of a legal entity with well-defined operations and a sound business plan.

Major Hardware/ Infrastructure available

BSC constitutes a reference center in High Performance Computing nationally and internationally, since its inception in 2005. BSC hosts the MareNostrum Supercomputer, which has been upgraded for the fourth time since it was installed to achieve a peak performance of 13.7 Petaflops/s. It counts on 165888 Intel Xeon v5 processors, distributed in 3456 nodes, and a central memory of 390 Terabytes. The ES-BSC counts on self-designed data infrastructure that allows easily combining datasets for emission modelling purposes. These HPC resources as well as the ES-BSC modelling tools will be available for CoCO2 developments. The EuroHPC has selected BSC as one of the institutions that will host a pre-exascale supercomputer in the high-capacity supercomputer network promoted by the EC, MareNostrum 5, which will have a peak performance of 200 Petaflops (200 x 1015 of operations per second), and it will be an heterogenous supercomputer.

4.1.13 CICERO

13 - CICERO SENTER KLIMAFORSKNING STIFTELSE (CICERO Center for International Climate Research)

About the Organisation

CICERO Center for International Climate Research is a leading inter-disciplinary climate research institute in the Nordics, with departments on the climate sciences, climate economics, climate policy and climate communication. Researchers undertake projects funded primarily by the EU Framework Programmes and the Research Council of Norway, with smaller funding from Government ministries and other national and international programmes or organisations. CICERO researchers regularly published in top academic journals in a range of fields (Science, Nature, etc) and has the highest publication ranking amongst the Norwegian environmental institutes. Communication, stakeholder management and process facilitation are of core importance to CICERO from its founding, with most CICERO projects involving dedicated communication and dissemination activities. CICERO participates in a broad network of national and international research communities: IPCC assessment reports (AR6 WGI vice-chair, SR15 Review Editor, six lead authors), global change programmes (e.g., Future Earth, Global Carbon Project) and EU research (eg Joint Programming Initiatives). CICERO has around 75 staff, 60 of which are research staff, 10 in administration and five dedicated to communication.

Role in this Project

CICERO will contribute to WP1 and WP7, with most activities based on CICERO's expertise on carbon dioxide emission estimates (WP1, WP7), short-term projections (WP1), comparisons (WP7), and graphical presentation (WP7)

Expertise with Relevance to this Project and Role

CICERO has led the emission components of the Global Carbon Budget for many years and develops most of the graphical material for use in the communication and outreach material.

Key Persons

Glen Peters (M) is a Research Director at CICERO, where he has worked for eleven years and managed several large interdisciplinary research projects. He is a worldwide authority on emission drivers and scenarios, demonstrated via highly-cited articles in high-level journals. Dr Peters has played an important role in the Global Carbon Budget in the last eight years, coordinating data and performing analysis on emission sources, and writing several synthesis articles. He has completed a six-year (maximum) term on the Scientific Steering Committee of the Global Carbon Project. He is a Lead Author for the IPCC Sixth Assessment Report on emission scenarios (WG3 Chapter 3). Peters is actively involved in communication activities, with 25,000 followers on Twitter and actively giving presentations to stakeholders (Ministries, Agencies, industry associations, financial industry, and oil and gas industry).

Robbie Andrew (M) is a leading authority in emission statistics and emission drivers, with several publications in high-level journals. Andrew performs most data analysis, management, and graphical presentation for the emission source component of the Global Carbon Budget. Andrew is behing most of the graphical material used in the Global Carbon Budget, and has also worked with geospatial data in previous employment in New Zealand.

Ms. Iselin Rønningsbakk (F) is a senior communications advisor at CICERO, where she has been responsible for various communications activities, including the websites, newsletters, social media, and has lead communication work in different Horizon 2020 projects.

Relevant Publications (up to 5)

1. Friedlingstein, P., et al. (2019), Global Carbon Budget 2019, *Earth System Science Data*, vol. 11, pp. 1783–1838. 5.Global Carbon Project (annual releases), data portal, website, graphical material, visualisations, synthesis reports, etc. http://www.globalcarbonproject.org/carbonbudget/index.htm
2. Hausfather, Z, Peters, GP (2020) Emissions – the 'business as usual' story is misleading, *Nature* 577, 618-620
3. Peters GP, LeQuéré C, Andrew RM, Canadell JG, Friedlingstein P, Ilyina T, Jackson RB, Joos F, Kosbakken JI, McKinley GA, Sitch S, Tans P (2017), Towards real-time verification of CO_2 emissions, *Nature Climate Change*, doi:10.1038/s41558-017-0013-9.
4. Peters, 2018, Beyond Carbon Budgets, *Nature Geoscience*, 11, 378-380.
5. Peters, 2016. The 'best available science' to inform 1.5°C policy choices, *Nature Climate Change* 6, 646-649

Recent Projects (up to 5)

- 2019-2023: Climate-Carbon Interactions in the Coming Century (CCiCC), Horizon 2020, WP leader
- 2019-2022: Delivering on the Paris Agreement: A demand-driven, integrated assessment modelling approach (Paris Reinforce), Horizon 2020, Participant
- 2018-2021: Observation-based system for monitoring and verification of greenhouse gases (VERIFY), Horizon 2020, WP leader
- 2016-2019: Rapid Response for Climate and Energy Policy, Strategic Institute Funding, Norwegian Research Council, Project Leader
- 2012-2016: Support for the Global Carbon Project, various Research Council of Norway sources (Project Leader)

Major Hardware/ Infrastructure available

Not relevant for CICERO's contribution

4.1.14 CMCC

14 - Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici

About the Organisation

The Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (Fondazione CMCC) is a non-profit research institution. CMCC's mission is to investigate and model our climate system and its interactions with society to provide reliable, rigorous, and timely scientific results, which will in turn stimulate sustainable growth, protect the environment, and develop science driven adaptation and mitigation policies in a changing climate. CMCC collaborates with experienced scientists, economists, and technicians, which work together in order to provide full analyses of climate impacts on various systems such as agriculture, ecosystems, coasts, water resources, health, and economics. CMCC also supports policymakers in setting and assessing costs, mitigation, and adaptation policies. CMCC benefits from the extensive applied research experience of its members and institutional partners: Istituto Nazionale di Geofisica e Vulcanologia (INGV); Università del Salento; Centro Italiano di Ricerche Aerospaziali (CIRA S.c.p.a.); Università Ca' Foscari Venezia; Università di Sassari; Università della Tuscia; Università di Bologna; Politecnico di Milano; Resources for the Future.

CMCC research activities are distributed among nine research divisions that share different knowledge and skills in the field of climate science: Advanced Scientific Computing (ASC) Division; Climate Simulation and Prediction (CSP) Division; Economic analysis of Climate Impacts and Policy (ECIP) Division; Impacts on Agriculture, Forests and Ecosystem Services (IAFES) Division; Ocean modeling and Data Assimilation (ODA) Division; Ocean Predictions and Applications (OPA) Division; Risk Assessment and Adaptation Strategies (RAAS) Division; Regional Models and geo-Hydrological Impacts (REHMI) Division; Sustainable Earth Modeling and Economics (SEME) Division.

CMCC acquired portfolio of research projects includes 368 funded projects: 37 projects in FP6 and FP7, 60 projects in H2020 and 271 projects under other EU and international research grants. In about a half of the implemented projects, CMCC acted as the coordinator. Since 2006, CMCC is the IPCC National Focal Point for Italy. Currently, CMCC is supporting the Italian Ministry of Environment in the UNFCCC negotiations on adaptation and land mitigation related issues.

CMCC is the coordinator of the Ecosystem Thematic Centre (ETC) of the Integrated Carbon Observation System (ICOS) an European Research Infrastructure (RI), together with the University of Tuscia in Viterbo and in collaboration with the University of Antwerp (Belgium) and the National Institute for Agricultural Research (France).

For further information on CMCC please see www.cmcc.it

Role in this Project

CMCC will lead two tasks: 5.1 providing the landscape of the policy needs and challenges within the Global Stocktake process under the UNFCCC, and 6.5 on the development of new methods and techniques in the observations. CMCC will contribute in WP6 also to the data delivery to task 1.1.

Expertise with Relevance to this Project and Role

Thanks to the expertise on the UNFCCC negotiation process and being part of the GHG inventory community, the CMCC will bridge the policy needs to the scenario development facilitating the continuous exchange between the two communities. CMCC is also coordinating the ICOS Ecosystem Thematic Centre and involved in the FLUXNET and European Database where also new methods and techniques are developed.

Lucia Perugini (Female) PhD in Forest ecology, she is currently a senior scientific manager at CMCC with scientific background in Forestry and climate change policies Since 2003 she is involved in land related negotiations at UNFCCC and EU level as part of the Italian Delegation. She is currently the Coordinator of the EU AFOLU issue group at the UNFCCC negotiations. Between 2013 and 2014 she was co-chairing the negotiation on LULUCF agenda item under Subsidiary Body for Scientific and Technological Advice of the UNFCCC. She is currently the Italian representative at the Working Group 5 at the EU Climate Change Committee on "Implementation of the LULUCF Decision and policy development of the land use, land use change and forestry sector (529/2013)". Expert

in GHG inventories in the land sector, she participated in the compilation of the GHG National Inventory Report of Italy (2018 and 2019). Involved as WP leader in EU Funded research projects (EU FP7: LUC4C-GA n.603542; H2020: VERIFY -GA n.776810) acting as expert in GHG Monitoring, Reporting and Verification (MRV) and providing a link between the scientific and policy communities. Besides, she is an expert in development and coordination of forestry carbon project in several developing countries (e.g. Argentina, Albania, Ukraine, China, India).

Dario Papale (Male) – Dario Papale is Associate Professor of Forest Ecology and Terrestrial Ecosystems Monotiring at the University of Tuscia (Viterbo, Italy) were he also got his PhD in Forest Ecology in 2003 working on artificial neural networks and eddy covariance data. His interests are in data-model integrations, biogeochemical empirical and data oriented models to assess carbon, water and energy fluxes from terrestrial ecosystems and their uncertainty. From 2004 he is scientific responsible of the European Eddy Covariance fluxes databases cluster (former ecosystem component database of the CarboEurope-IP project) where he mainly work in the eddy covariance data standardization, quality control and uncertainty estimation, data policy and database services development**.** He is member of the AmeriFlux Management Project Team and he has been nominated in 2013 Director of the Ecosystem Thematic Centre of the Integrated Carbon Observation System (ICOS) ESFRI Research Infrastructure in Europe at the CMCC. He published more than 100 papers in international journals and he is co-editor of a book on the Eddy Covariance technique. Since August 2014 he is Editorial Board member of Nature Scientific Data.

Relevant Publications (up to 5)

1. Duveiller, G., Caporaso, L., Abad-Viñas, R., **Perugini**, L., Grassi, G., Arneth, A., & Cescatti, A. (2020). Local biophysical effects of land use and land cover change: towards an assessment tool for policy makers. Land Use Policy, 91, 104382.
2. Savaresi, A.,and **Perugini,** L., (2019) The Land Sector in the 2030 EU Climate Change Policy Framework: A Look at the Future (April 5, 2019). Journal for European Environmental & Planning Law, Forthcoming. Available at SSRN: https://ssrn.com/abstract=3366948
3. Grassi, G., House, J., Kurz, W. A., Cescatti, A., Houghton, R. A., Peters, G. P., ... **Perugini** L., Rossi S., Sitch S., Viovy N., Wiltshire A. Zaehle S. (2018). Reconciling global-model estimates and country reporting of anthropogenic forest CO2 sinks. Nature Climate Change, 8(10), 914-920.
4. Vitale D., Bilancia M., **Papale** D (2019). Modelling random uncertainty of eddy covariance flux measurements. STOCHASTIC ENVIRONMENTAL RESEARCH AND RISK ASSESSMENT, vol. 33, p. 725-746, ISSN: 1436-3259, doi: 10.1007/s00477-019-01664-4
5. Jung M., Koirala S., Weber U., Ichii K., Gans F., Camps-Valls G., **Papale** D, Schwalm C., Tramontana G., Reichstein M. (2019). The FLUXCOM ensemble of global land-atmosphere energy fluxes. SCIENTIFIC DATA, vol. 6, p. 1-14, ISSN: 2052-4463, doi: 10.1038/s41597-019-0076-8

Recent Projects (up to 5)

1. **2018-2022 VERIFY - Verifying greenhouse gas emissions to support countries' emission reporting to the UN Climate Change Convention, H2020 GA n.776810**- The project develops a system to estimate greenhouse gas emissions (CO2, CH4 and N2O). to support countries' emission reporting to the UNFCCC. The emissions are estimated based on land, ocean and atmospheric observations. The project focuses on the three major greenhouse gases responsible for global warming: carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O).
2. **2019-2023 Paris Reinforce, Delivering On the Paris Agreement: A Demand-Driven, Integrated Assessment Modelling Approach, H2020 GA: No 820846**- the project aims to develop a novel, demand-driven, integrated assessment model-oriented framework for effectively supporting the design and analysis of climate policies in the European Union as well as in other major emitters and selected less emitting countries, in respect to the Paris Agreement and associated challenges.
3. **2017-2020 CHE CO2 Human Emissions, H2020 GA No.776186.** The project aims to bring together relevant expertise to develop the science and to scope out the necessary architecture for a European CO2 monitoring capacity.
4. **2016-2019 COP21 RIPPLES, Results and Implications for Pathways and Policies for Low Emissions European Societies H2020 GA No 730427 –** The project aims to analyse the transformations in the energy

systems, and in the wider economy, that are required in order to implement the Paris Agreement (NDCs), and investigate what steps are needed to attain deeper, more ambitious decarbonisation targets, as well as the socio-economic consequences that this transition will trigger.

5. **2019-2022 ENVRI-FAIR H2020 GA No 824068** the project connects the ESFRI Cluster of Environmental Research Infrastructures (ENVRI) and the European Open Science Cloud to improve the compliance with the data FAIR principles. Participating research infrastructures (RI) cover the subdomains Atmosphere, Marine, Solid Earth and Biodiversity / Ecosystems. The overarching goal is that all participating RIs is to build a set of FAIR data services which enhances the efficiency and productivity of researchers, supports innovation, enables data- and knowledge-based decisions and connects the ENVRI Cluster to the EOSC. CMCC represents the ICOS Ecosystem Thematic Centre and is in charge of co-coordinate a WorkPackage dedicated to the implementation of FAIR principles on the Ecosystem and Biodiversity RIs

Major Hardware/ Infrastructure available

The CMCC Supercomputing Center (SCC) is situated inside the Campus “Ecotekne” in Lecce and it provides dedicated technological infrastructure and computational capabilities. The main facility of the Supercomputing Center is the Athena system based on 482 IBM iDataPlex compute nodes and with 160TFlops capability. Each node is a dual Intel E5-2670 processor working at 2,6 GHz. The computing architecture comprises an IBM dx360M4 server cluster, an InfiniBand interconnection network and a storage subsystem. The huge amount of data produced by CMCC researchers is managed by a DLM system based on a hierarchical storage management solution. During 2019, CMCC updated its supercomputing facilities by deploying new high performance computing, storage and network systems. The new supercomputer is equipped with 12.528 cores Intel Xeon Gold 6154 at 3GHz and is able to reach a computing capability of 1.200 TFlops. The new storage systems provides about 10PB of total capacity across different storage tiers.

CMCC hosts the database, laboratories and tools of the ICOS Ecosystem Thematic Centre and developed the competences needed to run a complex and heterogeneous network of stations providing data in Near Real time

4.1.15 CNRS

15 - Centre National de la Recherche Scientifique

About the Organisation

The National Centre for Scientific Research (in French: Centre National de la Recherche Scientifique) is a public organisation for scientific and technological research and is under the authority of the French Ministry for Research. CNRS is the largest fundamental research organisation in Europe. Measured by the amount of human and material resources it commits to a great range of disciplines, CNRS is the hub of research activity in France. It is also an important breeding ground for scientific and technological innovation. The main tasks of CNRS are: the development of knowledge, its transfer to and its application in enterprises and all domains contributing to the progress of society, the dissemination of information and of scientific and technical culture to the public, and especially towards young people, the participation in early training and life-long training, training by research, and quality in the research management. CNRS was the first French research organisation to sign the European “Charter of Researcher” in 2005.
The scientists involved in the project are part of the "Laboratoire d'Aérologie”, which is a Joint Research Unit of University between CNRS and the University of Toulouse. The laboratory has a long and well-known experience in the field of atmospheric sciences. The scientific objectives of LA concern the observation, the understanding and the numerical modelling of dynamic, physical and chemical processes controlling the evolution of the atmosphere. The "Laboratoire d'Aérologie” is also part of the Midi-Pyrénées Observatory (OMP), which is a group of CNRS laboratories dedicated to research on the Universe, the Earth, and the environment. The laboratory also participates in the Observatoire Midi-Pyrénées Data Service (SEDOO): this service data centre is dedicated to

environmental data management and data distribution for international and multidisciplinary projects.

Role in this Project

Partner in WP1 : Prior information

Partner in WP8: Dissemination

Expertise with Relevance to this Project and Role

The CNRS group has worked for a long time on issues related to the emissions of atmospheric compounds, more particularly on the emissions from anthropogenic and biomass burning sources. They have developed several inventories of greenhouse gases and air pollutants, for example the MACCity inventory which has been used and is still used in many European and international projects. Claire Granier has been the co-chair of the GEIA (Global Emissions Initiative) from 2004 to 2011, and she is now the director of the databases and a member of the executive board of GEIA. Claire Granier is currently the coordinator of the CAMS-81 (Global and Regional Emissions) European project, in which emissions of greenhouse gases and air pollutants from anthropogenic and natural sources are developed and analyzed. The CNRS group is also coordinating and developing the ECCAD (Emissions of atmospheric Compounds & Compilation of Ancillary Data) database, which is the official database of the GEIA project, and is also distributing the CAMS-81 emissions. Claire Granier is currently the co-chair of the new AMIGO (Analysis of eMIssions usinG Observations) project of the International Global Atmospheric Chemistry Project (IGAC).

Key Persons

Dr. Claire Granier (female) is a « Directeur de Recherche" at the Laboratoire d'Aérologie/CNRS in Toulouse. She has a large experience in projects dealing with surface emissions and the distribution of pollutants. She is the coordinator of the Copernicus Atmosphere Monitoring Project CAMS-81 (surface emissions) since September 2017. She is the scientific director of the ECCAD (Emissions of Atmospheric Compounds & Compilation of Ancillary Data) database and she is the director of databases of the GEIA (Global Emissions InitiAtive) international project. She is the co-chair of the AMIGO (Analysis of eMissions using Observations) project of the international IGAC (International Global Atmospheric Chemistry) project.

Dr. Nellie Elguindi (female) is a research associate at the Laboratoire d'Aérologie/CNRS in Toulouse. After her PhD in regional climate studies at the University of Delaware (USA), she has worked on studies linking climate change, air pollution and data analysis in different laboratories in France, Italy and in the USA. She has worked on the precursor of the CAMS/Copernicus project, i.e. MACC (Monitoring Atmospheric Composition and Climate), and she is now responsible for the development of the global anthropogenic emissions for CAMS.

Relevant Publications (up to 5)

1. Granier, C., T. Doumbia, L. Granier, K. Sindelarova, G. Frost, I. Bouarar, C. Liousse, S. Darras and J. Stavrakou, Anthropogenic surface emissions in Asia, peer-reviewed book "Air Pollution in Eastern Asia: An Integrated Perspective", Springer - ISSI Series, DOI 10.1007/978-3-319-59489-7, 2017.
2. Granier, C., T. Doumbia, L. Granier, K. Sindelarova, C. Liousse, S. Darras, I. Bouarar, H. denier van der Gon, G.J. Frost, G. Janssens-Maenhout, M. Crippa, J. Stavrakou, R. Hoesly, and S. Smith, Trends in anthropogenic emissions from 1960 to 2015, Proceedings of the 2017 International Emissions Inventory Conference - Applying Science and Streamlining Processes to Improve Inventories, Baltimore, MD, August 2017.
3. Sun, W., M. Shao, C. Granier, Y. Liu, C. Ye, J. Zheng, Long-term Trends of Anthropogenic SO2, NOx, CO and NMVOCs Emissions in China, Earth Future, 6, 1112-1133, doi:10.1029/2018EF000822, 2018.
4. Darras, S., C. Granier, C. Liousse, D. Boulanger, N. Elguindi, and Hung Le Vu, Emissions of Atmospheric Compounds & Compilation of Ancillary Data, IGAC News issue 61, 2018. Publication on the ECCAD database, available at: https://eccad.aeris-data.fr
5. Granier, C., S. Darras, H. Denier van der Gon, J. Doubalova, N. Elguindi, B. Galle, M. Gauss, M. Guevara, J.-P. Jalkanen, J. Kuenen, C. Liousse, B. Quack, D. Simpson, K. Sindelarova The Copernicus Atmosphere Monitoring Service global and regional emissions, doi:10.24380/d0bn-kx16, 2019

Recent Projects (up to 5)

- CAMS-81; Title: Global and Regional Emissions (CAMS project, 2017-2020)

- GEMS, MACC, MACC-II and MACC-III, CAMS precursor projects
- PAPILA; Title: Prediction of Air Pollution in Latin America and the Caribbean (H2020 project, 2018-2021)
- AQ-WATCH; Title: Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health (H2020 project, 2020-2022)
- PANDA; Title: PArtnership with chiNa on space Data (FP7 project, 2014-2016)

Major Hardware/ Infrastructure available

ECCAD (Emissions of atmospheric Compounds & Compilation of Ancillary Data, eccad.aeris-data.fr

4.1.16 DWD

16 – Deutscher Wetterdienst

About the Organisation

The Deutscher Wetterdienst (DWD) is responsible for meeting the meteorological requirements arising from all areas of economy and society in Germany. Our duties result from the legal mandate to inform and undertake research. As part of its Climate & Environment activities, the Deutscher Wetterdienst carries out a comprehensive diagnosis of the climate system. In times of global climate change, climate monitoring, the documentation of its results and the prediction of the impacts of climate change have become essential. The findings of this work form the basis for political and business decision-making, contribute to improving preparedness for disasters related to weather and climate and help to provide sustainable support for disaster control.

Role in this Project

The role of DWD in this project is to research how a high-quality national greenhouse gas emission verification can be established in the operational environment of a weather service to serve the national information needs of the society and governmental agencies.

Also, together with MPI-BGC Jena, DWD provides the link to the German national research initiative on emission verification (ITMS).

Expertise with Relevance to this Project and Role

DWD is drawing on its expertise concerning the high resolution regional modelling and data assimilation capacity with ICON-ART, where ART stands for Aerosols and Reactive Trace gases, and denotes the extension of DWDs numerical weather prediction model ICON (ICOsahedral Nonhydrostatic model).

Key Persons

Dr. Kaiser-Weiss (female) – PhD ETH Zurich (2000), worked with emission modelling (Empa, Switzerland), data assimilation (Uni Reading), later as Project Officer for the Group for High Resolution Sea Surface Temperature (GHRSST) before managing the Climate Data Store (CDC) of DWD and contributing to the DWD regional reanalysis (in connection with the CORE-CLIMAX and UERRA FP7 projects). Since March 2019 she is building up a new department for national greenhouse gas emission verification at DWD.

Dr. Mamtimin (female) – PhD Uni Mainz (2000), worked with satellite based monitoring concept for land use (Uni Mainz), land-atmosphere interaction in terms of trace gas emissions (Biogeochemistry Department at MPI for Chemistry in Mainz), satellite-based observation and 3-D dispersion model simulation of emissions, (Satellite Remote Sensing Group at MPI for Chemistry in Mainz). She has been working at the new department for national greenhouse gas emission verification (DWD) since March 2019.

Relevant Publications (up to 5)

1. Kaiser-Weiss A K, Borsche M, Niermann D, Kaspar F, Lussana C, Isotta F, Van den Besselaar E, Schrier G, and Undén P: Added value of regional reanalyses for climatological applications. Environ. Res. Commun. 1, 071004, 2019.
2. Mamtimin B, Meixner F X, Behrendt T, Badawy M, and Wagner T: The contribution of soil biogenic NO and HONO emissions from a managed hyperarid ecosystem to the regional NOx emissions during growing

season, Atmospheric Chemistry and Physics 16, 10175-10194, 2016.

3. Mamtimin, B, Behrendt, T, Badawy, M , Wagner, T, Qi, Y, Wu, Z, and Meixner, F X: Tropospheric vertical column densities of NO2 over managed dryland ecosystems (Xinjiang, China): MAX-DOAS measurements vs. 3-D dispersion model simulations

   based on laboratory-derived NO emission from soil samples, Atmos. Chem. Phys., 15, 867–82, doi:10.5194/acp-15-867-2015, 2015.
4. Kaiser-Weiss A K, Kaspar F, Heene V, Borsche M, Tan D G H, Poli P, Obregon A and Gregow H: Comparison of regional and global reanalysis near-surface winds with station observations over Germany, Adv. Sci. Res.12187–98, 2015.
5. Mamtimin, B and Meixner, F X: Air pollution and meteorological processes in the growing dryland city of Urumqi (Xinjiang, China), Science of Total Environment, 409, 1277–1290, 2011.

Recent Projects (up to 5)

- FP7 UERRA (Uncertainties in Ensembles of Regional ReAnalyses) - Grant Agreement 607193 EU FP7 SPACE 2013-1- Objective was to produce ensembles of European regional meteorological reanalyses of Essential Climate Variables for several decades and to estimate the associated uncertainties in the data sets.
- FP7 CORE-CLIMAX (COordinating Earth observation data validation for RE-analysis for CLIMAte ServiceS) - Grant agreement no. 313085 – Objective was to substantiate how Copernicus observations and products can contribute to climate change analyses, by establishing the extent to which Copernicus observations complement existing Climate Data Records
- DFG (German National Research Foundation) project DEQNO– Grant agreement no. MA 4798/1_1 - Desert Encroachment in Central Asia - Quantification of soil biogenic Nitric Oxide emissions by ground- and satellite-based methodologies – Objective was to use in-situ and satellite measurements together with Lagrangian dispersion modelling to determine concentrations and fluxes.

Major Hardware/ Infrastructure available

A redundantly installed HPC system (consisting of Cray XC40 and Megware Miriquid Linux Cluster with joint batch system and global filesystems) is used for the computationally intensive numerical modeling as well as for data processing.

Also, the DWD computing resource allocation at ECMWF can be partly used.

4.1.17 ENPC

17 - École nationale des Ponts et Chaussées

About the Organisation

École nationale des Ponts et Chaussées (also named École des Ponts ParisTech and often abbreviated ENPC), created in 1747, is a higher education establishment that trains engineers and PhD students to a high level of scientific, technical and general expertise. The Research Directorate draws up and manages the implementation of the School's scientific and research policy within 12 laboratories, most of them run in partnership with other academic or economic actors. Four socio-economic challenges have been identified as strategic for research at ENPC: (1) City and mobility systems, (2) Management of risks, resources, and milieus, (3) Industry of the future and (4) Economy, practices, and society.

The Centre for Education and Research in Atmospheric Environment (CEREA), was created in 2003 as a joint laboratory between ENPC and EDF R&D. Its research activities are focussed on numerical modelling of air pollution. These activities range from academic research (aerosol modelling, data assimilation and inverse modelling, atmospheric boundary layer) to impact assessment studies (assessment of environmental impact of transport and thermal or nuclear energy production), using modelling/prediction of reactive pollutant transport at regional scale or even modelling at local scale (urban air pollution, indoor air quality).

Role in this Project

WP2 and WP5: CEREA will provide guidance to the methodological developments of the hybrid ensemble-variational system based on the IFS and will assist with the initial testing of the prototype by performing idealized experiments.
WP3, specifically Task 3.3: CEREA will co-develop with LSCE a plume inversion system based on an advanced scheme (non-local evaluation metrics and potentially machine/deep learning) and on a full 4D meteo-transport model to deal with complex cases. A simulation database will be generated from this full 4D meteo-transport model in order to train the inversion method. Tests of different theoretical options with case studies in OSSE mode and using real XCO2 and NO2 (or XCH4) images from OCO-3 and/or TROPOMI will be carried out. Comparisons with lighter methods from Task 3.2 will be made. CEREA will also help with the error statistics diagnostics in Task 3.4.

Expertise with Relevance to this Project and Role
CEREA is a laboratory of École des Ponts ParisTech and EDF R&D dedicated to numerical modelling of atmospheric chemistry from near-field to continental scale.

- Marc Bocquet is an expert in data assimilation methods, inverse problem methodologies and more recently machine learning. He has a focus on methodology with applications to atmospheric chemistry. In particular, he has worked extensively on ensemble-based techniques which will be used in the future IFS hybrid ensemble-variational system. He is the author of about 25 papers on inverse modelling of pollutant emissions, and about 25 papers on methodological data assimilation (ensemble and variational and combination of both techniques).
- Alban Farchi is an expert in data assimilation methods and atmospheric chemistry data assimilation. He has also worked on optimal transport metrics and has developed codes to use it on atmospheric pollutant plumes.

Key Persons
Marc Bocquet (Male) - PhD in fundamental physics (Ecole Polytechnique, 2000), and HdR in physics (Uni. Pierre et Marie Curie, 2007). Marc Bocquet is professor at École des Ponts ParisTech and deputy director of CEREA. He works in the field of data assimilation and inverse problems for the geosciences, as well as in environmental statistics. He develops new mathematical methods to better estimate the state of the atmosphere and the ocean, and their constituents, using large sets of observations and complex models. He is associate editor for the QJRMS, Frontiers, and Foundation of Data Science. He is a Fellow of the European Centre for Medium-Range Weather Forecasts (ECMWF). He is the author of about 103 publications in peer-reviewed journals, one book, and editor of another book. His h-index is 32.
Alban Farchi (Male) - PhD in physics and environmental sciences (Uni. Paris-Est, 2019). Alban Farchi is a recently hired permanent researcher at CEREA. He works in the field of data assimilation for the geosciences with application to atmospheric chemistry. Currently, he is a visitor of the ECMWF where he works on machine learning applications to numerical weather prediction. He is the author of about 5 publications.

Relevant Publications (up to 5)

1. T. Lauvaux, L. I. Díaz-Isaac, M. Bocquet, and N. Bousserez. *Diagnosing spatial error structures in CO_2 mole fractions and XCO_2 column mole fractions from atmospheric transport*. Atmos. Chem. Phys., 19:12007--12024, 2019.
2. Y. Liu, J.-M. Haussaire, M. Bocquet, Y. Roustan, O. Saunier, and A. Mathieu. *Uncertainty quantification of pollutant source retrieval: comparison of Bayesian methods with application to the Chernobyl and Fukushima-Daiichi accidental releases of radionuclides*. Q. J. R. Meteorol. Soc., 143:2886--2901, 2017.
3. Farchi, M. Bocquet, Y. Roustan, A. Mathieu, and A. Quérel. *Using the Wasserstein distance to compare fields of pollutants: application to the radionuclide atmospheric dispersion of the Fukushima-Daiichi accident*. Tellus B, 68:31682, 2016
4. M.Asch, M.Bocquet, and M. Nodet. Data assimilation: Methods, Algorithms and Applications. Society for Industrial and Applied Mathematics, 2016.
5. M. R. Koohkan and M. Bocquet. *Accounting for representativeness errors in the inversion of atmospheric constituent emissions: Application to the retrieval of regional carbon monoxide fluxes.* Tellus B, 64:19047, 2012.

Recent Projects (up to 5)

- Argonaut, 2020-2023, grant of the French Funding Agency (ANR): the project's objective is focused on estimating the emission of pollutants and green house gases using satellite measurements. It is led by Gaëlle Dufour from LISA. LSCE and CEREA are partners of the project.
- Redda, 2016-2020, grant #250711 of the Norwegian Research Council: the project *Reduced subspace in big*

data treatment: A new paradigm for efficient geophysical Data Assimilation, lead by Alberto Carrassi and Laurent Bertino from NERSC, Bergen, Norway. The project is focused on particle filtering and the AUS (assimilation in the unstable subspace) concept, as well as its application to sea-ice modelling. The last part of the project (Redda-ML) dedicated to the interaction between data assimilation and machine learning.

- Project (2018-2021) with the Institute for Radioprotection and Nuclear Safety (IRSN), with the goal to improve inverse modelling of atmospheric radionuclides plumes with a better characterization of the uncertainty of the best estimate.

Major Hardware/ Infrastructure available

Cluster of computational nodes (about 5 for the data assimilation team) – 4 Desktop stations equipped with GPU.

4.1.18 FMI

18 – Finnish Meteorological Insititute

About the Organisation

Finnish Meteorological Institute (FMI, www.fmi.fi/en) is a research and service agency that functions under the Ministry of Transport and Communications. It has the mandate of producing weather, atmosphere, climate and marine related services required by Finnish society. FMI provides reliable information on the state of the atmosphere, and its characteristics and phenomena, with the aim of promoting safety and serving various needs of the public, industry and commerce, as well as contributing to scientific ends. FMI makes observations of the physical state of the atmosphere, its chemical composition, and electromagnetic phenomena. FMI also develops and applies numerical models in order to analyse and forecast various atmospheric physical and chemical processes. FMI hosts the Arctic Space Centre in Sodankylä, which is also Copernicus Collaborative Ground segment. FMI employs about 680 people, about 350 of which are involved in research. Personnel from two Units of FMI will participate in this project: Earth Observation Research of Space and Earth Observation Centre and Climate System Research Unit of Climate Change Programme.

The Earth Observation Research Unit of FMI's Space and Earth Observation Centre (FMI-SPACE, www.space.fmi.fi) has expertise in atmospheric research including satellite instrument and algorithm development, satellite remote sensing of greenhouse gases and atmospheric composition, atmospheric modelling, UV research, development of mathematical methods and software applications. FMI-SPACE operates the Arctic Space Centre in Sodankylä, Northern Finland. The Arctic Space Centre maintains and develops versatile ground-based measurements in support of satellite calibration and validation activities, and to study the interlinkages in the Arctic atmosphere-ecosystem environment. In addition, the Arctic Space Centre hosts infrastructure for satellite data reception, storage, and distribution.

Climate Research Program (FMI-CLIMATE) does basic and applied research on the different components of the climate system. The Carbon Cycle Group of the Climate System Research Unit studies greenhouse gas exchange between atmosphere and land ecosystems in global and regional scales by using soil-vegetation-climate models, as well as atmospheric inversion modelling. The group has a strong background in using GHG observations in model development. During recent years, the Carbon Cycle Group has been part of Nordic and Finnish Centers of Excellence in Research related to atmospheric composition, climate change, cryosphere and ecosystem science.

Role in this Project

FMI will participate in WPs 3 and 4 and tentatively in 7. Our role in each WP is described below.

WP 3: FMI will participate in analysing anthropogenic CO2 emission signatures based on co-located satellite CO2 and NO2, plume modelling, development of plume inversion systems and uncertainty quantification. FMI will lead Task 3.2.

WP 4: FMI will participate in the development of the modelling systems in connection to representation of the uncertainties in inversions.

WP 7: FMI will participate in building the connection to UNFCCC reporting in country-scale and engagement with stakeholders, in particular with the authorities in Finland.

Expertise with Relevance to this Project and Role

Three research groups in two research units from FMI will contribute to the project. The Carbon Cycle Group of the Climate System Research Unit studies greenhouse gas exchange between atmosphere and land ecosystems in global and regional scales by using soil-vegetation-climate models, as well as develops atmospheric inversion modelling. The group has active connections to FMI experimental research groups and strong background in using GHG observations in model development. The Greenhouse Gases and Satellite Methods Group of the Earth Observation Research Unit studies remote sensing measurements of greenhouse gases, with an emphasis on the utilization of satellite retrievals in analysing the sources and sinks of greenhouse gases. The group has developed so called anomaly method for analysing CO2 emission regions from OCO-2 observations. The group participates in maintaining the Sodankylä TCCON (hosted by the FMI) and develops GHG retrieval methods that consider special circumstances in the Northern latitudes, e.g., the polar vortex. The Atmospheric Remote Sensing Group of Earth Observation Research Unit has strong expertise in studying air quality and emissions using satellite remote sensing. The Earth Observation Research unit participates in the Academy of Finland's Centre of Excellence in Inverse Modelling, and has active connections with the CO2M, GOSAT, TanSat, OCO-2/3, and Sentinel 5P TROPOMI team members.

Key Persons

Johanna Tamminen (Female) – Dr. Johanna Tamminen is a Research Professor in Atmospheric Remote Sensing research and Head of the Earth Observation Research Unit at the Finnish Meteorological Institute (FMI). She has strong expertise in atmospheric remote sensing, atmospheric composition research, mathematical inverse methods and uncertainty quantification. Recently she has been involved in projects enhancing the use of satellite observations for wider societal benefits and decision-making. She is the co-Principle Investigator of OMI (Ozone Monitoring Instrument) on-board NASA's EOS-Aura satellite, chair of the EUMETSAT's AC-SAF Steering Group and the vice-director of the Finnish Academy funded Centre of Excellence in Inverse modelling and Imaging. She has experience of ESA missions as a member of ESA Quality Working Group (QWG) for Sentinel 5 Precursor mission (2018->) and Mission Advisory Group (MAG) for Anthropogenic CO_2 Monitoring Mission (2018-2019) and QWG member of GOMOS (2002-2016). She has participated in several ESA projects as FMI team leader, and WP leader. She is presently leading the FMI's Earth Observation Research unit of about 30 persons, located in both Helsinki and Sodankylä. She has published over 90 peer-reviewed articles (H-index 26 web-of-science).

Hannakaisa Lindqvist (Female) – Dr. Hannakaisa Lindqvist is Head of the Greenhouse Gases and Satellite Methods Group at FMI, and Adjunct Professor in meteorology at the University of Helsinki. She has 12 years of experience on atmospheric radiation research, specialized in aerosol light scattering and space-based greenhouse gas retrievals. Her group runs the greenhouse gas satellite validation activities at the FMI Arctic Space Centre in Sodankylä, and develops novel retrieval approaches and data-driven methods for greenhouse gas source-sink estimation. She is a member of the ESA Anthropogenic CO2M Mission Advisory Group. She is a member of the OCO-2/OCO-3 Science Team, and a co-PI or WP Lead in several ESA-funded projects. She worked as a postdoc at Colorado State University, in the Nasa OCO-2 algorithm and validation teams for 1.5 years. She has published 24 peer-reviewed articles (H-index 16).

Janne Hakkarainen (Male) – Dr. Janne Hakkarainen is a Senior Research Scientist at Greenhouse Gases and Satellite Methods Group. He is a forerunner in combining greenhouse gas satellite data with other space-based data sources. His main scientific achievement is the development of a novel approach to derive the CO_2 anomalies from satellite observations, designed to highlight the anthropogenic CO_2 emission signatures (Hakkarainen et al., 2016). He is the PI in ESA EO Science for Society project DACES (Detection of Anthropogenic CO_2 Emission Sources). He is a member of the OCO-2/OCO-3 Science Team and in 2018 he received NASA Group Achievement Award for exceptional achievement in processing and using data from the Orbiting Carbon Observatory-2 mission to produce unprecedented insight into the global carbon cycle. He has published 26 peer-reviewed articles (H-index 15).

Tuula Aalto (Female) - Dr. Tuula Aalto is a leading the Carbon Cycle research group at Finnish Meteorological Institute. She has over 25 years of experience on modeling of carbon cycle gases, interpretation of the GHG atmospheric mixing ratio and ecosystem flux observations, and utilising EO data in GHG studies. She has participated as PI in FMI contribution in eight EU projects (most recently H2020-CRESCENDO and H2020-VERIFY). She is an author or co-author in >250 publications, of which >70 in peer-reviewed scientific journals (h-index 21;Web of Science, 25; Google Scholar), and has supervised six Ph.D. theses.

Aki Tsuruta (Female) - Dr. Aki Tsuruta is a postdoctoral researcher in the Carbon Cycle research group at Finnish Meteorological Institute. She finished her PhD in 2018 and has experience in atmospheric methane modeling and

utilising in situ and EO data in GHG studies. She has 7 publications.

Relevant Publications (up to 5)

1. Hakkarainen, J., I. Ialongo, and J. Tamminen (2016), Direct space-based observations of anthropogenic CO2 emission areas from OCO-2, Geophys. Res. Lett., 43, doi:10.1002/2016GL070885.
2. A. Eldering, P. O. Wennberg, D. Crisp, D. S. Schimel, M. R. Gunson, A. Chatterjee, J. Liu, F. M. Schwandner, Y. Sun, C. W. O'Dell, C. Frankenberg, T. Taylor, B. Fisher, G. B. Osterman, D. Wunch, J. Hakkarainen, J.Tamminen, B. Weir: The Orbiting Carbon Observatory-2 early science investigations of regional carbon dioxide fluxes, Science, Vol. 358, Issue 6360, doi:10.1126/science.aam5745, 2017.
3. Lindqvist, H., O'Dell, C. W., Basu, S., Boesch, H., Chevallier, F., Deutscher, N., Feng, L., Fisher, B., Hase, F., Inoue, M., Kivi, R., Morino, I., Palmer, P. I., Parker, R., Schneider, M., Sussmann, R., and Yoshida, Y.: Does GOSAT capture the true seasonal cycle of carbon dioxide? Atmos. Chem. Phys., 15, 13023–13040, 2015.
4. A. Tsuruta, T. Aalto, L. Backman, M. C. Krol, W. Peters, S. Lienert, F. Joos, P. A. Miller W. Zhang, T. Laurila, J. Hatakka, A. Leskinen, K. Lehtinen, O. Peltola, T. Vesala, J. Levula, E. Dlugokencky, M. Heimann, L. Kozlova, M. Aurela, A. Lohila, M. Kauhaniemi, and A. J. Gomez-Pelaez. Methane budget estimates in Finland from the CarbonTracker Europe-CH4 data assimilation system, Tellus B: Chemical and Physical Meteorology 71, 1445379, 2019, DOI: 10.1080/16000889.2018.1565030, https://doi.org/10.1080/16000889.2018.1565030
5. Tsuruta, A., Aalto, T., Backman, L., Hakkarainen, J., van der Laan-Luijkx, I. T., Krol, M. C., Spahni, R., Houweling, S., Laine, M., Dlugokencky, E., Gomez-Pelaez, A. J., van der Schoot, M., Langenfelds, R., Ellul, R., Arduini, J., Apadula, F., Gerbig, C., Feist, D. G., Kivi, R., Yoshida, Y., and Peters, W.: Global methane emission estimates for 2000-2012 from CarbonTracker Europe-CH4 v1.0, Geosci. Model Dev., 10, 1261-1289, doi:10.5194/gmd-10-1261-2017, 2017

Recent Projects (up to 5)

- H2020 project *AQ-WATCH Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health* (GA870301): AQ-WATCH will develop a supply chain leading to the generation of seven downstream products and services that are innovative for improving air quality forecasts and attribution. These prototypes will be based on existing space and in situ observations of air quality and tailored to the identified needs of international users.
- *H2020 project E-SHAPE (GA820852):* e-shape is a unique initiative that brings together decades of public investment in Earth Observation and in cloud capabilities into services for the decision-makers, the citizens, the industry and the researchers. The FMI team is involved in two pilots that address societal challenges, foster entrepreneurship and support sustainable development.
- *ESA EO Science for Society project DACES: Detection of Anthropogenic CO_2 Emission Sources:* Project studies both global and local XCO_2 anomalies from the Nasa OCO-2 satellite and analyses these with S5P TROPOMI NO_2 in order to distinguish anthropogenic signatures.
- *H2020 project VERIFY: Observation-based system for monitoring and verification of greenhouse gases:* FMI team is involved in the bottom-up and top-down modelling work related to monitoring and verification of methane budgets.
- *H2020 project CRESCENDO: Coordinated Research in Earth Systems and Climate: Experiments, Knowledge, Dissemination and Outreach:* Crescendo improves the process-realism and simulation-quality of European ESMs in order to increase the reliability of future Earth system projections. FMI team is involved in development and evaluation of wetland methane emission models

Major Hardware/ Infrastructure available

The models rum at FMI have recently been set up in a new supercomputing system targeted at a wide range of workloads. Simulations will be performed in FMI state-of-art supercomputing facility (Puhti, launched in 2019) at Finnish Center of Scientific Computing. It has a total of 682 CPU nodes**,** with a theoretical peak performance of 1,8 petaflops.

The model data used by the research team members will be stored after the project in CSC's Allas object storage. The CSC's IDA-Research data storage (https://openscience.fi/ida) will be used as a long-term storage of selected model results of long-term value for the life-time of the resource. All the data used in peer-reviewed scientific

publications will be stored and made available via Zenodo (Zenodo.eu)

4.1.19 FORTH

19 - Foundation for Research and Technology Hellas

About the Organisation

FORTH (http://www.forth.gr) was established in 1983 and is one of the largest research centres in Greece with well-organized facilities, highly qualified personnel and a reputation as a top-level research foundation worldwide. FORTH is consisting of seven research Institutes, four of which are located in Heraklion and it is a Centre of Excellence involved in advanced research in biology, applied physics, computer science, applied mathematics, chemistry and chemical engineering, and the humanities. More than half of FORTH's budget comes from competitive research grants from international organisations, such as the agencies of the EU and other public and private organisations. FORTH participates in R&D projects funded from organizations such as the European Union (EU), the General Secretariat of Research and Technology of Greece (GSRT), the National Statistical Service of Greece (NSSG), the Regional Development Agency of Crete, NATO and others. Additionally, several contracts from agencies such as the Statistical Office of Greece, the Agency of Small and Medium Enterprises, the Municipality of Heraklion, the Ministry of Health and others are secured. The Institute of Applied and Computational Mathematics of FORTH concentrates on the application of techniques from several disciplines including physics, geography, applied informatics, remote sensing, statistics, operations research, city planning and economics. Among others the Institute leads the development of tools, method, techniques and software to assist regional, urban and environmental planning. The Remote Sensing Lab (http://rslab.gr) operates within the Institute of Applied and Computational Mathematics of FORTH. The Lab focuses on Earth Observation (EO) and its area of research is the study of environmental phenomena and problems in both urban and natural environments. Understanding Earth system processes, as well as their interaction effects of the manmade activities is an urgent and important research direction. The activities of the Lab focus on urban climate and urban planning, with emphasis on climate change mitigation and adaptation activities. Areas of research include the estimation of energy, water and carbon exchanges between the surface and the atmosphere and the identification of several city typologies and climatically meaningful urban zoning systems based on satellite observations. Emphasis is also given to the synergy of remote sensing, numerical models and GIS in urban environmental studies.

Role in this Project

FORTH is involved in WP2 – "Global Modelling and data assimilation" and WP6 – "Observations" to support the benchmarking activities of the CO_2 emission modelling approaches related to urban areas using *in-situ* data from observation networks. Specifically, FORTH will contribute to the bottom-up emission model development activities of WP2 by providing expert knowledge and methodologies of how to involve urban *in-situ* Eddy Covariance observations of CO_2 flux and atmospheric turbulence characteristics to the regional scale model development and evaluation. In the framework of WP6, FORTH will provide standardized datasets of urban *in-situ* meteorological observations and local scale Eddy Covariance CO_2 flux measurements for selected cities. Moreover, FORTH will support the process of defining the requirements for *in-situ* observation networks regarding urban areas in partnership with ICOS, which will provide the coordination support and the hub of the *in-situ* observations.

Expertise with Relevance to this Project and Role

FORTH has expertise on analytical satellite and airborne remote sensing data interpretation, processing and modelling for extracting urban-related products and indicators that are relevant to the land-atmosphere interactions in various scales. This includes development and application of machine learning and support vector machine algorithms for detailed urban land cover characterization, photogrammetric applications for urban 3D structure extraction, surface atmospheric roughness indicators parameterization, urban surface temperature extraction from downscaling satellite observations and Urban Heat Island time-series interpretation.

Furthermore, FORTH conducts research related to urban boundary layer meteorology and micrometeorology, operating a dense meteorological sensor network in the city of Heraklion, Greece since 2016, an urban Eddy Covariance and Net Radiation station in the center of Heraklion since 2017, as well as a second urban Eddy Covariance and Net Radiation station in a residential zone of the city of Heraklion since 2020. Research related to urban micrometeorology includes the development of methodologies for monitoring energy and gas exchange form urban areas using satellite and ***in-situ*** observations and approaches for the discrimination of anthropogenic heat and CO_2 fluxes from biogenic (or natural) fluxes in urban areas. Finally, FORTH is the corresponding Host Institute (cHI) of the European Research Council Synergy (ERC-SyG) project *urbisphere*, which focuses on coupling dynamic cities and climate. *Urbisphere* is a 6-years project that is expected to start in early 2020, integrating different computational and observational approaches to create a coupled, dynamic and unified assessment and modelling system, to better understand feedbacks between cities and climate change.

Key Persons

Nektarios Chrysoulakis (M) - Dr. Nektarios Chrysoulakis is a Director of Research at FORTH and Head of the Remote Sensing Lab (http://rslab.gr). He holds a BSc in Physics, a MSc in Environmental Physics and PhD in Remote Sensing from the University of Athens. He has been involved in R&D projects funded by the European Union, the European Space Agency and the Ministries of Environment, Development, Culture and Education. His main research interests include urban climate, urban energy balance, urban resilience, urban planning and metabolism, natural and technological hazards, surface temperature and albedo, environmental monitoring and change detection. Dr. Chrysoulakis is the corresponding Principal Investigator (cPI) of the European Research Council (ERC) Synergy project *urbisphere* (ERC-SyG) focusing on coupling dynamic cities and climate. He is the coordinator of the H2020-Space project CURE, focusing on Copernicus services exploitation in the domain of urban resilience. He has coordinated the projects URBANFLUXES (H2020), SEN4RUS (ERA.Net-RUS Plus), BRIDGE (FP7) GEOURBAN (FP7). He has also participated projects ECOPOTENTIAL (H2020), THINKNATURE (H2020), IGIC (LIFE) and FLIRE (LIFE). He has more than 250 publications in per-review journals and conference proceedings.

Stavros Stagakis (M) - Dr. Stavros Stagakis is currently a postdoctoral researcher at the Atmospheric Sciences group of the Department of Environmental Sciences in the University of Basel. He is the PI of the project diFUME: Urban carbon dioxide Flux Monitoring using Eddy Covariance and Earth Observation (https://mcr.unibas.ch/difume), funded by the Marie Skłodowska-Curie Individual Fellowships programme (H2020-MSCA-IF-2018). He holds a BSc in Biological Applications and Technology and PhD in Plant Ecophysiology and Remote Sensing. His expertise is on remote sensing applications in biosphere monitoring and modelling. He has participated in several national and international scientific projects related to monitoring natural, agricultural and urban environments, using multiple types of satellite, aerial and *in-situ* meteorological and plant physiological data. During the last five years, he has been working at FORTH, in the framework of the H2020 projects URBANFLUXES and THINKNATURE. His latest research is focused on urban environment and urban climate, working extensively with Eddy Covariance measurements of turbulent CO_2 fluxes and the combination of *in-situ* measurements with remote sensing imagery for spatially disaggregated modelling **and** monitoring of urban CO_2 emissions.

Zina Mitraka (F) -Dr. Zina Mitraka is currently a research fellow at FORTH with a PhD in Earth Observation for Urban Climate and a MSc on Environmental Engineering. She is an EO specialist with experience working on a wide range of topics mainly focusing on optical and thermal satellite remote sensing with particular interest on the urban environment and extensive experience on methods development. She has extensive experience in city land surface monitoring from space, including downscaling algorithms development for land surface temperature and urban energy fluxes. She participates in research and development projects funded by FP7, H2020, ESA and national funds, being **actively** involved in the research activities, as well as the project management.

Relevant Publications (up to 5)

1. Stagakis, S., Chrysoulakis, N., Spyridakis, N., Feigenwinter, C. and Vogt R., 2019. Eddy Covariance measurements and source partitioning of CO_2 emissions in an urban environment: Application for Heraklion, Greece. *Atmospheric Environment*, **201**, 278 - 292.
2. Chrysoulakis, N., Mitraka, Z. and Gorelick, N., 2019. Exploiting satellite observations for global surface albedo trends monitoring. *Theoretical and Applied Climatology*, **137**, 1171 -1179.
3. Chrysoulakis, N., Grimmond, S., Feigenwinter, C., Lindberg, F., Gastellu-Etchegorry, J.-P., Marconcini, M.,

Mitraka, Z., Stagakis, S., Crawford, B., Olofson, F., Landier, L., Morrison, W., Parlow, E., 2018. Urban energy exchanges monitoring from space. *Scientific Reports*, **8**, 11498.

4. Beloconi, A., Chrysoulakis, N., Lyapustin, A., Utzinger, J. and Vounatsou, P., 2018. Bayesian geostatistical modelling of PM10 and PM2.5 surface level concentrations in Europe using high-resolution satellite-derived products. *Environment International*, **121**, 57 - 70.
5. Parastatidis, D., Mitraka, Z., Chrysoulakis, N. and Abrams, M., 2017. Online Global Land Surface Temperature Estimation from Landsat. *Remote Sensing*, **9**, 1208.

Recent Projects (up to 5)

- ***urbisphere***: coupling dynamic cities and climate (ERC-SyG, GA Nr. 855005) - Understanding, forecasting, and projecting feedbacks between climate change and drivers of urban transformation.
- **CURE**: Copernicus for Urban Resilience in Europe (H2020-Space, GA Nr. 870337) - Developing urban resilience applications, based on Copernicus Core Service.
- **diFUME**: Urban carbon dioxide Flux Monitoring using Eddy Covariance and Earth Observation (H2020-MSCA, GA Nr. 836443) – Providing a robust methodology for mapping and monitoring the actual urban carbon dioxide flux at optimum spatial and temporal scales, meaningful for urban design decisions.
- **URBANFLUXES**: URBan ANthropogenic heat FLUX from Earth observation Satellites (H2020-Space, GA Nr. 637519) - Investigate the potential of Earth Observation to retrieve the anthropogenic heat flux, as a key component in the urban energy budget and develop a method to derive it from space.
- **BRIDGE**: SustainaBle uRban plannIng Decision support accountinG for urban mEtabolism (FP7, GA Nr. 211345) - Bridging the gap between bio-physical sciences and urban planners and to illustrate the advantages of accounting for environmental issues on a routine basis in design decisions, focusing on the interrelation between energy, carbon and pollutants flows and urban structure.

Major Hardware/ Infrastructure available

The Remote Sensing Lab of FORTH owns 10 Workstations, a Cluster and access to the computational facilities and Servers of the Institute of Applied and Computational Mathematics. The Lab owns EO and GIS dedicated software and has developed in-house developed Matlab, IDL and Python codes. Available databases include very high resolution EO data, as well as GIS data related to the Heraklion urban morphology (3D city model). The Lab also runs its own Wireless Network of meteorological stations (http://rslab.gr/downloads_urbanfluxes.html) deployed in the city of Heraklion, a micrometeorological tower located at the centre of the city (http://rslab.gr/heraklion_eddy.html) equipped with Eddy Covariance instrumentation (IGARSON, Campbell Scientific, Inc, Utah, USA) for turbulent fluxes measurements and radiation sensors (CNR1 Net Radiometer, Kipp & Zonen B.V., Delft, The Netherlands) for shortwave and longwave radiation fluxes measurements.

Furthermore, a second micrometeorological tower will be deployed in the beginning of 2020 in a residential zone of the city of Heraklion, also equipped with Eddy Covariance instrumentation (IGARSON, Campbell Scientific, Inc, Utah, USA) for turbulent fluxes measurements and radiation sensors (CNR4 Net Radiometer, Kipp & Zonen B.V., Delft, The Netherlands) for shortwave and longwave radiation fluxes measurements. In the frame of the ERC-SyG project *urbisphere* the following equipment will be purchased by FORTH within 2020: hyperspectral Cameras (HySpex Mjolnir VS-620, Spectral Range 400-2500 nm with 200 bands at 3nm and 300 bands at 5.1 nm); thermal cameras and radiometers (thermal-imager-pi400ell, 6 x CNR4); two heavy-lift unmanned aerial vehicle (Camflight FX8HL robot UAVs, Trimble Applanix APX-15 UAV incl. navigation system); spectroradiometers (ASD FieldSpec 4 Hi-Res, Spectral Range 350-2500 nm).

Finally, in the frame of the ERC-SyG project *urbisphere* the, FORTH will have access to the following instrumentation: ALC network (5 x Vaisala CL31); doppler wind LIDAR network (3 x Halo Photonics Stream Line); stable isotope analysers for emission measurements (Campbell TGA-300, 2 x construction of novel path-averaging TDLAS systems with telescopes and laser parts); scintillometers (Scintec BLS-900, Kipp & Zonen Optical Microwave Scintillometer system).

4.1.20 iLab

20 - The Inversion Lab Thomas Kaminski Consulting

About the Organisation

The Inversion Lab (iLab) is an SME that was founded in January 2015 by Dr. Thomas Kaminski. Mr. Michael Voßbeck is with the company from the beginning, and Dr. Wolfgang Knorr joined in January 2020.. The permanent staff is complemented by a number of senior researchers working as freelancers for individual projects. The company focuses on the development and application of advanced software systems for modelling, retrieval, data assimilation and inverse problems in general. In this area the team has gathered over 25 years of experience at various scientific institutions and companies. iLab operates the JRC-Twostream Inversion Package (JRC-TIP), an advanced retrieval system which they apply to generate biogeophysical land surface products with uncertainty ranges from site to global scales. iLab has developed the first Carbon Cycle Data Fossil Fuel Assimilation System (CCFFDAS) was a member of the teams of the GreenHouse Gas (GHG) and Sea Ice (SI) projects of ESA's Climate Change Initiative (CCI), lead the ESA SMOS+VEG study, which demonstrates the synergetic use of soil moisture and vegetation products in a carbon cycle data assimilation system (CCDAS).

Role in this Project

iLab will contribute to various WPs with expertise on data assimilaiton and specifically on CCFFDAS and results of CCFFDAS experiments and will construct and operate process models and observation operators

Expertise with Relevance to this Project and Role

>25 years of experience in terrestrial biospheric modelling and inverse modelling of the carbon cycle (see also CVs below and description of the organisation above)

Key Persons

Dr. Thomas Kaminski (Male)

Dr. Kaminski is a mathematical physicist and graduated in 1992 from Technical University Berlin. He then moved to the Max-Planck Institute for Meteorology (MPI-M) in Hamburg, where he performed a series of pioneering atmospheric transport inversion studies for carbon dioxide (e.g. Kaminski and Heimann, 2001) and developed and operated the first Carbon Cycle Data Assimilation system. After his PhD in 1998, he continued this research at the Max-Planck Institute for Biogeochemical Cycles (MPI-BGC) in Jena, before he joined Arthur Andersen Financial and Commodity Risk Consulting Practise in Frankfurt as a consultant. In 2000 he co-founded FastOpt, an SME with focus on data assimilation, inverse modelling and automatic differentiation, which he led until he founded The Inversion Lab in 2015. Dr. Kaminski successfully led the ESA study contracts SMOS+VEG, SMOS-NEE, CarbonFlux, and RS-CCDAS for assimilation of passive (SMOS) and active (ASCAT) microwave and optical EO products into two models of the terrestrial carbon cycle at point and global scales (Kaminski et al., 2012a, 2013). He led the first CCDAS-based mission benefit analysis, which assessed the constraint of an active sensor concept on surface fluxes of carbon dioxide. Dr. Kaminski also took a key role in the development and operation of the Earth Observation Land Data Assimilation System (ESA study contracts EO-LDAS and OPTIRAD). Furthermore Dr. Kaminski led the network design activities within the EU FP6 project IMECC, which assessed the added value of land and atmospheric in situ observations in constraining terrestrial carbon fluxes (Kaminski et al., 2012b). In 2002 he received the NASA group achievement award for the development of the adjoint of the finite-volume GCM. Dr. Kaminski is an author on over 60 publications in the peer-reviewed literature.

Dr. Wolfgang Knorr (Male)

Dr. Wolfgang Knorr studied Physics at the Universities of Hannover, Konstanz and Cambridge and obtained his PhD in Geoscience at the Max-Planck Institute for Meteorology in Hamburg. He has been a group leader jointly at the Max-Planck institutes for Meteorology and for Biogeochemistry in Jena, where he led the development of the JSBACH land surface model and its coupling to the ECHAM5 climate model. He was Deputy Leader of the UK climate and earth system science programme QUEST (2005-10), after which he took up the position of a senior scientist at the Department of Geography and Ecosystem Science, University of Lund. Since 2020 he is employed at iLab. Wolfgang Knorr has developed two ecosystem models (SDBM and BETHY), a model of soil carbon dynamics, and recently a global fire model, and co-initiated the Carbon Cycle Data Assimilation System (CCDAS). He has been the PI on the ESA grants “Remote Sensing Inputs for Regional to Global CO_2 Flux Modelling and the

SPECTRA Phase-A study validation of Earth System Models by Land Surface Experiments the EU projects CAMELS, RETRO, CYCLOPES and COMPETE, the UK project Carbon Cycle Modelling, Assimilation and Prediction, the German ECOBICE and DEKLIM projects. He served as a member of the SPECTRA Earth Explorer Core Mission science team, as Detached National Export at the European Commission Joint Research Centre in Ispra, Italy, and external reviewer for the EU FP-5 SIBERIA II Project and is a member of the International Space Science Institute team 'Towards a full integration of Earth Observation products and concepts in land surface models'. He served as editor of Geophysical Research Letters for 6 years. Dr. Knorr is author of more than 70 publications in the peer reviewed literature. His work has been cited ca. 10,000 times, and he has an h-index of 42.

Relevant Publications (up to 5)

1. Knorr, W., Arneth, A. and Jiang L. Demographic controls of global future fire risk. Nature Climate Change, doi: 10.1038/NCLIMATE2999, 2016
2. T. Kaminski, W. Knorr, G. Schürmann, M. Scholze, P. J. Rayner, S. Zaehle, S. Blessing, W. Dorigo, V. Gayler, R. Giering, N. Gobron, J. P. Grant, M. Heimann, A. Hooker-Strout, S. Houweling, T. Kato, J. Kattge, D. Kelley, S. Kemp, E. N. Koffi , C. Köstler, P.P. Mathieu, B. Pinty, C. H. Reick, C. Rödenbeck, R. Schnur, K. Scipal, C. Sebald, T. Stacke, A. Terwisscha van Scheltinga, M. Vossbeck, H. Widmann, and T. Ziehn. The BETHY/JSBACH Carbon Cycle Data Assimilation System: experiences and challenges. J. Geophys. Res., 118:doi:10.1002/jgrg.20118, 2013.
3. T. Kaminski, P. J. Rayner, M. Voßbeck, M. Scholze, and E. Koffi . Observing the continental-scale carbon balance: assessment of sampling complementarity and redundancy in a terrestrial assimilation system by means of quantitative network design. Atmospheric Chemistry and Physics, 12(16):7867-7879, 2012b.
4. T. Kaminski, W. Knorr, M. Scholze, N. Gobron, B. Pinty, R. Giering, and P.-P. Mathieu. Consistent assimilation of MERIS FAPAR and atmospheric CO2 into a terrestrial vegetation model and interactive mission benefit analysis. Biogeosciences, 9(8):3173-3184, 2012a.
5. T. Kaminski and M. Heimann. Inverse modeling of atmospheric carbon dioxide fluxes. Science, 294(5541):259, 2001

Recent Projects (up to 5)

- ESA STSE SMOS+VEG (lead): Synergetic use of soil moisture and vegetation optical depth products in a Carbon Cycle Data Assimilation System.
- ESA GHG CCI (member of Climate Reserach Group): Development of XCO2 and XCH4 CDRs and their application to transport inversion/CCDAS.
- H2020 CHE
- ESA CCFFDAS (lead): Development and operation of a Carbon Cycle Data Fossil Fuel Assimilation System (CCFFDAS) to assess design options of CO2M and of the CCFFDAS in terms of the observational constraint on fossil fuel emissions.

Major Hardware/ Infrastructure available

The Inversion Lab is equipped with

- a Linux compute cluster based on modern Intel multicore prcessors
- a data server

4.1.21 MOi

21 – Mercator Ocean

About the Organisation

Mercator Ocean International is a privately-owned non-profit company. Mercator Ocean describes, analyses and forecasts the state of the ocean in an operational condition.

Role in this Project

Our contribution will focus on the improvement of the air/sea CO2 fluxes that are delivered today as part of the Copernicus Marine service so that on the long run this can be provided to a future Copernicus CO2 monitoring service.

Expertise with Relevance to this Project and Role

Mercator Ocean produces global and regional assimilative ocean carbon (biogeochemical) simulations in the

CMEMS framework

Key Persons

Dr Coralie Perruche (Female) is an expert in marine biogeochemical modelling. She obtained her PhD in Brest (France) in 2009 on the influence of meso- and submeso-scale dynamics on phytoplankton competition and coexistence. Since 2010, she has worked at Mercator Ocean. She is responsible for the development and assessment of global operational configurations of marine plankton ecosystems and associated biogeochemistry (biological carbon pump, carbonate chemistry) in the Copernicus Marine Environment Monitoring Service framework. She also works on the coupling between ocean dynamical and biogeochemical processes.

Dr Elodie Gutknecht (Female) is an expert in marine biogeochemical modelling. She obtained her PhD in Toulouse (France) on coastal/offshore biogeochemical interactions in the Benguela Upwelling System in the South Atlantic Ocean. She joined Mercator Ocean in 2012 and works on the development and assessment of regional coupled physical/biogeochemical configurations in the Copernicus Marine Environment Monitoring Service. She is involved in around 20 international peer reviewed publications.

Dr Julien Lamouroux (Male) is an expert in assimilation of biogeochemical observations at global scale. He defended his PhD in Toulouse (France) on assimilation in an ocean forecast system in 2006 and began to work at Mercator Ocean in 2015. He designed the assimilation method of ocean colour data in the global operational system. His field of expertise spans the assimilation (Kalman filter), biogeochemical modelling in the global operational system and a thorough knowledge of available observation-based datasets.

Dr Alexandre Mignot (Male) is an expert in BGC-Argo in situ observations. He obtained a doctorate in oceanography (PhD) in 2012 on seasonal dynamics of phytoplankton in oligotrophic environments. He pursued his research activities at MIT and joined Mercator Ocean in 2018. He is involved in around 20 international peer reviewed publications. He works on the assessment of biogeochemical simulations with BGC-Argo floats and on the design of the use of BGC-Argo data in next generation assimilation system.

Relevant Publications (up to 5)

1. Lellouche et al. (2018). Recent updates on the Copernicus Marine Service global ocean monitoring and forecasting real-time 1/12° high resolution system, Ocean Sci., 14, 1093-1126, https://doi.org/10.5194/os-14-1093-2018.
2. Gutknecht, E., Reffray, G., Mignot, A., Dabrowski, T., and Sotillo, M. G.: Modelling the marine ecosystem of Iberia–Biscay–Ireland (IBI) European waters for CMEMS operational applications, Ocean Sci., 15, 1489–1516, https://doi.org/10.5194/os-15-1489-2019, 2019.
3. Perruche C., Solidoro C. and Cossarini G., 2018. Sea-to-air carbon flux. Copernicus Marine Service Ocean State Report, Issue 2, Journal of Operational Oceanography, Chap1, s29
4. Lefèvre, N., Veleda, D., Tyaquiçã, P., Perruche, C., Diverrès, D., & Ibánhez, J. S. P. (2019). Basin-Scale Estimate of the Sea-Air CO2 Flux During the 2010 Warm Event in the Tropical North Atlantic. Journal of Geophysical Research: Biogeosciences, 124(4), 973-986.

Recent Projects (up to 5)

- ERACLIM2 – GA Nr – Produce a global ocean carbon simulation over the 20th century forced by the coupled ocean/atmosphere CERA20C system
- Atlantos – GA Nr – Optimize and enhance the integrated Atlantic Ocean observing system
- EUROSEA – GA Nr – Improving and integrating European ocean observing and forecasting systems for sustainable use of the oceans

Major Hardware/ Infrastructure available

Mercator Ocean International has access to High Performance Computers at Meteo-France. Meteo France computing center is based on two BULL DLC computers, one for research and one for operational activities. Each computer contains around 1800 Broadwell nodes with 40 CPUs on each. Mercator Ocean International uses this computing center for both R&D and operational activities. R&D activities are also conducted on internal computing and ECMWF facilities.

4.1.22 MF

22 – Meteo-France

About the Organisation

Meteo-France is the French weather service, a governmental organization. Centre National de Recherches Météorologiques (CNRM) is a joint research unit (JRU n°3589) of CNRS and Meteo-France in which both entities put together staff and resources for the benefit of the laboratory. In the context of this project, only Meteo-France staff working at CNRM will be involved.

Role in this Project

Meteo-France will contribute to the data assimilation task of the project by implementing and operating an updated version of its LDAS-Monde (Albergel et al. 2017) tool based on the latest version of the ISBA land surface model (Delire et al. 2020). Satellite-derived vegetation products will be assimilated in order to better represent terrestrial biospheric carbon exchanges at a global scale. The impact of using high resolution land use description on biogenic fluxes will be assessed using the ECOCLIMAP-SG component of the SURFEX modelling platform.

Expertise with Relevance to this Project and Role

The CNRM research lab of Meteo-France develops and transfer to operations tools for NWP, emergency, climate services, and IPCC simulations. CNRM has a long-term experience in remote sensing, NWP, land surface modelling, and land data assimilation which are key components of the project.

Key Persons

Jean-Christophe Calvet (Male) – He received the M. Eng. degree in agronomy from AgroParisTech, France, in 1990, the M.Sc./Eng. degree in meteorology from the Ecole Nationale de la Météorologie, Toulouse, France, in 1990, the Ph.D. degree from the University of Toulouse in 1996, and the Habilitation in 2002. He joined Météo-France, Toulouse, in 1990 and CNRM in 1994, where he has been the Head of a land modelling and remote sensing section since 2003. His research interests include land–atmosphere exchange modelling and the use of remote sensing over land surfaces for meteorology. His most recent works concern the joint analysis of soil moisture and vegetation biomass, and the representation of carbon cycle in climate models. His work has been published in numerous leading scientific journals (> 170 peer-reviewed articles, h-index = 44, January 2020).

Relevant Publications (up to 5)

1. Albergel, C., S. Munier, D. J. Leroux, H. Dewaele, D. Fairbairn, A. L. Barbu, E. Gelati, W. Dorigo, S. Faroux, C. Meurey, P. Le Moigne, B. Decharme, J.-F. Mahfouf, J.-C. Calvet: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.
2. Bonan, B., Albergel, C., Zheng, Y., Barbu, A. L., Fairbairn, D., Munier, S., and Calvet, J.-C.: An ensemble square root filter for the joint assimilation of surface soil moisture and leaf area index within the Land Data Assimilation System LDAS-Monde: application over the Euro-Mediterranean region, Hydrol. Earth Syst. Sci., 24, 325–347, https://doi.org/10.5194/hess-24-325-2020, 2020.
3. Calvet, J.-C., Lafont, S., Cloppet, E., Souverain, F., Badeau, V., Le Bas, C.: Use of agricultural statistics to verify the interannual variability in land surface models: a case study over France with ISBA-A-gs, Geosci. Model Dev., 5, 37-54, https://doi.org/10.5194/gmd-5-37-2012, 2012.
4. Calvet, J.-C., J. Noilhan, J.-L. Roujean, P. Bessemoulin, M. Cabelguenne, A. Olioso and J.-P. Wigneron: An interactive vegetation SVAT model tested against data from six contrasting sites, Agricultural and Forest Meteorology, Vol. 92, pp. 73-95, https://doi.org/10.1016/S0168-1923(98)00091-4, 1998.
5. Delire, C., Séférian R., Decharme B., Alkama R., Joetzjer E., Morel X., Rocher M., Calvet J.-C., Gibelin A.-L., Tzanos D., Carrer D.: The global land carbon cycle simulated with ISBA: improvements over the last decade, Journal of Advances in Modeling Earth Systems, in press, 2020.

Recent Projects (up to 5)

- FP6 GEOLAND – FP7 GEOLAND2 – GA Nr 502871 **/** 218795 – support the implementation of the Copernicus land service,
- FP7 GHG-Europe – GA Nr 244122 – support the implementation of the GHG component of the Copernicus atmosphere service,
- FP7 IMAGINES – GA Nr 311766 – consolidate the vegetation products and user uptake of the Copernicus global land service,
- FP7 CORE-CLIMAX – GA Nr 313085 – support the implementation of the Copernicus climate change service through the production of guidelines to validate Essential Climate Variables (ECV),
- FP7 eartH2Observe – GA Nr 603608 – benchmark global models and data assimilation systems for monitoring terrestrial water resources.

Major Hardware/ Infrastructure available

CNRM uses the supercomputer of Meteo-France. CNRM has its own work station under the LUSTRE environment. The section of CNRM involved in DA4CAST has a dedicated working space of about 600 Tb on LUSTRE.

4.1.23 UDEIN

23 - University of Edinburgh

About the Organisation

The University of Edinburgh is a higher education institute (HEI). It is typically ranked within the top 20 universities in the world. Within in the UK is a founding member of the Russell group Universities that promote excellence in teaching and research. According to Nature magazine the University of Edinburgh includes the largest number of world leading and internationally excellent staff in Earth and Environmental Science in any UK HEI. The School of GeoSciences includes established groups studying many experimental and theoretical aspects of atmospheric composition, dynamics, and land-surface processes related to greenhouse gases and carbon cycling.

Role in this Project

UEDIN will contributed to task T2.4 in WP4, tasks 3.3 and 3.4 in WP3, as well WP5.

Expertise with Relevance to this Project and Role

The group of Paul Palmer has played an active role in the interpretation of CO2 and CH4 measurement from in situ and remotely sensed measurements for the past decade. They have developed analysis tools to infer geographical distributions of GHGs from observed atmospheric measurements. They also developed methods to help infer ffCO2 from observed variations of CO2.

Key Persons

Paul Palmer (Male) - is a Professor at the University of Edinburgh and the Science Director of the UK National Centre for Earth Observation. He is also a science team member of GOSAT/GOSAT-2 and OCO-2/OCO-3, with a decade of experience using these data to quantitative understand fluxes of CO2 and CH4. I am a WP lead within the VERIFY project and was the UK lead on the NERC GAUGE project that quantified UK GHG emissions. Since 2017, he has been a member of the Copernicus CO2 Emission Monitoring Task Force that has a charge of refining the requirements and to further define the elements of the Copernicus monitoring and verification system, working closely with corresponding ESA Mission Advisory Group, in time for the second global stocktake of the Paris Agreement.

Relevant Publications (up to 5)

1. Lunt, M. F., Palmer, P. I., Feng, L., Taylor, C. M., Boesch, H., and Parker, R. J.: An increase in methane emissions from tropical Africa between 2010 and 2016 inferred from satellite data, Atmos. Chem. Phys., 19, 14721–14740, https://doi.org/10.5194/acp-19-14721-2019, 2019.
2. Palmer, P. I., L. Feng, D. Baker, F. Chevallier, H. Boesch, P. Somkuti, "Net carbon emissions from African land biosphere dominate pan-tropical atmospheric CO2 signal", Nature Comm., https://doi.org/10.1038/s41467-019-11097-w, 2019.
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Recent Projects (up to 5)

- H2020 VERIFY: Quantify European anthropogenic GHG emissions
- NERC DARE: Quantify UK GHG emissions focused on urban scales. Follow-on to GAUGE.
- NERC GAUGE: Quantify UK emissions of CO2, CH4 and N2O. Establishing an interlinked ground-based network and modelling infrastructure
- NERC MOYA: Understanding large-scale changes in CH4 emissions
- Title – GA Nr – Objectives

Major Hardware/ Infrastructure available

NA.

4.1.24 FC.ID

24 - FCiências.ID - Associação para a Investigação e Desenvolvimento de Ciências (FC.ID)

About the Organisation

FCiências.ID – Associação para a Investigação e Desenvolvimento de Ciências (FC.ID), is a Non-Profit Private Association, endowed with legal personality. It was created in 2017 as an common initiative of Faculdade de Ciências da Universidade de Lisboa (Ciências) - a Higher Education institution - and 6 private companies, in order to support, potentiate and develop Research and Development (R&D) and innovation activities of its seven associates, while, simultaneously enhancing FCUL strategic partnerships with market and services companies, therefore creating a more challenging environment for research and innovation. FCiências.ID is the legal representative of 20 research centres, in several scientific fields. FCiências.ID responsibilities are related to the

administrative, financial and scientific management of the research centres R&D projects, and also to performing research work. Many of these R&D activities are developed together with international teams and are funded both at National and European levels.

At European level, FC.ID is involved in 1 FP7 project, 36 H2020 projects (including 3 ERC Grants and 8 coordination projects), 1 COST Action as Grant Holder and 52 international projects funded by different sources.

Faculdade de Ciências da Universidade de Lisboa (Ciências), based on a third party agreement, acts as a third party of FC.ID carrying out its own share of work, notwithstanding the full responsibility of FC.ID for the contracted scientific and technical work under specific R&D projects.

IDL, a FCUL based Associate Laboratory, is focused on quantitative Earth Science research, combining analytical studies, data analysis, observational activities and modelling, relevant for Atmospheric, Ocean and Solid Earth processes, and Renewable Energy applications. As an integrated Earth System Science institute, IDL supports cross-discipline interactions, most relevant for the understanding of Earth processes driven by the interaction of different Earth components. At FCUL, IDL leads the FCT Doctoral Program on Earth System Science (EARTHSYSTEMS), and is a partner of the nationwide FCT Doctoral Program on Sustainable Energy Systems (MIT-Portugal), offering its researchers excellent opportunities to attract young gifted students to new areas of research.IDL operates a modern High Performance Computing system, and several state of the art laboratories in different domains of Geosciences and Applications.

Role in this Project

In CoCO2 FC.ID will contribute to work package 2 focusing on the carbon cycle modelling and on land cover

Expertise with Relevance to this Project and Role

IDL, the research institute contributing to the project has a long-term experience in land-surface modelling and remote sensing applies to land cover and vegetation variability with are key components on the contribution to the project

Key Persons

Emanuel Dutra (Male) is a researcher at IDL/Ciências. Emanuel Dutra (1983) expertise encompasses land surface processes, large-scale hydrology and drought monitoring and forecasting. After his PhD in 2011 he joined ECMWF for 6 years where he worked in several EU FP7 projects related with water resources and seasonal forecasting. He (co)-authored more than 60 publications in international peer-reviewed journals.

Relevant Publications (up to 5)

1. Albergel, C.; **Dutra, E**.; Munier, S.; Calvet, J.-C.; Munoz-Sabater, J.; Rosnay, P. de; Balsamo, G. ERA-5 and ERA-Interim driven ISBA land surface model simulations: which one performs better? *Hydrol. Earth Syst. Sci.* 2018, *22*, 3515–3532.
2. Johannsen, F.; Ermida, S.; Martins, J.P.A.; Trigo, I.F.; Nogueira, M.; **Dutra, E**. Cold Bias of ERA5 Summertime Daily Maximum Land Surface Temperature over Iberian Peninsula. *Remote Sensing* 2019, *11*, 2570.
3. Boussetta, S., Balsamo, G., **Dutra, E**., Beljaars, A., & Albergel, C. (2015). Assimilation of surface albedo and vegetation states from satellite observations and their impact on numerical weather prediction. Remote Sensing of Environment, 163, 111–126. doi: 10.1016/j.rse.2015.03.009.
4. Agustí-Panareda, A., Massart, S., Chevallier, F., Balsamo, G., Boussetta, S., **Dutra, E**., & Beljaars, A. (2016). A biogenic CO2 flux adjustment scheme for the mitigation of large-scale biases in global atmospheric CO2 analyses and forecasts. *Atmospheric Chemistry and Physics*, *16*, 10399–10418. doi: 10.5194/acp-16-10399-2016

Recent Projects (up to 5)

- ERA-CLIM2: EU FP7 607029
- EUPORIAS: EU FP7 308291
- FUME: EU FP7 243888

Major Hardware/ Infrastructure available

Linux based high performance computing system with 800 cores and 400TB of data storage

4.1.25 CyI

25 - The Cyprus Institute

About the Organisation

The Cyprus Institute (www.cyi.ac.cy) is a non-profit research and educational institution with scientific and technological focus. It consists of 4 research Centres that address challenging problems both at the regional and international levels. The novelty of the Institute derives from its structure that consists of issue-oriented, rather than discipline oriented research centres, in an interdisciplinary environment. The Government of Cyprus supports The Cyprus Institute, viewing its establishment as important to its overall policy of transforming Cyprus into a regional centre for research and education.

The Climate and Atmosphere Research Centre (CARE-C) is the fourth research centre of CyI. Established with the support of the European Commission and the Cyprus Government at the level of 45 million euros for the period 2019-2026, CARE-C currently holds 75 research staff (of 10 different nationalities) and aims to become a regional knowledge hub for Air Pollution and Climate Change research, aiming at sustainable solutions, addressing societal challenges of Cyprus and the Eastern Mediterranean and the Middle East region.

Role in this Project

Contribution in Work Package 1.

Contribution in Work Package 5.

Contribution in Work Package 7.

Expertise with Relevance to this Project and Role

- Responsible for the Monitoring/Reporting/Verification of the National Emission Inventory of Cyprus for Air Pollutants and Greenhouse Gases (on behalf of Cyprus Ministry of Environment) for compliance with EU directives and international agreement
- (ESA funded) Modelling of Emissions, Trends and Air quality, using Satellite measurements over the Eastern Mediterranean and the Middle East
- Development of a regional atmospheric monitoring network of GHG (on-line/off-line in-situ and remote sensing (TCCON)) in the framework of H2020 EMME-CARE project
- Middle East / North Africa regional Headquarter of international research networks relevant to the project (e.g. FUTURE EARTH, CORDEX, UN-SDSN)

Key Persons

Name (Gender) – brief CV

Jean SCIARE (JS; male) CV available at: https://www.cyi.ac.cy/images/rescvpdf/Jean_Sciare-CyI_CV.pdf. JS holds a tenured Professorship in Atmospheric Sciences at the Cyprus Institute since 2015 and is director of CARE-C. He has more than 20 years of experience in atmospheric chemistry, focusing on the various impacts of air pollutants (climate, air quality, health, global security). He has been leading a large number of French research projects (IPEV, ANR, ADEME, CNRS, CEA, PRIMEQUAL) and participated in many EU FP5, FP6, FP7, and H2020 projects (ELCID, BIOGEST, OOMPH, LAB-Claire, MEGAPOLI, BACCHUS, ACTRIS, ACTRIS2, ACTRIS PPP, ACTRIS IMP, EMME-CARE to name a few), performing field campaigns in contrasted environments (North/South Pole, Amazonian forest, megacities in Africa, Asia, and Europe, oceanographic cruises, aircraft). He is (co-)author of c.a. 130 international refereed publications in atmospheric chemistry and physics. He received his habilitation in 2009 and has supervised >15 Ph-D students and post-docs. (H index=42; Scopus; citation ~4,500).

Professor Johannes Lelieveld (JL, male) has become the director of the Atmospheric Chemistry Division at the Max Planck Institute for Chemistry (Mainz, Germany) in 2000. Since January 2008 he is a Professor at the Cyprus Institute and leads the Environmental Predictions Department of the CARE-C since beginning of 2020. He is (co)author of more than 300 peer reviewed publications, associated editor of several journals, a member of international committees, has been coordinator of many national and international projects and has supervised

50 PhD dissertations. His research interests encompass atmospheric chemistry changes and their effects on global and regional climate. According to ResearchID, his publications, including papers in high impact factor journals such as Science and Nature, have been cited a total number of >15,000 times at an average of 47.6 citations per article and has an h index of 62. Dr. Lelieveld has a wealth of experience in atmospheric modelling, satellite information, statistical processing and impact estimations on health and nature.

Dr. Jonilda Kushta (JK, female) has a B.Sc. in Physics, M.Sc. in Environmental Physics / Meteorology and PhD in Meteorology / Atmospheric Modeling from the University of Athens, Greece. Currently she is an Associate Research Scientist at CARE-C working on integrated atmospheric modelling of air pollution over EMME, emissions, atmospheric composition and impacts on climate and human health, leading the "Modeling of Emissions, Trends and Air quality, Using Satellite Measurements" META-Sat project that deals with the timely update of emission inventories over the EMME region with the use of satellite data, providing both managerial and scientific expertise. Dr. Kushta has twenty-eight publications in peer review journals and book chapters, with the majority dedicated to atmospheric composition, emissions fluxes and trends and impact of natural and anthropogenic aerosols on chemistry, climate and human activities.

Relevant Publications (up to 5)

1. Vrekoussis, M., Richter, A., Hilboll, A., Burrows, J.P., Gerasopoulos, E., Lelieveld, J., Barrie, L, Zerefos, C, and Mihalopoulos, N: "Economic crisis detected from space: Air quality observations over Athens/Greece", GRL, DOI: 10.1002/grl.50118, 2013
2. Lelieveld, J., J.S. Evans, M. Fnais, D. Giannadaki and A. Pozzer (2015) The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature 525, 367-371.
3. Zanis, P., Hadjinicolaou, P., Pozzer, A., Tyrlis, E., Dafka, S., Mihalopoulos, N., and Lelieveld, J. (2014) Summertime free-tropospheric ozone pool over the eastern Mediterranean/Middle East, Atmos. Chem. Phys., 14, 115-132, doi:10.5194/acp-14-115-2014,
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Recent Projects (up to 5)

- **Coordinator of H2020 "EMME-CARE"** (2019-2026; Funding: 45 million euros from EC and Cyprus Government; GA #856612,)**. E**astern **M**editerranean and **M**iddle **E**ast **C**limate and **A**tmosphere **Re**search centre CyI contribution: Establishment of a new (regional) centre of excellence on Air Pollution and Climate Change.
- **Coordinator of Cyprus Research and Innovation Foundation "AQ-SERVE"** (2018-2021; Funding: 1.2 million euros; REF INTEGRATED/0916/0016). Air **Q**uality **SERV**ic**E**s for a Cleaner Air in Cyprus. CyI contribution: Coordination and development of national atmospheric research infrastructure and air quality products and services (miniaturized sensors, air quality forecast, impact assessment)
- **Coordinator of ESA "META-SAT" (2018-2020). M**odelling of **E**missions, **T**rends and **A**ir quality, using **SAT**ellite measurements. CyI contribution: Coordination and Satellite based Air Quality data over the EMME for better mitigation and adaptation, funded by the Republic of Cyprus and the European Satellite Agency (Plan for European Cooperating States PECS)
- **Partner of H2020 "ACTRIS IMP**" (2020-2023, GA# 871115). CyI contribution: Implementation of the EU Research Infrastructure ACTRIS (Aerosols, Clouds, and Trace Gases) and provision of innovative transnational access (CyI-USRL facility)
- **Coordinator of the ERC Advanced Grant project "C8** (**C**onsistent **C**omputation of the **C**hemistry-**C**loud **C**ontinuum and **C**limate **C**hange in **C**yprus). CyI contribution: Coordination, Air pollution, climate change and public health; Atmospheric signs of crisis observed from space; Air quality, climate change and impacts in the 21st century.

Major Hardware/ Infrastructure available

- **Cyprus Atmospheric Observatory** (EMEP, GAW, ACTRIS, TCCON): Regional (Middle East) supersite for long-term atmospheric measurements of Greenhouse Gases and Air Pollutants
- **Unmanned System Research Laboratory** (): UAV-based technology for atmospheric profiling of GHG and Air pollutants. Provision of Transnational Access in the framework of H2020-ACTRIS IMP

4.2 Third parties involved in the project (including use of third party resources)

4.2.1 01 - ECMWF

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
ECMWF will subcontract ICLEI – Local Governments for Sustainability. ICLEI (https://www.iclei.org/en/Home.html) is a global network of more than 1,750 local and regional governments committed to sustainable urban development and provides a framework for city and regional collaboration to influence sustainability policy and drive local action for low emission, nature-based, equitable, resilient and circular development. They will help to promote the CoCO2 and Copernicus CO2 activities in cities around the world and, as part of task 7.3 in WP7, organise specific consultation meetings to get a better idea of what cities are looking for. The value of the subcontract is 15,000 EUR.	
Does the participant envisage that part of its work is performed by linked third parties	N
n/a	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	Y
ECMWF will include the following third parties: - Centre technique de référence en matière de pollution atmosphérique et de changement climatique, CITEPA, France - Umweltbundesamt, EAA, Austria - Environmental Protection Agency, EPA, Ireland - Istituto Superiore per la Protezione e la Ricerca Ambientale, ISPRA, Italy - Rijksinstituut voor Volksgezondheid en Milieu, RIVM, Netherlands - Umwelt Bundesamt, UBA, Germany - Instytut Ochrony Środowiska - Państwowy Instytut Badawczy, IOS-PIB, Poland These will provide the links to inventory agencies and will participate in meetings and discussions, in-kind-free of charge.	
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N
n/a	

4.2.2 24 - FC.ID

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
n/a	
Does the participant envisage that part of its work is performed by linked third parties	Y
Faculdade de Ciências da Universidade de Lisboa (FCUL), based on a third party agreement, acts as a third party of FC.ID carrying out its own share of work, notwithstanding the full responsibility of FC.ID for the contracted scientific and technical work under specific R&D projects. Ciências foreseen task includes scientific supervision of the model developments	
Does the participant envisage the use of contributions in kind provided by third parties	N

(Articles 11 and 12 of the General Model Grant Agreement)	
n/a	
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N
n/a	

5 Ethics and Security

5.1 Ethics

No ethics issues where identified.

5.2 Security

Please indicate if your project will involve:

- activities or results raising security issues: NO
- 'EU-classified information' as background or results: NO

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7 List of Acronyms

AFOLU Agriculture, Forestry and Other Land Use - *One of the emission sectors as defined in the 2006 IPCC guidelines (e.g., https://ghginstitute.org/wp-content/uploads/2015/04/Understanding_Land_Use_in_the_UNFCCC.pdf).*

AMIGO Analysis of eMIssions usinG Observations - *Project of IGAC to organize the international scientific community around a synthesis of research using observations-based analysis techniques that aim to better quantify emissions*

BP British Petrol - Annual d*ata set estimating carbon emissions from energy consumption (https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/co2-emissions.html)*

C3S Copernicus Climate Change Service - *https://climate.copernicus.eu/*

CAMS Copernicus Atmosphere Monitoring Service - *https://atmosphere.copernicus.eu/*

CAMS-GLOB CAMS Global Emissions - *Global emission data set of chemical species and greenhouse gases produced by CAMS*

CAMS-REG CAMS Regional Emissions - *European emission data set of chemical species and greenhouse gases produced by CAMS*

CCDAS Carbon Cycle Data Assimilation System

CCFFDAS Carbon Cycle and Fossil Fuel Data Assimilation System

CEMS Copernicus Emergency Management Service - *https://emergency.copernicus.eu/*

CEOS Committee on Earth Observation Satellites - *http://ceos.org/*

CG Conjugate Gradient method - *An algorithm for the numerical solution of particular systems of linear equations, namely those whose matrix is symmetric and positive-definite.*

CHE CO2 Human Emissions project - *https://www.che-project.eu/*

CIF Community Inversion Framework - *A modular system, developed in the VERIFY project, for estimating GHG fluxes. The framework enables the use of different atmospheric transport models to provide systematic uncertainty from modelled transport, and the random uncertainty component for a given ATM.*

CLMS Copernicus Land Monitoring Service - *https://land.copernicus.eu/*

CMEMS Copernicus Marine Environment Monitoring Service - *https://marine.copernicus.eu/*

CO2M CO2 Mission - *The current name for the foreseen Sentinel CO2 mission.*

CO2MVS CO2 Monitoring and Verification Support capacity

COP Conference of the Parties - *The supreme decision-making body of the UNFCCC.*

COS Carbonyl Sulfide

CTE Carbon Tracker Europe - *A system that calculates carbon dioxide uptake and release at the Earth's surface over time (https://www.carbontracker.eu/).*

DSS Decision Support System

EDGAR Emission Database for Global Atmospheric Research - *https://edgar.jrc.ec.europa.eu/*

EQC Evaluation and Quality Control

Eurocom Project to quantify CO2 ecosystem fluxes in Europe with their space and time variations over the last decades - *https://eurocom.icos-cp.eu/*

FFDAS Fossil Fuel data Assimilation System

FLUXCOM An initiative to upscale biosphere-atmosphere fluxes from FLUXNET sites to continental and global scales - *http://www.fluxcom.org/*

FPD Fitness for Purpose Document

FRSD Functional Requirements Specification Document

GAW Global Atmospheric Watch programme - *https://public.wmo.int/en/programmes/global-atmosphere-watch-programme*

GCOS Global Climate Observing System - *https://public.wmo.int/en/programmes/global-climate-observing-system*

GCP Global Carbon Project - *https://www.globalcarbonproject.org/*

GDP Gross Domestic Product

GEIA Global Emissions InitiAtive - *http://www.geiacenter.org/*

GEO Group on Earth Observations - *http://www.earthobservations.org/index.php*

GOSAT Greenhouse gases Observing Satellite - *http://www.gosat.nies.go.jp/en/*

GPP Gross Primary Production - Photosynthetic CO2 fixation by vegetation

GST Global Stocktake

HERMES High-Elective Resolution Modelling Emissions System

IASI Infrared Atmospheric Sounding Interferometer - *https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/MetopDesign/IASI/index.html*

IFS Integrated Forecasting System - The atmospheric model and data assimilation system at ECMWF (https://www.ecmwf.int/en/research/modelling-and-prediction)

IG3IS Integrated Global Greenhouse Gas Information System - *https://ig3is.wmo.int/en/welcome*

IGAC International Global Atmospheric Chemistry project - *https://igacproject.org/*

IPCC Intergovernmental Panel on Climate Change - *https://www.ipcc.ch/*

LAI Leaf Area Index - *Half the total area of green elements of the canopy per unit horizontal ground area. LAI quantifies the thickness of the vegetation cover.*

LDAS Land Data Assimilation System

LULUCF Land Use, Land Use Change and Forestry - *One of the emission sectors as defined in the 2006 IPCC guidelines (e.g., https://ghginstitute.org/wp-content/uploads/2015/04/Understanding_Land_Use_in_the_UNFCCC.pdf)*

META-Sat Modelling of Emissions, Trends and Air quality, Using Satellite Measurements project supported by ESA - *https://www.cyi.ac.cy/index.php/care-c/research-information/ongoing-projects/meta-sat-modeling-of-emissions-trends-and-air-quality-using-satellite-measurements.html*

MOPITT Measurement of Pollution in the Troposphere - *https://terra.nasa.gov/about/terra-instruments/mopitt*

NEE Net Ecosystem Exchange - *NPP minus the heterotrophic respiration*

NN Neural Network

NPP Net Primary Production - *GPP minus the autotrophic respiration*

NRT Near-Real-Time

NWP Numerical Weather Production

OCO Orbiting Carbon Observatory - *https://oco.jpl.nasa.gov/*

OOPS Object-Oriented Prediction System - *OOPS is an abstract control layer that can manipulate elements of the data assimilation system without needing to know their model-specific implementation details.*

OSSE Observing System Simulation Experiment

QG Quasi-Geostrophic

QND Quantitative Network Design

RECCAP2 REgional Carbon Cycle Assessment and Processes 2 - *http://cci.esa.int/reccap2*

SBSTA Subsidiary Body for Scientific and Technological Advice - *SBSTA is one of two permanent subsidiary bodies to the UNFCCC established by the COP. It supports the work of the COP through the provision of timely information and advice on scientific and technological matters as they relate to the Convention, its Kyoto Protocol and the Paris Agreement.*

SDBM3 Simple Diagnostic Biosphere Model

SIF Solar Induced Fluorescence - *SIF denotes reemitted light in the 650–850 nm range from the chlorophyll-a pigment, and this process is linked to initial steps in photosynthesis*.

SOCAT Surface Ocean CO_2 Atlas - *https://www.socat.info/*

TCCON Total Carbon Column Observing Network - *http://www.tccon.caltech.edu/*

Transcom Atmospheric Tracer Transport Model Intercomparison Project - *http://transcom.lsce.ipsl.fr/*

TROPOMI TROPOspheric Monitoring Instrument - *http://www.tropomi.eu/*

UAV Unmanned Aerial Vehicle

UNEP United Nations Environment Programme - *https://www.unenvironment.org/*

UNFCCC United Nations Framework Convention on Climate Change - *https://unfccc.int/*

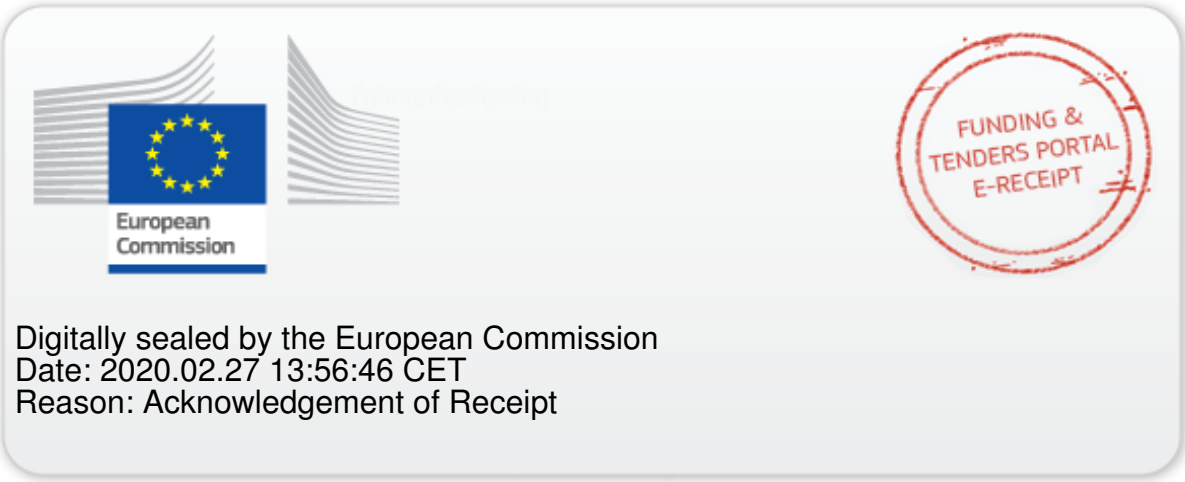
URD User Requirements Document

VERIFY Verifying greenhouse gas emissions project - *https://verify.lsce.ipsl.fr/*

VOD Vegetation Optical Depth - *derived from passive microwave observations, is sensitive to the water content in all aboveground vegetation and could serve as complementary information to optical observations for global vegetation monitoring*

VPRM Vegetation Photosynthesis and Respiration Model

WMO World Meteorological Organisation - *https://public.wmo.int/en*



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