Please check our wiki for help on navigating the form.

Horizon 2020

Call: H2020-LC-CLA-2018-2019-2020

(Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement)

SECOND STAGE

Topic: LC-CLA-08-2018

Type of action: RIA

Proposal number: SEP-210520751

Proposal acronym: FORCeS

Deadline Id: H2020-LC-CLA-2018-2

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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	LC-CLA-08-2018	Type of Action	RIA
Call Identifier	H2020-LC-CLA-2018-2019-2020	Deadline Id	H2020-LC-CLA-2018-2

Acronym	FORCeS
Proposal title	Constrained aerosol forcing for improved climate projections

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

Duration in months	*48*
Fixed keyword 1	Climatology and climate change
Fixed keyword 2	Atmospheric chemistry, atmospheric composition, air pollution
Fixed keyword 3	Meteorology, atmospheric physics and dynamics
Free keywords	*Radiative forcing, Earth system models, climate policy, air pollution policy, climate sensitivity, climate projections*

Abstract

The overall objective of FORCeS is to understand and reduce the long-standing uncertainty in anthropogenic aerosol radiative forcing, which is crucial in order to increase confidence in climate projections. These projections are highly relevant for decision makers, as they provide key information on emission pathways that will facilitate the targets of the Paris Agreement to be achieved. FORCeS will identify key processes governing aerosol radiative forcing, as well as climate feedbacks related to aerosols and clouds, and improve the knowledge about these processes by bringing together leading European scientists with trans-disciplinary expertise to i) exploit the wealth of in-situ and remote sensing data that have emerged during the recent decades; ii) perform dedicated laboratory and field experiments; iii) utilize a range of state-of-the-art computational models; and iv) apply novel theoretical methods including machine learning techniques. The process analysis within FORCeS will be conducted with the overall aim of improving a set of leading European climate models, which all provide essential information to climate assessments such as the IPCC report. The gap between knowledge on the process scale and model application on the climate scale is currently a main reason preventing the climate science community to move forward in terms of understanding the role of aerosols and aerosol-cloud interactions in the climate system. FORCeS will bridge this knowledge gap using systematically designed scale chains that involve methodologies for constraining processes on scales ranging from hours to decades, ultimately leading to the desired refinement of model-estimated aerosol forcing and climate sensitivity. FORCeS will reach out to decision makers and stakeholders and provide added-value information through e.g. workshops where climate science and climate policy experts meet to achieve maximum impact.

Remaining characters 71

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	STOCKHOLMS UNIVERSITET	SE	
2	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH	CH	
3	KARLSRUHER INSTITUT FUER TECHNOLOGIE	DE	
4	FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS	EL	
5	KONINKLIJK NEDERLANDS METEOROLOGISCH INSTITUUT-KNMI	NL	
6	UNIVERSITAET LEIPZIG	DE	
7	HELSINGIN YLIOPISTO	FI	
8	CONSIGLIO NAZIONALE DELLE RICERCHE	IT	
9	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	ES	
10	METEOROLOGISK INSTITUTT	NO	
11	ITA-SUOMEN YLIOPISTO	FI	
12	UNIVERSITY OF LEEDS	UK	
13	UNIVERSITETET I OSLO	NO	
14	FORSCHUNGSZENTRUM JULICH GMBH	DE	
15	THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD	UK	
16	ILMATIETEEN LAITOS	FI	
17	SVERIGES METEOROLOGISKA OCH HYDROLOGISKA INSTITUT	SE	
18	NATURVARDSVERKET	SE	
19	INSTITUT NATIONAL DE L ENVIRONNEMENT ET DES RISQUES INERIS	FR	
20	INTERNATIONALES INSTITUT FUER ANGEWANDTE SYSTEMANALYSE	AT	
21	THE UNIVERSITY OF EXETER	United Kingdom	

2 - Administrative data of participating organisations

PIC	***Legal name***
999885022	*STOCKHOLMS UNIVERSITET*

Short name: STOCKHOLMS UNIVERSITET

Address of the organisation

Street Universitetsvaegen 10

Town STOCKHOLM

Postcode 10691

Country Sweden

Webpage www.su.se

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: Department of Meteorology (MISU)

☐ not applicable

☐ Same as proposing organisation's address

Street: Universitetsvägen 10A

Town: Sockholm

Postcode: 106 91

Country: Sweden

Department 2

Department name: Department of Environmental Science and Analytical Chemistry

☐ not applicable

☐ Same as proposing organisation's address

Street: Svante Arrhenius väg 8,

Town: Stockholm

Postcode: 11418

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 Prof.

Sex ○ Male ● Female

First name **Ilona** Last name **Riipinen**

E-Mail **ilona.riipinen@aces.su.se**

Position in org. Head of Unit

Department Department of Environmental Science and Analytical Chemistry ☐ Same as organisation name

☐ Same as proposing organisation's address

Street Svante Arrhenius väg 8

Town Stockholm Post code 11418

Country Sweden

Website http://www.aces.su.se/

Phone +46 8 674 7284 Phone 2 +46735859251 Fax +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Anna-Karin	Tidén	anna-karin.tiden@su.se	+468161706
Tanja	Dallafior	tanja.dallafior@aces.su.se	+4686747642
Annica	Ekman	annica@misu.su.se	+468162397
Claudia	Mohr	claudia.mohr@aces.su.se	+4686747549
Ana	Cordeiro	ana.cordeiro@su.se	+468163655

PIC	***Legal name***
999979015	*EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH*

Short name: ETH Zürich

Address of the organisation

Street Raemistrasse 101

Town ZUERICH

Postcode 8092

Country Switzerland

Webpage www.ethz.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.....06/01/2009 - no

SME self-assessment ..... unknown

SME validation sme.....06/01/2009 - 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: Institute for Atmospheric and Climate Science

☐ not applicable

☐ Same as proposing organisation's address

Street: Raemistrasse 101

Town: ZUERICH

Postcode: 8092

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 Prof.

Sex ○ Male ◉ Female

First name **Ulrike** Last name **Lohmann**

E-Mail **ulrike.lohmann@env.ethz.ch**

Position in org. Professor

Department Institute for Atmospheric and Climate Science ☐ Same as organisation name

☒ Same as proposing organisation's address

Street Raemistrasse 101

Town ZUERICH Post code 8092

Country Switzerland

Website http://www.iac.ethz.ch/group/atmospheric-physics.html

Phone +41 44 633 0514 Phone 2 +41 44 633 2755 Fax +41 44 633 1058

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Regina E.	Notz	regina.notz@sl.ethz.ch	*+xxx xxxxxxxxx*
Agatha	Keller	grants@sl.ethz.ch	*+xxx xxxxxxxxx*

PIC	***Legal name***
990797674	*KARLSRUHER INSTITUT FUER TECHNOLOGIE*

Short name: KIT

Address of the organisation

Street KAISERSTRASSE 12

Town KARLSRUHE

Postcode 76131

Country Germany

Webpage www.kit.edu

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.....01/10/2009 - 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: Institute of Meteorology and Climate Research ☐ not applicable

☐ Same as proposing organisation's address

Street: KAISERSTRASSE 12

Town: KARLSRUHE

Postcode: 76131

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 Prof.

Sex ○ Male ◉ Female

First name **Corinna** Last name **Hoose**

E-Mail **corinna.hoose@kit.edu**

Position in org. Professor

Department Institute of Meteorology and Climate Research ☐ Same as organisation name

☒ Same as proposing organisation's address

Street KAISERSTRASSE 12

Town KARLSRUHE Post code 76131

Country Germany

Website www.imk-tro.kit.edu/14_1794.php

Phone +49 721 608-43587 Phone 2 +xxx xxxxxxxxx Fax +49 721 608-46101

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Kristine	Bentz	eu@for.kit.edu	*+49 721 608-45192*
Almut	Arneth	almut.arneth@kit.edu	*+49 8821 183131*
Jan	Cermak	jan.cermak@kit.edu	*+49 721 608-24510*

PIC	***Legal name***
999995893	*FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS*

Short name: FORTH

Address of the organisation

Street N PLASTIRA STR 100

Town HERAKLION

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 Chemical Engineering Sciences

☐ not applicable

☐ Same as proposing organisation's address

Street: Stadiou Str., PO Box 1414

Town: Platani, Patras

Postcode: 26504

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 Prof.

Sex (•) Male ( ) Female

First name **Spyros** Last name **Pandis**

E-Mail **spyros@chemeng.upatras.gr**

Position in org. Professor

Department Institute of Chemical Engineering Sciences

☐ Same as organisation name

☐ Same as proposing organisation's address

Street Stadiou Str., PO Box 1414

Town Platani, Patras Post code 26504

Country Greece

Website laqs.iceht.forth.gr

Phone +30 2610 969510 Phone 2 +30 2610 965300 Fax +30 2610 990987

PIC	***Legal name***
999518944	*KONINKLIJK NEDERLANDS METEOROLOGISCH INSTITUUT-KNMI*

Short name: KNMI

Address of the organisation

Street UTRECHTSEWEG 297

Town DE BILT

Postcode 3731 GA

Country Netherlands

Webpage www.knmi.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.....15/05/2008 - no

SME self-assessment ..... unknown

SME validation sme.....15/05/2008 - 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: R&D Weather and Climate Models ☐ not applicable

☐ Same as proposing organisation's address

Street: UTRECHTSEWEG 297

Town: DE BILT

Postcode: 3731 GA

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 **Twan** Last name **van Noije**

E-Mail **noije@knmi.nl**

Position in org. Senior scientist

Department R&D Weather and Climate Models ☐ Same as organisation name

☒ Same as proposing organisation's address

Street UTRECHTSEWEG 297

Town DE BILT Post code 3731 GA

Country Netherlands

Website http://www.knmi.nl/over-het-knmi/onze-mensen/twan-van-noije

Phone +31-30-2206562 Phone 2 +xxx xxxxxxxxx Fax +31-30-2210407

PIC	***Legal name***
999854564	*UNIVERSITAET LEIPZIG*

Short name: ULEI

Address of the organisation

Street RITTERSTRASSE 26

Town LEIPZIG

Postcode 04109

Country Germany

Webpage http://www.uni-leipzig.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 .....yes

Research organisation .....yes

Legal person .....yes

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

Enterprise Data

SME self-declared status.....31/12/2014 - no

SME self-assessment .....31/12/2014 - no

SME validation sme.....11/06/1999 - 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 for Meteorology ☐ not applicable

☐ Same as proposing organisation's address

Street: Stephanstr. 3

Town: Leipzig

Postcode: 04103

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 Prof.

Sex (•) Male ( ) Female

First name **Johannes** Last name **Quaas**

E-Mail **johannes.quaas@uni-leipzig.de**

Position in org. Professor

Department Institute for Meteorology ☐ Same as organisation name

☐ Same as proposing organisation's address

Street Stephanstr. 3

Town Leipzig Post code 04103

Country Germany

Website http://research.uni-leipzig.de/climate

Phone +49 341 97 32852 Phone 2 +xxx xxxxxxxxx Fax +49 341 97 32899

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Gerhard	Fuchs	eu@uni-leipzig.de	*+49 341 97 35012*

PIC	***Legal name***
999994535	*HELSINGIN YLIOPISTO*

Short name: UHEL

Address of the organisation

Street FABIANINKATU 33

Town HELSINGIN YLIOPISTO

Postcode 00014

Country Finland

Webpage www.helsinki.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 .....yes

Research organisation .....yes

Legal person .....yes

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

Enterprise Data

SME self-declared status.....09/02/2009 - yes

SME self-assessment ..... unknown

SME validation sme.....09/02/2009 - 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: Faculty of Science, Institute for Atmospheric and Earth System Re

☐ not applicable

☐ Same as proposing organisation's address

Street: Gustaf Hällströmin katu 2a

Town: University of Helsinki

Postcode: 00014

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 **Markku** Last name **Kulmala**

E-Mail **markku.kulmala@helsinki.fi**

Position in org. Professor, Head of Institute

Department Institute for Atmospheric and Earth System Research (INAR) ☐ Same as organisation name

☐ Same as proposing organisation's address

Street Gustaf Hällströmin katu 2 a

Town University of Helsinki Post code 00014

Country Finland

Website http://www.atm.helsinki.fi

Phone +358-40-5962311 Phone 2 +xxx xxxxxxxxx Fax +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Risto	Makkonen	risto.makkonen@helsinki.fi	+358504156796
Tuukka	Petäjä	tuukka.petaja@helsinki.fi	+358504155278
Mikael	Ehn	mikael.ehn@helsinki.fi	+358503199420
Ulrika	Backman	ulrika.backman@helsinki.fi	+358504487524

PIC	***Legal name***
999979500	*CONSIGLIO NAZIONALE DELLE RICERCHE*

Short name: CNR

Address of the organisation

Street	PIAZZALE ALDO MORO 7
Town	ROMA
Postcode	00185
Country	Italy
Webpage	www.cnr.it

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.....18/05/2016 - no

SME self-assessment ..... unknown

SME validation sme.....05/12/2008 - 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: Institute of Atmospheric Sciences and Climate (ISAC)

☐ not applicable

☐ Same as proposing organisation's address

Street: Via Gobetti 101

Town: Bologna

Postcode: 40129

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: **Cristina**

Last name: **Facchini**

E-Mail: **mc.facchini@isac.cnr.it**

Position in org.: Director of Research

Department: Institute of Atmospheric Sciences and Climate (ISAC)

☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Via Gobetti 101

Town: Bologna

Post code: 40129

Country: Italy

Website: http://www.isac.cnr.it/en/users/maria-cristina-facchini

Phone: +390516399563

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Stefano	Decesari	s.decesari@isac.cnr.it	+390516399560

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 **Carlos** Last name **Perez Garcia-Pando**

E-Mail **carlos.perez@bsc.es**

Position in org. Head of Atmospheric Composition Group, AXA Professor on Sand and Dust

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 www.bsc.es

Phone +34 93 413 77 22 Phone 2 +xxx xxxxxxxxx Fax +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Mar	Rodríguez	mar.rodriguez@bsc.es	*+34 93 413 75 66*

PIC	***Legal name***
999510893	*METEOROLOGISK INSTITUTT*

Short name: METEOROLOGISK INSTITUTT

Address of the organisation

Street HENRIK MOHNS PLASS 1

Town OSLO

Postcode 0313

Country Norway

Webpage www.met.no

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.....12/03/1995 - no

SME self-assessment ..... unknown

SME validation sme.....12/03/1995 - 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: Research and Development Division

☐ not applicable

☐ Same as proposing organisation's address

Street: HENRIK MOHNS PLASS 1

Town: OSLO

Postcode: 0313

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 **Michael** Last name **Schulz**

E-Mail **michaels@met.no**

Position in org. Co-leader Research Group

Department Research and Development Division ☐ Same as organisation name

☒ Same as proposing organisation's address

Street HENRIK MOHNS PLASS 1

Town OSLO Post code 0313

Country Norway

Website https://www.met.no/

Phone +4722963330 Phone 2 +xxx xxxxxxxxx Fax +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Per Helmer	Skaali	perhs@met.no	+4722963318

PIC	***Legal name***
991207984	*ITA-SUOMEN YLIOPISTO*

Short name: University of Eastern Finland (UEF)

Address of the organisation

Street YLIOPISTONRANTA 1 E

Town KUOPIO

Postcode 70211

Country Finland

Webpage www.uef.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 .....yes

Research organisation .....yes

Legal person .....yes

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

Enterprise Data

SME self-declared status.....09/09/2009 - no

SME self-assessment .....09/09/2009 - 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: Department of Applied Physics ☐ not applicable

☐ Same as proposing organisation's address

Street: YLIOPISTONRANTA 1 E

Town: KUOPIO

Postcode: 70211

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: **Annele**

Last name: **Virtanen**

E-Mail: **annele.virtanen@uef.fi**

Position in org.: Leader of the research group/laboratory

Department: Department of Applied Physics

☐ Same as organisation name

☒ Same as proposing organisation's address

Street: YLIOPISTONRANTA 1 E

Town: KUOPIO

Post code: 70211

Country: Finland

Website: http://www.uef.fi/en/web/aerosol

Phone: +358503164118

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

PIC	***Legal name***
999975426	*UNIVERSITY OF LEEDS*

Short name: UNIVLEEDS

Address of the organisation

Street WOODHOUSE LANE

Town LEEDS

Postcode LS2 9JT

Country United Kingdom

Webpage www.leeds.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 .....no

Legal person .....yes

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

Enterprise Data

SME self-declared status.....31/07/2015 - no

SME self-assessment .....31/07/2015 - 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: School of Earth and Environment

☐ not applicable

☐ Same as proposing organisation's address

Street: WOODHOUSE LANE

Town: LEEDS

Postcode: LS2 9JT

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: **Ken**

Last name: **Carslaw**

E-Mail: **k.s.carslaw@leeds.ac.uk**

Position in org.: Professor

Department: School of Earth and Environment

☐ Same as organisation name

☒ Same as proposing organisation's address

Street: WOODHOUSE LANE

Town: LEEDS

Post code: LS2 9JT

Country: United Kingdom

Website:

Phone: +44 113 3431597

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Siân	Evans	s.h.evans@leeds.ac.uk	+xxx xxxxxxxxx
Ben	Williams	eufunding@leeds.ac.uk	+xxx xxxxxxxxx

PIC	***Legal name***
999975814	*UNIVERSITETET I OSLO*

Short name: UNIVERSITY OF OSLO

Address of the organisation

Street PROBLEMVEIEN 5-7

Town OSLO

Postcode 0313

Country Norway

Webpage www.uio.no

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.....20/05/2008 - no

SME self-assessment ..... unknown

SME validation sme.....20/05/2008 - 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: Department of Geoscience ☐ not applicable

☐ Same as proposing organisation's address

Street: Sem Sælands vei 1

Town: Oslo

Postcode: 0371

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: **Trude**

Last name: **Storelvmo**

E-Mail: **trude.storelvmo@geo.uio.no**

Position in org.: Associate Professor

Department: Department of Geoscience

☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Sem Sælands vei 1

Town: Oslo

Post code: 0371

Country: Norway

Website: https://www.mn.uio.no/geo/english/

Phone: +47 22 85 66 56

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Ingse	Noremsaune	eu-team@mn.uio.no	+xxx xxxxxxxxx
Mette	Topnes	eu-office@admin.uio.no	+xxx xxxxxxxxx

PIC	***Legal name***
999980470	*FORSCHUNGSZENTRUM JULICH GMBH*

Short name: FZJ

Address of the organisation

Street	WILHELM JOHNEN STRASSE
Town	JULICH
Postcode	52428
Country	Germany
Webpage	www.fz-juelich.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.....05/12/1967 - no

SME self-assessment ..... unknown

SME validation sme.....05/12/1967 - 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 Energy and Climate Research, Troposphere (IEK-8)

☐ not applicable

☐ Same as proposing organisation's address

Street: WILHELM JOHNEN STRASSE

Town: JULICH

Postcode: 52428

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: Prof.

Sex: ○ Male ◉ Female

First name: **Astrid**

Last name: **Kiendler-Scharr**

E-Mail: **a.kiendler-scharr@fz-juelich.de**

Position in org.: Director IEK-8

Department: Institute of Energy and Climate Research, Troposphere (IEK-8)

☐ Same as organisation name

☒ Same as proposing organisation's address

Street: WILHELM JOHNEN STRASSE

Town: JULICH

Post code: 52428

Country: Germany

Website:

Phone: +49 2461 614185

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Petra	Insberg	p.insberg@fz-juelich.de	+xxx xxxxxxxxx

PIC	***Legal name***
999984350	*THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD*

Short name: UOXF

Address of the organisation

Street WELLINGTON SQUARE UNIVERSITY OFFICE

Town OXFORD

Postcode OX1 2JD

Country United Kingdom

Webpage www.ox.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.....22/12/1570 - 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: Department of Physics ☐ not applicable

☐ Same as proposing organisation's address

Street: Clarendon Laboratory, Parks Road

Town: Oxford

Postcode: OX1 3PU

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 **Philip** Last name **Stier**

E-Mail **philip.stier@physics.ox.ac.uk**

Position in org. Professor of Atmospheric Physics

Department Department of Physics, Climate Processes Group

☐ Same as organisation name

☐ Same as proposing organisation's address

Street Clarendon Laboratory, Parks Road

Town Oxford Post code OX1 3PU

Country United Kingdom

Website http://www2.physics.ox.ac.uk/research/climate-processes

Phone +44 1865 272887 Phone 2 +xxx xxxxxxxxx Fax +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Michele	Warren	grants@physics.ox.ac.uk	+441865272406
Gill	Wells	ecresearch@admin.ox.ac.uk	+441865289842
Joanna	Frost	joanna.frost@physics.ox.ac.uk	+xxx xxxxxxxxx

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: Atmospheric Research Centre of Eastern Finland

☐ not applicable

☐ Same as proposing organisation's address

Street: Yliopistonranta 1 F

Town: Kuopio

Postcode: 70211

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: **Sami**

Last name: **Romakkaniemi**

E-Mail: **sami.romakkaniemi@fmi.fi**

Position in org.: Head of Unit

Department: Atmospheric Research Centre of Eastern Finland

☐ Same as organisation name

☐ Same as proposing organisation's address

Street: Yliopistonranta 1 F

Town: Kuopio

Post code: 70211

Country: Finland

Website: www.ilmatieteenlaitos.fi

Phone: +358 50 4461061

Phone 2: +xxx xxxxxxxxx

Fax: +358 17 162301

PIC	***Legal name***
999507983	*SVERIGES METEOROLOGISKA OCH HYDROLOGISKA INSTITUT*

Short name: SMHI

Address of the organisation

Street Folkborgsvaegen 1

Town NORRKOEPING

Postcode 601 76

Country Sweden

Webpage www.smhi.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 .....no

Research organisation .....no

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: Rossby Centre, Research Department

☐ not applicable

☐ Same as proposing organisation's address

Street: Folkborgsvaegen 1

Town: NORRKOEPING

Postcode: 601 76

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 **Ralf** Last name **Doescher**

E-Mail **ralf.doescher@smhi.se**

Position in org. Head of global climate modelling

Department Rossby Centre, Research Department ☐ Same as organisation name

☒ Same as proposing organisation's address

Street Folkborgsvaegen 1

Town NORRKOEPING Post code 601 76

Country Sweden

Website www.smhi.se

Phone +46114958583 Phone 2 +46114958000 Fax +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Monica	Wallgren	monica.wallgren@smhi.se	+46114958104

PIC	***Legal name***
998884079	*NATURVARDSVERKET*

Short name: SEPA

Address of the organisation

Street	Valhallavagen 195
Town	STOCKHOLM
Postcode	106 48
Country	Sweden
Webpage	www.naturvardsverket.se

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 .....no

Research organisation .....no

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

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: Mr.

Sex: (•) Male ( ) Female

First name: **Erik**

Last name: **Adriansson**

E-Mail: **erik.adriansson@naturvardsverket.se**

Position in org.: Analyst

Department: NATURVARDSVERKET

☒ Same as organisation name

☒ Same as proposing organisation's address

Street: Valhallavagen 195

Town: STOCKHOLM

Post code: 106 48

Country: Sweden

Website: www.naturvardsverket.se

Phone: + 46 10 698 14 13

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

PIC	***Legal name***
999958063	*INSTITUT NATIONAL DE L ENVIRONNEMENT ET DES RISQUES INERIS*

Short name: INSTITUT NATIONAL DE L ENVIRONNEMENT ET DES RISQUES INERIS

Address of the organisation

Street Parc Technologique Alata

Town VERNEUIL EN HALATTE

Postcode 60550

Country France

Webpage www.ineris.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 .....no

Research organisation .....yes

Legal person .....yes

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

Enterprise Data

SME self-declared status.....19/08/2008 - no

SME self-assessment ..... unknown

SME validation sme.....19/08/2008 - 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: Environmental Modelling and Decision making

☐ not applicable

☒ Same as proposing organisation's address

Street: Parc Technologique Alata

Town: VERNEUIL EN HALATTE

Postcode: 60550

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 **Laurence** Last name **Rouil**

E-Mail **laurence.rouil@ineris.fr**

Position in org. Head of the Environmental Modelling and Decision making department

Department Environmental Modelling and Decision making ☐ Same as organisation name

☒ Same as proposing organisation's address

Street Parc Technologique Alata

Town VERNEUIL EN HALATTE Post code 60550

Country France

Website

Phone +33 344 55 61 13 Phone 2 +xxx xxxxxxxxx Fax +33 344 55 68 99

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Augustin	Colette	augustin.colette@ineris.fr	*+33 344 55 64 82*

PIC	***Legal name***
999452596	*INTERNATIONALES INSTITUT FUER ANGEWANDTE SYSTEMANALYSE*

Short name: IIASA

Address of the organisation

Street Schlossplatz 1

Town LAXENBURG

Postcode 2361

Country Austria

Webpage www.iiasa.ac.at

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..... 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: Air Quality and Greenhouse Gases (AIR)

☐ not applicable

☒ Same as proposing organisation's address

Street: Schlossplatz 1

Town: LAXENBURG

Postcode: 2361

Country: Austria

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: **Markus**

Last name: **Amann**

E-Mail: **amann@iiasa.ac.at**

Position in org.: Program Director

Department: Air Quality and Greenhouse Gases (AIR)

☐ Same as organisation name

☒ Same as proposing organisation's address

Street: Schlossplatz 1

Town: LAXENBURG

Post code: 2361

Country: Austria

Website:

Phone: +43(0)2236 807432

Phone 2: +xxx xxxxxxxxx

Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Zbigniew	Klimont	klimont@iiasa.ac.at	+43(0)2236 807547

PIC	***Legal name***
999864555	*THE UNIVERSITY OF EXETER*

Short name: UNEXE

Address of the organisation

Street THE QUEEN S DRIVE NORTHCOTE HOUSE

Town EXETER

Postcode EX4 4QJ

Country United Kingdom

Webpage www.ex.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.....06/08/2014 - 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: Air Quality and Greenhouse Gases (AIR)

☐ not applicable

☒ Same as proposing organisation's address

Street: THE QUEEN S DRIVE NORTHCOTE HOUSE

Town: EXETER

Postcode: EX4 4QJ

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 **Daniel** Last name **Partridge**

E-Mail **d.g.partridge@exeter.ac.uk**

Position in org. Lecturer in Mathematics

Department College of Engineering, Mathematics & Physical Sciences ☐ Same as organisation name

☐ Same as proposing organisation's address

Street Harrison Building, North Park Road

Town Exeter Post code EX4 4QF

Country United Kingdom

Website http://emps.exeter.ac.uk/mathematics/staff/dp410

Phone +44 1392724165 Phone 2 +xxx xxxxxxxxx Fax +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Sarah	Hill	euresearch@exeter.ac.uk	+44 1392 726206

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	Stockholms Universitet	SE	952800	200000	0	0	0	288200,00	0	1441000,00	100	1441000,00	1441000,00
2	Eidgenoessische Technische Hochschule	CH	452760	21000	0	0	0	118440,00	0	592200,00	100	592200,00	592125,00
3	Karlsruher Institut Fuer Technologie	DE	218792	18888	0	0	0	59420,00	0	297100,00	100	297100,00	297100,00
4	Foundation For Research And	EL	375060	98700	0	0	0	118440,00	0	592200,00	100	592200,00	592200,00
5	Koninklijk Nederlands Meteorologisc	NL	143115	14805	0	0	0	39480,00	0	197400,00	100	197400,00	197400,00
6	Universitaet Leipzig	DE	450072	23688	0	0	0	118440,00	0	592200,00	100	592200,00	592200,00
7	Helsingin Yliopisto	FI	304818	50337	0	0	0	88788,75	0	443943,75	100	443943,75	443943,75
8	Consiglio Nazionale Delle Ricerche	IT	138180	19740	0	0	0	39480,00	0	197400,00	100	197400,00	197400,00
9	Barcelona Supercomputing Center -	ES	142128	15792	0	0	0	39480,00	0	197400,00	100	197400,00	197400,00
10	Meteorologisk Institutt	NO	291850	24275	0	0	0	79031,25	0	395156,25	100	395156,25	395156,25

11	Ita-suomen Yliopisto	FI	271425	44415	0	0	0	78960,00	0	394800,00	100	394800,00	394800,00
12	University Of Leeds	UK	212420	24418	0	0	0	59209,50	0	296047,50	100	296047,50	296047,50
13	Universitetet I Oslo	NO	240649	75991	0	0	0	79160,00	0	395800,00	100	395800,00	395800,00
14	Forschungszentrum Julich Gmbh	DE	257629	54088	0	0	0	77929,25	0	389646,25	100	389646,25	389646,25
15	The Chancellor, Masters And	UK	411455	63975	0	0	0	118857,50	0	594287,50	100	594287,50	593662,50
16	Ilmatieteen Laitos	FI	222594	14805	0	0	0	59349,75	0	296748,75	100	296748,75	296748,25
17	Sveriges Meteorologiska Och	SE	428457	45303	0	0	0	118440,00	0	592200,00	100	592200,00	592200,00
18	Naturvardsverket	SE	2961	1974	0	0	0	1233,75	0	6168,75	100	6168,75	6168,75
19	Institut National De L Environnemen	FR	6415	3454	0	0	0	2467,25	0	12336,25	100	12336,25	12336,25
20	Internationales Institut Fuer Angewandte	AT	36274	3948	0	0	0	10055,50	0	50277,50	100	50277,50	50277,50
21	The University Of Exeter	UK	19740	0	0	0	0	4935,00	0	24675,00	100	24675,00	24675,00
	Total		5579594	819596	0	0	0	1599797,50	0	7998987,50		7998987,50	7998287,00

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

Declarations on stage-2 changes

The full stage-2 proposal must be consistent with the short outline proposal submitted to the stage-1- in particular with respect to the proposal characteristics addressing the concepts of excellence and impact.

Are there substantial differences compared to the stage-1 proposal?	○ Yes	◉ No

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.*

H2020 Research and Innovation Action

Constrained aerosol forcing for improved climate projections (FORCeS)

Coordinator: Stockholm University, Sweden

	Participant organization name	**Country**
1	Stockholm University (SU)	Sweden
2	Barcelona Supercomputing Centre (BSC)	Spain
3	ETH Zürich (ETHZ)	Switzerland
4	Finnish Meteorological Institute (FMI)	Finland
5	Forschungszentrum Jülich (FZJ)	Germany
6	Foundation for Research and Technology Hellas (FORTH)	Greece
7	Karlsruhe Institute for Technology (KIT)	Germany
8	National Research Council – Institute of Atmospheric Science and Climate (CNR-ISAC)	Italy
9	Norwegian Meteorological Institute (MetNo)	Norway
10	Royal Netherlands Meteorological Institute (KNMI)	Netherlands
11	Swedish Meteorological and Hydrological Institute (SMHI)	Sweden
12	University of Eastern Finland (UEF)	Finland
13	University of Helsinki (UHEL)	Finland
14	University of Leeds (ULEEDS)	United Kingdom
15	University of Leipzig (ULEI)	Germany
16	University of Oslo (UO)	Norway
17	University of Oxford (UOX)	United Kingdom
18	Swedish Environmental Protection Agency (NV)	Sweden
19	French National Institute For Industrial Environment and Risks (INERIS)	France
20	The International Institute for Applied Systems Analysis (IIASA)	Austria
21	University of Exeter (UEX)	United Kingdom

Abbreviations used:

AR – Assessment Report; CLA – Corresponding Lead Author; CMIP – Coupled Model Intercomparison Project; COP – Conference of Parties; CS – climate sensitivity; ECS – equilibrium climate sensitivity; ERF – Effective Radiative Forcing; ESA – European Space Agency; ESM – Earth System Model; GCM – General Circulation Model; GEBA - Global Energy Balance Archive; GEOSS - Global Earth Observation System of Systems; IPCC - Intergovernmental Panel on Climate Change; LA – Lead Author; PA – Paris Agreement; TCR – Transient Climate Response; TCS - Transient Climate sensitivity; TRL – Technology Readiness Level; UNFCCC - United Nations Framework Convention on Climate Change.

Preamble to FORCeS

Constraining Earth's climate sensitivity has proven notoriously challenging, and the range of climate sensitivity estimates presented in the IPCC assessment reports has been relatively unchanged despite decades of research efforts (1). In climate science, ***equilibrium climate sensitivity (ECS) and transient climate sensitivity (TCS) are commonly used for describing Earth's global average climate response to a prescribed change in carbon dioxide concentrations*** (2). While ECS and TCS are fundamental for objectively comparing and evaluating inherent climate model uncertainty in a projected climate response to (only) greenhouse-gas forcing, the high-demand interest from the general public and policy makers is the ***near-term climate evolution (i.e. climate change over the 21st century), which will be governed by the transient climate response (TCR) to a combination of changes in climate forcers, most dominantly emissions of greenhouse gases and atmospheric aerosols*** (3). Furthermore, while the analysis of the climate response has traditionally been focused around the evolution of the global average temperature, it is often the regional-scale changes in temperature, precipitation and other weather patterns that directly influence people's lives. These variables are strongly influenced by the magnitude and pattern of anthropogenic aerosol forcing (4). ***The main aim of FORCeS is to improve the description of key processes governing aerosol radiative forcing and feedbacks in climate models. This effort is needed to improve and constrain projections of near-term regional and global climate evolution and to strengthen the connection between climate science and climate policy.***

1. Excellence

1.1 Objectives

The challenge

The Paris Agreement (PA), adopted within the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015, requires the majority of the world's countries to limit global warming from anthropogenic activities within 2°C above pre-industrial levels. The actions needed to reach this goal, and the urgency and effectiveness of their implementation, rely crucially on accurately predicting the time-evolution of radiative forcing and the resulting climate response (5). Uncertainty in simulating the components of the atmosphere, especially those related to aerosol, clouds and their interactions severely hampers our ability to understand the past and project future climate change (1; 6). This is because anthropogenic aerosols exert a net cooling impact on climate (7) that offsets – but with large uncertainty - part of the warming effect from greenhouse gas emissions. As a result, the time left for achieving the necessary greenhouse gas reductions to achieve the PA target, and our understanding of the expected regional impacts of climate change, are hampered by the inability to robustly quantify the anthropogenic climate forcing associated with aerosols. In particular, the anticipated large reductions in aerosol emissions in the coming decades will result in a warming effect that is currently very poorly quantified (see Fig. 1.1.a and further information in (8)). ***It is therefore crucial to establish the extent to which aerosol changes, whether due to anthropogenic emissions or as a feedback induced by warming, offset greenhouse gas warming*** (9).

The goal of FORCeS

To resolve the above challenge and in support of the Intergovernmental Panel on Climate Change (IPCC), ***FORCeS will substantially increase the confidence in estimates of aerosol radiative forcing and its impact on transient climate response***. FORCeS will do this by bridging a crucial gap that currently exists between knowledge on the process scale and model application on the climate scale. FORCeS will identify, observationally constrain and efficiently parameterize the most important processes driving aerosol radiative forcing. With this knowledge, FORCeS will produce more robust estimates of the overall aerosol contribution to past climate change, leading to tighter constraints on climate sensitivity, and ultimately more accurate projections of the near-term climate change. Observations, computational models and theoretical considerations will be used to constrain and predict the anthropogenic aerosol impact on climate. A novel combination of computational and data mining techniques, brought together for the first time within FORCeS, will aid in establishing a good balance between an accurate representation of aerosol processes with

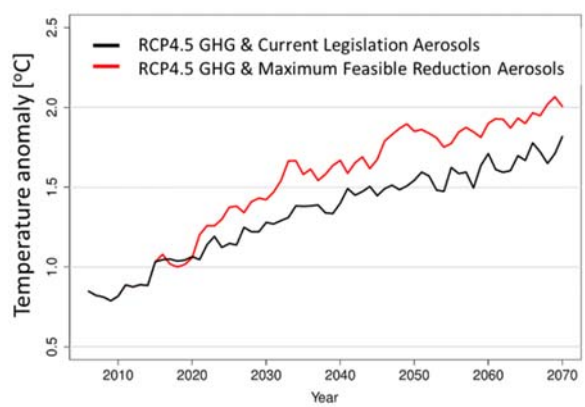

Figure 1.1a Modeled anomalies of the mean global surface temperature with respect to the 1880-1900 mean. Greenhouse gases follow the RCP4.5 scenario and aerosols follow either strong (red line, top) or weak (black line, bottom) global average aerosol emission reductions. (8)

computational requirements and need for simplification within climate models. FORCeS will operate on a continuum of temporal and spatial scales, focusing on metrics and outcomes with direct relevance for policy and ultimately for the quality of life. Based on the scientific knowledge gained, FORCeS will inform decision and policy makers about the effect of aerosol emission changes on regional and global climate evolution and on emission pathways to meet the targets of the PA.

The objectives of FORCeS

The following specific objectives have been designed to address the important knowledge gaps on aerosol forcing and its impacts on climate (see Fig. 1.1b and detailed motivation in Section 1.1.1).

No.	Objective	Expected impact
O1	Identify the most important cloud and aerosol processes or components controlling radiative forcing and transient climate response. Make targeted improvements of the corresponding parameterizations for a set of leading European climate models, to obtain more reliable transient climate simulations.	Increased confidence in climate change projections and strengthening and affirmation of Europe's leadership in climate science.
O2	Exploit models, statistical methods, data mining and the recent wealth of observations to reduce the uncertainty in anthropogenic radiative forcing associated with aerosols and aerosol-cloud interactions from more than ±100% (2) to closer to ±50%.	Invaluable new knowledge gained for upcoming scientific assessments (e.g. the next IPCC report), clarity with respect to the role of aerosols and greenhouse gases in the climate evolution of the industrial era.
O3	Quantify the near-term climate impact and associated uncertainty ranges for a set of plausible combinations of near-term greenhouse gas and aerosol emission pathways, in support of the PA.	Provide added-value to decision and policy makers, facilitating cost effective multi-beneficial mitigation strategies. Reduce complexity in interpreting and applying climate model results.

1.1.1 State-of-the-art

Negative anthropogenic aerosol forcing has masked some of the positive greenhouse gas (GHG) forcing during the industrial time (7) but the magnitude of this effect is not well quantified, and it varies strongly with time and location, which prevents us from understanding how the climate responds to changes in GHGs (7). Emissions of anthropogenic aerosol particles and their precursors are likely to decrease in the future, owing to controls aimed at improving air quality in different parts of the world (10). A strong reduction in aerosol emissions, and an unmasking of the associated cooling, is expected to significantly increase the rate of warming (8; 11) (Fig. 1.1a), bringing forward the date of reaching a 1.5°C warming by several decades, and potentially allowing for an overshoot of the 2°C target stated in the PA by 2070. To improve our predictions of climate sensitivity and future climate response, we urgently need to improve the constraints on the Effective Radiative Forcing (ERF) of aerosols on climate, which accounts for the immediate radiative effects as well as the subsequent adjustments of the climate system following an aerosol perturbation. The total aerosol forcing includes the direct interactions of aerosol particles with radiation (aerosol-radiation interaction, ERFari) but also the impact that aerosols have on climate through their interactions with clouds (aerosol-cloud interaction, ERFaci. Reducing the uncertainty in aerosol forcing requires simultaneous progress in:

i. Understanding the key aerosol- and cloud-related processes contributing to ERFari+aci and improving their parameterization in climate models;
ii. Understanding the components contributing to the overall uncertainty over a range of temporal scales (from seconds to decades) and spatial scales (from nanometers to hundreds of kilometers);
iii. Optimizing the use of existing observational data combined with targeted observations to close knowledge gaps and constrain aerosol impacts on the radiative balance of the Earth;
iv. Developing and applying novel theoretical and computational approaches for selecting the key aspects to be improved within climate models, and bridging the gap between different scales as well as between models and observations.

Furthermore, to maximize the impact of the scientific advances on societies and the global community, the results need to be communicated to stakeholders using relevant metrics.

Motivated by the importance of aerosols in quantifying the GHG induced warming, the research community has made important progress in simulating aerosol-cloud-climate interactions over the latest decades; The number of

climate models that include at least one prognostic equation for aerosols that is fully interactive and allows for climate feedbacks has increased from 4 in in the models simulations considered by the IPCC 4th assessment report (AR4) to 20 in AR5 (12).

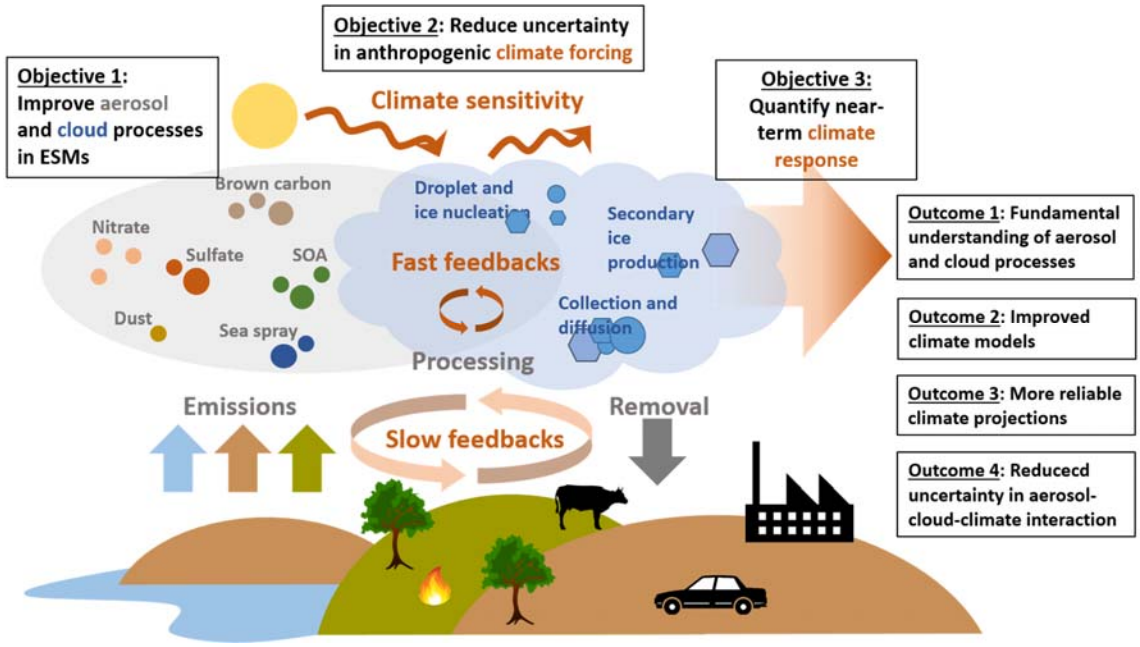

Figure 1.1b. The knowledge gaps addressed in FORCeS, expected outcomes, and contribution to objectives.

However, these models have been insufficiently constrained by observations and still do relatively poorly in reproducing observed aerosol impacts on the Earth's radiative budget; (13) compared the observed global all-sky downwelling shortwave radiation averaged over 1400 surface sites over the period 1961-2005 with that simulated by climate models referred to in the IPCC AR5. The observed shortwave radiation variations are known to be strongly influenced by aerosol direct and indirect effects and the models drastically underestimated the dimming and brightening trends occurring over the period of study (Fig. 1.1c). This result questions the ability of the models to reliably predict anthropogenic aerosol forcing and therefore also to project future climate change. A similar, albeit smaller, discrepancy exists between the total aerosol radiative forcing (ERFari+aci) calculated by coupled atmosphere-ocean general circulation models (GCMs) or Earth System Models (ESMs) used for the transient simulations in the Coupled Model Intercomparison Project Phase 5 (CMIP5, (14)) and those calculated by more-detailed aerosol-climate GCMs that are used for process studies and ERF estimates. The latter models normally estimate a more negative ERFari+aci than the CMIP5 models, as also discussed in the latest IPCC report (7). Consequently, some of the detailed aerosol-climate models that the IPCC reports rely on will have problems to reproduce the observed global warming because of their large ERFari+aci. The reasons for these discrepancies need to be resolved, and current aerosol and cloud parameterizations within climate models reconsidered and improved accordingly.

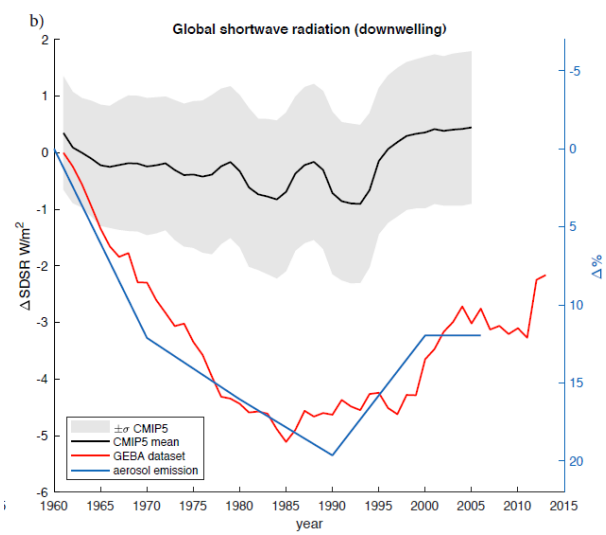

Figure 1.1c Observed and simulated global average shortwave downwelling radiation (13).

Representation of key aerosol components and aerosol-cloud-climate interactions in climate models

Much of the uncertainty in determining aerosol radiative forcing is caused by poorly constrained, potentially inaccurate, or completely missing representations of processes governing ERFari and ERFaci in climate models (3). Furthermore, the majority of processes need to be parameterized in climate models (GCMs and ESMs) rather than represented by resolved equations based on fundamental theories. The central problem in the parameterizations is the one of spatial and temporal scale: non-linear processes occurring at scales unresolved by

ESMs are represented only in terms of grid-box mean quantities, and only the average outcome is computed. The avenue to more reliably simulate the aerosol ERF is therefore via improved and observationally-constrained parameterizations of key processes. In terms of fundamental aerosol processes and components, the results and recommendations of previous EU projects (e.g. EUCAARI, PEGASOS, BACCHUS and ECLIPSE, see also Fig. 1.3a) highlight the urgent need of improving the understanding the following aerosol components, processes and associated parameterizations:

Ammonium nitrate: ammonium nitrate is an important aerosol component in e.g. China, Western United States and Northern Europe and its importance is expected to increase in the future (2; 15). Future emission scenarios project a 28−105% increase in agricultural ammonia emissions from 2000 to 2100, (16) with estimated changes of NH_3 emissions from pre-industrial to present day in the range +170% (see Table 2 in (17)). Atmospheric ammonia drives the conversion of gas-phase nitric acid to particle-phase nitrate, which has an estimated present day radiative forcing of −0.05 to −0.12 W m^{-2} ((17) and references therein). At the same time, the simulated burden of nitrates by large-scale chemical transport models (CTMs) vary by a factor of 13 (18). These CTMs are in general much more detailed than the coupled ESMs used for the latest IPCC climate assessment. FORCeS team members have proposed that better representation of aerosol pH is the key for overcoming these challenges in simulating aerosol nitrate (19; 20).

Organic aerosol (OA): Organic compounds constitute roughly half of the sub-micrometer mass (21; 22), which necessitates accurate representation of OA in climate models for capturing the overall aerosol loadings, properties and impacts on climate. The secondary fraction of OA (secondary organic aerosol, SOA) has proven to be particularly challenging due to its complex chemical transformation in the atmosphere (23). Most present climate models still assume a practically non-volatile SOA produced with a constant yield from known precursors (24). However, the models fail to reproduce observed OA concentrations in Europe and the United States (25; 26). The OA descriptions hence need to be revised to better account for e.g. the volatility of the SOA species (27) the anthropogenic effect on the formation of biogenic SOA (28; 29), and potential new chemical mechanisms in both gas as well as the particle phase. There are also important feedbacks between e.g. plant emissions and climate (heat waves, droughts, and inject infestations) that can regulate biogenic SOA formation (30; 2) that are still poorly understood.

Brown Carbon (BrC): the absorbing fraction of organic OA, is still disregarded by most climate models (31) and therefore missing from current IPCC radiative forcing estimates, despite its known impact on ERFari (32). Current climate models generally underestimate the absorbing properties of atmospheric aerosol although they reasonably estimate black carbon (BC) (33; 34). Several recent studies (35; 36) suggest that BrC can reduce the gap between model results and aerosol absorption observations. Similar to other absorbing aerosol, BrC could also reduce the snow albedo and thus accelerate the melting of polar and glacial ice (37).

Ultrafine (<100 nm) particle growth: Ultrafine particles dominate atmospheric aerosol number concentrations, and much progress has been made in understanding how nucleation of atmospheric vapors affects the concentrations of these particles (38). However, to have climatic relevance, the freshly-nucleated particles need to grow in size, but the representation of this growth in climate models is rudimentary. The contribution of secondary aerosol components to cloud condensation nuclei (CCN) concentrations is currently one of the most poorly constrained components of atmosphere-climate interactions (e.g. (39)). The growth is due to a combination of condensation of sulfuric acid and ammonia, extremely low volatility, low volatility, and semivolatile organics with coagulation playing a major role both as a sink of the smaller particles but also as another growth mechanism (40; 41). However, recent analyses have shown that the aerosol formation and growth to CCN sizes does not follow the simple theoretical considerations, but it is less regulated by the condensation/coagulation sink and thus less self-limiting process than expected (27). Even if our understanding of these processes has dramatically improved during the last few years and simulation frameworks (for example the volatility basis set) have been developed (42), most climate models either neglect or probably oversimplify the corresponding growth processes.

Although there is still a large ambiguity in estimates of the ERFari, the uncertainty in total anthropogenic aerosol forcing estimates is dominated by the uncertainty in ERFaci. This forcing is triggered by the cloud formation process, where aerosol particles act as CCN for cloud droplets to form on. Aerosol particles may also modify cloud properties by acting as ice-nucleating particles (INP), i.e. by initiating heterogeneous ice formation in clouds. For taking the step onward to the aerosol impacts on clouds and ultimately ERFaci, recent projects and results (43; 44) stress that climate models need to improve their representation of:

Liquid cloud processes: In general, additional aerosol particles result in more CCN, which in turn leads to more cloud droplets, a larger scattering cross section, and finally a higher cloud albedo (termed the Twomey effect, (45; 46)) At the same time, a change in the number of clouds droplets may also alter the ability of clouds to form precipitation leading to modified cloud liquid water paths, cloud albedos and potentially cloud cover and lifetime (Albrecht effect, (47). Accurate calculation of the Twomey and Albrecht effects requires a reliable parameterization of the cloud droplet formation and subsequent cloud liquid perturbations. While many aspects of the liquid-cloud droplet

activation processes are well understood, there is a central uncertainty when the processes are aggregated to the climate model grid-scale (48).

Ice cloud processes and INP concentrations: The problem is yet more complex for ice and mixed-phase cloud formation, where the determination of the ice crystal number concentration (and, as it is perturbed, the radiative forcing) depends on the capability of aerosol to serve as INP (49), on the cooling rates, and – in certain regimes – on ice multiplication, or "secondary ice" production (50). Despite immense recent progress in our understanding of these processes (51; 52), and indications that prognostic INP concentrations improve e.g. cloud radiative biases in the Southern Ocean (53), many ESMs providing information to the latest IPCC assessment have no explicit parameterizations of INP concentrations, heterogeneous ice formation or ice multiplication processes.

The overall cloud response to changes in CCN and INP concentrations: It is not only the number of cloud droplets and ice crystals that are altered upon a change in aerosol particle concentrations and properties. When these perturbations propagate through cloud microphysical processes, other cloud properties and precipitation mechanisms may be also altered, with potential feedbacks to aerosol concentrations. These adjustments can either dampen or amplify the first-order impacts that aerosol particles have on CCN and INP concentrations (54). Hypotheses that imply a positive feedback are amplification via precipitation formation (i.e. increase in CCN concentrations resulting in enhanced cloud lifetime, cloud cover, cloud depth and/or cloud water path, (54)) and aerosol processing (55; 56). Hypotheses on dampening ("buffering") are related to e.g. increased aerosol processing (57) cloud top entrainment and evaporation of cloud droplets in case of more aerosols (58), more efficient precipitation formation over the ice phase in mixed-phase clouds (59; 60; 61) an invigoration with eventually more precipitation in case of convective clouds (62).The mechanisms involved are different for different cloud types, and again particularly poorly understood for ice and mixed-phase clouds. This buffered two-way interaction between clouds and aerosols across the cloud life cycle and across scales needs to be better understood, and could be a possible explanation as to why detailed aerosol-climate models tend to suggest a stronger radiative forcing caused by aerosols compared to simpler models (see above), as buffering mechanisms involve scales that are often not parameterized nor resolved.

Observational constraints on aerosol processes and aerosol-cloud interactions

Ground-breaking progress has been made during recent decades in the scientific understanding and decadal-scale observation of relevant aerosol and cloud processes, for instance through several European collaborative projects (see Fig.1.3a). However, many of these discoveries have not yet been used to improve ESMs (63), or efforts have generally been scattered and ad-hoc without systematic investigation and coordination across model frameworks (64). The reason is partly the difficulty to use observations to fundamentally improve model frameworks (64) and partly that the work often is very time-consuming. Fortunately, recent pioneering work (65; 64; 66; 67; 68; 69; 70) in the development and application of various computational, statistical and machine learning techniques by the FORCeS partners has paved the way for successfully synthesizing large amounts of data, as well as parameterizing, scaling up and simplifying aerosol and cloud microphysical interactions. There is a large potential for using such novel techniques (including e.g. network analysis, see below) for bridging the gap between detailed process-level knowledge on aerosol and cloud processes and their representation in coupled ESMs.

The evaluation and constraint of model simulations of aerosol and cloud properties is a vital step in ensuring the robustness of projections. Recent efforts, such as the international aerosol intercomparison project AeroCom (where several FORCeS partners are leading participants) have taken significant steps forward in model evaluation. The focus of these efforts has been on the present-day base state of aerosol and cloud parameters, such as radiative properties (71), black carbon (72), organics (73), dust (74), microphysics (75), vertical distribution (76), and campaign-wise aircraft observations (77; 78). Early work on the constraints of indirect forcing in global models (e.g. (79)) started to exploit the relationship between observable parameters and the evaluated quantities to understand processes underlying aerosol-cloud interactions in a global mean sense (80). (81) highlighted the important contribution of non-aerosol processes to the uncertainty estimates of ERFari in current generation aerosol-climate models. However, these studies generally focused only on one element or a short section of a very long chain of uncertain processes that must be simultaneously constrained to constrain ERFari+aci and to quantify the uncertainty associated with it. FORCeS will use a holistic approach, utilizing the comprehensive set of observations that are presently available and maximize simultaneous constrains of processes affecting the aerosol climate forcing across temporal and spatial scales. New techniques developed by a FORCeS partner are able to exploit very large model ensembles and extensive measurements simultaneously, with the potential to provide much more robust model results (82).

Understanding the history of aerosol composition, feedbacks and forcing

The anthropogenic radiative forcing concept adapted by the IPCC builds on knowledge of a "pre-industrial state" from which observations of different climate forcing variables are rare by default. For aerosols, further complications arise as the short residence time of aerosol particles in the atmosphere (days to weeks) and strong anthropogenic

emission trends imply a large spatial and temporal variability in aerosol climate forcing since 1750 (7). Moreover, natural aerosol emissions may increase or decrease as a result of climate change causing a feedback on the overall aerosol burden and forcing (83). Understanding aerosol forcing history since pre-industrial times thus requires a high-level of understanding of the processes governing aerosol emissions, chemical formation of aerosol and aerosol physical processing as well as an adequate representation of these processes in models. It is not only the aerosol burden that is affected by climate change. The anthropogenic aerosol forcing is also strongly dependent on changes in other climate variables such as cloud amount and altitude (84; 85). Understanding these type of effects from climate feedbacks requires simulations with coupled chemistry-climate models, which are complex and computationally expensive. Therefore it is a clear necessity to make use of the (by the time of the envisioned start of FORCeS) freshly available simulations with up-to-date ESMs (including FORCeS ESMs, see Table 1.3) from the CMIP effort (CMIP6).

Climate feedbacks may strongly affect the global natural aerosol burden, which in turn may feedback on climate change. Mineral dust emissions dominate the global average aerosol mass and are coupled to aridity and surface winds (86). These emissions may be enhanced through anthropogenic land use change (87; 88) and significant dust increases and variations in all continents have also been found in climate records (North America: (89), (90); Asia: (91), (92); Africa: (93); South America: (94)). Sea spray emissions are affected by the sea ice extent in polar regions and will also respond to shifts in storm tracks and sea levels (95). Understanding how these aerosol feedbacks have changed through time, i.e. understanding the aerosol composition record, is an important part of understanding transient climate change. Changes in aerosol composition can also be used as a tracer for the time variability in anthropogenic emission sources. BC can be used as a tracer of anthropogenic activity; during early industrialization less efficient burners were used and several records indicate regionally enhanced aerosol absorption in the late 19th and early 20th century (94). Associated fossil fuel-derived sulfate particles have been made responsible for aerosol-induced cooling in the Northern hemisphere in the 60s and 70s (96) Lately and certainly in the future, the perturbed nitrogen cycle will be an important contributor to aerosol radiative forcing through ammonium nitrate (16). Ice cores, sediments and other deposition records and intensive observations in the last two decades provide insight into trends in aerosol composition. These will be exploited in FORCeS to better understand the historical record of aerosol forcing.

Impact of aerosols on transient climate sensitivity and climate evolution

The efforts to infer TCS and TCR from the observed climate change have been hampered by the poorly understood and quantified forcing from anthropogenic aerosols (1; 97). This issue has in turn allowed many ESMs to reasonably reproduce the historical global average temperature record, despite having a wide range of TCS values (98). In other words, many of the models must be producing "the right answer for the wrong reason", and therefore cannot be trusted for future climate projections. Recent, pioneering, work has used Bayesian frameworks and statistical emulators to examine the uncertainty space for aerosol forcing (65) and CS (99). These studies show that both aerosol and other physical atmospheric parameters are important for governing the uncertainty in ERFari+aci, while cloud parameters govern most of the spread in CS. However, the models applied in both studies still miss important aerosol components and feedbacks (see above) or the processes are described in a simplified way. For example, the conclusion about the influence of aerosols on CS was drawn based on a model that does not include explicit aerosol-cloud interactions. The aim of FORCeS is to continue this important work and further explore the uncertainty space for aerosol forcing, TCS and TCR using climate models that explicitly include and parameterize the important processes (cf. Section 1.3).

While the analysis of the climate response to different forcings has traditionally been strongly focused around the evolution of the global average temperature, it is often the regional scale changes in temperature, precipitation and weather patterns (including extreme events) that directly influence people's lives. More work focusing on these regional scales and relevant climate metrics is needed to improve the connection between climate science and policy and ultimately the quality of people's life. In general, ESMs with more explicit representation of aerosols and their effects on clouds and radiation are better at reproducing observed regional temperature trends and decadal temperature variability than models with a simplified descriptions of aerosols (100; 101). Furthermore, many important precipitation and circulation patterns, such as the Intertropical Convergence Zone, the Asian monsoon circulation and the Southern Annular Mode, are known to be strongly influenced by changes in aerosol forcing patterns (8; 102; 103; 104). ESMs that include temporal trends in anthropogenic aerosol forcing are generally better at representing spatial shifts in these important circulation patterns (104; 103; 105). An outstanding issue, however, is that although ESMs generally agree conceptually on the radiative forcing and temperature response to a given perturbation in aerosol emissions, they still differ strongly in terms of the absolute magnitude of the temperature change (106). This issue can only be resolved by an improved understanding of and better constraints on the whole

chain of events leading from the emission of an aerosol particle or aerosol precursor gas to the radiative forcing perturbation and final climate response.

1.2 Relation to the work programme

The proposed work relates to the Horizon 2020 Work Programme 2018-2020: ***"Climate action, environment, resource efficiency and raw materials"*** and the topic LC-CLA-08-2018: ***"Addressing key knowledge gaps in climate science, in support of IPCC reports"*** with specific emphasis on the sub-topic: ***"a) Improving the understanding of key climate processes for reducing uncertainty in climate projections and predictions". "Actions should achieve better understanding of key processes, and associated feedbacks, affecting the climate-Earth system over time in order to improve climate projections and predictions and constrain climate sensitivity estimates."***

As outlined in Section 1.1, the effects of aerosols on radiation, clouds and climate currently dominate the total uncertainty in anthropogenic radiative forcing estimates. ***Reducing the uncertainty range in anthropogenic aerosol forcing is crucial for robust quantification of the regional and global transient climate response and for projecting the evolution of climate during the 21st century***. In particular, although there are alternative methods of estimating climate sensitivity, it is only by developing robust models of the key forcing terms that we will be able to reliably simulate the future state of the whole climate system, rather than just the sensitivity of the global mean temperature to a prescribed change in carbon dioxide concentrations. Natural aerosol emissions, aerosol chemical and physical processing and aerosol-cloud interactions are known to be affected by climate change, e.g. (107). Nevertheless, these processes and their associated climate feedbacks are often described at a rudimentary level in many climate models (12; 108) Furthermore, key aerosol components and aerosol processes (e.g. brown carbon, nitrate, semi-volatile SOA, see Section 1.1) that are known to play a crucial role for predicting the overall aerosol burden and climate forcing are often not even considered in climate models, for example the ones forming the basis of the latest IPCC assessment report (2). Improving and consolidating fundamental and structural differences in the descriptions of aerosols and aerosol-cloud interactions in state-of-the-art climate models is crucial to minimize the risk that inaccurate or even wrong conclusions are drawn regarding the magnitude of anthropogenic aerosol forcing, aerosol-cloud-climate feedbacks and aerosol influence on climate sensitivity.

In line with the specific call text, ***FORCeS will identify and fill knowledge gaps regarding key aerosol and cloud processes*** by integrating and using i) the wealth of in-situ and remote sensing data that have become available during the latest decades together with ii) dedicated process-level laboratory and field experiments, iii) a range of state-of-the-art computational models and iv) novel theoretical methods including statistical emulation of perturbed physics ensembles and machine learning techniques (WP1-WP4). FORCeS will also address the large gaps in knowledge related to ***climate feedbacks related to aerosols and clouds, and improve quantification of how they affect Earth's climate system over time*** as well as their importance for accurately predicting Earth's climate sensitivity (WP5, WP6). FORCeS uses experience and results from several previous EU projects to pinpoint gaps in our knowledge related to processes and constituents that have the largest influence on the uncertainty range in aerosol forcing estimates (WP3, WP4). By focusing on refining parameterizations of these particular processes and constituents in models, ***climate sensitivity estimates will be constrained***, *but most importantly* ***more reliable models of the climate system will be developed that are essential for understanding the full range of changes in future climate.*** Finally, FORCeS will interact closely with stakeholders (e.g. representatives of the IPCC, international institutions developing strategies to mitigate climate change and air quality issues and non-governmental organizations) to make sure that the project delivers relevant and timely information regarding effects of aerosol on climate (WP7). More specifically, ***FORCeS will contribute to and support major international scientific assessments such as the IPCC reports***, by generating the crucial knowledge needed, by participating in coordinated model experiments (e.g. those endorsed by the Coupled Model Intercomparison Project, CMIP), and by actively participating in IPCC assessments (cf. Section 2.1).

1.3 Concept and methodology

(a) Concept

Overall concept underpinning the project: FORCeS will constrain the present-day and time-dependent aerosol forcing to reduce uncertainty in near-term climate projections, which is necessary for deciding which measures are needed to reach different climate policy targets. To succeed with this task, all process-level investigations within FORCeS will be guided by and conducted with the ultimate aim of improving the climate models used within FORCeS. The overall concept is based on three pillars, which are explained in detail below*:*

<u>Pillar I)</u> Quantifying aerosol loadings and aerosol climate forcing through combining "bottom-up" process knowledge with "top-down" constraints;

Pillar II) Targeted investigation of fundamental phenomena, their systematic up-scaling and climate model improvement using novel techniques such as machine learning;
Pillar III) Active communication using metrics and approaches relevant for climate assessment groups and stakeholders.

I) *Quantifying aerosol loadings and aerosol climate forcing combining "bottom-up" process knowledge with "top-down" constraints*

We will focus on the effective radiative forcing due to aerosol-radiation (ERFari) and aerosol-cloud interactions (ERFaci) as defined in the latest IPCC report. The best estimate of the anthropogenic ERF due to aerosols, comparing the years 2011 and 1750, is -0.9 Wm^{-2} with a range of -1.9 Wm^{-2} to -0.1 Wm^{-2}. Constraining the aerosol ERF is important as i) accurately determining the past time-dependent aerosol forcing means better constraints on the near-term future warming induced by greenhouse gases; ii) any change in aerosol emissions, e.g. due to air pollution mitigation, will result in an almost immediate response, i.e. the near-term climate evolution will largely depend on the atmospheric aerosol loading and forcing (8); iii) if strong reductions in greenhouse gas emissions occur, reductions in co-emitted aerosols are inevitable and may result in short-term warming, e.g. (109). Simulation of aerosol particles is challenging due to their physical and chemical complexity, and their convolute interactions with clouds. Vice versa, cloud microphysical processes are shaped by the aerosol particles on which cloud droplets and ice crystals form. Much progress has been made on the one hand in the molecular understanding of atmospheric chemistry involving aerosol particles and on the other hand in the development of global climate and Earth system models. These two, as such multi- and interdisciplinary, perspectives give to some extent contradicting answers on the magnitude of the aerosol forcing (110; 63; 111), and need to be efficiently combined to truly resolve the present uncertainties in aerosol impacts on climate. To iteratively reduce the uncertainty in aerosol forcing, the "bottom-up" view stemming from understanding the fundamental physical and chemical processes involving aerosol particles and clouds needs to be resolved with the "top-down" constraints from global models and observations.

II) Targeted investigation of fundamental phenomena, their systematic up-scaling and climate model improvement using novel techniques such as machine learning

Systematic work connecting the different scales is fundamental to take the step from understanding atmospheric aerosol properties and loadings to quantifying their true impact on clouds and their climate forcing. However, increased complexity of the models does not necessarily guarantee better predictive power (112; 113; 114). Efficient ways to identify and simplify key processes, which are often complex and small-scale, are urgently needed. Furthermore, there has been a persistent uncertainty in the aerosol loading and forcing caused by anthropogenic aerosols in all five major IPCC assessment reports published since 1990. An important cause is the lack of experimental data on clouds and aerosols during the pre-industrial time, which typically serves as the reference period for ERF estimates (2; 113). Robust data series are now available, collected over annual and decadal scales from both in-situ and remote sensing techniques (cf. Section 1.3 (b)). Novel, robust theoretical descriptions of the processes influencing aerosol emissions and loadings will help in reliably extrapolating to past and future conditions beyond the range of observations. Modeling and data analysis across different temporal and spatial scales is crucial as aerosol-radiation and aerosol-cloud interactions involve many feedbacks (54). FORCeS will exploit the untapped potential that lies in systematic analysis of the wealth of existing data to quantify the aerosol climate impacts over various climate-relevant temporal and spatial scales.

III) *Active communication using metrics and approaches relevant for climate assessment groups and stakeholders*

As mentioned in Section 1.1, the near-term temperature evolution is crucially dependent on changes in aerosol emissions: documenting and interpreting the response to rapidly-changing emissions as mitigation efforts begin will be critical to the PA stock taking process. Other climate variables that are important for peoples' livelihoods, such as precipitation patterns, monsoon circulations, and the hydrological cycle in general are also known to be strongly influenced by the inhomogeneous spatial and temporal forcing pattern induced by aerosols (103; 104; 4; 102; 8). Providing policy and decision makers with relevant information on the climate effect of near-future aerosol emission changes is key for developing efficient climate and air pollution mitigation strategies. FORCeS will work closely with stakeholders, involved as partners and through a *stakeholder group*, to design and deliver policy-relevant metrics and climate information**.**

Positioning of the project: Our project will start on a level corresponding to Technology Readiness Level 2 (TRL2) where our science concept for reducing aerosol ERF uncertainty is formulated. The aim is to have the methodology (e.g. the new metrics developed and the improved climate models) tested and evaluated (TRL6) at the end of the project. The current uncertainty in aerosol ERF is more than 100%, and our goal is to understand the reasons for the uncertainty, and to reduce it to closer to 50%. This will make it more similar to the uncertainty of other climate

drivers (2). We will make our results available for users in the scientific community, contribute to scientific assessments, and inform policy makers about relevant outcomes (cf. Section 2.1).

National and international research activities linked to FORCeS: An important aspect of FORCeS will be drawing upon past and ongoing research activities. These include the following projects where FORCeS consortium members have been or are currently actively involved:

Project acronym	Full name and scope	Type of activity and time frame
AeroCom	Aerosol Comparisons between observations and models	Open international collaboration research initiative, ongoing.
ACTRIS I and II	European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases	EU FP7 and H2020 Research and Innovation, 2011-2015 and 2015-2019.
APPLICATE	Advanced Prediction in Polar regions and beyond: modelling, observing system design and LInkages associated with a Changing Arctic Climate.	EU H2020 Research and Innovation project, 2016-2020.
BACCHUS	Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic UnderStanding	EU FP7 collaborative project 2013-2018.
CLOUD	Cosmics Leaving Outdoor Droplets	Experiment run by CERN, ongoing
CORDEX	Coordinated Regional Climate Downscaling Experiment	World Climate Research Program International Initiative, ongoing.
CRESCENDO	Coordinated research in Earth Systems and climate: experiments, knowledge, dissemination and outreach	EU H2020 Research and Innovation project, 2015-2020.
EUCAARI	European Integrated Project on Aerosol Cloud Climate and Air Quality Interactions	EU FP6 Integrated project 2007-2010.
EUCP	The European Climate Prediction system	EU H2020, Research and Innovation project, 2017-2021
EUROCHAMP 2020	Integration of European Simulation Chambers for Investigating Atmospheric Processes – Towards 2020 and beyond	EU H2020, Research and Innovation project, 2016-2020.
GAP	GEWEX Aerosol Precipitation initiative	Open international collaboration research initiative, ongoing.
GASSP	Global Aerosol Synthesis and Science Project	UK-funded (NERC, NCAS, N8, CEDA) project, 2013-2016.
GEWEX	The Global Energy and Water Exchanges project	Open, international collaboration research initiative, ongoing.
PEEX	Pan-Eurasian Experiment	Open international collaboration research initiative, ongoing.
PEGASOS	Pan-European Gas-aeroSOls-climate interaction Study	EU FP7 Large-scale integrating project 2011-2014.
PRIMAVERA	PRocess-based climate sIMulation: AdVances in high resolution modellingand European climate Risk Assessment	EU H2020 Research and Innovation project, 2015-2019.

Figure 1.3c. Previous and ongoing international projects and initiatives related to FORCeS.

(b) Methodology

The work within FORCeS will be organized around nine interconnected Work Packages (WPs, cf. Fig. 3.1), in effect co-led by leading European scientists specialized in different fields of atmospheric and climate science. The co-leadership facilitates interactions between climate scientists and stakeholders, the different scientific traditions within atmospheric science, different scales, and experimental as well as theoretical approaches (Fig. 3.1). FORCeS will make sure that key knowledge gaps identified both within FORCeS as well as by previous projects (cf. Fig. 1.3a) are filled and that the relevant processes are improved in climate models. These gaps can be related to aerosol emissions (e.g. brown carbon, nitrate, secondary organic aerosol, dust, sea spray), aerosol-cloud processes (e.g. droplet and heterogeneous ice nucleation, secondary ice formation, collection, aerosol cloud processing, sedimentation), and methodological questions (e.g. impact of model complexity for predictive power). More specifically, FORCeS will rely on observations, theoretical methods, computational models, and communication method, described further below (see also Table 1.3):

Observations: For constraining theories and computational models, we will make use of observational and experimental data series as well as databases of aerosol, cloud and radiation measurements, collected within FORCeS and established by previous research initiatives, i.e. from laboratory studies, in-situ observations (Fig. 1.3a) satellites and re-analysis (e.g. the European Earth Observation Programme (Copernicus), the Global Energy Balance Archive, the European Space Agency (ESA) and the Global Earth Observation System of Systems, GEOSS). We will develop robust constraints of fundamental atmospheric processes, aerosol forcing and climate response on decadal scales. The existing data will, where knowledge gaps exist, be complemented by new field and laboratory investigations of the key processes governing aerosol loadings, properties and their interactions with clouds. Existing observational platforms available within FORCeS, such as the Zeppelin Station (NO), the SMEAR stations at Puijo and Hyytiälä (FI) and the Po Valley (IT) (all participating in e.g. the ACTRIS in-situ measurement network) as well as simulation chambers such as SAPHIR (DE), will be utilized.

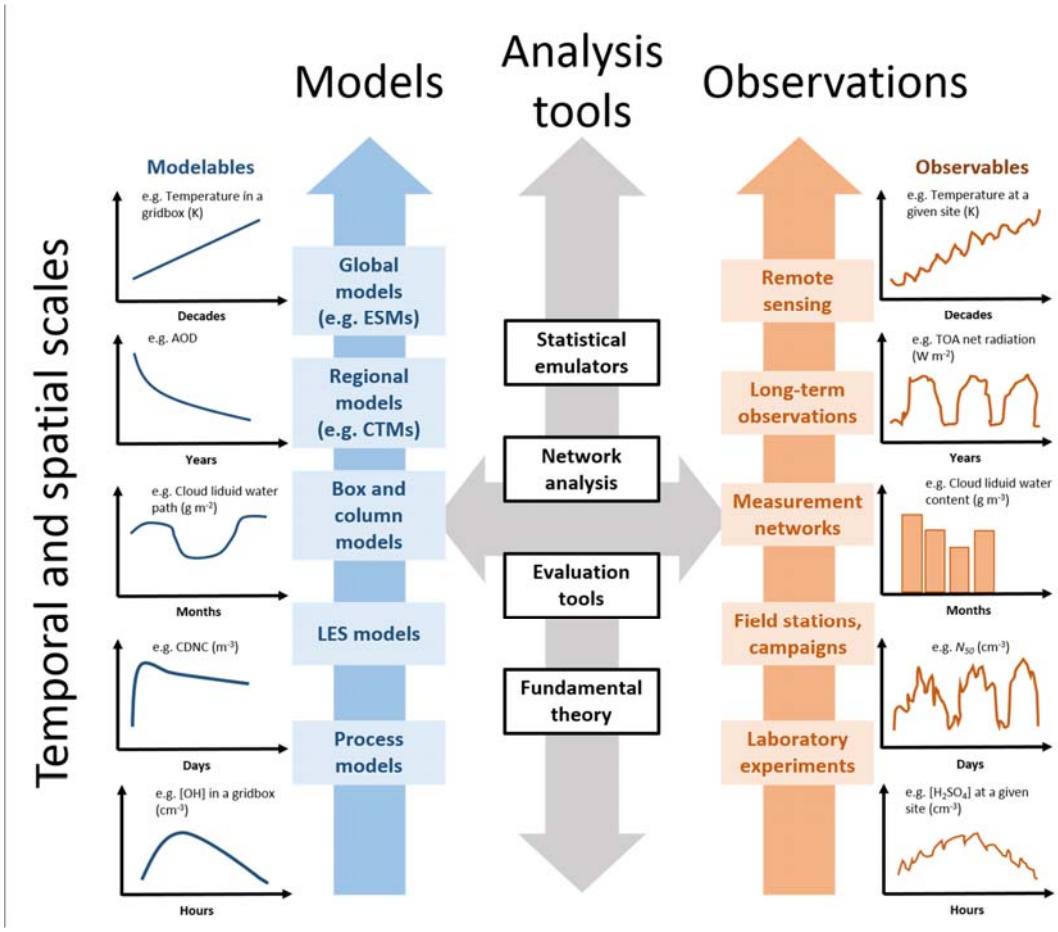

Figure 1.3b. The relevant scales and methods applied in FORCeS for moving between them, along with examples of time series of key variables needed for quantifying ERFari+aci.

Theoretical methods: We will use and develop new molecular theories and dynamic models targeted for interpretation of experimental data or prediction of aerosol and cloud processes and emissions (115). Mathematical methods and novel theoretical and statistical techniques including statistical emulation of perturbed physics ensembles, network analyses techniques and radiative kernels will also be used to understand the drivers of uncertainty in climate feedbacks, forcings and response in ESMs and in observations, as well as identification of critical processes and their upscaling to global predictions. These methods are described below.

A perturbed physics ensemble (PPE) is a set of simulations created using a single model structure with perturbations made to uncertain physical parameters (116) or inputs to the model, like aerosol emissions (117) within that structure. PPEs have been used to develop understanding of the causes of uncertainty in global aerosol concentrations ((118) (117) and references therein), precipitation (119), top-of-the-atmosphere radiative fluxes (120) and climate change projections (121; 116; 122). They are widely used in many fields of science to understand and quantify model uncertainty, such as in environmental models, hydrological models, astrophysics and disease transmission.

In climate network analysis, a field (e.g. sea surface temperature) is analyzed to identify a set of "nodes" through which information is exchanged and allowed to flow across the climate system; the links (connections) between the nodes then provides the representation of the dynamics of the whole climate system responsible for the TCS in a reduced and simple way (123; 124). The state of the art of network analysis is the δ-MAPS approach (67; 69), which allows for a robust and objective evaluation of climate models' ability to represent climate modes of variability and their connectivity patterns. The domain identification algorithm of δ-MAPS enables to reduce the complexity of large climate datasets in an automated way, with advantages when compared to more traditional dimensionality reduction methods (e.g. climate indices, empirical orthogonal functions, clustering and community detection algorithms). δ-MAPS can be used effectively to compare and rank climate model ensembles, taking into account differences resulting from the inherent internal variability of the system or from model structures. Moreover the same methodology can be used to compare the same climate model integrated using different parameters, parametrizations or forcing fields so to establish linkages between perturbations to the modelled climate system and its response.

Another statistical tool that will be used in FORCeS to simplify the complex Earth system dynamics is Bayesian modeling. The Bayesian Model consists of a dynamic process model with an idealized representation of the Earth's energy balance, a data model that describes how various observations are related to the process states, and finally a parameter model that expresses prior knowledge of the parameters (125; 126). The model is estimated based on temperature and ocean heat content observations from around 1850 and 1950, respectively. A Bayesian approach in the spirit of (127) on calibration of computer models is used, but without using an emulator to approximate the computer model. The model has been validated on artificial data generated from different ESMs in the Coupled Model Intercomparison Project phase 3 (CMIP3) (125). It gives a posterior estimate of the climate sensitivity parameter (in K/Wm^{-2}), which can be multiplied by the RF for a doubling of CO_2 to give the ECS, or the joint posterior distribution of the model parameters can be used in the dynamic process model to estimate the TCR based on a scenario with 1%/yr growth in CO_2.

Radiaive kernels are commonly used in climate science to quantify feedbacks (128; 129). The kernels describe the differential response of radiative fluxes (e.g. at the top-of-the-atmosphere) to incremental changes in different feedback variables This technique enables a decomposition of a feedback into one factor that depends on the radiative transfer algorithm and the unperturbed climate state and a second factor that arises from the climate response of the feedback variables. Such decomposition facilitates the understanding of the spatial characteristics of the feedbacks and causes of differences between models.

Table 1.3. Central tools and datasets used within FORCeS with their typical time resolution, temporal coverage and output frequencies.

Name	Related FORCeS Partner(s)	Spatial Coverage	Spatial resolution	Temporal Coverage	Output frequency	WPs	Reference
Earth System Models (ESMs)							
EC-Earth	FMI, UHEL, SMHI, KNMI, SU, BSC	Global	80 km	Decades/Centuries	Minutes	3,5,6	Hazeleger et al. 2012 (130); Döscher et al., in prep.
MPI-ESM-HAM	ETH, UOX, FMI, ULEI	Global	1°	Decades/Centuries	Minutes	2,3,4, 6	Folini et al., in prep.
NorESM2	MetNo, UO, SU	Global	1°	Decades/Centuries	Minutes	3,4,5, 6	CESM 2018 (131); Kirkevåg et al., 2018 (132); Bentsen et al., 2013 (133).
UKESM	ULEEDS, UEX	Global	1.25°	Decades	Minutes	3	https://ukesm.ac.uk
CMIP6 archive	N/A	Global	N/A	Decades/Centuries	Months	5, 6	Eyring et al., 2016 (134).
Atmospheric Models							
ECHAM6-HAM2/ICON-HAM	ETH, UOX, FMI, ULEI	Global	1°	Decades	Minutes	1,3	Neubauer et al. 2018 (135); Dietlicher et al., 2018 (136).
TM4-ECPL	FORTH	Global	2°×3°	Decades	Minutes	1	Kanakidou et al., JAS, 2016 (137).
PMCAMx PMCAMx-BC PMCAMx-UF	FORTH, SU	Continental	36km	Months	Minutes	1	Fountoukis et al. (2016) (138); Patoulias et al. (2018) (139).
ICON-LEM	KIT, ULEI	Regional	150 m	Days	Seconds	2	Heinze et al. 2017 (140)
MIMICA	SU	Meso-scale	50 m	Days	Seconds	2	Savre et al. (2017) (141)

UCLALES-SALSA	FMI	Meso-scale	50 m	Days	Second	2	Tonttila et al. (2017) [142]
Cloud parcel models	SU, ULEI, FMI	Local	Meters	Hours	Seconds	2	e.g. Partridge et al. (2012) [143].
Box / columnar chemistry models	FORTH, UHEL	Local	Meters	Days	Seconds	1	e.g. Jung et al. (2010) [144].
Simplified climate-carbon-cycle model (FAIR)	UOX	Global	NaN	NaN	NaN	6	Smith et al., 2018 [145]; Millar et al., 2017 [146].
Theoretical methods							
Bayesian modelling	UO	Regional/ Global	N/A	Decades/Centuries	Months	6	Skeie et al., 2018 [126].
Mie Theory Core Shell	SU	N/A	N/A	N/A	N/A	1	N/A
Network Analysis	FORTH	Regional/ Global	Model dependent	Decades/Centuries	Months	6	Bracco et al., 2018 [67]; Falasca et al., 2018 (69).
Perturbed Physics Ensemble	ULEEDS	Reginoal/ global	N/A	Decades/Centuries	Months	3	Lee et al., 2013 (117).
Experimental methods							
New field campaigns	SU, UEF, CNR, FORTH, UHEL	Regional	1 km	Months	Seconds	1,2	See Section 1.3b
Atmospheric In-Cloud measurements	SU, ETH, UEF, CNR, FZJ	Regional	1 km	Months	Seconds	2	e.g. Väisänen et al., 2017 [147]; Hao et al., 2014 [148].
Atmospheric simulation chambers	FZJ, UEF, FORTH	Lab	N/A	Days	Minutes	1,2,3	See Section 1.3b.
Satellite observations	FMI, SU, ULEI, UOXF	Global	1 km	Decades	Days	2,4	See Section 1.3b.

Computational models: The use and development of state-of-the-art ESMs will be at the heart of all FORCeS activities, focusing on those actively developed within the consortium, namely the European community model (EC-Earth), the Norwegian Earth System Model (NorESM), the UK Earth System Model (UKESM) and the suite of MPI-ESMs (based on e.g. the atmospheric models ECHAM and ICON) developed by the Max-Planck Institute in collaboration with other European partners. These models can all be used both in an ESM mode and in an atmospheric GCM mode (with prescribed sea surface temperatures). Existing climate model output archives e.g. from CMIP-endorsed experiments (in particular CMIP6) and international projects (cf. Fig. 1.3a) will also be used. The development of models with European scientific origin will "strengthen and affirm Europe's leadership in climate science" (cf. Section 2.1). To fill the gap between the ESM scale (tens to hundreds of kilometers) and the temporal and spatial scales where observations and parameterization development typically are done (nanometers to kilometers), FORCeS will also develop and use other computational models than ESMs such as Large Eddy Simulation (LES), cloud-resolving models (CRMs), cloud parcel models and chemical transport models (CTMs), cf. Table 1.3. These high-resolution 1- to 3-dimensional models will be used to study aerosol-radiation and aerosol-cloud interactions on spatial domains and time periods relevant for both the climate scale and the observational scale. LES and CRM will be used as testbeds for parameterization development and will include both detailed descriptions of e.g. the evolution of aerosol populations and cloud microphysics, as well as more simplified, computationally more efficient, parameterizations that are suitable for ESMs.

For examining the impact of aerosol constituents and processes on radiative forcing, feedbacks, and climate sensitivity and response, FORCeS will rely on three different types of ESM simulations, respectively:

Effective radiative forcing (ERF) simulation	*Transient climate evolution (TCR) simulation*	*Transient climate sensitivity (TCS) simulation*
Following the CMIP protocol for calculating ERF with prescribed sea surface temperatures, to evaluate the importance of different aerosol-cloud processes and aerosol components for aerosol ERF.	Interactive ocean-atmosphere simulations over the industrial time period and near-term future following historical emissions of aerosols and greenhouse gases or projections, to examine the climate response to anthropogenic aerosols and feedbacks in the climate system.	Interactive ocean-atmosphere simulations following the CMIP protocol for calculating TCS, i.e. the global mean temperature change for a 1% yr^{-1} carbon dioxide increase with subsequent stabilization at $2\times CO_2$ and $4\times CO_2$.

Communication method: FORCeS will organize workshops during different stages of the project where climate science experts, climate data users, and policy makers will meet to discuss and contrast potential climate implications of different greenhouse gas emission reductions and air pollution mitigation strategies. FORCeS will leverage on the networks provided by e.g. IPCC, Future Earth, the Arctic Council, the Convention on Long-range Transboundary Air Pollution (CLRTAP), the Climate and Clean Air Coalition (CCAC), the World Climate Research Programme (WCRP) and their initiatives such as the Global Energy and Water Exchanges (GEWEX) project, the European Commission and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) for workshop participation and for exploitation, dissemination and communication of the results (cf. Section 2.1).

Work plan

The work within WP1-WP6 will follow a common general approach involving three work phases to 1) find and understand the key processes and the way they are currently represented in the FORCeS ESMs; 2) ensure progress of knowledge from the process to the climate scale; 3) constrain aerosol forcing, feedbacks, and climate sensitivity: *Phase 1:* Investigating key components and processes identified in past efforts (WPs 1-3, see Sect. 1.1), evaluating the bottlenecks and links within "scale chains" (WPs 1-4), i.e. a chain of events, occurring on a range of spatial and temporal scales, following an aerosol (or aerosol precursor) perturbation in the climate system. This includes also evaluation of the starting point of the FORCeS ESMs with respect to the key processes and outcomes (WPs 5-6). A combination of experimental and theoretical techniques will be used to study and identify key processes governing the aerosol ERF, aerosol and cloud feedbacks, as well as transient climate evolution and climate sensitivity (WP3-WP6). The identified key processes will define the scale chains to be studied, which can be associated with perturbations of i) natural aerosol, ii) anthropogenic aerosol, iii) warm cloud microphysical processes, and iv) cold cloud microphysical processes in the Earth system scale. The scale chains will be traced through at least two temporal or spatial scales and involve at least one ESM, i.e. they will be designed to go across scales from e.g. the microphysical to the cloud scale, from the cloud scale to the cloud field scale, from the cloud field scale to the regional scale, and from the regional scale to the global scale (see the WP descriptions in Sect. 3.1). Interactions with the stakeholders to design studies that best target their needs in terms of understanding the near-term climate response to changes in aerosols and clouds (WP7).

Phase 2: Implementation of the most important processes, emissions or feedbacks identified in phase 1 in the ESMs employed by FORCeS with the best available knowledge from the smaller scales (WPs 1-3). Phase 2 includes also the development of metrics and approaches for model evaluation, data analysis and upscaling (WPs 1-6), including e.g. new software (WP4), application of network analysis (WP6) and development of relevant climate metrics to focus on together with the stakeholder group (WP6).

Phase 3: Testing and evaluating the effects of improved key model descriptions in the ESMs in terms of reproducing physical process constraints (WPs 3-6). Providing estimates and reducing uncertainty in predicted aerosol forcing, climate sensitivity, and near-term climate evolution. Fine-tuning the developed process parameterizations based on input from the re-evaluation as well as evaluation of new fundamental process knowledge acquired on aerosols and clouds and the related recommendations for outlook and future studies (WPs 1-2). Communicating the relevant results to stakeholders (WP7).

1.4 Ambition

The ultimate goal of FORCeS is to constrain the anthropogenic aerosol ERF with much better accuracy than available to date, use it to improve estimates of climate sensitivity and near-term climate projections, and finally communicate the implications of our results to stakeholders using novel metrics and information that are directly relevant to them and the communities they are serving. To achieve this, FORCeS will:

i. Explore currently underexplored aerosol and aerosol-cloud processes/feedbacks that recently have been identified and pointed out as potentially important (see Sect. 1.1.1);
ii. Define the processes that should be prioritized (based on their importance for aerosol forcing, climate sensitivity and climate response) in developing new parameterizations for climate models;
iii. Utilize vast amount of recent observations to constrain these processes and forcings, using novel theoretical approaches and computational techniques (see Sect. 1.2);

Focus on relating results to temporal and spatial scales and measures that are directly relevant for stakeholders, hence ensuring impact beyond what is typically expected of fundamental research (see Sect. 1.1).

Expected outcomes and advancement beyond state-of-the-art

They key expected outcomes from the work conducted in FORCeS include

i. New fundamental understanding of physical and chemical processes involving aerosols and clouds;
ii. Climate models with new and improved description of aerosols and aerosol-cloud interactions;
iii. Improved predictions of climate evolution in the context of climate policy, particularly the PA;
iv. Improved quantification and reduction of uncertainty related to aerosol radiative forcing, climate sensitivity and transient climate response.

FORCeS aims to understand, quantify and ultimately reduce the major factors contributing to the uncertainty in aerosol forcing on climate, far beyond to what has been achieved in past attempts.

FORCeS will improve the representation of aerosol and cloud processes in Earth System Models in an effort to increase the accuracy and reduce the uncertainty of the simulated aerosol effective radiative forcing. The combination of laboratory results, smaller-scale models and the corresponding constraints from field studies, and finally the development of parameterizations for ESMs using cutting edge statistical and theoretical approaches within FORCeS is novel. FORCeS will generate new fundamental knowledge on aerosol species (especially nitrate, organic aerosol, brown carbon) and processes (e.g. ultrafine aerosol formation and growth, cloud processing, and feedbacks involving aerosol particles) that are currently poorly constrained within ESMs used for climate projections (WP1). FORCeS will also produce new and improved parameterizations for cloud droplet activation, ice crystal formation via heterogeneous freezing as well as secondary ice formation; liquid-cloud condensational growth, precipitation formation, entrainment-mixing and dissolution, and for aerosol processing and wet scavenging within clouds (WP2). These improvements will be achieved and documented exploiting observations at the process scale and from satellite data, and using smaller-scale models as reference. On the experimental side, the advancements beyond state-of-the-art include new and innovative in-situ and remote observational approaches guided both by the development needs and constraints set by climate models. Throughout FORCeS activities, the scale interaction will be considered, i.e. the question about the relevance of processes observable experimentally in the laboratory or field, or in detailed models for large-scale aerosol and cloud radiative effects (WP1-WP4).

Methodologically, FORCeS will develop novel concepts in terms of aerosol and cloud parameterizations within ESMs such that it will not necessarily follow the traditional approach to only increase the complexity. Instead FORCeS will investigate, through sophisticated uncertainty analysis using both models and observations, which parameterizations are the most uncertain and should be the focus of ongoing and future developments (WP3, WP4). Another novel approach applied within FORCeS are the scale-chain experiments, in which we follow the full process from aerosol formation/emission to the resulting forcing (WP1-WP4). These studies will carry information on uncertainty at different scales, and the final uncertainty in aerosol forcing can be deduced from individual levels. The resulting holistic understanding of an individual scale-chain will indicate the level of justifiable complexity in aerosol and cloud microphysics in the models. Such experiments will provide unique quantitative insight into the components of the uncertainty in aerosol forcing.

FORCeS will use innovative approaches to overcome the challenge of lacking information on the pre-industrial state. As an example, FORCeS will use the modern-era variability in aerosols, which will provide analogues of aerosol-cloud interactions under distinct perturbations (WP4). Both natural (volcanoes, wildfires) and anthropogenic (decadal emission changes, ship-tracks, megacities) disturbances enable wide spatial and temporal constraints for aerosol sources. European-scale in-situ aerosol networks can capture not only the decadal decline in emissions, but also accelerated changes throughout e.g. the global economic crisis from 2008 onwards, e.g. (149). Modern-era analogues and state-of-the-art observations are crucial for disentangling the co-evolution of natural and anthropogenic aerosols and their climate effects. Atmospheric processing effectively combines the two sources and can provide distinct aerosol-chemistry feedbacks: for example, SOA formation from natural precursors can be substantially enhanced by anthropogenic chemistry involving anthropogenic species (28; 150).

The impact from FORCeS on the research community will be maximized through the development of new evaluation packages for community evaluation tools such as plug-ins for ESMValTool and the AeroCom interface based on the

Community Intercomparison Suite (CIS). These tools will be upgraded with robust observational constraints and metrics on aerosol-cloud interactions. Furthermore, throughout the project, WP3 and WP4 will collect information on crucial additional constraints (in-situ observations, remote sensing, model parameters) that are required to bring down uncertainties in aerosol forcing. These novel evaluation tools will be employed to provide a comprehensive evaluation of the base state and constraints on key processes in the ensemble of CMIP6 models in preparation for IPCC AR6, leading to the first observationally constrained aerosol forcing ensemble in CMIP climate models in preparation for IPCC AR7.

Results from original CMIP6 simulations, from process-related FORCeS simulations and upgraded post-CMIP6 simulations will allow for new or substantiated insights in the relative importance of aerosol processes and feedbacks under different climate conditions (WP5, WP6). Those cover e.g. changes in natural aerosol emissions and aerosol composition over time. Based on the resulting enhanced understanding and improved ESMs, it will also be possible to assess the overall transient climate sensitivity with the prospect of reduced uncertainty. As mentioned above, one of the expected outcomes of FORCeS is the identification of the most relevant processes governing ERFari and ERFaci. Improvement of the corresponding model descriptions should lead to more plausible climate change projections, as the most important processes are based on realistic parameterizations. This approach should lead to a more representative feedback behavior in response to climate forcing, with the potential for improved projections of regional and global climate. Furthermore, models with more realistic parameterizations can be better constrained by observations and thus allow for more relevant estimates of future climate change. By combining traditional methods (e.g. ESM analysis) with novel methodology (e.g. network analysis and machine learning), and by confronting models with present-day observations of relevance for aerosol forcing and TCS (i.e. emergent constraints), FORCeS ambition is therefore to move to a new paradigm in which climate projections are increasingly based on models that reproduce observed climate change for the right reason, and that simulate processes that are known to govern TCS with fidelity. The multi-pronged research framework within FORCeS has the potential to break the dead-lock in TCS research progress, and deliver a more constrained climate response estimate and uncertainty range that is well-founded and based on improved process understanding, bold new research approaches and better use of observations to confront models that have to date produced the right answer for the wrong reason. This will be achieved through a deviation from the conventional "one-model-one-vote" approach, and by making use of e.g. novel network analysis techniques that are well suited to identify links between forcings and climate response, as well as their underlying processes.

Finally, FORCeS will improve the knowledge of the relevant non-scientific stakeholder groups (such as policymakers and general public) beyond state-of-the-art through its communication activities (WP7). A stakeholder group will be defined and consulted for selecting climate metrics that are of interest to policy makers, non-governmental organizations and the general public. These metrics will then be used in the analysis of FORCeS ESM data to produce scientific knowledge that is of immediate interest to the public.

Innovation potential

The work in FORCeS is envisioned to lead to a number of potential innovations in various dimensions – both material and immaterial. Some of these opportunities are outlined below.

For users within the climate research community, FORCeS will produce a group of ESMs that have been updated with state-of-the-art knowledge on processes governing ERFari+aci. These models have the potential for molding the view on the main climate forcers and hence actions needed to reach PA targets. FORCeS will also produce novel and improved parameterizations of critical aerosol processes and feedbacks – which are envisioned to become the state-of-the-art and can be used within any GCM or ESM simulating aerosols.

The new data evaluation packages and statistical toolkits developed within FORCeS are products that have the potential for providing added value to a large number of users outside the FORCeS partners and scientific community in general. Such software might have the potential for being commercialized / trademarked for various data evaluation purposes, as these tools will be tailored to be able to analyze big data – a topic of which is of major interest for many actors in both private, public as well as the third sector. The commercial and non-commercial applications of artificial intelligence, machine learning tools, advanced statistics and numerical algorithms in general have been exponentially increasing and will likely do so in the future as well.

The experimental work particularly within WP 2 has the potential for leading to technological innovations within the sector of instrument development, particularly in terms of the development of new analytical techniques, portable sensor technologies and approaches for analyzing remote sensing observations.

FORCeS will develop and use innovative new metrics for describing climate evolution and aerosol impacts on it. These metrics will be designed with the end-users to yield products with high potential for being used and referred to in various contexts including e.g. policies for meeting the PA targets. Furthermore, the time-dependent aerosol

forcing data produced within FORCeS has a lot of potential for serving as input for various simplified climate modeling approaches, integrated assessment models and policy frameworks, applied outside the immediate atmospheric / climate research community. The results from FORCeS have a large potential for acting as seeds for new approaches for climate change mitigation and adaptation policies, also coupled to policies improving e.g. air quality and thereby human and ecosystem health. Such innovative win-win scenarios are, we believe, a necessity for breaking through the resistance for effective climate policies. In fact such disruptive steps forward in 1) the understanding of climate change by general public; 2) effective abatement policies are critical for meeting the PA targets.

2. Impact

2.1 Expected impacts

2.1.1 FORCeS contribution to specific impacts mentioned in the work programme

The objectives of FORCeS (Section 1.1) are specifically designed to meet the expected four impacts of the call. These impacts are listed below (denoted with letters with *I-IV*) and the corresponding FORCeS objectives (denoted with *O1-O3*) are given within parentheses. Table 2.1 presents quantifiable indicators and targets that FORCeS will use to measure its achievements.

I. Supporting major international scientific assessments (O2)

At a fundamental level, FORCeS will contribute with publication of scientific findings in the peer-reviewed literature (WP1-WP7). These results will be assessed at an international, global level by e.g. the IPCC, and for specific regions and pollutants by e.g. the Arctic Council through the Arctic Monitoring and Assessment Programme (AMAP), the Baltic Assessment for Climate Change (BACC), the North Sea Region Climate Change Assessment (NOSCCA), Future Earth and its global research program The International Global Atmospheric Chemistry Project (IGAC) through e.g. the Tropospheric Ozone Assessment Report (TOAR) and The Global Energy and Water Exchanges (GEWEX) project as a part of the World Climate Research Program (WCRP). In addition, FORCeS models (see Table 1.3) will contribute with simulations to CMIP6 and CMIP6-endorsed experiments, which are fundamental for the next IPCC assessment report. Analysis of CMIP6 models and simulations is also part of FORCeS (WP5 and WP6). This implies that the FORCeS team will contribute to the peer-reviewed literature being assessed by the IPCC both via the team's own studies but also via contributions from other scientists analyzing results from the FORCeS models. The improvement of FORCeS ESMs, for example by considering organic carbon, brown (absorbing) carbon, nitrates and ultrafine particle growth in an appropriate manner (WP1), as well as cloud microphysical processes and cloud impacts on aerosols (WP2), will generally lead to more accurate climate projections, benefiting future model intercomparison projects and scientific assessments. The FORCeS team will also participate in the writing and review process of the next IPCC assessment. Within the consortium, two participants (Prof. Myles Allen, Prof. Trude Storelvmo) will be coordinating lead authors (CLAs) of the IPCC AR6, three (Prof. Terje Berntsen, Prof. Astrid Kiendler-Scharr, Dr. Zbigniew Klimont) will be lead authors (LAs), and seven (Prof. Myles Allen, Dr. Markus Amman, Prof. Terje Berntsen, Prof. Maria Cristina Facchini, Prof. Maria Kanakido, Prof. Veli-Matti Kerminen, Prof, Ulrike Lohmann) have been CLAs and LAs in past IPCC assessment reports. The strong involvement of FORCeS scientists in the work of e.g. the IPCC and especially in the forthcoming AR6 report assures that findings from FORCeS will be considered and assessed by the IPCC, as well as in other international scientific assessments.

II. Increase confidence in climate projections (O1)

FORCeS will use observational data and novel methods to constrain and improve the description of aerosols and their impact on clouds and climate in Earth system models (WP1-WP6). By targeted improvements of critical model processes, the uncertainty in anthropogenic aerosol forcing estimates will be reduced (WP3, WP5). This will significantly narrow the temperature span for a certain emission scenario, resulting in a decreased uncertainty in estimates of the transient climate response (WP6). As the climate response to the atmospheric aerosol content is almost immediate, reducing the uncertainty in aerosol forcing is fundamental when addressing the near-term climate evolution. FORCeS will also increase confidence in climate change projections by eliminating implausible transient climate sensitivities and climate responses (WP5, WP6).

The response of the climate to changes in aerosol forcing can be highly regional (151; 8), thus having drastic implications for specific parts of the world. Work within FORCeS will lead to increased confidence in regional climate change projections, for example in the highly vulnerable Arctic and over the densely populated Europe, and help the communities in these regions prepare for and abate climate change through targeted mitigation and adaptation policies. Furthermore, FORCeS will move past the traditional global metrics for assessing climate change, producing metrics relevant for designing effective policy instruments in the context of meeting the PA targets (WP6, WP7). FORCeS consortium members are active within e.g. the AeroCom and GAP communities (cf. Fig. 1.3c) and will work jointly with them towards a better understanding and improvement of the predictive power of climate

models in reproducing measured aerosol loadings and properties as well as aerosol impacts on climate. The work in FORCeS will result in a group of leading European climate models (WP5, WP6) where the descriptions of aerosol and cloud properties are based on fundamental understanding of the relevant physical and chemical processes (WP1-WP3) as well as observational constraints from the most extensive set of data utilized to date for this purpose (WP3, WP4). Synthesis of this vast amount of knowledge and observational data will be achieved through the development and application of innovative numerical techniques and evaluation tools, which will be made openly available to the climate research community (WP4 and WP6). This open approach of FORCeS science will enhance the impact beyond the family of climate models and ESMs developed and applied within the consortium (see Table 1.3) and beyond the lifetime of FORCeS. After FORCeS, a considerably larger fraction of models used for climate prediction will stand the test of producing the right results for the right reasons. Furthermore, the components contributing to the uncertainty in aerosol will be quantified to a level not achieved to date, allowing future work after FORCeS to target the key uncertainties in a systematic manner.

III. Providing added value to decision- and policymakers (O3)

By improving our understanding of aerosol forcing, constraining transient climate sensitivity, and producing reliable projections of climate, FORCeS will provide added-value to decision and policy makers (WP6, WP7). Climate projections with a reduced uncertainty span will be of direct use in addressing climate change and developing co-beneficial air quality and climate mitigation and adaptation strategies. As a necessity for improving air quality and health, anthropogenic emissions of aerosol particles and their precursors are likely to decrease in the near future in many parts of the world (8) These emission changes may have profound impacts on important climate variables such as precipitation and circulation patterns (152; 103) potentially influencing the frequency and strengths of draughts and severe flooding. FORCeS will provide essential basic information for developing cost effective multi-beneficial abatement strategies not only for climate but also for air quality, providing better health, resilient food production and increased carbon-sequestration supporting several of the United Nations' Sustainable Development Goals (SDGs), in particular SDG 3, 7, 11, 13 and 15.

FORCeS will also exploit and benefit from the expertise of the Scientific Advisory Group of FORCeS (Section 3.2.6), the Swedish EPA, IIASA and INERIS in the dissemination of results to a wider user community including decision- and policymakers (WP7). In addition, the FORCeS project will coincide with the UNFCCC "Talanoa Dialogue" informing the first full stocktake of progress towards the long-term temperature goal of the PA (2019-2023). FORCeS will contribute extensively to this dialogue through Conference of Parties (COP) side-events stakeholder workshops (WP7). FORCeS will also organize a workshop and produce policy briefs to disseminate knowledge to climate data users and a wide range of other stakeholders (Identified in Task 7.1). Furthermore, FORCeS consortium members are active within the Climate and Clean Air Coalition (CCAC), the Arctic Council and its monitoring and assessment (AMAP), the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and Coordinated Regional Climate Downscaling Experiment (CORDEX) (cf. Section 1.3 (b)) and will work with them towards a better understanding of the regional impact of aerosols on climate as well as on the link between climate and air pollution mitigation. With organizations such as Future Earth and Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (Section 1.3 (b)), FORCeS will work towards better knowledge of the general impact of aerosols on the atmosphere, including implications for climate but also for humans, e.g. (153) and ecosystem health (154) as well as impacts on e.g. visibility in cities (155) or erosion of built infrastructure by air pollutants.

IV. Sustaining Europe's leadership in climate science (O1, O2)

This goal will be achieved through the i) continued long-term improvement by targeted development of key aerosol and cloud parameterizations of leading European ESMs (WP1-WP5); ii) profiting and building on a wealth of unique data and model development obtained in previous European projects (WP1-WP6); iii) fostering collaboration between European climate scientists working on different scales, from different perspectives and with different methods and external networks (WP1-WP9); iv) promoting and training researchers and research leaders within the project (WP1-WP9). FORCeS brings together leading scientists working on aerosol processes, cloud physics, radiative forcing and climate feedbacks from 21 research institutes and universities distributed over 13 European countries. The consortium will support and inspire the development of a new generation of leading scientists by recruiting and training outstanding early career scientists. For example, a summer and a winter school will be organized to further support this demand (Task 7.2). Furthermore, the consortium is led by two, female European mid-career scientists who through the project will be established as internationally recognized research leaders thus contributing to forming the next generation of European leadership in aerosol-climate science. In addition, all work packages are set up with two co-leaders (cf. Section 3.2) which will boost knowledge exchange between different scientific communities as well as between scientists at different stages of their careers, ensuring a strong European leadership in climate science also in the future. FORCeS will strongly promote gender equality aspects throughout

the project (see Section 3.2.10). It is worth noting that 6 out of 9 work packages are co-led by women and that the SAG consists of three female and two male experts.

The FORCeS consortium also includes six lead authors for IPCC AR6 chapters, constituting an important avenue for strengthening and consolidating Europe's leadership in climate science. Furthermore, the unique interaction created within FORCeS between the producers and end-users of climate science through i) the establishment of the Stakeholder Group (Task 7.1).; ii) the participation of users such as NV, INERIS and IIASA in the consortium; and iii) the other dedicated activities (e.g. workshops) within WP7; FORCeS will further enhance the applicability of the European climate science and its impact on society. The dialogue established in these interactions between the scientists and the stakeholder groups will ultimately result in better science, but also in a better understanding of the European public of the interactions between climate, air quality and weather.

Table 2.1: FORCeS overall impact targets and monitoring

Impact	**FORCeS specific impact**	**Indicator**	**Target**
Supporting major international scientific assessments	Radiative forcing estimates considering aerosol and cloud components/processes previously neglected or simplified by e.g. the IPCC.	Publications in peer-reviewed literature of revised forcing estimates where OA, absorbing carbon, nitrates and ultrafine particle growth are considered in an appropriate manner. Utilization and reference to FORCeS results in scientific assessment reports, in particular reports by the IPCC.	At least four peer-reviewed publications where each of the mentioned aerosol compounds/processes is considered. Mention and reference of the impacts of OA, absorbing carbon, nitrates and ultrafine aerosol dynamics in future international assessments, in particular reports by the IPCC.
		Publications in peer-reviewed literature of revised forcing estimates where cloud droplet activation, droplet growth, entrainment, aerosol scavenging and ice formation processes are considered in an appropriate manner. Utilization and reference to FORCeS results in scientific assessment reports, in particular reports by the IPCC.	At least four peer-reviewed publications where each of the mentioned cloud processes is considered. Mention and reference of the impacts of cloud droplet activation, droplet growth, entrainment, aerosol scavenging and ice formation processes in future international assessments, in particular reports by the IPCC.
	Reduced uncertainty in estimates of anthropogenic aerosol radiative forcing.	Publications in peer-reviewed literature of radiative forcing estimates constrained by observational data for the period 1950 to present. Utilization of the reduced uncertainty in anthropogenic aerosol forcing from FORCeS quoted in scientific assessment reports, in particular reports by the IPCC.	At least one peer-reviewed publication with constrained radiative forcing estimates. Mention and consideration of the components contributing to the uncertainty in aerosol forcing identified within FORCeS in future international assessments, in particular reports by the IPCC.
	Evaluation of CMIP6 ESMs in terms of their compliance with existing and new emergent constraints.	Publications in peer-reviewed literature. Utilization of the evaluation of FORCeS ESMs in scientific assessment reports, in particular reports by the IPCC.	At least one peer-reviewed publication on CMIP6 model compliance with emergent constraints. Mention and consideration of the evaluation of FORCeS ESMs in future international assessments, in particular reports by the IPCC.

Increase confidence in climate projections	Improved representation of key aerosol and cloud processes in ESMs contributing to the largest uncertainty in estimates of aerosol forcing.	Quantitative tools to identify key processes governing aerosol forcing. Number of ESMs with the processes identified and parameterized within FORCeS utilizing the parameterizations developed within FORCeS.	Top five aerosol and cloud processes influencing aerosol forcing identified. Peer-reviewed publication with recommendations on how to improve their representation in models and needs for future observations. In addition to the FORCeS ESMs, implementation of FORCeS parameterizations in at least one model outside the consortium.
	New community evaluation tools, emergent constraints and climate metrics to evaluate ESMs.	Quantitative tools and/or constraints. Use of the tools and metrics by the climate research community outside FORCeS consortium.	Tools or constraints tailored for at least five aerosol/cloud processes or feedbacks and a platform to share them with the research community. Downloads of the evaluation tools by at least two users outside the FORCeS consortium.
Providing added value to decision and policy makers	Compound-specific information on future anthropogenic aerosol concentrations and their impact on climate change.	Model scenario of near-future aerosol composition and aerosol forcing trends.	Policy brief on impact of future anthropogenic aerosol emission changes on aerosol composition and climate change.
	Contribute to the understanding of whether future anthropogenic aerosol and GHG emission scenarios comply with the PA.	Ensemble model simulations assessing emission pathways compatible with the PA goals.	Policy brief regarding how different GHG and aerosol emission scenarios comply with the PA.
	Develop and deliver climate projections using metrics relevant for regional decision-making.	Dialogue with end-users on the climate information with most relevance for them. Scientific publications at the interface of climate science and policy.	Workshop discussing the metrics and outcomes of interest for decision- and policy-makers. At least one publication in a journal with a broader readership than the traditional climate / atmospheric science community.
	Deliver FORCeS results to international organizations involving decision- and policymakers like the CCAC, the Arctic council, CLRTAP, CORDEX, GESAMP and Future Earth.	Presence and active participation of FORCeS researchers in international organizations involving decision- and policymakers.	At least one FORCeS representative in the general assemblies / meetings of each of the organizations mentioned over the duration of the project.
Sustaining Europe's leadership in climate science	Improved descriptions of key aerosol and cloud processes in European ESMs.	Implementation of new/revised parameterizations in ESMs.	Improved parameterizations implemented in three FORCeS ESMs and a peer-reviewed publication on the impact of this implementation.
	Training a new generation of	Winter and summer schools for early career scientists.	One winter and one summer school organized.

	European climate scientists.		
	Exploiting data and knowledge gained in previous EU projects.	Model parameterizations developed/revised based on recommendations from previous EU projects.	At least three developed/revised parameterizations reported in peer-reviewed publications.

2.1.2 FORCeS additional impact contributions

The main focus of FORCeS is to contribute to the specific impacts mentioned in the topic call as outlined in Section 2.1.1. Nevertheless, the close engagement with end-users and stakeholders (WP7, Task 7.1) ensures additional societal impacts during and beyond the lifetime of the project, e.g. on governmental policies that will affect air quality and climate and investments in innovation and infrastructure (Figure 2.1). A key objective of the global climate research community is to significantly reduce uncertainties in climate projections. FORCeS will contribute directly to this task and will outline recommendations for future model development and observational strategies to further narrow the uncertainty ranges in aerosol forcing (Table 2.1).

In general, the FORCeS research is likely to initiate additional impacts in the form of innovations stemming from the new knowledge created (see Sect. 1.4). Such innovations include e.g. new technologies, as well as data analysis software and new numerical algorithms that can be applied on other questions than those involving aerosols, clouds or even climate.

Aerosol particles affect both climate and air quality - two interlinked major global societal challenges. According to the World Health Organization, ambient and household air pollution cause about 7 million premature deaths per year globally. Air pollution also damages buildings, crops and disrupt air traffic. At the same time, the financial and human costs of climate change are difficult to estimate but are most likely just as severe. These challenges clearly demand a pan-European and globally integrated effort to develop, trial and implement effective mitigation strategies ranging from environmental management to socio-economic strategies. FORCeS will have a unique approach in that the project will inform stakeholders (Task 7.1) on how to simultaneously improve air quality and mitigate climate change in the most efficient way.

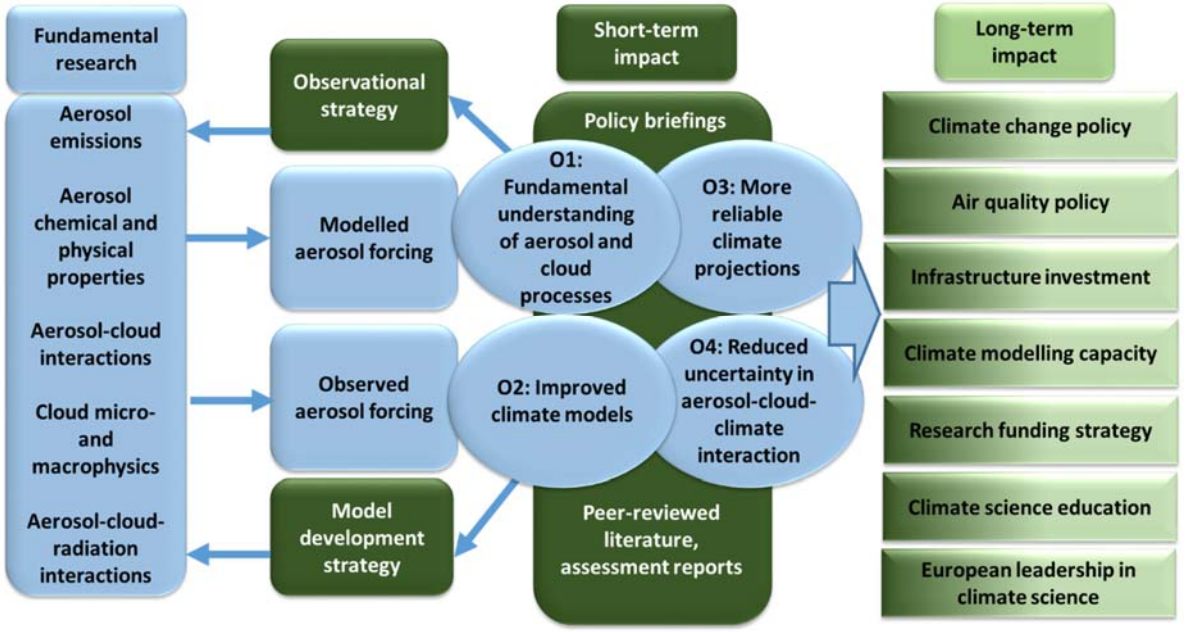

Figure 2.1 Schematic of the short-term (1-4 year) and long-term (>4 year) impacts of FORCeS outcomes.

2.1.3 Potential barriers and obstacles

No major risks or obstacles are foreseen that would prevent FORCeS from achieving its impact goals. Extensive measures will be taken to maximize the impact of the project as outlined in Section 2.2. One potential obstacle could be that the relevant scientific findings created within FORCeS are not sufficiently diffused to decision and policy makers. This potential issue will be mitigated by the synthesis of FORCeS science produced in WP9 (Task 9.4) and the stakeholder interaction organized in WP7 (Task 7.1). Furthermore, professional communicators (e.g. permanent staff members at SU and SMHI) will be involved in tailoring the communication activities so that they are

comprehensible by the target audiences, while delivering accurate and relevant messages, which allow the stakeholders to take the necessary decisions efficiently and within reasonable time frames (e.g. in relation to PA). Where necessary, the ***precautionary principle*** will be applied when communicating policy-relevant results and recommendations, following the principle 15 of the Rio Declaration (156) "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". Another, similar definition of the precautionary principle (which is also generally followed by European Union in its environmental policies) can be found in the Wingspread statement of the precautionary principle: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically".

2.2 Measures to maximize impact

The communication of FORCeS activities and dissemination of project outcomes to target groups are essential for achieving the operational and strategic objectives of FORCeS. A preliminary 'Plan for the exploitation and dissemination of FORCES Results' and plan for FORCeS communication activities are given below. These plans will be further developed during the project into a 'Plan for the Exploitation and Dissemination of Project Results (PEDR, WP8, D8.4) and 'Data Management Plan' (DMP, WP9, D9.2).The updated plans will have the overall goal of facilitating the uptake and exploitation of project results. The PEDR will contain a Media and Communications Strategy and contain more details about specific stakeholders, deadlines, tools and evaluation measures. Both plans will be working documents that are regularly modified and elaborated during the project's lifetime in order to reflect the latest findings as well as unforeseen changes. In general, FORCes will make the results as open and accessible as possible to all interested parties.

The SAG of FORCeS will be set up to maximize the expected impact on the scientific community, policy-making and the society in general (Section 3.2.6). The research and new knowledge generated within FORCeS will be of societal benefit, as it will contribute toward solutions of societal challenges. As such, the foreground knowledge needs to be disseminated in an optimum way for impact and re-use of results, according to Responsible Research & Innovation (RRI) principles. FORCeS will optimize the dissemination and impact of foreground knowledge along the full knowledge production chain, and integrate Open Science principles in its PEDR (D8.4) and DMP (D9.2). In support of the EC Digital Agenda and the Economic Growth agenda of the Innovation Union (Green Action Plan), FORCeS will integrate Grant Agreement Article 29 into its workflow.

(a) Dissemination and exploitation of results

Plan for the exploitation and dissemination of FORCeS results

Table 2.2a summarizes the most important dissemination channels of FORCeS results and activities while Table 2.2b displays FORCeS communication channels. WP8 will provide a more detailed plan in the PEDR (D8.4).

Peer-reviewed literature

In general, FORCeS will aim to publish its research in leading, peer-reviewed scientific journals in the field such as *Geophysical Research Letters, Journal of Geophysical Research, Atmospheric Chemistry and Physics, Journal of the Atmospheric Sciences, Journal of Climate, Environmental Science and Technology* and *Tellus.* FORCeS will also gather its results in a special issue in one of these journals. More technical results and development will be published in journals such as *Journal of Advances in Modeling Systems, Atmospheric Measurement Techniques* or *Geoscientific Model Development.* A selected number FORCeS publications, e.g. the scientific landmark papers, will target high-impact journals such as *Nature, Nature Geoscience, Nature Climate Change, Science or Proceedings of the National Academy of Sciences.*

International Conferences and meetings

The FORCeS team will disseminate and communicate FORCeS findings at relevant topical meetings (organized by e.g. GEWEX-GAP, AeroCom, cf. Fig 1.3c) as well as established international conferences such as the European Geosciences Union General Assembly, the American Geophysical Union Meetings, the International Conference on Clouds and Precipitation and the International and European Aerosol Conferences.

Table 2.2a: FORCeS Dissemination channels

Target groups	FORCeS results of interest	Dissemination channels
Stakeholders - Policy and decision makers (IPCC, European and international institutions with	Improved prediction of climate evolution in the context of climate policy	Stakeholder workshop organized as a side event to IPCC's Conference of Parties (COP) and/or CLRTAP meetings Policy briefings

responsibilities in climate and air quality issues, national environmental protection agencies)	Improved quantification and reduction of uncertainty related to aerosol-cloud-climate interaction	Project web page
Data users (FORCeS project participants, climate research community, climate assessment groups)	Key aerosol and cloud parameterizations to be incorporated in Earth System Models Metrics and emergent constraints for aerosol and cloud processes, radiative forcing, climate sensitivity and transient climate response. Community evaluation tools Field observations Model output User documentation	Data user workshop Peer-reviewed publications Project web page Data and software repositories used by the FORCeS team (e.g. EUDAT, EBAS, AeroCom, ESGF, PANGAEA, Bolin Centre Database, GitHub, etc.)
Climate and air quality research communities.	New fundamental understanding of physical and chemical processes involving aerosols and clouds; Climate models with new and improved descriptions of aerosols and clouds and their interactions.	Peer-reviewed publications, including landmark scientific papers. Project web page Participation in seminar, workshops and conferences.
All target groups	Peer-reviewed publications Project reports	Project web page

Management of research data and output

FORCeS will participate in the Open Research Data Pilot and will make the results of FORCeS as open and accessible as possible to all interested parties. WP9 will provide a first version of the Data Management Plan (DMP) in month 6 of the project (D9.2). The general aspects of both the PEDR and DMP are described below and the detailed aspects will be continuously updated during the project lifetime.

Software, metrics and other tools

FORCeS will develop different observational constraints and metrics (D4.1 and D6.2) as well as community evaluation tools (D4.2) and updated parameterizations of aerosol and cloud processes (D1.1, D1.2, D2.1). As far as license agreements permits, software, metrics and tools will be publically available through the project web site and source repositories maintained by the partners responsible for the development of the tools during and after the project. If suitable, they will also be submitted as part of journal publications, ensuring Open Access. The number of downloads of tools and metrics from the FORCeS web site will be monitored by the Project Office (Task 8.1).

Datasets and metadata

FORCeS will ***collect data*** and deliver synthesized and new observational datasets with substantial spatial coverage. Datasets are collected from laboratory, in-situ and flight observations as well as remote sensing (WP2 and WP7). FORCeS will also ***generate data*** using global climate models (WP3, WP5 and WP6). Careful measures will be taken to ensure maximum impact of the data within the consortium, throughout the spectrum of external users, before and after the project lifetime. As a rule, the partners producing the data will take the main responsibility in storing, processing and publishing the data produced, while the FORCeS website will serve as a metadata platform to guide the end-users to the relevant data sets. Where possible, FORCeS will make use of existing infrastructures for storing, managing and openly sharing data, such as the EBAS, AeroCom, PANGAEA and ACTRIS databases, eSTICC hub for data with relevance for the Arctic climate, as well as the databases of the respective partner institutes (e.g. the Bolin Centre database at SU).

User documentation, project reports and peer-reviewed literature

FORCeS will generate different types of documentation, reports and scientific articles. All of the material will be available on the project web site (most of it in the public domain, parts of it accessible for specified user groups

protected with a password) which is managed by the Project Office (D8.1, D8.2). The web site will serve as a central communication and dissemination source of FORCeS information. It will be user friendly and updated regularly. The scientific results from FORCeS will be published in peer-reviewed scientific journals with Open Access. Furthermore, the individual researchers participating in FORCeS are encouraged to share their publications and results through their social media presence, including platforms like Facebook, Twitter, ResearchGate and LinkedIn.

General data management considerations

Data Standards: Providing detailed information of metadata that describes the content and context of data is important, in particular since some of the data may initially be archived locally by each project partner due to large data volumes. The DMP (D9.2) will provide a template for the metadata information, which should be added to all datasets generated by FORCeS. Data submitted for long-term storage in public archives will require more detailed descriptive metadata suitable for data discovery and usage beyond the lifetime of the project. These metadata specifications and procedures for gaining access to project data sets will be available from the public FORCeS website. The infrastructure of FORCeS models produces data in variable formats. For targeted model intercomparisons, FORCeS model output will be harmonized and standardized accordingly, as in the CMIP-protocol (CMOR-standard). Regarding observational datasets, special attention will be given to model-observation data fusion and integration, e.g. using the Community Intercomparison Suite (www.cistools.net), managed by UOX.

Data Availability: The guiding rule is to have the data available with as open licences as possible, preferably Creative Commons CC-BY 4.0. There can be individual exceptions of this rule, and the produced datasets will stay as property of the beneficiaries so that the final decision of availability and licensing stays with the data owner. For ESM output, FORCeS will take full advantage of standard Earth System data distribution infrastructures such as Earth System Grid Federation (ESGF). Currently, several FORCeS partners either have an ESGF node or are in the process of acquisition. ESGF allows an open standard, secure global distribution channel with tens of thousands of users.

Data Curation and Preservation: Initial curation and quality control is the responsibility of the data producing beneficiary. Data produced in the project will be made available through EUDAT (http://www.eudat.eu/) services The European Data Infrastructure EUDAT provides services for research data covering the whole data life-cycle (157). The main services that are planned to be used are B2SHARE for storing and accessing small-to-medium-sized datasets and B2SAFE for safe data storage and replication. The metadata of datasets deposited in B2SHARE is automatically included in the EUDAT metadata catalogue B2FIND and they are assigned with persistent identifiers, making the data accessible to other researchers by default. For moving data between storage locations and large computing facilities EUDAT provides the B2STAGE service.

Knowledge management and protection

FORCeS will adopt a strategy for knowledge management that follows the guiding principles of H2020 on Intellectual Property (IP) management. Procedures for the execution of these principles will be defined in the Consortium Agreement (CA). The CA will regulate dissemination, protection and exploitation of IP and necessary Access Rights, Liability, Confidentiality and Indemnification arrangements between partners according to the specific requirements from the H2020 Model Grant Agreement (GA).

Knowledge management

The CA will define precisely which project outcomes will be published under the Creative Commons license, which information is owned by a third-party, which information is put under restricted access, and which information can be published attributed to specific individual of the consortium. FORCeS partners will be entitled to publish the project results in the usual scientific form. One of the pages of the FORCeS website will contain an overview and archive with direct, open access to all published information: scientific articles and preprints (green access), other publications, press releases and conference papers.

A strategy for innovation and knowledge management will be produced in WP8 within the PEDR (D8.4) by M6 in the project. A final version of this will be produced in M48 of the project (D8.11) to outline how knowledge management will be done after the end of the project. The project office will ensure that FORCeS complies fully with the GA and fulfils any requirements concerning knowledge management and protection.

Open Access publication

In line with the Grant Agreement obligations, all FORCeS publications, including peer-reviewed scientific publications and other possible types of scientific publications such as monographs, books, conference proceedings, and reports will be published as open (gold) access. In all cases, an electronic copy of the published or accepted version for publication will be deposited in academic or institutional repositories of the affiliated project partners. This will be done as soon as possible and at the latest upon publication. All published material will contain an acknowledgement to the research funding from the European Union and Horizon 2020.

Intellectual Property Protection

It is not expected that IP such as patents will arise during the lifetime of FORCeS. Each of the partners will have the right to exclude specific pre-existing knowledge (background IP) from the other partners' access, as far as the restrictions are announced before the signature of the Grant and Consortium Agreements or before the effective joining of a new partner. The overall aim of the knowledge management strategy and protection will be to maximize the chances of effective exploitation of the project's research results.

(b) Communication activities

A key objective with the communication activities is to engage the public, stakeholders and other scientists to raise awareness of FORCeS activities and receive feedback on the ongoing work. Efficient communication of FORCeS results is therefore key for the success of the project. The FORCeS team has ample experience in communicating science findings in a clear manner to a range of different recipients, including the general scientific community, media, policy and decision makers and the general public (cf. Section 3 and 4). Table 2.2 outlines proposed FORCeS communication activities. These will be updated and described in more detail in the Media and Communications Strategy that will be a part of the PEDR produced by WP8 (D8.4). The communication will be done in two different domains: (a) internally within the consortium and (b) externally with different target audiences. The updated PEDR plan will also contain measures, indicators and target values for the communication activities that can be used in the reporting to the EC.

To boost the reach of FORCeS communication, collaboration will also be initiated with other related projects within the LC-CLA-08-2018 call, with the aim to establish common communication channels (D9.3).

Table 2.2b FORCeS communication channels

Target audience	Objective	Material/Content	Channel	Frequency	Responsibility
FORCeS partners	Ensure an effective and integrated project	Progress and results Questions, risks, issues	Internal Project webpage General Assemblies Teleconferencing Teleconferencing Project newsletter	Regular updates of webpage Five GA's As required Every 3 months Every 6 months	WP7, WP8, WP9 WP8 All partners Executive Board WP 8
Early career scientists	Involvement in the forefront of climate science Feedback on their research Interaction with other early career scientists and experienced leading scientists Network building	Progress and results Methodologies Datasets	FORCeS website Summer and winter school Peer-reviewed publications Project newsletter	Regular updates Two As appropriate Every 6 months	WP7, WP8 and WP9 WP7 All WP8
Climate and air quality research communities	Share knowledge between projects and with interested scientists and the public	Project progress and results	FORCeS website Project newsletter Participation in workshops, seminars and conferences	Regular updates Every 6 months When appropriate	WP7, WP8, WP9 WP 8 All partners

Data users		Methodologies, Datasets	FORCeS website Project newsletter Participation in workshops, seminars and conferences	Regular updates Every 6 months When appropriate	WP7, WP8, WP9 WP 7 All partners
Stakeholders - Policy and decision makers	Ensure maximum societal benefit Ensure the project is conducted to deliver useful results	Project progress and results Contribution to IPCC AR6 Relevant user information	FORCeS website Project newsletter Policy briefings Stakeholder group workshop Lectures and presentations	Regular updates Every 6 months In line with publications timetable One When appropriate	WP7, WP8, WP9 WP8 WP7 WP7
Media	Ensure project is visible to public Ensure project is reliably communicated Engagement with the scientific process	Project progress and results	FORCeS website Press release and media contacts Public lectures and presentations Project flyer Social media	Regular updates Regular and proactive media activity Regular activity Invitations to relevant events Regular updates	WP7, WP8, WP9 WP7 WP7 WP7, WP8 WP9 WP7
General Public	Ensure the interested public is aware of the project Engagement with the scientific process	Relevant results and their implications FAQs	FORCeS website Public lectures and presentations Project flyer Social media	Regular updates Regular activity Invitations to relevant events Regular updates	WP7, WP8, WP9 WP7

3. Implementation

3.1 Work plan — Work packages, deliverables

3.1.1 Overall structure of work plan

The work within FORCeS is organized into nine interlinked Work Packages (WPs), listed in Table 3.1a and outlined in Fig. 3.1. WPs 1-6 contain the bulk of the research work, WP7 is dedicated for stakeholder interaction, dissemination and communication to maximize the impact of the research conducted in WPs 1-6, WP8 collects all the general management and coordination activities, and WP9 the scientific coordination activities.

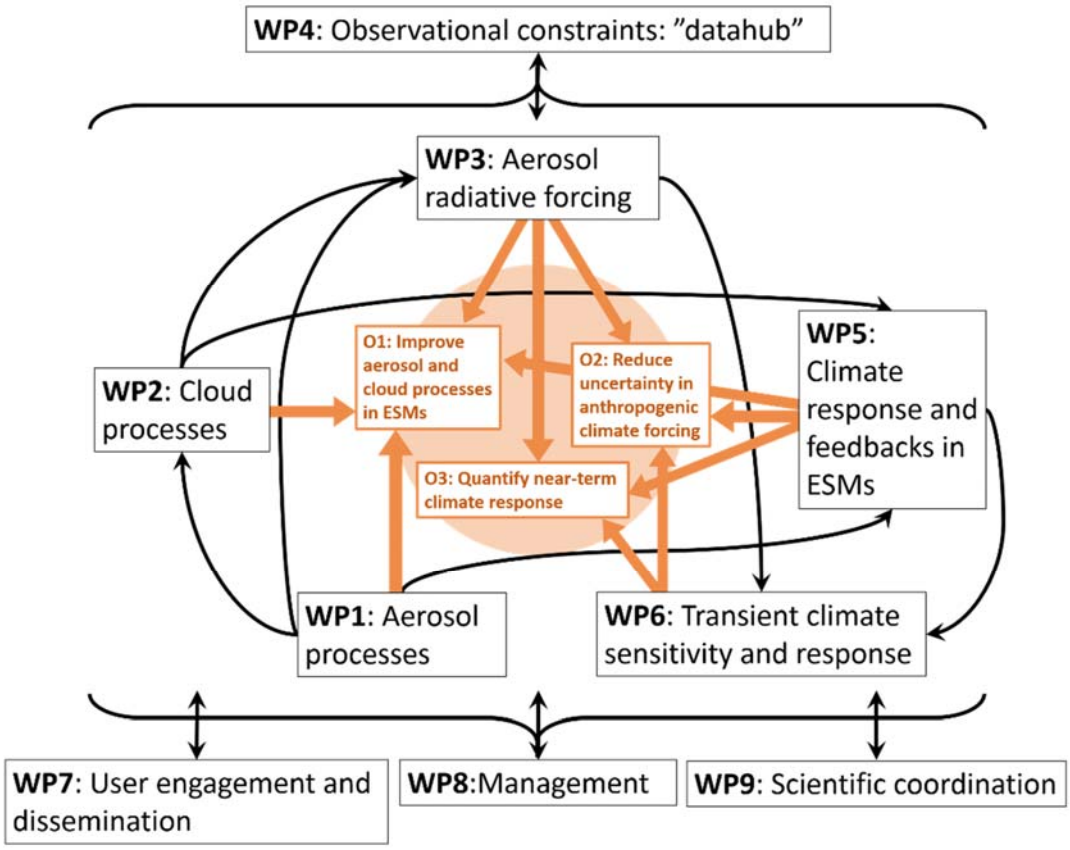

Figure 3.1 Graphical representation of FORCeS Work Package structure, their interactions (black arrows) and contribution to the overall objectives (O1-O3).

WPs 1 and 2 focus on improving the fundamental understanding of the key aerosol and aerosol-cloud interaction processes, ultimately targeting an improvement of the descriptions of these processes in the FORCeS ESMs. WPs 3 and 4 aim at constraining the transient aerosol forcing and its' uncertainty in the past and the near future (1950-2050), incorporating both modeling approaches and observational constraints, and thus feeding into WPs 5 and 6. Specifically, WP4 serves as a hub for the experimental data produced, collected and synthesized within the project and therefore interacts with all of the other scientific WPs. WPs 5 and 6 use ESMs as their main tools, and are the WPs quantifying the feedbacks related to aerosol forcing, and ultimately the impact of the new improved estimates of aerosol forcing on climate response and sensitivity. All WPs contribute to at least one of the overall objectives (see Sect. 1.1), and WPs 3-5 and 7-9 to all three. The interactions between the WPs are ensured by e.g. personal communication at meetings and workshops, teleconferencing, reporting of the major deliverables and updates on the project internal website (see also Sections 2.2 and 3.2), as well as the shared leadership of the WPs to ensure overlap in the personnel and partners contributing to the different WPs. The duration and timing of the different WPs and the Tasks within them is presented as Gantt Chart in Fig. 3.2, following the overall work plan (see Sect. 1.3).

3.1.2 Timing of the different work packages

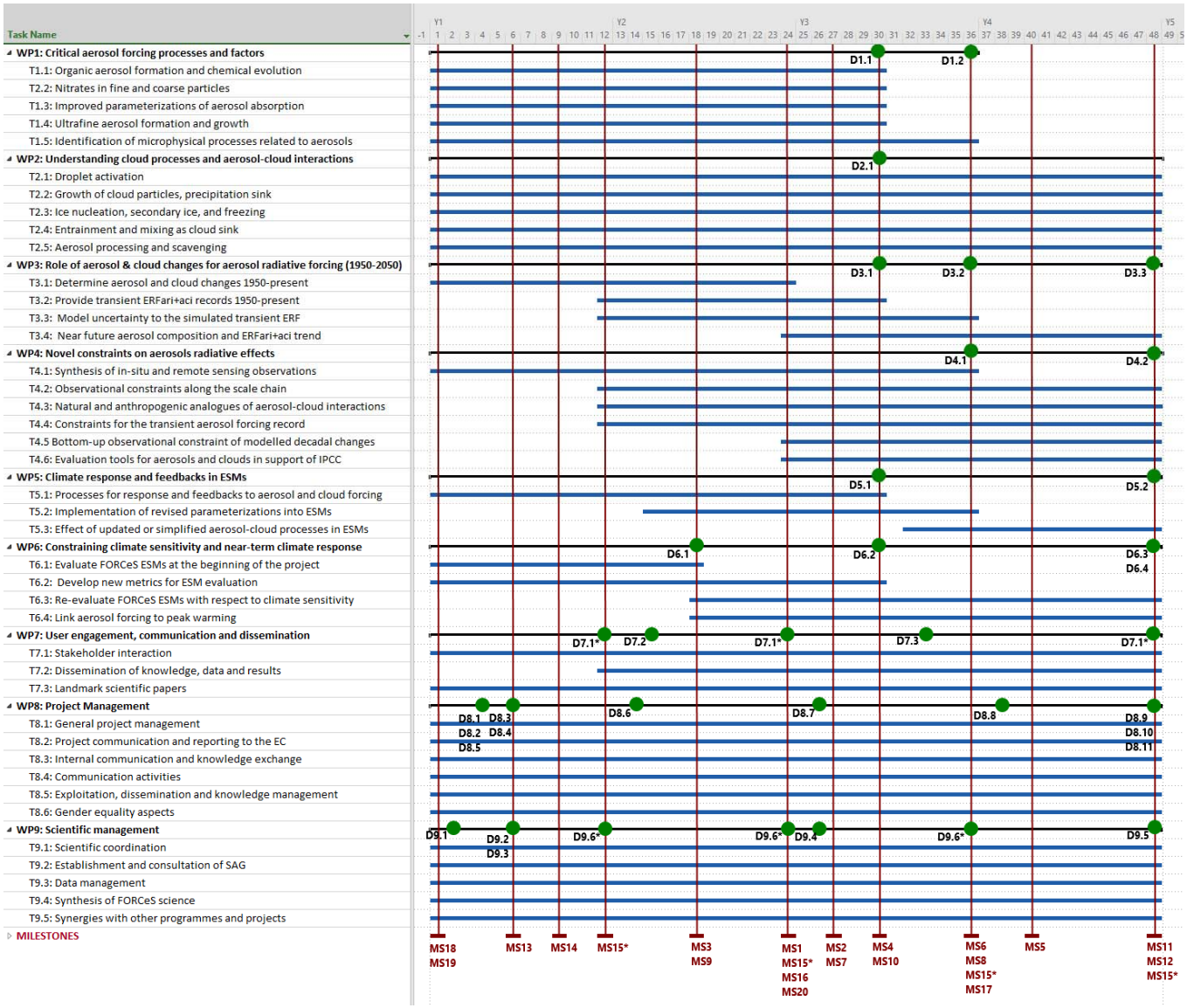

Figure 3.2 The timing of the FORCeS Work Packages, Deliverables and Tasks (Gantt Chart).

3.1.3 Work packages

Table 3.1a gives a summary of FORCeS WPs. Details descriptions of the WP contents, broken down into Tasks, Deliverables and Milestones are presented in Tables 3.1b and 3.1c.

Table 3.1a List of Work Packages

Work package No	Work Package Title	Lead Participant No	Lead Participant Short Name	Person-Months	Start Month	End month
1	Critical aerosol forcing processes and factors	6,5	FORTH, FZJ	196	1	36

2	Understanding of cloud processes and aerosol-cloud interactions	12,15	UEF, ULEI	212	1	48
3	Role of aerosol and cloud changes for aerosol radiative forcing between 1950 and 2050	9,3	MetNo, ETHZ	169	1	48
4	Novel constraints on aerosols radiative effects	13,17	UHEL, UOX	156	1	48
5	Climate response and feedbacks in ESMs	11,9	SMHI, MetNo	145	1	48
6	Constraining climate sensitivity and near-term climate response	16,6	UO, FORTH	188	1	48
7	User engagement, communication and dissemination	1,11	SU, SMHI	55	1	48
8	Project management	1	SU	51	1	48
9	Scientific management	1	SU	42	1	48
				1213		

Tables 3.1b. Work package descriptions

Work package number	1		**Lead beneficiary**				FORTH, FZJ		
Work package title	Critical aerosol forcing processes and factors								
Participant number	1	2	3	5	6	8	12	13	20
Short name of participant	SU	BSC	ETHZ	FZJ	FORTH	CNR	UEF	UHEL	IIASA
Person months per participant:	6	12	12	64	59	5	18	19	1
Start month	1				**End month**	36			

Objectives

WP1 will improve the representation of aerosol processes in the FoRCeS ESMs in an effort to increase the accuracy and reduce the uncertainty of the simulated aerosol ERF, targeting the uncertainty that is due to missing or misrepresented processes. Based on the results and recommendations of previous EU projects in this research area (EUCAARI, PEGASOS, BACCHUS and ECLIPSE) four key species and processes are selected, namely organic aerosol (OA), nitrate aerosol, brown carbon and ultrafine aerosol growth. The novel characteristics of this WP will be the combination of laboratory results, state-of-the-science models, regional models and the corresponding constraints from field studies, and finally development of parameterizations at the scale of ESMs along the scale chains defined in Section 1.3b. WP1 will improve the simulation of the critical processes and factors responsible for the uncertainties in ERF due to aerosol-radiation interactions (ERFari). The WP will address the following research questions:

- Which key processes (e.g., chemical evolution of organic aerosol and brown carbon, atmosphere-biosphere interactions, etc.) and factors (e.g., emissions, optical properties) are not well-represented in state-of-the-art ESMs used for climate projections?
- How can we better simulate these key aerosol processes in ESMs using the appropriate level of detail? Are there also processes that we can simplify?
- Which processes and factors are responsible for the largest uncertainties for aerosol radiative forcing?

The parameterizations developed here will be provided to WP3 and WP5 where they will be included and tested in the FoRCES atmospheric GCMs and ESMs. WP1 will also collaborate with WP2 on the concentrations and characteristics of CCN and INP.

This WP is co-led by Astrid Kiendler-Scharr (FZJ) and Spyros Pandis (FORTH).

Description of work, lead partner and role of participants

Task 1.1: Organic aerosol formation and chemical evolution (FZJ, FORTH, UHEL, UEF, CNR)

Despite the explosion in our understanding of organic aerosol processes during the last decade, the advancement of the simulation of the corresponding processes in ESMs has been slow. In this task we will combine the latest atmospheric simulation chamber results to first advance the state-of-the-science detailed models. In the second step, we will use the detailed model results to produce a version of the Volatility Basis Set that is suitable for ESMs (D1.1). This computationally efficient version of an organic aerosol module will be tested and further optimized in regional and global atmospheric chemistry models (PMCAMx, TM4-EPCL). Emphasis will be placed on processes that have been neglected in ESMs like the role of NOx and the continuous chemical aging of the OA components. The latest OA results from the ACTRIS network will be used for the model evaluation.

Task 1.2: Nitrates in fine and coarse particles (FORTH, FZJ, UHEL, BSC)

Even if our understanding of the formation of inorganic nitrate salts has advanced and the corresponding processes are reasonably-well simulated in regional CTMs, the computational cost has seriously limited and in most cases prohibited the simulation of this important aerosol component and its corresponding forcing. In this task we will explore ways of using e.g. machine learning to reduce the computational cost of the simulation of the following processes: formation and evaporation of ammonium nitrate, reactions of nitric acid with coarse sea-salt and dust particles, the competition of fine and coarse particles for the available nitric acid. We will also examine the potential importance of organic nitrates for the aerosol ERF. The outcome of this task will be missing aerosol nitrate parameterizations that can be added to the FoRCES AGCMs and ESMs. (D1.1). The parameterizations will once more be tested against the detailed aerosol modules and also will be included in CTMs so that they can be evaluated against field and long term observations studies both in Europe and around the world.

Task 1.3: Improved parameterizations of aerosol absorption (FORTH, CNR, BSC)

The change in absorption of black carbon as particles get coated with transparent inorganic and organic aerosol components and the absorption by brown carbon will be the targets of this task. The latest results from laboratory and more important field studies will be used to develop the next generation of parameterizations of these processes for ESMs (D1.1). We will use a variety of approaches to achieve this including fittings of detailed Mie-theory based models, use of recently proposed semi-empirical parameterizations based on the organic/elemental carbon ratio, and also machine learning techniques applied to ambient measurements.

Emphasis will also be placed on the evolution of the absorption by brown carbon as the corresponding particles age in the atmosphere.

Task 1.4: Ultrafine aerosol formation and growth (UHEL, FORTH, SU, UEF)

This task will focus on the role of the various processes (nucleation, growth by inorganics, growth by extremely low and low volatility organics, growth by semivolatile organics) in the formation of CCN-size particles and in their computationally efficient parameterization in ESMs. The work related to the growth by organic condensation will be coordinated with Task 1.1. The outcome of this task will be a computationally efficient module for the simulation of ultrafine and CCN-sized particle concentrations suitable for AGCMs and ESMs (D1.1). The module will include the latest understanding of these processes based on work in CLOUD and it will also be evaluated against the long term ACTRIS measurements.

Task 1.5: Identification of microphysical processes related to aerosols that can be simplified (ETHZ, SU)

In this task, we will identify microphysics processes related to aerosols to which the global models are less sensitive. We will use e.g. the pathway analysis of (158) and also emulator studies for the FORCeS models. In particular, we will use sensitivity analysis information from Task 3.3 to determine which processes are insensitive to uncertainties in the key parameters, and therefore deprioritized for further development. These processes will then be simplified in order to free up computational resources for the more important processes (D1.2). The importance of certain processes might depend on the spatial resolution. Therefore, the impact of both aspects (sources of uncertainty and simplifications of processes) for radiative forcing will be analyzed as a function of spatial scale.

Deliverables

D1.1 Parameterization recommendations for nitrate, organic aerosol, ultrafine aerosol growth and aerosol absorption (output from Tasks 1.1-1.4) (M30).

D1.2 Recommendation on simplifications for microphysical processes related to aerosol in global models (output from Task 1.5) (M36).

Work package number	2			**Lead beneficiary**				UEF, ULEI		
Work package title	Understanding of cloud processes and aerosol-cloud interactions									
Participant number	1	3	4	5	6	7	8	12	15	22
Short name of participant	SU	ETHZ	FMI	FZJ	FORTH	KIT	CNR	UEF	ULEI	UEX
Person months per participant:	36	35	14	6	20	17	7	30	47	2.9
Start month	1				**End month**	48				

Objectives

WP2 will improve the representation of cloud-, precipitation- and aerosol processes in ESMs, targeting a qualitatively more reliable simulation of ERFaci. Five key processes, each of which has a Task dedicated to it, are selected and parameterizations of these processes at the ESM scale will be improved. These processes reflect important forcing mechanisms and amplifying as well as “buffering” adjustments. The task teams for each of these processes will closely interact so that observations and modelling will be exploited across the scales from process- to climate scale, utilizing novel tools for connecting the scales and techniques. The work within WP2 aims specifically towards:

- An understanding of the response of cloud droplet concentrations to aerosol perturbations at aggregated scales (10 – 100 km), from observational data, as well as the development and evaluation of a revised parameterization for ESMs.
- An evaluation and revision of the cloud droplet growth mechanism parameterizations (condensational and coagulation growth) for ESMs, on the basis of cloud-resolving modelling.
- Revision and evaluation of parameterizations of ice formation (homogeneous and heterogeneous freezing, secondary ice formation) exploiting in situ observations and cloud-resolving modelling.
- An evaluation and revision of the entrainment-mixing parameterizations in the context of aerosol-cloud interactions
- A revision of cloud processing and scavenging parameterizations for the aerosol schemes in ESMs on the basis of observations and process-scale modelling.

WP2 interacts particularly closely with WP3 for constraints of the simulated forcing, providing input also to WP5 in the form of the parameterizations (particularly close interaction on D5.2). WP2 also collaborates with WP1 on the characteristics and concentrations of the aerosol particles serving as CCN and INP.

This WP is co-led by Annele Virtanen (UEF) and Johannes Quaas (ULEI).

Description of work, lead partner and role of participants

Each of the tasks below will lead to a recommendation of an ESM parameterization of a process within each category (D2.1).

Task 2.1: Droplet activation (SU, FORTH, CNR, UEF, ULEI, FZJ)

Droplet activation drives the radiative forcing due to aerosol-cloud interactions, and subsequently also the effective forcing. While at a fundamental level, droplet activation is well understood, the parameterized effect in ESMs is a key uncertainty: aerosol size distributions, hygroscopicity, as well as cooling rates at the scale of an ESM grid box need to be considered to predict activated droplets. We will perform field observations at the site of Ny Ålesund (updraft-driven cooling rates, pristine air), Puijo SMEAR IV cloud station (updraft driven cooling rates, boreal environment with anthropogenic influence) and in Italy (radiatively driven cooling rates, polluted air). The campaigns will be designed to investigate the relationships between the concentration and properties of aerosols and cloud droplet distributions, with one focus on the effect of co-condensation on droplet formation. Observations will be used to construct joint histograms as a function of the relevant large-scale meteorological environment and aerosol sources. Parcel modelling with a detailed representation of the microphysical processes constrained with the observations, will be used to evaluate and improve parameterizations designed for an AGCM framework. We will also employ the model emulators (developed at WP3) at these sites to assess whether the CCN-Nd relation can be captured within the uncertainty of the GCM.

Task 2.2: Condensational and coagulation growth of cloud particles, precipitation sink (FMI, ULEI, CNR; SU)

The presumably main adjustment mechanism for aerosol-cloud interactions is the response of cloud liquid water path (LWP) and cloud fraction to altered cloud particle number concentrations. Two processes are key drivers of LWP: the growth of cloud liquid water content with altitude, following a moist adiabat (reduced by mixing, Task 2.4), and the sink for cloud water via coagulation (parameterized as autoconversion) that is slowed down for more numerous cloud droplets. The condensational growth is not explicitly represented in current ESMs but rather simplified adjustments are considered. Task 2.2 will assess these condensation schemes in comparison to reference large-eddy simulations that explicitly treat the time-dependent condensation. A key uncertainty in cloud adjustments is the poor representation of coagulation (autoconversion). Using LES and a set of recently-developed process-oriented statistics from satellite data (in collaboration with WP4, task 4.2), these parameterisations will be examined and revised.

Task 2.3: Ice nucleation, secondary ice, and freezing (ETHZ, FORTH, FMI, KIT, ULEI, CNR, SU)

In all IPCC reports up to the latest one, aerosol-cloud effective forcing for ice- and mixed phase clouds is considered highly uncertain. The sign and magnitude of global effects are largely unknown. Task 2.3 aims at evaluating and improving the ESM representation of the relevant processes to an extent that the simulation outcome is reliable. Field measurements at the Ny Ålesund site using a set of aerosol and cloud particle measurements will be used to construct statistics relevant for the ESM grid box scale. The results will be used to assess and constrain LES of the relevant processes, which in turn will feed into the evaluation of the relevant

ESM parameterizations. A special focus is on secondary ice production in the LES, since this is potentially a buffering mechanism. AGCM simulations with ice parameterizations revised on the basis of the reference observations and LES will be evaluated using new ice microphysics retrievals from satellite active remote sensing.

Task 2.4: Entrainment and mixing as cloud sink (ULEI, SU, FORTH)

A key sink for cloudiness, and a potentially powerful mechanism dampening the ERFaci, is due to the entrainment and mixing of clouds with environmental air. Climate models only crudely resolve these processes due to the coarse horizontal and especially vertical resolution. A quantitative assessment and improvements in order to adequately represent the relevant aerosol-cloud adjustments is necessary. Task 2.4 will make use of a parcel model embedded in a GCM together with dedicated single-column model and numerical weather prediction studies, as well as of large-eddy simulations, to evaluate and adapt the mixing parameterizations in the GCM using the field observations as well as satellite retrievals.

Task 2.5: Aerosol processing and scavenging (UEF, SU, ETHZ, FMI)

When it comes to aerosol-cloud-precipitation interactions, a first-order effect is the sink for aerosol number due to cloud processing and scavenging. In turn, aerosol properties are also altered so that their relevance for droplet activation and heterogeneous ice nucleation is changed. A realistic representation of these delicate and very important processes is a key prerequisite to simulate buffering mechanisms correctly in climate models. We will use the existing long-term data and new observations to better constrain aerosol cloud processing and scavenging in climate models. Simultaneous ground based and in-cloud field observations at Ny Ålesund and at Puijo SMEAR IV cloud station will form an observational background needed both to gain the better understanding of the processes and to develop the improved parametrizations for models. In the measurement campaigns we will utilize recently developed online mass spectroscopy techniques both for gas phase and aerosol phase analysis, as well as aerosol characterization methods. These measurements, and earlier observations, will serve as process level reference for LES simulations facilitating improved descriptions of aerosol processing and scavenging in climate models.

Deliverables

D2.1 Parameterization recommendations for five key aerosol-cloud-precipitation processes (M30)

Work package number	3				**Lead beneficiary**					ETHZ, MetNo		
Work package title	Role of aerosol and cloud changes for aerosol radiative forcing between 1950 and 2050											
Participant number	1	2	3	4	6	7	8	9	10	12	14	20
Short name of participant	SU	BSC	ETHZ	FMI	FORTH	KIT	CNR	MetNo	KNMI	UHEL	ULEEDS	IIASA
Person months per participant:	12	12	35	12	40	6	6	9	6	15	12	3.5
Start month	1					**End month**	48					

Objectives

WP3 will study the development of key aerosol components and their physical characteristics as well as cloud changes between 1950 and 2050 using different scenarios, thereby contributing to all the FORCeS overall objectives. The specific objectives of WP3 include

- Determining transient changes in aerosols and clouds and the corresponding ERFari+aci from 1950 to present day.
- Understanding and quantifying the key uncertainties in the aerosol forcing between 1950-2050.
- Providing plausible near-future projections of ERFari+aci.

The importance of changes in clouds for the evolution of the ERFari+aci will be contrasted with the role of changes in the chemical and physical properties in aerosols from FORCeS climate models. This will be done using two different approaches: (1) the transient aerosol and cloud evolution will be constrained by observations and updated with new parameterizations developed in WP1 and WP2 that include aerosol components currently missing or crudely implemented in models and/or improved descriptions of cloud and aerosol processes. (2) the model uncertainty in ERFari+aci will be determined using perturbed physics ensembles and emulator techniques for model sensitivity studies as compared to observations. Several key periods will be of particular interest, e.g. the period with high aerosol loading during the 1970s and the near-term future when aerosols could play a role if employed in solar radiation management. WP3 interacts closely with WPs 1-2 providing the process parameterizations, and outputs the aerosol forcing time series that will be utilized in WP6 (particularly Task 6.4).

This WP is co-led by Ulrike Lohmann (ETHZ) and Michael Schulz (MetNo).

Description of work, lead partner and role of participants

Task 3.1: Determine aerosol and cloud changes 1950-present (MetNo, SU, BSC, CNR, FORTH, UHEL, KIT, FMI)

Relevant available model data for the period 1950-present will be assembled and complemented with aerosol and cloud specific aerosol composition and properties diagnostics from FORCeS climate model simulations. Interannual variability in natural and anthropogenic aerosol composition, including dust, biomass burning, and all components in focus of WP1 will be analyzed. A comprehensive large data set of the aerosol physical properties (size, number) and composition evolution will be assembled from in-situ data, wet deposition data and satellite remote sensing as well as of cloud properties from satellite remote sensing since 1979 (D3.1). This task will be done in close cooperation with WP1 and WP2.

Task 3.2: Provide transient ERFari+aci records 1950-present from the available FORCeS atmospheric global models constrained by observational data (ETHZ, MetNo, KNMI, UHEL)

Transient aerosol forcing records from FORCeS atmospheric global climate models (AGCMs) run with aerosol schemes of different levels of complexity will be assembled. The level of complexity in terms of aerosol composition and microphysical processes necessary to simulate the transient ERFari+aci in best agreement with observations assembled in Task 3.1 will be investigated. At the same time, the importance of various cloud microphysical processes and parameterizations of aerosol-cloud interactions for reproducing ERFari+aci will be investigated. The perturbed parameter ensembles (Task 3.3) will be used to generate a set of ~ 1 million model variants that span the model uncertainty. The uncertainty in the historical changes in aerosols and forcing will then be narrowed by selecting a set of model variants that are consistent with the observations from Task 3.1 (D3.1).

Task 3.3: Determine the main contributions to model uncertainty to the simulated transient ERF (1950-2050) using perturbed physics ensembles and emulators (ULEEDS, IIASA, ETHZ, MetNo).

Perturbed parameter (or perturbed physics) ensembles enable the model uncertainty to be quantified and attributed to the various processes and boundary conditions (such as emissions) in the model. This technique has been successfully demonstrated in a global model for the pre-industrial to present-day RFaci (e.g., (159; 160)), the aerosol ERF (65) and to understand climate model biases (161). This approach will be used in this task to estimate the uncertainty in the transient evolution of aerosols and clouds and the associated ERFari+aci in the FORCeS AGCMs. The prior knowledge of aerosol uncertainties will be guided by the findings from task 3.1. Emulators and sensitivity analysis will then be used to determine the key model processes that account for the uncertainty in the models (D3.2).

Task 3.4: Provide several likely near future (until 2050) aerosol composition and ERFari+aci trends (ETHZ, MetNo, SU, UHEL, FMI)

The knowledge acquired in WP1 and WP2 will be used to conduct transient FORCeS simulations in an AGCM mode using improved descriptions of aerosol composition, microphysical processes and aerosol-cloud interactions. Different processes may be considered in different FORCeS ESMs (MPI-ESM-HAM, NorESM and EC-Earth). This new knowledge will be combined with plausible recent aerosol composition changes and trends in clouds and aerosols (Task 3.1) as well as future aerosol emission scenarios (CMIP6) to establish an

ensemble of near future ERFari+aci trends (D3.3). The importance of future ERFari+aci and aerosol composition for climate sensitivity will be studied in WP6.

Deliverables

D3.1 Assessment of global past (1950-present) aerosol, cloud and ERFari+aci changes. (M30)

D3.2 Sensitivity of estimated aerosol radiative forcing of FoRCES models to aerosol and cloud processes and aerosol emissions. (M36)

D3.3 Global past and future (1950-2050) ERFari+aci changes using updated FORCeS ESMs. (M48)

Work package number	4			**Lead beneficiary**			UHEL, UOX		
Work package title	Novel constraints on aerosols radiative effects								
Participant number	1	6	7	8	9	13	14	15	17
Short name of participant	SU	FMI	KIT	CNR	MetNo	UHEL	ULEEDS	ULEI	UOX
Person months per participant:	12	13	16	7	4	21	22	17	44
Start month	1				**End month**	48			

Objectives

It has become clear that climate models in isolation are insufficiently constrained to provide reliable estimates of aerosol radiative effects. WP4 will tackle this issue through a comprehensive strategy to maximize observational constraints on global climate models. WP4 will synthesize and employ the most comprehensive set of observations to maximize simultaneous constraints on key processes for aerosol ERF. Based on dedicated scale-chain experiments combining LES, CRM and global climate models, and observational constraints for each scale, individual processes and their representation in climate models will be traced from the local to the global scale. Natural and anthropogenic analogues for aerosol-cloud interactions from ship-tracks, volcanic eruptions and megacities will serve as novel constraints. Based on this new set of observations and a large perturbed physics ensembles, WP4 will assess parametric, structural and numerical uncertainties of aerosol forcing and implement key metrics into open-source community evaluation tools.

Besides the specific scientific objectives outlined above, WP4 serves as the "data hub" of FORCeS activities, collecting and coordinating the activities related to using observational data for e.g. model evaluation and hence interacts will all other FORCeS WPs. WP4 thus interacts closely with all WPs.

This WP is co-led by Risto Makkonen (UHEL) and Philip Stier (UOX).

Description of work, lead partner and role of participants

Task 4.1: Synthesis of in-situ and remote sensing observations (UOXF, UHEL, KIT, FMI, MetNo)

This task builds on the observational efforts in WPs 1 and 2, as well as ongoing international activities, such as the Global Aerosol Synthesis and Science Project aerosol database, the NILU EBAS database hosting the Global Atmosphere Watch and World Datacentre for Aerosol, PEEX/SMEAR databases, the BACCHUS ice nucleating particles database as well as repositories of satellite retrievals (Section 1.3b) to compile and harmonise the most comprehensive set of observations of aerosol and cloud properties suitable for the constraint of aerosol radiative effects. This task will derive novel observational constraints going beyond the collection of traditional observables through the compilation of satellite retrieved relationship between cloud and aerosol parameters (e.g. the sensitivity of droplet numbers to aerosol optical depth or of cloud albedo to cloud liquid water). This will allow for a systematic analysis of the sensitivities of ERFari+aci in Tasks 4.2 and 4.5. Global data sets of aerosol, cloud, radiation and atmospheric conditions will be linked in statistical

models based on machine learning approaches such as artificial neural networks and gradient-boosting regression trees These models will be used to explore the sensitivities of ERFari+aci to systematic changes in aerosol and environmental conditions. In conjunction with Task 3.3, the most important parameter chains will be identified as constraints for model improvement

This task will serve as a FORCeS liaison to observational infrastructures and the datasets will be used to constrain FORCeS models in WP1,2,3.

Task 4.2: Observational constraints along the scale chain (SU, FMI, UOXF, ULEI)

Traditionally, the application of observational constraints has often been segregated by scales: in-situ observations for local process studies and high-resolution modelling and remote-sensing observations for global climate models. In this task we aim to brake this barrier applying observational constraints along the full scale-chain, from the point of emission to global scales. Through scoping work in WPs 1, 2 and 3 we will identify key processes where suitable observational constraints are of fundamental importance (D4.1). For example, warm rain formation via autoconversion has been identified as key process linked to the uncertainty of aerosol ERF in global climate models (79; 162). Here, we will constrain this key uncertainty through novel scale-chain experiments: performing high resolution LES simulations to understand crucial droplet growth mechanisms (e.g. turbulence) on large-enough scales to allow for statistical equilibrium (163) and for (statistical) comparison with the grid-box scale of global climate models. Detailed process observations from key observatories (e.g. Atmospheric Radiation Measurement facilities) and selected field campaigns compiled in Task 4.1) will be applied to the LES simulations and – in a statistical sense – to climate models. These will be combined with remote sensing-based constraints on warm rain formation combining CloudSAT radar with MODIS satellite imager data (CFODD analysis, (164)).

Task 4.3: Natural and anthropogenic analogues of aerosol-cloud interactions (UHEL, ULEI, FMI)

Both natural (volcanoes, wildfires) and anthropogenic (decadal emission changes, ship-tracks, megacities) disturbances enable wide spatial and temporal constraints for aerosol effects on radiation, clouds and climate. European-scale in-situ aerosol networks can capture not only the decadal decline in emissions, but also accelerated changes throughout e.g. the decay of heavy industry after the fragmentation of the fragmentation of the Eastern Bloc after 1989 or the global economic crisis from 2008 onwards. Well defined emission contrasts from modern-era analogues and state-of-the-art observations are crucial for disentangling the co-evolution of natural and anthropogenic aerosols and their climate effects. In this task we will establish the most comprehensive set of observations representative of natural and anthropogenic analogues from satellite and in-situ data (63; 162) (D4.1), test their representativeness through high resolution modelling and apply them as observational constraint to aerosol radiative forcing in global models. Spatial clustering and network analysis tools will be employed to satellite and model data to detect gaps in simulated responses to selected perturbations.

Task 4.4: Constraints for the transient aerosol forcing record (FMI, CNR, UHEL)

This task will apply constraints on the transient aerosol evolution during 1900–present. Historical sunshine duration (SD) observations will provide proxies for local Aerosol Optical Depth (AOD) records. Sunshine-duration data from selected sites will be evaluated against present-day AOD retrievals, and will provide a semi-continuous record for model evaluation. The task will quantify the relative contribution of climate and air quality change on fog occurrence change, focusing on the long-term daily visibility data collected at airports across the central Valley (California) and the Po Valley (Italy) starting from the mid-70s. Furthermore, the task will assess the applicability of BC deposition fluxes from ice cores as constraints for the 20th century transient simulations in Task 3.2 (D4.1).

Task 4.5 Bottom-up observational constraint of modelled decadal changes in aerosols and radiative forcing (ULEED, UOX)

This task will use a large perturbed parameter ensemble (PPE) of the UKESM climate model to constrain the magnitude of near-term (decadal) aerosol ERF (D4.1). The PPE, combined with model emulation, will be used to generate several million 'model variants' that span the complete uncertainty of the model caused by around 50 parameters related to emissions and aerosol and cloud processes. This dataset will be used for two purposes. Firstly, the model variants will be compared against the extensive timeseries of observations compiled in Task 4.1 to identify structural biases and deficiencies in the model (i.e., where observations persistently lie outside the range of the model variants.) These deficiencies will be examined in other global and high-resolution models (WP2) in order to guide the prioritization of model improvements. Secondly, the observations compiled in Tasks 4.1-4.4 will be used to constrain the model spread by retaining only the model variants that produce

observationally plausible values of aerosol, cloud and radiative properties. These retained model variants will be used to produce robust estimates of the aerosol ERF and its uncertainty on regional and global scales. A subset of the observationally plausible model variants (parts of parameter space) will be run forwards with various scenarios of changes in emissions to determine the impact of the remaining (observationally plausible) uncertainty on the spread of future forcings.

Task 4.6: Community evaluation tools for aerosols and clouds in support of IPCC (MetNo, UOXF, UHEL)

The impact FORCeS is maximized through the implementation of observational constraints as new evaluation packages for community evaluation tools such as for ESMValTool and the AeroCom interface (D4.2). These tools will incorporate the unique synthesis of observational datasets developed in Task 4.1 and develop robust observational constraints and metrics suitable to aerosols, clouds and their interactions. These tools will be employed to provide a comprehensive evaluation of the base state and constraints on key processes in the ensemble of CMIP6 models in preparation for IPCC AR6, leading to the first observationally constrained aerosol forcing ensemble in CMIP climate models in preparation for IPCC AR7.

Deliverables

D4.1 Observational constraints on aerosol, aerosol-cloud interactions, aerosol evolution and aerosol ERF (1950-present). (M36)

D4.2 Community model evaluation packages upgraded with FORCeS data and analysis methods. (M48)

Work package number	5		**Lead beneficiary**				SMHI, MetNo		
Work package title	Climate response and feedbacks in ESMs								
Participant number	1	2	3	6	8	9	10	12	15
Short name of participant	SU	BSC	ETHZ	FORTH	KNMI	MetNo	SMHI	UHEL	ULEI
Person months per participant:	24	6	12	20	13	13	35	13	9
Start month	1				**End month**	48			

Objectives

WP5 will examine the climate response and feedbacks related to the aerosol forcing as described in the existing and revised FORCeS ESMs. This will be done through 1) analyzing the CMIP simulations existing at the beginning of the project and 2) carrying out new ESM simulations using models with the updated parameterizations, motivated by the developments and constraints from WPs 1-4. Analyses will focus on quantification of feedbacks and sensitivity of models related to processes with regional effects and overall global implications. WP5 aims at quantifying the role of aerosol and cloud parameterizations in determining known typical regional biases in ESMs, leading to more reliable predictions of future climate. The specific objectives of WP5 are to

- Analyze simulated climate response, feedbacks and sensitivities to aerosol and cloud forcing in ESMs.
- Quantify simulated responses to specific key processes and their effects in regional focus areas that contribute to the global response.
- Improve the simulation of processes relevant for regional and global sensitivities.

WP5 will receive input from WPs 1, 2, 3 and 4 in the form of process parameterizations and observational data / constraints, and collaborate closely with WP6 on providing reliable estimates of the effects of aerosols on the near-term climate response. WP5 will also in collaboration with WP6 (Task 6.3 and 6.4) deliver climate information and metrics of relevance to the stakeholder group defined in WP7.

This WP is co-led by Ralf Döscher (SMHI) and Øyvid Seland (MetNo).

Description of work, lead partner and role of participants

Task 5.1: Identification of relevant processes for response and feedbacks to aerosol and cloud forcing (SMHI, ETHZ, MetNo, SU, UHEL). Simulations will be chosen from CMIP6-DECK, including historical runs, AerChemMIP, and RFMIP. This task follows the overall approach to find and understand the key processes contributing to uncertainty in aerosol ERF estimates (D5.1). Special attention will be given to geographical regions and processes that are considered problematic in ESMs and relevant for global climate sensitivity. Those include the southern ocean warm bias (SMHI), North Pacific (MetNo), North Atlantic and hemispheric scale circulation (MetNo), the Arctic Amplification (SU, MetNo), and biogenic OA feedbacks (UHEL). Analysis methods make use of growing process-based analysis tools (such as ESMvalTool and the new evaluation tools developed in Task 4.6) in combination with several data sets including novel ESA-CCI/CMSAF data. The analysis will also include radiative kernel methods to identify key feedbacks.

Task 5.2: Implementation of revised parameterizations into ESMs (FORTH, KNMI, SMHI, ETHZ, MetNo, UHEL, BSC, ULEI). Starting not later than month 6 of the project, pre-existing experience and results from WPs1,2,3 and WP5.1 in identifying critical processes, forcing mechanisms and constraints, will be evaluated and parameterizations will be selected for implementation into three ESMs (EC-Earth, NorESM, MPI-ESM-HAM). Implementation requires extensive testing, evaluation, model tuning and a spin-up procedure to allow for a proper comparison with the original CMIP simulations and to allow for scenario simulations.

Task 5.3: Effect of updated or simplified aerosol/cloud processes in ESMs (SMHI, KNMI, ETHZ, MetNo, SU, UHEL). Selected CMIP6 runs (from DECK, historical simulations and other MIPs) will be carried out and the impact and feedbacks will be analyzed with respect to the processes and regions chosen in task WP5.1. The effect of the new parameterizations on the transient climate response and TCS will be evaluated (in co-operation with WP6), and compared to the new, constrained time series of aerosol composition and forcing from uncoupled atmosphere models (WP3) and observations (WP4) (D5.2). Updated analysis tools (from Task 4.6) with new observational constraints will be used.

Deliverables

D5.1 Identification of relevant processes for response and feedbacks to aerosol and cloud forcing. (M30)

D5.2 Impact of revised parameterizations in ESMs on aerosol forcing estimates. (M48)

Work package number	6			**Lead beneficiary**			UO, FORTH	
Work package title	Constraining climate sensitivity and near-term climate response							
Participant number	1	3	6	11	13	16	17	20
Short name of participant	SU	ETHZ	FORTH	SMHI	UHEL	UO	UOX	IIASA
Person months per participant:	24	8	79	10	6	38	22	0.5
Start month	1			**End month**	48			

Objectives

WP6 will identify and evaluate observable quantities that govern transient climate response (TCR), the standard measure of transient climate sensitivity (TCS) in Earth System Models, thus moving towards a new paradigm in which the model-derived range of plausible TCR values is increasingly based on models that are sound with respect to these key observables. An understanding of the underlying mechanisms that relate the observables to TCR will be achieved through an innovative network analysis approach. This will ultimately allow for an assessment of how and why the improved process-understanding and ESM parameterization-improvements achieved in FORCES affect TCR. We will further combine this work with statistical and

simple/idealized modelling to arrive at a new central estimate and narrower uncertainty range for TCR/TCS, as well as a re-evaluation of the emission reductions needed to meet the Paris targets.

WP6 collaborates closely with WP5 on the development and application of the FORCeS ESMs and receives input from WP 3 (the transient time series produced) and WP5 (updated ESMs). WP6 will also in collaboration with WP5 (Task 6.3 and 6.4) deliver climate information and metrics of relevance to the stakeholder group defined in WP7.

This WP is co-led by Athanasios Nenes (FORTH) and Trude Storelvmo (UO).

Description of work, lead partner and role of participants

WP6 will analyze existing ESM simulations, specifically for the FORCeS ESMs but also for the CMIP6 archive in general, to understand what governs the current spread in TCR. WP6 will further work to reduce this spread by applying new and existing emergent constraints, as well as evaluating models in terms of their ability to resolve "patterns of climate change" using innovative data mining/machine learning techniques ("network analysis") and a novel set of metrics that will facilitate a deviation from the traditional "one-model-one-vote" approach. The impact of using new and/or improved cloud/aerosol parameterizations in FORCES ESMs (carried out in WP5) will be explored, both for TCR and near-term climate change, with particular focus on peak warming and the likelihood of achieving the goals of the Paris agreement. Revised aerosol forcing pathways delivered by WP3 will be used in statistical modelling to revise the TCR range consistent with observed climate change, to finally use multiple lines of evidence to support the updated TCR/TCS probability function.

Task 6.1: Evaluate FORCeS ESMs at the beginning of the project (transient climate response and emergent constraints) (UO, SU, FORTH). At the early stages of FORCeS, while other WPs are focused on the identification of key processes and fundamental work to improve process representation in climate models, WP6 will focus on evaluating the FORCeS ESMs in terms of their TCR and their relative climate feedback strengths using radiative kernel techniques (e. g. (128; 165)), and network analysis with δ-MAPS (166; 69) (D6.1). Taking stock of the FORCeS ESMs with respect to their climate sensitivity and the underlying feedbacks before the process implementation/improvement begins is critical, and will serve as a benchmark for new and revised model versions. We will specifically focus on the ESM's performance with respect to a number of observable quantities or interrelations with well-defined and explainable relationships to TCR that are used as so-called "emergent constraints" (e.g., (1)). Given that a model spread in this observable quantity or relation explains a model spread in estimated climate sensitivity, an indirect constraint on climate sensitivity emerges and estimates of sensitivity from models performing poorly with respect to that constraint can be given less weight. A few emergent constraints have already been established, and targeted simulations designed to test the models with respect to these will be performed within WP6. It is important that this evaluation is carried out in the early stages of FORCeS, so that it can inform the process improvements described in WPs 1-4.

Task 6.2: Develop new metrics for ESM evaluation with the goal of "getting the right answer for the right reason" (FORTH, SU). To unravel the individual contribution of each new process representation to the overall ESM climate response, we propose to make use of an innovative new network analysis technique (166; 69), that determines in climate simulations the regions that behave similarly, and the intensity and time lag with which they are linked. This approach reduces the highly complex climate simulations into a simple dynamic network representation. The networks of each simulation can be compared and evaluated against observation-derived networks, to evaluate the model ability to capture the patterns of climate change, a fundamental aspect of TCR. Shifts in the network structure with changes in the aerosol and aerosol-cloud process parameterization can identify the pathways through which individual processes impact climate response, and the patterns of change over space and time, so that at the completion of FORCeS we arrive at a complete understanding of both how and why climate sensitivity changed in the models. These techniques are also uniquely suited to determine the level of complexity required in ESM aerosol- and cloud representation, and potentially used as reduced-form models, which are topics of great interest. The end-product will be a new set of metrics for ESM performance particularly relevant for TCR, and thus for FORCeS (D6.2). Taking our analysis beyond just the FORCeS ESMs, we thereafter aim to apply these new metrics to the CMIP6 models, and based on their performance assigning different weights to each model for the purpose of TCR calculations. This will represent a deviation from the traditional "one-model-one-vote"-approach, and will almost certainly yield a revised and narrower climate sensitivity probability density function (PDF).

Task 6.3: Re-evaluate FORCeS ESMs with respect to climate sensitivity - what are the implications for near-term climate evolution? (UO, SU, ETH-Z, SMHI, UHEL) Once revised forcing ranges associated with aerosols and aerosol-cloud interactions begin to emerge from the work of other WPs, these revised historical forcing estimates will be utilized in WP6 in a suite of established statistical/observational approaches to produce another, independently derived, PDF for TCR. Furthermore, after the implementation of revised and/or new aerosol- and cloud-parameterizations (Task 5.2), the FORCeS ESMs will be re-evaluated with respect to TCR and near-term climate evolution (D6.3). This includes re-application of the emergent constraints of Task 6.1, and producing a new and updated model weighting. Part of this task will be to assess the relative importance and predictive power of different individual emergent constraints, by investigating the degree to which they explain climate sensitivity spread, and their robustness to the transition to a physics-improved model ensemble. Ultimately, at the final stages of FORCeS, WP6 will synthesize the TCR/TCS ranges/PDFs from the approaches described above into a single revised TCR/TCS distribution, and clearly lay out how FORCeS has impacted both its width and central estimate. Relevant results on the impact of aerosols on the near-term climate evolution will be communicated to the stakeholder group in WP7.

Task 6.4: Link aerosol forcing to peak warming by using statistical methods/simplified models (UOX, IIASA). As anthropogenic aerosol affects global mean surface temperature through its radiative forcing, it is essential to consider when evaluating human impact on the climate. Signatories to the PA have agreed to try and limit warming to 2C and aim for 1.5C, through achieving a balance of sources and sinks of emissions. Aerosol emissions will influence the time and level of peak warming, and temperature stabilization or rate of decline, whether they are included in the framework of the PA or not. This task is aimed at understanding what role aerosol has to play in the achievement of the PA goals. In some models and scenarios, aerosol is not carefully considered, for example it may be unrealistically assumed that sulfate aerosol remains constant with time. Such assumptions could cause certain scenarios to appear Paris-compliant, when they would break the temperature targets if sulfate aerosol declined consistently with declining fossil fuel combustion. Recent methods have shown it is possible to describe well the radiative impact of aerosol on global warming using relatively simple metrics, which will be developed in FORCeS for aerosol. CO_2-forcing equivalent (167) and GWP* (168) allow aerosol radiative forcing to be brought into post-Paris emissions reduction targets based on their effect on global mean temperatures, in line with other greenhouse gases. In this task, a simple climate-carbon-cycle model (FAIR, cf. Table 1.3) will be used to calculate CO2-forcing equivalent emissions for aerosol, and be used to evaluate the temperature response to aerosol scenarios using the different emissions metrics (GWP100, GTP100, GWP*) (D6.4). The simple models and metrics used here will also be evaluated against the global modelling work in other parts of the project, and refined accordingly.

Deliverables

D6.1 Compliance of FORCeS ESMs with respect to established emergent constraints. (M18)

D6.2 Assessment of new emergent constraints, as well as on the utility of "network analysis" in this context. (M30)

D6.3 New and more constrained estimate of transient climate response, based on multiple lines of evidence and approaches. (M48)

D6.4 Re-assessment of the emission reduction targets required in order to meet the Paris targets. (M48)

Work package number	7	**Lead beneficiary**			SMHI, SU		
Work package title	User engagement, communication and dissemination						
Participant number	1	11	18	19	Partners 1-17		
Short name of participant	SU	SMHI	NV	INERIS			
Person months per participant:	24	15	0.25	0.25	1 / partner		

Start month	1	**End month**	48

Objectives

WP7 is the interface between the research conducted in FORCeS and the stakeholder communities. Specifically, WP7 will

- Synthesize, disseminate, and exploit results obtained within FORCeS.
- Provide policy and decision makers with relevant climate information.
- Make sure that FORCeS' relevant scientific knowledge is transmitted to the scientific community and outputs are openly available.

WP7 will interact with all other WPs.

This WP is co-led by Erik Kjellström (SMHI) and Hans-Christen Hansson (SU).

Description of work, lead partner and role of participants

Task 7.1: Stakeholder interaction (SMHI, SU, all partners)

This task will define (MS14), establish and manage FORCeS interaction with the stakeholder group (SG). The SG will include representatives of the IPCC, European and international institutions with responsibilities in climate and air quality issues, non-governmental organizations, representatives from industry and manufacturing and managers of large scale Earth System modelling projects and programs. In addition to the confined stakeholder group FORCeS will also benefit from the existing collaborations and networks that the project participants act within including scientific networks, national environmental protection agencies, policy and decision makers on national and international levels, etc. This part of the task, which will start with a mapping of the networks (MS13), will make sure that FORCeS can benefit from already established channels for communication while maintaining a consistency in the communication from the project. A stakeholder workshop (MS16) will be organized with the goal of combining stakeholder knowledge with the project results allowing FORCeS to provide policy and decision makers with relevant information, in particular related to the development of strategies for reaching the goals of the PA and CLRTAP concerning air quality. In this aspect, WP7 will receive information in particular from WP5 and WP6. WP7 will also promote FORCeS in the context of the UNFCCC "Talanoa Dialogue" at Conference of Parties (COP) side-events stakeholder workshops. Besides these workshops, interaction with the stakeholders will be maintained through FORCeS website and newsletters (WP8) and also through dedicated policy briefs (D7.1).

Task 7.2: Dissemination of knowledge, data and results from FORCeS to the scientific community including early career scientists (SU, SMHI, all partners)

A Winter school (D7.2) and a Summer school (D.7.3) will be organized, allowing early career scientists to be involved in the forefront of climate science. Teaching activities will be mixed with opportunities for the young scientists to present and get feedback on their research. Teachers will be experienced scientists from FORCeS and also other earlier EU-funded research projects. Interaction with other early career scientists and experienced leading scientists in the field will promote network building. A data user workshop (MS17) will be held, with the goal of promoting the use of data produced within FORCeS, allowing the developments and data produced to be shared across the user community, ensuring users are aware of developments (such as key aerosol and cloud parameterizations that could be incorporated in leading European Earth System Models) and also of the availability of data and how to effectively use it. Included in this task is also the suggestion of, and if approved, organization of special sessions in relevant forums such as the European Geosciences Union General Assembly and the European Aerosol Conference.

Task 7.3: **Landmark scientific papers** (SU, SMHI, all partners)

Four open-access landmark scientific papers, accompanied by video abstracts and advertised through press releases, will be produced (MS15). The overarching goal is to make sure that FORCeS members contribute with high-impact scientific papers and results to major international scientific assessments, such as the ones produced by the IPCC and the Arctic Monitoring and Assessment Programme (AMAP). Also, work with these

papers will further strengthen collaboration across work packages and between project partners within FORCeS aiming at maximizing the success and scientific impact of the project.

Deliverables

D7.1 Policy briefs (M12, M24, M48)

D7.2 Winter school for early career scientists (M15)

D.7.3 Summer school for early career scientists (M33)

Work package number	8	**Lead beneficiary**				SU	
Work package title	FORCeS Project Management						
Participant number	1	11					
Short name of participant	SU	SMHI					
Person months per participant:	48	3					
Start month	1			**End month**	48		

Objectives

WP8 will be responsible for the overall management of the project. Specifically, WP8 will

- Establish and maintain efficient management of FORCeS, i.e. enable objectives and impacts to be achieved on time and within the resources budgeted.
- Ensure efficient communication with the European Commission as well as timely reporting.
- Establish and coordinate FORCeS internal and external dissemination, exploitation and communication strategies.
- Establish and maintain an action plan for gender equality.

WP8 will interact with all other WPs.

This WP is co-led by Ilona Riipinen (SU) and Annica Ekman (SU).

Description of work, lead partner and role of participants

The tasks within this WP will be the responsibility of the Coordinator or FORCeS (Prof. Ilona Riipinen), who will work in close collaboration with the Scientific Coordinator (Prof. Annica Ekman) to ensure efficient project leadership. The Coordinator and Scientific Coordinator will be supported by the Management structure outlined in Section 3.2 as well as the Project Office established at SU (Section 3.2, MS18). WP8 contributes therefore ultimately to all FORCeS objectives and interacts with all other WPs.

Task 8.1: General project management (SU) The Coordinator will be responsible for the communication with the European commission and all project partners and for reporting to the General Assembly and Scientific Advisory board. The Project Office that is led by the Coordinator will be responsible for project coordination tasks, project reports, gender equality aspects and overall day-to-day-management. The tasks of the Project Office include:

- Implementation and maintenance of the Grant Agreement and Consortium Agreement.
- Preparation of kick-off event (M2) and annual general assemblies (M12, M24, M36 and M48).
- Preparation of agenda and minutes of SC and annual meetings.
- Facilitation of communication between work packages and ensuring the distribution of documents/information among the consortium members.
- Establishment and maintenance of a web page for external and internal communication (in collaboration with WP7 and WP9) (D8.1 and D8.2).

- Monitoring downloads of metrics tools and data from the project web site.
- Project management guidelines for obtaining deliverables, data exchange and publication tracking.
- Checking that timing of activities, deliverables and milestones are on schedule.
- Managing project progress and responding to important changes during the lifetime of the project
- Controlling manpower resources and running costs, risk analysis and management (collaboration with WP9).
- Timely submission of reports, deliverables, cost statements, etc. to the EC.
- Maintenance of financial and legal aspects of the project.
- Communication of information from the EC to the project partners on due reports.
- Supervision of gender equality aspects.
- Preparation of project reviews.
- Handling of/facilitating the resolution of any ethics issue within the consortium and/or any disputes or complaints in accordance with the Consortium Agreement.
- Checking that reports from the general assembly and meeting minutes are written and that action points are followed up.

Task 8.2: Project communication and reporting to the EC (SU). The Coordinator will be responsible for communicating and reporting to the EC. All partners will deliver relevant information to leaders of their work package(s) and the information will be consolidated by the WP lead partners. The Coordinator sill make sure that the Project Office delivers proper and timely information relevant for each work package and will consolidate the information from the WP leaders into the reports that are submitted to the EC. The Coordinator will make sure that the advice and inputs of the FORCeS project officer at the EC will be communicated to the consortium and taken into consideration and that work plans and budgets are adjusted according to the agreed inputs from the EC.

Task 8.3: **Facilitating internal communication and knowledge exchange** (SU).The Project Office will ensure information exchange through different standard communication channels (email, web conferencing, phone conference, newsletters etc.) and set up standard tools for this communication (e.g. mailing lists). FORCeS will also develop and use a dedicated internal, password-protected website (D8.1), which will be hosted by SU. Project templates, tools and documents that the Project Office will develop will be available on the web site, which will aid the reporting and management of the project.

Task 8.4: Communication activities (SU, SMHI, all partners). An updated media and communications strategy will be developed by M6 and incorporated into the Plan for the Exploitation and Dissemination of project Results (D8.4). Section 2.2 outlines FORCeS communication activities that will be put in place to promote and disseminate the project findings. A public FORCeS website will be setup and managed by the project office at SU (D8.2). This website will be at the core of the media strategy; the website will link to other platforms, such as Twitter, YouTube and LinkedIn, with the goal to reach a wider audience. The dissemination strategy will change with time as the project will go through different phases: first focusing on general promotion and creating expectation; afterwards balancing between general and specific promotion with increasing efforts set in releasing formal outputs and getting feedback; and towards the end of the project exploiting the results to leave a mark. After defining a strategy at an early stage of the project this task will update the strategy and make adjustments when necessary. The Project Office will monitor FORCeS communication activities and include planned and completed communication activities as a part of the Interim Reports (D8.6-D8.8) and as a final report to the EC (D8.9). The Project Office will also provide the EC with information that could be useful to promote the project and European research in general.

Task 8.5: Exploitation, Dissemination and Knowledge Management (SU, SMHI, all partners). This task will coordinate exploitation and dissemination activities within FORCeS, in close collaboration with WP7 and WP9. A Plan for the Exploitation and Dissemination of Project Results (PEDR) will be produced (D8.4). The PEDR will be consistent with the Data Management Plan delivered by WP9. The PEDR will include a media and communications strategy (Task 8.4) and it will be formulated on the basis of the dissemination strategy and communication channels outlined in Section 2.2. It will make use of the mapping of existing network and channels for dissemination performed by WP7 (MS13). The PEDR will also include a strategy for innovation and knowledge management. At the end of the project, a Final Project Dissemination and Exploitation report will be delivered (D8.11) to ensure that project results and knowledge are efficiently exploited beyond the end of FORCeS. **Task 8.6: Gender equality aspects** (SU). A Gender Action Plan will be established (D8.3) by with the aim at raising awareness to gender inequality within the consortium and in general, maintaining or improving gender balance within the project, assisting female scientists within the consortium to build-up or

maintain a professional network and finding measures to help reconcile work and private life. The Coordinator, with support from the Project Office, is responsible for making sure that plan is monitored and evaluated in the Final Report on Gender Equality (D8.10).

Deliverables

D8.1 Generation of internal site (M4)

D8.2 Generation of public web site (M4)

D8.3 Gender Action Plan (M6)

D8.4 Project Plan for the Exploitation and Dissemination of project Results, including Innovation and Knowledge management strategy (M6)

D8.5 Inception report (M4).

D8.6 First Interim Report (M14). Report of the year 1 general assembly including recommendations for year 2.

D8.7 Second Interim Report (M26). Report of the year 2 general asembly including implementation plan for year 3 and mid-term report on gender equality and diversity (M18).

D8.8 Third Interim Report (M38). Report of the year 3 general assembly including recommendations for year 3.

D8.9 Report on FORCeS communication activities (M48)

D8.10 Final report on Gender Equality (M48)

D8.11 Final Project Exploitation and Dissemination Report (M48). This report will suggest pathways for further exploitation and dissemination of FORCeS results and knowledge.

Work package number	9		**Lead beneficiary**			SU	
Work package title	Scientific management						
Participant number	1	13	All other partners				
Short name of participant	SU	UHEL					
Person months per participant:	24	3	1 / partner				
Start month	1			**End month**	48		

Objectives

WP9 will

- Coordinate and facilitate scientific activities within FORCeS.
- Consult steering committee and advisory group and integrate their advice in FORCeS activities.
- Produce and implement Data Management Plan. Support exploitation of FORCeS data.
- Facilitate dissemination and exploitation of FORCeS scientific results, including knowledge exchange with the scientific community (e.g. other H2020 projects) and other target audiences.

WP9 will interact with all other WPs.

This WP is co-led by Annica Ekman (SU) and Ilona Riipinen (SU).

Description of work, lead partner and role of participants

The tasks within this WP will be the responsibility of the Scientific Coordinator or FORCeS (Prof. Annica Ekman), who will work in close collaboration with the Coordinator (Prof. Ilona Riipinen) to ensure efficient project leadership. The Scientific Coordinator and Coordinator will also be supported by the Management structure outlined in Section 3.2 as well as the Project Office established at SU.

Task 9.1: Scientific coordination (SU)**.** The Scientific Coordinator will coordinate and monitor scientific excellence within the project to ensure that a) the scientific objectives of the project are reached according to pre-defined indicators (Table 2.1); b) results are contributing (or are on track to contribute) to the predefined impact, as defined in the proposal (Section 2.2a); c) that potential risks are prevented or mitigated (D9.1). The Scientific Coordinator will have regular discussion and meetings with the Coordinator, Scientific Steering committee, SAG and WP leaders and incorporate necessary scientific aspects and advice into the project. The Scientific Coordinator will also be responsible for scientific aspects of the project coordination tasks (Task 8.1), including: scientific review of reports and deliverables to the EC as well as scientific contents of the project web site.

Task 9.2: Establishment and consultation of Scientific Advisory Group (SU). This task will ensure the formal establishment of the SAG (cf. Section 3.2) (MS19) and proper consultation of the SAG. The Scientific Coordinator will be responsible for organizing regular meetings with the SAG, ensure that the SAG receives relevant project information, invite the SAG to the General Assembly Meetings and make sure that their scientific advice is appropriately considered and incorporated into FORCeS activities.

Task 9.3: **Data Management** (SU, UHEL, UOX). The Scientific Coordinator and the leaders of WP4 and WP7 will produce a complete Data Management Plan (DMP) using input from all WP leaders (D9.2). The DMP will follow the template included in the H2020 manual and include (a) data format standards (b) data curation policy (c) meta data template (d) means for data exchange and storage within FORCeS (e) data exploitation strategy. Open Data Policy will be a key consideration for all data management. The Scientific Coordinator and leaders of WP4 will support WP7 in organizing a data user workshop (MS17) and make sure that relevant links to data, models software, metrics and other tools are available on the project web site. Each WP lead partner will keep records of information and data generated during the lifetime of FORCeS. The Scientific Coordinator will with support by the Project Office label each item generated and make the information, when suitable, publically available on the project website.

Task 9.4: Synthesis of FORCeS science (SU). The Scientific Coordinator, with support by WP7, will be responsible for synthesizing and summarizing FORCeS results and will make sure that relevant scientific information is available the project website. A range of target audiences (other scientists, early career scientists, media, stakeholders, general public) will be considered and the contents of the information will be shaped accordingly (Section 2.2). The Science Coordinator will also assist WP7 in deciding on the topics for landmark papers (MS15). A FORCeS science progress report will be produced in M28 (D9.4). In preparation, an internal workshop will be organized by the Scientific Coordinator (supported by the Coordinator) with relevant WPs and the SAG in attendance, to outline important next steps in the project (MS20). A final scientific summary report will also be produced at the end of the project, detailing and summarizing the overall outcomes of FORCeS (D9.5). The progress and summary reports will feed into the policy briefings for decision and policy makers that WP7 will produce (Task 7.1). The scientific progress and final summary reports will feed into the second interim report and final project exploitation and dissemination report produced by WP8, respectively.

Task 9.5: Communication with other relevant projects and programmes (SU).

The Scientific Coordinator will coordinate information exchange and linkages with related projects and programmes, in particular H2020 projects, to ensure cross-fertilization. Table 1 lists examples of such projects. The mapping of networks performed by WP7 (MS13) may identify additional channels and possibilities to enhance and make use of FORCeS science. The Scientific Coordinator will establish a plan at the beginning of FORCeS on how to best liaise with other projects and programmes (D9.3). This plan will be continuously updated and it will include a strategy for the participation of FORCeS in important international organizations involving decision and policymakers, such as CCAC, the Arctic Council, CLRTAP, CORDEX, GESAMP and Future Earth. The Scientific Coordinator will also ensure that representatives of other relevant, ongoing H2020 projects (e.g. APPLICATE, CRESCENDO and PRIMAVERA) are invited to FORCeS workshops and General Assembly Meetings. In addition, experienced scientists from other previous and ongoing EU-projects will be

invited as lecturers at FORCeS summer and winter schools (Task 7.2). All work package leaders will assist the Scientific Coordinator in Task 9.5.

Table 3.1c. List of deliverables.

Deliverable (number)	Deliverable name	WP number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
D1.1	Parameterization recommendations for nitrate, organic aerosol, ultrafine aerosol growth and aerosol absorption	WP1	FORTH	R	PU	30
D1.2	Recommendation on simplified parameterizations for microphysical processes related to aerosol.	WP1	ETHZ	R	PU	36
D2.1	Parameterization recommendations for five key aerosol-cloud-precipitation processes	WP2	ULEI	R	PU	30
D3.1	Assessment of global past (1950-present) aerosol, cloud and ERFari+aci changes.	WP3	MetNo	R	PU	30
D3.2	Sensitivity of estimated aerosol radiative forcing of FoRCES models to aerosol and cloud processes and aerosol emissions.	WP3	ULEEDS	R	PU	36
D3.3	Global past and future (1950-2050) ERFari+aci changes using updated FORCeS ESMs.	WP3	ETHZ	R	PU	48
D4.1	Observational constraints on aerosol, aerosol-cloud interactions, aerosol evolution and aerosol ERF (1950-present).	WP4	FMI	R	PU	36
D4.2	Community model evaluation packages upgraded with FORCeS data and analysis methods	WP4	UOX	OTHER	PU	48
D5.1	Identification of relevant processes for response	WP5	SMHI	R	PU	30

	and feedbacks to aerosol and cloud forcing					
D5.2	Impact of revised parameterizations in ESMs on aerosol forcing estimates.	WP5	MetNo	R	PU	48
D6.1	Compliance of FORCeS ESMs with respect to established emergent constraints.	WP6	UO	R	PU	18
D6.2	Assessment of new emergent constraints, as well as on the utility of "network analysis" in this context.	WP6	FORTH	R	PU	30
D6.3	New and more constrained estimates of transient climate response	WP6	UO	R	PU	48
D6.4	Re-assessment of the emission reduction targets required in order to meet the Paris targets	WP6	UOX	R	PU	48
D7.1	Policy briefs	WP7	SMHI	R	PU	M12, M24, M48
D7.2	Winter school for early career scientists	WP7	SU	OTHER	PU	15
D7.3	Summer school for early career scientists	WP7	SU	OTHER	PU	33
D8.1	Generation of internal web site	WP8	SU	OTHER	PU	4
D8.2	Generation of public web site	WP8	SU	OTHER	CO	4
D8.3	Gender Action Plan	WP8	SU	R	PU	6
D8.4	Project Plan for the Exploitation and Dissemination of project Results, including Innovation and Knowledge management strategy	WP8	SU	R	CO	6
D8.5	Inception report.	WP8	SU	R	PU	4

D8.6	First Interim Report. Report of the year 1 general assembly including recommendations for year 2.	WP8	SU	R	PU	14
D8.7	Second Interim Report. Report of the year 2 general asembly including implementation plan for year 3 and mid-term report on gender equality and diversity.	WP8	SU	R	PU	26
D8.8	Third Interim Report. Report of the year 3 general assembly including recommendations for year 3.	WP8	SU	R	PU	38
D8.9	Report on FORCeS communication activities.	WP8	SU	R	PU	48
D8.10	Final report on Gender Equality.	WP8	SU	R	PU	48
D8.11	Final Project Exploitation and Dissemination Report. This report will suggest pathways for further exploitation and dissemination of FORCeS results and knowledge.	WP8	SU	R	CO	48
D9.1	Risk management strategy.	WP9	SU	R	PU	2
D9.2	Data Management Plan.	WP9	SU	R	PU	6
D9.3	Plan for liaising with other projects and programmes.	WP9	SU	R	PU	6
D9.4	Scientific progress report.	WP9	SU	R	PU	26
D9.5	Final scientific summary report.	WP9	SU	R	PU	48
D9.6	Minutes of the Scientific Advisory Group meetings.	WP9	SU	R	PU	12, 24, 36

3.2 Management Structure

3.2.1 Organisational structure and decision-making procedures

The administrative, financial, legal and scientific coordination of FORCeS will be located at SU. A Project Office (cf. Section 3.2.4) will be established (MS18) consisting of the Coordinator, the Scientific Coordinator and a Project Manager, supported by an administrator. The FORCeS Project Office is supported by the Research Support Office at SU and will ensure that all project partners fulfil their joint responsibilities and obligations towards the European Commission including the accession of partners to the grant agreement.

FORCeS brings together partners from 13 different countries, including academic institutions, research institutes, met services and public agencies. The project is organized around 9 work packages (Section 3.1) where two (WP8 and WP9) are fully dedicated to efficient project and scientific management. Each work package has distinct responsibilities and deliverables (Table 3.1c) with milestones defined (Table 3.2a) to ensure effective project progress.

Figure 3.2 illustrates the general components of the FORCeS management structure, which has been setup following the DESCA Model Consortium Agreement for Horizon 2020 projects. The components are summarized below and further details are given in the following sub-sections.

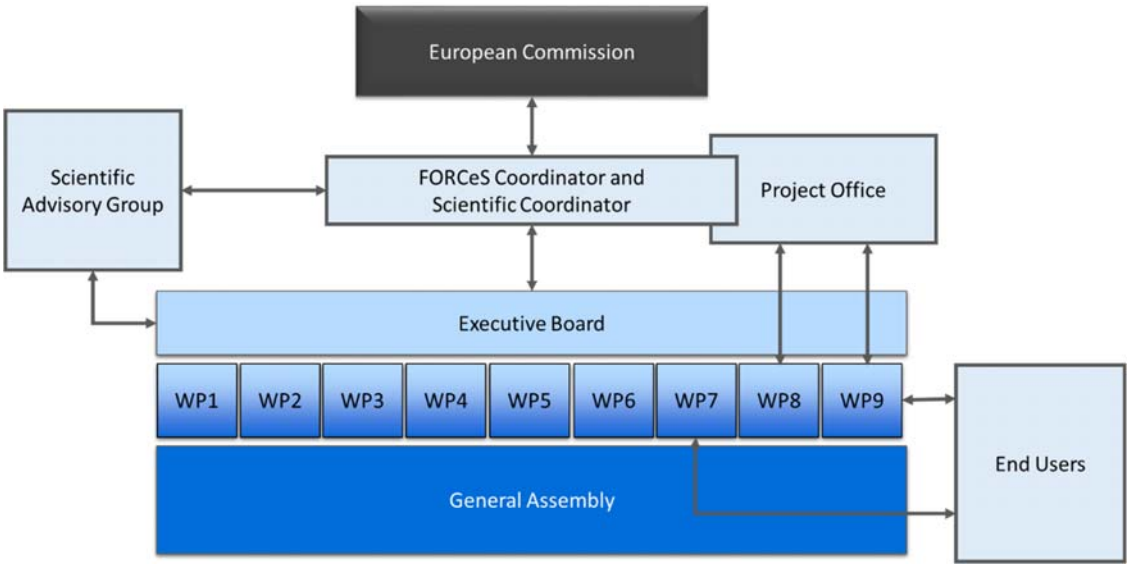

Figure 3.2. FORCeS management structure.

General Assembly: is the ultimate decision making body of FORCeS. It is chaired by the Coordinator and will consist of all the partner organizations.

Executive Board: is the supervisory body for the execution of FORCeS. It reports to and is accountable to the General Assembly. The Executive Board is chaired by the Coordinator and consists of the Scientific Coordinator, the Project Manager and all WP leaders.

Coordinator: is responsible for the overall project coordination and is the intermediary between FORCeS and the European Commission (EC). She has the ultimate responsibility that the project delivers as expected.

Scientific Coordinator: supports the Coordinator and is responsible for the overall scientific coordination of the project. She ensures that FORCeS maintains scientific excellence and that work packages are contributing to the planned objectives and outcomes.

Project Office: is responsible of the day-to-day management of FORCeS. It consists of the Coordinator, Scientific Coordinator and Project Manager, supported by an administrator.

Project Manager: assists the Coordinator in the day-to-day management duties and in monitoring the progress of FORCeS.

Work Package Leaders: are responsible for delivering according to their work package objectives and deliverables. They support the Coordinator and Scientific Coordinator in delivering the expected outcomes of FORCeS. Each work package has two leaders, as described and justified further below.

Science Advisory Group: will provide expert advice on project progress and help FORCeS align its activities according to the planned objectives and outcomes.

End Users: the ultimate target groups of FORCeS science and knowledge. They influence FORCeS activities and priorities through workshops and other communication measures (WP7)

Table 3.2a List of milestones.

Milestone number	Milestone name	Related WP(s)	Due Date	Means of verification
MS1	First versions of parameterizations of key aerosol processes and components.	1, 5	M24	Functional forms and parameterization input ready for implementation.
MS2	Recommendations on parameterizations for key aerosol-cloud-precipitation processes.	2, 5	M27	Functional forms and parameterization input ready for implementation.
MS3	Transient historical simulations providing aerosol composition and ERF.	3, 6	M18	Successful completion of model simulations.
MS4	Completion of assessment of the largest model ERF uncertainties in transient simulations.	3, 6	M30	Successful completion of model analysis.
MS5	Simulation of likely near future aerosol composition and ERF trends.	3, 5, 6	M40	Successful completion of model simulations.
MS6	First estimates of aerosol ERF and its uncertainty.	1-7	M36	Synthesis of observations and model outputs to meet the overall goal of FORCeS.
MS7	Final decisions on new parameterizations in the ESMs.	1, 2, 5	M27	Decision made on which parameterization should be implemented in which ESM.
MS8	Three Revised ESMs.	5, 6	M36	Revised / updated model codes.
MS9	Completion of analysis of CMIP6 and additional FORCeS simulations with respect to TCR and emergent constraints.	5, 6	M18	Successful completion of model simulations.
MS10	New metrics for ESM evaluation developed and tested on CMIP6/FORCeS ESMs.	6, 7	M30	ESM evaluation completed.
MS11	Completion of analysis of revised FORCES models and statistical modelling that combined form the basis for the revised TCS estimate.	5, 6	M48	New parameterizations implemented in FORCeS ESMs, models tested and evaluated.
MS12	Completion of the ensemble of simple model simulations required for re-assessment of emission pathways compatible with the Paris goals.	6, 7	M48	Model simulations successfully completed, analyzed and relevant results communicated to relevant stakeholder groups.

MS13	Mapping existing networks and channels for dissemination and communication.	7	M6	List of communication channels ready.
MS14	Stakeholder group defined including enquiry about their possible needs from FORCeS.	7	M9	List of relevant stakeholders and their contact information compiled. Survey for them prepared and sent onward.
MS15	Landmark scientific papers submitted.	7,9	M12, M24, M36, M48	Landmark scientific papers submitted to journal for peer-review.
MS16	Stakeholder workshop.	7	M24	Workshop organized.
MS17	Data user workshop.	7	M36	Workshop organized.
MS18	Establishment of project office (PO).	8, all	M1	Project manager team confirmed/recruited.
MS19	Establishment of Scientific Advisory Group (SAG).	9, all	M1	Composition of SAG confirmed and first teleconference held.
MS20	Internal workshop for consolidating FORCeS science.	9, all	M24	Workshop organized.

3.2.2 General Assembly (GA)

The General Assembly is the decision-making body of FORCeS and consists of representatives of all partner organizations. The GA will decide on the following issues: i) the political policy and strategic orientation of the project; ii) the FORCeS work plan and plan for using and disseminating the knowledge; iii) the structure and any restructuring of work packages; iv) budget-related matters including the Consortium's overall budget and the financial allocation of the EC's contribution to the different partners as well as reallocation of budgets between partners exceeding 10% of the EC contribution; v) changes in the Consortium membership as well as acceptances of new contractors or exclusions of contractors; vi) any alterations of the Consortium Agreement vii) The premature completion/termination of the project.

The GA will meet five times during the lifetime of FORCeS: the first time at the kick-off meeting (that will be held at the second month after the start of the project and thereafter at the General Assembly meetings held once per year (Task 8.1). The quorum and the rules of voting will be further defined in the Consortium Agreement. The Coordinator will be the chairperson of the GA.

3.2.3 Executive Board (EB)

The Executive Board oversees the integration and completion of FORCeS objectives and acts in response to decisions made by the General Assembly. Conversely, the EB will make suggestions to the General Assembly regarding the FORCeS work plan, budget, mitigation of risks, and other matters necessary for the advancement of the project and project success. The EB will also recommend resolutions for any dispute between partners and ensure that all work packages are fully integrated in FORCeS and that they contribute to the work plan and objectives. In the event of changes to the work plan or its contents, as well as financial or IPR issues, the EB will make recommendations for the GA to approve.

The members of the EB are the Coordinator (chair of the EB), Project Manager (Reports to the EB), Scientific Coordinator and all WP leaders. The WP7 leaders will ensure that communication with end-users is reported to the EB and that end-user requests are taken into consideration.

The EB will meet at project inception and thereafter every three months. Annually, the meetings will coincide with the General Assembly meetings. For the intermediate meetings, teleconferences will be used.

3.2.4 Project Coordination and Project Office

The Coordinator (Prof. Ilona Riipinen, SU) will be responsible for the overall management of FORCeS with assistance by the Science Coordinator (Prof. Annica Ekman, SU) who is responsible for the scientific aspects of FORCeS. The two of them have worked closely together during several years in numerous small- and large-scale projects. They have for example co-led the research area "Clouds, aerosols, turbulence and climate" within the Bolin

Centre for Climate Research, co-supervised several PhD students and Post-Doctoral researchers and they have (despite their relatively young age) co-authored close to 10 publications together.

The Project Office consists of the Coordinator, the Scientific Coordinator, the Project Manager (Dr. Ana Cordeiro, SU) and an administrator. All administrative, financial and management aspects of FORCeS will be coordinated by the Project Office, at the delegation of the General Assembly. Dr. Ana Cordeiro works at the Research Support Office, SU and she has extensive experience in coordinating and managing large-scale projects.

FORCeS Coordinator: The Coordinator is responsible for the overall management of FORCeS as well as the liaison with the European Commission on behalf of the project consortium. She will also be the principal contact with the financial administration at SU. The general duties and responsibilities of the Coordinator are outlined in Task 8.1 and include: communicating any required information or deviations from agreed plans with the European Commission; coordinating and monitoring the FORCeS Gender Action Plan (D8.3); coordinating and monitoring FORCeS communication, dissemination, exploitation, knowledge and innovation management tasks (D8.4); overall financial and administrative management; facilitating communication internally and externally (D8.1, D8.2). The Coordinator will open negotiations related to the Consortium Agreement and ensure that FORCeS will take into account all requirements and recommendations stated by the European Commission.

FORCeS Scientific Coordinator: The Scientific Coordinator is responsible for the scientific excellence within FORCeS. She will be responsible for monitoring the scientific progress and risks (D9.1) of the work plan; provide scientific leadership for the project; be responsible for FORCeS data management (D. 9.2); synthesize FORCeS results to achieve maximum benefit and impact (D9.4, D9.5); liaise with other relevant projects and programmes, in particular those funded by H2020 (D9.3), and make sure that advice and considerations from the Science Advisory Group are taken into account (Task 9.2).

FORCeS Project Manager: The Project Manager is in charge of the FORCeS Project Office, which will be established at SU (MS18). The Project Manager assists the Coordinator in day-to-day monitoring of project progress (project plan, reminders for task initiation or completion, general project management and all other items listed in Task 8.1); identifying and anticipating issues and obstacles and suggests ways to solve them. The Project Manager will prepare guidelines for the project consortium, including a timeline for monitoring and how to request and review project deliverables and send them to the European Commission. The Project Manager will also facilitate communication within FORCeS and maintain the different communication instruments: an external as well as internal (password protected) web site, mailing lists, etc. Another task of the Project Manager will be to assist the Coordinator in the financial reporting and in the financial actions between the European Commission and the project partners.

3.2.5 Work Package Leaders (WPLs)

All FORCeS work packages have been setup with two co-leaders. The aim is to effectively integrate knowledge and expertise from different communities within aerosol, cloud and climate science (cf. Section 1.3). Assigning co-leadership ensures an emphasis on a broader range of proficiency within each work package and a more efficient cross-fertilization of knowledge. The responsibilities of the WPLs include: management of the scientific and technical aspects of their work package; organization of work package meetings to discuss progress, problems and new ideas; maintaining a close contact with all work package participants; reporting to the Coordinator on progress, problems, and the achievement of deliverables and milestones; reporting on financial aspects of the work package. The WPLs will also assist the Scientific Coordinator in the exchange of information between FORCeS and other projects and programmes (Task 9.5).

3.2.6 Scientific Advisory Group (SAG)

A Scientific Advisory Group will be setup at the beginning of the project (MS19). The SAG of FORCeS is setup to maximize the expected impact on the scientific community, policy-making and the society in general (Table 3.2.6). Their letters of support are found in Appendix 1. The SAG will be invited to all General Assembly Meetings and they will take part in the project reviews. If members cannot attend in person, arrangements will be made for remote participation. The Coordinator and the Scientific Coordinator will also maintain regular contact with the SAG (Task 9.2) and provide them with information on project progress and results.

Table 3.2.6. FORCeS Scientific Advisory Group

Name	Expertise	Institute
Prof. Nicolas Bellouin (male)	Expert on numerical modelling of aerosol-cloud-climate processes. PI of several EU-funded projects including Copernicus	University of Reading, UK.

	Atmospheric Monitoring Service: Climate Forcings; PRIMAVERA.	
Ms. Cat Downy (female)	European Space Agency – Future Earth Liaison Officer. Responsible for developing new initiatives for exploiting ESA data with Future Earth.	European Space Agency's Climate Office, ECSAT, UK.
Prof. Hong Liao (female)	Expert on atmospheric aerosol processes and links between air quality and climate change. Corresponding Lead Author of the upcoming IPCC AR6.	Nanjing University of Information Science and Technology, China.
Dr. Jean-Noël Thépaut (male)	Head of the Copernicus Climate Change Service. Expert on using satellite data for enhancing numerical weather prediction.	European Centre for Medium-Range Weather Forecasts, UK.
Dr. Elisabetta Vignati (female)	Head of the European Commission's Joint Research Center's Air and Climate Unit. Coordinator of the Institute for Environment and Sustainability strategic activity on Sustainable Urban Living.	The European Commission Joint Research Center, Italy.

3.2.7 End-users

The end-users of FORCeS include policy and decision makers, representatives of the IPCC and other assessment groups, the science community and the general public. Work Package 7 is entirely dedicated to efficient and effective communication with end-users and includes a range of activities to have them engaged in FORCeS actitives (Task 7.1, Task 7.2). The Science Coordinator will also make sure that FORCeS liaise with other projects, in particular those funded within by H2020, e.g. PRIMAVERA and CRESCENDO (Task 9.5).

3.2.8 Innovation management

The Coordinator is responsible for formulating a strategy for Innovation and Knowledge Management at the start of the project (part of the PEDR, D8.4). The Coordinator has the full overview of FORCeS activities and will be supported by the technical expertise and end-user expertise available within the FORCeS consortium. The Scientific Advisory Group and the communication with end-users in work package 7 (Task 7.1 and Task 7.2) will allow channeling of ideas to services that are responding to societal interests. At the end of FORCeS, a plan for further exploitation of FORCeS results and knowledge will also be established (D8.11).

3.2.9 Risk management

The Coordinator and Science Coordinator are responsible for dealing with risks within the project (Task 8.1, Task 9.1, D9.1) supported by the Project Manager. The General Assembly will make decisions to prevent and mitigate risks at the suggestion of the Executive Board. The GA will also make the EB aware of risks within the project that have not been identified by the EB.

Identified risks will be monitored by the Project Office (Task 8.1) and will be managed (and shared between partners) using a risk register, which collects features such as risk category, description, probability, proximity, impact, response, work package(s) associated, and the risk owner. Each identified risk will be assigned to a partner responsible for monitoring it, and mitigation and contingency plans will be defined jointly with the Coordinator and Science Coordinator. The risks will be classified into categories (technical, organizational, financial, etc.) and a specific check will monitor whether a Grant Agreement amendment might be required. A number of critical risks for project implementation have already been identified and are listed in Table 3.2b. These risks will be actively monitored by the Project Office during the lifetime of FORCeS.

Table 3.2b. Critical risks for implementation of FORCeS.

Description of risk (Objective at risk)	**Risk level**	**WP(s) involved**	**Proposed risk-mitigation measures**
A partner or key scientific staff withdraws from the project (All)	Low	All	The setup with two co-leaders for each WP ensures continuity in WP leadership and overlap of expertise. Other key roles in the project should have identified deputies. If

			necessary, new members can be added to the consortium (Section 3.2.11).
Coordination problems, lack of understanding between partners, delays in the project implementation, insufficient rigor or timeliness in scientific and financial reporting (All)	Low	WP8, WP9	Revision of project management structure and methodology. Increase frequency of Executive Board meetings. Application of conflict resolution methods.
Individual partners are unable to complete their tasks for example due to wrong estimates of required efforts (All)	Low	All	The proposed work has been partitioned into detailed tasks that enable an as precise as possible estimation of required PM effort. Regular communications led by Coordinator, Scientific Coordinator and Project Manager between WPs to monitor progress and reassign work/resources if required.
Lack of delivery of parameterizations resulting in delay in model development and simulations (O1,O2)	Medium	WP1-WP6	The parameterization development work builds largely on already existing data minimizing the risk of delay. The combination of experimental and model experts in WP1 and WP2 ensures efficient parametrization development.
Low impact of updated parameterizations on uncertainty in aerosol radiative forcing and transient climate response (O1, O2)	Medium	WP1-WP6	FORCeS will use past knowledge and a range of novel methods to identify key processes causing the largest uncertainty in aerosol radiative forcing and transient climate response.
"Stakeholder fatigue", leading to lack of engagement and an inability to retrieve the climate information required by stakeholders (O3)	Low	WP6, WP7	Information from stakeholders will be gathered through different channels, at different time points and through different activities. A selected number of stakeholderse are also involved as active partners in FORCeS.
Low impact of communication and dissemination activities. (O3)	Low	WP7, WP8, WP9	The communication and dissemination strategy largely builds on existing, well-established channels, networks and collaboration. Communication and dissemination activities will be monitored by the Project Office and actions will be taken if needed.

3.2.10 Gender balance within FORCeS

FORCeS will strive towards gender balance in all their activities. A Gender Action Plan (D8.3) will be formulated at the beginning of the project to monitor and improve gender equality aspects. The FORCeS team is highly aware of the importance of attracting, keeping and advancing more women in science. The FORCeS Coordinator and Science Coordinator are both female and 6 of 9 work packages are co-led by women. The Scientific Advisory Group consists of three female and two male experts. One of the aims with the workshops and summer/winter schools will be to promote gender balance perspectives and considerations. At the end of FORCeS, a summary report of gender equality aspects within the project will be delivered including recommendations for future actions (D8.10).

3.2.11 Addition of new participants

If circumstances request that one or more partners are added to the FORCeS consortium, e.g. due to the withdrawal of a partner (cf. Table 3.2b), the executive board prepares the review of candidates, consults the Scientific Advisory Group and selects the new partner(s). The result will be submitted to the General Assembly for approval.

3.2.13 Justification of the organizational structure for FORCeS

The management structure of FORCeS has been setup according to DESCA recommendations for medium and large projects. The complexity of FORCeS science, and the number of partners involved, requires an efficient yet stable organizational structure. The division of management tasks between the Coordinator, Science Coordinator and

Project Manager (WP8 and WP9) will ensure that all issues are covered and that back up is available when needed. The Coordinator and Science Coordinator have successfully worked together in the past in small- and large-scale projects. They have well-defined areas of responsibility which will ensure efficient project coordination.

3.3 Consortium as a whole

The FORCeS consortium consists of in total 21 members. The partners are geographically distributed in 12 European countries and represent different fields of atmospheric chemistry and climate studies. The consortium has been designed to have the necessary expertise required to cover all the relevant methodologies including in-situ (SU, ETHZ, FORTH, CNR, UEF, UHEL), laboratory (FZJ, UEF, ETHZ, FORTH), remote sensing (FMI, KIT, ETHZ, UOX) and theoretical including fundamental theory (SU, UHEL, FORTH, ULEI, KIT), computational modeling (SU, BSC, ETHZ, FMI, FORTH, KIT, MetNo, KNMI, SMHI, UHEL, ULEEDS, ULEI, UO, UOX, IIASA, UEX) and novel statistical / computational approaches (ULEEDS, UOX, FORTH, ETHZ, UO, MetNo) for data analysis and model simplification techniques. Specific attention has been paid in ensuring the participation of, on one hand, a large enough number of partners developing and applying European ESMs (SU, BSC, ETHZ, FMI, MetNo, KNMI, SMHI, UHEL, ULEEDS, UO, UOX) and on the other hand fundamental processes related to atmospheric aerosols and clouds (SU, ETHZ, FZJ, FORTH, KIT, CNR, UEF, UHEL, ULEI). To ensure successful framing of the research problems addressed, metrics used and communication measures taken, expected end-users of the research results to be produced (e.g. IIASA, INERIS, NV) have been also involved as partners of the consortium, participating in the common workshops but also in some of the more applied research in WP6. This compilation of partners is unique, essentially bringing together the traditional climate science community and the community investigating the fundamental processes governing atmospheric chemistry and physics, topped up with representatives of the end-users of climate research results. We believe such a combination is the key for resolving the long-standing uncertainty in the climate forcing caused by atmospheric aerosol particles. The details of each of the individual partners and their contributions to FORCeS have been given in Sect. 4. The resources allocated to each of the partners have been chosen proportionally to the PMs they contribute with to the tasks specified above, and negotiated so that the tasks that the partners have committed to can be fulfilled with the allocated resources.

3.4 Resources to be committed

The overall budget requested for FORCeS is approximately 8 MEur, primarily utilized for covering the PMs specified below (Table 3.4) and costs related to travel, equipment, organization of meetings and workshops and experimental activities (Table 3.5). The size of the budget and the distribution of the PMs has been designed by the coordinators and the WPLs to ensure sufficient manpower for all of the activities described in Tables 3.1. We have worked closely with all consortium partners to ensure that the appropriate resources (budget, staff, equipment and materials) are available and that these resources are allocated to minimize the projects risks. Project management accounts for approximately 6% and hence about 94% of the project resource is allocated to the seven science and technology WPs. The projects major development risks are allocated the vast majority of the available resource to overcome them. In addition the resources are mainly applied during the high risk developments of the project. Using this approach we have been able to establish, with a high degree of confidence, the overall project costs and we are satisfied that the EC grant is sufficient to cover the costs of creating a resource that has the best chance of success of delivering the objectives. Combining skills, equipment and appropriate utilization ensures we have the critical mass of resource to deliver the FORCeS project. In addition to the personnel budget, we have proposed budget for travel costs, consumable expenses and subcontracting. The travel budget is meant not only for face-to-face project meetings (approximately twice yearly) but also for practical workshops/meetings within the various work packages to take advantage of the advanced facilities of the different partners. These workshops/meetings will link the researchers and stimulate closer collaboration also outside the workshops. The summary of the staff efforts is shown in Table 3.4.a. Where the sum of the costs for' travel', 'equipment', and 'goods and services' exceeds 15% of the personnel costs for a partner we have justified these costs in Table 3.4.b below.

Table 3.4a. Summary of staff effort.

	WP 1	WP 2	WP 3	WP 4	WP 5	WP 6	WP 7	WP 8	WP 9	Total PMs per Participant
SU	6	36	12	12	24	24	24	48	24	210
BSC	12		12		6		1		1	32
ETHZ	12	35	35		12	8	1		1	104
FMI		14	12	13			1		1	41

FZJ	64	6					1		1	72
FORTH	59	20	40		20	79	1		1	220
KIT		17	6	16			1		1	41
CNR-ISAC	5	7	6	7			1		1	27
MetNo			9	4	13		1		1	28
KNMI			6		13		1		1	21
SMHI					35	10	15	3	1	64
UEF	18	30					1		1	50
UHEL	19		15	21	13	6	1		3	78
ULEEDS			12	22			1		1	36
ULEI		47		17	9		1		1	75
UO						38	1		1	40
UOX				44		22	1		1	68
NV							0.25			0.25
INERIS							0.25			0.25
IIASA	1		3.5			0.5				5
UEXE		2.9								2.9
Total Person Months	196	212	169	156	145	188	55	51	42	

Table 3.4b. "Other direct costs" items.

FZJ	**Cost (€)**	**Justification**
Travel	21800	Project meetings, participation in field campaigns (WP2)
Equipment		
Other goods and services	33200	Operation of simulation chambers in WP1 (gases, chemicals, spare parts), operation of field equipment (chemical, spare parts)
Total	55000	

FORTH	**Cost (€)**	**Justification**
Travel	40000	Project meetings
Equipment		
Other goods and services	60000	Participation in laboratory experiments in WP1, increase in the storage capacity of the FORTH computational cluster
Total	100000	

UEF	**Cost (€)**	**Justification**

Travel	10000	Project meetings
Equipment		
Other goods and services	35000	Parts of the costs of campaign organization (WP2). UEF is hosting the SMEAR IV campaign. The partner is asking for less than the actual cost. The rest is covered by UEF resources.
Total	45000	

UHEL	**Cost (€)**	**Justification**
Travel	28000	Project meetings
Equipment		
Other goods and services	22000	Publication costs, financial certification.
Total	50000	

UO	**Cost (€)**	**Justification**
Travel	10000	Project meetings
Equipment		
Other goods and services	66000	Computational costs for the Bayesian modeling
Total	76000	

UOX	**Cost (€)**	**Justification**
Travel	18650	Project meetings
Equipment	15000	Laptops, computing items and storage
Other goods and services	29850	Supercomputing access charges and audit fees
Total	64000	

NV	**Cost (€)**	**Justification**
Travel	2000	NV is participating as a stakeholder group member. Contributions to FORCeS are mainly attendance of workshops which entails travel costs.
Equipment		
Other goods and services		
Total	2000	

INERIS	Cost (€)	Justification
Travel	3500	INERIS is participating as a stakeholder group member. Contributions to FORCeS are mainly attendance of workshops which entails travel costs.
Equipment		
Other goods and services		
Total	3500	

Appendix 1. Letters of Support

Copernicus Climate Change Service

Date 31-08-2018

Prof. Annica Ekman
Stockholms universitet
Meteorologiska institutionen (MISU)
106 91 Stockholm

Prof. Ilona Riipinen
Stockholms universitet
Enheten för atmosfärsvetenskap ACESl
106 91 Stockholm

Letter of Support

H2020 call LC-CLA-08-2018

Dear Coordinators of the FORCeS proposal,

With this Letter, as Head of the Copernicus Climate Change Service (C3S), I would like to note one of the scope of the Call: " Improving the understanding of key climate processes for reducing uncertainty in climate projections and predictions".

In this context, activities related to this theme and in particular reducing the uncertainty range in anthropogenic aerosol forcings in climate models and their impact on future climate evolution would improve the quality of underpinning climate predictions and projections that C3S will continue to rely upon for its products and services.

The Copernicus Climate Change Service (C3S) will combine observations of the climate system with the latest science to develop authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide. ECMWF operates the Copernicus Climate Change Service on behalf of the European Union and will bring together expertise from across Europe to deliver the service.

Yours sincerely,

Dr. Jean-Noël Thépaut
Head, Copernicus Climate Change Service
E-mail: jean-noel.thepaut@ecmwf.int

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futurearth
research for global sustainability

Swedish Hub, Future Earth Secretariat
Royal Swedish Academy of Sciences
Lilla Frescativägen 4A
SE-114 18 Stockholm
Sweden

www.futureearth.org

Dear Sir/Madam,

The proposed project "Forcing Constraints for Transient Climate Sensitivity" (FORCeS) in response to Horizon 2020 call LC-CLA-08-2018 shows a novel approach to addressing some of the key knowledge gaps in climate science. It should provide important progress in this area in time for the 6th IPCC Assessment.

I would therefore very much support the FORCeS project.

We will follow the project progress by communication with the project consortium and provide assistance and advice where needed.

Yours Sincerely

Cat Downy

European Space Agency – Future Earth Liaison

Ref. Ares(2018)4417331 - 28/08/2018

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Directorate C – Energy, Transport and Climate (Ispra)
Air and Climate Unit

Ispra, 28 August 2018

Annica Ekman
Department of Meteorology (MISU)
Ilona Riipinen
Department of Environmental Science and Analytical Chemistry (ACES)
Stockholm University
Sweden
Email: annica@misu.su.se / Ilona.Riipinen@aces.su.se

Subject: Letter of Support for the project proposal FORCeS

As Head of Unit of the Air and Climate Unit of the Joint Research Centre, I am convinced that the project "Constrained aerosol forcing for improved climate projections" (FORCeS) proposed to Horizon 2020 may effectively tackle some of the key uncertainties in climate science.

The novel approaches chosen in FORCeS will contribute to meeting the goals of the Paris agreement (COP21).

As a member of the science advisory board of FORCeS, I will provide expert advice to the consortium if needed and follow the project's progress through communication by the project consortium.

Yours sincerely

(signed in ARES)

E. Vignati
Head of Unit JRC.C05

European Commission, Via Enrico Fermi 2749, I-21027 Ispra (Varese) - Italy. Telephone: (39)0332-78-9111.
Electronically signed on 28/08/2018 10:26 (UTC+02) in accordance with article 4.2 (Validity of electronic documents) of Commission Decision 2004/563

University of Reading

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27 August 2018

Re: Horizon 2020 proposal "Constrained aerosol forcing for improved climate projections"

To whom it may concern,

I would like to express my conviction that the project "*Constrained aerosol forcing for improved climate projections*" (FORCeS) proposed to Horizon 2020 will effectively tackle some of the key uncertainties in climate science. As emphasised several times in past IPCC reports, constraining anthropogenic aerosol forcing is critical for understanding past and future climate evolution. Consequently, meeting the goals of the Paris agreement will require the improvement of understanding and the development novel approaches that the FORCeS consortium proposes.

The proposed work is of high interest to me and complements many other research projects on aerosol modelling and radiative forcing estimates in which I am involved in the UK, Europe and internationally.

As a member of the science advisory board of FORCeS, I will provide expert advice to the consortium when needed and follow the project's progress through communication by the project consortium.

Sincerely,

Nicolas Bellouin
Associate Professor in Climate Processes

The Queen's Anniversary Prizes 2011

LIMITLESS POTENTIAL | LIMITLESS AMBITION | LIMITLESS IMPACT

南京信息工程大學
Nanjing University of Information Science & Technology

February 17, 2018

Dear Sir/Madam,

As a dean of the School of Environmental Science and Engineering at the Nanjing University of Information Science and Technology, and lead author of the upcoming IPCC 6th Assessment Report, I would like to express my strong support of the Horizon 2020 project "Constrained aerosol forcing for improved climate projections" (FORCeS).

FORCeS aims to reduce the large uncertainty in the radiative forcing of anthropogenic aerosols that has persisted through all IPCC assessment reports since 1995 - despite significant developments in model complexity, increases in global observations and advances in our knowledge of aerosol processes. I am convinced that the project will make an important contribution in improving our understanding of aerosol forcing uncertainty, as the project proposal is based on novel and thorough approaches and as the consortium gathers many leading European theoretical, modelling and experimental scientists.

In addition to advancing the field of climate science, I believe the outcomes of the project will be of high interest for the upcoming IPPC report and also for policy and decision makers. Reducing air pollution emissions, including aerosols, is an important issue in many regions of the world – in particular China. Understanding how a future reduction in aerosol emissions may hinder or support climate warming abatement is essential.

I am happy to support FORCeS by following project progress through communication by the project consortium and through being a member of the science advisory board. If required, I will offer advice and assistance to the consortium.

Yours Sincerely,

Hong Liao

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4. Members of the consortium

4.1. Participants (applicants)

Stockholm University	**1-Stockholm University (SU)**	**SWEDEN**
Description of the legal entity		
Stockholm University (SU) is one of the world's top 100 higher education institutes (ARWU), with about 34000 students, 1700 doctoral students and 5000 employees with research, education and societal interaction as its three main tasks. It hosts Sweden's most substantial research within natural and human sciences, and is the home of a number of internationally prominent research environments. "Climate, seas, and the environment" is one of the strategic focus areas of SU, and SU is among the best universities in the world in research and education related to these topics (e.g. in the top-25 in both Atmospheric science as well as Environmental Science and Engineering in Shanghai rankings by subject). SU hosts the multidisciplinary Bolin Centre for Climate Research, with contributions to climate science ranging from climate-related molecular processes to the large-scale dynamics of the climate system and research on the consequences of contemporary air quality and climate policies. The Bolin Centre is an ideal environment for the integrative research activities proposed within FORCeS. The Bolin Centre for Climate Research is a collaboration between the Departments of Ecology, Environment and Plant Sciences (DEEP), Environmental Science and Analytical Chemistry (ACES), Geological Sciences (IGV), Meteorology (MISU), Physical Geography (NG), and Zoology at Stockholm University together with FLOW at the Royal Institute of Technology (KTH) and the Rossby Centre at the Swedish Meteorological and Hydrological Institute (SMHI).		
Main tasks in FORCeS		
The SU team will coordinate the efforts within FORCeS and thus be the main contributor to WP 8, along with co-leading WP 7 focusing on dissemination and impact. SU will also contribute scientifically to WPs 2 (through field experiments, data analysis and modeling), 4 (through development of sea spray parameterizations), 5 (through NorESM simulations on mechanisms and feedbacks related in particular to Arctic climate change), and 6 (through NorESM simulations on transient climate response and prediction).		
Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities		
Ilona Riipinen (female) is a professor in atmospheric science at SU, and will coordinate FORCeS. She has received her PhD in 2008 from University of Helsinki, and has been employed at SU since 2011 after a post-doctoral period at Carnegie Mellon University in Pittsburgh, PA, in the United States. She is currently the head of the atmospheric science unit with approximately 40 staff members at the Department of Environmental Science and Analytical chemistry at SU, and a member of the board for University of Helsinki. Prof. Riipinen's research interests span from molecular phenomena related to atmospheric phase transitions to the representation of these processes within global and regional scale models, and finally their implications for air quality and climate policies. Prof. Riipinen has been among the Clarivate Analytics Highly Cited Researchers (top 1% in the field of Geosciences) in 2016 and 2017, and has received a number of awards for her research work, including the Sheldon K. Friedlander award, Smoluchovski award, and the International Union for Geophysics and Geodesy early career scientist award. She has advised 11 Phd students (7 completed, 4 ongoing) and mentored 8 post-doctoral researchers. The PhD students and post-docs she has mentored now hold positions as e.g. tenure track academics, science coordinators, research scientists and scientific programmers in various academic and non-academic institutions. Besides her academic activities, Prof. Riipinen has engaged in various public outreach activities like		

talking in events like TEDx, as well as collaborated on creating an art performance for engaging the public in questions related to air composition, health and climate.

Peer-reviewed publications: 123; Book chapters: 8; Invited presentations and seminars in international scientific conferences and seminar series 46; Other oral presentations in scientific conferences: 29.

H-index: 41 **(based on Clarivate analytics Web of Science)** Web of Science citations: 6474 (5724 without self-citations).

Link to full CV: https://www.aces.su.se/aces/wp-content/uploads/2015/11/CV_for_website.pdf

Link to full list of publications: https://www.aces.su.se/aces/wp-content/uploads/2017/06/Publications_June2017-1.pdf

https://scholar.google.se/citations?user=9vtj8ckAAAAJ&hl=en

Annica M. L. Ekman (female), Professor in Meteorology at the Department of Meteorology, SU (MISU), will coordinate scientific activities within FORCeS. She received her PhD at SU in 2001 and has since then been active in the field of aerosol-cloud-climate research, where her research work focuses on numerical modelling of aerosol and cloud processes on local to global scales. AE has numerous present and past collaborations with national and international research institutes and she is currently the president of the Atmospheric Sciences Division of the European Geophysical Union. She is also the deputy head of MISU with approximately 80 staff members as well as a member of the Science Faculty Board at SU. AE has supervised 6 PhD students to their degree and mentored 6 postdocs. She is currently supervising 7 PhD students and 3 postdocs. AE has been engaged in numerous outreach activities, including science days for schools and contributing to a science book for children.

Peer revised publications: 54; Invited presentations and seminars in international scientific conferences and seminar series: 33;

H-index: 17 (based on ISI web of science) ISI citations: 1179

Link to full CV: https://www.su.se/english/profiles/aekma

Link to full list of publications: https://orcid.org/0000-0002-5940-2114.

Ana Cordeiro (female) is at Project Coordinator at the Research Support Office of SU since 2017 and will be the project manager of FORCeS, ensuring the effectual management of all administrative and financial matters and compliance to all legal requirements. She will additionally support the Coordinators and Executive Board in the monitoring of progress, the preparation of reports, the implementation of board decisions, and support the smooth communication within the consortium. She has broad experience in managing and coordinating large inter-institutional, interdisciplinary research projects across different countries. Prior joining SU, she served as the Scientific Coordinator of the Swiss National Center of Competence in Research Bioinspired Materials (total budget > 25 Mio CHF for 4 years; 18 research groups, ca. 95 researchers) at the University of Fribourg (Switzerland, 2014-2017), and coordinated an interdisciplinary research school at the Helmholtz-Zentrum Dresden-Rossendorf (Germany, 2011-2014). She has a comprehensive scientific background having worked as a researcher at the Leibniz Institute of Polymer Research Dresden, Germany (Research scientist / Group leader; 2006-2011), the Institute of Biomedical Engineering, Portugal (Postdoctoral researcher; 2004-2005) and the Max-Planck Institute of Colloids and Interfaces, Germany (PhD student; 2001-2004).

Gunilla Svensson (female) Professor of Meteorology at the Department of Meteorology, Stockholm University. She received her PhD at Uppsala University 1995. She is an expert on numerical modelling from process levels to global scales. Her main interest is in understanding, modelling and parameterization of boundary layer processes, surface exchange, cloud droplet - turbulence interactions, clouds and their effect on the general circulation and global climate. She has extensively evaluated global climate model performance in Arctic and elsewhere (CMIP3 and CMIP5 models), develop new parameterization for turbulent boundary layers, and lead a model inter-comparison project within GABLS. She is involved in international coordination of research as

member of the SSGs for GEWEX Global System Studies, WWRP Polar Prediction Project and WCRP Polar Climate Predictability Initiative. She has published more than 70 research articles in peer review journals. She has been main supervisor to nine PhD students and a mentored a handful of postdocs. She has substantial administrative and leadership experience for example as the coordinator of the strategic initiative on climate modelling within the Bolin Centre for Climate Research. She has a H-index of 29 (Google Scholar, https://scholar.google.com/citations?user=BeVzGfoAAAAJ&hl=sv).

Tanja Dallafior (female) is an career postdoc researcher with excellent expertise on aerosol-cloud-climate processes, radiative transfer in the atmosphere and aerosol impacts on large-scale atmospheric circulation patterns.

Hans-Christen Hansson (male) Hans-Christen Hansson is professor in Air pollution at the department of Environmental Science and Analytical Chemistry with a 30-year long carrier in science. His research is mostly within larger projects directed towards investigations of the life cycle of the atmospheric particles, later especially how atmospheric particles influence the radiation budget, both directly through scattering of radiation and indirectly through their influence on the clouds and their effect on the radiation balance. Influence on health is also a concern, which drives his involvement connecting urban research with the regional focused research. In this he has been acting as advisor to the Swedish EPA and participated in expert groups e.g. within EMEP/CLRTAP. Of special interest is how to abate both air pollution and climate change through a common action plan. HC Hansson was a founding partner in the Nordic Centre of Excellence (NCoE) BACCI as well as major EU projects as EUCAARI and EUSAAR. Presently he is active in NCoE CRAICC (Cryosphere-atmosphere interactions in a changing Arctic climate) and Nordic ENVRI (Research Infrastructure Network for Nordic Atmospheric and Earth System Science) of which the first include extensive model studies with Earth System Models and the second focus on interdisciplinary cooperation to facilitate Earth System Studies. HC Hansson is also a scientific leader in several national projects focused on Air Quality and Climate Change interaction.

H-index: 48 (based on ISI web of science) ISI citations: 8136

Link to full list of publications: https://www.aces.su.se/staff/hans-christen-hansson-2/

Frida Bender (female), associate professor in climate modelling at the Department of Meteorology, SU (MISU), will contribute to the climate modelling activities within FORCes. She received her PhD at SU in 2009 and has since then been in the field of aerosol-cloud-climate interactions, with specific expertise on model evaluation with satellite observations, and focus on large-scale effects of small-scale processes. FB has a broad national and international research network and has spent time at several renowned international institutes. Currently advisor of 2 PhD students and 1 MSc student, FB has previously supervised 11 MSc and BSc degree projects and also mentored one postdoc. FB has engaged in several synergistic activities including hands-on science displays and large live science Q&A sessions for school children. FB is currently co-leader of the research area Aerosols, clouds, turbulence and climate of the Bolin Centre for Climate Research. FB has between 2007 and 2018 been on parental leave for a total of 3.5 years.

Peer revised publications: 23; Invited presentations and seminars in international scientific conferences and seminar series: 11;

H-index: 8 (based on ISI web of science) ISI citations: 284 (260 without self citations)

Link to full CV: https://www.su.se/polopoly_fs/1.385922.1526556815!/menu/standard/file/cv.pdf

Link to full list of publications: https://www.su.se/english/profiles/fbend-1.182438

Radovan Krejci (male) Senior Researcher at the Department of Environmental Science and Analytical Chemistry (ACES). He will be responsible for SU experimental activities and data analysis together with other members of SU FORCeS team, especially CM and PZ. His work focuses on aerosols and clouds interactions and links between meteorology and physico-chemical processes driving aerosol and clouds lifecycle. RK received PhD in 2002. Currently he is deputy head of atmospheric science unit at ACES. He is a chair of Atmospheric Flagship program coordinating atmospheric research at Ny Ålesund, Svalbard. He has supervised 11 PhD students, 4 PostDocs and

numerous master students.

Peer reviewed publications: 80, H-index 27, ISI citations without self citations: ~2500.

Claudia Mohr (female), Assistant Professor in atmospheric science at the Department of Environmental Science and Analytical Chemistry (ACES) at SU since 2017, will be responsible for the experimental activities of SU within FORCeS, together with PZ and RK. In her research she focuses on the chemical composition of aerosol particles and gases using advanced mass spectrometric techniques to derive sources, formation processes, and effects for air quality and climate. CM has recently received the 2018 Atmospheric Sciences Division Outstanding Early Career Scientists Award of the European Geosciences Union. She has mentored 2 Postdoc (1 ongoing) and is currently supervising 2 PhD students and 1 master student.

Peer-reviewed publications: 52; H-index: 28 (based on ISI web of science); ISI citations: 2836

Link to full list of publications: http://www.researcherid.com/rid/D-9857-2011

Paul Zieger (male) Assistant Professor in atmospheric science at the Department of Environmental Science and Analytical Chemistry (ACES) at SU since 2017, will be responsible for the experimental activities of SU within FORCeS, together with CM and RK. His focus is the study of microphysical and chemical properties of aerosols and clouds using various measurement techniques (in-situ, airborne, remote sensing both field and laboratory based work). He has received his PhD in 2011 at ETH Zurich (Switzerland), which was awarded by the Swiss Academy of Sciences with the Atmospheric Chemistry and Physics Award. From 2007 to 2013 he has worked as a PhD student and PostDoc at the Paul Scherrer Institute (Villigen, Switzerland), followed by a postdoctoral period at SU (Advanced PostDoc.Mobility fellowship by SNF). PZ is engaged in several international research collaborations and organizations (e.g. International Arctic Science Committee and the SOLAS/IGAC project CATCH: the Cryosphere and Atmospheric Chemistry). He is currently supervising two PhD students, 1 PostDoc and 2 master students.

Peer-reviewed publications: 30; H-index: 15. citations: 650 (558 w/o self-citations based on ISI web of science)

Link to full CV and list of publications: http://www.aces.su.se/staff/paul-zieger/

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Murphy, B. N., Julin, J., Riipinen, I. and Ekman, A. M. L., 2015. Organic aerosol processing in tropical deep convective clouds: Development of a new model (CRM-ORG) and implications for sources of particle number, J. Geophys. Res., 120, 19, doi: 10.1002/2015JD023551;
2. Acosta Navarro, J.C., Ekman, A. M. L., Pausata, F.S., Lewinschal, A., Varma, V., Seland, Ø., Gauss, M., Iversen, T., Kirkevåg, A., Riipinen, I., and Hansson, H.C., 2017. Future Response of Temperature and Precipitation to Reduced Aerosol Emissions as Compared with Increased Greenhouse Gas Concentrations. J. Climate, 30, 939–954, https://doi.org/10.1175/JCLI-D-16-0466.1;
3. Rastak, N., Pajunoja, A., Acosta Navarro, J. C., Ma, J., Song, M., Partridge, D. G., Kirkevåg, A., Leong, Y., Hu, W. W., Taylor, N. F., Lambe, A., Cerully, K., Bougiatioti, A., Liu, P. Krejci, R., Petäjä, T., Percival, C., Davidovits, P., Worsnop, D. R., Ekman, A. M. L., Nenes, A., Martin, S., Jimenez, J. L., Collins, D. R., Topping, D. O., Bertram, A. K., Zuend, A., Virtanen, A., and Riipinen, I., 2017. Microphysical explanation of the RH-dependent water affinity of biogenic organic aerosol and its importance for climate, Geophys. Res. Lett., 44, doi:10.1002/2017GL073056;
4. Bourgeois, Q., Ekman, A. M. L., Renard, J.-B., Krejci, R., Devasthale, A., Bender, F. A.-M., Riipinen, I., Berthet, G., and Tackett, J. L.: How much of the global aerosol optical depth is found in the boundary layer and free troposphere?, Atmos. Chem. Phys., 18, 7709-7720, https://doi.org/10.5194/acp-18-7709-2018, 2018;
5. Riipinen, I., Yli-Juuti, T., Pierce, J. R., Petäjä, T., Worsnop, D. R., Kulmala M., Donahue, N. M. 2012. The contribution of organics to atmospheric nanoparticle growth. Nature Geosci., 5, 453.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal
1. FP7 integrated project EUCAARI (participant) 2. FP7 integrated project PEGASOS (participant) 3. H2020 integrated project PRIMAVERA (participant) 4. European Research Council starting grant ATMOGAIN (coordinator) 5. Knut and Alice Wallenberg foundation projects AtmoRemove (coordinator), ACAS (coordinator), CLOUDFORM (coordinator)
Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work
The SU departments participating in FORCeS, namely ACES and MISU, host a suite of infrastructure relevant for the FORCeS proposal. Both departments have well-equipped laboratory facilities for investigating aerosols, clouds and their interactions with e.g. state-of-the-art tools including mass spectrometers and aerosols and clouds instrumentation, ACES also runs a number of field stations. The Arctic Zeppelin station in Ny Ålesund is the most relevant one with respects to goals of the FORCeS. Besides the experimental facilities, the FORCeS researchers at SU will have access to supercomputing facilities at the Swedish national supercomputing centre, supported by two full time scientific programmers present in the research environment. SU has a professional EU team (9 FTE – fulltime-equivalents), within the Research Support Office, that supports coordinators of EU-funded projects to ensure that all financial and administrative commitments are met throughout the project. SU's legal counsels will prepare the Consortium Agreement (CA) for the project and together with the Research Support Office advise on contractual and IPR matters.

Barcelona Supercomputing Center Centro Nacional de Supercomputación	**2-Barcelona Supercomputing Center (BSC)**	**SPAIN**

Description of the legal entity

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 ~80 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 (2013-2017), BSC-ES was granted 9 EU H2020 projects, 5 EU FP7 projects, 5 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 FoRCES. 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.

Main tasks in FORCeS

BSC will contribute to FORCeS with its expertise on mineral dust and SOA in WP1, WP3 and WP5. In tasks 1.1 and 1.3 BSC will explore the effect of the reactive uptake of nitrogen-containing species by SOA on the optical properties and burden of anthropogenic and biogenic SOA. ESM´s typically assume that dust aerosols have a globally uniform composition, neglecting the known local and regional variations in the mineralogical composition of the sources, and disregarding the effect of variations in composition upon chemistry and forcing. In task 1.2 BSC will explore the role of variations in dust mineralogical composition on the formation of coarse nitrate. In WP3 BSC will contribute to tasks 3.1 and 3.2 by constraining the dust cycle in long term runs, and in WP5 BSC will contribute to task 5.2 on the implementation of improvements on dust emission, size distribution and composition.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Dr. Carlos Pérez García-Pando (male) is AXA Professor, Ramón y Cajal Researcher and Head of the Atmospheric Composition Group at BSC. He holds a long-term Chair on Dust Storms at BSC funded by the AXA Research Fund and an ERC Consolidator Grant entitled FRAGMENT (starting in October 2018). His research group (the AC group) is composed of ~20 people including senior researchers, postdocs, PhD students and technical support staff. His research focuses on understanding the physical and chemical processes controlling atmospheric aerosols, and evaluating their effects upon climate, ocean biogeochemistry, air quality and health. His core area of expertise is atmospheric mineral dust. He is also a model developer with a large experience in supercomputers. Previously he has held research positions at the NOAA/National Centers for Environmental Prediction, the International Research Institute for Climate and Society, the NASA Goddard Institute for Space Studies and Columbia University. He has participated in ~30 international and national projects (in 7 of them as PI or co-PI). In the US, he has been PI and co-PI of competitive projects funded by the Department of Energy, NASA and NOAA. His work has resulted in ~60 peer-reviewed publications, 20 chapters in books, proceedings and reports, more ~200 contributions to conferences/workshops/seminars (~30 as invited speaker) and the edition of a book of proceedings (Google scholar; citations 3655)

H-index: 30 Link to full CV: https://orcid.org/0000-0002-4456-0697

Dr. Oriol Jorba (male) is co-leader of the Atmospheric Composition group of the Barcelona Supercomputing Center (BSC). He holds a PhD degree on Environmental Engineering. His research expertise includes high-resolution mesoscale meteorology and air quality, development of online meteorology-chemistry models, boundary layer, atmospheric chemistry studies and environmental impact assessment. He has lead the research project on the development of the multiscale chemical weather forecasting system NMMB-MONARCH (CGL2008-02818, CGL2013-46736) at BSC, which is the official model used by the Barcelona Dust Forecast Center (BDFC), the World Meteorological Organization (WMO) Regional Meteorological Center specializing in Atmospheric Sand and Dust. He has participated in projects funded by the European Commission on air quality, specifically in aerosols, (APPRAISAL, EARLINET, FIELD-AC, ACTRIS1, ACTRIS2) and in the application of atmospheric modeling in HPC (IS-ENES, IS-ENES2, RETHINK big). He has been a Spanish representative member of the management committee of COST Actions ES1002 and ES1004, and is part of the International Technical Meeting on Air Pollution Modelling and its Application (ITM) scientific committee since 2012. He is an active member of the International Cooperative for Aerosol Prediction (ICAP).

H index: 23 (Scopus) Link to full CV: https://orcid.org/0000-0001-5872-0244

Dr. Sara Basart (female) is a Researcher in the BSC. Her main research background covers mineral dust modelling, air quality and aerosols. She is the scientist in charge of the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) Regional Center for Northern Africa, Middle East and Europe, and the Barcelona Dust Forecast Center (BDFC), hosted in BSC. She has also participated in ~20 international projects. She is PI of competitive EU projects and she is leading the BSC participation in Copernicus (CAMS-84). She has authored or co-authored more than 35 peer-reviewed publications in international journals, 15 book chapters, proceedings and reports and more than 100 contributions to conferences/workshops/seminars (ORCID: https://orcid.org/0000-0002-9821-850).

H-index: 18 (Scopus) Link to full CV: https://www.bsc.es/basart-sara

Dr. María Gonçalves-Ageitos (female) is a tenure-track 2 lecturer at the Technical University of Catalonia (UPC), and associate researcher at the ES-BSC. She teaches different subjects at graduate and undergraduate level on Environmental Sciences and Technology, and Project Management of multiple engineering programs, and she is actively involved in the Environmental Engineering PhD program. Her research interests lie on the atmospheric modelling field. By means of numerical models and thanks to High Performance Computing environments, she explores atmospheric processes and interactions in the short-term and climate scales, with a focus on atmospheric chemistry and aerosols. She has collaborated in a range of national and international projects and initiatives focusing on atmospheric models development and evaluation (e.g. CALIOPE, NMMB-MONARCH) or regional climate modelling (e.g. ESCAT, MedCORDEX) and, more recently, Earth System Modelling (e.g. ECEarth, AerChemMIP). As a result, she has co-authored 16 JCR scientific articles, several books and book-chapters, and

she has contributed to numerous national and international conferences in the geosciences area (ORCID: https://orcid.org/0000-0003-3857-6403).

H index: 9 (WOS) Link to full CV: http://futur.upc.edu/182440

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Scanza, R. A., Mahowald, N. M., Perez Garcia-Pando, C., Buck, C., Baker, A., and Hamilton, D. S.: Atmospheric Processing of Iron in Mineral and Combustion Aerosols: Development of an Intermediate-Complexity Mechanism Suitable for Earth System Models, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-80, 2018. (accepted)

2. Gkikas, A., Obiso, V., Pérez García-Pando, C., Jorba, O., Hatzianastassiou, N., Vendrell, L., Basart, S., Gassó, S., and Baldasano, J. M.: Direct radiative effects of intense Mediterranean desert dust outbreaks, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-932, 2017.

3. Pérez García-Pando, C., R.L. Miller, J.P. Perlwitz, S. Rodríguez, and J.M. Prospero, 2016: Predicting the mineral composition of dust aerosols: Insights from elemental composition measured at the Izaña Observatory. Geophys. Res. Lett., 43, no. 19, 10520-10529, doi:10.1002/2016GL069873.

4. Perlwitz, J.P., C. Pérez García-Pando, and R.L. Miller, 2015: Predicting the mineral composition of dust aerosols — Part 1: Representing key processes. Atmos. Chem. Phys., 15, 11593-11627, doi:10.5194/acp-15-11593-2015.

5. Perlwitz, J.P., C. Pérez García-Pando, and R.L. Miller, 2015: Predicting the mineral composition of dust aerosols — Part 2: Model evaluation and identification of key processes with observations. Atmos. Chem. Phys., 15, 11629-11652, doi: 10.5194/acp-15-11629-2015

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. ERC Consolidator Grant 2017: "*FRontiers in dust minerAloGical coMposition and its Effects upoN climaTe"* FRAGMENT (PI: Dr. Carlos Pérez García-Pando)

2. AXA Chair on Sand and Dust Storms 2016-2031 (PI: Dr. Carlos Pérez García-Pando)

3. NASA ROSES *Contribution to radiative forcing and climate by anthropogenic sources of dust aerosol 2014-2016 (co-IP:* Dr. Carlos Pérez García-Pando*)*

4. NGGPS *Implementation and testing of dust models for regional and global forecasting 2015-2016 (co-IP:* Dr. Carlos Pérez García-Pando)

5. WMO Sand and Dust Storms – Warning Advisory System (SDS-WAS) regional center for North Africa, the Middle East and Europe (host-coordinators)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

BSC constitutes a reference center in High Performance Computing nationally and internationally, since its inception in 2005. The center computational resources will be available for FORCeS to develop and test the group contributions related to dust modelling. 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 observations and model outputs for evaluation purposes. The infrastructure routinely downloads and processes aerosols' observations from multiple sources and

formats them for model assessment. These formatted data as well as the ES-BSC evaluation tools will be available for FORCeS developments.

ETH zürich	**3-ETH Zurich (ETHZ)**	**SWITZERLAND**

Description of the legal entity

ETH Zurich (ETHZ) stands on a bedrock of true Swiss values of freedom and individual responsibility, entrepreneurial spirit and open-mindedness. Our university for science and technology dates back to the year 1855, when the founders of modern-day Switzerland created it as a center of innovation and knowledge. At ETH Zurich, students discover an ideal environment for independent thinking, researchers a climate which inspires top performance. Situated in the heart of Europe, yet forging connections all over the world, ETH Zurich is pioneering effective solutions to the global challenges of today and tomorrow.

Some 500 professors teach around 20,000 students – including 4,000 doctoral students – from over 120 countries. Their collective research embraces many disciplines: natural sciences and engineering sciences, architecture, mathematics, system-oriented natural sciences, as well as management and social sciences. The results and innovations produced by ETH researchers are channelled into some of Switzerland's most high-tech sectors: from computer science through to micro- and nanotechnology and cutting-edge medicine. Every year ETH registers around 90 patents and 200 inventions on average. Since 1996, the university has produced a total of 355 commercial spin-offs. ETH also has an excellent reputation in scientific circles: 21 Nobel laureates have studied, taught or researched here, and in international league tables ETH Zurich regularly ranks as one of the world's top universities.

IAC: The Institute for Atmospheric and Climate Science (IAC) at ETH Zurich pursues leading-edge research on atmospheric physics, chemistry and dynamics, and on global and regional past, present and future climate, and it pioneers activities at the interfaces of these subcomponent fields and the interfaces to other disciplines. IAC has over 120 members and consists of seven research groups. IAC is closely connected to the Centre for Climate Systems Modelling (C2SM), a multi-institutional research center based at ETH with the goal to improve our understanding of the climate system and our ability to predict it.

The Atmospheric Physics group focuses on aerosol-cloud interactions in warm, mixed-phase and ice clouds and their importance for the radiation budget and the hydrological cycle. It develops improved parameterizations of cloud microphysics and aerosol-cloud interactions in regional and global climate models. In addition, it develops instrumentation and observation methods, applying these to aerosol and cloud microphysics in field experiments and in the laboratory and uses these results for the improvements of key processes in climate models.

Main tasks in FORCeS

ETHZ will contribute to WP2 with cloud microphysical measurements especially in Ny Ålesund and to WP1 and WP3 with numerical simulations with the ICON-HAM GCM in which she will analyze the advantages and disadvantages of a drastically simplified description of aerosol processes as well as different cloud microphysics schemes for aerosol-cloud interactions and climate sensitivity. Transient simulations with the MPI-ESM-HAM for the evaluation of TCR will be conducted for WP6.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Ulrike Lohmann (female) is a professor in atmospheric physics at ETHZ. She will co-lead WP3 of FORCeS. She has received her PhD in 1996 from the University of Hamburg/Max Planck Institute for Meteorology, and has been employed at ETHZ since 2004 after a post-doctoral period at the Canadian Centre for Climate Modelling and Analysis and being Assistant and Associate Professor at Dalhousie University in Halifax, N.S. in Canada. Prof. Lohmann has been among the Clarivate Analytics Highly Cited Researchers (top 1% in the field of Geosciences) since 2014. She has been elected a fellow of the American Geophysical Union, the German Academy of Sciences Leopoldina, received the AMS Henry Houghton award and will become a honorary doctorate of SU in September 2018. She has advised 51 PhD students (39 completed, 12 ongoing) and mentored 32 post-doctoral researchers. Several of her supervised PhD students and post-docs now hold faculty positions or other prestigious position. Besides her research activities, Prof. Lohmann is engaged in teaching (vice president of the ETH lecturers conference) and wrote a textbook "An Introduction to Clouds" for advanced undergraduate students.

252 peer-reviewed publications, 15 book chapters, 1 textbook

H-index: 58 (based on Clarivate analytics Web of Science, July 6, 2018, n=245); Web of Science citations: 15'004 (13'743 without self-citations), ORCID ID: 0000-0001-8885-3785.

Link to full list of publications: http://www.iac.ethz.ch/groups/lohmann/publications

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Dietlicher, R., D. Neubauer and U. Lohmann, Prognostic parameterization of cloud ice with a single category in the aerosol-climate model ECHAM(v6.3.0)-HAM(v2.3), Geosci. Model Dev., 11, doi.org/10.5194/gmd-11-1557-2018, 2018.
2. Lohmann, U. and Neubauer, D.: The importance of mixed-phase and ice clouds for climate sensitivity in the global aerosol–climate model ECHAM6-HAM2, Atmos. Chem. Phys., 18, 8807-8828, doi.org/10.5194/acp-18-8807-2018, 2018.
3. Andersen, H., Cermak, J., Fuchs, J., Knutti, R., and Lohmann, U.: Understanding the drivers of marine liquid-water cloud occurrence and properties with global observations using neural networks, Atmos. Chem. Phys., 17, 9535-9546, doi.org/10.5194/acp-17-9535-2017, 2017.
4. Beck, A., J. Henneberger, S. Schöpfer, J. Fugal and U. Lohmann, HoloGondel: in-situ cloud observations on a cable car in the Swiss Alps using a holographic imager, Atmos. Meas. Tech., 10, doi.org/10.5194/amt-10-459-2017, 2017.
5. Possner, A., A. M. L. Ekman and U. Lohmann, Cloud response and feedback processes in stratiform mixed-phase clouds perturbed by ship exhaust, Geophys. Res. Lett., 44, 1964–1972, doi.org/10.1002/2016GL071358, 2017.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. EU FP7 integrated project EUCAARI (participant)
2. EU FP7 integrated project EUCLIPSE (participant)
3. EU FP7 integrated project BACCHUS (coordinator)
4. EU PF7 integrated project DACCIWA (participant)
5. Swiss National Fond "Exploiting orographic clouds for constraining the sources of ice crystals" (principal investigator)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

Professor Lohmann's research group hosts a suite of infrastructure relevant for the FORCeS proposal. For example, they have well-equipped laboratory facilities for investigating the potential of aerosol particles to act as CCN and INP. They have holographic imagers for in-situ cloud microphysical measurements that were successfully employed on cable cars and on a tethered balloon (175 m^3) that is available for this project for measurements in Ny Ålesund. In terms of climate model simulations, they have access to the supercomputer facilities at the Swiss supercomputing center and a Linux cluster at ETH Zurich.

FMI	4-Finnish Meteorological Institute (FMI)	FINLAND

Description of the legal entity

Finnish Meteorological Institute (FMI) The FMI works for the safety and success of the Finnish society providing high-quality services and scientific know-how on the weather, atmosphere and seas. FMI is one of the most research intensive meteorological services in the world, as illustrated by the highest number of international peer-reviewed publications (based on the latest benchmarking survey of national meteorological institutes) from a meteorological institute. It produces more than 350 peer-reviewed publications per year which receive more than 12000 citations.

FMI employs approximately 650 people, about 350 of which are involved in research programmes focused on Climate Change, Air Quality, Atmospheric composition and chemistry, Meteorology, Marine Research, Earth Observation, and Arctic Research. FMI participates in many (inter)national collaborative projects (e.g., currently ca. 40 FP7 projects) with in situ observations, satellite and ground-based remote sensing and modelling on local, regional and global scales of atmospheric composition (e.g., WMO/GAW, EMEP, AMAP, HELCOM/EGAP, GMES, GEOSS).

Atmospheric Research Centre of Eastern Finland - The Atmospheric Research Centre of Eastern Finland within the Finnish Meteorological Institute (FMI) has studied the composition of the atmosphere from all angles: from process scale to global scale. The research subjects are especially past, current and future climate as well as the composition of the atmosphere and its effects on climate change and air quality. Atmospheric Research Centre of Eastern Finland is one of the FMI-CLIMATE units and has expertise in particular on aerosols and clouds, their role in atmospheric radiation and climate forcing by clouds and aerosol, by exploiting modeling, remote sensing with satellites and from the ground, and laboratory and field measurements.

Climate System Modelling Group - The Climate System Modelling Group group studies the physical and chemical processes, interactions and feedbacks of the climate system. Aerosols of the atmosphere, radiation, clouds, snow and interactions between atmosphere and oceans are the main research subjects. Different models from microphysical models to global circulation models are used. The contribution of FMI to CMIP6 (Coupled Model Intercomparison Project 6) is done in this group. In addition, the group does climate simulations to support regional and global adaptation and impact studies of climate change. One of the strategically prominent tasks of the group is to co-operate with the atmospheric

Main tasks in FORCeS

FMI contribute scientifically to WPs 2 (analysis of aerosol-cloud interactions in field campaigns, simulation observed quantities of cloud-interactions and parameterizing the results), 3 (providing modelled time series of different aerosol components), 4 (providing state-of-the arts methods improving quality of satellite algorithms, producing observational data for century long time series of aerosol optical properties).

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Sami Romakkaniemi (male) is the Head of FMI unit Atmospheric Research Centre of Eastern Finland with approximately 30 staff members. He is also a Docent (Adj. Prof.) of computational aerosol physics at the University of Eastern Finland. He received his PhD in 2005 from the University of Kuopio and worked after that as postdoctoral fellow in the University of Manchester and University of Eastern Finland before starting in the current position in 2013. He has been active in the field of aerosol-cloud-climate research with the main personal research focus on numerical modelling of aerosol and cloud processes in different scales.

Peer reviewed publications 58

H-index: 16 (based on ISI Web of Science), ISI citations 764

Link to full CV: http://en.ilmatieteenlaitos.fi/cv-sami-romakkaniemi

Link to full list of publications: http://www.researcherid.com/rid/C-1308-2012

Hannele Korhonen (female) is the director of Climate Research Programme (Research Professor) at FMI having 17 years of international research experience in atmospheric aerosol-cloud-precipitation interactions. She has recently received the European Research Council consolidator grant for the use of statistical emulation techniques to investigate complex atmospheric problems.

Peer reviewed publications 66

H-index: 23 (based on ISI Web of Science), ISI citations 1553

Link to CV: http://en.ilmatieteenlaitos.fi/cv-hannele-korhonen

Link to full list of publications: http://www.researcherid.com/rid/E-4489-2011

Antti Arola (male) is a Research Professor at the FMI. He is currently leading the Atmospheric Radiation group at the FMI's Atmospheric Research Centre of Eastern Finland. He is also Docent (Adj. Prof.) in Remote Sensing at the University of Eastern Finland. He has longstanding experience and expertise on aerosol radiative properties taking advantage of both satellite- and ground-based remote sensing measurements. His group has established a strong links with ESA, NASA, and the AERONET group.

Peer reviewed publications 80

H-index: 22 (based on ISI Web of Science), ISI citations 1332

Link to CV: http://en.ilmatieteenlaitos.fi/cv-antti-arola

Link to full list of publications: https://www.researchgate.net/profile/Antti_Arola

Harri Kokkola (male) leads the Atmospheric Modelling group in the Atmospheric Research Centre of Eastern Finland. His group is part of the Finnish Academy Center of Excellence in Atmospheric Science, which has been involved in international model development communities (EC Earth, HAMMOZ, AeroCom) working on aerosol and aerosol-cloud interactions in from process scale to global scale, e.g. developing a sectional aerosol module SALSA for aerosol-climate, cloud-scale, and chemical transport models.

Peer reviewed publications 56

H-index: 17 (based on ISI Web of Science), ISI citations 896

Link to full CV: http://en.ilmatieteenlaitos.fi/cv-harri-kokkola

Link to full list of publications: http://www.researcherid.com/rid/J-5993-2014

Antti-Ilari Partanen (male) leads the Climate System Modelling Group at the Finnish Meteorological Institute. He has studied e.g. aerosol-based climate engineering methods; the relationship between cumulative CO_2 emissions with regional and seasonal climate change; and climate and health impacts of different aerosol emission scenarios. His primary research interest is policy-relevant climate science, being very eager to work on multidisciplinary research questions related to climate change and environmental issues in general.

Peer reviewed publications 19

H-index: 8 (based on ISI Web of Science), ISI citations 175

Link to full CV: http://en.ilmatieteenlaitos.fi/cv-antti-ilari-partanen

Link to full list of publications: http://www.researcherid.com/rid/D-7834-2014

Antti Lipponen (male) is a post doc researcher in the Atmospheric Radiation group at the Finnish Meteorological Institute, Atmospheric Research Centre of Eastern Finland. He completed his PhD thesis about computational and statistical inverse problems from the University of Eastern Finland in June 2014. He has worked both in industrial imaging and atmospheric science related research projects, and he is the main developer of the BAR aerosol retrieval algorithm. He is specialized to study satellite aerosol retrieval algorithms, data analysis and statistical methods, and machine learning techniques.

Peer reviewed publications 14

H-index: 5 (based on ISI Web of Science), ISI citations 86

Link to CV: http://en.ilmatieteenlaitos.fi/cv-antti-lipponen

Link to full list of publications: https://orcid.org/0000-0002-6902-9974

Juha Tonttila (male) Dr. Juha Tonttila is a post doctoral researcher in the Atmospheric Modelling group of the Finnish Meteorological Institute, Atmospheric Research Centre of Eastern Finland. His PhD was completed in April 2015, with his theses focusing on subgrid-scale modelling of aerosol-cloud interaction in climate models. Since then, his work has focused on aerosol and cloud microphysical modelling in cloud-resolving frameworks, including a 1-year post doc period at the Karlsruhe Institute of Technology, Germany, in 2016-2017. He is the main author of UCLALES-SALSA.

Peer reviewed publications 8

H-index: 3 (based on ISI Web of Science), ISI citations 54

Link to CV: http://en.ilmatieteenlaitos.fi/cv-juha-tonttila

Link to full list of publications: http://www.researcherid.com/rid/L-7124-2014

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Lipponen, A., Mielonen, T., Pitkänen, M. R. A., Levy, R. C., Sawyer, V. R., Romakkaniemi, S., Kolehmainen, V., and Arola, A.: Bayesian aerosol retrieval algorithm for MODIS AOD retrieval over land, Atmos. Meas. Tech., 11, 1529-1547, https://doi.org/10.5194/amt-11-1529-2018, 2018.
2. Mielonen, T., Hienola, A., Kühn, T., Merikanto, J., Lipponen, A., Bergman, T., Korhonen, H., Kolmonen, P., Sogacheva, L., Ghent, D., Arola, A., de Leeuw, G., and Kokkola, H.: Summertime aerosol radiative effects and their dependence on temperature over the southeastern USA, Atmosphere, 9(5), 180; ,https://doi.org/10.3390/atmos9050180, 2018
3. Kühn T, Partanen AI, Laakso A, Lu Z, Bergman T, Mikkonen S, Kokkola H, Korhonen H, Räisänen P, Streets DG, Romakkaniemi S. Climate impacts of changing aerosol emissions since 1996. Geophysical Research Letters. 2014 Jul 16;41(13):4711-8.
4. Tonttila, J., Maalick, Z., Raatikainen, T., Kokkola, H., Kühn, T., and Romakkaniemi, S.: UCLALES–SALSA v1.0: a large-eddy model with interactive sectional microphysics for aerosol, clouds and precipitation, Geosci. Model Dev., 10, 169-188, doi:10.5194/gmd-10-169-2017, 2017.
5. Huttunen, J., Kokkola, H., Mielonen, T., Mononen, M. E. J., Lipponen, A., Reunanen, J., Lindfors, A. V., Mikkonen, S., Lehtinen, K. E. J., Kouremeti, N., Bais, A., Niska, H., and Arola, A.: Retrieval of aerosol optical depth from surface solar radiation measurements using machine learning algorithms,

non-linear regression and a radiative transfer-based look-up table, Atmos. Chem. Phys., 16, 8181-8191, https://doi.org/10.5194/acp-16-8181-2016, 2016.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. FP7 integrated project BACCHUS (participant)
2. FP7 integrated project GAIA-CLIM (participant)
3. Finnish Academy Center of Excellence in Atmospheric Science
4. Several research projects funded by the Academy of Finland including e.g. Academy Fellowship project "Extensive study on aerosol-cloud interactions: from measurements to modeling (2013-2018, 775k€)"
5. ERC consolidator grant "Emulation of subgrid-scale aerosol-cloud interactions in climate models: towards a realistic representation of aerosol indirect effect"

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

FMI provides infrastructure for model simulations which will be performed on FMI's own Cray XC40 supercomputer Voima (17200 cpu cores), which is dedicated to scientific use. Voima has 17200 cpu cores dedicated for computational use. FMI has also access to the Finnish CSC IT Center for Science facilities. These facilities include massive parallel computing (~1000 cores) on the supercomputer Sisu (Cray XC40 comprising about 40 000 computing cores) as well as memory-intensive calculations (48GB/process) on the supercluster Taito (HP Apollo 6000 XL230a/SL230s). The Atmospheric Radiation group of FMI Atmospheric Research Centre of Eastern Finland has the necessary skills and knowledge on satellite measurements, satellite retrieval algorithms, and radiative transfer modeling that are vital in the proposed research. Therefore, the infrastructure and knowledge that has been build up, combined with the strong link with NASA, ESA, and AERONET.

JÜLICH Forschungszentrum	**5-Forschungszentrum Jülich (FZJ)**	**GERMANY**

Description of the legal entity

Forschungszentrum Jülich GmbH (JUELICH) is a member of the Helmholtz Association of German National Research Centres. With 4000 staff members it is the largest interdisciplinary research center in Germany focusing its research in the fields of health, environment and energy, and information technology. Forschungszentrum Jülich administrates projects from third party funds with an overall budget of ~200Mio € annually through its central technology-transfer unit. Institute IEK-8: Troposphere is part of the Institute for Energy and Climate Research (IEK) and has over 25 years of experience in the field of Atmospheric Chemistry with a strong focus on the measurements of trace compounds and global to regional scale modeling. It is directed by Prof. Astrid Kiendler-Scharr and Prof. Andreas Wahner. About 70 scientists, engineers, technicians and doctoral students are currently working at the institute in the field of atmospheric chemistry. Targets of the research are the physical and chemical processes in the atmosphere that are responsible for the conversion, distribution and removal of trace substances. The SAPHIR (Simulation of Atmospheric Photochemistry In a large Reaction Chamber) is a unique facility to investigate atmospherically relevant chemical and physical processes in more detail under reproducible conditions. The IEK-8 with its unique facilities is an attractive place for international leading scientists, which is demonstrated in regular international campaigns at the institute.

Main tasks in FORCeS

The JUELICH team will co-coordinate the efforts in WP1 and contribute to Tasks in WP1 by studies in simulation chambers and by aimed process modelling making existing and new experimental findings available for regional and global models. JUELICH will also contribute to Task 2.1 in WP2.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Astrid Kiendler-Scharr (female) is director of IEK-8 Troposphere at JUELICH and Professor (W3) for experimental physics at Cologne University. She received the Helmholtz Excellence support for her project on process studies of Biosphere – Atmosphere Climate Feedbacks (BACfeed), the original development of the plant chamber concept (SAPHIR-PLUS) at the atmospheric simulation chamber SAPHIR of IEK-8. She was PI in the FP7 projects EUCAARI and PEGASOS and member of the PEGASOS steering group. Here fields of work are (i) Process oriented studies on the formation of secondary organic aerosol, (ii) Identification of sources and atmospheric chemical aging of aerosol using mass spectrometric techniques, and (iii) Feedbacks of global change on secondary pollutant formation. At IEK-8 currently 17 PhD students and 13 post-doctoral researchers are involved in atmospheric chemistry research. The PhD students and post-docs she has mentored now hold positions as e.g. tenure track academics, science coordinators, research scientists and scientific programmers in various academic and non-academic institutions. Astrid Kiendler-Scharr serves on the Editorial boards of Atmospheric Chemistry and Physics and Frontiers in Forests and Global Change and is IPCC Lead Author of AR6, WG1 Chapter 6 on "Short lived climate forcers". She published more than 95 peer reviewed articles, with more than 3960 citations (excluding self-citations, Web of Science) and *h*-index of 30 (Researcher ID: E-8439-2011).

Thomas Mentel (male) is head of the Aerosol Section and the Heterogeneous Reactions group at the IEK-8 Troposphere at FZJ. He is adjunct Professor for Aerosol Chemistry at Dept. of Chemistry and Molecular Biology at the University Gothenburg. He led the Zeppelin field campaigns and the aerosol measurements in the EC integrated project PEGASOS. His fields of work are (i) Mechanisms of VOC oxidation and secondary organic aerosol formation, (ii) Microphysics and Chemistry of aerosols, and (iii) Mass spectrometric techniques in atmospheric applications. Thomas Mentel was work package leader in several EC integrated projects including EUCAARI, PEGASOS and ECLAIRE. He supervised more than 10 PhD students and mentored 13 post-docs

(currently 1 PhD student, 2 post-docs). He published more than 90 peer reviewed articles, 6 of those in Nature (2), Nature Communications, Science (2) and PNAS with more than 5840 citations (excluding self-citations, Clarivate) and h-index of 34 (http://www.researcherid.com/rid/A-3576-2011).

Thorsten Hohaus (male) is the head of the Aerosol group at IEK-8. His research areas include detailed physical and chemical characterization of ambient aerosol in atmosphere simulation chamber experiments and short and long term field studies using mass spectrometry and gas chromatography. An important focus lies on the identification and quantification of the gas-particle partitioning of important semi-volatile compounds in rural and polluted environments and understanding the effect of complex BVOC emissions from vegetation on OA formation and climate feedback mechanisms. He published 17 peer reviewed publication with more than 400 citations (excluding self-citations, ISI web od Science) and h-index 9 (http://orcid.org/0000-0001-5722-6244).

Vlassis Karydis (male) is researcher of the Global Modeling group at IEK-8. His research areas include the development of advanced atmospheric aerosol modules incorporated in chemistry climate models for the study of the tropospheric aerosol effects on air quality as well as topics related to aerosol-cloud interactions and their impacts on Earth's energy balance and climate. He was awarded a Marie Curie Career Reintegration Grand and he published 23 peer reviewed journal articles with more than 500 citations (excluding self-citations) and h-index 14 (ISI web of Science).

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Zhao, D. F., Buchholz, A., Tillmann, R., Kleist, E., Wu, C., Rubach, F., Kiendler-Scharr, A., Rudich, Y., Wildt, J., and Mentel, T. F.: Environmental conditions regulate the impact of plants on cloud formation, Nature Communications, 8, 10.1038/ncomms14067, 2017.
2. A. Kiendler-Scharr, A. A. Mensah, E. Friese, D. Topping, E. Nemitz, A. S. H. Prevot, M. Äijälä, J. Allan, F. Canonaco, M. Canagaratna, S. Carbone, M. Crippa, M. Dall Osto, D. A. Day, P. De Carlo, C. F. Di Marco, H. Elbern, A. Eriksson, E. Freney, L. Hao, H. Herrmann,L. Hildebrandt, R. Hillamo, J. L. Jimenez, A. Laaksonen, G. McFiggans, C. Mohr, C. O'Dowd, R. Otjes, J. Ovadnevaite, S. N. Pandis, L. Poulain, P. Schlag, K. Sellegri, E. Swietlicki, P. Tiitta, A. Vermeulen, A. Wahner, D. Worsnop, and H.-C. Wu, Ubiquity of organic nitrates from nighttime chemistry in the European submicron aerosol, *Geophys. Res. Lett*.,43, 7735–7744, 2016
3. T. Hohaus; U. Kuhn, Z. Yu, S. Andres, M. Kaminski, R. Tillmann, F. Rohrer, A. Wahner, R. Wegener, and A. Kiendler-Scharr, A new plant chamber facility, PLUS, coupled to the atmospheric simulation chamber SAPHIR, *Atmos. Meas. Tech.*, 9, 1247 – 1259, 2016
4. Ehn, M., Thornton, J. A., Kleist, E., Sipila, M., Junninen, H., Pullinen, I., Springer, M., Rubach, F., Tillmann, R., Lee, B., Lopez-Hilfiker, F., Andres, S., Acir, I.-H., Rissanen, M., Jokinen, T., Schobesberger, S., Kangasluoma, J., Kontkanen, J., Nieminen, T., Kurten, T., Nielsen, L. B., Jorgensen, S., Kjaergaard, H. G., Canagaratna, M., Maso, M. D., Berndt, T., Petaja, T., Wahner, A., Kerminen, V.-M., Kulmala, M., Worsnop, D. R., Wildt, J., and Mentel, T. F.: A large source of low-volatility secondary organic aerosol, Nature, 506, 476-479, 10.1038/nature13032, 2014.
5. Tsimpidi, A. P., Karydis, V. A., Pandis, S. N., and Lelieveld, J.: Global-scale combustion sources of organic aerosols: sensitivity to formation and removal mechanisms, Atmos. Chem. Phys., 17, 7345-7364, 2017

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. FP7 integrated project EUCAARI (participant)
2. FP7 integrated project PEGASOS (participant)
3. FP7 integrated project ECLAIRE (participant)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The IEK-8 hosts a suite of infrastructure relevant for the FORCeS proposal. Most prominent the SAPHIR chamber, with SAPHIR-PLUS and SAPHIR++, chambers for studies of atmospheric photochemistry and secondary aerosol formation. One specialty of these simulation experiments is the direct use of trees as representative biogenic emissions sources for constitutive and stress (climate) induced emissions (SAPHIR-PLUS). As analytical instruments IEK-8 deploys the state of the art high resolution mass spectrometers, HR-TOF-AMS, TAG-AMS, CI-API-TOF, HR-PTR-MS, VOCUS-PTR-LTOF. Several methods for measurement of gas-particle partitioning of oxygenated organics and CCN properties of aerosols are available.

FORTH/ICE-HT Foundation for Research & Technology - Hellas	**6-Foundation for Research and Technology Hellas (FORTH)**	**GREECE**

Description of the legal entity

The **Foundation for Research and Technology-Hellas (FORTH)**, is one of the largest research centers in Greece with well-organized facilities, highly qualified personnel and a reputation as a top-level research foundation worldwide.

The Institute of Chemical Engineering Sciences (**ICE-HT**) was established in 1984, and is one of the six research institutes that constitute FORTH. Currently, ICE-HT runs approximately 60 RTD projects in cooperation with industrial partners, universities and research institutes from all over the world. ICE-HT has its own 6000 square meter facility, and more than 115 staff members and research associates (40 of which are PhD holders). The Institute has well equipped laboratories that have been used in a variety of research and technology problems involving physicochemical phenomena. ICE-HT is in close cooperation with the Department of Chemical Engineering in the University of Patras. Energy and the Environment is one of the three major areas of research and development of ICE-HT.

The Laboratory for Air Quality Studies (**LAQS**) in FORTH has approximately 25 years of experience in the study of urban, regional, and global air quality and has participated during the last 10 years in the EUCAARI, MEGAPOLI, CITYZEN, EUSAAR, ACTRIS, ECLIPSE, PEGASOS and BACCHUS projects. The group consists of about 20 researchers and its work focuses on the role of aerosols on air quality and climate change.

Main tasks in FORCeS

FORTH will co-coordinate WP1 and WP6 and will contribute to WPs 2, 3, and 5. The team will perform regional and global scale air quality and climate simulations and will participate in the analysis and synthesis of the results.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Spyros Pandis is the director of the Air Quality Laboratory in ICE-HT/FORTH, Professor in the University of Patras in Greece. He has been the Coordinator of two EU projects and the Principal Investigator of ten projects in the US funded by the EPA, National Science Foundation, Dept. of Energy, etc. He is the author of approximately 270 peer-reviewed papers (3 in Science and Nature) (17000 citations, *h*=73), the ex-president of the American Association for Aerosol Research (AAAR), and recipient of the Sinclair and Whitby Awards of AAAR, the Vaughn Lectureship by Caltech, and the Kun Li, Teare and Tallman Ladd awards.

Maria Kanakidou (female) is a collaborating faculty member of ICE-HT/FORTH and Professor in the Chemistry Dept. of the University of Crete. She has been the Coordinator of two and the Principal Investigator of 11 EU projects. She is a member of the UN/WMO Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) WG 38 on 'The Atmospheric Input of Chemicals to the Ocean' since 2008, honorary member of iCACGP and receipt of the 2016 Vilhelm Bjerknes Medal of EGU. She has 120 publications in scientific journals (2 in Nature), 43 invited presentations at international Scientific Conferences (7700 citations, *h*=43).

Athanasios Nenes is an affiliated researcher of ICE-HT/FORTH and Professor in Earth & Atmospheric Sciences at the Georgia Institute of Technology. He is the recipient of an ERC Consolidator Grant, and the Principal Investigator of twenty projects in the US funded by the National Science Foundation, NASA, EPA, NOAA, Dreyfus Foundation, and others. He is a member of the UN/WMO on the GESAMP WG 38 on 'The Atmospheric Input of Chemicals to the Ocean', and co-author of the 2016 US National Academies Report on the “Future of

Atmospheric Chemistry Research". He is recipient of the AGU Ascend award, the Whitby and Friedlander Awards of AAAR, the Vaughn Lectureship by Caltech and the Houghton Award by the American Meteorological Society. He served as Atmospheric Sciences secretary of the AGU and is currently president elect of Atmospheric Sciences section of the EGU. He is the author of approximately 270 papers (3 in Science) (11500 citations, *h*=57).

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Robinson A. L., N. M. Donahue, M. K. Shrivastava, E. A. Wietkamp, A. M. Sage, A. P. Grieshop, T. E. Lane, J. R. Pierce and S. N. Pandis (2007) Rethinking organic aerosols: Semivolatile emissions and photochemical aging, *Science*, **315**, 1259-1262.
2. Megaritis, A. G., C. Fountoukis, P. E. Charalampidis, H. A. C. Denier van der Gon, C. Pilinis, and S. N. Pandis (2014) Linking climate and air quality over Europe: effects of meteorology on $PM_{2.5}$ concentrations, *Atmos. Chem. Phys.*, **14**, 10283-10298.
3. Kanakidou, M., J. H. Seinfeld, S. N. Pandis, I. Barnes, F. J. Dentener, M. C. Facchini, R. van Dingenen, B. Ervens, A. Nenes, C. J. Nielsen, E. Swietlicki, J.P. Putaud, Y. Balkanski, S. Fuzzi, J. Horth, G. K. Moortgat, R. Winterhalter, C. E. L. Myhre, K. Tsigaridis, E. Vignati, E. G. Stephanou, J. Wilson (2005) Organic aerosol and global climate modelling: A review, *Atmos. Chem. Phys.*, **5**, 1053-1123.
4. Weber, R.J., Guo, H., Russell, A.G., Nenes, A. (2016) High aerosol acidity despite declining atmospheric sulfate concentrations over the past 15 years, *Nature Geosci.*, doi:10.1038/ngeo2665**.**
5. Bracco, A., Falasca, F., Nenes, A., Fountalis, I., Dovrolis, C. (2018) Advancing climate science with knowledge-discovery through data mining, *Clim. Atmos. Sci.*, 1, doi:10.1038/s41612-017-0006-4.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. FP7 integrated project EUCAARI (participant)
2. FP7 integrated project PEGASOS (coordinator)
3. H2020 integrated project EUROCHAMP (participant)
4. European Research Council advanced grant ATMOPACS (coordinator)
5. European Research Council consolidator grant PYROTRACH (coordinator)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

ICE-HT/FORTH hosts the Center for Air Quality and Climate Studies which has a suite of infrastructure relevant for FORCeS. It features the Environmental Simulation Chamber, which is a world-class (EUROCHAMP) facility for simulating the formation and evolution of atmospheric particulate matter under atmospherically-relevant conditions. Mobile chambers and laboratories supplement allow the study of atmospheric aerosol in-situ with chamber-like precision during field intensives. These facilities are well equipped with e.g. state-of-the-art mass spectrometers, CCN counters and numerous other gas/aerosol/cloud instrumentation for investigating the interactions between chemistry, aerosols, clouds and their impacts. FORTH researcher Kanakidou is PI of the Finokalia, Crete station, an ACTRIS site in the E.Mediterranean that have been in operation in for over 20 years and routinely hosts field campaign intensives. The FORTH researchers maintain a number of high-performance computing cluster facilities and have access to supercomputing facilities at the Greek national supercomputing centre. ICE-HT/FORTH has a professional administration team, that supports coordinators of EU-funded projects (including a number of ERC and H2020 projects) to ensure that all financial and administrative commitments are met throughout the duration of projects.

Karlsruhe Institute of Technology	**7-Karlsruhe Institute of Technology (KIT)**	**GERMANY**

Description of the legal entity

Karlsruhe Institute of Technology (KIT) combines the traditions of a renowned technical university and a major large-scale research institution in a very unique way. In research and education, KIT assumes responsibility for contributing to the sustainable solution of the grand challenges that face the society, industry, and the environment. KIT was founded in 2009 as a merger of its long-established and well-respected precursory institutions, the former state University of Karlsruhe and the former federal Karlsruhe Research Center. KIT is one of the largest scientific-technical research and education institutions in Europe, with about 9,300 employees of which roughly 5,800 are involved in research and teaching. KIT has roughly 3,000 doctoral researchers as well as 26,000 Bachelor and Master students. The Shanghai ranking places KIT first in Germany in the atmospheric sciences, and at world rank 16. In the current International Ranking of the National Taiwan University (NTU) KIT is ranked in first place of all German universities in the geosciences (world rank 40), the natural sciences as a whole (rank 62 worldwide) and engineering (place 95 worldwide). KIT is a significant driving force in the region with regard to economic, cultural and social development within the "Karlsruhe TechnologyRegion". Atmospheric sciences in Karlsruhe can be traced back to Heinrich Hertz, discoverer of electro-magnetic waves, who delivered his inaugural lecture here on the energy budget of the atmosphere. Since its official foundation in 1929, the KIT Institute of Meteorology and Climate Research (IMK) has developed into the largest German research institute dedicated to the atmospheric sciences. With its Campus in Garmisch-Partenkirchen, it also includes the oldest environmental research institute in Germany, founded in 1954.

Main tasks in FORCeS

The KIT team will contribute expertise in modeling and machine-learning analysis of observation data sets.

In work package 2, KIT will contribute to the improvement of mixed-phase and ice microphysics schemes in models on different scales, and to an improved understanding of the impact of aerosols in cold clouds.

Within work packages 3 and 4, KIT will contribute to an improved understanding of the sensitivity of atmospheric radiation to changes in aerosol via multivariate analysis of remote sensing data in a machine-learning approach.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Corinna Hoose (female) is professor of theoretical meteorology at KIT. She received her PhD from ETH Zurich in 2008, conducted postdoctoral research at the University of Oslo, and came to KIT as Helmholtz young investigator group leader in 2010. In 2017, she received the International Association for Meteorology and Atmospheric Sciences (IAMAS) Early Career Scientist Medal. She has supervised 10 PhD theses (5 completed, 5 ongoing) and her group currently consists of 10 doctoral and postdoctoral researchers. Her research is focused on cloud physics, aerosol-cloud interactions and their representation in models from large-eddy to global scales. To improve mixed-phase cloud microphysics schemes, she has developed parameterizations of heterogeneous ice nucleation and secondary ice formation. In her ongoing ERC Starting Grant project "C2Phase – Closure of the Cloud Phase", microphysical and dynamical drivers of the cloud phase distribution are investigated by cloud resolving model simulations and remote sensing observations. Previous work on convective cloud microphysics includes studies of aerosol-cloud interactions in idealized simulations of convective clouds, mid-latitude convection and self-aggregated radiative-convective equilibrium simulations.

Peer-reviewed publications: 51; Invited presentations and seminars in international scientific conferences and seminar series 43

H-index: 26 (based on Clarivate analytics Web of Science); Web of Science citations: 2940.

Link to full CV: http://www.imk-tro.kit.edu/download/hoose_cv.pdf

Link to full list of publications: http://www.imk-tro.kit.edu/14_1794.php

Jan Cermak (male) is a professor of geophysical remote sensing at KIT. He received his PhD from the University of Marburg in 2006. After a post-doctoral period at ETH Zurich (2008 to 2011) he became a professor of climatology at Ruhr-Universität Bochum, before moving to KIT in 2016. His research focuses on remote sensing of atmospheric aerosol and its impacts on clouds and radiation. Specific activities range from the development of remote sensing retrieval techniques from satellite and ground-based instrumentation to system studies of aerosol-cloud interactions and other processes governing aerosol and cloud systems. Machine learning, radiative transfer and digital image processing constitute his main techniques. Jan Cermak has supervised 7 PhD students (4 completed); his group currently consists of 7 scientists. He has been involved in a range of outreach activities, including television interviews, lectures for children, and science fairs for the general public.

Peer-reviewed publications: 41; Invited presentations and seminars in international scientific conferences and seminar series 25

H-index: 15 (based on Clarivate analytics Web of Science); Web of Science citations: 1178.

Link to full CV and list of publications: http://www.ipf.kit.edu/english/staff_cermak_jan.php

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Andersen, H., Cermak, J., Fuchs, J., Knutti, R., & Lohmann, U. (2017). Understanding the drivers of marine liquid-water cloud occurrence and properties with global observations using neural networks. *Atmospheric Chemistry and Physics*, *17*(15), 9535–9546. doi:10.5194/acp-17-9535-2017
2. Fuchs, J., Cermak, J., Andersen, H. (2018). Building a cloud in the Southeast Atlantic: Understanding low-cloud controls based on satellite observations with machine learning. Atmospheric Chemistry and Physics Discussions, doi:10.5194/acp-2018-593
3. Loewe, K., Ekman, A. M. L., Paukert, M., Sedlar, J., Tjernström, M., and Hoose, C. (2017): Modelling micro- and macrophysical contributors to the dissipation of an Arctic mixed-phase cloud during the Arctic Summer Cloud Ocean Study (ASCOS), Atmos. Chem. Phys., 17, 6693-6704, doi:10.5194/acp-17-6693-2017
4. Schaller, N., Cermak, J., Wild, M., & Knutti, R. (2013). The sensitivity of the modeled energy budget and hydrological cycle to CO2 and solar forcing. *Earth System Dynamics*, *4*(2), 253–266. doi:10.5194/esd-4-253-2013
5. Sullivan, S. C., Hoose, C., Kiselev, A., Leisner, T., and Nenes, A. (2018): Initiation of secondary ice production in clouds, Atmos. Chem. Phys., 18, 1593-1610, doi:10.5194/acp-18-1593-2018

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. GEOPAC – A geographical perspective on aerosol-cloud interactions. Deutsche Forschungsgemeinschaft (DFG), PI Jan Cermak, 2012-2016.
2. NaFoLiCA – Namib Fog Life Cycle Analysis. Deutsche Forschungsgemeinschaft (DFG) and Schweizerischer Nationalfonds (SNF), PI Jan Cermak, 2017-2020.
3. ERC Starting Grant "C2Phase – Closure of the Cloud Phase", PI Corinna Hoose, 2017-2022.
4. BMBF project HD(CP)2, work package S1_TP4: "Response of mixed-phase clouds to aerosol perturbations", PI Hoose, 2016-2019.
5. DFG project "Statistics of ice nucleation conditions in mixed-phase clouds" within the research unit INUIT (Ice nucleation research unit), 2PI Hoose, 2015-2017

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work
The computing resources required for the successful completion of the proposed contribution are available at KIT.

	8-National Research Council – Institute of Atmospheric Science and Climate (CNR-ISAC)	**ITALY**

Description of the legal entity

National Research Council – Institute of Atmospheric Science and Climate (CNR), the Italian National Research Council The National Research Council (CNR) is the largest public research institution in Italy (funded in 1923), the only one under the Research Ministry performing multidisciplinary activities. CNR's capital comprises more than 8.000 employees (> 50% are researchers and technologists). Some 4.000 young researchers are engaged in postgraduate studies and research training within the organization's top-priority areas of interest.

ISAC The Institute of Atmospheric Sciences and Climate (ISAC) is a national institute of the Italian National Research Council (CNR). ISAC counts 200 staff members, postdoctoral researchers, and students whose research activities focus on understanding atmospheric processes and climate. ISAC mission is to perform research, and to promote and facilitate knowledge transfer in the following areas: i) meteorology and its applications, ii) climate change and predictability, iii) atmospheric structure and composition, and iv) Earth observations. The research activity of ISAC includes the study of air quality and impacts on human health, the interaction of air quality and climate, and the links between the observed atmospheric composition change and the policy.

Main tasks in FORCeS

CNR-ISAC will contribute with observational data for aerosol chemical composition and optical properties from high-altitude stations in Europe, Asia and Africa (WP1). It will undertake chemical and microphysical measurements in the Arctic (Ny-Alesund) and in the Po basin aiming to assess aerosol effects on low-level clouds and fogs (WP2). CNR-ISAC will elaborate and analyze long-term (> 15 y) records of aerosol and fog observations in Italy (WP3). Comparison with observations from the late XX century when pollution levels were higher in the region will provide hints on the effects of decadal changes in aerosol concentrations on fog properties and occurrence. Constraints employing combined metrics for fog and aerosol properties for the Po Valley and for other areas in the world (Californian Central Valley) will be used to assess the performance of state-of-the-art models in simulating fog formation in polluted continental areas (WP4).

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Maria Cristina Facchini (female) is Director of the Institute of Atmospheric Sciences and Climate (CNR-ISAC). He has received his PhD in 1985 from University of Bologna and has been researcher at ISAC since 1996 after a post-doctoral period at the same institute.

The main research interests are physical and chemical processes in multiphase atmospheric systems (aerosols and clouds) and their effects on atmospheric composition change and climate. Scientific career started in the late 80s', during the graduate studies, investigating the chemical properties of fog and clouds in the pioneering sector of the effects of soluble organic compounds on aerosol and cloud microphysics. Specifically, the importance of organic surface-active compounds on CCN activity was firstly recognized by MCF, giving birth to a fertile – and still active – research line (Ovadnevaite et al., Nature, 2017). In addition, MCF has achieved important findings on the nature and origin of biogenic marine particles by identifying key organic components of sea spray as well as new tracers of nitrogenated marine SOA. MCF has established a large number of stable and long-standing collaborations with leading atmospheric groups in the field of organic aerosol in the US and Europe, as evidenced by the scientific production, the invitations as a key presenter at several prestigious international conferences.

MC Facchini is first author of 18 research papers, coauthor of other 158. In 2014 she was awarded among the "Highly cited researchers" ranked by Thomson Reuters among the top 1% most cited scientists in the field of Geosciences. She was involved in several international and national projects (PI in 12 of them), and she has coordinated 2 intensive field campaigns. She is – or has been - member of international scientific committees and panels (SOLAS since 2015; ICNAA since 2006; CACGP since 2014; IGAC between 2008 and 2011). *She was Lead Author of the 5th Assessment Report - Intergovernmental Panel on Climate Change (IPCC)*. She takes part to PhD thesis committees and she is regularly involved in panels for the evaluation of science (e.g., ERC panel PE10 for consolidator grants since 2015).

Peer-reviewed publications: 176; Book chapters: 12; Contribution in conference proceedings: 91; Other contributions in scientific conferences: > 300

H-index: 58 (based on Clarivate analytics Web of Science); Web of Science

citations: 12.879 (12.100 without self-citations).

Link to full CV: http://www.isac.cnr.it/sites/default/files/curricula/CV%20Facchini%20Lug%202018.pdf

Link to full list of publications:

http://www.isac.cnr.it/en/user/815/biblio

Web of Science citation report:
http://apps.webofknowledge.com/CitationReport.do?product=WOS&search_mode=CitationReport&SID=D59iIHpgtItvzGwBBcR&page=1&cr_pqid=2&viewType=summary&colName=WOS

Orcid ID 0000-0003-4833-9305

Stefano Decesari (male) is a researcher in atmospheric science at the Institute of Atmospheric Sciences and Climate of the Italian National research Council (CNR-ISAC). He has received his PhD in 2001 from University of Bologna and has been employed at ISAC since 2009, after a post-doctoral period at the same Institution.

He is an expert of atmospheric organic aerosol chemistry and he was trained in nuclear magnetic resonance (NMR) spectroscopy applications at the University of Bologna and at EMSL-PNNL (Richland, WA, US). He adapted proton-NMR techniques to the analysis of water-soluble organic carbon (WSOC) in aerosol and atmospheric aqueous samples (fog and clouds). In fifteen years, the method was employed during several field experiments at both polluted and unperturbed environments, resulting particularly useful for the redefinition of elusive classes of atmospheric organic compounds, like humic-like substances (HULIS). More recently, SD was involved in research on marine organic aerosols in polar areas and light-absorbing organic particles (brown carbon) in mountain environments. In particular, he coordinated a Marie Sklodowska Curie action on brown carbon measurements and source apportionment in the Himalayas.

S. Decesari is first author of 14 research papers, coauthor of other 82. He was involved in 18 international projects (coordinated 1) and 6 nationals (coordinated 1) He takes part to PhD thesis committees and he has experience in atmospheric science educational activities.

Peer-reviewed publications: 96; Book chapters: 7; Contribution in conference proceedings: 68; Other contributions in scientific conferences: > 200

H-index: 43 (based on Clarivate analytics Web of Science); Web of Science citations: 6.830 (6.456 without self-citations).

Link to full list of publications: http://www.isac.cnr.it/en/user/865/biblio

Researcher ID publication report: http://www.researcherid.com/rid/B-9588-2015

Orcid ID: 0000-0001-6486-3786

Stefania Gilardoni (female) is a researcher at the Institute of Atmospheric Science and Climate since 2011. She

received her PhD at the University of Milan in 2003, then she worked as a post-doctoral scholar at the University of California Davis (2004-2005), at the University of California San Diego (2005-2007) and at the Joint Research centre of the European Commission (2007-2010). Dr. Gilardoni research focuses on chemical and physical characterization of atmospheric aerosol with particular attention to the carbonaceous components, their climate-relevant properties, and their health impacts. She coordinates the working group of organic aerosol source apportionment inside the COST action "Colossal" and the "Black Carbon Tool" project to analyze short lived climate forcers, in particular brown carbon and black carbon. Dr. Gilardoni's studies on cloud-aerosol interactions span from the formation of light absorbing organic aerosol through aqueous phase chemistry, to fog scavenging, and impact of climate and air quality parameters on fog occurance long-term trend.

Peer-reviewed publications: 40; Book chapters: 5; Invited presentations and seminars in international scientific conferences and seminar series 15; Other contributions in scientific conferences: > 50 (of which 14 oral presentations).

H-index: 19 (Web of Science); Web of Science citations: 1134.

WoS Researcher ID : P-1283-2014

Scopus ID : 6602523027

Orcid ID: 0000-0002-7312-5571

Google Scholar ID : hWrqe0sAAAAJ

Link to full CV: http://www.isac.cnr.it/en/users/stefania-gilardoni

Link to full list of publications:
http://www.researcherid.com/ProfileView.action?returnCode=ROUTER.Unauthorized&Init=Yes&SrcApp=CR&queryString=KG0UuZjN5WkRP73pO7%252FT5VFmWO8j86xnYxiQcOv5IEo%253D

Matteo Rinaldi (male) is a researcher at the Atmospheric Chemistry group of the Institute for Atmospheric Sciences and Climate (ISAC), within the Italian National Research Council (CNR) since 2011. He received his Ph.D. in Environmental Sciences from the University of Urbino (Italy) in 2009, defending a thesis titled "Marine aerosol: distinguishing properties of primary and secondary components". Dr. Rinaldi's research interests are in aerosol composition, atmospheric aerosol sources and aerosol evolution processes in the troposphere. In particular, his research deals with the chemical compositions and formation processes of organic marine aerosols, which he investigates through an ensemble of analytical techniques (aerosol mass spectrometry, elemental analysis, ion chromatography, liquid chromatography, proton nuclear magnetic resonance spectroscopy and surface tension measurements).

Peer-reviewed publications: 41; Book chapters: 1; Contributions in scientific conferences: > 50 (of which 10 oral presentations).

H-index: 21 (Web of Science; Researcher ID: K-6083-2012); Web of Science citations: 1378.

Link to full list of publications: http://www.isac.cnr.it/it/user/888/biblio

Mauro Mazzola (male) is a researcher at the Institute for Atmospheric Sciences and Climate (ISAC), within the Italian National Research Council (CNR) since 2015, where he had post-docs position since 2007, after the Ph.D. in physics obtained at the Univeristy of Ferrara (Italy) in 2006. His research interests include experimental and modellistic activities on aerosol physical and optical properties, both in-situ and in the vertical column, their interaction with radiation and radiative forcing, transport and deposition. Another main interest is meteorology and energy budget in the planetary boundary layer. All these activities are based on polar areas, mainly in the Arctic, since 2010. Specific experimental techniques include photometry (solar and lunar), use of tethered balloon for aerosol profiles, eddy-covariance.

He is author of more than 40 scientific papers, 5 book chapters, and tens of oral and poster communications.

WoS Researcher ID (h-index: 9): K-9376-2016

Scopus ID (h-index: 10): 24367405100

Orcid ID: 0000-0002-8394-2292

Google Scholar ID (h-index: 12): 5y4acbQAAAAJ

Link to full list of publications: http://www.isac.cnr.it/en/user/783/biblio

Paolo Cristofanelli (male) is a researcher in atmospheric science at the Institute of Atmospheric Sciences and Climate of the Italian National research Council (CNR-ISAC). He has received his PhD in 2003 from University of Urbino and has been employed at ISAC since 2009, after a post-doctoral period at the same Institution.

He is an expert in atmospheric composition variability study (trace gases and aerosols) with a special emphasis on transport processes occurring over different spatial scales, remote regions (mountain areas, Antarctica), long-term trend analysis. He has competence on measurement techniques, mainly related to near-surface observations of atmospheric composition and data analysis related to observational time series and model outputs.

P. Cristofanelli is first author of 17 research papers, coauthor of other 55. He was involved in 8 international projects and 5 nationals. He is director of the "O. Vittori" observatory, part of the WMO/GAW Mt. Cimone global station. He was supervisor for PhD and master thesis and he has experience in atmospheric science educational activities.

H-index: 24 (based on Scopus); Scopus citations: 1.615 (without self-citations).

Link to full list of publications: http://www.isac.cnr.it/en/user/865/biblio

Scopus author ID: 55663790800

Orcid ID: 0000-0001-5666-9131\

Angela Marinoni (female) has degree and PhD in Environmental Science, with experience on aerosol properties, cloud and precipitations in different environments.

After a PhD on aerosol-cloud interaction at Clermont-Ferrand University (Physical Meteorology Laboratory) and a Post-Doc at Bologna University (Chemistry Department), she is working since 2005 at CNR-ISAC (Institute of Atmospheric Sciences and Climate), where she gained experience on integration of observations concerning chemical, physical and optical aerosol properties, especially in mountain and remote areas. She is responsible for the atmospheric aerosol observations at the WMO/GAW global station of Monte Cimone (Northern Apennines, 2165 m) and at the regional station of Capo Granitola. She has also been in charge of the aerosol observations at the WMO/GAW global station Nepal Climate Observatory-Pyramid (Himalayas, 5079 m asl) during the almost ten years of activity.

She has been responsible of ISAC activities in the framework of EUSAAR (FP6) and ACTRIS/ACTRIS-2 (FP7 and H2020) EU-projects.

She has been responsible of the WP1 of the Infrastructure Project I-AMICA (2011-2015), funded by FESR for the implementation of observing facilities for climate and environmental monitoring in order to strengthen laboratories and instrumentation for observations and monitoring, data processing and information storage. The I-AMICA Project led to the design and installation of four environmental climate observatory in different environment in Southern Italy, all of them are now affiliated at the GAW program.

She is also performing several scientific dissemination and educational activities with workshops, seminars and guided tour for different audiences on atmospheric pollution, impact on climate, environment and human health.

She is author or co-author of about 60 papers in ISI journals.

H-index: 26 (based on Clarivate analytics Web of Science); Web of Science citations: 2.053 (1828 without self-citations).

Link to full CV: http://www.isac.cnr.it/sites/default/files/curricula/Europass_CV_eng_ACTRIS_PON.pdf

Link to full list of publications: https://scholar.google.it/citations?user=pV9Pk9wAAAAJ&hl=i

Orcid ID: 0000-0002-6580-7126

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Atmospheric Ice Nucleating Particle measurements at the high mountain observatory Mt. Cimone (2165 m a.s.l., Italy), Rinaldi, M., Santachiara G., Nicosia A., Piazza M., Decesari S., Gilardoni S., Paglione M., Cristofanelli Paolo, Marinoni A., Bonasoni Paolo, et al. , Atmospheric Environment, Volume 171, p.173-180, (2017)
2. Surface tension prevails over solute effect in organic-influenced cloud droplet activation, Ovadnevaite, J., Zuend A., Laaksonen A., Sanchez K.J., Roberts G., Ceburnis D., Decesari S., Rinaldi M., Hodas N., Facchini M.C., et al. , Nature, Volume 546, Number 7660, p.637-641, (2017)
3. Antarctic sea ice region as a source of biogenic organic nitrogen in aerosols, Dall'Osto, M., Ovadnevaite J., Paglione M., Beddows D.C.S., Ceburnis D., Cree C., Cortés P., Zamanillo M., Nunes S.O., Pérez G.L., et al. , Scientific Reports, Volume 7, Number 1, (2017)
4. Long-term cloud condensation nuclei number concentration, particle number size distribution and chemical composition measurements at regionally representative observatories, Schmale, J., Henning S., Decesari S., Henzing B., Keskinen H., Sellegri K., Ovadnevaite J., Pöhlker M., Brito J., Bougiatioti A., et al. , Atmospheric Chemistry and Physics, Volume 18, Number 4, p.2853-2881, (2018)
5. Direct observation of aqueous secondary organic aerosol from biomass-burning emissions, Gilardoni, S., Massoli P., Paglione M., Giulianelli L., Carbone C., Rinaldi M., Decesari S., Sandrini S., Costabile F., Gobbi G.P., et al. , Proceedings of the National Academy of Sciences of the United States of America, Volume 113, Number 36, p.10013-10018, (2016)

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. FP7 integrated project EUCAARI (participant)
2. FP7 integrated project PEGASOS (participant)
3. FP7 integrated project BACCHUS (participant)
4. ACTRIS
5. GAW network

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The ISAC-CNR hosts infrastructures, equipment, and databases relevant for the FORCeS project. The institute has collected data on chemical composition and physical properties of fog water in the Po valley over more than 20 years, offering a unique database to study the interactions of aerosol and cloud water and to investigate the changes in atmospheric composition over the last two decades. In addition, the institute runs the Monte Cimone Observatory (2165 m a.s.l.) (ICO-OV). Monte Cimone is the highest peak of the northern Apennines and it is the only Italian high mountain station for atmospheric aerosol research located south of the Alps and of the Po basin. Due to the completely free horizon, high altitude and great distance from major pollution sources, ICO-OV represents a strategic platform to study the chemical-physical characteristics and climatology of the free troposphere in the South Europe and North Mediterranean basin. In addition to the Italian observatories, ISAC-CNR operates the Arctic Gruvebadet Aerosol Laboratory, located nearby the village of Ny-Alesund, in the Svalbard archipelago. It is equipped to host aerosol sampling for measurements of chemical, physical and optical

properties. It's managed by CNR-ISAC personnel and operative from March to October each year. The institute is also equipped with instrumentations for the on-line and off-line characterization of aerosol chemical and micro-physical properties and for the analysis of fog and cloud water characterization.

Norwegian Meteorological Institute	**9-Norwegian Meteorological Institute (MetNo)**	**NORWAY**

Description of the legal entity

Norwegian Meteorological Institute (MetNo) METNO is the national meteorological service in Norway. In addition to national and aviation weather forecasting, and climate monitoring for Norway and adjacent sea areas, the institute represents Norway in ECMWF, EUMETSAT, EUMETNET, WMO and other international fora, and takes active part in national and international research projects (e.g. EU, Copernicus, ESA-cci, EMEP) on climate, atmospheric and marine research, and air pollution. The number of employees is ca. 400, with nearly 80 scientists doing research relevant for prediction and analysis of weather, ocean and sea ice, climate, air pollution, instrumentation, and remote sensing. MET Norway has extensive experience in operational applications for innovation and added value in private and public sectors.

METNO is together with the universities in Oslo and Bergen the main developer of the Norwegian Earth System model NorESM, providing up-to-date climate projection results to CMIP and IPCC. The scientific contributions particularly concern better understanding of the interactions between aerosols, clouds, atmospheric composition, climate dynamics, variability, and change. Results were delivered to CMIP5 based on NorESM1. Final adjustments and spin-up for NorESM2 productions to be used for CMIP6 are finalized in 2018.

The Research Department with around 80 scientists do research within numerical weather prediction, ocean modelling, remote sensing, air pollution, product development, instrumentation, climatology and climate research. Numerical models for atmospheric, oceanographic and sea-ice forecasting are continuously improved. Considerable R&D is also centred on environmental models (air pollutants, oil spills, etc.).

MET Norway has extensive experience in developing and validating the Norwegian Earth System model, providing education and tools for other users in the scientific community, including other Nordic institutions.

Main tasks in FORCeS

The MetNo team will co-coordinate the WP3 and WP5 efforts within FORCeS, contributing with the NorESM model simulations and analysis of joint FORCES model experiments. MetNo will contribute scientifically to WPs 3 (through data analysis and modeling), WP4 (development and application of powerful diagnostic tools), WP5 (Analysis of experiments; Include and test a selected number of improved parameterizations in NorESM). Extensive knowledge on aerosol forcing, model evaluation and ESM feedback analysis will be utilized to pursue the goals of the FORCeS project.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Michael Schulz (male): Deputy Head of MetNo's Climate Modelling and Air Pollution Section with 25 researchers, as well as Professor II (20%) at University of Oslo. He assumes responsibility for atmospheric chemistry, aerosols, climate and earth system modelling at MetNo. Earlier career achieving PhD at university of Hamburg (1993), Group leader at LSCE, France, as guest scientist at NASA Goddard, and supervising more than 20 graduate and PhD students. He is the leader of AeroCom since 2002, with internationally leading contributions to the understanding of aerosol-climate interactions. PI in multiple EU and national projects in Germany, France and Norway. Lead and Contributing Author of IPCC AR4 and AR5. Now co-chair of AerChemMIP contributing to CMIP6. Co-coordinator of the large Norwegian Infrastructure project INES supporting the NorESM climate model development, starting in July 2018.

Peer-reviewed publications: >150; H-index: 55 ; citations: 12944 (12311 without self-citations) (based on Clarivate analytics Web of Science); ranked as Highly Cited Researcher by Thomson Reuters for 2014, 2015 and 2016; ORCID: 0000-0003-4493-4158

Ada Gjermundsen (female): Early career postdoc researcher with excellent expertise on atmosphere-ocean exchange processes, general circulation of ocean and atmosphere and feedback analysis.

Lise Seland Graff (female): Researcher with expertise in atmospheric dynamics, specializing in extratropical storm tracks and synoptic-scale mixing. She recently has contributed to analysis of atmospheric circulation patterns in the HappiMIP project contributing to the special IPCC report on the 1.5 degree target. She has also experience in utilizing a radiative kernel method to analyse feedbacks. PAMIP representative of NorESM.

Alf Kirkevåg (male): Senior researcher with key expertise on representing aerosols physics in NorESM, model tuning, and performing NorESM-experiments for AeroCom. PI in EVA. Contributes NorESM-results to RFMIP.

Dirk Olivie (male): Researcher in earth system modelling with emphasis on atmospheric chemistry and climate. Recent key contributions to NorESM-development in EVA, and to chemistry-climate experiments in EU FP7 ECLIPSE, and development of metrics for climate impact studies. AerChemMIP representative.

Øyvind Seland (male): Senior researcher with expertise on aerosol modelling in NorESM, model tuning, and production runs. PI in EVA, EU FP7 PEGASOS and ACCESS, and in CRAICC and eSTICC. Key contributor to the preparatory and production-runs for CMIP6 with particular responsibility DECK, ScenarioMIP and DAMIP.

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Kirkevåg, A. et al. (2018): A production-tagged aerosol module for earth system models, OsloAero5.3 – extensions and updates for CAM5.3-Oslo Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-46
2. Iversen, T. et al (2013): The Norwegian Earth System Model, NorESM1-M – Part 2: Climate response and scenario projections, Geosci. Model Dev., 6, 389–415, doi:10.5194/gmd-6-389-2013.
3. Collins, W. J., Lamarque, J. F., Schulz, et al.: AerChemMIP: quantifying the effects of chemistry and aerosols in CMIP6, Geoscientific Model Development, 10, 585-607, 2017.
4. Myhre, G., Samset, B. H., Schulz, M., et al.: Radiative forcing of the direct aerosol effect from AeroCom Phase II simulations, Atmos. Chem. Phys., 13, 1853-1877, doi:10.5194/acp-13-1853-2013, 2013.
5. Samset B.H:, G. Myhre, M. Schulz: Upward adjustment needed for aerosol radiative forcing uncertainty; Nature Climate Change 4, 230–232 (2014); doi:10.1038/nclimate2170

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. Norwegian Infrastructure project INES to support the development of the Norwegian Earth System Model (Co-coordination, start July 2018)
2. H2020 integrated project CRESCENDO, improving process realism in European ESMs in preparation for CMIP6 (participant, 2015-2020)
3. Aerosol Model Comparison Project (AeroCom): (coordination, since 2003)
4. H2020 integrated project APPLICATE for improvement of weather forecast and climate prediction in the Arctic (participant, 2016-2021)
5. National research council project EVA (Earth system modelling of climate Variations in the Anthropocene) for development and application of NorESM for CMIP6 (Co-coordination)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The MetNos hosts a suite of infrastructure relevant for the FORCeS proposal. It will have access to supercomputing and national storage facilities at the Norwegian national supercomputing centre in Tromsø, supported by full time scientific programmers in the INES infrastructure. MetNos new lustre post-processing

system was scaled up to be the efficient backbone of the AeroCom database, with big data handling, visualization and data exchange capabilities. MetNo's cooperation with ACTRIS as well as earlier developed AeroCom software packages will allow for efficient data analysis of relevant observations in FORCeS.

Royal Netherlands Meteorological Institute Ministry of Infrastructure and Water Management	10-Royal Netherlands Meteorological Institute (KNMI)	NETHERLANDS

Description of the legal entity

The **Royal Netherlands Meteorological Institute (KNMI)** is the national service and research centre for weather, climate, and seismology in the Netherlands. KNMI has a long tradition in operational and scientific activities. Climate research at KNMI aims at observing, understanding and predicting changes in the climate system. KNMI produces climate scenarios to support stakeholders for developing adaptation and mitigation strategies. KNMI has initiated the development of the global climate model EC-Earth and has since been a leading partner in the consortium.

The division R&D Weather and Climate Modelling develops and applies high-resolution limited area models (HIRLAM, HARMONIE) and data assimilation techniques for numerical weather prediction, regional climate (RACMO, HARMONIE-Climate) and air quality models (LOTOS-EUROS), and global climate (EC-Earth) and atmospheric composition models (TM5, C-IFS). With EC-Earth the division currently participates in various CMIP6 activities (AerChemMIP, ScenarioMIP, RFMIP, etc.) and EU Horizon 2020 projects such as CRESCENDO and PRIMAVERA.

Main tasks in FORCeS

The KNMI team will contribute to improving the description of aerosols and aerosol-climate interactions in the global climate model EC-Earth. KNMI will implement revised parameterizations in EC-Earth (Task 5.2), and run the revised model in coupled mode, in order to assess impacts on transient climate simulations (Task 5.3). In addition, KNMI will make atmosphere-only simulations to produce time series of aerosol effective radiative forcings (Task 3.2).

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Dr. **Twan van Noije** (male) is a senior scientist in the R&D Weather and Climate Modelling division. He obtained a PhD in theoretical physics from Utrecht University in 1999. He joined the atmospheric composition modelling group at KNMI in 2003, and started working in the field of global climate modelling in 2007. He has since been leading the developments related to the description of aerosols and atmospheric chemistry in EC-Earth. He is actively involved in the preparation of the various model configurations for CMIP6, and is coordinating the consortium's contributions to the Aerosols and Chemistry MIP (AerChemMIP). Over the years he has participated in various EU and international projects (such as RETRO, AMMA, ACCENT, ACCMIP, SPECS, and AeroCom). He is currently participating in the Horizon 2020 project CRESCENDO. He has authored 54 peer-reviewed publications and has an H-index of 32 (based on Google Scholar Citations, dd. 02-07-2018). He is a co-author of the KNMI'14 climate scenarios, and is contributing author of the IPCC Fourth and Fifth Assessment Reports.

For a full list of publications, see https://scholar.google.com/citations?user=IznF8JEAAAAJ

Prof. **Bart van den Hurk** (male) is head of the R&D Weather and Climate Modelling division of KNMI, and holds a chair at VU University Amsterdam. His main expertise is on diagnosing and understanding land-atmosphere interaction, on the impact of land surface initialisation on predictability of weather and climate, and on developing climate scenarios for the Netherlands. He coordinated an EU and national climate research projects.

Dr. **Philippe Le Sager** (male) is a scientific programmer in the R&D Weather and Climate Modelling division of KNMI. He provides technical support for the development and application of TM5 and EC-Earth. In recent years he has developed a massively parallel version of TM5, has implemented couplings between new Earth system components in EC-Earth, and has supported the release of various TM5 and EC-Earth versions. He is chair of the EC-Earth working group on technical issues. He is currently actively involved in the EU Horizon 2020 projects

CRESCENDO and PRIMAVERA.

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Bruine, M. de, M. Krol, T. van Noije, P. Le Sager and T. Röckmann, 2018. The impact of precipitation evaporation on the atmospheric aerosol distribution in EC-Earth v3.2.0, Geosci. Model Dev., 11, 1443-1465, doi:10.5194/gmd-11-1443-2018.
2. Chuwah, C., T. van Noije, D.P. van Vuuren, P. Le Sager, and W. Hazeleger, 2016. Global and regional climate impacts of future aerosol mitigation in an RCP6.0-like scenario in EC-Earth, Climatic Change, 134, 1-14, doi:10.1007/s10584-015-1525-9.
3. Lacagnina, C., O. P. Hasekamp, H. Bian, G. Curci, G. Myhre, T. van Noije, M. Schulz, R. B. Skeie, T. Takemura, and K. Zhang (2015), Aerosol single-scattering albedo over the global oceans: Comparing PARASOL retrievals with AERONET, OMI, and AeroCom models estimates, J. Geophys. Res. Atmos., 120, 9814–9836, doi: 10.1002/2015JD023501.
4. Van Noije, T.P.C., P. Le Sager, A. J. Segers, P. F. J. van Velthoven, M. C. Krol, W. Hazeleger, A. G. Williams, and S. D. Chambers, 2014. Simulation of tropospheric chemistry and aerosols with the climate model EC-Earth, Geosci. Model Dev., 7, 2435-2475, 2014, doi:10.5194/gmd-7-2435-2014.
5. Hazeleger, W., X. Wang, C. Severijns, S. Ştefănescu, R. Bintanja, A. Sterl, K. Wyser, T. Semmler, S. Yang, B. van den Hurk, T. van Noije, E. van der Linden, K. van der Wiel., 2012. EC-Earth V2.2: description and validation of a new seamless Earth system prediction model, Clim Dyn., 39, 2611-2629, doi:10.1007/s00382-011-1228-5.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. H2020 integrated project CRESCENDO (participant)
2. H2020 integrated project PRIMAVERA (participant)
3. FP7 integrated project SPECS (participant)
4. AeroCom – Aerosol Comparisons between Observations and Models (participant)
5. CAMS – Copernicus Atmosphere Monitoring Service (KNMI coordinates the subprojects CAMS_42 and CAMS_84)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The EC-Earth climate model can be run on the Bull720 supercomputer of KNMI and on the High Performance Computing Facility of the European Centre for Medium-range Weather Forecasts (ECMWF), which consists of two Cray XC40 clusters.

SMHI	**11-Swedish Meteorological and Hydrological Institute (SMHI)**	**SWEDEN**

Description of the legal entity

The **Swedish Meteorological and Hydrological Institute (SMHI)** is a public body with some 670 employees under the Swedish Ministry of Environment and Energy, running both governmental services and commercial businesses. SMHI is providing decision support to a broad range of end-users, based on meteorology, hydrology, oceanography and climate information. SMHI is responsible for national monitoring and modelling in these fields, data archives and refinement of information for societal needs. On behalf of the government SMHI runs a national knowledge centre for adaptation to climate change. SMHI has a long tradition in developing customized products and services, as well as 24/7 production of forecasts with early warnings, and operates the dissemination of flood alerts to other EU member states in the EFAS system for EU Copernicus. It has a strong R&D focus with 110 full time scientists. SMHI is active in many GEOSS, Copernicus and ESA projects. SMHI is representing Sweden in relevant international organizations, e.g. ECMWF, WMO, EUMETSAT and IPCC. The institute is involved in many national and international projects including those under FP7, H2020 and Copernicus. The SMHI management system has been certified under the quality standards ISO 9001 and ISO 14001.

The Rossby Centre, that is part of the R&D at SMHI, work on climate model development and evaluation, as well as modelling applications for process studies and climate change research in support of impact and adaptation studies. The focus lies on increasing knowledge of the future climate, covering meteorological, oceanographical and hydrological aspects. The Rossby Centre is involved in a number of national and international projects within climate modelling, climate change research and the application of climate change information in support of downstream research and decision-making. The Rossby Centre has been deeply involved in the development and application of the global earth system model EC-Earth that is currently being set up for use in CMIP6.

Main tasks in FORCeS

The SMHI team will co-lead WP5 on examination of climate response and feedbacks in response to aerosol forcing and WP7 focusing on dissemination and impact. SMHI will also contribute scientifically to WPs 5 (through EC-Earth simulations on mechanisms and feedbacks related in particular to Arctic climate change), and 6 (through EC-Earth simulations on transient climate response and prediction).

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Ralf Döscher (male) is the head of global climate modelling at the Rossby Centre. He received a PhD in physical oceanography from University of Kiel/Germany in 1994 and has been working at AWI (German Polar institute, 1995-1996) and the University of Washington in Seattle/USA as visiting assistent professor (School of Oceanography, 1997-1998). Since 1998, Ralf is carrying out climate research at SMHI. Science areas include ocean turbulence and large scale circulation, development of coupled regional and global climate models, Baltic Sea and Arctic climate change. Ralf is currently chairing the European EC-Earth consortium that prepares ESM configurations for CMIP6.

Bibliometric summary since 2013 Since 2013, citation indexes are as follows: 733 since citations (2387 total), a h-index of 14 (21 in total), a i10-index of 20 (27 in total). The vast majority of publications are peer- reviewed papers. Google-Schoolar counts 16 publications since 2013, including 2 book chapter and 2 conference papers.

Link to homepage with CV and publication list:
https://www.smhi.se/forskning/forskningsomraden/klimatforskning/ralf-doscher-1.871

Erik Kjellström (male) is a professor in climatology at SMHI. He has received his PhD in chemical meteorology in 1998 from University of Stockholm, and has with the Rossby Centre at SMHI since 2003 after a post-doctoral period at Massachusetts Institute of Technology, Cambridge, MA, the United States. From 2012 he also acts as Adjunct Professor at the Department of Meteorology at the Stockholm University. Between 2013 and 2018 he was the head of the Rossby Centre at the research department of SMHI with approximately 25 staff members. He has more than 25 years of experience from atmospheric modelling covering atmospheric chemistry, biogeochemical cycles and climate modelling. During the last 15 years he has worked in the field of regional climate modelling at the Rossby Centre. His main research interests relate to aspects of RCM evaluation, regional climate change and use of RCM data for climate impact research and for building climate services in close collaboration with a wide range of users. He has been working in a series of European research projects involving regional climate modelling starting with PRUDENCE (FP5) and ENSEMBLES (FP6). In recent years he has been, and is, work package leader on climate scenarios in the EU projects IMPACT2C (FP7), ECLISE (FP7) and IMPREX (H2020) as well as the Nordic project on Climate and Energy. In FORCeS he will be co-leading WP7.

Peer-reviewed publications: 64; Book chapters: 8; Presentations and seminars in international scientific conferences and seminar series > 100.

H-index: 29 (based on Web of Science); Web of Science citations: 3868 (3737 without self-citations).

Link to homepage with CV and publication list: https://www.smhi.se/en/research/research-departments/climate-research-rossby-centre2-552/erik-kjellstrom-1.10694

Helena Martins (female) is science communicator in the Rossby Centre, SMHI's climate research unit. She has a PhD in Sciences Applied to the Environment and for 15 years conducted research in atmospheric sciences. In the Rossby Centre since early 2016, she is responsible for general communication of the research conducted by the Rossby Centre. She is currently leading H2020 CRESCENDO dissemination and communication activities, and is also team member of H2020 project Climateurope. In FORCeS she will be working on WP7.

Peer-reviewed publications: 17; Book chapters: 7; Presentations and seminars in international scientific conferences and seminar series 30.

ORCID-ID: https://orcid.org/0000-0001-8430-0446 .

Link to homepage with CV and publication list: https://www.smhi.se/en/research/research-departments/climate-research-rossby-centre2-552/helena-martins-1.109747

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Kjellström, E., Nikulin, G., Strandberg, G., Christensen, O. B., Jacob, D., Keuler, K., Lenderink, G., van Meijgaard, E., Schär, C., Somot, S., Sørland, S. L., Teichmann, C., and Vautard, R., 2018. European climate change at global mean temperature increases of 1.5 and 2 °C above pre-industrial conditions as simulated by the EURO-CORDEX regional climate models, Earth Syst. Dynam., 9, 459-478, https://doi.org/10.5194/esd-9-459-2018.
2. Döscher, R., Martins, H., Hewitt, C., Whiffin, F., van den Hurk, B. (Eds.), 2017. European Earth System Modelling for Climate Services. Climateurope Publication Series Vol.1, 65 pp. DOI: https://doi.org/10.17200/Climateurope.D6.5/1
3. Kjellström, E., Bärring, L., Nikulin, G., Nilsson, C., Persson, G., and Strandberg, G., 2016. Production and use of regional climate model projections – a Swedish perspective on building climate services. Climate Services, 2-3, 15-29. Doi: 10.1016/j.cliser.2016.06.004.
4. Van den Hurk, B., Bouwer, L., Pouget, L. Ward, P., Ramos, M.-H., Buontempo, C., Klein, B., Wijngaard, J., Hananel, C., Kjellström, E., Manez, M., Döscher, R., Ercin, E., Hunink, J., Pappenberger, F. and Weerts, A., 2016. Improving Predictions and Management of Hydrological Extremes through Climate Services. Climate Services, 1, 6-11.
5. Wormbs, Nina, Ralf Döscher, Annika E. Nilsson, and Sverker Sörlin. "Bellwether, exceptionalism and other tropes: Political coproduction of Arctic climate modelling.", 2017. 133-155.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal
1. H2020 integrated project CRESCENDO (participant) 2. H2020 integrated project PRIMAVERA (participant) 3. H2020 project CLIMATEUROPE (participant) 4. FP7 project EMBRACE (coordinator) 5. Swedish funded MACCII project (activities feeding into the Copernicus MACC project)
Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work
In FORCeS SMHI will make extensive use of the computer cluster Bi at the Swedish National Supercomputer Centre (NSC). All EC-Earth simulations will be run on this computer. To store the many Tb of expected output SMHI will make use of its mass-storage facility, Accumulus (2.7 Pb online disks plus tape storage), which is co-located with Bi at NSC. The key software tool for this project is the global climate modelling system EC-Earth. SMHI has in-house software tools for pre- and post-processing as well as visualisation of model output.

UNIVERSITY OF EASTERN FINLAND	**12-Uniersity of Eastern Finland (UEF)**	**FINLAND**

Description of the legal entity

The University of Eastern Finland (UEF) was founded 1st of January 2010 by the merge of University of Joensuu and University of Kuopio. UEF is one of the largest universities in Finland, and home to approximately 15,000 students and 2,800 members of staff. UEF shows courage in crossing academic boundaries and our interdisciplinary approach is internationally recognised. The research is ranked among the best in the world in several fields. ”Shanghai Global Ranking of Academic Subjects” has ranked Atmospheric Sciences in Univ. Eastern Finland in position 51-75. Research carried out at the University of Eastern Finland is of a high international standard and has significant impact, with an emphasis on interdisciplinarity. UEF has identified four global challenges for which we seek solutions through our interdisciplinary research and education. These challenges are Ageing, lifestyles and health; Learning in a digitized society; Cultural encounters, mobilities and borders; and Environmental change and sufficiency of natural resources.

Department of Applied Physics employs some 80 researchers working in the research fields of Environmental Physics, Medical Physics and in Computational Physics. **Aerosol Physics Group** at the Department of Applied Physics is a host for 25 researchers. The group’s major research questions are related to the atmospheric aerosols: how they form, what are their properties and what is the role they play in the Earth’s climate through their interactions with water vapor. To study these questions in a comprehensive way the group has established wide international collaborative networks and consistently developed the research infrastructure at UEF. The group has a unique capability of integrating laboratory and outdoor measurements with theories and models in order to understand and predict the impacts of human-caused and natural changes on climate. Aerosol physics group is in a central role in UEF top level strategic profiling area Environmental changes and sufficiency of natural resources.

Main tasks in FORCeS

The UEF team will co-lead the WP2 and thus be one of the main contributors to WP 2 focusing on cloud processes and aerosol-cloud interactions. UEF will contribute to WPs 2 (through organizing and carrying the field experiments at Puijo SMEAR IV station and by analyzing the data and participating in implementing the process level observations to GCMs) and 1 (through data analysis and process modeling).

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Annele Virtanen (female) is a professor in Aerosol Physics at UEF. She received her PhD in Tampere University of Technology (TUT, Department of Physics) 2004. After that she continued working as a postdoc and later, as a group leader at TUT. On January 2012 she moved to University of Eastern Finland (UEF) to lead the Aerosol Physics Laboratory. She has a strong background in measurement method development and applications related to atmospheric aerosols. Her major research questions are related to the atmospheric aerosol properties and aerosol-cloud interactions. She has supervised 13 PhD students (8 completed , 5 on-going) and 7 post-doctoral researches. She is currently an ERC Starting Grant holder. Prof. Virtanen has engaged in various activities within international scientific community, including memberships in scientific committees and evaluation panels, and in journal editorial boards. She has also engaged in numerous outreach activities, including video interviews and presentations popularizing science, and participating in public seminars.

Peer-reviewed publications: 88; Invited presentations and seminars in international scientific conferences and seminar series: >20.

H-index: 27 (based on ISI Web of Science); Web of Science citations: 2730 (2504 without self-citations).

Link to full list of publications: http://www.researcherid.com/rid/E-7699-2010

Siegfried Schobesberger (male), Assistant Professor in the Aerosol Physics Group at the Department of Applied Physics at UEF since 2017, will be responsible for the experimental activities of UEF within FORCeS, together with Annele Virtanen. In his research he uses advanced mass spectrometric and micrometeorological techniques to investigate sources, oxidation processes and sinks of organic compounds in the atmosphere and the consequent physical and chemical properties of aerosol particles. He is currently mentoring 1 postdoc and supervising 1 PhD student.

Peer-reviewed publications: 51; H-index: 21 (based on ISI Web of Science, 30.7.2018); ISI citations: 2986. Link to full list of publications: http://www.researcherid.com/rid/L-4454-2014

Taina Yli-Juuti (female) is a tenure-Track Assistant Professor at UEF. After receiving her PhD in 2013 at University of Helsinki, she worked as postdoc at Max Planck Institute for Chemistry before joining UEF in 2014. She is the leader of the Aerosol modelling sub- group of the Aerosol research group at UEF Department of Applied Physics. She is currently supervising 4 PhD students. Her research focuses on formation and transformation of atmospheric aerosols, especially secondary organic aerosols. She will be responsible for process modelling activities (WP1 and WP2) of UEF and will participate in implementing the process level observations to GCMs.

Peer-reviewed publications: 27; H-index: 16 (based on ISI Web of Science); Web of Science citations: 1168 (1110 without self-citations). Link to full list of publications: http://www.researcherid.com/rid/O-9496-2018

Kari Lehtinen (male) is professor of atmospheric physics and chemistry at UEF and head of the Applied Physics Department. His research focus is data analysis, theory and modeling of atmospheric aerosol dynamics. He has supervised 20 PhD students and published 182 peer reviewed journal articles with an H-index 44 (ISI WoS 1.8.2018). He will participate in data analysis and process modelling activities in WP1. Link to full list of publications http://www.researcherid.com/rid/O-9559-2018

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Väisänen, O., Ylisirniö, A., Ruuskanen, A., Miettinen, P., Hao, L., Portin, H., Leskinen, A., Komppula, M., Romakkaniemi, S., Lehtinen, K., and Virtanen, A. In-cloud measurements highlight the role of aerosol hygroscopicity in cloud droplet formation, *Atmos. Chem. Phys*., 16, 10385-10398, doi:10.5194/acp-16-10385-2016, 2016.
2. Pajunoja, A., Lambe, A.T., Hakala, J., Rastak, N., Cummings, M.J., Brogan, J.F., Hao, L., Paramonov, M., Hong, J., Prisle, N.L., Malila, J., Romakkaniemi, S., Lehtinen, K.E.J., Laaksonen, A., Kulmala, M., Massoli, P., Onasch, T.B., Donahue, N.M., Riipinen, I., Davidovits, P., Worsnop, D.R., Petäjä, T., Virtanen, A. Adsorptive uptake of water by semisolid secondary organic aerosols in the atmosphere, *Geophys. Res. Lett.,* 42,3063–3068, 2015 doi:10.1002/2015GL063142
3. Frey, W., Hu, D., Dorsey, J., Alfarra, R.M., Pajunoja, A., Virtanen, A., Connolly, P., and McFiggans, G. The efficiency of secondary organic aerosol particles to act as ice nucleating particles at mixed-phase cloud conditions, Accepted to Atmos. Chem. Phys., 2018
4. Rastak, N., Pajunoja, A., Acosta Navarro, J. C., Ma, J., Song, M., Partridge, D. G., Kirkevåg, A., Leong, Y., Hu, W. W., Taylor, N. F., Lambe, A., Cerully, K., Bougiatioti, A., Liu, P. Krejci, R., Petäjä, T., Percival, C., Davidovits, P., Worsnop, D. R., Ekman, A. M. L., Nenes, A., Martin, S., Jimenez, J. L., Collins, D. R., Topping, D. O., Bertram, A. K., Zuend, A., Virtanen, A., and Riipinen, I., 2017. Microphysical explanation of the RH-dependent water affinity of biogenic organic aerosol and its importance for climate, Geophys. Res. Lett., 44, doi:10.1002/2017GL073056;
5. Zieger, P., Väisänen, O., Corbin, J., Partridge, D.G., Bastelberger, S., Mousavi-Fard, M., Rosati, B., Gysel, M., Krieger, U.K., Leck, C., Nenes, A., Riipinen, I., Virtanen, A., and Salter, M. E. Revising

the hygroscopicity of inorganic sea salt particles, Nature Comms. 8 (15883), doi:10.1038/ncomms15883, 2017.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. H2020-INFRAIA project EUROCHAMP2020 (participant)
2. European Research Council starting grant QAPPA (coordinator)
3. Finnish Academy Center of Excellence in Atmospheric Science (Participant)
4. Several projects funded by Academy of Finland including e.g. Consortium AquBor (Importance of aqueous phase processing of organic aerosols in boreal areas; consortium coordinator)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

UEF runs the SMEAR IV Puijo cloud station relevant for the proposal. The characteristic features at SMEAR IV are the elevated location in a semi-urban area and the site being frequently in cloud. The instrumentation at the station covers measurement of aerosol dynamics, cloud droplet properties, cloud optical measurements, relevant cloud properties, trace gases and meteorological parameters. In addition, the state-of the-art aerosol characterization devices, including e.g. comprehensive mass spectrometric methods, and devices for aerosol-water interaction studies enables extensive measurement campaigns relevant for WP2. SMEAR IV station also offers long-term data set for aerosol and aerosol-cloud interaction studies. In addition, the laboratory facilities with two atmospheric simulation chambers combined with real combustion sources and living plants offers data relevant to WP1.

UNIVERSITY OF HELSINKI INAR Institute for Atmospheric and Earth System Research	**13-University of Helsinki (UHEL)**	**FINLAND**

Description of the legal entity

University of Helsinki (**UHEL**; http://www.helsinki.fi/university/), established in 1640, is among the leading multidisciplinary research universities in the world. High-level research is carried out in 11 faculties, as well as at independent research institutes, some of which are jointly operated with other universities. Some 35,000 students are currently pursuing an undergraduate or a postgraduate degree at the University of Helsinki and the University lays special emphasis on the quality of education and research. The University of Helsinki is a member of the League of the European Research Universities (LERU) and European University Association (EUA).

Institute for Atmospheric and Earth System Research (**INAR**) is a multi- and interdisciplinary research unit that strengthens the internationally leading, integrated multidisciplinary research and education environment for atmospheric and Earth system science and to feed in scientific results for the national and international environment and climate policy. INAR has a strong role in European research infrastructures and their integration. INAR is a joint Institute between the Faculty of Science and Faculty of Agriculture and Forestry at the University of Helsinki and it has national collaboration with Finnish Meteorological Institute, University of Eastern Finland and Tampere University of Technology. INAR researchers also collaborate widely with other departments ant the faculties, national and international universities and research organizations. INAR staff participates in teaching in two bachelor programmes, several other educational programmes and are responsible for master and doctoral programmes in atmospheric sciences.

Research in INAR is based on physics, chemistry, meteorology, forest sciences, environmental sciences and increasingly also on social sciences. The group has special expertise on aerosol science, environmental physics and air chemistry. It performs multiscale research from molecular to global scale and focuses on climate change, air quality, biogeochemical cycles and ecosystem processes. Business collaboration is strong especially in air quality –related issues.

The institute follows its activities and development annually with different measures including total funding (14 M euros), external funding (55% of total funding), peer-reviewed scientific articles (250), Science and Nature papers (annually on average 3), ERC grants (annually on average 2) and highly cited researchers (5).

Main tasks in FORCeS

The UHEL team leads Task 1.4, where we will produce, in co-operation with other partners, a novel module for describing the new particle formation and aerosol growth to CCN sizes. This module and the parameterizations for it will be formulated based on the data from WP4. UHEL team will also participate in other WP1 Tasks with laboratory and ambient measurements on the formation of highly oxidized multifunctional organic molecules and organonitrates. UHEL will contribute to data collection, harmonization, model simulations and their analysis, as well as to model-observation integration in WPs 3 and 4. In WP 5 UHEL will participate in implementing the module developed in Task 1.4 in Earth System Models and in identifying and analyzing feedback loops from Earth System Model simulations.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Markku Kulmala (male). Director of INAR, and professor at the University of Helsinki since 1996. Kulmala also acts as coordinator for the Centre of Excellence, appointed by the Academy of Finland first time in 2002 and for Nordic Center of Excellence, appointed by Nordforsk ("Cryosphere-atmosphere interactions in a changing Arctic climate" (CRAICC)), which is the largest joint Nordic research and innovation initiative to date, aiming to strengthen research and innovation regarding climate change issues in the Nordic and high-latitude Regions. Prof. Kulmala together with Prof. Pertti Hari is the primary inventor of the SMEAR (Stations Measuring Ecosystem Atmospheric Relations) concept. According to the ISI Web of Knowledge, M. Kulmala is in the first place in the Citation Rankings in Geosciences (since 1.5.2011). His h-factor is 103. Prof. Kulmala has received several international awards such as the Smoluchovski Award (1997), the International Aerosol Fellow Award (2004), the Wilhelm Bjerkenes medals (2007), Fuchs Memorial Award (2010) and Litke Medal (2015). In 2015 he was acknowledged by a membership of the CASAD, Chinese Academy of Sciences, (CAS). Kulmala together with the Prof. Sergej Zilitinkevich is the initiator of the large scale multi - disciplinary Pan-Eurasian Experiment (PEEX) Program. Academician in Finland, China (CAS) and Russia (IAES).

Veli-Matti Kerminen (male) has been working in the field of atmospheric sciences since 1990, with the main areas of expertise being the formation and transformation of atmospheric aerosols and aerosol-cloud interactions; has published 268 peer-reviewed research articles with >13 000 citations and H-factor of 62. He has participated in 6 EU projects and lead 8 nationally-funded research projects. He received the "Marian Smoluchowski Award for Aerosol Research" in 2007 and acted as a "Lead Author" in the Working Group I of the IPCC Assessment Report 5 (2013). He has supervised 16 PhD theses, reviewed 22 doctoral thesis, acted 12 times as an opponent in a PhD defense, and reviewed > 300 papers in 38 different journals. He is currently editor in "Atmospheric Chemistry and Physics" and "Boreal Environment Research".

Tuukka Petäjä (male) Scientific expertise: over 15 years of research experience related to atmospheric sciences. He leads the experimental aerosol group (size of 60 people) at UHEL of consisting of 3 sub-groups; 10-15 PhD students and 2-5 post-doc level members per group; educated 16 PhDs and currently supervising 10 students. has published 334 peer reviewed articles (9 in Science, 8 in Nature), with total cit. of 13286 and h-factor of 57. He is highly cited scientist (2014-, Thompson Reuters). He obtained the FAAR Award in excellent aerosol science and Vaisala Award 2013 for his work on combining state-of-the-art science and instrument development. PI of Biogenic Aerosols – Effects on Clouds and Climate (BAECC), multiplatform research campaign to elucidate the role of secondary aerosols to clouds, supported by US Department of Energy. Science director of Pan Eurasian Experiment (PEEX), national delegate to SAON board, board member of PACES initiative, academician in International Eurasian Academy of Sciences (IEAS). Managerial expertise: head of technical staff of Kumpula science campus, head of Värriö sub-arctic research station in Lapland. He has participated practical organization of 11 EU projects, UHEL PI in ACTRIS2 H2020 infrastructure project, which is constructing European-wide harmonized observations on atmospheric trace gases, aerosol particles and clouds. Petäjä is a team leader in Finnish Center of Excellence of Academy of Finland on atmospheric sciences responsible for long-term, comprehensive observations in Finland and developing observational capacity in Russia and China.

Katrianne Lehtipalo (female) is associate professor in atmospheric science at INAR and FMI. She received her PhD in aerosol physics in 2011. After that she worked as post-doctoral researcher and MSCA fellow at Paul Scherrer Institute, Switzerland and University of Helsinki. Her research concentrates on atmospheric new particle formation and growth, using both laboratory experiments and field studies. She is specialist in detection methods of clusters and nano-particles. She is involved e.g. in CLOUD and ACTRIS projects. Number of peer-reviewed publications: 70, H-index 26, citations (without self-citations): 2821.

Risto Makkonen (male) is leading the Earth System Modeling group at INAR. He is also a research professor (tenure-track) at Finnish Meteorological Institute. He has been developing several climate models (EC-Earth, NorESM, ECHAM), also towards CMIP6. He is coordinating INAR CMIP6 contributions. He has 22 peer-reviewed publications with altogether 190 citations to his first-author papers, and two of his first-author papers were cited in IPCC AR5. He received the Finnish Association for Aerosol Research (FAAR) award for "pioneering

work in global aerosol modeling" in 2015. He has been a work package leader in European (FP7, BACCHUS), Nordic (eSTICC) and national (GRASS) projects, and he is coordinating national projects on climate communication and Earth System feedbacks. Dr. Makkonen will co-lead FORCeS WP4.

Pauli Paasonen (male), university researcher. He completed PhD in Aerosol physics in 2012 at UHEL. After PhD he has worked at IIASA (International Institute for Applied Systems Analysis, Austria) and SYKE (Finnish Environment Institute, Finland), in addition to UHEL INAR. He is a leader of the Aerosol-Cloud-Climate-Interactions –group at INAR. Main research interests are in data analysis and parameterizations of biogenic formation and anthropogenic emissions of aerosols, their transport and climate impacts. 43 published peer reviewed articles with >2300 citations, h-index 23.

Hanna Lappalainen (female), Pan-Eurasian Experiment (PEEX) Secretary General, works currently at PEEX Headquarters at the University of Helsinki. She has a long-term experience of coordinating large-scale research projects and funding applications and has been working as a research coordinator and a science coordinator in the projects such as "European Integrated Project on Aerosol Could Climate and Air Quality Interaction" EU-FP7-EUCAARI (2007-2010) and "Finnish Center of Excellence in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change" (2012-2013). Lappalainen has received NASA Goddar Team Award EOS-AURA satellite OMI-Team in 2005 and an International Eurasian Academy of Sciences (IEAS) Silver medal in 2015. Since 2014 Lappalainen has been a representative of Finland in the Sustainable Arctic Observing Network (SAON) Data working group and a Future Earth - iLEAPS Steering Group Member. She obtained her PhD from the Department of Biological and Environmental Sciences, University of Helsinki, Finland and has been engaged in analysis of the atmospheric concentration of the Biogenic Volatile Organic Compounds (BVOCs) and plant phenological time series and modelling.

Ekaterina Ezhova (female), postdoctoral researcher. Her PhD is in Physics of Atmosphere and Hydrosphere (2012). She has work experience in dynamics of turbulent plumes and jets in stratified fluids (including analysis of experimental data, theoretical models and high-fidelity numerical modelling), theoretical models of air-sea interaction, and analysis of continental biosphere-atmosphere-cloud-climate feedback loops (Russian Academy of Science, the Royal Institute of Technology, Sweden and UHEL). She has received Medals of the Russian Academy of Sciences and Ministry of Russian Science and Education for the scientific work during Master and PhD projects, Young Scientist Award 'Aerosols of Siberia', and she has given an invited seminar at the Geophysical Fluid Dynamics summer school at Woods Hole Oceanographic Institution, USA. 15 published peer-reviewed articles, h-index 5.

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Kerminen, V.-M., Paramonov, M., Anttila, T., Riipinen, I., Fountoukis, C., Korhonen, H., Asmi, E., Laakso, L., Lihavainen, H., Swietlicki, E., Svenningsson, B., Asmi, A., Pandis, S. N., Kulmala, M., and Petäjä, T.: Cloud condensation nuclei production associated with atmospheric nucleation: a synthesis based on existing literature and new results, Atmos. Chem. Phys., 12, 12037-12059, 2012, https://doi.org/10.5194/acp-12-12037-2012, 2012.
2. Kulmala, M., J. Kontkanen, H. Junninen, K. Lehtipalo, H. E. Manninen, T. Nieminen, T. Petaja, M. Sipila, S. Schobesberger, P. Rantala, A. Franchin, T. Jokinen, E. Jarvinen, M. Aijala, J. Kangasluoma, J. Hakala, P. P. Aalto, P. Paasonen, J. Mikkila, J. Vanhanen, J. Aalto, H. Hakola, U. Makkonen, T. Ruuskanen, R. L. Mauldin, J. Duplissy, H. Vehkamaki, J. Back, A. Kortelainen, I. Riipinen, T. Kurten, M. V. Johnston, J. N. Smith, M. Ehn, T. F. Mentel, K. E. J. Lehtinen, A. Laaksonen, V. M. Kerminen ja D. R. Worsnop, 2013: Direct Observations of Atmospheric Aerosol Nucleation. *Science*, **339,** 943-946.
3. Paasonen, P., Asmi, A., Petäjä, T., Kajos, M. K., Äijälä, M., Junninen, H., Holst, T., Abbatt, J. P. D., Arneth, A., Birmili, W., van der Gon, H. D., Hamed, A., Hoffer, A., Laakso, L., Laaksonen, A., Leaitch, W. R., Plass-Dülmer, C., Pryor, S. C., Räisänen, P., Swietlicki, E., Wiedensohler, A., Worsnop, D. R., Kerminen, V-M. and Kulmala, M.: Warming-induced increase in aerosol number concentration likely to moderate climate change, Nature Geoscience, 6, 6, 438-442, 2013.

4. Jokinen, T., Berndt, T., Makkonen, R., Kerminen, V.-M., Junninen, H., Paasonen, P., Stratmann, F., Herrmann, H., Guenther, A. B., Worsnop, D. R., Kulmala, M., Ehn, M. and Sipilä, M.: Production of extremely low volatile organic compounds from biogenic emissions: Measured yields and atmospheric implications., Proc. Natl. Acad. Sci. U. S. A., 112(23), 7123–7128, doi:10.1073/pnas.1423977112, 2015.
5. Paasonen, P., Peltola, M., Kontkanen, J., Junninen, H., Kerminen, V.-M., and Kulmala, M.: Comprehensive analysis of particle growth rates from nucleation mode to cloud condensation nuclei in boreal forest, Atmos. Chem. Phys., 18, 12085-12103, https://doi.org/10.5194/acp-18-12085-2018, 2018.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. FP7 integrated project EUCAARI (coordinator)
2. FP7 integrated project BACCHUS (participant)
3. H2020 infrastucture project ACTRIS-2 (participant)
4. European Research Council advanced grant ATM_GTP (coordinator)
5. Academy of Finland, Centre of Excellence in Atmospheric Sciences (coordinator)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

SMEAR stations (Stations for Measuring Ecosystem-Atmosphere Relations) are super-sites, based on comprehensive, continuous and long-term measurements of atmospheric-biosphere relationships. They have been recognized as high-standard atmospheric and environmental observation stations, offering services to a wide community including scientists, education, public authorities and local community. The SMEAR databases are all open access, and archived in an efficient manner enabling their use in models, experimental work and monitoring studies. The stations are famous for the highly skilled technical assistance, and have developed measurement device and methods that have been adopted by other sites as well. The SMEAR II (flagship site) hosts annually ca. 120 visiting researchers. Institute for Atmospheric Research and Earth System Science (INAR) coordinates and develops the stations and defines the scientific goals.

PEEX - The Pan-Eurasian Experiment (PEEX) is a multidisciplinary, multi-scale program focused on solving grand challenges in northern Eurasia and China focusing in Arctic and boreal regions. PEEX will also help to develop service, adaptation and mitigation plans for societies to cope with global change. It is a bottom-up initiative by several European, Russian and Chinese research organizations and institutes with co-operation of US and Canadian organizations and Institutes. The PEEX approach emphasizes that solving challenges related to climate change, air quality and cryospheric change requires large-scale coordinated co-operation of the international research communities. The promoter institutes of this initiative are the University of Helsinki and the Finnish Meteorological Institute in Finland; the Institute of Geography of Moscow State University, AEROCOSMOS, and the Institute of Atmospheric Optics (Siberian branch) of the Russian Academy of Sciences (RAS) in Russia; the Institute of Remote Sensing and Digital Earth (RADI) of the Chinese Academy of Sciences (CAS) and the institute for climate and global change research of Nanjing University in China. PEEX involves scientists from various disciplines, experimentalists and modelers, and international research projects funded by European, Russian and Chinese funding programs. The first active PEEX period is 2013–2033, though PEEX will continue until 2100. The first PEEX meeting was held in Helsinki in October 2012. PEEX is open for other institutes to join.

UNIVERSITY OF LEEDS	**14-University of Leeds (ULEEDS)**	**UNITED KINGDOM**

Description of the legal entity

The University of Leeds (UNIVLEEDS) is acclaimed world-wide for the quality of its teaching and research, and is ranked 93rd in the QS World University Rankings 2019. Leeds is in the top 10 universities in the UK (Times/Sunday Times, 2018) and was named the UK University of the Year in 2017 for its outstanding commitment to student education (Times/Sunday Times). Leeds is one of the largest universities in the UK 34,000 students (including >9,000 post graduate students) from more than 150 countries, attached to over 500 different undergraduate and around 300 postgraduate degree programmes, and approximately 8,000 staff of over 90 different nationalities. Leeds is also a leading member of the UK's prestigious research intensive Russell Group universities. In 2016/17 it had an annual income of €794m and its annual research income exceeded €154m, of which 15.2% was derived from EU awards. Under Horizon 2020 Leeds is currently coordinating 91 projects and is a partner in a further 60 successful projects. Grant Agreements for a further 10 Horizon 2020 projects are under preparation, 3 of which are coordinated by Leeds. Leeds' total research income from Horizon 2020 is currently over €77m.

The University of Leeds is one of the UK's top institutions for climate-related research with world-leading expertise cutting across: climate and weather modelling; climate risk and sustainable development; low carbon transitions; and the social, political and economic dimensions of climate change. Leeds has over 170 academics and 130 PhD students researching in this area and an active research award portfolio of over €70m (of which 18% is derived from EU awards). It hosts four national centres in climate related research (including the NERC National Centre for Atmospheric Science (NCAS) and Centre for Polar Observation and Modelling (CPOM)). The University of Leeds is building on its outstanding reputation for climate research through strategic investment of more than £10m in the Priestley International Centre for Climate to deliver research to underpin robust and timely climate solutions.

The School of Earth and Environment is a diverse hub of scientific research, with over 130 academic staff researching across the full spectrum of Earth and Environmental Sciences, including geophysics, atmospheric science, glaciology and conducting research into the social impacts of environmental change. The University of Leeds has been recognized as the top UK university for impact of its environmental research and eighth in the world (THE, 24.11.16), and ranked first in the UK for the power of its world leading environmental science research (UK Research Excellence Framework 2014).

The Institute for Climate and Atmospheric Science, where the research will be carried out, is one of five institutes of the School of Earth and Environment. The institute has 28 academic staff and more than 30 postdocs and 50 PhDs students engaged in research spanning climate, climate impacts, atmospheric dynamics, global chemistry and aerosol modelling, and laboratory measurements of aerosol and cloud processes.

Leeds is heavily engaged in the Intergovernmental Panel on Climate Change (IPCC) providing: 5 lead authors and 11 contributing authors covering all four reports that made up the overall fifth assessment (AR5); 250 papers with Leeds authors cited in AR5; 7 lead authors and 1 review editor covering all 3 working groups for AR6; and 2 lead authors on each of the forthcoming IPCC Special Reports on Global Warming of 1.5°C and Climate Change and Land.

Main tasks in FORCeS

ULEEDS will contribute to FORCeS with expertise on global aerosol-climate modelling, aerosol radiative forcing and model uncertainty quantification in WP3 and WP4. In task 3.X ULEEDS will use the UKESM model combined with a perturbed parameter ensemble, model emulation and Monte Carlo sampling to perform a rigorous sensitivity analysis of around 30-40 parameters and boundary condition that affect the aerosol forcing. The results will be used to direct effort to improving the processes that most strongly affect the forcing uncertainty. In task 4.X ULEEDS will use around 1 million samples from the emulator to identify 'model variants' that are consistent with measurements compiled in WP3, and thereby constrain the uncertainty in aerosol effective radiative forcing.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Prof Ken Carslaw (male) is a professor in atmospheric science at UNIVLEEDS. He received his PhD in 1994 from the University of East Anglia, and has been employed at UNIVLEEDS since 2000 after a post-doctoral period at the Max Planck Institute for Chemistry in Mainz, Germany. He has been Director of Research in the School of Earth and Environment and Director of the Institute for Climate and Atmospheric Science (2013-2017), with approximately 28 members of staff. Prof Carslaw's research interests span global aerosol and cloud modelling, radiative forcing and uncertainty quantification. He was the lead developer of the aerosol model (GLOMAP) within the UK's global composition-climate model to be used in this project. Prof. Carslaw has been a Clarivate Analytics Highly Cited Researchers in 2014, 2015, 2016 and 2017. He has received several awards for his research, including the Royal Society Wolfson Merit Award and the AGU Ascent Award. He has been co-investigator on 13 EU projects from FP5 to H2020 as well as 3 Marie Curie Sklodowska training networks. He has advised 22 Phd students (20 completed) and mentored 21 post-doctoral researchers. Prof. Carslaw was also founding Editor of the journal Atmospheric Chemistry and Physics.

Dr Lindsay Lee (female) is a Leverhulme Early Career Fellow at UNIVLEEDS. She received her PhD Probability and Statistics from the University of Sheffield in 2010, working with the NERC funded Centre for Terrestrial Carbon Dynamics (CTCD). She has been employed at UNIVLEEDS since 2010 working on novel ways of quantifying and understanding the effect uncertainty in complex computer codes, particularly global aerosol models. Her fellowship involves leading three international teams of scientists to produce coordinated statistical analyses of global aerosol models via multi-model perturbed physics (or parameter) ensembles (MMPPEs). The MMPPEs will be the first attempt to quantify both structural and parametric uncertainty in global aerosol models linking the normally separate analysis of each. She is co-investigator on 6 projects providing uncertainty quantification expertise and has two current PhD students. She advises on the uncertainty quantification aspects of two external, international projects. She was recently an invited programme participant on the Uncertainty Quantification for Complex Systems programme at the Isaac Newton Institute for Mathematical Sciences, Cambridge.

Peer-reviewed publications: 23 journal articles with 615 citations; 4 lead author with 172 citations; H-index: 11 (Statistics taken from Scopus).

Peer-reviewed publications: 181; H-index: 56 (based on Clarivate analytics Web of Science); Web of Science citations: 10,700 (9600 without self-citations).

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Regayre LA; Johnson JS; Yoshioka M; Pringle KJ; Sexton DMH; Booth BBB; Lee LA; Bellouin N; Carslaw KS (2018) Aerosol and physical atmosphere model parameters are both important sources of uncertainty in aerosol ERF, Atmospheric Chemistry and Physics, 18, pp.9975-10006. doi: 10.5194/acp-18-9975-2018
2. Carslaw KS; Lee LA; Regayre LA; Johnson JS (2018) Climate Models Are Uncertain, but We Can Do Something About It, Eos, 99, . doi: 10.1029/2018EO093757
3. Reddington CL; Carslaw KS; Stier P; Schutgens N; Coe H; Liu D; Allan J; Browse J; Pringle KJ; Lee LA; Yoshioka M; Johnson JS; Regayre LA; Spracklen DV; Mann GW; Clarke A; Hermann M; Henning

S; Wex H; Kristensen TB; Leaitch WR; Pöschl U; Rose D; Andreae MO; Schmale J; Kondo Y; Oshima N; Schwarz JP; Nenes A; Anderson B; Roberts GC; Snider JR; Leck C; Quinn PK; Chi X; Ding A; Jimenez JL; Zhang Q (2017) The global aerosol synthesis and science project (GASSP): Measurements and modeling to reduce uncertainty, Bulletin of the American Meteorological Society, 98, pp.1857-1877. doi: 10.1175/BAMS-D-15-00317.1.

4. Lee LA; Reddington CL; Carslaw KS (2016) On the relationship between aerosol model uncertainty and radiative forcing uncertainty, Proceedings of the National Academy of Sciences, 113, pp.5820-5827. doi: 10.1073/pnas.1507050113.

5. Regayre LA; Pringle KJ; Lee LA; Rap A; Browse J; Mann GW; Reddington CL; Carslaw KS; Booth BBB; Woodhouse MT (2015) The Climatic Importance of Uncertainties in Regional Aerosol-Cloud Radiative Forcings over Recent Decades, JOURNAL OF CLIMATE, 28, pp.6589-6607. doi: 10.1175/JCLI-D-15-0127.1.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. NERC *Aerosol-Climate Uncertainty Reduction project* (A-CURE) (PI: Prof. Ken Carslaw)
2. NERC *AErosol model Robustness and Sensitivity study for improved climate and air quality prediction (AEROS)* (PI: Prof. Ken Carslaw)
3. NERC *Global Aerosol Synthesis and Science Project (GASSP) to reduce the uncertainty in aerosol radiative forcing* (PI: Prof. Ken Carslaw)
4. 4. NERC Studentship with Met Office *Reducing uncertainty in climate projections* (PI: Prof. Ken Carslaw)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

ULEEDS has access to High Performance Computing service at Leeds comprised of 6048 cores. The department supports dedicated research computing staff as part of the Centre of Excellence for Modelling the Atmosphere and Climate (CEMAC). The FORCES project will also have access to national data processing service JASMIN for storing, handling and post-processing large model datasets and observations.

UNIVERSITÄT LEIPZIG	15-University of Leipzig (ULEI)	GERMANY

Description of the legal entity

The **University of Leipzig (ULEI)** was founded in 1409 and hence belongs to the oldest universities in Europe (2nd oldest in Germany after Heidelberg) and has hosted many prominent scientists including e.g. Werner Heisenberg, Peter Debye, Felix Bloch and Gustav Hertz in the faculty of Physics and Earth Sciences, or Vilhelm Bjerknes as the founder of the Institute for Meteorology. In the course of its history, it grew to encompass a wide selection of disciplines comprising almost all areas of knowledge. The University of Leipzig is one of the large Universities in Germany, with 30.000 students, 1.400 of which in the Faculty for Physics and Earth sciences (one of 14 faculties), of which again 150 in Meteorology (largest in Germany). An annual budget of 340 M€ has a share of one third from project funding. Of the 440 professors at University of Leipzig, 31 teach in the Faculty of Physics and Earth sciences.

The Institute for Meteorology and its partner institutes in Leipzig form one of the most vibrant hot-spots for aerosol-cloud-climate research in Germany with almost 150 scientists at all levels working with various methods and at diverse scales on the problem. There are now seven full-time professors (three of which are also department heads at the Leibniz-Institute for Tropospheric research), plus three external professors. PhD candidates in Leipzig will become part of the Research Academy Leipzig (RAL) in its Leipzig Graduate School for Clouds, Aerosols and Radiation.

Main tasks in FORCeS

ULEI will contribute to FORCeS essentially to WP 2, for which PI Johannes Quaas will serve as co-leader, and with contributions to WPs 4 and 5 on satellite-based constraints and GCM improvements to the ICON/ICON-HAM GCM. ULEI specifically will contribute analyses of simulations with general circulation modelling as well as process-resolving modelling, and analysis of satellite observations.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Johannes Quaas (male) is Professor for Theoretical Meteorology at the University of Leipzig. He has worked at three of the major climate modelling centres in Europe (PhD at Laboratoire de Météorologie Dynamique / Institut Pierre Simon Laplace in Paris, France , 2000 – 2003 ; Post-Doc at UK Met Office, Exeter, 2005 – 2006 ; Post-Doc and Junior Research Group lead at Max Planck Institute for Meteorology, Hamburg, 2004 ; 2006 – 2011) and in the USA (research stays at NASA GISS, New York, 2015 and 2017). His expertise is in the application of satellite retrievals to assess aerosol-cloud-precipitation interactions and their radiative forcing (31 peer-reviewed papers on the topic), and to evaluate clouds in climate models, including the improvement of cloud parameterizations (18 papers).

Johannes Quaas is lead author in the upcoming 6th assessment report by the IPCC, working group 1, chapter 2 « Changing state of the climate system ».

12 PhD projects supervised (adviser or co-adviser, Universities of Hamburg and Leipzig)

30 Master's or Diploma projects (adviser or co-adviser, Universities of Hamburg and Leipzig)

Rapporteur for 15 PhD in France (7), UK (4), Finland, Sweden, Switzerland, The Netherlands

Co-chair Aerosols, Clouds, Precipitation and Climate (joint activity of IGBP/iLEAPS and WCRP/GEWEX; since 2013; member of scientific steering committee since 2010)

Vice chair, COST Action ES0905, Basic concepts for convection parameterization in weather forecast and climate models (2010 – 2014)

Member, International Commission on Clouds and Precipitation (IAMAS-ICCP, 2008 – 2017)

Member, Editorial Board, Atmospheric Chemistry and Physics (since 2007)

Associate Editor, Atmospheric Research (2008 – 2011)

Convener or co-convener of 22 sessions at international conferences or workshops.

7.3 M€ research grants (ERC, DFG, BMBF, EU FP7/Horizon2020, MPG, Deutscher Wetterdienst)

151 reviews for 31 journals (including Atmos. Chem. Phys., Clim. Dyn., Geophys. Res. Lett., J. Atmos. Sci., J. Clim., J. Geophys. Res., Nature, Nature Geosci., PNAS, Science).

73 reviews for projects for 21 agencies (e.g., Atmospheric Radiation Measurement Programme, Academy of Finland, Agence Nationale de Recherce, Deutsche Forschungsgemeinschaft, Dutch Research Council, European Research Council, Humboldt Foundation, Research Council of Norway, UK Natural Environment Research Council).

81 invited presentations at international conferences (including AGU, EGU, AMS, Gordon conference, ICCP, IRS) or institutes (including Universities of Oxford, Cambridge, Princeton, LMD, ETH Zurich, IIT Bombay, UK Met Office, NASA GSFC, NASA GISS).

85 papers, 2357 citations, h-index 26; 15 first, 20 second, 25 senior author (ISI Web of Science, 14 August 2018).

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Reseachgate: www.researchgate.net/profile/Johannes_Quaas

ResearcherID: I-2656-2013

Google Scholar: hbOfD1cAAAAJ

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Baker, L. H., W. J. Collins, D. J. L. Olivié, R. Cherian, Ø. Hodnebrog, G. Myhre, and **J. Quaas**, Climate responses to anthropogenic emissions of short-lived climate pollutants, Atmos. Chem. Phys., 15, 8201-8216, doi:10.5194/acp-15-8201-2015, 2015.
2. Goren, T., D. Rosenfeld, O. Sourdeval, and **J. Quaas**, Satellite observations of precipitating marine stratocumulus show greater cloud fraction for decoupled clouds in comparison to coupled clouds, Gephys. Res. Lett., 45, 5126-5134, 2018.
3. Gryspeerdt, Edward, **J. Quaas**, S. Ferrachat, A. Gettelman, S. Ghan, U. Lohmann, Hugh Morrison, D. Neubauer, D. G. Partridge, P. Stier, T. Takemura, Hailong Wang, M. Wang, and K. Zhang, Constraining the instantaneous aerosol influence on cloud albedo, Proc. Nat. Acad. Sci. USA, 119, 4899-4904, doi:10.1073/pnas.1617765114, 2017.
4. Heinze, R., A. Dipankar, C. Carbajal Henken, C. Moseley, O. Sourdeval, S. Trömel, X. Xie, P. Adamidis, F. Ament, H. Baars, C. Barthlott, A. Behrendt, U. Blahak, S. Bley, Slavko Brdar, M. Brueck, Susanne Crewell, H. Deneke, P. Di Girolamo, R. Evaristo, J. Fischer, C. Frank, P. Friederichs, T. Göcke, K. Gorges, L. Hande, M. Hanke, A. Hansen, H.-C. Hege, C. Hoose, T. Jahns, N. Kalthoff, D. Klocke, S. Kneifel, P. Knippertz, A. Kuhn, T. Laar, Andreas Macke, V. Maurer, B. Mayer, C. I. Meyer, S. K. Muppa, R. A. J. Neggers, E. Orlandi, F. Pantillon, B. Pospichal, N. Röber, L. Scheck, A. Seifert, P. Seifert, F. Senf, P. Siligam, C. Simmer, S. Steinke, B. Stevens, K. Wapler, M. Weniger, V. Wulfmeyer,

G. Zängl, D. Zhang, and **J. Quaas**, Large-eddy simulations over Germany using ICON: A comprehensive evaluation, Quart. J. Roy. Meteorol. Soc., 143, 69-100, doi:10.1002/qj.2947, 2017.

5. **Quaas, J.**, Approaches to observe effects of anthropogenic aerosols on clouds and radiation, Current Climate Change Reports, 1, 297-304, doi:10.1007/s40641-015-0028-0, 2015.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. German National Project "High Definition Clouds and Precipitation for Climate Prediction" (sub-project PI and steering committee member)
2. German Research Foundation, ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms (participant)
3. COPERNICUS Atmospheric Monitoring Service CAMS74 – Radiative forcings (participant)
4. European Research Council starting grant QUAERERE (PI)
5. FP7 Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants (WP lead)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The central administration of Universität Leipzig has great experience in conducting research projects of national and international funding institutions. There are established procedures for handling project finances, ordering, travel, audits, personnel contracts, access rights to facilities etc. Regarding both scientific and administrative matters, fellows from abroad mostly deal with efficient, English language permanent staff of the host institution. State-of-the-art IT infrastructures (hardware, software, and supporting expertise) for handling, processing and visualising large datasets are available at the Institute for Meteorology.

	16-University of Oslo (UiO)	**NORWAY**

Description of the legal entity

The University of Oslo was founded in 1811 as the first University in Norway. Today it is the country's largest public institution of research and higher learning with 27 000 students and 7 000 employees. UiO is the highest ranked institution of education and research in Norway, and ranked among the 100 top universities in the world. UiO has eight faculties, and three museums affiliated. As a classical university with a broad range of academic disciplines, UiO has top research communities in most areas. Four scientists affiliated with the University of Oslo have been awarded Nobel Prizes for their research, and one for his efforts to promote peace. Moreover, UiO currently has 8 National Centres of Excellence, of which one and a strategic focus on interdisciplinary research in the field of energy and life sciences in particular. This broadly based, non-profit research university has access to good public funding schemes. Most of the funding comes from the Norwegian government. Lab and office facilities, libraries and technical support are at the high end. The Department for Geosciences comprises disciplines of Geophysics, Geochemistry, Geology, and Remote Sensing.

The Meteorology and Oceanography section of the Department of Geoscience is located in the Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS), along with multiple other research institutes focused on the science and implications of climate change. The long-term strategy is to develop CIENS as an internationally leading centre for research and innovation, providing new knowledge on environment, climate and society, as a basis for sustainable development.

Main tasks in FORCeS

UiO will contribute to FORCES mainly by co-leading WP6, and specifically by

(1) Running additional simulations with the NorESM model required for WP6.

(2) Analysing NorESM and the other FORCeS ESMs with respect to climate feedbacks (cloud feedbacks in particular) and climate sensitivity.

(3) Evaluating FORCeS ESM performance with respect to existing *emergent constraints*, as well as those developed within FORCeS.

(4) Computing Bayesian estimates of climate sensitivity based on revised historical forcing pathways emerging from FORCeS.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Dr. Trude Storelvmo (female) Associate Professor in Atmospheric Science; trude.storelvmo@geo.uio.no is a climate scientist, focusing her research on the role of aerosol particles and clouds in Earth's climate. She also works on questions related to cloud-climate feedback mechanisms, climate sensitivity and climate engineering involving aerosols and/or clouds. To date she has published 43 papers in peer-reviewed journals (including *Science*, *PNAS* and *Nature Geoscience*), and contributed to Chapter 7 (Clouds and aerosols) of the last IPCC report (IPCC AR5). She was part of the team of experts scoping the upcoming IPCC report (AR6) and she is a Coordinating Lead Author for IPCC AR6 Ch. 7 ("The Earth's energy budget, climate feedbacks, and climate sensitivity"). As of July 2018, her h-index according to Google Scholar is 26, and the total number of citations is 4122.

Dr. Terje Berntsen (male) Professor in Atmospheric Science; terje.berntsen@geo.uio.no is a climate scientist

working mostly on numerical modelling of atmospheric composition including areosols and clouds, atmosphere-land interactions and estimation of climate sensitivity. To date he has published about 150 peer-reviewed papers, book chapters or contributions to assessment reports. He was a lead author for chapter 2 in IPCC (IPCC AR4) and has been chosen as a lead author for chapter 6 in IPCC AR6. As of July 2018, his h-index according to Google Scholar is 60, and the total number of citations is 22900.

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

Storelvmo, T., 2017: Aerosol effects on mixed-phase and ice clouds, Annual Reviews of Earth and Planetary Science, 45, 199-222.

Tan, I., **T. Storelvmo** and M. Zelinka, 2016: Observational constraints on mixed-phase clouds imply higher climate sensitivity. Science, 352, doi:10.1126/science/aad530.

Storelvmo, T., T. Leirvik, U. Lohmann, P.C. B. Phillips and M. Wild, 2016: Disentangling Greenhouse Warming and Aerosol Cooling to Reveal Earth's Transient Climate Sensitivity. Nature Geoscience, doi:10.1038/ngeo2670.

Skeie R.B., **Berntsen, T.K**., M Aldrin, M Holden, G Myhre, 2018. Climate sensitivity estimates–sensitivity to radiative forcing time series and observational data. Earth System Dynamics. https://doi.org/10.5194/esd-9-879-2018

Sand, M., **Berntsen, T.K**., K Von Salzen, MG Flanner, Joakim Langner, DG Victor, 2016. Response of Arctic temperature to changes in emissions of short-lived climate forcers, Nature Climate Change, 10.1038/nclimate2880

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

"Mixed-phase Clouds and Climate (MC^2) – from process-level understanding to large-scale impacts" (European Research Council, ERC-StG, 2018-2023) PI: **T Storelvmo**

"Climate Change Modelling and Prediction of Economic Impact" (NFR, 2018-2021) PI: **T. Storelvmo**

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

In support of the contributions described above, UiO has access to National high-performance computing facilities and storage. Furthermore, the Department of Geoscience has recently hired two persons to work exclusively with HPC support and scientific programming. For general project support, the university has an "EU team" that can assist with all administrative aspects of the project.

UNIVERSITY OF OXFORD	**17-University of Oxford (UOX)**	**UNITED KINGDOM**

Description of the legal entity

University of Oxford (UOXF) The University of Oxford is consistently ranked amongst the top-ten research universities in the world. With substantial investment in physical climate science research, faculty and infrastructure, the University now employs >180 staff and PhD students directly working within climate science. Atmospheric, Oceanic and Planetary Physics in the Department of Physics, the Environmental Change Institute (ECI), School of Geography and the Oxford Martin School are at the core of climate science at Oxford. Philip Stier is the current and Myles Allen the former academic convener of the Oxford Climate Research Network.

Main tasks in FORCeS

OUXF will co-lead and contribute to WP4 on observational constraints, along with taking the lead in Task 6.4, to investigate the role of aerosol for the Paris Agreement, and contribute to WP7 to engage with policy end users.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Philip Stier (male) is Professor of Atmospheric Physics in the Department of Physics at the University of Oxford. He is currently the head of the sub-department of Atmospheric, Oceanic and Planetary Physics with 17 faculty where he also heads the Climate Processes Group. Prof. Stier's research covers physical climate processes with focus on clouds, aerosols and their interactions. He has published 97 peer-reviewed publications, has an h-index of 40 (ResearcherID), been a Clarivate Highly Cited Researcher since 2014 and received a number of awards for his work, including the Friedrich Wilhelm Bessel Research Award of the Alexander von Humboldt Foundation, an Amazon AWS Machine Learning Research Award and two personal grants by the European Research Council.

Myles Allen (male) is Professor of Geosystem Science in the Environmental Change Institute and in the Department of Physics, University of Oxford. His research focuses on human and natural influences on observed climate change and risks of extreme weather. He has served on the IPCC as Lead Author for the 3rd and 5th Assessments in 2001 and 2013, as Review Editor for the 4th Assessment in 2007, on the IPCC Synthesis Report Core Writing Team in 2014 and as Coordinating Lead Author, Chapter 1, of the Special Report on 1.5C. He proposed the use of Probabilistic Event Attribution to quantify human influences on specific weather events and leads climateprediction.net, using distributed computing to run the world's largest ensemble climate simulations.

Michelle Cain (female) is an Oxford Martin Fellow and Science and Policy Research Associate based jointly in the Oxford Martin School and ECI at the University of Oxford. Her current work is about the impact of short lived climate forcers on climate, with a focus on how policies can be defined that are consistent with science. She is working with JPI-Climate (an EC Joint Initiative) on a series of workshops and a report on requirements for the "balance of sources and sinks of greenhouse gases" that is outlined in the Paris Agreement.

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. White, B. et al. (2017), Uncertainty from the choice of microphysics scheme in convection-permitting models significantly exceeds aerosol effects, Atmos. Chem. Phys., doi: 10.5194/acp-17-12145-2017.
2. Stier, P. (2016), Limitations of passive remote sensing to constrain global cloud condensation nuclei, Atmos. Chem. Phys., 16(10), 6595-6607 doi: 10.5194/acp-16-6595-2016.
3. Open source software: Watson-Parris, D. et al. (2016), Community Intercomparison Suite (CIS) v1.4.0: a tool for intercomparing models and observations, Geosci. Model Dev., doi: 10.5194/gmd-9-3093-2016.
4. Allen, M. R. et al. (2018). A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. Npj Clim. and Atm. Sci., doi: 10.1038/s41612-018-0026-8
5. MR Allen, JS Fuglestvedt, KP Shine, et al, New use of global warming potentials to compare cumulative and short-lived climate pollutants, Nature Climate Change, 6, 773-776, 2016.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. European Research Council starting grant ACCLAIM (Stier, PI)
2. FP7 integrated project BACCHUS (Stier, SC member, WP leader)
3. European Research Council consolidator grant RECAP (Stier, PI)
4. Climateprediction.net, (2000 – present, £4m), citizen-science climate prediction (Allen, PI)
5. Coordinating Lead Author IPCC Special Report on 1.5C, Chapter 1, Framing and Context, 2017-2018 (Allen)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work
The relevant Oxford departments provide all relevant infrastructure to support the proposed work, including access to the Oxford Advanced Research Computing centre and national HPC and big-data facilities.

	18-Naturvårdsverket (NV)	**SWEDEN**

Description of the legal entity

The Swedish Environmental Protection Agency (Naturvårdsverket) is the public agency in Sweden that is responsible for environmental issues. The Agency carries out assignments on behalf of the Swedish Government relating to the environment in Sweden, the EU and internationally.

The Agency's remit is threefold:

- Compiling knowledge and documentation - to develop our own environmental efforts and those of others
- Developing environmental policy - by providing the Government with a sound basis for decisions and by giving an impetus to EU and international efforts
- Implementing environmental policy - by acting in such a way as to ensure compliance with the Swedish Environmental Code and achievement of the national environmental objectives

The work of the Agency is funded through government appropriations. A proportion of the funding is spent on staff, premises and other ongoing efforts. The rest of the funding is allocated to environmental monitoring, environmental research and international environmental and climate collaborations.

Every year, the Swedish Government establishes objectives, requirements and a budget for the Agency's efforts in what are known as 'appropriation directions'.

The Agency's remit includes the allocation of government appropriations to other actors within fields such as the protection and maintenance of valuable natural environments, clean-up and remediation of polluted areas, compensation for damage caused by wildlife and support for outdoor recreation organizations.

Main tasks in FORCeS

NV will participate in WP7 with dissemination of FORCeS results. In particular, NV is interested in the links between air quality and climate policy, and how the society can reach the SDG targets of United Nations. NV will provide FORCeS with information on the needs of policy makers in terms of the effects of changes in anthropogenic aerosol emissions on climate. NV will help in the interpretation and the promotion of these results in that perspective.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Erik Adriansson (male) is an administrative official at NV. He has experience in producing and auditing sustainability reports (GRI) and climate reports (GHG Protocol) for companies. He holds a MSc in aquatic- and Environmental Engineering from Uppsala University (2009). Before working in the sustainability sector his work was related to hydrology, geology and environmental field research.

Pelle Boberg (male) is administrator for climate at the Environmental Protection Agency's analysis and research department. He is coordinating the Swedish monitoring of the SDG "climate action".

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

Reports on Swedish climate statistics and sustainability efforts in the Swedish industry sector (in Swedish):
https://www.naturvardsverket.se/Om-Naturvardsverket/Publikationer/ISBN/6700/978-91-620-6782-3/
https://www.naturvardsverket.se/Om-Naturvardsverket/Publikationer/ISBN/6600/978-91-620-6665-9/

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

- The Swedish Clean Air and Climate Research Program (2014-2016; 2016-2018)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

Not applicable.

INERIS maîtriser le risque pour un développement durable	**19-Institut National de l'Environment Industriel et des Risques (INERIS)**	**FRANCE**

Description of the legal entity

INERIS (National Institute for Industrial Environment and Risks) provides expertise and support to the French authorities and private bodies in the field of industrial and chemical risks management and environmental protection. Air quality management and the assessment of the environmental policies related to air pollution are one of the main missions of the institute. INERIS hosts the PREV'AIR system, a pioneer system since 2003 for air quality forecasting which prefigured the European air quality forecasts now performed in the framework of the Copernicus Atmosphere Monitoring Services, where INERIS is largely involved. INERIS has also a strong experience in managing crisis situations in the field of air quality, such as large wild fires, industrial accidents, volcanic eruptions; the institute can deploy a large panel of tools to provide a quick impact analysis to the public authorities. The air pollution modelling chain developed by INERIS, coupled with health impacts and economic tools, is implemented to fit and evaluate national air pollution control policies and advise the Ministry in charge of the environment on the most cost-efficient approaches. INERIS is regularly involved in EU projects (ATOPICA, CITYZEN, EC4MACS) and national projects funded by the PRIMEQUAL program (funded by ADEME) or other mechanisms. INERIS is also the coordinator of the EURODELTA project in the framework of the UN LRTAP Convention, aiming at evaluating air quality models and their response to emission reductions. INERIS is also a part of the technical consortium ETC/ACM working for the European Environment Agency. The air quality modelling tools developed at INERIS are instrumental in the activities of policy support of the Institute for both short term air quality forecasts, and long term assessment of mitigation scenarios. The expertise of Ineris in the field of policy support in atmospheric sciences led to the Election of Mrs L. Rouïl as Chair of the EMEP Programme supporting the work of the Convention on Long-Range Transboundary Air Pollution (LRTAP).

Main tasks in FORCeS

INERIS will focus on dissemination and evaluation of the results of FORCeS, in terms of policy decision. Considering its role within the LRTAP Convention, Ineris has an excellent vision of the needs of policy makers to better understand the sources of uncertainties in aerosol and climate interactions at the European and International level. Linkages between climate and air pollution is a key issue that should take benefit from the Forces project and INEIS will help in the interpretation and the promotion of these results in that perspective.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Laurence ROUIL is the head of the "Environmental modelling and decision making" department of the Chronic risks division at INERIS. She received her Ph.D in 1995 in the field of applied mathematics. Her main area of experience is air quality modelling. She has developed skill and competence being the leader of research activities closely linked to operational applications. The PREV'AIR system is one of the example of such projects that she developed with her team, 15 years ago and in cooperation with other research partner, to answer to policy makers expectations taking advantage of the current know-how in the field of air pollution. She participates actively to the air quality monitoring strategy in France providing technical expertise to the Ministry in charge of the Environment. She is mandated by the Ministry as national head of delegation or competent authority in several bodies: the EMEP steering body, the FAIRMODE initiative. Since September 2014, she chairs the EMEP Steering Body within the Convention on Long Range Transboundary Air pollution. She has been involved in European research projects which developed in this domain for a long time. She takes part to management board activities related to several research EU projects, especially the FP7 initiatives for the development of the pre-operational

COPERNICUS/GMES atmosphere services, and coordinates in this framework part of regional air quality services development.

Augustin COLETTE is head of the Atmospheric Modelling and Environmental Mapping Unit of the French public Institute INERIS (Institut National de l'Environnement Industriel et des Risques). He holds a PhD in Atmospheric Sciences from University Pierre et Marie Curie and worked in the past for UNESCO, Stanford University, Ecole Polytechnique and the private sector for Meteorological Risk Assessment. He has co-authored more than 60 peer reviewed articles in the field of atmospheric modelling, with a specific interest in past and future evolution of air pollution. Augustin COLETTE is chair of the Task Force on Measurement and Modelling in support of the UNECE Geneva Convention on Long Range Transboundary of Air Pollution, Member of the Scientific Committee of the French Primequal Research Programme and editor for the journal Geosciences Model Development.

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Colette, C. Andersson, A. Baklanov, B. Bessagnet, J. Brandt, J.H. Christensen, R. Doherty, M. Engardt, C. Geels, C. Giannakopoulos, G.H. Hedegaard, E. Katragkou, J. Langner, H. Lei, A. Manders, D. Melas, F. Meleux, L. Rouïl, M. Sofiev, J. Soares, D.S. Stevenson, M. Tombrou-Tzella, K.V. Varotsos and P. Young, Is the ozone climate penalty robust in Europe?, Environmental Research Letters 10(2015), p. 084015.
2. L. Hamaoui-Laguel, R. Vautard, L. Liu, F. Solmon, N. Viovy, D. Khvorosthyanov, F. Essl, I. Chuine, A. Colette, M.A. Semenov, A. Schaffhauser, J. Storkey, M. Thibaudon and M.M. Epstein, Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe, Nature Clim. Change 5(2015).
3. V.N. Likhvar, M. Pascal, K. Markakis, A. Colette, D. Hauglustaine, M. Valari, Z. Klimont, S. Medina and P. Kinney, A multi-scale health impact assessment of air pollution over the 21st century, Science of The Total Environment 514(2015), pp. 439-449.
4. A. Colette, B. Bessagnet, R. Vautard, S. Szopa, S. Rao, S. Schucht, Z. Klimont, L. Menut, G. Clain, F. Meleux, G. Curci and L. Rouïl, European atmosphere in 2050, a regional air quality and climate perspective under CMIP5 scenarios, Atmos. Chem. Phys. 13(2013a), pp. 7451-7471.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. Presidency of the EMEP Programme of the LRTAP Convention
2. Chair of the Task Force on Measurement and Modelling of EMEP
3. Copernicus Atmosphere Monitoring Service (CAMS50 co-lead, CAMS71 lead)
4. Coordination in France of the SALUTAIR project (for the Ministry in charge of the environment) which aims at assessing and quantifying co-benefits of climate and air pollution policies

IIASA	**20-International Institute for Applied System Analysis (IIASA)**	**AUSTRIA**

Description of the legal entity

International Institute for Applied Systems Analysis (IIASA) is a non-governmental, multi-national, independent organization devoted to interdisciplinary, policy-oriented research focusing on selected aspects of environmental, economic, technological and social issues in the context of human dimensions of global change. IIASA uses advanced systems analysis to conduct policy-oriented research into the most pressing areas of global change – energy and climate change, food and water, poverty and equity – and their main drivers. This work is supported by research into the drivers of the transformations taking place in our world – population, technology, and economic growth. In this project IIASA will participate with its Air Quality and Greenhouse Gasses (AIR) Programme.

AIR employs IIASA's expertise in applied interdisciplinary research to develop innovative modelling tools to identify strategies to protect the local, regional and global atmosphere while imposing least burden on the economic development. AIR has developed a model to explore Greenhouse gas – Air pollution INteractions and Synergies (GAINS) between the control of local and regional air pollution and the mitigation of global greenhouse gas emissions (http://gains.iiasa.ac.at). GAINS has been used to provide scientific support to the development of various European policy processes, such as the National Emissions Ceilings Directive of the European Commission (NEC), the Clean Air For Europe (CAFE), and European Climate Change Programme (ECCP). In 2008, it was implemented for Asia under the FP6 project GAINS-Asia and in 2010 extended to global coverage. AIR has been involved in activities of AMAP (Arctic Monitoring and Assessment Programme) Task Forces addressing black carbon and methane mitigation. At a global level, AIR has proposed a methodology and a set of SLCF (Short-Lived Climate Forcers) mitigation measures within the UNEP 'Tropospheric Ozone and Black Carbon Assessment' and IIASA's GAINS model has been used in the development of air pollutant component of the RCP8.5 scenario and more recently in the development of the air pollution in the Shared Socio-economic pathways (SSPs).

Main tasks in FORCeS

The IIASA team will contribute to WP 1 and WP 3 (developing global emission datasets with updated representation of aerosol emissions for the period 2010-2030, including improved ammonia emissions, and air pollution mitigation strategy addressing acute PM2.5 exposure) and WP 6 (estimating impacts of several air pollution scenarios on near term temperature change applying newly developed RTPs (regional temperature potentials)).

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Markus Amann (male) is Program Director of the Air Quality and Greenhouse Gases (AIR) Program and co-leader of IIASA's Greenhouse Gas Initiative. He also serves as the head of the Centre for Integrated Assessment Modelling (CIAM) of the European Monitoring and Evaluation Programme (EMEP) under the Convention on Long Range Transboundary Air Pollution (CLRTAP). Dr. Amann has been appointed as a member of the Clean Air Commission of the Austrian Academy of Sciences. He is a member of the Editorial Board of "Environmental Modelling and Software" and lead author for the Working Group III report of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). He was a member of the Environmental Assessment Group of EUROTRAC-II, member of the Management Committee of Topic Centre for Air and Climate Change of the European Environment Agency (EEA), member of the Scientific Oversight Committee of the APHENA

"Air Pollution and Health, A European and North American Approach" project of the Health Effects Institute (HEI, Boston, USA), reviewer for the AFO2000 German Atmospheric Research program and reviewer for the United States Acid Deposition Research Program NAPAP. Dr. Amann graduated from the Technical University Vienna in electrical engineering and holds a Ph.D. in economics from the University of Karlsruhe, Germany. His research interests include the interface between science and policy and methods for the integrated assessment of environmental issues.

Link to full list of publications: https://www.scopus.com/authid/detail.uri?authorId=34568413600

Zbigniew Klimont (male) is Research Scholar with the Air Quality and Greenhouse Gases (AIR) Program at IIASA. He has a degree in environmental engineering from the Technical University of Warsaw, Poland. He has been working on the assessment of regional and global emissions of various air pollutants and their control costs. Contributing author to IPCC WGI AR5 and Lead author in WGI AR6, Coordinating lead author and lead author in a number of UNEP Assessments, co-author of the Bounding Black Carbon study.

Link to full list of publications: https://www.scopus.com/authid/detail.uri?authorId=42662973900

Wilfried Winiwarter (male) is a Senior Research Scholar at IIASA since 2003. He earned a PhD in environmental analytical chemistry at Vienna University of Technology in 1988. Following post-doctoral research in the U.S. and again in Vienna he joined Austria's largest non-university research center, the Austrian Research Centers at Seibersdorf, on mostly project-related research related to emission inventories and emission abatement. Between 2012 and 2014 he was a Professor of Systems Sciences at the University of Graz. Since October 2017, he has also been Professor of Environmental Chemistry at the Institute of Environmental Engineering, University of Zielona Gora, Poland. At IIASA, he has been contributing to the Air Quality and Greenhouse Gases (AIR) Program with a special focus on the biogeochemical cycle of nitrogen. Dr. Winiwarter's interest in systems analysis derives from the overarching challenges of climate research. Originally an atmospheric scientist and specialist in assessing the release of trace compounds into the atmosphere, his expertise was called upon to quantify current and potential future emissions of climate relevant greenhouse gases, specifically nitrous oxide in the GAINS model. The interaction between physical and social systems and their respective interferences now also serves as a major focus of his work. Having served as a Director of the European Centre of the International Nitrogen Initiative (2013-16), he is the deputy chairman to the Climate and Air Quality Commission of the Austrian Academy of Sciences, and also chairs the scientific advisory board to the ATB (Institut fur Agrartechnik und Biookonomie) in Potsdam, Germany, an institute of the Leibniz association.

Link to full list of publications: https://www.scopus.com/authid/detail.uri?authorId=7003767429

Chris Heyes (male) is a Senior Research Scholar with the AIR Program at IIASA. He worked on the development of a simplified ozone formation module for the GAINS integrated assessment model. Subsequently, he has been involved in various elements of the further enhancement of the GAINS model and its application to air quality policy questions, mostly in the areas of atmospheric dispersion and environmental impacts. More recent activities include the implementation of radiative forcing impacts from relatively short-lived species to extend the model's capability to assess interactions between air quality and climate policies, and the generation of global emission fields. Mr. Heyes studied chemistry at Oxford University, UK, where he received his BA degree in 1976. Subsequently, he carried out research on aspects of the atmospheric chemistry of chlorofluorocarbons relevant to the depletion of stratospheric ozone. Before joining IIASA, Mr. Heyes worked at the former Warren Spring Laboratory, Stevenage, UK, gaining experience in a wide range of air pollution problems, ranging from odor abatement to acid deposition and air quality modeling.

Link to full list of publications: https://www.scopus.com/authid/detail.uri?authorId=7007120936

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

1. Hoesly, R. M., Smith, S. J., Feng, L., Klimont, Z., Janssens-Maenhout, G., Pitkanen, T., Seibert, J. J., Vu, L., Andres, R. J., Bolt, R. M., Bond, T. C., Dawidowski, L., Kholod, N., Kurokawa, J.-I., Li, M., Liu, L., Lu, Z., Moura, M. C. P., O'Rourke, P. R., and Zhang, Q. (2018) Historical (1750–2014)

anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS), Geosci. Model Dev., 11, 369-408
2. Rao S, Klimont Z, Smith SJ, Van Dingenen R, Dentener F, Bouwman L, Riahi K, Amann M, et al. (2017) Future air pollution in the Shared Socio-economic Pathways. Global Environmental Change 42: 346-358.
3. Klimont Z, Kupiainen K, Heyes C, Purohit P, Cofala J, Rafaj P, Borken-Kleefeld J, Schöpp W. (2017) Global anthropogenic emissions of particulate matter including black carbon. Atmospheric Chemistry and Physics 17 (14): 8681-8723.
4. Amann M, Klimont Z, Wagner F (2013) Regional and Global Emissions of Air Pollutants: Recent Trends and Future Scenarios. Annual Review of Environment and Resources 38:31–55
5. Shindell D, Kuylenstierna JCI, Vignati E, et al. (2012) Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security. Science 335:183–189.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

1. Horizon 2020 project CD-LINKS; grant agreement No 642147 (coordinator)
2. WORLD ENERGY OUTLOOK: Energy and Air Pollution: World Energy Outlook Special Report 2016
3. FP7 project ECLIPSE; grant no. 282688 (Co-beneficiary)
4. FP7 integrated project PEGASOS; grant no: 265148 (Co-beneficiary)
5. FP6 project EUCAARI; grant no. 34684 (Co-beneficiary)

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The AIR programme at IIASA, has developed the integrated assessment model GAINS that is available on-line [gains.iiasa.ac.at/models] at no cost. The model is run by an apache tomcat webserver with an ORACLE database. The Webserver as well the Database are hosted and maintained at IIASA

UNIVERSITY OF EXETER	**21-University of Exeter (UOE)**	**United Kingdom (UK)**

Description of the legal entity

The University of Exeter (UOE), combines world class research with excellent student satisfaction at its campuses in Exeter and Cornwall. It is a member of the UK Russell Group of leading research-intensive universities. Formed in 1955, the University has 22,540 students, including 4,300 postgraduates, from more than 130 different countries and almost 5,000 staff. It is ranked amongst the UK's top universities in the Higher Education league tables produced by the Times and the Sunday Times. It is also ranked amongst the world's top 200 universities in the QS and Times Higher Education rankings.

CEMPS/XCS: The College of Engineering, Mathematics and the Physical Sciences (CEMPS) at the University of Exeter is committed to undertaking research that will help to tackle some of the biggest problems of the 21st century such as climate change. Exeter Climate Systems (XCS) is an innovative interdisciplinary research centre located within the mathematics research institute at the University of Exeter. XCS is a world-leading centre for research at the frontier of mathematics/statistics and climate science. The centre's main themes of research are: Storm risk - stochastic modelling of tropical and extra-tropical cyclones relevant to natural catastrophe risk; Prediction and evaluation - new approaches for constructing probabilistic forecasts of weather and climate and methods for the evaluation of weather and climate prediction systems; Environment and health - statistical modelling of how weather and climate forecasts can be incorporated into disease risk prediction models to assist in public health decision making; Improving weather and climate models - developing the next generation of numerical weather prediction models; Climate dynamics – integrated modelling of key processes in the carbon and water cycles and quantifying the role of aerosols in climate; Statistical Science - research at the interface of statistics and environmental science relevant to real world problems. Much of our research is interdisciplinary, with academics from across the College collaborating to research topics in more depth. The College plays a pivotal role in four of the five key interdisciplinary research themes within the University's Science Strategy, one of which is climate change and sustainable futures. XCS is actively involved in the interdisciplinary research led by the Environment and Sustainability Institute (ESI) based on our Cornwall Campus near Falmouth.

Researchers in XCS successfully develop and apply mathematics/statistics to solve real world problems raised by industrial partners such as the nearby UK Met Office. Many of the researchers in XCS are actively involved in the development of the UK Met Office's next generation of Earth system and climate models, e.g. HadGEM3 and UKESM1. Members are world-renowned for their expertise, for example, four professors are lead authors for the forthcoming 5th IPCC report. Exeter Climate Systems is a key node in the University of Exeter's Climate Change and Sustainable Future's major science theme.

Main tasks in FORCeS

The UOE will contribute expertise in modeling, specifically bridging the gaps between process level modelling and global climate modelling (GCM) of aerosol – cloud interactions with a new modelling framework for representing cloud droplet formation, the embedded GCM cloud parcel model. In work package 2, UOE will contribute to the development and improvement of droplet activation parameterizations by supporting the use of the embedded cloud parcel modelling framework to aid evaluation of parameterizations online in GCMs.

Description of the profile of the persons primarily responsible for carrying out the proposed research and innovation activities

Daniel Partridge (male) is a lecturer in atmospheric science at UOE and will contribute to WP2 within FORCeS. He received his PhD in 2011 from Stockholm University, and has been employed at the University of Exeter since 2017 after undertaking post-doctoral research fellowships at the University of Oxford and Stockholm University. Dr Partridge's research interests in climate change with a focus on the interaction between aerosols and clouds. I work with both detailed cloud-scale process level numerical modelling and global climate modelling to further understand the complex processes governing the impact aerosols have on cloud properties and subsequently the climate system. Specifically, my interests involve development and application of novel computational strategies (Markov Chain Monte Carlo (MCMC) simulation; Lagrangian source receptor analysis) that link observations with models spanning a range of scales (droplet formation > cloud radiative impact of volcanic eruptions) for improved understanding and representation of atmospheric processes relevant for cloud formation in GCMs. He is strongly involved in national and international research collaborations and is currently leading an international AeroCom experiment involving 12 modelling centres worldwide. He has co-supervised 1 PhD students to their degree and several masters students. He is currently supervising 4 PhD students.

Peer-reviewed publications: 15; H-index: 10 (based on ISI web of science); Presentations and seminars in international scientific conferences and seminar series 18.

Link to full list of publications: https://scholar.google.com/citations?user=A3gsO2MAAAAJ&hl=en

List of up to 5 relevant publications, products, services, or other achievements relevant to the project

6. Malavelle, F, Haywood, J, Jones, A et al., 2017. Strong constraints on aerosol-cloud interactions from volcanic eruptions. Nature.
7. Gryspeerdt, E, Quaas, J, Ferrachat, S et al., 2017. Constraining the instantaneous aerosol influence on cloud albedo. Proceedings of the National Academy of Sciences of USA, 114 (19), 4899–4904.
8. Zhang, S., Wang, M., Ghan, S. J., Ding, A., Wang, H., Zhang, K., Neubauer, D., Lohmann, U., Ferrachat, S., Takeamura, T., Gettelman, A., Morrison, H., Lee, Y., Shindell, D. T., Partridge, D. G., Stier, P., Kipling, Z., and Fu, C.: On the characteristics of aerosol indirect effect based on dynamic regimes in global climate models, Atmos. Chem. Phys., 16, 2765-2783, 2016.
9. Ghan, S., Wang, M., Zhang, S., Ferrachat, S., Gettelman, A., Griesfeller, J., Kipling, Z., Lohmann, U., Morrison, H., Neubauer, D., Partridge, D.G., Stier, P., Takemura, T., Wang, H., and Zhang, K.: Challenges in constraining anthropogenic aerosol effects on cloud radiative forcing using present-day spatiotemporal variability, PNAS 2016., doi:10.1073/pnas.1514036113.
10. Partridge, D. G., Vrugt, J. A., Tunved, P., Ekman, A. M. L., Struthers, H., and Sorooshian, A.: Inverse modelling of cloud-aerosol interactions – Part 2: Sensitivity tests on liquid phase clouds using a Markov chain Monte Carlo based simulation approach, Atmos. Chem. Phys., 12, 2823-2847, 2012.

A list of up to 5 relevant previous projects or activities, connected to the subject of FORCeS proposal

6. AeroCom experiment: Aerosol Lagrangian trajectory experiment (Coordinator).
7. AeroCom experiment: Constraining Global Model Estimates of Aerosol Effects on Clouds (Participant).
8. CLARIFY: Reduce uncertainty in radiative forcing of aerosols above clouds, UK, NERC (Participant).
9. BACCHUS: Impact of Biogenic vs Anthropogenic emissions on Clouds & Climate, EU FP7 (Participant).
10. GASSP: Global Aerosol Synthesis and Science Project, UK, NERC (Participant).
11. ACID-PRUF: Reduce Uncertainty in Aerosol-Cloud interactions, UK-NERC (Participant).

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The computing resources required for offline development of the embedded cloud parcel model framework are available at UOE.

4.2. Third parties involved in the project (including use of third party resources)

No third parties involved

5. Ethics and Security

5.1 Ethics

No ethics issues are entered in the ethical issue table in the administrative proposal form.

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

European Commission

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