Horizon 2020

Call: H2020-MSCA-ITN-2016
(Marie Skłodowska-Curie Innovative Training Networks)

Topic: MSCA-ITN-2016

Type of action: MSCA-ITN-ETN
(European Training Networks)

Proposal number: 721963

Proposal acronym: CODA

Deadline Id: H2020-MSCA-ITN-2016

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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 previous steps in the submission wizard.

1 - General information

Topic	MSCA-ITN-2016
Call Identifier	H2020-MSCA-ITN-2016
Type of Action	MSCA-ITN-ETN
Deadline Id	H2020-MSCA-ITN-2016
Acronym	CODA
Proposal title	Coupled Data assimilation for climate prediction and climate change attribution

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

Duration in months	*48*
Panel	ENV

Please select up to 5 descriptors (and at least 1) that best characterise the subject of your proposal, in descending order of relevance. Note that descriptors will be used to support REA services in identifying the best qualified evaluators for your proposal.

Descriptor 1	*Climatology and climate change*	Add	
Descriptor 2	*Scientific computing and data processing*	Add	Remove
Descriptor 3	*Application of mathematics in sciences*	Add	Remove
Descriptor 4	*Environment, resources and sustainability*	Add	Remove
Descriptor 5	*Earth observations from space/remote sensing*	Add	Remove

Free keywords	*Climate Prediction; Data Assimilation*

Abstract

Environmental modeling is experiencing major improvements due to the better understanding of natural processes and to increasing computational resources. Earth System Models (ESMs) couple atmosphere, oceans, land surface and cryosphere components, and have become integral in environmental prediction over time scales from a few days to decades. The Earth is also observed over a wide range of spatial and temporal scales, with a variety of observation platforms, including satellites. Thus, there is now a unique opportunity to combine ESMs with new generation of observations, and the techniques of Data Assimilation (DA) are the natural framework to do this. Their use with ESM is currently the focus of intense research toward coupled DA (CDA) methods able to process all data and propagate the information consistently across model subcomponents. Along this line, CODA's scientific goal is to study unified CDA strategies to initialize weather-to-decadal forecast. The impacts will include the improvement of climate prediction, a robust observation-based identification and understanding of climate variability mechanisms, and a better estimate of the external forcing causing climate change. CODA relies on a team of experts in geoscience and applied mathematics with the mission of training young climate scientists. The network comprises 11 PhDs in 6 countries with 9 Academic Beneficiaries and 4 Industrial Partners, in an original program that includes broad international mobility, schools, workshops as well as training in dissemination, scientific writing and entrepreneurship. CODA is a powerful interdisciplinary initiative designed to train a much-needed new generation of PhDs with both a robust basis in mathematics and a physical understanding of the climate system. The project will contribute to increasing the awareness and popularity of new DA methodologies by the wider scientific community and will help in maintaining the EU at the forefront of climate science.

Remaining characters 12

Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under the 7th Framework Programme, Horizon 2020 or any other EU programme(s)? (●) Yes ( ) No

Please give the proposal reference or contract number.
675729

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/her 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

Your reply to the grant application will involve the recording and processing of personal data (such as your name, address and CV), which will be processed 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 processing of your personal data are available on 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 Warning System (EWS) only or both in the EWS and Central Exclusion Database (CED) by the Accounting Officer of the Commission, should you be in one of the situations mentioned in:
-the Commission Decision 2008/969 of 16.12.2008 on the Early Warning System (for more information see the Privacy Statement), or
-the Commission Regulation 2008/1302 of 17.12.2008 on the Central Exclusion Database (for more information see the Privacy Statement) .

List of participants

#	Participant Legal Name	Country
1	STIFTELSEN NANSEN SENTER FOR MILJOOG FJERNMALING	Norway
2	INSTITUT ROYAL METEOROLOGIQUE DE BELGIQUE	Belgium
3	ECOLE NATIONALE DES PONTS ET CHAUSSEES	France
4	INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE	France
5	THE UNIVERSITY OF READING	United Kingdom
6	CONSEJO NACIONAL DE INVESTIGACIONES CIENTIFICAS Y TECNICAS	Argentina
7	UNIVERSITETET I BERGEN	Norway
8	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	Spain
9	CENTRE EUROPEEN DE RECHERCHE ET DE FORMATION AVANCEE EN CALCUL SCIENTIFIQUE	France

Information on partner organisations

Partner Organisation number	PIC Search PIC	Organisation legal name	Country	Academic Sector	Role of associated		
					Provide training	Host secondmends	
1	999939827	STATOIL ASA	Norway	No	Yes	Yes	
2	999926829	ELECTRICITE DE FRANCE S.A.	France	No	Yes	Yes	
3	933597065	BKK Produksjon AS	Norway	No	Yes	Yes	
4		ACA	Spain	No	Yes	Yes	

2 - Administrative data of participating organisations

Coordinator

PIC	***Legal name***
999477913	*STIFTELSEN NANSEN SENTER FOR MILJOOG FJERNMALING*

Short name: NERSC

Address of the organisation

Street THORMOHLENSGATE 47

Town BERGEN

Postcode 5006

Country Norway

Webpage www.nersc.no

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....no

Non-profit ....yes

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....yes

Legal person ....yes

Academic Sector ....yes

Enterprise Data

SME self-declared status.................................2007 - yes

SME self-assessment .... unknown

SME validation sme.......................................2007 - no

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

Nace code - Not applicable

Department(s) carrying out the proposed work

Department 1

Department name: Mohn-Sverdrup Center

☐ not applicable

☒ Same as organisation address

Street: THORMOHLENSGATE 47

Town: BERGEN

Postcode: 5006

Country: Norway

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **NERSC**

Person in charge of the proposal

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Alberto** Last name: **CARRASSI**

E-Mail: **alberto.carrassi@nersc.no**

Position in org.: Researcher

Department: STIFTELSEN NANSEN SENTER FOR MILJOOG FJERNMALING ☒ Same as organisation

☒ Same as organisation address

Street: THORMOHLENSGATE 47

Town: BERGEN Post code: 5006

Country: Norway

Website: www.nersc.no

Phone: +4746747817 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Laurent	Bertino	laurent.bertino@nersc.no	
Knut	Holba	knut.holba@nersc.no	

Participant

PIC	***Legal name***
996699154	*INSTITUT ROYAL METEOROLOGIQUE DE BELGIQUE*

Short name: IRM/ KMI

Address of the organisation

Street AVENUE CIRCULAIRE 3

Town BRUXELLES

Postcode 1180

Country Belgium

Webpage www.meteo.be

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

Academic Sector ....yes

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.

Nace code L - Public administration & defence

Proposal ID **721963** *Acronym* **CODA** *Short name* **IRM/ KMI**

Department(s) carrying out the proposed work

Department 1

Department name: Research and Development Department

☐ not applicable

☒ Same as organisation address

Street: AVENUE CIRCULAIRE 3

Town: BRUXELLES

Postcode: 1180

Country: Belgium

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID 721963	Acronym CODA	Short name IRM/ KMI

Person in charge of the proposal

Title	Dr.	Sex	(●) Male ( ) Female
First name	**Stephane**	Last name	**Vannitsem**
E-Mail	**svn@meteo.be**		
Position in org.	Senior Scientist (SW3)		
Department	Research and Development Department		☐ Same as organisation
	☒ Same as organisation address		
Street	AVENUE CIRCULAIRE 3		
Town	BRUXELLES	Post code	1180
Country	Belgium		
Website	climdyn.meteo.be		
Phone	+3223730552	Phone 2	+xxx xxxxxxxxx
Fax	+xxx xxxxxxxxx		

Participant

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

Short name: ENPC

Address of the organisation

Street AVENUE BLAISE PASCAL-CITE DESCARTES

Town MARNE LA VALLEE CEDEX 2

Postcode 77455

Country France

Webpage http://www.enpc.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Non-profit ....yes

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....yes

Research organisation ....yes

Legal person ....yes

Academic Sector ....yes

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.

Nace code 853 -

Department(s) carrying out the proposed work

Department 1

Department name: CEREA

☐ not applicable

☒ Same as organisation address

Street: AVENUE BLAISE PASCAL-CITE DESCARTES-CHAM

Town: MARNE LA VALLEE CEDEX 2

Postcode: 77455

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **ENPC**

Person in charge of the proposal

Title	Prof.	Sex	(•) Male ( ) Female
First name	**Marc**	Last name	**Bocquet**
E-Mail	**bocquet@cerea.enpc.fr**		
Position in org.	Deputy director of CEREA / Researcher		
Department	CEREA		☐ Same as organisation
	☒ Same as organisation address		
Street	AVENUE BLAISE PASCAL-CITE DESCARTES-CHAMPS-SUR-MARNE 6-8		
Town	MARNE LA VALLEE CEDEX 2	Post code	77455
Country	France		
Website	http://cerea.enpc.fr/HomePages/bocquet/		
Phone	+33164152151	Phone 2	+xxx xxxxxxxxx
Fax	+33164152170		

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Carolina	Olmedo-Garcia	carolina.garcia-olmedo@enpc.fr	0033164153646

Participant

PIC	***Legal name***
999547074	*INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE*

Short name: INRIA

Address of the organisation

Street Domaine de Voluceau, Rocquencourt

Town LE CHESNAY Cedex

Postcode 78153

Country France

Webpage www.inria.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Non-profit ....yes

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....yes

Legal person ....yes

Academic Sector ....yes

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.

Nace code 72 - Computer & related activities

Department(s) carrying out the proposed work

Department 1

Department name	Centre de Recherche Inria Grenoble Rhône-Alpes	☐ not applicable
	☐ Same as organisation address	
Street	655 Avenue de l'Europe - ZIRST INOVALLEE	
Town	SAINT ISMIER	
Postcode	38334	
Country	France	

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **INRIA**

Person in charge of the proposal

Title: Dr.

Sex: (●) Male ( ) Female

First name: **Arthur** Last name: **Vidard**

E-Mail: **arthur.vidard@inria.fr**

Position in org.: Researcher

Department: Inria Grenoble Rhône-Alpes - AIRSEA ☐ Same as organisation

☐ Same as organisation address

Street: LJK - 51 rue des Mathématiques, BP 53

Town: Grenoble cedex 9 Post code: 38041

Country: France

Website: www.inria.fr

Phone: +334 76514256 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Laurent	Debreu	laurent.debreu@inria.fr	+33476514860
Fanny	Rossetti	recettes-grenoble@inria.fr	+33476615568

Participant

PIC	***Legal name***
999984156	*THE UNIVERSITY OF READING*

Short name: THE UNIVERSITY OF READING

Address of the organisation

Street WHITEKNIGHTS CAMPUS WHITEKNIGHTS H

Town READING

Postcode RG6 6AH

Country United Kingdom

Webpage http://www.rdg.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

Academic Sector ....yes

Enterprise Data

SME self-declared status.................................2011 - no

SME self-assessment .... unknown

SME validation sme.......................................2011 - no

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

Nace code - Not applicable

Department(s) carrying out the proposed work

Department 1

Department name	Department of Mathematics and Statistics	☐ not applicable
	☐ Same as organisation address	
Street	Whiteknights, PO Box 220	
Town	Reading	
Postcode	RG6 6AX	
Country	United Kingdom	

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **THE UNIVERSITY OF READING**

Person in charge of the proposal

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Amos Stephen** Last name: **Lawless**

E-Mail: **a.s.lawless@reading.ac.uk**

Position in org.: Lecturer in data assimilation and inverse problems

Department: Department of Mathematics and Statistics

[ ] Same as organisation

[ ] Same as organisation address

Street: Whiteknights, PO Box 220

Town: Reading Post code: RG6 6AX

Country: United Kingdom

Website: http://www.personal.reading.ac.uk/~sms00asl/

Phone: +441183785018 Phone 2: +xxx xxxxxxxxx Fax: +441189313423

Participant

PIC	***Legal name***
934741374	*CONSEJO NACIONAL DE INVESTIGACIONES CIENTIFICAS Y TECNICAS*

Short name: CONICET

Address of the organisation

Street Av. Rivadavia 1917

Town Buenos Aires

Postcode (C1033AAJ)

Country Argentina

Webpage www.conicet.gov.ar

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

Academic Sector ....yes

Enterprise Data

SME self-declared status..................................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.

Nace code 72 - Computer & related activities

Department(s) carrying out the proposed work

Department 1

Department name: IFAECI

☐ not applicable

☐ Same as organisation address

Street: Intendente Güiraldes 2160

Town: Buenos Aires

Postcode: 1428

Country: Argentina

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **CONICET**

Person in charge of the proposal

Title: Dr.

Sex: (•) Male ( ) Female

First name **Alexis** Last name **Hannart**

E-Mail **alexis.hannart@cima.fcen.uba.ar**

Position in org.: Research Scientist

Department: IFAECI

☐ Same as organisation

☐ Same as organisation address

Street: Intendente Güiraldes 2160

Town: Buenos Aires Post code: 1428

Country: Argentina

Website:

Phone: +5491168374999 Phone 2: +541147822773 Fax: +541147883572

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Jorge	Tezon	jtezon@conicet.gov.ar	

Participant

PIC	***Legal name***
999974456	*UNIVERSITETET I BERGEN*

Short name: UiB

Address of the organisation

Street Museplassen 1

Town BERGEN

Postcode 5007

Country Norway

Webpage www.uib.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

Academic Sector .... yes

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.

Nace code 853 -

Department(s) carrying out the proposed work

Department 1

Department name	Geophysical Institute
	☐ not applicable
	☐ Same as organisation address
Street	Allegt 70, PO Box 7803
Town	Bergen
Postcode	5020
Country	Norway

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **UiB**

Person in charge of the proposal

Title: Prof. Sex: (•) Male ( ) Female

First name **Noel** Last name **Keenlyside**

E-Mail **noel.keenlyside@gfi.uib.no**

Position in org.: Professor

Department: Geophysical Institute ☐ Same as organisation

☐ Same as organisation address

Street: Allegt 70, PO Box 7803

Town: Bergen Post code: 5020

Country: Norway

Website: http://www.uib.no/gfi/

Phone: +47 55 58 20 32 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Francois	Counillon	francois.counillon@nersc.no	+4745288557
Liv-Grethe	Gudmundsen	post@fa.uib.no	+4755584965

Participant

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

Academic Sector ....yes

Enterprise Data

SME self-declared status...................................2011 - 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.

Nace code 72 - Computer & related activities

Proposal ID **721963** *Acronym* **CODA** *Short name* **BSC**

Department(s) carrying out the proposed work

Department 1

Department name: Earth Sciences

☐ not applicable

☒ Same as organisation address

Street: Calle Jordi Girona 31

Town: BARCELONA

Postcode: 08034

Country: Spain

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721963** *Acronym* **CODA** *Short name* **BSC**

Person in charge of the proposal

Title: Dr.

Sex: ○ Male ◉ Female

First name: **Virginie** Last name: **Guemas**

E-Mail: **virginie.guemas@bsc.es**

Position in org.: Group Leader- Climate Prediction Group

Department: BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SU ☒ Same as organisation

☒ Same as organisation address

Street: Calle Jordi Girona 31

Town: BARCELONA Post code: 08034

Country: Spain

Website: www.bsc.es

Phone: +34934137679 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Francisco	Doblas-Reyes	francisco.doblas-reyes@bsc.es	
Marina	Azor	marina.azor@bsc.es	+34934134082
Francesca	Arcara	francesca.arcara@bsc.es	+349341377774

Participant

PIC	***Legal name***
999940118	*CENTRE EUROPEEN DE RECHERCHE ET DE FORMATION AVANCEE EN CALCUL SCIENTIFIQU*

Short name: CERFACS

Address of the organisation

Street Avenue Gaspard Coriolis 42

Town TOULOUSE

Postcode 31057

Country France

Webpage www.cerfacs.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....no

Non-profit ....no

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....no

Legal person ....yes

Academic Sector ....no

Enterprise Data

SME self-declared status.................................2007 - no

SME self-assessment .... unknown

SME validation sme.......................................2007 - no

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

Nace code - Not applicable

Department(s) carrying out the proposed work

Department 1

Department name: Global Change and Climate Modeling team (GLOBC) ☐ not applicable

☒ Same as organisation address

Street: Avenue Gaspard Coriolis 42

Town: TOULOUSE

Postcode: 31057

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

Title: Dr.

Sex: ◯ Male ◉ Female

First name: **Sophie** Last name: **Ricci**

E-Mail: **sophie.ricci@cerfacs.fr**

Position in org.: Researcher in the GLOBC team

Department: GLOBC ☐ Same as organisation

☒ Same as organisation address

Street: Avenue Gaspard Coriolis 42

Town: TOULOUSE Post code: 31057

Country: France

Website: www.cerfacs.fr

Phone: +33561193128 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Proposal ID **721963** *Acronym* **CODA**

3 - Budget

Researcher Number	Recruiting Participant (short name)	Planned start month	Duration (months)
1	NERSC	6	36
2	IRM/ KMI	6	36
3	ENPC	6	36
4	INRIA	6	36
5	THE UNIVERSITY OF READING	6	36
6	CONICET	6	36
7	NERSC	6	36
8	UiB	6	36
9	BSC	6	36
10	BSC	6	36
11	CERFACS	6	36
Total			396

Proposal ID **721963** *Acronym* **CODA**

Participant Number	Organisation Short Name	Country	IOEI	No of researchers	Number of person.months	Researcher Unit Cost			Institutional Unit Cost		TOTAL
						Living allowance	Mobility Allowance	Family Allowance	Research, training and networking costs	Management and overheads	
1	NERSC	NO	no	2	72	295350,48	43200,00	18000,00	129600,00	86400,00	572550,48
2	IRM/ KMI	BE	no	1	36	111960,00	21600,00	9000,00	64800,00	43200,00	250560,00
3	ENPC	FR	no	1	36	124275,60	21600,00	9000,00	64800,00	43200,00	262875,60
4	INRIA	FR	no	1	36	124275,60	21600,00	9000,00	64800,00	43200,00	262875,60
5	THE UNIVERSITY OF REA	UK	no	1	36	134687,88	21600,00	9000,00	64800,00	43200,00	273287,88
6	CONICET	AR	no	1	36	65496,60	21600,00	9000,00	64800,00	43200,00	204096,60
7	UiB	NO	no	1	36	147675,24	21600,00	9000,00	64800,00	43200,00	286275,24
8	BSC	ES	no	2	72	218545,92	43200,00	18000,00	129600,00	86400,00	495745,92
9	CERFACS	FR	no	1	36	124275,60	21600,00	9000,00	64800,00	43200,00	262875,60
Total				11	396	1346542,92	237600,00	99000,00	712800,00	475200,00	2871142,92

4 - Ethics issues table

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? *For data imports, please fill in also section 4.* *For imports concerning human cells or tissues, fill in also section 3.*	○ Yes ◉ No	
Do you plan to export any material - including personal data - from the EU to non-EU countries? *For data exports, please fill in also section 4.* *For exports concerning human cells or tissues, fill in also section 3.*	○ Yes ◉ No	
If your research involves low and/or lower middle income countries, are 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? *For research involving animal experiments, please fill in also section 5.*	◯ 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? *For research involving human participants, please fill in also section 2.*	◯ Yes ◉ No	
8. DUAL USE		Page
Does your research have the potential for military applications?	◯ Yes ◉ No	
9. MISUSE		Page
Does your research have the potential for malevolent/criminal/terrorist abuse?	◯ Yes ◉ No	
10. 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

Open Research Data Pilot in Horizon 2020

If selected, all applicants have the possibility to 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. Participating in the Pilot does not necessarily mean opening up all research data. Actions participating in the Pilot will be invited to formulate a Data Management Plan in which they will determine and explain which of the research data they generate will be made open.

We wish to participate in the Pilot on Open Research Data in Horizon 2020 on a voluntary basis	○ Yes	◉ No

Participation in this Pilot does not constitute part of the evaluation process. Proposals will not be evaluated favourably because they are part of the Pilot and will not be penalised for not participating.

[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.

Data management activities

The use of a Data Management Plan (DMP) is required for projects participating in the Open Research Data Pilot in Horizon 2020, in the form of a deliverable in the first 6 months of the project.

All other projects may deliver a DMP on a voluntary basis, if relevant for their research.

Are data management activities relevant for your proposed project?	○ Yes	◉ No

START PAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Innovative Training Networks (ITN)
Call: H2020-MSCA-ITN-2016

PART B

"CODA"

COupled DAta assimilation for climate prediction and climate change attribution

MSCA Innovative Training Network

This proposal is to be evaluated as:

ETN

LIST OF PARTICIPANTS

Consortium Member	Legal Entity Short Name	Academic (tick)	Non-academic (tick)	Awards Doctoral Degrees (tick)	Country	Dept./ Division / Laboratory	Scientist-in-Charge	Role of Partner Organisation
Beneficiaries								
1) Nansen Environmental and Remote Sensing Center	NERSC	YES	NO	NO	Norway	Mohn-Sverdrup Center	Alberto CARRASSI, Laurent BERTINO	Project Coordination Leader of WP3 Hosting and Supervision of ESR 1 and 7 Hosting Secondments
2) Royal Meteorological Institute of Belgium	RMI	YES	NO	NO	Belgium	Dynamical Meteorology and Climatology Unit	Stéphane VANNITSEM	Supervision of ESR 2 Hosting Secondments
3) École des Ponts Paris Tech	ENPC	YES	NO	YES	France	Environment Research Center (CEREA)	Marc BOCQUET	Leader WP1 Supervision of ESR 3 Hosting Secondments
4) Institut National de Recherche en Informatique et en Automatique	INRIA	YES	NO	NO	France		Laurent DEBREU, Arthur VIDARD	Co-Leader WP1 Supervision of ESR 4 Hosting Secondments
5) University of Reading	UR	YES	NO	YES	United Kingdom	School of Mathematical and Physical Sciences	Amos LAWLESS, Alison FOWLER	Supervision of ESR 5
6) Consejo Nacional de Investigaciones Científicas y Técnicas	CONICET	YES	NO	NO	Argentina		Alexis HANNART	Supervision of ESR 6 Hosting Secondments
7) University of Bergen	UiB	YES	NO	YES	Norway	Geophysical Institute	Noel KEENLYSIDE, Francois COUNILLON	Leader of WP4 Supervision of ESR 8 Hosting Secondments
8) Barcelona Super-Computing Center	BSC	YES	NO	NO	Spain	Earth Sciences Department	Virginie GUEMAS, François MASSONNET, Francisco DOBLAS-REYES	Leader of WP2 Co-Leader WP4 Supervision of ESR 9 and 10 Hosting Secondments
9)Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique	CERFACS	YES	NO	NO	France		Sophie RICCI	Co-Leader WP2 Supervision of ESR 11 Hosting Secondments
Partner Organisations								
STATOIL	STATOIL	NO	YES	NO	Norway	TPD RDI	Geir EVENSEN, Remus	Hosting Secondments & Supervision

							HANEA	
Électricité de France	EDF	NO	YES	NO	France		Nicole GOUTAL	Hosting Secondments & Supervision
BKK	BKK	NO	YES	NO	Norway		Ina T. KINDEM	Hosting Secondments & Supervision
ACA	ACA	NO	YES	NO	Spain		Arnau C. ALONSO	Hosting Secondments & Supervision

Data for non-academic beneficiaries:

Name	Location of research premises (city / country)	Type of R&D activities	No. of full-time employees	No. of employees in R&D	Web site	Annual turnover (in Euro)	Enterprise status (Yes/No)	SME status (Yes/No)
STATOIL	Bergen, Norway	Petroleum ensemble applications	23000	650	www.Statoil.com	90 billions (2012)	YES	NO
EDF	Clamart, France	Electricity production	158 467	2125	www.EDF.fr	75.6 billions	YES	NO
BKK	Bergen, Norway	Coordinated projects with research institutions on new technology and renewable energy	1100	–	www.bkk.no	0.4 billion (2013)	YES	NO
ACA	Catalonia, Spain	Water resources, ecosystem and water waste management	560	6	ACA	440M€ (2015)	YES	NO

1. EXCELLENCE

1.4 Quality, innovative aspects and credibility of the research programme

1.1.1 Introduction, objectives and overview of the research programme

State estimation theory in geosciences is commonly referred to as **Data Assimilation**, **DA**, [48]. This term encompasses the entire sequence of operations that, starting from the observations of a system, and from additional statistical and/or dynamical information (*i.e.* the model), provides the best possible estimate of its state. Environmental modelling is experiencing a sustained trend of improvement driven by new understanding of the fundamental processes at smaller scales and by the increase of computational resources. Earth System Models (ESM) that couple atmosphere, ocean, land surface and cryosphere have become unavoidable tools for environmental predictions over timescale from a few days to decades and are being tested at higher resolution so that the complexity of the processes they describe is continuously increasing. Predictability over seasonal-to-decadal time scales arises from the interaction between the atmosphere and the more slowly varying components of the climate system, like the ocean. Understanding the coupling mechanisms is therefore of paramount importance to improve climate prediction beyond a couple of weeks. While weather forecasting is a well-established scientific practice serving society, numerical climate prediction in contrast is in its infancy, although its societal relevance is potentially higher; for instance it can guide adaptation to near-term climate change and related risks. DA has been key in the continuous improvement of weather forecast and receives much attention today for its use in long-term predictions with coupled ESM. DA is also used to evaluate the cost-efficiency of the highly heterogeneous observation network. Indeed, the Earth is observed over a wide range of spatial and temporal scales, thanks to an increasingly wider variety of sustained observing systems including satellites. **The times are thus mature for questioning whether the combined use of large non-linear coupled ESMs with the new generation of Earth observations can improve the forecast skill and our understanding of the coupled phenomena that drive the climate predictability.** While DA appears as the natural methodological framework to optimally merge and exploit both sources of information, this also opens challenging questions on how to best adapt, extend and develop DA strategies for this new class of problems. Climate systems include complex, coupled phenomena over a wide range of spatial and temporal scales (atmosphere, ocean, land surface, cryosphere), while current DA procedures are mostly designed to deal with a single dominant scale of motion and/or assuming weak coupling.

This is the main motivation behind CODA whose **scientific objective is to develop advanced coupled DA (CDA) methods suitable for coupled ESM**. CODA relies on an interdisciplinary team of EU-based leading experts in geoscience and applied mathematics working together with the aim of contributing to the genesis of novel groundbreaking solutions. The ultimate goal is the development of unified DA strategies able to initialize predictions across all time scales from days to decades, and **CODA´s key impacts will be the improvement of the climate prediction and reconstruction**, particularly of **poorly observed areas**, a robust **observation-based identification and understanding of climate variability mechanisms**, and a **better estimate of the external forcing causing climate change**. These problems have a substantial mathematical complexity and require a double level of research which is reflected in the two research Work Packages (WP) of CODA, one theoretical and one application-oriented**:** **WP1 –** Advanced methods for CDA and **WP2 –** Exploitation of DA for initialization, attribution and parameter calibration of environmental systems. The team reflects this twofold approach and the network "nodes" in CODA accommodate expertise in applied mathematics, dynamical systems, statistics, climate dynamics and climate prediction with state-of-the-art ESMs, all leading worldwide experts gathered together by an appealing scientific problem and with the mission to train a new generation of young researchers active in DA for climate research with a robust mathematical and theoretical background. The relation and interplay between WP1 and WP2 makes CODA a naturally interdisciplinary project joining mathematical and environmental science expertise.

CODA proposes a European Training Network of **11 PhDs students** across **6 countries.** The network comprises 9 Beneficiaries Academic Partners, including Universities and Research Centres, along with 4 Industrial Partners, brought together in an original research and training program which includes co-supervision, secondments, schools and workshops as well as additional trainings in dissemination, scientific writing and entrepreneurship. Students will also be trained in numerical and visualization tools to handle the huge datasets that make environmental science an exemplary case of the Big Data problem. CODA will collaboratively train the ESR fellows in a framework of strong interdisciplinary, mutual exchanges, and complementarity. CODA is a powerful interdisciplinary PhD training platform with a key position in training a much-needed new generation of European PhDs with a robust theoretical basis in mathematics as well as a physical understanding of the climate system. The project will not only provide valuable outputs to society, but also contribute to the awareness and endorsement of new DA methodologies by the wider scientific community and will help to keep the EU at the forefront in the research and development in DA and climate science in general. The ESRs will use the private partners to build their post-CODA career strategy.

1.1.2 Research methodology and approach

CODA is organized in **4 Work Packages**: WP1 and 2 are related with the research activities described in the PhD research sub-projects (see Section 1.2.1), WP3 and 4 concern “Management & Training” and “Dissemination” activities respectively. Details about their execution plan, subdivision, partner’s involvement, deliverables and milestones are given in Sect. 3. An overall description is provided in Table 1.1a.

Table 1.1a: Work Package (WP) List and ESR involvement

WP No.	WP Title	Lead (Co) Benef. No.	Start Month	End month	Activity Type	Lead (Co) Participant(s) Short Name	ESR involvement
1	Advanced methods for CDA	3 and (4)	1	48	Research	Leader ENPC (M. Bocquet) Co-Leader INRIA (A. Vidard)	ESR 1 to 6
2	Exploitation of DA for initialization, attribution and parameter calibration of environmental systems	8 and (9)	1	48	Research	Leader BSC (V. Guemas) Co-Leader CERFACS (S. Ricci)	ESR 7 to 11
3	Management & network-wide Training	1	1	48	Management and Training	Leader NERSC (L. Bertino) Co-Leader NERSC (A. Carrassi)	None
4	Dissemination & Outreach	7 and (8)	6	48	Dissemination	Leader UiB (N. Keenlyside) Co-Leader BSC (F. Doblas-Reyes)	All

The two research WPs, 1 and 2, are further subdivided in 6 and 5 Sub-Projects, respectively (See Tab. 1.1b).

Table 1.1b – Sub-Projects per fellow in WP1 and 2

WP	WP Title	Sub-Project No. & Title	ESR	Host Beneficiary
1	Advanced methods for CDA	*1.1 Ensemble methods for CDA*	1	NERSC
		1.2 Low-frequency variability and predictability of ocean-atmosphere coupled systems	2	RMI
		1.3 Error dynamics characterization within an ensemble-variational DA system	3	ENPC
		1.4 Multigrid preconditioning for variational DA	4	INRIA
		1.5 Observation impact in coupled variational DA	5	UR
		1.6 Assimilation of time-averaged observations with application to detection and attribution of climate change.	6	CONICET
2	Exploitation of DA methods for applications with coupled environmental models	*2.1 Multi-methods CDA*	7	NERSC
		2.2 Strongly CDA for seasonal-to-decadal prediction	8	UiB
		2.3 Toward reduced surface biases in EC-Earth 3 climate forecast system through parameter calibration based on the ensemble Kalman filter	9	BSC
		2.4 Impact of the balanced initialization of dynamical climate forecasts on forecast quality	10	BSC
		2.5 Ensemble DA for coupled sediment-hydrodynamics modelling in estuaries	11	CERFACS

CODA numerical test-ground is based on the extensive use of a **hierarchy of models** from low-order to intermediate complexity up to state-of-art ESMs (see Table 1.1c), which will be shared between partners. Note furthermore that, a new intermediate complex coupled system will be developed as part of the Sub-Project 1.2 (see Sect. 3.1.4 for details). The participants to CODA will benefit from some utilities for numerical integration and DA already at disposal of some members. This includes the assimilation and model codes of the *educational EnKF Matlab toolbox* developed at NERSC and that already incorporates different assimilation methods in several models. We will migrate this to the open source Python platform. The intermediate coupled models VDDG15, SCM, L95-GRS and SPEEDO are coded using Fortran that offers higher computational performance.

Table 1.1c – Models available to the CODA partners

Complexity	Model Name	Dim	Coupled	Ref
Low	L63	3	NO	[54]
	GJ98	5	YES	[33]
	PK04	3 -- 9	YES	[67]
	MFPV	6	YES	[62]
Low/Medium	L96	N (large scale) x M (small scale)	YES / NO	[55]
	VDDG15	24 -- 56	YES	[88]
Medium/Complex	SCM	400	YES	[77]
	L95-GRS	$O(10^3)$	YES	[12]
	SPEEDO	$O(10^5)$	YES	[76]

State-of-the-Art	NorESM	O(10^8)	YES	[8]
	EC-Earth 3.2	O(10^8)	YES	[40]

Two ESMs are available in CODA: the Norwegian Earth System Model (NorESM) and the EC-Earth ESM. They are two out of ~20 climate models that have produced output for the CMIP5 (http://cmip-pcmdi.llnl.gov/cmip5) project. NorESM is developed in Norway based on the Community Climate System Model version 4 (CCSM4) while EC-Earth is developed and used by a European consortium of about 15 institutes. Both models fully couple atmosphere, ocean, sea-ice and land models. The main version of NorESM1-M has a horizontal resolution of approximately 2° for the atmosphere and land components and 1° for the ocean and sea ice components. NorESM is also available at lower resolution version (NorESM1-L), and with high-top version with specified and full chemistry. The low-resolution configuration of EC-Earth3 will be used in CODA with a horizontal resolution of about 1° in the ocean and 75 levels and a T255L91 grid for the atmosphere. Codes and data will be all shared among the partners in appropriate common-utility drop-boxes.
Observation system simulation experiments (OSSE) will be extensively performed to benchmark the new methods before assimilating real observations. In OSSE a model solution is taken to represent the true climate evolution to be estimated, and the "true" trajectory is sampled to give the record of synthetic observations. The OSSE framework provides high flexibility: sampling characteristics of observations can be easily modified and degraded to study the response of the CDA algorithms, and model error can be straightforwardly introduced by, for instance, using a different set of model parameters in the "nature" and model equations, or by running the former at a higher resolution.

1.1.3 Originality and innovative aspects of the research programme

Background & State-of-the-Art: ***DA methods***

Formally, weather and climate prediction are a combination of an initial value and forced boundary problem where the importance of the latter grows with the length of the prediction [54,60]. Such initial and/or boundary conditions are estimated through DA. It relies on numerical models that represent the governing equations of the system, on observation of said system, and on statistical assumptions about related errors. The need for accurate environmental predictions has motivated the research for advanced DA techniques, and has led to a flourishing field of novel algorithms, some of them implemented nowadays in operational contexts.
DA methods are usually grouped into *variational* and *sequential*. In the *four-dimensional variational DA* (4DVar), the model trajectory is adjusted to fit the observations distributed within a given time interval [75]. The 4DVar, with some specific approximations aimed at reducing its computational cost, has been successfully applied to both atmospheric and oceanic models and it is in particular adopted at the European Centre for Medium range Weather Forecast, ECMWF, [70], at Météo-France and at the UK MetOffice. In parallel to the variational approach, ensemble-based methods represent a successful and fruitful alternative. In this case, the DA problem is formulated in a sequential way with a forecast step, where the state estimate and its associated error statistic are propagated in time, alternates with the analyses steps when these estimates are updated using the observations. The ensemble-based schemes are Kalman filter (KF)-like algorithms [47] in which the error description is obtained using an ensemble of model trajectories aimed at representing relevant moments of the unknown error probability density function (PDF). The best-known ensemble-based scheme is the ensemble Kalman filter (EnKF; [30]); a version of the EnKF is nowadays operational for the atmospheric model at the Canadian Meteorological Centre, CMC [44] and for the ocean system TOPAZ developed at NERSC [22] and exploited operationally by MET Norway. It also constitutes the official Arctic Ocean, sea ice and ecosystem forecasts in the Copernicus Marine Services (marine.copernicus.eu) and the Norwegian contribution in GODAE (https://www.godae-oceanview.org/).
Model deficiencies are a major cause of error in NWP and climate predictions [24]. Two main difficulties in the estimation of the model error are the huge size of the geophysical models and the wide range of possible error sources. The former problem implies the need to estimate large error covariance matrices on the basis of a limited amount of available observations while the presence of multiple model error causes (incorrect parameters, numerical discretization, unresolved scales, among others) makes difficult to outline a general and unified approach. In long-term predictions with coupled models, model error is often originated at the level of the coupling interaction and is among the causes of large long-term forecasts error bias. In variational DA different solutions have been proposed to estimate and account for model error [94, 82]. It has also been the object of intense research in KF-like schemes, particularly in the perspective of bias correction for the atmospheric [26] and ocean prediction [6]. In the context of ensemble based schemes a lot of efforts have been devoted to the representation of model error through an optimal ensemble design. A straightforward approach consists in the artificial inflation of its explained variance [1]. In a new approach, referred to as **deterministic model error treatment**, its evolution is described using a deterministic law and on a short-time approximation suitable for realistic applications. This approach has proven to be competitive in a number of different applications with prototypical chaotic dynamics, in the framework of sequential [15, 61] and variational schemes [16] as well as for parameter estimation [17]. DA can also be used to **infer model parameters that are not directly**

connected to the observables, a very useful feature in the perspective of the applications with coupled dynamics where one is often interested in optimizing the coupling parameters (see CODA Sub-Project 2.2). Successful parameter estimation has been obtained in the context of simple prototypes of nonlinear dynamics with the EnKF [3, 4], with the maximum likelihood ensemble filter [95], and with the iterative ensemble Kalman smoother [9]. A review about the estimation of model parameters using EnKF can be found in [71]. Similarly, efficient state and parameter estimation using the Extended Kalman Filter [32] has been demonstrated in the context of a coupled ocean–atmosphere model used for prediction of ENSO [49] and for soil analysis with the Short-Time-Augmented-Extended Kalman Filter [18].

*Background & State-of-the-Art: **CDA***

DA algorithms have been conceived mainly for NWP applications and have been usually designed for the state estimation in systems possessing a single dominant dynamical scale and/or for an observational network having a dominant spatiotemporal density. Only recently, research in DA has started to cope with the state estimation problem in systems possessing multiple scales of motion. The case of a sparsely observed flow possessing a wide range of scales has been tackled using KF-like DA procedures [39], and the performance of the EnKF in a prototypical nonlinear dynamics possessing two scales of motion has been explored in [5]. A novel formulation of variational analysis, suitable for NWP with multiscale systems, has been recently presented [53].

The need of a coupled DA (CDA) approach is felt particularly in the field of seasonal-to-decadal forecasting. Interesting results have been obtained for coupled ocean and sea-ice model, demonstrating that successful assimilation of sea ice concentration requires a coupled, multivariate and time-dependent assimilation method [58, 73]. Typically, seasonal-to-interannual predictions are done using coupled atmosphere-ocean models, but the sources of initial data from the various model components are usually not consistent. This "decoupled" initialization is known to induce problems, particularly at the boundary between the ocean and the atmosphere, where unwanted dynamical initial shocks can be introduced. To alleviate this problem, the research community has begun to consider new DA approaches allowing for the simultaneous adjustment of the ocean and atmosphere assimilating the observations from both compartments. Most of the solutions that have been proposed so far use a sort of **weak-coupling** in which the background field is obtained through the evolution of the full coupled model, but the different model compartments are then subject to independent analyses. A first attempt to create a weakly coupled reanalysis has been done at the National Centers for Environmental Prediction [72] and has shown a marked improvement over the standard uncoupled DA. [80] has developed a 4DVar for the coupled global ocean-atmosphere model of the Japan Agency for Marine Science and Technology. In their implementation the control variable includes the ocean initial conditions plus a set of parameters controlling the sea-air fluxes. The approach acted as a proof-of-concept for successfully producing balanced initial conditions for the coupled system and optimal coupling parameters, and enhancing the skill of the seasonal to decadal prediction. At ECMWF, ocean and atmosphere DA are currently done separately but research is active on weakly coupling the two schemes and the 20th century reanalysis, based on it, recently started [51]. Similarly, both atmosphere and ocean are constrained independently using the ensemble-based approach at the Geophysical Fluid Dynamics Laboratory (GFDL) using the Ensemble Adjustment Kalman Filter (EAKF) [92], and [56] achieved some success in OSSE for strongly coupled DA between ocean and atmosphere with the GFDL-EAKF, relying on a strong hypothesis about the coupled dynamic. The assimilation successfully reconstructs relevant climate fields over the period of interests and, being based on an ensemble of trajectories, automatically provides the initial condition to run an ensemble of forecasts. The EnKF in a weakly-coupled DA setting has been recently used to assimilate data to initialize seasonal-to-decadal prediction with the Norwegian Earth System Model (NorESM, 22]). All these studies have clearly highlighted that **using an advanced flow-dependent DA procedure pushes forward the predictability horizon** and the error reduction is efficiently propagated from unobserved-to-observed areas. A review on the state-of-the-art in CDA can be found in [36] and also [27].

*Innovation & Main Research Ideas in **CODA***

Despite the positive impact of using weakly CDA, this procedure only mitigates the imbalances between atmosphere and ocean since the analysis is still based on separate assimilations and it does not fulfil the simultaneous adjustment of the system across all of its components. Climate research requires the development of CDA to improve the forecast capabilities of coupled phenomena, such as those connected to the air-sea exchange like hurricanes or coastal weather or in seasonal-to-decadal prediction where climate conditions are often driven by coupled processes such as ENSO. By producing reanalyses for the coupled systems, CDA will allow reconstructing the climate of areas for which adequate measurements are still unavailable. CDA is the natural way to add value to new Earth observations such as the ARGO ocean global array of profiling floats measuring temperature and salinity, down to 6.000 m depths (www.argo.ucsd.edu) or the European Space Agency mission Soil Moisture and Ocean Salinity (www.esa.int). CODA research is also consistent with the objective of the latest Intergovernmental Panel on Climate Change Fifth

Assessment Report (IPCC-AR5) that addressed initialised prediction; an effort that, along with parameter and external forcing estimation, will be pursued in the scope of CMIP6 [60].

The research activity in CODA is organised in WP1 and WP2. The focus in **WP1** is on understanding the fundamental and theoretical issues that hamper the use of standard DA procedures in climate models, provide proof-of-concepts for novel methods and favour a renewal of the discipline. Low-order numerical models will be central research tools, shared by students, and allowing extensive statistical and numerical computation. A distinctive feature of the research approach in WP1 stands on the extensive use of concepts and tools from dynamical system theory, statistics and optimal control theory to guide new developments adapted to climate modelling. The use of state-of-the-art ESMs and operational geophysical datasets will characterise **WP2**, where practical CDA and initialization approaches, suitable for large nonlinear numerical systems, will be investigated. WP1 and 2 integrate and complement each other offering a natural framework to exchange ideas between scientists with diverse expertise and backgrounds.

WP1 is the theoretical hub of the CODA research activities and is subdivided in 6 Subprojects whose specific original contributions are explained below. Its focus in on four research problems: **1. Coupled system dynamics, 2. Ensemble-based CDA, 3. Variational CDA** and **4. DA for detection and attribution of climate change.**

SubProject 1.1 aims at designing **new strategies for ensemble-based coupled DA, and at understanding the fundamental dynamical reasons limiting the use of standard procedures**. A cornerstone idea in **Sub-Projects 1.1, 1.2** and **1.3** will be the use of the unstable manifold of chaotic dynamics. Its importance in controlling the error evolution in nonlinear systems has been investigated recently in connection with DA. Algorithms referred to as Assimilation in the Unstable Subspace (AUS) exploit the unstable subspace, the span of the leading Lyapunov vectors. The successful applications of AUS with atmospheric and oceanic models [14, 84, 85] demonstrate the robustness of its fundamental paradigm. Can the same paradigm be useful in coupled dynamics? Addressing this question requires a deep study of the error dynamics, correlations and interaction in coupled systems. Suitable unstable manifold estimation methods for this class of systems have to be introduced. The assimilation can then be done using the AUS philosophy: the analysis update is confined in the unstable subspaces of each of the model components, and represents a natural way to target the relevant instabilities associated to each model subcomponent. Much of the understanding of coupled system dynamics required for Subproject 1.1 (and 1.3 below) is provided by **Subproject 1.2** which studies **the low frequency variability and predictability in low-order coupled systems**. Weather forecasting has reached a mature stage whose usefulness extends up to 15 days. Beyond that period, the dynamics of the atmosphere (within the extra-tropical troposphere) is predominantly determined by the boundary forcing associated with the other climate components, displaying longer time scales. The evolution of these components is expected to provide information determining the statistical characteristics of the short-time scale atmospheric dynamics. In view of the difficulty in providing definitive conclusions using complex ESMs, simpler description of the climate dynamics based on low-order modelling is explored. This is the central concern of subproject 1.2 and it is articulated around three different themes about extended-range forecasting (see Section 3.1.4). The research strategy will be based on the use of tools developed in the context of nonlinear dynamics and chaos theory [64, 87, 65]. The coupled model studied in Sub-Project 1.2 will be used in Sub-Project 1.1, 1.3 and 1.5, creating a natural interchange of expertise. **Ensemble-variational methods** that truly account for nonlinear dynamics have been recently developed [74, 9, 10] for tracking chaotic geophysical systems such as the weather. One of them, the *Iterative Ensemble Kalman Smoother* (IEnKS) [10] allows for a full nonlinear variational analysis over an extended temporal DA window while keeping track of the error dynamics from one window to another. The IEnKS has shown to significantly outperform standard ensemble and variational methods on low-order models, and to offer an efficient tool for estimating parameterized model error [9]. However, as emphasized in [10], its high accuracy, as well as some limitations on the DA window maximum length in chaotic dynamics, are not fully understood and appear to be fundamental. Since the nonlinearity of the models is naturally incorporated in the IEnKS within the temporal assimilation window, this must be related to the interplay of the dynamics and variational assimilation. **Sub-Project 1.3** will analyze the advantages and drawbacks using tools of dynamical systems such as covariant Lyapunov vectors. It will further confront the findings by devising and testing, in relation with Sub-Project 1.1, an AUS variant of the IEnKS. Although the issue is largely unexplored yet, we believe that the use of the IEnKS may also be an efficient tool to perform CDA. In particular, as an ensemble-variational method, it does not require the need of an adjoint model, which is usually difficult to compute. **Subproject 1.3 is the natural bridge between ensemble and variational methods, the latter being the subject of the Subprojects 1.4 and 1.5**. In variational methods the initial condition is optimized under constraint so that the model trajectory behaves similarly to the observations. The DA problem is then set as a minimisation of a function depending on the misfit between model output and observations. This optimization is made difficult by the indirect and non-linear nature of the relationship between the initial conditions and the observations. The second difficulty is the size of the problem (up to several billions of unknowns in geoscience) that makes the minimization extremely expensive and therefore requires good convergence properties. Both these problems are exacerbated within a system of coupled models. In order to deal with non-linearities, operational implementations use the incremental strategy where the full non-linear problem is approximated by successive linear and lower resolution problems [89]. However, [35] showed that such scheme does not converge toward the right minimum, and a proper use of **multigrid methods** has been recently proposed in [63] to solve the non-linear case. Furthermore [25] proposed a more robust algorithm using a multigrid iteration as a preconditioner for a Krylov optimization method. So far this has only been applied to very simple models. Extension to more realistic applications is challenging and constitutes the focus of **Subproject 1.4**. When switching to coupled models strong non-trivial multi-physics and multi-scales interactions will arise that may be difficult to approximate at lower resolution. Still using a variational framework, **Subproject 1.5** aims to develop methods for **quantifying observation impact** in weakly-coupled CDA. With the development of new CDA and forecast systems it is necessary to understand which observations are needed to initialize these systems correctly. Impact measures indicate which of these observations are most likely to be of benefit to future coupled forecasting and can also aid the development of CDA. However, current measures of observation impact on the analysis (*e.g.* sensitivity of the analysis to observations, degrees of freedom for signal and entropy measures [20]) are mainly based on a linear approximation to the assimilation system. This means that they are unable to give a true measure of impact in weakly-CDA systems, where the tangent linear model used in the inner loop is uncoupled. In particular they do not correctly quantify the information that is passed across the atmosphere-ocean interface. The objectives of Subproject 1.5 are (i) extend measures of the analysis sensitivity to observations to weakly-coupled DA; (ii) develop new forecast impact measures for weakly-coupled DA, by using ensemble sensitivities to approximate the adjoint [52]); (iii) use these new measures to understand the likely effect of different observation types on CDA. A different theoretical challenge is at the core of **Subproject 1.6** which investigates the potential of DA for a new type of application: the **Detection and Attribution (D&A)** of observed climate changes. D&A investigates causal relationships between human activity and climate changes. Conventional D&A methods are based on linear regression of observations on space-time patterns extracted from climate models [42]. They are successful in a variety of situations, yet they show key limitations for a number of variables and scales [79]. Causal counterfactual theory, as recently introduced in climate science [37], shows that causal evidence can be obtained by deriving the likelihood of the sequence of climatic observations under causal scrutiny in two models successively: (i) the factual one which represents the world as it is, and (ii) the counterfactual one which represents the world as it would be without the forcing of interest. The ratio of these two likelihoods can next be interpreted in terms of causal attribution. DA is thus relevant to tackle D&A in so far as it is able to yield the likelihood of assimilated observations [38]. In practice, an immediate computational difficulty consists in assimilating observations over the entire instrumental period. One way to circumvent this issue is to focus on the assimilation of time-averaged observations – a general problem that has recently raised interest for distinct climatic applications [29]. The objectives of Subproject 1.6 are therefore to: (i) contribute to methodological research on the assimilation of time-averaged observations; (ii) establish a proof-of-concept of the relevance of a DA treatment for the attribution of long term observed changes.

WP2 aims at enhancing climate prediction capability and at improving estuaries modelling through two main angles: **1. improving the quality and consistency of initial conditions provided to climate forecast systems; 2. reducing climate model errors in capturing physical processes by observation-based calibration of the parameters.** WP2 is organised in 5 Subprojects.

Sub-Project 2.1 focuses on **multi-method coupled assimilation**. Modern coupling technology (for example the Community Earth System Model, CESM coupling framework, www.earthsystemcog.org/projects/espc-infrastructure/) allows flexible features such as connecting a fixed- to an adaptive-grid model or running several probabilistic instances of one component of the ESM for a single – deterministic – instance of another. This latter capability can be exploited to use targeted DA methods in each compartment of the ESM (with different ensemble size, localization radius). Nevertheless, it opens new questions about the probabilistic consistency of the information passed across the coupler. For instance, is the ensemble mean the best information to pass to deterministic components? These questions become relevant as new models use adaptive horizontal coordinates (such as the neXtSIM sea ice model in Lagrangian grid [12]), which defy the applicability of traditional DA methods. It also become more arduous as couplers need to handle arbitrary spatial grids and time stepping for the different components, adding a statistical problem of change of support. The work in **Subproject 2.1** will take as focal point the hypothetical coupling of a fixed-grid model to another using an adaptive grid and assume that the former uses an EnKF while the latter rather uses a range of methods from simple nudging to an efficient version of the particle filter. The independent initialisation of the different components of climate forecast systems tends to introduce imbalances between the compartments that dissipate as form of shock and degrade the skill of the forecast. Strongly CDA between these compartments is challenging because it includes complex, coupled phenomena over wide, separated spatial and temporal scales. The Norwegian Climate Prediction model (NorCPM) has demonstrated promising results towards skilful decadal prediction by assimilating ocean observations in the fully coupled NorESM with the EnKF ([22, 23]). Development of strongly CDA between ocean and sea ice are progressing, taking advantage of the years of experiences with the TOPAZ system [73]. **Sub-Project 2.2** focuses on **enhancing strongly coupled DA, using NorCPM**. In a first stage, the leading averaged coupled covariance (LACC) [56] that shows potential for strongly CDA between the ocean and atmosphere will be implemented and tested with NorCPM and compared against weakly CDA approach for different forecast range. This will set a benchmark for the method tested in Stage 2 exploiting the outcome of WP1. In particular, Sub-Project 1.2 may help relaxing the hypothesis made with the LACC method, while the variational framework of the IEnKS tested in Sub-Project 1.3 may further improve the accuracy of the analysis. Coupled general circulation models used to produce climate forecasts exhibit strong climate biases that cause the model to drift. In this context, WP2 builds on the ideas explored in FP7 projects like SPECS (www.specs-fp7.eu) and PREFACE (preface.b.uib.no) where the drift and systematic error [31] of operational climate forecast systems have been thoroughly documented. Climate model biases, for a large part, originate from unresolved processes occurring at the sub-grid scale level and that are represented by parameterizations, with a large associated uncertainty, but the number of parameters increases with its complexity and the calibration process is challenging. DA has been widely applied in geosciences for state estimation [48, 13] but less for **parameter estimation and calibration**. A significant bulk of research and knowledge on parameter estimation techniques exist [19], but their use in climate models is still at an early stage and rarely reported [58]. **Sub-Project 2.3** will tackle from end-to-end the issue of **minimizing the model biases originating from parameters in the EC-Earth coupled general circulation model**, with an original and highly innovative approach relying on DA techniques. Sophisticated parameter calibration techniques alone might not be sufficient to remove completely the climate prediction drift and one needs to also rely on robust, DA based, initialization techniques. Indeed, an alternative approach to reduce the climate prediction drift rely on initializing climate forecast systems closer to their attractor, but still holding as much observed climate information as possible. An initialization of this sort is currently being implemented in EC-Earth, and includes an EnKF of sea-ice observations and a nudging towards reanalyses in the atmosphere and the ocean. The DA phase provides ensembles of initial conditions that can be used to perform climate predictions. **Sub-Project 2.4** aims at testing initialization approaches finding a compromise between the best estimate of the state of the system, which will be obtained with the current tools of DA applied to each model component, and an **initial condition that eliminates the initial shock** and controls the impact of the drift on the model dynamics [93]. The optimal choice of DA coefficients that reduce the drift and, potentially, could improve different aspects of the forecast quality, will be investigated. In **Subproject 2.5**, WP2 moves to small-scale coastal oceanographic applications (central to land-ocean coupling), and merge the complementary state and parameter estimation problems, addressed in Subproject 2.1 to 2.4, into their simultaneous treatment. Dynamics in estuaries are complex as various interactions occur between water masses that are driven by different physics. A model with the TELEMAC software was developed for the Gironde estuary area where the nuclear power plant of Blayais is located. Over this area the bathymetry has a temporal variability induced by the presence of a mud plug resulting from the merging of fluvial and oceanic waters. Subproject 2.5 aims at correcting the TELEMAC model using water level in-situ DA to correct both the model state and the model parameters, especially the bathymetry input field. This work will be extended to coupled physics using SISYPHE-TELEMAC that allow for the **coupled evolution of the sediment field in coherence with the hydrodynamics fields**.

1.2 Quality, innovative aspects and credibility of the training programme

1.2.1 *Overview and content structure of the training*

Multidisciplinary training

Training programs offered locally: The Universities where the ESRs will be enrolled and that will issue the doctoral degrees are listed in Table 1.2a. **Each ESR will have Chief supervisor(s) in the hosting team and co-supervisor(s) in another team (see Sect. 3)**. The ESR will have his/her working place at the same institute as the main supervisor, which is not necessarily at a university. In this case a co-supervisor is appointed at the university that will issue the doctoral degree (see Sect. 3). The host supervisor(s) will guide the scientific programme pursued by the ESRs through mentoring during weekly meetings and will ensure that the ESR has access to all material and personnel assistance needed for his/her research and training. The co-supervisor(s) will assess progress and give advice on the PhD project through regular e-mail exchanges, Skype meetings and during the network meetings (see Table 1.2b). **The universities involved in the project have locally available postgraduate courses that the ESRs will benefit from (see Sect. 1.4 and Table 1.2a).** The training in CODA is ultimately designed to make the ESRs acquire autonomy and maturity in their research field, but also in relation with the network and thus the capacity to build a personal project. A characteristic of our approach, whose details are given below, is that the ESRs themselves will play an active role in the decision phase and will be correspondingly represented in the CODA management structure (see Sect. 3.2).
Note that the 4 axes of scientific knowledge along which the ESR(s) will be trained in CODA are: (1) DA, (2) Climate Prediction, (3) Dynamical System and (4) Scientific Programming. Table 1.2a summarises which of these 4 subjects will be covered per ESR.

*Table 1.2a - Recruitment per Beneficiary, **all ESRs will start between Month 1-9 and last for 36 months**. L: Training available locally. N: Network-wide training events, S: Training obtained during Secondment.*

Researcher No.	Recruiting Participant	Registered at University	DA	Climate Predictions	Dynamical Systems	Scientific Programming
ESR 1	NERSC	UiB	L	L	N/S	S
ESR 2	RMI	UL Bruxelles	L	N	L	S
ESR 3	ENPC	U Paris Est	L	N	N	S
ESR 4	INRIA	U Grenoble Alpes	L	N	N	S/L
ESR 5	UR	UR	L	L	N	S
ESR 6	CONICET	U Buenos Aires	L	L	N/S	N/S
ESR 7	NERSC	UiB	L	L	N	S
ESR 8	UiB	UiB	N	L	N	N
ESR 9	BSC	UA Barcelona*	S	L	N	L
ESR 10	BSC	UA Barcelona*	S	L	N	L
ESR 11	CERFACS	U P. Sabatier, Toulouse	L	L	N	L
Total 11						

(*): The ESR will either be registered at Universidad Autonoma, Politecnica or at the Universidad de Barcelona.

Network-wide training events: **Three yearly international schools** will be organized within CODA to which all ESRs are required to participate, the courses will also be opened to participants outside the network (under a limit of 40 participants in total). Each school will include a course in dissemination and writing, although CODA will offer a specific workshop for this as explained below. We describe here the first two schools; the third is about the post-CODA strategy and is described in the next paragraph as transferable skill. The **first school will focus on DA**, and NERSC, ENPC and INRIA will lead its scientific and practical organization. RMI will take care of organizing a lecture in dynamical system for geoscience, CERFACS and UR on advanced DA methods, and CONICET on statistics. The industrial partner STATOIL will give lectures on DA applications and state-of-art on reservoir and solid Earth in general. The school will cover the theory of DA, with emphasis on methods designed for highly nonlinear and non-Gaussian phenomena, as well as practical methods for implementation along with numerical exercises. CODA WP1 members have a consolidated experience in organizing world-wide leading schools in DA for geosciences (See Beneficiaries in Part B2). Partners in WP2 (UiB, BSC and NERSC) will lead the organization of the **second CODA school**, this time on Climate Prediction. Teaching experience is available within WP2, as well as experience in organising and lecturing at summer schools. This CODA climate prediction school will present an overview of the state-of-the-art seasonal-to-decadal prediction skill, describe the sources and mechanisms of predictability linked to each climate system component, introduce the practical applications of climate prediction and the climate services emergence and provide an extensive review of the initialization methods currently in use in the scientific community. **EDF and ACA** will give a talk on climate services for the energy sector and water management while **BKK** will present how the renewable electricity production in Scandinavia depends on seasonal to decadal climate forecasts. The dissemination activities will target writing articles for general press and training for radio/TV dissemination of their research (UiB or BSC in charge).

On each of the **yearly progress meetings** (See section 3.2), half a day will be dedicated to a meeting of the ESR working groups to review each other's posts and give constructive feedback. The **final CODA conference** (months 46-48) will synthetize the project findings. All network participants, including associated partners, will attend the conference. Four worldwide experts, two on DA, and two on initialization of climate models will give lectures, along with members of the external advisory board, and the conference will be opened to a broad international audience. All ESRs will present their final PhD thesis work. To enhance the international visibility of the project results, the final conference may be organized jointly with other international working groups or programmes to which the beneficiaries take part such as the *International Workshop on Ensemble Kalman Filter* (http://enkf.iris.no/) or the World Climate Research Programme (WCRP) Decadal Climate Prediction Panel. **A special issue** of a relevant journal and/or the publication of the conference proceedings will better disseminate the conference outcomes (see Sect. 2.3.1). Another element of the training is represented by the **Scientific Guests** that the network members will host. There will be short stays of about 1 week for leading experts from all around the world. Their seminar will be broadcasted in real-time across the entire network and will later be uploaded to the CODA website. CODA members are also encouraged to broadcast within the network the key seminars or lectures held at their institute, after permission from the speaker.

Transferable skills (Dissemination, Entrepreneurship and Outreach)

Training available locally: The ESRs will learn **presentation techniques**, **scientific and popular science writing** from their local universities (see for example the courses offered by the Norwegian Research School in Climate Dynamics RESCLIM/CHESS in Bergen www.resclim.no/activities/courses/). The ESRs will also be encouraged to start writing groups at their institutes to improve networking with other researchers, but most importantly assemble a community supporting good science communication. Courses for **proposal writing** are also available locally as well as information days with funding agencies. CODA must also enable the ESRs to establish as entrepreneurs if such a business opportunity arises during their PhD. To this effect, the ESRs will follow the courses in **entrepreneurship** offered by the local Chambers of Commerce in the respective partner's city (for example in in Barcelona: www.barcelonactiva.cat/barcelonactiva/en/, Toulouse www.toulouse.cci.fr/creer-transmettre-construire-votre-projet-les-etapes-recommandees/passer-de-lidee-au-projet or Bergen: bergen-chamber.no/article.php?group_id=8557).

Network-wide training events: CODA proposes the following measures to make the ESRs gain **writing skills, critical reading and confidence for outreach**:

1. The ESR working group will be established during the **workshop on dissemination and outreach** where ESRs will learn from each other how to improve their writing (see Table 1.2b). The workshop is organized by UiB and NERSC, based on the consolidated in-house experience from RESCLIM (www.resclim.no). CODA will task the ESRs to write 2-3 blog posts a year about their research or topics relevant to CODA. The ESRs will peer-review each other's posts and give constructive feedback.
2. During the **first school on DA**, the dissemination of research results will be covered by a course in writing scientific articles (by UiB and NERSC) and use of multimedia web/video supports (by UiB).
3. In the absence of local writing groups, CODA will arrange monthly/bi-monthly remote writing groups where the ESRs meet online and give each other feedback on their writing.
4. During the **second school on climate predictions**, a beginner's course on writing proposals will also be included.
5. The **third summer school** will focus on **preparing the ESRs post-CODA strategy**: intensive training on writing proposals for both public funding and industrial funding. Each ESR will learn to identify societal-relevant topics within the scope of his/her PhD and adapt the ideas to the needs of an industrial partner or a public funding agency, define the objectives, plan the activities 3 years ahead and defend the proposal orally. The ESRs will review each other's proposals according to the guidelines given by the industrial partners or those from public funding agencies. On every school, experts from outside CODA and/or the CODA external Advisory Board (see Sect. 1.4) will be invited to give lectures, contributing to the prestige of the schools and to the quality of the training offer.

Sections 2.3 and 2.4 give further details on CODA's activities aimed at disseminating results and outreach.

Table 1.2b provides a complete overview of the network-wide events, conferences and school, along with the leading institutions, and tentative dates.

Table 1.2b - Main network-wide training events

	Main Training Events & Conferences	**ECTS (*if any*)**	**Lead Institution**	**Project Month (*estimated*)**
1	**Kick-Off Meeting (incl. ESR writing groups on KO meeting*)**	None	**NERSC**	**1-3**
2	**Workshop on Dissemination & Outreach (incl. establish ESR working groups)**	None	**UiB**	**3-12**
3	**Progress Meeting 1 (incl. ESR writing group meeting)**	None	**INRIA**	**12-15**
4	**School 1 – DA**	None	**ENPC**	**12-15**
5	**Progress Meeting 2 (incl. ESR writing group meeting)**	None	**BSC**	**24-28**
6	**School 2 – Climate Prediction**	None	**BSC**	**24-28**
7	**Progress Meeting 3 (incl. ESR writing group meeting)**	None	**RMI**	**36-39**
8	**School 3 – post-CODA strategy**	None	**NERSC/BSC**	**36-39**
9	**Final CODA conference**	None	**NERSC**	**46-48**

(*): meeting of the ESR writing groups to review posts and give constructive feedback.

1.2.2 Role of non-academic sector in the training programme

CODA gathers **four leading companies in the area of energy, oil and water resources: STATOIL, EDF, BKK and ACA in three European countries**. As partner organizations, they will contribute to multiple aspects of the training in CODA: they will **stimulate the ESRs reflection on the societal needs** for their research and then provide them with **opportunities to build their follow-on projects in niche topics** identified to exploit the fruits of their research**. They will host in their facilities up to three ESRs** each during their secondments. The ESR will present their project there (see Sect. 3.1). Specific details on the activities carried out at the Private Partner facilities are provided in Sect. 3.1.4. After the secondment at the partner organizations, the ESRs will share their work experience in a private R&D and consultancy environment with the other scientists in CODA, thus fostering the impact of the interplay between research and innovation through early demonstration of their work in commercial settings.
STATOIL has a consolidated record of research in DA for petroleum applications. The R&D department includes the worldwide pioneer experts in Ensemble Kalman Filter: **Prof. G. Evensen and Dr. R. Hanea**, who act as the scientists in charge for STATOIL in CODA. STATOIL has recently dedicated large efforts to the development of

ensemble DA methods to optimize the deployment of oil extraction facilities, so leading to a significant increase in efficiency and perforation costs. **STATOIL will interact in WP1, co-mentoring and advising on the theoretical research for ensemble-based methods**. In particular, STATOIL will contribute to structuring the PhD projects, and in some cases will directly participate to the co-supervision of 2 ESRs. **BKK and ACA will work with partners in WP2, while EDF with both WP1 and 2**.

At BKK, Ina T. Kindem holds a Ph. D. in dynamical meteorology. She has worked several years as a climate researcher at the Bjerknes Centre and contributed to the development of the first ESM in Bergen called Bergen Climate Model. At BKK she develops seasonal forecasts based on teleconnections and the dynamical states of the atmosphere and ocean. To ensure optimal use and planning of hydro power production reliable weather information on time scales from days to decades is important. Without multi-year reservoirs BKK is particularly vulnerable to seasonal variations in snow reservoirs and precipitation amounts. **As a representative of the user sector BKK will participate to co-supervision in WP2 with focus on the need of the end user as seen from a hydropower perspective**. The area of interest will be both for Northern Europe and Western Norway, and the temporal scale from weeks to decades.

EDF is strongly involved in CODA via Dr. N. Goudal who is the co-supervisor of ESR11 and **will host three ESRs, in its premises**. In connection with the electricity production, EDF has a strong expertise in hydro-environmental modelling and provides to ESR11 its own open-source suite of software Télémac-Mascaret. Besides, environmental data being increasingly accessible, we envisage the development of DA techniques to better estimate model parameters and predict the electricity production.

The Directive 2000/60/EC establishes the framework for Community action in the field of water policy, promoting sustainable water use based on a long-term protection of available water resources and contributing to the provision of sufficient water supply for sustainable, balanced and equitable water use. According to the Directive, **water managers such as ACA have to design the strategy for the forthcoming months to distribute water resources between agriculture use, human consumption (residential, commercial and industrial) and maintenance of the river's ecological flow**. To estimate future precipitation over the coming months and seasons is crucial to manage water reservoirs. Current practices are based on retrospective climatology, with an assumption that the past will also represent the future. **The objective of the secondment of the ESR10 to ACA is to apply seasonal forecast simulations to predict the future variability of precipitation to provide useful information for water management activities**.

All private partners will contribute actively to the CODA schools 1 and 2 presenting lectures related to their specific expertise as outlined in the Section "Meeting, Conferences and School" above. CODA will also benefit from other type of support provided by the private partners. For instance, STATOIL is the main sponsor of the international workshop on EnKF (co-organized with NERSC; Sect. 1.2.1), where top researchers from academies and industries are gathered: the workshop is now at its 11th edition (http://enkf.iris.no/). STATOIL is also involved and sponsors the bi-annual *Summer School on DA and its applications - Oceanography, Hydrology, Risk & Safety and Reservoir Engineering*. The next edition, the 5th will take place in the summer of 2017. CODA will largely benefit from this experience: the two experts from STATOIL will provide key advice on the School organization and setup, and the possibility exists to coordinate and merge the CODA DA School with the STATOIL 5th Edition in 2017 to where CODA ESRs will be encouraged to attend.

Table 1.2c – Summary of the Partners Participation

STATOIL	**1** – Participate in the Recruitment of ESR 1
	2 – External mentoring on ESR 1
	3 – Hosting Secondments for ESR 1, 2 and 3
	4 – Participation in the organization of School 1
EDF	**1** – Participate in the Recruitment of ESR 11
	2 – External mentoring on ESR 11
	3 – Hosting Secondments for ESR 4, 5 and 11
	4 – Participation in the organization of Schools 1 and 2
BKK	**1** – Participate in the Recruitment of ESR 8
	2 – External mentoring on ESR 8
	3 – Hosting Secondments for ESR 7 and 8
	4 – Participation in the organization of School 2
ACA	**1** – Participate in the Recruitment of ESR 10
	2 – External mentoring on ESR 10
	3 – Hosting Secondments for ESR 10
	4 – Participation in the organization of School 2

1.3 Quality of the supervision

NERSC (the Coordinator) has hosted PhD students since the early 1990s, and there are an average of 3 successful PhD dissertations each year ever since. Most of the doctoral students are registered at the University of Bergen and follow its standard doctoral curriculum, and so will be for ESR 1 and 7. From the review of Earth Sciences in Norway to the Research Council of Norway: "*NERSC makes a significant contribution to the education of Masters and PhD students in Earth Sciences, mainly in collaboration with UiB. It has also supported a large number of international Doctoral students as part of a Nansen Fellowship program*". Alberto Carrassi has years of expertise in DA theory and applications to geoscience and has been involved in several international research projects. He has co-supervised 2 PhD theses and supervised 2 Master theses. Laurent Bertino is a research director at NERSC and is an expert of DA, stochastic modelling and oceanography and has largely contributed to the migration of theory into multidisciplinary operational applications, mainly with the TOPAZ system. He presently leads the Arctic Marine Forecasting Center of the Copernicus (http://marine.copernicus.eu, Arctic MFC) project and has supervised 5 PhD students. NERSC organises summer schools on climate research and participates to similar short-term schools, teaching DA, on a yearly basis.

Stéphane Vannitsem (**RMI**) has been teaching "dynamical meteorology" (Mnemonic: PHYS-F-450) at a master level at the Université Libre de Bruxelles for about 10 years, and has been advisor or co-advisor of 7 master theses and 1 PhD thesis. He has also followed 6 student trainings at RMI, and regularly appointed in PhD's and master thesis' evaluation committees. ESR 2 will be enrolled at the Université Libre de Bruxelles. Stephane Vannitsem has regular contacts with the members of the CENOLI (Center for Nonlinear Sciences) group at the Université Libre de Bruxelles led by Prof. Gaspard, and with the 'George Lemaitre Center for Earth and Climate Research" at the Université Catholique de Louvain, led by Prof. Fichefet.

ENPC. The student will be enrolled to the SIE (Science Engineering and Environment) doctoral School of University Paris-Est of whose ENPC is a founding institute member. As a consequence, the successful PhD candidate will graduate from Université Paris-Est. She/He will be hosted at CEREA, a joint research laboratory between ENPC and Électricité de France R&D. CEREA has currently more than 10 PhD students. There is an average of 3 to 4 PhD dissertations each year on topics related to atmospheric environment. About one of them on average is dedicated to DA with applications to atmospheric chemistry. In the 1st of January 2015, CEREA has joined the Institute Pierre-Simon Laplace (IPSL, http://www.ipsl.fr/), which is a significant contributor to the IPCC reports. Marc Bocquet has supervised or co-supervised 12 PhD students since 2005, and about 10 master students. He also coordinates the SAMA group (Statistics for Analysis, Modelling and Assimilation) of IPSL.

INRIA is the only French public research body fully dedicated to computational sciences. Dr. Arthur Vidar is an expert of variational DA for ocean applications and Dr. Laurent Debreu is a leading expert of multi-scale numerical ocean modeling and variational DA. The AIRSEA team regularly hosts 2-3 new PhD students per year.

UR is home to the DA Research Centre, an academic group in the School of Mathematical and Physical Sciences involving 9 academic staff and over 20 research staff and students. The group works on all aspects of DA, from developing theoretical ideas in simplified models, to practical applications using satellite data in large complex systems. Amos Lawless has over 20 years' experience in DA, in the operational and academic environments. He was recently involved in a European Space Agency project on CDA, in which he interacted regularly with ECMWF, and is currently PI on 2 projects in the area of CDA. He has supervised 7 PhD students and currently supervises a further 4. Dr Alison Fowler is a research fellow of the National Centre for Earth Observation, based at the University of Reading. She has recently been working with Dr Lawless on coupled atmosphere-ocean DA. Previously she worked with Prof Peter Jan van Leeuwen at the University of Reading on measuring observation impact in highly non-linear DA.

CONICET-IFAECI currently hosts 16 PhD students who are enrolled at the University of Buenos Aires. Among these, two PhD theses are dedicated to DA at present. Alexis Hannart has several years of expertise in the development of statistical methods with several applications in climate science, in particular in the field of detection and attribution, as well as in DA's statistical aspects. He coordinates the field "mathematical methods for weather and climate studies" at IFAECI. Within this field, the group involved on DA research also includes two recognized experts (Juan Ruiz, Manuel Pulido) and it benefits from well-established international collaborations with research groups in Chile (A. Osses), in the US (E. Kalnay) and in Japan (T. Miyoshi). In Europe, the DA research group has strong links with members of the SAMA group of IPSL (M. Bocquet, P. Naveau, O. Talagrand) as well as an active collaboration with DA experts at IFREMER and INRIA (P. Tandéo, R. Fablet), and finally with Alberto Carrassi at NERSC. These fruitful collaborative links have lead to the organization of several international events on DA and two regional intensive courses on DA over the past few years. Over the past two years, Alexis has organized two international workshops on DA and got involved as co-advisor into the supervision of two PhD students working on the development of statistical methods.

UiB is the primary academic marine research organization in Norway with internationally acknowledged expertise in physical oceanography, climate research, and meteorology. The ESRs 1, 7 and 8 will take PhD degrees at the Geophysical Institute (GFI), UiB. The GFI provides sound and stimulating teaching environments for PhD students, with currently more than 40 active PhD students. Noel Keenlyside has extensive experience in climate variability, modeling and prediction, and currently coordinates several national and international projects on climate prediction and the development of the Norwegian Climate Prediction Model (NorCPM). He is experienced in the supervision of ESRs, and has supervised 8 PhD students and is currently supervising 4 PhD students. Five postdoctoral scientists in his group will also help in the training and supervision of the ESR. François Counillon has a dual position at UiB and NERSC. He is the leader of the DA and prediction group at NERSC, involved in the development of several prediction systems, namely: the NorCPM and the TOPAZ system.

BSC is one of the four hosting members of the European PrACE Research Infrastructure as well as one of the Spanish "Severo Ochoa Centre of Excellence" awarded by the Spanish Government. Over the years, the department has been active in numerous European projects and most of BSC group leaders are also university professors, with broad experience in teaching. BSC has participated in 4 ITNs from FP7 and one from H2020, and has been involved in the organization of summer schools, workshops and other training events related to climate modeling and atmospheric sciences. The director of the Department, Prof. Francisco J. Doblas-Reyes, is an active member of the climate prediction community, where he plays a leading role in the connection between global climate modeling and climate services. He is currently the supervisor of two PhD students. Dr Guemas is head of the climate prediction group; she has so far supervised 1 PhD student and she is currently supervising two PhD students. Dr Massonnet is a research fellow from the Université Catholique de Louvain (UCL) currently undertaking a long-term scientific visit at BSC, expert on sea ice DA. Francisco Doblas-Reyes, Virginie Guemas and François Massonnet have given several lectures at the university and have solid experience in mentoring MsC/PhD students.

CERFACS is a research institute where a great number of PhD students have been hosted since 1988 working in computer sciences applied in the field of computational fluid dynamics. The main research axis at CERFACS are climate modeling, combustion, aerodynamics and algorithmic. Most of the doctoral students are registered at Université Paul Sabatier (UPS) in Toulouse, in École doctorale that correspond to their research project. As for climate related students, most of them are related to the Ocean-Atmosphere École doctorale at UPS, still some of them are registered at other universities in France (Paris, Grenoble, Montpellier...) depending on their supervision configuration. CERFACS occupies a leading position regarding climate modeling and coupling software development. CERFACS also has a strong expertise in DA applied to geosciences with an historical background in oceanography and a strong will to broaden the scope of application for DA towards other geosciences projects such as hydraulics and hydrology for instance. Sophie Ricci has been leading this activity since 2010 and supervised about 10 PhD students (co-supervision).

1.4 Quality of the proposed interaction between the participating organisations

1.4.1 Contribution of all participants to the research and training programme

The main strength of CODA is the interdisciplinary composition of the network, and the training effort is organized along 4 axes that reflect the spectrum of expertise brought in by all CODA partners. The scientific training of the ESRs will address the following skills (see also Table 1.2a), using the measures (seminars, workshops, schools and visiting scientists) described in Sect. 1.2, and the regular courses offered at members institutes described in Sect. 1.4.2 and 1.4.3. These are summarised below, along with the distribution of duties and responsibilities:

1) DA. Leading Partners: **NERSC**, **ENPC**, **INRIA, CERFACS**, **UR**, **STATOIL** and **EDF**
The ESRs will be trained on the foundation of the state estimation theory, filtering and optimal control. This encompasses knowledge of probability and statistics, linear algebra and differential calculus. The partners have strong expertise in DA and will provide the ESRs on-site and on-line training and guidance. ESRs will share bibliography and numerical tools such as the educational DA toolbox developed at NERSC (http://enkf.nersc.no/Code/EnKF-Matlab) that already includes different assimilation methods (EnKF, ETKF, among other) in several models.
2) **Climate Prediction**. Leading Partners: **UiB**, **BSC, BKK and ACA**
The ESRs will be trained on climate dynamics with special emphasis on the initialization of seasonal-to-decadal forecast. Advanced methodology will be considered to constrain each of the system compartments (assimilation

window, multi-stage initialisation, iterative methods, coupled updates). This training embeds knowledge of oceanography and climate system dynamics and thermodynamics.

3) **Dynamical System**. Leading Partners: **RMI and NERSC**
The ESRs will learn the fundamental of the dynamical systems theory and nonlinear analysis. This will include Lyapunov stability, chaos theory and numerical methods therein. The ESRs supervised by RMI will be following courses on nonlinear sciences and dynamical meteorology at ULB as well as during the CODA schools for all the participants.
4) **Scientific Programming**. Leading Partners: **All, notably BSC and CERFACS**
All ESRs will be trained to program using Fortran-90 on parallel high-performance computing facilities (HPC), Matlab and Python. They will also learn the use of R for statistical analysis and advanced graphical visualization of geophysical fields. In particular, the ESRs will learn how to prepare, monitor and post-process simulations using advanced computing platforms.

1.4.2 Synergies between participants

The partners of the consortium have different levels of expertise with respect to the four disciplines listed above. Synergy is warranted by the natural complementarity of the participants and by the fact that most of them **are already involved, or have been involved, in a number of common research projects, co-authoring papers and sharing PhD students**. CODA will exploit further these synergies by enhancing the exchange of knowledge between large climate modelling communities (*e.g.*, EC-Earth and NorESM), providing an opportunity to share parts of their DA and coupled modelling tools and in turn facilitating future collaborative research projects. **CODA members have a supervisorial arrangements for non-university based ESR** (see Sect. 1.2.1), meaning that there is a clear established agreement between ESR based at an academic partner that is not entitled to issue doctoral titles and a local close university (the exact list is provided in Sect. 1.2.1). These agreements, that pre-exist CODA, are based on a consolidated collaboration between the research institute and the local university. **These Universities offer a wide spectrum of courses**, some of them given by some of the scientists involved in CODA: 4 of them on DA, 1 on climate dynamics, 1 dynamical systems (See Part B2, *Beneficiaries* for the details and Table 1.2a for an overview). **All these courses are open to all ESRs in CODA**, no matter the University where they are appointed. Each ESR, with the support of her/his supervisor and the aid from the CODA management, may attend some or all of them.
The ESRs will be involved in a dense intersection of **secondments to other institutes of the network, and** – for 9 ESRs out of 11 – **to partners from the industrial/private sector** (see Sect. 3.1). One goal is to maximize the exchange of expertise between partners. Another key motivation for secondment is **the attendance to courses offered at one of the universities linked to CODA that are not given at the host location** (see Sect. 1.4.3). The secondment plan will also be made in order to expose the ESRs to the widest possible spectrum of training offer within the network.

1.4.3 Exposure of recruited researchers to different (research) environments, and the complementarity thereof

Not a single country alone could program training with all complementary skills that CODA incorporates. Such an effort requires funding schemes explicitly designed to support international collaboration such as the ITN. Three different types of **work environments** will be made available to each ESR: (partners counted between parentheses)

1. **Universities** (3) offer the full depth of long academic traditions with focus on fundamental research questions and teaching. They can offer academic careers to ESRs.
2. **Research institutes** (6) have a more applied focus than universities, more pressure from external projects with concrete deliverables, although research and writing publications remains a central objective. They can offer research positions to ESRs if these can be funded by research projects of societal relevance.
3. **Non-academic partners** (4) do not have any obligation to write scientific publications but rather need to address concrete questions, with results that they can provide to their users within a time horizon of weeks/months rather than years. They will react rapidly if an opportunity for profit arises and can provide jobs accordingly to the ESRs.

All three perspectives should be experienced within the time of a PhD in order to take maximum benefits of the respective strengths of each environment: the most precise definitions of mathematical concepts and natural processes she/he will find among academic partners and the most precise definition of a practical societal need will be given by the non-academic partners. From there, **every ESR has the option to reflect on her/his research topic from either a top-down (from fundamental ideas to applications) or a bottom-up perspective (new ideas inspired by practical problems)**. Being exposed to a variety of working environments and European countries from the CODA partners will also help the ESRs projecting themselves to their future career and gather the funds for their post-CODA project.

Specific network-wide training on complementary skills will be organized (see for instance the specific training in dissemination and outreach described in Sect. 1.2.1), taking advantage of the experience of our private partners in, for example, software development, entrepreneurship, project management, outreach, training in Ethics, IPR and environmental issues. To minimize travels, these training events will take place at the same time as the progress meetings, but CODA will also make use of Facebook, Linkedin groups, web-seminars or Adobe Connect when necessary. We will work with doctoral schools to make sure that CODA training events on complementary skills are fully recognized (in term of credits) for the student's PhDs.

2. IMPACT

2.1 Enhancing the career perspective and employability of researchers and contribution to their skills development

The ESR(s) in CODA will benefit from top-level training and outstanding mobility opportunities across leading laboratories and universities in EU and at four major private companies, world leaders in oil, energy and water production and distribution. The international mobility will expose the young ESRs to different cultures (in different countries) so that they will develop their language and communication skills as well as their personal abilities much faster than it would be possible at a single institute/country. Internships and visits to private partners will help them be at ease in the non-academic sector. ESRs will gain maturity, openness, and practical transferable skills that will help them become key actors in the future of European research in climate.

Specific Actions:

- CODA fellows will learn to use each other's expertise to set themselves ambitious goals, for example by performing model and/or DA method inter-comparisons or coordinated sensitivity experiments. They will broaden their scientific perspective by making links between different disciplines.
- **The ESRs will participate to develop their own research project**, carrying out their own mobility plan within the network and assessing their need for complementary skills, thus gaining experience in project management. Research in climate science requires nowadays a strong collaborative network in order to address the multi-facets character of the scientific questions: CODA will naturally train its ESR to establish, maintain and benefit from the collaborative work.
- The ESR(s) will prepare their own **career plan** at the end of the 1st year of their PhD. The career plan will be then continuously updated by the ESR and submitted to the supervisors and the network for monitoring every 6 months. It will be discussed within the network during the PM meetings. The final career plan will be discussed during the **CODA third summer school** "***preparing the ESRs post-CODA strategy*"** (Section 1.2) and later submitted with the PhD thesis submission (see Milestones & Deliverables in Sect. 3).

After CODA:

- The career plan will be oriented to **academic institutions, climate services (a fast-growing sector with new job opportunities, ec.europa.eu/research/environment/index.cfm?pg=climate_services), regular calls for service enhancement proposals, and the private sector**. The ESR training as **climate system forecasters** and their intimate **understanding of key processes** will be valuable in all these sectors.
- The CODA team will also assist the ESRs who wish to **pursue a career in the academic sector** to apply for prestigious post-doctoral programs such as **Marie Curie individual fellowships**.
- Gaining skills in the use of complex climate models, prestigious tools within the EU High Power Computer network (ec.europa.eu/programmes/horizon2020/en/h2020-section/high-performance-computing-hpc), will also undoubtedly enhance the ESR future job opportunities well beyond the academic arena.

2.2 Contribution to structuring doctoral/early-stage research training at the European level and to strengthening European innovation capacity

An immediate impact of CODA will be to **strengthen cooperation across Europe** among key institutions and centers working on DA and climate prediction, and with industry partners. CODA will demonstrate the need for such network to train much-needed researchers with the key expertise to advance the skill of climate predictions for their increased use in climate services for society. In the EU, " *[…] there is increasing demand for translating the existing wealth of climate data and information into customised tools, products and information ('climate services'). **Climate services** have the potential to become the intelligence behind the transition to a climate-resilient and low-carbon society. They can help decision-makers take informed decisions in order to boost resilience and adaptation capacity by addressing existing or emerging risks.*" (see //bookshop.europa.eu/en/a-european-research-and-innovation-roadmap-for-climate-services-pbKI0614177/). The main impact of CODA in the EU capacity for early-stage research training will be **to force the restructuring of PhD programs in climate science having the required interdisciplinary competence**

and links to industry/climate services. Similar to the concept of the ECMWF for the weather forecast, there is interest in centralizing climate prediction activities in Europe: CODA training and network could be important also in this initiative.
The EU has launched the ambitious **Copernicus Services** covering all aspects of our planet's global environment (www.copernicus.eu/pages-principales/services/). These services represent an enormous opportunity for European businesses who will first be able to harness these powerful sources of information to propose innovative services to society and reduce anthropogenic environmental and climate footprint (for example reducing electricity consumption, reducing environmental footprint of fossil fuel exploitation), but they are unlikely to reach their potential without an ambitious training programme. **The vision of CODA is that the exchange of knowledge is the key of a successful integration of Copernicus services to the private sector** and that knowledge needs to be at the state-of-the-art. The Copernicus services primarily targets are the *Climate Change Services* and the *Marine Services*, in which the partners already hold (Arctic MFC of CMEMS at NERSC) or participate significantly to precursor projects (MyOcean, SWARP, MAIRES, EUPORIAS, SPECS, CLIM-RUN).
The involvement of the private sector is central in CODA and for the impact in structuring the future EU training platform for PhD in climate science. The four industrial partners are ideal examples of economical sectors needing updated climate information and using of this information according to their own needs (*i.e.* water management, reservoir capacity etc.). **This is the key contribution of the private partner in CODA: proving the strategic importance of climate information and training the ESR to manage these data in a cost-effective way.** Finally the ESRs will take advantage of the CODA cutting-edge expertise and create their own opportunities either in the private sector or in academia by submitting targeted proposals for research grants.

2.3 Quality of the proposed measures to exploit and disseminate the project results

2.3.1 Dissemination of the research results

The dissemination strategy in CODA is organised along three axes: 1. Academies, 2. General Public and 3. Media. This section describes mainly the CODA plan in regard to the first axis, the Academies, and is thus intended for a qualified arena. We largely refer to Section 2.4.1 for the communication approach to the broader audience and to the WP4 description in Sect. 3.1.1.
A key characteristic of CODA is that it involves two close but distinct disciplines, DA and Climate Prediction (linked here via the mathematical dimension of the research strategy) that have their own scientific communities, meetings and agendas. Dissemination of research results will thus be confronted with this aspect.

JOURNALS – A representative, albeit non-exhaustive, list of relevant journals includes *Quarterly Journal of the Royal Meteorological Society, Tellus, Monthly Weather Review, Atmospheric Science Letters, Climate Dynamics, Journal of Climate, Journal of Geophysical Research, Geophysical Research Letters*. When possible, CODA will encourage submission to journals that are **open access**, and will use **web-based archive** such as *Arxiv* (arxiv.org) to enhance visibility vie e-print publications already during the review process and to the extent of which this does not conflict with the copy right policy of the journal where the article is being reviewed. CODA team is committed to apply for a **Special Issue** in the aftermath of the final conference. A EU-based publisher will be chosen for the scope such as the European Geoscience Union Publisher that offers several open access journals of large impact factors already largely found in the CODA members research record.

CONFERENCES – Large conferences, such as the *General Assembly of the European Geoscience Union* (EGU - www.egu2016.eu), where some CODA members are also conveners in relevant sessions in DA and Climate Science, offer the advantage of a large audience with mixed expertise that matches with the expected research outcomes of CODA. The American counterpart of the EGU represents a similar large conference hub, the fall meeting of the *American Geoscience Union*, and it will also considered as well as the *DA International Symposium*, or the *International Union of Geodesy and Geophysics* (IUGG). CODA will also be present on more targeted conferences of the Copernicus community, for example the European Space Solutions week (www.european-space-solutions.eu).

ESRs will be encouraged to submit contributions to relevant meetings and conferences. CODA will also rely on the online list of DA-related conferences (www.met.reading.ac.uk/~darc/conferences/) maintained by UR (member 5 in CODA) and that will be linked via the CODA website.

The CODA website will be setup in the first 3 months by the partners leading WP4. UiB will take responsibility of the website maintenance and update. It will be updated by the PhD projects and the associated results explained in *layman's terms*. The website will include the list of publications and presentations and it will be complemented by newsletters disseminated once a year to the partners and their networks. A Wiki-Page on *CDA* will also be set up (the Wikipedia page does not exist as of today). Indeed the CODA website will address the three axes of dissemination mentioned above. The CODA website will contain an online example of coupled DA similar in spirit to the Monash

Simple Climate Model (monash.edu/research/simple-climate-model/mscm/overview_i18n.html) but in which DA can switched from strongly coupled to weakly coupled and uncoupled.

2.3.2 Exploitation of the results and intellectual property

The **results from WP1** will help producing free educational open-source codes useful for other graduate students and researchers world-wide, such as NERSC's Matlab code (enkf.nersc.no/Code/EnKF-Matlab), Statoil's Ensemble Reservoir Tool (ERT - ert.nr.no/wiki/index.php/Main_Page) or NERSC's operational EnKF code (svn.nersc.no/enkf); the codes will be protected by one of the adapted licenses (see opensource.org/licenses).
The r**esults from WP2** will contribute to existing complex climate modeling and DA systems such as EC-Earth, NorCPM, TELEMAC and TOPAZ, which are part of high-profile projects like those underlying the IPCC or the Copernicus services. These complex codes already follow their own dissemination strategies and IPR rules and the ESRs will obtain fair citations for their contributions to their developments. The CODA project will eventually strengthen the commonalities of some of these codes but each partner institute will remain sole owner of its background.
The common points between the codes adopted in CODA will strength the liaisons among the members, both academic and non-academic, making natural the future career prosecution of the ESRs after the project completion into another of its members. The shoulder-shoulder work on coding will fortify the member's collaboration seeding the basis for teaming up for **future relevant EU calls for proposals**. The developed **codes may have commercial value**, as it has been for the TOPAZ system in different Joint Industry Projects (SeaFINE, ART JIP). In general, the commercial value lies in the licensing of output products (data files) rather than in the source code, which can remain an open-source freeware. The CODA industrial partners can be involved in their commercial use without reducing the level of distribution of the source codes. However, in general we do not foresee that patents will come out from this project.
CODA will contribute significantly to the awareness and to the setup of the Copernicus *climate services* for society by training a new generation of scientists ready to become key actors in this new framework: *transforming of the climate-related data and other information into customised products such as* ***projections, trends, economic analysis, advice on best practices, development and evaluation of solutions, and any other climate-related service liable to benefit that may be of use for the society***.

2.4 Quality of the proposed measures to communicate the project activities to different target audiences

2.4.1 Communication and public engagement strategy of the project

The CODA strategy combines targeted communication to "**flagship users**" and broad public dissemination to spread the new concepts to society at large. "Flagship users" associated to the project will provide concrete examples of returns on investment in DA research and these examples will motivate other potential users to follow the same path, proving in turn that research does lead to both valuable returns on investment and (invaluable) evolutions of a knowledge-based society. The ESRs will take the opportunity of their stay at the non-academic partner to present their work there and initiate follow-up projects, either within the industry or supported by public funding if appropriate. They will participate to the CODA conference (see chapter 1.2.1), which will contribute to the international visibility of the project.
The ESRs will contribute actively in communicating the project activities using skills they have achieved during CODA training programs (see chapter 1.2.2.). Each ESR should become able to explain his PhD to the first passer-by in the street. This ability will be trained in addressing a younger generation, in the goal to motivate more of them for higher education and research. Each ESR will then be a Marie Curie Ambassador either holding a presentation in a high school / college or organizing a visit to his/her own host institution. The PhD students will also be enrolled in public outreach happenings, like the **European Researcher's Nights** (ec.europa.eu/research/researchersnight/about_en.htm) or the **Research Days** in Bergen each year in September (www.forskningsdagenebergen.com/).
As part of the **CODA communication approach to media**, the ESRs will also have to describe their topic in an article aimed for a broad public (for example, *La Recherche* magazine in France, Bertino and Wackernagel, 2004 or a local newspaper). Their activity in both online and live debates will also be evaluated as part of their progress. They can contribute to related blogs (for example in Arctic climate neven1.typepad.com/) or happenings bringing together scientists and non-experts (for example in the frame of the Climate Snacks www.scisnack.com/event-where-the-science-story-burns/). The objective is to confront the students to the societal expectations for our research, and to train them at communicating in written and oral forms to a non-specialized audience. To this effect, the simple online coupled DA example will be adapted in a "basic" version. Each **ESR will be encouraged to take part in at least one**

event aimed at the general public, either at his/her institution or in collaboration with other partners, showing the two facets of DA (theoretical and applied). These public events will be announced on the CODA web site.

3. QUALITY and EFFICIENCY of the IMPLEMENTATION

3.1 Coherence and effectiveness of the work plan

3.1.1 Work Packages Description

The content and organization of the work packages is given in the four Tables that follow, one for each WP.

Table 3.1a – Description of Work Packages (4 tables)

WP Number: **1**	Start month **1** – End Month **48**
WP Title: **Advanced DA methods for coupled dynamics**	
Lead/Co-Lead Beneficiary	**ENPC/INRIA – Marc Bocquet/Arthur Vidard**
Objectives: **Development of CDA Methods**	

Distribution of Work and Role of Partners:

1. **NERSC**
   Supervise ESR 1 working on PhD Sub-Project 1.1 : *Ensemble based DA methods for coupled systems*
   Secondment and Co-Supervision for ESR 2 and 3
2. **RMI**
   Supervise ESR 2 working on PhD Sub-Project 1.2: *Low-frequency variability and predictability of ocean-atmosphere coupled systems*
   Secondment for ESR 1 and 6
3. **ENPC** (WP Leader)
   Supervise ESR 3 working on PhD Sub-Project 1.3: *Error dynamics characterization within an ensemble-variational DA system*
   Secondment and Co-Supervision for ESR 1 and 5; Secondment for ESR 8 and 11.
4. **INRIA** (WP Co-Leader)
   Supervise ESR 4 working on PhD Sub-Project 1.4: *Multigrid preconditioning for variational DA*
   Secondment for ESR 5, 9 and 11.
5. **UR**
   Supervise ESR5 working on PhD Sub-Project 1.5 *Observation impact in coupled variational DA.*
6. **CONICET**
   Supervise ESR 6 working on PhD Sub-Project 1.6 – *Assimilation of time-averaged observations with application to detection and attribution of climate change.*

Description of Deliverables:

Deliverables of WP1 SubProj 1.1: **Ensemble based DA methods in coupled systems**

D1.1.1 *Comparison of standard EnKF in different regime of scale separation – Article submitted to DA journal (month 16 of PhD thesis)*
D1.1.2 *Adaptive EnKF for coupled system – Articles submitted to a DA journal (PhD thesis submission + 3 months)*

Deliverables of WP1 SubProj 1.2: **Low-frequency variability and predictability of ocean-atmosphere coupled systems**

D1.2.1. *Dynamics of instabilities in coupled dynamics - Article submitted to a nonlinear/geoscience journal (Month 15 of the PhD)*
D1.2.2 *Dynamics of error beyond the linearized regime - Article submitted to a nonlinear/geoscience journal (Month 24 of the PhD thesis)*
D1.2.3 *Impact of DA on the error dynamics - Article submitted to a nonlinear/geoscience journal. (PhD thesis Submission + 2 months)*

Deliverables of WP1 SubProj 1.3: Error dynamics characterization within an ensemble-variational DA system

D1.3.1 *Numerical dynamical analysis of the iterative ensemble Kalman smoother (IEnKS) - Article submitted to a DA journal (month 15 of PhD thesis)*
D1.3.2 *IEnKS in the unstable subspace; tests on low-order Lorenz models - Article submitted to a DA journal (month 24 of PhD thesis)*
D1.3.3 *Applications with a coupled low-order air quality model - Article submitted to a DA or atmospheric chemistry journal (PhD thesis submission + 3 months)*

Deliverables of WP1 SubProj 1.4: Multigrid preconditioning for variational DA

D1.4.1 *Theoretical design of the new multigrid-based preconditioning techniques and application to an intermediate complexity uncoupled system – Article submitted to a DA journal (month 18 of PhD thesis)*
D1.4.2 *Theory and applications with a coupled low-order model - Article submitted to a DA journal (PhD thesis submission + 2 months)*

Deliverables of WP1 SubProj 1.5 Observation impact in coupled variational DA

D1.5.1 *Development of new measures for analysis sensitivity to observations – Article submitted to a DA journal (month 12 of thesis).*
D1.5.2 *Development of new measures for forecast sensitivity to observations – Article submitted to a DA journal (month 22 of*

thesis).
D1.5.3 *Observing system design experiments with new sensitivity measures in a single-column model – Article submitted to a geosciences journal (PhD thesis submission + 2 months).*

Deliverables of WP1 SubProj 1.6: Assimilation of time-averaged observations with application to the detection and attribution of climate change
D1.6.1 *Evaluation of recent methods for assimilating time-averaged observations on low-order coupled models (month 12 of PhD thesis)*
D1.6.2 *Design of a new method for assimilating time-averaged observations - Article submitted to a DA journal (month 24 of PhD thesis)*
D1.6.3 *Application to Detection and Attribution of climate change within a forced low-order climate model - Article submitted to a DA or climate journal (PhD thesis submission + 3 months)*

WP Number: **2**	Start month **1** – End Month **48**
WP Title: **Exploitation of DA methods for initialization, attribution and parameter calibration of environmental systems**	
Lead/Co-Lead Beneficiary	**BSC/CERFACS – Virginie Guemas/ Sophie Ricci**
Objectives: **Exploitation of DA methods for applications with coupled environmental models**	

Distribution of Work and Role of Partners:

1. **NERSC**
   Supervise ESR 7 working on PhD Sub-Project 2.1 – *Multi-methods CDA*
   Secondment for ESR 10.
2. **UiB**
   Supervise ESR 8 working on PhD Sub-Project 2.2 – *Strongly CDAfor seasonal-to-decadal prediction*
   Secondment and Co-Supervision for ESR 10. Secondment for ESR 9.
3. **BSC** (WP Leader)
   Supervise ESR 9 working on PhD Sub-Project 2.3: *Toward reduced surface biases in EC-Earth 3 climate forecast system through parameter calibration based on the Ensemble Kalman Filter*
   Supervise ESR 10 working on PhD Sub-Project 2.4 – *Impact of the balanced initialization of dynamical climate forecasts on forecast quality*
   Secondment for ESR 1, 2, 3, 6
   Co-Supervision and Secondment for ESR 4.
4. **CERFACS**
   Supervise ESR 11 working on PhD Sub-Project 2.5: *Ensemble DA for coupled sediment-hydrodynamics modeling in estuaries*
   Secondment for ESR 4 and 7.

Description of Deliverables:

Deliverables of WP2 SubProj 2.1: Multi methods coupled DA
D2.1.1 An new idealized coupled adaptive-fixed grid system (*month 12 of PhD thesis, paper I*)
D2.1.2 Multi-methods DA experiments in the new idealized system (*month 24 of PhD thesis, paper II*)
D2.1.3 Good practices for multi-method DA (*month 36 of PhD thesis, paper III*).

Deliverables of WP2 SubProj 2.2: Strongly coupled DA for seasonal-to-decadal prediction
D2.2.1 *Implementation of the leading averaged coupled covariance in NorCPM (month 12 of PhD thesis; paper I)*
D2.2.2 *Exploring improved coupled covariance and variational framework (month 30 of PhD thesis; Paper II)*
D2.2.3*Demonstration of strongly coupled DA in real framework (month 36 of PhD thesis; Paper III and PhD thesis submission)*

Deliverables of WP2 SubProj 2.3: Toward reduced surface biases in EC-Earth 3 climate forecast system through parameter calibration based on the Ensemble Kalman Filter
D2.3.1. *Mechanisms controlling the development of surface biases in EC-Earth3.1 - Article submitted to a climate dynamics journal (Month 15 of the PhD)*
D2.3.2 *Validation of the parameter estimation in EC-Earth - Article submitted to an applied science journal (PhD thesis + 2 months)*
D2.3.3 *Correction of General Circulation Model biases using DA - Article in an oceanography journal. (PhD thesis + 3 months)*

Deliverables of WP2 SubProj 2.4: Impact of a balanced initialization of dynamical climate forecasts on forecast quality
D2.4.1. *Illustration of the links between the drift and the forecast quality in S2S climate predictions (Month 18 of PhD thesis)*
D2.4.2. *Recommendations for operational climate forecast institutions concerning the relevance of implementing balanced initialization of climate forecasts (Month 36 of PhD thesis)*

Deliverables of WP2 SubProj 2.5: ***Ensemble DA for coupled sediment-hydrodynamics modelling in estuaries***
D2.5.1 *Validation of the TELEMAC2D model for the Gironde estuary with and without SISYPHE coupling. - Article in an hydrodynamics journal (Month 18 of the PhD Thesis)*
D2.5.2 *Gathering available in-situ data* completed *(Month 18 of the PhD Thesis)*
D2.5.3 *Implementation of the ensemble based DA for TELEMAC2D achieved. (Month 24 of the PhD Thesis)*
D2.5.4 *Coupled TELEMAC2D and SISYPHE with DA- Article in an hydrodynamics journal (Month 36 of the PhD Thesis)*

WP Number: **3**	Start month **1** – End Month **48**

WP Title: **Management & Network-Wide Training**	
Lead/Co-Lead Beneficiary	**NERSC – Laurent Bertino/Alberto Carrassi** + Project Manager
Objectives: **Management of the Project and Supervision of the Training**	

Distribution of Work and Role of Partners:

- **NERSC -** WP Leader
  Managing the Project:
  1. network management structure: management team, supervisory board, training and recruitment committees (see Sect. 3.2);
  2. oversee the recruitment of ESRs;
  3. organize progress meetings and reporting;
  4. financial management.

  Organizing the Network-Wide Training (based on Section 1.2):
  1. organize and oversee the progress meetings and reporting
  2. organize and supervise the three CODA schools and the training events
  3. organize the writing groups for ESR in the progress meeting
  4. coordinate the training offered locally with those at the network level
  5. compile and make available information regarding skills audits, needs and available training in complementary skills;
  6. ensure the flow of information in the network, including job/career opportunities;
- **UiB, ENPC and BSC**
  Organizing the Network-Wide Training:
  1. organize workshop in dissemination and outreach and coordinate the training in climate prediction **(UiB)**
  2. coordinate the CODA school 1 in DA (**ENPC**)
  3. coordinate the CODA school 2 in Climate Prediction (**BSC**)
  4. coordinate the CODA school 3 on the CODA exit strategy (**UiB**)

Description of Deliverables:

- **D3.1** – Selection of the Supervisory Board and Training and Recruitment Committees (Month 1)
- **D3.2** – 1st Financial Status Report and 1 Year Projection (Month 1)
- **D3.3** – Kick-Off Meeting Organization (Month 1)
- **D3.4** – Recruitment Start (Month 3)
- **D3.5** – ESR mobility plan (Month 4)
- **D3.6** – Network-wide Training & Secondment Plan (Month 6; see also Section 1.2.2 for secondment to the industrial partners)
- **D3.7** –Workshop on Dissemination & Outreach (Month 3 – 12; see Section 1.2.1)
- **D3.8** – CODA School 1 on DA (Month 12 - 15; see Section 1.2.1)
- **D3.9** – 2nd Financial Status Report and 1 Year Projection (Month 13)
- **D3.10** – Progress Meeting 1: ESR project status and career plan monitoring (Month 12-15)
- **D3.11** – 3rd Financial Status Report and 1 Year Projection (Month 25)
- **D3.12** – Progress Meeting 2: ESR project status and career plan monitoring (Month 24-28)
- **D3.13** – CODA School 2 on Climate Prediction (Month 24-28; see Section 1.2.1)
- **D3.14** – Progress Meeting 3: ESR project status and career plan monitoring (Month 36-39)
- **D3.15** – Submit the ESR career plan (Month 38)
- **D3.16** – CODA School 3 on the post-CODA strategy (Month 36-39; see Section 1.2.1)
- **D3.17** – Final Conference (Month 46-48)
- **D3.18** – Final Management Meeting (Month 48)

WP Number: **4**	Start month **6** – End Month **48**
WP Title: **Dissemination and Outreach**	
Lead/Co-Lead Beneficiary	**UiB – Noel Keenlyside / BSC – Francisco Doblas-Reyes** + NERSC - Project Manager
Objectives: **Dissemination of Scientific Results to Experts and Broad Public**	

- Setup and maintain the CODA website, which will be hosted by UiB. The website will include the list of publications and presentations and it will be complemented by newsletters disseminated once a year to the partners and their networks (see Section 2.3.1)
- Setup and maintain the WikiPage on CDA.
- Update the list of relevant conferences and publish them on the CODA website.
- Update the list of relevant journals and keep informed on the CODA Special Issue
- Coordinate the ESR direct involvement in the dissemination activity for the general public (see Section 2.4.1): EU research nights, articles in journals for general public and outreach seminars.
- Prepare a series of outreach talks given by the ESR to the public and relevant stakeholder organizations (see Section 2.4.1). These talks will be broadcasted and recorded whenever possible.
- Facebook and twitter accounts may also be setup if desired by the ESR; nowadays many young scientists use these as a means of communication.
- Prepare brochures summarizing project results and disseminate to potential future employers (*e.g.*, ECMWF, stakeholders interested in climate prediction and services) and international organizations (e.g., Copernicus Services, WMO, ESA) interested in the CODA training program; an appropriate list will be drawn up with the help of all partners and the web site, among other vehicles, will be used to spread this information.
- Link to UiB, BSC and Bjerknes Centre divisions of communication. These divisions have skilled scientific journalists who will help the researchers to disseminate project results to national and international media by preparing press releases, articles and also

videos.
- Announce project activities, summer schools, targeting the main mailing lists and announcement channels, such as specialized magazines and newsletters of other projects

Description of Deliverables:
D4.1 CODA Webpage (month 3)
D4.2 First project brochure for dissemination to prospective employers and relevant organisations (month 24)
D4.3 Final project brochure for dissemination to prospective employers and relevant organisations (month 48)
D4.4 Special issue in a high-impact journal (month 48)

3.1.2 List of Major Deliverables

This section contains the composed Table 3.1b where the major deliverables are described, separately into scientific and management/training/dissemination ones respectively. Note that the estimated due date is given in months from the beginning of the project and that only the major deliverables are reported in Table 3.1b; the full list is found in the WP description tables in Sect. 3.1.1.

Table 3.1b – List of Major Deliverables

Scientific Deliverables						
Deliverable Number	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Dissemination Level**	**Due Date** (estim.)
D1.2.3	Impact of DA on the error dynamics .	**1**	**RMI**	**PDE**	**PU**	**38**
D1.4.2	Multigrid-based preconditioning techniques for coupled systems	**1**	**INRIA**	**PDE**	**PU**	**38**
D1.1.2	Adaptive EnKF for coupled system	**1**	**NERSC**	**PDE**	**PU**	**39**
D1.3.3	Applications with a coupled low-order air quality model -	**1**	**ENPC**	**PDE**	**PU**	**39**
D1.5.3	Observing system design experiments with new sensitivity measures in a single-column model	**1**	**UR**	**PDE**	**PU**	**38**
D1.6.3	Application to Detection and Attribution of climate change within a forced low-order climate model	**1**	**CONICET**	**PDE**	**PU**	**39**
D2.1.3	Good practices for multi-methods DA	**2**	**NERSC**	**PDE**	**PU**	**39**
D2.2.3	Test of advanced method for strongly coupled assimilation	**2**	**UiB**	**PDE**	**PU**	**39**
D2.3.3	Correction of General Circulation Model biases using DA	**2**	**BSC**	**PDE**	**PU**	**39**
D2.4.2	Recommendations for operational climate forecast institutions concerning the relevance of implementing balanced initialization of climate forecasts	**2**	**BSC**	**PDE**	**PU**	**39**
D2.5.4	Coupled TELEMAC2D and SISYPHE with DA	**2**	**CERFACS**	**PDE**	**PU**	**39**

Management, Training, Recruitment and Dissemination Deliverables						
Deliverable Number	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Dissemination Level**	**Due Date** (estim.)
D3.1	Selection of the Supervisory Board and Training and Recruitment Committees	**3**	**NERSC**	**AMD**	**CO**	**1**
D3.3	Kick-Off Meeting Organization	**3**	**NERSC**	**ADM**	**CO**	**1**
D3.4	Recruitment Completion	**3**	**NERSC**	**OTHER**	**PU**	**3**
D4.1	Setup and maintain project website and blog	**4**	**UiB**	**OTHER**	**PU**	**3**
D3.5	ESR mobility plan	**3**	**NERSC**	**OTHER**	**CO**	**4**
D3.6	Network-wide Training Plan	**3**	**NERSC**	**OTHER**	**CO**	**6**
D3.8	Overview Organization School 1	**3**	**ENPC**	**OTHER**	**PU**	**12**
D4.2	First project brochure	**4**	**UiB**	**OTHER**	**PU**	**24**
D3.13	Overview Organization of School 2	**3**	**BSC**	**OTHER**	**PU**	**27**
D3.14	ESR career development plan	**3**	**NERSC**	**OTHER**	**CO**	**38**
D3.17	Organize Final Conference	**3**	**NERSC**	**OTHER**	**PU**	**47**
D4.4	Special issue in a high-impact journal	**4**	**BSC**	**OTHER**	**PU**	**48**
D3.18	Final Management Meeting	**3**	**NERSC**	**ADM**	**CO**	**48**

3.1.3 List of Major Milestones

Table 3.1c is used to list in chronological order the main milestones in CODA. In some cases Milestones coincide with deliverables, as given in Tab. 3.1b.

Table 3.1c – List of Major Milestones

Number	Title	Related Work Package(s)	Lead Beneficiary	Due Date (estimated)	Means of Verification
M1	Kick-Off Meeting and ESR PhD project and mobility plan	All	NERSC	1	Minutes of meeting
M2	ESR recruitment and skill audit	All	All	1	Minutes of meeting
M3	International School on DA	1	ENPC	12	Minutes of meeting
M4	1th Review of Individual Sub-Project status	1 and 2	ENPC and BSC	15	Minutes of Supervisor Committee meeting
M5	International School on Climate Prediction	2	BSC	27	Minutes of meeting
M6	2nd Review of Individual Sub-Project status	1 and 2	ENPC and BSC	27	Minutes of Supervisor Committee meeting
M7	PhD Theses Submission	1 and 2	All	34	Minutes of Supervisor Committee meeting
M8	3rd Review of Individual Sub-Project status	1 and 2	ENPC and BSC	38	Minutes of Supervisor Committee meeting
M9	ESR Career Development Plan	3	NERSC	38	Minutes of meeting

3.1.4 Fellow's individual projects

In the tables that follow the individual research projects are described. Note that estimated due date for the deliverable is given in months of PhD thesis: when reporting them in the deliverables Tab. 3.1b 3 months have been added, assuming that it is the minimum time required to recruit the ESR.

<table>
<tr><th>Fellow
ESR 1</th><th>Host institution
NERSC</th><th>PhD enrolment (University of Bergen)</th><th>Start date
3</th><th>Duration
36</th><th>Deliverables
D1.1.1 and D1.1.2</th></tr>
<tr><td colspan="2">Project Title and Work Package(s) to which it is related:</td><td colspan="4">Ensemble DA methods in Coupled Systems (WP1)</td></tr>
<tr><td>Objectives:</td><td colspan="5"><u>Supervisor</u>: Alberto Carrassi and Laurent Bertino (NERSC)
<u>Co-Supervisor</u>: Marc Bocquet (ENPC)

<u>Phase 1</u>: Error Dynamics Characterization in Coupled Systems (months 1 – 9 of the PhD thesis)
A deep study of the error dynamics as a function of the coupling type and strength will be carried out. Lyapunov stability analysis (i.e. the exponents spectrum and vectors) will be used to characterize the system's stability properties. Two estimation methods will be used. First the classical approach from [7] that allows for computing the time-dependent unstable subspaces, but the information about the specific directions is lost. Second the new algorithm developed by [28] that exhibits faster convergence (exponential vs linear) and, most importantly, allows for estimating the individual Lyapunov vectors and so precisely identify the coupling effect on the direction of instabilities. This will ultimately be used to generate a map, $\Gamma_{Lyap\rightarrow Model}$, linking the spectrum of instabilities to each of the model subcomponents.
<u>Phase 2</u>: Comparison of standard EnKF in different regime of scale separation (months 9 – 16 of the PhD thesis)
Stochastic and Deterministic EnKFs will be implemented in low order coupled systems. The objective is to identify the regime of scale separation causing the collapse of the fully CDA approach. The weakly- and strongly-coupled EnKF will be compared in relation with the type and strength of the coupling and in a range of different observational and model error scenarios to understand under which circumstances and why the strongly-coupled formulation fails. This will guide, along with the error dynamics characterization, the exploration of novel strongly-coupled EnKF formulations.
<u>Phase 3</u>: Comparison of standard EnKF in different regime of scale separation (months 16 – 33 of the PhD thesis)
Research will focus to adapt standard methods in order to successfully propagate information across all compartments will be investigated. Attention will be driven toward the design of the error covariance to cross-infer the different model compartment using all available observations simultaneously. Target observations strategies based on unstable modes will be tested: the phase-space location of the observations is chosen in the maximum of the unstable modes. The map $\Gamma_{Lyap\rightarrow Model}$ is used to select the instability to be used in the targeting procedure according to the model compartment to be observed. A systematic study will be done to assess the impact on prediction error at different time-horizons/model-compartment as a function of the target observations type and location. The unstable modes themselves will then be used in the assimilation step following the AUS approach.
<u>Phase 4</u>: PhD Dissertation writing (months 33-36 of the PhD thesis)</td></tr>
<tr><td>Expected Results:</td><td colspan="5">New Methods for Ensemble based DA in Coupled Systems</td></tr>
</table>

Planned secondment (s)	1. **Secondment Host**: ENPC (Marc Bocquet) months 3-5 of the PhD thesis **Purpose**: Ensemble-based methods. The IEnKS applied to low-order models. 2. **Secondment Host**: STATOIL (Geir Evensen and Remus Hanea) months14-16 of the PhD thesis **Purpose**: Practical applications of EnKF to petroleum sector. 3. **Secondment Host:** BSC (Virginie Guemas) months 28-30 of the PhD thesis **Purpose**: Initialisation and prediction with state-of-the-art ESMs: Low frequency variability and Predictability in comparison with low-order systems used in the PhD work.

Fellow ESR 2	Host institution RMI	PhD enrolment (Université Libre de Bruxelles)	Start date 3	Duration 36	Deliverables D1.2.1, D1.2.2 and D1.2.3
Project Title and Work Package(s) to which it is related:		Low-frequency variability and predictability of coupled ocean-atmosphere coupled systems **(WP1)**			
Objectives:	***<u>Supervisor</u>: Stephane Vannitsem (RMI)*** ***<u>Co-Supervisor</u>: Alberto Carrassi (NERSC)*** **<u>Phase 1</u>: Dynamical instability of coupled systems (months 1 – 12 of the PhD thesis)** Different approaches of the evaluation of the dynamical instabilities of atmospheric models have been explored to describe the error dynamics and generate ensemble forecasts, namely singular vectors (SV), bred vectors (BV), and Lyapunov vectors (LV) [48]. Recently new tools have been developed known as covariant Lyapunov Vectors (CLV) whose main property is to be invariant through the action of the flow [50]. This interesting property makes these vectors natural instability structures of the flow. The purpose is therefore to investigate the properties of these vectors when a slow dynamics (long term variability) is present in coupled multi-scale systems, coexisting with fast variability, in the perspective of ensemble DAs developed in WP1 that will be learned by the ESR 2 during his/her stay at NERSC and STATOIL. **<u>Phase 2</u>: Dynamics of the error beyond the linearized regime (months 12 – 24 of the PhD thesis)** Beyond the linearized regime well described by LVs and BVs, the error is growing nonlinearly, and saturates after a typical time scale associated with the inverse of the dominant Lyapunov exponent [63]. In multiscale systems, the picture is more complicate with the error rapidly saturating at the shorter time scales, but continuing to grow for longer time scales. This feature opens the question on the actual dynamics of the error at these long time scales. It will be addressed from a theoretical perspective in the context of idealized slow-fast dynamics and low-order coupled ocean-atmosphere models. This question will also be addressed in state-of-the-art climate models during the stay at BSC. **<u>Phase 3</u>: Impact of DA on the error dynamics (months 24 – 33 of the PhD thesis)** The behaviour of the forecast error after is strongly conditioned by the quality and quantity of information gathered during the DA. This dynamics will be evaluated in the light of the recent theories on the short-term error dynamics [64]. The analysis will be performed in the context of the reduced-order coupled ocean-atmosphere models in which the DA schemes of the other Sub-Projects of WP1 have been implemented. ***<u>Phase 4 -</u> PhD Dissertation writing (months 33-36 of the PhD thesis)***				
Expected Results:	**The development of a theory for the error dynamics in slow-fast systems and the impact of DA**				
Planned secondment (s)	1. **Secondment Host**: NERSC (Alberto Carrassi) months 11-13 of the PhD thesis **Purpose**: AUS and ensemble methods. Implementation of EnKF methods (including IEnKS) to the 36-variables coupled model from [87], and study of the choice of the unstable vectors for AUS. 2. **Secondment Host**: STATOIL (Geir Evensen and Remus Hanea) months 14-16 of the PhD thesis **Purpose**: Study of the applications of DA to petroleum sector, in particular parameter estimation 3. **Secondment Host**: BSC (Virginie Guemas) months 28-30 of the PhD thesis **Purpose**: Initialisation and prediction with state-of-the-art ESMs: Investigation of the Low frequency variability and Predictability in comparison with the properties found in [87]				

Fellow ESR 3	Host institution ENPC	PhD enrolment (Université Paris-Est)	Start date 3	Duration 36	Deliverables D1.3.1, D1.3.2 and D1.3.3
Project Title and Work Package(s) to which it is related:		*Error dynamics characterization within an ensemble-variational DA system* **(WP1)**			
Objectives:	***<u>Supervisor</u>: Marc Bocquet (ENPC)*** ***<u>Co-Supervisor</u>: Laurent Bertino and Alberto Carrassi (NERSC)*** ***<u>Phase 1</u>: Numerical dynamical analysis of the iterative ensemble Kalman smoother (months 1 – 12 of the PhD thesis)*** We plan to study the dynamical propagations of errors within the DA temporal window of the iterative ensemble Kalman smoother (IEnKS) [9, 10] on several key meteorological low-order models (Lorenz systems; possibly 2D barotropic and quasi-geostrophic models). Focusing on its analysis within a DA temporal window but also in between analysis steps (i.e. the forecast steps), we will use Lyapunov vectors to study this dynamics. We also plan to study this propagation of errors in between two coupled systems. **<u>Phase 2</u>: *IEnKS in the unstable subspace; tests on low-order Lorenz models* (months 12 –20 of the PhD thesis)** Building on the results of phase 1, we plan to define and implement an AUS (assimilation in the unstable subspace) variant of the IEnKS. This will be carried out on low-order Lorenz systems. This potentially powerful numerical tool should help validate the results of phase 1. Expertise on AUS systems will be acquired during a stay at NERSC. ***<u>Phase 3</u>: Applications with a coupled low-order air quality model (months 20 – 33 of the PhD thesis)*** One typical application is that of an online air quality model, which is composed of a meteorological model, whose				

	meteorological fields drive a chemical transport model (CTM), with possible feedback from the CTM to the weather forecast model. We have recently developed a low-order model (L95-GRS) with these dynamical features that will be used in this study. This application is typical of a coupled DA system where one of the system is chaotic (meteorology) but accurate and relatively well controlled and of a non-chaotic though highly nonlinear and uncertain system (constituents transport and chemistry). The results of phase 3 will be confronted to larger online CTM systems during a stay at the BSC. ***<u>Phase 4</u>: PhD Dissertation writing (months 33-36 of the PhD thesis)***
Expected Results:	**Better understanding of new ensemble variational methods, and evaluation of their potential for DA in coupled systems. Application to online CTMs.**
Planned secondment (s)	1. **Secondment Host**: NERSC (Alberto Carrassi) months 11-13 of the PhD thesis **Purpose**: AUS and ensemble methods. Implementation of EnKF methods (including IEnKS) to the VDDG model [87] 2. **Secondment Host**: STATOIL (Geir Evensen and Remus Hanea) months 14-16 of the PhD thesis **Purpose**: Practical Applications of EnKF to petroleum sector. 3. **Secondment Host**: BSC (Francisco Doblas-Reyes) months 28-30 of the PhD thesis **Purpose**: Complementary/Related Skill: Learning on the EnKF in the coupled transport-chemical model of BSC

Fellow ESR 4	Host institution INRIA	PhD enrolment (Université Grenoble-Alpes)	Start date 3	Duration 36	Deliverables D1.4.1, and D1.4.2
Project Title and Work Package(s) to which it is related:	*Multigrid preconditioning for variational DA* **(WP1)**				
Objectives:	***<u>Supervisor</u>: Arthur Vidard and Laurent Debreu (INRIA)*** ***<u>Co-Supervisor:</u> Francisco Doblas-Reyes (BSC)*** ***<u>Phase 1</u>: Bibliography and theoretical study of multigrid techniques and preconditionning (months 1 – 12 of the PhD thesis)*** Only very simple multigrid techniques have been used in the optimization part of variational DA while more advanced and robust methods exist in the literature. The first phase of this will be to browse through these techniques and select the ones relevant to our large-scale problem. Some adaptations are likely to be necessary and the convergence properties will be carefully studied and some novel preconditioning techniques will be proposed. ***<u>Phase 2</u>: Application to an uncoupled academic model*** **(months 12 –20)** The methods proposed in phase one will be tested on academic uncoupled models of intermediate complexity and compared with classical approaches. Both the quality of the results and the computing efficiency will be evaluated. ***<u>Phase 3</u>: Theoretical extension to coupled models, Applications to a coupled academic model (months 20 – 33)*** The extension of the proposed methods to coupled models will be studied with a particular focus on the validity of the necessary hypotheses for the convergence result. The case where models are coupled through a bulk formula (like in ocean-atmosphere) will be especially investigated. Once the relevant theory designed, we will test the methods on an academic coupled model from table 1.1c ***<u>Phase 4</u>: PhD Dissertation writing (months 33-36 of the PhD thesis)***				
Expected Results:	**New efficient preconditioning methods for variational DA**				
Planned secondment (s)	1. **Secondment Host**: CERFACS (Sophie Ricci) months 10-12 of the PhD thesis (phase 1) **Purpose**: Optimization techniques play a key role in DA but are most of the time seen as back box. This ESR requires a deep knowledge of such methods and CERFACS is a major player in the field 2. **Secondment Host**: BSC (Francisco Doblas-Reyes) months 16-20 of the PhD thesis (phase 2) **Purpose**: Aiming at realistic applications requires to design methods fit for HPCs today and futures paradigms. BSC is an obvious place to learn about these issues. 3. **Secondment Host**: EDF (Nicole Goutal) months 26-28 of the PhD thesis (phase 3-4) **Purpose:** This ESR is mainly methodological, but operational applications, induce some additional constraints: what is at stakes, scale interactions, strong and weak hypotheses, and numerical challenges. EDF has obviously a strong experience on this aspect				

Fellow ESR 5	Host institution UR	PhD enrolment (University of Reading)	Start date 3	Duration 36	Deliverables D1.5.1, D1.5.2 and D1.5.3
Project Title and Work Package(s) to which it is related:	*Observation impact in coupled variational DA* **(WP1)**				
Objectives:	***<u>Supervisor</u>: Amos Lawless and Alison Fowler (UR)*** ***<u>Co-Supervisor</u>: Marc Bocquet (ENPC)*** The objective of the project is to develop new methods for assessing observation impact in coupled atmosphere-ocean DA. ***<u>Phase 1</u>: Development of analysis impact measures (months 1-12)*** A theoretical derivation of the analysis sensitivity to observations in weakly-coupled variational assimilation will be carried out. It is expected that the full expression is likely to be intractable in practice, so approximations will be sought that retain the essential information of observation sensitivity across the air-sea interface. Methods will be tested numerically using the low order coupled ODE model MFPV and compared with standard measures. ***<u>Phase 2</u>. Development of forecast impact measures (months 13-22)*** Standard measures for quantifying forecast impact of observations often rely on adjoint sensitivities. In weakly-coupled				

	assimilation the adjoint of the full coupled model is not available. Here we will develop approximations to these sensitivities based on ensemble methods, to allow assessment of forecast impact in the coupled system. In particular measures will be developed to assess the impact of ocean observations on the atmospheric forecast and *vice versa*. Methods will again be tested in a low order ODE model. ***Phase 3.* Observing system design coupled atmosphere-ocean models (months 24-32)** In this phase the measures developed in phases 1 and 2 will be implemented on a single-column atmosphere-ocean model (SCM) assimilation system already available at UR. Results from assimilation experiments will be compared with predictions from the new measures. By considering different observation types we will study the likely effects of different observations on the analysis and forecast from coupled assimilation systems. ***Phase 4*: PhD Dissertation writing (months 33-36)**
Expected Results:	**Methods for quantifying the impact of different observation types on the analysis and forecast from weakly-CDA. An understanding of the effect of different observation types in CDA.**
Planned secondment (s)	**1. Secondment Host**: ENPC (Marc Bocquet) months 10-12 of the PhD thesis **Purpose**: Understand mathematical methods for optimal design of observing systems. **2. Secondment Host**: EDF (Nicole Goutal) months 18 – 20 of the PhD thesis **Purpose**: Develop practical measures of forecast impact for the electricity generation industry. **3. Secondment Host**: INRIA (Arthur Vidard) months 30 – 32 of the PhD thesis **Purpose**: Learn about practical aspects of ocean DA.

Fellow	Host institution	PhD enrolment	Start date	Duration	Deliverables
ESR 6	**CONICET**	**(Universidad de Buenos Aires)**	**3**	**36**	**D1.6.1, D1.6.2 and D1.6.3**

Project Title and Work Package(s) to which it is related:	*Assimilation of time-averaged observations with application to detection and attribution of climate change.* **(WP1)**
Objectives:	***Supervisor*: Alexis Hannart (CONICET)** ***Co-Supervisor*: Marc Bocquet (ENPC) and Alberto Carrassi (NERSC)** ***Phase 1*: Evaluation of methods for assimilating time-averaged observations (months 1-12 of the PhD thesis)** We will tackle the problem of assimilating observations that are time-averaged over a time window which is long respective to the fast atmospheric timescale of a coupled climate model (i.e. year to decade). This problem may indeed be viewed as the most critical issue in order to unlock the use of DA for D&A. We will start by implementing within the VC13 and L96 models the relatively few existing methods that were developed for this purpose [80], which were all formulated under an EnKF context. We will adapt them to D&A by deriving the associated likelihood, and next assess their strengths and weaknesses for D&A in particular w.r.t. computational cost. ***Phase 2*: Design of methods for assimilating time-averaged observations (months 13-24 of the PhD thesis)** We will then design a few theoretical improvements attempting to address the most obvious weaknesses identified in Phase 1. For this purpose, we will revisit the EnKF formulation which is underpinning all the existing methods and release some fundamental assumptions which are inherent to the latter and may be considered too restrictive, in an attempt to obtain a more general, improved class of estimators for the update equations. We will then assess the potential benefit of the resulting improved DA method. ***Phase 3*: Application to Detection and Attribution (months 25-33 of the PhD thesis)** The most relevant time-averaged DA method resulting from Phase 1 and 2 will be implemented and tested by using an ad-hoc D&A testbed consisting of a double factual-counterfactual assimilation into a forced version of the coupled climate-model of VDDG [87], using a twin experiment set-up. The results obtained will be analysed and compared with those obtained from conventional D&A methods (i.e. optimal fingerprinting) applied to the above experimental set-up. ***Phase 4*: PhD Dissertation writing (months 33-36 of the PhD thesis)**
Expected Results:	**Method for assimilating time-averaged observations in a coupled climate model; Method for attributing climate changes**
Planned secondment (s)	1. **Secondment Host**: RMI (Stéphane Vannitsem) months 6-8 of the PhD thesis **Purpose**: EnKF methods to the nonlinear coupled model from [87]. 2. **Secondment Host**: NERSC (Alberto Carrassi) months 13-15 of the PhD thesis **Purpose**: EnKF methods and theoretical explorations around time-averaged DA. 3. **Secondment Host**: BSC (Francisco Doblas-Reyes) months 25-27 of the PhD thesis **Purpose**: Interaction with the team running the global climate model in order to precisely assess the benefits and requirements of a potential implementation of the time-averaged DA method in an ESM model.

Fellow	Host institution	PhD enrolment	Start date	Duration	Deliverables
ESR 7	**NERSC**	**(University of Bergen)**	**1**	**36**	**D2.1.1, D2.1.2 and D2.1.3**

Project Title and Work Package(s) to which it is related:	Multi methods CDA **(WP2)**
Objectives:	***Supervisor*: Laurent Bertino and Alberto Carrassi (NERSC)** ***Co-Supervisor*: Francisco Doblas-Reyes (BSC)** ***Phase 1*: Implementation and set up of an idealized test case *(months 1-12 of PhD)*** Set up a 1-dimensional idealized coupled model that justifies the exploration of multi-method coupled DA: a toy model in Lagrangian coordinates (inelastic shocks of pinballs, as an analogy of sea ice floes) is coupled to a fixed-grid model (a static

	ocean as a heat reservoir, which exchanges are modulated by the opening and closing of sea ice leads). Testing the numerical stability and the dynamical properties of the idealized system. ***<u>Phase 2</u>: Testing of multi-methods coupled DA, their probabilistic consistency. (months 13-24 of the PhD)*** The DA methods EnKF, nudging and EWPF are implemented in the "sea ice" component and the EnKF is applied to the "ocean" of the system developed in Phase 1. All combinations are tested with variable ensemble sizes and assimilation window lengths. Various options are also tested for the communication between its "sea ice" and "ocean" compartments: passing the mean state or the most likely member, bootstrapping. The performances are evaluated both in terms of accuracy and consistency of the coupled solution: statistical properties of the fields exchanged (smoothness, temporal variability) and preservation of equilibrium properties. ***<u>Phase 3</u>:*** **Synthesis of best practices for multi-method assimilation** ***(months 25 – 36 of the PhD)*** Practical aspects of the assimilation are tested: localization, interpolation of the adaptive grid to a fixed grid. A synthesis paper is written targeted to users in climate modeling. If the neXtSIM model is coupled to the TOPAZ system at the beginning of Phase 3, a realistic coupled ice-ocean application in the Arctic Ocean will be tested in collaboration with the TOPAZ development team at NERSC.
Expected Results:	**Improved understanding of the probabilistic content of multi-method CDA methods and best practices for their applications in coupled climate forecasting models.**
Planned secondment (s)	1. **Secondment Host**: BSC (Francisco Doblas-Reyes) months 6-8 of the PhD. **Purpose**: Improved design of an idealized system analogous to an ice-ocean system. 2. **Secondment Host**: CERFACS (Sophie Ricci) months 21-23 of the PhD **Purpose**: Better understanding of the design of a coupling software. Initiation of Phase 3. 3. **Secondment Host**: BKK (Ina K. Kindem) month 28 of the PhD **Purpose**: Understand requirements of end user in real framework.

Fellow	Host institution	PhD enrolment	Start date	Duration	Deliverables
ESR 8	**UiB**	**(University of Bergen)**	**1**	**36**	**D2.2.1, D2.2.2 and D2.2.3**

Project Title and Work Package(s) to which it is related:	Strongly coupled DA for seasonal-to-decadal prediction **(WP2)**
Objectives:	***<u>Supervisor</u>: Noel Keenlyside (UiB) and Francois Counillon (UiB)*** ***<u>Co-Supervisor</u>: Stephane Vannitsem (RMI)*** ***<u>Phase 1</u>:*** Implementation of the leading averaged coupled covariance in NorCPM ***(months 1-12 of the PhD thesis)*** *During the first 6 months, the student will get familiar with the EnKF, first with toy models from the enkf-matlab educational toolbox and within NorCPM. Twin experiments (with synthetic observation) will be used to test leading averaged coupled covariance for strongly coupled DA between the ocean and the atmosphere. The observation network will mimic todays observation network of ocean and atmosphere.* ***<u>Phase 2</u>:*** *Exploring improved coupled covariance and variational framework* ***(months 13-27 of the PhD thesis)*** *In phase 1, a strong assumption is made in the expression of the coupled covariance between the ocean and the atmosphere. The student will visit RMI to explore how this assumption can be relaxed, taking advantage of the progress of ESR2.* The advantages of using a variational framework with the IEnKS for handling the highly chaotic behaviour of the atmosphere would be also evaluated during a visit at ENPC; strengthening the link with ESR3. ***<u>Phase 3</u>: Demonstration of strongly coupled DA in real framework (months 28-36 of the PhD thesis)*** *The student will visit the BKK for a month in order to fully understand the requirement of the end-user and set up a real scenario to assess the skill of NorCPM for precipitation in the west coast of Norway. The system will be validated in hindcast mode and depending of the skill obtained, a prediction will be attempted and delivered to the end-user.*
Expected Results:	**Consistent initialization of the Earth system for enhanced seasonal-to-decadal prediction skills**
Planned secondment (s)	1. **Secondment Host**: RMI (Stephane Vannitsem) months 13-14 of the PhD thesis **Purpose:** Exploring the formulation of coupled covariance in low-order coupled ocean-atmosphere models. 2. **Secondment Host**: ENPC (Marc Bocquet) months 15-16 of the PhD thesis **Purpose**: Investigate the benefit of the IEnKS for couple assimilation between atmosphere and ocean 3. **Secondment Host**: BKK (Ina K. Kindem) months 28 - 31 of the PhD thesis **Purpose**: Setting up of a real framework to test NorCPM with strongly couple assimilation

Fellow	Host institution	PhD enrolment	Start date	Duration	Deliverables
ESR 9	**BSC**	**(Universitat Autònoma de Barcelona)**	**3**	**36**	**D2.3.1, D2.3.2 and D2.3.3**

Project Title and Work Package(s) to which it is related:	Toward reduced surface biases in EC-Earth 3 climate forecast system through parameter calibration based on the Ensemble Kalman Filter **(WP2)**
Objectives:	***<u>Supervisors</u>: Virginie Guemas and François Massonnet (BSC)*** ***<u>Co-Supervisor</u>: François Counillon (UiB)*** ***<u>Phase 1</u>: Identification of biases in EC-Earth and their relation to parameters (months 1-12 of the PhD thesis)*** Several observational datasets and metrics will be exploited to identify robustly the surface biases of the EC-Earth model in an ensemble of historical simulations and their development in a set of retrospective decadal climate predictions covering the satellite period. A list of 3-4 parameters susceptible to affect the surface biases will be identified by doing sensitivity tests. A

<table>
<tr><td></td><td>stay at INRIA is planned during this period to ensure a deep knowledge of DA and prepare phase 2.
<u>Phase 2</u>: Implementation of a global parameter estimation DA method using the ensemble Kalman filter (months 13-34 of the PhD thesis)
The PhD student will spend months 13-14 at NERSC where the EnKF is used for state estimation. He/she will then return to BSC's premises and modify the EnKF scripts to allow parameter estimation along two steps:
a. Twin experiments (months 13-18)
An integration of the EC-Earth model will be performed using the default values for the 3-4 parameters identified in Phase 1 to obtain a reference considered as the "truth". The ESR will attempt to estimate one of the parameters only, using the modified-EnKF version he/she developed. The focus will be put on specific regions where large model biases were identified (North Atlantic, Tropical Pacific, Southern Ocean, depending on the outcome from Phase 1). He/she will then attempt to estimate more parameters simultaneously.
b. Realistic experiments (months 19-34)
Once the methods for parameter estimation have been assessed in the "perfect" case (Phase 2.a), the ESR will apply them to realistic cases. He/she will estimate one, and then several parameters using real observations. The ESR will assess whether the parameter values returned by the filter are more appropriate than the original, default values in two steps. First, he/she will run the model with these new values and assess the performance of this new simulation against observations. Second, he/she will investigate how model biases are affected by the new choice of parameters for another time period and discuss the results. A stay at CERFACS is planned during this period to assess the benefit of this methodology on operational oceanography cases as well as a stay at ACA to estimate the potential outcome for water management.
<u>Phase 3</u>: PhD Dissertation writing (months 34-36 of the PhD thesis)</td></tr>
<tr><td>Expected Results:</td><td>Original and innovative methods/Strategies to efficiently reduce surface biases in coupled general circulation models</td></tr>
<tr><td>Planned secondment (s)</td><td>1. Secondment Host: INRIA (Arthur Vidard) months 6-8 of the PhD thesis
Purpose: Training on the theory of DA
2. Secondment Host: UiB (Francois Counillon) months 13 - 15 of the PhD thesis
Purpose: Training on the theory of DA and the Ensemble Kalman Filter
3. Secondment Host: CERFACS (Sophie Ricci) months 25 - 27 of the PhD thesis
Purpose: Investigation on the possible use of parameter estimation methods for operational oceanography and confrontation with lead scientists</td></tr>
</table>

<table>
<tr><th>Fellow
ESR 10</th><th>Host institution
BSC</th><th>PhD enrolment (Universitat de Barcelona)</th><th>Start date
3</th><th>Duration
36</th><th>Deliverables
D2.4.1 and D2.4.2</th></tr>
<tr><td colspan="2">Project Title and Work Package(s) to which it is related:</td><td colspan="4">Impact of a balanced initialization of dynamical climate forecasts on forecast quality (WP2)</td></tr>
<tr><td>Objectives:</td><td colspan="5"><u>Supervisor</u>: Francisco Doblas-Reyes (BSC)
<u>Co-Supervisor</u>: Noel Keenlyside (UiB)
The objective of this ESR consists in exploring the links between the reductions of the drift of dynamical climate forecasts, in particular in sub-seasonal-to-seasonal (S2S) predictions. The EC-Earth3 global model will be used for the exercise.
<u>Phase 1</u>: Drift and forecast quality in the standard initialization approaches used in EC-Earth3 (months 1-12 of the PhD thesis)
Full-field and anomaly initialization have been explored in EC-Earth to perform climate predictions. The drift of these predictions will be estimated for a range of variables in the atmosphere, land surface, sea ice and ocean components. The forecast quality, including measures of reliability and accuracy, will be estimated as well as the characteristics of the drift. A stay is planned at UiB to compare the behaviors of EC-Earth3 and NorCPM models.
<u>Phase 2</u>: Impact of the drift reduction obtained by using ensemble Kalman filter of sea-ice observations on the forecast quality (months 13-34 of the PhD thesis)
An initialization methodology is currently being implemented in EC-Earth that includes an EnKF of sea-ice observations and a nudging towards reanalyses in the atmosphere and the ocean. The DA phase provides ensembles of initial conditions that can be used to perform climate predictions. This phase will begin by a stay at NERSC to ensure sufficient training on the EnKF to conduct the subsequent two stages:
a. Experimental set up for the generation of the initial conditions and the climate forecasts (months 13-18)
The standard set of coefficients will be used in a reference DA experiment to provide initial conditions and generate subsequent reference predictions. The affordable set up, in particular in terms of ensemble size, forecast length and period of study needs to be assessed during this stage. Given the interest in S2S prediction, special attention will be paid to how the Madden Julian Oscillation, El Niño-Southern Oscillation and the Arctic sea ice are predicted at those time scales.
b. Sensitivity tests to the coefficients to optimize the forecast quality (months 19-29)
The experiment set up of stage a will be repeated as many times as both computing resources and time allow to investigate the sensitivity of the forecast quality (both reliability and accuracy) to changes in the DA coefficient that reduce the drift in the forecasts. The stay at ACA is planned during this stage to assess the benefits from the forecast quality improvement on renewable energy and water resource management sectors respectively.
<u>Phase 3</u>: PhD dissertation writing (months 30-36 of the PhD thesis)</td></tr>
<tr><td>Expected Results:</td><td colspan="5">Illustration of the links between the drift and the forecast quality in S2S climate predictions
Recommendations for operational climate forecast institutions concerning the relevance of implementing balanced initialization of climate forecasts</td></tr>
<tr><td>Planned</td><td colspan="5">1. Secondment Host: UiB (Noel Keenlyside) months 6-8 of the PhD thesis
Purpose: Training on the relationship between drift and forecast quality</td></tr>
</table>

secondment (s)	2. **Secondment Host**: NERSC (Laurent Bertino) months 13 - 15 of the PhD thesis **Purpose**: Training on DA, the Ensemble Kalman Filter and its application in global models 3. **Secondment Host**: ACA(Arnau Cangros Alonso) months 25-27 of the PhD thesis **Purpose**: Assessment of the benefits of improved initial conditions and forecast quality for water management

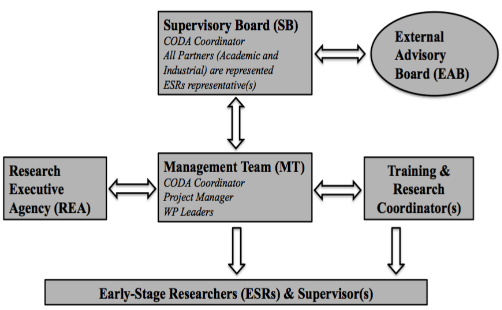
Fellow **ESR 11**	**Host institution** **CERFACS**	**PhD enrolment (Université Paul Sabatier)**	**Start date** **3**	**Duration** **36**	**Deliverables** **D2.5.1, D2.5.2, D2.5.3 and D2.5.4**
Project Title and Work Package(s) to which it is related:	Ensemble DA for coupled sediment-hydrodynamics modelling in estuaries **(WP2)**				
Objectives:	***<u>Supervisor</u>: Sophie Ricci (CERFACS)*** ***<u>Co-Supervisor</u>: Nicole Goutal (EDF)*** The objective of the project is to demonstrate the benefits of DA for modeling the hydrodynamics of estuarine areas such as the Gironde estuary. On the Gironde estuary, a TELEMAC 2D model (developed by EDF-CEREMA) is used for real-time operation of the Blayais nuclear power plant that is cooled by the estuary waters. Over this area the bathymetry has a temporal variability induced by the presence of a mud plug resulting from the merging of fluvial and oceanic waters. <u>Phase 1</u>**: Implement the DA (DA) method for the hydrodynamics model TELEMAC2D**. The scope is to correct both the model state and the model parameters, especially the bathymetry input field. An ensemble-based approach will be favoured (Ensemble Kalman Filter) in order to partially take into account the non linearities in the relationship that maps the model parameters onto the observation space. Particular care will be addressed to the description of spatial and multivariate covariances within the ensemble, and an hydrib En-Var approach will be tested if needed. A re-analysis study will be carried out over several decades with in-situ observation and will improve knowledge on the estuarine dynamics. <u>Phase 2</u>**: Extending to the coupled hydrodynamics-sediment model SISYPHE-TELEMAC2D.** Assimilation of water level data will first constrain the hydrodynamics model, then the coupled model. This work will first be carried out in the framework of an Observing System Experiments using synthetic data with arbitrary spatio-temporal distribution. The benefits from assimilating real in-situ data will finally be shown. ***<u>Phase 3</u>: PhD Dissertation writing (months 33-36 of the PhD thesis)***				
Expected Results:	**Method for assimilating in-situ water level observations in 2D hydrodynamics model in order to correct bathymetry variability. Method to implement DA in a hydrodynamics-sediment estuary model.**				
Planned secondment (s)	1. **Secondment Host**: EDF (Nicole Goutal) months 2-4 of the PhD thesis **Purpose**: Training in hydraulic modeling with the TELEMAC-SISYHE model developed at EDF. 2. **Secondment Host**: ENPC (Marc Bocquet) months 18 – 20 of the PhD thesis **Purpose**: Training in Stochastic and Deterministic EnKF 3. **Secondment Host**: INRIA (Arthur Vidard) months 30 – 32 of the PhD thesis **Purpose**: Training in model coupling				

3.1.5 Gantt Chart

The Gannt Chart is reported in Section 4 of Part B2.

3.2 Appropriateness of the management structure and procedures

3.2.1 <u>Network organisation and management structure</u>



The management strategy aims at achieving the scientific and training program goals as **described in the WP3 table of Section 3.1.1**, as well as fostering interactions between the partners in the most flexible and efficient way. The entire structure of the management is illustrated in Fig. 1. The **Management Team (MT),** which comprises the project Coordinator and a **professional Project Manager (PM) that will be hired for the entire duration of CODA**, holds the responsibility for the execution of the project. Each year the MT will nominate the **Research and Training Coordinator** that will help executing the action planned by the SB and MT and ensure their implementation. **The PM, for which the CODA members have agreed in sharing the cost, will assist the coordinator with financial, administrative, practical and logistical issues.** The coordinator will ensure a regular contact with the **Research Executive Agency**, coordinate the Consortium Agreement procedures, chair and organize progress meetings, supervise the preparation and submission of progress reports, and finally organize the audit certification. The PM will prepare the agenda of the annual meetings, the Supervisory Board meetings and the reporting, aid on the organization of the schools, workshops and advertising out of the network (announcements at the European level), and monitor the financial management of the project. **The Training and the Research Coordinators** will be in charge of the elaboration and implementation of the scientific training and secondment program, reviews ESR's project during the progress meetings and supervises their career development plan. They will be contact points for the ESRs who have possible problems or conflicts.

3.2.2 Supervisory Board

The Supervisory Board (SB) will be composed by the Coordinator and representative(s) from all partners, both Academic and non-Academic, as well as from the ESR(s) fellow. The Supervisory Board will coordinate the actions of the committees and approve the general plan of the project research and training directions as well as for allocation of costs. It will meet every year in conjunction with school/progress meeting. The Supervisory Board is the organ where important strategic decisions are taken. In particular in relation to recruitment (see Sect. 3.2.3), risk management (Sect. 3.2.5), training coordination and project monitoring (Sect. 3.2.4). The SB will be supported by an **External Advisory Board (EAB)** composed of six members (see Table): four outstanding scientists in climate science, DA and applied mathematics to climate, one from the private-industrial sector and one expert representing stakeholders from climate prediction services. The commitment of **the EAB will entail attending the CODA annual meetings, gives guidance, comments and suggestions on the research and training program**.

CODA - External Advisory Board EAB		
Name	***Affiliation***	***Sector***
Prof M. Ghil	Ecole Normale Supérieure de Paris & University of California in Los Angeles	Academic
Prof C. K.R.T. Jones	University of North Carolina	Academic
Prof E. Kalnay	University of Maryland	Academic
Prof O. Talagrand	Ecole Normale Supérieure de Paris	Academic
Dr B. Å. Hjøllo	NAVTOR AS www.navtor.com	Industrial
To be selected		Stakeholder from Climate Service

3.2.3 Recruitment Strategy

The recruitment process will be implemented in the six months following the start of the project to allow time to ensure a good selection procedure. ESRs will be recruited for a period of 36 months. We will try to lure promising young scientists, those who appear to have a potential to become leading scientists in the field. The positions will be advertised via:

- Personal follow-up and motivation of local Master students with a strong potential for research, with particular focus on female students in view of gender parity.
- In the scientific community, by postings at the partners and university web sites, announcements at international conferences and workshops, advertisements in newsletters;
- At the European level on websites: Euraxess.eu, Cordis, Nature jobs, jobs.ac.uk web portal, or mailing-list like met-jobs.

The SB will oversee the recruitment process which will be based on three main principles: the ESR best working conditions, the transparency of recruitment and the ESR career development, in respect of the European Charter for Researchers and of the Code of Conduct for the Recruitment of Researchers (Brussels, 11/03/2005). The local supervisors will base the selection on network-wide guidelines to ensure transparency and equality of the process. Firstly, they will take into accounts the Marie Curie rules as regards nationality, mobility and research experience and secondly they will have an interview with the candidate by videoconference or in person. This interview will aim to check the ESR existing skills, her/his knowledge and relevant research experience as well as her/his capacity and enthusiasm to be part of an ETN network. The impact of her/his participation in the ETN on their future career will be also carefully evaluated. Everyone is treated equally based on competence, however to mitigate the fact that only few women are found in the DA scientific community, priority will be given to female candidature when equal to all other selection criteria.

3.2.4 Progress monitoring and evaluation of individual projects

The monitoring of the progress and of the management quality will be done mainly during the progress meetings and summer schools:
The **Kick-Off meeting (KM)** will be organized at the coordinator facilities (NERSC) in the 1th month. The meeting will last 2-3 days and will be opened to the whole network, including personnel from the associated partners. The first day will be dedicated to scientific talks and will provide the context and overview of the research objectives of the network. In the next day, the training and the start-up of individual PhD projects, their liaisons with other participants, the involvement of the private sector partners and the synergy for secondments will be discussed. Bi-, or three-lateral, discussions between partners will be setup first, followed by a network-wide session where the overall strategy is approved.

Three **Progress Meetings (PM)** will be organized every 12 months, starting between month 12 and 15, at which the ESRs will present their objectives, report about the status of their research and discuss the collaborative research between partners. PMs will be opened to the students and network scientists only and will take place at the facilities of 3 different partners (a tentative list is given in Table 1.2b).
The ESR will be required to submit a PhD project plan during his/her first year (a 10 to 20 page document), and status-reports (5 pages max) every 12 months before the Progress Meetings (see Tab. 1.2b). During the Progress Meetings, ESRs will present her/his scientific objectives within the network's overall goals, the methodology and the expected outcomes (with a timeline), and identify the necessary collaborations and stays at other institutes and private partners. The PhD project plans will be first evaluated and amended by the (co)-supervisor(s) and then circulate among all partners who will judge the overall consistency with the network broad objectives. They will be reviewed by the TC to ensure that the overall research and training objectives are addressed.
WP leaders will organize phone or videoconferences with the ESRs involved in their WP, in-between the network-wide project meetings and schools. This will ensure that progress is monitored on a regular basis (typically every 3 months). For each of these phone/video meetings, one ESR will volunteer to report the conclusions in writing to the management team.

3.2.5 Risk Management

Table 3.2a summarises the potential risks along with the proposed measures for mitigation.

Risk No.	Description of Risk	WP Number	Proposed mitigation measures
R1	Difficulty in recruitment of PhD candidates	1, 2	Delay the start of the corresponding PhD project
R2	New DA method does not converge / perform well	1, 2	Find alternative DA method within the consortium
R3	Insufficient access to supercomputers	2	Revert to cheaper algorithms
R4	Coupled model system unstable / does not perform	2	Use alternative model within the consortium

R1: A collective announcement of 11 positions is usually more attractive than a single position. A centralized application also allows the redirection of candidates from one ESR to another. However, this does not warrant the sufficient availability of skilled candidates. The recruitment campaign will thus be repeated if is not successful at once. This is possible since the project duration is 12 months longer than the 36-months ESR funding but the ESRs starting later may miss the first workshop on dissemination and outreach. If the second round is still unsuccessful, the supervisor will decide whether a candidate with a lower level can be hired or if plans must be changed. Reasons for changes in the start-month are related to delay in the recruitment process in consideration also of the fact that the peak of request of PhD positions usually coincides with summers. This makes the project start-date in slight delay with respect to the period of the year when most EU Master courses have completed and students start looking for PhD positions (see Sect. 3.2.3 for details of the recruitment process and counteractions).
R2/R4: The DA methods and climate models proposed are novel and the risks of algorithmic failure (or lack of performance) exist and can be severe for an ESR. These risks are mitigated by the gathered expertise of the consortium, of the larger community developing the climate models used in CODA and the frequency of contacts between the PIs within and outside CODA.
R3: WP2 depends on highly reliable access to state-of-art supercomputing facilities (including storage facilities). The risk of failure of such facilities or insufficient availability can be severe for an ESR but is mitigated by the access to different facilities within the CODA consortium and the applications to PRACE infrastructure.
We did not consider any risk on the availability of input data because climate data are widely available on the public domain and their quality checked independently of CODA.

3.2.6 Intellectual Property Rights

The ESRs hosted in the partners' infrastructures will respect the local rules and will commit themselves with confidentiality and intellectual property clauses when needed. As mentioned in Sect. 2.3.2, the intellectual property rights of the ESRs will be protected by their respective work contract with the partner institute. The issue of IPR will be on the program of the first workshop on dissemination and outreach, as well as on the School 3 (post-CODA strategy). The practices that protect both the ESRs and their institute will be then shared between the partners.

3.2.7 Gender Aspects

CODA already has five women in the network, of which three from the Academic sector and two from the private sector, making the female representation in CODA at 25%. Most importantly two female scientists are the leaders of the scientific WP2. The scientists in charge of two (over four) of the CODA private partners are females as well. The

CODA EAB includes an outstanding female scientist, one of the most important geoscientist in the last 3 decades, Prof Eugenia Kalnay, who has been also very much committed in her career to facilitate woman inclusion in the Academic world. A special emphasis will be put on the gender balance in the recruitment of ESRs within CODA (for candidates with the same qualifications, preference will be given to women). We are therefore confident that the gender parity in the project is likely to improve during its lifetime.
The gender dimension of CODA is that of climate research in general: women are more often exposed to adverse effects of climate change in poorer countries[1] and CODA will bring a contribution towards gender equality by providing more reliable climate projections to the broader public, with better described uncertainties.

3.3 Appropriateness of the infrastructure of the participating organisations

The ESRs will need a desktop in an office space and a computer. All hosts can satisfactorily fulfil this need since all infrastructures and research premises belong to the host organizations and all have sufficient space and facilities to appropriately host the PhD students (see Tables in Sect. 5). This includes: office space, PCs, software, libraries and top state-of-the-art equipment and facilities. In addition the ESRs in WP2 will also have access to state-of-the-art national HPC facilities through their host institutions or through their secondments:

- Norway: via the national NOTUR (www.notur.no) for CPU and NorStore (www.norstore.no) for data-storage resources available to UiB and NERSC.
- Spain: BSC hosts MareNostrum III, a Tier-0 PrACE system with 1.1Pflop/s capacity as well as other HPC resources, which will be used by the ESRs during their training in performing climate simulations. The BSC is also responsible for granting and managing computing resources at the national level. The ESRs will be able to apply to these computing time grants if considered necessary.
- France: ESRs will have access to several of EDF supercomputers through the secured CEREA access at ENPC

At the same time a common CODA application will be sent to other high performance computing facilities in Europe through PRACE competitive calls, for which a strong experience of successful proposals is available within the CODA network. Since coupled DA in ESMs requires a substantial amount of computing time, ESRs will be encouraged to interact closely with ITs in order to optimize their codes. BSC has developed tools to quantify the time spent in all parts of a program, providing powerful and rapid computer performance metrics. CODA will make collaborative wiki pages available for the ESRs to share their know-how.

3.4 Competences, experience and complementarity of the participating organisations and their commitment to the programme

3.4.1 Consortium composition and exploitation of partners' complementarities

The CODA consortium counts 9 academic partners (out of which 3 universities) and 4 industrial partners. CODA covers 5 European countries and one third-country, which will favour the mobility of ESRs across all latitudes. CODA needs this diversity in order to gather the top expertise in the four scientific disciplines listed in Section 1.4.1. The apparent bias towards DA expertise is actually desirable in view of the central role of DA in CODA. The exchange of scientific expertise (both bottom-up and top-down) is structured logically by the two scientific WPs. All ESRs will have access to this expertise (see Table 1.2a), as well as the necessary training in transferable skills (Section 1.2.1). In order to maximize the chances of post-CODA employment of the ESRs, CODA covers a diversity of industrial applications in the water and energy sectors (ACA, Statoil, EDF, BKK) and a link to the Copernicus services (NERSC, BSC, UR), which are both in need of expertise related to CODA (Section 1.2.2). The ESR topics cover applications from small scales (CERFACS) to global scales (UiB, BSC), which is also desirable. There is therefore only very limited redundancy in the CODA consortium.

3.4.2 Commitment of beneficiaries and partner organisations to the programme

The beneficiaries are committed to provide the best available training, supervision and facilities to each ESR, they will also provide supervision time, access to external collaborative research projects (see the PIs CVs) and research and dissemination infrastructures. The non-academic partner organizations are committed to co-supervise one ESR, host him/her in their premises for a duration of a few months and participate to project meetings and other project activities.

[1] See the related United Nations factsheet www.un.org/womenwatch/feature/climate_change/downloads/Women_and_Climate_Change_Factsheet.pdf

4. Gantt Chart

	Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Researcher Recruitment	ESR 1								S	S	S						
	ESR 2																S
	ESR 3																S
	ESR 4															S	S
	ESR 5															S	S
	ESR 6											S	S	S			
	ESR 7											S	S	S			
	ESR 8																
	ESR 9											S	S	S			
	ESR 10											S	S	S			
	ESR 11							S	S	S							
Training	Workshop																
	Conference																
	Visiting Scientist							V				V					
	Schools																
Management																	
	Meetings	K											1				
	Dissemination																
	Public Engagement																

	Months	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Researcher Recruitment	ESR 1			S	S	S											
	ESR 2	S	S	S	S	S											
	ESR 3	S	S	S	S	S											
	ESR 4	S				S	S	S	S	S						S	S
	ESR 5	S						S	S	S							
	ESR 6		S	S	S										S	S	S
	ESR 7										S	S	S				
	ESR 8		S	S	S	S											
	ESR 9		S	S	S										S	S	S
	ESR 10		S	S	S										S	S	S
	ESR 11							S	S	S							
Training	Workshop																
	Conference																
	Visiting Scientist	V					V								V		V
	Schools																
Management																	
	Meetings								2								
	Dissemination																
	Public Engagement																

	Months	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Researcher Recruitment	ESR 1	S	S	S												
	ESR 2	S	S	S												
	ESR 3	S	S	S												
	ESR 4	S														
	ESR 5			S	S	S										
	ESR 6															
	ESR 7	S														
	ESR 8	S	S	S	S											
	ESR 9															
	ESR 10															
	ESR 11			S	S	S										
Training	Workshop															
	Conference															
	Visiting Scientist					V				V						
	Schools															
Management																
	Meetings			3												E
	Dissemination															
	Public Engagement															

S = Secondment
K = Kick-off Meeting
V = Visiting Scientist
E = End of project

Note that all dates are estimated and can vary in the course of the project.

5. Participating Organisations

For **Beneficiaries**:

Beneficiary Legal Name	Nansen Environmental and Remote Sensing Center (NERSC)
General Description	NERSC is a non-profit research centre affiliated with the University of Bergen since 1986, with core expertise in remote sensing, data assimilation, ocean, sea ice and climate modelling. It is a project-based centre receiving funding from EU research programmes, the Research Council of Norway, the European Space Agency, the Nordic Council NordForsk, and the industry. Currently NERSC participates in 10 EU funded projects, and coordinates 2 of them. The staff counts 74 employees from 15 countries and includes scientific personnel, 5 Ph.D. candidates, and 10 administrative/technical positions. Within NERSC, the modelling and data assimilation department counts 15 scientists. It has initially introduced the EnKF (Evensen 1994) and kept applying that method in real-time ocean forecasting systems. NERSC is the main developer of the operational TOPAZ system, presently the Arctic Marine Forecasting Center in the European Copernicus Marine Environment Monitoring Services (http://marine.copernicus.eu) and it has more recently introduced the EnKF in NorCPM.
Role and Commitment of key persons (including supervisors)	Dr. Alberto Carrassi (30%) will coordinate the CODA, and co-lead WP3. He will supervise ESR 1 and 7 and co-supervise ESR 2, 3 and 6. Dr. Laurent Bertino (15%) will lead WP3, will supervise ESR 7 and co-supervise ESR 1 and 3.
Key Research Facilities, Infrastructure and Equipment	NERSC has access to Norwegian supercomputing facilities (computer time, storage, visualization software and technical support), including a 200Tflop/s Cray XE6.
Independent Research premises	NERSC facilities (servers, library, software licenses) are available for use in CODA. NERSC maintains an EnKF Matlab package (http://enkf.nersc.no/Code/EnKF-Matlab).
Previous Involvement in Research and Training Programmes	Each year, about 3-4 PhD students complete their education at NERSC (since 1992). NERSC has organized summer schools on ocean and climate dynamics in China, India, and Norway and participated to about 5 similar schools with contributions on data assimilation. Les Houches 2015 one-week workshop, *Theoretical aspects of ensemble DA for the Earth system, in April 2015* (http://lgge.osug.fr/meom/pages-perso/cosme/LesHouches2015/index.php), which has welcomed about 15 students.
Current Involvement in Research and Training Programmes	NERSC leads the Nordic Center of Excellence EmblA (2014-2018), which aims at applying data assimilation across different environmental forecasting problems. EmblA funds 4 ESRs in 3 Nordic countries. 5 externally-funded ESRs are associated to EmblA. NERSC participates to the EU FP7 projects SANGOMA, GROOM, MyOcean, CarboChange, GeoCarbon, EUCISE, national projects EPOCASA, EVA with contributions on data assimilation. NERSC has taken the initiative to establish five independent Nansen Centers in Russia, P.R. China, India, South Africa and Bangladesh, where doctoral training in climate research is a central focus.
Relevant Publications and/or Research / Innovation Product	1. Raanes P., **A. Carrassi** and **L. Bertino** (2015), Extending the Square Root method to account for additive forecast noise in ensemble methods. Mon. Wea. Rev., 143, 3857–3873 2. Sakov, P., F. Counillon, **L. Bertino**, K. A. Lisæter, P. R. Oke, and A. Korablev (2012), *TOPAZ4: an ocean-sea ice data assimilation system for the North Atlantic and Arctic*, Ocean Sci., 8, 633–656. 3. Mitchell L. and **A. Carrassi**, 2014. *Accounting for model error due to unresolved scale in Ensemble Kalman filtering*. *Q.J.Roy.Meteor.Soc*. 141:1417–1428 4. Sakov, P., D. Oliver and **L. Bertino**. 2012. *An iterative EnKF for strongly nonlinear systems*. Mon. Wea. Rev., 140(6), pp 1988-2004. 5. Simon, E and **Bertino, L.** 2012. *Gaussian anamorphosis extension of the DEnKF for combined state parameter estimation: application to a 1D ocean ecosystem model*. J. Mar. Sys. 89. pp.: 1-18

Beneficiary Legal Name	Institut Royal Météorologique de Belgique (RMI)
General Description	The Institut Royal Météorologique de Belgique is a Scientific federal institution of Belgium, depending from the State Secretary in charge of Science Policy. The RMI is responsible for providing weather forecasts and early warnings to the public and the Belgian authorities. RMI delivers official certificates for assurance companies, climatological information to the disaster fund, researchers, universities, companies. To reach these goals and support the government policy, RMI has developed important research activities in atmospheric and climate sciences. About 200 persons are working at the RMI, with 1/3 of scientists. Strong links exist with many Universities of the different Communities of Belgium for both teaching and research activities.
Role and Commitment of key persons (including supervisors)	Dr Stéphane Vannitsem (20%), senior scientist: Supervisor ESR 2. Dr Lesley De Cruz, Researcher (10%): support in the supervision of ESRs involved in the training.
Key Research Facilities, Infrastructure and Equipment	The training activities will be mostly organised in the context of the "Meteorological and Climatological Research and Development" Department of the RMI, located in one of the main buildings of RMI. About 25 scientists and PhD students are currently working in the Department. The computational facilities of RMI consist of four Intel 64-bit compute servers, all of which have shared memory. A 192-core 1.66 GHz IA-64 machine with 580GB of RAM is used for research purposes as well as for running the operational forecasts for Belgium. A second server has 144 Xeon cores (2.67 GHz) and 396GB of RAM. Furthermore, there are two scientific application servers with 64 Xeon cores (2.70GHz and 2.27 GHz, respectively) with 132GB RAM each. A tender for a new supercomputer has been made, which will be used by RMI, ROB (Royal Observatory of Belgium) and BIRA-IASB (Belgian Institute for Space Aeronomy) (due 2015).
Independent Research premises	The beneficiary has own facilities, which are not shared with any other beneficiary.
Previous Involvement in Research and Training Programmes	The beneficiary has been involved in several research projects at national and international levels as coordinator, principal investigator or contributor. These are: **National project** - *Approche nouvelle de l'assimilation de données intégrant les propriétés dynamiques et statistiques de l'erreur de modélisation*. SPP project: MO/34/017. Coordinator : Prof. C. Rouvas-Nicolis. 2007-2010. Role of the Beneficiary: Responsible of the project from February 1st 2010. - *Dynamique de l'erreur de modélisation et correction des prévisions dans des modèles atmosphériques réalistes*. SPP project: MO/34/020. Coordinator : Dr S. Vannitsem, 2009-2010. - *Understanding and predicting Antarctic Sea Ice variability at the decadal timescale.* Projet SPP: SD/CA/04A. 2011-2014. Coordinator of RMI node : Dr. S. Vannitsem, 1 ETP/year over 4 years. - Projet SPP « Additional Researcher » : *Model error dynamics and forecast correction in realistic atmospheric models*. Coordinator : Dr S. Vannitsem, 2013. - Projet BRAIN-BE, *Improving the representation and prediction of climate processes through stochastic parameterization schemes* (STOCHCLIM), 2013-2017. Coordinator : Dr S. Vannitsem. **International project** *Extreme events : causes and consequences.* European project E2C2, du programme FP6-2003-NEST-PATH. Coordinator of RMI node: Prof. C. Rouvas-Nicolis. 2005-2008. Site internet : http://e2c2.ipsl.jussieu.fr/. Role of the beneficiary: participant in the research activities. At the Université Libre de Bruxelles, different courses related to the core aspects of CODA are delivered: *Dynamical Meteorology*, in which basics of predictability and dynamics of instabilities within the atmosphere are provided (Dr Vannitsem).
Relevant Publications and/or Research / Innovation Product	1. Nicolis, C., R. Perdigao and **S. Vannitsem**. 2009. *Dynamics of prediction errors under the combined effect of initial condition and model errors*. J. Atmos. Sci., 66, 766-778. 2. Carrassi A and **S. Vannitsem**. 2011. *State and parameter estimation with extended Kalman Filter. An alternative formulation of the model error dynamics*. Q.J.Roy.Meteor.Soc., 137, 435-451. 3. **Vannitsem S**. 2014 *Dynamics and predictability of a low-order wind-driven ocean – atmosphere coupled model.* Climate Dynamics, 42, 1981-1998, 2014. 4. **Vannitsem S**. and L. De Cruz. 2014. A 24-variable low-order coupled ocean-atmosphere model: OA-QG-WS v2. Geoscientific Model Development, 7, 649-662. 5. **Vannitsem, S.** 2014. Stochastic modelling and predictability: Analysis of a low-order coupled ocean-atmosphere model. Phil Trans Roy Soc, A372, 20130282.

Beneficiary Legal Name	**École nationale des ponts et chausses ENPC**
General Description	École nationale des ponts et chaussées (legal name), or École des Ponts ParisTech, abbreviated ENPC. École des Ponts ParisTech, created in 1747 under the name École Royale des Ponts et Chaussées, is a higher education establishment that trains engineers to a high level of scientific, technical and general competency (www.enpc.fr).
Role and Commitment of key persons (including supervisors)	Professor Marc Bocquet (20%): WP1 Leader, Supervisor ESR 3. Co-Supervision ESR 1 and 5. Sylvain Doré research engineer (5%)
Key Research Facilities, Infrastructure and Equipment	ENPC (and in particular its laboratory CEREA) whose primary goals are the training of future engineers, as well as research has its own facility and infrastructure, perfectly suited to support the training of PhD students and the research of this project.
Independent Research premises	Research facilities are owned by ENPC and available for use in CODA.
Previous Involvement in Research and Training Programmes	Focusing on ENPC/CEREA laboratory: Les Houches 2012 summer school, a three-week international summer school on *Advanced DA for Geosciences* in Les Houches, France, May-June 2012, (http://houches2012.gforge.inria.fr) with 53 students.
Current Involvement in Research and Training Programmes	Focusing on ENPC/CEREA laboratory: Les Houches 2015 Data Assimilation Workshop Les Houches 2015 one-week workshop, *Theoretical aspects of ensemble DA for the Earth system, in April 2015* (http://lgge.osug.fr/meom/pages-perso/cosme/LesHouches2015/index.php), which has welcomed about 15 students, ANR DADA project, INSU/LEFE DAVE project, IPSL/AVES project Prof Bocquet teaches a graduate class on *Introduction to DA* in the Master of Sciences program *OACOS/WAPE* (ocean, atmosphere, climate) of the leading universities and institutes in Paris.
Relevant Publications and/or Research / Innovation Product	1. **Bocquet, M.**, Pires, C. A. and L. Wu, 2010: *Beyond Gaussian statistical modeling in geophysical data assimilation.* Mon. Wea. Rev. **138**, 2997-3023. 2. **Bocquet, M.** and Sakov, P., 2014: *An iterative ensemble Kalman smoother*. Q. J. R. Meteorol. Soc. **140**, 1521-1535. 3. **Bocquet, M.** and Sakov, P., 2013*: Joint state and parameter estimation with an iterative ensemble Kalman smoother*, Nonlin. Processes Geophys. **20**, 803-818. 4. **Bocquet, M.**, 2012: *Parameter field estimation for atmospheric dispersion: Application to the Chernobyl accident using 4D-Var*, Q. J. R. Meteorol. Soc. **138**, 664-681. 5. **Bocquet, M.**, Elbern, H., Eskes, H., Hirtl, M., Žabkar, R., Carmichael, G. R., Flemming, J., Inness, A., Pagowski, M., Pérez Camaco, J. L., Saide, P. E., San Jose, R., Sofiev, M., Vira, J., Baklanov, A., Carnevale, C., Grell, G. and Seigneur, C. , 2014: *Data Assimilation in Atmospheric Chemistry Models: Current Status and Future Prospects for Coupled Chemistry Meteorology Models*, Atmos. Chem. Phys., 15, 5325--5358.

Beneficiary Legal Name	Institut National de Recherche en Informatique et Automatique - Inria
General Description	Established in 1967, INRIA is the only French public research body fully dedicated to computational sciences. It is a national operator in research in digital sciences and is a primary contact point for the French Government on digital matters. Under its founding decree as a public science and technology institution, jointly supervised by the French ministries for research and industry, Inria's missions are to produce outstanding research in the computing and mathematical fields of digital sciences and to ensure the impact of this research on the economy and society in particular. Inria covers the entire spectrum of research at the heart of these activity fields and works on digitally-related issues raised by other sciences and by actors in the economy and society at large. Beyond its structures, Inria's identity and strength are forged by its ability to develop a culture of scientific innovation, to stimulate creativity in digital research. Throughout its 8 research centres and its 180 project teams, Inria has a workforce of 3 400 scientists with an annual budget of 265 million euros, 29% of which coming from its own resources. In 2013, INRIA hosted a total of 1 219 doctorates and 258 postdoctorates.
Role and Commitment of key persons (including supervisors)	Arthur Vidard (20%): WP1 co-leader, Supervisor ESR 4. Laurent Debreu (20%), supervisor ESR 4
Key Research Facilities, Infrastructure and Equipment	Inria gives access to its PhD student to numerous lectures and to national-grade computing facilities whose primary goals are the training of future engineers, as well as research has its own facility and infrastructure, perfectly suited to support the training of PhD students and the research of this project.
Independent Research premises	In addition to national facilities, ESR4 will have access to our local cluster: BullX DLC supercomputer (Bull Newsca) made of 190 nodes, 2 processors per node, 8 cores per processor of Intel Sandy Bridge EP E5-2670, 8c/2.6 GHz/20M/8 GT/s (45.8 TFlops) as well as a few lesser clusters.
Previous Involvement in Research and Training Programmes	Inria (A. Vidard) was coordinator of the French-funded VODA project whose aim was to produce a variational data assimilation system for the ocean model NEMO
Current Involvement in Research and Training Programmes	Inria (A. Vidard) is a partner in FP7 project ERACLIM2 (2014-2016) which will produce a coupled (ocean-atmosphere-ice–land) reanalysis of the 20th century. Contribution to a yearly 1-week course *Introduction to DA* (http://lgge.osug.fr/meom/pages-perso/cosme/info_cours_AD2015.html) at the University of Grenoble Alpes.
Relevant Publications and/or Research / Innovation Product	1. Chabot V., M. Nodet, N. Papadakis and **A. Vidard** (2015). *Accounting for observation errors in image data assimilation*. Tellus A, **67**. doi:10.3402/tellusa.v67.23629 2. **Debreu L.**, E. Neveu, E. Simon, F.X. Le Dimet and A. Vidard (2015), Multigrid solvers and multigrid preconditioners for the solution of variational data assimilation problems. Q.J.R. Meteorol. Soc.. Accepted Author Manuscript. doi:10.1002/qj.2676 3. **Debreu L.**, E. Neveu, E. Simon, F.-X. Le Dimet. Multigrid algorithms and local mesh refinement methods in the context of variational data assimilation. *In: E. Blayo et al. (eds): Advanced Data Assimilation for Geosciences. Lecture notes of Les Houches summer school 2012.* Oxford University Press, 395-412, 2014. 4. Simon, E., **Debreu, L.** and Blayo, E., 2011. 4D variational data assimilation for locally nested models: Complementary theoretical aspects and application to a 2D shallow water model. *Int. J. Numer. Meth. Fluids*, 66: 135–161. doi: 10.1002/fld.2244 5. **Vidard A.**, M. Balmaseda and D. Anderson, 2009. *Assimilation of altimeter data in the ECMWF ocean analysis system 3*. Mon.Wea.Rev. 137 (4), pp.1393-1408

Beneficiary Legal Name	University of Reading (**UR**)
General Description	**UR** was established in 1892, and is now ranked in the top 1% of universities worldwide (QS University World Rankings 2015/16), with a world-class reputation for the quality of teaching, research and links to business. Research at UR is split into five major themes, of which on is Environment. The **School of Mathematical and Physical Sciences** includes the Department of Mathematics and Statistics and the Department of Meteorology. The Department of Meteorology is internationally renowned for its research in weather, climate and ocean sciences. It is home to over 200 research scientists, working in all aspects of weather, climate and Earth observation, including many scientists of the NERC National Centre for Earth Observation and of the NERC National Centre for Atmospheric Science. The Department of Mathematics and Statistics is home to a strong numerical analysis group and strong and productive links with industry are maintained. The **Data Assimilation Research Centre** (DARC), was founded in 2001, incorporates scientists throughout the School working in data assimilation theory and applications. DARC involves 9 academic staff and over 20 research staff and students working on all aspects of data assimilation, from developing theoretical ideas in simplified models, to practical applications using satellite data in large complex systems.
Role and Commitment of key persons (including supervisors)	Dr Amos Lawless (10%), supervisor ESR 5 Dr Alison Fowler (10%), supervisor ESR 5
Key Research Facilities, Infrastructure and Equipment	The School of Mathematical and Physical Sciences has a very large PhD programme with appropriate facilities for a project of this kind, including personal computing and a computing cluster.
Independent Research premises	Facilities are owned by UR and are available for use in CODA.
Previous Involvement in Research and Training Programmes	DARC has organised national courses on data assimilation in 2010, 2011, 21012, 2014. As part of this a suite of training tools for teaching data assimilation has been developed and made available on the Web. Support for use of these tools at the ESA summer school on Earth observation has been given since 2002.
Current Involvement in Research and Training Programmes	In 2016 DARC will deliver courses linked to the ECMWF data assimilation course, with an introduction for the 2 days before and a computing "hands-on" course for 2 days after. A further week-long course in data assimilation is being planned for April/ May 2016. Dr Lawless teaches an *Introductory course on DA* at UR and organizes UK-wide training courses in DA.
Relevant Publications and/or Research / Innovation Product	1. **Fowler, A.M**. and **Lawless, A.S.** (2015), Coupled atmosphere-ocean variational data assimilation in the presence of model error. *Submitted for publication.* 2. Smith, P.J., **Fowler, A.M.** and **Lawless, A.S.** (2015), Exploring strategies for coupled 4D-Var data assimilation using an idealised atmosphere-ocean model. Tellus A, 67, 27025 3. **Fowler, A. M.** and van Leeuwen, P. J. (2013), Measures of observation impact in Data assimilation: the effect of a non-Gaussian measurement error, Tellus A, 65, 20035. 4. **Fowler, A. M.** and van Leeuwen, P. J. (2012), Measures of observation impact in non-Gaussian data assimilation, Tellus A, 64, 17192. 5. Haben, S., **Lawless, A.S.** and Nichols, N.K. (2011), Conditioning of incremental variational data assimilation, with application to the Met Office system. Tellus A, 63, 782-792.

Beneficiary Legal Name	Consejo Nacional de Investigaciones Científicas y Técnicas **(CONICET),** Instituto Franco-Argentino sobre Estudios de Clima y sus Impactos (**IFAECI**)
General Description	The National Scientific and Technical Research Council (CONICET) is a large public research organization founded in 1958. As the largest fundamental research organization in Argentina, CONICET is active in all disciplines, from mathematics to human sciences, as well as environmental and climate sciences. CONICET laboratories employ a large body of tenured researchers, engineers and support staff and are located throughout Argentina. CONICET also maintains a strong international collaboration through partnership agreements with more than thirty countries as well as several international associated laboratories and research centres in Argentina and in Europe.The French research organization CNRS (Centre National de la Recherche Scientifique) is one of the main international partners of CONICET. The IFAECI (French-Argentinean Institute for the Study of Climate and its Impacts) is one of the aforementioned international units. The IFAECI has been created in 2010 and renewed in 2014 as a joint laboratory between CONICET, its French counterpart CNRS and the UBA (University of Buenos Aires). Its mission is to develop a large and multidisciplinary array of scientific interactions between Argentina and France on climate related issues. The broad blend of research expertises present throughout the lab's three facilities provide an excellent synergetic framework to tackle its scientific agenda which is organized under nine main research themes: Climate variability and change in southern South America; Mathematical methods for studies of Weather and Climate; Weather and Climate Prediction; Regional climate modeling and sensitivity studies; Impact studies; Ground-based remote sensing of the atmosphere and its applications; South Atlantic Studies; Physical atmospheric processes at meso and synoptic scales; Physical processes in coastal areas and the Rio de la Plata Estuary.
Role and Commitment of key persons (including supervisors)	Dr. Alexis Hannart (20%) coordinates research theme Mathematical methods for studies of Weather and Climate at IFAECI – Supervisor of ESR6.
Key Research Facilities, Infrastructure and Equipment	IFAECI research facility consists of a computing and data storage system based on a network of 33 servers, a cluster of 248 processors, 2 mass data storage systems with a capacity of 45 terabytes together with an internet service allowing high-speed transfers and connections. The whole system is protected by a central UPS system maintaining energy supply in the event of power outages. IFAECI has 90 personal workstations (PCs) connected in network with structured cabling. ESR5 will have access to IFAECI's facility, which is adapted to support the research planned in the context of this subproject.
Independent Research premises	The research facility is owned by the University of Buenos Aires and is attributed to IFAECI for its research and training activities, and as such will be available for CODA activities.
Previous Involvement in Research and Training Programmes	WWRP/THORPEX workshop on 4D-VAR and Ensemble Kalman Filters intercomparisons (2008), Intensive Course on Data Assimilation (2008, 2011)
Current Involvement in Research and Training Programmes	DADA project, funded by ANR (2014-2017).
Relevant Publications and/or Research / Innovation Product	1. **Hannart A**., J. Pearl, F. E. L. Otto, P. Naveau, M. Ghil (2015) *Counterfactual causal theory for the attribution of weather and climate-related events*, Bull. Am. Met. Soc., accepted. 2. **Hannart A**., A. Carrassi, M. Bocquet, M. Ghil, M. Pulido, J. Ruiz, P. Tandéo (2015) *DADA : Data Assimilation for the Detection and Attribution of weather and climate related events,* Clim. Change, submitted. 3. **Hannart A**., A. Ribes, P. Naveau (2014) *Optimal fingerprinting under multiple sources of uncertainty*, Geophys. Res. Lett., 41, 1261-1268, doi:10.1002/2013GL058653. 4. **Hannart A**. and P. Naveau (2014) *Estimating high dimensional covariance matrices: A new look at the Gaussian conjugate framework,* J. Multivariate Anal., 131, 149-162. 5. **Hannart A**., O. Mestre and P. Naveau (2014) *An automatized homogenization procedure via pairwise comparisons with application to Argentinean temperature series*, Int. J. Climatol. 34: 3528–3545

Beneficiary Legal Name	University of Bergen **UiB**
General Description	**UiB** is a young, modern university with about 14 000 students and 3,400 faculty and staff. Six faculties cover most of the traditional university disciplines, and include 60 different specialized departments, multi-disciplinary research centers and institutes. UiB is engaged in the European Union's Framework programmes for research and technological development and has been designated as a European Research Infrastructure and a Research Training Site in several scientific fields. Since 1997 more than 500 European researchers (professors, senior researchers, post docs and PhD candidates) have visited Bergen on EU grants, making Bergen one of the most international universities, setting out to attract both established and junior scientists to contribute to research teams and work in multidisciplinary research groups. UiB is currently involved in 104 FP7 projects, 39 of which it coordinates. The **Geophysical Institute** (GFI) at UiB is the primary academic marine research organisation in Norway with internationally acknowledged expertise in physical oceanography, climate research, and meteorology. The GFI, with a total of more than 40 active PhD students, provides sound and stimulating teaching environments for PhD students. The institute's research strategy rests upon use of own cutting edge measurement techniques developed in collaboration with technology partners in combination with theoretical studies and modelling in geophysics. GFI is partner in the **Bjerknes Centre for Climate Research**, and has a leading role in the development of the Norwegian Earth System Model (**NorESM**) and climate prediction system (**NorCPM**).
Role and Commitment of key persons (including supervisors)	Prof. Noel Keenlyside (15%) will supervise ESR 8 and co-supervise ESR 10. Dr. François Counillon (20%) will supervise ESR 8 and co-supervise ESR 9.
Key Research Facilities, Infrastructure and Equipment	GFI is the largest such institute in Norway (and likely in the Nordic countries) in climate research and has in its strategic plan to continue to lead in both observational, modeling and prediction oriented studies. The institute provides an excellent environment for the CODA in terms of a competent staff, and provides access to key research infrastructure. In particular, CODA will have access to the necessary super computing facilities and technical support available to UiB through the national NOTUR (www.notur.no) and NorStore (www.norstore.no) projects. Climate model experiments will be performed on the Hexagon (205 TFlop) and Vilje (467 Tflop) super computers. GFI will provide assistance in application of NorESM and NorCPM, through numerous project staff.
Independent Research premises	Research facilities are owned by UiB and available for use in CODA.
Previous Involvement in Research and Training Programmes	GFI coordinated MARECLIM, joint Nordic Master Program in Marine Ecosystems and Climate (2007-2010); GFI coordinated NOMA Sudan, Development of Master programmes in physical and chemical oceanography at Red Sea University (2008-2013); GFI hosted several Marie Curie, ERASMUS, DAAD grant fellows GFI has coordinated a series of EU projects in the field of climate research, among others TRACTOR, PACLIVA, CYCLOPS, CARBOOCEAN, and been a partner in many others
Current Involvement in Research and Training Programmes	GFI is coordinating **(1)** the EU Marie Curie IRSES project SOCCLI, an international exchange scheme for early stage and experienced researchers between Europe and South Africa; **(2)** RESCLIM, The Norwegian Research School in Climate Dynamics which is a national training environment for PhD candidates in climate dynamics. GFI coordinates projects related to climate prediction that include development of the NorCPM: EU-PREFACE, NordForsk-GREENICE, and NFR-EPOCASA UiB gives graduate level courses in climate dynamics, and in particular Prof Keenlyside teaches *Physical Climatology* and *General Atmospheric Circulation* courses.
Relevant Publications and/or Research / Innovation Product	1. Shen, M.-L., **N. Keenlyside**, F. Selten, W. Wiegerinck, G. Duane, Dynamically combining climate models to "supermodel" the tropical Pacific, Geophys. Res. Lett., in press 2. **Counillon, F**., I. Bethke, **N. Keenlyside**, M. Bentsen, L. Bertino, and F. Zheng, 2014: *Seasonal-decadal prediction with the EnKF and NorESM: a twin experiment*. Tellus A, 66, 21074 3. Gulev, S.K., M. Latif, **N. Keenlyside**, W. Park, and K. P. Koltermann, 2013: *North Atlantic Ocean Control on Surface Heat Flux at Multidecadal Timescales*, Nature, 499, 464-467 4. **Keenlyside, N**., H. Ding, and M. Latif, 2013: *Potential of Equatorial Atlantic Variability to Enhance El Niño Prediction,* GRL, 40, 2278-2283. 5. **Keenlyside, N**. S., M. Latif, J. Jungclaus, L. Kornblueh, and E. Roeckner, 2008: *Advancing Decadal-Scale Climate Prediction in the North Atlantic Sector*. Nature, 453, 84-88

Beneficiary Legal Name	Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC)
General Description	The Barcelona Supercomputing Center - Centro Nacional de Supercomputación (BSC), created in 2005, has the mission to research, develop and manage information technology in order to facilitate scientific progress. At the BSC, more than 450 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. The ES-BSC conducts research on emissions, air quality, mineral dust and global and regional climate modelling and prediction. The department operates the high-resolution air quality forecasting system CALIOPE for Europe and Spain; it also maintains the BSC-DREAM8b model for daily operational mineral dust forecasts for the Euro-Mediterranean region, collaborates with the WMO and the Spanish Meteorological Agency (AEMET) to host the Regional Centre for Sand and Dust Warning System (SDS-WAS) covering Europe, Northern Africa and the Middle East and is an active member of the EC-Earth consortium, whose global climate model is widely used at ES-BSC at very high resolution for research and teaching purposes.
Role and Commitment of key persons (including supervisors)	**Prof. Francisco Doblas-Reyes** (10%) will supervise ESR 10, co-supervise ESR 4 and co-lead WP4. **Dr Virginie Guemas** (15%) will supervise ESR9 and lead WP2. **Dr Francois Massonnet** (20%) will supervise ESR9.
Key Research Facilities, Infrastructure and Equipment	The BSC hosts MareNostrum III, a Tier-0 PRACE system with 1.1 Pflop/s capacity as well as other High-Performance Computing (HPC) resources, which will be used by ESRs during their training in climate modelling to conduct their experiments. The BSC also coordinates the Spanish Supercomputing Network, which is the main instrument to grant competitive computing time to Spanish research institutions. The BSC is located within a university campus, and has special agreements to use the university residence and other university facilities (libraries, EDUROAM network, etc.). In fact, most of BSC's group leaders are also university professors, with broad experience in teaching and proved training skills. As a consequence, the BSC profits from an important educational environment.
Independent Research premises	The BSC is a consortium of recent creation. As a consequence, the research premises are all rented. This has never been a problem to provide the space required by all engineers and scientists who either work at or visit the Center. The BSC is located within a university campus, but keeping a complete administrative, financial and research independence. It is worth mentioning that the BSC will have its own building in 2016, which will host all BSC researchers under the same roof.
Previous Involvement in Research and Training Programmes	Over the years, the department has been active in numerous European Projects, including MEDSPA-91, INCO, EUREKA, EARLINET, DEISA, EARLINET-ASOS, ACTRIS, IS-ENES, FIELD_AC, SPECS, EUPORIAS, PREFACE, PRIMAVERA, EUCLEIA, IMPREX and CMUG2. The BSC has participated in 4 ITNs from FP7 and one from H2020, and is continuously involved in the organization of summer schools, workshops and other training events related to the use of high-performance computing in climate modeling and atmospheric sciences.
Current Involvement in Research and Training Programmes	The BSC has around 80 PhD students and 30 postdoctoral researchers. In addition, the BSC is currently involved in several Marie Curie Actions, namely NEMOH and COPA-GT FP7 ITNs, MDRAF, EEPPIBM and MatComPhys FP7 Individual Fellowships, and GEAGAM H2020 RISE.
Relevant Publications and/or Research / Innovation Product	1. **F. Massonnet**, H. Goosse, T. Fichefet, F. Counillon, 2014 *Calibration of sea ice dynamic parameters in an ocean-sea ice model using an ensemble Kalman filter*, Journal of Geophysical Research, **119**, doi:10.1002/2013JC009705. 2. **F. Massonnet,** P. Mathiot, T. Fichefet, H. Goosse, C. König Beatty, M. Vancoppenolle, T. Lavergne, 2013, *A model reconstruction of the Antarctic sea ice thickness and volume changes over 1980-2008 using data assimilation*, Ocean Modelling, **64** 67-75, doi:10.1016/j.ocemod.2013.01.003 3. **Guemas V,** Doblas-Reyes F J, Mogensen K, Keeley S. , Tang Y., 2014, Ensemble of sea ice initial conditions for interannual climate predictions. Climate Dynamics, in press, doi:10.1007/s00382-014-2095-7 4. **Doblas-Reyes, F.J.**, J. García-Serrano, F. Lienert, A. Pintó Biescas and L.R.L. Rodrigues (2013). *Seasonal climate predictability and forecasting: status and prospects.* WIREs Climate Change, doi:10.1002/WCC.217. 5. **Doblas-Reyes, F.J.**, I. Andreu-Burillo, Y. Chikamoto, J. García-Serrano, V. Guemas, M. Kimoto, T. Mochizuki, L.R.L. Rodrigues and G.J. van Oldenborgh (2013). *Initialized near-term regional climate change prediction.* Nature Communications, 4, 1715, doi:10.1038/ncomms2704.

Beneficiary Legal Name	Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique **CERFACS**
General Description	CERFACS is a research organization that aims to develop advanced methods for the numerical simulation and the algorithmic solution of large scientific and technological problems of interest for research as well as industry, and that requires access to the most powerful computers presently available. CERFACS hosts interdisciplinary teams, both for research and advanced training that are comprised of: physicists, applied mathematicians, numerical analysts, and software engineers. Approximately 150 people work at CERFACS, including more than 130 researchers and engineers, coming from 10 different countries. They work on specific projects in nine main research areas: parallel algorithms, code coupling, aerodynamics, gas turbines, combustion, climate, environmental impact and data assimilation. CERFACS is interested in "Global Change and Climate modelling". For more than 10 years, one of the axes of the team is the development and use of data assimilation techniques for geosciences, mostly in ocean and more recently in atmospheric chemistry and hydraulics. Studies on data assimilation for hydraulics and hydrology are currently on going at CERFACS in the framework of several thesis in collaboration with EDF, CNES and several academic labs.
Role and Commitment of key persons (including supervisors)	Sophie Ricci (30%) will supervise ESR 11 in the field of ensemble -based data assimilation for hydrodynamics. ESR will have access to CERFACS training courses (advanced data assimilation).
Key Research Facilities, Infrastructure and Equipment	Technical and scientific high performance supercomputing is becoming more and more important. Realistic combustion computation using complex geometries, chemical kinetics, aircrafts aerodynamics, climate variability ... for each of these CERFACS' research domains high performance computing is a prerequisite to stay competitive. Indoors CERFACS' computing servers deliver 75 Tflop/s with BUL, HP and IBM super computers along with external resources.
Independent Research premises	Research facilities are owned by CERFACS and available for use in CODA.
Previous Involvement in Research and Training Programmes	Data assimilation training program at CERFACS (3 day)
Current Involvement in Research and Training Programmes	There are DA training courses at CERFACS where CODA ESRs can enrol (www.cerfacs.fr/19-25768-Program.php). These courses will provide an overview of the theory and practical methods of DA. The lectures will also cover more specialized topics including covariance modelling and estimation, advanced minimization algorithms, preconditioning, and hybrid ensemble-variational methods. HydrAssim project submitted to ANR
Relevant Publications and/or Research / Innovation Product	1. **Ricci, S**., Piacentini., A., Weaver, A., Ata, R., Goutal, N A Variational *Data Assimilation Algorithm to Estimate Salinity in the Berre Lagoon with Telemac3D*, IAEG, 15-19, September, Turin, Italy. 2. V. Pedinotti, A. Boone, **S. Ricci**, S. Biancamaria, and N. Mognard: *Assimilation of satellite data to optimize large scale hydrological model parameters: a case study for the SWOT mission.* Hydrol. Earth Syst. Sci. Discuss., 11, 4477-4530, 2014 3. Borrell Estupina, V., P.-O. Malaterre, **S. Ricci**, P. Fleury, O. Thual, C. Bouvier, A. Marchandise, M. Jay-Allemand, M. Coustau, E. Harader, M. Guilhalmene, J.-C. Maréchal (2014): *Flood part II: Genesis, propagation and forecasting of flooding at Montpellier city*. Karstologia - Submitted. 4. Coustau M., **Ricci S**., Borrell-Estupina V., Bouvier C. and O.Thual , 2013: *Benefits and limitations of data assimilation for discharge forecasting using an event-based rainfall-runoff model.* Nat. Hazards Earth Syst. Sci., 13, 583-596. DOI 10.5194/nhess-13-583-2013. http://www.nat-hazards-earth-syst-sci.net/13/583/2013/nhess-13-583-2013.html 5. **Ricci S**., Piacentini A., Thual O., Pape E. L., Jonville G., 2011. *Correction of upstream flow and hydraulics state with a data assimilation in the context of flood forecasting*. Hydrol. Earth Syst. Sci 15, 1-21.

For **partner organisations**

Partner Organisation Legal Name	**Statoil ASA**
General description	Oil and Energy company.
Key Persons and Expertise	Geir Evensen and Remus Hanea, experts in ensemble data assimilation.
Key Research Facilities, Infrastructure and Equipment	Statoil Research department co-supervises and hosts approximately 5-8 PhD and master students a year. Statoil provide proper equipment and facilities for the adequate hosting and guidance of the students. Open-source data assimilation software: Ensemble Reservoir Tool (ERT - ert.nr.no/wiki/index.php/Main_Page)
Previous and Current Involvement in Research and Training Programmes	Data assimilation school, bi-annual in Romania through Remus Hanea.
Relevant Publications and/or Research / Innovation Product	1. **Hanea, R**., **G. Evensen**, L. Hustoft, T. Ek, A. Chitu and F. Wilschut: Reservoir Management under geological uncertainty using Fast Model Update. SPE-173305-MS, 2015 2. **Evensen G**., Data Assimilation: The Ensemble Kalman Filter, 2nd ed., Springer, 2009a 3. Sebacher, B., **Hanea, R**.G. and Heemink, A.W. A probabilistic parametrization for geological uncertainty estimation using the ensemble Kalman filter (EnKF), Computational Geosciences, Volume 17, Issue 5, pp 813-832. (2013)

Partner Organisation Legal Name	**Électricité de France**
General description	Energy Production and Distribution.
Key Persons and Expertise	Dr Nicole Goutal, EDF-R&D, has a strong expertise in hydraulic modelling for the purpose of water resource management and operation of electricity generating facilities. During 10 years, she has been the main developer of an open channel finite element and finite-volume modelling suite. More recently, she was rewarded through the successful academic accreditation to supervise PhD students, for which uncertainty quantification in environmental sciences was one of the main subjects. Nicole leads research projects and cross-field engineering and environmental studies for which uncertainty quantification and data assimilation are critical.
Key Research Facilities, Infrastructure and Equipment	EDF-R&D (Laboratoire National d'Hydraulique et Environnement de Électricité de France Recherche et Développement). EDF-R&D develops and implements modelling tools (TELEMAC-MASCARET system) and analytical methods (numeric and experimental) in response to EDF requirements, and conducts research and development activities and studies mainly for the benefit of nuclear, hydraulic and, to a lesser extent, thermal power plants. Some of its activities are also focused on marine renewable energies
Previous and Current Involvement in Research and Training Programmes	CERFACS and EDF-R&D are participating in the so-called "Hydrassim" project in collaboration with the UPMC (Pierre and Marie Curie University), LHSV (Saint-Venant Laboratory for Hydraulics) and SCHAPI (Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations). This project aims at promoting use of uncertainty quantification and data assimilation for modelling of rivers, lakes and estuaries. CERFACS and EDF-R&D participate in TOSCA project led by CNES and purpose as the use of satellite data for data assimilation. A thesis is in progress on this topic. EDF-R&D conducted in Stresa (Italy) in 2012 a workshop on quantifying uncertainties in hydraulic modeling.
Relevant Publications and/or Research / Innovation Product	1. Ricci S., A. Piacentini, A. Weaver A., **N. Goutal** and R. Ata. 2013: *A Variational Data Assimilation Algorithm to Estimate Salinity in the Berre Lagoon with Telemac3D*. Proceedings of the Telemac User Conference, Karlsruhe, (2013). 2. Bozzi S., G. Passoni, P. Bernardara, **N. Goutal,** and A. Arnaud. 2011. *Roughness and discharge uncertainty in 1D water level computations*. Environ. Model Assess DOI 10.1007/s10666-014-9430-6 3. Audusse, E., S. Boyaval, **N. Goutal** and M. Jodeau. 2014. *Numerical simulation of the dynamics of sedimentary river beds with stochastic exner equation*., Ph. Ung ESAIM Proceedings 2014

Partner Organisation Legal Name	BKK Produksjon AS
General description	Hydro Power Company
Key Persons and Expertise	Ina K. Thorstensen Kindem, Ph. D Meteorology. Areas of expertise: Seasonal predictability and teleconnections, weather forecasting for the energy sector, future climate hydrology. Investigating the potential for solar energy in Bergen.
Key Research Facilities, Infrastructure and Equipment	Each year students are offered summer jobs or writes their master thesis by cooperating with BKK. With 1100 employees BKK cover several disciplines, the biggest within hydro power production and transmission of electricity, but we also have employees working with for example trading of electricity, human resources, hydrology and meteorology.
Previous and Current Involvement in Research and Training Programmes	Participating in GREENICE (NordForsk, Top-level Research Initiative; Project n. 6184, Feb. 2014 – Jan. 2017) BKK goal: Improve forecasts of regional climate in the near future, hence improving hydro power planning. Innovation projects related to local renewable energy production and electrification of the transport sector (http://www.bkk.no/om_oss/innovasjon-innovation/innovasjonsportefoljen/)
Relevant Publications and/or Research / Innovation Product	1. Neu et al., (2012) IMILAST - a community effort to intercompare extratropical cyclone detection and tracking algorithms: assessing method-related uncertainties. Bull. Am. Met. Soc 2. Orsolini et al., (2011) On the potential impact of the stratosphere upon seasonal dynamical hindcasts of the North Atlantic Oscillation: A Pilot study. Climate Dynamics 3. Kindem and Christiansen (2001) Tropospheric response to stratospheric ozone loss. G, Res. Lett.

Partner Organisation Legal Name	Catalan Water Agency (ACA)
General description	Hydraulic public autorithy of Catalonia, Spain
Key Persons and Expertise	Expert and senior technicians in the water management resource and the prevention of flood through the downstream basin of the dams.
Key Research Facilities, Infrastructure and Equipment	ACA provide the computers and guidance of the students, as the transfer of knowledge of the hydraulic sector and the feedback necessary for the complete assimilation.
Previous and Current Involvement in Research and Training Programmes	Participation and collaboration in European Projects as member of different projects as end-user
Relevant Publications and/or Research / Innovation Product	1 Recent participation in FP7-WatERP and ECO-Optimedar, Other european projectes (ACA webpage)

6. Ethics Issues

It is expected that the project participants will adopt and conform to all EU policies and changes in these policies. The research topics addressed by the proposed consortium do not raise any sensitive ethical issues related to human beings, human biological samples, personal data, genetic information or animals. At this stage, no potential ethical and/or safety aspects of the research topic [objectives, methodology and possible implications of the results] have been identified.

7. Letters of Commitment

Our date	Our reference	Administrative officer
03.12.2015	Remus Gabriel Hanea	Denise Anne Røsten
Your date	**Your reference**	
03.12.2015	Alberto Carrassi	

Statoil

Page 1 of 2

Mohn-Sverdrup Center / NERSC
Thormoehlensgt. 47
N-5006 Bergen - Norway

Attn. Alberto Carrassi

Project: Coupled Data Assimilation for climate prediction and climate change attribution

Letter of Support

ORIGINAL

Dear Sir;

We hereby have the pleasure of informing you of our intention to support the Project *"Coupled Data Assimilation for climate prediction and climate change attribution"* by the following maximum contribution during a 3 month period in the total time framework of the project (Sept 2016 – Sept 2020).

Our maximum contribution will be as follows:

- In-kind contribution under the form of internal manpower (supervision and hosting of approximately 3 PhD per year.) (2018 or 2019: 75 hours)

Our support to the Project is dependent on support from other industry or institutional partners as described in your Project summary (ref. Attachment 1).

Our support shall be based on your Project description entitled *"Coupled Data Assimilation for climate prediction and climate change attribution,"* enclosed in Attachment 1.

Our support is dependent on the following principles/requirements:

- Statoil giving input to/having influence on the technical content of the research activities, including Statoil's consent required change of scope of work,
- decision gates each year for evaluation of the Project and further support,
- decision gates with the possibility for exit/termination each year, and
- total maximum frame for contribution to be fixed as described above.

DR

This Letter of Support shall automatically be cancelled if the Contractor does not obtain support from other industry or institutional partners as described in your Project Summary.

Contractor shall not publish information concerning this Letter of Support without Company's prior approval.

This Letter of Support shall be governed by the laws of Norway, with Stavanger District Court as legal venue.

Please confirm the receipt of this Letter of Support by e-mail to the attention of Denise Anne Røsten- ddc@statoil.com, within 24 (twenty-four) hours from receipt of this Letter of Support.

Statoil Petroleum AS

Yours faithfully,
for Statoil Petroleum AS (Incorporation number: NO 990 888 213 MVA)

Denise Anne Røsten
Senior Consultant Supply Chain Management

Mobile: +47 95015128
Email: ddc@statoil.com

Visitor address: Arkitekt Ebbells veg 10, Rotvoll Norway

<u>ATTACHMENT 1: "Coupled Data Assimilation for climate prediction and climate change attribution"</u>

DR

Electricité de France
Recherche & Développement
Département Laboratoire National
d'Hydraulique et Environnement

Chatou Lab
6, quai Watier
78400 - CHATOU

T +33 1 30 87 72 58

Nos références : NG/ML- P70/2015/60

Interlocuteur : Nicole Goutal
✆ 01 30 87 82 37
Nicole.goutal@edf.fr

OBJET :

LETTER OF COMMITMENT

With this letter I, Jean-Daniel Mattei, in my capacity as legal representative of Electricity of France – Research and Development (EDF R&D) hereby declares that EDF R&D commits itself to participate in and contribute as partner organisation to the Innovative Trainings Networks (ITN) « CODA », more precisely to host up 3 ESRs for periods of 1 – 3 months (max), to co-supervise their theses and to contribute to the training.

Done at Chatou the 26th of November,

For the organisation
The legal representative

Jean-Daniel Mattei
Chef du département
Laboratoire National d'Hydraulique et Environnement

Morgendagen er her | bkk.no

BKK

Alberto Carrassi
Mohn-Sverdrup Center / NERSC
Thormøhlensgt 47
N-5006 Bergen – Norway
www.nersc.no

Your ref.:
Our ref.:

Date: 18.12.2015

Letter of Commitment CODA

This is a letter to confirm our participation as a partner in the proposal for a Marie Curie Innovative Training Network called "COupled DAta assimilation for climate prediction and climate change attribution" (CODA).

CODA offers a unique opportunity to improve forecast skill by combining highly non-linear coupled Earth System Models with new generations of Earth observations.

Reliable weather information on timescales from days to seasons to decades is of vital importance to ensure optimal use and planning of hydro power. Vestlandet is a core area for hydropower generation in Norway. BKK owns and pursues 32 hydropower stations along the west coast of Norway with a yearly mean production of 6,7 TWh.

Our contribution will be to participate in the recruitment and co-supervision of a Ph. D student (ESR 8). In addition ESR 7 and ESR 8 will spend a short period on secondment to BKK. We will also contribute in the organization of a school on climate prediction. The expected outcome for BKK will be to evaluate the benefits of using seasonal-to-decadal climate prediction in planning and also the provision of a real-time forecast.

Yours sincerely,
BKK PRODUKSJON AS

Erik Spildo
Head of Production Department

Yours sincerely,
BKK PRODUKSJON AS

Toril H. Christensen
Head of Analysis Department

BKK PRODUKSJON AS Kokstadvegen 37, PO Box 7050, NO-5020 Bergen | **T:** +47 55 12 70 00 | **E:** firmapost@bkk.no
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Agència Catalana de l'Aigua

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N-5006 Bergen - Norway

Letter of Commitment

With this letter I, Diego Moxò Güell, Manager of the Catalan Water Agency (ACA), hereby declares that ACA commits itself to participate and contribute as partner organisation to the Innovative Trainings Networks (ITN) "CODA". More precisely, ACA commits to host up 3 ESRs (PhD students) for periods of 1 to 3 moths, co-supervise their thesis and contribute to develop rain forecast systems up to seven months, and therefore integrate them in our daily procedure.

In Barcelona, on December 23th, 2015

Generalitat de Catalunya
Departament de Territori
i Sostenibilitat
Agència Catalana de l'Aigua

Diego Moxó Güell
Manager of
Catalan Water Agency

Ref.: 20151115 (5566598)

Generalitat de Catalunya
Departament de Territori
i Sostenibilitat

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