Horizon 2020

Call: H2020-EO-2016
(Earth Observation)

Topic: EO-3-2016

Type of action: RIA
(Research and Innovation action)

Proposal number: 730070

Proposal acronym: COPPER

Deadline Id: H2020-EO-2016

Table of contents

How to fill in the forms

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

1 - General information

Topic	EO-3-2016
Call Identifier	H2020-EO-2016
Type of Action	RIA
Deadline Id	H2020-EO-2016

Acronym: COPPER

Proposal title*: Connecting Ocean Prediction Products and European Research

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

Duration in months: *36*

Fixed keyword 1: *S2 - Marine monitoring (Copernicus service)* Add

Free keywords:
Copernicus
Marine Service
Earth Observation
Models
High resolution
Operational Oceanography

Proposal ID **730070** *Acronym* **COPPER**

Abstract

The overarching goal of COPPER is to ensure that the Copernicus Marine Environment Service (CMEMS) will have continuing access to world-class marine modelling tools that will allow it to address the ever-increasing demands for marine monitoring and prediction in the 2020s and beyond. In response to the future priorities for CMEMS identified in the call, COPPER will develop new capabilities to:
• enable the production of ocean forecasts and analyses that exploit upcoming high resolution satellite datasets such as SWOT altimetry,
• deliver ocean analyses and forecasts with the higher spatial resolution and additional process complexity demanded by users,
• exploit the opportunities of new high performance computing (HPC) technology
• allow easy interfacing of CMEMS products with detailed local coastal models.

These developments will be delivered in the NEMO ocean model, an established, world-class ocean modelling system that already forms the basis of the majority of CMEMS analysis and forecast products. Hence the pathway from the research in COPPER to implementation in CMEMS will be simple and seamless, as the model code developed will be directly applicable in CMEMS models.

NEMO has a long track record of producing and maintaining a stable, robustly engineered code base of the type that is needed for operational applications, including CMEMS. The COPPER consortium includes all six members of the NEMO consortium, with two further partners who bring complementary expertise in numerical modelling and HPC. The COPPER consortium combines world-class expertise in ocean modelling and HPC, established software engineering processes and infrastructure, and in- depth knowledge of the CMEMS systems and processes. Thus COPPER is exceptionally well placed to deliver the operational-quality model code required to meet the emerging requirements of CMEMS, and maintain it into the future.

Remaining characters 88

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

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	MET OFFICE	United Kingdom
2	FONDAZIONE CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI	Italy
3	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	France
4	ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA	Italy
5	NATURAL ENVIRONMENT RESEARCH COUNCIL	United Kingdom
6	MERCATOR OCEAN	France
7	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	Spain
8	INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE	France

2 - Administrative data of participating organisations

PIC	***Legal name***
999892685	*MET OFFICE*

Short name: MET OFFICE

Address of the organisation

Street FitzRoy Road

Town EXETER

Postcode EX1 3PB

Country United Kingdom

Webpage www.metoffice.gov.uk

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Legal person .... yes

Non-profit ....no

International organisation ....unknown

International organisation of European interest ......unknown

Secondary or Higher education establishment ....unknown

Research organisation ....no

Enterprise Data

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

SME self-assessment .... unknown

SME validation sme....................................... unknown

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

NACE Code: - - Not applicable

Department(s) carrying out the proposed work

Department 1

Department name: Met Office

☐ not applicable

☒ Same as organisation address

Street: FitzRoy Road

Town: EXETER

Postcode: EX1 3PB

Country: United Kingdom

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **730070** *Acronym* **COPPER** *Short name* **MET OFFICE**

Person in charge of the proposal

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

Title: Dr.

Sex: (•) Male ( ) Female

First name **Mike** Last name **Bell**

E-Mail **mike.bell@metoffice.gov.uk**

Position in org.: Fellow in Ocean Dynamics

Department: Met Office Hadley Centre ☐ Same as organisation

☒ Same as organisation address

Street: FitzRoy Road

Town: EXETER Post code: EX1 3PB

Country: United Kingdom

Website: http://www.metoffice.gov.uk/

Phone 1: +44 1392885516 Phone 2: +xxx xxxxxxxxx Fax: +44 1392885681

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Paula	NEWTON	paula.newton@metoffice.gov.uk	+441392884834
Katie	Herring	katie.herring@metoffice.gov.uk	

PIC	***Legal name***
999419422	*FONDAZIONE CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI*

Short name: CMCC

Address of the organisation

Street VIA A IMPERATORE 16

Town LECCE

Postcode 73100

Country Italy

Webpage www.cmcc.it

Legal Status of your organisation

Research and Innovation legal statuses

Public body .... no

Non-profit .... yes

International organisation .... no

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

Secondary or Higher education establishment .... no

Research organisation .... yes

Legal person .... yes

Enterprise Data

SME self-declared status.. 2013 - 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: 721 - Research and experimental development on natural sciences and engineering

Department(s) carrying out the proposed work

Department 1

Department name: ODA - Ocean modeling and Data Assimilation ☐ not applicable

☐ Same as organisation address

Street: Via Franceschini, 31

Town: Bologna

Postcode: 40128

Country: Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **730070** *Acronym* **COPPER** *Short name* **CMCC**

Person in charge of the proposal

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

Title: Dr.

Sex: ◯ Male ◉ Female

First name: **Simona** Last name: **Masina**

E-Mail: **simona.masina@cmcc.it**

Position in org.: Head of ODA Division

Department: ODA - Ocean modeling and Data Assimilation ☐ Same as organisation

☐ Same as organisation address

Street: Via Franceschini, 31

Town: Bologna Post code: 40128

Country: Italy

Website: www.cmcc.it

Phone 1: +39 051 3782604 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Giulia	Galluccio	giulia.galluccio@cmcc.it	+390243986856

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

Short name: CNRS

Address of the organisation

Street Rue Michel -Ange 3

Town PARIS

Postcode 75794

Country France

Webpage www.cnrs.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Legal person .... yes

Non-profit ....yes

International organisation ....no

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

Secondary or Higher education establishment ....no

Research organisation ....yes

Enterprise Data

SME self-declared status.................................2013 - no

SME self-assessment .... unknown

SME validation sme.......................................2013 - 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: 721 - Research and experimental development on natural sciences and engineering

Department(s) carrying out the proposed work

Department 1

Department name: LGGE

☐ not applicable

☐ Same as organisation address

Street: rue Moliere 54

Town: Saint Martin d'Heres cedex

Postcode: 38402

Country: France

Department 2

Department name: LOCEAN

☐ not applicable

☐ Same as organisation address

Street: Place Jussieu 4

Town: Paris cedex 05

Postcode: 75252

Country: France

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **730070** *Acronym* **COPPER** *Short name* **CNRS**

Person in charge of the proposal

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

Title: Dr.

Sex: ◉ Male ◯ Female

First name: **Julien**

Last name: **Le Sommer**

E-Mail: **julien.lesommer@lgge.obs.ujf-grenoble.fr**

Position in org.: Researcher

Department: LGGE

☐ Same as organisation

☐ Same as organisation address

Street: Rue Moliere 54

Town: Saint Martin d'Heres

Post code: 38402

Country: France

Website: lgge.osug.fr/

Phone 1: +33476825065

Phone 2: +XXX XXXXXXXXX

Fax: +XXX XXXXXXXXX

Other contact persons

First Name	*Last Name*	*E-mail*	*Phone*
Isabelle	Raynaud	a.spv-europe@dr11.cnrs.fr	+33476881006

PIC	***Legal name***
999472675	*ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA*

Short name: ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Address of the organisation

Street Via di Vigna Murata 605

Town ROMA

Postcode 00143

Country Italy

Webpage www.ingv.it

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Legal person .... yes

Non-profit ....yes

International organisation ....no

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

Secondary or Higher education establishment ....no

Research organisation ....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: - - Not applicable

Department(s) carrying out the proposed work

Department 1

Department name: INGV-Bologna ☐ not applicable

☐ Same as organisation address

Street: Via Franceschini 31

Town: BOLOGNA

Postcode: 40128

Country: Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

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

Title: Dr.

Sex: ○ Male ◉ Female

First name: **Emanuela**

Last name: **Clementi**

E-Mail: **emanuela.clementi@ingv.it**

Position in org.: Researcher

Department: INGV-Bologna

☐ Same as organisation

☐ Same as organisation address

Street: Via Franceschini 31

Town: BOLOGNA

Post code: 40128

Country: Italy

Website: www.ingv.it

Phone 1: +39 0510406244

Phone 2: +xxx xxxxxxxxx

Fax: +39 0514151463

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Livia	Cassai	livia.cassai@ingv.it	+390510406401

PIC	***Legal name***
999989200	*NATURAL ENVIRONMENT RESEARCH COUNCIL*

Short name: NERC

Address of the organisation

Street Polaris House, North Star Avenue

Town SWINDON WILTSHIRE

Postcode SN2 1EU

Country United Kingdom

Webpage http://www.nerc.ac.uk

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Legal person .... yes

Non-profit ....yes

International organisation ....no

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

Secondary or Higher education establishment ....no

Research organisation ....yes

Enterprise Data

SME self-declared status..................................2015 - no

SME self-assessment ....2015 - no

SME validation sme.. unknown

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

NACE Code: 721 - Research and experimental development on natural sciences and engineering

Department(s) carrying out the proposed work

Department 1

Department name	National Oceanography Centre	☐ not applicable
	☐ Same as organisation address	
Street	6 Brownlow Street	
Town	Liverpool	
Postcode	L3 5DA	
Country	United Kingdom	

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **730070** *Acronym* **COPPER** *Short name* **NERC**

Person in charge of the proposal

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

Title: Dr. Sex: (•) Male ( ) Female

First name **Jason** Last name **Holt**

E-Mail **jholt@noc.ac.uk**

Position in org.: Head of Marine Systems Modelling

Department: National Oceanography Centre ☐ Same as organisation

☐ Same as organisation address

Street: 6 Brownlow Street

Town: Liverpool Post code: L3 5DA

Country: United Kingdom

Website: www.noc.ac.uk

Phone 1: +44 151 7954843 Phone 2: +xxx xxxxxxxxx Fax: +44 151 7954918

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Phil	Worrall	pgwo@noc.ac.uk	+44151 7954842

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

Short name: MERCATOR OCEAN

Address of the organisation

Street RUE HERMES 8-10 PARC TECHNOLOGIQUE

Town RAMONVILLE SAINT AGNE

Postcode 31520

Country France

Webpage www.mercator-ocean.fr

Legal Status of your organisation

Research and Innovation legal statuses

Public body .... no

Legal person .... yes

Non-profit .... yes

International organisation .... no

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

Secondary or Higher education establishment .... no

Research organisation .... yes

Enterprise Data

SME self-declared status................................. 2013 - 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: 721 - Research and experimental development on natural sciences and engineering

Department(s) carrying out the proposed work

Department 1

Department name	Research and Development Service	☐ not applicable
	☒ Same as organisation address	
Street	RUE HERMES 8-10 PARC TECHNOLOGIQUE DU CA	
Town	RAMONVILLE SAINT AGNE	
Postcode	31520	
Country	France	

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **730070** *Acronym* **COPPER** *Short name* **MERCATOR OCEAN**

Person in charge of the proposal

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

Title: Dr. Sex: ◉ Male ○ Female

First name **Jerome** Last name **Chanut**

E-Mail **jerome.chanut@mercator-ocean.fr**

Position in org.: Researcher

Department: Research & Development ☐ Same as organisation

☒ Same as organisation address

Street: RUE HERMES 8-10 PARC TECHNOLOGIQUE DU CANAL

Town: RAMONVILLE SAINT AGNE Post code: 31520

Country: France

Website: www.mercator-ocean.fr/

Phone 1: +33 561393814 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Lydie	Marty	lydie.marty@mercator-ocean.fr	

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

Legal person .... yes

Non-profit ....yes

International organisation ....no

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

Secondary or Higher education establishment ....no

Research organisation ....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 - Scientific research and development

Department(s) carrying out the proposed work

Department 1

Department name: Earth Science ☐ not applicable

☐ Same as organisation address

Street: Jordi Girona Street, 29th

Town: Barcelona

Postcode: 08034

Country: Spain

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **730070** *Acronym* **COPPER** *Short name* **BSC**

Person in charge of the proposal

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

Title: Mr.
Sex: (•) Male ( ) Female

First name: **Kim** Last name: **Serradell**

E-Mail: **kim.serradell@bsc.es**

Position in org.: Group Manager (Computational Earth Sciences)

Department: Earth Sciences Department ☐ Same as organisation

☐ Same as organisation address

Street: Jordi Girona Street, 29th

Town: Barcelona Post code: 08034

Country: Spain

Website: www.bsc.es/

Phone 1: +34 934134051 Phone 2: +xxx xxxxxxxxx Fax: +34 934137721

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Marina	Azor	marina.azor@bsc.es	+34934134082
Miguel	Castrillo	miguel.castrillo@bsc.es	+34934134051

Proposal ID **730070** *Acronym* **COPPER** *Short name* **INRIA**

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

Legal person .... yes

Non-profit .... yes

International organisation .... unknown

International organisation of European interest ...... unknown

Secondary or Higher education establishment .... unknown

Research organisation .... 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 - Scientific research and development

Proposal ID **730070** *Acronym* **COPPER** *Short name* **INRIA**

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 **730070** *Acronym* **COPPER** *Short name* **INRIA**

Person in charge of the proposal

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

Title: Dr.   Sex: (●) Male ( ) Female

First name **Florian**   Last name **Lemarié**

E-Mail **florian.lemarie@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 1: +33 476514860   Phone 2: +xxx xxxxxxxxx   Fax: +xxx xxxxxxxxx

Other contact persons

First Name	***Last Name***	***E-mail***	***Phone***
Fanny	Rossetti	recettes-grenoble@inria.fr	+33476615568

Proposal ID **730070** *Acronym* **COPPER**

3 - Budget for the proposal

No	Participant	Country	(A) Direct personnel costs/€	(B) Other direct costs/€	(C) Direct costs of sub-contracting/€	(D) Direct costs of providing financial support to third parties/€	(E) Costs of inkind contributions not used on the beneficiary's premises/€	(F) Indirect Costs / € (=0.25(A+B-E))	(G) Special unit costs covering direct & indirect costs / €	(H) Total estimated eligible costs / € (=A+B+C+D+F+G)	(I) Reimburse-ment rate (%)	(J) Max.EU Contribution / € (=H*I)	(K) Requested EU Contribution/ €
1	Met Office	UK	334879	50050	5000	0	0	96232,25	0	486161,25	100	486161,25	486161,25
2	Cmcc	IT	227778	11000	0	0	0	59694,50	0	298472,50	100	298472,50	298472,50
3	Cnrs	FR	130222	13000	0	0	0	35805,50	0	179027,50	100	179027,50	179027,50
4	Istituto Nazionale Di Geofisica E	IT	176731	9000	0	0	0	46432,75	0	232163,75	100	232163,75	232163,75
5	Nerc	UK	205020	15000	0	0	0	55005,00	0	275025,00	100	275025,00	275025,00
6	Mercator Ocean	FR	206237	11500	0	0	0	54434,25	0	272171,25	100	272171,25	272171,25
7	Bsc	ES	48000	9900	0	0	0	14475,00	0	72375,00	100	72375,00	72375,00
8	Inria	FR	100220	9900	0	0	0	27530,00	0	137650,00	100	137650,00	137650,00
	Total		1429087	129350	5000	0	0	389609,25	0	1953046,25		1953046,25	1953046,25

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

Title of Proposal: Connecting Ocean Prediction Products and European Research (COPPER)

LIST OF PARTICIPANTS

Participant No	Participant organisation name	Country
1	Met Office (Met Office)	UK
2	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)	IT
3	Centre National de la Recherche Scientifique (CNRS)	FR
4	Instituto Nazionale di Geofisica E Vulcanologia (INGV)	IT
5	Natural Environment Research Council (NERC)	UK
6	Mercator Ocean (Mercator Ocean)	FR
7	Barcelona Supercomputing Center – Centro Nacional de Supercomputacion (BSC)	SP
8	Institut National de Research en Informatique et en Automatique (INRIA)	FR

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1. EXCELLENCE

1.1 Objectives of COPPER

The over-arching goal of COPPER is to ensure that the Copernicus Marine Environment Monitoring Service will have continuing access to world-class marine modelling tools that allow it to address the ever-increasing demands for marine monitoring and prediction in the 2020s and beyond.

The Copernicus Marine Environment Monitoring Service (CMEMS) provides a suite of observation- and model-based products to support monitoring and sustainable exploitation of the marine environment across multiple user sectors. CMEMS products are delivered through three Thematic Assembly Centres (TACs) and seven Monitoring and Forecasting Centres (MFCs). The MFCs, covering the global ocean and six regional partitions of European waters, each provide (i) near-real-time analyses of the current state of the ocean; (ii) reanalyses, i.e. consistent, observation-constrained estimates of the ocean's evolution over recent decades; and (iii) forecasts of ocean evolution a few days ahead. For (i) and (ii) observations from multiple sources are assimilated into an ocean model, providing a synthesis of the different observations and a dynamically consistent estimate of the ocean state where there are no observations. To produce (iii) models are run forwards in time from the current analysis state. Thus ocean models are at the centre of CMEMS MFC products.

NEMO (**N**ucleus for **E**uropean **M**odelling of the **O**cean) is a flagship European modelling framework, developed by six European partners, all of whom contribute to this proposal. NEMO has around 1300 registered users in all continents except Antarctica, and the latest user version of the NEMO code has been downloaded around 550 times since its release in June 2015. NEMO, configured for different regions, is used in six of the seven CMEMS MFCs, and so underpins the CMEMS services.

NEMO is internationally recognised as a state-of-the-art ocean modelling framework, providing high quality analysis and forecast products. However, user demands for marine monitoring do not stand still, and analysis by CMEMS identified a number of future requirements for development of the CMEMS service, summarised in the Guidance Document[1] accompanying this call. The goal of COPPER is to address the requirements for long term (Tier 3) ocean modelling research identified in the Guidance Document, and to deliver the results of this research as thoroughly proven and assessed code in the NEMO reference code repository, ready for rapid implementation by the CMEMS MFCs in future versions of CMEMS.

Specifically, COPPER will address the ocean modelling aspects of the four key Tier 3 research requirements identified in the Guidance document, through the following objectives:

Objective 1: Develop a new version of the NEMO reference code that addresses the key challenges of delivering ocean state estimates and forecasts at ever-higher resolution.

This objective addresses the requirement *"Solving ocean dynamics at kilometric resolution"* (Guidance document section 5.1.1): The need to address user demands for high resolution information, and to exploit new, high resolution satellite and in situ observations, cannot be achieved simply by running NEMO at higher resolution with current numerical discretisations and algorithms. COPPER will perform the research and development needed to deliver the required accuracy, physical process fidelity and computational speed, focusing specifically on: advanced space-time discretisation methods with improved accuracy and stability (WP6); multi-scale modelling approaches to allow high resolution to be focused where it is needed (WP7); efficient numerical algorithms for future high performance computing architectures (WP8); tidal physics in global models, in preparation for high-resolution altimetry and for global models that begin to resolve shelf seas processes (WP3), and wave-current interactions expected to operate at kilometre scale (WP4). The outcome will

[1] http://ec.europa.eu/growth/sectors/space/research/horizon-2020

be a new version of the NEMO reference code, tested, evaluated, and ready for deployment in future, high resolution CMEMS modelling systems.

Objective 2: Develop improved data assimilation for the next generation of high resolution observing networks.

This objective addresses the requirement *"Designing future observing systems and related assimilation methods"* (Guidance document section 5.1.2). The development of new high resolution datasets such as wide-swath altimetry, high resolution SST and sub-surface profile data from gliders poses challenges to current data assimilation systems. COPPER will: evaluate the impact of assimilating different data types at high resolution; evaluate the impact of different potential configurations of satellite constellations and sampling; and recommend optimal data assimilation approaches for use at high resolution (WP5). The outcomes will be recommendations for data assimilation methods in future high resolution CMEMS systems, and for future EO programmes to optimise the beneficial impact on CMEMS products.

Objective 3: Develop a NEMO capability to calculate complex biogeochemical processes efficiently while maintaining high physical resolution.

This objective addresses the requirement *"Developing seamless information chains linking dynamics, biogeochemistry and ecosystem essential variables"* (Guidance Document Section 5.1.3). A fundamental challenge in modelling ocean biogeochemical processes is to link the biogeochemical models to high resolution physical models in a way that is computationally affordable. COPPER will develop a proven and sustainable NEMO code for 'online coarsening' in which biogeochemical variables are calculated on a coarser grid than the physics. The code will be integrated with the new developments outlined in Objective 1, and tested in a range of ocean regimes (WP7). The outcome will be new NEMO code, tested, evaluated and ready for deployment in future CMEMS systems to allow efficient production of complex biogeochemical products.

Objective 4: Develop a flexible, generic interface between CMEMS observational and model-based products and detailed, downstream coastal modelling systems

This objective addresses the requirement *"Seamless interaction between CMEMS and coastal monitoring systems"* (Guidance Document Section 5.1.4): For many applications of CMEMS products, further downscaling is required to address end-user scales, using nested coastal models. COPPER will develop a prototype generic interface system between CMEMS products and coastal modelling systems, and trial this with a number of potential users (WP9). The outcome will be tested prototype interface code, suitable to be packaged and delivered as a user utility alongside future CMEMS products.

A final objective concerns the dissemination and exploitation of the results of COPPER by the CMEMS service and its users.

Objective 5: Provide proven model code and assessments suitable for rapid deployment in the CMEMS service.

The COPPER outputs will be code and scientific assessments that are designed and tested to allow rapid assessment and uptake by the CMEMS services as part of their system evolution cycle. Code will be developed according to the rigorous NEMO software engineering standards in order to assure easy transition to operational use. A detailed roadmap to deployment will be developed as a deliverable of COPPER (WP2). Additionally, COPPER will use a range of engagement mechanisms with downstream users of the CMEMS services (WP2, 9) to capture their requirements, to inform them of upcoming capabilities and to build user skills in exploitation of future CMEMS products.

1.2 Relation to the Work Programme

COPPER relates to work programme topic **EO-3-2016: Evolution of Copernicus Services.** Specifically, COPPER will deliver the key developments in ocean modelling and data assimilation capability identified in the accompanying Guidance Document by the Copernicus Marine Environment Monitoring Service (CMEMS) as critical to deliver the CMEMS model-synthesised products of the future (near-real-time ocean analyses and forecasts, and delayed mode reanalyses of the evolving ocean state over recent decades).

Below we summarise how COPPER addresses the scope of the call, the expected impact, and the specific CMEMS priorities in the Guidance Document.

Relation to the specific challenge and scope of the call

"Demonstrating the technical operational feasibility of a specific service evolution proposal"
COPPER will deliver a package of developments to the NEMO ocean model, which is widely used by the CMEMS Monitoring and Forecasting Centres (MFCs) in the production of CMEMS products. These code developments will be tested individually and together in model configurations that are chosen to be close to the operational configurations used by the MFCs. The developments will be implemented in the NEMO reference code, which is the code repository, centrally maintained by the NEMO Systems Team, that forms the source of all NEMO applications. Hence the code will have been tested and demonstrated to a high level of robustness and in a context that is close to operational CMEMS configurations.
Further details of the proposed developments can be found in section 1.4 (WPs 3,4,6,7) and the detailed WP descriptions.

"Providing a proof-of-concept or a prototype for a proposed evolution of the Copernicus services" (respecting the border between Copernicus services and downstream services)
In addition to the NEMO code developments above, which will be in the form of prototypes for CMEMS MFC model configurations, COPPER will also deliver insight into the configuration of observing systems and the associated data assimilation systems to derive maximum value from expected new high-resolution satellite sea surface height and temperature datasets. As well as providing recommendations to the CMEMS MFCs for optimal configuration of their data assimilation systems to exploit these observations, this work will also provide scenarios for Earth Observation mission planners to evaluate the relative benefits of different satellite constellation designs. Further details can be found in section 1.4 (WP5) and the detailed WP description.

Recognising the boundary between the generic CMEMS services and downstream uses such as high resolution coastal modelling for marine planning and services, and the need for easy interfacing of CMEMS products with these downstream systems, COPPER will develop a generic software interface that allows CMEMS products (both model- and observation-based) to be quickly linked to the wide variety of downstream modelling systems that are in use. This will be provided as a software library ready for consideration by CMEMS to be adopted as a CMEMS user utility, served from the CMEMS website. Further details can be found in section 1.4 (WP9) and the detailed WP description.

"Demonstrate the appropriateness to implement the proposed Evolution later on at a European level"
Modelling, data assimilation and user interface capabilities developed by COPPER will be developed and tested in the context of existing configurations used by the CMEMS MFCs. Therefore the suitability for future adoption by Copernicus is built into the COPPER approach.

"One or more possible scenarios how this evolution could potentially be integrated into the existing service"
COPPER's Dissemination and Communication Plan (D2.3), and Exploitation Plan (D2.2) are tightly integrated with the research and development in the Work Packages. Specifically, close contact will be maintained with the CMEMS MFCs throughout the development process, in order to ensure that code developments and data assimilation recommendations are in a form that can quickly be pulled through to operations. These links will be maintained partly through common institutional links between the COPPER consortium and several MFCs, but also through a formal programme of communication with the MFC leads responsible for system evolution. See Section 2.2 and WP2 for further detail.

"If it could be built on the existing observation data or if new observation requirements would be needed"
COPPER WP5 will specifically investigate how to configure operational data assimilation systems to make optimal use of planned developments in high resolution altimetry, while WP3 will make model developments essential for its use. Therefore a focus of COPPER is on preparing to exploit the next generation of ocean remote sensing instruments. Additionally COPPER will develop recommendations to make best use of existing high resolution sea surface temperature instruments.

"To what extent the proposed evolution could be a candidate for the operational Copernicus service in terms of cost-benefits, calendar and operational feasibility"

The philosophy of COPPER is to deliver new ocean modelling capability at a level of technology readiness where it can be rapidly evaluated and implemented into CMEMS operations if desired, through Tier 1 implementation activities. Thus the deliverables of COPPER are expected to be around 1 year away from operational implementation. Regular contact with CMEMS lead personnel for system evolution, through the COPPER Exploitation Plan (Section 2.2 and WP2), will ensure that CMEMS can build the upcoming capabilities from COPPER into its thinking in its review.

The NEMO code developed will be implemented in the NEMO reference code, which is a stably supported repository. Hence it will deliver the level of robustness and longevity required for operational use. (See Section 1.3 for details of the NEMO development process).

Regarding cost-effectiveness, the focus of COPPER WPs 7 and 8 is on developing NEMO to offer the next-generation ocean modelling capabilities demanded by CMEMS users, at a practical computational cost given expected evolutions in High Performance Computing (HPC) technology. Further details can be found in Section 1.4 (WPs 7 and 8) and the detailed WP descriptions.

"The conditions for making available the results to the entities implementing the EU Copernicus programme"

All the outputs of COPPER will be made freely available to entities implementing the Copernicus programme (and others). This will be through the open-source NEMO code repository, through open access reports and journal articles, or (for the coastal model interface tool developed in WP9) through an open-source code repository hosted initially by one of the COPPER partners (with the possibility of later transitioning to hosting by CMEMS itself). See Section 2.2 for more detail.

A Specific Challenge of the call is to ***"have the results of the R&D available in a timely manner to support an informed discussion, if and under which conditions an evolution of the operational service portfolio of the Copernicus service is appropriate"***

Proposed optimisations of data assimilation from COPPER WP5 will be delivered around 2020 (with early results made available to CMEMS sooner). This timing will be ideally suited to allow CMEMS to implement relevant changes in their models and data assimilation systems ready to exploit the SWOT altimetry missions anticipated around 2020 (https://swot.cnes.fr).

The model developments proposed here arise from a scoping exercise by the NEMO consortium of what resolution and process complexity may be physically achievable on the timescale of 2020-2025, considering expected developments in HPC capability. Thus the modelling developments proposed are well timed to deliver new capabilities at the same time as the required HPC resources to run them become available.

Our Exploitation plan will be ready in time to feed into CMEMS as it develops its plans for its second implementation phase (May 2018-April 2021). Full results from the project will be available in time for the review of the next phase of Copernicus starting in April 2021.

Relation to the Copernicus evolution priorities in the Guidance Document

The focus of COPPER is on the four evolution priorities identified by the Copernicus Marine Environment Monitoring Service. Indeed the first four objectives of COPPER (see Section 1.1) are each directly motivated by one of the CMEMS priorities. Specifically COPPER will address the four CMEMS priorities as follows:

1. Solving ocean dynamics at kilometric resolution *(Guidance Document section 5.1.1)*

COPPER will develop the capability for global models to represent tidal processes, crucial to make best use of future ***wide-swath altimetry*** (WP3). It will develop ***numerical schemes*** (WP6) and ***multi-scale methods*** (WP7) appropriate for kilometric resolution, and develop the representation of ***interfaces*** (coupling) ***with wave components*** (WP4). Additionally it will develop ***new algorithms to solve the model equations efficiently on next generation computing*** systems (WP8).

2. Designing future observing systems and related assimilation methods *(Guidance document section 5.1.2)*

COPPER WP5 will conduct ***observing system impact studies*** focusing on the expected new high resolution altimetry and surface temperature datasets. These studies will deliver a ***consistent assessment of observation data and assimilation techniques,*** as well as recommendations for the ***design of assimilation methods***. Additionally studies will be carried out to inform ***choices in the design and exploitation of observation networks and satellite constellations***.

3. Developing seamless information chains linking dynamics, biogeochemistry and ecosystem essential variables *(Guidance document Section 5.1.3)*
Biogeochemical and ecosystem models are underpinned by the physical transport processes of advection and diffusion, and it is these processes which represent the bulk of the computational cost in biogeochemical models, and an effective barrier to increased sophistication in biogeochemical modelling. To allow CMEMS to deliver the required ***model-data integration*** at affordable computational cost, WP7 will develop highly sophisticated methods to compute at high resolution only the specific processes and regions where high resolution is needed. These ground-breaking multi-scale techniques will open up the capability to ***improve the representation of key processes***, and focus on ***monitoring of regional/coastal areas and the land-ocean interface***.

4. Seamless interaction between CMEMS and coastal monitoring systems (Guidance document section 5.1.4)
COPPER WP9 will deliver ***connectivity between the Marine Service and downstream coastal systems***, by developing a generic code library that will allow easy linking of CMEMS products with the full range of coastal modelling systems in use for monitoring and planning.

Contributions to Copernicus Climate Change Service
While not the focus of the COPPER work plan, many of the developments to NEMO will also contribute substantially to the future requirements of the Copernicus Climate Change Service (C3S), particularly ***Climate Modelling at High Resolution*** (Guidance document section 5.5.2), through the enhancements to the capability of NEMO to run at high resolutions accurately (WP 6), with good process representation (WP 3, 4) and with high computational efficiency (WP7, 8). The majority of European climate models used to provide the C3S services use NEMO as their ocean component, so results can be quickly applied. The recommendations on data assimilation of new high-resolution satellite datasets (WP5) will be equally applicable to the initialisation of climate forecasts (C3S requirement on ***Climate Prediction***, Guidance Document paragraph 5.5.1), specifically the C3S requirement "*To ensure high quality initial fields for climate forecasts long term high climate-quality data are necessary enabling data assimilation for seasonal to decadal climate forecasts*".

The guidance document calls for ***active links*** with the Copernicus services. In COPPER these links will be delivered through direct engagement with staff at the CMEMS Monitoring and Forecasting Centres (MFCs), particularly the System Evolution leads for the MFCs. This will take the form of regular updates on progress with COPPER developments, emerging evidence on impacts of these developments, and discussion about the requirements to ensure a smooth pathway to implementation in the CMEMS services through Tier 1 implementation activities by the MFCs. Issues to be addressed might include, for example, implications of particular code design or coordinate configurations for operational data assimilation systems, or for accurate calculation of particular user-relevant outputs. Through regular discussion any potential barriers to implementation will be identified early and design choices made to minimise the issues. The institutions of the COPPER consortium are participants in five of the seven CMEMS MFCs. Discussions of the proposed approach to links with COPPER have been held with representatives of several of the MFCs, and they are supportive of this approach. Discussions have also been held with the C3S management team, who have also expressed interest and support for this interaction. Interactions with CMEMS and C3S will be led by COPPER WP2.

1.3 Concept and methodology

(a) Overall concept

The concept of COPPER is to use the internationally recognised NEMO model, already used for the majority of CMEMS model-based products, as the basis for developing the new capabilities required by CMEMS, facilitating rapid and seamless transition from research to implementation.

To realise the full value of the new Earth Observation (EO) capabilities implemented under Copernicus, the EO data will need to be integrated with other observation types and synthesized into spatially and temporally complete products using ocean models. The NEMO model is well-established, with around 1300 registered users around the world. NEMO is used in the production of CMEMS products in five of the seven CMEMS regional Monitoring and Forecasting Centres (MFCs), and is under consideration for use in a sixth. NEMO is also well-established in global climate modelling, forming the ocean component of eight of the climate models assessed in the IPCC 5th Assessment Report (expected to increase to twelve in the 6th Assessment).

The NEMO model is well designed to deliver CMEMS products that are state-of-the-art given the current observing system and computational capabilities. However, to derive the value from new EO capabilities, and to deliver higher-resolution products based on the next generation of supercomputers, further development of the capability of NEMO and its associated data assimilation systems is needed.

NEMO is developed and maintained by a consortium comprising six European partners, all of whom are partners in COPPER (Partners 1-6). NEMO is underpinned by core funding from the six partners, which supports a small systems team to maintain the code and develop its functionality and configuration tools at a baseline rate. The formal consortium process allows the pooling of the different expertise and resources of the partners, while maintaining the ability to set and follow clear strategic priorities. Since 2013, the NEMO consortium has maintained a development strategy, which was agreed following a structured workshop and drafting process involving both NEMO consortium scientists and other ocean modelling experts (http://www.nemo-ocean.eu/About-NEMO/News/Development-Strategy-2014 , requires free registration and login). Many of the NEMO development goals contribute to the requirements identified by CMEMS to serve its future service requirements (reflecting the fact that MyOcean/CMEMS scientists were involved in the development of the NEMO strategy), and the work proposed in COPPER focuses on these areas, enabling development to take place on a timescale that will deliver the required functionality improvements on the timeframe (around 2020) when the computational resources available to CMEMS are expected to have reached a level where it is viable to implement them operationally, and when new satellite instruments are expected to become operational. In other words, ***COPPER will deliver the ocean modelling developments needed for CMEMS to exploit the next generation of satellite instruments and High Performance Computers (HPC).***

The COPPER consortium consists of the NEMO consortium partners (Partners 1-6), plus two further partners (Partners 7 and 8) who bring complementary expertise in numerical analysis and modelling algorithms, and in High Performance Computing. The resulting team covers all the required expertise to deliver the objectives, while remaining small enough to keep a clear focus. The COPPER partners have extensive experience of working together and have evolved working practices over a number of years to deliver robust model developments in a consortium environment. Some key research collaborators have also been identified who will bring specific expertise to individual work packages; these are identified under the relevant work packages in Section 1.4.

COPPER also delivers developments in two key areas connected to NEMO that have been identified by CMEMS for development. First, data assimilation is an essential component of operational ocean modelling systems, and COPPER draws in staff from its institutions with leading expertise in ocean data assimilation, to prepare data assimilation systems to exploit the next generation of high resolution satellite instruments. The results of the COPPER data assimilation analysis are expected to be timely for application the new high resolution SWOT altimetry mission planned for launch in 2020 (https://swot.cnes.fr). So, as with the modelling developments, the goal is to ***deliver the data assimilation developments needed for CMEMS to exploit the next generation of high resolution satellite data.*** Secondly, easy interfacing from CMEMS products to the wide range of downstream coastal modelling systems is crucial to develop the full range of uses of the CMEMS products, and the goal of this COPPER activity is to ***deliver a generic interfacing tool to CMEMS products that can be used by the full range of coastal modelling systems in use.***

Inter-disciplinary considerations and use of stakeholder knowledge

The NEMO developments in COPPER require collaboration between ocean dynamicists, numerical analysts, experts in High Performance Computing and software engineers. The COPPER consortium has been designed to bring experts in these areas together.

A primary stakeholder in COPPER will be the CMEMS delivery team. Work in COPPER will maintain close contact with CMEMS to ensure regular feedback on the relevance and applicability of the research in an operational environment. A second, indirect stakeholder will be the downstream users of CMEMS products. COPPER will engage with the full CMEMS user community in collaboration with the existing CMEMS user engagement programme, while for the case of the generic interface with coastal models, specific user trial and feedback activities are planned (WP9). For further detail of stakeholder engagement activities, see Section 2.2 and WP2.

Positioning of the project

In terms of the EC's definitions of Technology Readiness Levels[2], the starting point for COPPER will mainly be concepts and theoretical developments (TRL 1-2), in some cases demonstrated in simple proof-of-concept tests (TRL 3). COPPER will move these ideas beyond proof-of-concept, to a point where they have been demonstrated in an operationally-relevant environment (TRL 6), in some cases with early testing in operational environments (TRL 7). This is the appropriate end point for targeted Tier 3 research, to be followed by operational implementation by CMEMS MFCs through Tier 1 activities. An explicit roadmap to operational implementation of COPPER deliverables in CMEMS, developed in consultation with the CMEMS MFCs, will be delivered (D2.3).

Links to other national and international activities

The groups involved in the current proposal obtain considerable gearing from their position in other international research projects. Some specific projects include:

- National (France, Italy, UK) programmes providing baseline support for the NEMO Systems Team
- CMEMS MFCs, several of which are based at the home institutions of COPPER scientists, so providing easy access to operational oceanography expertise
- Horizon 2020 PRIMAVERA which includes developments of NEMO parametrisations relevant for high resolution climate modelling (and complementary to the developments in COPPER)
- Horizon 2020 AtlantOS which delivers data impact studies to understand the impact of assimilating different in situ data types into operational systems. The focus on in situ data complements the satellite focus in COPPER.
- ESI-Wace Centre of excellence in High Performance Computing

Additionally, COPPER scientists are active members of several important international panels, providing links to the global ocean modelling and operational oceanography communities, e.g.:

- CLIVAR Ocean Model Development Panel (OMDP).
- DRAKKAR (a European group developing global NEMO configurations, primarily as a research tool)
- GODAE Ocean View (GOV) Observing System Evaluation Task Team (GOV-OSEval-TT) (provides links between modellers and Earth Observation Mission Planners)
- GOV Task Team on Data Assimilation (GOV-DA-TT)
- GOV Coastal Ocean and Shelf Seas Task Team (GOV-COSST-TT) (provides links to coastal modelling internationally)

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[2] *European Commission, G. Technology readiness levels (TRL), HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995.*

(b) Methodology

COPPER WPs 3, 4, 6, 7, 8 provide developments to the NEMO code. Experience in many operational modelling centres has shown that to develop model code that is suitable for use in a range of operational configurations requires substantially more effort than to develop working code that is to be used in 'research mode' by a single researcher or team. The development of NEMO follows a carefully defined process which has been steadily refined over the 10 years since the NEMO consortium was initiated. Developments are supported by the NEMO System Team funded by the consortium members, whose job is to incorporate new scientific developments into the NEMO reference code and ensure that the code and its documentation are of robust quality. The NEMO software development process consists of:

1. Initial code design, reviewed by science and software experts ('Preview');
2. definition of specific test cases;
3. development of code in a separate code branch, including validation and documentation by the developer;
4. run and evaluate the test case(s), write report to demonstrate success of development;
5. full expert review of development and testing;
6. NEMO Systems Team merges code into main NEMO reference code, usually as part of the annual NEMO 'merge party'.

This process has been tested and refined over a number of development cycles, and guarantees that COPPER will deliver robust, operational quality code in NEMO that is ready for rapid deployment in CMEMS. WP9, which delivers a stand-alone software library, will follow a similar development process.

Test cases will be selected in advance by each work package, as appropriate to (a) demonstrate and evaluate the expected impacts, and (b) be close to operational CMEMS configurations. Within this it is expected that some test cases will be common to several work packages, and these are likely to be consolidated into standard test cases that are distributed with the NEMO code. This approach will also be applied to the data assimilation experiments in WP5.

A key feature of COPPER's methodology is to establish effective channels of communication with the key stakeholders, so that developments can rapidly be brought into operational use in CMEMS and exploited by end users. These channels exploit the existing close links between COPPER consortium institutions, the NEMO Systems Team, and CMEMS personnel. Figure 1.3.1 and the text following it summarise data and information flows between COPPER, the NEMO Systems Team, various bodies of CMEMS, and downstream CMEMS users. The detailed methods of dissemination and exploitation are described in more detail in Section 2.2.

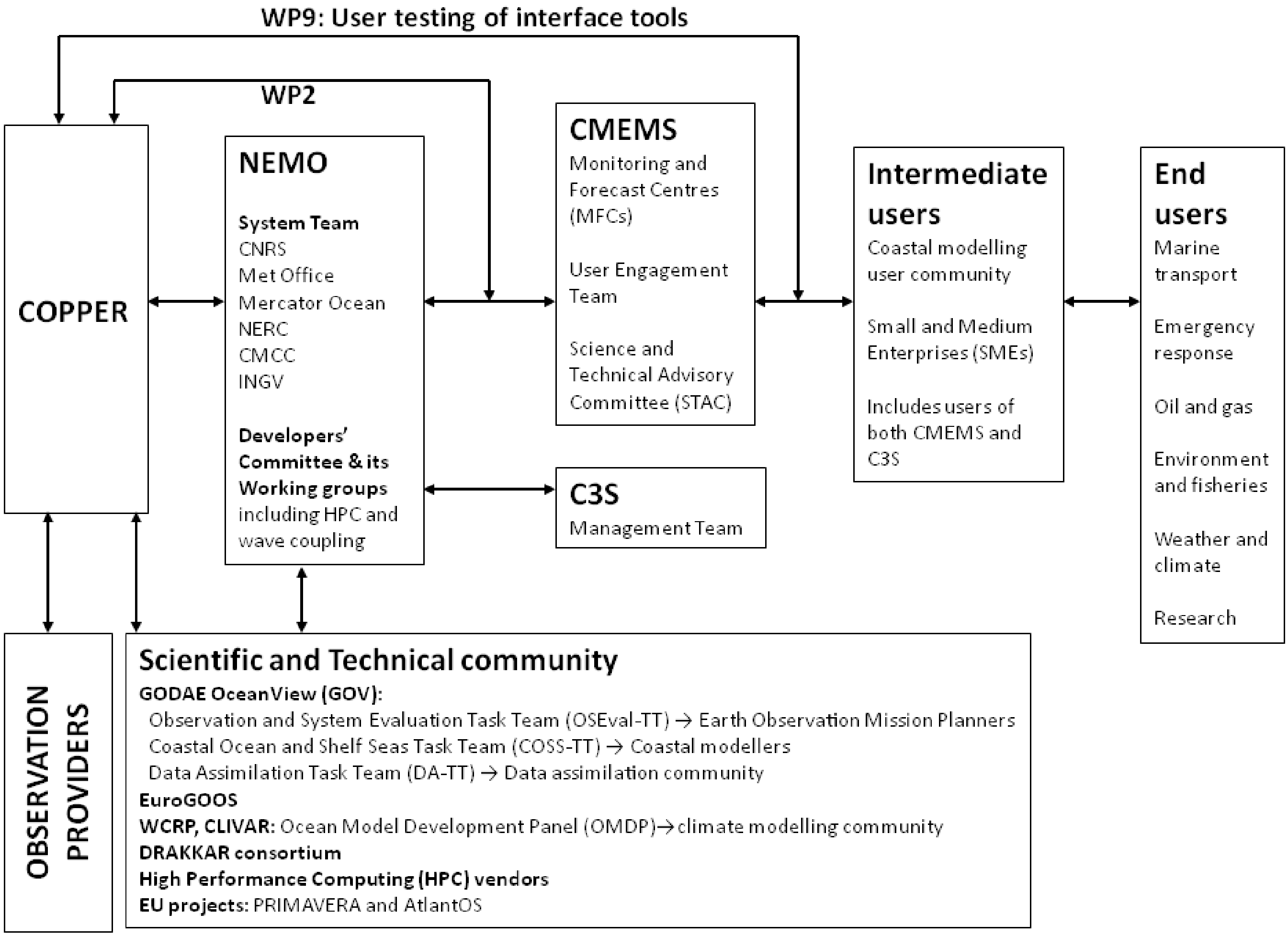


Figure 1.3.1: Links between COPPER and key impact areas

Definitions and interactions with COPPER:

NEMO Systems Team: the core team supporting and implementing developments to the NEMO reference code. Recipients of COPPER code developments. Recipient of COPPER developments.

NEMO Developers' Committee: an expert group consisting of NEMO consortium members and external experts, advising on strategy for NEMO development. Provide feedback on COPPER developments.

CMEMS Monitoring and Forecast Centre: CMEMS centre producing analyses, reanalyses and forecasts for one of seven regions (including global). Potential implementor of COPPER developments (via NEMO reference code).

CMEMS User Engagement Team: the team in CMEMS responsible for developing downstream use of the CMEMS services. COPPER interaction with downstream users will be in close collaboration with this team.

CMEMS Science and Technical Advisory Committee: external expert committee advising CMEMS on overall science and technical development strategy (potentially including COPPER developments).

C3S*:* Copernicus Climate Change Service. Potential user of COPPER developments via the NEMO reference code.

Intermediate Users: Individuals/bodies who translate the generic Copernicus products to user scales to inform end users, for example by downscaling or integrating with socio-economic models. Benefit from COPPER developments primarily indirectly through improvements to CMEMS products. Coastal Interface (COPPER WP9) feeds directly to intermediate users.

End Users: decision makers who are dependent on knowledge of the state of the marine (or climate) environment. Benefit from COPPER developments primarily indirectly through improvements to CMEMS products.

GOV-OSEVal-TT: International committee bringing together experts on marine observations with experts on their use in operational oceanographic systems. Provides established pathway for insights on observing system design from COPPER WP5 to feed into EO mission planning.

GOV-COSS-TT: International committee promoting and guiding the development of operational oceanography for coastal and shelf waters. Provides established pathway for two-way communication with coastal users.

GOV-DA-TT: International committee promoting and guiding the development of data assimilation methods for operational oceanography. Provides established pathway for two-way communication with the international data assimilation community (WP5).

EuroGOOS: European body promoting the science and practice of operational oceanography in Europe. Provides established pathway for two-way communication with intermediate and end users.

WCRP/CLIVAR OMDP: International committee promoting and guiding the development of ocean models, particularly for climate. Provides established pathway for two-way communication with the international ocean modelling community.

DRAKKAR: Collaborative European grouping developing high resolution global ocean models based on NEMO, primarily for research purposes. Provides established pathway for two-way communication with the wider European ocean modelling community.

HPC Vendors: Provide detailed technical insights into optimisation methods and upcoming HPC technology (WP8). Benefit from understanding of NEMO code optimisation issues on their own platforms.

EU projects: PRIMAVERA delivers complementary ocean modelling developments focusing on physical parametrisations for climate modelling. AtlantOS provides complementary observing system impact studies focusing on in situ observations.

Sex and/or gender analysis

EO-3-2016 does not have a gender dimension explicitly integrated into it, but the COPPER consortium does recognise the importance of considering whether sex and/or gender analysis can be taken account in the project's content. This has been considered, but because of the nature of the work done by the project, much of the work and the results will be gender neutral. Areas where the project may need to consider the gender dimension in more detail will be in the context of dissemination, exploitation, communication and engagement activities; in general, those activities where the project is in contact with groups external to the project. The project will consider how these activities can be designed such that there is no gender (or other bias) within them, so that the project both gathers information effectively from the full range of potentially impacted areas, as well as disseminates and communicates in ways that do not discriminate against any potentially interested areas (or people within them).

A Gender Strategy and Action Plan (MS2) will be produced by M3 of the project, and will act as a living document, detailing how gender considerations will be managed within the project. The Coordinator will maintain awareness of sex and gender dimension research within areas relevant to COPPER, to ensure that it organises any activities (in particular those involving groups external to the project), in line with the best knowledge on sex and/or gender analysis.

MS2 will also provide strategy for the management of gender balance within the consortium. Further information on this can be found in Section 3.2.10.

1.4 Ambition

Overall ambition

The ambition of COPPER is to deliver innovative developments to NEMO and its interfaces, to enable CMEMS to take advantage of future Earth Observation and computing platforms. The developments are organized in COPPER into seven work packages (WP 3-9), and below we describe the advances to be made by each work package.

Global tidal capability in NEMO (WP3)

Global ocean forecast systems do not at present explicitly represent tides (although regional systems do include tides). In COPPER we will develop the tidal capability within a global configuration of NEMO at 1/12° which uniquely will include ice shelves (important for representing the phase and amplitude of global tides). We expect implementing tides in a geopotential coordinate global model to be particularly challenging due to issues of spurious numerical mixing and the need to accurately represent energy loss by unresolved gravity wave breaking. We will draw on the experience from the hybrid-isopycnal model, HyCOM (Arbic et al., 2010) and Dr. Brian Arbic has agreed to act as an informal advisor to the project.

Diagnostic tools for barotropic and baroclinic tides and numerical mixing will be developed and used to evaluate the model prototype. Based on this evaluation, improved vertical coordinates for representing tides and reducing numerical mixing will be implemented and optimized for use in the global model, based on the z-tilde approach (Leclair and Madec, 2011). The diagnostic tools will be made available to the international ocean and climate modeling communities through the ESMVal community model evaluation library, which is the pathway being used by other Horizon 2020 climate modelling projects such as PRIMAVERA and CRESCENDO.

Global tidal modeling with NEMO is a new and exciting prospect that has the potential to place CMEMS at the cutting edge of global ocean products, since no other global operational ocean forecast system currently exploits this capability. By making the global tidal capability available within NEMO, COPPER will deliver the ocean modeling infrastructure to enable two key advances in future CMEMS products:

- Enabling CMEMS to exploit the upcoming wide-swath altimeter to provide improved forecasts of ocean surface currents. Forecasts of surface currents rely on assimilation of satellite altimetry but at the resolution of the wide-swath altimeter, it will be essential that CMEMS is able to resolve the internal tide for accurate assimilation.
- By representing global tides, global NEMO configurations at the resolutions expected in the next few years will be able to better represent the density structure in shelf seas. Current global configurations cannot do this because of their lack of tidal mixing on the shelf. This will extend the reach of CMEMS beyond the European shelf seas (where regional systems currently exist) and allow downstream users the ability to investigate marine impacts in coastal regions on a global scale, as well as improving sea ice forecasts in the Arctic where the interaction of sea ice with tides on the extensive Arctic shelf regions is crucial.

Additional wave processes within NEMO (WP4)

Wave-current interactions processes influence the boundary fluxes, momentum and energy exchange between the atmosphere and the ocean and within the water column (a summary is given in Cavaleri et al. 2012). The importance of wave coupling to improve the skill of ocean predictions (for example of surface currents) has been identified in the CMEMS analysis of future requirements (Guidance document) and represents a common development issue for many CMEMS MFCs in the coming years.

Currently the wave coupling in NEMO is achieved by using a surface drag coefficient obtained directly from a wave model in order to compute the surface wind stress.

A wave coupling working group within the NEMO consortium has assessed two different approaches proposed in the literature: the "vortex force" (VF – Ardhuin et al. 2008) and the "radiation stress" (RS – Mellor 2011) formulations. The approach preferred for NEMO is VF, since it presents a more rigorous mathematical derivation and a larger range of applicability. The VF representation treats the conservative (vortex force, Bernoulli head and quasi-static pressure gradient) and non-conservative processes (breaking acceleration etc.) separately since the former has a known vertical distribution, while the latter can presently only be expressed with an empirical vertical profile. The NEMO wave working group has produced a preliminary code implementation of meso- to large-scale processes; however some important conservative terms (e.g. interaction of Stokes drift with the large scale flow) are missing in the implementation. COPPER WP4 will, first, build on the preliminary development by introducing key missing terms. A second stage of model development will be then performed by including new terms related to wave induced mixing and small scale wave-current interaction processes, in order to achieve a full wave coupling in NEMO. The objective is to improve the prediction of sea-state estimates, reducing errors due to unresolved nonlinear feedbacks between currents and waves that affect the oceanic circulation (in particular on shelf and coastal waters) as well as the sea level, mixing, bottom stress, surface temperature and upwelling.

The combined role of the implemented processes, as well as their individual contributions, will be evaluated in a suite of three test cases using off-line wave information that are closely related to CMEMS operational configurations (Mediterranean Sea, North West Shelf, Global Ocean) and one on-line fully coupled test to investigate effects on both the hydrodynamics and waves.

Investigation of the impact of data assimilation on CMEMS systems (WP5)

Ocean data assimilation is a crucial component of CMEMS systems, for both operational predictions and reanalyses. Present and forthcoming EO missions such as wide swath altimeter data will require CMEMS data assimilation systems to deal with unprecedentedly high spatial- and temporal-resolution observing networks. The optimal use of recent high resolution sea surface temperature data also appears to cause particular difficulties that need to be understood, e.g requiring a very good representation of the diurnal cycle within the observation oerator (Pimentel et al. 2008). This questions the optimality of current strategies for the assimilation of EO data.

WP5 will perform assimilation sensitivity experiments to establish optimal practices for high-resolution data assimilation, including understanding the impact of different observing systems and indicating the best approaches to assimilate high-resolution data, especially sea-surface temperature and altimetry data from satellites. This exercise will help both EO mission planners and CMEMS MFCs in understanding how best to exploit present and future missions, for instance in terms of sub-sampling of high resolution observations (averaging vs thinning) or synergy of missions (impact of different setups for EO satellite constellation). This information will be fed back to mission planners through the GODAE Ocean View Observing System Evaluation Task Team (GOV-OSEVal-TT), on which the COPPER team is represented. Sensitivity experiments will also be conducted with the with-holding of satellite observations or change in the observation operator to assess the impact of them on the analysis system.

WP5 will also perform investigations on assimilation diagnostics such as analysis increments from available reanalyses. Comparing analysis increments in a suite of experiments assimilating different observing networks may reveal information about the impact of observation types, and/or weaknesses in the formulation of current analysis systems or observation operators. For instance, with present systems (e.g. the Met Office's GloSea5, the CMCC's C-GLORS, the Mercator Ocean's GLORYS and the INGV's MFS) it is possible to detect robust signatures of the model and atmospheric forcing systematic errors, possibly attributable to NEMO model configurations. These errors reveal serious shortcomings in the quality of current Copernicus ocean re-analyses and limit the effectiveness of the assimilation of Earth Observation data (and hence the value extracted from those data). By comparing results from systems using different assimilation schemes, and different NEMO resolutions, we expect to be able to identify the origin of at least some of the errors and adjust the systems so as to reduce them.

The groups involved have led several international inter-comparison exercises and developed novel data assimilation schemes (Bell et al. 2004, Adani et al., 2011, Waters et al. 2015, Storto et al., 2015), as well as having a deep knowledge of CMEMS ocean data assimilation, forecast and reanalysis systems. Investigations will be carried out with systems close to the operational CMEMS systems. This will ensure that the outcomes of the investigations can be efficiently transferred into the CMEMS systems.

A coupled space-time discretisation scheme (WP6)

The accuracy of flow predictions based on NEMO depends on the discretization strategy used to resolved model equations. NEMO relies on explicit time-stepping algorithms that are subject to Courant–Friedrichs–Lewy (CFL) stability criteria. In practice, the current version of NEMO uses the Leapfrog (LF) scheme with Robert–Asselin (RA) filtering because it has good discrete conservation properties in the context of low-resolution climate applications (in particular with respect to time dissipation of variance). For higher resolution applications, it is well-known that the RA filter increases phase errors, dissipates the physical mode and affects stability. Moreover, the LF-RA time-stepping algorithm being unconditionally unstable for diffusive process, it can be combined only with centered advection schemes so that monotonicity or positive- definiteness comes at a substantial cost because it must be done on 2Δt thus dividing the CFL criteria by 2. The lack of damping of the computational mode for well-resolved scales is also a long-standing problem. Preparing NEMO for kilometric resolution therefore requires a revisit of time-stepping schemes.

Lemarié et al (2015) have considered the efficiency of possible alternatives to LF-RA in a three-dimensional framework (i.e. centered in the vertical and upwind biased in the horizontal). An attractive approach for oceanic models is to use high-order one-step space–time schemes built on the extension of the Lax–Wendroff methodology to higher-order. If space and time discretizations are separated, as usually done in oceanic models, the resulting scheme requires large spatial stencils and multi-step time integration to reach high-order accuracy. In contrast Lemarié et al. (2015) have shown that approaches that genuinely combine discretization in space and time are significantly more efficient than any existing alternatives because high order of accuracy can be obtained with compact stencils. But it remains to be seen how to combine those schemes with mode-splitting in ocean models.

We here propose to overcome the above challenge and implement a coupled space–time discretization approach in NEMO. The expected benefit of the proposed task is an improvement of the accuracy of CMEMS flow predictions at constant numerical cost. We can expect a significant reduction of phase errors for kilometric scale applications and a reduction of spurious energy dissipation. Better constrained stability properties of NEMO can also improve the robustness of operational production chains. The proposed approach is based on state-of-the-art research in applied mathematics. The research activities required to reach a fully operational implementation in NEMO will lead to one or several publications.

Multi-resolution capabilities (including coarsening of biogeochemical component within NEMO) (WP7)

Multi resolution capabilities will be an essential component of future ocean modelling systems. Given the expected evolution of high performance computing (HPC) technology, the need for effective kilometric resolution can only be met by focusing the explicit kilometric scale only in the regions and for the model components where they are most critical. For example it is likely that global models, even at eddy resolving resolution, will still need local refinement and, more importantly, vertical coordinate change in key areas such as narrow straits or where dense water cascading feeds deep and intermediate water masses.

Recent research has demonstrated, at least formally, that it is feasible to save HPC resource without loss of information, and indeed to reach effective kilometric resolution in an operationally feasible way, using multi-resolution methods. In particular, the AGRIF multigrid library as implemented in NEMO, allows two-way nesting of fine grid regions within a larger, coarser grid domain (Debreu et al. 2008). One of the scientific challenges here is to ensure that the subgrid parametrisations remain appropriate for the different resolutions. To address this AGRIF allows for flexibility in the parameter choice for each grid and even adaptive displacement of embedded grids (Blayo et al. 1999).

However, to be ready for implementation as a practical ocean modelling tool for CMEMS, some substantial further developments are needed to AGRIF. In particular, the ability to run the costly biogeochemical component on a coarser grid than the dynamics without loss of information (so called "on-line coarsening", Levy et al. 2012) needs to be brought from concept stage ('hard wired' code developed under FP7 programme EMBRACE) to a pre-operational prototype, and the ability to nest finer resolution in the *vertical* needs to be developed (for example to improve representation of small-scale overflow regions).

This work package will develop AGRIF to

- Develop the "on-line coarsening" approach for the biogeochemical component to operate successfully in the context of CMEMS global and regional models. A preliminary 'hard coded' version of the coarsening is available but is not suitable for use in an operational CMEMS context, where multiple global/regional configurations must be serviced. The developments in WP7 will involve both the design of novel numerical schemes and software design to ensure that the needed information is seamlessly sent from dynamics to the coarser biogeochemical component with all required conservation properties, even on complex grids such as the tripolar grid used by the CMEMS global MFC. The developments will be evaluated in test cases that are close to CMEMS configurations.

- Develop the ability of local vertical grid refinement, including the ability to change the vertical coordinate change in key areas (for example to a terrain following coordinate with a lerger number of levels near overflow regions or the shelf break). This goes beyond state of the art since two-way, online nesting with different vertical coordinates systems is, to our knowledge, unexplored so far.

The proposed two-level time stepping (WP6) fits well into the WP7 multi-grid nesting paradigm, facilitating the conservation properties near grid interfaces and the reactivation of adaptive capabilities. Developments will be carried out in close coordination with the timestepping developments in WP6, to ensure consistent implementation into the NEMO reference code.

The new features will be implemented in the NEMO reference code, and the test cases used will be close to CMEMS operational configurations, facilitating rapid incorporation in future CMEMS systems.

Preparing NEMO for emerging High Performance Computers (WP8)

In order to address future requirements for operational ocean modelling it is essential that NEMO runs efficiently on current and future high performance computers (HPC). Ensuring this is difficult since the current implementation of the code was once developed for serial computation on computing architectures which are significantly different to nowadays high-performance computing systems. This code was parallelized to take advantage of new architectures and increasingly frequent clusters facilities, but without actually altering the previous algorithmic structure. Therefore, a deep analysis is needed to understand the factors that are limiting performance in order to take the right actions. This analysis will ensure that NEMO will be able to take full advantage of emerging developments in HPC technology.

Recently, work has been undertaken by the NEMO consortium and key partners, to improve the NEMO code parallel efficiency, focusing on two bottlenecks: (i) the communication, and (ii) the I/O time. The effect of the communication overhead can be mitigated by increasing the computation/communication ratio. Regarding the communication, some work has been done in this direction optimizing different modules (e.g. sea-ice, open boundary conditions and the 'north-fold' in the tripolar grid used in global NEMO configurations) and the communications routine (message packing), but further improvements are required to allow NEMO to be executed efficiently on massively parallel HPC architectures. Regarding the time spent performing I/O operations, the integration of the 'I/O server' XIOS (http://forge.ipsl.jussieu.fr/ioserver) allowed allocate dedicated resources to be allocated to I/O operations and, consequently, to allow model execution to contiunue while outputs are being written.

The efficient use of many-cores HPC systems depends on the code vectorization level and memory hierarchies management. This requires major changes in the code to allow efficient exploitation of these architectures. The first task of this project is to determine the performance limiting parts (focusing on single-core and single-node analysis) and to define a strategy to apply alternative coding approaches aimed at (i) improving the bandwidth requirements e.g. with algorithms which are aware of the memory architecture (e.g. techniques to optimize memory access and cache reuse) and (ii) increasing the computational efficiency within each core (e.g. mask/blend techniques to increase SIMD instructions) and each node (e.g. techniques to increase the multi-threading exploitation) on a set of key subroutines. The most promising approaches will be integrated into the NEMO reference code. A report describing the new coding approaches will be also provided. It will contain the main rules for the application of the alternative approaches to future developments.

The objective is ambitious but is based on analysis by the NEMO HPC Working group, which brings together the HPC experts from the COPPER partners plus a number of external experts, including technical experts from major HPC manufacturers. Dr. Martin Schreiber of the University of Exeter, an expert in algorithm development for weather and climate applications (e.g. Schreiber et al. 2014), will be a collaborator with COPPER, and travel costs for his attendance at WP8 meetings are included in the budget.

The performance analysis for representative ocean configurations close to CMEMS configurations will be carried out on a representative set of HPC systems. The access of the COPPER partners and their collaborators to a variety of machines will assure performance portability.

Seamless interaction with coastal monitoring systems (WP9)

Coastal monitoring systems generally rely on a combination of *in situ* and Remote Sensed Observations, integrated with high resolution, local modelling systems, which play a crucial role in putting the observational base in a wider context. The overall coastal monitoring systems have a vital role in, for example, coastal protection and flood warning and monitoring and ensuring good environmental status, but are specifically outside the scope of CMEMS. However they require high quality boundary condition, initialisation and validation/assimilation information, and the accuracy of the system is highly dependent on this information and how it is applied. CMEMS is ideally placed to provide this both in a European context and globally. We therefore aim to **develop a seamless approach to interfacing the model and remote sensed observed information available from the CMEMS systems with the modelling component of coastal monitoring systems, using a generic interface.**

Many different model codes (e.g. finite difference, volume and element approaches in 2 and 3 dimensions) are employed for coastal applications by many different organisations. Hence we must take a generic rather than model-specific approach and, as appropriate, develop a user community for this. The elements of the environment covered here are hydrodynamics, waves, ecosystems and biogeochemistry. The approach we adopt is that of a generic coupling tool to the CMEMS information augmented by a 'lightweight' coastal model system-specific interface that simply translates the generic data structure to that needed by the coastal model (Fig 1.4.1.).

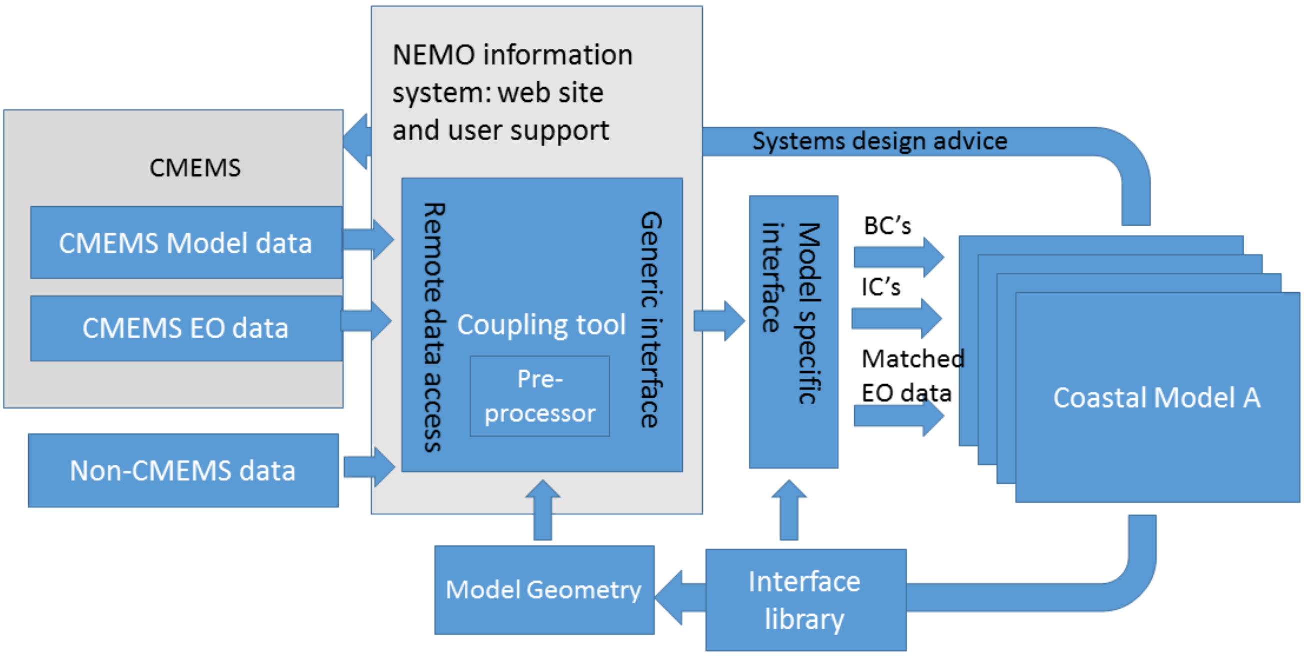


Figure 1.4.1: Design of generic coastal interface

With this system the coastal modelling user will be able to: i. download and install a Python coupling tool to their computer systems; ii. code a Python interface between the generic coupling tool and their model, following clear instructions and examples; iii. Configure the coupling tool for specific data required and any transformation options (e.g. filtering and integral constraints); iv. Interface remotely to CMEMS web based data services and extract the required data to then run their system.

Such a system is novel in the context of NEMO and CMEMS, particularly in its ability to link generically to any coastal model. While other multi-model systems do exist (e.g. www.marvl.org.au focuses on a selection of structured grid community models), here we aim to be substantially more flexible, for example supporting real time operational systems and unstructured mesh models. The outcome of this work will enable coastal modelling to substantially accelerate the setup time (from months to weeks) of their models, improving robustness and traceability of the downscaling system, and facilitating access to Remote Sensed data. This will particularly aid users without substantial resources for model setup e.g. SMEs. Alongside providing the information system for coastal-monitoring systems, we will also aim to capture as much of the local expertise as possible and use it, where practical to inform the development of the CMEMS systems, accepting that they are limited to a kilometric or coarser scale.

Innovation Potential

The primary route to innovation for COPPER is through enhancements to the capability and quality of the CMEMS services. This innovation is an integral part of the COPPER programme, described in detail elasewhere in this document, so we do not discuss it further here. We have identified two other specific areas of innovation potential, which are described briefly below.

First, the data assimilation experiments in WP5 will help to define optimal configurations of future satellite instruments and constellations, and will show how to derive optimal value for ocean state estimates from high resolution satellite data. These outcomes therefore support the development of space-based environmental monitoring technology and the associated industries. The appropriate dissemination and interaction with mission planners and industry will be achieved through international fora such as the GODAE Ocean View Observing System Evaluation Task Team.

Secondly, innovation impact will be delivered by COPPER through the wealth of opportunities opened up to the downstream CMEMS user community through the improvements in the quality, resolution and capabilities of CMEMS products. These will allow downstream users such as marine consultancies, many in the SME sector, to propose new and cost-efficient approaches to environmental monitoring and prediction, in support of EU, government and industrial users (see Section 2.1 for some specific examples). Interaction with these downstream users will be delivered in collaboration with the existing CMEMS User Engagement activities. See Section 2.2 for more detail.

2. IMPACT

2.1 Expected impacts ;

"Enhance European industry's potential to take advantage of emerging market opportunities and capacity to establish leadership in the field"

CMEMS is Europe's primary resource for marine environmental information based on Earth Observations data. The first MyOcean User workshop (Stockholm, April 2011) concluded that the quality, reliability and sustainability of the service is key to its exploitation. In order to support European industries providing or dependent on such information, it is essential that CMEMS provides products of world class quality for exploitation. The over-arching goal of COPPER is to ensure that the CMEMS will have access to marine modelling tools that allow it to address the ever-increasing demands for world-class marine monitoring and prediction in the 2020s and beyond. Retaining the world leading quality of CMEMS is key to achieving the expected impacts of the call.

A primary pathway to impact of COPPER, described in Section 2.2, is through delivering improved modelling and monitoring tools to the CMEMS Monitoring and Forecasting Centres (MFCs). The resulting value to end-users such as marine managers, infrastructure planners and policymakers will typically be delivered by intermediate users who process the CMEMS products to develop application-specific information. Because the marine economy is wide-ranging, we expect these downstream benefits of COPPER to be correspondingly wide-ranging. Therefore, rather than aiming at a comprehensive catalogue of benefits, we provide examples below of areas where the specific R&D that we plan in COPPER is expected to deliver clear enhancements. The examples are classified according to the expected impacts mentioned in the work programme for this call.

Marine operations and safety:
Improved forecasts of near-surface currents are expected to result from the inclusion of tides and wave-current interactions (WP3,4), while the higher resolution enabled through WP5-8 will provide more accurate and location-specific current information, including sub-mesoscale features and bottom, as well as surface currents. These developments will provide an unprecedented level of accuracy and resolution in CMEMS products, which can be expected to increase efficiency in many aspects of marine operational planning, including shipping, renewable and non-renewable energy production, and underwater cable laying/maintenance. Safety at sea will also be enhanced through improved surface current information to search and rescue operations.

Energy supply:
Improved and higher-resolution forecasts of regional shelf seas, resulting from the model and data assimilation developments in WP 4-8, will provide a new level of accuracy in location-specific bottom temperature forecasts, allowing increased operational efficiency in oil and gas distribution through seabed pipeline networks (whose capacity is dependent on temperature). Inclusion of tides in the globally modelling capability (WP3) will improve sea bed temperatures for all shelf seas, and so expand the impact in this sector outside the European region.

Sustainable exploitation of marine resources including fisheries:
The ability to run increasingly comprehensive ecosystem models, underpinned by improved high-resolution physics (WP3-8), will be enabled by COPPER WP7. This is expected to improve the quality of ecosystem forecasts and reanalyses, and so enable marine management to maximise the sustainable exploitation of marine resources (e.g. Maximum Sustainable Yield under the Common Fisheries Policy) and improve the assessment of Good Environmental assessment, needed for on-going Marine Strategy Framework Directive implementation.

Development and exploitation of ocean monitoring technologies, including from space:
Improved ability to assimilate high resolution datasets into ocean models (WP5) is an essential step in the development of global monitoring technologies (both space-based and in situ, e.g. gliders), and delivery of value from them. WP5 therefore makes a key contribution to developing the global market in environmental monitoring technologies. European industry has substantial expertise in these monitoring technologies and the associated instrumentation, and stands to benefit from the development of this market.

Marine consultancy:
The marine consultancy community is a substantial European industrial sector in its own right, including significant representation from SMEs. It operates not just in Europe but throughout the world. This sector acts as 'intermediate users', downscaling and interpreting CMEMS products to answer specific end-user questions. Improved CMEMS products (WP3-8), and simpler interfacing of these with the high resolution coastal modelling systems operated by this sector (WP9), will provide a major advance over the currently common approach of using climatological or simple tidal boundary conditions for near-coastal models at the sub-kilometric, and so give the sector a competitive advantage on the global stage.

Developing global marine environmental markets:
The development of tidal capability for global models (WP3), alongside increased resolution (WP4-8), will allow European industry, for the first time, to access baseline reanalysis and forecast information about conditions in any region of the global ocean, including the shelf seas where many economic activities and natural resources are concentrated. This will provide a competitive edge by allowing quick technical scoping of business opportunities anywhere in the world. Costly development of bespoke regional models would only be needed for the most promising projects where more detail is required.

"Boost competitiveness of industrial actors in EU and national procurements"
WP8 will work closely with the NEMO High Performance Computing (HPC) working group, which includes a number of European-based experts from HPC vendors. This mutually beneficial engagement should give these Europe-based organisations an edge in future procurements by environmental institutions. Since many of the issues to be addressed by WP8 are generic and can be applied to other environmental modelling codes, the opportunities opened up by this extend well beyond NEMO and well beyond Europe.

European nations have a number of marine monitoring and management obligations under directives such as the Marine Strategy Framework Directive (MSFD) and the Bathing Water Directive (BWD), and in management of Marine Protected Areas (MPAs). The CMEMS data products and services are a crucial tool in the efficient fulfilment of these obligations. Developments in COPPER are designed to provide an unprecedented level of quality in CMEMS predictions/analyses of ocean physical (WP3-6) and biogeochemical (WP7) properties relevant to all these areas, for example bottom currents for MPA management, large scale biogeochemical properties for MSFD and BWD assessments. Access to these products will enable the marine consultancy sector to offer new levels of quality and cost-effectiveness to marine monitoring procurements at national and European level, and beyond.

COPPER's Dissemination and Communication plan (D2.3) and Exploitation plan (D2.2) (Section 2.2), which will plan to work in collaboration with the CMEMS User Engagement team where relevant, will drive the development of expertise in the Intermediate User/Marine Consultancy community in the exploitation of CMEMS products for marine monitoring, and increased familiarity with the products. User workshops in WP9 will particularly aim at promoting this development by providing information and training which will act to boost their competitiveness.

"Establish a proof-of-concept or a prototype, which can act as reference for the independent assessment of Copernicus service evolution, in light of product extensions and service improvements"

A key output of COPPER will be prototype ocean model code, within the NEMO quality assurance framework, accompanied by a scientific assessment of its impact, that is very close to operational readiness for CMEMS (e.g. Deliverables D3.2, D4.1, D4.2, D6.3, D7.2, D7.3, D8.3).

In terms of the EC's definitions of Technology Readiness Levels[3], the starting point for COPPER will mainly be concepts and theoretical developments (TRL 1-2), in some cases demonstrated in simple proof-of-concept tests (TRL 3). COPPER will move these ideas beyond proof-of-concept, to a point where they have been demonstrated in an operationally-relevant environment (TRL 6), in some cases with early testing in operational environments (TRL 7). This is the appropriate end point for targeted Tier 3 research, to be followed by operational implementation by CMEMS MFCs through Tier 1 activities. An explicit roadmap to operational implementation of COPPER deliverables in CMEMS, developed in consultation with the CMEMS MFCs, will be delivered (D2.2) to assist in determining Copernicus service evolution.

The work plan of COPPER is designed with the pathway to assessment and implementation in the CMEMS services at its heart. Many of the deliverables of COPPER will be in the form of proven NEMO code, and the developments will be evaluated in model configurations that are based on or close to current operational CMEMS configurations. Because the NEMO model is already widely used in the CMEMS MFCs, the deliverables will therefore be in the ideal form to be assessed by the CMEMS MFCs and incorporated quickly into the MFC modelling products.

Substantial impacts not mentioned in the work programme

The developments in COPPER are targeted at the needs of CMEMS, but they will also deliver major advances to climate modelling and prediction, including the Copernicus Climate Change Service (C3S), as outlined below.

The NEMO ocean model is widely used as a component of global climate models. For example the EC-Earth, French, , Italian and UK contributions to the next Coupled Model Intercomparison (CMIP6), feeding into the next IPCC Assessment report will be based on NEMO. A number of leading seasonal forecasting systems around the world are also based on NEMO. This includes contributions to the C3S from ECMWF, the Met Office and CMCC as well as systems based outside Europe such as the Canadian and Australian systems. It is also used for

[3] European Commission, *G. Technology readiness levels (TRL), HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995.*

oceanographic research worldwide, with 200 projects up to 2015 (including very large projects such as EC Earth), and 1000 registered users, all accessing NEMO.

Sustainable improvements to the NEMO model (WP3-4, 6-8) and associated data assimilation (WP5) will substantially benefit the above range of climate modelling activities, including the seasonal forecasting component of C3S and European contributions to the CMIP6 and IPCC processes. A particular advance will be provided by the inclusion of tidal capability in NEMO (WP3), which will enhance the role of the shelf seas in global climate change to be included in climate models. This will allow climate scientists to assess the role of carbon and nutrient cycling on the shelf in global change, and quantify climate feedbacks due to marine methane and nitrous oxide (particularly important in the coastal zone) emissions, leading to more confident climate projections.

End users with interests in marine planning frequently have a requirement for long term outlooks that take into account climate change (for example for planning of coastal defences or lifetime planning for offshore renewables and aquaculture infrastructure). The generic interfacing tools developed in WP9 will be equally applicable for downscaling of climate change scenarios and seasonal forecasts, allowing marine planning decisions to be informed by consistent information across timescales from days to decades.

A current focus of international ocean-climate research is how atmosphere-ocean interactions at small scales can impact on variability in large scale weather patterns. Current climate models are thought to underestimate the signal-to-noise ratio of predictable climate variability (e.g. Eade et al 2014). By enabling resolution (WP 5-8) and better representation (WP4) of these interactions, COPPER is likely to facilitate the development of the next generation of more reliable probabilistic seasonal predictions (including for C3S).

Current ocean reanalysis products differ in their estimates of the recent history of ocean heat content, a key driver of regional sea level rise and possibly an important factor in the recent slowdown in surface warming (Palmer et al. 2015). The assimilation diagnostics of WP5 should give significant insights into the causes of the differences and the reliability of the products.
Improvements in the ocean observing system, including new high resolution EO and in situ datasets, hold out the prospect of better understanding of ocean heat content, sea level, and eddy kinetic energy in the future. COPPER WP5 performs the essential design work on data assimilation systems to exploit these new observing systems and so improve our future understanding of long term climate change.

Barriers to implementation

Because COPPER is explicitly designed with ease of implementation in CMEMS in mind, we do not anticipate major barriers. The COPPER science coordination team will work closely with the CMEMS MFC System Evolution leads over the course of the project to facilitate this transition and anticipate and mitigate any issues.

A generic barrier to quick uptake is the broad shortage of expertise around Europe (and globally) in quantitative modelling and high level IT skills. This generic shortage cannot be addressed at the level of COPPER, but by contributing to the CMEMS User Training Workshops and through our own user workshops (WP9), we will contribute to the development of understanding and skills in the specifics of marine modelling and services.

2.2a Measures to maximise impact

Draft plan for dissemination and exploitation of results

This draft plan will be used by WP2 as the basis on which to develop the Dissemination and Communication Plan (D2.3), and Exploitation and Roadmap (D2.3), which will be living documents in the project. The approach of this draft has been to identify the five areas which are expected to be key for dissemination and exploitation, in order for COPPER to achieve its stated impacts. Each of these is described in turn, with information on the results that will be relevant to them and how they will be made available for dissemination and exploitation by these varied areas. Other areas/audiences are identified in Section 2.2, which will also be considered for inclusion in D2.2 and D2.3. As the project progresses, dissemination and exploitation to these areas may become more and more relevant, and will therefore be reviewed and planned for accordingly.

COPPER plans to use existing methods of dissemination and channels for user engagement as effectively as possible, to avoid duplication and potential confusion, and to ensure that all the relevant existing audiences will be reached. Existing workshops that will be utilised are shown in table 2.2.1.

WORKSHOP TITLE	FREQUENCY	TARGET AUDIENCE
CMEMS User Uptake and Service Evolution workshop	Occasional	CMEMS STAC CMEMS MFCs Intermediate users
CMEMS Service Evolution meeting	Annual	CMEMS MFCs
CMEMS User Training Workshops	~6-monthly	Intermediate users
NEMO Users' Workshops	Annual	NEMO system team CMEMS MFCs Wider scientific community
NEMO Developers' Committee	6 monthly	Nemo system team CMEMS (Mercator)
Extended Developers Committee	Next meeting 2017	Nemo System Team CMEMS (Mercator)
NEMO System Team meeting	3-weekly	
Oceanology International	Annual (attend 2018)	Intermediate users End users

Table 2.2.1: Workshops which have been identified for COPPER dissemination, exploitation and engagement.

COPPER will also develop links with any relevant areas that are not already adequately provided for. The key impact areas and audiences to be considered are first introduced in Section 1.3 (Figure 1.3.1).

This figure helps to identify the key areas relevant to COPPER; we have identified five primary ***impact areas*** from the research performed in COPPER:

a. CMEMS (in particular Monitoring and Forecasting Centres (MFCs)). These are the primary direct recipient of COPPER developments, and end user value will often be delivered indirectly via improvements to the CMEMS services produced by the MFCs
b. Intermediate users of CMEMS services, who add value to the CMEMS products to deliver information and advice relevant to end-user decision-making
c. End-users, using CMEMS data to inform decisions that are sensitive to or impact on the marine environment
d. Earth Observation mission planners, who need information on the best configurations of instruments and satellite constellations to deliver value to ocean state estimates
e. The wider Scientific and Technical Community, who will benefit from the developments in COPPER – particularly climate change and oceanographic researchers, as well as a number of providers of the Copernicus Climate Change Service.

The plans for each of these impact areas are treated separately in more detail below. Most dissemination, exploitation and communication activities cross several COPPER WPs, and these activities are therefore managed by WP2. WP9 produces a set of software tools targeted at the Coastal Modelling User Community (a specific case of intermediate users), and so dissemination and exploitation activities for these are included in WP9.

A COPPER project website will be set up and administered by the NEMO website IT team under WP2. Aims of the website will be to:

- Provide visibility of the project for specialists such as CMEMS MFC staff and all intermediate users, through project overview, technical overviews and science contacts for each WP, and periodic research highlights

- Provide visibility of the project for end users, and the wider scientific and technical community, as well as other audiences through descriptions of the COPPER objectives, contacts to the COPPER Science Leadership team, project highlights, and links to the detailed technical WP pages which will include detailed technical highlights. Links will also be included to CMEMS web pages.
- Internal communication within the project, including meeting planning and minutes, technical details of code configurations, model runs and shared datasets, and project documents.

a. CMEMS

The Specific Challenge of this call is to perform long term R&D that will inform the future development of the Copernicus services. Therefore ensuring that COPPER R&D can feed through effectively to CMEMS service evolution is a key task. *The **specific recipients** here are system developers at the CMEMS MFCs, who will evaluate and implement system evolutions through Tier 1 R&D activities.*

Many of the deliverables of COPPER will be in the form of proven, quality assured, NEMO code, accompanied by a scientific assessment of their impact in realistic model configurations (often based on current operational CMEMS configurations). Because the NEMO model is already widely used in the CMEMS MFCs, the deliverables will therefore be in the ideal form to be assessed and incorporated quickly into the MFC modelling products. Code developed will be incorporated into the NEMO code repository through a robust and well-established software engineering process that has been operated successfully by the NEMO Systems Team for a number of years[4]. The leader and other key members of the NEMO Systems Team are named experts (research and IT) in the COPPER consortium. Hence the code delivered can be guaranteed to be of high quality, suitable for rapid implementation in the operational systems of CMEMS.

Results of the development and evaluation activities of COPPER will be published in the open-access peer-reviewed literature (e.g. in a special issue of Geoscientific Model Development) and presented at international conferences, providing quality assurance to the CMEMS developers that our developments and assessments are scientifically robust.

Close communication will be maintained with system developers at the CMEMS MFCs throughout COPPER by building on working relationships that have been well established over many years through the MyOcean and Mersea projects, which were the forerunners of CMEMS. This will give the MFC developers early sight of the results, allowing them to work with COPPER to identify and address potential issues with operational implementation, so that the COPPER deliverables are as close as possible to ‘operations-ready’. This two-way communication will be achieved through:

- Participation in the NEMO Users’ Workshop and NEMO Developers Committee meetings; established fora for exchange of information between developers and users of NEMO
- COPPER Scientific Coordination team (WP2) establishing direct links with the Service Evolution lead for each of the MFCs, ensuring that MFC Service Evolution plans are fully informed of upcoming COPPER developments. This will be through individual contact ahead of the annual CMEMS Service Evolution Meeting, followed by possible attendance at the meeting.
- Close institutional links will allow day-to-day contact with several of the MFCs (the COPPER consortium includes institutions that are contributing to five of the seven MFCs, and COPPER partner Mercator-Océan is the Trusted Entity for overall CMEMS delivery)
- The COPPER website will include overview technical descriptions of the individual work packages, science contacts for each work package, and periodic research highlights

b. Intermediate users of CMEMS services

These users are a key bridge between the generic Copernicus services and end users. They perform their role, for example, by interpretation of the CMEMS data to produce value-added products, by downscaling the CMEMS

[4] The NEMO software development method is described in Section 1.3b

products using high resolution coastal models, or by feeding CMEMS data into broader, application-specific models (e.g. socio-economics, energy production-supply-demand). ***Specific recipients*** *here could include downstream modellers and decision analysts in private consultancies, research institutions/universities, and public sector marine policy and management organisations.* As well as targeted information on the COPPER website, the following will be undertaken.

For the outputs of COPPER, which deliver value through improvements to the CMEMS services (WP 3-8), the role of COPPER will be to enhance and complement the existing user engagement activities of CMEMS in this area, rather than setting up a separate process. COPPER will work with the CMEMS User Engagement team[5] to provide intermediate users with a forward look at the capabilities they can expect when COPPER developments have reached operational implementation, seeking early user feedback to help refine development plans. Specific fora for this engagement include the planned CMEMS User Engagement and Training Workshops. COPPER partner institutions are active contributors to the GODAE Ocean View Coastal Ocean and Shelf Seas Task Team (GOV COSSTT) and this forum will be used to disseminate COPPER research on a wider international stage and to ensure that we are remaining at the forefront of international ocean prediction (see letter of support from Dr. Pierre de Mey in Appendix 1). Some intermediate users also attend the NEMO Users' Workshop, and COPPER intends to present results at these, providing further opportunities for interaction.

COPPER WP9 is a special case, as its output is a software tool to facilitate the interfacing of CMEMS products with the downstream models. Intermediate users are thus a key target user group for WP9. The engagement of these users with the development of the interface will be assured by a dedicated user workshop/webinar early in the project (MS25), engagement of users in the expert review of the interface tool design (MS26), and in a hands-on workshop to trial the prototype interface code towards the end of the project (MS27). We have received initial expressions of expressions of interest in being engaged with these developments from two SMEs who are potential users (Noveltis www.noveltis.com and HR Wallingford www.hrwallingford.com). The interface tool is of particular relevance to GOV-COSS-TT (see letter of support from Drs. Villy Kourafalou and Pierre de Mey) and the help of non-European experts will be sought in the reviewing of its design.

The WP9 interface code will be a stand-alone software library that is not part of the main NEMO code, but will also be available under open licence. It is envisaged that the interface tool would eventually be made accessible as a CMEMS user utility downloaded from the CMEMS website, via the NEMO or other code repository. COPPER will liaise with the CMEMS User Engagement team regarding this. WP9 will also provide documentation for tools, worked examples and training sessions to enhance the dissemination and exploitation to the Coastal Modelling Community in particular.

Travel and subsistence is included in the budget for attendance by COPPER staff at five CMEMS Training Workshops and GOV COSSTT events over the course of the project. Additionally we plan to host or co-host a stand at Oceanology International 2018, which provides a forum for rapid, informal engagement with a wide range of intermediate and end users. The COPPER project management team will consider the results of the Copernicus User survey currently (2016) being carried out by DG GROW[6], to identify further user requirements or key sectors for engagement, and other relevant opportunities will be identified and prioritised by WP2 as they arise.

c. End users of CMEMS services

In addition to those in Figure 1.3.1, ***specific recipients*** *here could be decision makers in marine management and operations, regulatory compliance and infrastructure planning, in private and public sector organisations.*

[5] The CMEMS User Engagement team, based at Mercator-Océan, coordinates dissemination, exploitation and training for downstream users of CMEMS services. It builds on long-standing experience through the MyOcean projects which were the fore-runners to CMEMS. Their activities include organising CMEMS User Uptake workshops and regional User Training workshops, providing use cases via the CMEMS website, and promotion of CMEMS products at conferences and industry events.

[6] https://ec.europa.eu/eusurvey/runner/CopernicusForEOcompanies

Most of the value of COPPER for end users will be delivered through improvements to the CMEMS services, in many cases via intermediate users. In this way they will benefit from COPPER's model and data assimilation improvements.

The needs of end users who are direct users of CMEMS products are similar to those of Intermediate Users, and for these we will adopt the same approach as in (b) above, in particular the provision of a forward look on possible future CMEMS capabilities through the CMEMS User Engagement and Training Workshops. COPPER partner institutions are active contributors to GOV COSSTT and this forum will be used to disseminate COPPER research on a wider international stage (see letter of support from Dr. Pierre de Mey in Appendix 1). Interfacing tools and assessments of the developments published in the peer-reviewed literature as described in (a) and (b) above, and will be accessible to end users.

The COPPER website is envisaged to be an important source of dissemination to end users. It will include descriptions of the COPPER objectives, targeted at these users, with links to detailed technical WP pages which will include progress highlights and information on results. Links will also be included to CMEMS web pages. Newsletters and other communication material produced by WP2 will also be used to disseminate information to this audience.

d. Earth Observation mission planners

Specific recipients *are EO mission planners and industrial partners who wish to deliver optimal cost-effective remote sensing systems for marine monitoring.*

Insights into the potential impact of different satellite constellation design, as well as constraints on how observational data can be assimilated into ocean models, will be delivered by WP5 and are essential information for EO mission planners. The appropriate lines of communication exist through the GODAE Ocean View Observing System Evaluation Task Team, of which one of the COPPER team (Dr. Dan Lea, Met Office) is a member. The team members are well-known in the ocean data assimilation community and will exploit a number of other formal and informal channels, including with the CMEMS Thematic Assembly Centres, to ensure a wide dissemination of COPPER results to this audience.

e. Wider scientific community

In addition to those in Figure 1.3.1, ***specific recipients*** *here are ocean modelling scientists beyond the community of CMEMS providers and users, including climate modellers and specifically providers of the modelling elements of the Copernicus Climate Change Service.*

While the developments in COPPER WPs 3-9 are primarily motivated by the future requirements of the CMEMS services, many of them will benefit a wider scientific community.

Developments to enable higher resolution modelling and improved data assimilation (WPs 3-8) will also contribute to the requirement of the Copernicus Climate Change Service (C3S) for "*Climate Modelling at High Resolution*" (Guidance Document Section 5.5.2), since many of the C3S services are based on the NEMO ocean model. The generic model interface developed in COPPER WP9 will facilitate downscaling of climate model outputs by C3S Intermediate Users.

There is already strong engagement from the climate modelling community (including C3S partners) with the NEMO consortium, through attendance at the annual NEMO Users' Workshops and membership of the NEMO Extended Developers' Committee. COPPER partners are also prominent members of these fora. COPPER will exploit these well-established channels to inform users in this category of upcoming developments, and obtain feedback.

Further communication with this group will be through presentations at scientific conferences and publications in peer reviewed journals and newsletters. The COPPER website will include overview technical descriptions of the individual work packages, science contacts for each work package, and periodic research highlights. Newsletters and other communication material produced by WP2 will also be used to disseminate information to this audience.

The COPPER Scientific Coordination team (WP2) will establish direct links with the Service Evolution lead for C3S, ensuring that C3S Service Evolution plans are fully informed of upcoming COPPER developments. Initial contact between COPPER and the C3S Management team has been established.

Actual delivery will be largely via the provision of robust model and data assimilation improvements, and interfacing tools, to the CMEMS services, as described in (a) and (b) above. Thus the wider scientific community will benefit from the same quality assurance standards for COPPER outputs as are applied for CMEMS developers.

Follow-up of COPPER advances beyond the end of the project
The long term legacy of COPPER will be realised through implementation of NEMO developments and data assimilation improvements from COPPER into CMEMS products. This is likely to require an element of Tier 1 R&D work, to apply the developments both to individual MFC model configurations, and to the associated data assimilation systems. Implementation work will be informed by the COPPER Implementation Roadmap (Deliverable D2.2). The adoption by COPPER of the rigorous NEMO software engineering process is designed to ensure that costs of the Tier 1 implementation work are kept to a minimum.

COPPER developments to the NEMO code will be consolidated into the NEMO code shared reference in collaboration with the NEMO System Team, which is well represented in the COPPER consortium. Maintenance and further developments after this point will be the responsibility of the NEMO System Team rather than CMEMS. The NEMO System Team has a long-established track record in this work.

Project web pages will be hosted after the end of the project by CNRS, and will include links to project reports and published papers, all of which will have been deposited in long term archives.

Outline strategy for knowledge management and protection

COPPER has chosen not to voluntarily take part in the Open Research Data Pilot, however due consideration will be given to effective knowledge management and protection. COPPER will adopt a strategy which encapsulates the guiding principles of Horizon 2020, both on openly accessible research and effective exploitation of results. The processes for this will be guided by the Consortium Agreement which will be agreed by all beneficiaries, and the processes will be managed by the Met Office as project Coordinator, through WP2. Details of this strategy will be developed and included as part of D2.2.

Background management and protection
In preparation for an effective knowledge management and protection strategy, at the proposal phase the consortium have identified the background that they will each bring to the project. This is particularly relevant for data sources that will be used. Data from sources other than partners in the consortium have also been considered.

Background of the partners will be protected as per the DESCA Consortium Agreement. As well as the background register in the CA, an internal catalogue of all data sources will be created following the project start date. Details will include what access rights apply to each of these data sources, and a statement as to any restrictions of its use and subsequent dissemination or incorporation within any knowledge generated by COPPER. This will ensure that any restrictions are accounted for and are correctly adhered to.

The consortium have already started to gather a list of the datasets that are external inputs to the project, typically to be used for model evaluation. Data sets owned by Oil and Gas producers will not be used within the project, because they are not freely available. Table 2.2.1 shows examples of data owned by members of the consortium, that will need to be shared with other consortium members, but that may have licence restrictions on it. These tables will be added to once the project commences, but our initial assessment is that the potential for significant issues for access rights of background seems very small.

Description of data/software	Owner	User	Use	WP
FOAM/GloSea reanalysis assimilation increments	Met Office	CMCC	Plotting of results	Assimilation diagnostics
BSC Extrae/Paraver	BSC	CMCC Met Office	Performance analysis	HPC

Table 2.2.1: Software and data owned by consortium members that may be used by other members during the project (i.e. data sharing within the project).

Results management and protection

The most valuable outcomes are embodied in the NEMO code, in order to improve its functionality. The NEMO code is open source and freely downloadable from the NEMO website www.nemo-ocean.eu under a CeCILL Free Software Licence. The software and the source code are therefore freely and openly available to any interested party who wishes to use it.

Code developments will be incorporated into the NEMO reference code, where they will be maintained by the NEMO System Team, which is resourced by all six of the NEMO consortium partners. The NEMO consortium has operated under a formal consortium agreement since 2008 and provides a stable and proven mechanism to support this open access modelling capability.

WP9 will produce separate code and capability for a flexible downstream interface. As above, this will be made available under an open access licence and will be freely available for all who wish to use it, but ownership will be maintained by the relevant consortium members, and IP such as the source code will be protected for future development and exploitation by the consortium, rather than being made immediately publically available.

Other outputs of COPPER will be in the form of scientific assessments and reports. These will be published in the peer-reviewed scientific literature, ideally under the 'gold' open access model, but always under the 'green' model. In parallel we will make use of the COPPER website, and institutional and subject based repositories available through the partners, to provide further access to publications. Authors will avoid entering into any copyright agreements with publishers that will not allow them to fulfil the EC Open Access requirement. These publications will be advertised and logged through the project website. All published material will contain an acknowledgement to the research funding from the European Union and Horizon 2020 which has led to the results and outcomes.

2.2b Communication activities

In order to successfully promote COPPER, its progress, results and achievements, key messages will be communicated at suitable times, to the appropriate target audiences. There will be agreement on who will carry out the communicating, and on how the successful communication will be measured, monitored and evaluated. All of these elements will be included in the communications plan which will be part of D2.2. The impact areas identified in Section 2.1 and shown in Figure 1.3.1 are included in the communication plan. Additional audiences have also been identified as those who will benefit from communication by COPPER.

The communication matrix below (Table 2.2.2) details some of the already identified measures for communication by the project.

Table 2.2.2: COPPER communication measures

Target audience	Objective	Material/content (and responsibility)	Method/communication measures	Frequency
COPPER partners	•Ensure an effective and integrated project	•Progress and results (WP2) •Risks/benefits/issues (WP2) •Queries/questions (WP1)	•Internal project wiki •General Assemblies •Email, Web and teleconferencing	•Regular updates of wiki •Four General Assemblies •Frequent
EC Project Officer	•Ensure EC is fully informed of project progress	•Overall project progress (WP1) •Issues (WP1 & WP2) •Deliverable progress (WP1)	•One page progress reports •Deliverable and periodic reports •COPPER website	•Quarterly •As per deliverable dates •As per reporting periods
NEMO System Team	•Effective development and integration of new code	•Code design & reviews (WP2, WPLs) •Code documentation (WP2, WPLs) •Test case results (WP2, WPLs)	•On twiki •On twiki •Results on twiki	• As per deliverable dates •As per deliverable dates •As per deliverable dates
CMEMS MFC Leads	•Exploitation of developments	•Roadmap, concept documentation, summaries of results, presentations, reports & papers (WP2, WPLs)	•Teleconferencing •CMEMS STAC	• As required •Annual
C3S management team	•Exploitation of developments	•Roadmap, concept documentation, summaries of results, presentations, reports & papers (WP2)	•Teleconferencing •workshops	•As required Annual
Intermediate users (and end users)	•Awareness of capabilities and discussion of needs	•Presentations (WP2) •Workshop discussions (WP9)	•CMEMS user workshops •Oceanology Interntaional 18 •GOV COSS-TT meetings	•as they occur •2018 •As required
Observation providers	•clarify needs for and impacts of observations	•Presentations and reports (WP5)	•GOV OSEval workshops	•as they occur
Wider scientific and technical community	•Advertise progress and obtain expert advice	•Deliverables and other reports (WPLs) •Presentations at conferences (WPLs) •Papers (WPLs)	•Project web-site •Project & task team meetings •Conferences & discussions •Publication in open literature	•As per timetable •As they occur •As opportunities arise •When ready
Other EU bodies	•Mutual awareness	•Discussion of needs (WP2) •Plans and results (WP2)	•Project website •EC or project meetings	•Regular updates •As required
Policy and decision makers	•Exploitation of new capabilities	•Presentations (WP2) •Summary information (WP2)	•Meetings organised by EC •COPPER web site	•As they occur •Updated annually
Wider public	•Project visibility and raise public awareness	•Relevant results and their implications (WP2)	•COPPER website	•As opportunity arises

3. IMPLEMENTATION

3.1 Work plan — Work packages, deliverables

COPPER has a relatively simple project work package structure, summarised in Figure 3.1.1 below. There are seven science WPs, supported by WPs on Project Management (WP1) and Scientific Coordination (WP2).

The WP structure has been chosen to minimise inter-dependencies between WPs. The Gantt chart (Figure 3.1.2) and detailed WP tables below show that tasks within WPs have strong inter-dependencies that will be managed by the WP leaders. The tasks within WPs have been designed to provide clear critical paths within the WPs.

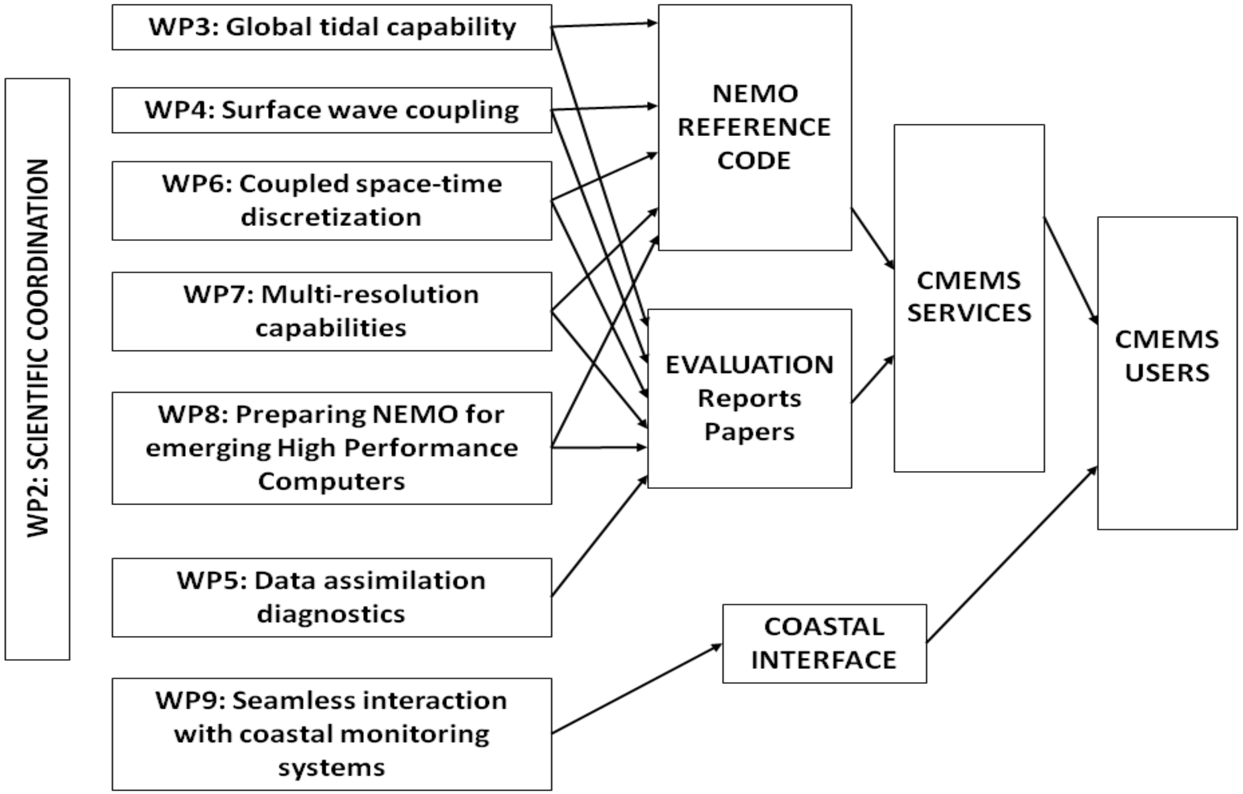


Figure 3.1.1 COPPER Work package structure and flow of outputs

WPs 3, 4, 6, 7 and 8 will develop NEMO ocean model code. The developments will proceed in parallel using code branches from the main NEMO reference code, and will be integrated into the reference code through the regular NEMO software merge/test/release cycle (described in Section 1.3b). There will be inter-dependencies between tasks aiming to submit code to the NEMO trunk, and these will be managed through the annual 'NEMO Merge Party' process (Section 1.3b). Apart from a specific dependency of WP7 on WP6, which will be managed as detailed in the WP tables below, we have not specified in advance the detailed timeline for the code merging, since it is dependent on the wider NEMO System Team plans for new versions of the reference code. Close liaison will be maintained with the NEMO System Team by the Coordinator and the System Team Leader (who is also a member of the COPPER consortium), to schedule individual developments for specific reference code releases during the course of the project. Additionally the Coordinator will facilitate and ensure regular communication between the COPPER WPs, for example through the code design review process, to ensure early identification of possible points of code interaction. These coordination activities are included in Task 2.2. The NEMO Systems Team and the COPPER partners have a long track record of successfully integrating parallel code developments in this way.

WP5 delivers its output to CMEMS through reports and papers on its data assimilation experiments that are largely independent of the developments in other WPs

WP9 delivers its output as a separate code library. However it may need to modify its interfaces to deliver new variables introduced by the NEMO development WPs (e.g. wave-current interactions from WP4). Communication will be maintained with the other WPs to ensure that this happens, but it is expected to be a relatively simple technical task. The interface tool will initially be delivered directly to CMEMS Intermediate Users (coastal modellers) through an open code repository.

A detailed list of the work packages and their tasks follows:

WP1: Project management of COPPER

WP2: Scientific coordination

WP3: Global tidal capability in NEMO

- T3.1: Implementation of tides in ORCA12 test case
- T3.2: Improvements to tidal simulation
- T3.3: Evaluation of tidal simulation

WP4: Surface wave coupling

- T4.1: Finalization of meso-large scale wave-current processes formulation
- T4.2: Small scale wave-current processes and wave induced mixing
- T4.3: Test cases

WP5: Data assimilation diagnostics

- T5.1: Collection and homogenization of available assimilation statistics
- T5.2: Assimilation sensitivity experiments
- T5.3: Diagnostics and recommendations

WP6: Coupled space-time discretization

- T6.1: Definition of expected benefit in prototype test cases
- T6.2: Stability analysis of the mode splitting in the new kernel
- T6.3: Definition of the flow-chart for implementation in NEMO
- T6.4: Implementation and a posteriori evaluation in idealized test cases
- T6.5: Test in realistic model configuration

WP7: Multi-resolution capabilities

T7.1: On-line coarsening of biogeochemistry with AGRIF

T7.2: Develop two ways nested grids on the vertical

T7.3: Enhancement of grid interactions. Compliance with the new time stepping algorithm of NEMO

T7.4: Overall WP7 test case/demonstrator

WP8: Preparing NEMO for emerging High Performance Computers

T8.1: NEMO benchmark suite

T8.2: NEMO code scalability on emerging architectures

T8.3: NEMO code single-node efficiency on many-core architectures

T8.4: Performance improvement impacts on real test cases

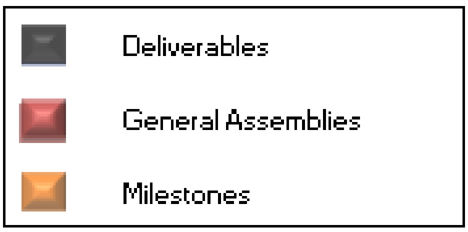
WP9: Seamless Interaction with Coastal Monitoring Systems

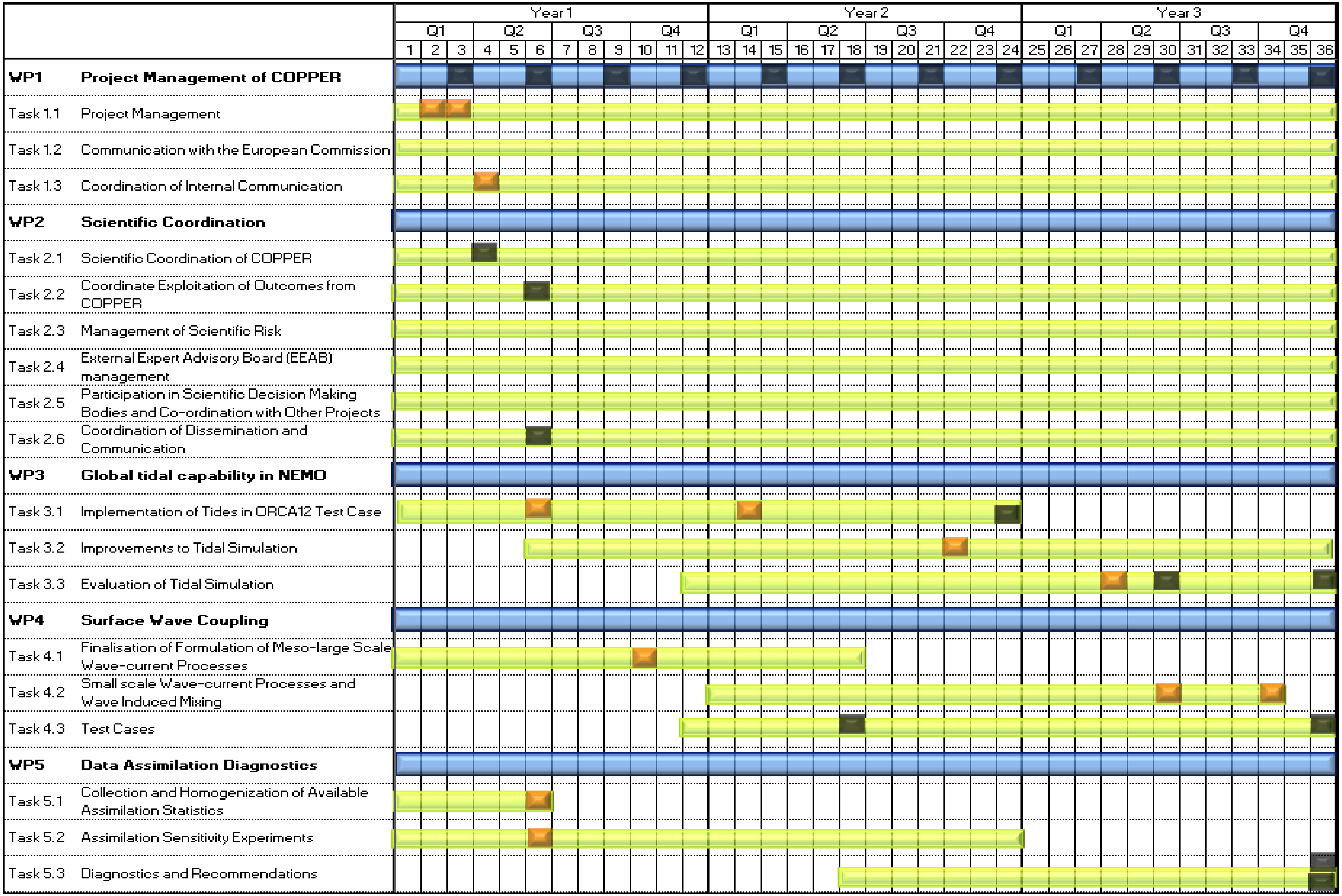
T9.1: System scoping, design and out-reach

T9.2: System development

T9.3: Dissemination and up-take

Key to Figure 3.1.2:




Year 1
Year 2
Year 3
Q1
Q2
Q3
Q4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
WP1 Project Management of COPPER
Task 1.1 Project Management
Task 1.2 Communication with the European Commission
Task 1.3 Coordination of Internal Communication
WP2 Scientific Coordination
Task 2.1 Scientific Coordination of COPPER
Task 2.2 Coordinate Exploitation of Outcomes from COPPER
Task 2.3 Management of Scientific Risk
Task 2.4 External Expert Advisory Board (EEAB) management
Task 2.5 Participation in Scientific Decision Making Bodies and Co-ordination with Other Projects
Task 2.6 Coordination of Dissemination and Communication
WP3 Global tidal capability in NEMO
Task 3.1 Implementation of Tides in ORCA12 Test Case
Task 3.2 Improvements to Tidal Simulation
Task 3.3 Evaluation of Tidal Simulation
WP4 Surface Wave Coupling
Task 4.1 Finalisation of Formulation of Meso-large Scale Wave-current Processes
Task 4.2 Small scale Wave-current Processes and Wave Induced Mixing
Task 4.3 Test Cases
WP5 Data Assimilation Diagnostics
Task 5.1 Collection and Homogenization of Available Assimilation Statistics
Task 5.2 Assimilation Sensitivity Experiments
Task 5.3 Diagnostics and Recommendations

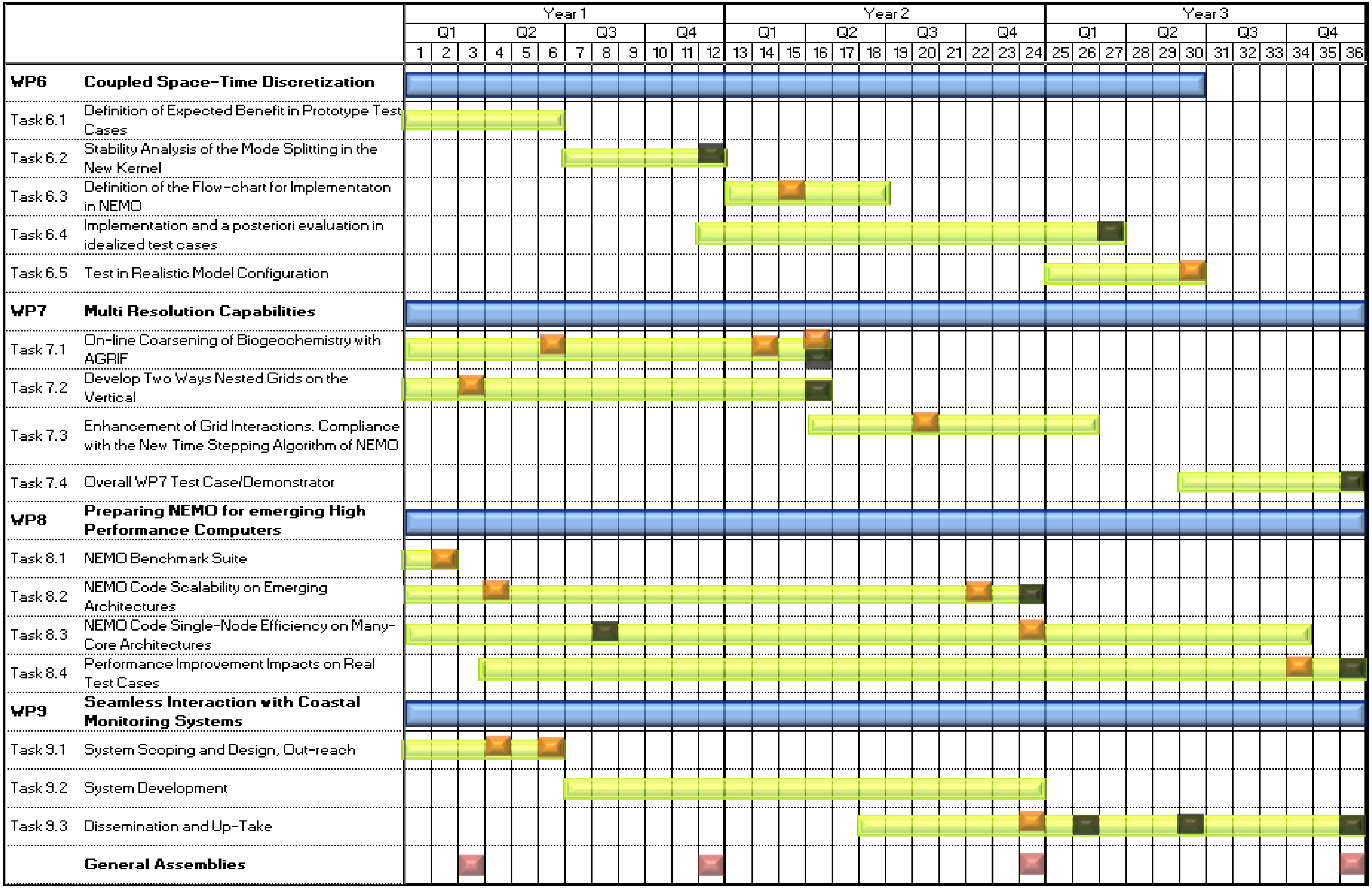


Figure 3.1.2: Timings of the work packages and their components

COPPER Work Package descriptions (Tables 3.1.1)

The following tables describe each Work Package in turn, and give details of the work involved.

Work package number	1	**Lead beneficiary**				Met Office	
Work package title	Project Management of COPPER						
Participant number	1						
Short name of participant	Met Office						
Person/months per participant:	7						
Start month	M1			End month	M36		

Objectives

- Establish and maintain top-level project management of COPPER to ensure that the objectives and impacts are efficiently and effectively achieved, on time and within the resources budgeted.
- Establish and maintain an effective working relationship between COPPER and the European Commission (EC), which includes regular reporting on project progress.
- Coordinate and facilitate effective relationships, collaboration and coordination between partners within COPPER, including sharing of information associated with all project management aspects.

This work package is led by: Met Office

Description of work

This Work Package will manage the day to day running of the project, ensuring that all obligations under the Grant Agreement and the Consortium Agreement are successfully fulfilled.

T1.1 [M1-M36] Project management (Lead: Met Office)

Manage the project using effective management procedures based on PRINCE2 (Projects IN Controlled Environments) formal methodology. These will primarily be the responsibility of the Met Office. Managing the project includes the following, non-exhaustive activities:

(i) Implementation and maintenance of the Grant Agreement and the preceding Consortium Agreement;

(ii) Overall legal, financial, administrative management and reporting, including:

- Designing and maintaining partner specific templates for collecting inputs to the required EC documents;
- Implementing and maintaining a project-specific process for reporting;
- Preparing for periodic reviews by the EC and supporting the implementation of recommendations;
- Handling of project correspondence and day-to-day requests from partners and external bodies;
- Adaptation of project and management structure after changes in the work plan and the consortium;
- Organisation of meetings relating to the management of the project; then executing, and post-processing, of major project meetings (i.e., agendas, invitations, locations, preparation, distribution and archiving of material, minutes and action lists);
- Financial management – including transfer of project funds to partners (in compliance with directives from EC), providing clarification on any budget/financial issues, monitoring and controlling the budget.

(iii) Appropriate management of ethics issues (MS1); gender aspects and equality (MS2); and risks/benefits on behalf of the General Assembly (including the production and monitoring of the Gender Strategy and Action Plan (MS2));

(iv) Handling of/facilitating the resolution of any ethics issues, and any disputes/complaints in accordance with the Consortium Agreement;

(v) Implementation of competitive calls by the consortium for the participation of new beneficiaries.

T1.2 [M1-M36] Communication with the European Commission (EC) (Lead: Met Office)
Provide regular and comprehensive communication with the European Commission in Brussels. The conduit for this will be the COPPER Coordinator and the Project Manager. This will be partly fulfilled through the provision of regular summary reports outlining the project's progress and developments (D1.1).

This task will ensure the appropriate follow-up of project obligations from the Grant Agreement (formal reporting – of science results and finances, project reviews, communication, and management). The COPPER Coordinator will ensure that the appropriate EC representative is invited to the General Assembly meetings.
If there are any major problems within the project that cannot be resolved through the appropriate management structure, the Coordinator will liaise with the EC in order to seek advice and a solution.

T1.3 [M1-M36] Coordination of internal communication (Lead: Met Office)
Share knowledge as widely as possible across the project. The Project Office will ensure optimal internal information exchange through regular and routine communications. For example, an information sharing platform in the form of a dedicated internal password-protected project website/Trac Wiki System, will be provided and managed (MS3). This will also host links to milestones and deliverables, as well as templates, documents and tools that the project office will develop to aid the management and reporting of the project. There will be space for each partner and work package in order to encourage continual conversations, dialogue and knowledge exchange amongst the partners. This task will also ensure the implementing and maintenance of mailing lists for scientific contacts and administrative contacts.

Deliverables (Summary)

D1.1: **Summary reports on project progress:** Short summary reports to be provided to the EC every quarter, starting from M3 (**M 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36**)

Work package number	2	**Lead beneficiary**		Met Office			
Work package title	Scientific Coordination						
Participant number	1	3					
Short name of participant	Met Office	CNRS					
Person/months per participant:	9	3					
Start month	M1			End month	M36		

Objectives

- Establish and maintain the scientific coordination of COPPER activities, to ensure that the objectives, outcomes and impacts of the project are fully achieved.
- Effectively manage the Intellectual Property (IP) and innovation within COPPER to ensure maximum exploitation potential and continuing impact.
- Ensure that the advice of the External Expert Advisory Board (EEAB) is integrated into the project.
- Establish and coordinate the communication and dissemination processes for COPPER.
- Formulate high-level synthesis of progress and results, using this and other information to represent COPPER at relevant external events and meetings.

Description of work

There are 6 tasks within this work package. These will primarily be the responsibility of the COPPER Scientific Coordinator who provides the scientific leadership for the project.

T2.1 [M1-M36] Scientific coordination of COPPER (Lead: Met Office, Participants: CNRS)
Maintain a holistic view of ongoing work, and provide direction. Carry out the scientific coordination and monitoring of work packages, work package leaders and project milestones. This task also includes verifying the quality, consistency and timeliness of the work and deliverables, and synthesising the results of the project. It includes reviewing the scientific element of the reports and deliverables to be submitted to the European Commission (EC).

T2.2 [M1-M36] Coordinate exploitation of outcomes from COPPER (Lead: Met Office. Participants: CNRS)
Coordination of the implementation of new code within the NEMO repository and the exploitation of results from the project within CMEMS is necessary in order to maximise use of the scientific and innovative research within the project, ensuring that it meets the needs of the users, avoids duplication of effort and identifies any gaps. For example, this task will ensure that: new code designs from each work package are reviewed against consistent criteria before proceeding with implementation into NEMO; that the impact of the new developments in dedicated test-cases is reviewed; and that the new code is properly incorporated into the NEMO reference code and future versions. It will also help the CMEMS Service Evolution Leads for each MFC to consider what adaptations they will need to make to best exploit the results and give them the opportunity to influence the work so that it is of greatest value to them. The Science Coordinator will organise meetings (utilising electronic remote methods wherever possible) with the work package leaders and/or CMEMS Service Evolution Leads to facilitate this task. A roadmap for exploitation of outcomes from COPPER by the CMEMS will be included in deliverable D2.2.

Knowledge and innovation management will also be carried out under this task, with the Scientific Coordinator being well placed to take the overview of all ongoing tasks and results, to ensure that it is correctly handled within the context of the project. IPR management will involve ensuring the correct level and understanding of background IPR, and of protection for results, is in place. There will be Legal support available from the Project Coordinator to advise on this, and partner insight will also be used. Since the deliverables of COPPER will be in the form of open source computer code and scientific papers, we envisage few IPR issues. Knowledge and innovation management will adhere to the Consortium Agreement requirements, and as described in Section 2.2a will manage results in a way appropriate to the project, and will work to maximise exploitation and impact. The strategy for this is described in D2.2.

T2.3 [M1-M36] Management of scientific risk (Lead: Met Office)
This will include resolving any conflict relating to technical issues. It will mean acting on unforeseen events and adapting work packages as required. It will also mean monitoring foreseen risks (see risk register in Section 3.2), and highlighting any unforeseen risks as early as possible, then considering the necessary mitigation.

T2.4 [M1-M36] External Expert Advisory Board (EEAB) management (Lead: Met Office)
Ensure the appropriate level of consultation with the scientific EEAB. It is essential that the project receives independent advice and feedback from the EEAB, especially in relation to the direction of the scientific research and application. This task will be led by the COPPER Science Coordinator to ensure that the consultations with the EEAB are organised and co-ordinated in an efficient and effective manner, that the appropriate level of information is provided to the EEAB, and that advice given is reviewed and acted on appropriately.

T2.5 [M1-M36] Participation in scientific decision making bodies and co-ordination with other projects (Lead: Met Office. Participants: All)

The Science Coordinator, and other project participants if appropriate, will actively participate in relevant scientific decision making bodies such as scientific advisory boards and panels, executive and steering committees. This will be to provide specialist advice based on results of the project, and to promote the project, its methodologies and outcomes. Representation for the project will be sought at the CMEMS Scientific and Technical Advisory Committee.

The Science Coordinator will also provide overall coordination (including information exchange) and linkages with the associated projects and programmes which COPPER will need to work in close conjunction with in order to ensure success (e.g. EC, CMEMS, NEMO Consortium Science Committee [NCSC] and some of the activities listed in Section 1.3). The project partners will use their knowledge and connections with other projects to assist with this task.

T2.6 [M1-M36] Coordination of Dissemination and Communication (Lead: CNRS. **Participants:** All**)**

The management of dissemination and communication activities will be undertaken in this task. An updated dissemination and communication plan (D2.3), which will include updates to the communication activities plan, will provide guidance for the project on these important aspects. Typical activities will include presenting on and promoting COPPER at scientific events. This will be the responsibility of the Science Coordinator and all partners, who will each undertake to do this as part of their WPs. These activities will ensure the continued awareness and exploitation of COPPER science during and after the project, meaning that it will be used in future decision making for next-generation CMEMS model development, as well as influencing model development and modelling practices at the MFCs.

This task will also facilitate the production of the COPPER website (D2.1), which will act as a central point of information on the project for all interested audiences.

This task will oversee the involvement and integration of COPPER into the existing dissemination, communication and user engagement channels which COPPER will make use of, as described in Section 2.2a. This will also involve working closely with WP9 to facilitate dissemination and communication through the planned user workshops.

Deliverables (Summary)

D2.1: Public website **(M4)**

D2.2: Exploitation plan including a roadmap for implementation of COPPER outcomes within the CMEMS systems (M6)

D2.3: Updated dissemination and communication plan **(M6)**

Work package number	3	**Lead beneficiary**		Met Office		
Work package title	Global tidal capability					
Participant number	1	5	6			
Short name of participant	Met Office	NERC	Mercator			
Person/months per participant:	12	9	8			
Start month	M1		End month	M36		

Objectives

- Develop and evaluate a global 1/12 degree configuration of NEMO with tides
- Implement a) improved tide-related parameterisations in NEMO and b) an improved vertical coordinate

in the global configuration

- Fully assess a long global ocean simulation with tides, including large-scale climate features, internal tides and numerical mixing
- Provide recommendations to CMEMS on suitability for implementation in the global MFCs.
- Deliver operational-quality NEMO code, proven and documented to NEMO standards

This work package is led by: Helene Hewitt, Met Office

Description of work

This work package is focussed on bringing tidal capabilities within NEMO (which are well established in regional applications) into the global system and developing the additional capability which is required for the global problem. Within this work package the representation of global tides at 1/12 degree will be extensively validated and the impact of tides on the large-scale simulation will be thoroughly assessed.

Tasks

T3.1 [M1-M24] Implementation of tides in ORCA12 test case (Lead: Met Office, Participants: NERC, Mercator**)**

The target global configuration (eORCA12) will be built making use of tidal forcing and diagnostics which are currently available in NEMOvn3.6 (D3.1). We will develop a *test case*, which consists of a one year run of the global configuration with appropriate diagnostics (MS5). Detailed analysis will assess the accuracy of both the barotropic and baroclinic tide and levels of physical and numerical mixing.

Met Office will be responsible for a) the eORCA12 configuration, implementing and testing with existing tidal forcing and b) validating the barotropic tidal constituents (including provision of enhanced code for tidal harmonics in high-resolution global models). NERC will be responsible for assessing physical and numerical mixing through the application of water mass transformation theory. Mercator will be responsible for validating the baroclinic (internal) tide.

T3.2 [M6-M36] Improvements to tidal simulation (Lead: NERC, Participants:Mercator, Met Office**)**

Based on the initial implementation, we will make a set of targeted model developments (MS6) aimed at achieving an accurate representation of tidal processes (guided by experience with other models, e.g. HyCOM) and ameliorating any deficiencies introduced into the solution (e.g. through numerical mixing). Model developments will focus on development of self attraction and loading parameterisation and introduction and calibration of the z-tilde approach to minimise numerical mixing resulting in code suitable for inclusion in the NEMO reference code. The need for a parameterised wave drag scheme (to represent tidal dissipation at unresolved scales) in NEMO will be ascertained.

Mercator and NERC will be responsible for implementing and testing z-tilde. NERC will be responsible for implementing and testing self-attraction and loading. Met Office will be responsible for scoping parameterised wave drag.

T3.3 [M12-M36] Evaluation of tidal simulation (Lead: Mercator, Participants: NERC, Met Office**)**

Software for evaluation of global tides and implied mixing rates will be developed as a resource for the international modelling community (deliver via the community ESMval library) (D3.2). We will conduct a substantial assessment of the (positive and negative) implications of including tides in a full-physics high resolution ocean model run through a multi-year simulation (20 years or longer). These will focus both on large scale physical properties of the model, (e.g. water-masses, overturning circulation, mixing in shelf-seas) and aspects identified by CMEMS users as requiring improvement through tidal information (e.g. depth-resolved high frequency currents). The report describing this evaluation and assessment (D3.3) will go forward to help inform the CMEMS service evolution, including discussion of the implications for data assimilation.

Met Office will be responsible for a) running a 20 year run of eORCA12 with tides (MS7), b) assessing the large-scale climate of the simulation (currents, temperature, salinity and sea ice) and c) a detailed evaluation of barotropic tides against altimetry. NERC will be responsible for a) assessing the simulation of global shelf-seas, b) assessing numerical and physical mixing and c) detailed assessment against tide gauge data. Mercator will be responsible for assessing a) internal tides, b) energy budgets and c) high frequency currents.

Interactions with other work packages

Overall coordination between WPs of code implementation in the NEMO reference code will be managed by Task T2.2

Deliverables (Summary)

D3.1: Prototype eORCA12 configuration available to CMEMS global MFC **(M24)**

D3.2: Tidal evaluation software released to NEMO community **(M30)**

D3.3: Report/paper on assessment of the global tidal model to enable CMEMS to assess the value of operational implementation **(M36)**

Work package number	4		**Lead beneficiary**	INGV			
Work package title	Surface wave coupling						
Participant number	4	5	6				
Short name of participant	**INGV**	NERC	Mercator				
Person/months per participant:	36	6	4				
Start month	M1	End month	M36				

Objectives

- Revise, improve and include additional terms to the preliminary NEMO wave coupling developments related to meso-large scale wave-current interaction
- Conduct a second phase of model development that will include wave effects at small scale and wave induced mixing in order to achieve a full wave coupling in NEMO
- Test the new code implementations on selected test cases (Mediterranean Sea, North West Shelf, Global Ocean, and evaluate the effects of wave coupling on the hydrodynamic and wave fields
- Deliver operational-quality NEMO code, proven and documented to NEMO standards

This work package is led by: Emanuela Clementi, INGV

Description of work

WP4 deals with wave-current model coupling which can strongly drive the ocean circulation, modifying the surface boundary fluxes, the momentum and energy exchange between atmosphere and the ocean and the transfer of energy within the water column. WP4 will build on an existing, partial demonstration code for the Vortex Force approach to wave-ocean coupling in NEMO. WP4 will add and assess the key missing processes, assess their impact in CMEMS-relevant test configuration, and deliver NEMO code that is ready to bring to operational use in CMEMS.

Tasks

T4.1 [M1-M18] Finalization of meso-large scale wave-current processes formulation (Lead: INGV, Participants: NERC**)**

Starting from the existing NEMO VF demonstration code, the following key additional processes will be implemented and tested:

1. Update the Stokes-Coriolis consistent with Coriolis discretization;
2. Implementation of vortex force to represent the radiation stress gradient (interactions between Stokes drift and the vorticity of the mean flow);
3. Momentum advection by Stokes velocity;
4. Bernoulli head, the adjustment of pressure in accommodating incompressibility;
5. Coupling between the barotropic and baroclinic mode: the surface boundary condition has to include the quasi-static pressure response (wave setup/down);
6. Careful formulation of lateral boundary conditions: a zero mass flux formulation will be evaluated and implemented.

The code design will be previewed (MS8) and functionally and ocenographically tested model code will be delivered to Tasks 4.2 for further development and 4.3 for evaluation.

T4.2 [M13-M34] Small scale wave-current processes and wave induced mixing (Lead: INGV, Participants: NERC**)**
Based on the results achieved in T4.1, a second phase of development will be performed, covering wave induced mixing effects and wave-current interactions at small scale to achieve a full wave coupling in NEMO:

1. wave mixing effects due to wave breaking, white capping and Langmuir circulation
2. wave induced tracer diffusivity
3. wave effects on bottom friction

These code designs will also be previewed (MS9) and all validated and verified code submitted to the NEMO trunk (MS10).

T4.3 [M12-M36] Test cases (Lead: INGV, Participants: Mercator, NERC**)**
Four test cases have been selected in order to evaluate the combined role of the implemented processes as well as their individual contributions in different areas and at different resolutions. Reports will be written on results with the initial code (D4.1) and updated code (D4.2).

1. CMEMS Mediterranean Sea MFC Test case (INGV): uses the next upgrade model set up of the CMEMS Med-MFC developed at INGV (1/24˚ resolution) forced by ECMWF 1/8˚ atmospheric fields and coupled off-line with WWIII (WaveWatch3). Model surface currents will be validated using CODE drifters. Temperature and salinity vertical profiles will be compared to ARGO data (Copernicus INSITU TAC).

2. North-West Shelf (NWS) Test case (NERC): uses NEMO at 1.5km resolution forced off-line by WWIII (this model version will be the next upgrade for the CMEMS system in the NWS). Test the impact of implemented model changes on surface trajectories, in short simulations.

3. Fully coupled test (NERC): Building on the UK national Met Office-NOC-CEH UKEP project, and alongside the CMEMS OWAIRS project, the NEMO-OASIS-WWIII system will be tested in fully coupled mode for the NWS region, to assess the effects of the hydrodynamics back on the waves through changes in water depth and currents. Consequential changes in dispersion, dissipation, refraction and blocking will be investigated, with a focus on near coastal, tidally active regions (e.g. Liverpool Bay and Celtic Sea). These will be validated and assessed using wave buoy or other observations during short test simulations.

4. Global configuration (Mercator): The impact of the most promising new developments will be assessed at a global scale with the ORCA025 configuration, forced offline with Météo-France wave model MFWAM (1/4° resolution, forced with CEP 1/8° analysis). Tests cases with the newly-implemented wave/current coupling terms will focus on several cyclonic events observed during 2013-2014, and on the assessment of the Langmuir parameterization.

Interactions with other work packages

Code modifications from this WP will be provided to:

- WP 6 in order to incorporate the new space-time discretisation in the wave coupling terms;
- WP 9 in order to deal with lateral boundary conditions for wave-current coupled equations.

Detailed discussion will be held between these WPs to ensure effective and well-engineered merging of the developments into the NEMO code trunk.

This work package will receive information from WP8 on developments and recommendations for HPC optimization. These recommendations concerning code efficiency will be followed when adding new wave-current processes developments.

Overall coordination between WPs of code implementation in the NEMO reference code will be managed by Task T2.2

Deliverables (summary)

D4.1: Report on scientific assessment of wave-current interaction processes and model implementations **(M18)**

D4.2: Report on implementation and evaluation of wave coupling developments in NEMO **(M36)**

Work package number	5	**Lead beneficiary**		CMCC		
Work package title	Data assimilation diagnostics					
Participant number	2	1	4	6		
Short name of participant	**CMCC**	Met Office	INGV	Mercator		
Person/months per participant:	14	11	11	3		
Start month	M1			End month	M36	

Objectives

- Diagnosis of common systematic errors revealed by the averaged analysis increments, associable to deficiencies in NEMO model, atmospheric forcing or data assimilation configuration and provision of recommendations to the NEMO ocean model developers about the main systematic errors of the NEMO model
- Provision of recommendations to the observational community and CMEMS TACs and MFCs about the optimal configuration of CMEMS data assimilation systems for the design and exploitation of high-resolution (satellite) data

This work package is led by: Andrea Storto, CMCC

Description of work

The work package goal is twofold:

i) detection of robust features in time-averaged analysis increments from global and regional reanalyses, providing insight into the main NEMO systematic errors, and

ii) performance of assimilation sensitivity experiments to establish optimal practices for high-resolution data assimilation, including understanding the impact of different observing systems and indicating the best approaches to assimilate high-resolution data, especially sea-surface temperature and altimetry data from satellites.

The work package is divided into three tasks: the collection of analysis increments already available; the design and performance of sensitivity experiments aimed at assessing best practices for the assimilation of high-resolution observations; and the computation and analysis of assimilation increment diagnostics

The concept of the ensemble of data assimilation systems that use NEMO will be exploited throughout the work package as a powerful tool to detect model biases and diagnose observational impact.

Tasks

T5.1 [M1-M06] Collection and homogenization of available assimilation statistics (Lead: CMCC, Participants: Met Office, Mercator, INGV**)**

This task aims at collecting analysis increments data for existing datasets. Assimilation data from global ocean reanalyses produced with the NEMO model in the framework of MyOcean (C-GLORS, ORA. GLORYS, MFS) or national initiatives (GloSea5) will be the primary source of data for this task (MS11). This task will also establish a common strategy (period, data format, etc.) for the analysis increments intercomparison.

T5.2 [M1-M24] Assimilation sensitivity experiments (Lead: Met Office, Participants: CMCC, INGV**)**

In this task, we will design (MS12) and perform sensitivity experiments during a common period to investigate the best design of data assimilation systems dealing with high-resolution data, in the context of present and future satellite missions.

- Met Office will investigate the effect of the SST data assimilation on analysis increments through data denial experiments, in order to quantify how important are the assumptions implicit in the SST assimilation strategy, and hence assess and improve the SST impact. Met Office will also run assimilation experiments with different choices for the way the satellite SST data are assimilated, focussing on the vertical propagation of SST information and the interactions of that with biases in the model's representation of vertical mixing. The objective here is to improve the SST assimilation in order to make the most of data from existing and future satellite SST missions.
- INGV will study the sensitivity to different configurations of the sea level anomaly (SLA) assimilation scheme, changing in particular the constellation and sampling of altimetry data, also in light of forthcoming altimetric missions, and the multi-variate balances in the data assimilation scheme. The focus is again the optimal design of observation operator and satellite constellation, here for altimetry data.
- CMCC will conduct experiments at both eddy-permitting and eddy-resolving resolutions and with different satellite observing network for SST and SLA. CMCC will test different strategies for high-resolution data assimilation such as simulated wide swath altimeter data, ranging from full satellite view data assimilation, to "superobbing" (observation averaging) and "thinning" (observation sub-sampling) at eddy-permitting and eddy-resolving resolutions. These two resolutions represent the CMEMS systems currently used for reanalyses and forecast, respectively. This will establish whether optimal choices for the assimilation may depend on the model resolution.

T5.3 [M18-M36] Diagnostics and recommendations (Lead: CMCC, Participants: Met Office, Mercator, INGV**)**

This task will inter-compare the analysis increments coming from the previous tasks, summarize the results and provide recommendations. The analysis increments presented in Task 5.1 represent an ensemble of analysis increment realizations, all with the NEMO model. This will allow us to detect systematic errors that can intrinsically be attributed to NEMO, or depend on a certain NEMO configuration, or simply arise from the data assimilation or model configurations chosen. Robust features detected in most experiments will form the basis for providing recommendations to the community of NEMO developers, through channels such as the NEMO Users' Workshop an dDevelopers' Committee (see Section 2.2a) (D5.1). Meanwhile, the main outcomes from the sensitivity experiments concerning the best strategies for high-resolution data assimilation will be outlined, with a particular focus on the assessment of observation operators, satellite constellation and data sampling strategy (D5.2). Results can be immediately transferred to CMEMS reanalysis and forecast systems, and to EO mission planners through the channels outlines in Section 2.2a.

Interactions with other work packages

This work package will provide indication on the more dominant biases present in the global configuration of the NEMO model. This will be of crucial importance for a broad community of NEMO developers and users, fo rth eongoing development of NEMO beyond the end of COPPER. Through early interaction with the model development work packages of COPPER, these work packages will be able to target evaluation of their model developments toward some of the errors detected in WP5.

Dissemination and exploitation of the results, particularly by the CMEMS MFCs, will be integrated into the Dissemination and Communication Plan, and the Exploitation Plan (WP2)

Deliverables (Summary)

D5.1: Summary and diagnosis of systematic errors of the NEMO model diagnosed from CMEMS reanalyses **(M30)**

D5.2: Summary and recommendations on the optimal exploitation of high resolution observations in CMEMS systems **(M36)**

Work package number	6	**Lead beneficiary**			CNRS	
Work package title	Coupled space-time discretization					
Participant number	3	8	6			
Short name of participant	CNRS	INRIA	Mercator			
Person/months per participant:	17	19	3			
Start month	M1		End month	M30		

Objectives

The overall objective of this work package is to implement an innovative coupled space–time discretization strategy in NEMO in order to improve the accuracy and the stability of the code for kilometric scale applications.

More precisely, the specific objectives are the following :

- demonstrate the impact of coupled discretization approached on key small scale ocean processes
- document the stability constraints of coupled discretization approaches when used with mode splitting
- define the flow chart for a robust implementation of the coupled space-time discretization strategy in NEMO
- implement the coupled space-time discretization strategy and document its impact on both idealized test cases and realistic applications.
- Deliver operational-quality NEMO code, proven and documented to NEMO standards

This work package is led by Julien Le Sommer, CNRS.

Description of work

The general concept and constraints of coupled space–time discretization approaches have been studied for more than a decade so that the science basis is now robust enough for a transition to Copernicus services. We therefore here propose to organize the work-package as to seamlessly transfer this innovative approach to numerical discretization from the field of applied mathematics to operation within Copernicus services.

We will combine a test driven approach with dedicated idealized test cases and proceed to a strict design review before implementation (MS13). This is particularly needed with the proposed new coupled space–time discretization approach because this new numerical kernel will require a substantial reorganization of NEMO code, that will first be described in a dedicated flow-chart (T6.3).

The dedicated idealized test cases will allow to verify a posteriori that the actual implementation reaches the expected solutions first obtained a priori in prototype codes (T6.1). The implementation in NEMO will then be tested in realistic model configurations (T6.5) before reaching MS14.

Specific research work will first be needed in order to define how to optimally combined coupled space–time discretization with baroclinic/barotropic mode splitting. Work is also need in order to document the stability constraints of the new kernel (T6.2).

Tasks

T6.1 [M1-M6] Definition of expected benefit in prototype test cases (Lead: INRIA, Participants: CNRS, Mercator)

We will here define of a suite of idealized test cases associated with specific small scale ocean processes (internal waves, barotropic waves, inertia-gravity waves, advection x-z). For each test case, a prototype code will be implemented in order to show-case the impact of the new discretization on the model solution. The work will be done by INRIA. CNRS and Mercator partners will participate to a series of meetings at the WP level.

T6.2 [M7-M12] Stability analysis of the mode splitting in the new kernel (Lead: INRIA, Participants: CNRS, Mercator**)**

A stability analysis of the mode-splitting technique will be carried in order to check the consistency between the internal and external modes as to ensure proper conservation properties (D6.1). Indeed, the steep stability constraint imposed by fast surface waves associated with free-surface evolution on the time-step of numerical models is usually handled using a splitting between slow (internal / baroclinic) and fast (external / barotropic) motions to allow the possibility to adopt specific numerical treatments in each component. A key question is here to decide whether to use the same numerical schemes in each mode for the time and space discretizations.

The work will be done by INRIA. CNRS and Mercator partners will participate to scientific discussions when needed.

T6.3 [M13-M18] Definition of the flow-chart for implementation in NEMO (Lead: INRIA, Participants: CNRS, Mercator**)**

The purpose of this task is to analyse how to integrate the new schemes defined in T6.1 and T6.2 within NEMO. We will here define the flow chart of the new numerical kernel with a specify focus on the interaction with other code components (in particular with the sea-ice model, AGRIF and wave interface). The flow-chart will be distributed to NEMO System Team through NEMO wiki for internal review before the opening of a branch dedicated to the implementation of the new kernel (MS13).

The analysis will be performed jointly by INRIA, CNRS and Mercator under the responsibility of INRIA.

T6.4 [M13-M24] Implementation and a posteriori evaluation in idealized test cases (Lead: CNRS, Participants: INRIA, Mercator**)**

We will here proceed with the actual implementation of the new coupled space-time discretization approach within NEMO. A significant of the work will be dedicated to the a posteriori evaluation of the implementation in idealized test cases in order to ensure the robustness of the code. The results obtained will be compared with the results obtained with the prototype codes of T6.1 and eventually documented on NEMO wiki pages (D6.2). The work will start with the implementation of the idealized test cases in NEMO (M12-M15) followed by the reorganization of the code according to the flow-chart defined in T6.3 at M15. The overlap with T6.3 over M12-M18 is necessary for a smooth transition to the implementation phase.

The work will be done by CNRS. Input and discussion with INRIA and Mercator will be sought when needed.

T6.5 [M25-M30] Test in realistic model configuration (Lead: Mercator, Participants: CNRS, INRIA**)**
The new numerical kernel will be tested in realistic model configurations (operated at Mercator) in order to check the full compatibility of the new code with existing systems in CMEMS (MS14).

Interactions with other work packages

- Work in required in WP7 as to ensure the full compatibility of AGRIF with the new coupled time-space discretization scheme. This work will be undertaken in WP7 as soon as the flow chart is validate (M15) and fully validated during M30-M36.
- The development to be undertaken in WP6 will certainly have implications on the propagation of internal tides as studied in WP3. The impact of the new kernel on WP3 will need to be tested during M30-M36.
- Potential benefits of the new time-stepping on code performance as discussed in WP8 are to be expected. This impact will be tested during M30-M36.

Deliverables (Summary)

D6.1: Report on stability analysis and impact of new discretization in prototype test cases **(M12)**

D6.2: New scheme available in NEMO repository and impact demonstrated in idealized test cases (documented on NEMO wiki) **(M27)**

Work package number	7	**Lead beneficiary**			Mercator-Océan	
Work package title	Multi resolution capabilities					
Participant number	6	1	8	3		
Short name of participant	Mercator	Met Office	INRIA	CNRS		
Person/months per participant:	25	5	2	2		
Start month	M1			End month	M36	

Objectives
The overall objective of this work package is to develop and improve the multi-resolution capabilites of NEMO using the AGRIF library, to allow easy implementation of NEMO applications at kilometric scale, and effective seamless chains between dynamics and biogeochemistry.

Specific objectives :

- Develop on-line grid coarsening of the biogeochemical component of NEMO, to operate in CMEMS-like model configurations with all required conservation properties.
- Develop ability to run vertical grid refinement, including compatibility between different vertical

coordinates, in some specific key regions

- Ensure compliance of these new functionalities with the new time discretisation (see WP6)
- Deliver operational-quality NEMO code, proven and documented to NEMO standards

This work package is led by: Claire Lévy (CNRS), and co-led by Jérôme Chanut (Mercator-Océan)

Description of the work

T7.1 [M1-M16]: On-line coarsening of biogeochemistry with AGRIF (Lead Mercator, Participants: INRIA)
This task will develop the AGRIF library as a component of NEMO, to provide a sustainable and accurate way to run biogeochemical components on a coarser grid to the dynamics, while retaining their accuracy and conservation properties.

Subtask 7.1.1 [M1-M8]: Adding functionalities in NEMO-AGRIF interface to on-line coarsening (Lead INRIA, Participants: Mercator)
The AGRIF-NEMO interface (NEMO code and nesting tools) will be designed (MS15) and developed to allow periodic boundary conditions, including the 'north fold' in the tripolar global grid used in the CMEMS Global MFC.

Subtask 7.1.2 [M9-M15]: On-line coarsening of biogeochemistry by activating "grandmother grid concept" (Lead Mercator, Particpants: CNRS)
This task is dependent on the completion of Subtask 7.1.1 to start. The The design (MS16) of the on-line coarsening for biogeochemistry will take advantage of AGRIF "grand mother grid" concept, e.g. the capability to handle in memory a coarsened space of the root (parent) grid.

- This functionality will be activated and adapted to the sole use of passive tracers on such a grid.
- Dynamical fields needed to perform advection and diffusion of passive tracers will be degraded in a similar fashion as currently done in the existing coarsening implementation.

Results will be reported from a test case demonstrating the new functionality from Task 7.1 using a global ORCA025 (1/4°) dynamical configuration with a biogeochemical component running on a coarsened grid, first with age tracer and then will full PISCES biogeochemical component (MS17 and D7.1).

Task 7.2[M1-M16]: Develop two ways nested grids on the vertical (Lead: Met Office, Participants: Mercator)
This task will make the required developments to allow different vertical grids and different vertical coordinate systems between the nested grids, in order to (i) to improve modelling of overflows (ii) to facilitate seamless dynamical interaction across the shelf break.
The tasks required for vertical grid refinement are:

- Implementation of interpolation for TKE mixing scheme
- Implementation of vertical interpolation in the sponge layer between the nested and parent domains
- Implementation of interpolation in the "update" routines for 2 way nesting
- Testing of a configuration

The code design will be previewed (MS18) and the test results described in a report (D7.2).

For the further work to allow the change of vertical coordinate the main task will be in further modifying the nesting tools to set up the bathymetry correctly.

Task 7.3 [M16-M26] Enhancement of grid interactions. **Compliance with the new time stepping algorithm of NEMO (Lead: Mercator. Participants: INRIA)**
This task requires the successful preview of the new time stepping scheme as defined in WP6 MS13 [M15]. It will consist in the adaptation of AGRIF coupling procedure to the new (baroclinic) step architecture as well as incorporating two-way exchanges at the sub-stepping (barotropic) level. The latter is expected to

improve the propagation of fast waves through nested grid and facilitate exact reproductibility of results over a subset of the root grid. The design of the code will be previewed (MS19).

Task 7.4 [M30 – M36] Overall WP7 test case/demonstrator (Lead: Mercator. Participants: CNRS, MetO, INRIA)
A consolidated demonstrator for the WP7 developments will be defined as a global ORCA025 dynamical configuration with on-line coarsening of passive tracers, and 2 local zooms with vertical grid refinements in the critical regions of Atlantic overflows (Denmark and Gibraltar straits).
This task will configure and run the demonstrator and evaluate the results, both from the perspective of conservation and other fundamental properties, and from the perspective of oceanographic quality (D7.3).

Interactions with other work packages

A pre-requisite of task 7.3 is successful preview of the new time stepping scheme as defined in WP6 T6.3 (MS 13).

Overall coordination between WPs of code implementation in the NEMO reference code will be managed by Task T2.2

Deliverables (summary)

D7.1: Report on implementation and evaluation of on-line coarsening of biogeochemistry using AGRIF. Test case should demonstrate full coherency with previous results of on-line coarsening **(M16)**

D7.2: Report on implementation and validation use of nested grids on the vertical using AGRIF **(M16)**

D7.3: Report on overall demonstrator run, including compliance with new time stepping algorithm in NEMO **(M36)**

Work package number	8	**Lead beneficiary**	CMCC
Work package title	Preparing NEMO for emerging High Performance Computers		
Participant number	2	1	7
Short name of participant	**CMCC**	Met Office	BSC
Person/months per participant:	12	6	12
Start month	M1	End month	M36

Objectives

- Improve NEMO code parallel efficiency focusing on the reduction of the communication overhead.
- Analyse NEMO single-node performance on a set of heterogeneous architectures.
- Define alternative coding approaches to increase single-node performance.
- Demonstrate performance improvement impacts in real test cases.
- Deliver operational-quality NEMO code, proven and documented to NEMO standards

Description of work

This WP is led by Silvia Mocavero, CMCC

T8.1 [M1-M2] NEMO benchmark suite (Lead: Met Office, Participants: CMCC, BSC**)**
This task will set up a suite of benchmark configurations which are representative for various realistic scenarios, starting from the last official NEMO release (MS20). At least two target configurations will be

included: the idealized GYRE configuration, provided to easily change the domain resolution, and the global ORCA025 configuration (close to operational CMEMS global configurations).

T8.2 [M1-M24] NEMO code scalability on emerging architectures (Lead: BSC, Participants: CMCC, Met Office**)**
Starting from past analysis of the parallel code on different NEMO configurations and HPC systems, provided by the partners in the IS-ENES2 project, this activity will focus on reducing the communication overhead during code execution in parallel mode. New approaches will be analysed by using message-passing advanced capabilities, which can simplify further the communications interface, to ensure its maintainability as well as improve its performance. BSC will lead the development, validation of a first version of the code, optimized for emerging architectures. The strategies will be defined (MS21), the first version of the optimised code released (MS22) and the improvements reported (D8.2).

T8.3 [M1-M34] NEMO code single-node efficiency on many-core architectures (Lead: CMCC, Participants: Met Office, BSC**)**
This task is devoted to the evaluation and improvement of single-node efficiency. The suite of benchmarks, built in task T8.1, will be used to perform tests based on performance counters. These counters give e.g. insight into the maximum performance with the roofline model. Detailed information on instruction throughput per second, stall cycles and cache hits will provide insights on the performance limits on existing and in particular future machines. Analysis of these results will facilitate the identification of alternative coding approaches and solutions to better exploit the features provided by the emerging architectures. The implementation will focus on some key (from the computational structure point of view) elements of the NEMO code, selected because of their significant contributions to the total wallclock time of NEMO runs. All the work related to the analysis, the implementation, and the testing, performed during the project will drive the definition of future strategies for code development.

T8.3.1 Analysis of NEMO single-node performance

- Define a set of metrics to be evaluated. This will include metrics such as the memory bandwidth, Flop/s, packed/unpacked load/store operations, instruction throughput, stall cycles, etc.
- Select tools to extract the performance metrics, taking into account the metrics provided by each of these, how easily these metrics can be extracted and how many architectures are supported, also considering their availability on emerging architectures (i.e. GPUs, MIC,...).
- Select a set of heterogeneous architectures where we will test the code and perform the analysis. A diverse set of HPC systems is available from the project partners and will include new XeonPhi architectures and GPUs. This activity will benefit from the inputs provided by technical experts from some HPC manufacturers, involved through the NEMO HPC working group.
- Report on results (D8.1).

T8.3.2 Definition of alternative coding approaches to improve single-node performance
This subtask will design (MS23) and implement new coding approaches starting from the analysis outcomes from T8.3.1. These approaches will be applied to a set of kernels identified as key from the computational point of view and will be tested using ‘mini-apps’ (lighter versions of more complex full code, designed to capture and reproduce the essential features). The advantage is to work on small kernels, without changing whole the NEMO code. A report will describe the approaches and results (D8.3). Only the best solutions will be integrated and tested on the configurations of the benchmark suite and this last activity will be performed in task 8.4.

T8.4 [M3-M36] Performance improvement impacts on real test cases (Lead: CMCC, Participants: Met Office, BSC**)**
This task will define and execute a test plan according to the outcomes of the previous tasks. The tests will evaluate the improvements on the computation/communication ratio provided by T8.2 and the improvement

on the single-node peak performance achieved in T8.3. The test plan will employ the methodology defined in task 8.3.1 (for the analysis on single-node) and the application of standard metrics (e.g. speedup, SYPD, I/O time, computation/communication ratio), used to evaluate parallel efficiency.
This test plan will be developed by CMCC in collaboration with the other two partners. The execution of the test plan will be a shared action among the partners. Tests will be performed at least on the Met Office, CMCC and BSC HPC systems. However, added systems provided by collaborators and/or HPC manufacturers involved in the NEMO HPC working group will also be used where available and complementary. A set of code optimisations will be released (MS24) and the results and final recommendations included in D8.3.

Interactions with other Work Packages

This work package provides a version of the optimized code (focused on the improvement of parallel efficiency) to all the WPs. This version, provided at M22, will be used for other WPs developments.
Overall coordination between WPs of code implementation in the NEMO reference code will be managed by Task T2.2.

Deliverables (Summary)

D8.1: Report on single-node benchmarks. The document will describe the analysis methodology and single-node performance evaluation on the benchmark suite target configurations (GYRE and ORCA025) **(M8)**
D8.2: Report on the parallel efficiency improvements. The document will describe the optimizations to improve the parallel efficiency and analyse the impacts on target configurations **(M24)**
D8.3: Report on the final release computational performance. The document will describe the single-node new coding approaches and analyse the impacts on the benchmark suite configurations. It will also provide recommendations to extend the application of the coding approaches to whole the code **(M36)**

Work package number	9	**Lead beneficiary**			NERC		
Work package title	Seamless Interaction with Coastal Monitoring Systems						
Participant number	5	2					
Short name of participant	NERC	CMCC					
Person/months per participant:	21	12					
Start month	1			End month	36		

Objectives

- Develop a seamless approach to interfacing the ocean model and remote sensed observed information, global and regional, available from the CMEMS systems with the modelling component of coastal monitoring systems. This will take the form of a flexible Python-based code tool kit, with code development following NEMO quality control and documentation standards.
- To disseminate this system to the coastal modelling community and accept feedback from that community to assist the development of the CMEMS services and their use.

This work package is led by: Jason Holt (NERC)

Description of work

The approach will be to develop a suite of interoperable Python tools that form a generic coupling to CMEMS information, augmented by a ‘lightweight’ coastal model system-specific interface that simply translates the generic data structure to that needed by the coastal model. This builds on the UK pyNEMO project which has developed a suite of NEMO-specific boundary condition tools (http://pynemo.readthedocs.org/en/latest/intro.html)

While each coastal-model may require different forcing information, we can anticipate a basic set of variables to be delivered:

- High frequency (hourly) boundary condition:
    - Sea surface height
    - Depth averaged current vectors
- Low frequency (daily) boundary condition and initial condition
    - 3D Temperature, salinity and current vectors
- Daily Remote Sensed surface fields
    - SST, KD490, CHL

Additional parameters (e.g. relating to surface waves) will be identified through user interaction at a remote-workshop/webinar. The system will also accommodate the addition of user-specific fields that are not currently available from the CMEMS system (e.g. tidal harmonics). We can also anticipate some common transformations that will be required and these will be included in the process train, for example integration to ensure volume conservation , filtering and removal of tidal signals. These will be included in a pre-processing tool box that can be interfaced with the main system.

While the system will allow interfacing to any coastal model system, it is important to provide some working examples to demonstrate its utility and help users configure the model for their own systems. These will include examples covering a range of existing systems developed within the consortium (outside of COPPER funding):

- The Adriatic-Ionian Forecasting System (http://oceanlab.cmcc.it/aifs/). A high resolution NEMO application within an operational suite
- The Southern Adriatic Northern Ionian Forecasting Systems (http://oceanlab.cmcc.it/sanifs/). A very high resolution unstructured mesh model in an operational suite
- The FVCOM Bangladesh Delta Model. A standalone very high resolution model in a non-European area.
- POLCOMS Liverpool Bay. A very high resolution (200m) non-nemo structured mesh model

Tasks

T9.1 [M1-M6] System scoping, design and out-reach (Lead: NERC, Participants: CMCC**)**

We will hold a remote workshop (webinar) to introduce the concept to the coastal modelling community including operational users, research community, commercial users and SMEs (MS25). We will take advice on the systems specifications and its utility, within the constraints of the CMEMS service, and through the process identify a community of interested users. We will specifically build links with the GODAE Coastal Ocean and Shelf Seas Task Team (GOV-COSS-TT) and the EuroGOOS Coastal Ocean and Shelf Seas Modelling working group as key international fora, and invite specific users for early systems testing. We will also contact the relevant CMEMS web teams to discuss and requirements and adjust the design accordingly. We will finalise the design of the system following feedback from the workshop (MS26).

T9.2 [M7-M24] System development (Lead: NERC, Participants: CMCC**)**

We will develop the pyNEMO tools to couple to the CMEMS data servers and code a generic interface to extract this data. This will include interpolation to an unstructured data type, including 1D for depth integrated boundary conditions, 2D for depth resolved boundary conditions and surface data fields, 3D for depth resolved initial conditions. We will develop the specifications for the model specific interface tool (NERC, CMCC).

We will develop the generic interface to ingest model specific geometric and configuration information, e.g. coast lines, bathymetry, and horizontal and vertical mesh information. (CMCC)

We will develop a set of processing options including tidal filtering (e.g. using the Doodson X0 filter) and volume conservation constraints. (CMCC, NERC)

T9.3 [18-36] Dissemination and up-take (Lead: CMCC, Participants: NERC**)**
We will write documentation for the tools (D9.1) and install them in a freely available code repository (MS27). User support will be provided via the NEMO mail list (or an alternative if this becomes overloaded) and actioned by NERC, but will be limited to the Python tools we provide. It will not cover the users' model code, specific interface or computer systems. (NERC, CMCC).

We will develop a set of worked examples of applications of the coupling tool (D9.2). These will include the model specific interface, and basic meta-data describing the coastal model code and its configuration, and a short (<1 year) test simulation. In the first instance these will be applied to existing coastal models available to the consortium (Adriatic-Ionian Forecasting System; Southern Adriatic Northern Ionian Forecasting System; POCLOMS Liverpool Bay; FVCOM Bangladesh delta model) (CMCC, NERC).

We will hold a workshop training session to introduce the system to a range of users. This will also provide an opportunity for the coastal modelling community to inform the development of the larger scale CMEMS systems. This information will be captured by inviting the relevant MFC and TAC representatives to the workshop and in the work package report (D9.3). (CMCC, NERC)

The system will then be opened to the community and we will invite users to try with their models and provide feedback, making minor modifications as necessary. (NERC, CMCC)

Interactions with other work packages

This work package will benefit from the NEMO model developments e.g. global tidal model developments, but is not contingent on them.

Interaction will be maintained with WP4 to bring changes to wave current interaction terms implemented there, into the specification of boundary conditions by the interface tool.

Deliverables (Summary)

D9.1: Python coupling tool box and documentation (**M26**)

D9.2: Example interface library (**M30**)

D9.3: Report on example test cases and suggestions for CMEMS evolution (**M36**)

List of work packages

WP no.	WP Title	Lead Ppt No	Lead Ppt Short Name	PMs	Start Month	End month
1	Project management	1	Met Office	7	1	36
2	Science leadership and knowledge management	1	Met Office	12	1	36
3	Global tidal capability in NEMO	1	Met Office	29	1	36
4	Surface wave coupling	5	INGV	46	1	36
5	Data assimilation diagnostics	2	CMCC	39	1	36
6	Coupled space-time discretization	3	CNRS	39	1	30
7	Multi resolution capabilities	6	Mercator-Océan	34	1	36
8	Preparing NEMO for emerging High Performance Computers	2	CMCC	30	1	36

9	Seamless Interaction with Coastal Monitoring Systems	5	NERC	33	1	36
				269		

List of Deliverables

Deliv. (no.)	Deliverable name	WP no.	Short name of lead participant	Type	Diss. level	Delivery date (M)
D1.1	Summary reports on project progress	1	MET OFFICE	R	CO	M3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36
D2.1	Public website	2	MET OFFICE	R	DEC	M4
D2.2	Exploitation plan including a roadmap for implementation of COPPER outcomes within the CMEMS systems	2	MET OFFICE	R	CO	M6
D2.3	Updated dissemination and communication plan	2	CNRS	R	CO	M6
D8.1	Report on single-node benchmarks.	8	CMCC	R	PU	M8
D6.1	Report on stability analysis and impact of new discretization in prototype test cases	6	INRIA	R	PU	M12
D7.1	Report on implementation and evaluation of on-line coarsening of biogeochemistry using AGRIF. Test case should demonstrate full coherency with previous results of on-line coarsening	7	MERCATOR	R	PU	M16
D7.2	Report on implementation and validation use of nested grids on the vertical using AGRIF	7	MET OFFICE	R	PU	M16
D4.1	Report on scientific assessment of wave-current interaction processes and model implementations	4	INGV	R	PU	M18
D3.1	Prototype eORCA12 configuration available to CMEMS global MFC	3	MET OFFICE	R	PU	M24
D8.2	Report on the parallel efficiency improvements.	8	BSC	R	PU	M24
D7.3	Report on overall demonstrator run, including compliance with new time stepping algorithm in NEMO	7	MERCATOR	R	PU	M36
D9.1	Python coupling tool box and documentation	9	NERC	OTHE R	PU	M26
D6.2	New scheme available in NEMO repository and impact demonstrated in idealized test cases (documented on NEMO wiki)	6	CNRS	OTHE R	PU	M27

D3.2	Tidal evaluation software released to NEMO community	3	NERC	R	PU	M30
D5.1	Summary and diagnosis of systematic errors of the NEMO model diagnosed from CMEMS reanalyses	5	CMCC	R	PU	M30
D9.2	Example interface library	9	CMCC	OTHE R	PU	M30
D3.3	Report/paper on assessment of the global tidal model to enable CMEMS to assess the value of operational implementation	3	Mercator	R	PU	M36
D4.2	Report on implementation and evaluation of wave coupling developments in NEMO	4	INGV	R	PU	M36
D5.2	Summary and recommendations on the optimal exploitation of high resolution observations in CMEMS systems	5	CMCC	R	PU	M36
D8.3	Report on the final release computational performance.	8	MET OFFICE	R	PU	M36
D9.3	Report on example test cases and suggestions for CMEMS evolution	9	CMCC	R	PU	M36

3.2 Management structure and procedures

COPPER brings together eight partners and is considered to be a small to medium sized project. We have devised a management structure and decision making processes appropriate for the nature of the project and the size of the consortium, that can ensure that the project is well managed and that all objectives are achieved. Two distinct Work Packages (WPs) – WP1: Project Management and WP2: Scientific Coordination, will ensure that this management structure is established. As the Project Office will be at the Met Office, the project will also be able to draw on the Met Office's established in-house expertise in teams such as Legal, Finance and Communications.

The project will be led and coordinated by Dr Mike Bell, who has had considerable experience in leading projects within large ocean modelling research work programmes. Mike was the leader of the Implementation and Production WP in MERSEA Integrated Project (for 4 years) and a member of the Board of MyOcean (the preparatory project for CMEMS, for 6 years). He was joint chair of the Global Ocean Data Assimilation Experiment (GODAE) International Science Team for 5 years, Chair of the GODAE OceanView Patrons Group for 4 years and Head of the Met Office Ocean Forecasting R&D team (around 25 staff) for 10 years.

3.2.1 Overview of structure and decision-making bodies/mechanisms

The structure that has been adopted for COPPER follows the DESCA Model Consortium Agreement for Horizon 2020 projects (the model favoured by the Coordinating Institution), and specific roles and decision making responsibilities have been assigned accordingly. These are illustrated in Figure 3.2.1, and further detail is given below.

In summary:

- The **General Assembly** is the ultimate decision making body for COPPER and will be the supervisory body ensuring successful execution of the project. This will be chaired by the Scientific Coordinator and will consist of representatives from all of the partner organisations.

- The **Scientific Coordinator** is responsible for the overall coordination of the project and will act as the point of contact for the European Commission (EC). The Scientific Coordinator has ultimate responsibility for ensuring the scientific and technical integrity of the project and that it delivers what is expected.
- The **Project Office** will conduct the routine management of COPPER on behalf of the General Assembly.
- The **Work Package Leaders** (**and their co-leaders**) have a responsibility to ensure delivery of their Work Package objectives and deliverables, working closely with the Scientific Coordinator to support the outcomes of COPPER as a whole.
- The **External Expert Advisory Board** is a group of independent experts, whose role is to provide advice on project progress and plans.
- The **Stakeholder Groups** that COPPER will interact with were defined in Section 1.3 and 2.1. They will be represented on the General Assembly by the Scientific Coordinator.

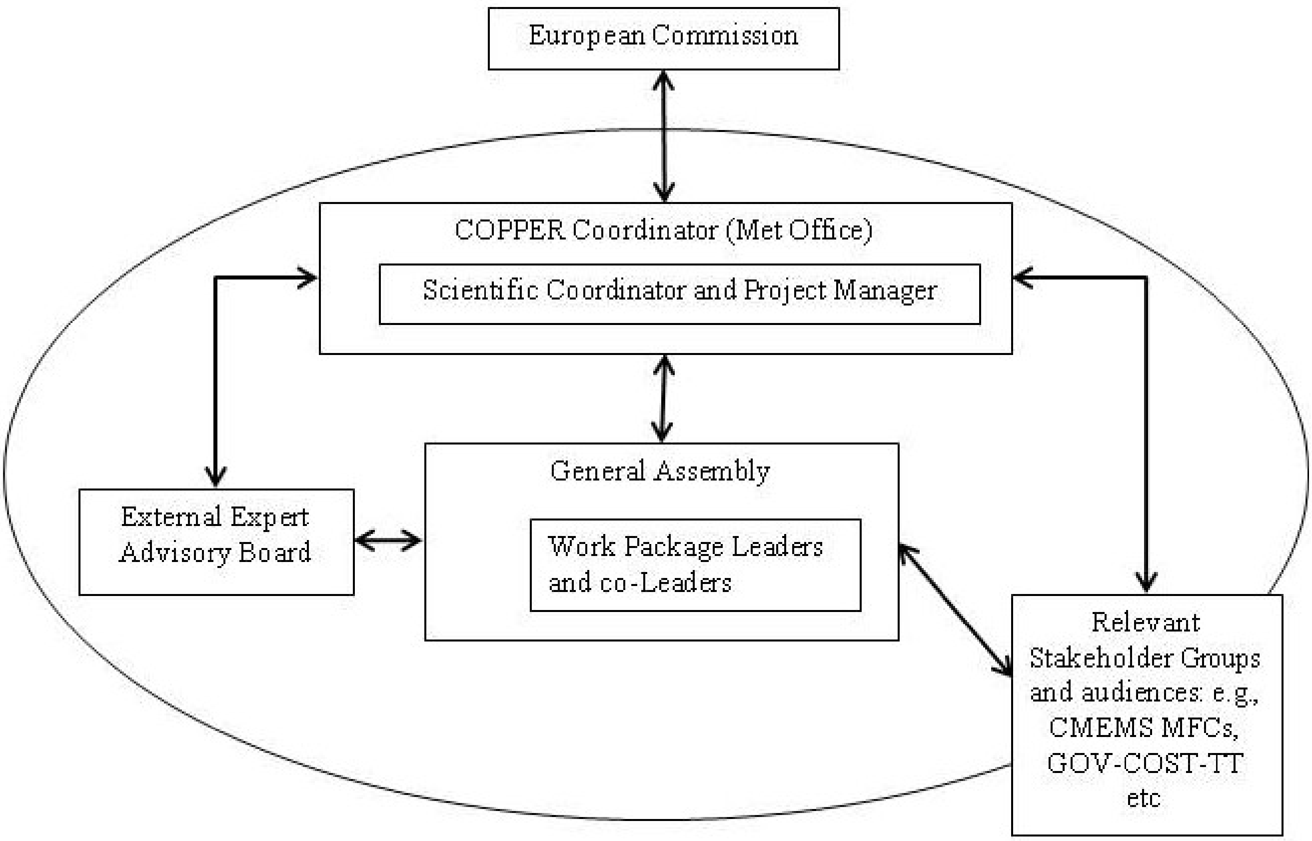


Figure 3.2.1: COPPER Management Structure

3.2.2 General Assembly (GA)

The GA will have oversight of the entire project and its purpose will be to:

- Act as the overall decision-making body for the project and be responsible for agreeing on how to implement these decisions;
- Deliver the aims, deliverables and milestones of the project;
- Oversee political and strategic orientation of the project;
- Share and disseminate knowledge as widely as possible across and beyond the project;
- Agree the work plan, and any changes to the plan;
- Ensure the proper operation of the consortium, including financial management, reporting and communication;

- Make and approve recommendations in the event of changes to the consortium composition or budget allocations;
- Act on any necessary alterations to the Consortium Agreement;
- Responsible for overseeing and resolving risks; any ethical issues that may arise; disputes and complaints; and intellectual property;
- Oversee the cross-cutting theme of gender balance.

There will be four General Assembly meetings; the first at project inception and then annually thereafter until project end. Additional meetings can be called at any time as required by any member of the General Assembly. These can be conducted via video-conferencing/Skype/Webex if appropriate. In principle, approval by the General Assembly to any decisions taken outside of the four core meetings; shall be given by e-mail vote. The framework for these voting procedures will be laid down in the Consortium Agreement.

3.2.3 COPPER Coordinator

COPPER will be coordinated in all the administrative, financial and management aspects by the Met Office. This is at the delegation of the General Assembly. Day-to-day management tasks are listed in the WP1 table under Section 3.1.

COPPER Scientific Coordinator (Dr Mike Bell)

Responsible for the overall coordination of the project; coordination with other EU funded and international projects; intermediary between the European Commission and the project, including communicating any agreements and proposed deviations from agreed plans; acting as the project point of contact for the independent advisory board. Responsible for monitoring scientific progress of the work packages; provides science leadership and quality assurance or the project; identifying any gaps; manages the scientific risks within COPPER, oversees effective innovation management for the project; and reports to the General Assembly. Coordinates and monitor the projects' gender balance strategy, plan and activities; and the knowledge management strategy (including managing dissemination and communication (D2.3) and exploitation (D2.2) plans). Has overall responsibility for the communications plan. Provides formal reports to the European Commission and is assisted by the project manager.

Project Manager

Responsible for facilitating internal communication within the project; providing support and planning tools for work package management; scheduling and organising meetings of the project; providing regular communications to the EC and COPPER; managing, monitoring and reporting of project finances and budget; management of the risks, benefits and issues registers; production of Gender Strategy and Action Plan; providing administrative support to the COPPER coordinator. The project manager reports to the General Assembly.

The Project Manager will be appointed from a pool of specialist project management staff at the Met Office, who have extensive experience of European research programmes. Specialist support (e.g. finance, legal and communications) will be provided to the project office by the appropriate Met Office departments (who also have extensive experience of European research programmes); and other partners' institutes when necessary.

3.2.4 Work Package Leaders

Work Package Leaders (and any co-leaders) have been appointed. They will have the autonomous responsibility for coordinating the tasks within their work package to contribute to the delivery of the project goals and deliverables. These work package leaders will therefore provide the necessary support to the project's scientific coordination. They will ensure that the progress of their work package is tracked, monitored and reported on; including highlighting and discussing any departure from the proposed work and any problems with the Scientific Co-ordinator as early as possible. The work package leaders will assist with exchanges with other projects and the scientific community. To achieve these aims, the WPLs will meet face-to-face at the annual General Assemblies, and take advantage of other meetings that they will be attending outside of the project (e.g. various NEMO meetings). They will arrange other more regular teleconference meetings between those involved in their WP, and will communicate regularly with the Scientific Coordinator.

3.2.5 Stakeholder Groups

WP2 in COPPER will promote, coordinate and facilitate the exploitation of progress within COPPER by each of the regional Monitoring and Forecasting Centres contributing to the CMEMS, using the mechanisms outlined in Section 2.2. They will be represented at the COPPER General Assembly by the Scientific Coordinator.

For engagement with downstream users of CMEMS, COPPER will exploit primarily suitable existing user forums and other channels. It will coordinate with the CMEMS User Engagement Team in order to make appropriate inputs to the CMEMS Regional User Workshops and take advantage of Oceanology International OI2018 in London to highlight the anticipated quality improvements to CMEMS to a wide range of SMEs and commercial companies. It will coordinate user workshops for its down-scaling tool (WP9) with the GOV COSS-TT and take advantage of other GOV Task Team meetings (such as joint meetings of the biogeochemistry and data assimilation Task Teams). It will also present its work to scientists who are well placed to exploit it at the Operational Oceanography sessions at EGU assemblies, the EuroGOOS Science Conference in 2017, and the annual Drakkar workshops and NEMO user workshops.

3.2.6 External Expert Advisory Board (EEAB)

This small independent group will be created by the COPPER Scientific Coordinator and will be made up of distinguished experts whose specialist subject matter is specifically relevant to this project. The EEAB members will provide independent evaluation and recommendations about improvements to the project's work plans, progress, tools and techniques. Consulting with the advisory board will ensure that the deliverables, milestones and associated prototypes of COPPER, support the overall aims of COPPER (e.g. respond to the needs of independent CMEMS service providers and national service suppliers downstream of CMEMS) and parallel European and international policies and activities. The EEAB will receive information detailing the project status and results. The advisory board has currently received formal commitment from: Glenn Nolan (EuroGOOS Secretary General), Enrique Alvarez Fanjul (leader of IBI CMEMS service) and Pierre de Mey (Joint Chair of GOV COSS-TT and ocean data assimilation expert). The intention is to recruit another member to the EEAB, which COPPER will ensure will be female. Potential candidates have been identified.

The EEAB will be invited to attend each of the General Assembly meetings (arrangements will be made for those who cannot attend to participate via, for example, video-conferencing). The Scientific Co-ordinator will also hold telephone conferences with the EEAB at six monthly intervals. The advisory board will receive information detailing the project status and results from the Co-ordinator.

3.2.7 How the organisational structure is appropriate to COPPER

It is essential that the project management and decision making procedures are rigorous enough to manage all the complex technical developments and information exchange within the COPPER project environment (i.e., between partners, users, CMEMS and the European Commission) and the 'outside world' (i.e., adjoining projects, advisory board, wider user community) in as rapid and efficient a manner as possible. At the same time, since COPPER is a small to medium sized consortium, the management structure will be kept simple in order to optimise important interactions between all parties and to reflect the number of project partners. So COPPER only has one management body, which is its General Assembly; thus all partners will be involved in major decisions that need to be made. It is also worth remembering that COPPER is going to exploit the quality control around the technical developments of the NEMO code and system that exists within the NEMO consortium. This is another reason for the simple COPPER management structure. The representation of the stakeholder groups in the General Assembly means that they too have a voice in the decision making of COPPER.

The General Assembly will delegate some responsibilities and decisions to specific subsets of the General Assembly. For example, the management of specific areas of importance such as gender, ethics and IPR is expected to be carried out centrally through the Scientific Coordinator and Project Manager.

3.2.8 List of milestones

Table 3.2.1 details the project's milestones. These milestones will ensure that the project's progress is continually monitored.

Table 3.2.1: List of milestones

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
MS1	Description of process and procedures for treatment of personal data	WP1	M2	Procedures will be implemented for the collection, storage, protection, access, retention and destruction of any personal data. These procedures will be documented through this milestone report
MS2	Gender Strategy and Action Plan for COPPER defined and adopted by the consortium	WP1	M3	Plan written and agreed by consortium
MS3	Design and implement internal communication platform and tools	WP1	M4	Internal communication platform ready for use
MS4	Design of tidal validation and model improvements, including both science and software	WP3	M6	Production of design document for scientific and technical review
MS5	Early results from global tidal simulation for aligning with other WPs to allow discussion on implications of tidal modelling	WP3	M14	Report made available to other WPs
MS6	Implementation of model improvements	WP3	M22	Code will be reviewed and made ready for merging to the NEMO code base.
MS7	20 year plus simulation with tidal forcing completed	WP3	M28	Validation and timeseries data from the simulation made available to CMEMS global MFC.
MS8	Code design preview of model developments at Task 4.1	WP4	M10	Agreement of code reviewer on appropriateness of code design for implementation in NEMO.
MS9	Code design review of model developments at Task 4.2	WP4	M30	Agreement of code reviewer on appropriateness of code design for implementation in NEMO.

MS10	Implementation of verified code in NEMO code trunk	WP4	M34	Code modifications at T4.1 and T4.2 merged into NEMO
MS11	Collection of analysis increments from reanalysis	WP5	M6	A repository remotely accessible to all partners will be created and populated with the analysis increments coming from global ocean reanalyses using NEMO.
MS12	Design of sensitivity experiments to be performed in Task 5.2	WP5	M6	A list of data assimilation sensitivity experiments with inputs from each partner.
MS13	Code design review before proceeding with the actual implementation in NEMO	WP6	M15	The proposed flow-chart will be distributed internally to NEMO System Team. NEMO System Team will review the flow-chart and either approve or suggest modifications before the beginning of the implementation phase of T6.4. This will lead to the opening of a dedicated branch on NEMO repository.
MS14	New discretization scheme implemented, tested and ready for dissemination to other work packages	WP6	M30	The new kernel will be released in a branch of NEMO repository at M27. Before dissemination to other work-packages, the branch will be tested in realistic applications (T6.5), and updated until M30.
MS15	Code design review for Task 7.1.1 before proceeding with actual implementation in NEMO	WP7	M6	Agreement of code reviewer on appropriateness of code design for implementation in NEMO.
MS16	Code design review for Task 7.1.2 before proceeding with actual implementation in NEMO	WP7	M14	Agreement of code reviewer on appropriateness of code design for implementation in NEMO.
MS17	Demonstration of	WP7	M16	Short report comparing

	reproducibility of results of on line coarsening with AGRIF compared to previous 'hard coded' version of the implementation			parallel runs.
MS18	Code design review for Task 7.2 before proceeding with actual implementation in NEMO	WP7	M3	Agreement of code reviewer on appropriateness of code design for implementation in NEMO.
MS19	Code design review for Task 7.3 before proceeding with actual implementation in NEMO	WP7	M20	Agreement of code reviewer on appropriateness of code design for implementation in NEMO.
MS20	Setup of the benchmark suite including two target configurations (GYRE and ORCA025)	WP8	M2	The benchmark suite including two target configurations and related forcings will be available on a remote repository.
MS21	Definition of new strategies for the parallel efficiency improvement.	WP8	M4	Workplan for the development activity to be submitted to the NEMO Consortium for the preview process.
MS22	First release of the optimized code.	WP8	M22	A new NEMO development branch including NEMO optimizations on code scalability.
MS23	Definition of the new coding approaches, already tested on mini-apps, to be integrated in the benchmark suite configurations	WP8	M24	Work plan for the integration activity to be submitted to the NEMO Consortium for the preview process.
MS24	Final release of the optimized code,	WP8	M34	Final review and integration of the single-node performance improvements in the NEMO official release.
MS25	User Remote Workshop (webinar)	WP9	M4	Assessed by attendance of feedback
MS26	Final coupling tool design	WP9	M6	Assessed by expert review
MS27	Coupler tool released for community testing	WP9	M24	Assessed by Coordinator and relevant WPs

3.2.9 Innovation Management

Effective innovation management within this project will require an overview of the project in its entirety and for this reason the Scientific Coordinator will be responsible for the process. Due to the nature of the project deliverables, both the technical and operational aspects of innovation are considered together. There is scientific expertise, technical and system expertise, and user engagement expertise within the consortium. Through the Scientific Coordinator, these elements will be brought together and will ensure that COPPER achieves its aim of CMEMS having access to the best marine modelling tools, which can be exploited by them and all users. This is the primary innovation impact of COPPER, and our approach to achieve the impact is discussed in Section 2.2a (Impact area a).

Two further innovation areas were identified in Section 1.4, namely supporting the technical development of environmental monitoring from space, and supporting the technical development of the 'Intermediate User' sector. The pathways toachieve impact in those areas are described in Section 2.2a (Impact areas, c,d)

3.2.10 Further Management Considerations

Gender Balance within COPPER

By signing the Grant Agreement, the COPPER consortium will commit to promoting equal opportunities during the implementation of the project, and makes a commitment to aim to achieve gender balance at all levels of personnel assigned to the project, including at supervisory, management and decision-making levels, as well as in the research team (Article 33.1 Grant Agreement). COPPER will ensure that where possible it works to satisfy the three primary Horizon 2020 gender balance objectives.

In COPPER, there is a 14:20 ratio of females to males as named individuals to work on the project, and four of the work package leaders are female. The named EEAB members are currently male, however COPPER will ensure that the final member is female. Suitable candidates have been identified. All partners will be encouraged to stay up to date with gender training, and if necessary the Project Office will facilitate this training.

Gender Strategy

The promotion and monitoring of gender equality throughout the project will be the responsibility of the Scientific Coordinator, with support from the Project Manager. A Gender Strategy and Action Plan (MS2) will be produced by month three of the project, and will be monitored and updated during the project. The Scientific Coordinator will ensure that the Strategy is applied throughout the project, and that a process is followed for monitoring gender equality. The strategy will encompass both internal and external participants, and all partners are obliged to aim for gender equality. The strategy and plan will detail specific activities under each of the Horizon 2020 gender equality objectives, and associated measures. Links will be made with initiatives and commitments within each partner organisation to promote gender equality and advance women's careers in science, thus COPPER will benefit from existing efforts and expertise in this area and pull through lessons learnt to this project and to the wider ocean modelling community within Europe. For example, the Met Office is actively working to improve the gender balance across science teams in the organisation and has formed a team to identify the barriers to gender balance. The work of this team will result in an application for an Athena Swan award which includes an action plan for the Met Office.

A section of the Project Progress Reports, produced by the project manager, will be dedicated to reporting on the Gender Strategy and will contain information on the Specific Performance Indicators for Horizon 2020 needed by the European Commission for monitoring the gender equality in this programme.

Ethics

The Ethics criteria have been considered. However, the nature of the activities proposed under COPPER means that there are very few ethical issues and it is not anticipated that the criteria will need to be invoked. Consideration has been given to the external groups and organisations who will be involved in the project. Mainly organisational data will be collected. On occasions where any personal data is collected, procedures will be followed for the collection, storage, protection, retention and destruction of such data. Where commercially sensitive data is concerned, this will be identified and the relevant information will be withheld accordingly. All information will be gathered in accordance with guidelines laid down by the European Commission, and national legal requirements.

Knowledge Management

The partners have a collective responsibility to ensure that any knowledge collected, generated and disseminated by this Action, is appropriately protected and shared (intellectual property). However, the Scientific Coordinator is responsible for the action's knowledge management strategy and processes, ensuring they are kept up to date and that the associated protocols are adhered to. More detail on this is given in Section 2.2.

3.2.11 Critical risks for implementation

The General Assembly will be responsible for dealing with the risks, issues and benefits realisation of this project. The scientific coordinator will be responsible for management of these risks, including mitigation the risks, and proposing preventative and corrective solution in case of their occurrence. Day-to-day maintenance of the risk register will be undertaken by the project manager.

Critical risks to the project's implementation, which have the potential to impact the objectives being achieved, have been identified and described in Table 3.2.2 below. These risks will be actively managed and monitored throughout the period of the project, as will any new risks that arise. Where there are risks that exist specifically within individual WPs, these have been identified already and the design of the WPs has taken account of preventative measures for each.

Table 3.2.2: Critical Risks for Implementation

Description of risk (indicate level of likelihood: Low/Medium/High)	Work package(s) involved	Proposed risk-mitigation measures
Model developments are too computationally expensive for operational use (L)	3, 4, 6, 7	Careful review at code design stage. Draw on HPC expertise in WP8 if difficult areas arise.
Some developments do not initially increase the model/data assimilation skill (M)	3, 4, 5, 6, 7	Preparatory selection of developments has been informed by expert discussion in NEMO development strategy process. WP plans include a substantial evaluation phase which will allow tuning/modification.
Alternative coding approaches do not yield expected single-node performance improvements (L)	8	The use of the mini-app approach allows to obtain some preliminary performance results in time to refine the development strategy
Code developments from different WPs are difficult to integrate (M)	3-8	Most likely to involve WP6. WP6 delivers code to the NEMO reference code with some time left for other WPs to adjust. Task 2.2 maintains regular communication between WPs. Consortium members have strong experience and track record in

		integrating parallel developments through NEMO annual merge process.
The coastal interface system is not taken up by coastal modelling user community (L)	9	Proactive, early, constructive engagement with key groups to establish user requirements, including WP9 workshops and CMEMS user workshops. Responsive and open systems development.
Difficulty in recruiting/deploying appropriately skilled staff for some of the technical tasks, resulting in delays (L)	3-9	Established staff numbers with NEMO expertise in partner institutions mitigates this risk. Reduce reliance on single points of expertise by making sure that multiple team members are able to work on project

3.3 Consortium as a whole

The COPPER consortium includes academic institutions and operational service providers that together can make transformational changes to the NEMO ocean repository that are needed to satisfy the CMEMS user community. The COPPER consortium relies on the existing NEMO Consortium, and includes two additional institutions as described below.

The NEMO Consortium was formed in 2008 through a formal Agreement and their purpose was "to set up appropriate arrangements for the successful and sustainable development of the NEMO System as a well-organised, state-of-the-art ocean model code system suitable for both research and operational work." The Consortium now contains six European research and operational institutions all of whom are participating in COPPER (CMCC, CNRS, INGV, Mercator-Ocean, NERC and the Met Office). The evolution and maintenance of NEMO relies on a team of expert developers from within these organisations, the NEMO System Team. This team is responsible for the validation, documentation and distribution of the open source NEMO code repository (also called the "NEMO reference code"). Since 2008, this Team and the Consortium as a whole has proven its effectiveness, both for the development of NEMO itself and in gathering, enhancing and increasing the NEMO community involved in research and operational applications.

Complementarity of the partners and coverage of the value chain

The operational institutes involved in COPPER have strong links with the teams providing the CMEMS and with the intermediate users downstream of CMEMS. They also have experience and skills in the assessment of the suitability of developments for CMEMS, some skills in the development of new schemes, and strong links with ocean research institutes. Most of the research institutes in COPPER have a track record of working with these operational institutes, and have very strong links with the international research community. They have in depth expertise in many aspects of the science and technology of ocean modelling.

Expertise matched to objectives

The consortium as a whole has the expertise needed to deliver the five main objectives described in Section 1.1. The consortium members have a high level of scientific and technical expertise in each of the issues that will be tackled for the first objective (see details below). Several members of the NEMO System Team, including its leader will work on the project. This will ensure that the project's developments feed through into new versions of the NEMO reference code. The COPPER team also contains several internationally recognised ocean data assimilation experts, who are very well placed to perform the proposed work towards Objective 2. For Objective 3, the consortium includes the developers of the AGRIF multi-scale code and teams with experience in its application to NEMO, who are fully capable of completing the design and implementation of a sustainable, grid-coarsening solution. The team working on the flexible external interface (Objective 4), has considerable experience in coastal modelling, and skills in developing flexible python tools for NEMO inputs and outputs. The teams in the operational institutes are very experienced in assessing the readiness of development for operational implementation, and together with the NEMO system team members, are well placed to achieve Objective 5.

Roles and contributions of individual members

The ***Met Office*** is very experienced in leading EC proposals and the scientific coordinator has had a long-term involvement and high scientific reputation in NEMO, CMEMS and ocean data assimilation. He is also leader of the NEMO HPC working group. The WP3 leader leads the development of NEMO and its configurations within the Met Office and has an international reputation in ocean modelling including a strong interest in high resolution coupled models and introducing tides into global models. The team involved in WP5 includes leading experts in ocean data assimilation and the analysis of its impacts. The Met Office has a long-standing experience in operational oceanography and engagement with users (for example they were the initial leaders of the MyOcean Service desk).

The WP9 leader from ***NERC*** has considerable expertise in shelf-seas and tidal modelling and is joint leader of the UK's National Partnership for Ocean Prediction (NPOP). The team has individuals with expertise in developing flexible python tools for NEMO inputs and outputs and in numerical mixing in ocean models (WP3).

The WP8 leader from ***CMCC*** is an expert in the development of NEMO for modern HPCs, and the WP5 leader is a well respected member of the ocean data assimilation community. CMCC is the CMEMS MFC for the Mediterannean.

The WP4 leader from ***INGV*** leads the NEMO Waves working group and INGV has a long experience and expertise in operational oceanography and engagement with downstream users.

Mercator-Ocean has wide-ranging expertise in operational oceanography. The team members have specific expertise in the application of AGRIF to NEMO and the numerics of the time-stepping of the external (barotropic) mode.

The WP6 leader from CNRS has strong expertise in ocean model numerics, close links with the INRIA team members and led the writing of the NEMO Development Strategy. The WP7 leader original has been the leader of the NEMO System Team since 2008.

The INRIA team brings outstanding expertise in applied mathematics and ocean numerics to the COPPER consortium and includes the lead developers of the AGRIF code. Their contribution is vital to WP6.

The BSC team members have made valuable improvements to the performance of NEMO on modern HPCs and are key members of WP8. Martin Schreiber (University of Exeter) will be funded to attend WP8 meetings as he is an active and innovative member of the NEMO HPC group.

Collaborators and industrial partners

Key experts Drs.Brian Arbic (University of Michigan, WP3) and Martin Schreiber (University of Exeter, WP8) have agreed to act as collaborators with their respective work packages.

Early interest in involvement in the design and demonstration of the coastal interface tool (WP9) has been expressed by two potential SME users, HR Wallingford (www.hrwallingford.com) and Noveltis (www.noveltis.com).

Contact with several CMEMS MFCs has confirmed interest in the potential uptake by CMEMS of COPPER developments (e.g. see Letters of Support from Dr. Yann Drillet, Head of the CMEMS Global MFC and Dr. Enrique Alvarez Fanjul, Coordinator of the CMEMS Iberian-Biscay-Ireland regional MFC).

The GOV-COSS-TT chair has confirmed interest in the potential of COPPER developments to support the international development of capability for future coastal modelling (see Letter of Support in Appendix 1from Drs. Pierre de Mey and Villy Kourafolou).

The three agreed members of the External Expert Advisory Board (Drs. Glenn Nolan, Enrique Alvarez Fanjul and Pierre de Mey) bring a wealth of experience in operational oceanography in a global context.

3.4 Resources to be committed

The total requested European Commission contribution for COPPER is 1,953,046 €. The eight partners have offered 269 person months to the project.

3.4.1 Financial planning approach

The largest percentage of the funding for COPPER is required for personnel costs, as the project will rely on the skills and many years of expertise of the partner organisations and key personnel involved. Therefore it was key that the budget was calculated using an estimation of the costs associated with these experts that have been identified to deliver the project's objectives. As tasks and the scope and description of COPPER developed; the associated estimate of personnel resources developed. This iterative approach to calculating the required budget will ensure a good estimate of the resources required; and associated funding required.

A simple travel and meeting plan for the project was drafted, and as a result, the partners' travel budgets were calculated. It is assumed that many of the COPPER meetings, including General Assemblies, will utilise existing NEMO community meetings, thus keeping the budget incurred by COPPER to a minimum. It is worth remembering that two partners, BSC and INRIA, are not members of the NEMO consortium, therefore adequate provision has been made for them to be able to travel as required. However, all unnecessary travel will be avoided, and alternative forms of communication will be used if possible (i.e., teleconference/Skype); certainly in the case of internal meetings and discussions.

3.4.2 Distribution and breakdown of resources

3.4.2.1 Personnel costs

Personnel costs represent 92% of the direct cost budget. Table 3.4.1 shows the amount of staff effort broken down by beneficiary and by work package. The original estimate of effort across work packages 3 to 9 was very even. As the technical scope of these work package matured, the effort altered accordingly.

Management activities – 19 person months (PM) are allocated to project management and the coordination of COPPER, through work packages 1 and 2. These are mainly allocated to the Met Office, though 3PM are allocated to CNRS. CNRS will manage the code previews and coordinate the introduction of the code from COPPER into the NEMO 'shared framework'.

Resources required for dissemination activities - The dissemination, exploitation and communication activities detailed in Section 2.2, will be formally managed under WP2 by CNRS, with assistance from the Met Office, due to their strong links to the four primary impact areas for dissemination. All partners will undertake these dissemination and communication activities. The effort required for these activities is not explicitly itemised under WP2, but will be conducted through their activities across the project.

Table 3.4.1: Summary of staff effort

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	Total Person Months per Participant
1/Met Office	**7**	**9**	**12**		11		5	6		50
2/CMCC					**14**			**12**	12	38
3/CNRS		3				**17**	2			22
4/INGV				**36**	11					47
5/NERC			9	6					**21**	36
6/Mercator			8	4	3	3	**25**			43
7/BSC								12		12
8/INRIA						19	2			19
Total PMs	7	12	29	46	39	39	34	30	33	**269**

3.4.2.2 Other direct costs

Travel budget – 6% of the direct costs budget has been put aside for travel. This includes small allocations for the Advisory Board to attend the COPPER General Assemblies, for Dr Martin Schreiber (University of Exeter) to attend WP8 meetings, and to cover the travel for the users attending the WP9 workshop.

Others – The majority of channels for user engagement and methods of dissemination (as detailed in Section 2.2) will be through active links with existing communities and audiences. However, a specific workshop for the Coastal Modelling User Community will be arranged through WP9, and a small budget (5,000 €) has been set aside to cover the costs of NERC hosting this. One major event that COPPER will target is Oceanology International 2018, with the plan to host or co-host a stand. Also, the draft dissemination and exploitation plan details that results of the development and evaluation activities will be published in open access peer-reviewed literature, so 27,000 € has been put aside for associated publications and printing costs. One partner (Met Office) will require an **external audit** (for certification of financial statements).

Two of the partners have other direct costs budgets that are greater than 15% of their personnel costs. Table 3.4.2 provides the breakdown in detail of these other direct costs.

Table 3.4.2: Summary of other direct costs for participants Met Office and BSC

1/ Met Office	Cost (euros)	Justification
Travel	2,000	Travel/subsistence associated with management, coordination & high level engagement (WP2)
	11,000	Travel/subsistence to WP meetings and Gen Assemblies (WP1,2,3,5,7,8)
	5,900	Travel/subsistence to CMEMS training workshops / GOV-COSS-TT events (WP2)
	1,000	Travel/subsistence to Oceanology International 2018 (WP2)
	8,400	Travel/subsistence for Advisory Board (WP2)
	2,000	Travel/subsistence for WP8 Expert (WP8)
Equipment	0	None
Other goods/services	6,000	Logistical support for organising management & other 'project' meetings
	2,000	Technical support for setting up & managing e-mail lists and internal WIKI
	3,000	Hosting a stand at Oceanology International, 2018 (WP2)

	4,000	Publication/open access & printing charges
Total	45,300	

7/ BSC	Cost (euros)	Justification
Travel	8,400	Travel/subsistence to WP8 meetings and General Assemblies
Equipment	0	None
Other goods/services	1,500	Publication/open access & printing charges (WP6)
Total	9,900	

Large research infrastructure – None of the participants will be declaring costs of large research infrastructure under Article 6.2 of the General Model Grant Agreement.

Sub-contracts – The Met Office is planning to sub-contract one discrete element of the COPPER work. The Met Office will comply with applicable national law on public procurement procedures and the rules for sub-contracting as laid out in the Horizon 2020 General Model Grant Agreement (Article 13). This includes awarding the sub-contracts under conditions of transparency and equal treatment and ensuring best value for money. See Section 4.2 for further details of the planned sub-contract.

References

Arbic, B.K., Richman, J.G., Shriver, J.F., Timko, P.G., Metzger, E.J., Wallcraft, A.J., 2012. Global modeling of internal tides within an eddying ocean general circulation model. Oceanography-Oceanography Society 25, 20.

Ardhuin, F., N. Rascle and K. A. Belibassakis, 2008, Explicit wave-averaged primitive equations using a Generalized Lagrangian Mean, Ocean Modelling, 20, 235-264.

Bell MJ, Martin MJ, Nichols NK. 2004. Assimilation of data into an ocean model with systematic errors near the equator. Q. J. R. Meteorol. Soc. 130: 873–893.

Blayo E. and L. Debreu, 1999: Adaptive Mesh Refinement for Finite-Difference Ocean Models: First Experiments. J. Phys. Oceanogr., 29, 1239–1250.

Callies, J., Ferrari, R., 2013. Interpreting Energy and Tracer Spectra of Upper-Ocean Turbulence in the Submesoscale Range (1–200 km). Journal of Physical Oceanography 43, 2456–2474. doi:10.1175/JPO-D-13-063.1

Cavaleri L., B. Fox-Kemper, and Hemer, M.: Wind waves in the coupled climate system, Bull. Amer. Meteor. Soc., 93, 1651–1661, 2012.

Debreu L., C. Vouland and E. Blayo, 2008: AGRIF: Adaptive Grid Refinement In Fortran, Computers and Geosciences, vol. 34(1), 8-13.

Eade, R., D. Smith, A. Scaife, E. Wallace, N. Dunstone, L. Hermanson and N. Robinson, Do seasonal to decadal predictions underestimate the predictability of the real world?, GRL, DOI: 10.1002/2014GL061146, 2014.

H. von Storch, H. Langenberg, and F. Fezer: “A Spectral Nudging Technique for Dynamical Downscaling Purposes”, Monthly Weather Review, American Meteorological Society, 128 (2000): 3664-3673.

K. R. Thompson, D. G. Wright, Y. Lu, E. Demirov:. “A simple method for 735 reducing seasonal bias and drift in eddy resolving ocean models”, Ocean Modeling 736 13 (2006), 109–125.

Leclair, M., Madec, G., 2011. (z)over-tilde-Coordinate, an Arbitrary Lagrangian- Eulerian coordinate separating high and low frequency motions. Ocean Modelling 37,139-152.

Lemarié, F., L. Debreu, G. Madec, J. Demange, J.M. Molines, M.Honnorat (2015): Stability constraints for oceanic numerical models: implications for the formulation of time and space discretizations. Ocean Model., 92, pp124-148, doi:10.1016/j.ocemod.2015.06.006

Lévy, M., L. Resplandy, P. Klein, X. Capet, D. Iovino and C. Ethé, 2012: Grid degradation of submesoscale resolving ocean models: Benefits for offline passive tracer transport. Ocean Modelling, 48, 1-9.

Maraldi, C., Chanut, J., Levier, B., Ayoub, N., De Mey, P., Reffray, G., Lyard, F., Cailleau, S., Drévillon, M., Fanjul, E.A., Sotillo, M.G., Marsaleix, P., the Mercator Research and Development Team, 2013. NEMO on the shelf: assessment of the Iberia–Biscay–Ireland configuration. Ocean Sci. 9, 745–771. doi:10.5194/os-9-745-2013

Mario Adani, Srdjan Dobricic, and Nadia Pinardi, 2011: Quality assessment of a 1985–2007 mediterranean sea reanalysis. J. Atmos. Oceanic Technol., 28, 569–589.
doi: http://dx.doi.org/10.1175/2010JTECHO798.1

Mellor, G.L., 2011. Wave Radiation Stress. Ocean Dynamics, doi:10.1007/s10236-010-0359-2

Palmer, M., et al., 2015: Ocean heat content variability and change in an ensemble of ocean reanalyses. Climate Dynamics, 1–22, doi:10.1007/s00382-015-2801-0

M. W. Stacey, J. Shore, D. G. Wright, and K. R. Thompson: "Modeling events of sea-surface variability using spectral nudging in an eddy permitting model of the northeast Pacific Ocean", Journal of Geophysical Research, 111 (2006): C06037, doi:10.1029/2005JC003278.

Pimentel, S., Haines, K. and Nichols, N.K. (2008) The Assimilation of Satellite Derived Sea Surface Temperatures into a Diurnal Cycle Model. Journal of Geophysical Research, 113 (C9). C09013. ISSN 0148-0227 doi: 10.1029/2007JC004608

Pinardi, N., I. Allen , E. Demirov, P. De Mey, G. Korres, A. Lascaratos, P-Y. Le Traon, C. Maillard, G. Manzella, C. Tziavos "The Mediterranean ocean Forecasting System: first phase of implementation (1998-2001)", Annales Geophysicae, 21: 3-20 (2003), doi:10.5194/angeo-21-3-2003

Schreiber, M., C. Riesinger, T. Neckel, H.-J. Bungartz and A. Breuer, 2014: Invasive Compute Balancing for Applications with Shared and Hybrid Parallelization. International Journal of Parallel Programming, 43,1004-1027.

Shriver, J.F., Arbic, B.K., Richman, J.G., Ray, R.D., Metzger, E.J., Wallcraft, A.J., Timko, P.G., 2012. An evaluation of the barotropic and internal tides in a high-resolution global ocean circulation model. Journal of Geophysical Research: Oceans 117, n/a–n/a. doi:10.1029/2012JC008170

Storto, A., Masina, S. and Navarra, A. (2015), Evaluation of the CMCC eddy-permitting global ocean physical reanalysis system (C-GLORS, 1982–2012) and its assimilation components. Q.J.R. Meteorol. Soc.. doi: 10.1002/qj.2673

Waters, J., Lea, D. J., Martin, M. J., Mirouze, I., Weaver, A. T. and While, J. (2014), Implementing a variational data assimilation system in an operational 1/4 degree global ocean model. *Q. J. R. Meteorol. Soc.*. doi: 10.1002/qj.2388.

Appendix 1: Letters of support

Dear Dr Mike Bell,

This letter is to express my strongest support for the COPPER project submitted to the H2020 EO-3-2016 call on evolution of Copernicus services. This project will support the development of the NEMO ocean model, will allow to maintain this model state of the art and will offer new capabilities to NEMO users especially users involved in the Copernicus Services. I am currently in charge of the management of the global monitoring and forecasting center (GLO-MFC), one of the forecasting center in place in Copernicus Marine Environment and Monitoring Service (CMEMS). As several other forecasting centers in CMEMS, the GLO-MFC systems are based on the NEMO model and uses all the components available in NEMO (the physics, the biogeochemistry, the sea ice, interfaces with other models or data assimilation systems …). Currently, two global near real time systems based on NEMO are operated, a high resolution global component at 1/12° and an ocean atmosphere coupled system at lower resolution (1/4°) both systems produce daily global ocean forecasts. Global ocean reanalysis based on NEMO model are also disseminated through CMEMS portal, these ocean reanalysis assimilate available observations in a ¼° configuration and cover at least the altimetric period from 1993. A 3 to 6 years evolution plan has been written by the GLO-MFC partners and the main evolutions of the system concern the horizontal and vertical resolution, interaction between ocean atmosphere and waves, improvement of the marine biogeochemistry modelling and data assimilation, another strong objective concerns interaction between the global monitoring and forecasting system and regional or coastal systems inside or outside CMEMS. The problem of high performance computing of NEMO code is crucial especially for the near real time operational need, developers shall anticipate new technology on HPC sciences and technics.

The COPPER project will address all these topics and new developments will be available in the NEMO reference version at the end of the project which is perfectly in agreement with the 2020 objectives of the GLO-MFC. The links between the project and the CMEMS MFC are well identified and are ensured thanks to a coordination based on several existing mechanism or organization as the NEMO consortium and CMEMS.

Yann Drillet

Dr. Enrique Alvarez Fanjul, as leader of the physical oceanography department at Puertos del Estado and coordinator of the CMEMS IBI-MFC, certify, through this letter, his interest in the NCH20 proposal.

The main focus of the project, to make sustainable improvements to the NEMO base code and to demonstrate their readiness for implementation in CMEMS, is truly relevant important for Puertos del Estado and for IBI-MFC.

As Mentioned on the proposal, CMEMS relies heavily on NEMO. NEMO is a well established and well organized consortium but the code system needs continuous investment to retain its flagship status. Therefore I understand that the approval of this project is of paramount importance.

Best Regards

Enrique Alvarez Fanjul

Dear Dr Bell,

We would like to offer the fullest support of the GODAE OceanView Coastal Ocean and Shelf Seas Task Team (GOV-COSS-TT) for the COPPER proposal, and specifically for WP9 on "Seamless Interaction with Coastal Monitoring Systems". The Copernicus Marine products represent a vital resource for the coastal modelling community in terms of data to force and validate coastal models, and also to put them in a wider oceanographic context. The tools proposed in COPPER WP9 to access this data in order to drive and validate coastal models in a straightforward fashion that is traceable and robust is an important capability, with potentially substantial benefits for the coastal modelling community.

We will support this work by allowing the project team to introduce and discuss the proposed system at GOV-COSS-TT meetings. We will also welcome them to use this forum as a way of building connections between this project and the coastal modelling community, both to promote the uptake of the COPPER generic coupling system and to inform the development of this system and, as practical, the wider CMEMS services, based on the evolving needs of coastal modellers.

Yours faithfully,

Villy Kourafalou, Ph.D.

Pierre De Mey, Ph.D.

Co-Chairs GOV-COSS-TT

4. MEMBERS OF THE CONSORTIUM

4.1 Participants (applicants)

Participant 1: Met Office (Met Office)

The Met Office, founded in 1854, is the National Meteorological Service (NMS) for the United Kingdom. It employs around 1,800 staff including meteorologists, hydrologists, oceanographers, climate scientists, IT and support staff. A world renowned centre of excellence for research and operational services in meteorology, oceanography, forecasting and climate prediction, the Met Office supports a large number of customers globally, including governments, civil aviation, defence, commerce and industry. The Met Office is a Trading Fund within the UK Government's Department for Business, Innovation and Skills (BIS), and this status engenders a business approach in addition to the R&D activities, resulting in successful products and service delivery. There are over 500 people actively involved in strong research and development programmes in the areas of ocean and atmospheric modelling, observational research, data assimilation and reanalysis, ensemble forecasting and forecast verification on all timescales from days to centuries, as well as climate impacts and consultancy services. This global reputation in these areas requires an infrastructure that not only includes a high performance computing environment, but also the processes and the people and software to manage those processes.

Ocean modelling activities have taken place at the Met Office since the 1980s both for climate applications and later for ocean forecasting applications. Over 60 staff are directly involved in the ocean modelling effort supporting ocean and coupled prediction on timescales ranging from days to centuries. The Met Office was one of the founding members of the NEMO consortium which has now expanded to six members. The NEMO consortium provides significant ocean modelling infrastructure across Europe, notably beyond the countries represented by the consortium (France, UK and Italy). The Met Office was one of the leading partners in the EU MyOcean project and makes a significant contribution to the Copernicus Marine Environmental Management System (leading delivery of the North-West European Shelf Seas Monitoring and Forecasting Centre (NWS-MFC), providing the coupled model component of the Global MFC and the global component of Ocean and Sea Ice Thematic Assembly Centre (OSI TAC) and working towards provision of the global component of the in-situ TAC. The Met Office leads the UK National Partnership for Ocean Prediction and, as part of the Met Office-NERC Joint Weather and Climate Research Programme, co-leads Ocean Modelling programmes on both global and shelf seas modelling.

The Met Office will project manage the proposal. There is a team of experienced project managers, who hold formal project management qualifications. This team has much experience in managing projects involving multiple partners and users. The Met Office has co-ordinated projects such as the FP6 ENSEMBLES project, and is currently coordinating and managing ongoing FP7 and H2020 collaboration projects including ECOMS2 (Coordination and Support Action for Earth-system Modelling and Climate Services) and PRIMAVERA (Process-based climate sIMulation AdVances in high-resolution modelling and European climate Risk Assessment). The Met Office will call upon this wealth of experience when appointing a project manager for COPPER.

It will also contribute to the scientific coordination of COPPER – Dr. Mike Bell has significant previous experience in project and scientific coordination related to ocean forecasting (see relevant projects below). The Met Office also has established links with numerous established projects and has strong, influential international relationships, for example via GODAE OceanView, CLIVAR (Decadal Climate Variability and Predictability), World Climate Research Programme (WCRP).

The Ocean Modelling group will form the core team for the development of tides in the global model, as well as contributing to multi-resolution capability and NEMO on modern HPCs. This group makes the Met Office contribution to the NEMO system team and builds the global and North-west shelf configurations [to support the wider Met Office], so are well qualified to ensure the successful implementation of the proposed developments. Expertise in data assimilation diagnostics will be contributed by the Ocean Forecasting Research and Development group.

Short profile of key personnel involved:

Dr. Mike Bell (male), Fellow in Ocean Dynamics [COPPER Coordinator]: Mike developed the ocean data assimilation scheme originally used by the Forecasting Ocean Assimilation Model (FOAM) system and led the operational implementation of daily global ocean forecasts by FOAM in 1997. He was the leader of the Implementation and Production WP in MERSEA Integrated Project (for four years) and a member of the MyOcean Board (for six years). He also played a key role in initiating the NEMO consortium. He was joint chair of the Global Ocean Data Assimilation Experiment (GODAE) International Science Team for 5 years, Chair of the GODAE OceanView Patrons Group for four years and Head of the National Centre for Ocean Forecasting for 10 years. His scientific interests include conceptual models of meridional overturning circulations, the interactions between ocean dynamics and data assimilation and the detailed numerics of the representation of vorticity and bathymetry in the NEMO model.

Dr Helene Hewitt (female), Manager of Ocean Model Development and Evaluation team, and Met Office Science Fellow in High Resolution Ocean Modelling [Leader WP3]: Helene has 23 years of experience in ocean and sea ice model development and evaluation, including understanding projections of future changes. In her role at the Met Office she leads the Ocean modelling group which contributes towards the NEMO systems team and develops global and North-west shelf configurations for ocean forecasting, seasonal to decadal forecasting and climate projection. She is the co-chair of the UK Joint Ocean Modelling Programmes on both global and coastal modelling. She led the HadGEM3 project to build new model components (including NEMO) into the Met Office coupled model and has over 13 years of experience successfully managing teams and projects. She has over 30 peer-reviewed publications and is a member of the CLIVAR Ocean Model Development Panel. Helene is part of a Met Office team working to improve gender balance across science including application for an award under the Equality Challenge Unit's (ECU) Athena Swan Charter.

Dr Matt Martin (male), Manager of the Marine Data Assimilation Group and Met Office Science Fellow [WP5 Science Manager]: Matt has over 15 years of experience developing ocean data assimilation systems for operational ocean forecasting and reanalysis applications, as well as contributing to the development of the OSTIA SST and sea-ice analysis system. He leads the group which develops the data assimilation system, NEMOVAR, used to initialise the FOAM operational ocean forecasting system in various deep-ocean configurations and in shelf-seas. The data assimilation system is also used for reanalysis and operational forecasting in the GloSea seasonal forecasting system. He has over 8 years of experience successfully managing teams and projects, and currently leads a work package within the ERA-CLIM2 EU project as well as contributing to the AtlantOS project. He has over 55 peer-reviewed publications and co-chairs the GODAE OceanView (GOV) Data Assimilation Task Team as well as being the UK representative on the GOV Science Team, and is a member of the NEMOVAR Steering Group.

Dr Dan Lea (male) [WP5 Senior Scientist]: Dan has 18 years experience in ocean data assimilation. He worked at Oxford, John Hopkins and Reading Universities before joining the FOAM team in 2007. He has devised and implemented a novel altimeter bias correction scheme, pioneered a framework for near real-time observation system experiments and taken the lead role in the implementation of a weakly coupled atmosphere-ocean data assimilation. He has been lead author on 6 and co-author on 14 other peer-reviewed publications.

Dr Tim Graham (male), Senior Ocean Modelling Research Scientist [WP7/8 Scientist]: Tim is a member of the ocean model development group and has worked with the NEMO model since joining the Met Office in 2008. For the last two years he has been the NEMO officer for the Met Office and has an extensive knowledge of the NEMO code and working practices. In his role at the Met Office he has contributed to the development and assessment of global ocean model configurations for use in ocean forecasting, monthly to decadal forecasting and climate predictions.

Relevant publications, and/or products, services, achievements:

Hewitt, H. T., D. Copsey, I. D. Culverwell, C. M. Harris, R. S. R. Hill, A. B. Keen, A. J. McLaren and E. C. Hunke, Design and implementation of the infrastructure of HadGEM3: the next-generation Met Office climate modelling system, Geosci. Model Dev., 4, 223-253, doi:10.5194/gmd-4-223-2011, 2011.

Martin, M.J., M. Balmaseda, L. Bertino, P. Brasseur, G. Brassington, J. Cummings, Y. Fujii, D.J. Lea, J.-M. Lellouche, K. Mogensen, P.R. Oke, G.C. Smith, C.-E. Testut, G.A. Waagbo, J. Waters and A.T. Weaver, Status and future of data assimilation in operational oceanography, Journal of Operational Oceanography, 8:sup1, s28-s48, 2015.

Megann, A.P., D. Storkey, Y. Aksenov, S. Alderson, D. Calvert, **T. Graham**, P. Hyder, J. Siddorn and B. Sinha, GO 5.0: The joint NERC-Met Office NEMO global ocean model for use in coupled and forced applications. Geosci. Model Dev., 7 (3). 1069-1092. 10.5194/gmd-7-1069-2014, 2014.

O'Dea, E. J., A. K. Arnold, K. P. Edwards, R. Furner, P. Hyder, **M. J. Martin**, J. R. Siddorn, D. Storkey and J. While, J. T. Holt, H. Liu, An operational ocean forecast system incorporating NEMO and SST data assimilation for the tidally driven European North-West shelf. Journal of Operational Oceanography, 5(1), 3-17, 2012.

Williams, K.D., C. M. Harris, A. Bodas-Salcedo, J. Camp, R. E. Comer, D. Copsey, D. Fereday, **T. Graham**, R. Hill, T. Hinton, P. Hyder, S. Ineson, G. Masato, S. F. Milton, M. J. Roberts, D. P. Rowell, C. Sanchez, A. Shelly, B. Sinha, D. N. Walters, A. West, T. Woollings and P. K. Xavier, The Met Office Global Coupled model 2.0 (GC2) configuration**.** Geosci. Model Dev., 8, 1509-1524, doi:10.5194/gmd-8-1509-2015, 2015.

Relevant previous projects or activities:

CMEMS: The Met Office leads the North-West European Shelf-Seas monitoring and forecasting centre (MFC), contributes to the Global MFC and produces the global SST analysis product, OSTIA. The Met Office was previously involved in the EC FP7 MyOcean and MyOcean2 projects to develop a coordinated pre-operational European ocean monitoring and prediction system which was the prototype for the CMEMS.

NEMO consortium: Met Office is one of the members of the NEMO consortium with representatives on the steering committee and developer's committee as well as contributing at least 1 person equivalent of effort to the maintenance and development of NEMO via the systems team.

FOAM: The Forecasting Ocean Assimilation Model system has produced global daily operational ocean forecasts since 1997 and regional higher resolution forecasts since 1999. It is based on the NEMO ocean model and the NEMOVAR data assimilation system.

PRIMAVERA: An EU project coordinated by the Met Office to look at process-based assessment of high resolution modelling and European climate. As part of the project improved process-representation and focussed metrics for ocean models will be developed.

AtlantOS: An EU project aimed at designing an integrated ocean observing system for the Atlantic. The Met Office is involved in design studies and impact assessments.

Relevant significant infrastructure and/or any major items of technical equipment:

The Met Office has benefited from a recent £97 Million (approximate €130 Million) investment by the UK government in supercomputing, and operates a powerful High Performance Computing facility based on a CRAY XC40 supercomputer system. From March 2016 it will have approximately 6,000 user nodes, with a further ~6,000 nodes due to be added in March 2017, by which stage it will be able to perform more than 16,000 trillion calculations per second. The computing engine is supported by the Met Office's MASS-R storage system, which uses the IBM HPSS (High Performance Storage System: http://www.hpss-collaboration.org/) to provide hierarchical storage management of IBM disk and tape hardware, and services for very large storage requirements. It enables high data transfer rates to move large files between storage devices and computers, and an environment that can scale to multiple petabytes (10^{15} bytes). Access to these facilities will allow the Met Office to test model developments and carry out test case simulations for COPPER.

No third parties involved.

Participant 2: Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (Fondazione CMCC)

The Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (Fondazione CMCC) is a non-profit research institution (www.cmcc.it). CMCC's mission is to investigate and model our climate system and its interactions with society to provide reliable, rigorous, and timely scientific results, which will in turn stimulate sustainable growth, protect the environment, and develop science driven adaptation and mitigation policies in a changing climate. CMCC collaborates with experienced scientists, economists, and technicians, who work together in order to provide full analyses of climate impacts on various systems such as agriculture, ecosystems, coasts, water resources, health, and economics. CMCC also supports policymakers in setting and assessing costs, mitigation, and adaptation policies.

CMCC benefits from the extensive applied research experience of its members: Istituto Nazionale di Geofisica e Vulcanologia (INGV); Università del Salento; Centro Italiano di Ricerche Aerospaziali (CIRA S.c.p.a.); Università Ca' Foscari Venezia; Fondazione Eni Enrico Mattei (FEEM), Università di Sassari, Università della Tuscia, Università degli Studi del Sannio. CMCC research activities are distributed among eight research divisions that share different knowledge and skills in the field of climate science: Advanced Scientific Computing (ASC) Division; Climate Simulation and Prediction (CSP) Division; Economic analysis of Climate Impacts and Policy (ECIP) Division; Impacts on Agriculture, Forests and Ecosystem Services (IAFES) Division; Ocean modeling and Data Assimilation (ODA) Division; Ocean Predictions and Applications (OPA) Division; Risk Assessment and Adaptation Strategies (RAAS) Division; Regional Models and geo-Hydrological Impacts (REHMI) Division.

CMCC acquired portfolio of research projects includes 172 funded projects: 2 funded projects in FP6, 35 funded projects in FP7, 16 funded projects in H2020 and 119 funded projects under other EU and international research grants. In about a half of the implemented projects, CMCC acted as the coordinator.

For further information on CMCC please see Annual Report and CMCC Strategic Plan (www.cmcc.it/publications-type/annual-report).

The team involved in COPPER from CMCC has an excellent understanding of the tasks therein proposed and established capacity in using, developing and improving the NEMO ocean model from a scientific, numerical and computational point of view. In particular, the ASC (Advanced Scientific Computing) Division (Prof. G.Aloisio, Dr.S.Fiore, Dr.S.Mocavero) has a long-term experience on scalability improvement, optimisation and parallelisation of numerical models and documented contributions both about the HPC related developments for the NEMO model and international exascale roadmaps for next generation climate models, providing valuable expertise for the Work Package 8 objectives on HPC optimisation. The Ocean Modeling and Data Assimilation (ODA) Division (Dr.S.Masina and Dr.A.Storto) focuses its activity on ocean reanalyses and operational oceanography. The people involved in the proposal have in-depth knowledge of data assimilation methods and ocean observation methodologies that will help achieve the goals of Work Package 5 (Data assimilation diagnostics). The Ocean Predictions and Applications (OPA) Division (Dr. G. Coppini and Dr. S. A. Ciliberti) has long-term experience and involvement in the development of ocean numerical models, operational systems at regional and coastal scales,(in particular with the NEMO model), and consolidated experience in the framework of CMEMS Med-MFC, providing valuable expertise to reach the objectives of Work Package 9 on External Interface. Three team members from CMCC are also part of the NEMO System Team.

Short profile of key personnel involved:

Dr. Simona Masina (female), Head of Ocean Modeling and Data Assimilation Division: Simona holds a PhD in Atmospheric and Oceanic Sciences from Princeton University. She is also a Senior Researcher at Istituto Nazionale di Geofisica e Vulcanologia (INGV). She has more than fifteen years of experience in the field of global ocean modelling, data assimilation and interactions between physical and biogeochemical processes in the climate system. During this time she has been involved in several national and international projects and has been principal investigator for many European projects. In particular, she has been involved as CMCC PI in MyOcean and during MyOcean2 and MyOcean-FO she was the coordinator of the WP on the Multi-Year Assessment. Since 2007 she has taught the PhD Programme on Science and Management of Climate Change at Ca' Foscari University in Venice and is a Member of the Faculty Board. She is vice-President of the "Italian Society for Climate Sciences"

(SISC), and INGV representative at the "Commissione Oceanografica Italiana" (Italian IOC). She is also a member of the CLIVAR Ocean Model Development Panel (OMDP) and has been coordinator of the PRACE Project Ens4Ocean. Since November 2014 she has been a Member of the Management Committee of the ESSEM COST Action Evaluation of Ocean Syntheses.

Dr. Andrea Storto (male), Environmental Engineer [Leader WP5]: Andrea obtained his PhD in 2009 at the University of Rome "La Sapienza" in close collaboration with the Norwegian Meteorological Institute (met.no), studying the optimal assimilation of satellite radiances for regional medium-range NWP models by using variational assimilation schemes. He gained a research fellowship from EUMETSAT and further to Met.No he has been also worked with Meteo-France and JAMSTEC. In 2009, he joined the Ocean Modeling and Data Applications Division of CMCC to develop a Global Ocean variational analysis system at eddy-permitting resolution for use in the context of ocean reanalyses, in particular within the EU-funded MyOcean project and its follow-up MyOcean2, and high-resolution operational oceanography. His expertise includes variational data assimilation, satellite altimetry, techniques for improving the representation of model errors in data assimilation and evaluation of ocean reanalysis.

Dr. Giovanni Coppini (male), Director of the Ocean Predictions and Applications Division [WP9 Scientist]: Since May 2015, he is the CMEMS Mediterranean-MFC (Med-MFC) Leader. He holds a PhD in Environmental Sciences from Alma Mater Studiorum University of Bologna. From 2003 to 2012 he worked at INGV in the operational oceanography division where he was responsible for environmental applications. He has 12 papers in peer reviewed Journals on operational oceanographic system development and applications. He co-chairs MONGOOS (Mediterranean Oceanography Network for the Global Ocean Observing System) and he is the Emergency Response Office Manager for the MONGOOS-REMPEC agreement. He is a member of the JCOMM Expert Team on Maritime Safety and Security (ETMSS-4). He has represented INGV and now CMCC in the European Topic Centre - Inland, Coastal and Marine waters (ETC-ICM) project of the European Environment Agency. In the MyOcean project he is responsible for liaison with the European Environment Agency (EEA) for the development of climate and environmental indicators and for the contribution of MyOcean to EEA reports.

Dr. Stefania Angela Ciliberti (female), Research Leader of the Numerical Modeling Group at the Ocean Predictions and Applications Division [CMCC lead for WP9]: Stefania holds a PhD in Hydraulic Environmental Engineering in 2012 from the University of Calabria (Italy) and a MSc Degree in Environmental Engineering in 2007 from the same University. From 2007 to 2012, she had research grants in the framework of advanced numerical modeling of flood events over complex topographies using high performance computing techniques suitable for unstructured grid models and for the study of turbulence in the wall region of a turbulent channel flow using multicore and hybrid CPU/GPU architectures. Since 2012, she has been a researcher at CMCC, focusing her activity on regional and sub-regional ocean modeling. In particular, she is leading research activities for the development of the new Adriatic-Ionian regional model and the design and numerical implementation of the operational Adriatic-Ionian Forecasting System (http://oceanlab.cmcc.it/aifs/). Since May 2015, she has been a member of the CMCC working group for the Mediterranean Monitoring and Forecasting Centre (Med-MFC) in the framework of CMEMS. Since 2014 she has been a member of the NEMO Consortium System Team and a member of the Configuration Manager Working Group.

Prof. Giovanni Aloisio (male), Director of CMCC Supercomputing Centre [WP8 Scientist]: Giovanni is a member of the CMCC Strategic Council. He is a full professor of Information Processing Systems at the Department of Innovation Engineering of the University of Salento, Lecce, Italy, where he leads the HPC laboratory. He is the former director of the "Advanced Scientific Computing" (ASC) Division at the CMCC Foundation. He is also a member of the ENES (European Network for Earth System modelling) HPC Task Force. His areas of expertise include high performance computing, grid & cloud computing and distributed data management. He has responsibility for ENES of the EU-FP7 EESI-EESI2 (European Exascale Software Initiative) projects chairing the Working Group on Weather, Climate and solid Earth Sciences. He has also contributed to the

IESP (International Exascale Software Project) exascale roadmap. He has been the chair of the European panel of experts on WCES that has contributed to the PRACE strategic document "The Scientific Case for HPC in Europe 2015-2020". Presently, he is coordinating CMCC activities into several EU FP7 projects such as IS-ENES2 and CLIP-C as well as in the EU H2020 BIGSEA, ESiWACE and INDIGO-DataCloud. As University of Salento (PRACE Third Party), he is responsible for the EU H2020 EXDCI project, chairing the Working Group on Weather, Climate and solid Earth Sciences. He is the author of more than 100 papers in referred journals on high performance computing, grid computing and distributed data management.

Dr. Sandro Fiore (male), Director of the Advanced Scientific Computing (ASC) Division [WP8 Scientist]: Sandro received his PhD degree in Computer Science at the University of Lecce in 2004. His research activities focus on scientific data management and high performance computing. He has also contributed to the IESP (International Exascale Software Project) and EESI2 (European Exascale Software Initiative) roadmaps. He is Visiting Scientist at Lawrence Livermore National Laboratory (LLNL) working in the context of ESGF. He is involved in the EU FP7 IS-ENES2 and CLIP-C projects as well as on the EU H2020 BIGSEA, ESiWACE, INDIGO-DataCloud and PRIMAVERA. He is author and co-author of more than 60 papers in refereed books/journals/proceedings on parallel and distributed computing and holds a patent on data management topics. He is editor of the book "Grid and Cloud Database Management" (Springer, 2011). Sandro is a member of the Association for Computing Machinery (ACM).

Dr. Silvia Mocavero (female), Lead of High-End Computing Research Group in the Advanced Scientific Computing (ASC) Division [Leader WP8]: Silvia is a research scientist. She holds a PhD in Innovative Materials and Technologies in 2006 from ISUFI at the University of Lecce (Italy). In 2010 she was visiting researcher at the Barcelona Supercomputing Centre (BSC) within the HPC-Europa2 initiative for the optimization of the Biogeochemical Flux Model, coupled with NEMO. In 2013 she was visiting scientist at the Argonne National Laboratory (ANL) of Chicago for the porting, scalability analysis and improvement of the NEMO oceanic model on BG/Q architecture. Her areas of expertise include high performance computing, grid & cloud computing. Her skills include parallel programming on HPC systems and distributed environments, with extensive experience on several programming models such as message passing, shared memory and many-threads programming with accelerators. Since 2011 she has been exploring new issues related to the exascale computing. She works on the analysis and optimization of climate models with a particular focus on NEMO as member of the System Team and the HPC group of the NEMO Consortium. She is currently involved in EU FP7 IS-ENES2 (as project chief scientist for CMCC) and EU H2020 ESiWACE projects.

Relevant publications, and/or products, services, achievements:

Storto, A., **S. Masina**, A. Navarra (2015). Evaluation of the CMCC eddy-permitting global ocean physical reanalysis system (C-GLORS, 1982-2012) and its assimilation components. Q.J.R. Meteorol. Soc. DOI: 10.1002/qj.2673.

Masina, S., **Storto A**., Ferry N., Valdivieso M., Haines K., Balmaseda M.A., Zuo H., Drevillon M., Parent L. (2015). An ensemble of eddy-permitting global ocean reanalyses from the MyOcean project. Clim. Dyn., DOI: 10.1007/s00382-015-2728-5.

Pinardi N., Zavatarelli M., Adani M., **Coppini G**., Fratianni G., Oddo P., Tonani M., Lyubartsev V., Dobricic S., Bonaduce A. (2013). Mediterranean Sea large scale low frequency ocean variability and water mass formation rates from 1987 to 2007: a retrospective analysis. Prog. Oceanogr., doi: http://dx.doi.org/10.1016/j.pocean.2013.11.003

Epicoco I., **Mocavero S.**, **Aloisio G.** (2012). The performance model for a parallel SOR algorithm using the red-black scheme. International Journal of High Performance Systems architecture, vol. 4, p. 101-109, ISSN: 1751-6528.

Dongarra J., P. Beckman, T. Moore, P. Aerts, **G. Aloisio**, J. C. Andre, D. Barkai, J. Y. Berthou, T. Boku, B. Braunschweig, F. Cappello, B. M. Chapman, X. Chi, A. N. Choudhary, S. S. Dosanjh, T. H. Dunning, S. **Fiore, A.** Geist, B. Gropp, R. J. Harrison, M. Hereld, M. A. Heroux, A. Hoisie, K. Hotta, Z. Jin, Y. Ishikawa, F. Johnson, S. Kale, R. Kenway, D. E. Keyes, B. Kramer, J. Labarta, A. Lichnewsky, T. Lippert, B. Lucas, B. Maccabe, S. Matsuoka, P. Messina, P. Michielse, B. Mohr, M. S. Mueller, W. E. Nagel, H. Nakashima, M. E. Papka, D. A. Reed, M. Sato, E. Seidel, J. Shalf, D. Skinner, M. Snir, T. L. Sterling, R. Stevens, F. Streitz, B. Sugar, S. Sumimoto, W. Tang, J. Taylor, R. Thakur, A. E. Trefethen, M. Valero, A. van der Steen, J. S. Vetter, P. Williams, R. Wisniewski, K. A. Yelick: "The International Exascale Software Project roadmap". International Journal of High Performance Computing Applications (IJHPCA) 25(1): 3-60 (2011), ISSN 1094-3420, doi: 10.1177/1094342010391989.

Relevant previous projects or activities:

ERA-CLIM2 - European Reanalysis of the Global Climate System, Framework Programme 7 (EC-FP7), Project Number: 607029, 01/2014 – 12/2016. Fondazione CMCC is involved in the Work Package 2 on the "Future coupling methods". This work package aims at establishing practices and assessing benefits of new coupled data assimilation methods. CMCC in particular investigates the use of hybrid and coupled background-error covariances for data assimilation.

PRIMAVERA - PRocess-based climate sIMulation: AdVances in high-resolution modelling and European climate Risk Assessment, Horizon 2020 (EC-H2020), Project Number: 641727, 11/2015 – 10/2019. Fondazione CMCC is involved in developing and improving the sea-ice and land components coupled to NEMO in the CMCC physical climate system, and in assessing the impact of increased resolution in global coupled climate model for processes affecting European climate and its variability. CMCC also contributes to development and application of metrics for process-based evaluation and projections.

Copernicus Med-MFC Copernicus Marine Environment Monitoring Service - Mediterranean Monitoring and Forecasting Centre, Mercator Ocean, 05/2015 – 04/2018. Fondazione CMCC, since May 2015, leads the consortium (composed of Italian National Institute of Geophysics and Vulcanology - INGV; Hellenic Centre for Marine Research - HCMR and Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS) responsible for the Mediterranean Monitoring Forecasting Centre (Med-MFC) of the Copernicus Marine Environment Monitoring Service (CMEMS). CMCC, among other tasks, is responsible for the overall service management and for the Local Service Desk.

IS-ENES2 - Infrastructure for the European Network for Earth System modelling - Phase 2 (EC-FP7), Project Number: 312979, 04/2013 – 03/2017. IS-ESES2 is the second phase project of the distributed e-infrastructure of models, model data and metadata of the European Network for Earth System Modelling. IS-ENES2 combines expertise in climate modelling, computational science, data management and climate impacts. Fondazione CMCC leads the WP3/NA2 "Towards next generation models", which aims at creating connections within the climate modelling community and promulgating best practice model developments to run these codes on HPCs looking at the Exascale.

ESiWACE - Excellence in SImulation of Weather and Climate in Europe (EC-H2020), Project Number: 675191, 09/2016 – 08/2019. ESiWACE aims at improving efficiency and productivity of numerical weather and climate simulation on high-performance computing platforms by supporting the end-to-end workflow of global Earth system modelling in HPC environment. Fondazione CMCC is involved in the WP2 "Scalability" working on NEMO scalability issues, such as compute/communication performance improvements.

Relevant significant infrastructure and/or any major items of technical equipment:

CMCC operates its own Supercomputing Center (located in the "Ecotekne" Campus in Lecce) whose HPC facilities have been ranked among the most powerful supercomputing systems in the world and among the most powerful computational facilities in Italy.

The CMCC HPC facility, Athena, is an IBM iDataplex supercomputer based on Intel E5-2670 multicore architecture and InfiniBand FDR interconnection, with two DDN SFA10000 storage subsystems capable to offer a storage capacity of about 840TB in total and an I/O performance of 6GBytes/sec per disk array (about 8000 Intel Xeon Sandy Bridge cores , 160 TFlops peak performance).

No third parties involved.

Participant 3: Centre National de la Recherche Scientifique (CNRS)

Founded in 1939, the Centre National de la Recherche Scientifique (National Center for Scientific Research) is a public organization under the responsibility of the French Ministry of Education and Research. With about 33 000 staff (11,116 tenured researchers and 13,631 engineers and technicians) and a budget of 3.29 billion euros (in 2014), 22% of which comes from its own resources, CNRS is the largest fundamental research organization in Europe. With its 1,100 units across France, CNRS carries out research in all fields of knowledge through its10 institutes, covering the fields of mathematics, physics, information technologies, high energy and nuclear physics, geosciences and astrophysics, chemistry, biology, humanities, engineering sciences. CNRS has been very active in previous European framework programmes (FP7 projects, ERC Grants) and is currently involved in a large number of funded H2020 projects. For more information please visit: http://www.cnrs.fr. CNRS has developed the first versions of NEMO dynamical core (OPA). Since the creation of the NEMO consortium, CNRS has been involved in the development and in the coordination of the NEMO consortium. In the COPPER project, the CNRS team will provide members of the NEMO System Team from LOCEAN (Paris) and LGGE (Grenoble) including NEMO Scientific Leader (Gurvan Madec), NEMO Project Manager (Claire Levy) and the NEMO Scientific Coordinator for France (Julien Le Sommer).

Short profile of key personnel involved:

Gurvan Madec (male), Research Scientist [WP6 Scientist]: Gurvan has been a CNRS research scientist in physical oceanography and ocean modeling since 1990. Gurvan Madec is a NEMO expert and a member of the NEMO System Team. He is the main developer of NEMO and the scientific leader of the NEMO consortium. He is a funded member of DRAKKAR group (International Research Network whose focus is to coordinate global high resolution simulations based on the NEMO modelling platform) and a former member of CLIVAR (Decadal Climate Variability and Predictability) Ocean Model Development Panel. He has contributed to more than 200 research papers covering a range of topics in the field of ocean modeling and numerical methods, small scale ocean processes, ocean biogeochemistry, air-sea interaction, high latitude processes and climate studies.

Claire Levy (female), Research Engineer [contribute to WP2, Co-leader WP7]: Claire has been a CNRS research engineer in ocean modeling since 1984. She is a NEMO expert and a member of NEMO System Team. Since 2008, she has been the Project Manager for NEMO. She is in charge of setting-up appropriate arrangements for the successful and sustainable development of the NEMO System, thus ensuring it is a well organised, state-of-the-art ocean model code system suitable for both research and operational applications. She is specifically in charge of organising the annual NEMO Steering Committee meetings and NEMO Developers Committee meetings.

Julien Le Sommer (male), Research Scientist [contribute to WP2, Leader WP6]: Julien has been a CNRS research scientist in physical oceanography and ocean modeling since 2006. He is a member of the DRAKKAR group; a member of CLIVAR Ocean Model Development Panel and a PI in the SWOT (Surface Water and Ocean Topography) Science Defintion Team (SWOT is composed of a group of international and interdisciplinary scientists dedicated to the study of Earth's ocean and surface waters,). Since 2013, he has been in charge of the coordination of scientific activities contributing to NEMO development at CNRS and Mercator-Ocean. He is an expert in ocean fine scale processes and their interaction with ocean large scale circulation. He has contributed to 33 publications and led 10 national and international projects.

Simona Flavoni (female), Engineer in Ocean Modelling [contribute to WP2 and WP6]: Simona is a NEMO expert and a member of NEMO System Team. She is the leader of NEMO working group on 'robustness and test-cases'. Over the last two years, this group has defined how idealized test-cases should be used in the NEMO development process.

Nicolas Martin (male), Engineer in Programming and Information Technology [contribute to WP 2]: Nicolas is a member of the NEMO system Team. He is in charge of the web infrastructure for NEMO and for external and internal communications.

Relevant publications, and/or products, services, achievements:

Madec, G., NEMO ocean engine, version 3.6, Institut Pierre-Simon Laplace (IPSL). ed, Note du Pôle de modélisation. ISSN No 1288-1619.

Lemarié, F., Debreu, L., **Madec, G**., Demange, J., Molines, J.M., Honnorat, M., 2015. Stability constraints for oceanic numerical models: implications for the formulation of time and space discretizations. Ocean Modelling 92, 124–148. doi:10.1016/j.ocemod.2015.06.006

Leclair, M., **Madec, G**., 2011. Z-Coordinate, an Arbitrary Lagrangian–Eulerian coordinate separating high and low frequency motions. Ocean Modelling 37, 139–152. doi:10.1016/j.ocemod.2011.02.001

Leclair, M., **Madec, G**., 2009. A conservative leapfrog time stepping method. Ocean Modelling 30, 88–94. doi:10.1016/j.ocemod.2009.06.006

Le Sommer, J., Penduff, T., Theetten, S., Madec, G., Barnier, B., 2009. How momentum advection schemes influence current-topography interactions at eddy permitting resolution. Ocean Modelling 29, 1–14. doi:10.1016/j.ocemod.2008.11.007

Relevant previous projects or activities:

FP7-SPACE-2011-1 MYOCEAN2: Prototype Operational Continuity for the GMES Ocean Monitoring and Forecasting Service. The main objective of the MyOcean2 project will be to operate a rigorous, robust and sustainable Ocean Monitoring and Forecasting component of the GMES Marine Service (OMF/GMS) delivering ocean physical state and ecosystem information. CNRS (J. Le Sommer) was heavily involved in R&D activities in WP 19.2 - NEMO developments and applications.

FP7-ENVIRONMENT EMBRACE: Earth system model bias reduction and assessing abrupt climate change. EMBRACE is a collaboration between nineteen institutes, organizations and universities from different parts of Europe. This project has brought together the leading Earth system models (ESMs) in Europe around a common set of objectives to improve their ability to simulate the Earth system and make reliable projections of future global change. CNRS (G. Madec) was involved in particular in WP2 - Ocean and cryosphere processes.

ANR (French National Research Agency) COMODO (2011-2015): French numerical Ocean Modeling Community (PI Laurent Debreu, INRIA). Other institutes involved: IRD, **CNRS**, SHOM, IFREMER (Total grant: 1,3 million euros). The aim of this project was to conduct research in numerical methods for ocean modeling and also to produce a benchmark suite of idealised test cases.

ANR (French National Research Agency) PULSATION (2012-2015): Peta scale mULti-gridS ocean-ATmosphere coupled simulatIONs (PI Sebastien Masson, CNRS). Other institutes involved: Mercator-Ocean, BULL SAS (Total grant: 582,666 euros). The aim of this project was to perform multi-scale coupled ocean-atmosphere simulations on petascale computer in order to quantify upscaling processes from small to large scale.

LEFE-GMMC (Groupe Mission Mercator Coriolis) TANGGO (2011-2014): Toward AN Eddying Global Green Ocean (PI: J. Le Sommer, M. Lévy, L. Bopp). The objective of this project was foster collaborative research in order to guide the evolution of global coupled ocean-biogeochemistry models within NEMO framework for both research and operational applications.

Relevant significant infrastructure and/or any major items of technical equipment:
Not applicable.

No third parties involved.

Participant 4: Istituto Nazionale di Geofisica e Vulcanologia (INGV)
INGV is an independent organisation working under the supervision of the Italian Ministry of Education, University and Research. (www.ingv.it). The operational oceanography group in Bologna is responsible for the Mediterranean nowcasting/forecasting activities, both at the national (RITMARE Project) and European (Copernicus Marine Environment Monitoring Service) level. The operational oceanography group develops the numerical modelling at the basin and coastal scales, the data assimilation algorithms and the service for users such as coast guards, the national environmental protection agency, the Italian meteorological office, the Italian navy and the CMEMS service. Other important research activities are dedicated to the development of optimal estimation techniques for production of analyses for short term forecasting, the study and production of model error statistics and quality indices, the real time and delayed mode quality control procedures for in situ data, the production of regional high resolution climatologies. INGV was the responsible of the Mediterranean Monitoring and Forecasting Centre in MyOcean, MyOcean2 and MyOcean Follow On and is responsible of the Med-MFC physical component production in CMEMS. It coordinated, in SeaDataNet and SeaDataNet2 projects, the data quality assessment activities and the production of data products (regional aggregated datasets and climatologies) from historical data. INGV is now coordinator of the EMODnet MedSea Checkpoint project. It has representatives in JCOMM-WMO-IOC, EuroGOOS and MONGOOS.

INGV is one of the 6 partners of the NEMO consortium and since 2013 has led the NEMO-WAVE working group , actively contributing to the definition of the main scientific issues and model developments related to wave-current interaction processes to be included in NEMO. Moreover the INGV operational oceanography group in Bologna has decadal experience in providing Mediterranean nowcasting/forecasting services both at the national and European (CMEMS Med-MFC) levels, the physical component of which is supplied by the NEMO model.

INGV deals with the development of NEMO model focusing on marine operational forecasting with a particular emphasis on the physical and wave ocean models and the development of data assimilation methods for the production of Mediterranean Sea reanalysis. INGV has experience on the assessment of the ARGO sampling characteristics within the overall real time multi-platform (satellite and in situ) monitoring system of the Mediterranean Sea throughout Observing System Experiment (OSE) and Observing System Simulation Experiments (OSSE). INGV will both provide expertise into, and benefit from the technical and scientific improvements of NEMO model foreseen by this project and of additional efforts and further collaborations between partners.

Short profile of key personnel involved:
Dr Nadia Pinardi (female), Associate researcher and Director of the Operational Oceanography Group [Contribute to WP 4]: Nadia holds a PhD in Applied Physics from Harvard University, and is an associate tenure Professor of Oceanography at Bologna University, Italy. Her interests range from ocean numerical modelling and forecasting to data assimilation for the physical components of the marine environment, development of the marine biogeochemical models and oil spill numerical modelling coupled to operational oceanographic forecasts. She has written more than one hundred papers in peer reviewed journals on a wide range of oceanographic modelling and oceanographic data analysis subjects. Her latest research topics include; the understanding of uncertainties in ocean forecasting; large scale, long term variability of the Mediterranean Sea; sea level trends and the energetics of semi-enclosed seas. She has coordinated, since the middle of the nineties, the development and implementation of operational oceanography in the Mediterranean Sea. She is associate researcher at INGV and has directed the Operational Oceanography Group since 2004. She is now co-president of the Joint Committee for Oceanography and Marine Meteorology (JCOMM), a WMO and Unesco-IOC coordinating group for the development of operational meteo-marine and oceanographic services. In 2007 she was awarded the European Geophysical Union (EGU) Fridtjof Nansen Medal for Oceanography and in June 2008 the Roger Revelle Unesco Medal. She is the coordinator of the EU DG MARE Project "Growth and Innovation in Ocean Economy-Gaps and Priorities in Sea Basin Observation and data. Lot2: The Mediterranean Sea".

Dr Emanuela Clementi (female), Researcher [Leader WP4]: Emanuela holds a degree in Environmental Engineering and a PhD in Hydraulic and Maritime Engineering, with a main focus on wave interactions with coastal structures through experimental analysis and numerical modelling. She has experience on numerical modelling of the marine ecosystem dynamics and production of marine environmental forecasting in the Adriatic Sea through a coupled physical/biogeochemical modelling system. During last year, she focused her research activity on ocean and wave numerical modelling in the Mediterranean Sea, on the study of wave-current interaction processes and their numerical development and implementation. She is the INGV Officer for the NEMO consortium and responsible for the NEMO-WAVE working group. She participated in several European and National projects such as: DELOS, ENCORA (responsible for the management of the Italian Network), MEECE, VECTOR, EMODnet MedSea Checkpoint (scientific manager), MyOcean2, MyOcean FO, CMEMS Med-MFC (Product Quality responsible of the consortium, responsible for model development of the physical component).

Dr Gelsomina Mattia (female), Numerical Modeller [WP4/5 Scientist]: Gelsomina holds a PhD in Marine Sciences and Engineering. She focused her study on physical oceanography with a particular interest on coastal circulation, transport and diffusion of passive tracers through the Lagrangian approach. She participated in oceanographic cruises dealing with acquisition and processing of insitu data. In recent years she has participated in two European projects: SESAME and PERSEUS. The main tasks of her work were the implementation, upgrade and testing of a physical-ecological coupled modelling system: NEMO (Nucleus for European Modelling of the Ocean)/ BFM (Biogeochemical flux model). Her main scientific activity is in the field of numerical modelling of the ocean general circulation and ecosystem dynamics, with particular interest in the Mediterranean and North Adriatic Sea. Now, she is working at INGV on the development of the coupled wave-ocean modelling system in the Mediterranean Sea and on data assimilation for numerical oceanographic analysis.

Dr Jenny Pistoia (female), Technologist [WP4/5 Scientist]: Jenny holds a PhD in Geophysics with a main focus on uncertainty estimation, SuperEnsemble techniques and ocean high resolution modelling. She is now focused on data assimilation. During the last year she developed an improved Background error covariance matrix, by defining a new set of more realistic EOFs. Improvements concern also the observation error covariance matrix. She also participated in oceanographic cruises dealing with the acquisition and processing of in-situ data. She participates in the Data Assimilation NEMO working group and has also participated in several European projects such as GEMINA, MyOcean, MyOcean2, MyOcean FO, E-AIMS and CMEMS Med-MFC.

Relevant publications, and/or products, services, achievements:

Clementi E., Oddo P., Korres G., Drudi M. and **Pinardi N.**, 2013. Coupled wave-ocean modelling system in the Mediterranean Sea. Extended abstract, 13th International Workshop on Wave Hindcasting and Forecasting, 2013, Banff (Canada), 8pp.

De Dominicis M., Bruciaferri D., Gerin R., **Pinardi N.**, Poulain P.M., Zodiatis G., Perivoliotis L., Fazioli L., Sorgente R., 2016. Accepted at Deep Sea Research Part II.

Dobricic S., Wikle C.K., Milliff R.F., **Pinardi N.**, Berliner, L.M., 2015. Assimilation of oceanographic observations with estimates of vertical background-error covariances by a Bayesian hierarchical model Quarterly Journal of the Royal Meteorological Society, 141, 182-194, doi: http://dx.doi.org/10.1002/qj.2348.

Oddo P., Bonaduce A., **Pinardi N.**, Guarnieri A., 2014. Sensitivity of the Mediterranean sea level to atmospheric pressure and free surface elevation numerical formulation in NEMO. Geosci. Model Dev., 7, 3001–3015. doi:10.5194/gmd-7-3001-2014.

Pinardi N. and G. Coppini, 2010. Operational Oceanography in the Mediterranean Sea: the second stage of development". Ocean Sci., 6, 263–267.

Relevant previous projects or activities:
MyOcean and MyOcean2: Coordinator of the Mediterranean Monitoring and Forecasting Centre in MyOcean, MyOcean2 and MyOcean Follow On Projects.

Copernicus Med-MFC Copernicus Marine Environment Monitoring Service - Mediterranean Monitoring and Forecasting Centre: Responsible for the Mediterranean Sea Monitoring and Forecasting Centre (MFC)-physical component within the Copernicus Marine Environment Monitoring Service.

RITMARE: Partner and WP leader of RITMARE, an Italian flagship Project on marine research, implementing the National forecasting system

E-AIMS FP7: Partner and WP leader of E-AIMS FP7 Project.

SeaDataNet FP6 SeaDataNetII FP7: Partner and WP leader in SeaDataNet FP6 SeaDataNetII FP7 Projects.

Relevant significant infrastructure and/or any major items of technical equipment:
A High Performance supercomputer Linux cluster IBM (named EKMAN), Intel processor (28 nodes with 16 cores/nodes) will be used to perform model development and model runs.

An internal archiving infrastructure (named ARCH-181) E4-E9212, Intel processor (3 nodes with 8cores/node).

A Server infrastructure (named MARSILI) E4 -E9316, Intel processor (2 nodes with 24 cores/node).

No third parties involved.

Participant 5: Natural Environment Research Council (NERC)
This work will be carried out at the National Oceanography Centre, which is a NERC Research Centre that maintains world class oceanographic research. It is situated across two sites, Liverpool (NOCL formerly the Proudman Oceanographic Laboratory) and Southampton (NOCS). NOC maintains world-class interdisciplinary research strengths in shelf sea and coastal systems, sea level, global ocean and climate modelling, global-scale hydrographic and satellite observations, air-sea fluxes, ocean biogeochemistry, seafloor geology and geophysics, oceanographic data archiving and dissemination, plus strong capabilities in marine technology and operational oceanography, as a partner in the National Centre for Ocean Forecasting (NCOF). NOC-L contributes expertise in shelf scale, ocean-margin, coastal and estuarine modelling of hydrodynamics, coupled ecosystems and surface waves. It has a substantial international reputation and has particularly contributed to the development of operational shelf sea forecast services at the Met Office and to the investigation of the impact of climate change in the marine environment. In Southampton, NOC-S specialises in high-resolution global ocean circulation models and physical processes, ecosystems, sea-ice, and uncertainty. The group contributes substantially to the development of UK coupled climate models through a joint initiative with the Met Office under the Joint Weather and Climate Research Programme (JWCRP). This work primarily sits within the Marine System's modelling group at NOC, but we also draw on expertise from the Sea Level subgroup, within the Marine Physics and Ocean Climate. NERC will be involved in developing NEMO as a global tidal model, in developing coupled wave-current capability and in developing the interface between CMEMS and coastal systems.

Short profile of key personnel involved:
Dr Jason Holt (Male), Head of Marine Systems Modelling group [Lead WP9]: Jason has 20+ years' experience of physical oceanography, particular areas of interest include the impact of climate change/variability on shelf-seas, fluxes/budgets of carbon and nutrients and ocean-shelf exchange. He is lead PI in ReCICLE project on climate change impacts in shelf seas. He leads the modelling component in the NERC FASTNEt (ocean-shelf exchange) programme, and led the Global Coastal Ocean Modelling project and the Next Generation Dynamical Core Roadmap Project. He is an expert on shelf seas for the NEMO developers Committee. He has published 60+ peer reviewed papers primarily on the modelling of hydrodynamics and ecosystems in shelf seas and ocean margins. WP9 Lead, where he will supervise the development of the coastal-coupling system and advise on shelf-sea processes.

Prof Adrian New (male), Associate Head of the Marine Systems Modelling group at NOC [WP3 Scientist]: Adrian has over 30 years' experience of science research and management, with wide ranging interests in most aspects of physical oceanography and 60 research publications. His interests cover both numerical ocean models and direct observations at sea. Specific interests include ocean general circulation and coupled climate modelling, decadal to centennial timescale variability of the ocean and climate system, large-scale ocean circulation and dynamics, and internal waves and their associated mixing processes. He is the NERC representative on the NEMO Steering Committee. He will work on the global internal tide modelling and assessment in WP3.

Dr Michela De Dominicis (Female), Engineer in the Marine System Modelling group [WP9 Scientist]: Michela holds a PhD in hydraulic engineering (2011) and during the past eight years she gained significant experience in marine numerical modelling and physical oceanography, with 10+ peer reviewed papers. Specific interests include high resolution model downscaling, marine renewable energy, operational oceanography and Lagrangian modelling. Her work currently involves setting up and running hydrodynamic models, both on structured (NEMO - Nucleus for European Modelling of the Ocean) and unstructured grids (FVCOM - Finite Volume Community Ocean Model). She is involved in the EcoWatt2050 project using an FVCOM model of the Scottish Shelf Waters to evaluate the near and far-field effects of very large scale tidal stream arrays. In COPPER she will work on WP9 on the development of the coupling to coastal systems.

Dr James Harle (male), Physical oceanographer [Contribute to WP 3 and 9]: James' research interests include numerical modelling of ocean basins and shelf seas, model development and analysis techniques. Other interests include climate downscaling and effective use of high performance computing and associated data management. He works in the Marine System Modelling group of the National Oceanography Centre and is currently involved in: model development and analysis in the NERC ReCICLE project, exploring the impacts of climate change on the marine ecosystem. FASTNEt: a NERC funded consortium project to examine shelf edge exchange using basin and shelf sea numerical simulations. He is also part of the NEMO Systems Team developing model code and associated configuration tools. He also assists in project management for the ocean modelling consortium on the ARCHER HPC facility. Involvement in previous projects include: the Global Coastal Ocean Modelling (GCOMS) NERC e-science funded project and developing and analysing basin scale modelling capability in the EU EuroBASIN Project. He was principle investigator of the pyNEMO project. In COPPER he will advise on shelf sea aspects of the global tidal model (WP3) and on aspects of the coastal coupling toolkit (WP9).

Dr Joanne Williams (female), Researcher in the Sea-Level and Ocean Climate sub-group [Contribute to WP 3]: Joanne has worked at NOC since 2008, specialising in analysis of sea-level and bottom pressure in global ocean models, including NEMO; and in precise calculation of elements of the sea-level budget from in-situ and satellite observations. This includes knowledge of long-term tidal components, and self-attraction and loading corrections to tides. She is currently working on statistical forecasting of storm surges from tide gauges. She will work on WP3, advising on the implementation of shelf-attraction and loading in NEMO and on the tide gauge validation.

Dr Lucy Bricheno (female), Oceanographer [WP4 Scientist]: Lucy is an oceanographer based at NOC in Liverpool. She is an experienced hydrodynamic and wave modeller, with particular expertise in the representation of interface processes and model coupling. As a part of the Marine System Modelling, Shelf Seas and Coastal Processes group Lucy's focus is on developing NOC's coastal modelling capability. To this end Lucy leads the WP3 enterprise to couple waves and hydrodynamics in the Met Office led UK Environmental Prediction project. She also has a track record in downscaling, improved ocean forecasting, flood risk, and changing wave and surge climate. As part of the European FP-7 project Field_AC, she has previously coupled the Weather Forecasting and Research model (WRF) with POLCOMS and WAM. Dr Bricheno has published 10 papers, and is a member of the GODAE international Coastal Ocean and Shelf Seas Task Team (COSS-TT) and currently supervises one postdoc.

Prof Chris Hughes (male), Professor of Sea Level Science [WP3 Scientist]: Chris is a professor at the University of Liverpool, jointly funded by NOC, with 20+ years' experience of research in physical oceanography and sea level science. Particular areas of interest include the interface between open ocean dynamics and coastal sea level, and geodetic oceanography. He was the lead PI on a major component of the RAPID research project to monitor the North Atlantic Meridional Overturning Circulation, and has been PI or CoI on a series of NERC and ESA grants. He sits on a number of national and international committees which focuse on the interface between oceanography and geodesy, and has been a member of the Science teams for most altimetry and gravity satellite missions since 1992. He has published over 70 papers in leading international journals, and will contribute expertise particularly to issues of tidal loading and modelling.

Dr Alexis Megann (male), Ocean Modeller [WP3 Scientist]: Alexis is a highly-experienced ocean modeller with a particular interest in the role of the ocean in climate variability and climate change. He is an active contributor to the Joint Ocean Modelling Project (JOMP), which is developing, jointly between NERC and the Met Office, the ocean component of the next-generation Earth System Model for the IPCC Sixth Assessment Report (AR6) and the associated Coupled Model intercomparison Project CMIP6. His current interests are in numerical mixing in ocean models, in alternative vertical coordinates, and in Bayesian model ensembles. He will work on the global tidal modelling in WP3.

Relevant publications, and/or products, services, achievements:

Dominicis, M.D., Falchetti, S., Trotta, F., Pinardi, N., Giacomelli, L., Napolitano, E., Fazioli, L., Sorgente, R., Haley Jr., P.J., J. Lermusiaux, P.F., Martins, F., Cocco, M., 2014. A relocatable ocean model in support of environmental emergencies. Ocean Dynamics, 64, 667-688.

Holt, J., Allen, J.I., Anderson, T.R., Brewin, R., Butenschon, M., **Harle, J.**, Huse, G., Lehodey, P., Lindemann, C., Memery, L., Salihoglu, B., Senina, I., Yool, A., 2014. Challenges in integrative approaches to modelling the marine ecosystems of the North Atlantic: Physics to Fish and Coasts to Ocean. Progress in Oceanography, doi:10.1016/j.pocean.2014.04.024.

New, A. L., J. M. Magalhaes, J. C. B. da Silva, 2013. Internal solitary waves on the Saya de Malha bank of the Mascarene Plateau: SAR observations and interpretation. Deep-Sea Research I, 79, 50-61, doi:10.1016/j.dsr.2013.05.008.

Williams, J., Hughes, C. W.; Tamisiea, M. 2015 Detecting trends in bottom pressure measured using a tall mooring and altimetry. Journal of Geophysical Research: Oceans, 120 (7). 5216-5232. 10.1002/2015JC010955

Stepanov, V. N., and **C. W. Hughes**, 2004: Parameterization of ocean self-attraction and loading in numerical models of the ocean circulation. J. Geophys. Res. 109(C3) C03037, doi: 10.1029/2003JC002034.

Relevant previous projects or activities:
pyNEMO ARCHER eCSE Project (http://pynemo.readthedocs.org/en/latest/intro.html): Developing a python based boundary condition tool box for NEMO.

EuroBASIN FP7 (http://www.euro-basin.eu/): Developing a basin-scale tidal model based on NEMO.

FIELD_AC FP7 (http://www.hzg.de/about_us/eu_projects/fp7/index.php.en): Developing a coupled wave-current coastal modelling system.

NOWMAPS CMEMS: Supporting and developing the NW Shelf MFC CMEMS service.

GOCE++DYCOT (DYnamic COastal Topography and tide gauge unification) ESA: Estimating a consistent dynamic topography at tide gauges, coastal areas, and in open ocean.

Relevant significant infrastructure and/or any major items of technical equipment:
Cluster computers at NOC Liverpool and Southampton

Access to UK National HPC Facilities ARCHER and JASMIN and joint NERC-Met Office HPC facility MONSOON.

No third parties involved.

Participant 6: Mercator Ocean

Between observation infrastructures and users, Mercator Ocean is a non-profit company employing a team of 50 persons which ensures the continuity from research to oceanographic operational services. Mercator Océan has five research and operational governmental shareholders (Centre National de la Recherche Scientifique (CNRS), Institut pour la Recherche et le Développement (IRD), Météo France (the French Meteorological office), SHOM (Naval Hydrographic and Oceanographic Service) and IFREMER (Institut Français de Recherche pour l'Exploitation de la MER). Over the last 15 years, Mercator Ocean has been playing a leading role in operational oceanography at the international level and European level. After having successfully coordinated the European MyOcean projects since 2009, Mercator Ocean was officially appointed by the European Commission in November 2014 to define, manage, implement and operate the "Copernicus Marine Environment Monitoring Service" (CMEMS) (as part of the European Earth observation program, Copernicus) on its current multi-annual financial framework 2014-2020. Mercator Ocean also defines and manages the service evolution and user uptake of the CMEMS activities.

Short profile of key personnel involved:

Clément Bricaud (male), Ocean Engineer [WP7]: Clement is a MERCATOR Ocean engineer graduated from MatMeca in 2005. He is currently the NEMO Officer for MERCATOR. As such he is deeply involved in the development and testing of the code.

Jérôme Chanut (male), Ocean Research Engineer [WP3, WP4, WP6, WP7]: Jérôme has been a MERCATOR Ocean research engineer since 2004, soon after his PhD in physical oceanography. During his 12 years experience in ocean modelling, he has been involved in the development of many numerical aspects of the NEMO code. He has strongly participated to the development of coastal modelling capacities of NEMO during Mersea and MyOcean projects. During the latter, he coordinated the "Iberian Biscay Irish" Marine Forecasting Center.

Elisabeth Rémy (female), Ocean Researcher [WP5]: Elisabeth has been working as researcher for MERCATOR Ocean since 2001 after a PhD at Ifremer (1999) and a post-doc at SCRIPPS, both of them on ocean data assimilation. Since she arrived at Mercator Ocean, she has been working on ocean modelling, ocean reanalysis and more recently on observation impact studies.

Relevant publications, and/or products, services, achievements:

Chanut, J., B. Barnier, W. Large, L. Debreu, T. Penduff, J. M. Molines, and P. Mathiot, 2008: Mesoscale Eddies in the Labrador Sea and Their Contribution to Convection and Restratification. J. Phys. Oceanogr., 38, 1617–1643.

Gehlen, M., A. Yool, M. Vichi, R. Barciela, C. Perruche, A. El Moussaoui and C. Ethé, 2012, Coupled physical-biogeochemical ocean modeling using NEMO components. Mercator Quarterly Newsletter#46, Oct 2012, 10-23.

Lellouche, J.-M., Le Galloudec, O., Drévillon, M., Régnier, C., Greiner, E., Garric, G., Ferry, N., Desportes, C., Testut, C.-E., **Bricaud**, C., Bourdallé-Badie, R., Tranchant, B., Benkiran, M., Drillet, Y., Daudin, A., and De Nicola, C., (2013): Evaluation of global monitoring and forecasting systems at Mercator Océan, Ocean Sci., 9, 57-81, doi:10.5194/os-9-57-2013.

Maraldi, C., **Chanut**, J., Levier, B., Ayoub, N., De Mey, P., Reffray, G., Lyard, F., Cailleau, S., Drévillon, M., Fanjul, E. A., Sotillo, M. G., Marsaleix, P., and the Mercator Research and Development Team: NEMO on the shelf: assessment of the Iberia–Biscay–Ireland configuration, Ocean Sci., 9, 745-771, doi:10.5194/os-9-745-2013, 2013.

Turpin, V., **Remy**, E., and Le Traon, P. Y.: How essential are Argo observations to constrain a global ocean data assimilation system? Ocean Sci., 12, 257-274, doi:10.5194/os-12-257-2016, 2016.

Relevant previous projects or activities:

EU FP7 Project MyOcean2 FollowOn (2012-2015). Mercator Ocean has been the coordinator of the EC/FP7 MyOcean2 follow-on project and leads the European Copernicus Marine Service. In these projects, Mercator Ocean is in charge of the global ocean forecasts and reanalysis.

EU FP7 Project ERA-Clim2 (2014-2016). It is a collaborative research project funded by the European Union, with the goal of preparing input data and assimilation systems for a new global coupled reanalysis of the 20th century. Mercator Ocean contributes to the sea-ice data assimilation system and the coupling with biochemistry.

ANR COMODO (COmmunauté de Modélisation Océanique). COMODO is a research project supported by the French national research agency (ANR), which regroups the whole French ocean modelling community. This common effort is directed towards two main objectives: improvement of existing models and numerical methods and providing guidelines for the development of future generation ocean models.

Mercator Ocean is a member of the **NEMO consortium**. As such, Mercator Ocean participates to the definition of the code roadmap (parameterisations, technical choices, etc) and the developments themselves. The participation is up to one man/year.

Mercator Ocean is involved in the **DRAKKAR consortium**. DRAKKAR is a scientific and technical coordination between French research teams (LGGE-Grenoble, LPO-Brest, LOCEAN-Paris), Mercator Ocean, NOC Southampton, IFM-Geomar Kiel, and other teams in Europe and Canada. DRAKKAR proposes to design, carry out, assess, and distribute high-resolution global ocean/sea-ice numerical simulations based on the NEMO platform performed over long periods, and to improve and maintain a hierarchy of state-of-the-art ocean/sea-ice model configurations for operational and research applications. In this context, the Mercator Ocean global 1⁄4° and 1/12° models have been shared.

Relevant significant infrastructure and/or any major items of technical equipment:
Access to High Performance Computers at Meteo-France and ECMWF and internal computing facilities.

No third parties involved.

Participant 7: Barcelona Supercomputing Center (BSC)

BSC was established in 2005 and is the Spanish national supercomputing facility and a hosting member of the PRACE distributed supercomputing infrastructure. BSC houses MareNostrum, one of the most powerful supercomputers in Europe. The mission of BSC is to research, develop and manage information technologies in order to facilitate scientific progress. BSC combines HPC service provision, and R&D into both computer and computational science (life, earth and engineering sciences) under one roof and currently has over 400 staff from 41 countries. BSC has collaborated with industry since its creation, and participates in various bilateral joint research centres with companies such as IBM, Microsoft, Intel, NVIDIA and Spanish oil company Repsol. The centre has been extremely active in the EC Framework Programmes and has participated in seventy-nine projects funded by it. BSC is a founding member of HiPEAC, the ETP4HPC and other international fora.

The Earth Sciences department of the Barcelona Supercomputing Center (ES-BSC) conducts multi-facet research in Earth system modelling. Established in 2006, the initial core activity was focused on atmospheric composition modelling. The designation of Prof. Francisco J. Doblas-Reyes as Director of the ES-BSC in 2014 initiated the merging of the ES-BSC with the Climate Forecast Unit of the Institut Català de Ciències del Clima (IC3-CFU), which he was leading and who had become in a short time a main European actor in the development of climate predictions and climate services. The newly merged department is structured around four groups with more than 50 employees, including technical and support staff: 1) climate prediction group, 2) atmospheric composition group, 3) earth system services group, and 4) computational earth sciences group.

The Computational Earth Sciences (CES) group is a multidisciplinary team with different IT profiles that interacts closely with all the other groups of the Department. The group provides help and guidance to the scientists on technical issues related to their research, and develops a framework which ensures the most efficient usage of HPC resources. In order to maximise the utilization of the variety of computing resources available at the BSC and other HPC institutions, a solid software development, profiling and optimisation area for Earth system model codes aiming towards Exascale computing has been created, devoted also to provide feedback on this subject to modellers around Europe. The group provides HPC Services such as performance analysis to identify bottlenecks and apply optimizations, or scientific experiments automation and diagnoses.

Short profile of key personnel involved:

Kim Serradell Maronda (male), Co-manager of the Computational Earth Science (CES) group [WP8 Scientist]: Kim holds a Bachelor (2005) in Computer Sciences for the Facultat d'Informàtica de Barcelona (FIB-UPC) and for the Grande école publique d'ingénieurs en informatique, mathématiques appliquées et télécommunications de Grenoble (ENSIMAG). He also gained an MSc in High Performance Computing from the Facultat d'Informàtica de Barcelona (FIB-UPC) in 2014. Currently, he is the co-manager of the CES group at the Earth Sciences department at BSC. The CES group is a multidisciplinary team of 15 members with different IT profiles that interacts closely with all the other groups of the Earth Sciences Dept. In recent years he has been in charge of the system administration of all the computational resources of the department and he was also responsible of supervising the operational runs of the NMMB/BSC-Dust model and CALIOPE Air Quality System in the HPC infrastructures of the BSC. He has been involved in European projects like IS-ENES (1 & 2), ESiWACE, SDS-WAS, BDFC or CONSOLIDER.

Miguel Castrillo (male), Computer Scientist in the Computational Earth Sciences group [WP8 Scientist]: Miguel holds an MSc in computer science from the University of León. Having more than nine years of experience as software analyst and developer, he has worked for different associations (XBRL Spanish Association) and companies (Municipia SL, Grupo TEVA), combining his full-time work with a degree in Geography and History by the Univesidad Nacional de Educación a Distancia (UNED). He currently works in the Computational Earth Sciences group at the Earth Sciences department of the Barcelona Supercomputing Center (BSC). His extensive expertise in HPC ranges from HPC data management and visualization tools, to parallel applications performance. He is developer for the CALIOPE air quality system mobile application, winner of the European Commission MYGEOSS project (2015-2016) for innovative applications using open data. During recent years he has been intensely focused on HPC performance, involved in IS-ENES2 and ESiWACE European projects, and collaborating with the EC-Earth and NEMO models development teams. He has been working on the performance optimizations for the NEMO 3.6 alpha version, and all of his contributions are now part of the 3.6 official version. Miguel is currently a permanent member of the NEMO HPC WG and EC-Earth technical group.

Relevant publications, and/or products, services, achievements:

Tintó Prims, O., **M. Castrillo**, **K. Serradell** , O. Mula-Valls and F.J. Doblas-Reyes (2015). Optimization of an ocean model using performance tools, Technical memoranda, 2015.

M. Castrillo, Tintó-Prims, O., Servat, H., **Serradell, K.**, and Markomanolis, G. S., "Applying clustering and folding techniques to study performance issues on the NEMO global ocean model", HPCKP15. HPCKP15, 2015.

M. Castrillo, Tintó-Prims, O., and **Serradell, K.**, "BSC tools to study the computational efficiency of EC-Earth components", EC-Earth Meeting. Reading, United Kingdom, 2015.

O. Tintó Prims, **Castrillo, M.**, Servat, H., Llort, G., **Serradell, K.**, Valls, O. Mulla, and Doblas-Reyes, F. J., "Optimization of an ocean model using performance tools", Poster. CS15, Austin, US, 2015.

O. Tintó-Prims, **Castrillo, M., Serradell, K.**, Mula-Valls, O., Cortés, A., Doblas-Reyes, F. J., and Labarta, J., "Understanding Scientific Application's Performance using BSC performance tools", International Conference on Computational Sciences. Reykjavik, 2015.

Relevant previous projects or activities:

IS-ENES: https://is.enes.org/

IS-ENES2: In the framework of the IS-ENES2 project (end date, March 2017), BSC has been working in a work package entitled "Towards next generation models", which aims at creating connections within the climate modelling community and promulgating best practice model developments to run these codes on HPCs looking at the Exascale. In particular the BSC was in charge of doing scalability analysis on the NEMO model through a trace analysis methodology and contributing with performance simulations. The outcomes and experience obtained from these tasks will be direct inputs to the 8.2 task from NCH20. https://is.enes.org/

ESiWACE: The ESiWACE project (start date, September 2015) includes a WP on the models scalability. Within this WP, there is a task on the NEMO model optimization assessing scalability issues, such as compute/communication performance improvements. The work on parallel efficiency has been also included in NCH20 (task 8.2 - NEMO code scalability on many-cores architectures), but investigating and targeting different aspects and techniques. It is clear that also in this case there will be a mutual benefit for the two projects. https://www.esiwace.eu/

PRIMAVERA: The goal of the H2020 PRIMAVERA project (started on November 2015) is to deliver novel, advanced and well-evaluated high-resolution global climate models (GCMs), capable of simulating and predicting regional climate with unprecedented fidelity, out to 2050. In support of the HighResMIP, PRIMAVERA will lead the European contribution to the CMIP6 High-Resolution Model Intercomparison Project. BSC is one of the seven groups across Europe that will participate in the development of these models, and NEMO will be the ocean model used by five of these institutions in their simulations. Particularly, BSC will perform high resolution coupled simulations at the 0.25 deg and as high as 1/12 degree in the NEMO ocean model. Having this in mind, is clear that PRIMAVERA and also CMIP6 experiments would highly benefit from improved model performance carried out through NCH20. https://www.primavera-h2020.eu/

Relevant significant infrastructure and/or any major items of technical equipment:

MARE NOSTRUM: MareNostrum has a peak performance of 1,1 Petaflops, with 48,896 Intel Sandy Bridge processors in 3,056 nodes, including 84 Xeon Phi 5110P in 42 nodes, with more than 115 TB of main memory and

2 PB of GPFS disk storage. At June 2013, MareNostrum was positioned at the 29th place in the TOP500 list of fastest supercomputers in the world.

BSC PERFORMANCE TOOLS: Parallel architectures enable the targeting of more complex and ambitious problems each year. In many cases, the achieved performance is far away from what the theoretical values promised us. Performance analysis tools therefore allow application developers to identify and characterize the inefficiencies that caused a poor performance. We feel that this analysis must be the first step towards the optimization of an application. Optimizing without a previous analysis could be like driving without directions as it could mean wasting efforts improving parts of the code that were not the real performance bottlenecks. (https://www.bsc.es/computer-sciences/performance-tools).

Participant 8: Institut National de Research en Informatique et en Automatique (INRIA)
Established in 1967, Inria is the only French public research body fully dedicated to computational sciences. Under its founding decree as a public science and technology institution, (jointly supervised by the French ministries for research and industry) Inria's mission is to pursue excellent research in computer science and applied mathematics in order to play a major role in resolving scientific, societal and industrial challenges. Throughout its eight research centres and its 172 project teams, Inria has a workforce of 3 400 scientists with an annual budget of 233 million euros, 37% of which coming from its own resources. Inria has been very active in the previous European framework programmes (in FP7: 231 projects and 32 ERC grants). Inria is currently involved in 27 H2020 funded projects. More information: http://www.inria.fr. In this Project, Inria represents the Team AIRSEA. The general scope of the AIRSEA project-team is to develop mathematical and computational methods for the modelling of oceanic and atmospheric flows. The mathematical tools used involve both deterministic and statistical approaches. The domains of applications range from climate modeling to the prediction of extreme events.

Short profile of key personnel involved:
Florian Lemarié (male), Researcher [Contribute to WP6]: Florian has been an Inria researcher in applied mathematics since January 2013. He has contributed to several topics including mesh-refinement methods for structured grids, numerical methods for multi-physics coupling, discrete algorithms for ocean models, and air-sea interactions. During his PhD in applied mathematics within the INRIA MOISE project-team, he has worked on ocean-atmosphere coupling methods. During his four years at the UCLA Department of Atmospheric and Oceanic Sciences he has gained a truly multi-disciplinary vision with strong knowledge of the numerical and physical aspects of oceanic and atmospheric models. He has authored or co-authored 12 international publications. During the last two years he has been involved in several ANR projects and PI of two research projects with the privately-owned company Mercator-Ocean. http://www-ljk.imag.fr/membres/Florian.Lemarie/.

Laurent Debreu (male), Researcher [Contribute to WP 7]: Laurent is an Inria researcher in applied mathematics with primary interests in numerical methods for ocean and atmosphere modeling. L. Debreu successively worked on nesting implementation (NEMO, ROMS, HYCOM and MARS models), advection schemes (NEMO and MARS), spurious diapycnal mixing (ROMS and MARS), vertical coordinate systems (HY- COM). In the last four years, Laurent has been PI or co-PI of eight contracts with research or industrial organisms and has authored or co-authored 11 international publications. He is the coordinator of COMODO a research project which brings together the whole French ocean modelling community. He is the main developer of the AGRIF software, a library for the integration of local mesh refinement features, internationally recognized and currently included in several ocean models of the international community. Since January 2015 he has been the head of the INRIA Project-Team AIRSEA. https://sites.google.com/site/laurentdebreu1/.

Relevant publications, and/or products, services, achievements:
Y. Soufflet, P. Marchesiello, **F. Lemarié**, J. Jouanno, X. Capet, L. Debreu, R. Benshila: On effective resolution in ocean models. Ocean Modelling, 98, pp 36-50, 2016

F. Lemarié, **L. Debreu**, G. Madec, J. Demange, J.-M. Molines, M. Honnorat: Stability constraints for oceanic numerical models: implications for the formulation of time and space discretizations. Ocean Modelling, 92, pp 124-148, 2015

F. Lemarié, **L. Debreu**, A. Shchepetkin, J.C. McWilliams: On the Stability and Accuracy of the harmonic and biharmonic isoneutral mixing operators in ocean models. Ocean Modelling, 52-53, pp 9-35, 2012

L. Debreu, P. Marchesiello, P. Penven, G. Cambon: Two-way nesting in split-explicit ocean models: algorithms, implementation and validation. Ocean Modelling, 49-50, pp 1-21, 2012

AGRIF : Adaptive Grid Refinement In Fortran : **L. Debreu** is the main developer of the AGRIF software. AGRIF is a sofware for the integration of full adaptive mesh refinement (AMR) features within a multidimensional finite difference/finite volume numerical model written in the Fortran language. AGRIF is routinely used in several state of the art ocean models. http://www-ljk.imag.fr/MOISE/AGRIF/

Relevant previous projects or activities:

ANR (French National Research Agency) COMODO (2011-2015): French numerical Ocean Modeling Community (PI Laurent Debreu). Other institutes involved : IRD, CNRS, SHOM, IFREMER (Total grant: 1,3 million euros). The aim of this project was to conduct research in numerical methods for ocean modeling and also to produce a benchmark suite of idealized test cases.

ANR (French National Research Agency) HEAT (2014-2018): Highly Efficient Atmospheric modelling (Co-PI Laurent Debreu). Other institutes involved: CEA, CERFACS, CNRS, Ecole Polytechnique (PI T. Dubos), CNRM. This research project focus on the development on a latest generation atmospheric model, based on a icosahedral dynamical core (DYNAMICO), for climate and weather modelling.

LEFE-GMMC (Groupe Mission Mercator Coriolis) CHRONOS (2013-2015) : the CHRONOS project (PI Florian Lemarié) is dedicated to the study of time-stepping algorithms in primitive equations oceanic models. The aim is first to study the constraints on the numerics in terms of stability and accuracy for a given application, and then to propose alternatives to existing time-stepping schemes used in global models.

Relevant significant infrastructure and/or any major items of technical equipment:

Not applicable.

4.2 Third parties involved in the project (including use of third party resources)

4.2.1 Third parties (ICREA and UGA) and their relation to COPPER partners BSC and INRIA respectively

ICREA (**Institució Catalana de Recerca i Estudis Avançats**) will provide resources (professor/researcher) *free of charge to the BSC as a third party* (Article 12 Grant Agreement). ICREA is a foundation supported by the Catalan Government and guided by a Board of Trustees which aims to recruit top scientists for the Catalan R&D system: scientists capable of leading new research groups, strengthening existing groups, and setting up new lines of research.

Following the rules of ICREA, although the salary costs of Dr. Francisco Doblas-Reyes are paid by ICREA, he is assigned to physically work at Barcelona Supercomputing Center (Earth Science Department). The terms and conditions of this cooperation between ICREA and Barcelona Supercomputing Center are reflected in a bilateral agreement between the two parties.

The beneficiary, BSC, is free to use these resources at will. They are therefore assimilated as "own resources" of the beneficiary, and will be charged to the project without being considered as a receipt. The cost will be declared by the beneficiary and it will be recorded in the accounts of the third party. These accounts will be available for auditing if required.

In this Project, INRIA represents the Team AIRSEA. AIRSEA is a "Joint Project Team" of both **Université Grenoble Alpes** (**UGA**) and INRIA, with contributions from UGA and INRIA. At INRIA, a Joint Project Team is an administrative entity created by the signature of a contract between one or more research laboratories of a higher education and research establishment (such as a University) with INRIA. AIRSEA is located inside the UGA building, and in this Joint Project Team, some people are paid by INRIA and others by UGA. INRIA contributes, together with UGA, to pay researchers travel expenses and to buy machines, chemical products and other consumables. An agreement among parties describes all the details**.** In this project, INRIA will represent UGA as a *Third Party linked to INRIA* in future Grant Agreement and Consortium Agreement: UGA will carry out part of the work attributed by the future Grant Agreement. They will fill Third Party's Financial Reports with their own costs.

4.2.2 Implementation of action tasks by subcontractor to Met Office

Met Office, WP2: The website construction and design will be carried out by a specialised subcontractor. The website and associated products will be graphically designed in a professional style which will guarantee consistency with the image (logo) of the project, in an effective and up-to-date graphic fashion. 5,000€ has been put aside for this subcontract.

5. ETHICS AND SECURITY

5.1 Ethics

There are no ethics issues to declare. However, we will only collect personal information that is necessary for the project, and use it exclusively for the relevant objectives of COPPER. All beneficiaries will ensure that they adhere to EC legislation and their own national legislation with regard to data protection (including EU Directive 95/46/EC and any subsequent updates to this directive).

Procedures will be implemented for data collection, storage, protection, access, retention and destruction (MS2). This includes an informed consent procedure, thus ensuring that all interviewees, workshop attendees (WP9) etc will understand and agree to how the data they provide will be handled. These procedures will be developed by the end of the second month of the project. No personal data will be collected until these procedures are in place.

5.2 Security

Project COPPER will NOT involve:

- Activities or results raising security issues; nor
- ‘EU-classified information’ as background or results.

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