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15 November 2013

Report on Activities for SAWG 2013

During 2013 the Science Advisory Working Group has been re-activated with a specific mission: to develop of a set of “EuroGOOS” RTD priorities in view of Horizon2020.

The two co-chairs (Nadia Pinardi and Johnny Johannessen) organized a meeting of SAWG in Cork (April 15th , back to back with MyOcean2 annual review). The main objectives of the meeting were:

- Review and update Terms of References (ToR) for SAWG
- Outline first draft for R&D activities to be proposed in HORIZON2020

There was good participation from old and new members of SAWG and representation of all ROOSs:

1.	SAWG Co-chairs:	J.Johannessen and N.Pinardi
2.	Coastal WG:	Ole Krarup Leth
3.	Technology WG:	Glenn Nolan
4.	Arctic ROOS:	J.Johannessen
5.	NOOS:	H. Wehde
6.	BOOS:	Jan Reissmann
7.	IBI ROOS:	Tomasz Dabrowsk
8.	MONGOOS:	Alessandro Crise, G.Korres, G. Coppini
9.	MyOcean Tier 2 R&D:	E. Stanev, P. Brasseur
11.	EUROGOOS	Mike Bell (Board), K.Nittis (SG)

The group agreed to:

- Work during 2013 to produce a short document with research priorities for operational oceanography. The document should be primarily used for promotion of O.O. in Horizon 2020 but also in other relevant initiatives (e.g. JPI Oceans, SEASERA, national programs etc).
- Revise the ToR of the group and present the new membership at the General Assembly of November 2013.

A preliminary revision of the SAWG ToR was also carried out during the meeting. The following terms are proposed:

– Tor1: Continuously identify the S&T need for advancing prediction and analyses of the marine environment and relate them to 3 main ‘drivers’: society, science and technology

– Tor2: Maintain a 2-way feedback between operational science and ocean dynamical studies;

– Tor3: Enhance the connection between environmental and climate change research and operational oceanography. Merge 2 and 3

– Tor4: Identify the R&D needs for new applications that will benefit from the Marine Core Service products. Look in view of ROOSes

– Tor5: Support educational programs for operational oceanography, strengthening the combination of Science and Engineering

The present draft of the white paper is included below.

A Science Strategy for EuroGOOS

DRAFT WHITE PAPER

Nadia Pinardi, Johnny A. Johannessen
and
The EuroGOOS SAWG

October 20, 2013

1. Introduction

Operational oceanography, including ocean analysis, reanalyses and forecasting is a branch of science that requires continuous implementation of the most advanced research findings to comply with ocean user needs. Inherent to operational oceanography is also the access to observations in near real time. Moreover, operational oceanography delivers products and information that are crucial for the research community to pursue major understanding and advance knowledge and technology in the marine sector.

Active feedback between research and operational sciences therefore needs to be enhanced, maintained and secured since it is at the basis of a competitive development of services in operational oceanography but also of new scientific and technological advancements. If the link between services and science is discontinued operational oceanography will fail to deliver the high quality products and services of a given standard required by the pressing environmental problems.

The EuroGOOS Science Advisory Working Group (SAWG) is focusing its effort to maintain a close connection between science and the European and international operational oceanographic services, namely the Copernicus Marine Service (http://www.copernicus.eu/pages-principales/services/marine-monitoring/), the GOOS program (http://www.ioc-goos.org/), the other Regional Alliances developments and the JCOMM (http://www.jcomm.info/) Program Areas.

Fig. 1 shows the present state of development of the Marine Service system as designed by the ECOMF Consortium[1] in response to the EC Copernicus program in HORIZON2020 Framework Program and Fig. 2 presents the UNESCO-IOC Medium Term Strategy document that sets the basis for the scientific developments of GOOS and other IOC programmes for the period 2014-2021. Other international frameworks for the development of operational oceanography are:

- GODAE (https://www.godae-oceanview.org/) for the development of common practises at the global level and for selected topics of relevance for EuroGOOS;
- GEOSS (http://www.earthobservations.org/geoss.shtml) which will provide a forum for connecting operational oceanography to policy makers and societal needs at large.

At the European level, the Marine Board of the European Science Fundation (ESF) has recently organised a foresight document that describes the European science and maritime policy landscape, giving important priorities for operational oceanography developments.

[1] The ECOMF is at the moment an MoU between 14 European Partners: Mercator (FR), INGV (IT), UkMetOffice (UK), BSH (DE), NERSC (NO), DMI (DK), CNR (IT), Puertos de l'Estado (ES), HCMR (GR), SHMI (SE), CLS (FR), IFREMER (FR), MHI (UK), MetNO (NO)

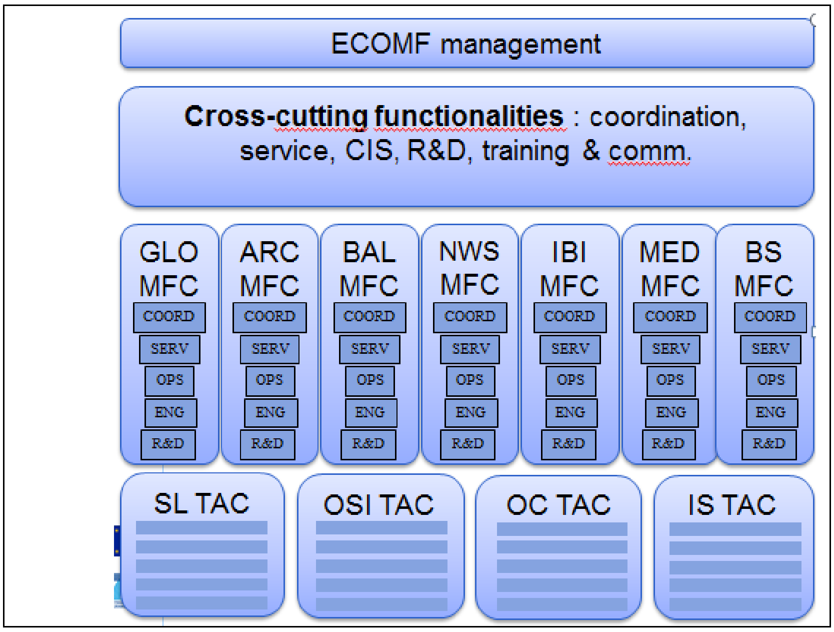

Fig. 1. *The ECOMF mission targeting the delivery of the Copernicus Marine Service with central functions (Cross-Cutting Functionalities), MFCs and TACs. Acronyms: Thematic Assembly Centers (TAC), Monitoring and Foecasting Centers (MFC), Central Information System (CIS), Global Ocean (GLO), Arctic Ocean (ARC), Baltic Sea (BAL), North West Shelves (NWS), Ireland-Bay of Biscay-Iberian area (IBI), Mediterranean Sea (MED), Black Sea (BS), Sea Level (SL), Ocean Sea Ice, Sea Surface Temperature and Sea Winds (OSI), Ocean Color (OC).*

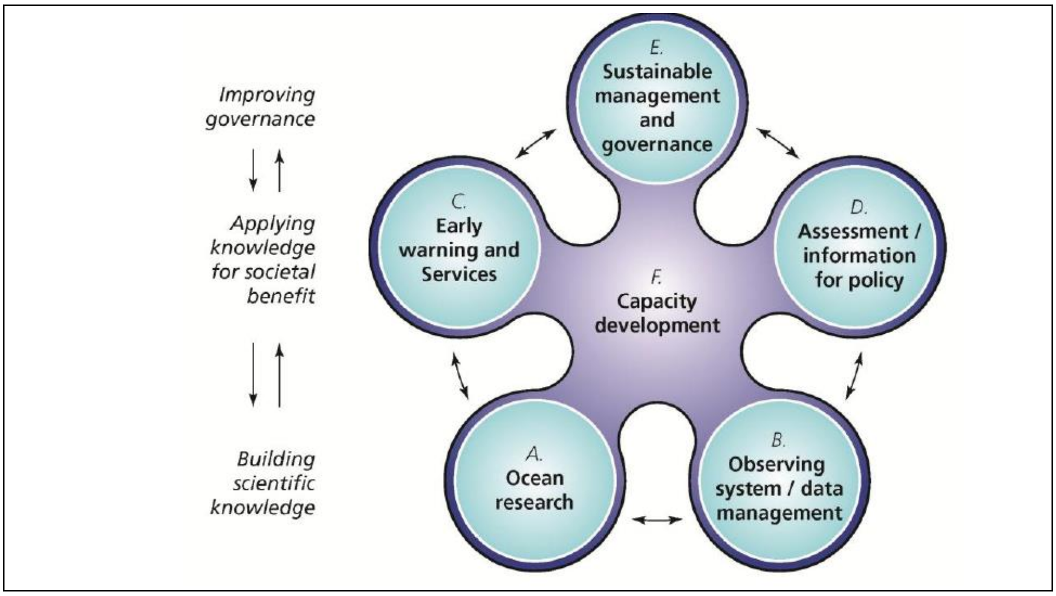

Fig.2. *The conceptual framework of the UNESCO-IOC Medium Term Strategy: 'Functions' are shown A through F.*

2. White paper Objectives

This white paper aims to address key scientific issues and research priorities for the development of operational oceanography and analysis and forecasting capabilities in Europe for the next 5-10 years. Knowledge gaps and deficiencies are discussed first in general terms and thereafter scientific developments required by the Regional Ocean Observing System (ROOS) components of EuroGOOS and the other Regional Alliances (MONGOOS and Black Sea GOOS) that contribute to EuroGOOS are considered.

3. Relevant Research and Development issues for EuroGOOS

The science of ocean predictions is at the basis of operational oceanography developments. As shown in Fig. 3 forecasting is at the center of earth science challenges, together with innovation, observing, responding and confining the impacts.

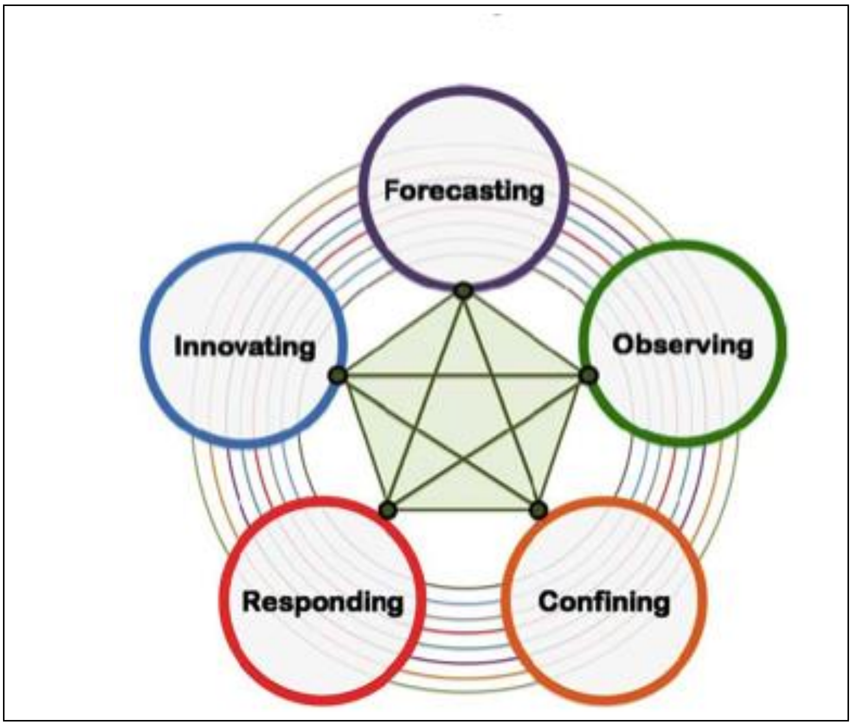

Fig. 3*. Schematic of grand challenges from the 'Earth System Science for Global Sustainability', ICSU (2010)*

The basic challenges for operational oceanography can be described as follows:

- Predict the future state of the (open and coastal) oceans and ice covered seas for both biotic and abiotic marine state variable components and quantify their uncertainties;
- Characterize and estimate as accurately as possible, and as far in the past as possible, the state of the ocean and the ice covered seas from all information available and quantify uncertainties;
- Understand changes and impacts of human activities on the oceans to manage adaptation and mitigation with a 'science based approach';
- Design an efficient and cost effective sustained ocean observing system both in real time as well as in delayed mode;
- Develop new applications for the sustainable management of resources using a new approach, the 'operational approach'.

Several science and technology priority activities could be extracted to approach and partially solve the challenges outlined above:

- design, test and make sustainable a *global* and *pan-European* observing system (satellite and in situ based), with innovative sensors and components, to serve the real time needs of operational oceanography and its applications at appropriate spatial and temporal scales to resolve the dominant processes, interactions and mutual feedbacks;
- improve deterministic physical models and assimilation methods for open ocean, shelf seas and sea ice covered regions (coupling of different physical processes, air-sea-ice interactions and exchanges of momentum, heat and gas, internal sea ice rheology, 2-way hydrodynamics nesting, hydrology and atmospheric coupling, multivariate statistics and 4Dvar, etc.);
- extend the forecasting capabilities to marine biogeochemical components and marine ecosystems at the appropriate spatial and temporal scales and include freshwater runoff with transport of nutrients and suspended matter;
- quantify and reduce uncertainties on the ocean and sea ice state variables (with a transition from deterministic to ensemble predictions);
- understand how to use calibrated/validated operational models for environmental and climate change scenarios and develop the 'what if scenario' methodologies;
- develop the information system that will catalog, discover and make feasible the access to the ocean observations, models and new operational oceanography products and information;
- develop educational and training tools and activities.

Specific scientific issues contained in these priority activities include:

(i) Rationalizing the range of forecasting models
(ii) Data assimilation improvements
(iii) Ensemble forecasting and uncertainty estimation
(iv) Assembling test-bed data sets
(v) Exploitation of remote sensing data sets
(vi) Development of a monitoring strategies
(vii) Optimum design of observational networks (including OSSE)
(viii) Generic aspects of coupling numerical models
(ix) Extension of forecasts towards biological/ecological state variables
(x) Training and education in Operational Oceanography
(xi) Dissemination: visualisation, analysis
(xii) Access to high performance computing
(xiii) Coastal operational oceanography, including coastal engineering
(xiv) Liaison with existing European & International agencies
(xv) Operational oceanography in ice covered seas
(xvi) Marine Rapid Environmental Assessment methods
(xvii) Science-based Marine Environmental Indicators
(xviii) Extension of short range ocean forecasts toward long range ocean forecasting

In order to make significant progress in the coming 5-10 years with respect to these specific scientific research issues funding opportunities must be explored nationally and internationally. The table below summarizes this with regards to HORIZON2020 and ESA scientific support studies under DUE, STSE, Sentinel and Explorer funding lines.

Scientific Research Activities	**EU HORIZON2020 funding opportunities**	**ESA DUE, STSE, Sentinel and Explorer funding opportunities**
Rationalizing the range of forecasting models		

Data assimilation improvements		
Ensemble forecast and uncertainty improvement		
Assembling test-bed data set		
Exploitation of remote sensing data sets	H2020 - EO 1 – 2014 H2020 - EO 2 – 2014 H2020 - EO 5 – 2014 H2020 - EO 1 – 2015 H2020 - EO 2 – 2015 H2020 - EO 3 – 2015	DUE, STSE, Sentinel, Explorer Need to be more specific here
Development of monitoring strategies	H2020 – SC5_16 – 2015	
Optimum design of operational networks including (OSSE)	H2020: Developing In-situ observing system for the Atlantic Ocean H2020 – SC5_18 – 2015 H2020 – SC5_19 – 2014/2015	
Generic aspect of coupling numerical models	H2020 - SC5_1 - 2014	
Extension of forecast to biology/ecosystem state variables	H2020 – SC5_17 – 2014 H2020: Marine ecosystem in the Atlantic	
Training and education	H2020 – EO - COMPET 10 -2014	
Dissemination: visualization, analysis		
Access to high performance computing		
Liaison with existing agencies	H2020 – SC5_20 – 2014/2015	STSE, Explorer, Sentinel
Coastal operational oceanography		
Op. oceano. in ice covered seas		
Marine Rapid Environmental Assessment methods		
Marine environmental indicators		
Short-to-long range ocean forecast		

In Appendix A some of these specific scientific issues are further addressed followed by a mapping of the key research and development areas in the HORIZON2020 Framework Program (Appendix B) that are also indicated in the table above. This table should also be extended to include and cover emerging JPI research possibilities.

4. ROOS R&D priorities

Capital to EuroGOOS is the focus on the global ocean and the ROOS working networks that develop operational oceanographic services at the global level and in the different European and non-European Seas. EuroGOOS shares the ROOS with MONGOOS and Black Sea GOOS that are other two Regional Alliances.

4.1 Global Ocean

4.2 Arctic ROOS

4.3 BOOS

4.4 NOOS

4.5 IBIROOS

4.6 MONGOOS

4.7 Black Sea GOOS

5. Recommendations

6. The SAWG Composition

SAWG met for the first time in Cork, April 2013. The Participants are listed below.

1. Nadia Pinardi	SAWG Co-Chair	INGV, IT
2. Johnny A. Johannessen	SAWG Co-Chair	NERSC, NO
3. Tomasz Dabrowski	IBIROOS	MI, IE
4. Henning Wehde	NOOS	IMR, NO
5. Ole Karup Jeth	BOOS	DMI, DK
6. Emil Stanev	WP19 Myocean Leader	HZG, DE
7. Kostas Nittis	EuroGOOS Director	BE
8. Gerasimos Korres	MONGOOS	HCMR, GR
9. Jan H.Reissmann	BOOS	BSG, DE
10. Glenn Nolan	IBIROOS	IMR, IE
11. Alessandro Crise	MONGOOS	OGS, IT
12. Pierre Brasseur	MyOcean	CNRS, FR
13. Mike Bell	Myocean	UK Met Office, UK
14. Giovanni Coppini	MONGOOS	CMCC, IT

Appendix A: Specific R&D issues

(i) Rationalizing the range of forecasting models

The transition from eddy-permitting (~1/4°) to eddy resolving (~ 1/12°) resolutions at basin- and global scales is now gradually achieved. For coastal applications, downscaling to eddy resolving scales (~ 1/60°) smoothly nested into basin-scale configurations must be developed. For the global and basin scales the ~1/12° horizontal resolution is a good compromise between the wave lengths resolved by numerical grids and those captured by present-day observing systems. For the shelf-and coastal seas, on the other hand, the data coverage is in-sufficient and many of the dominant processes poorly incorporated and resolved. The strategy for progress towards resolving the finer scales (~ 1/60°) will rely on research and development into new physical parameterizations and discretization schemes that can be adapted to the interactions of large-scale, mesoscale and coastal scales down to turbulence effects. In particular there are needs to gain understanding of: (i) processes governing variability in the surface layer (mixed layer turbulence, interactions with air-sea fluxes) and linking surface wave, currents and sediment resuspension; (ii) processes in the bottom boundary layer including resuspension that are important, e.g., for the exchange of properties across shelf breaks and for the behavior of dense sill overflows and better water column optics; (iii) effects of the sub-mesoscale part of the eddy spectrum not resolved by the operational systems; and (iv) diapycnal mixing processes in the ocean's interior (internal wave breaking).

Research and development effort are also needed to enable advancement regarding temporal scales, notably: (i) improved short term predictions (forecasts) based on the best possible atmospheric forcing functions, and (ii) qualified re-analyses (hindcasts) of the past variability on seasonal to decadal time scales. The optimal reconstruction of the dynamical ocean using remote sensing and *in situ* measurements recorded during the past 20-50 years will require well-tuned systems including new developments to comply with the expected applications from the reanalysis. Specifically, the "smoothers", 4D versions of statistical assimilation schemes, will progressively substitute the conventional 3D sequential schemes implemented today, as in hindcast mode both "past" and "future" data will be available for assimilation. In addition, the scope of re-analyses will gradually encompass the biological component coupled to the physical component.

Advancement of numerical schemes are also relying on testing and implementation of high-order advection schemes, numerical treatment of side wall boundary layers using partial coast lines, specific dissipation schemes and improved open boundary conditions (for regional models).

(ii) Data assimilation

The reduction of uncertainties is a central challenge for operational modeling and services, which requires permanent innovations in data assimilation. Present day assimilation approaches encompass a hierarchy of methods of increasing complexity, ranging from optimal interpolation to non-linear stochastic methods. Ensemble-based assimilation methods (including the EnKF and the SEEK filters) has led to significant improvements in theoretical foundations and practical implementations. To provide more reliable estimation of associated errors on the ocean state variables the research and development effort needs to focus on:

- 4-D extension of statistical assimilation algorithms to comply with new operational products such as reanalyses of global ocean and regional seas.

- New implementations to improve atmospheric forcing using available observations via the ensemble Kalman filter and smoother.

- Non-Gaussian extensions for non-linear transformations of probability distributions (lognormal or empirical polynomial fits, spatially or temporally varying transformations) to reduce data assimilation biases by more realistic stochastic models.

- Data assimilation for coastal regions must be constructed to assimilate physical data (sea level, surface waves, surface currents, temperature & salinity, in situ profile data (from fixed moorings and / or gliders) into operational models of shelf seas.

(iii) Uncertainty estimation for ensemble and super-ensemble forecasting,

Atmospheric and oceanic ensemble forecasting is a way to deal with uncertainty related to inaccurate knowledge of the initial state of the atmosphere and the ocean, the lateral and vertical boundary condition errors and the model physics shortfalls (Lewis, 2005, Epstein, 1969). Since the atmosphere and the ocean are extremely non-linear systems (Lorenz, 1993, Saravanan et al., 2000) initial uncertainties can amplify and limit the predictability of short term forecasts (Kleeman and Majda, 2005).

Ensemble forecast methods are well established in meteorology but much less in oceanography. Traditionally initial conditions are perturbed and several forecasts are run forming an ensemble of predictions used to study and calculate the probability distribution of the forecasts. The different initial conditions are produced by perturbation techniques, some of them very sophisticated (Cai et al., 2003). In complement, one may also perturb the boundary conditions as is often done often in oceanography (Barth et al. 2009; Melsom et al. 2012) and turn model parameters into stochastic variables (Plant and Craig, 2008). Using these methods the uncertainty in the predicted events of the forecast, typically jet stream intensification, synoptic events moving across the domain of interest, are quantified in terms of the ensemble variance. When the ensemble variance is high, the uncertainty in the prediction is also high, indicating a sensitivity of the system to amplify small initial perturbations. Ensembles can also provide a fully multivariate and flow-dependent covariance matrix that can be used for data assimilation, as in the Ensemble Kalman Filter initially proposed by Evensen (1994). A variety of practical implementations of ensemble techniques for weather forecasts have been proposed (Toth and Kalnay, 1993, Molteni et al., 1996, Houtekamer et al., 1996) and ensemble systems are now used operationally in weather forecasting centers (e.g. Houtekamer et al., 2009) as well as in operational oceanography (Sakov et al., 2012). Ensembles play a crucial role in providing probabilistic information on the forecast variables of interest, especially for difficult but important state variables such as precipitation, and they have a large potential for applications (Zhu et al., 2002). Operational oceanography is presently developing these methods for marine short term forecasting (Counillon and Bertino, 2009).On the other hand, multi-model ensemble forecasting is being developed in atmospheric forecasting that helps to evaluate uncertainty due to model errors provided there are no common error sources. Such techniques are now used to successfully evaluate climate change scenario experiments. Such methods should also be developed and explored for operational oceanography.

(iv) Assembling test-bed data sets

The quality of ocean modeling products and services critically depend on the availability of state-of-the art *in situ* and remote sensing input data sets. Major improvements in data assimilation systems are expected thanks to the systematic use of new or improved data sets (e.g. Argo T and S profiles, velocities from drifters and floats, ocean colour, high resolution altimetry, GRACE and GOCE, SMOS, CRYOSAT, new SST sensors, SAR for sea ice). Research and development activities for high level processing issues (validation, intercalibration, error characterization, development of new products) are mandatory for an effective use of data in assimilation systems and/or for services.

(v) Exploitation of remote sensing

Research and development efforts are needed to advance the error characterization of satellite data, improve the synergy and merging of different satellite sensor data such as from the Sentinels (in particular Sentinel 1, Sentinel 2 and Sentinel 3), and secure that recent satellite sensor data such as from GOCE, SMOS and Cryosat are effectively assessed and validated by the operational oceanography system. In this respect specific attention must be paid to the HORIZON2020 Space call for 2014 and 2015, in particular the call for Earth Observations including (a) space based applications, (b) tools for access to space data and (c) climate change relevant monitoring and reprocessing:

EO 1 - 2014: New ideas for Earth-relevant space applications

EO 2 - 2014: Stimulating wider research use of Copernicus Sentinel Data

EO 5 – 2014: Observation capacity mapping and needs for Climate change monitoring

EO 1 – 2015: Bringing EO applications to the market

EO 2 – 2015: Stimulating science use of Copernicus Sentinel Data

EO 3 – 2015: Climate Change relevant space-based Data reprocessing and calibrationFurther details are provided in Appendix B.

(vi) Development of a monitoring strategies

In H2020 – SC5_16 – 2015: Strengthening the European Research Area in the area of Earth Observation there is a very good opportunity to seek dedicated funding for the development of comprehensive and sustained global environmental and information system. It is clear that it is necessary to capitalize on this with respect to the need to develop and design a sustainable marine observing system for climate and environment. Further details on this funding opportunity are found in Appendix B.

(vii) Optimum design of observational networks

Observing system simulation experiments (OSSEs) are expected to be more routinely applied for design of observational networks in the 2020 time frame. In HORIZON 2020 there is a special call line (still under discussion) in BLUE GROWTH: UNLOCKING THE POTENTIAL OF THE OCEANS targeting: developing in-situ Atlantic Ocean Observations for a better management and exploitation of the maritime resources [2014]. It is highly necessary to take advantage of this funding opportunities to advance the development and design of an optimum observational network with particular focus on the in-situ aspect. Likewise it is important to take benefit of the call line H2020 – SC5_18 – 2015: Developing and demonstrating 'next-generation' in-situ community observatories. There is also an additional specific call for coordination and supporting the strengthening of Earth Observation networks which need action, notably: H2020 – SC5_19 – 2014/2015: Coordinating and supporting Earth Observation research and innovation in Europe and in the North African, Middle East, and Balkan region. Appendix B provides further details.

(viii) Generic aspects of coupling numerical models

The climate science community will need to enter into a new era of climate information systems, which take into account the usefulness, provision, accessibility and quality of data. In order to maintain Europe’s leadership in this field and meet the challenges of climate change, significant progress is required in parallel in the development of both climate modelling and climate services. In H2020 - SC5_1 - 2014: High resolution Earth-system models funding opportunities are specified (see Appendix B).

(ix) Extension of forecasts towards biological/ecological state variables

The maturity already achieved in global and regional ocean circulation needs to be extended in other aspects of the marine environment. Major challenges are to accurately estimate and forecast the distribution of marine bio-resources, and to provide real-time monitoring of global or basin-scale air-sea carbon exchanges. Specific research and development efforts needs to be deployed to improve ecosystem process parameterizations, physical/biological interactions, forcing functions and integrated modeling systems with data assimilation capabilities. More robust approaches will be developed to extract key information from operational products to constrain the biological models, and also efficient methods to assimilate satellite ocean color data into predictive models.

In particular improved ecosystem models to forecast small pelagic fisheries are relying on research and development of: - coupling functions between hydrodynamic/plankton models and Individual Bases Model (IBM) models; - incorporation of inequality constraints during the analysis phase of assimilation schemes (SEEK, EnKF, OI, 3D-VAR), - more accurate parameterizations and forcing functions (e.g. light penetration) of the coupled model equations using ocean color information (such as intrinsic optical properties, and possibly other *in situ* data) assimilation and parameter estimation techniques. A complementary demanding requirement in this respect is the access to data from an observing system that can capture the processes and interactions at appropriate spatial and temporal scales, hereunder also river fluxes and transport of nutrients and suspended matter.

Research and development of biogeochemical models for monitoring air-sea carbon fluxes are also needed for inferring reliable pCO2 and carbon fluxes from ocean color data combined with basin-scale models. Such models must reliably convert from ocean color measurements of chlorophyll to carbon within the phytoplankton, account for sub-annual variations in upper-ocean dissolved organic carbon, and link phytoplankton biomass to carbon export associated with sinking.

A measure that is supporting new research and development in this particular field emerges in HORIZON2020 under the call line H2020 – SC5_17 – 2014: Making Earth Observation Data usable for ecosystem modelling and services (see Appendix B for further specific information) and the call (still under discussion) targeting**:** BLUE GROWTH: UNLOCKING THE POTENTIAL OF THE OCEANS - improving the preservation and sustainable exploitation of Atlantic marine ecosystems [2015]

(x) Education and Training in Operational Oceanography

A potential obstacle for the development of operational oceanography and its support to marine services and cutting-edge scientific research is the lack of scientists, engineers and technicians with specific interest in this challenging and multidisciplinary area of research and development. It is therefore necessary to initiate activities and program to attract the interest of a significant number of students towards the field of operational oceanography. This might be further pursued in n the HORIZON2020 Space call line COMPET 10 – 2014: Outreach through education. Further details are found in the Appendix B.

(xi) Dissemination: visualisation, analysis

New technological platforms and innovative software has to be developed in order to make accessible the information and the products of operational oceanography. The amount of data available and the challenges of diaplaying them in a form useful to many end-users is one of the cornerstones of innovation in the field of data exploration and mining. Analysis tools should be devised that bring together scientific ocean state estimates and forecasts and other public sector information, including diverse topics such as demographics, health, economy and crime.

(xii) Access to high performance computing

(xiii) Coastal operational oceanography, including coastal engineering

(xiv) Liaison with existing European & International agencies.

ESA Living Plant Program – Scientific Challenges

The scientific challenges specified in the ESA Living Planet Program is currently under revision. It contains the following specification of priorities regarding ocean and sea ice research.

- Quantify the interaction between variability in ocean dynamics, thermohaline circulation, sea level, and climate.
- Understand physical and bio-chemical air/sea interaction processes
- Understand internal waves and the mesoscale in the ocean, its relevance for heat and energy transport and its influence on primary productivity.
- Quantify marine-ecosystem variability, and its natural and anthropogenic physical, biological and geochemical forcing.
- Understand land/ocean interactions in terms of natural and anthropogenic forcing.
- Quantify the distribution of sea-ice mass and freshwater equivalent, assess the sensitivity of sea ice to climate change, and understand mechanical behavior of sea ice and thermodynamic and dynamic feedbacks to the ocean and atmosphere.
- Quantify the mass balance of grounded ice sheets, ice caps, and glaciers, partition their relative contributions to global eustatic sea-level change, and understanding their future sensitivity to climate change through dynamic processes
- Quantify the influence of ice shelves, high-latitude river run-off and land ice melt on global thermohaline circulation, and understand the sensitivity of each of these fresh-water sources to future climate change

Moreover in H2020 – SC5_20 – 2014/2015 call line: Coordinating and supporting research and innovation in the area of climate action, environment, resource efficiency and raw materials there is an opportunity to create better transnational cooperation and coordination of research and innovation policies, programmes and initiatives in the area of climate action and environment (further details are annotated in the Appendix B).

(xv) Operational oceanography in sea ice covered seas.

Better sea ice models based on a solid mechanical modelling framework are needed to adequately represent the present sea ice state in coupled sea ice and ocean models. Currently new development with wide scientific targets, from forecasting sea ice conditions in near real-time to predicting the state of future Arctic climate (P. Rampal, NERSC) is currently taking place based on a new Elasto-Brittle (EB) sea ice rheology that allows simulation of the very high localization of sea ice deformation along so-called linear kinematic features (LKFs), and the associated sea ice motion. The model is strongly constrained by both satellite and in-situ observations of sea ice drift and deformation. An evaluation of the simulations is performed using a metrics that take advantage of these observations. The observations are thus highly critical for the development and assessment of this model.

The next step will be to fully couple the sea ice model to an ocean model. Further development of the sea ice model also needs to evolve toward a full dynamic-thermodynamic sea ice model in order to, for instance, adequately account for refreezing of cracks and solidification of ridges. These remaining theoretical and technical modelling challenges highly rely on research and mulitdisciplinary expertise in sea ice physics, sea ice-ocean physical interactions and computational modelling. Complementary, there will also be need for research to:

(i) sustain the development of current or new algorithms for sea ice tracking from SAR images;

(ii) improve the way available drift datasets are processed to retrieve sea ice deformation; (iii) process all the available satellite datasets (SAR) to generate one consistent Lagrangian ice motion dataset as well as an associated ice deformation dataset;

(iv) facilitate continuous processing of Sentinel 1A/B data in near real-time.

(xvi) Marine Rapid Environmental Assessment methods

(xvii) Science-based Marine Environmental Indicators

(xvi) Extension towards long range forecasting

Extension of short range forecasts toward long range forecasting and the improvements of two-way interaction of operational oceanography and marine environmental and climate change research are also relying on fundamental science.