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Oral presentations

INTAROS: Integrated Arctic observation system development under Horizon 2020

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INTAROS is a research and innovation action under the H2020-BG-09 call in 2016 and will run from 2016 to 2021. The main objective of INTAROS is to develop an integrated Arctic Observation System (iAOS) by extending, improving and unifying existing systems in the different regions of the Arctic. INTAROS has a strong multidisciplinary focus, with tools for integration of data from atmosphere, ocean, cryosphere and terrestrial sciences, provided by institutions in Europe, North America and Asia. Satellite earth observation (EO) data plays an increasingly important role in such observing systems, because the amount of EO data for observing the global climate and environment grows year by year. EO data will therefore be integrated into iAOS based on existing products and databases. In situ observing systems are much more limited due to logistical and technological constraints. The sparseness of in situ data is therefore the largest gap in the overall observing system. INTAROS will assess strengths and weaknesses of existing observing systems and contribute with innovative solutions to fill some of the critical gaps in the in situ observing network. The evolution into a sustainable Arctic observing system requires coordination, mobilization and cooperation between the existing European and international infrastructures (in-situ and remote including space-based), the modeling communities and relevant stakeholder groups. INTAROS will include development of community-based observing systems, which are combined with scientific data. An integrated Arctic Observation System will enable better-informed decisions and better-documented processes within key sectors (e.g. local communities, shipping, tourism, fishing), in order to strengthen the societal and economic role of the Arctic region and support the EU strategy for the Arctic and related maritime and environmental policies.

Multipurpose Acoustic Networks in the Arctic.

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The largest gap in the overall Arctic observing system is in the in situ ocean observing system. Advanced drifting ice-ocean observatories provide multi-disciplinary data in near real time, but they relay on stable ice conditions, which can be difficult to find in the new Arctic. Profiling floats and gliders, frequently used on open ocean, have to surface to transmit data, update the clocks, and geo-position via satellite. In ice covered regions it might not be possible to surface for several months, and during this time the sensors will collect data, but the positions were the data is taken will be unknown and the clocks will not be corrected. This presentation will focus on how acoustic networks can contribute to development of a sustainable Arctic Ocean Observing System. A fixed acoustic mooring systems in the Arctic Ocean will provide underwater geo-positioning system all users as well as acoustic thermometry and passive acoustic. Drifting acoustic networks are cheaper more accurate as long as the float or the glider is within range, but limited to specific experiments and users. Moored multipurpose acoustic network in the Fram Strait has been developed in a sequence of experiments. A pilot experiment

in 2008-2009 was followed by the implementation of a multipurpose acoustic network (2010-2012) with a triangle of acoustic transceivers for ocean acoustic tomography, ambient noise, and glider navigation. The thermometry and passive acoustic measurements were continued with eight acoustic paths crisscrossing the Fram Strait from 2014 to 2016. A similar experiment is currently carried out in the Beaufort Sea. New initiatives for deploying acoustic systems in the Baffin Bay and north of Svalbard have been taken. These initiatives to establish multipurpose acoustic networks in the Arctic are timely in the context of the new cluster of Arctic projects funded by EU's research program HORIZON 2020.

The strategy for evolution of Argo in Europe

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The international Argo programme is a major element of the global in-situ ocean observing system. More than 3900 floats are now globally measuring temperature and salinity throughout the whole ocean down to 2000 meters depth, delivering data both in real time for operational users and after careful scientific quality control for climate change research and monitoring. The Euro-Argo research infrastructure organizes and federates European contribution to Argo. A legal and governance framework (Euro-Argo ERIC) was set up in May 2014 that allows European countries to consolidate and improve their contribution to Argo international. We will provide an overview of the development of Euro-Argo over the past years and present the now agreed Euro-Argo long term organization. The ability of the Euro-Argo infrastructure to organize Argo floats procurement, deployment and processing at European level will be highlighted. During the recent years, within the H2020 E-AIMS project, Euro-Argo fostered R&D activities for enhancements of Argo floats, equipped with biogeochemical sensors or able to dive down to 4000m, acting from the floats design up to the analysis of their measurements. European Argo data centres have been adapted so that they can now handle the new data formats. In addition to its contribution to the core-Argo programme, one of the main challenges for Euro-Argo is now to implement the next phase of Argo with an extension towards biogeochemistry (e.g. oxygen, biology), the polar oceans, the marginal seas and the deep ocean. Meeting such challenges is essential for the research and the long-term sustainability and evolution of the Copernicus Marine Service. Euro-Argo has recently revised its deployment's strategy for the next decade. We will present this strategy and provide some highlights on the implementation-plan for the years to come.

The Arctic Marine Forecasting Center: an EU Copernicus service.

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The Arctic Marine Forecasting Center (MFC) from the Copernicus Marine services have been operational since May 2015 and offer near-term forecasts out to 10 days as well as 25-years reanalysis products assimilating satellite and in situ observations in the whole Arctic, including physical ocean, sea ice and wave variables, as well as biogeochemical variables. We will go through the present performance of the different Arctic MFC products and present the plans for further developments. See more on http://marine.copernicus.eu and http://cmems.met.no/ARC-MFC/index.html

Towards an integrated EU data system within AtlantOS

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The H2020 AtlantOS project started in June 2015 and aims to optimise and enhance the Integrated Atlantic Ocean Observing Systems (IAOOS). One goal is to ensure that data from different and diverse in-situ observing networks are readily accessible and useable to the wider community, international ocean science community and other stakeholders in this field. To achieve that, the strategy is to move towards an integrated data system within AtlantOS that harmonises work flows, data processing and distribution across the in-situ observing network systems, and integrates in-situ observations in existing European and international data infrastructures (Copernicus marine service, SeaDataNet NODCs, EMODnet, OBIS, GEOSS) so called Integrators. The targeted integrated system will deal with data management challenges for efficient and reliable data service to users: • Quality control commons for heterogeneous and nearly real time data • Standardisation of mandatory metadata for efficient data exchange • Interoperability of network and integrator data management systems To facilitate the access to the Atlantic observations and avoid “mixing apples with oranges”, it has been necessary to agree on (1) the EOVs list and definition across the Networks, (2) a minimum set of common vocabularies for metadata and data description to be used by all the Networks, and (3) a minimum level of Near Real Time Quality Control Procedures for selected EOVs. Then a data exchange backbone has been defined and is being setting up to facilitate discovery, viewing and downloading by the users. Some tools are recommended to help Network plugging their data on this backbone and facilitate integration in the Integrators. Finally, existing services to the users for data discovery, viewing and downloading have been enhanced to ease access to existing observations

JERICO-RI The integrated coastal component of the European Ocean Observing System

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The JERICO European research infrastructure (RI) is integrating diverse platform types such as fixed buoys, piles, moorings, drifters, FerryBoxes, gliders, HF radars, coastal cable observatories and the associated technologies dedicated to observe and monitor coastal European seas. The first steps including setting up, coordination and harmonization were done during 2011 to 2015 in the framework of JERICO (FP7), a 4-year long infrastructure project co-funded by the European Commission with 27 partners from 17 European countries under the coordination of IFREMER. Next steps are driven in the H2020-JERICO-NEXT European project until 2019, involving 34 partners. The main objective of the JERICO consortium is to establish a Pan European approach for a European coastal marine observatory network. This is a dynamic activity going beyond a project's lifetime including continuous efforts towards harmonization in terms of design, operation, and maintenance, the evolution and extension of the current systems as well as the delivery of data and products to the users. To reach this main target an important work needs to be coordinated farther from FP7-JERICO to JERICO-NEXT, and after, at both hardware and software levels. More specifically, the existing network and its possible evolution are continuously assessed taking in account the harmonization effort to be driven, the existing sensors and technologies, their upgrades for integration on dedicated platforms, also the accompanying of under development sensors and/or systems with involvement of providers and stakeholders when possible. The main issue deals with the sustainability of the infrastructure by considering its economics and it governance framework on long term, in addition to the scientific and technological one. The 6 scientific areas to be derived from the scientific strategy to their technology implementation are namely: (1)the pelagic biodiversity, (2)the benthic one, (3)the chemical contaminant occurrence, and related biological responses, (4)the transboundary hydrography and transports, (5)the carbon fluxes and carbonate systems and (6)the operational oceanography.

Deployment of new observing systems thanks to the JERICO-RI

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A key message of the JERICO-RI consortium (2014): "The complexity of the coastal ocean cannot be well understood if interconnection between physics, biogeochemistry and biology is not guaranteed.

Such integration requires new technological developments allowing continuous monitoring of a larger set of parameters". In agreement with this consideration, several new observing systems are developed, tested and deployed in the framework of the JERICO-NEXT H2020 project, amongst which a few of them will be presented as well as some preliminary results after the first deployments. Focus will be given on i) coastal transports ii) phytoplankton biodiversity at high temporal and/or spatial resolution iii) benthic biodiversity. In the first case, we will present a low cost 2D moored system dedicated to acquire vertical temperature profiles in shallow waters and their application to study the high frequency hydrodynamics. In addition, during one of the campaigns foreseen for testing these new systems in an area covered by HF radar, floating marine litter will be collected. In the second case attention will be drawn on phytoplankton automated measurement methods: comparison and deployment according to the trophic and environmental water characteristics. In the last case a new floating pulled system dedicated to observe benthic habitat without disturbing it will be presented.

COAST-HF - A fixed-platform network along French coasts

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COAST-HF (Coastal OceAn observing SysTem – High Frequency) is an observation network of the physical and biogeochemical high frequency dynamics of the coastal ocean. COAST-HF aims understanding and analysing the evolution of the coastal ecosystem at different temporal scales from extreme or intermittent high frequency (hour, day) events to multi-year trends. Since several years (from 2000 for the longest time series in Bay of Brest), the network extends along the Atlantic and Mediterranean French coasts through 13 fixed platforms instrumented for the in situ high-frequency (≤ 1h) observations. Several French research institutes (IFREMER, CNRS, Marine Universities) are operating these systems. This organization in a unique network for these coastal observing systems aims operating an optimal system to pool efforts and initiatives (e.g. human resources for data management), to converge on best practices, and to support common measurement standards. On this basis, scientific key questions can be addressed as the eutrophication processes and effects on dissolved oxygen or the influence of main river plumes on sediment dynamics. This coastal observing network is part of a national Research Infrastructure (ILICO) dedicated to the nearshore and the coast. COAST-HF is also contributing to the Marine Strategy Framework Directive. Time series obtained from these multi-parameter moorings will be presented highlighting specific events that have been observed based on this network.

The Coastal Observing System for Northern and Arctic Seas (COSYNA): Challenges and Solutions for an Integrated Measurement and Modelling Approach

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The automated observing and modelling system COSYNA has been established in order to better understand the complex interdisciplinary processes governing the Northern Seas and the Arctic coast in a changing environment. It is designed to monitor real-time conditions and provide short-term forecasts, data, and data products to help assess the impact of anthropogenically induced change. Observations are carried out by combining satellite and radar remote sensing with various in situ platforms (such as under water nodes and FerryBoxes). Novel sensors, instruments, and algorithms are developed to further improve the understanding of the interdisciplinary interactions between physics, biogeochemistry, and the ecology of coastal seas. New modelling and data assimilation techniques are used to integrate observations and models in a quasi-operational system providing descriptions and forecasts of key hydrographic variables (as, for instance, current fields), while taking the challenges of different scales and resolutions between models and observations into account. In COSYNA, scientific questions related to topics such as environmental effects of offshore wind farms, the importance of sub-mesoscale processes for the marine environment, coastal flooding and defence against storm surges as well as morphology changes due to sediment transport, to name a few, are addressed. Data and knowledge tools are developed and provided for the use of multiple interest groups in industry, agencies, politics, environmental protection, or the public. For the years ahead major challenges for the further development of COSYNA and similar systems will lie in a stronger integration of regional and continent-scale processes, i.e., in communicating and bridging with other European observing and analysis systems as well as in the integration of biological and ecosystem aspects into models and data assimilation. Such a system will be a substantial element of the European Ocean Observing System integrating coastal and open-ocean observatories, aiming to provide answers to the pressing questions that the oceans and coastal regions are facing.

Toward integrated marine observing system in Croatia

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In Croatia, there are more marine operational stations, which have been performed by more institutions. Recently several Croatian marine institutions have been formed Consortium for upgrading marine monitoring system and its integration. As a part of this activity, Institute of oceanography and fisheries (IOF) in collaboration with other members of Consortium has been upgrading of existing and developing new oceanographic stations with the aim to install integrated marine data and information system. This system includes the observational network of various types of operational oceanographic stations, data transmission in “real time” and receiving centre for data management. Existing observational network consists of more real-time observational stations including six coastal sea level gauges, VF radar stations, two oceanographic buoys, several coastal meteo-oceanographic stations, three microbarographs for studying of meteocunamys, and more stations at the ships. Management centre, as a part of the integrated system, serves for the management of classical oceanographic data collected by R/V cruises, and “real-time” data measured by “real-time” operational systems. As a part of the integrated system it has been developing subsystems for automatic presentations outputs from statistical and numerical models, generation of aggregated data of national marine indicators and monitoring data from Croatian

marine beaches in the framework of the implementation of MFSD and WFD in Croatia. According to plan, Consortium has been led by Croatian Meteorological Service prepared plan for installation at least five meteo-oceanographic buoys in the open sea of the Adriatic and more wave stations in the next two years, IOF will upgrade and extension more coastal stations including three additional sea level stations at with additional meteorological and oceanographic sensors at the Croatian islands located in open sea and implements forecasting system, providing marine information service and facilitate decision support needs and other users (Government, counties, municipalities, coastal guard, scientists, etc.).

The POSEIDON system, an integrated observing infrastructure at the Eastern Mediterranean as a contribution to the European Ocean Observing System

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The scarcity of oceanic observations of the air-sea interaction together with the oceanic processes (coastal, open, deep ocean) in the proper spatial and temporal scales under long-term recording schemes is one of the challenges that a European Ocean Observing System should meet. This is mainly due to the complexity of the marine environment in conjunction with the technological barriers. In the Mediterranean Sea, the existing gaps in the observing facilities are high, especially in the eastern part of the basin. POSEIDON is one of the very first efforts towards a comprehensive marine monitoring and forecasting system, that aims to improve environmental monitoring and facilitate sea transport, rescue and safety of life at sea, fishing and aquaculture and protection of the marine ecosystem. Over the last few years POSEIDON has adopted a multiplatform-multiparameter approach with the current system's status including open and coastal sea fixed platforms, deep-ocean observatory, Ferrybox system, HF radars, and Argos floats. Since 2010, the list of biogeochemical-ecosystems parameters has been expanded by the addition of sediment traps, frequent R/V visits for water-plankton sampling, and of an ADCP delivering information on macrozooplankton-micronekton vertical migration. Gliders and drifters are the platforms currently under integration. Land-based facilities, such as data centre, technical support infrastructures, calibration laboratory, mesocosms, provide the added value to the observatory. The collected data enhance the atmospheric and the marine physical and biogeochemical-ecosystem forecasts as well as the provided wrap-up services such as the oil spill predictions. Besides replying to scientific questions at regional and international level, the observatory provide services to marine policy-makers and the society, and is a technological test bed for marine technology. It is evident that, with its present characteristics -a national system with an integrated approach and a centralized management- POSEIDON can be considered as a direct contribution towards EOOS implementation.

FerryBoxes within Europe: State-of-the-art and Integration in the European Ocean Observation System (EOOS)

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The development and use of FerryBox systems as a cost-effective instrument for continuous observations of the marine environment has been well established since more than 15 years. The systems have evolved to maturity and are since widely used around the coastal ocean of Europe. The availability of newly developed sensors allows the extension of FerryBox measurements to more biogeochemical parameters which are of interest for the requirements of the Ma, rine Strategy Framework Directive (MSFD). The FerryBox community initially formed from the partners of an EU funded FerryBox project provides mutual exchange of experience and is now organized within EuroGOOS as a so called FerryBox Task Team (www.ferrybox.org). Within the EU funded infrastructure projects JERICO and JERICO-NEXT the technical harmonization as well as the developing of best practise guides for FerryBox systems have been a step further to high quality environmental data products. Within JERICO-NEXT it has been decided to build up a common FerryBox database and data portal in order to make the FerryBox data more available and visible. Furthermore this database will be function as a close link to the Copernicus Marine Environmental Monitoring Services (CMEMS) and the EMODnet portal. The presentation will give an overview about the FerryBox network in Europe including examples of application as well as the status of the European FerryBox database/data portal and the connection to the European Marine data services.

Future scenarios for the growing European HF Radar network

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JERICO-NEXT (H2020 2015 Programme) is largely contributing towards an integrated and sustained European coastal network of High-Frequency Radars (HFRs). The work in progress is focused on seeking harmonization, data and metadata standardization, on developing and giving access to quality control procedures and new products, and finally on demonstrating the use of such technology in the general scientific strategy focused by the Coastal Observatory. The efforts in JERICO-Next are encompassed with the work being done by the EuroGOOS HFR Task Team, which provides an umbrella for enhancing the contribution of different projects to maximize the impact of the HFR data on the maritime economy and coastal management. In this way, EMODnet Physics started to assemble HFR metadata and data products within Europe in a uniform way, while, INCREASE (Copernicus Marine Environment Monitoring Service Evolution 2016) is setting the necessary developments towards the integration of existing European HFR operational systems into CMEMS. In this contribution, we provide, in addition to an overview of JERICO-NEXT progresses, an update of the European HFR inventory including the short-term plans for installing new stations at national or local level. On top of this coming infrastructure, different scenarios of the European network have been designed from a larger perspective. The proposal considers the capabilities of the HFR emerging technology to monitor coastal ocean processes in key areas of specific regions, the geographical distribution of the maritime activities, monitoring needs arising from a gap analysis, and possible integrations with other observing platforms or modeling tools. These outlines integrating HFR platforms as important operational components of EOOS, aims to meet the demand for frequent provision of current measurements. The potential of HFR data, with synoptic observations in wide coastal areas, opens real perspective to drive at European level the improvement of the coastal ocean observing and forecasting capacity.

CMEMS Present and Future Requirements for Satellite and In-Situ Observations

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The Copernicus Marine Environment Service (CMEMS) provides regular and systematic information on the state of the Physical Ocean at global and regional level. The products delivered by the service are used in many domains, from the commercial to the R&D sectors. Daily operations and evolution of the service are tightly linked to the supply of upstream data, from the Copernicus space and in-situ components, and the proper specification of requirements. This core dependency must be managed strategically to ensure the requirements of the future are in the observing plans of today. Regular access to Remote Sensing data is managed in collaboration with ESA and EUMETSAT, in charge of the dissemination of Copernicus Satellite data (Core and Contributing missions). This is regulated by well-

defined operational requirements set to keep the quality of the service to an appropriate level. Requirements for the long term evolution of the Copernicus Satellite Component are regularly gathered and discussed by a dedicated CMEMS scientific and technical committee and reported to EC and Space Agencies. An important contribution to the definition of in-situ requirements and to the identification of area of potential improvement is ensured by a strong working relationship with EUROGOOS and Rooses. Operational aspects of the in-situ provision are managed in strict collaboration with the CMEMS In-Situ Thematic Assembling Center, while the high-level coordination points are coordinated together with the European Environment Agency (EEA) All these aspects will be the subject of the present work. Details about present strategy and future requirements will be presented and discussed; main recommendations from CMEMS will be outlined.

Assessment of Baltic Sea observations for operational oceanography

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Baltic Sea is a semi-enclosed sea with many active on-going monitoring activities: operational monitoring coordinated by BOOS partners with tidal gauges, ferrybox, moorings, gliders, argo profilers and research vessels; regular environment monitoring in the HELCOM framework covering a comprehensive list of physical, biogeochemical and ecological parameters, and field experiments for research purposes. Based on the outcomes of previous and on-going EU projects ODON, ECOOP, OPEC, JERICO and BSCP as well as national projects in BOOS partners, this presentation will describe the status of Baltic Sea marine observations, assess the data adequacy for operational oceanography and give recommendations for future Baltic contribution to a sustained European Ocean Observing System (EOOS).

New sources of in-situ marine data to support EC Marine Strategy Framework Directive Implementation in the Black Sea

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Maintaining good environmental status of marine and inland waters is essential for Bulgaria. It will ensure that the resources of the ecosystems are maintained along with the economic and social benefits deriving from them. Initial assessment of ecological state of Bulgarian marine waters showed lack of data for some descriptors of MSFD. Knowing this Bulgarian government established programme BG02 INTEGRATED MARINE AND INLAND WATER MANAGEMENT, managed by Bulgarian Ministry of environment and waters and co-financed by the Financial Mechanism of the European Economic Area (EEA FM) 2009 – 2014. Two of the projects supported under the programme (IMAMO and MARLEN) were dedicated to the improvement of the monitoring capacity and expertise of the organizations

responsible for marine waters monitoring in Bulgaria to meet the requirements of EU and national legislation. The main goals are to establish a real time monitoring and to build up tools for assessment of marine environment by implementing new technologies and best practices for addressing three main areas of interest with lack of marine data in particular: a) Marine litter detection and classification in coastal areas; b) Regular near real time surface water eutrophication monitoring on large aquatory; c) Underwater noise monitoring. The main outcomes of the projects are to fill the gaps in information from the Initial assessment of the marine environment and to collect data to assess the current ecological status of marine waters including information as a base for revision of ecological targets established by the monitoring programme prepared in 2014 under Art. 11 of MSFD. Developed tools are an important source of real time, near real time and delay mode marine data for Bulgarian Black Sea waters. Project results supported implementation of MSFD in Bulgarian marine waters for the benefit of coastal population, marine industry, tourism, marine research and marine spatial planning.

Novel, multi-platform acoustic and optical sensors and data services developed in the NeXOS project

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Two main sensing techniques were implemented in the European Union FP7 project “Next generation, Cost- effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management” (NeXOS, 2013-2017), reported on here. NeXOS developed two types of innovative passive acoustic sensors - one having a single detector with increased dynamic range and internal processing to reduce communication requirements and the other having an array of four such sensors providing directional capabilities. The optical sensors were Matrix fluorescence sensors, Flow-through cavity absorption sensors, and sensors for monitoring the carbon system. The selected platforms for the sensors were gliders, voluntary observing ships (Ferrybox), a seafloor cabled observatory, an autonomous surface vessel (Sailbuoy) and fishing vessels.

The aims of the NeXOS project were to provide innovative and practical solutions to some of the challenges of comprehensive ocean observations such as the need to reduce power requirements, reduce data communication bandwidth, introduce new frameworks for interoperability and provide operations and users with improved information.

In the integration work, the sensors were modified to enable plug-and-play capabilities on basis of the Open Geospatial Consortium (OCG) PUCK protocol embedded in the internal software. This protocol ensures that measured data are accompanied by metadata describing the sensor and its history. The OGC Sensor Web Enablement (SWE) and the Sensor Observation Service (SOS) web server make data from the NeXOS sensors available in real-time by the end-users.

The sensor systems were functionally and scientifically validated at sea under real conditions. The final demonstrations took place over several weeks during summer of 2017 in the Northeast Atlantic, Central Atlantic and the Mediterranean with replicas of each sensor type. This manuscript provides an overview of the NeXOS project and the functionality of the sensors and services, shown through selected examples from the 1-month demonstration missions. Results are presented, including system functioning, timeliness, operational and user's experiences and data, and data quality assessment.

Acoustic tomography as a component the Atlantic Ocean Observing System: Opportunities and Challenges

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Since its inception 40 years ago, ocean acoustic tomography has proven to be a unique measurement of large-scale ocean variability. The travel times of acoustic signals have measured large-scale temperature, barotropic current, and, with an array of transceivers, relative vorticity. Applications range from measurement of currents in shallow harbors, to measurement of basin- and global-scale temperature, to monitoring the evolution of deep-water formation events at high latitudes. Acoustical measurement often extends into abyssal depths. Acoustical observations and applications in ice-covered regions are compelling (cf. INTAROS). All such systems provide the dual purpose of providing an underwater GPS system for AUVs. One common perception is that the existence of the Argo float system obviates the need for acoustic tomography, but that perception has been demonstrated to be an error. While deployments of tomographic systems as components of the Ocean Observing Systems (regional or global scales) represent real opportunities for new insights into long-term ocean variability, the practical implementations of sustained acoustical systems are a challenge. At present, such challenges are programmatic or cultural, rather than scientific, however. Given the extraordinary climatological changes presently occurring in the Earth's ocean-atmosphere system, it is imperative that all available observational capabilities undergo a thorough consideration. There is an obvious need for studies employing numerical ocean models to design optimized observing strategies that exploit the complementary nature of various ocean measurement technologies. Observing Systems rely on data assimilation techniques to derived ocean state estimates as stakeholder products, so practical techniques are needed to implement data assimilation with the line-integral measurements that tomography affords. Programmatic technical capability and manpower to sustain acoustical measurements is lacking.

Ultimately, successful implementation of tomographic systems will require a stronger symbiotic relation between acousticians and oceanographers.

New acoustic profiling instrumentation with measurements of pCO2 and pH tested in the Southern Adriatic

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In the framework of the FP7-European project FIXO3 (Fixed point Open Ocean Observatory network) a new type of Acoustic Doppler Current Profiler (SeaguardII-DCP) recently developed at Aanderaa was installed and tested at the E2M3A site (http://www.fixo3.eu/observatory/E2-M3A/) in the southern Adriatic Sea (Eastern Mediterranean). The aim of the experiment was to evaluate the performance of this technology in clear/oligotrophic waters, which are known to affect negatively the acoustic range and performance. This instrument, together with new auxiliary sensor for pCO2 and pH, gave us valuable information about seasonal dynamics of the upper layer. The SeaguardII-DCP was installed in April 2014 at the E2M3A surface buoy, in a dedicated cage at 2m below the surface. The buoy is located in an area of dense water formation and seasonal phytoplankton blooms. Hence, collected data allow us an assessment of the role of the carbon pump during dense water formation events. Additionally, the sub surface currents recorded by the SeaguardII-DCP compared with meteorological data, deep-sea thermohaline and currents time-series measured at the site represent a unique opportunity to have a more complete overview of the complex dynamical system of the area. The collaboration between OGS and Aanderaa provided also the interesting opportunity to improve the data quality of the RCM-Seaguard installed at 1160m depth (20m above the bottom) at the E2M3A deep mooring. Technical experiments were performed in situ to verify and reduce the disturbance induced by zinc anodes and metal ballasts on the instrument.

Current and emerging in situ biogeochemical observations using the FerryBox platform in Subarctic and Arctic Norwegian waters

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In situ observations of the Norwegian coasts and oceans have been made with a network of ships of opportunity (FerryBox) since 2001. The FerryBox system is an autonomous, sensor-equipped, underway flow-through system deployed on passenger and container ships that operate in socioeconomically and environmentally relevant ocean regions including the North Sea/Skagerrak, the Barents Sea opening, and the western Norwegian coast. The basic sensor package measures seawater temperature, salinity, oxygen, chlorophyll-a fluorescence, and turbidity; and above water sensors measure wind, air pressure, and radiance/irradiance. In recent years, as part of EU sensor and ocean observation projects (JERICO-NEXT, NeXOS, MariaBox, INTAROS), we have been developing emerging sensor and sampling technologies for use with FerryBox systems to measure to inherent optical properties (including cDOM), phytoplankton functional groups, contaminants/toxins, microplastics, and carbonate system variables (pH, pCO2, [CO_3^{2-}]. These sensors provide knowledge pertaining to satellite ocean colour validation (EU HighROC, AquaUSERS, and Sentinel satellite validation projects), and Marine Strategy Framework Directives-related issues including the timing and duration of eutrophication and harmful algal blooms, the prevalence and dispersion of contaminants and marine litter, and temporal and spatial variability in ocean acidification. These observations are also used to inform national monitoring programs, as well as a demonstration platform in the EU Ocean Literacy project ResponSEAble.

Novel biogeochemical sensors: Operation of a newly developed total alkalinity analyser (TA) in combination with a FerryBox for better quantification of the carbon dynamics in the North Sea

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The North Sea is thought to be a site of efficient pumping of carbon dioxide from the atmosphere to the North Atlantic Ocean; however more measurements are necessary to fully understand the carbon cycling in this region. In addition to salinity and temperature, the variability in the carbonate system, necessitates high-frequency measurements of at least two of the carbonate system parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), pH, pCO2 or CO3. FerryBoxes have been successfully used over the past years to continuously measure pH and pCO2 along different sections of the North Sea. However, due to the low precision of standard pH sensors and the strong negative correlation of pCO2 and pH, the combination of TA and pCO2 measurements will give more reliable data about the total carbon budget. Within the EU project NEXOS, a newly developed autonomous flow-through TA analyser has been extensively tested and optimized in cooperation with the manufacturer (KM CONTROS). For the first time such a TA analyser has been successfully installed alongside a FerryBox aboard a cargo ship travelling between Cuxhaven (DE) and Immingham (UK). This flow-through TA instrument combined with continuous pH and pCO2, salinity, dissolved oxygen, CDOM and chlorophyll fluorescence measurements will provide better insights in the North Sea carbon cycling. Initial results will be presented and discussed. Combined with dissolved oxygen, these measurements can be used to quantify carbon fluxes and primary production in surface waters.

GlobCurrent – A Pre-operational monitoring system for surface current and upper ocean dynamics based on sensor synergy

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The GlobCurrent project (http://www.globcurrent.org) aims to advance the quantitative estimation of ocean surface currents from combined use of satellite and in-situ sensor synergy. It is demonstrated that sharp gradients in the sea surface temperature, the sun-glitter, the surface current and the ocean chlorophyll-a distribution are often spatially correlated with the sea surface roughness anomalies across a wide range (1-100 km) of spatial scales. Such expressions of 2-dimensional surface structures often represent evidence of the dynamics in the upper (~100-200 m) ocean. In this presentation we will demonstrate that systematic utilization of sensor synergy integrated into an advanced visualization platform strengthen the ability to study sub-mesoscale to mesoscale processes associated with upper ocean dynamics. As such, it is also highly valuable for regular intercomparison and validation of ocean models.

Euro-Argo in work and new potential of gliders in the Baltic Sea BOOS

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Argo-floats have been a part of the routine monitoring of the Baltic Sea since 2012. Finnish Meteorological Institute (FMI) began routine use of Argo floats in the Baltic Sea in 2012 after successful tests in 2011. As Finland is a partner of Euro-Argo ERIC and FMI is the representing entity there, FMI maintains a couple of Argo-floats in the North Atlantic and in the Baltic Sea. FMI's strategy is to keep continuously at least one Argo-float in the central basin of the Baltic Sea and another one or more in the

Gulf of Bothnia that is the northern part of the Baltic Sea. The Baltic Sea floats send profiles once a week. They are recovered and replaced about once a year and reused after maintenance service. The floats have proven to complement in a valuable way the ship based monitoring. FMI was a partner in European glider infrastructure project Gliders for Research, Ocean Observation and Management (GROOM) in 2011-2014. FMI has one glider in use and has done several glider missions in the Baltic Sea in 2016 and 2017. In May 2017 two gliders from two countries worked for the first time in the Baltic Sea together. Similar Slocum G2 gliders from FMI and Marine Systems Institute of Tallinn Technical University, Estonia worked in the same area in the same time within a project on water exchange between the Baltic Proper and Gulf of Bothnia. Both of the institutes have demonstrated that gliders are very potential instruments also for monitoring the shallow Baltic Sea.

Tracking mesoscale eddies from combined use of satellite altimetry and Argo profiling floats

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Mesoscale eddies in the North Atlantic Ocean and Nordic Seas are automatically tracked from satellite altimetry and collocated with Argo profiling floats for the period between 2002 and 2016. This provides an opportunity to monitor both the eddy propagation and the changes in the vertical structure of the water masses properties inside the eddies. In addition the spatial distributions of lifetime, occurrence, generation sites, size, intensity and drift of the eddies can be detailed and categorized versus cyclonic and anticyclonic eddies. This combination of satellite altimetry and Argo profiling floats is further shown to be highly important for validation of operational ocean models such as those used in the Copernicus Marine Environmental Monitoring Services (CMEMS).

Cross-shelf exchanges in the Bay of Biscay

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The Bay of Biscay is one of the key constituents of the Western European Continental Shelf, playing an important role in the interactions between the continental shelf and the open ocean waters. Southern part of the Bay of Biscay has been subject to various studies on these interactions. Despite these studies, interactions between the coastal sea and the open ocean remain unclear (as related with instability processes with short time scales) and are not quantified. In the frame of H2020 AtlantOS project, with the aim of identifying and quantifying these interactions, we investigate the shelf break region looking for cross-shelf exchanges from temperature and salinity in-situ measurements (Cruises, ARGO, RECOPESCA, Glider, XBT and others) for 2007-2014 from CORA-IBI dataset. Satellite derived Sea Surface Temperature (SST) is used as supplementary dataset in order to identify mesoscale or submesoscale structures in the area (i.e. filaments). In order to investigate exchange events,

simultaneously co-existing (and within short periods up to 1 month) profiles around the shelf break are categorized in main sub-regions (their area of existence). These sub-regions were then divided into three categories (based on bathymetry criteria) as: continental shelf, shelf break and open-ocean. Monthly averaged profiles (as well as climatological mean profiles) are calculated. Monthly averaged profiles of the shelf, shelf break and open-ocean of the sub-regions were used to identify imprints of cross-shelf exchanges (as anomalous profiles). These exchanges are further explored using remotely sensed SST. Based on this first identification, domains of interest using the identified cross-shelf exchange events are defined. First comparisons with a high-resolution numerical model experiment (1 to 2.5km spatial resolution - MARS3D model) are presented in order to mechanistically define cross-shelf exchange processes and their quantification. The present study is also contributing to the evaluation of the gaps between coastal and open ocean observation networks.

Operational Wave Height Monitoring Using Navigation Buoys and Marine Radars in the Baltic Sea

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Operational measurements at sea get more importance as navigation aids and becoming as a natural component in e-Navigation systems. Wave height is most critical parameter for safe navigation at sea. Most commonly wave buoys are used for measurements in real time mode, poor coverage of those and dependence on ice situation, are well known problems. We present methodology based on use of conventional navigational buoys as wave measurement instruments. Automated wave calculation algorithm WHAPAS (Wave Height and Period Software) was developed using high frequency motion data of the buoys as input. Calculated wave heights were validated with pressure based wave measurements near typical navigational buoys. Comparison results showed that method well captures local wave field peculiarities and pilot version of wave height network consisting 32 buoys at Estonian coast showed good performance and stability during the test run period. Marine radars scan the water surface at grazing incidence with HH polarization. Unlike other remote sensing systems, marine radars cover smaller areas, but these sensors are able to obtain short-term temporal information about wave fields using consecutive antenna rotations. Ordinary X-Band marine radars working in HH-polarization are suitable to be used as an oceanographic microwave remote sensing device to analyse different phenomena related to the sea surface features, such as ocean waves, local wind fields, ocean currents, etc. The method is developed and tested in Tallinn Bay, Gulf of Finland the Baltic Sea, to derive wave height from the clutter of marine radar is based on backscatter of the electromagnetic waves by the ripples and the roughness of the free sea surface due to the local wind. Wave data are directly broadcasted to mariners via same AIS channels, as well web-based METOC service.

Sea surface velocity retrievals from Synthetic Aperture Radar

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The synthetic aperture radar (SAR) Doppler centroid shift has been demonstrated to contain geophysical information about sea surface wind, waves and current at an accuracy of 5 Hz and pixel spacing of 3.5-9x8 km2. This corresponds to a horizontal surface velocity of about 20 cm/s at 35 degrees incidence angle. The ESA Prodex ISAR project aims to implement new and improved SAR Doppler shift processing routines to enable reprocessing of the wide swath acquisitions available from the Envisat ASAR archive (2002-2012) at higher resolution and better accuracy than previously obtained, allowing combined use with Sentinel-1 and Radarsat-2 retrievals to build time-series of the sea surface velocity in the Nordic Seas. Estimation of the geophysical Doppler shift from new SAR Doppler centroid shift retrievals will be demonstrated, addressing key issues relating to geometric (satellite orbit and attitude) and electronic (antenna mis-pointing) contributions and corrections. Geophysical Doppler shift retrievals from one month of data in January 2010 and the inverted surface velocity are then addressed and compared to other direct and indirect estimates of the upper ocean current, in particular those obtained in the ESA GlobCurrent project. The retrieval of Doppler shift information from satellites, and sub-sequent signal partitioning into wind, wave, and current information, has potential for application within both operational oceanography (e.g., ship routing, offshore operations) and climate research.

The IEO coastal observatory: understanding variability of coastal circulation and ecosystem response off North and North-West Iberia

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The IEO coastal observatory is mainly research-driven and its key scientific goal is the assessment of coastal ocean variability at different spatial and temporal scales and of the response of marine populations to this variability. The coastal observatory area lies into two ICES(International Council for the Exploration of the Sea, http://www.ices.dk) Divisions: VIII (Bay of Biscay and Cantabrian Sea) and IXa (western and southern Iberia). Therefore one of the purposes of the observatory is to provide environmental and ecosystem knowledge and information to fisheries assessment in ICES subdivisions VIII (Bay of Biscay and Cantabrian Sea) and IXa (western and southern Iberia)., where stocks of economical importance to coastal fleets are exploited. In this contribution, we show how the sustained observations of the IEO coastal observatory serve to validate the results of a high resolution (~3 km) configuration of the ROMS model coupled to the Fasham-type Fennel biogeochemical model (N2PZD2) with full physics and high resolution meteorological forcing from the regional agency Meteogalicia (http://www.meteogalicia.es). The ROMS model configuration is downscaled on the coarser global ocean configuration PSY2V4 run by Mercator Ocean. Apart from routine validation, we show how the use of a numerical model combined with sustained observations of physics and biogeochemistry from the coastal observatory allow us study variability of plankton productivity and also the effect of circulation on early life stages of fish at different temporal and spatial scales in the area, with special

emphasis on the spring transition. Additionaly, several downstream services based on the model combined with observations are under development, like a HAB warning system in the Galician region

Relocatable ocean modelling for downscaling to the shelf and coastal areas

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A new operational service is being developed for the provision of meteo-marine forecast data in order to define an adaptation strategy and a risk analysis for ENI Spa Company. The operational oceanography services includes the provision of high-resolution ocean forecast data at 1/64 resolution in following regional areas: Mediterranean (western, central, eastern), Red Sea, Guinea Gulf, Angola, Gulf of Mexico (northern, southern), Caribbean Sea, Mozambique, South China Sea, Australia, Britain, Caspian Sea. We will present the implementation of a new numerical platform named Structured and Unstructured grid Relocatable ocean platform for Forecasting (SURF, Trotta et al., 2016). The platform is a rapidly deployable modelling system based upon the NEMO code and is designed to be embedded into any region of a large scale ocean prediction system via downscaling and has been coupled with the large-scale Global Ocean Forecasting System (GOFS16) at 1/16 degree resolution. SURF will provide operational forecasts of the circulation in all 15 proposed areas with horizontal grid resolutions of 1/64 with about 100 vertical levels.

Performance and quality assessment of the global ocean eddy-permitting physical reanalysis GLORYS2V4

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The purpose of this presentation is to give an overview of the upgrade of GLORYS2 (GLORYS2V4), the latest ocean reanalysis produced at Mercator Ocean that covers the altimetry era (1993-2016) and performed in the framework of Copernicus Marine Environment Monitoring Service (CMEMS; http://marine.copernicus.eu/). The reanalysis is run at eddy-permitting resolution (¼° horizontal resolution and 75 vertical levels) with the NEMO model and driven at the surface by ERA-Interim reanalysis from ECMWF (European Centre for Medium-Range Weather Forecasts). The reanalysis

system uses a multi-data and multivariate reduced order Kalman filter based on the singular extended evolutive Kalman (SEEK) filter formulation together with a 3D-VAR large scale bias correction. The assimilated observations are along-track satellite altimetry, sea surface temperature, sea ice concentration and in-situ profiles of temperature and salinity from CORA data base. With respect to the previous version, GLORYS2V4 contains a number of improvements, in particular: a) a new initial temperature and salinity conditions derived from EN4 data base and better balanced with altimetry, b) the use of the updated delayed mode CORA4.1 in situ observations from CMEMS, c) a better observation operator in the assimilation scheme for altimetry observations d) a new hybrid Mean Dynamical Topography (MDT) referenced over the 1993-2013 period e) an updated correction of large scale ERA-Interim atmospheric surface precipitations fluxes and f) an update of the global climatological runoff data base. The new reanalysis outperforms the previous version in many aspects and the presentation will give an overview of main results. The particular attention dedicated to altimetry and water masses equilibrium in the new system largely improves the representation of global thermo-haline content ending with a linear trend of 3.56 mm/year for Global Mean Sea Level together with a 1.8 mm/year for the thermo-steric signal; values in very good accordance with recent estimations.

A North Sea-Baltic Sea regional coupled models: Atmosphere, wind waves and ocean

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The coupling of models is a commonly used approach when addressing the complex interactions between different components of earth system. In climate and forecasting research and activities, advanced models are needed and there is an urge towards the use of coupled modelling. This study presents the development of a new, high-resolution, coupled atmosphere, ocean and wave model system for the North Sea and the Baltic Sea, which is part of the Geestacht COAstal model SysTem GCOAST. We focus on the nonlinear feedback between strong tidal currents and wind-waves, which can no longer be ignored, in particular in the coastal zone where its role seems to be dominant. The proposed coupling parameterizations account for the feedback between of the upper ocean on the atmospheric circulation by accounting for the effects of sea surface temperature and the sea surface roughness. Several sensitivity experiments are performed to estimate the individual and collective effects of different coupling components. The performance of the coupled modelling system is illustrated for the cases of several extreme events. For example, the inclusion of wave coupling leads to decreases strong winds through wave dependent surface roughness or changes sea surface temperature, the mixing and ocean circulation; leading to better agreement with in-situ and satellite measurements. We demonstrate how the satellite altimeter observations (including the newly available Sentinel-3A ones) and other altimeter products (CryoSat-2, Jason and Saral/Altika) can be used to support further the regional and coastal oceanography. The model comparisons with data from satellite altimeter and in-situ observations showed that the use of the fully coupled system reduces the errors, especially under severe storm conditions. This justifies the further developments and implementation of the coupled model systems and its synergy with the newly available satellite observations, for both, operational and climate research and development activities.

Towards seamless modelling in the Baltic

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Seamless approaches to ocean modelling have been developed in the recent years to follow the user needs from the first generation of basin scale wide operational storm surge prediction systems to local, high-resolution model applications for ocean waves-currents-and bio-geochemical parameter. They have successfully conquered the basin and the near-coastal scales, but they have to evolve further, to cover the large scales in the required high resolution necessary to serve decision support systems. To serve as a high quality seamless prediction system, an ocean model has to fulfil certain requirements on model physics, grid configuration, code's computational standard and efficiency and also the coupling interface with other system components. The purpose of this paper is to illustrate these requirements and gaps between a state-of-the-art ocean model and the seamless model. In this context, a widely used Baltic Sea operational ocean model HBM is evaluated, as an example, against the requirements for seamless ocean modelling. Future research towards the seamless ocean modelling in the Baltic Sea is also identified.

A two-way nested high resolution coastal simulation in a tidally dominated area: preliminary results

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Kenmare Bay, at the southeast coast Ireland, is a typical example of a tidally dominated area with an average tidal range of 2 meters. Almost all physical and biogeochemical processes are mainly controlled by the tides and in smaller scale by the rivers outflow. In this work we have set up a fully two-way nested 3D hydrodynamic simulation to focus on an even smaller bay (Kilmakilloge) inside the Kenmare and to investigate the impact of tides in it. Kilmakilloge is an economically important region due to intensive aquaculture activity. At the current stage only the hydrodynamic component of model is activated and the output data is under validation, but in the near future a set-up of a fully coupled physical – biogeochemical – shellfish model is planned. The Regional Ocean Modelling System (ROMS) was used for the simulation. The donor grid covers the Kenmare bay with 120 meters resolution and a second grid with a refinement factor of 3 (approximately 40 meters resolution) constitutes the receiver grid and covers the Kilmakilloge bay. The vertical resolution for both grids is 15 sigma levels. The initial and high temporal resolution (10 min) boundary conditions which include the tidal signal are provided from MI's high resolution coastal operational model of Bantry Bay. Atmospheric forcing fields from ECMWF were used with spatial resolution 0.125 × 0.125 degrees and three-hour time step. Four major rivers are included and the input data comes from E-HYPE model (SMHI) and OPW (Ireland).

The preliminary results of the numerical experiments are hereby presented and discussed. We also assess the ability of ROMS to simulate physical processes in a tidally dominated area.

Ocean forecasting from regional to coastal scales: two-way nesting and seamless modeling

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This paper describes recent advances of nested and cross-scale numerical modeling. The presented applications address the nonlinear behavior of the coastal ocean manifested by the tidal distortion and generation of shallow-water tides. An inter-comparison of the performance of two operational models and several open-source ocean models for the region of North Sea and Baltic Sea is presented. One example demonstrates that using a two-way nesting method and a fine-resolution model interface in the area of straits connecting the North and Baltic seas substantially enhanses the model performance. The main focus of the presentation is on the concepts for seamless approaches to link coastal and regional forecasting systems. They are exemplified by the application of an unstructured-grid model for inter-connected basins. The North Sea-Baltic Sea and Black Sea-Mediterranean have been used as test-areas because of the dominant role of processes in narrow straits. An illustration is also given on the recent advancements of seamless modelling of the estuarine dynamics of the German Bight.

Performance and quality assessment of the current Copernicus Marine Service global ocean monitoring and forecasting real-time system

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Since October 19, 2016, and in the framework of Copernicus Marine Environment Monitoring Service (CMEMS), Mercator Ocean delivers in real-time daily services (weekly analyses and daily 10-day forecasts) with a new global 1/12° high resolution (eddy-resolving) system. The model component is the NEMO platform driven at the surface by the IFS ECMWF atmospheric analyses and forecasts. Observations are assimilated by means of a reduced-order Kalman filter with a 3D multivariate modal decomposition of the forecast error. Along track altimeter data, satellite Sea Surface Temperature and sea-ice concentration, and in situ temperature and salinity vertical profiles are jointly assimilated. A 3D-VAR scheme provides a correction for the slowly-evolving large-scale biases in temperature and salinity. An assessment of the hindcasts (2007-2016) has been conducted and has highlighted improvements compared to the previous system thanks to the following updates: large-scale correction of atmospheric quantities with satellite data, new freshwater runoff from ice sheets melting, global steric effect added to the model sea level, new Mean Dynamic Topography taking into account the last version

of GOCE geoid, new adaptive tuning of some observational errors, new Quality Control on the assimilated temperature and salinity vertical profiles, assimilation of satellite sea-ice concentration, week constraint imposed on temperature and salinity in the deep ocean (below 2000 m) to prevent drift. Since the real-time implementation of this system, the validation exercise continued, with for instance, the validation of the performance of the forecasts. Moreover, in parallel with the operational system, two other simulations over the same period have been performed. The first one is a free simulation (without any data assimilation) and the second one benefits only of the 3D-VAR large-scale biases correction in temperature and salinity. Some comparisons between the three simulations have been conducted to try to quantify the impact of each component in the system.

Overview of CMEMS BAL MFC Service and Developments

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Copernicus Marine Service (CMEMS) model component for the Baltic Sea is provided by a consortium formed by five national oceanographic institutes around the Baltic Sea: DMI-Denmark, BSH-Germany, FMI-Finland, MSI Tallinn University-Estonia and SMHI-Sweden. All five institutes have national obligations within operational oceanography. The consortium builds on a philosophy to join forces within operational oceanography in the Baltic Sea and shares the operational work load behind the Baltic service. We will present progress of our provided Baltic model products during the past 2.5 years within the CMEMS contract with Mercator-Ocean. This includes scientific progress and upgrades made in the modelling systems, improvements in the quality of the products and new products and parameters included in our service product portfolio.

A 1/24 degree resolution Mediterranean analysis and forecast modeling system for the Copernicus Marine Environment Monitoring Service

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The Mediterranean Forecasting System (MFS) is a numerical ocean prediction system that operationally produces analyses, reanalyses and short-term forecasts of the main physical parameters for the entire Mediterranean Sea and its Atlantic Ocean adjacent areas. This work is specifically focused on the description and evaluation of the analysis and forecast modeling system that covers the analysis of the current situation and produces daily updates of the following 10 days forecast. The system has been recently upgraded in the framework of the Copernicus Marine Environment Monitoring Service (CMEMS) by increasing the grid resolution from 1/16o to 1/24o in the horizontal and from 72 to 141 vertical levels, by increasing the number of fresh water river inputs and by updating the data assimilation scheme. The model has a non-linear explicit free surface and it is forced by surface pressure, interactive heat, momentum and water fluxes at the air-sea interface. In order to validate the modeling system and to estimate the accuracy of the model products, a quality assessment is regularly performed including both pre-operational qualification and near real time (NRT) validation procedures. Pre-operational qualification activities focus on testing the improvements of the quality of the new system with respect to the previous version and relies on past simulation and historical data, while NRT validation activities aim at routinely and on-line providing the skill assessment of the model analysis and forecasts and relies on the NRT available observations. The focus of this work is to present the new operational modeling system and the skill assessment including comparison with independent (insitu coastal moorings) and quasi-independent (insitu vertical profiles and satellite) datasets.

High resolution operational analysis and forecasts for the Mediterranean Sea biogeochemistry

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In the framework of the Mediterranean Monitoring and Forecasting Centre (Med-MFC) embedded within the European Copernicus Marine Environment Monitoring Services (CMEMS), we have upgraded the current operational modelling system for the analysis and short-term forecast of the biogeochemical state of the Mediterranean Sea, increasing the spatial resolution from 1/16 degree and 72 vertical levels to 1/24 degree and 125 vertical levels.

The high resolution version is based on the upgrade of the 3DVARBIO-OGSTM-BFM model system, which has been aligned with the Mediterranean physical model system in terms of the free-surface formulation and the river inputs configuration. Moreover, the data assimilation module that integrates the satellite surface chlorophyll concentration in the OGSTM-BFM has been parallelized, contributing, together with the optimization of the OGSTM, to increase the performance of the upgraded model system and to keep the total computational time within the target time set by CMEMS requirements.

The validation of the new system version is based on GODAE-like metrics and exploits a number of available reference observations data, which includes CMEMS satellite ocean colour data, World Ocean Atlas 2013, dedicated Mediterranean climatology data sets, in-situ observations and the recent BGC-Argo floats data. The results show that the accuracy of modelling products can be achieved at different levels (from basin-wide and climatological scale to mesoscale and weekly scale) depending on the specific variables. In particular, we show how the use of the BGC-Argo float data allows for a relevant improvement of the validation framework of operational biogeochemical models providing new skill metrics for key biogeochemical processes and dynamics (e.g. deep chlorophyll maximum, nutricline, maximum oxygen depth).

Modeling in the Mediterranean Sea: the MonGOOS contribution

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In the past years, the MonGOOS modeling community has developed an important expertise in the application and development of numerical models to the Mediterranean Basin. The applications cover both operational systems and process modeling, in the whole or in part of the Mediterranean. The present contribution pretends highlight the main successes and challenges derived from this MonGOOS activity. Operational forecasting models show a wide spectrum of application areas and parameters predicted. Specific areas where the models are applied range from Spain, via the Italian peninsula, Cyprus to the Israeli coast. Basin wide scales as well as regional and sub-regional scales are resolved. Most of the forecast models use CMEMS products that are then downscaled to the desired resolution and the chosen area. Parameters modeled are currents and waves, as well as biogeochemical parameters. An active field

of research is the simulation of meteorological tsunamis that can lead to high flooding in otherwise less vulnerable parts of the Mediterranean Sea. Improvement of resolution from open sea models is a common need of operational systems and process oriented implementations. Some of the models apply nesting techniques to zoom to the desired resolution; others use finite elements that allow a flexible increase in resolution. Whereas the finite elements describe by default two-way interactions, with nesting the two-way interaction is more difficult to obtain. Even if the Mediterranean is a micro-tidal basin, the effects of tides can be important. This is especially true in areas of relative high tides (North-Adriatic Sea) and of important tidal currents, such as in the Messina Strait. Here the focus is on the description of the interaction of the open sea with the coastal zone. This interaction is bi-directional, where the small-scale features can also influence the open sea.

Downscaling the Copernicus CMEMS Med MFC in the Eastern Mediterranean: The new CYCOFOS forecasting systems at regional and sub-regional scales

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One of the well known downscaled ocean forecasting systems in the Mediterranean is the CYCOFOS-Cyprus coastal ocean forecasting system, which is operational since early 2002. Following the establishment of the Copernicus Marine Environmental Monitoring Service -CMEMS, CYCOFOS has been improved to downscale the Mediterranean MFC products, with the implementation of new hydrodynamic, wave and atmospheric models, all targeting higher resolution domains at sub-regional and regional scales. The new CYCOFOS hydrodynamic model use a novel parallel version of POM covering the Eastern Mediterranean with a resolution of 2 km. The hydrodynamical model is coupled with the SKIRON high frequency surface forcing for the first 5 days and with the ECMWF for the rest 5 days. Moreover, the hydrodynamical model is coupled with the new CYCOFOS WAM model providing the surface drag coefficient. The new WAM model incorporates the surface currents from the CMEMS Med MFC, providing a second independent forcing input to the new wave model, in addition to SKIRON winds. The Weather Research and Forecasting atmospheric model-WRF has been implemented in the same domain as SKIRON atmospheric model, in order to provide the backup forcing for the new CYCOFOS forecasting systems. Extended validations for all the new CYCOFOS forecasting systems were carried out using in-situ and satellite data, as well as inter-comparisons with the parent models. Data from the new CYCOFOS forecasting systems is used for the EU CISE 2020 project aiming to establish a Common Information Sharing Environment to improve the Maritime Situational

Awareness, particularly forSAR operations, as well as for addressing the EMODnet MedSea and Black Sea Check points challenge on oil spill predictions.

North-West European Shelf Monitoring and Forecasting Centre: system evolution since the beginning of CMEMS

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The North-West European Shelf monitoring and Forecasting Centre is delivering physical, biogeochemical, and wave products for the European continental shelf area. The system and its component are continuously evolving in order to increase the number of products offered and their quality. One of the most significant improvements during the last couple of years has impacted the physical component of the system with the introduction of Sea Level Anomaly and temperature, and salinity profiles data assimilation. The latest modification has positively impacted the temperature and salinity fields, with a evident improvement in the model capability to better resolve the water masses at subsurface and mid depth. The temperature RMS error has been reduced of 0.7°C between 500 and 1300m and the salinity RMS error has decreased of 0.4 PSU at surface, up to 1.2 PSU at 1000-1300m. Improved quality for the analysis should reflect in a better predictability capacity of the system. Preliminary assessment of the forecast accuracy has been done for SST to understand how the improved quality of the analysis impacts the forecast accuracy. The analysis from the new system has a lower RMS error than the old system and the mean error increases to a less extent in the new system through the forecast.

Evolution of the IBI MFC Services along the CMEMS Phase I (2015-2018): Success stories and Future Challenges

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The CMEMS IBI-MFC (Iberia-Biscay-Ireland Monitoring & Forecasting Centre) delivers daily ocean model estimates and forecasts of different physical and biogeochemical parameters for the Atlantic façade, supporting all kind of marine applications. Along CMEMS Phase-I (2015-2018), the IBI-MFC service is continuously evolving, upgrading its Near-Real-Time (NRT) forecast capabilities (in 2015 only the physical forecast in place, today 3 NRT services, including wave and biogeochemical forecasts). The IBI-MFC delivers also multi-year (MY) products derived from a physical re-analysis and a non-assimilative biogeochemical hindcast. These MY products are updated to: a) improve product quality (on-going a new reanalysis with updated model, data assimilation scheme and observational data), b) extend temporal coverage (back to 1992), and c) include new variables (waves). The IBI products are generated by model applications able to deal with a large range of physical processes (from tidal to seasonal timescales). Noticeable efforts are in progress to define meaningful skill scores and statistical metrics to quantitatively assess the quality and reliability of these IBI model solutions. To evaluate prognostic capabilities in operations, the NARVAL skill assessment software (with web application) routinely compares IBI forecast products against in-situ and remote-sensing measurements. Operational validation outcomes and assessments from the qualification performed together with any system upgrade are compiled in Product Quality Information Documents, available in the CMEMS web. Additionally, there is an increase of scientific literature on IBI MFC products (result of the growing scientific research activity performed mostly by users outside CMEMS framework). Consequently, the today IBI user has a more complete picture of what expect from the regional IBI products. Maturity of the IBI-MFC operational service is a reality today and some of the on-going actions (i.e. generation of regional IBI analysis in 2018) will certainly increase the meet of user requirements, easing downstreaming, and reinforcing links with the IBI-ROOS community.

Ensemble-based data assimilation of observations into NEMO-Nordic

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The operational ocean forecasting system at SMHI, for the North Sea and the Baltic Sea, is based on the model NEMO-Nordic (based on NEMO-3.6) and the ensemble-based data assimilation method 3D EnVar. This presentation shows some details of both the ocean forecasting model setup as well as the data assimilation system with some results from assimilation real-time observations. In addition, we have a new reanalysis system based on NEMO-Nordic, coupled to the biogeochemical model SCOBI, and the ensemble-based data assimilation method LSEIK. Some recent results will be shown.

Last improvements in the data assimilation scheme for the Mediterranean Analysis and Forecast system of the Copernicus Marine Service

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The Mediterranean Forecasting System (MFS) is a numerical ocean prediction system that produces analyses, reanalyses and short term forecasts for the entire Mediterranean Sea and its Atlantic Ocean adjacent areas. The system is now part of the Copernicus Marine Environment Monitoring Service (CMEMS) providing regular and systematic information about the physical state and dynamics of the Mediterranean Sea through the Med-MFC (Mediterranean Monitoring and Forecasting Center). MFS has been implemented in the Mediterranean Sea with 1/16o horizontal resolution and 72 vertical levels and is composed by the hydrodynamic model NEMO (Nucleus for European Modelling of the Ocean) 2-way online coupled with the third generation wave model WW3 (WaveWatchIII) and forced by ECMWF atmospheric fields at 1/8o horizontal resolution. The model solutions are corrected by the data assimilation system (3D variational-3Dvar scheme adapted to the oceanic assimilation problem, Dobricic and Pinardi, 2008) with a daily assimilation cycle of satellite Sea Level Anomaly (SLA) and vertical profiles of Temperature and Salinity. In this study we present a new estimate the of the background error covariance matrix with vertical Empirical Orthogonal Functions (EOFs) that are defined at each grid point of the model domain in order to better account for the error covariance between temperature and salinity in the shelf and open ocean areas. Moreover the Error covariance matrix is z-dependent and varies in each month. This new dataset has been tested and validated for more than 2 years against a background error correlation matrix varying only seasonally and in thirteen sub-regions of the Mediterranean Sea. Latest developments include the implementation of an upgraded 3Dvar (Storto et al. 2012) for a high-resolution model, 1/24o in the horizontal and 141 vertical levels

The roles of the sea ice thickness measurements from satellites in the TOPAZ system

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Sea Ice Thickness (SIT) is a key variable both in operational navigation and climate perspectives. Recently, a merged weekly product of SIT from two different satellites CryoSat2 and SMOS has been distributed on meereisportal.de, available during the winter months since October 2010 and named CY2SMOS. At present, the Arctic Marine Forecasting Center ice-ocean system (aka. TOPAZ) assimilates jointly most of the observed ocean and sea ice properties using the ensemble Kalman filter (EnKF), but SIT has not been included yet. The quality of the present operational sea ice thickness TOPAZ simulations are first assessed by comparison against SMOS data and the impact of SIT

assimilation is then evaluated. In this study, there are two parallel data assimilation runs in the same time period. In the Test run, the merged CS2SMOS measurements are assimilated into the system as an additional observation type from 19th March 2014 to 31st March 2015. The innovation diagnostics show the SIT misfits are reduced as expected by CS2SMOS data, and no degradation of other model variables. Validation against independent SIT observations from the Ice Mass Balance (IMB) buoys and from the IceBridge campaigns shows error reductions between 11.5% and 24.2%. The results suggest the SIT observations can be assimilated into the Arctic MFC, which leads to multivariate and dynamical adjustments of the SIT, the sea ice drift and the surface water salinity. Further diagnostics based on the degrees of freedom for signal (DFS) obtained from the data assimilation system show the relative impacts of different observations confirm that the CY2SMOS is the main source of information in the ice pack.

The SAMOA project: downscalling operational oceanography for improving Harbour operations

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Approximately 85% of total imports and 60% of Spanish exports are channeled through ports, a fact that speaks for itself of the vital role they play in the national economy. The ports suffer the extreme events of the essential physical variables, specially wind, waves and sea level. These affects the installations during all phases of the harbor life, from design to operation. To respond to these complex needs. the SAMOA initiative (System of Meteorological and Oceanographic Support for Port Authorities) was born, co-financed by Puertos del Estado and the Port Authorities. SAMOA is a revolution in the way Puertos del Estado is providing solutions to the Operational Oceanography needs of the Port Authorities. An integrated system, ultimately based on CMEMS data, has been developed. A total of 10 new high-resolution atmospheric models (1 km resolution, based on Harmonie), 10 wave models (5 m., mild slope model) and 8 circulation models (40 m., ROMS) have been developed and operationally implemented. In terms of instrumentation, SAMOA improved the already existing large network of Puertos del Estado by means of 13 new meteorological stations and 3 GNSS associated to the tide gauges. 25 Ports from 18 Port Authorities will benefit from these new modeling and monitoring advances. All previously existing and new products are fully integrated in a specfic visualization tool that that is being managed by administrators in the harbors. In addition, there is a new alert system via e-mail and SMS, fully configurable by the users in the Port community. Finally, an extended set of applications, such as oil spill models and air pollution monitoring tools, have been fully integrated into the system. SAMOA results will have multiple applications for the ports: operation of infrastructures, aids to navigation, fight against spills, control of water and air quality, etc ...

Towards a new sea level forecast system in Puertos del Estado

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In the last years, there has been a major development of forecast systems including a sea level solution in the European domain, improving coverage in the Mediterranean area, development of baroclinic models and availability of high resolution systems. The establishment of the CMEMS programme has fostered model development and data exchange policies, allowing real-time operational access to observations and sea level forecasts, thereby saving the burden of establishing specific data exchange agreements with providers. In the framework of the Spanish national SOPRANO project, the Spanish Ports and Harbours Authority (PdE) has analyzed the sea level solution of the CMEMS models covering the IBI (Iberia-Biscay-Ireland) and Mediterranean regions, in terms of its performance at locations with tide gauges. PdE's operational sea level forecasting barotropic system, Nivmar, has also been included in the study. A dedicated pre-processing has been carried out both on tide gauge data and model output, including de-tiding and/or reduction of model system bias prior to analysis. The simple yet effective data assimilation scheme applied in the Nivmar system, has been extended to all models: the analysis has been therefore applied to the original and assimilated solutions. Additionally, a new sea level forecast is created, combining the existing ones at each location by means of a Bayesian Model Average (BMA) method. Results show how baroclinic models are now outperforming Nivmar especially in the original model signal. This means that baroclinic models have improved its capability to solve the longer period baroclinic signal, which is introduced in barotropic Nivmar via data assimilation. The new BMA joint solution provides a better solution than the individual models. These results mean that it is possible to create a better sea level forecast system and that we are able to obtain a clear advantage from the synergies derived from overlapping in the MFC domains.

The Copernicus Marine Service User Uptake programme, a way to show the value added chain till the end users.

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Every month approximately 250 new subscribers choose to discover products and information of the Copernicus Marine Environment Monitoring Service (CMEMS – marine.copernicus.eu). At present, close to 10000 users visit the CMEMS website and/or download products. The excellent CMEMS user response is a real incentive to pursue and boost a strategy built on an open and free service and support the development of downstream services. The CMEMS users and more specifically "intermediate users" are key to the success of the service. They bring an expert added-value to specialised contracts to leverage the existing economic activity. The delegation agreement between the European Commission and Mercator Océan requires the development and the implementation of a User Uptake strategy to firstly secure the loyalty of its users and secondly to attract new user communities. With the User Uptake Mercator Océan aims to reinforce its relationship with its intermediate users, to explain and enhance its

service and the services of these key players. This is based on their direct involvement to ease the CMEMS use and promote inspiring exemplary cases. This will contribute to the development of the whole chain and will raise new user interest and allow communities to exchange and propose relevant evolutions to the current European service. This CMEMS User Uptake component draws its foundations from all users' feedback and will accompany CMEMS during all its operations and evolution. There is a budget of 1M€/year (2016-2021) for successive calls for tender. A first round of calls for tender was published in 2016. It focused on coastal operational downstream services using CMEMS products including services linked to the EU Marine Strategy Framework Directive (www.msfd.eu). The presentation will focus on the first User Uptake contracts and the second round of User Uptake calls for tender priorities.

CMEMS Baltic Monitoring and Forecasting Centre: High-resolution wave forecasts in the seasonally ice-covered Baltic Sea

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The Baltic Monitoring and Forecasting Centre (BAL MFC) is providing high resolution wave forecasts for the Baltic Sea as part of the Copernicus Marine Service. The BAL MFC wave forecasting system is based on wave model WAM cycle 4.5.4. The model has a horizontal resolution of ca. 1 nmi (1.852 km) with open boundary at Skagerrak. The wind forcing is provided by FMI's numerical weather prediction system HARMONIE (2.5 km resolution). The wave forecast system accounts for the seasonal ice cover by excluding grid points that have ice concentration of over 30 % from calculations. The ice data are obtained from FMI's ice charts. For the next version upgrade, due on April 2018, methods to account for attenuation of wave energy in partly ice-covered areas will be implemented in the wave model and also one-way coupling to a 3D ice-ocean model will be studied to enable updating the ice conditions during the forecast run. Also, the different characteristics of the Baltic Sea shorelines have be taken into account. E.g. to obtain sufficiently accurate wave forecasts also in coastal archipelagos of the northern Baltic Sea a method to account for unresolved islands with the given grid resolution is used. The quality of the BAL MFC wave forecasting system was evaluated by comparing a two year simulation period against wave buoy measurements. The quality of the wave model was found to be good, with slight tendency to over estimate the significant wave height. The capability of the BAL MFC wave forecast system was further evaluated in the pre-operational phase, when the storm 'Toini' (Jan 11th 2017) caused high waves in the Baltic Proper . The highest hindcast value of significant at the Norhtern Baltic Proper buoy location during the storm was 7.8 m, which was a good match to the measured maximum value of 8.0 m.

The new CMEMS IBI-WAV forecasting system: skill assessment using in situ and HF radar data

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Within the frame of the Copernicus Marine Environment Monitoning Service (CMEMS), The Iberia-Biscay-Ireland Monitoring & Forecasting Centre (IBI-MFC) has recently extended its near real-time forecast capabilities, coincident with the V3 CMEMS Service release. Nowadays, a new operational forecast system is operationally run to generate high resolution wave (WAV) products on the IBI area. The IBI-WAV system is based on a MeteoFrance-WAM 10-km resolution model application and runs twice a day using ECMWF wind forcing. The main goal of this work is to conduct a thorough skill assessment of IBI-WAV product during a two-year period (2015-2016). Special emphasis has been placed on the characterization of wave features at the Galician coast (NW Spain). To this aim, in situ and remote-sensed data (from a deep-water buoy and a CODAR HF radar, respectively) have been used as benchmark to validate the outputs from CMEMS IBI-WAV operational wave forecasting system. In this context, an analysis of extreme wave height events during wintertime has been performed due to the significant impact on maritime operations and safety in coastal waters.

Sea ice monitoring system based on satellite data to support safe navigation in Arctic Seas

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A sea ice monitoring system is developed to support safe operations and navigation in Arctic Seas. The system is capitalized on the Geo-Scientific Platform as a Service (GeoSPaaS) developed at NERSC for aggregation of satellite, modeling and in situ data. It exploits Synthetic Aperture Radar (SAR) data from satellites as a major component of this system. Sentinel-1 data is delivered every day in near realtime for monitoring of sea ice and other environmental parameters. The system is based on the algorithms for (1) sea ice classification of different ice types and open water; (2) ice drift with sufficient resolution to map mesoscale ice motion and deformation fields; and (3) iceberg detection by combined use of SAR and high-resolution optical images. Furthermore, the system integrates SAR data with AIS data (Automatic Identification System) from vessels operating in sea ice areas. With AIS positions combined with SAR images it will be possible for ship captains to find sailing routes through open leads or thin ice and avoid areas ice with ridges and other difficult ice situations. Key user groups for the system include be shipping companies, oil and gas companies, operational met-ocean services, coastal and ship traffic authorities, risk management, and environmental organizations working in the Arctic. The system is

developed under project SONARC, supported by the Research Council of Norway (proj. Number 243608).

Satellite data based automated arctic sea ice monitoring system

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Comprehensive monitoring of sea ice in Arctic area with continuous collection and accumulation of data are necessary not only to ensure safe navigation and operational tasks of navigation, but also for understanding the nature and variability of the large-scale processes in the ocean and atmosphere in the global climate change conditions. At the Saint Petersburg Nansen Center during the last years developed and improved algorithms for sea ice drift estimation, classifications of sea ice, iceberg detection and others. In complex, they allow deriving ice conditions from satellite data in the operational mode and based on archival information. For accumulation of satellite and other spatial information and its integration with methods of processing, searching and reporting there are developing automated system that provides access to the original data and thematic products. The system kernel manages processes of automatic loading and processing of available satellite data, providing also the possibility for storing any other spatial information. Access to all data is provided via the universal interface which is implemented as an HTTP API. This allows to develop the independent user interfaces of different types and specializations across all platforms. As the main interface web portal NIERSC Data Center is developing, enabling to search, download, and administrate all data available with web interface. Additional interface is desktop in the form of expansion NIERSC QGIS Toolbox for open QuantumGIS geographic information platform, providing search capabilities and load data directly into the GIS environment. Continuous improvement of thematic data processing methods and mechanisms of collecting, cataloging and publishing data allows to provide operative tasks and research in more and more details. Work is performed under support of RFBR – NRC project (RFBR No. 15-55-20002) "Development of sea ice monitoring and forecasting system to support safe operations and navigation in Arctic Seas".

Stress testing the EU monitoring capacity for the Blue economy

Nadia Pinardi and the EMODnet Checkpoint partners

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A coordinated EMODnet activity has been started in 2013 to assess how well the European marine monitoring data meets the requirements of the sustainable blue economy. The activity is done by six European Sea Basin Checkpoints listed in the EMODnet central web page: http://www.emodnet.eu/checkpoints. Checkpoints should develop an assessment framework that

considers “Use Cases” or “Challenges” to evaluate the fitness for use of input monitoring data sets. The Challenge products are related to both Blue Growth and the Marine Strategy Framework Directive objectives that map all the GEO thematic focus areas. The quality of the Challenge products will inform on how monitoring data set are “fit for use”. The Checkpoint assessment developed for the Mediterranean Sea is a “Service” composed of: 1) a GIS metadatabase with information about upstream data sources for Challenge products and availability indicators; 2) a Web GIS product display with links to the upstream data sources; 3) a browser and dashboard tool to evaluate statistics of indicators. User requirements are recorded in the product catalogue (Data product Specifications) which can be viewed for later corrective actions. The methodology developed for this assessment is now being applied to the Atlantic and the Black Sea basins thus producing in the near future the first large basin scale assessment of input monitoring data set adequacy for societal applications.

EMODnet Physics: tackling new challenges

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EMODnet - the European Marine Observation and Data network – is a long term marine data initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) involving and networking more than 150 organizations for assembling marine data, products, and metadata. The data infrastructure has been developed through a stepwise approach in 3 major phases by running 8 thematic portals, 6 regional check points and a Data Ingestion facility. EMODnet Physics (www.emodnet-physics.eu), one of the thematic portals, is developing a combined array of services and functionalities such as facility for viewing and downloading, dashboard reporting and machine-to-machine communication services, to obtain, free of charge data, meta-data and data products on the physical conditions of the ocean from many different distributed datasets. The work of the EMODnet Physics partners is built on the EuroGOOS network of observing platforms and the SeaDataNet protocol for accessing archived physical data from national oceanographic data centres. The collection of physical parameters is largely an automated process that allows the dissemination of near real time information. The infrastructure for storing and distributing these data is shared with the Copernicus Marine Environment Monitoring Service (MoU signed in 2016). The EMODnet Physics portal is currently providing easy access to data and products of: wave height and period; temperature and salinity of the water column; wind speed and direction; horizontal velocity of the water column; light attenuation; sea ice coverage and sea level trends. EMODnet Physics is continuously increasing the number and type of platforms in the system by unlocking and providing high quality data from a growing network. In this

presentation, we give an overview of how EMODnet Physics is organized, progress made to date and planned activities to include and make available river data, underwater noise, and parameter oriented products.

The new services provided by the Copernicus Marine In Situ thematic centre

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Copernicus Marine Environment Monitoring Service (CMEMS) is an operational service designed to respond to issues emerging in the environmental, business and scientific sectors. The In Situ TAC is organized around 7 oceanographic regions: the global ocean and the 6 EuroGOOS regional alliances. Each center homogeneously implements 4 functions: data acquisition, quality control, validation and distribution. Although there are 7 portals, the products are distributed the same way (same format, same portal organization, same advanced web services, …) and relies on widely used standards The In Situ TAC provides vertical profiles and time series data coming from different types of instrument (floats, drifters, moorings, gliders, vessels, …) and different physical parameters (temperature, salinity, currents, sea level, …). In the frame of the first phase of CMEMS , the IN Situ TAC has consolidated the Near real Time products developed within MyOcean series of projects and added to the calalogue : • A merged product (1950-2016) between the V1 CMEMS product and ENACT4 product managed by MetOFFICE. The coverage in time and space has been enhanced as well as the assessment method that took the best of each process to provide a product that both serve the Research and the Operational user needs • A surface current product designed for reanalysis purposes that integrates the best available version of in situ data for Ocean surface currents for the period 1990-2016. • A wave product that integrate quality-controlled wave data, both near-real time and historical, collected from more than 400 platforms around the globe. The 2017 focuses on the integrated parameters, either from zero crossing or spectral analysis. Complete spectral data are planned to be integrated in 2018. • A first version of an historical BGC (O2 and Chla) product will be provided in 2018

CORA 5.0: global in-situ temperature and salinity dataset.

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The ability of the scientific community to monitor and understand the oceanic variability is widely based on the quality and the availability of ocean measurements. The particular feature of the CORA dataset

(Coriolis Ocean Dataset for Reanalysis) is to distribute all types of in-situ temperature and salinity measurements with a maximal sampling, including high frequency profilers (Argo, CTD, etc...) surface and sub-surface timeseries (Thermosalinographs and surface drifters, etc...). The current version of the CORA dataset (CORA5.0) stands out from the previous version by including millions profiles from the historical period (1950-1990) and the addition of year 2015 profiles from Coriolis. A very careful validation process is performed on the CORA measurements since the probably erroneous profiles are individually checked by an oceanographer which changes the data quality flags if necessary. This work flow reduces the amount of unnecessary flags leading to a better estimation of the ocean variability. The CORA dataset is distributed by the Copernicus Marine and Environment Monitoring Service online catalogue: http://marine.copernicus.eu/services-portfolio/access-to-products/

Virtual access activity in JERICO-NEXT: guiding users to relevant services and data.

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The objective of JERICO-NEXT consists of strengthening and enlarging the European network for the provision of operational services to deliver timely, continuous and sustainable high quality environmental data and information products related to the marine environment in European coastal seas. Under Horizon 2020, Virtual Access is a new activity in European-funded projects. This activity guaranties free access of information to scientists to carry out not only high-quality research but also promotes improvement of existing services and potentially the development of new services for nautical communities, maritime and port authorities, local decision makers, economic agents, schools and the general public. Under this activity JERICO-NEXT has developed a web portal for guiding users to data and services through a list of providers as well as a close link to EMODnet-Physics. The activity is assessed not only on data visibility, access, format, downloading time, terms of use and interoperability of services but also on quantity, geographical distribution of users and, whenever possible, information/statistics on scientific outcomes (publications, patents, etc.) acknowledging the use of the infrastructure. This presentation will describe the steps involved in enabling the virtual access, and give examples of successful user uptake.

Societal benefits from observing and modelling systems – pilot actions in Ireland in the framework of the AtlantOS project.

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Work Package 8 of the EU H2020 funded AtlantOS project aims to deliver a suite of downstream marine products and services targeted at issues of societal concern, such as climate, disasters, ecosystems, health and water. The main objective is to enhance the safety of coastal communities and promote economic development in key emerging marine and maritime sectors through better decision support tools and resource assessment. The Marine Institute, together with AtlantOS partners, is focused on pilot actions related to harmful algal bloom (HAB) alerts, coastal flooding/storm surges and offshore aquaculture siting. These downstream services integrate data from existing services, such as the Copernicus Marine Environment Monitoring Service, in-house operational observational programmes and modelling tools. This paper reports on the developed systems: • The HAB warning system amalgamates in-situ, satellite data and model forecasts, which then undergo expert interpretation to produce an early warning bulletin for the aquaculture industry • The Marine Institute operational modelling system is capable of providing a 3-day storm surge forecast for Irish coasts; an overview of the system and its skill will be provided, with a particular emphasis on winter storms of 2013 - 2014. • Developed products for offshore aquaculture siting consist of model-derived layers of wave heights and current velocities, combined with a bathymetric dataset. Simple raster analysis in GIS was used to identify suitable sites. A weather window tool was developed to provide end users real-time access to sea state observations and model forecasts in order to allow aquaculturists plan day to day farm operations. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 633211.

Offshore aquaculture site selection along the Spanish, Norwegian and Irish Atlantic coasts

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European policy intends to expand the space available to aquaculture by cultivating sites that are offshore. This presents challenges in terms of building structures e.g. fish cages that withstand the effects of offshore weather conditions along the Atlantic coast. Recommendation COM/2013/229 Strategic Guidelines for the sustainable development of EU aquaculture stated “having spatial plans in place can help reducing uncertainty, facilitating investment and speeding up the development of sectors such as aquaculture or offshore renewable energy. The lack of space often cited as a hindering factor for the expansion of EU marine aquaculture can be overcome by identifying the most suitable sites amenable for aquaculture” In order to establish possible future sites for offshore aquaculture production, in the framework of H2020 project ATLANTOS (http://www.atlantos.eu) we have gathered relevant model data as well as administrative layers from the coasts of Ireland, Norway and Spain for site assessment models of the potential new offshore aquaculture sites. We have concentrated on selected requirements related to wave, current velocity, temperature, and chlorophyll a. In addition, some spatial restrictions such as protected areas and habitats, fisheries areas, existing aquaculture sites and maritime activities (ship routes and oil & gas installations) were included. A geographical information systems (GIS) approach was chosen as analytical tool. In our presentation we will discuss to the gaps between the data available and the requirements for aquaculture site selection. A discussion and comparison of the results of the common methodology used in the three coastal areas will be complemented with an assessment of

the stakeholder (e.g. decision makers and farm operators) involvement and feedback obtained in the three countries.

Operational oceanography to serve sustainable development in Baltic-North Sea

Jun She

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Capacity of European Operational Oceanography (OO) has been significantly improved in the past decade. In Baltic-North Sea, cost-effective technologies, e.g., ferrybox, glider, Argo profiler, HF radar and mooring, have been used for observing the sea. New observations, such as ice thickness, suspended sediment and near coastal sea level etc., are also made available by using satellites, e.g., Sentinels. The transient kilometric scale marine status has been observed, although still gapped, in many parts of sea. Models for simulating and forecasting ocean physics, sea ice, waves and biogeochemistry are now available both in European and national levels, on a wide range of scales and resolutions, some with data assimilation. In the coming years, it is expected that more observations will be available in near-real time and assimilated in operational models. The quality, especially in biogeochemical products, will be significantly improved. The product uncertainties, both for observations and forecast, will be further quantified via e.g., ensemble techniques. The models will be further coupled, codes further modernized for new generation architectures and ocean phenomenon resolved from coastal-estuary continuum to inter-basin and from operational to climate scales via seamless modelling. Operational monitoring and forecasting capacity will be further extended to high trophic level and pollutants (including plastics) etc. By integrating observations and models, the on-going advancement of the OO in Baltic-North Sea will bring huge benefits for sustained development. It will provide strong support for fact-, knowledge- and risk-based adaptive management and planning. This presentation analyzes the needs, benefits and challenges for operational oceanography in seven services, based on examples in Baltic-North Sea: public service (storm surge, coastal flooding, ice service), coastal tourism, shipping, offshore energy, marine spatial planning, ecosystem-based management (rapid environment assessment, monitoring plastics and pollutants, operational fishery service, fishery management) and climate change adaptation (ecosystems, sea level rise and extremes etc.).

HNS-MS: Improving Member States preparedness to face an HNS pollution of the Marine System

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When dealing with a HNS pollution incident, one of the priority requirements is the identification of the hazard and an assessment of the risk posed to the public and responder safety, the environment and socioeconomic assets upon which a state or coastal community depend. The primary factors which determine the safety, environmental and socioeconomic impact of the released substance(s) relate to their physico-chemical properties and fate in the environment. Until now, preparedness actions at various levels have primarily aimed at classifying the general environmental or public health hazard of an HNS, or at performing a risk analysis of HNS transported in European marine regions. Operational datasheets have been (MIDSIS-TROCS) or are being (MAR-CIS) developed collating detailed, substance-specific information for responders and covering information needs at the first stage of an incident. However, contrary to oil pollution preparedness and response tools, only few decision-support tools used by Member State authorities (Coastguard agencies or other) integrate 3D models that are able to simulate the drift, fate and behaviour of HNS spills in the marine environment. When they do, they usually consider simplified or steady-state environmental conditions. As a significant step forward, a 'one-stop shop' integrated HNS decision-support system has been developed in the framework of the HNS-MS project. Focussing on the Bonn Agreement area, the system integrates 1. A database containing the physico-chemical parameters needed to compute the behaviour in the marine environment of 120 relevant HNS; 2. A digital atlas of the HNS environmental and socioeconomic vulnerability maps ; 3. A three dimensional HNS spill drift and fate model able to simulate HNS behaviour in the marine environment (including floaters, sinkers, evaporators and dissolvers). 4. A user-friendly web-based interface allowing Coastguard stations to launch a HNS drift simulation and visualize post-processed results in support of an incident evaluation and decision-making process. All these results, available at http://www.hns-ms.eu/, will be further presented.

Present and future capacities of the Copernicus Marine Service

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The Copernicus Marine Environment Monitoring Service (CMEMS) has started in May 2015 and confirmed its expected value on a growing number of users, its operational reliability and its constant search for innovation. More than ever, there is a need to continuously monitor the oceans : they provide essential services to society, they regulate climate, they provide food and energy, and many economic activities depend on our seas and oceans. But our oceans and marine ecosystems are under threat. CMEMS provides a unique monitoring of the global ocean and European seas based on satellite and in situ observations and models. CMEMS monitors past (over the last 30 years) and current marine conditions and provide short-term forecasts. Mercator Ocean is entrusted by the EU to implement the service, and has chosen a service organisation based on a strong European partnership with more than 60

marine operational and research centres in Europe that are involved in the service and its evolution, and also key partnerships with EuroGOOS and other initiatives such as Emodnet, GEO, and UN/SDG. An overview of CMEMS, its drivers, organization and initial achievements will be given. The essential role of in-situ and satellite upstream observations will be discussed as well as CMEMS Service Evolution Strategy, associated R&D priorities and future scientific technological and cooperation challenges.

Poster presentations

Latest advances in the Spanish Institute of Oceanography Observing System (IEOOS)

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The Spanish Institute of Oceanography (IEO) has been observing and measuring the ocean characteristics as part of its institutional activity. The tide gauges network has been working for more than 80 years, and standard sections began at different moments depending on the local projects, taking physical as well as biochemical measurements. In the latest years, according to the research demands, the IEO hasa added some sections and shorted other ones. The Observing System (IEOOS) includes permanent currentmeters moorings, an open-sea ocean-meteorological buoy offshore Santander and an SST satellital image reception station and regional prediction models, but also incorporates continuous timeseries from IEO coastal infrastructures. The contribution to the ARGO international program and the continuous monitoring thermosalinometers, meteorological stations and ADCP installed on the IEO research vessels complete the system. All these networks are linked to international iniciatives like SeaDataNet, Emodnet, IbiROOS or MONGOOS; and allow IEO to give responses to research activities, official requirements and main society demands.

A long-term strategy for monitoring the salt water inflows in the southern Baltic Sea.

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Deep inflows of the North Sea origin salty, oxygen reach waters are vital for the Baltic Sea ecosystem. The inflow route passes through the Bornholm Deep, Slupsk Channel and Gdansk Deep. Institute of Oceanology Polish Academy of Sciences (IOPAN) has investigated these key regions since the late 80s. Every year 3-4 cruises of the IOPAN research vessel R/V Oceania are devoted to study the deep water dynamics and inflow processes. However, there is still lack of the long-term integrated observing strategy to cover different spatial and temporal scales. To improve data coverage and establish the sustained observations, additional observational methods has to be employed. The Argo float system has been originally developed for observations in deep oceans. At present almost 4000 floats collect measurements in the global ocean. A part of these floats is deployed under the Euro-Argo program. The next phase of the Euro-Argo incudes the extension of the float system into the polar oceans and the marginal seas and IOPAN contributes to both efforts. For the last decade IOPAN has deployed floats in the Nordic Seas and in 2016 we started Argo floats deployments in the southern Baltic. To complement measurements with Argo floats, the NRT continuous measurements collected by a moored surface buoy will be integrated in the SatBaltic system and available online. The refurbished and modernized Oceanor buoy will be moored in the Slupsk Channel. Standard meteorological data, hydrographic data from the surface and bottom layers as well as ADCP profiles will be transmitted via satellite connection. Three sources of data and various measurements techniques: synoptic cruises, Lagrangian data from Argo floats and Eulerian data from the moored buoy will provide extensive, complementary data set for

monitoring the inflows properties and dynamics, improvement of numerical models and validation of satellite observations.

Operational in situ oil spill detection in the Baltic Sea, using FerryBox system equipped with oil sensor

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The Baltic Sea, with its high maritime traffic has increased probability for oil pollution occurrence. Spatial distribution of detected oil spills show that they are most probably noted on major ship routes, which leads to idea to monitor oil in water with Ships Of Opportunity (SOOPs). UV (Ultra-violet) fluorescence is highly sensitive and straightforward method to determine oil-based aromatic compounds in seawater, in lab and on field. In-situ field operable UV fluorometers are nowadays compact, robust and sensitive - up to 0.001 µg/L. FerryBox system developed by TUT Marine Systems Institute is used on board ferry M/S BALTIC QUEEN. During GRACE project, UviLux (Chelsey Instruments Ltd) UV-fluorometer is used for monitoring oil compounds in surface layer of the open sea. With excitation wavelength at 360nm and emission at 450nm, detecting the concentration of polycyclic aromatic hydrocarbons (PAHs) in seawater. Other properties are recorded by the same system in parallel – temperature, salinity and turbidity. Such an system enables asset for automated detection and monitoring of oil spills on fairways, where occurrence of those is highest and namely on fairway on Tallinn – Stockholm route. First results show reliable operation of the FerryBox system equipped with UviLux oil sensor and showed PAH concentrations (in terms of Carbazole) varying between 0,12-0,74 µg/ with remarkable and quite stable variability patterns of PAH concentrations. Repeated tracks of ferry allow to obtain statistics of oil compounds in water in different sea areas. Especially important is monitoring of small spills, which stay undetected with conventional remote sensing methods, but are most numerous and detectable only with in situ measurements. Study is performed in H2020 project GRACE (InteGrated oil spill Response ACtions and Environmental effects) focusing on comparing and evaluating the effectiveness and effects of different oil spill response methods in a cold climate.

Multiscale and multidisciplinary Marine Rapid Environmental Assessment data collection methodology for operational and forecasting oceanography

Ivan Federico, Francesco Maicu, Nadia Pinardi, Paolo Oddo, Marco Zavatarelli, Vladyslav Lyubartsev, Salvatore Causio, Maurizio Demarte, Paola Picco, Alfredo Falconieri, Rita Lecci, Teodosio Lacava, Matteo Lisi, Augusto Sepp-Neves, Giuliano Lorenzetti, Giorgia Manfe', Francesco Trotta, Luca Zaggia, Stefania Angela Ciliberti, Claudia Fratianni, Alessandro Grandi

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The work provides an overview on MREA (Marine Rapid Environmental Assessment) experimental methodology developed in last years, thanks to the synergies between oceanographic research centers and Italian Navy Hydrographic Institute. The approach is based on optimal strategy - to collect evidences on ocean mesoscales and submesoscales with synoptic coverage and repeated surveys, - to increase skills of ocean forecasting, producing initialization and verification datasets for models. Starting from experiences of so-called REA (Rapid Environmental Assessment) implementations in Mediterranean areas in late 1990s (Robinson and Sellschopp, 2002), here we illustrate our three MREA strategies, progressively improved and adapted to physical processes to be investigated. The first application (MREA14) carried out in Taranto Gulf (EasternMediterranean) in October2014 (Pinardi et al., 2016) was based on classical-regular-grid CTD sampling strategy at different oceanographic scales. The analysis on geostrophic circulations highlighted the presence of submesoscale eddy, also reproduced in modeling based on multiple nesting (Trotta et al., 2017). The observed data were adopted to assess performances of forecasting systems (Federico et al., 2017) and downscaling from subregional to coastal scale (Gaeta et al., 2016). The second experiment (MREA16) was performed in 2016 again in Taranto Gulf, but in different season (Summer). The main objective was to evaluate possible changes of large-scale circulation, compared with previous MREA. The sampling methodology tested in 2014 was strengthened integrating the CTD data collection with simultaneous measurements of currents through vessel-mounted-ADCP. The comparison with MREA14 shows the reverse of circulation from the large-scale gyre anticyclonically-oriented in Autumn and cyclonically-oriented in Summer. The next campaign (MREA17) planned in Autumn 2017 in Ligurian Sea (WesternMediterranean) will adopt a new approach, consisting in use of sampling schemes with increasing spatial resolution. The multiscale-multidisciplinary aspects are addressed combining remote sensed data with unmanned underwater vehicles and shipborne instrumentations equipped with multidisciplinary sensors. This will allow to capture possible submesoscale structures and simultaneously characterize the large scale dynamics.

Operative met-ocean measurements - challenges and options

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Meteorological and Hydrological service of Croatia has been state authority for meteorological and marine meteorological analyses, forecasts and warnings for more than 70 years. The operative met-ocean monitoring of the sea state has been provided by observations and measurements. The real-time monitoring at 3h frequencies at marine stations and marine traffic lighthouses has been the main origin of real-time data for the decades. Recently Met service of Croatia started with the update of the sea state and sea physical measurements in the three directions: new design for real-time network of met-ocean moored buoys measurements; new real time sea surface temperature buoys network for sea climatology; real time Voluntary observing ships automatic weather stations from E-SURFMAR actions. Solutions are seeking for the real time GPRS and satellite data transfer. Innovative IT options with data transfer via radio dissemination has been explored - Application Specific Messages (AMS) for Automatic Identification System (AIS). Different measurements sensors with AIS ASM AToN compliance criteria are under the tests. Actions are planned as integrated system of the measurements over the Croatian Coastal waters.

Error assessment of multi-source satellite-derived sea ice leads products

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Arctic sea ice is undergoing dramatic changes in the context of global climate change. Satellite observation data shows a decreasing Arctic sea ice extent about 13% every decade in recent years, accompany with an accelerate thinning. Sea ice leads as a dynamics and thermodynamic driven sea ice features, it is the important heat flux window for the ocean and atmosphere, especially during wintertime. Poor performance of model simulation and the lack of long series satellite observation data with high resolution limited our focus on characterizing and understanding the variability of Arctic sea ice leads. Hence there is a rising demand for high resolution and accuracy sea ice leads product. A daily AMSRE based product with 6.25 km spatial resolution from 2002 to 2011 and a daily MODIS based product with 1.5 km spatial resolution from 2003 to 2015 and a daily Advanced-MODIS based product with 1 km spatial resolution from 2002 to 2017 have been introduced in this passage. In this context, Synthetic Aperture Radar images are employed to quantify this three kinds of sea ice leads products. Our results highlight that the AMSRE product has a consistent overestimation in pan-Arctic, the MODIS product has a significant omission in Beaufort Sea and a remarkable misclassification in GIN (Greenland, Iceland and Norway), and the A-MODIS product adjusts the accuracy of leads discrimination and can be useful to apply in forecast model.

A new AERONET-OC site for the northern North Sea.

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The need for high-frequency, high-quality optical measurements at sea level to support and validate satellite measurements of ocean colour has long been recognised (Zibordi et al. 2009). With the aims of creating new satellite products for Sentinels 2 and 3, and greatly increasing the availability of marine in situ data for validation, the HIGHROC proposal was successful, and received funding for four years. In the project, a large dataset of in situ measurements of water quality will be generated using automated SMARTBUOY and FERRYBOX systems to generate high quality measurements of parameters such as suspended sediment load, chlorophyll concentration and underwater light penetration. These are the types of data which are typically used in national assessments of water quality, and in Environmental Statements by maritime industry. Utilisation of automated in situ measurements can greatly increase the number of match-ups with satellite data. In addition to the in-water measurements, readings of the radiance leaving the water surface are very important for satellite validation (Zibordi et al. 2015). The water-leaving radiance (Lw) is equivalent to the radiance measured by a satellite after correction for attenuation of light in the atmosphere. There are at present no suitable operational measurements of Lw

in UK waters, indeed there were none in the whole of the North Sea prior to HIGHROC. To improve the coverage of sea-level radiance in the North Sea, Cefas and the University of Hull are working together with the Offshore Renewable Energy Catapult centre in the development of an AERONET ocean-colour measuring station to be located at an experimental meteorological tower in the northern North Sea. The presentation will describe the steps involved in the design and installation of the new AERONET-OC site, and show initial results of the optical characterisation of the case-2 waters in the northern North Sea.

A new database of quality-controlled phytoplankton pigments for the European north-west shelf.

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High-quality geo-referenced in situ samples are invaluable for the validation of biogeochemical models (Ford et al. 2017) and satellite ocean colour products (Ruddick et al. 2016). Here, we present a detailed description of a publically-available database of 686 phytoplankton pigment samples from a variety of cruises. Geographically, the sampling extent covers two important shelf sea areas: the North Sea using gridded sampling on summer International Bottom Trawl Survey cruises between 2010 and 2016, and the Celtic Sea/English Channel using autumn pelagic survey between 2012 and 2016. Water samples were taken from the ferrybox intake of the research vessel "Cefas Endeavour" for surface samples, or from Niskin bottles deployed from a CTD rosette at depth. Samples were filtered on GFF and frozen immediately in liquid nitrogen or at -80° C before shipment to the international pigment analysis laboratory at DHI. Results were quality controlled after Aiken et al. (2009) and entered into a relational database. The HPLC-derived chlorophyll a was used to convert fluorescence from the vessel's ferrybox fluorometer and depth-profiling fluorometers on a per cruise basis. This enabled the use of data from the high-frequency autonomous instruments to be used to provide chlorophyll estimates along the ship route at the surface, and for selected underwater profiles. The quality-controlled data are incorporated into ecosystem assessments (e.g. MSFD), and are used to validate chlorophyll estimates derived from remote sensing where matchups are available.

Effective vertical mixing over a deep basin via the use of an ARGO float

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The programme ARGO has become an essential component of the GOOS project. Its observations are regularly used for data assimilation in ocean forecasting. In the recent years the ARGO float data have

been used also for assessing the global mixing induced by internal waves. However, internal-waves constitute just one of the numerous oceanic processes causing mixing. In this work we have estimated the effective (i.e. the overall) mixing as revealed by successive CTD profiles of an ARGO float trapped within a deep sub-basin of the North Aegean Sea during 2014-2015. These observations enabled the identification of the deep-water ventilation episodes and the determination of effective vertical eddy diffusivity during the stagnation period that followed these events. Differences between the initial eddy diffusivity estimates obtained from the temperature, salinity and density profiles, and the observation of a gradual drift of theta/S values towards higher salinities, led to a correction for the conductivity sensor calibration. Application of the correction to the salinity profiles generated almost identical eddy diffusivity profiles. These eddy diffusivity estimates were at least one order of magnitude higher than eddy diffusivities based on internal wave strain, revealing the dominance of other processes in mixing within the deep basin. This method can be applied to several oceanic basins where topographic steering turns ARGO floats into virtual moorings. Thus, it can provide mixing estimates over previously unstudied oceanic basins. These estimates can be used for tuning the vertical mixing schemes of oceanic models and eventually lead to the improvement of long-term forecasting accuracy.

Bio-ARGO as a potential source of regular validation and model improvement in an operational biogeochemical model

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The advancements of marine ecosystem models as part of monitoring and forecasting services has become a scientific challenge. In the context of rapid environmental change and its potential impacts on marine ecosystems there is a growing demand for better monitoring and forecasting services. This raises the need for high-resolution products that are corrected with extensive datasets and assimilation techniques that are routinely evaluated. These services already exploit observations of physical parameters from remote sensing and autonomous instruments. For biogeochemical variables, the primary source has been cruise data, but these are not autonomous or available in real time. Remote sensed data are limited to the surface and by cloud cover. Biogeochemical sensors mounted on ARGO-floats (bio-ARGO) are a growing source of real time observations. We investigate the potential for using the bio-ARGO observations for evaluation of an operational model of the North Atlantic and Arctic. The model system uses ECOSMO, a 3d NPZD type ecosystem model coupled to HYCOM simulated in TOPAZ4 coupled ocean-sea ice data assimilation system and provides regular forecast for the region north of 62N. ECOSMO includes 2 phytoplankton functional types (PFT), with decoupled chlorophyll to carbon dynamics. Bio-ARGO can have sensors for nitrate, oxygen, chlorophyll, and pH in addition to temperature and salinity. Thus, we can potentially evaluate the quality of information that can be gathered such as the actual values, the shape of the chlorophyll profiles, location of deep chlorophyll maxima and the timing of spring bloom and of initial drawdown of nutrients, in the context of improving model dynamics. The comparison to bio-ARGO will be supplemented by remote-sensing observations of chlorophyll and algorithms estimating dominating PFTs from remote sensing to evaluate the spatial and temporal extent of information by use of cluster analysis, and comparisons with the model results.

Particle transport model sensitivity on wave-induced processes in the forecasting coupled model system

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Different effects of wind waves on the hydrodynamics in the North Sea-Baltic Sea are investigated using a coupled wave (WAM) and circulation (NEMO) model system. The terms accounting for the wave-current interaction are: the Stokes-Coriolis force, the sea-state dependent momentum and energy flux and their role on particle-drift model simulations is investigated. Those particles can be considered as simple representations of either oil fractions, or fish larvae. In the ocean circulation models the momentum flux from the atmosphere, which is related to the wind speed, is passed directly to the ocean and this is controlled by the drag coefficient. However, in the real ocean, the waves play also the role of a reservoir for momentum and energy because different amounts of the momentum flux from the atmosphere is taken up by the waves. In the coupled model system the momentum transferred into the ocean model is estimated as the fraction of the total flux that goes directly to the currents plus the momentum lost from wave dissipation. Additionally, we demonstrate that the wave-induced Stokes-Coriolis force leads to a deflection of the current. During the extreme events the Stokes velocity is comparable in magnitude to the current velocity. The resulting wave-induced drift is crucial for the transport of particles in the upper ocean. The performed sensitivity analyses demonstrate that the model skill depends on the chosen processes. The using of a coupled model system reveals that the newly introduced wave effects are important for the operational drift-model performance and search and rescue, oil-spill, transport of biological material, or larva drift applications.

Towards the Arctic Ocean bio-geochemistry reanalysis by EnKF data assimilation system

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Bio-geochemistry and physical coupled reanalysis system for the CMEMS ARC-MFC is under development at the Nansen Environmental and Remote Sensing Center (NERSC). The system is based on the TOPAZ4 ocean modelling system, HYCOM-ECOSMO II coupled ocean-biogeochemical model, and the data assimilation system, an Ensemble Kalman Filter (EnKF). It was demonstrated in a 1D and 3D configurations that joint estimation of state variables and model parameters are important for the current NPZD type bio-geochemical model to track data, inferring existence of region and time-dependencies in its model parameters (Simon et al., 2015; Gharamati et al., 2017). In this study, we extend the state-parameter estimation system to the TOPAZ4 coupled modelling system aiming at

constructing bio-geochemical reanalysis data over the Arctic Ocean during the last decade. In a preliminary experiment, filter divergence due to joint assimilation of in-situ bio-geochemical tracer data and satellite chlorophyll a (chl-a) data is detected and a conflict in representativeness of chl-a data from the two independent sources are being suspected. Re-adjustment of the observational error covariance for resolving this conflict based on model representativeness and satellite chl-a processing system will be discussed.

Calculation and analysis of sea ice drift in Arctic region using satellite data

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The first systematic observation of the ice drift had been held more than a century ago. Initially it was the visual (or using optical instruments at polar stations), then using the Arctic drifting buoys. The main objective includes to find supplementary ways to study sea ice motion. Spatial ice drift vector fields can be retrieved from remote sensing data. The sea ice motion is estimated by comparing the points of sea ice patterns in two subsequent snapshots. We propose a feature tracking algorithm for sea ice drift retrieval from sequential satellite synthetic aperture radar (SAR) images. The method is based on feature tracking comprising of feature detection, description and matching steps. The approach exploits the benefits of nonlinear multi-scale image representations using keypoints, which is a method that detects and describes image features in an anisotropic scale space that preserves important object boundaries while adaptively removing noise and small image details. These techniques were implemented as a part of ice drift retrieval algorithm and tested on dual polarized Sentinel-1A C-SAR extra wide swath mode data over Arctic Seas. Method contain several processing steps: SAR data preprocessing, feature point detection using scale-space image representation, feature description - construction of so-called descriptor which describes the area around feature point in a format of 1- D vector, feature matching step that results in ice feature displacement through the images and filtering of erroneous vectors. To evaluate the developed of sea ice drift retrieval algorithm we performed a series of experiments over the Arctic seas. Data collection and processing is done in real time. Validation of the results performed in parallel and includes comparisons with other statistical and manual methods.

ANALYSIS OF BIOCHEMICAL TIME SERIES DATA FROM RADMED MONITORING PROGRAMME AT IEO

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Since 2007, Spanish Institute of Oceanography (IEO) is supporting a Mediterranean monitoring programme (RADMED) that is the result of merging four previous projects:, some of them starting in

1992, and the inclusion of new transects not sampled before. Four times per year several sections are sampled routinely, from Cabo Pino (close to Straits of Gibraltar) to Barcelona, including Balearic channels. Coastal, shelf and deep stations are monitored, from 20 to 2500 m depth, and are located in such way that all water masses from western Mediterranean are sampled regularly. This monitoring comprises from westernmost productive areas such Alboran Sea, oligotrophic waters such as those to the North of Cabo Palos and around Balearic Islands, or areas of special biological interest as those surrounding the delta of the Ebro river. At each station, water column temperature, salinity, dissolved oxygen, fluorescence and turbidity are measured and water samples at standard depths are taken for analysis of: inorganic nutrients, chlorophyll concentration, microphytoplankton and picophytoplankton abundance, etc. In this work, all nutrients, chlorophyll and oxygen data are analyzed in order to establish seasonal and spatial patterns. In some cases, as in Cabo Pino or Malaga transects, a total of 67 surveys from 1992 to 2016, have been analyzed. In other sections, as Mahon (westernmost Balearic Island), only data from 17 surveys are available, as this section was the last included in RADMED project. Nutricline depth, maximum chlorophyll concentration and maximum chlorophyll depth are also studied. Different patterns are detected depending on the area. As an example, in Alboran Sea are located the lowest values of mean nutricline depth (9.62 m) and the highest ones of mean maximum chlorophyll a concentration (1.19 mg/m3), while in Balearic transect the mean values are 55 m and 0.5 mg/m3, respectively, indicating higher oligotrophy when waters are “more Mediterranean”

Development of a regional NEMO-based configuration for the Black Sea in the framework of Copernicus Marine Environment and Monitoring Service: recent developments and future perspectives

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The Black Sea Monitoring and Forecasting Center (BS-MFC) is part of the Copernicus Marine Environment and Monitoring Service since 2016 and provides regular and systematic information on the time-evolving Black Sea ocean state. The purpose is to document the specific improvements in the Black Sea model physics, which ranges from near-real-time products to ocean retrospective analysis, from the modeling and the operational oceanography perspectives. Here, we present the model setup and product quality assessment, describing the main characteristics of the Black Sea circulation dynamics. The core model, based on NEMO, is developed by the Foundation Euro-Mediterranean Center on Climate Change in collaboration with the Sofia University and the University of Bologna. The spatial domain is resolved with 1/27◦×1/36◦ horizontal resolution and 31 z-levels with partial steps, using GEBCO bathymetry data set. The circulation is forced by momentum, water and heat fluxes interactively computed by bulk formulae that use high resolution operational analyses atmospheric forcing provided by the European Centre for Medium-Range Forecast. Precipitation field has been computed from the climatological GPCP rainfall monthly data, while the evaporation is derived from the latent heat flux. The climatological monthly mean river runoff is derived by a hydrological dataset provided by SESAME project. Concerning the operational system, BS-MFC physical model provides daily 10-day forecasts, 3-

days analyses and 1-day simulation. Once a week, the system runs 15-days analyses to compute the new optimal initial condition for the forecast cycle. The assimilation is performed by a three-dimensional variational data assimilation system that ingests all hydrographic profiles, sea level anomaly data from available altimetry missions and sea surface temperature measurements retrieved from infrared sensors on-board polar orbiting satellites. This paper will document also future updates in the next system release, with main focuses on improved vertical resolution, data assimilation scheme and open boundary at the Bosporus Strait.

Development of operational oceanography system for fishery management and its application in the Central North Pacific Ocean

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The central North Pacific region centred on the international date line and 40N is known to be one of the richest fishing ground of neon flying squid in the North Pacific Ocean. We developed regional ocean environment analysis system, Scalable Kit of Under-sea Information Delivery system (SKUIDs) for providing potential fishing ground information to fishing operators for achieving quasi-operational habitat monitoring/management and economical optimization of fishing operation at this site. Key components comprising the analysis system are four dimensional data assimilation system operated in quasi-operational mode, statistical analysis scheme for detecting potential fishing ground at an oceanic frontal scale and the web-based visualization system for delivering the information to fishing vessels. In this presentation, we report application of SKUIDs for assisting neon-flying squid fishing operation in the Central North Pacific ocean conducted from 2013 to 2016.

Improving the IEO/NODC activity by a distributed and coordinated infrastructure

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Since 1964, the Instituto Español de Oceanografía (IEO) runs the National Oceanographic Data Center (NODC), responsible for the compilation, storage and distribution of marine data for researching, advising and the different demands that have been evolving among the times. The integration into larger international frameworks includes the Global Ocean Observing System (GOOS) and its regional groups, International Oceanographic Data and Information Exchange (IOC/IODE), or European consortiums as SeaDataNet and EmodNET have been contributed to move forward under the guidelines of standardization for geospatial data and related information as marine research projects, vessels and observatories. Taking advantage of IEO coastal centers experience in data acquisition as well as the last

software developments, the NODC has implemented a distributed infrastructure that shorts the time taken to incorporate the data and marine information from its acquisition into the permanent database. This organization includes survey acquired data, but also continuous data from research vessels, the ocean-meteorological buoy and coastal tide gauges. Metadata and data are spread to the research community and society through SeaDataNet infrastructure but also lets the IEO maintaining its own national data portal giving response to governmental and national inquiries.

Data Sharing Tools for the Southern Ocean Observing System

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The Southern Ocean Observing System (SOOS) faces many of the same data challenges as observing systems in other parts of the globe. To better understand the processes at play in the Southern Ocean, we need to collate datasets that are currently scattered across the world's data repositories. In addition, the size and remoteness of the Southern Ocean means that international cooperation in collecting observations is particularly important. At SOOS, we are developing a number of data sharing projects to bridge the gaps between these repositories. In this presentation, we will share our experiences in developing DueSouth: A Database of Upcoming Expeditions to the Southern Ocean - a publicly editable spatial database of voyage and project plans. We will also present SOOSmap, which gives a snapshot of the status of observing platforms in the Southern Ocean at any given time. Finally, we will discuss plans to federate searching for individual datasets across the world's data repositories. These SOOS data initiatives may be of interest to our colleagues facing similar challenges in European oceans.

The Data Lifecycle at SOCIB: responding to science and society needs

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The Balearic Islands Coastal Ocean Observing and Forecasting System, is a Marine Research Infrastructure (ICTS) that provides world-class, quality controlled metocean data, in both real time and delayed mode, from across its multi-platform coastal to open ocean observing and forecasting system. This multi-platform approach is needed to properly capture oceanographic processes, that take place at different spatial and temporal scales, and that characterise both ocean state and ocean variability. The observing system provides physical and biogeochemical variables from different platforms like research

vessel, high-frequency (HF) radar system, weather stations, tide gauges, moorings, drifting buoys, ARGO profilers, gliders and sensors attached to sea turtles. The forecasting system uses high-resolution numerical models for hydrodynamics and waves. SOCIB Data Centre is responsible for the different stages of data management, covering the whole data life-cycle, ranging from data acquisition using observational platforms, numerical models or information generated by other divisions, to distribution and visualization through the development of specific tools for visualising the data sets, including both dedicated web and mobile applications. The implemented system relies on open source solutions and facilitates the transfer of data from SOCIB to other international portals, such as EMODnet-Physics, CMEMS INSTAC or MONGOOS. Data services and applications were developed in line with EU-funded initiatives as CMEMS, Jerico-Next, ODIP2 to provide response to scientific and societal needs, by targeting user profiles such as researchers, technicians, policy and decision makers, educators, students and society in general. Other applications are being developed as an adaptation to different sectors within SOCIB's new Products and Services 2017 strategy (coast guard and Bluefin tuna apps). SOCIB organizational and conceptual structure as a facility of facilities is a good example of Marine Information System within the framework of new Ocean Observatories and/or Marine Research Infrastructures, a system that through opendata principles, generates added value to both cover the scientific community demands and respond to the general society needs.

The national research infrastructure NMDC, Norwegian Marine Data Centre

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NMD, the Norwegian Marine Datacentre hosted by IMR Institute of Marine Research is the responsible NODC National Ocenaographic Data Centre of Norway and is coordinating the national research infrastructure NMDC Norwegian Marine Data Centre. Datamanagement of marine data at IMR put into a distributed system with 6 nodes managing data from 16 institutions. Seamless access to marine data.

Scientific Platform as a Service - Tools and solutions for efficient access to and analysis of oceanographic data

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Existing international and Norwegian infrastructure projects, e.g., ESA GlobCurrent, NRC NorDataNet, NRC NMDC and NRC NORMAP, provide open data access through the OPeNDAP protocol following the conventions for CF (Climate and Forecast) metadata, designed to promote the processing and sharing of files created with the NetCDF application programming interface (API). This approach is now also being implemented in the Norwegian Sentinel Data Hub to provide satellite EO data to the user community. Simultaneously with providing simplified and unified data access, these projects also seek to

establish and use common standards for use and discovery metadata allowing development of standardised tools for data search and web streaming to perform scientific data analysis. A combination of software tools and actual data access, which we call the Geo-Scientific Platform as a Service (SPaaS), takes advantage of these opportunities to harmonise and streamline the search, retrieval and analysis of integrated satellite and auxiliary observations of the oceans in a seamless system. The core part of the Geo-SPaaS is a metadata catalog to store granular metadata describing the structure, location and content of available satellite, model, and in situ datasets. Data analysis tools include software for visualisation, interactive in-depth analysis, and server-based processing chains. The Geo-SPaaS components are integrated in virtual machines (e.g., VirtualBox, VMware), of which provisioning and deployment are automatised using existing state-of-the-art open-source tools (e.g., Vagrant, Ansible, Git, Python). The open-source code for scientific tools and virtual machine configurations is available on GitHub (https://github.com/nansencenter/), and is coupled to an online continuous integration system (Travis CI). The Geo-SPaaS enables researchers to more quickly develop and test scientific algorithms, which then can be operationalized on server systems (Geo-SPaaS nodes).