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10th EuroGOOS International Conference

3-5 Oct 23
Galway, Ireland

European Operational Oceanography for the Ocean we want – addressing the UN Ocean Decade Challenges

Book of Abstracts

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Edited by: Dina Eparkhina, Joseph E. Nolan, Alicia Blanco

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Dina Eparkhina	EuroGOOS, Belgium

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Session A

Towards digital twins of the ocean

EDITO: two innovative projects for an operational European Digital Twin of the Ocean

Authors

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2 Institut Mines-Telecom, France
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4 Centre National De La Recherche Scientifique Cnrs, France
5 Deltares, Netherlands
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Keywords

Digital twin of the ocean, Ocean modelling, Ocean forecasting, Ocean observations datasets, Co-development environment

Abstract

A Digital Twin of the Ocean is a virtual representation of all marine and coastal environments around the globe. It gives access to real-time and historical observations from thousands of sensors across the world ocean, as well as numerous satellites in space.

By integrating advanced numerical modelling, artificial intelligence, machine learning and high-performance computing, digital twins are able to generate the information needed to design the most effective and sustainable ways of protecting marine and coastal habitats, supporting a more sustainable blue economy, and mitigating and adapting to climate change.

The European Commission launched the European Digital Twin of the Ocean (EDITO) at the One Ocean Summit in Brest, France, in February 2022. As a main element of the Digital Ocean Knowledge System under the European Union's "Mission Restore our Ocean and Waters", its ambition is to make ocean information readily available to all - international policymakers, national governments, researchers, innovators, businesses, entrepreneurs, activists, and citizens.

EDITO will provide an innovative set of user-driven, interactive and decision-making tools, backed by the best science and data. Its core development is underway with the funding from the European Union (EU). The EU will build the infrastructure backbone of EDITO through two projects, namely EDITO-Model Lab and EDITO-Infra. It will further construct and evolve a thriving digital ecosystem through a number of other relevant, complementary actions, aiming for an operational Digital Twin of the Ocean by 2024.

EDITO-Infra will build the public infrastructure backbone for EDITO by integrating key data service components (among which Copernicus Marine Service and EMODnet), and by sharing cloud processing capabilities and software into a single digital framework.
https://edito-infra.eu/

Piloting the concept of an Information Management Framework for Environmental Digital Twins (IMFe) and connecting the results to the UN decade DITTO programme

Authors

J. Buck[1], J. Siddorn[1], G. Blair[2], D. Boot[1], A. Kingdon[3], A. Kloker[1], A. Kokkinaki[1], G. Moncoiffe[1], E. Blyth[2], M. Fry[2], R. Heaven[3], E. Lewis[4], B. Marchant[4], B. S. Pepler[4], P. Townsend[4], J. Watkins[2] and K. Winfield[4]

[1] NOC, National Oceanography Centre
[2] UKCEH
[3] GS
[4] STFC

Keywords

Digital Twins, UN Decade DITTO action, Marine protected areas, FAIR data

Abstract

Environmental science is primarily concerned with assessing the impacts of changing environmental conditions on the state of the natural world. Environmental Digital Twins (EDT) are new technology that significantly improves our understanding of the natural environment and, in particular, delivers the capacity to visualise the impacts of environmental change scenarios upon the environment.

The UK Natural Environment Research Council (NERC) has recently published its first digital strategy[1], which sets out a vision for digitally enabled environmental science for the next decade. This strategy places data and digital technologies at the heart of UK environmental science. EDT are one such technology. These are needed to demonstrate the complex impacts of anthropogenic changes on the natural environment to non-specialist stakeholders in a form where these impacts can be effectively understood and, hopefully, aid planning to remediate those impacts.

[1] https://www.ukri.org/publications/natural-environment-research-council-nerc-digital-strategy-2021-2030/

The capacity to build EDT are an outcome of the increasing availability of large and diverse, baseline data sources, combined with real-time monitoring data from dynamic environmental sensor networks and time-variant process modelling. When integrated with visualisation technologies, they provide the components necessary to build EDT technologies and deliver the capability for the environmental science community to make a step-change in our understanding of the environment. Whilst the components may be developed separately but can act collectively as a wider network that can be combined to deliver environmental digital twins.

Enabling this interoperability requires procedures and rules that specifies the components necessary for effective information management within and across the EDT ecosystem. It must enable secure, resilient interoperability of data, and is a reference point to facilitate data use in line with security, legal, commercial, privacy and other relevant concerns. Our recommendations for the development of an information management framework for EDT (IMFe).

Replicating the behaviour of environmental systems is inevitably a multi-disciplinary activity. Therefore, components will need to be developed following agreed standards to make sure the information can be trusted by the user, and that they are semantically interoperable so that data can be shared. A digital Asset Register will be showcased to provide access to and enable linking of such components.

This conceptual project has developed into a project aiming to define the architectures, technologies, standards and hardware infrastructure of the IMFe. These will then be tested by develop a fully functioned pilot environmental digital twin for the Haig Fras Marine Conservation Zone (MCZ). Not only will this test the applicability of the conceptual IMFe but will also provide a clear demonstration of the power of EDT to monitor and scenario test a complex environmental system for the benefit of stakeholders. As a UN Decade Digital Twin of the Ocean (DITTO) project the Haig Fras EDT pilot is trailing the Ocean Data Interoperability System (ODIS) standards. This presentation will show the results of the Haig Fras EDT pilot, sharing its findings and the first results on connecting a EDT to ODIS and by extension DITTO.

Ireland's Digital Twin of the Ocean

Authors

Michael Arrigan[1]

[1] Marine Institute, Ireland

Keywords

Digital twin of the ocean, Ocean modelling, Ocean forecasting, Ocean observations datasets, Co-development environment

Abstract

As part of Ireland's Digital Ocean programme Ireland's Digital Twin of the Ocean (IDTO) aims to harness the full potential of Ireland's comprehensive oceanographic and ecological marine data to better understand, manage and interact with our marine environment.

The concept of a Digital Twin of the Ocean (DTO) is to mirror the marine system in a virtual environment. By integrating data from different disciplines, sensors, models, and digital infrastructures, a DTO will enable real-time monitoring, predictive analysis, and decision support tools, providing a unique opportunity to understand and manage marine ecosystems.

Ireland is in an ideal position with a comprehensive archive of oceanographic and ecological marine data, extensive ongoing monitoring and real-time data pipelines which will enable a more accurate Digital Twin of the Ocean.
Phase 1) of developing IDTO will be to develop a prototype. Using a suitable platform, data will be integrated from multiple sources and visualised with interactive tools to demonstrate functionality. Stakeholder feedback will inform the further development and scope of IDTO.

Phase 2) will expand the data services to incorporate additional marine data into the virtual environment.

Phase 3) will build advanced visualisation capabilities, predictive analysis, and decision support tools, providing a unique opportunity to understand and manage marine ecosystems.

Collaborating with international partners, IDTO will help inform and build a cohesive network of DTO's for sharing and interacting with data in a unified approach to support monitoring, simulation, decision-making and planning in our marine environment.

Serverless QC for Ocean Gliders: A SeaChange

Authors

Thomas Gardner[1]

[1] National Oceanography Centre, UK

Keywords

Digital twin of the ocean, Ocean modelling, Ocean forecasting, Ocean observations datasets, Co-development environment

Abstract

Ocean gliders are autonomous underwater vehicles that are used to collect data on oceanographic conditions. They are typically deployed for extended periods of time, and the data they collect are critical for understanding the ocean and its changes. However, the data collected by ocean gliders are often noisy and requires quality control (QC) before it can be used. Serverless QC is an innovative approach to QC that uses local or cloud-based services to run the process of identifying and correcting errors in data. This approach has several advantages over traditional ways of running QC methods, including:

- It is more scalable, as it can be easily adapted to manage substantial amounts of data;
- It is more cost-effective, as it does not require the purchase and maintenance of dedicated hardware; and
- It is more dependable, as it is not subject to the same hardware and software failures as traditional QC methods.

In this talk, we will discuss the use of serverless QC for ocean gliders. We will describe the challenges of running QC models for ocean glider data, and we will show how serverless QC can be used to address these challenges.

One of the challenges is that it is often difficult to find what QC has been applied to the datum. To address this challenge, we will link the QC methods to the NERC controlled Vocabulary Server (NVS). This will allow us to use the NVS to define the terms and concepts

that are used in these methods. We can also link back to the QC performed from within the final data product.

To increase the uptake and interoperability of these QC modules, we will use Open Container Initiative (OCI) based containers. These containers will hold the software and prerequisite data that are needed to perform the QC, and they will be available to users through 3rd party hosting solutions like docker hub, GitHub, etc.

We believe that the use of serverless QC, NVS, and OCI-based containers will improve the quality of oceanographic data and make it easier to share and use this data.

The talk will conclude with a discussion of the future of serverless QC for autonomous platforms. We will discuss the potential of serverless QC to improve the quality of oceanographic datum, and we will show the challenges that need to be addressed to realise this potential.

In the shoes of a Marine Data Manager in an autonomous world

Authors

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Keywords

Digital twin of the ocean, Ocean modelling, Ocean forecasting, Ocean observations datasets, Co-development environment

Abstract

The British Oceanographic Data Centre (BODC) would like to take this opportunity to present the data management life cycle for operating an autonomous data system in the context of glider missions.

Autonomous platforms, such as ocean gliders, are increasingly being used by the community to answer the oceans' big questions. In recent years, the technologies used in these platforms have advanced so that more sensors can be integrated, and missions can operate for longer. The UK Research and Innovation (UKRI) and the Natural Environment Research Council (NERC) are looking to become greener and have set a target of being a net zero organisation by 2040. To meet this target, NERC are planning to grow their marine autonomy capabilities, with an expectation that the autonomous fleet will double every 5 years with a total fleet of 200 gliders plus other autonomous vehicles being available to the national marine equipment pool by 20351.

To accommodate this pace of change, Data Assembly Centres (DACs) are required to have automated processing workflows that are reliant 24/7 all year round. Their data systems also need to be capable of scaling out to be able to operate for multiple deployments and deliver data in a timely fashion for use in operational centres and at Global Data Assembly Centres (GDACs). The UK DAC for gliders (BODC, based at the UK's National Oceanography Centre, NOC) see this as a big challenge to overcome for the marine data management community.

The BODC are using innovative solutions including a Semantic Sensor Network (SSN) database to register sensors and platforms. This database uses the NERC Vocabulary Server (NVS) to allow our metadata records to stay consistent and interoperable globally. We are utilising community open-source tools to help plug the gaps such as ERDDAP and established community-maintained quality control toolboxes.

The presentation will cover a discussion on the lessons learnt along the way and how we are trying to make glider data Findable, Accessible, Interoperable, Reusable (FAIR) and data management more efficient for marine autonomy in alignment with the EuroGOOS 2030 strategy vision for sustained ocean observing.

[1] https://noc.ac.uk/facilities/ships/future-marine-autonomous-systems

EOSC-FUTURE – ENVRI-FAIR Dashboard of the State of the Environment

Authors

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Keywords

Dashboard, EOVs, datalakes, subsetting API, ocean viewer

Abstract

In the EOSC-Future project, ENVRI-FAIR partners developed a Dashboard of the State of the Environment. This provides easy means for users to determine the state of the environment and follow trends for selected parameters from Atmosphere, Ocean, and Biodiversity. MARIS leads the development of the Ocean component in cooperation with IFREMER, OGS and NOC-BODC. It consists of two components:

- A Map Viewer that displays *in situ* measurements of selected Essential Ocean Variables (EOVs); and
- Dynamic trend indicators for European sea regions based on the *in situ* measurements.

The map viewer is designed for (citizen) scientists and allows them to interact with large data collections retrieving parameter values by geographical area and using sliders for date, time and depth. At present, the ocean indicators concern temperature, oxygen, nutrients and pH measurements, from Euro-Argo and SeaDataNet. The *in situ* values are co-located with product layers from Copernicus Marine, based upon modelling and satellite data. The data sets are also used in algorithms to generate dynamic trend indicators for EOVs for sea regions. These are published at the Dashboard, while users for more background can go to the Map Viewer to browse deeper into the data and details facilitating the trends.

For this Dashboard and many other societal and scientific challenges, such as Digital Twins of the Oceans, access to a large number of multidisciplinary data resources is key. However, achieving performance is a major challenge as original data is organized in millions of observation files which makes it hard to achieve fast responses. Next to this, data from different domains are stored in a large variety of data infrastructures, each with their own

data-access mechanisms, which causes researchers to spend much time on trying to access relevant data. In a perfect world, users should be able to retrieve data in a uniform way from different data infrastructures following their selection criteria, including for example spatial or temporal boundaries, parameter types, depth ranges and other filters.

Therefore, as part of the EOSC Future and Blue-Cloud projects, MARIS has been developing a software system called 'Beacon' with a unique indexing system that can, on the fly, extract specific data based on the user's request from millions of observational datafiles containing multiple parameters in diverse units. This system and its data can be accessed via a REST API that is exposed by Beacon itself meaning clients can query data via a simple JSON request. The system is built in a way that it returns one single harmonized file as output, regardless of whether the input contains many different datatypes or dimensions. It also allows for converting the units of the original data if parameters are measured in different types of units. It is important to mention that the system can be applied to different data infrastructures and is not tailor made for one specific type of database. As part of the Environmental Dashboard, the beacon API is applied to the SeaDataNet CDI database and the ERA5 dataset from the Climate Data Store, to showcase its performance and user friendliness.

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Session B

Strategic developments in ocean observing – 1

The Science We Need for the Mediterranean Sea We Want (SciNMeet) Programme: the Mediterranean Region's contribution to the UN Decade of Ocean Science for Sustainable Development (2021-2030)

Authors

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Keywords

Mediterranean Region, UN Ocean Decade, co-design, transboundary cooperation

Abstract

The Science We Need for the Mediterranean Sea We Want (SciNMeet) Programme is a groundbreaking initiative aimed to be the Mediterranean Region's contribution to the UN Decade of Ocean Science for Sustainable Development (2021-20230) (hereafter UN Ocean Decade) , and designed to address major challenges and gaps in scientific knowledge related to the Region, with the ultimate goal of better understanding and managing the impacts of climate change, pollution, overexploitation of resources, and marine hazards on the marine environment toward the development of a sustainable future for the region that promotes economic growth and protects its rich natural resources.

The SciNMeet Programme is built on the outcomes of regional consultations and relevant initiatives active in the Mediterranean region,mobilizing the scientific community, policy-makers, private sector, and society as a whole to increase education, awareness, and international collaboration in addressing the seven outcomes of the UN Ocean Decade (including the implementation of Agenda 2030).

One of the main objectives of the programme is to turn the Mediterranean area into a "model region" where the challenge of strengthening the science-policy-society interface towards reversing the cycle of decline of the Mediterranean marine environment is fully tackled. To achieve this, the program focuses on addressing thematic and cross-cutting lines of action such as climate change, marine pollution, marine hazards, ocean literacy and education, ocean observing and prediction, data sharing, and knowledge transfer capacity building. This is being done through the engagement of a broad community of stakeholders, according to the principle of co-design and in line with the principles outlined in the UN Ocean Decade Implementation Plan.

The SciNMeet Programme is supported by a tailored governance structure, with seven technical task teams working together to achieve its objectives. The teams are focused on addressing specific areas of concern, such as Climate Change, Marine Pollution, Marine Hazard, Ocean Literacy & Education, Ocean Observing & Prediction, Data Sharing, and Knowledge Transfer/Capacity Building. By working together, these teams are able to create cross-cutting solutions that address multiple challenges simultaneously engaging the broad community of stakeholders, according to the principle of co-design and in line with the principles outlined in the UN Ocean Decade Implementation Plan.

In addition to addressing scientific challenges, the SciNMeet Programme is also focused on increasing awareness and education around the state of the Mediterranean Sea. This includes enhancing regional capacity building and ocean literacy, and reducing inequalities between the North and South Mediterranean shores by reinforcing partnerships and transboundary cooperation.

At the 10th EuroGOOS International Conference, the goal is to further promote the SciNMeet Programme by presenting its high-level objectives, preliminary outcomes, and the next implementation steps.

EuroGOOS Scientific Strategy: Advancing a Seamless Earth System Approach for European Operational Oceanography

Authors

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Keywords

EuroGOOS Scientific Strategy; Seamless Earth System approach; fit-for-purpose ocean observing; machine learning for operational oceanography, impact-resolving ocean prediction

Abstract

The EuroGOOS Scientific Advisory Working Group (SAWG) has been working on a comprehensive scientific strategy to advance a seamless earth system approach for European Operational Oceanography. This strategy addresses several key research priorities and challenges, including the integration of fit-for-purpose monitoring, improved

cost-effectiveness, and shared responsibility for ocean observing. The strategy also aims to improve data management, develop seamless marine system modeling, and enhance monitoring and modeling for understanding the transportation and transformation of nutrients, carbon, and pollutants in the Land-to-Ocean Aquatic Continuum (LOAC). In addition, the strategy highlights important emerging areas, such as model-observation integration with use of ML/AI in operational oceanography, nature based solution and impact-resolving coastal prediction. Recent research in these areas has made significant strides, with the development of new technologies and observational platforms enabling more efficient and effective monitoring of the ocean environment. Advances in modeling techniques have improved our ability to understand and predict the behavior of the earth system, while efforts to improve our understanding of the LOAC have revealed new insights into the transport and fate of nutrients, carbon, and pollutants, which are essential for ecosystem-based management. The strategy also emphasizes the scientific challenges in providing information services for offshore energy, nature-based solutions using impact-resolving coastal models which modelling impacts of large scale offshore farms and nature-based solutions. This addresses application areas on mitigation to climate change, reducing the risk of coastal hazards and improving the resilience of coastal communities. The presentation will introduce the methodology used and the current status of the SAWG effort to define the EuroGOOS scientific strategy.

Eurofleets: Long-term sustainable development of capacity sharing through multidisciplinary research cruise funding programmes

Authors

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Abstract

The ability to explore remote and challenging areas at sea, across a range of oceanographic disciplines, is becoming increasingly important if we are to understand the complex nature of our oceans and predict future change. Research vessels are at this time a primary method of oceanographic observation, through direct observation and via deployment of autonomous vehicles.

To deliver sustainable improvements in capacity sharing across marine research infrastructures there is a recognised need to enhance the level of coordination in planning and execution of cruises on board European RV's to avoid fragmentation and at times duplication of effort. Our research vessels have the capacity to carry out a wide range of marine research activities including fisheries and deep sea surveys, environmental monitoring, climate change related research, seabed mapping and marine spatial planning.

Eurofleets+ has demonstrated that the provision of single point funded open access to a fleet of 27 State of the Art Research Vessels and associated Marine Research Equipment designed to meet the evolving and challenging needs of the Marine and Environmental science user communities improves capacity sharing through complementary access programmes such as Ship-time and marine Equipment Application (SEA-Programme) Call 'OCEANS' and 'Regional' calls, Co-Principal Investigator (PI) Programme and the Remote Transnational Access (RTA) Programme. In addition to funded Transnational Access training opportunities were leveraged for Marine Technicians and outreach through the Eurofleets+ Ship to Shore broadcasts.

Eurofleets+ has facilitated improved global co-operation between international and EU operators of Research infrastructure as well as between international and EU users. Improved

cooperation between non-EU operators of vessels and equipment based in New Zealand and Bermuda had been demonstrated with more efficient use of research infrastructures located globally and through sharing of information and best practice. The requirement to include multiple countries in teams as part of the TA calls fosters further international co-operation. The Transnational Access calls have a pre-requisite for a minimum of three countries to form the applicant teams for access proposals offering enhances capacity sharing across research teams not only at a European level but internationally also.

The Eurofleets+ project has funded 23 Research Cruises, with in excess of 350 research participants over three years in the eastern and western Atlantic, Baltic, Black Sea, Southern Ocean, Mediterranean and North Sea the results of which adhere to the FAIR data principles (Findability, Accessibility, Interoperability, and Reuse) guarantying their impact now and into the future.

Future Marine Research Infrastructure – defining the scope, scale and pace to help identify and accelerate international partnership opportunities

Authors

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Abstract

The UK is embarking upon a transformation where the imperative to remove fossil fuels from its ocean observation activities will align with the increased scope and scale of autonomous systems within national, regional and international contexts. A recent scoping review (Net Zero Oceanographic Capability [NZOC]) conducted by the UK identified the requirement to build up a transformational ecosystem within which autonomous platforms (USVs, AUVs, gliders, crawlers) play an increasingly important role but also integrate more effectively across other capabilities such as satellites, floats and research ships: system interoperability and FAIR data principles becoming embedded within infrastructures and observational methodologies. The NZOC programme is testing the outcomes and objectives it hopes to achieve over the coming decade and is embarking upon a linked series of development activities and in-water demonstrators aimed at filling specific technology gaps and engaging the user community in the development of novel observational techniques.

The true value of a national network of marine autonomous systems like NZOC is only realised if it is positioned within national strategies for current and future research ships, global programmes such as Argo and Copernicus and across national and regional (ocean basin) partnerships and international initiatives such as GOOS. The UK has set a target of 2040 for removing fossil fuels from its marine research activities but committed to maintaining or enhancing its current research capabilities: that sets the scope and pace of change required and reinforces the need for partnerships with both industry and with other countries to better define the scale.

Advancing European Ocean Observing System: Fit-for-Purpose Monitoring Integration, Cost-Effectiveness, Shared Responsibility and network optimization

Authors

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Keywords

Fit-for-purpose, cost-effectiveness, inclusivity in oceanography

Abstract

The development of the European Ocean Observing System (EOOS) is crucial to providing efficient information services for climate change adaptation and mitigation, ocean health, and sustainable blue economy. This observing system has to be fit-for-purpose, cost-

effectiveness, and with shared, which present a complex challenge that requires innovative solutions. Effective monitoring of the ocean is increasingly important, as oceanic changes continue to have far-reaching impacts on both natural and human systems. Recent research and developments within the EuroGOOS community have made significant progress in developing new, cost-effective technologies and approaches to address these issues, e.g., for monitoring biodiversity and biogeochemical parameters. This includes the use of autonomous vehicles, new satellite data, and machine learning techniques. Despite these advancements, several significant challenges still need to be addressed to ensure the success of EOOS. These challenges include the standardization of data collection and near real-time data delivery, the development of effective data management strategies, the transfer of new monitoring technologies and concepts from research to operations, the assessment and optimal design of observational networks, shared monitoring strategies, and the need to ensure the long-term sustainability of monitoring programs. This presentation will discuss recent research achievements and challenges in these areas. It will emphasize the importance of innovation and collaboration in developing effective solutions for fit-for-purpose monitoring integration, improved cost-effectiveness, and shared responsibility in European ocean observing. By working together and addressing these challenges, we can ensure the success of EOOS.

Towards a new phase for Argo at the European scale: Euro-Argo RISE contribution

Authors

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Keywords

In situ ocean observations, OneArgo, Euro-Argo community

Abstract

Euro-Argo ERIC aims to provide essential ocean observations for a better understanding of ocean health and of the global warming consequences on the ocean. It coordinates and strengthens the European contribution to the international Argo Programme. Among the leverage actions to reach this goal and align Euro-Argo ERIC missions with those of the ambitious OneArgo, Euro-Argo RISE project was a key enabler. By pooling together the effort of 19 European partners, it further developed Euro-Argo contribution towards biogeochemistry, greater depth, ice-covered and shallower water regions.

During 4 years, work progressed through 4 major topics: technological progress, data management, services to users and community enhancement.

Technological developments in Euro-Argo RISE helped support OneArgo implementation to reach a new global, full-depth and multi-disciplinary Argo array. By building and deploying prototypes fitted with alternative sensors and assessing their accuracy and stability, European players helped improve the performance of the new generation of sensors. Geographical coverage expanded in partially ice-covered areas and European Marginal Seas, and recommendations to better sample boundary currents in a cost-effective manner were issued. In high latitude regions, the Ice Sensing Algorithm software was used with locally adapted configuration parameters, improving the reliability and operating capabilities of Argo. Test deployments in shallower waters of the 3 European Marginal Seas (Baltic, Black and Mediterranean Seas) provided demonstration of the potential use of Argo in shallow coastal areas.

Euro-Argo RISE contributed to enhancing the existing Argo data system in order to handle new float types tested. New delayed mode quality control methods were developed to cover the OneArgo quality requirements. In particular, significant improvements for the quality

control of the 6 biogeochemical parameters and definition of procedures for the deep floats (>2000 m depth) were achieved. The project has been central to enhancing the European component to the OneArgo data system through efficient developments with euroargodev, a collaborative framework hosted on GitHub. This allowed providing more accessible (open-source software), transparent and reproducible (code and expertise sharing) procedures.

New services and tools were developed and made known to the Argo community and beyond. Some of these tools, like the Argo Online School, have been endorsed by the international community while others, like the float recovery web service, facilitate Euro-Argo operational activities. Collaboration between Euro-Argo and main operational users (Copernicus Marine, ECMWF and EMODnet) was strengthened and collaborative actions will facilitate their uptake of Argo data.

Finally, key events developed new partnerships, resulting in a Euro-Argo community better structured and a strengthening of the links with other Research Infrastructures. Actions were taken for raising awareness among young people and is continuing both at national and European level in partnership with OceanOPS and EuroGOOS. New countries and institutes expressed their interest and will collaborate with Euro-Argo through the new EuroGOOS Argo task team.

Finally, Euro-Argo RISE project proposed a forward-looking vision with the drafting of 3 key documents for the ERIC: a Euro-Argo strategy for next decade, a 5-year implementation plan and a Long-Term sustainability plan.

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Session C

Enhancing capacity in ocean observing and services

Applications of ocean gliders for climate change monitoring of Essential Ocean Variables (EOVs) in the North East Atlantic

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Keywords

Ocean gliders, Primary Productivity, Oxygen, Phytoplankton, Harmful Algae Bloom

Abstract

Primary productivity and respiration form the foundation of food web and life in the ocean and drive the biogeochemical cycling of oxygen. Oxygen and phytoplankton abundance are two essential ocean variables (EOV) in the monitoring of the state of the ocean and of the impact of climate change on the marine ecosystem. To estimate primary productivity and respiration in the ocean, ocean gliders deployed in the Northeast Atlantic, are equipped with oxygen optodes and chlorophyll fluorescence sensors to obtain critical data in the upper water column, at a much larger spatial and temporal scale than is possible with research vessels.

During the first missions near the ESTOC Station in the Canary Islands led by PLOCAN, oxygen, turbidity and chlorophyll fluorescence data was measured with sensors installed on SeaExplorer gliders. The processing of this data by MatLab scripts provides estimates of primary productivity and respiration in the medium term. Future short deployments of Slocum Gliders with the Marine Institute in the Celtic Sea and along the continental shelf will provide higher temporal resolution data of phytoplankton diel cycle.

The potential for gliders to detect phytoplankton thin layers and/or vertical migration of HAB species as part of an integrated operational oceanography platform for the early warning system for HABs will also be evaluated during these missions.

Copernicus Observations *In Situ* Networking and Sustainability (COINS) – Arctic Data

Authors

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Abstract

The Arctic region is becoming more accessible due to climate change, leading to higher temperatures and the consequent reduction of land and sea ice. This strongly affects the Arctic ecosystem, marine environment, fish stocks, etc. and the living conditions of the Arctic population. Climate change in the Arctic region together with technological developments offers new opportunities but also new challenges. Increased use of marine, sea and land ice, and atmospheric *in situ* observations, satellite data and modelling will help address these challenges.

Copernicus Observations *In Situ* Networking and Sustainability (COINS), a consortia established to support the Copernicus *in situ* component lead by the European Environmental Agency (EEA), has, in a work package focused on the Arctic, identified Copernicus service requirements for Arctic *in situ* data, mapped data availability and compiled a meta-database of research projects and activities with significant Arctic observational components, which potentially can support the Copernicus services and the space component of ESA and EUMETSAT.

An important task of COINS Arctic Data is to make additional *in situ* data available to the Copernicus services and space component. Furthermore, COINS, together with international organizations, will promote the design of a sustained fit-for-purpose Arctic Observing System and promote the definition of Copernicus requirements. This presentation provides an overview of the COINS Arctic data activities, as well as the work done and the acquired

results on identifying Arctic marine *in situ* observations, not yet available to Copernicus Services and European data portals and aggregators like EMODnet, Copernicus Insitu TAC. Such *in situ* measurements are important for, e.g., ground-based studies, calibration and validation of current and future satellite missions as well as for ocean and climate model products generation, validation and assimilation.

Capacity sharing: Provision of data to The Met Eireann integrated Coastal Flood Forecast Service (ICFFS)

Authors

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Keywords

Operational Monitoring, Flood Forecasting

Abstract

This paper describes a collaboration between multiple Irish sectoral organizations, bringing together and developing existing capacity to address the national priority issue of coastal flood forecasting and hence the expansion of the existing coastal observation network. The activity going into making use of shared capacity is described, including levelling up on specification, data handling, operations and maintenance procedures as well as increasing data availability. The work is coordinated through working groups for waves, tides and HF Radars to date.

In 2022, the Government department (Housing, Local Government and Heritage) took a decision to establish the Integrated Coastal Flood Forecast Service, the ICFFS led by Met Éireann. This advanced initiative makes use of integrated forecasting approaches, which require model development for tidal, surge, and ocean-wave forecast, but is also focused on the sharing of existing national infrastructure, where programs either at or close to operational readiness can provide valuable and critical input.

Two pilot projects have been undertaken to inform and trial the activities. One pilot is working around multiple Aids To Navigation (ATON) buoy sites (for wave observation) and the second: sample tidal monitoring infrastructure in Galway Port. Details of these trials, results and outputs are discussed.

Wave buoys are mainly operated by the Marine Institute and Commissioners for Irish Lights in Ireland. The primary purposes of the observations to date has been for operational monitoring, ocean energy resource assessment, aiding marine research and safety and navigation.

In Ireland the main operators of coastal tide gauges are the Office of Public Works (OPW) and the Marine Institute (MI). In the case of the MI stations the program has been built up from discretionary funds over a 20-year time frame with various validated products, culminating in 2020 to include two of the nation's 3 global sea level observing stations (GLOSS). One is in Union Hall harbour (west Cork) with a second in Howth Harbour (County Dublin). The third GLOSS station, located at Malin Head (Co. Donegal), is operated by the OPW.

An account is provided outlining the approaches being undertaken to integrate the various data feeds to support the high quality, high availability needs of the ICFFS.

Demonstration of a transnational cooperation for harmonized chlorophyll a monitoring in the North East Atlantic Ocean

Authors

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Keywords

Chlorophyll a, methodological harmonization, MFSD; *in situ* data, satellite remote sensing

Abstract

The concentration of chlorophyll a (Chla), a proxy for phytoplankton biomass, is used as indicator for several criteria of three Marine Strategy Framework Directive (MSFD) descriptors (D1C6, the biodiversity of pelagic habitats; D4, food webs; and D5, eutrophication).

Satellite Earth observation utilises algorithms that link the satellite observations of waterleaving radiance and the in-water Chla. Among the main sources of variability around this regression to define algorithms are the uncertainties in the *in situ* measurements due to the lack of consistency in the approaches employed in monitoring programs and research cruises. For example, global analyses based on measurements of Chla by high-performance liquid chromatography (HPLC), considered the reference technique for Chla, are usually derived from studies of independent investigators, so methodological differences between laboratories can introduce significant uncertainties. In addition, since HPLC is a relatively expensive and expertise-demanding technique, Chla concentration have been customarily determined in long-term oceanographic time-series programs by alternative techniques, such as spectrofluorometry (e.g., in RADIALES (Spain)) and fluorometry (e.g., in Plymouth Station L4, Western Channel Observatory (UK)). However, the agreement in the results obtained with these techniques has only been compared in a few ancient studies.

The cooperation among Member States required by the MSFD for methodological harmonization has triggered a transnational collaboration involving some partners of the Interreg Atlantic Area project iFADO (Innovation in the framework of the Atlantic deep ocean) for a joint monitorization of Chla in the North East Atlantic Ocean (NEA) region. *In situ* data have been obtained in 21 research cruises and sampling sites, from coastal to offshore environments, by using standardized sampling and analytical methods. We will report on the results obtained from this operational demonstration and how this collaborative transnational initiative allowed us: **i)** to intercalibrate the methods currently used for the analysis of discrete samples (HPLC, spectrofluorometry, fluorometry) and assess them in terms of accuracy, costs and effectiveness; **ii)** to calibrate continuous measurements obtained with optical sensors and remote sensing results with HPLC data; **iv)** to extend *in situ* observations temporally and spatially through remote sensing for MSFD assessments; **iii)** to contribute to the integration of data of different accuracy, spatial scale and resolution in databases and to their dissemination in data hubs according to FAIR principles. This work will provide detailed guidelines for *in situ* sampling, analysis, and data quality control for Chla monitoring and will contribute harmonized data for the next MSFD assessment cycles for the target descriptors.

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Session D

Advances in ocean forecasting

The Copernicus Marine Service: recent achievements and future plans

Authors

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Keywords

Observations, forecasting, services, networking, users

Abstract

The Copernicus Marine Service implemented by Mercator Ocean International (MOi) provides operational, regular, and systematic reference information on the blue/white/green ocean state for the global ocean and European regional seas. More than 50,000 expert downstream services and users are connected to the service. The Copernicus Marine Service responds to public and private user needs and supports policies related to all marine and maritime sectors.

An overview of Copernicus Marine Service recent achievements, service evolution strategy and plans for the coming 5 years will be given. The objective is to further establish Copernicus Marine Service products as a worldwide reference, continue to foster the service uptake and respond to increasing and pressing user and policy needs for improved ocean monitoring and prediction capabilities. This requires preparing the implementation of the next generation of ocean monitoring and forecasting systems (e.g. new satellite and *in situ* observations, improved resolution, ensemble forecasting approaches) and new service lines for Coastal, Biology, Climate and Arctic while embracing new capabilities of digital services in synergy with the Digital Twin Ocean developments. An important priority is to offer new services for the coastal ocean through a co-design and co-development approach between the EU Copernicus Marine Service and coastal marine services operated by member states. International cooperation and impact (UN Decade of Ocean Science, GOOS, G7 FSOI, GEO Blue Planet, UNEP) will continue to be a key element of Copernicus Marine evolution strategy.

The cooperation with EuroGOOS and its members is essential for the Copernicus Marine success and long-term sustainability. Areas of collaboration exist all along the operational

oceanography value chain. Of particular importance are the interactions related to ocean observations in the framework of the European Ocean Observing System (EOOS) and the coastal ocean through the links with national coastal forecasting services and downstream applications.

Forecast uncertainty and ensemble spread in surface currents from a regional ocean model

Authors

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Keywords

Surface currents, regional ocean forecasting, ensemble prediction systems, forecast uncertainty, high-frequency radar

Abstract

This study assesses the capability of a regional ocean model to resolve surface currents and their predicted uncertainty. An operational ocean ensemble prediction system (EPS) for the coastal seas off Northern Norway is evaluated by comparing with high-frequency-radar current speed estimates. The EPS is composed of 24 members for which the ocean current is not perturbed nor constrained, but forced with an atmosphere ensemble.

The ocean ensemble spread stems from **(i)** accumulated differences in wind-forcing history over forecast cycles, leading to subsequent growth in model state differences, and **(ii)** constraints of sea surface temperature by data assimilation. The intention of the ensemble is to reflect the actual uncertainty in the initial condition, which is largely unknown in terms of the mesoscale circulation. The ensemble is evaluated by creating rank histograms and calculating the reliability of probabilities to exceed current speed thresholds. We find a low but pronounced predictive skill in surface currents, i.e., a correlation of 0.63 for radial surface current speed. However, the model's current speed exhibits statistic skill. In addition, current speeds show deterioration of the validation metrics over the forecast range (0-66 hours). This indicates that, in short-term forecasts, the forecast skill relative to the analysis results from updated atmospheric forcing. We also find that high-resolution wind forcing provides better forecast skill in currents compared to lower resolution forcing. The ensemble spread is fair over the entire forecast range but lacks the most extreme speeds probabilities to exceed 0.2 m/s (0.4 m/s) are underestimated by 10 (20) percentage points. In general, the ensemble exhibits the ability to predict forecast uncertainty.

Forecasting the sea level in the mediterranean sea using the assimilation of coastal tide-gauge data

Authors

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Keywords

Storm surge forecasting, data assimilation, *in situ* observations

Abstract

In this work, we have studied the various components of the barotropic sea level in the Mediterranean. Tides, surges and seiches, often in conjunction, are responsible for flooding events in this area. These events have a time scale that requires a short-term forecast (up to 5-10 days), which is linked to the weather forecast. We used a finite element hydrodynamic model and, to reduce the forecast error linked to the initial-state error, we used the data assimilation of sea levels from the coastal stations of the Italian Institute for Environmental Protection and Research (ISPRA), through an Ensemble Kalman Filter (EnKF). The assimilation of coastal data significantly improves the forecast of both the surge and the total sea level, especially for extreme events where there are pre-existing seiche oscillations. The data assimilation, thanks to a correct formulation of the spatial correlations, manages to improve the forecast even in areas far from the assimilated stations, such as the south-eastern basin of the Mediterranean Sea. The system has recently been made operational at ISPRA and performs two runs a day based on the weather fields of 00 and 12 and assimilates all the measurements available at the time of the run. This system uses the sea-level forecast in the Mediterranean Sea to force other simulations in three coastal areas of the Adriatic Sea. These areas are the Venice Lagoon, the Marano Lagoon, and the Po Delta. As these local simulations consider limited-area coastal grids, the data assimilation is not used further. The results of these three simulations are then compared to data from local tide gauges. For example, in the case of Venice, this allows a local forecast of the sea level in the Venice Centre, which can be used to alert the population or to manage the flood barriers in case of strong storm surge events.

The Baltic Sea model system and products delivered into the Copernicus Marine Service

Authors

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Keywords

Baltic Sea, physical-biogeochemical-wave modeling, ocean forecast products, ocean reanalysis products, data assimilation

Abstract

Five national oceanographic institutes from five countries around the Baltic Sea have since 2015 formed the Baltic Sea Monitoring and Forecasting Centre (BAL MFC) under EU's Copernicus Marine Service coordinated by Mercator Ocean International. All five institutes have obligations within operational oceanography at national level and have decades of experience for running full operational services for the Baltic Sea area. We are pooling this knowledge and expertise into a joint developed model system complex used to deliver the Copernicus Marine Service's Baltic Sea forecast and reanalysis products. The production system we use is based on these state-of-the art models: the wave model WAM, the ocean-ice model NEMO-SI3, and the biogeochemical model ERGOM all tuned for and applied for the Baltic Sea area. Observations as satellite surface temperature, *in situ* temperature and salinity profile observations are assimilated into the present available Baltic Sea model products. The production system is continuously developed with the goal to deliver improved Baltic products. Within the recent years we have updated the production system behind the Baltic reanalysis products to be as close as possible to the production system used for the forecast products, for the benefits to users applying both product types. Additionally,

we have increased the forcing between the online coupled ocean-ice-biogeochemical system and the wave system via exchange of sea level anomalies, ice concentration and Stokes drift values, and we have enhanced the assimilation of observations into the production. With this presentation we will present the status and quality of the Baltic Sea products within the Copernicus Marine Service, and introduce our development plans for the next few years.

Developing coupled wave-ocean model to improve Baltic Sea forecasts

Authors

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Keywords

WAM, NEMO, coupling, Baltic Sea

Abstract

The Baltic Sea is a semi-enclosed marginal sea divided into several small sub-basins. In the northern part, the coasts are covered by dense archipelagos with thousands of small islands, islets and shoals. The northern parts also have seasonal ice cover, the ice winter typically starting in November and lasting until May. To obtain reasonably accurate forecasts for this area, high enough resolution and additional methods to resolve the effects of the complex coastline are needed. Typically the basin scale grids have 1 NM resolution and higher resolution (0.25 NM) nested systems are applied for the key coastal areas.

In recent years, work done at the Baltic Monitoring and Forecasting Centre of the Copernicus Marine Service, has improved the quality of the wave forecasts, especially in the coastal areas, by coupling the wave forecast models with the 3D ocean models. At present the BAL MFC NRT wave system utilises pre-calculated surface current, sea surface height and ice concentration fields from the BAL MFC physical NRT system run with NEMO model. The most significant impact on the wave forecast accuracy is due to the varying ice conditions during the forecast, as long as they are sufficiently well represented by the NEMO model. Surface currents and SSH variation only occasionally influence the wave conditions and the effects are mostly limited to coastal areas. However, the verification carried out shows that in case of strong coastal currents, the coupling between wave and ocean model affects the quality of wave forecast in the Baltic Sea.

Currently only surface Stokes drift calculated by WAM is taken into account in the BAL MFC physical NRT system. This was found to have relatively small effects on the results.

To enhance the coupling, the effects of water-side-stress modified by the wave field are currently being studied.

In this presentation we will briefly describe the recent developments in the BAL MFC NRT forecast systems focusing on the coupling of the WAM and NEMO models and on the accuracy of the coastal forecasts.

Copernicus Marine forecasting systems: current configurations and future developments

Authors

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Keywords

Ocean forecasting, ocean modelling, forecast, reanalysis, digital twin of the ocean

Abstract

The Monitoring and Forecasting Centres (MFCs) of the Copernicus Marine Service provide information for the blue (physics), green (biogeochemistry and biology) and white (sea ice) components of the ocean at global and at regional scales. The regional scale systems cover the Arctic Sea and all the European regional seas, providing tailored information in all these regions. The MFCs provide information on the past and on the future state of the ocean, delivering reanalysis, covering the past 30 years and forecasts, with a lead time of ten days. The MFCs have similar architecture and components to guarantee a certain level of service homogeneity. Nevertheless, differences are allowed for being at the state of the art in each region and for prioritising developments taking into consideration the oceanographic characteristics of each basin. They do share a common development strategy for continuously evolve in each of their components and in the level of interconnections complexity between these components. Among the most important future evolution:

enhanced representation of marine ecosystems, production of probabilistic forecast using advanced ensemble techniques; development of bespoken interfaces for serving coastal systems and the production of multi-decadal reanalysis, covering at least the last 50 years, for climate monitoring. The information provided by the MFCs will contribute to and will be further exploited by the European digital twin of the ocean for generating knowledge contributing to provide a comprehensive information on the ocean to scientist, governments, and citizens. The activities of the MFCs are connected also at international level, contributing to the Ocean Prediction UN Decade Collaborative Centre activities

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for the Ocean we want – addressing
the UN Ocean Decade Challenges

Session E

Strategic developments in ocean observing – 2

ITINERIS - Italian Integrated Environmental Research Infrastructures System: Marine Domain

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Abstract

ITINERIS Project is building the Italian Hub of Research Infrastructures in the environmental scientific domains (atmosphere, marine domain, terrestrial biosphere, and geosphere) providing access to data and services. The main goal is to develop cross-disciplinary research in environmental sciences through the use and re-use of existing (or pre-operational) data and services and new observations, to address scientifically and societally relevant issues such as sustainable use of natural resources, implementation of Nature-Based Solutions, Green and Blue Economy, pollution reduction, critical zone and ecosystem management and restoration, carbon cycle, mitigation of the downstream effects of climate and environmental change.

The ITINERIS Marine Domain, a crucial component of system, will integrate all marine relevant Research Infrastructures (RIs) with the aim to guarantee access to Italian facilities, services and marine data and to ensure long term monitoring of EOVs, EBVs and ECVs. The Italian Integrated Ocean Observing System (IOOS) will be established to coordinate national observations to improve quality and interoperability of ocean data, for three critical themes: climate, operational services, and marine ecosystem health. ITINERIS Marine Domain is

building up IOOS by incorporating and scaling-up existing ocean observing capabilities via integration and harmonization of observations carried out by RIs. The involved marine RIs are the Italian nodes of DANUBIUS, eLTER, EMSO ERIC, EURO-ARGO, EUROFLEETS, ICOS ERIC, JERICO, Laboratori Nazionali del Sud, N/R Laura Bassi, SIOS, GeoSciences. The National Marine Data Center, designed by the Italian Oceanographic Commission as a distributed system, will be implemented in order to provide a single access point to Italian marine data. The IOOS data center will be interfaced with existing RI data centers as well as thematic data centers and ITINERIS central HUB. During the Project, crucial data gaps in EOVs and EBVs observation will be filled in order to ensure continuity and increase monitoring of. biochemistry, biological and ecosystem EOVs. On this aim, key sites will be upgraded to improve acquisition of biological observations at ecosystem level by exploiting both automated and new technologies. The capability of Italian research ships to provide continuous NRT ship-based observations will be expanded to contribute to the international effort on full-depth, coast-to-coast ship based transect measurements. Data will be made available through the IOOS data center interfaced with the ITINERIS HUB in order to guarantee data fairness. Finally, pilot services will be developed to tackle overarching marine issues and to respond to key stakeholder requirements, this will allow to demonstrate the impact of the integration and harmonization of data and facilities.

The ITINERIS Marine Domain constitutes the Italian contribution to GOOS (Global Ocean Observing System) and EOOS (European Ocean Observing System) responding to the major challenge of UN Ocean Decade of Science for Sustainable Developments.

Baltic Sea Ocean Observatories; two years of continuous autonomous operations, data delivery and science applications

Authors

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Abstract

Long term, continuous ocean measurements are critical for both monitoring and research activities and important for ensuring a healthy ocean in the future. If they are performed with a high temporal-spatial resolution, the resulting datasets can offer a unique insight to trends and processes on multiple scales. Ocean gliders are mobile autonomous platforms, capturing high-resolution measurements between the surface and 1000 m depth across multiple sensors simultaneously. By exploring their role as part of an operational oceanography system, we can assess their skill to provide near real time data and potential for future applications outside of the traditional hydrographic parameters.

Using SeaExplorer gliders, the Voice of the Ocean Foundation (VOTO) has collected a near continuous time-series of data from three observatory locations around the Baltic Sea since March 2021. With at least one glider *in situ* for more than 98% of the time, the data collected provides a rich resource for both monitoring and research requirements and will expand to more sites in a long-term (>10 year) vision for the ocean observatories. As part of the commitment to FAIR principles, VOTO Ocean Observatory data are made publically available within 30 minutes of transmission via an ERDDAP data server. Datasets are subjected to automated quality control using the IOOS flagging system. To promote transparency, reproducibility and community best practices, all processing and quality control scripts are published to open online repositories. Notebook style scripts for dataset discovery, subsetting, download and analysis are available for use in workshops and by end users.

Here, we review the fieldwork operations and data management pipelines introduced over the first 2.5 years of the VOTO Ocean Observatories, and present initial applications and output from both the monitoring and research communities, including rapid response to the Nordstream methane leaks. We reflect on future opportunities for ocean glider applications in the Baltic, including both technological and sensor developments that may be required.

The iFADO PAAnoramic mission: the first European Atlantic area international multi-platform ocean monitoring mission

Authors

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Keywords

Atlantic Area, international mission, PAAnoramic, iFADO, monitoring, gliders

Abstract

The aim of the European Union's ambitious Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) is to protect more effectively the marine environment across Europe. Its implementation in the European Atlantic Region (EAR) and the need to extend periodic monitoring programs to offshore waters is very challenging due its surface extension and large deep-water areas. To overcome these difficulties, the iFADO project (innovation in the Framework of the Atlantic Deep Ocean; www.ifado.eu; 2017-2023) combined traditional monitoring with cost-effective state-of-the-art technologies: remote sensing, numerical modelling and emerging observation platforms such as gliders and oceanic buoys.

After several successful international glider missions, the consortium proposed a flagship action for the project's final year: the PAAnoramic mission. This mission will extend to the Atlantic Area, the annual glider endurance line between mainland Portugal and the Canary

Islands (Spain), established during the iFADO project since 2018. The PAAnoramic mission covered the European Atlantic façade using autonomous underwater vehicles combined with *in situ* monitoring cruises and supported by satellite imagery and operational numerical modelling. This is the first international multi-platform ocean monitoring mission covering the European Atlantic area.

The PAAnoramic glider mission was divided into several sections:

- Marine Institute covered a return transect from the initial release point and the Porcupine Abyssal Plain Sustained Observatory (PAP-SO);
- National Oceanographic Centre covered the section from the Irish coast to Portugal;
- IPMA designed a mission in Western Iberia from the open ocean to the coastal area;
- PLOCAN completes the mission with the route from Portugal to the Canaries.

First two gliders were deployed next to the Irish coast on early December 2022, while a third one was launched in mainland Portugal in April 2023. After its recovery, it will be relaunched during May 2023 to complete the mission in the Canary Islands.

The scientific payload sensors installed in the glider (CTD, DO and fluorometer) will allow collection of data related to physical and biogeochemical essential ocean variables. On their way, the gliders will visit various offshore Marine Protected Areas, such as the Savage Islands and the Gorringe Bank among other seamounts. The mission will also visit some buoys moored in the open ocean such as PAP-SO and the ESTOC (European Station for Time-Series in the Ocean Canary Islands). The mission also demonstrated how gliders can reduce logistics, costs, and risks of ocean monitoring and covering remote areas during harsh weather conditions.

The PAAnoramic mission involved participation of four Atlantic Area countries (Ireland, UK, Portugal and Spain), including two archipelagos (Madeira and Canary Islands). The mission was also supported by two non-iFADO project partners: Cyprus Subsea (Cyprus) and Instituto Hidrográfico (Portugal).

The mission main goal was to demonstrate how international collaboration is key for monitoring the ocean, to implement MSFD, achieve Good Environmental Status, and contribute to the UN Sustainable Development goals such as SDG14. This ambitious action will set a milestone for a future Atlantic Area international unmanned monitoring strategy.

Acknowledgements

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Implementation of the oceanographic platform “ZIPIHUS” at the Al Hoceima Marine Observatory: towards operational oceanography in Morocco for a sustainable management of marine resources

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Keywords

Oceanographic platform, Marine Observatory, Operational oceanography, Digital Twins of the Ocean, Blue economy

Abstract

The establishment of the “ZIPIHUS” oceanographic platform at the Al Hoceima Marine Observatory marks an important step towards operational oceanography in Morocco. This platform, developed in collaboration with our research team of national and international

experts, integrates various biogeochemical data from high resolution in situ sensors, underwater glider missions and fixed monitoring systems. The collected data, such as temperature, chlorophyll and current energy profiles, are used to improve our understanding of ocean processes in the Moroccan Mediterranean region.

The Odyssea and ILIAD Data Twining Ocean projects, funded by the European Union, have been instrumental in the development of the ZIPIHUS platform. They have enabled the acquisition of new oceanographic data and the development of modeling tools to process these data in real time. Thanks to ZIPIHUS, we have been able to obtain essential information on marine biodiversity, monitor marine activities, control marine pollution, support fishing and aquaculture activities, and study marine renewable energy.

Looking ahead, our team is committed to continuing to advance the ZIPIHUS platform through strategic collaborations with national and international partners. Our primary goal is to improve the platform's autonomy in processing and analyzing raw data, while providing tailored services and information to meet the unique needs of different end users. We believe that by strengthening the capabilities of the ZIPHIUS platform, we can contribute to the sustainable management of marine resources, promote marine conservation efforts, and foster the growth of a thriving blue economy in Morocco.

Exciting opportunities await us as we leverage the ILIAD marketplace to enhance our pilot sites. Through this innovative marketplace, we plan to leverage a wide range of resources, expertise and technologies that will help us optimize our operations and achieve meaningful results. We are committed to maximizing the potential of this partnership to enhance our offerings and deliver exceptional value to our users.

EMSO ERIC progress in data harmonisation and physical access for the benefit of marine science and technology

Authors

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Keywords

European Rsearch Infrastructre, Fixed-point observatories, EOVS, FAIRness, ERDDAP technology, Physical and Remote access

Abstract

EMSO is a distributed European Research Infrastructure (RI) focused on seafloor and water column observation systems, offering resources and services primarily to the scientific community and other stakeholders based on their Regional Facilities (RFs). EMSO's mission is to promote cutting-edge research and improve knowledge of the complexity of global changes and natural phenomena in the deep-sea regions surrounding Europe's oceans. EMSO has recently implemented core Data and Access Services using ERDDAP (Environmental Research Division Data Access Program) technology, which is widely used in the Community and has been adopted by other environmental research infrastructures, to address challenges such as data and metadata harmonization and providing Physical and Remote Access through a single-entry point. These efforts are facilitated by adopting community standards, best practices, and FAIR (Findable, Accessible Interoperable, Reusable) data principles, leading to a high level of metadata harmonization for Physical Oceanography and Marine Ecology of Essential Ocean Variables (EOVs). An integrated approach to the EMSO Data Management Plan (DMP) considers existing RF DMPs and complements harmonization, resulting in a common framework adaptable to local workflows. The development of the related Data Services strengthens EMSO's position within the European Ocean Observing System (EOOS) enabling it to address societal needs through high-quality marine research and essential data for operational services like Copernicus. EMSO works on efficient mechanisms to connect with organizations designing and implementing policy at the EU level, such as EOOS, EuroGOOS (in particular through the Fixed Platform Task Team) and the European Marine Board, to name a few. The Access Service is a core to any ERIC, operates based on a policy that enables Physical

and Remote Access, applies excellence-driven criteria and peer selection of users' proposals, and offers financial support to users and providing RFs. Proposals accepted under the first EMSO Calls for Access focus on acquisition of new data or testing of new sensors and technologies, with added value for proposals promoting innovation, industry connections, or patents. This overview of EMSO's RF Data and Access Services shows the challenges, benefits, outcomes and impacts of service implementation promoting access to Regional Facilities, and using ERDDAP technology.

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Session F

Strengthening Europe's oceanographic fleet

Mediterranean Sea Ship-based Hydrography Programme (Med-SHIP)

Authors

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Keywords

Mediterranean Sea, hydrography, biogeochemistry, repeat sections, North-South cooperation, UNDOS contribution

Abstract

The Mediterranean Sea (MedSea) is a hotspot for climate and environmental change, with impacts and risks above the global average (MedECC, 2020). The Mediterranean has a densely populated coastal area where major economies and activities are located. These pressures on key climate-related issues such as warming, sea level rise, salinization, and acidification are exacerbated in the basin due to its particular oceanography: it is a relatively small, semi-enclosed basin with limited exchanges, high turnover time with active deep and intermediate water formation, and a particular biogeochemistry. The MedSea behaves like a miniature ocean where the temporal and spatial scales of variability are much shorter, allowing observation of climate-driven changes in physical, chemical, and even biological oceanography at the scale of human lifetimes. However, observing the coastal and open MedSea is very complex due to socio-political and economic differences between the countries of the European Union and those of the Middle East and North Africa (MENA). Clearances issues to work in EEZs, as well as GDP and income disparities between North and South, limit observation in several marine areas and, more worryingly, hinder any adaptation or mitigation strategies to address climate and environmental risks.

Ocean operational observations in the MedSea are coordinated by the Mediterranean Oceanographic Network for the Global Ocean Observing System (MonGOOS). For MonGOOS, the addition of a ship-based component is of strategic importance, as a sustainable program of regularly repeated coast-to-coast full-depth zonal and meridional cruises to

collect Essential Ocean Variables (EOVs) is missing in its portfolio. The Mediterranean Sea Ship-based Hydrography program (Med-SHIP) builds on the international program GO-SHIP and is implemented thanks to ship access provided by individual countries such as Germany (2001, 2011, and 2018) or by EuroFleets RI (2016 and 2022). Med- SHIP monitors changes in the deep MedSea through oceanographic cruises to document the budget of heat, freshwater, carbon, oxygen, inorganic and organic nutrients, and transient tracers.

The Med- SHIP initiative needs to be directly recognized and supported by MonGOOS and EuroGOOS with two main objectives: i) to provide sustained support to the monitoring efforts of European and MENA countries through capacity building training on target topics such as climate change and ocean acidification, and ii) to raise public and stakeholder awareness of the importance of Med- SHIP for detecting and predicting global change risks affecting Mediterranean marine ecosystems.

EuroGOSHIP: A potential new research Infrastructure supporting European hydrography

Authors

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Abstract

Investigating the Marine Environment by collecting vertical profiles of water column properties, a discipline known as Hydrography, is one of the oldest ways of observing the ocean and remains a cornerstone of modern oceanography undertaken by virtually every coastal state. These observations, particular those from high quality on board analysis of various parameters including nutrients, dissolved inorganic carbon, oxygen and salinity, are useful for quantifying water quality, ocean change and climate impacts, initializing models and calibrating autonomous platforms. Internationally hydrographic observations are organized at the European Scale within regional clusters as part of EuroGOOS and globally by GOSHIP, one of the core GOOS observing programmes. Each of these elements have independently identified a series of weaknesses/ areas for improvement including in the areas of best practices, training and standards. These, together with uncertainties around long term funding commitments, mean that the hydrographic networks are delivering key information streams at suboptimal efficiency. This situation has lead to the initiation of the Horizon Europe Programme EuroGoShip, designed to address some of these needs and to determine if in the longer term European Hydrography would benefit from a more formal coordination and support structure via the Research Infrastructure route. EuroGOSHIP will undertake an extensive programme of shipboard and laboratory based work to benefit operational aspects of European and global hydrography and consult widely with

stakeholders from various groups to determine the optimal model for future organizing within the RI concept. A key issue will be to determine whether services required by the EuroGOSHIP community are available elsewhere and what financial model can be used to access these. In this presentation we will describe the initial results of the EuroGOSHIP activity programme in 2023 and our early thinking around how the existing resource base present within Europe can better support European Hydrography within EuroGOOS.

The contribution of Eurofleets RI to respond to the European societal needs

Authors

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Keywords

Research Vessels, access, excellent research, European Union Missions, EOOS

Abstract

The objective of this paper is to illustrate the progress in the establishment of the new pan-European Research Infrastructure (RI), Eurofleets RI, built on the successful experience and the results achieved through the Eurofleets projects and activities of the European Research Vessel Operators (ERVO) Group.

Eurofleets RI aims at uniting world-class Research Vessels (RVs) and associated equipment among European partners to facilitate access to unique marine infrastructure for a wide user community, enabling excellent research, increased cooperation in technical development and sharing of knowledge in RV operations and management, as well as increasing ocean literacy, and providing a clear roadmap for the continued integration and advancement of the European research fleet.

The Pan-European relevance of the Eurofleets RI is to work as a catalyst in the continuous efforts to better coordinate the institutional, national and international collaboration in marine monitoring and research in national and international waters across the globe, in the most cost-effective use of the available infrastructure driven by the need to understand the inevitable impacts of climate and other global changes based on the best scientific knowledge available. Eurofleets RI will play a central role in delivering the European Union Missions by the provision of access to our Seas and Oceans through facilitation of multidisciplinary science teams, advancing the European Green Deal, the Ocean Digital Twin, Sustainable Blue Economy Partnership and the UN Decade of Ocean Science for Sustainable Development (2021-20230).

In this scenario, by providing a complementary research platform across the entire Atlantic Ocean and European seas, the Eurofleets RI will enable the delivery of additional key data for understanding climate change, plastic pollution, ocean acidification, impact of blue energy developments, deep-sea mining, tourism and other human activities in the marine environment.

RVs will also form an essential part of the planned wider European Ocean Observing System (EOOS), and the Eurofleets RI will also cooperate closely with European and international observatory and remote sensing communities, environmental observing agencies, hydrographic services etc. improving dialogue and interaction between scientists, stakeholders, and decision makers. The Eurofleets RI will work with a variety of stakeholder communities, and in close cooperation with other RIs, to investigate the urgent scientific questions in marine research, critical for understanding the Earth system.

Eurofleets+ Joint Research Activities Advanced Innovative Integrated Services

Authors

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1 CSIC Consejo Superior De Investigaciones Científicas

2 MARIS Mariene Informatie Service

3 UdG Universitat de Girona

Abstract

Operational oceanography involves the systematic observation and prediction of oceanographic phenomena to support a range of applications, from maritime safety and navigation to climate monitoring and ecosystem management. Eurofleets+ Joint Research Activities addressed three main areas including Advancing shipboard data management and data access, Equipment innovations for deep sea operations from vessels and Intelligent robot exploration.

Eurofleets+ data management aims ultimately at publishing the metadata and data sets as collected by scientific teams during all the Eurofleets+ TNA cruises. This publishing is done through the EVIOR portal (European Virtual Infrastructure in Ocean Research) – integrated into the Eurofleets+ Website, and towards the larger community through inclusion in SeaDataNet and EMODnet portals and in a F.A.I.R. way. Therefore, the data management (DM) is deployed in synergy with SeaDataNet and its European network of NODCs. Scientific cruise teams formulate cruise DM plans for review by SDN NODCs. They NODC's validate and archive the cruise data sets for long term stewardship, and publishing. Scientific teams can make use of the EMODnet Ingestion for transfer of processed cruise data sets to the NODCs.

Exploration of the deep sea is a major challenge and opportunity in marine research. Rigs and related technologies are fundamental to the study of the sea as they are needed to deploy equipment. Eurofleets+ explored improving interoperability of Large Exchangeable Instrumentation (LEXI) is a primary aim of Eurofleets+, especially in terms of improvement and standardisation of tools/rigging for more efficient operations. The project designed a new deep-sea winch, a multipurpose crane/handling system for deep water operations by exploring the use of Knuckle-jib cranes for deployment of heavy equipment and a dual

mode handling system design for the deployment and recovery of research tools seabed through moon-pools or/and over the side.

New technologies were developed for Autonomous Surface Vehicles (AUVs) and Autonomous Underwater Vehicles (ASVs) and the innovations were validated prior to field testing. The research activities involved researchers from academia and industry working closely together and interaction with innovation and exploitation activities, and remote access. Technologies addressed include AUV-ASV cooperation using an acoustic modem /usbl system, a seafloor classifier and up-to-scale 3d reconstruction using a monocular camera system.

Overall, the innovations addressed by Eurofleets+ Joint Research Activities have advanced operational oceanography further and will help to improve our understanding of the ocean and its role in the Earth system, and to support a range of important applications that rely on accurate and timely ocean information.

Norwegian Ships of Opportunity Program for marine and atmospheric research

Authors

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Keywords

Ships of Opportunity, FerryBox, Essential Ocean Variables (EOVs), marine ecosystem change, carbonate system

Abstract

NorSOOP (Norwegian Ships of Opportunity Program) is a national research infrastructure which began in 2018 and is financed by the Research Council of Norway. Its main goal is to build a network of ships of opportunity capable of providing marine and atmospheric observations that are relevant for improving our understanding of coastal and oceanic ecosystems and also covers a subset of the Global Ocean Observing System (GOOS) essential ocean variables. NorSOOP ships of opportunity are part of the European GOOS (EuroGOOS) FerryBox Task Team and have contributed to various projects focused on marine ecosystem change, carbonate system/ocean acidification, pollution/microplastics, and remote sensing – at the local/municipality, national, and European level (including Horizon 2020 JERICO-S3, NAUTILOS, AquaINFRA and MINKE projects). The objectives of NorSOOP include: **(1)** upgrade existing FerryBox installations and establish new ships of opportunity in Norwegian waters and the Arctic and North Atlantic; **(2)** provide and support high-quality and cost-efficient basic and applied ocean and atmosphere research; **(3)** foster innovation and growth for maritime, environmental sensor, and aquaculture industries. This talk will provide the latest developments, installations, and scientific results as well as updates of the past and future activities within the project.

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Session G

Scientists for ocean literacy

Ocean of changes. Modern approach to ocean knowledge transfer

Authors

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Keywords

Knowledge transfer, effective communication, marine education, ocean literacy

Abstract

Ocean of changes (OoCH) is an ongoing project, coordinated by the CORE (Climate and Ocean Research and Education Laboratory at Institute of Oceanology PAN) in close cooperation with international partners. OoCH is a part of the European educational platform, EU4Ocean Coalition. Since 2021, the Ocean of Changes is an official partner of the UN Decade of Ocean Science for Sustainable Development (2021-2030). Our team consists of people with different background and skills, allows us to approach various topics with a broad perspective.

The idea of the Ocean of Changes project is to exchange information on matters relating to the seas and oceans in order to build a community operating under the UN Sustainable Development Goals, and in the case of local activities, with particular emphasis on the Baltic Sea.

We organize workshops, ecological and scientific picnics; we take part in interviews, discussion panels, prepare blog notes and articles; we are co-organizers of art competitions, summer schools, as well as conferences for young researchers from students to young doctors and conferences for school youth.

We want to stressed out the challenges in bringing researchers, data managers and educators together to provide consistent, up-to-date messages that can appeal to and can be understood by modern societies. We propose a pathway for improving communication on ocean changes that takes advantage of the technological abilities for environmental data collection and processing, global and regional research, as well as good practices in ocean literacy and climate and ocean education.

In this work we want also to present one of the our most popular activity - Not Another Ocean Textbook which is a series of short videos covering all sorts of issues related to the marine environment, from the ocean current system, to relations with the atmosphere, ocean life, ecology, fisheries and the activities of international organizations such as the United Nations. This bottom-up project have been started during COVID pandemic outbreak in Europe, since conducting maritime education in face-to-face form were impossible. So far, our project is very successful and popular, driving its educational value, awakening the sea consciousness and convey ocean literacy. We want to show you not only the history of the ”Textbook”, but also an important aspect of the technological changes that took place during its creation.

OCEAN LITERACY and EU blue schools network as tools for integration of OCEAN ISSUES into schools curricula

Authors

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Keywords

Ocean literacy, eu blue schools network, UN sustainable development goals

Abstract

Originated in the USA, ocean literacy has now become a wide spread concept in Europe thanks to several EU funded projects, initiatives and the EU4Ocean Coalition. One of its communities – Network of EU Blue Schools is actively working on bringing the ocean into the classroom curriculum by developing blue projects with pupils and local communities. To test this approach in the Mediterranean Sea region we have developed a three-year project funded by Erasmus+ (2020-2023) entitled "Supporting the development of socially-inclusive Blue Challenges in schools in the Mediterranean Sea basin". Its main objective is

to support the development of educational activities related to the sea in schools in the Mediterranean basin, by testing and evaluating different tools integrating marine themes into the curricula. The project brings together scientists, schools, teachers and pupils from four Mediterranean countries: France, Greece, Italy and Malta.

Throughout the project, pilot schools developed and implemented 18 blue projects (following the requirements of the Network of EU Blue Schools) and participated in several trainings organised by partners. To analyse the impact and effectiveness of this approach, the project also focused on monitoring and evaluation of these pilot projects (including a framework, a web-based interactive platform, teachers'/pupils' surveys). This study presents the results of the surveys with teachers (from 12 primary and 10 secondary schools of 4 countries), which allowed to evaluate the performance of the blue projects developed and implemented in different subjects of the schools' curricula (e.g. geography, life sciences, mathematics etc.), while producing different outputs (e.g. campaigns, tools, art work, posters, videos etc.). One method of evaluation was a 5-points Likert scale to investigate: **(a)** to what extend did the blue challenge achieve the principles of the project (e.g., co-building, inclusivity, interactivity, sustainability), **(b)** the processes determined (e.g., election of ambassadors and reporters, multidisciplinary approach, monitoring), **(c)** the achievements that took place (e.g. collaboration with other teachers, stakeholders), **(d)** the impact on the pupils' behaviour, attitudes, etc. **(e)** the challenges faced (e.g., Covid-19 limitations, time and bureaucracy constraints, financial), **(f)** the elements that worked well (e.g. originality).

In addition, approximately 200 pupils (~9-19 years old) of both primary and secondary schools from all countries (~including 14, mostly coastal, cities) participated in another survey in order to evaluate the performance of the blue challenges and BlueS_Med project in general from their point of view. Initially, they indicated their favourite school subject (e.g., sports, mathematics, arts), sources of information about nature and the marine environment (e.g. teachers, internet, TV) as well as the subject that has given them most of the information on the sea (e.g. biology). They have also made statements concerning attitudes, awareness, behaviour, emotions, activism.

This study also highlights the results from the national and Mediterranean multiplier events, which brings together key stakeholders from the marine sectors and educational ecosystems to share best experiences and results, get inspiration and to develop a roadmap for Blue Schools to integrate ocean education in the curriculum in the Mediterranean Sea region.

Galway Atlantaquaria & the Irish Ocean Literacy Network – The role aquariums can play in fostering global Ocean Literacy (OL)

Authors

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Keywords

Ocean literacy, all-island network, local to global collaborations, dialogue

Abstract

Irish Ocean Literacy Network (IOLN) is the working name of an informal network established in 2016, aimed at bringing together individuals and organisations who are currently involved in, or would like to become involved in, working towards the IOLN vision, which is to achieve an Ocean Literate society across the Island of Ireland. Since its inception, the IOLN has hosted many networking events, workshops, etc., including the 'We are islanders' national campaign. The Network has also become recognised internationally as an advocate of OL and is involved in large scale initiatives like the UNESCO Ocean Literacy With All, the EU4Ocean Platform, the EuroGOOS Ocean Literacy Working Group, and is part of both the All-Atlantic and the European Blue Schools Network. As part of these initiatives, in June 2022 the IOLN was one of the ten organisations to sign the Charter for Blue Education in Europe developed within the frame of the EU4Ocean Coalition and its Network of Blue schools, whereas in October 2022 the IOLN participated to the 2nd Ocean Literacy Dialogues event held in Brazil. Currently, the IOLN is one of the OL networks involved in 'PREP4BLUE', a Horizon Europe project whose focus is to set the foundations for co-creating and coimplementing the research and innovation required to enable the 'EU Mission: Restore Our Ocean and Waters', and the IOLN will contribute to the project's work focused on enabling stakeholders to empower citizen and community-led action in support of the Mission, through deepening and widening citizen engagement by leveraging participatory innovations.

Galway Atlantaquaria (GA), National Aquarium of Ireland, is the current Secretariat of the IOLN. In this role, it acts as a central contact and dissemination point for the Network supporting initiatives and collaboration opportunities between the IOLN members and providing a platform for engagement with relevant stakeholders. To facilitate this, GA organised a series of regional members meetings in the four provinces, Connacht, Leinster, Munster and Ulster, in spring 2023 the aim of which was to give the Network members the opportunity to come together in person to exchange ideas and discuss future plans for common ocean literacy initiatives after the long break caused by Covid. Coinciding with this, GA is supporting the first specific objective of the Mission 'protect and restore marine and freshwater ecosystems and biodiversity' via the establishment of a working group within the IOLN focused on key marine ecosystems under threat, like e. g. seagrass meadows and coastal dunes, as well as via the funding of small conservation grants aimed at supporting and encouraging individuals or community groups working in marine conservation and education. These grants were awarded to several projects stretching from Donegal to Kerry.

Through this talk, we would like to highlight the role zoos and aquariums can play in improving dialogue and interaction between civil society, decision makers, stakeholders and scientists. By showcasing a range of GA and IOLN initiatives, we will explore how local and cross-border ocean literacy-focused initiatives can help meet the Mission's 2023 targets and European societal needs.

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Session H

Ocean data assimilation trends and challenges

Use and impact of *in situ* observations in global and regional ocean monitoring and forecasting systems

Authors

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Abstract

Global Ocean real time forecasts and reanalysis highly rely on in situ physical and BGC observations to deliver accurate estimate of the state of the ocean. The need of strengthening the link between the observing and modeling communities is necessary for a better understanding of the observation information content and error but also to inform on the use and impact of observation in ocean monitoring systems. Those different aspects will be illustrated.

At global scale, the Argo floats are the major source of information allowing to constrain the water mass properties in the open ocean. We will review the impact of the present and future Argo observations based on assimilation experiments conducted with a global ocean analysis system. The complementarity of *in situ* and satellite observations to constrain different scales of the global ocean analysis will also be addressed. On the shelf, dominated by different processes than the open ocean, a different observing strategy is required to adequately sampled the coastal ocean dynamic. The efficiency of repeated glider lines to constrain regional analysis in the Western Mediterranean Sea will be explored. Those studies help to give feedback on the future planned observing network expansions.

The limitation and best practices associated with observation impact assimilation experiments and diagnostics will be discussed as well as future plans and challenges. An efficient feedback loop is needed to ensure a fit for purpose observing system and advocate for its sustainability and improve the integration of observations in forecasting systems.

The Met Office Forecast Ocean Assimilation Model (FOAM) using a 1/12 degree grid for global forecasts

Authors

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Keywords

Forecast, ocean, global, 1/12 degree grid, data assimilation, neighbourhood verification

Abstract

The Met Office Forecast Ocean Assimilation Model (FOAM) ocean/sea-ice analysis and forecasting system has run operationally for 10 years using an ORCA tripolar grid with 1/4 degree horizontal grid spacing, the Nucleus for European Modelling of the Ocean (NEMO) for the ocean component, and the Community Ice CodE (CICE) for the sea-ice component, plus NEMOVAR (NEMO VARiational) as data assimilation system. The surface forcing is provided by Numerical Weather Prediction (NWP) fields from the operational global atmosphere Met Office Unified Model (UM). In May 2022, the operational global atmosphere NWP system became a coupled atmosphere/land/ocean/sea-ice system, incorporating a 1/4 degree FOAM ocean/sea-ice configuration. We present results from a two-year FOAM experiment using a 1/12 degree global ocean/sea-ice model configuration while keeping a 1/4 degree data assimilation setup. Our experiments inform development work to enhance the coupled model's ocean/sea-ice forecasts using a 1/12 degree ocean grid, with expected improvements to atmosphere/land forecasts as well. We compare model values at analysis and forecast times against observations of sea surface temperature, sea surface height as well as temperature and salinity profiles. Estimates of sea-ice volume and area are also provided. We also present an overview of sea surface currents and eddy kinetic energy fields. The level of improvement at higher resolution is moderate but consistently satisfactory when measured using neighbourhood verification metrics that provide fairer quantitative comparisons between gridded model fields at different spatial resolutions than traditional root-mean-square metrics.

Recent data assimilation developments in the Mediterranean Sea Analysis and Forecasting System (MedFS)

Authors

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Abstract

The Mediterranean Sea Analysis and Forecasting System (MedFS) is continuously under development to provide improved ocean state estimates and daily forecasts through the Copernicus Marine Service. Since the beginning of the second phase of the Copernicus Marine Service, there have been various upgrades in the data assimilation (DA) component of the MedFS and in the ingestion of newly available observations. MedFS consists of a specific implementation of the NEMO ocean general circulation model in the MEditerranean Sea coupled with the wave model WW3 for improved hydrodynamic representation and it is interfaced to OceanVar, the CMCC 3D variational ocean data assimilation scheme to incorporate observations. The system assimilates Sea Level Anomaly (SLA) along track data from altimeters and in-situ vertical profiles of temperature and salinity. Here we present the major novelties recently included in the operational system which consist in the use of a new observation-based Mean Dynamic Topography (MDT) and a new set of Empirical Orthogonal Functions (EOFs) computed from 35 years of Mediterranean high-resolution reanalysis, both extended also to the Atlantic side of the domain thus enabling the assimilation of observations in the Mediterranean Sea and an adjacent box in the Atlantic Ocean. Additionally the assimilation of gliders observations has been tested and we will show the impact of ingesting these data in the MedFS.

An initial assessment of the assimilation of 5 Hz (~1 km) SLA observations will be presented and we will outline our future plans for this phase of the Copernicus Marine Service towards higher-frequency assimilation with an improved background representation for altimeter assimilation.

Integrating data assimilation and deep learning to maximize the impact of BGC-Argo observations in the Mediterranean Sea biogeochemical forecasting system

Authors

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Keywords

Model predictions, deep learning, data assimilation, BGC-Argo

Abstract

As part of the EU Marine Copernicus Service, the Mediterranean Biogeochemical Operational System (MedBFM) provides decadal reanalyses and short-term forecasts. The model system already includes a multivariate and multiplatform variational data assimilation (DA) scheme for Ocean Color chlorophyll observations and BGC-Argo chlorophyll, nitrate and oxygen profiles.

Although the results are very encouraging, there are still a number of challenges that need to be addressed to improve the effectiveness of BGC-Argo impacts on modelled ecosystem dynamics and predictions.

To further increase the benefits of assimilating profiles of biogeochemical variables, several deep learning methods (DL) such as multilayer perceptron (MPL) and convolutional networks (CNN) are tested to produce relationships between high-frequency sampled/observed variables and low-frequency ones. The innovative DL models based on CNN appear to be able to predict better vertical profiles than classical MLP models due to their ability to learn typical profile shapes in different marine ecoregions and seasons.

Using ARGO profiles of temperature, salinity, and oxygen (i.e., the most commonly available BGC sensor), the DL models generate synthetic measurements of nutrients that can be

integrated into the operational MedBFM system through data assimilation. Synthetic nutrient profiles are quality controlled and merged with measured BGC-Argo profiles since their uncertainties are of the same order of magnitude. The number of ingested nutrient profiles more than double compared to BGC-Argo measurements, following the trend of oxygen profile availability. Various combinations of BGC-Argo and synthetic biogeochemical profiles are assimilated by the MedBFM system to evaluate the effectiveness of the enhanced observing system in constraining model dynamics and improving model predictions.

Our results first demonstrate the feasibility of integrating DL and DA into an operational model forecast system. Then, it is shown that the model prediction performances for assimilated variables are improved by the integrated DL / DA system, while no degradation is detected for other observed variables. Moreover, the positive impact extends to vertical ecosystem dynamics, such as nutricline and deep chlorophyll maximum in summer, as well as ecosystem indicators such as vertically integrated primary production, demonstrating the importance of vertical measurements to constrain simulations of the ocean interior. The spatial and temporal impact of the integrated DL / DA system is much higher than that of BGC-Argo DA and shows a potential solution to extend the effectiveness of the BGC-Argo observing system, even in the case that expensive biogeochemical sensors may limit their future availability.

Direct Assimilation of Sentinel-1 C-SAR Backscatter Data to Update a Baltic Sea Ice Forecasting Model using 4D EnVar Data Assimilation

Authors

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Keywords

Data assimilation, Sea ice forecasts, Baltic Sea

Abstract

Several operational ice-ocean forecast models for the Baltic Sea exist today, that attempt to predict the sea ice state of the Baltic. As none of these currently assimilate ice observations, the quality of these ice forecasts are limited. However, a pre-operational forecast model (NEMO-Nordic) which assimilates ice chart data is currently being tested at the Swedish Meteorological and Hydrological Institute with promising results. This presentation describes a method to update a sea ice forecasting system for the Baltic Sea (also NEMO-Nordic), using backscatter data from Sentinel-1 C-SAR, an ice forecast ensemble, and a four-dimensional ensemble variational (4D EnVar) data assimilation system (called NOVA). This is done by using a Machine Learning (ML) technique called Extreme Gradient Boosting (XGBoost) as a forward model to map the model state vector to observation space. Model state increments are then obtained through cross covariances between increments of the modelled backscatter data and the model state variables. The results show a clear improvement in sea ice extent compared to a reference run without data assimilation. Further, HH polarization of the Sentinel-1 data gave better results than HV polarization data. Despite positive results, more work is required on the new data assimilation system, e.g. improving the forecast ensemble to improve the results further.

European Sea marine forecast for maritime service by aggregating multi-forecasts and observations

Authors

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Keywords

Multi-model ensemble forecast, model-observation integration, seamless pan-European sea forecast

Abstract

Safety at sea depends greatly on the sea surface conditions. European agencies, such as FRONTEX, require access to met-ocean information for pan-European seas, including the Baltic Sea, North Sea, Mediterranean Sea, Black Sea, Norwegian Sea and parts of Atlantic and Arctic oceans, for coordinated maritime activities such as search and rescue operations and planning. Such forecast services often require an update of 4-times a day and with a forecast range of 7 days. Currently, none of the community or national forecast services is able to meet this requirement. Global forecasts produced by organizations like Copernicus Marine Environment Monitoring Service (CMEMS), and national service such as CMCC (Euro-Mediterranean Centre for Climate Change), cover the pan-European seas, but they are only updated once a day, and their forecast skills have not been specifically tuned for the European seas. Regional oceanographic forecasts, both from national and CMEMS forecast services, have higher resolution and update frequency but they typically cover only part of the European seas, and their forecast ranges sometimes are less than seven days. Therefore it is necessary to combine different oceanographic forecasts to generate an optimal forecast to meet the user needs. There are two ways to make this seamless European Sea forecast. One way is to use smooth spatial weighting functions for different forecasts so that they can be smoothly aggregated at the boundaries of the forecasts. A more complicated method is to use a weighted multi-model ensemble (MME) approach based on best forecast features of individual models and possibly including near real time observations. This study has applied both approaches to generate a 4-times a day, 7day pan-

European sea forecast for FROTEX service. The developed method explores how satellite observations can be used to assess spatially varying, near real time weights of different forecasts. The results showed that, although a MME based on multiple forecast only may improve the forecast, if the forecasts are unbiased, it is essential to use observations in the MME approach so that proper weights from different models can be calculated and forecast bias can be corrected. It is also noted that, in some months, e.g., June in Baltic Sea, even SST was assimilated, the forecast still show quite high error. There are also visible difference between different CMEMS satellite products, e.g. OSTIA and regional SST products, which can lead different forecast quality if different SST observation products are assimilated.

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Session I

Ocean observing co-design and stakeholder engagement

Co-development of an Ocean Observatory with the Aquaculture Industry

Authors

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Keywords

Co-develop, Databuoy, Aquaculture, Ocean Observing

Abstract

It is clear that climate change is exacerbating the day to day issues experienced by the aquaculture industry. For example, oxygen, heat and storm related "extreme marine events" are significantly impacting aquaculture in many regions globally, with serious economic consequences. To provide support in this area, the EU's H2020 funded EuroSea project combined the unique perspectives and knowledge of scientists, technical developers, and aquaculture industry representatives to develop an "extreme marine event" decision support service based on scientific research. A co-development approach was taken to define specific customer needs, responsibilities, maintenance capabilities and the level of end-user training required. Continuous dialogue helped guide development of the service. Multiple meetings were conducted with co-developers to clarify their requirements and to make the solutions practical and useful for them. Once the user requirements were determined, two marine data buoys were deployed in 2022. In Ireland, a buoy that collects data on essential climate/ocean variables (ECVs/EOVs) related to currents and winds and air pressure, as well as pH, conductivity, oxygen, temperature and total algae was deployed at Deenish Island salmon farm facility (MOWI) in southwest Ireland. A second bespoke buoy with sensors that collect data on water currents, waves, winds, oxygen, temperature, salinity, chlorophyll and turbidity was deployed in the Mediterranean at Avramar facilities in El Campello, Spain. Training of local personnel was carried out in connection with the deployments. The buoys deliver data, by telemetry, to a local display solution and are ingested into the Copernicus

Marine Service *in situ* Thematic Assembly Centre. Data products were developed using EOV measurements from the buoys and from Copernicus data products (satellite and numerical models), with information displayed in an easy to access custom designed web platform. By adopting a focussed approach of engaging and cultivating trust with a small number of aquaculture companies, an integrated understanding of the problem was established, and a more effective solution to meet industry needs was possible. Service development and evaluation was carried out through face-to-face meetings, user training workshops (to become familiar with sensor maintenance and web platform use and interaction), online surveys and a web platform helpdesk. Feedback is a critical part of stakeholder engagement activities to obtain an insight into how the service is used and what improvements are needed to ensure further uptake.

Ultimately, the goal is to ensure that the scientific research is used in a way that is both scientifically sound and socially acceptable. By involving stakeholders early in the process, we were able to gain valuable insights into the real-world implications of our work and ideally help aquaculture farmers to improve the sustainability and profitability of their operations.

Talking with the potential end-users of the Observatorio Costeiro da Xunta de Galicia as a starting point of their engagement: perceptions and necessities

Authors

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Keywords

Operational Oceanography, Coastal Observatory, Blue Economy, Stakeholder engagement

Abstract

The Observatorio Costeiro da Xunta de Galicia, as part of the European cross-border RAIA Observatory, leads the operational oceanography in Galicia (NW Iberian Península), carrying out observing and forecasting systems and the implementation of services and products for more than 30 years. The Observatorio is partnered by Dirección Xeral de Calidad Ambiental, sostenibilidad y Cambio Climático (DXCASCC-MeteoGalicia), under Consellería de Medioambiente, Territorio e Vivenda (Ministry of Environment of the Government of Galicia), and Intecmar and CETMAR, dependent on Consellería do Mar (Ministry of Sea of the Government of Galicia). Therefore, the Observatorio provides efficient and reliable tools to manage the marine ecosystem services, to boost the Blue Knowledge and Economy or to deal with climate change challenges, what become especially outstanding in Galicia where the society, the economy and the environment are directly influenced by the Atlantic Ocean and its Rías.

In order to design the forthcoming future of the Observatorio the stakeholder viewpoint has been taken into account, as a first step of a co-creation process. ATLAZUL Project, financed by INTERREG V-A España-Portugal Program, aims to impulse the Atlantic coastal alliance for blue growth and has provided the ideal context to assess how well-known, how much used and how useful the observatory information is and which other information could be interesting for end-users. More than 30 talks have been carried out with stakeholders. During these interviews, a large catalogue of oceanographic capabilities in Galicia from Observatorio RAIA has been shown, where specifications as spatial and temporal distribution, parameters and units are included, likewise how to find and handle all data series on the websites www.observatoriocosteiro.gal and www.marnaraia.org and on the main European Data Aggregators as CMEMS, EMODnet and SeaDataNet.

Regarding to the current information, meteorological, hydrodynamic and wave models, supported and improved by the observational data, and the meteo-ocean daily forecast bulletin are well-known and widely often used. Besides, other information like automatic ocean-meteorological platforms or the new handy viewers for surface currents, upwelling index or wave parameters based on the HF Radar Network (recently launched), catch the attention of end-users and encourage them in their application.

In relation with which new information could be convenient and suitable for stakeholders to improve their activities, a large list of new necessities and matters has been also provided. However, some of these required data do already exist, what points the necessity of making an effort on diffusion and dissemination to reach more potential end-users, training and encouraging them to take advance of all this information and services to enhance their professional outcomes and their quality of life. In addition, some progress should be done to improve the accessibility, standardization and harmonization of the data to ensure their usability.

As a conclusion, *Observatorio Costeiro da Xunta de Galicia* highlights that end-users involvement and engagement is crucial to face society necessities and requirements.

Copernicus Marine and EU Member States: towards new services and co-designed solutions

Authors

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Keywords

Copernicus Marine Service, user engagement, informed decision-making, seamless marine monitoring

Abstract

The Copernicus Marine Service, managed by Mercator Ocean International (MOi), is a vital source of global and European regional seas information. It uses satellite and *in situ* observations, along with 3D model simulations, to provide reference information on physical, biogeochemical, and sea ice conditions. As one of six pillar services of the Copernicus program, and the European Union service advancing a sustainable use of the Ocean the Copernicus Marine Service is critical in supporting decision-making processes.

MOi plays a crucial role in the Copernicus Marine Service by providing and enhancing the data and the service but also strives to establish seamless connections throughout the oceanography data value chain. To achieve this goal, MOi aims to foster collaboration and partnership with stakeholders to develop ocean information that aligns with policy and governance needs. Initiatives such as the Marine Forum, Copernicus Thematic Hubs, and User Engagement call for tender, promote synergies, develop new downstream services, and support decision-making in marine and maritime sectors. The Marine Forum facilitates interactions and exchanges between marine stakeholders from EU Member States and MOi to implement the Copernicus program in the marine domain. The Copernicus Thematic Hubs, focused on coastal and polar environments, will facilitate access to Copernicus Information and identify information gaps to stimulate the development of new downstream services. The User Engagement call for tender reinforces collaboration with marine policy and governance stakeholders within EU Member States aiming to develop a seamless marine monitoring service to support the implementation of EU Policies and Directives.

Overall, these initiatives represent a crucial step towards better aligning ocean information with policy and governance needs. By working collaboratively with stakeholders, Mercator Ocean International ensures that its services and data are more relevant and accessible to those who need them most.

An open source user-focused technology to process, visualise and automate publication of quality controlled CTD data

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Keywords

Conductivity, Temperature, Depth (CTD) data, data quality, automated process, FAIR data principles

Abstract

Ship-based Conductivity, Temperature, Depth (CTD) instrumentation and associated bottle sampling are central oceanographic equipment utilised on research vessels globally. The data collected by the CTD instrument provides vital information on Essential Ocean Variables (EOVs), used widely by marine and climate disciplines. Some of the main challenges with profiling CTD data are the complex configurations associated with it, inconsistency of data processing between groups and research cruises where hydrography is not the primary focus and a physical oceanographer might not be present. This can lead to divergence in data processing and create data quality issues.

The aim of the work presented here was to develop tools to consistently process and visualise data at sea by scientists unfamiliar with CTD processing and post-cruise to automate the archiving and publication of quality controlled data. We will present a processing routine, using open source technology (Jupyter Notebooks written in Python), which allows scientists to process and visualise CTD data at sea or in the lab. Additional Jupyter Notebooks provide the ability to correct sensor values against bottle samples, where available, and interactively quality control the data as part of a database upload process. Once approved for publication, data are made publically available from the Marine Institute's website within 24 hours and are submitted to European data aggregators (SeaDataNet on a weekly basis and ICES on an annual basis).

This tool has transformed a manual, time consuming method into a quick, automated procedure, which is easier for new users and allows for near real-time data visualisation to identify data quality issues while at sea. The procedure makes CTD acquired EOV data findable and interoperable (through INSPIRE compliant metadata), accessible (ERDDAP data broker) and reproducible, complying with the FAIR data principles. Publishing the tool externally, using non-proprietary technology, adds transparency to the process and makes it accessible to a wider audience, following the TRUST data principles.

This presentation will cover the technology and pipeline used from data collection through to data publication, including stakeholder engagement, the challenges encountered and lessons learnt during the process.

MARine Biodiversity and Ecosystem Functioning leading to Ecosystem Services (MARBEFES): Stakeholder Engagement in Heraklion Gulf, Crete, Greece

Authors

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Keywords

Marine biodiversity, ecosystem services, stakeholders, societal needs, European seas

Abstract

MARBEFES is a Horizon Europe research project working on the links between marine biodiversity and the goods and services provided by the marine ecosystem. It is an international and interdisciplinary project, involving 22 research partners from 11 European countries. The aim of the project is to develop tools and instruments with and for users to allow for better informed decision-making and management of marine and coastal areas, considering human and ecosystem needs.

To bridge the gap between research, policy and practice, the project focuses on stakeholders – the users and custodians of the sea. The project investigates how people working and living in coastal communities perceive the relationship between the sea, society and economy, and the pressures acting on this relationship. In this way stakeholder experience and interests can be considered and represented in the decision-making tools and instruments. To this end, representatives from a range of different sectors have been invited to become involved in MARBEFES and share their point of view.

HuFoSS is a research foundation from the Netherlands that conducts socio-ecological research and coordinates stakeholder engagement for MARBEFES. From February to September 2023 the first round of stakeholder interviews and surveys are taking place across Europe (12 research areas named Broad Belt Transects, BBTs). In each research area, HuFoSS team meet representatives from four stakeholder domains: public audience, public authorities, industry and private sector, and academia and research.

Interview and survey are designed to uncover how stakeholders see the relationship between nature, economy and society in their area, as well as the most important pressures. Fuzzy cognitive mapping (FCMs) is central to the research method. In order to prevent stakeholder fatigue and to make participation as pleasant as possible for stakeholders as well as researchers, interview and survey are game-like, invoking an informal atmosphere. A second and third round of visits to the research areas will take place later in the project. During these visits HuFoSS will again engage in dialogue with stakeholders. Feedback on the research results will be provided and demos of the tools and instruments that have been developed will be presented. Stakeholders will experiment with the demos, providing feedback and evaluating them according to their usefulness, user-friendliness and accuracy.

Between 3rd and 7th April 2023, HuFoSS team undertook their third research trip for MARBEFES, to Crete. Interviews and surveys were conducted -by HuFoSS team in collaboration with HCMR team- with 19 different stakeholders (30 individuals) from the four above-mentioned stakeholder domains (representatives of e.g., museums, aquaria, research centres, Region of Crete, Ministry of Environment, NGOs, municipalities, cruise sector, commerce, tour guides, divers, teachers, hotel owners) related to the marine research area of Heraklion Gulf (BBT of Greece). Most of the stakeholders were very enthusiastic expressing their valuable insights concerning balance between nature, society and economy. The next step is another visit to Crete which is to be organized within next year for a round of feedback, to present and discuss the first results.

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Session J

Operational oceanography in the coastal zone

Integrating Coastal and Riverine Research – A Case Study for the German Bight and the Elbe River

Authors

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Abstract

Operational coastal oceanography has traditionally focused on its proper domain. Integration was sought between disciplines and substantial progress has been made integrating physics with biogeochemistry and, to a lesser degree, with biology. Models are now, more or less routinely, employed to fill gaps that observations cannot provide. In recent years, the research community has become increasingly aware that the treatment of land and riverine inputs into the coastal ocean as a mere boundary value problem is not doing justice to the complexity of processes and variability of the coastal system.

Here we present the results from various cruises along the River Elbe and the German Bight that intended to understand the nutrient and carbon dynamics within the river-estuary-coastal water system and to identify key processes regarding the matter fluxes from the terrestrial environment to the ocean. In a large-scale study we employed a sampling approach based on the travel time of water. We started with a nearly Lagrangian sampling of the River Elbe (Germany; 580 km within eight days travel time). After a subsequent investigation of the estuary, the plume of the river was followed by raster sampling the German Bight (North Sea) using three ships simultaneously.

This approach is appropriate to better understand land-ocean fluxes, particularly if it is performed under different hydrological conditions including extreme event and taking into account operational measurements along the river and in the estuary at fixed stations. The study was conducted within the frame of the Helmholtz MOSES initiative (Modular observation solutions for Earth Systems) targeting processes and impacts of hydrological extremes.

Synthesis of JERICO-RI coastal Pilot Supersite implementation: towards integrated pan-European multiplatform coastal observations

Authors

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1 SYKE
2 HCMR
3 CNRS
4 Hereon
5 IFREMER
6 DELTARES

Abstract

The Joint European Research Infrastructure for Coastal Observatories, JERICO-RI, is developing pan-European multidisciplinary and multiplatform observing capacity delivering data and products for various key scientific challenges and meeting the needs of several user groups. To facilitate this process, JERICO-RI Pilot Supersites (PSS) have been implemented in 2021-22, as a proof of concept for coastal Supersites, to study how the coastal observations are best integrated, for provision of sustained multidisciplinary observations. PSS studies were realised at five regions (Baltic Sea, English Channel and North Sea, North-West Mediterranean Sea and Cretan Sea), with a total of twenty JERICO-RI partner institutes, to test how transnational and trans-institutional integration and sharing are best achieved. Diverse and well-defined transnational Actions (n=31) included studies related to data collection for specific key scientific challenges (e.g., carbonate system, phytoplankton), sharing the knowledge (e.g., best practices, research methods), linking to other communities (e.g., modelling, ocean colour, other RIs) or connecting to end-users (e.g., regional conventions). Use of emerging technologies and multiplatform sampling strategies were part of some Actions, while some others concentrated in harmonising existing observation protocols and data flows. This presentation provides a synthesis of JERICO-RI PSS implementation, highlighting the lessons-learned for regional and pan-

European integration of coastal observations and identifying gaps and challenges in transnational operations. Study underlines the need for a pan-European strategy for coastal observations, to advance impactful scientific research in complex coastal waters and to yield common and consistent pan-European data and products, but at the same time to be inclusive for regional specificities. JERICO-RI with its regional observation structures and coastal Supersites are seen as a key component in such developments.

Climate-Proofing Coastal Cities: The SCORE Project's Triple-Win Approach

Authors

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Keywords

Co-creations; Nature-based Solutions; Smart Technologies; Living Lab

Abstract

Climate change and sea-level rise pose significant threats to coastal areas, with a 2-meter rise in sea level being almost inevitable. The uncertainty lies in the timing, which could occur in the next century or within the next two thousand years, depending on polar ice sheet melting and socio-economic pathways. The potential consequences of exceeding this level are drastic and will fundamentally change European coastal zones. Therefore, it is imperative to develop systematic transformative solutions to enhance climate resilience and mainstream nature-based solutions (NBS) and smart technologies to mitigate these risks.

The SCORE project (Smart Control Of the climate Resilience in European coastal cities) aims to design, develop, monitor, and validate robust adaptation measures in coastal and low-lying areas to protect them from increasing climate and sea-level risks. One of the key activities under SCORE is the implementation of a novel framework of Coastal City Living Labs (CCLL), which will enable citizens and stakeholders to co-create and co-design solutions with scientists, researchers, and engineers to ensure sustainability and societal acceptance.

NBS is a triple-win solution that benefits the environment, society, and economy. These solutions can be implemented alone or in combination with smart technologies to maximize their impact on societal challenges. The integration of NBS, living lab approaches, and networks of sensing technologies can significantly contribute to climate change mitigation and adaptation. SCORE develops and delivers a new generation of tools and methodologies, as well as validated Ecosystem Based Approaches (EBAs), to enhance citizen engagement, improve climate and erosion monitoring and projections, facilitate knowledge sharing, and enable exploration of different mitigation actions and risks.

The SCORE project's overarching concept is to develop a framework for the deployment of integrated EBAs and smart technologies to improve the climate resilience of European coastal cities. This approach will provide a comprehensive, scalable, and adaptive strategy for addressing the current and future challenges posed by climate change and sea-level rise. The urgency of taking action on sea-level rise and climate change is highlighted by the policy-brief presented in COP27, co-written by PROTECT, CoCliCo, and SCORE. This policy-brief emphasizes the need for immediate action and provides a comprehensive overview of the risks associated with sea-level rise.

In conclusion, the integration of NBS, living lab approaches, and networks of sensing technologies is crucial to achieving climate change mitigation and adaptation. The SCORE project's framework of CCLL and the development of tools and methodologies will enhance citizen engagement and facilitate the deployment of EBAs and smart technologies to improve the climate resilience of European coastal cities. Immediate action is necessary to address the risks associated with sea-level rise and climate change, as highlighted in the policy-brief presented in COP27.

High resolution coastal ocean model of Galway Bay, Ireland, supporting oyster aquaculture and native oyster restoration

Authors

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Keywords

Galway Bay, hydrodynamic model, oyster aquaculture

Abstract

The hydrodynamic model of Galway Bay has been developed based on ROMS 3.9. The model constitutes a 2nd level one-way offline nesting in Marine Institute's regional North East Atlantic model (c.1.1 km resolution) and a Connemara model (c. 200 m resolution), resulting in 336 x283 grid cells and a horizontal resolution of less than 70 meters. The NE Atlantic model is forced by the Copernicus Global model. The Galway Bay model covers the eastern and innermost part of the bay and has 8 vertical layers. At the open ocean boundaries, the time series of water levels, 2-D and 3-D momentum, temperature and salinity are provided every 10 minutes. Surface forcing is obtained from the hourly 0.1º ECMWF atmospheric fields. At the open boundaries, clamped boundary conditions have been imposed for 3-D momentum and tracers, whilst a combination of Chapman and Flather conditions have been applied for the free-surface and the barotropic velocity. Heat fluxes are calculated from the bulk formulae and surface freshwater fluxes are obtained from the prescribed rainfall rates and the evaporation rates computed by the model. A wetting and drying scheme has been introduced to allow for proper representation of intertidal areas. Near real-time freshwater inputs from the Corrib, Clarin and Dunkellin rivers have been added to the model, where water level data is obtained from the Office of Public Works (OPW) and converted to a volumetric discharge using rating curves. Moreover, freshwater inputs from a Submarine Groundwater Discharge (SGD) occurring at Kinvara Bay have been added from a karst hydrogeological model developed by researchers from Trinity College Dublin.

Model validation includes comparisons with the sea surface height from tide gauges, currents from ADCP deployments and drifter releases, temperature and salinity records from several aquaculture farms and data from CTD profiles taken c. every quarter of a year at c. 30 stations. The validation includes both hindcast and forecasts and shows a high level of predictive skill.

The model has been developed as part of a European Union's Horizon 2020 project FORCOAST and provides services supporting oyster aquaculture and native oyster restoration efforts in Galway Bay. Areas of primary interest are mapping of marine conditions that determine suitable grounds and mortality of native oysters, retrieval of sources of coliform contamination (i.e., pollution backtracking) and forecasting of low salinity events, that increase mortality at oyster farms. A mortality function that determines mortality based on the daily mean temperature, salinity and the exposure time has been constructed following laboratory's mortality experiments. This function has been applied to a 10-year (2012-2021) temperature and salinity near-seabed time series from the Galway Bay model, and the resulting cumulative mortality after 10 years has been used to produce a mortality map for the entire bay.

New initiatives for multidisciplinary and integrated oceanography in the SE Bay of Biscay

Authors

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Keywords

Integrated operational observations, sustainable blue economy, autonomous vehicles, numerical modelling, multidisciplinary

Abstract

Reliable, high-quality, harmonized, and accessible data in oceans and coastal areas are a prerequisite for the integrated management of marine ecosystems and the sustainable transformation of the blue economy. In line with the need to enhance integration, enabling multiplatform and multidisciplinary approaches, and data provision in the era of the digital twin, two projects funded by the Basque government were launched in 2022, in the SE Bay of Biscay. Here, we present the main worklines under these two independent but interconnected initiatives and several snapshots of the first science results, including glider, videometry, ferrybox data, and numerical models.

The project ebegi aims to develop a multidisciplinar marine super-observatory in the Basque Country with the aim of better addressing the critical need linked to the sustainable management of fisheries, the conservation and recovery of biodiversity and habitats, the challenges of Global Change, the implementation of policies and directives on the management of the marine environment (in particular, the Marine Strategy Framework Directive), and, in general, to the integrated management of its coastal zone. This augmented observatory is built upon the following requirements: (i) design a multiplatform and multidisciplinary sampling strategy; (ii) provide response to a wide range of research questions and uses; (iii) ensure continuous and sustained observations over time; (iv) establish clear links with existing activity communities, both technical (for example, numerical modelling community) and sectoral (fishing, tourism) to initiate the development of integrated coastal data products and services in a co-design process with the main users of the data; and (v) embrace transnational endeavours (given the geographical area covered, which transcends

administrative borders). The already achieved main outcomes are the building of the ebegi dashboard (an online platform that gathers all the metadata of the existing observations in the area), two glider campaigns gathering hydrographic, biogeochemical and biological (echosounder) data, and several steps towards more FAIR data.

Then, at a much smaller scale within the land-sea continuum of the Pasaia Harbour area, the project Oarsoaldea Blue Hub OOS is working towards the development of a Smart Bay capable of providing innovative and value-added operational oceanography services in the framework of the blue economy. One of the main outcomes has been the setup of different technologies for the autonomous observation of coastal oceanographic conditions: video monitoring at the port mouth, the acquisition of two gliders and one autonomous surface vehicle, the installation of a ferrybox in a fixed location inside the harbour for the testing and promotion of the technology, and the development of a data centre and an operational high-resolution wave-current coupled numerical model. Using these technologies, we aim to improve ocean monitoring in the port and surrounding waters for the sustainable management of its activities and activate a pole of relocatable operational services for coastal monitoring, adaptable according to demand for different applications (oil spills, specific studies of coastal areas, and technology tests for specific processes).

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Session K

Evolution of ocean modelling

Automatized generation of user oriented ocean model configuration with varying resolution in Baltic Sea – North Sea

Authors

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Keywords

On-demand modelling, automatic model configuration, GUI, HBM, seamless modelling

Abstract

Reliable, high-quality, harmonized, and accessible data in oceans and coastal areas are Ocean modeling is increasingly focusing on higher resolutions to better resolve coastal features. However, creating dedicated operational model configurations to resolve all coastal-estuarial areas of interest remains challenging. Therefore, it eventually requires that a user has a capability to create setup at his interested coastal area with required resolution. This involves three issues: i) to have an open source bathymetry and coastline data with sufficient resolution, ii) to ensure proper representation of narrow water channels and dam-like land features in the model bathymetry; iii) to match the nested high resolution grid depth with the coarse grid. This study focuses on the automatized generation of setup files, such as land-sea mask file, river grid file, and water depth grid file, for user defined geographic areas and resolutions. This is required for building up on-demand modelling tool in Digital Twin Ocean project EDITO MODEL LAB. The used oceanographic circulation model HIROMB BOOS Model (HBM) is one of the coastal models for the Digital Twin Ocean, that enables two way nesting suitable for very high coastal resolutions and seamless transition to the open seas. The baseline data for river locations, coastline and bathymetry used are from OpenStreetMap and EmodNet Bathymetry, respectively. Both are open source data. Gridded baseline datasets for river mouth location, land-sea mask and water depth has a resolution of about 37-50 m or 1/50 of nautical miles. Model configuration variants can choose horizontal resolutions that are factor of the base resolution. A QGIS-based Graphical User Interface is used in generating needed files. Advanced users can add additional high

resolution bathymetries of coastal areas, such as ports, to be incorporated into the model setup. To ensure that the most important straits are connected at given resolution, a special vector layer of waterways (strait, fjord, large river, estuary, channel, etc.) has been created, and parameterized with nominal width and depth of the given waterway. When moving from high-resolution bathymetries to lower resolution ones, it could happen that water bodies separated by a narrow land line (dam, narrow-long island or peninsula, road, narrow land form that separates lagoon, etc.) are wrongly connected. Therefore, a special vector layer of dams is made to ensure that there is no transport between the cells divided by a dam line. In addition, the river inflow points have to move towards the open sea. In order to ensure correct placement of the river inflow points at any resolution, the same vector layer of waterways is examined to place the inflow points correctly. The automated setup creation ensures that atmospheric forcing, boundary conditions, tides, and model-specific execution parameters are supplied correctly.

Ocean Model products for efficient monitoring of undersea cables

Authors

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Keywords

Sea cable exposure, sediment erosion, seabed shear stress, critical shear stress, sediment erosion risk

Abstract

Undersea cables are vital infrastructures for telecommunications and energy transmission. However, their exposure to offshore ocean conditions and seabed sediment transport increases the vulnerability of the cable network. Cable exposure and breaking might have strong economic consequences and can result in substantial costs for cable repair. For this reason, the Danish energy network agency (EnergiNet) and the Danish Meteorological Institute (DMI) have undergone an alliance to predict the risk of cable exposure, which could lead to undersea cable breaking. The aim is to streamline cable monitoring, reduce the costs of the cable surveillance and focus the monitoring cruises on cable stretches that are at risk of exposure. The cable exposure occurs when the sediment in which the cable is embedded is eroded and transported away. The study focuses on the erosive process and aims to analyze the risk of sediment erosion and mobilization. The sediment mobilization depends on the seabed shear stress velocity, which is derived from the combined stress of ocean wind waves and currents on the seabed. If the shear stress velocity exceeds a critical value, the sediment is eroded and mobilized. The critical velocity depends on sediment properties, particularly grain size, as well as other factors, such as sediment density, friction factor and composition. The assessment derives indicators for the sediment erosion risk, which are useful for identifying cable sections that are prone to exposure. The study focuses on the Skagerrak cable SK4, connecting Norway and Denmark, and covers a period of six years from cable deployment in 2014 to the most recent full survey in 2019. The modelled results of frequency and severity of sediment mobilization events are compared with cable survey data to assess the applied method. It was found that the model is able to predict events that could lead to cable exposure.

Evolution of the Copernicus Marine Service global ocean analysis and forecasting high-resolution system: potential benefit for a wide range of users

Authors

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Keywords

Ocean forecasting, global ocean modelling, high-resolution, data assimilation

Abstract

Since October 2016, and in the framework of Copernicus Marine Service, Mercator Ocean International delivers in real-time daily services (weekly analyses and daily 10-day forecasts) with a global 1/12° high resolution (eddy-resolving) system (Lellouche *et al.*, 2018). Oceanic observations are assimilated in the model using a reduced-order Kalman filter method. Along track altimeter Sea Level Anomaly (SLA), satellite sea surface temperature (SST) and sea ice concentration, and *in situ* temperature and salinity vertical profiles are jointly assimilated to estimate the initial conditions for numerical ocean forecasting. A 3D-VAR scheme is also used to better control the slowly evolving large-scale biases in temperature and salinity.

A major release of this analysis and forecasting system is available since November 2022 with the following main changes and updates:

- A new version of NEMO ocean and sea ice models (new numerical schemes, coherent bulk formulation with the atmospheric forcing, multi-categories sea ice model);

- Higher spatial and temporal resolution (1/15° - 1 hour) atmospheric forcing from IFS ECMWF analyses and forecasts;

- A new assimilated SST observation (assimilation of L3 ODYSSEA SST high-resolution product instead of L4 OSTIA gridded product);

- A new Mean Dynamic Topography for SLA assimilation;;

- An improved parametrization of the model error covariance with a new anomalies base deduced from the Mercator Ocean reanalysis at 1/12° (Lellouche *et al.*, 2021);

- A 4D extension of the data assimilation scheme allowing a better spatiotemporal continuity of mesoscale structures;

- The assimilation of "super-observations" to filter out noisy data and scales that the model does not resolve;

- The use of satellite-based monthly estimates of the Global Mean Sea Level to better constrain the ocean mass and the steric height.;

- An improvement of the parameterizations of the temperature and salinity bias correction method.

This presentation will describe all components of the system which have been revisited and will show how some identified weaknesses present in the previous system have been improved. It will also highlight the new system's performance in terms of analysis and forecast capacities, in the representation of mesoscale activity and water masses, and in the representation of the dynamics. Improvements also include the accuracy of polar sea ice coverage, thickness, and concentration. The new system is very close to altimetric satellite observations with a forecast RMS difference below 5 cm (best analysis is around 4 cm). The description of the ocean water masses is also very accurate and departure from *in situ* temperature and salinity observations are generally below 0.3 °C and 0.05 PSU respectively. In addition, a global comparison with independent (not assimilated) velocity measurements shows that the location of the main currents is accurately represented.

The improvements made to this release will potentially benefit a wide range of users, including several marine sectors as ocean health, trade and marine navigation, polar environment monitoring, natural resources and energy, extremes, hazard, and safety, climate and adaptation.

The Syrian oil spill predictions in the Eastern Mediterranean using SAR images, CMEMS and CYCOFOS forecasts

Authors

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Abstract

Following the 12,000-ton crude oil spill from the fuel tanks of the Syrian's Baniyas power plant in the summer of 2021, MEDSLIK and MEDSLIK-II models conducted daily operational oil spill predictions of the spill transport and fate in the NE Levantine basin and Eastern Mediterranean, assisting REMPEC and national response organizations.

The Syrian pollution incident lasted from August 23 to September 12, 2021, and was of the same magnitude in terms of spilled oil and similar source type as the one caused by the Jieh power plant during the Lebanon oil pollution in July 2006.

The sea currents and sea surface temperature forecasting data from the CYCOFOS (Cyprus Coastal Ocean Forecasting and Observing System) and CMEMS Med MFC products were used together with ECMWF and the high-frequency SKIRON winds to initiate the predictions of the Syrian oil spills traced from satellite SAR images provided by EMSA-CSN (European Maritime Safety Agency- CleanSeaNet).

The operational response during the Syrian oil pollution crisis, which threatened also the neighbouring countries in the NE Levantine, demonstrated a best practice within the

broader context of the operational oceanography developments in the Mediterranean and the usefulness of the downstream applications to the local and regional response agencies to support their decisions during major oil pollution incidents.

To assess the oil spill predictions produced by the MEDSLIK and OpenDrift Lagrangian particle-tracking models under various met-ocean forcings and configurations, and particularly to evaluate the two models' ability to adequately reproduce the oil spill spreading by comparing the SAR observed oil spillages against the model results, four statistical indicators were used.

The MANIFESTS project or how to assess acute risk by volatile, gaseous, and explosive Harmful Noxious Substances?

Authors

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Abstract

Accidental release of volatile Hazard Noxious Substances (HNS) at sea can lead to the formation of toxic, flammable or even explosive gas clouds potentially hazardous for nearby population and the environment. The objective of MANIFESTS is to address the lack in response guidance on dealing with such airborne releases and with decisions over sheltering or evacuation of the crew, responders and the coastal population. The project improved response capacities of marine pollution responders through the development of innovative decision support tools and operational guidelines and by facilitating access to relevant knowledge and databases, particularly on volatile HNS spills.

In the framework of the MANIFESTS project, RBINS has developed and improved several modelling tools to assist the Marine authorities in case of a volatile HNS (Hazardous and Noxious Substances) release. First, the OSERIT implementation of evaporation, dissolution, and volatilization processes has been refactored and thoroughly validated against newly acquired experimental data. Second OSERIT capacities have been extended thanks to a new atmospheric transport and dispersion module. This module allows to simulate within the same tool the drift of a chemical slick at the sea surface, its evaporation and the concentration and trajectory of the evaporated gas cloud. Third, a stand-alone fire module has been developed to compute the thermal energy flux as a function of distance to the fire source. It computes safety distance at which e.g. a boat can approach a fire while keeping the crew safe. Finally, an explosion module computes the overpressure of the shockwave

caused by the combustion of a chemical. This overpressure can be dangerous for people and infrastructure, causing wounds from minor injury to death and destruction of building. The model could be used to predict what could happen in case of the explosion of a stored explosive for instance. All these models are made available to Maritime Authorities through a new one-stop-shop web application.

Can biophysical models of small pelagic fish be used for fish stock management? An example of the European Iberian sardine

Authors

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Keywords

Biophysical models, Individual based models, Fish recruitment, Fish stock management

Abstract

Lagrangian Individual-Based Models forced with 3D hydrodynamic models are frequently used to study the advection and dispersion of the planktonic stages of small pelagic fish, considering also their biological behaviour (growth, vertical migration patterns, etc). Different layers of complexity can be added to these biophysical models to build an end-to-end model, such as using the results of a biogeochemical model to feed the larvae stages in the calculation of growth and mortality, adding fish movement, etc. Environmental variability during the Early Life Stages (ELS) of fish has been recognized to be key for recruitment (the incorporation of young fish to the fish stock) and population connectivity studies and can be assessed with biophysical models.

In this contribution we will describe and show examples of the application of an IBM ELS model to a small pelagic fish: the European sardine. We will discuss how the use of this biophysical model simulating the biology and the physical environment can provide insight on the complex interaction of factors driving variability in the connectivity of fish populations and in recruitment. There is uncertainty in the underlying effect of the physics, represented by the forcing of hydrodynamic models and to this respect, we will show examples of the fact that the ability of hydrodynamic models to reproduce the processes relevant for the simulation of Lagrangian trajectories strongly depends on model resolution, parametrizations and the input forcing. For model validation, we will present spatio-temporal distributions of fish ELS obtained with the biophysical model compared with estimations from Generalised Aditive Models (GAM) based on *in situ* observations from fish monitoring cruises in the area.

Modeling approaches that consider the interplay of the physical and biological traits involved are becoming established tools and now the challenge is to use this information to understand marine population dynamics and to improve the management of fishery stocks. Our operational modelling group is currently joining forces with fish scientists to compare estimations of recruitment obtained with the population dynamics models used in the ICES stock assessments with those estimated from Lagrangian ELS models. In this contribution, we will discuss the strengths and weaknesses of state of the art biophysical models of the Iberian sardine and will assess how far we are in the process of converting these models in tools to provide advice to managers in charge of fish stock management.

This abstract is related to topic:

(4) Operational Oceanography meeting European societal needs

(a) New scientific developments to respond to specific societal needs (sustainable blue economy, European Green Deal, Mission Ocean and Waters, etc.)

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Session L

Ocean observing meeting societal challenges

The Northwest European Ocean Climatology Product (NEOClime)

Authors

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Abstract

Climatologies of physical oceanographic properties and the analysis of variance from them, provide an important aspect of marine and climate research into short and longer term variation in the ocean-atmosphere system. Anomalies from climatological averages can identify stressors on a marine ecosystem or region, for example by ocean heatwaves or cold snaps. Climatologies, which have become a common research tool, are each based to varying degrees on observational or modelled ocean data, and each having associated merits and drawbacks.

Presented here is the Northwest European Ocean Climatology Product (NEOClime), which aims to provide an observationally based, statistically robust, running 30-year climatology of temperature and salinity over the last half a century (1971–2020). The product encompasses the northwestern European continental region, including the Celtic Sea, the continental margin west of Ireland and Scotland and the North Sea (47–63° N, -18–10° E). NEOClime is co-developed between the Marine Institute of Ireland and Marine Scotland Sciences (MSS) and builds, in scope and methodology, on a previous product from MSS over a standard (World Meteorological Organisation; WMO) 30-year climatology. The new product adds two further 30-year WMO sets, a wider spatial extent and introduces product adaptability that is translated to the end-user. Gridding and interpolation is performed on a conglomerate of ship-based CTD datasets extracted from international repositories (SeaDataNet, ICES, World Ocean Database), augmented with all available ARGO Float profiles that have taken place within the region. Climatologies will be calculated for surface and bottom layers and for a number of water column depth bins; yearly, seasonally and where possible, monthly; and at spatial gridding that is subset for data density (and error fields) to attain the finest resolution achievable, while maintaining statistical significance.

NEOClime will provide easy to access information on variability and trends for the Essential Ocean Variables (EOVs) of temperature and salinity in the region, intended for uptake by fisheries scientists; oceanographic and climate research; MSFD and Marine Spatial Planning work; evidence based maritime regulation, such as Marine Protected Areas. The product, adhering to FAIR and TRUST data principles, will be made available in open source format, through a web portal. This service will incorporate as much customisation as is practicable, enabling the user to tailor their climatological and variance field requests to suit their specific application. It is anticipated that NEOClime will support cross disciplinary research making strides into topics like biophysical interaction between key marine species and the underlying processes and trends; all the more important in a warming ocean under global change.

A biophysical model of the Celtic Sea for hindcasting and climate services

Authors

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Abstract

The Celtic Sea on the NW European shelf is a highly productive marine ecosystem with significant importance to fisheries. Marine ecosystems in the Celtic Sea are vulnerable to multiple pressures including climate change (e.g. ocean acidification) and offshore renewable energy activities. In the context of these emergent pressures, along with reporting requirements of directives and conventions such as the EU Marine Strategy Framework Directive (Directive No. 2008/56/EC), the Oslo-Paris convention for the protection of the marine environment of the northeast Atlantic (OSPAR) and information needs for marine spatial planning, there exists a need for a Celtic Sea model of ocean physics and biogeochemistry. To address the needs of our stakeholders (e.g. scientists and Irish government departments), a CROCO-PISCES model of the Celtic Sea was established (20 vertical layers, kilometre-scale), extending from 49.00° to 52.95° N and 10.75° to 5.83° W.

For hindcasting purposes, the model was initialised and forced at the ocean boundary with CMEMS IBI reanalysis ocean physics [IBI_MULTIYEAR_PHY_005_002] and biogeochemistry [IBI_MULTIYEAR_BGC_005_003] products. Bulk atmospheric forcing was provided using hourly ECMWF ERA5 data, whilst tidal forcing at the boundary was provided by OSU TPXO8. Daily flow volumes from the Irish EPA and OPW, nutrient concentrations were derived from flow-normalised flow-nutrient relationships OSPAR RID reporting from 1990-2021. A 29 year hindcast simulation, covering 1993 to 2021, was executed to provide robust estimates of the state and trends of essential ocean- and climate- variables (EOVs; ECVs). Moreover, the hindcast provided an initial state for climate projections to explore potential trajectories of EOVs and ECVs up until 2100.

The biophysical model was executed to dynamically downscale a range of climate scenarios from a selection of IPCC CMIP6 earth system models (ESMs), to inform national stakeholders and marine-related sectoral climate adaptation plans. Each projection spanned from 2015 to 2100. Projection datasets were made available to stakeholders and a number of analyses applied to the datasets.

The underlying procedures followed in this research provides a template to facilitate replication of the approach in other marine areas around Ireland and if required an extension of the model configuration to all Irish EEZ waters. The gridded outputs from this project are also available for ecosystem models to translate potential ecosystem effects from lower to higher trophic levels.

Development of a storm surge forecasting model for the NW of Ireland and its validation and calibration using low-cost sensors

Authors

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Abstract

Lack of observational data in high-risk areas from storm surge flooding can be a limiting factor towards the development of a reliable operational storm surge model. Tide or more appropriately "sea-level" gauges can be expensive and difficult to deploy. The scientific literature has shown the availability of low-cost sensors satisfactorily measuring water level based on hydrostatics, however there is a dearth of sufficient peer reviewed studies on these low-cost sea level sensors, and in general on the overall low-cost coastal hazards monitoring sensors, unlike numerous studies on the low-cost air quality sensors. Due to the commitment to sea level rise as a result of the thermal expansion of the seawater and external addition of mass due to melting of land-based ice, many regions around the world are projected to have increase in the risk of coastal inundation due to extreme sea levels (ESLs). Lack of observational data could make development of an operational storm surge model challenging for such high-risk local areas. A storm surge model has been developed for the first time for the NW of Ireland using a finite element hydrodynamic modelling suite called Shallow water HYdrodynamic Finite Element Model (SHYFEM), a 3D hydrodynamic model particularly suitable for application in areas of complex geometry and bathymetry. This model is validated and calibrated with low-cost water level sensors after the subsequent validation of these low-cost sensors with standard reference instruments. Such a framework could be replicated for development of a storm surge model in any high-risk ungauged coastal areas, especially in face of the rising coastal flooding risk from increasing sea levels. The NW of Ireland has sparse coastal observation systems and hence has been conducive for implementing such a modelling approach using low-cost water level sensors for validation and calibration.

Organic carbon dynamics and darkening of Norwegian coastal waters assessed from Ferrybox continuous measurements and earth observation satellites

Authors

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Keywords

NorSOOP, Ferrybox data, CDOM, coastal darkening, Sentinel-2, Sentinel-3

Abstract

All coastal areas, including Norwegian, are affected by anthropogenic impacts that lead to changes in the ecosystems often associated with declining water quality. In recent years, it has been observed that the coastal waters of Norway have become less saline, whilst also becoming warmer and browner. A documented increase in river discharge and transport of dissolved organic matter (DOM) from land to coastal waters has been observed in Norway over the last 30 years. Dissolved organic matter, and especially DOM from land, includes a strongly light absorbing fraction, often called colored dissolved organic matter (CDOM). Recent studies have also documented a long-term reduction of light penetration in Norwegian coastal waters observed as an increased light attenuation coefficient (Kd) and substantial reductions in Secchi depths (a measure of water transparency) during the last century. The observed changes are expected to persist and may increase due to climate change due to milder winters with increased precipitation, which leads to more run-off and to an increase of optically active constituents entering the coastal water.

For Norwegian coastal waters, the interaction between land and ocean will increase, making it crucial to understand the current situation to be able to predict the effects of future change. The Norwegian coastline is long and complex, and experiences a high degree of seasonality, making it challenging to observe dynamic processes on appropriate time and spatial scales. Hence, relevant data for improving our understanding the changes in the the coastal and oceanic ecosystems are deficient.

Hence, in this study the topic has been addressed by two methods, **(1)** Samples collected by NorSOOP (Norwegian Ships of Opportunity Program), a national research infrastructure financed by the Research Council of Norway with a network of ships of opportunity providing continuous marine and atmospheric observations along the Norwegian coast, **(2)** by the use of Earth Observation (EO) remote sensing data from the EC Copernicus satellites Sentinel-2 and Sentinel-3. The Ferrybox systems provide a high temporal resolution and the EO satellites the spatial distribution, providing unique opportunities to study the coastal dynamics. The dataset provides information of CDOM hotspots and drivers for change as well as validation datasets for satellite-based retrieval of CDOM.

OLAMUR: offshore low-trophic aquaculture in multi-use scenario realisation

Authors

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Keywords

Seaweed and mussels, Wind farm, Fish farm, Data-based service system, Baltic Sea and North Sea

Abstract

Globally, food security, human health and human well-being are under serious threat because aquatic ecosystems and natural fisheries can no longer sustain the production of living aquatic resources. Furthermore, agricultural expansion cannot meet future human food needs without massive impacts on ecosystems. OLAMUR is an innovative Horizon Europe project that promotes commercially viable and sustainable Multi-Use Low-Trophic

Aquaculture (MU-LTA) in wind farms or fish farms in offshore waters. OLAMUR aims to bring together the existing state-of-the-art practices in the key sectors related to MU-LTA in order to develop and demonstrate a sustainable solution for commercial MU-LTA (e.g., seaweed and mussel farming) in both low and high salinity, high eutrophic and high energy offshore waters.

Through a holistic and interdisciplinary approach, the project proposes to demonstrate the possibilities of co-use of marine space and how multipurpose low-trophic aquaculture can contribute to more resilient and sustainable food production with low impacts and emissions. Indeed, MU-LTA has several environmental, social and economic benefits, contributing to the achievement of many Sustainable Development Goals. MU-LTA has a low stress on the climate and the environment, preserving the ecosystem integrity, without damaging fisheries and not being dependent on agricultural feed. Low-trophic aquaculture reduces import dependency and food and nutrition insecurity, and tackles malnutrition. A strength of OLAMUR is the direct involvement of producers and stakeholders as direct partners of the project throughout the decision-making process.

OLAMUR, strongly encouraged by European Community, will contribute to the improvement of marine data standardisation, accessibility and interoperability, also through EU programmes and projects (e.g. Copernicus, EMODnet), enhancing access to observational data at all stages of their life cycle, and fostering the development of integrated services targeted to research, regulatory and operational users. A data-based service system will be developed to support policy makers in making knowledge-based smart decisions, and innovative governance arrangements and related policy levers will be developed to achieve effective and sustainable governance of multiple uses. The system aims to support producers in all stages of the production chain, including planning, implementation, operation, production, impact assessment, commercialisation, and capacity building. Moreover, the proposed system will provide useful information for estimating the potential and prospects of co-localised low-impact aquaculture. For this purpose, the relevant data, information, products and standards for the establishment, operation and evaluation of such a solution will be monitored, simulated, stored and customised.

OLAMUR focuses on three geographically and ecologically diverse pilot sites in the Baltic and North Seas to test and demonstrate the feasibility and replicability of multi-use low-trophic aquaculture and the possibility of multi-use of marine space.

Subsurface temperature anomaly observed by Argo floats during the 2022 Mediterranean Marine heatwave

Authors

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Keywords

Marine heatwaves, Argo floats, vertical heat penetration, subsurface

Abstract

Marine Heatwaves (MHWs) are periods of sustained anomalously warm ocean temperatures that can have significant impacts on ecosystems, coastal communities and economies. Their magnitude and frequency have increased in recent decades as indicated by satellite observations at the surface, but our understanding of their depth structure is still limited.
In this work, we investigate the 2022 MHW temperature anomaly in the Mediterranean Sea down to 2000 m depth using *in situ* observations from Argo floats. Mean gridded (0.125° x 0.125°) monthly climatological temperature profiles (1985-2018) derived from SeaDataCloud, were linearly interpolated at the positions of float profiles and used to compute the temperature anomaly T'(z) at each depth z for each profile. The regions most affected by warming in different layers were selected based on the 2022 ocean heat content anomaly estimated with respect to a float-derived climatology for the period 2001-2020. In these areas (northwestern Mediterranean Sea, southwestern Mediterranean Sea, central Ionian Sea, Pelops Gyre, southern Adriatic Sea), temperature anomaly profiles computed during the period of the MHW (May-September 2022) were divided into three categories based on vertical heat penetration (MHW depth; see Elzahaby and Schaeffer, 2019): Category 1 (shallow, 0-150 m), Category 2 (intermediate, 150-700 m), Category 3 (deep, > 700 m). Mean and median anomaly profiles were computed for each category and compared to climatology, i.e. the anomaly profile for the period May - September 2001-2020 derived from the float dataset.

In the northwestern Mediterranean and central Ionian, the anomaly profiles of Category 1 showed a warming in the first 20 m of the water column (about 1.6-2°C) and in the intermediate layer (about 0.2-0.35°C), while a cooling was observed in a thin layer between 20 m and 130 m depth (maximum of 0.6°C). This behaviour can be attributed to the stratification, intensified by the additional warming of the surface layer due to the MHW.

Stronger stratification leads to less mixing and thus less heat exchange with the underlying layers. The heat stored in the surface layer is distributed into the water column the following fall, making it warmer than climatology. The profiles with the highest MHW depth (categories 2 and 3) are characterized by larger positive temperature anomalies than those in category 1 in the surface layer and thermocline.

The Pelops Gyre and South Adriatic regions, characterized by dynamic mechanisms that enhance mixing, tend to transport the MHW effect to deeper layers faster in all categories, with no heat retention at the surface.

This study highlights the impact of 2022 MHW on the Mediterranean Sea water column and the influence of ocean circulation on their properties, which paves the way for describing their consequences on deep ecosystems.

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Session M

Oceanographic services for ocean health

Improving ocean ecosystem predictions by coupled data assimilation of physical and biogeochemical observations

Authors

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Keywords

Data Assimilation, Ensemble, Biogeochemistry, Satellite Observations

Abstract

The CMEMS Monitoring and Forecasting Center for the Baltic Sea (BAL-MFC) computes reanalysis and forecasts for the Baltic Sea utilizing the NEMO ocean model coupled to the ERGOM, which simulates biogeochemistry and the carbonate system. Operationally, observations are assimilated using the open-source soQware PDAF (Parallel Data Assimilation Framework, hTpsti//pdaf.awi.de) using a fixed ensemble read from model snapshots. In the EU-project SEAMLESS, the operational model setup builds the basis for enhancements by a fully dynamical data assimilation approach. For this, the coupled NEMO-ERGOM model system is augmented by the data-assimilation functionality of PDAF and NEMO-ERGOM is run in ensemble mode. The system allows to assimilate a variety of observations. Here satellite surface temperature and chlorophyll observations are assimilated daily using an ensemble of 30 members. We assess the impact of the assimilation on the forecast skill with a focus on the biogeochemical variables. In addition, additional ecosystem indicators, like tropic efficiency, pH, and phytoplankton community structure are analyzed. The developments on the data assimilation system are in wide parts generic an can also be applied with other model configurations or components. The open-source character of the developments will help to enhance co-design and inter-operability including the initialization for digital twins and inclusion of possible developments in machine learning.

MARBEFES – comprehensive approach to understanding reasons and sharing knowledge on biodiversity changes in European seas

Authors

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Abstract

Europeans need to value coastal and marine biodiversity and their ecosystem services and societal goods and benefits, as a basis for cost-effective environmental management, which requires ecological and monetary as well as non-monetary valuation.

The MARBEFES (MARine Biodiversity and Ecosystem Functioning leading to Ecosystem Services) project is one of those initiatives which tackles the above challenges, since its overall aim is to determine links between biodiversity, ecosystem functioning and the resulting ecosystem services and societal goods and benefits and to achieve ecological and socio-economic valuation through a validated set of innovative tools in a distributed toolbox to enhance policy and governance for the marine environment to secure its benefits for current and future generations. The goal is to progress substantially beyond the current state-of-the-art regarding causes and consequences of biodiversity decline, and the loss and gain of ecological and economic value and the consequences for marine management and governance across European seas.
In order to link these aspects of natural capital to the ecosystem services provided by the natural system from which society then obtains societal goods and benefits after investing human capital. MARBEFES works on an integrated system of concepts that span natural to

socio-economic perspectives and aims to provide data and new knowledge by quantifying these aspects to directly measure ecosystem services and ecological and economic connectivity in complex socio-ecological systems. For these purposes, 12 Broad Belt Transects (BBTs), spanning from the Arctic to the Mediterranean Sea, have been selected.

The main objectives of MARBEFES are to:

i. Characterize marine biodiversity in selected areas in Europe and understand the links between ecological structure and functioning across biological organization levels;

ii. Establish biodiversity-ecosystem functioning-ecosystem service links for focal habitats and selected important or iconic species in a range of ecological and socio-economic contexts;

iii. Capture ecological value related to the fragility, connectivity, uniqueness, irreplaceability and vulnerability of selected genes, species, habitats and ecosystems;

iv. Demonstrate how different European coastal ecosystems provide services, and societal goods and benefits, including cultural value, and clarify how this provision is dependent on healthy biodiversity;

v. Recommend how management interventions should be directed and addressed to maximize the ecological value and optimize the economic value of the marine system;

vi. Inform action to meet the major global and European societal and marine management and governance demands; and

vii. Foster biodiversity and human well-being by creating a toolbox for biodiversity and ecosystem valuation to support international and EU-level policy and decision making.

In order to promote the project results as well as using the outstanding potential of the project research and dissemination teams we have developed a multitude of modern mechanisms for the support of the outreach actions dedicated to a variety of stakeholders as well as to general public. These include the use of social media, non-formal education techniques, including, science fairs and open days, bioblitz type of activities, as well as events focused on stakeholders and decision makers.

Resolving the bloom dynamics and ecological role of *Noctiluca scintillans* in the southern North Sea

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Keywords

Noctiluca, North Sea, Underwater cameras, Remote Sensing

Abstract

Plankton communities worldwide undergo drastic changes in response to climate change and anthropogenic pressures, affecting the functioning of entire ecosystems. The dinoflagellate *Noctiluca scintillans* is highly tolerant to changing conditions and proliferates in eutrophic environments, leading to globally more intense and frequent blooms over the past decades. With competitive advantages over other plankton species such as polyphagous feeding habits and fast development, *N. scintillans* might induce shifts in community composition and reduced productivity. We here present data from a series of cruises in the southern North Sea during summer 2022, covering the evolution of a *N. scintillans* bloom while applying an integrative sampling approach including traditional sampling techniques, remote sensing and underwater camera systems. Preliminary results show a shift from diatoms dominating the plankton community in the first half of June to dinoflagellates in August, whereas *N. scintillans* abundances peaked in the second half of June. The images recorded with the CPICS (Continuous Plankton Imaging and Classification Sensor) and VPR (Video Plankton Recorder) were analyzed with applied machine learning techniques and revealed detailed *in situ* feeding strategies of *N. scintillans*, prey types, and interactions with other organisms at high resolution. Moreover, high ammonium and phosphate concentrations were measured within the dense bloom patches at the surface, suggesting an important role of *N. scintillans* in nutrient recycling. Through satellite images, the total extent of the bloom could be visualized allowing an extrapolation of the locally observed impacts to the entire bloom area. The frequently observed ingestion of chain-forming diatoms by *N. scintillans* followed by a shift to phosphate-affine dinoflagellates, indicates a potentially important role of *N. scintillans* in shaping plankton community composition. Our results provide new

insights in the functional role and the dynamics under current and future climate conditions of this dinoflagellate in the North Sea. Considering the development of *N. scintillans* over the last decades and its great adaptability to changing conditions, it can be expected that in the future this species might play a leading part within coastal plankton communities at global level.

Potential of CMEMS products for assessing eutrophication status of the Baltic Sea sub-basins

Authors

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Keywords

Eutrophication, indicators, Baltic Sea, HELCOM, CMEMS

Abstract

Plankton communities worldwide undergo drastic changes in response to climate change and The Baltic Marine Environment Protection Commission (HELCOM) has developed a set of core indicators to reflect the achievement or non-achievement of good environmental status of the Baltic Sea. This comprehensive indicator-based system requires long-term and systematic measurements to minimize the influence of natural (spatial and temporal) variability on the trend estimates. However, routine environmental monitoring is carried out with a low spatial and temporal resolution and model data, which could be used as an addition, are not applied largely yet.

We assessed the possibility of using the model data provided by the Copernicus Marine Service (CMEMS) to calculate HELCOM eutrophication indicators. CMEMS reanalysis products BALTICSEA_REANALYSIS_BIO_003_012 and BALTICSEA_REANALYSIS PHY_003_011 were used. Indicators on winter dissolved inorganic nitrogen and phosphorus, summer chlorophyll-a and yearly average total nitrogen and phosphorus and sub-halocline oxygen debt were calculated following the HELCOM methodology. We compare the indicator results with the most recent HELCOM indicator reports, analyze the found discrepancies between model-based and monitoring-based results in selected sub-basins and suggest ways forward to improve the confidence of assessments by combining model and observational data.

While the absolute values of indicators based on CMEMS and HELCOM data differ, the patterns of changes agree well, especially in the central Baltic Sea. The largest discrepancies between the CMEMS-based and HELCOM indicator results were revealed in the Gulf of

Riga and the Gulf of Finland. Sub-halocline oxygen debt depends significantly on vertical stratification. If it is not well simulated by the model in the sea areas with more dynamic stratification, such as the Gulf of Finland, the CMEMS-based indicator results lead to lower oxygen debt than the monitoring-based estimates. Faster availability of monitoring data and more frequent reanalysis can improve the confidence of model-based assessments (e.g. Lips *et al.,* 2022).

Lips, U., Samlas, O., Korabel, V., She, J., Stoicescu, S.-T. and Cusack, C. (2022) Demonstration of annual/quarterly assessments and description of the production system. Open Access. EuroSea Deliverable, D6.2 . EuroSea, 54 pp. DOI 10.3289/eurosea_d6.2

Multiscale harmonised automated observations of phytoplankton biomass, diversity and productivity dynamics in the English Channel and North Sea as part of the coastal Pilot Super Site approach (JERICO RI)

Authors

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Keywords

Multiscale automated observations – Phytoplankton biomass, diversity and productivity dynamics, North Sea and English Channel, Coastal Pilot Super Site

Abstract

Multiscale harmonised automated observation of phytoplankton are currently carried out within the English Channel and North Sea coastal Pilot Super Site of the Joint European Research Infrastructure for Coastal Observatories (JERICO RI) for provision of sustained

multidisciplinary observations. This site is characterized by significant connectivity to adjacent seas, strong hydrodynamics and high riverine inputs, influencing biogeochemical and biological processes as high productivity and recurring phytoplankton blooms, including Harmful Algal Blooms-HABs with potential impact on marine food webs as well as human health and economy. The intrinsic knowledge on phytoplankton biomass, diversity and productivity dynamics are completed, at different spatial and temporal scales, through the harmonisation of observations (including near-real time in vivo automated approaches implemented for almost a decade). Integrated phytoplankton observations are carried out combining reference methods with innovative automated in vivo imaging inflow/*in situ*/ benchtop devices, pulse shape-recording flow cytometers as well as in vivo multispectral and variable fluorometers. These approaches are implemented in different platforms (fixed autonomous stations, moorings, dedicated cruises and measurements on boards ships of opportunity-FerryBox). Functional and taxonomical diversity are addressed in the frame of different monitoring networks carried out in four different systems from the Celtic seas and English Channel to the German Bight in the North Sea. Moreover, the models used to compute high resolution-resolved photosynthetic parameters and production using variable fluorescence measurements give insights into different seasonal patterns, which are respectively synchronous or in delay compared to chlorophyll biomass and community changes. These high spatial and temporal resolution measurements provide more precise information on the distribution and dynamics of phytoplankton functional types (flow cytometry) and main taxa (imaging) and consequently improved the discrimination between temporal and spatial changes in communities defining the different bloom situations and pelagic habitats state, as a complement of physical, biogeochemical and biological variables. Finally, harmonisation in data pipelines and synthesis makes it possible to address scientific, societal and economic challenges through a new perspective, facing global and regional change.

10th EuroGOOS International Conference

3-5 Oct 23
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European Operational Oceanography
for the Ocean we want – addressing
the UN Ocean Decade Challenges

Abstracts presented in plenary

The future of operational oceanography

Blue-Cloud 2026, a Federated European Ecosystem to deliver FAIR & Open data and analytical services, instrumental for the Digital Twins of the Oceans

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Keywords

Open Science, Virtual Research Environment, Datalakes

Abstract

The pilot Blue-Cloud project as part of 'The Future of Seas and Oceans Flagship Initiative' of EU HORIZON 2020 combined interests of developing a thematic marine EOSC cloud and serving the Blue Economy, Marine Environment and Marine Knowledge agendas. It deployed a versatile cyber platform with smart federation of multidisciplinary data repositories, analytical tools, and computing facilities in support of exploring and demonstrating the potential of cloud based open science for ocean sustainability, UN Decade of the Oceans, and G7 Future of the Oceans. The pilot Blue-Cloud delivered:

- **Blue-Cloud Data Discovery & Access service (DD&AS),** federating key European data management infrastructures, to facilitate users in finding and retrieving multi-disciplinary datasets from multiple repositories;

- **Blue-Cloud Virtual Research Environment infrastructure (VRE)** providing a range of services and facilitating orchestration of computing and analytical services for constructing, hosting and operating Virtual Labs for specific applications; and

- **Five multi-disciplinary Blue-Cloud Virtual Labs (VLabs),** configured with specific analytical workflows, targeting major scientific challenges, and serving as real-life **Demonstrators,** which can be adopted and adapted for other inputs and analyses.

Since early 2023, Blue-Cloud 2026 aims at a further evolution into a Federated European Ecosystem to deliver FAIR & Open data and analytical services, instrumental for deepening research of oceans, EU seas, coastal & inland waters, and building a major data ground segment for the Digital Twins of the Oceans (DTO's).

The DD&AS already federates leading Blue Data Infrastructures, such as EMODnet, SeaDataNet, Argo, EuroArgo, ICOS, SOCAT, EcoTaxa, ELIXIR-ENA, and EurOBIS, and facilitates common discovery and access to more than 10 million marine datasets for physics, chemistry, geology, bathymetry, biology, biodiversity, and genomics. It is fully based on machine-to-machine brokering interactions with web services as provided and operated by the Blue Data Infrastructures. As part of Blue-Cloud 2026 it will expand by federating more leading European Aquatic Data Infrastructures, work on improving the FAIRness of the underpinning web services, incorporating semantic brokering, and adding data subsetting query services.

The Blue-Cloud VRE, powered by D4Science, facilitates collaborative research offering computing, storage, analytical, and generic services for constructing, hosting and operating analytical workflows for specific applications. Blue-Cloud 2026 will expand the VRE by federating multiple e-infrastructures as provided by EGI, Copernicus WEkEO, and EUDAT. The seamless expansion will support orchestrating workflows, with algorithms and computing resources, divided over and running at the different e-infrastructures, and making use of the multidisciplinary data, provided through the participating repositories.

Earlier Virtual Labs will be upscaled and upgraded, and new VLabs will be added. Moreover, the consortium is going to develop, test, validate, and document new Blue-Cloud analytical Big Data WorkBenches generating harmonised and validated data collections of Essential Ocean Variables (EOVs) in physics (temperature and salinity), chemistry (nutrients, chlorophyll, oxygen) and biology (plankton taxonomy, functions and biomass). Such EOV collections are highly relevant for analysing the state of the environment. This way, Blue-Cloud 2026 will provide a core data service for EMODnet, Copernicus Marine, various marine research communities, and the Digital Twins of the Oceans.

European contribution to the OneArgo array: scientific rational & deployment strategy

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Keywords

In situ observations, OneArgo, Argo

Abstract

The Argo Programme is a major component of both the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), providing near-real time data for ocean and atmospheric services and high-quality data for climate research. Although originally designed to provide temperature and salinity profiles in the upper 2 km of the ice-free ocean, the array has been expanded into seasonal ice zones. In addition, regional pilot programmes have demonstrated that some Argo floats can now measure biogeochemical parameters to address oceanic uptake of carbon, acidification, and deoxygenation (BioGeoChemical, BGC-Argo) and some floats are also able to make measurements throughout the water column down to 6000 m depth (Deep-Argo). These new BGC-Argo and Deep-Argo Missions, together with the initial Core-Argo Mission form the new global, full-depth and multidisciplinary OneArgo programme (Roemmich *et al.,* 2019).

Euro-Argo aims at maintaining ¼ of the global OneArgo array, with a regional perspective and focusing on European marginal seas (Mediterranean, Black and Baltic seas) and the European part of the Arctic Sea.

The Euro-Argo strategy focuses on providing sustained high quality oceanic data to the science community to better understand the role of the ocean in the Earth climate, to address issues of climate change and to expand their scope is at the centre of the Euro-Argo strategy. Another domain of grand challenges is related to the health of the oceanic ecosystem and its impacts on society. The recent advance in biogeochemical instrumentation on Argo floats has greatly improved the ability to address these ecosystem topics, and data gathered in the European area support climate and biodiversity policies set up by the European Union. Moreover, Argo is a major source of information for operational centres such as Copernicus (Marine and Climate Services) and the European Centre for Medium-Range Weather

Forecasts (ECMWF) in Europe, to produce ocean and weather forecasts and seasonal predictions. Euro-Argo supports the enhancement of monitoring and observing systems at regional scales for model-assimilation and model-validation purposes. In particular, the extensions of Argo into the deep ocean and ecosystem parameters offer new possibilities and will help to constrain and improve the models and resulting products.

Within this context, Euro-Argo is currently revising its deployment strategy for the next decade, taking into consideration specific European needs in terms of *in situ* ocean observations, while contributing to the global OneArgo new ambitious design.

We will present this deployment strategy and provide some highlights on the challenges for the years to come.

ANERIS: Towards a network of Operational Marine Biology

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Abstract

In the recent funded ANERIS HE project (operAtional seNsing lifE technologies for maRIne ecosystemS), we propose to develop the next generation of scientific instrumentation tools and methods for sensing marine-life. ANERIS will improve and integrate different acquisition technologies based on genomics, imaging and participatory systems to cover the wide range of body sizes of the different organisms that lives in the ocean. The project proposes the concept of Operational Marine Biology, understood (in analogy with the Operational Oceanography) as a systematic and long-term routine measurements of the ocean and coastal life, and their rapid interpretation and dissemination.

The main reason to develop this concept is that biological observations need to improve radically to serve our understanding of marine ecosystems and biodiversity under long-term global change and multiple stressors. However, this is not trivial as biological properties are more difficult to measure and integrate compared to physical or chemical parameters. The achievement of the Operational Marine Biology network is a key goal for the next decade and will enable a base line of biological information related to Essential Biodiversity Variables (EBVs) and Essential Ocean Variables (EOVs). It will also deliver critical data for descriptors for Marine Policies, in particular the Marine Strategy Framework Directive (MSFD)

The Operational Marine Biology information chain. We propose to stablish an automatic system of flow information to develop the Operational Marine Biology: **(1)** acquisition, **(2)** Validation, **(3)** Curation and **(4)** Interpretation and dissemination. The technologies will be tested and validated in different case studies, involving the ANERIS innovations, commercial instruments to be improved and different world-class research infrastructures (RI). The project will develop a training program for the operation and use of these new solutions for all the involved stakeholders and particularly the research infrastructures staff.

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Poster Presentations

Physical/biogeochemical modelling of the global coast with ICON-coast/ECOSMO

Author

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Keywords

Ocean model, unstructured grid, global coast, biogeochemistry

Abstract

In the recent funded ANERIS HE project (operAtional seNsing lifE technologies for maRIne ICON-coast is the coastal version of the newly developed global ocean model ICON-O, which is itself part of the ICON (Icosahedral Non-hydrostatic) earth system modelling framework, developed by the Deutscher Wetterdienst and the Max-Planck-Institute for Meteorology. ICON-coast uses an unstructured, triangular computational mesh with a regular bisection-type mesh refinement technique to increase the horizontal resolution along the global coast. The global tides are included by adding gradients of the full tidal potential to the equations of motion. Furthermore, an interface to the FABM 1.0 framework was implemented, which enables a coupling with the biogeochemical model ECOSMO. We present first ICON-coast/ECOSMO experiments in order to investigate the impact of tides and continental runoff on the global coastal ecosystem.solutions for all the involved stakeholders and particularly the research infrastructures staff.

Evaluating the economy value of Oceans and the Western Indian Ocean

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Keywords

Ocean, Western Indian Ocean, Economy, Value

Abstract

There are different economy values of the oceans and in the western Indian ocean which have not be documented, unknown, and discovered In which the different private sectors will not been able to see the needs of the investment oppournities that may be available., while some lived species are in crisis. Such as the tiny, soft- bodied organisms know as coral which form reefs mostly found in shallow tropical waters, also threatened by pollution, sedimentation, and global warming, We are able to use the search engines to look at the various studies and used on line interview and survey, to have the first add information about the definition of the ocean, the various economy importance, the ideas of sustainable development, various issues of management systems and provides different suggestions of the maximum used of the ocean and western Indian ocean. The ocean is a continuous body of salt water that covers more than 70 percent of the Earth's surface. Ocean currents govern the world's weather and churn a kaleidoscope of life. Humans depend on these teeming waters for comfort and survival, but global warming and overfishing threaten Earth's largest habitat. Geographers divide the ocean into five major basins the Pacific, Alantic, Indian, Arctic Indian, Arctic, and Southern. Smaller ocean regions such as the Mediterranean Sea, Gulf of Mexico, and the Bay of Bengal are called seas, gulfs, and bays. Inland bodies of saltwater such as the Caspian Sea and the Great Salt Lake are distinct from the world's oceans. The oceans hold about 321 million cubic miles (1.34 billion cubic kilometers) of water, which is roughly 97 percent of Earths water supply, Seawater's weight is about 3.5 dissolved salt oceans are also rich in chlorine, magnesium and calcium. The oceans absorb the sun's heat, transferring it to the atmosphere and distributing it around the world. This Conveyor belt of heat, drives global weather patterns and helps regulate temperatures on land, acting as a heater in the winter and an air conditioner in the summer. The oceans are home to millions of Earth's plants and animals-from tiny single-celled

organisms to the gargantuan, blue whale, the planet's largest living animal. Fish, octopuses, squid, eels, dolphins, and whales swim the open waters while crabs, octopuses, starfish, oysters, and snails crawl and scoot along the ocean bottom. The Western Indian Ocean represents can hold.8% of the world's oceans but generates only 4% of the global industrial catch. The Western Indian Ocean is a region of great diversity. Few oceans share the same ichthyofauna richness with at least 2200 species recorded, some 15% of the global total of marine fishes (Smith & Heemstra 1986). This richness is due to the large variety of habitats and oceanographic conditions of this region, giving rise to zones of high endemism and unique groups of fishes.. Therefore the needs to mapped, know more oceans, conduct more research, on how to preserve some of the fragile, ailing creatures and the ecosystems and explored more business oppournities of discovering, to the private sectors and developing it into a tourism center and making it as an economy activities.

Contributing to the improvement of ocean biogeochemical data quality in a cloud environment as part of FAIR-Ease use case

Authors

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Abstract

The observation of marine biogeochemical (BGC) properties is fundamental to address scientific processes regarding the health of marine ecosystems (e.g. ocean acidification, oxygen minimum zone, biological carbon pump, phytoplankton communities, etc.) and needs for ocean resource management. BGC sensors have been deployed through various autonomous platforms (floats, gliders, sea mammals, moorings, etc.) by observing networks under GOOS-OCG international coordination (Global Ocean Observing System - Observations Coordination Group), leading to a dramatical increase of BGC observations at global scale for last decades. There are currently more than 900,000 BGC profiles measured either by a BGC-Argo float, a glider or a sea-mammal throughout the global ocean, including European marginal seas (source: Copernicus Marine Service - https://doi.org/10.48670/moi-00036, Dec. 2nd, 2022): 18% are already in delayed mode status (usable by scientists in total confidence), 10% are automatically adjusted in real time whereas the remainder is being qualified as bad data potentially correctable. Thus, BGC data adjustment and validation represent a major challenge to significantly increase the volume of high quality BGC data available for the scientific community.

At present, the BGC-Argo science team is a major contributor on an international level to calibrate, validate and trigger alerts on *in situ* BGC data at global level. In recent years, BGC-Argo sensors have diversified (oxygen, nitrate, chlorophyll, suspended particles, pH) and methods of data quality assessment and control, validation and adjustment have become more complex. Most of the methods are available as open source tools, available on various public github repositories. These methods require an efficient access to external data: gridded climatologies, model outputs (meteorologic, oceanographic), discrete *in situ* data, satellite data, etc. Moreover, applying these methods requires combining the data in

space and in time using extraction and colocation. Thus, a massive, high-performance, distributed data infrastructure that would combine *in situ*, satellite and models data would definitely help the data scientist community.
Today, softwares development and metadata standards are specific to the Argo format. However, methods are essentially sensor-dependent and not platform-dependent, meaning that it is applicable to BGC sensors deployed on gliders, sea-mammals or other platforms.

As part of FAIR-EASE, a Horizon Europe project which objective is to customize and operate distributed and integrated services for observation and modelling of the Earth system, a demonstrator is being developed for contributing to the overall improvement of BGC data quality, through softwares standardisation and easy cloud development. The aim of the demonstrator presented here is to provide a single and efficient access to three services: qualification/calibration/validation of BGC data through a web portal. Tools deployed for the calibration focus on ocean BGC observations essentially measured by sensors deployed on BGC-Argo floats, gliders or sea mammals.

An operational sub-Regional Ocean Prediction Model for the Sicily Channel: system integration and evaluation

Authors

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Keywords

Sicily Channel, ocean forecasting system, observations, trajectory, model's skill

Abstract

The use of ocean forecast systems and oil spill transport models enables risk assessment since they provide information needed to analyse several events and scenarios and predict how an oil slick would evolve. Accuracy is crucial in calculating accurate oil trajectories and fate to deal with oil spill accidents.

In this study, the accuracy of an about 2 km resolution , nested, sub-regional ocean and oil spill forecasting system for the Sicily Channel (Central Mediterranean) was assessed by comparing system's prediction with satellite measurements of Sea Surface Temperature (SST), from autumn 2021 to summer 2022, and with a tracked drifter trajectory carried out in the Malta Channel from August to September 2021.

For the ocean forecast circulation and the transport of an oil slick, the Princeton Ocean Model (POM) and a Lagrangian particle trajectory model were utilised, respectively. They were both forced at the surface by the Skiron Weather Forecasting Model, while POM was one-way nested within the Copernicus Marine Service's Regional Forecasting System for the entire Mediterranean Sea at the lateral open boundaries. The results of the SST prediction system indicate that winter has a high skill score with a root-mean-square error at the third day of forecast of 0.46°C. In the other seasons it is over 0.70 °C. About the sea surface currents, the skill scores range from 0.51 to 0.49 at the third day of simulation, with a mean separation distance between 75 and 83 km.

This kind of validation of the system is helpful for supplying crucial details about the forecasting system's ability to handle troublesome issues such as hazard oil slick mitigation, as well as search and rescue, water property, defence, and transportation.

Chasing the Mediterranean Outflow Water along the Portuguese coast with Argo floats

Authors

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Abstract

The Argo Programme is an important component of the Global Ocean Observing System (GOOS). The core programme is based in drifting floats that make a 2000m profile of temperature and salinity, every 10 days. The ambition is to populate the global ocean with a spatially complete array of floats at a 3-degree spacing global grid. The Mediterranean Water (MW) outflow spreads in the north-eastern part of the Gulf of Cadiz (GoC) as a bottom-gravity current but at the western part of the gulf the flow stabilizes and continues flowing against the slope between the depths of 400 to 2000 m along the Atlantic coast of the Iberian Peninsula and reaching latitudes of up to 55° N. The MW is characterized by temperature and salinity maxima at the depths of the main cores (400 m, 800 m and 1200 m), low-nutrient and oxygen contents, and relatively high abundance of particles. Along its path, the current at times separates from the slope forming eddies (called meddies). The MW is an important salt and heat source to the North Atlantic Ocean, and its variability could have also important consequences for the thermohaline circulation of the Atlantic Ocean. However, since the 2000s the observation effort of the MW is very scarce.

Furthermore, the GoC is a region poorly sampled by Argo and surface floats. In this study, we will present the results of 4 Argo floats deployed by IPMA's research vessels along the Portuguese coast: two core Argo in the western coast at about the same latitude but in 2013 and 2016; and two with dissolved oxygen (DO) sensor in the GoC in 2020. The first two floats, although launched at the same latitude, had an opposite behaviour. One drifted poleward along the slope until reaching the north of France and keeping tracked in the Gulf of Biscay; and the other to the south, keeping close to the entrance of the GoC describing a cyclonic circulation. The floats deployed in the GoC exit and re-enter into the gulf and

exhibited a cyclonic circulation. In these, floats it is very clear the low DO signature of the MW. In view of these results, the presence of the MW at the levels of the core Argo floats parking depths should be taking into consideration if someone wants to monitor this region using Argo floats.

Shallow-coastal operations with Argo floats in the Mediterranean Sea

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Keywords

Shallow-coastal missions, Argo floats, Mediterranean Sea

Abstract

(continental shelf) as part of the European H2020 project Euro-Argo Research Infrastructure Sustainability and Enhancement (Euro-Argo RISE). Experiments were conducted in the Adriatic and Aegean Sea, and the Balearic Islands to demonstrate that Argo floats designed for open-ocean operations can be deployed in these shallow-coastal areas as part of a new extension of Argo. Park pressure and cycle time are critical parameters that must be accurately set and potentially adjusted during missions to achieve the best results. Park pressure was set at specific depths (typically quite deep and even on the seafloor) to limit platform drift from target areas. The cycle time was set between 1 and 5 days. The choice of cycle time is critical and is often a compromise to collect as many profiles as possible and greatly reduce the risk of drifting far away or becoming stranded.

Four Arvor I floats were deployed in the central and northern Adriatic Sea between 2019 and 2022. The Argo floats were parked very close to or on the seafloor using a virtual mooring configuration to try to keep them within a limited range from the deployment sites. Results showed that displacements from deployment sites were severely limited thanks to the configurations chosen, and it was demonstrated that these platforms could be deployed in shallow and narrow sub-basins such as the Adriatic Sea.

In the northern part of the Aegean Sea, three Arvor I floats were deployed in 2021-2022. The floats were configured to drift at depths of 600 to 800 m to remain in the targeted area and sample at short intervals (less than 120 hours). Although the northern Aegean basin is not an ideal area for Argo float deployments due to its rapidly changing bathymetry (shallow plateaus, deep trenches) and complicated coastline, missions have been successful to date. An Arvor I float was deployed off the coast of Mallorca island in 2020. After testing several mission parameters, a virtual mooring configuration and cycles of 48-120 hours proved to be the optimal sampling strategy, which allowed limiting the float's time in the surface layer and keeping it in shallow waters.

However, the influence of the Balearic Current made it difficult to keep the float near the deployment site. Another Spanish float with the same configuration and that drifted in the same area confirmed the success of the missions.

The investigation of the quality of float profiles acquired in shallow coastal waters is complicated due to the complexity of the different areas and the high variability of the near-surface layers. For this reason the delayed-mode procedures proposed by the Argo community cannot always be used. Several qualitative analyses have been developed to try to obtain a reliable quality control. A robust reference dataset is required to obtain useful statistics.

EDITO-Model Lab: towards the next generation of ocean numerical models

Authors

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Keywords

Digital twin Ocean, Ocean modelling, Ocean forecasting, Marine and ocean management, Ocean and climate change

Abstract

The European Commission launched the European Digital Twin of the Ocean (EDITO) at the One Ocean Summit in Brest, France, in February 2022. The EU will build the infrastructure backbone of EDITO through two projects: EDITO-Model Lab and EDITO-Infra. It will further construct and evolve a thriving digital ecosystem through other relevant, complementary actions, aiming for an operational Digital Twin of the Ocean by 2024.

EDITO-Model Lab will prepare the next generation of ocean models, complementary to Copernicus Marine Service to be integrated into the EU public infrastructure of the European Digital Twin Ocean that will ensure access to required input and validation data (from EMODnet, EuroGOOS, ECMWF, Copernicus Services and Sentinels satellite observations) and to high-performance and distributed computing facilities (from EuroHPC for HPC and other cloud computing resources) and that will be consolidated under developments of Destination Earth (DestinE). The objective is to make ocean knowledge available to citizens, entrepreneurs, policymakers, decision-makers and scientific experts alike, thus enabling them to become partners in knowledge generation, explore desirable futures and develop ocean management scenarios (and assemble their own twins), with the overarching goal of ensuring a safe, healthy and productive ocean. EDITO-Model Lab will deliver a Virtual Ocean Model Lab (VOML) including **(1)** a core model suite including global high-resolution models and coastal configurations, **(2)** downstream user toolkits and (3) a developer's toolkit for a sustainable ocean. The VOML will be an interactive and co-development environment to operate models. EDITO core model suite will be based on modelling and simulation software, artificial intelligence (AI) algorithms and specialised tools to form a new service capacity for accessing, manipulating, analysing and understanding marine information. Intermediate and downstream stakeholders will find digital tools, data and information for 'focus applications' (FA) that refer to the Mission Ocean Lighthouses (MOLs) and the sustainable Blue economy, including 'what-if scenarios' to find solutions to natural and man-induced hazards. EDITO-Model Lab will be delivered end of 2025 by a consortium of 14 partners covering ocean knowledge, modelling and technological expertise.

https://edito-modellab.eu/

The EuroGOOS Fixed Platforms Task Team

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Keywords

Eulerian, research infrastructure, observing technology, EOVs, EOOS

Abstract

The EuroGOOS Fixed Platforms Task Team (FP TT) was established in 2020 and unites at present 24 institutes from 15 countries in Europe. Fixed platforms are defined as infrastructure supporting observations with a fixed position (i.e. Eulerian) from sea surface, along with water column to seabed. The FP TT includes wave and met-ocean buoys, moorings, seafloor observatories and offshore facilities, and represents a large number of European fixed platforms in the coastal and open sea. The fixed platform observations include Essential Ocean Variables (EOVs).

The objectives of the FP TT are manifold. First and foremost, the FP TT aims at developing a reference network of Europe's fixed platform operators in which information and best practices are shared on technology, operations and maintenance, data processing chains and network integration. The FP TT also aims to contribute to the further development of the European Ocean Observing System (EOOS). The Task Team contributes to the identification of gaps, both in geographical coverage and observed variables (e.g., biogeochemical and biological measurements). This is especially as, through its members, connections are ensured with other relevant programs and projects at global and European levels with complementary and overlapping scopes. By fostering cooperation with Research Vessel operators, Marine Research Infrastructures and other relevant coordination initiatives with large and wellequipped facilities, the deployment, recovery and maintenance efforts can be optimized. A mapping of existing fixed platforms represented by the FP TT has been performed with a long-term goal to maintain an up-to-date inventory. A series of webinars on selected topics and common issues is organized in order to share knowledge, best practices and expertise among the wider community.

This contribution presents an overview of the FP TT organization, members, objectives and plans for future activity.

Future Challenges of Operational Oceanography in the Northern Baltic Sea - High-Resolution Hydrodynamic Modelling for Finnish Coastal Areas

Authors

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Abstract

The coastal areas of northern Baltic Sea are unique, including the complex archipelagos and shallow waters. High-resolution data and modelling tools are required to accurately predict oceanographic conditions there. Users expect high quality products, including accurate environmental data, reanalyses, hindcasts, and forecasts of phenomena critical for industries such as aquaculture and renewable energy. Reliable environmental information is essential for the safety of coastal communities and infrastructure. Finnish Meteorological Institute (FMI) operates an oceanographic forecasting system and several hydrodynamic modelling configurations to respond to these needs.

Scientific and technological advances have enabled the development of increasingly sophisticated models and new techniques. High-resolution modelling configurations can provide more accurate and detailed forecasts for the area. Increasingly, the use of machine learning and artificial intelligence techniques can help to customize forecasts to user needs. The integration of real-time data from autonomous oceanographic instruments, such as gliders and buoys, can also improve forecasts.

FMI has developed high-resolution hydrodynamic modelling configurations for focus areas near the Finnish coast. Modelling configurations based on the NEMO model (Nucleus for European Modelling of the Ocean) exist for the Gulf of Finland and for the Archipelago Sea-Åland Sea area. These configurations use approximately 500 m horizontal and up to 1 m vertical resolution, which enable them to resolve dynamics previously unresolved by coarser configurations. For example, currents and transports between Baltic Sea Proper and Gulf of Bothnia can be more accurately represented when the model is able to more faithfully reproduce bathymetric features of the area.

In this work, some results from these models are shown, along with examples of currently ongoing development activities aiming to further improve FMI's hydrodynamic ocean modelling system. The future of operational oceanography lies in the continued development and integration of advanced technologies and new scientific innovations. By providing accurate and high-resolution data and forecasts tailored to the specific needs of this region, operational oceanography can support the growth of industries and activities while promoting sustainable development.

SO-CHIC: Southern Ocean Carbon and Heat Impact on Climate

Authors

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Keywords

Antarctic Ocean, Climate models, Data management, Data visualization, Carbon and Heat exchange

Abstract

The Southern Ocean plays a critical role in regulating global climate by controlling the exchange of heat and carbon between the atmosphere and the ocean. However, a lack of understanding of the underlying processes has made it one of the major weaknesses in climate simulation and projection. To address this gap, the Southern Ocean - Carbon and Heat Impact on Climate (SO-CHIC) project was launched in 2019.

SO-CHIC addresses the exchange of heat and carbon between the atmosphere and the deep ocean by measuring their fluxes at the air-sea-ice interface and the estimation of their variability in time and space. It uses a combination of old and new observations, ranging from

in situ and satellite data to model output.To ensure that the collected data are accessible and effectively used, the project has adopted common standards and recommendations from European marine data integrators such as EMODnet, CMEMS, as well as international ones e.g. SOOS.

A robust back-end system has been implemented to manage the large amount of data collected by the project. Data from various partners are made available to SO-CHIC backend through a data pipeline to ensure consistency and accuracy before being stored in the SO-CHIC data repository. The backend consists of two containers, one public and one private, which can be accessed using a username and password. Both containers include GeoServer and ERDDAP, which provide tools for data visualization and analysis. A WebGis portal that uses graphical widgets to create plots and web APIs to download the data are also available. On top of such architecture a mapviewer offers FAIR access to data and measurements, providing users with a comprehensive overview of the project's progress and areas of focus. The user experience prioritizes accessibility and ease of use in its data visualization tools to maximize the usefulness of its data to a wide range of users.

OCEAN:ICE interactions and exchanges and their climate and Earth impacts

Authors

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Keywords

Antarctic Ocean, Ice-sheet-ocean, Climate change, Prediction models

Abstract

OCEAN:ICE (Ocean-Cryosphere Exchanges in ANtarctica: Impacts on Climate and the Earth System) is a new 4-year Horizon Europe project, funded by the European Commission and UKRI. The aim is to overcome the limits in our understanding of the influence of the Antarctic Ice Sheet and surrounding Southern Ocean on our global climate, deep water formation and ocean circulation. The project also aspires to reduce uncertainties in projections of freshwater fluxes and sea-level rise from future melting. Spatial and knowledge gaps in ocean observations around Antarctica are expected to be reduced. OCEAN:ICE will bring together the individual elements of this topic, which many past and present projects consider singularly, and consider the important role of feedbacks between them and the global climate.

The OCEAN:ICE interdisciplinary consortium is a collaborative effort that unites 17 centres from various regions within the EU and the UK. In addition to several partner nations and organisations, many of whom are members of SOOS, the consortium includes ice sheet and ocean modelling experts, *in situ* and remote sensing scientists with specialisation in polar-global ocean circulation and ice-ocean-atmosphere interactions, and policy experts and communicators.

The project uses an ambitious and innovative combination of remote sensing, ocean and ice sheet observations (AUV under 'warm' ice shelves, ice shelf under 'cold' ice shelves, quasi-stationary floats over continental shelves and under seasonal sea ice, mooring deployments), novel data processing techniques and numerical modelling. This will provide numerous new observations, including unexplored bottom water export pathways, improve our understanding of the fundamental ice-ocean interactions and our ability to model them, and consequently improve the understanding and prediction of these processes and their impacts.

The combination of these observations and historical datasets will support the controls on the export/import of the continental shelves to/from the open ocean and the circumpolar connections between regions of significant ocean-ice sheet interaction. This will support modelling efforts to constrain the ice sheet melt and to understand the impacts and feedbacks of such melt will have on the global climate system over the coming centuries. OCEAN:ICE will, therefore, provide policy-relevant advice for planning horizons from decades to centuries. OCEAN:ICE will interface with and directly contribute to European and international observing initiatives, centres and projects, as well as policy interface bodies to ensure efficient coordination, implementation and communication of the project objectives at the international climate assessment and policy level. The project will emphasise the importance of a circumpolar approach to assessing the climate-scale impact of the changing Southern Ocean and Antarctic ice sheet, and how the SOOS network can help support such observations and be of particular benefit to the development of coupled ice sheet-climate models.

Bridging communities for the ocean we want

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Keywords

Ocean literacy, community engagement, sustainable ocean

Abstract

The international ocean science community has made enormous efforts to prove and communicate the vital role the ocean plays on the planet – by regulating the Earth's climate and contributing to human wellbeing. Their efforts are finally bearing fruit: in the recent years the ocean has reached top positions in the international agenda, and its importance is more and more emphasised in the media.

At the heart of the Ocean Decade, it is now more than ever crucial to keep this momentum and generate, explain and disseminate targeted, science-based ocean information and knowledge. Why? To keep raising awareness, bridging communities and inspiring future generations.

Mercator Ocean International (MOi) is committed to supporting action paving the way towards the ocean we want. Through the Copernicus Marine Service, MOi provides reliable ocean data and information, and shares knowledge on the state of the ocean and its role on Earth's ecosystems. By working towards ocean literacy, MOi reaches policymakers and governments, the ocean science community and citizens at large. The Ocean State Report, an annual report providing the latest evidence on the state of the ocean, includes a summary adapted to the general public and decision-makers, allowing the dissemination of important ocean facts to a non-scientific public. Through training activities, we target not only ocean science students and researchers but also government bodies and more recently, journalists and science communicators. The Ocean Explainers provide the citizens at large with accessible information on operational oceanography and ocean phenomena and threats, through structured texts, tables and infographics. They also explain the existing policies scenario, as well as the international goals to protect the ocean. The

objective is to bridge the gap between these communities in terms of ocean knowledge and to help find solutions to the immense challenges facing the marine environment, while advocating for a sustainable ocean.The combination of these observations and historical datasets will support the controls on the export/import of the continental shelves to/from the open ocean and the circumpolar connections between regions of significant ocean-ice sheet interaction. This will support modelling efforts to constrain the ice sheet melt and to understand the impacts and feedbacks of such melt will have on the global climate system over the coming centuries. OCEAN:ICE will, therefore, provide policy-relevant advice for planning horizons from decades to centuries. OCEAN:ICE will interface with and directly contribute to European and international observing initiatives, centres and projects, as well as policy interface bodies to ensure efficient coordination, implementation and communication of the project objectives at the international climate assessment and policy level. The project will emphasise the importance of a circumpolar approach to assessing the climate-scale impact of the changing Southern Ocean and Antarctic ice sheet, and how the SOOS network can help support such observations and be of particular benefit to the development of coupled ice sheet-climate models.

Designing and delivering user-driven services through Copernicus Marine Service

Authors

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Keywords

User-driven, Service evolution, Co-design

Abstract

The Copernicus Marine Service is one of the six pillar services of the Copernicus program. It follows a user-driven process by taking into consideration user feedback to consistently improve its portfolio of products and services. Mercator Ocean International (here Moi) is entrusted by the European Union for implementing the Copernicus Marine Service over the 2021-2027 period. Consequently, MOi is maintaining a permanent dialogue with users to collect their requirements and support them in the use of the service. Public Core users, such as policy stakeholders and regional sea conventions, are the main target, but Copernicus Marine Service is open to all communities (Core and non-Core users). Thus, MOi manages and analyses feedback from all users on the current service and their requirements for the service evolution. The user feedback process is dynamic and constantly evolving to target specific audiences and expertise. Currently, user needs are being collected through diverse channels and sources, such as through the User Support team, providing direct interaction with users, but also through training and workshops, which are opened to the whole community, and questionnaires and surveys. To plan the service evolution, feedback from groups with specific expertise is needed to help to fill the gap in what is being offered and to improve the data quality. As an example of these target audiences, the Champion User Advisory Group (CUAG), formed by active users of Copernicus Marine Service, and the National Marine Stakeholders Group, formed by member states, were consolidated. These groups allow regular interactions and communication among expert users and policymakers, which have been proven to be resourceful sources of feedback that help towards better services and data products. With the added value of feasibility studies, these inputs are considered and evaluated internally and discussed with the producer's centers to be finally integrated into the service evolution, giving Copernicus Marine Service the lead in global ocean monitoring.

Joint venture to maintain a permanent glider observation line between Nazaré Submarine Canyon (W Portugal) and Canary Islands

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Keywords

Permanent glider line; capacity sharing, Jerico S3, iFado, real time observation

Abstract

Since 2019, Plataforma Oceánica de Canárias (PLOCAN) and Instituto Hidrográfico (IH) have been collaborating to maintain a sustainable glider observation line between the Nazaré Submarine Canyon (off the west coast of Portugal mainland) and Canary Islands. PLOCAN provides the glider (Seaglider) and the expertise about the technology, while IH provides ship time and infrastructure to test and deploy the glider, as well as retrieval in case of mission abortion. In addition, IH performs the calibration of the glider's CTD, which increases confidence in the collected data and reduces the costs of manufacturer calibration. In 2019 the PLOCAN Seaglider sailed 780 nm from Nazaré to Madeira Island, from April 2nd to June 12th, 2019, and in the following year, from February 7th to May 5th of 2020, the glider cruised 968nm. In the most recent mission, conducted in 2021, the glider only sailed 212nm, from August to September, due to technical problems on the glider. The mission had to be aborted and the glider needed to be rescued from 60nm off Portugal coast with the PT navy SAR ship. A new mission is planned to be conducted in May 2023, contributing both to the European projects iFado and JERICO S3 (in this case, profiting from Transnational Access funding). In all missions, the Seaglider was equipped with a Glider payload Seabird CTD sensor that measured temperature, conductivity and depth, WETlabs chlorophyll-a and turbidity sensors and Aanderaa dissolved oxygen. This joint venture has been very productive in leveraging the resources of the two institutions towards the increase of observations available along the eastern boundary layer of the North Atlantic (leading to new insight on the dominant processes prevailing in this area) and the exchange knowledge and services that strengthen ties between both institutions and countries.

JERICO-RI: A Decade of Delivering Access to Strengthen Operational Oceanography in Europe

Authors

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Abstract

The Joint European Research Infrastructure of Coastal Observatories (JERICO-RI) is a network of European coastal observatories providing operational service for the delivery of high quality environmental data and information products related to the marine environment. A key service of JERICO-RI is the Transnational Access (TA) programme which offers scientists and researchers free of charge access to high-quality coastal infrastructures that are not available in their home country. With over 17 countries participating in JERICO-RI, facilities offer access to research infrastructures such as gliders, fixed platforms, ferryboxes, cabled observatories, multi-platform facilities, and supporting facilities (ie. Calibration laboratories). This access enables capacity building through the formation of new collaborative relationships between users and the JERICO-RI partners; it also encourages knowledge transfer during users' on-site visits to the host facility. In addition, applications were encouraged for projects with new collaborative initiatives for RI-RI interactions and multi-facility use projects to strengthen the TA access programme.

Throughout the decade of TA provided by JERICO-RI, numerous projects contributing to improving or utilising operational observation systems have been facilitated. This paper will aim to explore the development of the TA access over the last decade of JERICO-RI, and how this has facilitated a diverse and inclusive user group in the oceanographic community. It will explore TA projects that have accessed JERICO-RI facilities in the capacity of operational oceanography to illustrate the benefits of the long-term TA programme providing access to a variety of coastal observation infrastructure.

Access has been provided since the initiation of JERICO-RI in January 2012 during the JERICO-FP7 project following through to the most recent JERICO-S3 access running until early 2024. Throughout three JERICO-RI projects (JERICO-FP7, JERICO-NEXT, JERICO-S3)

in over 10 years, there has been a significant increase in facilities participating in providing more access to a wider range of infrastructure which addresses the growing needs of the user base. The increase of access provided in JERICO-S3 encourages a more diverse user group within the observational oceanographic field of research. The TA coordination strategies that were implemented for incorporating increased equity and inclusivity will be highlighted.

In this paper, TA projects supported by JERICO-RI are explored as case studies for testing and validating operational observation systems as well as using observational infrastructure for ocean monitoring across the lifetime of JERICO-RI while utilising different JERICO-RI facilities. The case studies will include a Small and Medium-Sized Enterprise (SME) testing and validating a micro-AUV using a cabled observatory for reference of essential ocean variables, an SME testing an ocean monitoring sensor utilising multiple types of JERICO-RI facilities in different locations, and finally, access to a glider across all three JERICO-RI projects to maintain a consistent ocean monitoring line in the Algerian Basin. These TA projects demonstrate the diverse uses of the TA access provided by a wide array of JERICO-RI infrastructures and the strengthening of collaborative relationships between users and the JERICO-RI community.

Implementing machine learning method based on profile classification approach in the QC of Argo floats

Authors

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Keywords

Machine learning, delayed mode quality control, Argo data, Profile Characterization Model

Abstract

Argo is a collaborative international partnership that for more than 20 years continuously collects information from across the global oceans. Argo data continue to have a remarkable impact on ocean and climate services, predictions and research, and enabling ground-breaking developments in understanding ocean ecosystems, forecasting ocean productivity, and constraining the global carbon and energy budgets. Through the data system, Argo provides fundamental physical observations with broad societally valuable applications, built on the cost-efficient and robust technologies of autonomous profiling floats. Moreover, these observations are crucial in the development of policies and legislation to protect vulnerable areas of our coasts and to better recognise patterns and trends in forecasting future changes.

With a quarter of a century of lessons learnt and an established global network delivering high quality data, Argo as part of the wider GOOS has a key role in building many various ocean observing networks, extending their coverage in space and time, their depth range and accuracy, and enhancing them through the addition of physical and biogeochemical (BGC) oceanographic measurements.

To ensure the highest quality of core (pressure, temperature and salinity) data by Argo floats, one of the significant data management activities undertaken in BODC is performing a delayed mode quality control (DMQC) analysis. Some ocean regions like the Southern Ocean (SO) is characterised by very strong ocean dynamics with a very wide spectrum of

ocean regimes, with relatively limited temporal and spatial coverage of hydrographic data from climatologies used to verify the quality of Argo data. This makes the quality control often very challenging for DMQC operators and needs to be performed with very high care.

This study provides a new method and tool for improving the selection of the hydrographic data which can be added to the traditional well-defined DMQC analysis. The developed method uses the pre-classified core Argo float and climatological data belonging to similar water mass regimes using the Profile Characterization Model (PCM) working based on the machine learning method (Maze *et al.,* 2017). The output of the DMQC-PCM software is further used in the DMQC software analysis (Cabanes *et al.,* 2018).

The key achievement of this method tested for the SO and also in various global ocean seas shows an improvement in reduction of the noise from other water masses and a decrease of the error bars of suggested corrections by the software during the analysis. The DMQC-PCM allows the DMQC operators to improve their confidence in decision-making during performing the analysis.

The successful implementation of this new sophisticated method based on machine learning might also find their implementation in quality assessment of data from other parameters of various oceanographic platforms. This will lead to a more robust quality control analysis of oceanographic data in delayed mode and thereby higher-quality of science-ready data.

Improving BGC-Argo chlorophyll-a concentration data quality using innovative machine learning-based methods

Authors

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Keywords

BGC-Argo, chlorophyll-a concentration, machine learning

Abstract

Phytoplankton biomass, at the basis of the oceanic food web, is commonly estimated from the concentration of chlorophyll a (Chla). In vivo chlorophyll-a fluorescence (fluo), a proxy of Chla, is one of the most frequently measured biological properties in the ocean, especially since the integration of miniaturized fluorometers to autonomous platforms such as BioGeoChemical-Argo (BGC-Argo) profiling floats. In the past decades the number of fluo profiles has increased at least twofold compared to the historical number of measurements ever made from oceanographic vessels. However, the fluo/Chl ratio is extremely variable and depends on many factors such as the composition and physiological status of phytoplankton communities. Thus, the accurate calibration of fluo into Chla appears both challenging and critical for an optimal use of the valuable amount of fluo data that increases very rapidly.

In this context, an important effort is made by the Argo Data Management Team (ADMT) to calibrate and qualify fluo data measured from BGC-Argo floats in order to deliver Chla with the best possible accuracy. It has been shown that using radiometric data associated with fluo measurements is an effective way to improve fluo calibration (Xing *et al.,* 2011, Xing *et al.,* 2018). However, not all BGC-Argo floats are equipped with radiometers, making it impossible to calibrate the entire fleet homogeneously. Recently, new methods based on machine learning have made it possible to derive radiometric profiles, from merged satellite ocean color observations and hydrological data, for any BGC-Argo float, equipped

or not with a radiometer. These synthetic radiometric profiles can thus be coupled to the fluo profiles to consistently calibrate the whole BGC-Argo fleet. Similar machine learning methods, trained using BGC-Argo reference data, have been developed to estimate synthetic BGC-Argo Chla profiles. Such synthetic profiles can be compared to any measured Chla profile of reference obtained from High Performance Liquid Chromatography (HPLC) in order to evaluate the accuracy of the Chla data used for the training of the machine learning model. Thus, it is now possible to quantify the improvement of the calibration method by training a model using the newly calibrated data for training and then confront it with our HPLC database of reference. Using this new workflow, we have shown that the new suggested method of global calibration based on synthetic radiometric profiles as explained above decreases the BGC-Argo Chla error of more than 50% in the Southern Ocean.

To conclude, we would like here to present how machine learning opens new avenues for both the improvement of BGC-Argo Chla data quality and a quantitative improvement assessment

Oxygen trend and variability from a biogeochemical reanalysis of the Mediterranean Sea

Authors

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Keywords

Oxygen, Reanalysis, Mediterranean Sea, Trend, Monitoring

Abstract

Dissolved oxygen is one of the indicators of ocean health and monitoring its trend and variability is of crucial importance for life on Earth. The Copernicus Marine Service biogeochemical reanalysis produced by the Mediterranean Sea Monitoring and Forecasting Centre provides a valuable overview of oxygen variability in the Mediterranean Sea from 1999 till present, at a relatively high horizontal resolution (1/24°) and with daily output (monthly for interim period). The reanalysis, built on a coupled hydrodynamic-biogeochemical modeling system, includes data assimilation of ocean colour and shows good performances in reproducing the dissolved oxygen dynamics, especially in the epipelagic layers. Thus, it can constitute a benchmark for the computation of climatologies to be used as a reference for climate projections, operational forecasts and, in perspective, a Digital Twin of the Mediterranean Sea.

So far, the reanalysis allowed us to: **(i)** evaluate possible multi-decadal trends in the marine oxygen content; **(ii)** detect signals of oxygen variations at temporal scales ranging from inter-annual to subweekly in areas particularly sensitive to meteo-marine drivers; **(iii)** characterise different oxygen phenomenologies depending on local physical and biogeochemical processes. In fact, dissolved oxygen is affected by air–sea interactions, horizontal and vertical transport, mixing and stratification of the water column, and production and consumption by marine organisms. As a result, in the Mediterranean Sea

oxygen dynamics include: **(i)** a summer subsurface oxygen maximum (SOM) at around 50 m depth; **(ii)** an oxygen minimum layer (OML) between 300 and 1000 m shallowing westwards; **(iii)** winter deep maxima in the areas characterized by deep water formation (e.g., Gulf of Lion, southern Adriatic Sea, Cretan Sea).

On the long-term scale, the reanalysis shows a small but significant deoxygenation trend at surface in most of the basin. The estimated value of the trend is in the range -0.1 ÷ -0.05 $mmolO_2\ m^{-3}\ y^{-1}$, which is consistent with the oxygen solubility decrease due to the observed increase in sea surface temperature in the Mediterranean Sea No clear signal of decreasing oxygen is simulated in the subsurface layers. In fact, the summer SOM shows a mesoscale spatial variability that depends on summer biological production and vertical motions and that is associated with concentration and depth in the range 230 ÷ 250 $mmolO_2\ m^{-3}$ and 30 ÷ 100 m, respectively, but with negligible inter-annual variability and trends. Moreover, a study focusing on a winter deep convection area (southern Adriatic Sea) highlighted how the oxygen long-term variability is affected by shorter-term signals. For instance, lower oxygen concentrations along the water column were detected in the area after 2019 and associated with modifications in water mass formation and transport. Possible consequences for marine organisms and the ventilation of the Ionian-Adriatic area will be carefully monitored in the future thanks to the interim production, which continuously updates the reanalysis time series. Furthermore, for this specific site, we proposed a bias correction methodology taking advantage of BGC-Argo floats availability.

Decadal variability of air quality over the Tricity agglomeration based on ARMAG data

Authors

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Keywords

Air quality, coastal city, anthropogenic emission

Abstract

ARMAG Foundation activity focuses on Tricity Agglomeration. Its activity contributes to environmental monitoring and air quality supervision. Furthermore, it lends support to observing anthropogenic impact on environmental pollution in city agglomerations, as well as the beneficial influence of the sea on the coastal area.

This work examines ARMAG Foundation results of selected pollutants during the chosen decade (2011-2021) of three Polish coastal cities: Gdańsk, Gdynia and Sopot. This analysis focuses on certain air pollutants variability in terms of ten years of measurements along with establishing a trend of air pollution in coastal agglomeration. The examined period of ten years was chosen to establish long-term trend correctly. Ten years of data were obtained from ARMAG from five different stations, considering two profiles (coastal stations and urban stations). Received data contained daily and hourly measurements of air pollutants: PM10, PM2.5, SO_2, NO, NO_2, NO_x, CO, O_3 along with meteorological data (temperature, wind velocity and direction, humidity).

On the basis of data sourced from ARMAG, a series of statistical analyses were conducted to establish decadal, annual, and seasonal trends including specific episodes of higher concentration of pollutants measured. Based on processes of annual averages on examined stations, a long-term trend for different pollutants was established. Similarly analyzed was seasonal data, with attention paid to the heating season, when the emissions from domestic heating increase. The meteorological situation, which directly affects the values of these parameters by purifying state of the atmosphere, was also examined.

Another crucial factor was the amount of year, diurnal and hour exceedances considering European Union Directives connected with WHO Recommendations and its variability. Establishing a long-term trend is important to determine if air quality is changing and if it is improving as a consequence of anti-emission activities, direct influence of the sea or if it is the opposite on account anthropogenic emissions. This research also focused attention on short episodes of massively increased concentrations of main air pollutants measured. These episodes were submitted to detailed analyses towards establishing human activity pollution emission to the atmosphere and its contribution to deterioration of air and environmental quality. A number of short-term exceedances were considered.

Linking science to society through case studies showing benefits of the ocean observing and forecasting

Authors

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Keywords

Earth observation value chain, societal benefits, marine environmental management, coastal

Abstract

The poster will present a series of case studies on how the Earth Observation (EO) value chain is helping to find solutions for ocean and coastal challenges. From satellite and *in situ* observation, to monitoring and forecasting services, to data access and cloud services, to marine and coastal derived applications and services, the case studies will highlight Europe's contribution along the EO value chain to support thematic areas with significant socioeconomic and environmental impacts for coastal communities. These include EO for monitoring and prediction of **(i)** marine debris (trajectories, abundance, distribution) **(ii)** Arctic sea ice extent **(iii)** Sargassum inundation events **(iv)** eutrophication (harmful algae blooms, ecosystem degradation) and to support **(v)** sustainable fisheries management (detection of IUU, ensure safety at sea, monitor fish populations).

The use cases presented in this poster will set out to illustrate the main problems in the abovementioned topics and illustrate the important role and use of ocean and coastal observations for more effective assessments and decision-making to prevent or reduce societal and environmental impacts (e.g. for early-warning systems, mitigation and adaptation strategies, biodiversity restoration actions, etc.). Concrete examples will be provided European-supported projects and services using EO to address each of the topics. Lastly, the poster will present cross-cutting gaps in ocean and coastal observations, monitoring and forecasting, and data access.

From policy makers, national and local authorities, to blue economy actors and maritime security, to coastal communities, different end users will be able to see and understand the direct benefits of the Earth observation value chain and the need for ocean and coastal observing and forecasting.

Croatian Dissemination of Adriatic Sea Marine Met-ocean Data Buoy Observations to Ships via AIS messages

Authors

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Keywords

Adriatic, data buoy network, AIS AtoN, safe maritime navigation

Abstract

The poster will present a series of case studies on how the Earth Observation (EO) value Automatic Identification System (AIS) is an autonomous broadcast system, operating in the VHF maritime mobile band. It exchanges information such as vessel identification, position, speed, forecast etc. between fixed and mobile stations.

By placing 5 met-ocean data buoys at Adriatic open sea , Croatian Meteorological and Hydrological service (DHMZ) contributed to the development of information exchange for optimal/efficient/effective and safe maritime navigation in the Adriatic. DHMZ met-ocean data buoys are broadcasting meteorological data in real-time via the AIS system every 10 minutes.

The use of AIS within marine aids to navigation services is broadcasting of the aids to navigation (AtoN) report message (Message 21) and other AIS messages, in our line of work is Message 8 (weather conditions, wind speed and direction, sea waves, sea temperature, currents, etc.).

Croatian national maritime waterways and radio service company Plovput cooperates with DHMZ on AIS AtoN message quality procedures. AIS messages are collecting via AIS base stations at Adriatic coast operated by Plovput. Plovput ships are also one of the many AIS AtoN users.

The exchange of information between all systems is necessary for cooperation and improvement of each segment in the monitoring of maritime traffic in Adriatic sea. monitoring and forecasting, and data access.

Argo floats as part of monitoring the state of the Baltic Sea

Authors

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Keywords

Argo floats, Baltic Sea, monitoring

Abstract

The Argo floats have been used in the Baltic Sea since 2012. The first deployment took place in the Bothnian Sea and since then the operations have expanded to include the Gotland deep, Bornholm basin, Gdansk Basin, Bothnian Bay and northern Baltic proper. Although the Argo missions do not cover all the Baltic Sea basins, the increased number of temperature and salinity profiles as well as wider temporal coverage of measurements have significantly increased the possibilities to monitor changes in the state of the Baltic Sea. In addition, an increasing number of floats also measure biogeochemical parameters.

Argo floats have become a viable addition to the Baltic Sea measurement and monitoring activities. The experiences and best practices to operate Argo floats in marginal seas and seasonally ice-covered areas compiled during the Euro-Argo RISE project (2019-2022) further enhance the availability of Argo data in the Baltic Sea. Measurements throughout the year are now possible in the seasonally ice-covered northern Baltic Sea. Also, methods to perform delayed mode quality control for the Argo data in the shallow Baltic Sea were developed and are now being put to practice by the Baltic Argo community.

We will present the advances made in the use of Argo floats in the Baltic Sea. Use cases of the Argo float data will also be given and the status and future possibilities for utilizing Argo floats in the Baltic Sea for monitoring will be discussed.

Knowledge Transfer for capacity building in Operational Oceanography – requirements and implementation on national and basin scales

Authors

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Keywords

Operational Oceanography, Capacity Building, Ocean Basin

Abstract

Operational Oceanography is a new and rapidly developing discipline that builds on existing oceanographic skills in monitoring and modelling to provide nowcasts, forecasts or hindcasts of the ocean state (physical, biological and chemical). Currently there is a global need for capacity building and training related to Operational Oceanography, to address the need for scientists with skillsets that map on to the broad range of ocean data sets, are able to handle big data and can develop the value chain of operational ocean monitoring and forecasting.

This presentation will examine the requirements and implementation of a new post-graduate module designed specifically for Operational Oceanography. This course grew out of discussions with international students and teachers during recent POGO/NF/AWI NoSoAT ship board training expeditions on the RV Polarstern, as a frequent comment was that there was a need for knowledge transfer related to operational oceanography skills and best practice at both the national and basin scale.

The new module is targeted at marine PhD students and MSc students in the Ocean, Atmosphere and Climate course at the University of Galway, which is run in connection with the SOLAS (Surface Ocean Lower Atmosphere Study) International Project Office. This course will provide students with a broad understanding of the different data types (EOVs and ECVs) routinely used in Operational Oceanography, how they are collected (platform, sensor etc), and importantly, the uncertainties (Metrology) in these measurements and how these may impact the modelled results and subsequent interpretation.

ARGO.PT: the Portuguese contribution to the Argo Programme

Authors

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2 IDL, Instituto Dom Luiz, Lisbon, Portugal
3 FCUL, Faculty of Sciences, University of Lisbon, Lisbon, Portugal
4 IPS, Polytechnic Institute of Setúbal, Setúbal, Portugal
5 ADENE, Agency for Energy, Lisbon, Portugal
6 CCMAR, Centre of Marine Sciences, University of Algarve, Faro, Portugal

Abstract

Under the contribution of Portugal for the Argo Programme (ARGO.PT), the Portuguese Institute for the Sea and the Atmosphere (IPMA, I.P.) has acquired six Argo floats funded by projects "Atlantic Observatory - Data and Monitoring Infrastructure" (EEA Grants Blue Growth programme) and "OBSERVA.PT - Observations on board national commercial ships to support the conservation of marine biodiversity in the Portuguese Seas" (Mar 2020 programme).

These floats will integrate the global ocean observation network, which is an important component of the global ocean observing system, and include four core Argo ARVOR-I floats equipped with CTD for Conductivity, Temperature and Pressure measurements; one core Argo ARVOR-DO-I float equipped with an additional sensor for Dissolved Oxygen (DO) measurements; and one full BGC Argo PROVOR CTS4 float equipped with six additional sensors (pH, DO, Nitrate, Chlorophyll a, Suspended Particulates and, Downwelling Irradiance).

We analysed the spatial and temporal coverage of measurements of water column parameters with Argo floats in the North-East Atlantic, in the area of interest to Portugal, since the beginning of the Argo global programme in 1998. The results obtained show that throughout the area of interest (with resolution of 1°lat x 1°long) there are temperature and salinity data, with a frequency of at least 10 cycles per cell. There is a higher concentration of cycles in the northeastern area of the study area and, occasionally, north and west of Madeira Island and southwest of Flores island in the Azores. There is less density in the Argo

data coverage in the western half of the study area, over the Mid-Atlantic Ridge and most of the area surrounding the Azores archipelago, and in the Gulf of Cadiz region (southern Mainland Portugal). The coverage map allowed to define the locations for deployment of the floats in order to collect information in undersampled areas in the national maritime territory.

The Argo floats will be deployed from IPMA's research vessel Mário Ruivo during the first half of 2023 between mainland Portugal and the Azores Archipelago during the Atlantic Observatory Summer School. In this scope, postgraduate students will use Argo data to study the structure and pattern of the Mediterranean Water outflow when propagating through the North Atlantic, influencing ocean circulation and climate, and in turn marine ecosystems.

Spatiotemporal variation of turbidity in the north Bay of Bengal water and the processes regulating turbidity

Authors

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Keywords

Turbidity, North Bay of Bengal, pH, Sea Surface Temperature, Suspended Matter

Abstract

Under the contribution of Portugal for the Argo Programme (ARGO.PT), the Portuguese INorthmost Bay of Bengal supports a large ecosystem by providing species with food resources and habitats. Climate change may affect largely this ecosystem, but very few studies have been done in regards to its impact on the near coastal water of the north Bay of Bengal, where huge amounts of nutrients come from riverine fresh water playing a crucial role in the food supporting to the ecosystem. Turbidity is an important factor limiting sunlight and, consequently, primary food production. For the first time, a long term trend analysis of turbidity for twenty-one years (2000 to 2020) is demonstrated in order to know about the trend of north bay coastal water opacity using ocean color level 4 data, and the processes modulating turbidite conditions over time due to climatic changes, are also observed in this study. Mostly eastern coast shows significant change over this time period, and near the coast of Chittagong from ~22°N to 23°N at the shallow water depth, turbidity is increasing at 0.12myr-1 while a bit south of the northmost coastal water from 21.25 °N to 18°N, turbidity is decreasing, with a maximum rate of 0.16myr-1 at 21°N, near the Marine Protected area Nijhum Dwip. Both sea surface temperature (SST) and suspended matter are increasing at the shallow depth of coastal water, as well as the pH decreasing trend combinedly making turbidity higher.

On the other hand, relatively deeper water along the northeast, coastal area, SST decreasing trend as well as pH increasing trend making turbidity low. Fresh water content in the mixed layer depth also indicates the precipitation impact on turbidity of north bay water.

Examining vertical structure of particulate organic carbon in the Lofoten Basin using optical sensors on BGC-Argo floats and gliders

Authors

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Keywords

Particulate organic carbon, biological carbon pump, Biogeochemical Argo and glider observations, marine optics

Abstract

The fate of carbon in the ocean is driven by several interconnected processes, including the biological carbon pump which describes the transfer of dissolved and particulate organic carbon from the surface ocean to the deep ocean. The development of quantitative understanding of the biological carbon pump and its potential for long-term sequestration of carbon requires continuous observations of the vertical distribution of particulate organic carbon concentration (POC). The Lofoten Basin Eddy (LBE) is a seemingly permanent eddy feature situated in the northern Norwegian Sea containing nutrient rich and relatively cool surface waters. The LBE is an important site for heat fluxes to the atmosphere of Atlantic Ocean water in the Norwegian Sea and can produce mixed layers as deep as 800 m in spring. As such, the LBE is a convenient location for various long-term observation systems including BGC-Argo floats and gliders, although little is known regarding the strength of the biological carbon pump in the LBE. Importantly, new methods now exist which can provide improved optical estimates of POC using simultaneous measurements of optical backscattering and chlorophyll-a fluorescence. As part of the NorArgo and NorGlider programs, several BGC-Argo floats and one glider equipped with necessary optical sensors will survey the Lofoten Basin providing a unique opportunity to examine the vertical structure of POC during the onset of increased surface production in late spring 2023. Notably, two NorArgo floats to be deployed in May 2023 will contain advanced optical instrumentation

including an underwater vision profiler instrument (UVP6-LP) to provide estimates of particle size distribution and an optical sediment trap to assess the sinking particle flux. In the current study we will present preliminary analysis of observations from these autonomous systems in spring and summer 2023, including advanced approaches for characterizing particle assemblages and merging of data products from various platforms to examine the vertical structure of POC in the Lofoten Basin.

The GROOM 2 data roadmap: Shaping the open science collaborative future of glider data operations

Authors

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Keywords

OceanGliders, Global Ocean Observing System (GOOS), Operational Oceanography, Co-design

Abstract

The Glider for Research and Operational Ocean Monitoring (GROOM) 2 project aims to scope a research infrastructure (RI) for Marine Autonomous Systems (MAS) in Europe.

With the vision:

"Be the European Research Infrastructure harnessing the advantages of Marine Autonomous Systems (MAS) to provide high-quality ocean observation data and services for the benefit of society, enabling scientific excellence and moving towards net-zero activities."

And the mission:

"This European Research Infrastructure integrates national infrastructures for Marine Autonomous Systems (MAS) to provide access to platforms and services to the broadest range of scientific and industrial users, as well as other ocean observing RIs. It maintains a unique centralized provision of cyber-infrastructure, data and knowledge for the optimized use of MAS to study climate and marine environments, and to support operational services and the blue economy."

Evolution of a stakeholder focused data system and infrastructure is a crucial element of a future MAS RI with evolution needed of the data systems, software and infrastructure to meet the needs of the growing number and diversity of platforms.

The GROOM 2 project has developed a roadmap to scope and shape the data ecosystem to be included in any potential MAS RI. The roadmap involved extensive stakeholder engagement including a dedicated online community workshops in the summer of 2022, followed by project level workshops to distil the results into a roadmap.

The roadmap outlined recommendations for next 1-2 years, 5 years and 10 years with key themes in the recommendations including; the move toward open source community governed software environments, the need to address key gaps in capability such as quality control, the need for tools and service to be readily adopted by new nodes as the MAS networks grow, and that training of the research community so ensure a sustainable future.

The roadmap also has broader implication for the wider Global Ocean Observing System (GOOS) with the need for interaction between networks on aspects such as common infrastructure (e.g. for data assembly centres to enable rapid addition of new nodes), and quality control where common sensor types are used across GOOS networks with the essential alignment of data quality to enable data across networks to be readily utilised.

The GROOM 2 data roadmap is currently being integrated into the wider GROOM 2 RI scoping. This paper aims to present the results of the data roadmap to the EuroGOOS community to solicit feedback on the results that will be incorporated into the GROOM roadmaps for the formation of a MAS RI in Europe.

EMODnet Physics: Setting Up and Operating the European River Data Operational Node

Authors

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Abstract

In the field of oceanographic research, interoperability practices and standards have become fundamental to the flourishing of a shared data environment, as a consequence of increasing data accessibility and promoting cooperation between institutions and individual researchers.

In this framework, EMODnet Physics has successfully designed, organised and managed operational services providing open access ocean physics data and data products based on common standards. EMODnet Physics, based on ERDDAP, GeoServer, GeoNetwork and a set of APIs, provides a single point of access to near real time and historical achieved data, harmonising integrated data from different diverse ocean observing "systems", "systems of systems", multi-scale, multi-platform/sensor observations (i.e., fixed stations, ARGO floats, drifting buoys, gliders, and ferry-boxes).

Although EMODnet Physics has already demonstrated significant advancements in the development of solutions for ocean analysis, accounting for river inputs is essential when dealing with coastal management and observations Rivers represent the natural element connecting land and ocean through the coastline. They impact both coastal and basin un-wide circulation and dynamics through net freshwater flux; additionally, they are responsible for biotic diversity and eutrophication, particularly in coastal waters.

EMODnet Physics is developing an operational open and FAIR product offering near real time outflow data at the nearest river mouth station.

EMODnet Ingestion: M2M Technology for Marine Data Integration

Authors

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Keywords

EMODnet, machine-to-machine, interoperability, standards

Abstract

In the field of oceanographic research, interoperability practices and standards have become Access to reliable and accurate information for a specific area of interest is critical, particularly in addressing threats to the marine ecosystem. However, data can be missing or be incomplete: this may be due to problems of monitoring coverage, network integration or simply because of low accessibility due to the high barriers to entry to data processing activity.

The European Marine Observation and Data network (EMODnet) is a long-term marine data initiative consisting of a fully operational platform making marine data, products and metadata freely available in standardised formats to public and private users.

EMODnet Ingestion is a fundamental part of the EMODnet infrastructure that helps public and private data holders release their data for safekeeping and distribution as open data. In particular, it seeks to identify and reach data holders (from public and private sectors) who possess marine datasets that are not yet connected to marine data management data centres, and who are not yet familiar with the marine community data management practices and standards. EMODnet Ingestion motivates and supports them to share their datasets for storage and subsequent free distribution and publication through EMODnet and to become partners in the EU data management infrastructures for data exchange.

The EMODnet Data Ingestion portal plays a role in the pathways towards the EMODnet data portal. Specifically, the services it provides to data holders include: (a) data submission, with integrated services such as the online submission form, user management service, tracking service, (b) discovery and access, operating on the ingested and completed data submissions, and (c) operational data integration.

In case of real time data, exchange is possible by the implementation of a series of interfaces including SWE SOS, DAB, ERDDAP, etc.

Here we present the available tools and standards to ease the integration process from the providers to the final presentation into the EMODnet central portal.

Uncrewed Surface Vehicles (USV) Network Initiative in support to EOOS

Authors

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Keywords

EOOS, USV, Ocean Observing, network

Abstract

The Ocean Observing System includes different observing networks, integrating their data output in data assimilation centres to feed assimilation and forecast systems. A wide range of platforms and systems shape the current global ocean observing infrastructure, including satellites, research vessels, floats, underwater gliders, fixed-point observatories, sea level stations, high frequency radar and autonomous surface vehicles. Currently the ocean observing system remain largely immature and is composed of a large and diverse set of actors, such as research institutes, governmental agencies and the private sector. However, *in situ* ocean observing capacity is still fragmented and broadly un-sustained as required to meet the societal challenges.

The European Ocean Observing System (EOOS) is a coordinating framework designed to align and integrate Europe's ocean observing capacity, promote a systematic and collaborative approach to collecting information on the state and variability of our seas, and underpin sustainable management of the marine environment and its resources. An overarching strategy across all measurement platforms is required to ensure that best use is made of limited resources in Member States and at European level. EOOS attempts to link the currently disparate components of the observing system in Europe and promote novel technology and infrastructure development, standardization, open access to data, and capacity building.

Within the framework of EOOS is the EU-funded EuroSea project, with the overall goal to consolidate an integrated and interdisciplinary ocean-observing-system to deliver essential information for the wellbeing, blue growth and sustainable management of the ocean, based on the implementation and coordination of the different observing networks above-

mentioned, being the Uncrewed Surface Vehicles (USV) technology one of the novelties in terms of network initiative attempting to engage existing and forthcoming actors from public and private sectors, to consolidate an international USV network under common Best Practices standard procedures in support to EOOS strategy.

A bathymetric digital twin to design the bathymetric product of tomorrow

Authors

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Keywords

Digital Twin; Bathymetric data; Quality analysis; Data fusion and management; S-102

Abstract

The French Hydrographic Service, Shom, provides hydrographic services, compliant with regulation 9 of chapter V of the SOLAS convention by collecting, compiling and disseminating up-to-date hydrographic information on nautical publications, hence ensuring safenavigation. Since 1720, Shom collects hydrographic information on the physical marine environment, particularly bathymetric measurements, allowing the elaboration of nautical products (including nautical charts).

Currently, Shom's bathymetric data are archived in a dedicated Bathymetric Database (SBDB), managed as a stack of overlapping or intersecting surveys. Data from these surveys are derived from different types of sensors. Therefore, data held in the SBDB is of varying quality as acquisition procedures have evolved over time. Presently, each cartographic operator generating nautical charts or digital terrain models must currently go through laborious process of selection of bathymetric information from the SBDB.

Following a recent effort to digitalizeall the bathymetric information collected by Shom through the last 300 years, the Téthys project aims at constituting the best current bathymetric knowledge as a bathymetric reference surfaceand a bathymetric digital twin, in which a selection of the best quality soundings is being done. Generating this surface, see figure 1,will then allow Shom to speed up the generation of nautical charting and bathymetric modelling process by capitalizing on the selection efforts, along with strengthening the management and the valorisation of the source information.

From this compiled, homogeneous and machine-readable data source, it becomes very simple to produce new bathymetric products useful for sea users.Thus, the article will detail

how to use this reference data source to produce the new S-102 bathymetric products (standards still under development) of the International Hydrographic Organisation and which will allow in the future a strong interoperability with the new digital cartographic products (S-1XX).

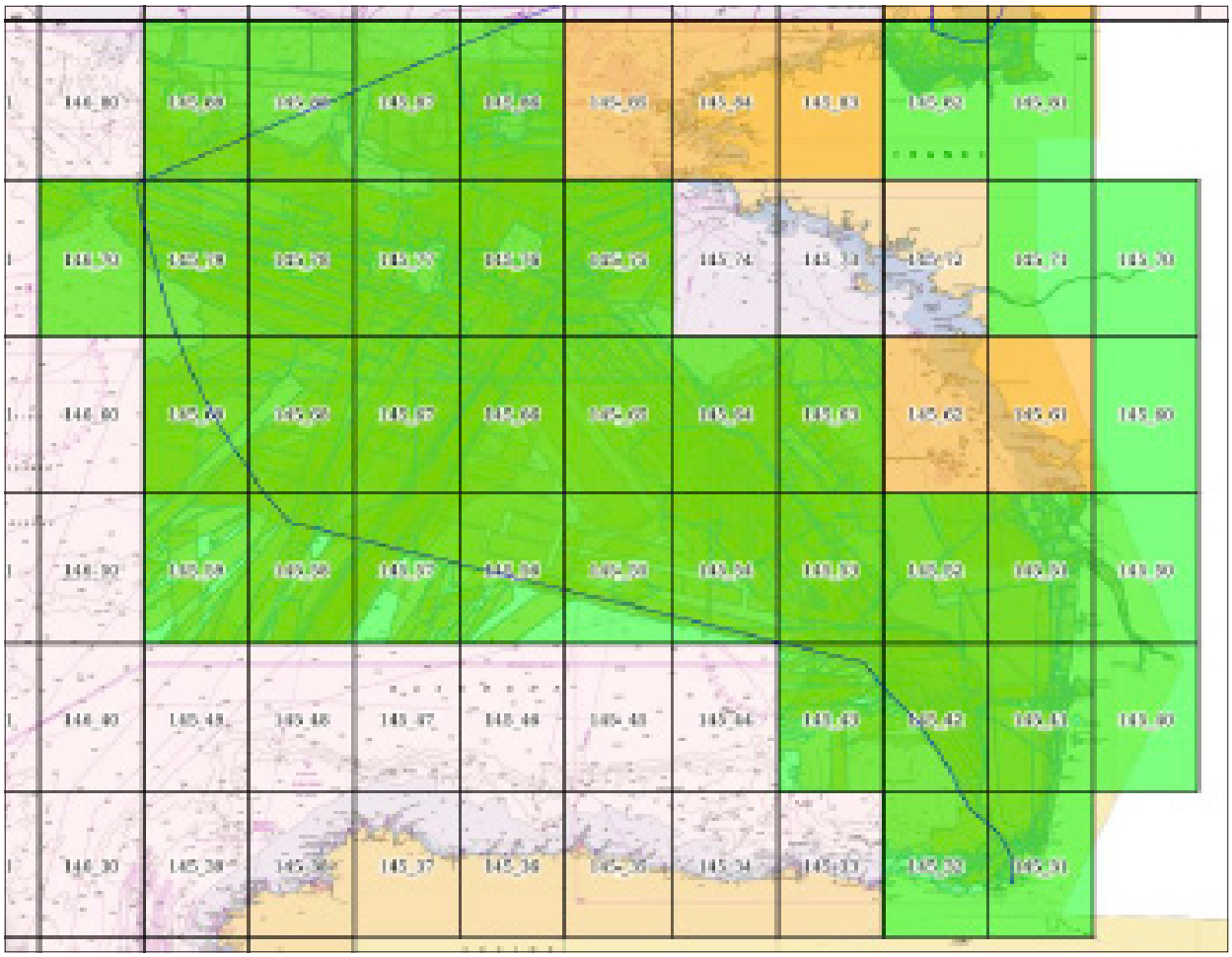

Figure 1 : The green tiles correspond to the digital bathymetric twin already completed off France

Technologies for ocean sensing (TechOceanS project)

Authors

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Keywords

In situ sensors, samplers, essential ocean variables

Abstract

The Ocean Observing System includes different observing networks, integrating their data To address oceanographic community requirements for autonomous observations, new types of technology must be developed. New *in situ* sensors and samplers will have to measure new parameters, reduce in size and power consumption, increase measurement traceability, improve stability, reduce mechanical engineering requirements and improve communication and automatic data transfer to data centres. TechOceanS project will fill the existing gaps by delivering sensors, samplers and improved image processing workflows capable of remotely measuring essential ocean variables (EOVs) as well as regulatory targets such as the Marine Strategy Framework Directive and OSPAR. To test the technology, a set of experiments and integration on a suit of platforms have been organised. The final tests will be carried out in Gran Canaria in spring 2024 where at least 7 new technologies developed in this project will be combined and integrated in 4 different autonomous vehicles. This unique opportunity will be used to provide a multidisciplinary practical training with students directly involved in the preparation (i.e. calibration/validation of sensors, preparation of the platforms) and management of deployments and will include at least 4 students and technicians from ODA recipient states.

In alignment with the objective of the UN Ocean Decade to secure "a transparent and accessible ocean", TechOceanS has joined a growing partnership of initiatives and has a repository of methodological documents and candidate best practices in both the Ocean Best Practices System (OBPS) and Better Biomolecular Ocean Protocols (BeBOP). These protocols are followed during sensor tests and are available for a community review in these platforms alongside sensor development templates developed in the project.

TechOceanS project has received funding from the Horizon 2020 research and innovation programme of the European Union under Grant Agreement No 101000858 (TechOceanS). This output reflects only the authors' view and the Research Executive Agency (REA) cannot be held responsible for any use that may be made of the information contained therein.

Achieving Accurate Return Period Estimation of Significant Wave Height Using FAIR-Compliant Data

Authors

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Keywords

FAIR principle, return period, block maxima, peak over threshold, point process approach

Abstract

This paper presents the calculation of the return period for the significant wave height using three different methods: Block Maxima (BM), Peak Over Threshold (POT) and Point Process (PP). The data used for the calculation is in accordance with the FAIR (Findable, Accessible, Interoperable and Reusable) principle, with an example provided for the case study of Marina di Massa, Italy, for an hourly dataset of 40 years (1979-2018). The BM method is based on evaluating the maximum waves over a given period, while the POT method focuses on the peak values of the waves. The POT method is a widely used technique which can be used to estimate the return period of extreme waves. This method can determine the threshold values of the wave heights that represent extreme events. With this method, one can choose between graphical approach or an automatic threshold estimation approach to determine the threshold values of the wave heights representing extreme events. This study further includes the main characteristics of the POT method, provides insight into the two threshold estimation methods, while the Point Process approach is based on the identification of extreme wave events. All three methods are compared in terms of accuracy, and goodness-of-fit score (i.e negative log-likehood, AIC and BIC) and the results are then used to calculate the return period of the significant wave height for 25, 50 and 100 years. This analysis shows that POT is the most accurate and reliable method for calculating the return period of the significant wave height. The BM and the PP approaches show marginally lower accuracies.

With the specific case study at Marina di Massa, Italy, for a 40-year period, this study provides a comprehensive overview of different methods to calculate the return period for the significant wave height. Nevertheless, the systematic approach adopted in this work makes it applicable to other geographic contexts throughout Europe.

Challenging forecasting habits - Noise audit with storm surge forecasters

Authors

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Keywords

Masterclass knowledge transfer, operational storm surge forecasting, Noise Audit

Abstract

Operational forecasters have often long years of experience. In the Netherlands a group of 15 experts is responsible for making the final forecast in a severe storm surge situation – often modifying the basic model forecast according to their knowledge and insight. As a new generation is entering within the next years this service we have been developing a masterclass system for knowledge transfer. As part of it we performed a NOISE AUDIT, as described in [1]. Noise and Bias in forecasting are two –undesirable- effects of human interpretation of a complex situation and given conditions. To identify the present noise and bias in our operational forecasting team we have set up an experiment and asked the experts to perform individual forecasts of identical storm surge situations. The aim was not to check who would make the most accurate forecast, but rather to analyze the results of the whole group in terms of noise and bias. The results of this noise audit will help us to identify faulty assumptions in the forecasting process and hopefully minimize noise and bias in our final forecasts.

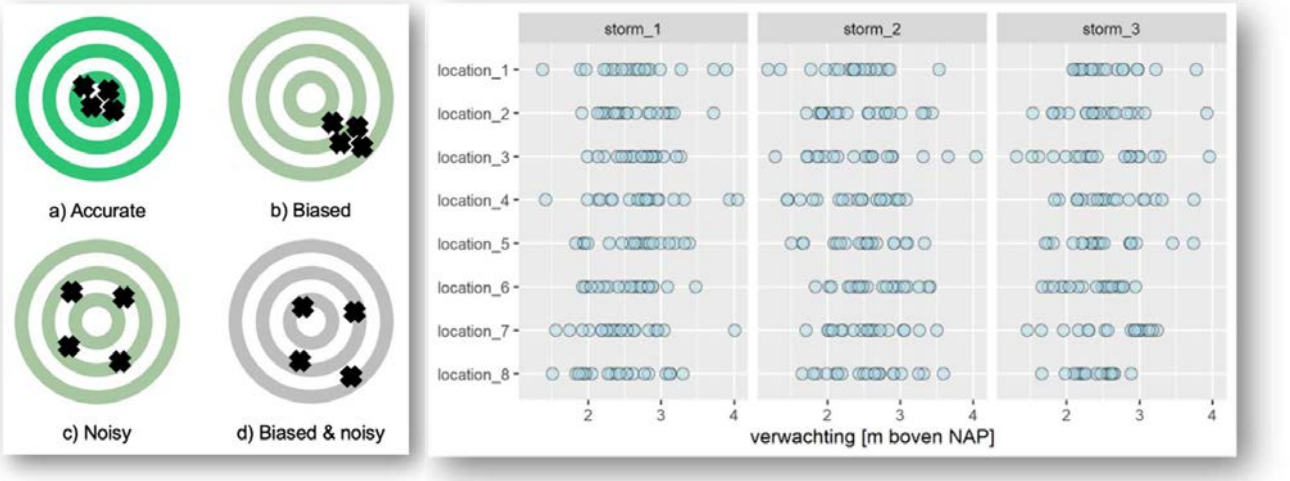

Figure 1 (left): visualization of the parameters Noise and Bias (from [1])
Figure 2: (right): example of an noise audit result, the poster will present the real outcome.

Lit: [1] Phillip Tetlock /Dan Gardner: Superforecasting: the art and science of prediction

The Copernicus Marine IBI-MFC operational model solutions for the European Northeast Atlantic: Status and Service evolution

Authors

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Keywords

*O*cean forecasting, reanalysis, ocean modelling, innovation in operational ocean products

Abstract

Operational ocean monitoring and forecasting services, combining observations and numerical models, advance oceanography and provide the baseline for practical applications of societal relevance. The Copernicus Marine IBI-MFC (Iberia-Biscay-Ireland Monitoring & Forecasting Centre) delivers daily ocean model forecasts, analyses and reanalyses of different physical and biogeochemical parameters for the Atlantic façade, supporting all kind of marine applications.

A continuous upgrade of the IBI-MFC service quality through innovation is planned and on-going. The IBI operational forecasts are being evolved, with recent advances related to upgrades of both their model capabilities (i.e. updates of circulation, wave and biogeochemical model set-ups; enhancement of the operational scenarios used to generate products, increasing the number of delivered IBI essential variables and datasets) and data assimilation systems (e.g. update of mean dynamic topography and new observational data sources, such as the high-resolution ODYSEA SST and CFOSAT wave spectra products, already assimilated by the IBI systems).

The IBI-MFC supports climate service applications, ensuring a multi-year data production based on ocean and wave reanalyses together with a non-assimilative biogeochemical

hindcast. Addressing climate stakeholders' requirements, these long IBI products (spanning the full altimetric era: 1993-present) are being evolved, increasing significantly their spatial resolution (one major goal is to bring the IBI reanalysis products resolution to that of the real-time forecasts, so that all IBI products are finally distributed in a common single service grid), and enhancing their operational scenario (such as including new interim datasets to get multi-year products' update closer to the present time).

In addition, Artificial Intelligence techniques are being explored and tested to improve forcing data (specially on the winds and ocean currents used in the regional IBI wave forecasting service in the context of Service Evolution Project). Product quality assessment is performed to provide users science-based consistent information, being processes used to qualify IBI model systems and to make required operational validation of IBI products (through the NARVAL Tool), continuously evolved.

The Copernicus Marine IBI-MFC service, and its service evolution represent a big-data challenge. Indeed, the scientific progresses here presented that support this service evolution are aligned with innovations in Operational Oceanography that pave the way towards digital twin approaches, and they are being achieved and thanks to a significant advance in the technics related to data science technologies, including an optimized use of HPC resources.

Presentation of the updated operational forecasting chain of MFC-Belgium

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Keywords

Operational forecasting infrastructure, hydrodynamic model set-up, Belgian part of the North Sea, river boundary conditions

Abstract

In answer to changing user demands, the Marine Forecasting Centre of Belgium (MFC) has updated its operational forecasting chain with an upgraded hydrodynamic software, an updated model set-up and a new operational infrastructure. Most of the changed user demands can be traced back to the installation of off shore structures such as wind mills, solar panes parks, aquaculture sites in the Belgium Part of the North Sea. These have an impact on the local hydrodynamics, but also on sediment transport, temperature and biogeochemical processes. The upgraded software has the potential to provide sediment and biogeochemical forecasts and monitor these processes. The proper simulation of those processes requires a higher spatio-temporal resolution than what MFC has currently available, so apart from a software upgrade, the model set-up was changed. Higher resolutions typically require higher computational demands which are partly absorbed by the semiimplicit solver of the upgraded software and partly by migrating pieces of the forecasting chain to the HPC system of the Belgium government called spacepole. This migration required the development of a new operational infrastructure which should also allow to meet the request of our main end user (marine coastal protection service of Belgium) for a 7 days forecasting cycle, updated four times a day.

This works gives an overview of the new model set-up of the MFC and the foreseen improvements for the coming years. A validation of the new model set-up and a comparison with the performance of the old model set-up is provided for the year 2021. The first item on the to do list for improvements was to investigate the river forcing at the Scheldt estuary. The results show that a river forcing with two tidal constituents outperformed a river forcing with monthly river discharge climatologies. Future investigations should reveal if modeled river discharges outperform the tidal constituent approach and if the tidal constituent approach holds up in case of extreme river water discharges.

Twenty Thousand Leagues Under the Seas

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Keywords

Engagement, board game, underwater soundscape, museum, marine science

Abstract

"20,000 Sounds Under the Sea" is an AR-enhanced card game part of an Italian national research project named "CULTURGAME". It aims to create several game-based solutions for the dissemination of science and cultural heritage. ETT Solutions and the Anton Dohrn Zoological Station, Naples, designed this game to convey the importance of the underwater soundscape in aquatic environmental ecology as well as raise awareness of the noise pollution problem, highlighting how anthropogenic sounds impact marine ecosystems. The players become research submarine crew members and are split into teams, each with their own sub. They will explore the ocean using cards from three decks (one for each depth level) and placing them on the table to form the game board. When a team discovers a "sound card", they analyse it using a mobile application with image recognition (Augmented Reality). First, they access a dashboard to filter the sound from surrounding noise. The players then need to recognise its source so that they can acquire it and continue with their mission. To win the game, a team must collect one sound per depth level and return to shore before their tank is empty. As with all Culturgame.it games, "20.000 Sounds Under the Sea" has followed a data-driven approach in its design and development. The alpha release has been tested by a team of experts and a group of high school students. The qualitative and quantitative playtesting results have been taken into account to refine the game. The beta version will be tested by dozens of players before being released at the end of 2023.

The structure of the game allows for an ever-growing set of sounds, as well as personalised missions and expansions by adding new marine settings.

The game was designed for use as an informal learning tool in the Darwin Dohrn Museum in Naples. A simplified version of the deck, together with introductory information on underwater seascapes, gives schools and families some engaging activities. The complete version of the game, however, has all the components of a commercial high-tech board game and maximises engagement.

Game-based solutions provide a playful approach to complex issues and are a powerful social inclusion tool. They can undeniably be used to reach new audiences and engage sections of the population that are not usually involved with such topics.

Next generation multiplatform Ocean observing technologies for research infrastructures (GEORGE Project)

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Keywords

In situ sensors, samplers;, ocean carbonate system

Abstract

Large improvements in oceanic observations are necessary to deliver a fit for purpose observing system capable of real time estimates of the uptake of carbon by all relevant parts of the ocean. This includes the deep ocean and coastal zone and will in turn support better decision making relevant to both climate (the scale and timing of mitigation and adaptation measures) and food production (the scale and location of aquaculture). The challenges include developing better technologies, and improving network organisation and standardisation. Advances will provide more consistent data streams with greater accessibility to support and improve the related science and assessment associated with the state and variability of the oceans.

The main aim of the GEORGE project is to develop and demonstrate a state-of-the-art biogeochemical, multi-platform observing system operated across ERICs that can carry out integrated biogeochemical observations for characterisation of the ocean carbon system. One of the principal aims of the project is to advance the technology readiness level of state-of-the-art sensors, enabling for the first time systematic autonomous, *in situ*, seawater CO2 system characterisation and determination of CO2 fluxes on moving and fixed platforms. Together with sensor manufacturers, GEORGE will optimise sensor technologies for measurements on platforms operated by ERICs and according to their operational requirements. Technology will be co-developed between industry and ERICs ensuring direct route to market and potential for scalability. The technologies will be validated according to a rigorous TRL progression engineering process and demonstrated at sea as an integrated multi-platform observing system during several field campaigns where ERICs are active.

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List of EuroGOOS
MEMBERS (October 2023)

Belgium
- Agency for Maritime and Coastal Services (MDK), Coastal Division
- Royal Belgian Institute of Natural Sciences (RBINS), OD NATURE

Croatia
- Croatian Meteorological and Hydrological Service (DHMZ)
- Croatian Institute of Oceanography and Fisheries (IZOR)

Cyprus
- The Cyprus Marine and Maritime Institute (CMMI)

Denmark
- Danish Meteorological Institute (DMI)
- Defence Centre for Operational Oceanography (FCOO)

Estonia
- Tallinn University of Technology (TalTech)

Finland
- Finnish Meteorological Institute (FMI)

France
- French Naval Hydrographic and Oceanographic Service (SHOM)
- French Research Institute for Exploitation of the Sea (Ifremer)
- Mercator Ocean International
- The French National Centre for Scientific Research (CNRS)

Germany
- Federal Maritime and Hydrographic Agency (BSH)
- Helmholtz-Zentrum Hereon

Greece
- Hellenic Centre for Marine Research (HCMR)

Ireland
- Marine Institute (MI)

Italy
- Euro-Mediterranean Center on Climate Change (CMCC)
- National Research Council of Italy (CNR)
- Italian National Agency for new technologies, energy and sustainable economic development (ENEA)
- National Institute of Geophysics and Volcanology (INGV)
- Italian National Institute for Environmental Protection and Research (ISPRA)
- National Institute of Oceanography and Experimental Geophysics (OGS)

Netherlands
- Deltares
- Royal Netherlands Meteorological Institute (KNMI)
- Rijkswaterstaat

Norway

- Norwegian Institute for Water Research (NIVA)
- Institute of Marine Research (IMR)
- Norwegian Meteorological Institute (MET Norway)
- Nansen Environmental and Remote Sensing Center (NERSC)

Poland

- Institute of Meteorology and Water Management (IMGW-PIB)
- Institute of Oceanology, Polish Academy of Sciences (IO PAN)

Portugal

- Hydrographic Institute
- Portuguese Institute for the Ocean and Atmosphere (IPMA)

Slovenia

- Slovenian Environment Agency
- National Institute of Biology (NIB)

Spain

- Balearic Islands Coastal Observing and Forecasting System (SOCIB)
- Oceanic Platform of the Canary Islands (PLOCAN)
- AZTI
- Spanish Institute of Oceanography (IEO)
- Puertos del Estado

Sweden

- Swedish Meteorological and Hydrological Institute (SMHI)

United Kingdom

- Centre for Environment, Fisheries and Aquaculture Science (Cefas)
- National Oceanography Centre (NOC)
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