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EuroSea/OceanPredict workshop - 2

1-day virtual event

"A vision for the Ocean information value-chain: systematically connecting up components from observations to user applications"

11 July 2023

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Executive summary

Keynote presentations provided insight into the current activities and progress of the development of the ocean information value chain. It has become clear that the community approach of connecting ocean information value chain components (*see figure 1*) into an integrated structure by improving communication and interaction, with a strong emphasis on ocean best practice, is the future for operational oceanography. The Eurosea project had already recognized this when it set up its work packages resembling some of the value chain components and encouraged interdisciplinary exchanges. It must also be emphasized that the initiation of the UN Decade for Ocean Science during the time of the EuroSea project strongly supports better collaboration and interaction with everyone engaged in ocean science.

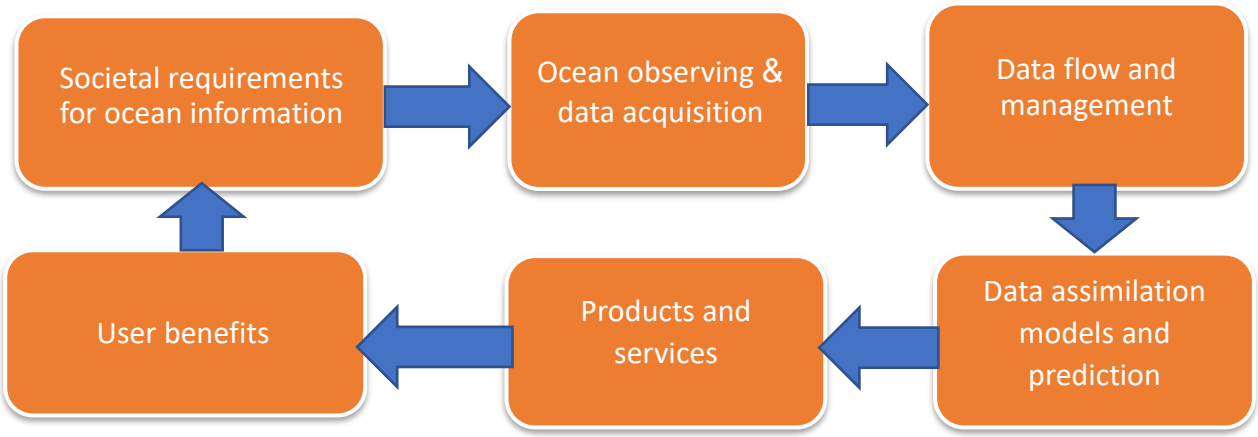


Fig 1: Ocean information value chain – basic schematic

The workshop ended with a panel discussion focusing on the present value chain status, gaps and issues and future developments. A few aspects are standing out. These included suggestions and recommendations for the:

- Improvement to the ocean observing system by
  - creating a sustained funding mechanism for ocean observations contributing to the sustained ocean observing system by observations of EOVs
  - increasing ecological and biological observations
  - setting up a rolling review of requirements for the improvement of the ocean observing system
- Improvement of operational prediction systems by
  - implementing digital twin set ups
  - defining an operational readiness level
  - setting up observing system experiments and system assessments operationally
- Improvement to ocean product user experience by
  - developing ways to deliver ocean product confidence
  - setting up feedback loops with users to learn of ocean product performance and requirements
- Setting up the ocean information value chain by
  - developing good relationships between value chain components
  - working interdisciplinary and reaching out to social science and economics

    - using the increasing visibility and relevance of the ocean to develop links with industry (e.g tap into private data to make a case for a data marketplace)
- Ocean best practice
    - setting up a Federated Network for the approval, distribution, application and community-based repository of ocean best practice

The workshop attendance was strong reaching almost 90 participants and attracted attendees from 25 countries (please compare Appendix 3).

1. Introduction

The 2nd EuroSea/OceanPredict followed on from the 1st workshop in June 2022 which highlighted the wealth of research efforts that was carried out in ocean observing, ocean modelling and predictions in various countries around the world, resulted in a list of recommendations related to the improvement of observing and modelling community interaction and communication, the need to improve outreach to users of ocean services and products, the requirement to widely adopt ocean best practice and the plan of combining all the aspects and components of operational oceanography into a comprehensive structure, the ocean information value chain.

Taking the recommendations from the first workshop into account, the 2nd workshop focused deeper on the ocean information value chain, its concept, organisation, and set-up. Several high-level experts in the field of ocean observations, ocean predictions, ocean best practice and ocean governance were invited to present their perspectives, and to answer questions and inform the community about the status and opportunities of the ocean information value chain. The one-day workshop provided presentations about

- the introduction to the ocean information value chain structure and components
- the contributions from EuroSea and UN Decade programmes
- the interoperability, collaborations and best practice within the value chain
- the utility and requirements of ocean service and products for users

The workshop was concluded by a panel discussion highlighting the most relevant aspect of the value chain focussing on its status, gaps and issues and future developments.

This report provides an overview of the invited presentations and a summary of the panel discussion.

2. Workshop sessions

2.1. Top Session – Ocean information value chain descriptions

The top session focused on answering the question of what the ocean information value-chain is, how the value chain components are linked together and how far the construction of the value chain has progressed. Speakers in the session included representatives from the OceanPrediction Decade Collaborative Center (OP-DCC), IOC/UNESCO and Environment and Climate Change Canada.

2.1.1. OceanPrediction Decade Collaborative Centre

Enrique Alvarez Fanjul (Mercator Ocean international) is the OceanPrediction Decade Collaborative Center (OP-DCC) Technical coordinator. His presentation ***"OceanPrediction-DCC on establishing a global operational oceanography architecture"*** focused on the current plans of the OceanPrediction Decade Collaborative Centre to describe the architecture of the ocean information value chain on a global scale. Currently, ocean prediction systems provide forecasts and services on a national level but are technically disconnected internationally. The aspiration of the OP-DCC together with ForeSea and other UN Decade actions is to transform this current silo set-up into a connected framework employing the concept of the digital twin, to develop an ocean prediction architecture that can deliver as one. This will include developing the right tools, standards, and best practices to support the expansion of the value-chain in a coordinated manner, inviting new contributors taking advantage of those building blocks. He described the roadmap and design plans for the new architecture, which is currently being developed by over 40 international experts.

In support of this effort, a survey was conducted to collect information from science experts as well as ocean product users, on how they perceived the current status of ocean observing and forecasting quality and availability. The survey showed that the scientists were less optimistic about solutions, quality, accessibility and timeliness of their ocean products than the users, specifically in coastal areas and for biogeochemistry and biological products. It showed that the current system delivering products to users is often just based on simple models, sometimes even without data assimilation, and often with intermediate users doing the forecast analysis.

To improve that system it was proposed that the OP-DCC together with ocean experts and the associated UN Decade programmes will work on a new set-up for ocean forecasting that will integrate systems and develop a fully interoperable environment, moving from an "Independent-Complex-Interoperable" system (type A), via as "Independent-Complex-Digital Twin" system (type B) to an "Fully Integrated-Complex-Digital Twin" (type C) – see presentations (link above) for details. This will include developing tools, standards, and best practices at each step of developing the A, B and C systems, and will also allow to set up the operational readiness level (ORL) to identify the system's maturity.

The OP-DCC is the key element for the ocean prediction we need today and builds on an active community of users, scientist and policymakers organising the regional teams, and involving all relevant UN Decade programmes and projects. The substantial benefit from this shared architecture would be a connected, and well-integrated community, that can provide better, faster and easier readable and useable products.

Q&A

Integration of digital twin in value chain: The integration of the digital twin concept in the OO architecture will be done in progressive steps and first requires the agreement on the tools, standards, and best practices.

Operational readiness level (ORL): The ORL does currently not include information on the quality of observations. It will require more discussions and expert input to resolve this question.

2.1.2. The Ocean Observing System in the value chain

Emma Heslop (UNESCO/IOC) is Programme Specialist for the Global Ocean Observing System (GOOS) and Deputy Head of the GOOS Project Office. Her presentation focused on the "***The role of IOC/GOOS on establishing an integrated and sustained ocean observing system and its link with the ocean information value-chain*****".** She highlighted the reach of GOOS in working with IOC, WMO and the international science council to establish and fund a coordinated structure with input from many nations and regions to deliver information, mostly ocean observations and forecasts for ocean health to weather, to climate and hazard warnings. The links along the value chain underpin the delivery of data to all of the application areas, which is described in the GOOS 2030 strategy. The data management, analysis and models through to applications along the value chain are key to building the integrated sustainable system that is anticipated.

EuroSea contributed to this effort by dedicating time to a paper on ocean integration, which was showing that ocean management will require effective collaboration at each step of the value chain, looking at science becoming more mission orientated towards goals and outcomes, connecting the diverse communities and transitions from research to an integrated and sustained system. Emma highlighted the opportunity to involve other disciplines like social science and economics to grow the community and to be better prepared to address societal impacts.

The work across the EuroSea "demonstrators" advanced the integration of value chain components, from observing through to delivering a service to end users. An important aspect was the challenge of gaining and maintaining the user interest, trust and engagement during this process. Although EuroSea could provide its experience on the public and private partnership (which was carried out in WP5, WP6 and WP7), there was still a lot of ground to be explored and work to be done on user engagement.

Integration with the private sector would be beneficial to ocean observing as well as users, in developing standards and identifying common goals. Emma also pointed out the need of encouraging investment throughout the UN Decade, also highlighting that in the GOOS Steering Committee are various areas in need of clear and transparent data flow.

Emma also highlighted the Observing Co-Design UN Decade programme which was further described by David Legler (compare 2.2.3).

Q&A

Recommendation on user exchange: The EuroSea demonstrator work packages helped generate new connections with users as well as new data and forecasts capabilities but was not well geared towards supporting successful product development. It would have been useful to engage with users on product development before the project and apply for funds to then concentrate of the creation of the product.

2.1.3. Ocean prediction in the value chain

Fraser Davidson (ECCC/DFO) is a research manager at Environment and Climate Change Canada and co-chair of OceanPredict. His presentation "***OceanPredict's perspective on the ocean information value chain***" provided an overview of the ocean prediction component in the value chain. He introduced the

work of OceanPredict as a long-term international network for Ocean Prediction research and development which strives to continuously improve operational oceanography for sustainable economic and societal benefit. OceanPredict has set up a new operational system working group to contribute to the resolution of common issues in ocean prediction and to work towards best practice, with all associated operational systems providing a baseline for tools and standards. As the initiator of the ForeSea programme, OceanPredict is working closely with the OP-DCC and other UN Decade programmes. The OP strategy includes becoming a component of the full operational oceanography value chain to better deliver societal benefits from ocean predictions.

There are more aspects to delivering valuable ocean products than observing and forecasting. Quality control, verification, accuracy assessments, intercomparison, etc. are relevant and needed procedures to gaining user confidence. These processes represent different value chains in themselves, making the ocean information value chain "A value chain of value chains". It will be challenging to map out how each component is influencing the other and how a useful architecture should look like.

Another important aspect already raised by the previous speaker, is the importance to providing products that are reliable and trusted. It needs good relationships with users to establish a value chain that produces useful outcomes, including iterative processed to increase ocean product applications and feedback loops to report back on the quality and utility of the products. There should also be a mutual exchange process set up between all value chain components and groups to improve its overall performance as the value chain grows.

Q&A

Value chain stakeholders: There should be stakeholder input of requirements at the beginning of the value chain, and there should be feedback loops from the end user point back to the stakeholder point to assess whether the requirements have been met. This should be followed up by an improvement process throughout the value chain. Those stakeholders could represent society, social sciences, economics, etc. to evaluate the value chain benefit and help build trust in scientific output.

2.2. Session 1 – UN Decade activities and interaction with EuroSea

2.2.1. EuroSea and EOOS progress

Toste Tanhua (GEOMAR) is Senior Scientist in the Research Division 2: Marine Biogeochemistry at GEOMAR Helmholtz Centre for Ocean Research Kiel, and the lead PI of EuroSea. He presented the talk "***Highlighting the effort of EuroSea in designing and getting underway a European Ocean Observing System (EOOS)***". Toste briefly introduced the EuroSea project which conclusion will be celebrated at the final conference in Paris in September 2023. He iterated that EuroSea has been a truly interdisciplinary project focused on research and innovation with a new user focus and was dedicated to improving and integrating the European Ocean Observing and Forecasting System. EuroSea used a value chain structure to define the project set-up, showing the interconnection of its components, represented in the work packages (WPs), showing the necessity of system integration to serve societal benefit. The main goal of EuroSea was the improvement of the European Ocean Observing System as a regional system and to align it with the global observing effort, by uniting the ocean observing community, developing collaboratively the observing system design, and to work towards a multi-platform, multi-network and multi-thematic EOOS to meet the specific needs of users. To achieve this, engagement with European service and product providers was vital, specifically regarding coastal resilience and operational services, ocean health and links to end users, and climate. EuroSea will help strengthen European leadership in ocean observing, provide foresight at an international level and in particular strengthen the EOOS in contributing to implementation of the global Ocean Observing System strategy.

Q&A

EOOS continuation: It is hoped that other EU funded project will contribute to continue building the European structure for ocean observing, increasing and improving communication and coordination within Europe and creating synergies around the world.
Discussion with the European Commission are ongoing to support long term strategies, but to achieve this we need funding for a permanent entity (office).

2.2.2. The SynObs project

Elisabeth Remy (MOi) is Senior Scientist in the Operational Oceanography department at Mercator Ocean international and is co-chair of the OS-Eval TT and SynObs, a UN Decade endorsed science project. She presented the talk "***SynObs: A UN Decade project on Synergistic Observing Network for Ocean Prediction***". SynObs is a project initiated under ForeSea, but with strong connections to the Ocean Observing Co-Design programme (endorsed under the UN Decade). The activity of this project includes running multi-system observing system experiments (OSEs), analysing results, providing reports to highlight observing system gaps and requirements, and supporting DA scheme developments. The project brings together partners and contributors from around the world, including UN Decade programmes, observing system agencies, EU projects as well as GOOS and potentially GSOP/CLIVAR, and presents an important milestone in the development of the ocean information value chain.

Q&A – see next presentation

2.2.3. The Ocean Observing Co-Design programme

David Legler (NOAA) is the director of the Ocean Observing and Monitoring Division at the NOAA Climate Program Office and co-lead of the UN Decade endorsed and GOOS supported programme Ocean Observing

Co-Design. He presented the talk "***Realizing the Benefits of Ocean Knowledge through Ocean Observing Co Design***". The programme is designed to transform the thinking of how to develop designs and implementation of the global Ocean Observing System to be more responsive to user perspectives, building on the past knowledge and to better address user needs and stakeholder interests. The programme acknowledges the importance of engagement and communication between the observation component of the value chain, predictions, downstream models and product users, and will take these connections into account when implementing and demonstrating the effectiveness of the observing system co-design. David provided information about exemplars (or exemplar areas) around which the programme was configured, including the ocean carbon cycle, tropical cyclones, or marine life, which should help design a more purposeful and intentional adoption of the observing system to prepare for future needs. This can include addressing key policy or carbon market questions, providing better observations on tropical cyclone intensity and impacts especially in coastal regions, and provide predictive capabilities and knowledge of ocean resource management or marine heat waves.
The programme has been busy to organise workshops, supporter forums and engagement forums to find funders and stakeholders to invite them to become part of the exemplar activities.

Q&A

Observation gaps: *SynObs* could help find and fill observation gaps by identifying regions with a high forecast error or growing forecast error, and to reduce that error through assimilation of certain variables, and then to find the best platform that could be applied. A project is planned that will explore different methods for running specific OSEs and OSSEs to answer such questions in near-real time. It would also be beneficial to investigate the impact of individual observations, and if needed get more/better observations at that location.
By looking at cyclones or hurricanes, the *Ocean Observing Co-design programme*, has experimented with reprogrammable Argo floats to change their frequency at which they cycle to the surface to take more measurements. They are still evaluating the results and it could prove valuable. However, although platforms can be made programmable to a degree, changing mission parameters and making them responsive to an urgent need or a new need on the fly, doesn't come without cost. Increasing the Argo float cycle frequency shortens its life.

2.3. Sessions 2&3 - Interoperability, collaborations and best practice

2.3.1. Ocean Best Practice in EuroSea and beyond

Johannes Karstensen (GEOMAR) is a senior researcher in the Research division 1 (Physical Oceanography) at the GEOMAR Helmholtz Centre for Ocean Research Kiel and co-lead of EuroSea work package 3 (WP3 on Network Integration and Improvement). He presented the talk "***EuroSea achievements regarding Ocean Best Practice in support for the Ocean Information Value-Chain (OIVC)***". Ocean Best Practices (OBP) has been a central part of EuroSea and was represented in various work packages. An important aspect was the development of articulation of OBP, to improve discovery and access to OBP, best practice documentation of observational networks and to deliver best practice knowledge & technology transfer from scientist to stakeholders. He showed an example of OBP applied in WP3 which worked on improving integration of observations per nation (which included various observing system from HR radar to Argo and tide gauges) for "optimal" use in European (EuroGOOS) and contributing to global (GOOS). WP3 supported the convergence of the different observing systems using gap analysis and understanding the barriers for adaptation.
Making best practice useful for a large community includes overcoming silos in best practice access and dissemination and could be set up as a federate network of ocean best practice.

Q&A

Ocean best practice guide: To practically define and apply ocean best practice, it needs an agreed process. It was suggested to follow a similar path to with the IPCC report, by getting experts together to synthesize and draw up a best practice guide until it is advanced enough to be opened up to the global community through an Open Access Review. Once an agreed it can be published widely and improved through regular review cycles. It was stated that the better the quality of the best practice users will want to apply it.

Jay Pearlman (IEEE, FourBridges) is director of FourBridges and is the EuroSea task lead for 1.1.4 (Ocean Best Practice). He presented the talk "***The benefits, challenges and gaps for implementing Ocean Best Practices***". The ETOOFS manual, the guide to operational oceanography states that "Building a framework with standards and best practices for the full operational oceanography value chain will enable further harnessing of prediction systems in supporting a healthy ocean at the same time of a blue economic growth for all countries." This presentation summarised the main principles of ocean best practice, provided use cases of value chain applications and highlighted the importance of following OBP when developing standards. Furthermore, he presented issues and gaps that still exist in setting up and implementing OBP, and the benefits of OBP when applied to governance and global / international collaborations. There is need for a cultural change toward "best practices" documentation and use with significant credit given towards creators and adopters and requires endorsement by expert engagement. The bottom line is that ocean best practices will increase trust in ocean products, improve interoperability, make it easier for all to work within the value-chain and encourages broad engagement within the community.

2.3.2. Observing system design in EuroSea

Sabrina Speich (LMD/ENS) is Professor of Physical Oceanography and Climate Sciences at the Ecole Normale Supérieure, PSL, Paris and is co-lead of EuroSea WP2 (Ocean Observing System Design). She presented the talk "***Observing system design in EuroSea and integration with forecasting systems***", providing an overview of the work of the observing system design work package which assessed, designed and integrated all the different European observing systems (often only sustained through research

funding) into the EOOS, working closely with the other WPs. The objective was to deliver guidance, to improve existing elements or implement a new ocean observing component to the European Sea, using regional OSSEs to optimally merge in-situ and satellite observation with models to provide accurate estimate for indicators. It required close collaboration with the EuroSea demonstrator WPs to co-define the stakeholder needs of indicators (which might differ depending on the stakeholder), and included refinement of EOV definition and description of EOV requirements.

2.3.3. Interoperability between observation and prediction systems

Peter Oke (CSIRO) is Senior Principal Research Scientist at CSIRO and Executive member of the Argo Steering Team. He presented the talk "***Interoperability between observation and prediction systems - Example Argo***". Peter highlighted the importance of Argo as an exceptional ocean observing system on which ocean prediction rely very strongly, but which is only built on limited, mostly unsustained research funding. He emphasized Argo achievements, it being the only in-situ observing system programme with near-global coverage, fast data provision, exceptional vertical resolution, complementarity with satellite altimetry, QC and strict data formatting, but he also stated the issues, which include unsustained funding, mesoscale resolution problems, calibration issues, and support for real-time delivery often not 24-7. OneArgo, the plan to combine core, deep and BGC Argo as one system is the next step. However, it is expensive and requires collaboration of many communities which have often different objectives, so good communication is key to being successful. He urged research, science groups and operational systems to carry out observation impacts studies (via OSEs or OSSEs) to show the value of Argo data, and demonstrate impacts on coupled predictions, including NWP systems to help move the Argo Program onto a sustainable footing.

Q&A

Argo float issues: SEATREC could be a good alternative float as it does not need batteries to run but could have issues with biofouling which could impact the data quality. However, Peter was keen to highlight that technical improvements like SEATREC are very welcome.

Support for Argo: Promoting Argo expansion requires a lot of effort. The Argo Steering Team is reaching out to specific operational centres including UK Met and ECMWF to engage and promote Argo. Also, projects like SynObs providing a shared focal point on observation requirements are helpful partners in promoting Argo.

Pierre-Yves Le Traon is the scientific director of Mercator Ocean international, co-chair of the OceanPredict advisory Board and co-lead of the EuroSea WP4 (Data integration, assimilation, and forecasting).
He presented the talk "***How well does interoperability between observation and prediction systems function? - Example satellite observations***". Pierre-Yves presented an overview of the current efforts in satellite oceanography and its interaction with ocean prediction. Satellites are a vital tool for measuring the ocean globally, in real-time and at high resolution. Satellites provide the only option for observing mesoscale variability globally and are complementary with in-situ observing systems. Interoperability between satellite observing and ocean prediction is based on operational interfaces, data processing, feedback to satellite agencies, provision of requirements for future missions and advocacy. Such exchanges require regular interaction with space agencies on the satellite status, technical issues, data quality, etc. Copernicus Marine Service, as a European marine data and service provider, is highly dependent on satellite observations and works closely with space agencies providing observation impact assessments. Effective interoperability between the satellite observing system and prediction efforts is vital for the future on operational oceanography. It is hoped that further improvements, such as more standardised interfaces can be shared at international level with OceanPredict and OP-DCC supporting this effort.

Q&A

Observing system assessments: Interoperability between satellite observing system and ocean prediction depend on the effectiveness and quality of the satellite data for improving ocean forecasts, so it is very important to implement observing system assessments as part of the operational prediction system processes.
Best practices experiences about the interaction of CMEMS with the satellite agencies are recorded and it is planned to communicate these through the OP-DCC

2.3.4. End user perspective on use of ocean forecast product

Mark Gould (DFO) is an Operations Officer for Fisheries and Oceans Canada and the Regional Supervisor for Maritime SAR (Search and Rescue) at MRSC St John's, Canada. He presented the talk "***Search and Rescue and the use of ocean prediction products***". Mark introduced Canadian search and rescue planning program (CANSARP) currently used at MRSC in St John's and showed examples of SAR use cases. The main process involves the calculation of the search object drift, given their type, the estimated position and the environmental conditions, mainly wind and currents, followed by drawing up an optimised search plan using a probability weighted search-area-map including search patterns. This is not always accurate and requires expertise for its interpretation. Success of finding a drifting object also depends on the available resources and rescue assets. To check the system's effectiveness, tests were conducted to understand the model behaviour and to adjust errors to improve model results. This process depends on the search area and is not always successful. He highlighted the need for some measure of confidence for model results as it would allow faster and more targeted recue action. It became clear that emphasis should be put on generally improving communication and interaction of the groups involved in the SAR efforts.

Q&A
Forecast confidence: Many groups are involved in providing the ingredients for a successful search operation, which includes scientists, CANSARP software developers, operational system, SAR operators, rescue units, etc. Gaining confidence in forecasts is very important. It was suggested to consider improving the accuracy by incorporating real-time drifter data in the forecast system or by post processing. Another solution could come through use of ensemble forecasts, or by using AI in interpreting forecast discrepancies and providing improved search maps or using a collection of historical drifting buoy data and analysing how the forecast compares.

3. Round table discussion – ocean information value chain

Discussion about "A vision for the Ocean information value-chain: systematically connecting up components from observations to user applications".

The discussion focused on the present and future of the establishment of the ocean information value chain, exploring gaps and issues. The purpose of the panel discussion was to dive deeper into the important aspects of these topics and to complement what has already been presented at the workshop.

The discussion is following the components connected through the ocean information value chain (*compare fig 1*). Beginning with the user perspective, the discussion moved to the observation component, ocean predictions, EuroSea contribution and ocean best practice.

3.1. The panel

The panel discussion was chaired by **Enrique Alvarez Fanjul** (Mercator Ocean international) is the OceanPrediction Decade Collaborative Center (OP-DCC) Technical coordinator. Panel members included:

- **Mark Gould** (DFO) is an Operations Officer for Fisheries and Oceans Canada and the Regional Supervisor for Maritime SAR (Search and Rescue) at MRSC St John's, Canada.
- **Emma Heslop** (UNESCO/IOC) is Programme Specialist for the Global Ocean Observing System (GOOS) and Deputy Head of the GOOS Project Office.
- **Fraser Davidson** (ECCC/DFO) is a research manager at Environment and Climate Change Canada and co-chair of OceanPredict.
- **Toste Tanhua** (GEOMAR) is Senior Scientist in the Research Division 2: Marine Biogeochemistry at GEOMAR Helmholtz Centre for Ocean Research Kiel, and the lead PI of EuroSea.
- **Jay Pearlman** (IEEE, FourBridges) is director of FourBridges and is the EuroSea task lead for 1.1.4 (Ocean Best Practice).

3.2. Status and utility of the value chain

User perspective

End users are a fundamental component of the value chain as all effort made in the value chain are for the benefit of users. However, information about interaction with end users, collaboration with science and usefulness of the data and products provided to users are not widely available. Mark Gould, an Operations Officer for Fisheries and Oceans Canada and the Regional Supervisor for Maritime SAR (Search and Rescue) is providing information about user communication with science and utility of forecast products. He explained that interaction with the science community is ongoing since the 90s, and that over time tools for SAR have been developed and advanced, moving from deterministic models to probabilistic model products. Interaction has been strengthened through training and workshops, including a develop team that helps monitor and keep up to date with the most recent advances. Mark also reported about the importance of

having confidence in the forecast that helps the searches, as these can provide different advice to local knowledge of ocean behaviour.

Main points:

- Confidence in the forecast products is vital for use with applications

Observing system perspective

The ocean observing system is a vital component of the value chain and is undergoing a lot of changes. Currently, the implementation of best practices across all parts of the system, and the progress on the visibility of data flows, tracking data into ocean observing networks as well as other parts of the ocean information value chain, supporting integration and assessments across networks are important works in progress. However, all these efforts are fragile as funding is not sustained in many areas. Tracking the utility of observations through intermediate and end user interaction and determining the requirements for ocean observing for society will be supported by a better-connected ocean information value chain. The UN Decade, through its programmes will give visibility to the needs and issues of the value chain components. Programmes like Ocean Observing Co-design are reaching out, integrating modelling and observing while being much more user orientated from the outset. Although it might take time to getting partnerships established, once in place, it could lead to much improved interaction between all components. This would be underpinned by other UN Decade effort, such as the OP-DCC who would provide a structure for the interaction. This in turn could open opportunities for collaboration with industry. GOOS is looking at what role the private sector can play in the ocean observing system in using services.

Main points:

- Effort of tracking data flows in various parts of the value chain
- UN Decade programmes foster the integration of value chain components and could open up links with industry / private sector

Ocean prediction perspective

Government departments, national defence and coast guards are working closely with the national ocean prediction centres and so their relationships are established and strong. Links of prediction systems to industry is less developed and knowledge of what prediction centres (e.g. CMEMS) can provide is less known. However, the blue economy and green energy are waking up to the opportunities provided by the ocean predictions, so efforts should be made to engage industry. They are very likely interested in big data and use of the digital twin of the environment, which hopefully will create a lot of applications and insight for the blue economy.

Main points:

- Ocean prediction using digital twins products could open up links with industry / private sector

Ocean Best Practice

Ocean Best practice (OBP) is also very much linked to developing trust in the products provide by the ocean observing and ocean prediction communities. This is true for longstanding users as well as for new groups coming in wanted to take advantage of what the ocean information value chain can provide. Using ocean

best practice will allow to learn and document progress and passing it on to new generations. This could include creating curricula at universities, develop training courses and methods and make ocean best practice a sustained activity.

In the past years, best practice has grown in its recognition and is now seen as a key element for capacity building. OBP is not only essential in developed countries, but in providing the capabilities in the developing world and those with limited infrastructure. For new generations new formats for OBP dissemination should be considered (videos, etc.), and English might not always be the best language to use. Adaptation to local need and cultural difference should be considered. AI translation capabilities have been proven to be useful. The OBP repository is now accepting entries using different languages.

Main points:

- Ocean Best Practice builds trust in ocean products
- The developing world will increase its capabilities using OPB
- OBP dissemination will be vital to pass it on to new generations

EuroSea perspective

The value chain principles have been very important in constructing the EuroSea project, as its work packages (WPs) reflect value chain components and interaction between the WPs resemble the ideal scenarios for value chain collaborations. With WP1 looking at requirements setting and governance, the other WPs were aligned to contribute to designing the EOOS by developing it as a value chain, involving observation assessments, data collection and platform design, DA, OSEs and ocean prediction as well as demonstrators to engage users. At the same time the EuroSea was linked to European and global networks to help align outcomes. Standard and best practice have been applied to the WP interactions allowing the smooth exchanges, including for work with end users.

Main points:

- EuroSea has used the ocean information value chain structure to design the project work package interactions

3.3. Value chain gaps and issues

User perspective

Mark highlighted that the biggest gap or issue he is facing is related to choosing the correct product or model to provide the forecasts for SAR. Again, confidence is a very strong factor. Relatively low resolution for the purpose of the application (sometimes deciding about life and death) is not allowing a focused search as the search areas are too large. Notification about new products as they are developed, using higher resolution models and providing a better product are needed, but at the same time confidence and trust in new products need to be grown. Using drifter buoys in support of the forecast is possible but can only be deployed delayed and then takes time to provide information in the current directions, which is often too late for the casualty. If time is available, drifter data can be used for interpolating observed currents with the model, but the challenge is to get the current data in real time.

Main points:

- OP-DCC will include the issue of low-resolution models and delayed current observations in its gap analysis

Observing system perspective

Although the ocean observing system is generally in a reasonable state, there are gaps in certain areas. These are concerning governance and coordination at regional and national level, as well as gaps in the data (under sampling). Examples include lack of development for biological & ecological observation/monitoring, limited collaborations between regions and national contacts, with some regions or coastal areas not covered, limited feedback lops in the global system/efforts, low level of interaction with users on their requirements and subsequent adjustment of forecast products and service delivery.

Possible advances in filling the gaps could be the efforts of UN Decade programmes. For example, the Ocean Observing Co-design programme uses exemplars to explore high impact areas like carbon budget, boundary currents, marine heatwaves, tropical cyclones or biodiversity, to better understand impacts, learn about user needs and delivery forecasts products that are fit for purpose. In the future a "rolling review of requirements" (similar to the WMO effort already in place) could deliver information of gaps and issues on a regular basis and help to improve the system.

A major need is to find the drive and investment to advance the observing system in all its parts and to link it up with the other ocean information value chain components. Investment does not only mean financial support but opening up the debate with value chain partners and user on sustaining the ocean observing system through interaction with and input from social and economic sciences as well as carrying it closer to politics and policy makers. If observing, modelling and prediction communities can collectively make the case for increased investment, improving value-chain components and benefits for users, we could speak with a stronger voice.

Main points:

- Lack in ecological and biological observations/monitoring, as well as some coastal areas
- Recommendation to employ a "Rolling review of requirements" to deliver information of gaps and issues on a regular basis and help to improve the system
- Improve investment to sustain the ocean observing system

Ocean prediction perspective

A few examples were given about the gaps and issues related to the ocean prediction part of the value chain. Generally, global ocean predictions are good, but due to most human ocean-related activities happening on or near the coast, modelling and forecasts are specifically important in the coast. Although efforts to unify coastal ocean prediction efforts and support forecast groups, collaborations to find common solution remain difficult, including to linking prediction systems to user needs. As mentioned before interaction with new partners from social sciences would be beneficial. In setting up a two-way interaction between users and science we keep a broad perspective on the whole value chain and develop it further collectively.

Ocean prediction evaluation is another effort that needs improvement and should be implemented as an operational step as it would raise confidence in the forecast and would encourage users to engage and use ocean products more.

Main points:

- Develop interdisciplinary interaction with social sciences and economics to improve the applicability of ocean products
- Implementing ocean prediction evaluations (e.g OSEs) as an operational step in the ocean prediction system

Ocean Best Practice

Standards and tools for ocean observing and ocean prediction are available but more needs to be done to make them as widely available and adopted as possible. Using ocean best practices widely will help to also establish a better understanding of impacts and benefits of ocean observations and predictions, and through that can heighten visibility and increase funding. The user community, as mentioned before, includes the social, economic and political science communities. An example of good collaboration of the different communities was described as aquaculture farms which use shellfish below their fish farm to clean the water and get rid of waste material. For this layered approach to aquaculture knowledge and expertise from various communities was needed and has provided a nice synergy that benefits all involved. Similar approaches need to be explored to close gaps, increase interdisciplinary collaboration and to extend the use of ocean best practice.

Collaboration is now needed to put ocean best practices up to the community for assessment, let them be examined and then eventually come up with endorsements.

Main points:

- Strongly emphasise the importance of endorsing and adopting OBP widely

EuroSea perspective

EuroSea has demonstrated that setting up the project in the form of value chain components (the project work packages) was beneficial. Having teams set up that made a strong contribution to the interactive work, especially in the demonstrators, expanded the benefits of interdisciplinary work of all involved.

This is not widely applied in the normal science environment where people usually work with members of their own group and not across value chain components. This is a gap that needs to be addressed, as interdisciplinary collaboration and better interaction between the ocean value chain components will be an important future development.

Main points:

- Interdisciplinary collaboration and better interaction between the ocean value chain components will be an important future development

3.4. Future developments of the value chain

User perspective

Ocean monitoring and forecasting is expected to continue to be key tools for the marine applications. A confidence factor given to model results/forecasts used for SAR operations would be a helpful addition and would increase ocean product quality. It was suggested to in future consider providing model ensembles to improve forecast probability information and through that improve its confidence.

End user communication with science communities on forecast product quality regarding application success is so far not part of the operational service. It was proposed to consider setting up a feedback form or other regular and automated mechanisms to inform scientist about the forecast performance to allow for product improvements. However, the diverse applications and forecast products utilised by the end user might make effective feedback procedures difficult to implement.

Main points:

- Improving confidence in ocean products by using ensemble forecasts
- Developing better feedback loops between value chain components including users

Observing system perspective

Generally, developing better engagement with industry could evolve ocean observing as a market sector for new technologies, harnessing private investment. Another aspect is trying to engage with the private sector on data usage for societal benefit. Currently, privately (commercially) collected observations, often done by separate companies to the data users, are much more localised and concentrated in certain locations, often embedded in lower resolution public data. This makes them expensive and so they are not shared publicly. To tap into these private data a case would need to be made for a data marketplace in some way where private sector and public sector data could be traded. However, so far private sector data quality and collection methods are often unknown, so it would be helpful to be able to check sample data for the public to see the potential of these data. In future this could lead to policy changes when is come to infrastructure planning (like aquaculture, wind forms, etc.) where licences for developing buildings or structure are linked to providing data collections to the public sector, so that observation data is available from the outset.

Main points:

- Implementing ocean best practice widely and working on improving efficiency internally
- New observing system technologies and improvement of efficiency without losing system integrity
- Better links with public and private partnerships on providing observing system technologies for open use
- Harnessing private sector investment

Ocean prediction perspective

It is very likely that improving the ocean information value-chain connections, for example by enhancing user-linked processes, will become more important over time than solely the improvement of models. Such development would help with event detection and improves user experience. The advancement to digital twin systems will be a game changer, including the fast accessibility of big data via user-friendly interfaces and the ability to visualize application scenarios. This might also include fast responses to emergencies.

In addition, prediction system processes should be guided by ocean best practices, including providing an operational readiness level index. Ocean product users should be involved in providing feedback on new innovations and all partners in the value-chain should be informed about progress of all components and develop an overall understanding of value-chain contributors, their workings, interconnections, benefits, etc.

Another aspect of improving ocean predictions is to resolve the question of what scales to go for in which environment or model area, and which produces the best fitting forecasts.

Main points:

- Advancement of user benefit through application of digital twin set-ups

Ocean Best Practice

There is need to make ocean best practice and info about standards more and better accessible. A proposal could be to set up a federated network for the distribution and application of best practice, not only including ocean science but the wider science communities. This could include setting up methodology repositories for setting up intercomparison, proposing metrics for practices, mechanism for feedback on practices, etc. to give people better access. This is not easy to achieve and requires communities to work together to assess the methods and adopt them. The basic principle of achieving a community-based repository of agreed practices and standards is good communication which needs to be built into the system more thoroughly.

Main points:

- Consideration to set up a Federated Network for the distribution, application and community based repository of ocean best practice

EuroSea perspective

EuroSea unfortunately, will not have a follow-on project. There are a number of EU funded projects planned that have ocean observing elements. There are also three project proposals which concerns Essential Ocean Variables (EOVs) for biology/ecology, BGC, and physics closing research gaps, which will work in tandem, but not across the value chain as EuroSea did.

In general, project funding is generous, but unfortunately does not sustain core ocean observing efforts long-term. It is hoped that future projects could help to support the observing system core funding, and that together with the EC we can find ways of creating a little bit more of a permanent structure around ocean observing. Currently, the community is trying to find some of that sustained core funding through project money, which is not very efficient and not really the purpose of research funding.

EuroSea will hold its final assembly in September in Paris to present project results. A discussion with the Sustainable Blue Economy Partnership is also planned to explore possible collaborations.

Appendix

Appendix 1: Workshop agenda

Min	Title	Speakers
<u>Top session - Operational Oceanography and the ocean information value-chain:</u> What is the full ocean information value-chain? (15+5)		
20	OceanPrediction-DCC on establishing a global operational oceanography architecture	Enrique Alvarez (MOi)
20	The role of IOC/GOOS on establishing an integrated and sustained ocean observing system (including reflecting on EOOS and the EuroSea effort) and its link with the ocean information value-chain	Emma Heslop (IOC/GOOS)
20	OceanPredict's perspective of the ocean information value chain, its links with the operational ocean prediction systems and the option of integration it into a global architecture	Fraser Davidson (ECCC/DFO)
<u>Session 1 - UN Decade impacts:</u> How did UN Decade programmes and projects benefit from the EuroSea project? What are the impacts of the EuroSea project contributing to the ocean information value-chain? (15+5)		
20	Highlighting the effort of EuroSea in designing and getting underway a European Ocean Observing System (EOOS)	Toste Tanhua (GEOMAR)
20	SynObs	Elisabeth Remy (MOi)
20	Ocean Observing Co-Design	David Legler (NOAA)
<u>Session 2 and 3 combined - Interoperability, collaborations and best practice:</u> What has been achieved in setting up ocean best practice methods and processes across the ocean information value-chain, where are the gaps and how can we develop optimal interoperability? **Includes Examples (from EuroSea and OP) of engagements between the observing, modelling, and operational prediction and end-users communities: Challenges, issues and opportunities (15+5)**		
20	Perspectives on what has been achieved through EuroSea regarding Ocean Best Practice and how can this inform the ocean information value-chain long term?	Johannes Karstensen (GEOMAR)
20	Observing system design in EuroSea and integration with forecasting systems	Sabrina Speich (LMD/ENS)
20	How well does interoperability between observation and prediction systems function? - Example Argo	Peter Oke (CSIRO)
20	How well does interoperability between observation and prediction systems function? - Example satellite observations	Pierre-Yves Le Traon (MOi)
20	An end-user experience : how useful are the ocean products to end-users and what are the needs and issues (example - Coast Guard)	Mark Gould (DFO)
20	What are the pitfalls, gaps and issues that need addressing when planning to implement Ocean Best Practice?	Jay Pearlman (OBP, Four Bridges)

	Panel discussion	
50	Questions for the panel will be discussed and shared asap	Discussion chair: Enrique Alvarez Rapporteur: Kirsten Wilmer-Becker

Appendix 2: Presentations

No	Title	Presenter	Presentation (pdf)	Recording (mp4)
1	OceanPrediction-DCC on establishing a global operational oceanography architecture	Enrique Alvarez (MOi)	PDF	REC
2	The role of IOC/GOOS on establishing an integrated and sustained ocean observing system and its link with the ocean information value-chain	Emma Heslop (IOC/GOOS)	PDF	REC
3	OceanPredict's perspective on the ocean information value chain	Fraser Davidson (ECCC)	PDF	REC
4	Highlighting the effort of EuroSea in designing and getting underway a European Ocean Observing System (EOOS)	Toste Tanhua (GEOMAR)	PDF	REC
5	SynObs: A UN Decade project on Synergistic Observing Network for Ocean Prediction	Elisabeth Remy (MOi)	PDF	REC
6	Realizing the Benefits of Ocean Knowledge through Ocean Observing Co Design	David Legler (NOAA)	PDF	REC
7	Perspectives on what has been achieved through EuroSea regarding Ocean Best Practice and how can this inform the ocean information value-chain long term?	Johannes Karstensen (GEOMAR)	PDF	REC
8	Observing system design in EuroSea and integration with forecasting systems	Sabrina Speich (LMD/ENS)	PDF	REC
9	Interoperability between observation and prediction systems? – Example Argo	Peter Oke (CSIRO)	PDF	REC

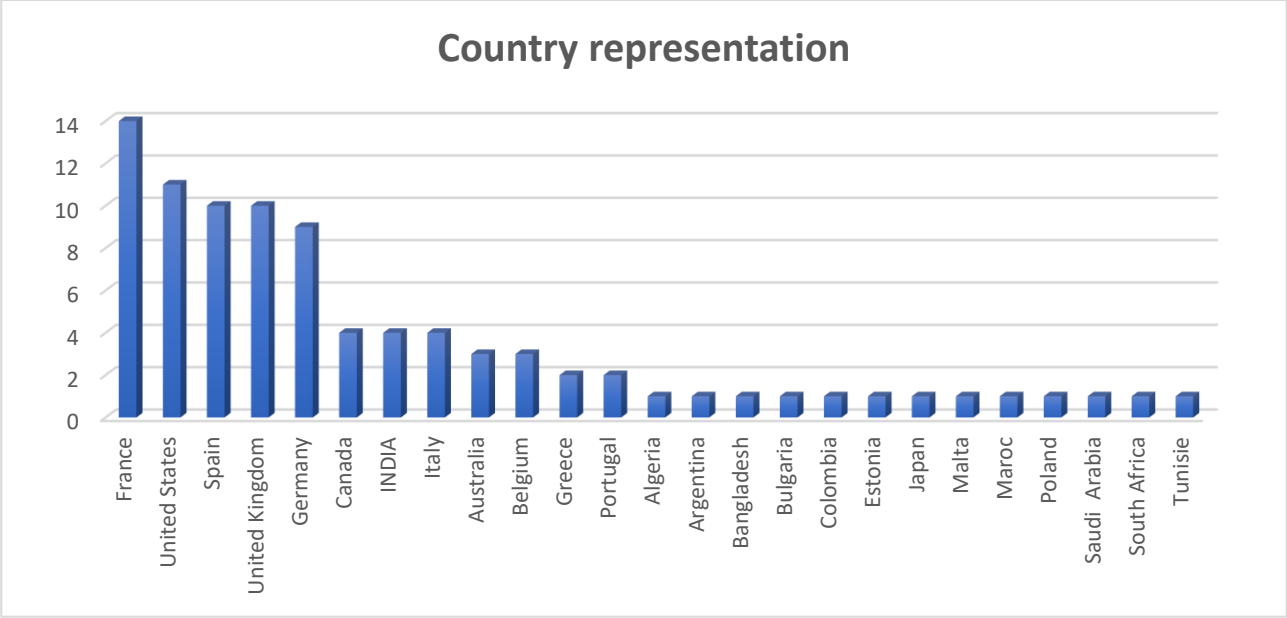
10	Interoperability between observation and prediction systems? – Example satellite observations	Pierre-Yves Le Traon (MOi)	**PDF**	**REC**
11	An end-user experience: how useful are the ocean products to end-users and what are the needs and issues (example – Coast Guard)	Mark Gould (DFO)	PDF	**REC**
12	The benefits, challenges and gaps for implementing Ocean Best Practices	Jay Pearlman (IEEE, Four Bridges)	**PDF**	**REC** (first 5 min of recording missing)

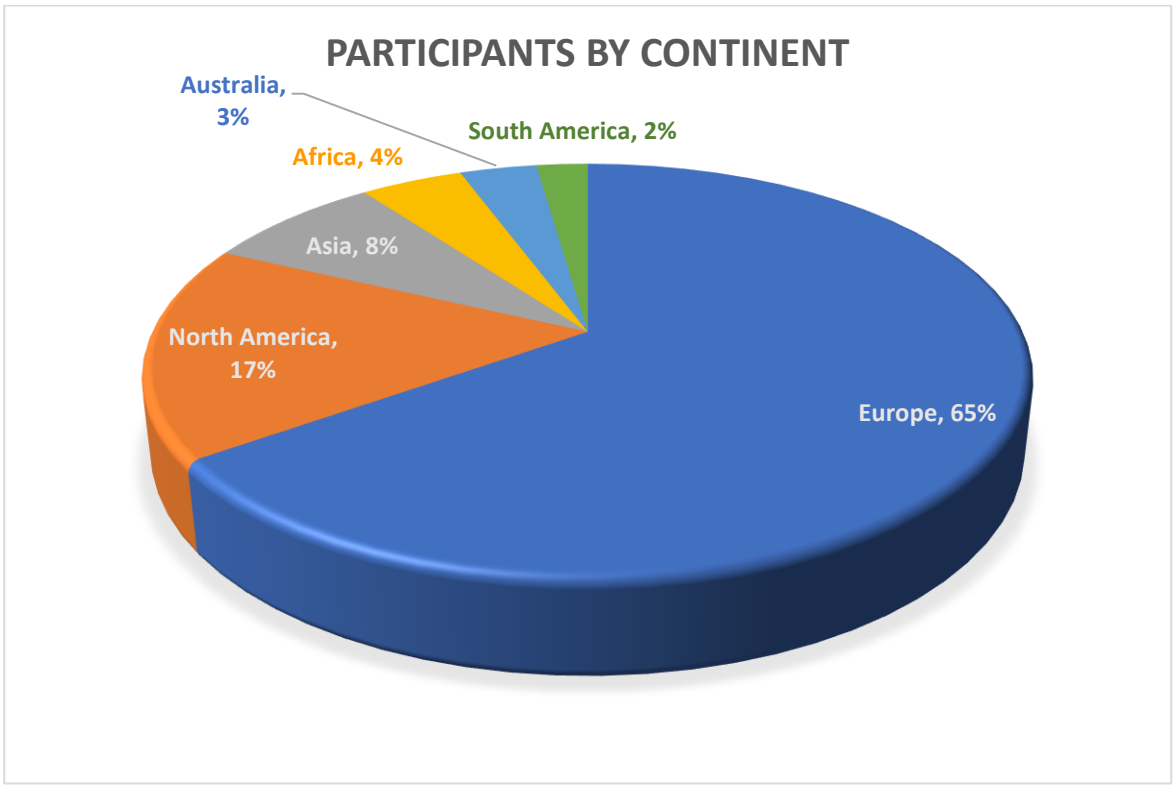
Appendix 3: Workshop statistics

Th workshop was a fully virtual event and number of participants was **89**. Below is a brief overview of the attendees' background, country and links with EuroSea and OceanPredict.

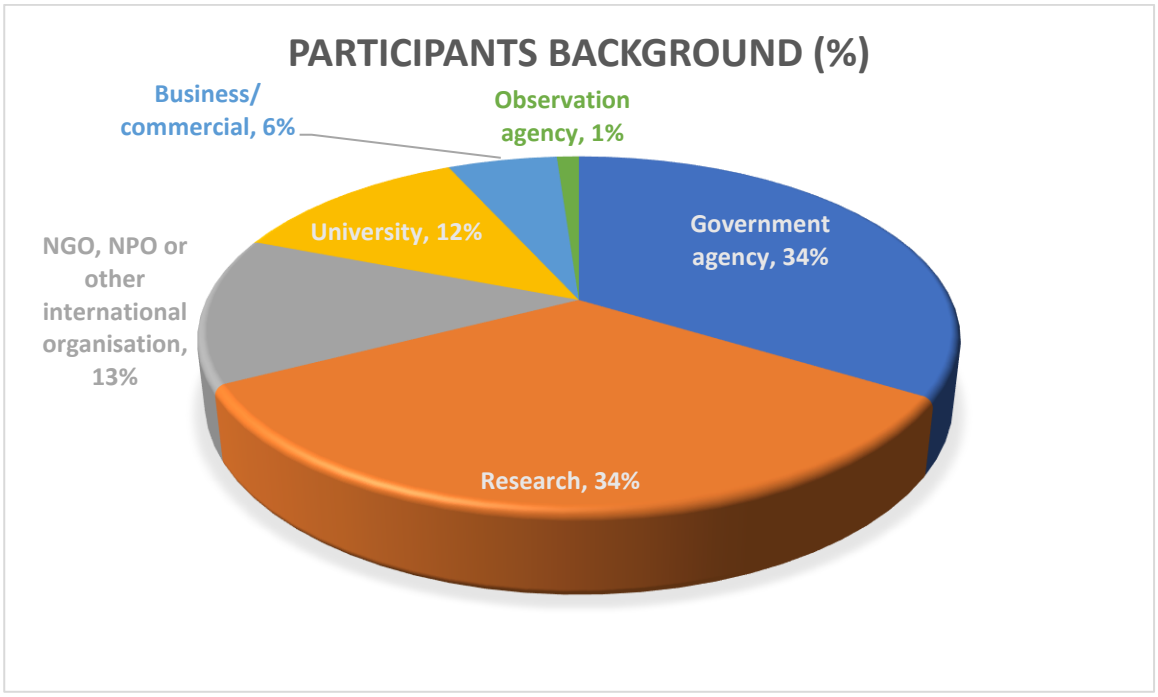
Gender information was not collected for this workshop.

Distribution of attendees by country/ continent

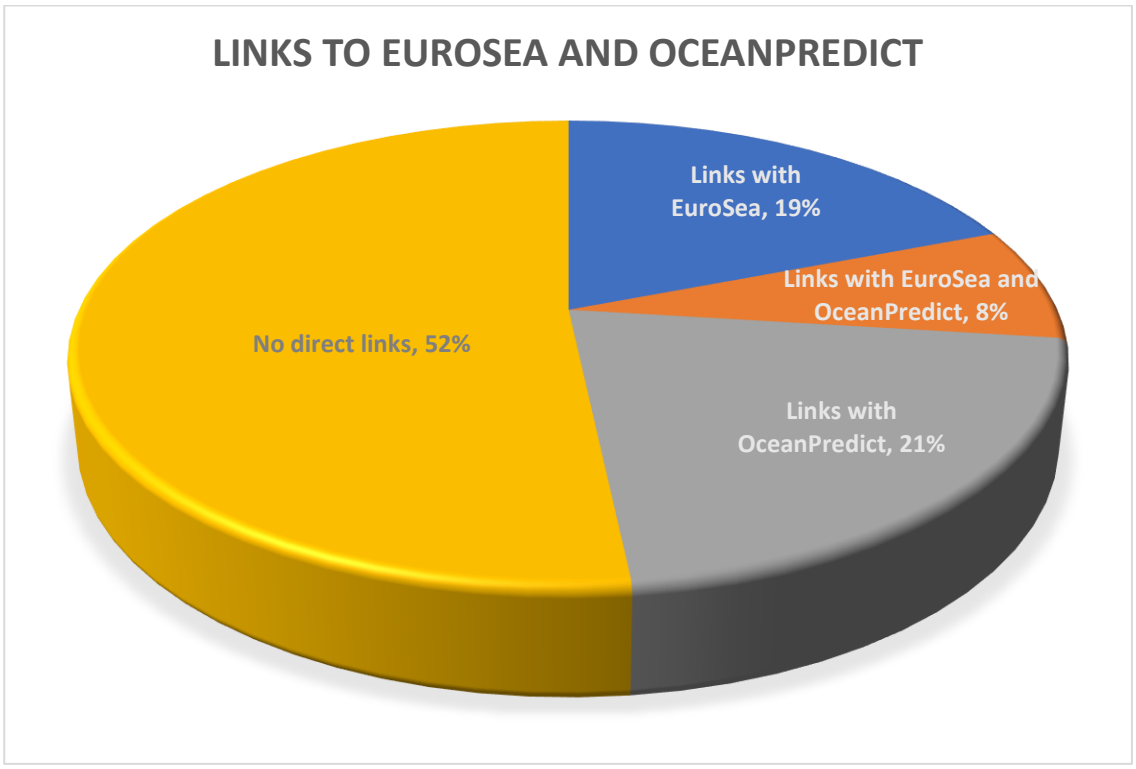




Representation by organisation background



Links with EuroSea (some overlaps)


LINKS TO EUROSEA AND OCEANPREDICT
Links with EuroSea, 19%
Links with EuroSea and OceanPredict, 8%
Links with OceanPredict, 21%
No direct links, 52%