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EuroSea/OceanPredict workshop

3-day hybrid event

Met Office

29 June – 1 July 2022

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Executive summary

The main objective of the EuroSea/OceanPredict workshop was to strengthen the linkages of the EuroSea community with the leading edge of global forecast and prediction through representative of the OceanPredict community and other international research efforts. This was achieved by setting up a workshop that allowed focus on a specific set of sessions, exploring observation and ocean prediction efforts in a global context, discussing issues and developing recommendations for solutions. Furthermore, the workshop highlighted the UN Decade of Ocean Science current programmes' initiatives for the "Predicted Ocean", which showed the importance of global efforts for the improvement and advancement of the observing system and prediction system capabilities.

The workshop sessions (see Sessions below) culminated in the round table discussion. Outcomes from the four workshop sessions were collated and passed on as questions to the round table panel, summarised under the topics: Ocean Observations, Sustainability, Essential Ocean Variables, Ocean Prediction and Ocean Best Practice. The recommendations from the round table discussion highlighted the

- need for better communication and closer collaboration of the observation and prediction communities, the
- importance to involving intermediate and end-users in questions of ocean observations, the
- consideration of a fully integrated ocean observing system (including all regions and observation types), the
- plan to create a fully ocean information value-chain (from user needs, to observations, data assembly and distribution, ocean prediction and services to user and societal benefits) and the
- value of defining and describing all processes involved in operational oceanography through ocean best practice methodology.

With over 150 participants in total, the overall workshop participation was higher than expected and despite Covid-19 almost 40 people joined the workshop in person. This added a lot of positive energy at the event and provided a good backdrop for strong engagement and valuable discussions. Although Covid-19 is generally limiting the number of in-person attendees, the advance in remote/hybrid meeting technology is providing improved opportunities for new communities to join the discussion. New research groups and initiatives from South America and Asia have joined and their contribution were welcomed.

1. Introduction

This workshop was organised by EuroSea, a European funded project that works on "Improving and integrating the European Ocean Observing and Forecasting System". The workshop linked EuroSea with the international activities of OceanPredict in support of connecting, exploring and advancing observation and ocean prediction efforts in a global context. Furthermore, the workshop was intended to contribute to the UN Decade initiative through interaction with Decade science programmes, GOOS and other science partners. The workshop was of a technical nature with the themes and topics reflecting this.

The event provided an opportunity of gathering representatives from the global ocean observation and prediction communities to exchange on issues, progress and future outlook with EuroSea and the European efforts at its core.

2. Workshop sessions

2.1. Session 1 - OSEs & OSSEs in support of observing system design

Session chair and rapporteur: Elisabeth Remy (MOI) and Matthew Martin (Met Office)

Session 1 was on Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) in support of observing system design. There were 11 oral presentations providing examples of OSEs and OSSEs applied to various in situ and satellite observing systems in different regions. There were also 10 poster presentations which gave further examples of the use of OSEs and OSSEs. A summary of the oral presentations is given here, followed by a list of the main questions which came out of the session which were presented to the round table discussion on the final day of the workshop.

Joao Azevedo Correia de Souza (MetOcean Solutions, a division of Meteorological Service of New Zealand) presented **Assimilation of fishing vessel derived observations into an operational ocean forecast system**, (www.moanaproject.org) investigating the impact of observations on board fishing vessels in the waters surrounding New Zealand. A 5 km resolution version of the ROMS model was used with a 4DVar scheme to assimilate sea surface temperature (SST) and sea level anomaly (SLA) data. Additional data from the Mangopare fishing vessel temperature profiles were then assimilated with those existing data and their impact assessed. The data were available at depths down to 100 m or 1000 m depending on the location and were shown to provide large improvements to the subsurface temperature structure, particularly at the depth of the mixed layer. The plan is to make the system operational in the next few months.

Peter Oke (CSIRO) presented "**Using Argo data for ocean reanalysis: some pitfalls to avoid**", showing issues with making good use of Argo data for ocean reanalysis. One of these is in terms of accessing the data through datasets such as CORA or EN4 which are not updated with the latest version of the delayed mode Argo data as frequently as the Argo GDACs. The Argo floats are reprocessed every year and quality control decisions and corrections to the data can change on each reprocessing. These can include significant changes to the estimates of salinity bias which was shown in OSEs to have a large impact on reanalyses, particularly during recent times when there were issues with salinity sensors. Using real-time data can give up to 10% increase in the errors compared to the delayed time data. Updates to the Bluelink reanalysis system to include a multi-scale EnOI scheme gave up to 30% improvements in accuracy compared to the previous system.

Florent Gasparin (IRD/LEGOS) presented **Identifying constrained scales by ocean observations in global ocean analyses**, showing work to identify the scales which are constrained by assimilating ocean observations in global reanalysis. OSSEs were run to show the impact of satellite data and in situ data on the constrained scales. The magnitude of errors at the mesoscale were of the same order as those at larger scales. Satellite-only assimilation (SST/SLA) gives a strong decrease of error at the mesoscale but only a small decrease of error at the large-scale. In situ-only assimilation reduced the errors less overall, and mainly at large scale. With the existing observing system the combination of satellite and situ reduces error mainly at the large-scale while the satellite data reduces mainly the mesoscale errors, both at the surface and at depth. The impact of doubling the Argo array in western boundary currents gives up to 15% improvement for salinity. The work shows that more development of DA methods is still needed to make best use of all the data at different scales.

Paul Arya (INCOIS) presented **A study of forecast sensitivity to observations in Bay of Bengal using LETKF** (recorded presentation). He described the use of the Ensemble Forecast Sensitivity to Observations (EFSO) in the Arabian Sea and Bay of Bengal, with the ROMS-LETKF system. A new error norm was chosen for the EFSO computation based on baroclinity to get more sensitive results. The observations that have the largest beneficial impact are the salinity observations compared to temperature observations. The region with the highest impacts is the Bay of Bengal, characterize by a very strong stratification during the monsoon.

Ali Aydogdu (CMCC) presented **Assimilation of glider profiles in the Mediterranean Analysis and Forecasting System MedFS**, demonstrating the impact of assimilating glider profiles in the Western Mediterranean. Gliders were assimilated in high resolution data assimilation systems and were shown to improve the RMSE of the misfits to observations in the subsurface but there were some degradations near the surface. A Github site has been set up to create a community best practice for the assimilation of glider data (see https://github.com/OceanGlidersCommunity/data_assimilation_practices). There was interest from the OceanPredict DA-TT and MEAP-TT to share experiments on glider assimilation and help develop best practices.

Jennie Waters (Met Office) presented **Assessing the impact of assimilating Total Surface Current Velocities in global ocean forecasting systems.** The largest impacts of TSCV data were in the WBCs, ACC and equatorial regions for velocity with significant impacts on other variables including SSH and temperature profiles. Further work was planned to improve the retention of assimilation increments to the ageostrophic velocities and also to look at the impact of the TSCV assimilation on the vertical velocities.

Robert King (Met Office) presented **The impact of upcoming wide-swath and along-track altimeter constellations in global and regional ocean forecasting systems**. The impact of 12-nadir vs 2 wide swath altimeters (WiSAs) was assessed and showed significant improvement in SSH and surface velocities from both constellations. There was slightly more improvement from the 12-nadir constellation in the FOAM system. The impact of SWOT assimilation in a regional 1.5 km system was also discussed with observation error correlations shown to degrade results if not treated.

Davi Mignac Carneiro (Met Office) presented **Improving the Met Office's Forecast Ocean Assimilation Model (FOAM) with the assimilation of satellite-derived sea-ice thickness data from CryoSat-2 and SMOS in the Arctic**. There were good improvements from assimilating both datasets together with CS2 improving the thicker ice and SMOS constraining the ice edge. The CS2 along-track data should include observation uncertainty estimates and be provided closer to real time to be useful for operational assimilation.

Eric Chassignet (FSU) presented **Towards a next generation AMOC observing system**, describing changes to the organisation of the next generation AMOC observing system. The US AMOC team is being subsumed in a wider CLIVAR AMOC task team with new terms of reference. There is a plan to coordinate a workshop on assessing and transforming the AMOC observing system. Some questions were raised about OSSEs and the observing system design: the nature run in OSSEs – how realistic does it need to be?; can gaps in the existing AMOC arrays be filled using altimeters? It was noted that assimilation of AMOC type observations is not straightforward.

Bàrbara Barcelo-Llull (IMEDEA (CSIC-UIB) presented **Evaluating in situ sampling strategies for SWOT satellite validation**. A pre-SWOT experiment was carried out to optimise the multi-platform sampling strategies through OSSEs. An OI scheme was used to combine the data, and this included new temporal correlation scales for SSH – there was low sensitivity to this for timescales between 2 and 10 days. In idealised experiments, reconstructions with 10km separated CTDs down to 1000m depth gave similar results to the simulated truth.

Andrew Moore (UCSC) described results from **Forecast Sensitivity-based Observation Impact (FSOI) and Forecast Sensitivity to Observations (FSO) in an Analysis-Forecast System of the California Current Circulation**. Overall, there were positive impacts from all observing systems, but it was noted that only 50% of data improve the forecast, a result which is expected given experience in NWP. Further work includes implementing and testing the impact of thinning high-resolution data from SST and HF radars as well as improving the HF radar assimilation (e.g. by increasing the number of inner loops).

Discussion and questions for the Round Table (session 1):

In the discussion session after the oral presentations, the following questions were put forward to be addressed during the round table on the last day of the workshop:

1. How to improve the links between modelling/DA groups (including those running OSE/OSSEs) and the groups designing and implementing the observing systems?
    a. How to influence observation producers to ensure requirements from modelling/DA are met, e.g. including observation uncertainties in all datasets, reducing data latency?
    b. How to improve the knowledge in the modelling/DA community of the observations they are using and ways to assimilate particular data types? E.g. developing best practice for assimilation of glider data.
2. Where is the community in terms of assimilating both physical and biogeochemical data assimilation? Also, which BGC variables should be observed to improve the forecasts?
3. What characteristics should a common community nature run have for OSSEs and how should it be produced?
4. Which components of the earth system need to be included in observing system design?
5. How best to demonstrate the complementarity of remote sensing and in situ observations and to ensure this is taken into account in observing system design?

2.2. Session 2 – Extreme marine events – observing, modelling, forecasting and user accessibility

Session chair and rapporteur: Tomasz Dabrowski (MI) and Martha Dunbar (ICMAN-CSIC)

In total session 2 had 9 oral presentations and 9 posters from across Europe, the US, Argentina, Mexico and Morocco. The subjects covered by the presentations included Storms & Hurricanes, Marine Heat Waves (MHWs), Benguela upwelling and Harmful algae blooms (HABs).

Hyun-Sook Kim (NOAA/AOML) presented a **Numerical study of the upper ocean response to Hurricane Laura**. A three-way coupled modelling system: HWRF-HYCOM-WW3 (atmosphere, ocean and wave) was employed to study of the upper ocean response to Hurricane Laura - see presentation slides for the set-up of the models and how they are nested. Different configuration of coupling was used. 13 cases were tested when storm Laura transited the global ocean model:

- 3-way coupling induces higher SST/MLT cooling by O(<2C) compared to one-way ocean wave coupling and 2-way (no tuning - not shown in presentation).
- 3-way vs 2-way coupling wave current interactions reduced the magnitude of tendency and advection term in the ML heat budget balance.
- In general, tendency and advection terms dominate the ML heat budget, except dominant tendency and entrainment flux for a pre-storm period at the LC front
- Wave-current interaction shift and split wave spectrum (refraction and trapped?)

Hyun-Sook Kim *et al.* 2022. Skill Assessment of NCEP Three-way Coupled HWRF-HYCOM-WW3 Modeling System: Hurricane Laura Case Study https://journals.ametsoc.org/view/journals/wefo/aop/WAF-D-21-0191.1/WAF-D-21-0191.1.xml

Matthieu Le Henaff (University of Miami/CIMAS-NOAA/AOML) presented **Ocean OSSEs and OSEs for hurricane applications**. The work was carried out in collaboration with the AOML (NOAA) and the University of Miami. After introducing OSE and OSSE definitions he highlighted the current efforts with the AOML ocean OSSE system. The nature run used is based on the HYCOM global model with 0.04° resolution. The ocean forecast system used is HYCOM with a substantially different configuration than the nature run. He showed an example of an OSSE with gliders to show the reduction of errors supporting fixed profiler locations (nature run used to deliver stationary profiles at 2 degrees resolution). Results are presented in:

Halliwell, G.R. et al. (2020). OSSE assessment of underwater glider arrays OSSE Assessment of Underwater Glider Arrays to Improve Ocean Model Initialization for Tropical Cyclone Prediction https://journals.ametsoc.org/view/journals/atot/37/3/JTECH-D-18-0195.1.xml

He also highlighted an AOML coupled ocean-hurricane OSE system and showed impact of observations on hurricane forecasts during Hurricane Michael in 2018 (5-day coupled forecasts). Key findings can be viewed in the presentation, while results are presented in:

Le Hénaff, M. et al. (2021). The Role of the Gulf of Mexico Ocean Conditions in the Intensification of Hurricane Michael (2018). JGR Ocean https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020JC016969

Emanuela Clementi (CMCC) presented **The September 2020 Medicane Ianos predicted by the Copernicus Mediterranean Forecasting systems**. She gave an overview of the Copernicus Marine Service, highlighting the Med-MFC as one of the seven MFC (Marine Forecasting Centres), a consortium of 4 institutes CMCC, OGS, HCMR and CINECA), providing NRT analysis & forecast systems for the Mediterranean Sea. Emanuela introduced the definition of Medicanes or Mediterranean hurricanes, and specifically focused on the Medicane Ianos which was one of the strongest storms measured (in terms of intensity and duration) since records started in 1969. Med-MFC numerical analysis data were used to analyse Ianos impacts on the physical, wave and biogeochemical upper layers fields. The Copernicus Marine Mediterranean analysis products allowed a comprehensive assessment of Medicane Ianos footprint on the Ionian Sea and Greek coastal areas affected by this event. Model solutions were validated showing a general good skill in representing the increased sea level, wave height and decreased temperature in the area these data can provide accurate boundaries to high resolution coastal applications. Thanks to the alignment of the 3 Med-MFC components, we show to which extent this Medicane perturbed the surface ocean fields in terms of sea level, currents, temperature, wave height and chlorophyll, but also the vertical dynamics by increasing the mixing and consequently affecting the biogeochemical properties at depth.

Samuel Adiprabowo (Badan Meteorologi Klimatologi dan Geofisika) presented on the **Utilization of water-level measurement and analysis under extreme conditions: Case Study Severe Tropical Cyclone Seroja**. He introduced maps of the Seroja trajectory (3-12 April 2021) and highlighted its impact. He showed animations of the wave model results and of the BMKG InaWave Forecast model, as well as HFRadar, MAWS and VAMS observations during the cyclone, and was asking how to fill gaps in extreme wave height observations. The main part of the presentation was focussing of how to eliminate the tidal harmonic component and to extract the sea level anomaly and storm surge, and how applying filters can eliminate the low frequency elevation.

Madsen, K. S., J. L. Høyer, W. Fu, and C. Donlon (2015), Blending of satellite and tide gauge sea level observations and its assimilation in a storm surge model of the North Sea and Baltic Sea, J. Geophys. Res. Oceans, 120, 6405–6418, doi:10.1002/2015JC011070.
Pascual, A., M. Marcos, and D. Gomis (2008), Comparing the sea level response to pressure and wind forcing of two barotropic models: Validation with tide gauge and altimetry data, J. Geophys. Res., 113, C07011, doi:10.1029/2007JC004459.
Pawlowicz, R., Beardsley, B., & Lentz, S. (2002). Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE. Computers & Geosciences, 28(8), 929-937.

Ronan McAdam (CMCC) presented **Seasonal forecasting of surface and sub-surface marine heat waves: a global validation and comparison**. He showed that at the time of presenting MHW were present in the Med-Sea with temperature anomalies of +5°C. The main focus of the talk was to look at sub-surface MHW and define them using ocean heat content (OHC) information from 0-40m. Furthermore, the presentation aims to validate forecast systems against reanalysis and to compare prediction skills of sub-surface and surface HMWs. Related EuroSea is looking at EOVs and indicators for MHWs and at the possibility to move towards operational marine seasonal forecasting. Ronan concluded that

- OHC should be considered as a complementary MHW indicator to SST, that
- Seasonal marine forecasts predict subsurface events with greater skill than surface events, and that the longer-duration and slow-changing nature of subsurface MHWs is easier to predict, and that
- More subsurface monitoring would help event tracking and, in the long run, boost validation reliability. Extending seasonal forecast records of “unused” marine variables would help too!

Hugo Dayan (Laboratoire de Météorologie Dynamique/IPSL, Ecole Normale Supérieure, CNRS, Paris, France) presented **Marine Heat Waves in the Mediterranean Sea: an assessment from the surface to the subsurface to meet national needs**. This presentation represents a **c**ross-work package collaboration in

EuroSea to **a**ssess MHWs from surface to subsurface to meet national needs. A web-based application for the Med-Sea provides more info. Following a definition of MHWs and a brief description of the data used, the talk showed trend and mean characteristics of MHWs in the surface and sub-surface. It was also highlighted that the impact of MHWs requires EEZ integrated information to establish mitigation & adaptation strategies at local and national scales.

Mélanie Juza (SOCIB) presented **The "Sub-regional Mediterranean Marine Heat Waves" monitoring and visualization tool**. Melanie introduced MHWs as extreme warm ocean temperatures during prolonged periods of time, and highlighted causes and consequences, like coral bleaching, harmful algae blooms, etc. She focused on MHWs in the Med-Sea and provided an overview of the multi-platform observations that can help to provide a comprehensive characterisation of the MHWs, adding a paper by Juza for information:

Juza et al, 2022: "Sub-regional marine heat waves in the Mediterranean Sea from observations: long-term surface changes, sub-surface and coastal responses" Front. Mar. Sci., 02 March 2022, Sec. Ocean Observation, https://doi.org/10.3389/fmars.2022.78577

Results from continuous monitoring since 1982 showed the long-term variations of HMWs intensity, duration and frequency (also an example for 2021) and showed that there is a constant increase of MHWs in the Med with acceleration in the last decade in all sub-regions. Profiling floats were used to also explore the ocean interior for MHWs (btw 2012-2020), and showed propagation of surface MHWs in sub-surface, sub-regional / seasonal response in sub-surface resulting in enhanced upper-ocean stratification.

A web-based application was introduced https://apps.socib.es/subregmed-marine-heatwaves which was set up to monitor and visualize MHWs at sub-regional scale in the Med.

Coline Poppeschi (Ifremer, Univ. Brest, CNRS, IRD, Laboratory for Ocean Physics and Satellite remote sensing (LOPS), IUEM, 29280 Brest, France) presented **Coastal and regional marine heatwaves and cold-spells in the Bay of Biscay and the English Channel**. Observations used in this study included OISST (a long-term climate data record from different platforms (satellites - AVHRR, ships, buoys and Argo floats) and in-situ data from the COAST-HF network and the Western Channel Observatory. Recent studies confirm an increase of MHWs in the coastal ocean with regard to number and intensity with 2003 and 2018 being the most active years. The next steps will include documenting of the drivers for the observed MHWs and the decrease of marine cold-spells in the researched area.

Louise Darroch (NOC) presented **The use of Internet of Things sensors and ERDDAP in a nowcast hazard alerting coastal flood system**. Louise introduced a nowcast hazard altering coastal flood system that is using the Internet of Things and ERDDAP, building on previous projects. It includes the project CreamT or Coastal REsistance: Alerts and Monitoring Technologies and will allow for early detection of hazards and validation of coastal models and forecasts. ERDDAP is a data server that provides a simple, consistent way to download subsets of scientific datasets in common file formats and make graphs and maps, e.g. for oceanographic data (for example, data from satellites and buoys). It manages provision of data in 10 min (from measurement to data access) and can therefore be used for nowcast applications. Other uses, like data mapping to enable analysis on other software platforms, and risk-informed decision making is well supported.

Discussion and questions for the Round Table (session 2):

a) Few presentations addressed the interaction with stakeholders/customers (scientific and non-scientific), and very limited mention of progress towards the development of best practice in this regard. **Do the experts think that scientists are overlooking the interactions with stakeholders/co-developers?** Has this been changing in recent years? How can scientists be assisted with these interactions? e.g. dedicated experts/social scientists, or rather as equal partners in the project, for example, industry partners or even policy makers.

   How can we find the balance between a top-down and bottom-up approach, by providing just enough info and background/scientific basis to get stakeholders to feel engaged and invested from the very start of the process, i.e. facilitating feeling of ownership? How can we build mutual trust from the start?

   Stakeholder involvement (session discussion): *Very few presentations touched on the topic of co-development with stakeholders, and whether some research is needed first before approaching them. Stakeholders are often unsure of what they want, so it is useful to bring them some ideas and suggestions forward first.*
   Some groups are exploring the impact of using citizen science. It was highlighted that stakeholders should be involved from the very onset of a project in order for them to really be invested. Engagement with stakeholders from the start, will also be useful because as the project develops, their involvement will be richer, as they can see results.

b) Most, if not all contributions concerned hurricane /storm events and Marine Heat Waves and their impacts, including not only physics, but also phenomena such as upwelling of nutrients and increased productivity. **Do the experts agree Hurricane /Storm Events and Marine Heat Waves are the most pressing events at the moment or have we missed some important contributions?** Some talks mentioned a need to investigate Marine Cold Spells, which is something new. Are there other extreme events important from the economic, environmental, societal perspective that need to be researched?

c) We saw presentations concerning MHW in which the basic concept was the same, but some differences were presented in the way the climatologies are derived, i.e. the duration and the time periods. Using different datasets and different time periods may lead to different results for the same regions. **Is a standardization / harmonization follow-on workshop required?**

d) **How do we convince funders to support highly technical basic research projects that scaffold the development of important downstream services of importance to society?**

e) <u>Background:</u>
   Some of the talks concerned the improvement of the forecasting skill, reduction of the errors, e.g. through three-way coupling, DA. It is a highly technical area and some of the comments during the session concerned convincing the authorities to fund projects. **Any thoughts on this?** There is often basic research that needs to be done before a solid service can be developed.

2.3. Session 3 - Coastal Ocean: Modelling, observing system design and product utility

Julie Jakoboski (MetOcean Solutions (Meteorological Service of New Zealand) presented **Crowd Sourcing Ocean Observations for Ocean Forecasting Data Assimilation**.

- Argo is not covering coastal regions (depth < 1000m) around New Zealand well, but fishing operations do.
- Mangopare is a temperature and pressure sensor that is used by on fishing vessels.
- The sensor requires no human interaction, has a low cost and a battery lifetime of about 2 years.
- More than 150 vessels are currently taking part in the project: information from the sensor is passed to a deck unit via Bluetooth, from there it is transferred to a server via Wi-Fi or the cellular network, and quality control is performed.
- The deck unit provides the GPS location for each measurement, special processing is applied to clay pods or other stationary sensors.
- Data is provided back to the fisheries via email, fishing locations are not shared, unless given permission. The fishing community is generally supportive of the project.
- Soon, 300 sensors will be deployed, there are 5 million measurements which are used for data assimilation by the Meteorological Service of New Zealand.
- The Mangopare sensor project is moving from New Zealand to Australia and other places worldwide.

Nelly Florida Riama (The Agency for Meteorology Climatology and Geophysics) presented **Improvement of Ocean Forecasting System for Enhancing Marine Information in Maritime Continent**.

- Marine meteorology and oceanography are important for weather and climate predictions.
- The Indonesian forecasting system is being improved, it includes models for waves, currents, and coastal inundation.
- The wave model is changing from a 9 km resolution model without DA to 3 km model with DA.
- The coastal inundation model output is shown on a dashboard and part of an early warning system.
- The BMKG (Agency for Meteorology Climatology and Geophysics of the Republic of Indonesia) also has the goal of improving the marine observing infrastructure.

Christopher Stokes (PML) presented **Sources of uncertainty in coastal overtopping forecasts: observation and modelling of waves, water levels, and discharge**. Forecasting wave overtopping hazard will be increasingly important as sea levels rise to help communities prepare for nuisance and extreme coastal flooding events. A multi-model approach is required to forecast wave overtopping discharge/hazard, which incurs various sources of uncertainty. Using novel field measurements, the relative importance of the uncertainties on the predicted overtopping rate, Q was initiated:

- Wave forcing (2-4 times variation in Q over study period)
- Water level forcing (0.15 times variation in Q over study period)
- Coastal profile (1-2 times variation in Q over study period, order of magnitude for older profiles)
- Onshore/offshore wind (2-4 times variation in Q over study period)

Real time field measurements complement forecast systems, will help to quantify and reduce these uncertainties and can provide real-time warnings at key locations.

David Ford (Met Office) presented **Towards adaptive monitoring of coastal oceans integrating marine robots and operational forecasts**. This presentation explores the uses of smart systems for observations, models and statistics to simultaneously improve ocean information by reducing costs and maximizing impact.

Adaptive monitoring could automatically direct a robot toward a likely feature of interest (e.g. an algal bloom). The study uses NEMO, ERSEM + NEMOVAR to provide pseudo-operational forecasts, assimilating glider chlorophyll and oxygen data. Then employing a stochastic prediction model, which uses the glider data a set of waypoints for the glider are calculated and automatically emailed to pilot, based on location of forecasted chlorophyll maximum. Results confirm a successful proof-of-concept of an autonomous and adaptive "smart" observing system integrating models and gliders and show that observations improve models and models improve observations.

Emma Reyes Reyes (SOCIB) presented **European high-frequency radars as a valuable asset to validate and improve ocean prediction in coastal areas.**. HF radar systems utilize high frequency radio waves to measure the surface currents in the coastal ocean. There are 72 operational HF radar sites in Europe, providing 2D surface current maps and waves & wind information. The presentation introduced some of the HF radar stations and showed the HF radar data are used for model assessment & model improvements, including HFR data assimilation in WMOP and COSYNA.

Xin Li (BSH) presented **A comparison of data assimilation experiments in an operational model system for the North and Baltic Sea**. Li introduced the 3D (& 2D) ocean circulation models based on BSHcmod & HBM (HIROMB-BOOS-MODEL). The HBM model system assimilates different observations including sea ice chart using PDAF. The two different DA experiments use: Ice DA + SST DA using CMEMS SST and Ice DA + SST DA using AVRHH SST. DA generally improved the results. Ensemble perturbations used should be large enough. Especially, in areas with large differences between model results and observations. This should be improved in HBM-PDAF for ice assimilation. Ice forecasts using DA need both better ice and better SST satellite data.

Alice Soccodato (EMBRC) presented an **Towards an extended biological and oceanographic observatory for marine ecosystem monitoring**, which core mission is to provide access to marine biodiversity for research and innovation purposes. The focus of the presentation was to present the activities associated with an extended genomic observatory for biodiversity monitoring and seek integration with coastal ocean monitoring, modelling and remote sensing initiatives. This initiative represents the first coordinated, long-term European Marine Omics Biodiversity Observation Network (EMO BON). EMO-BON will provide long-term baseline genomic biodiversity data, supporting biodiversity research and EOVs (Essential Ocean Variables) and EBVs (Essential Biodiversity Variables) monitoring, and ensuring continuity between the many current short-term genomics observatory projects.

Yongzuo Li (IMSG at NOAA/NWS/NCEP/EMC) presented the **Sensitivity of HAFS to MOM6 Data Assimilation initialization** when it uses ocean initial conditions from the Modular Ocean Model version 6 (MOM6), which implements a 3DVAR data assimilation scheme. NOAA/OAR/AOML/PhOD, in collaboration with NOAA/OAR/GFDL, developed a 1/12-degree regional MOM6 model that covers the transatlantic, and in collaboration with the JCSDA Joint Effort for Data Assimilation Integration (JEDI) development team, implemented a 3DVAR data assimilation interface to MOM6, using the Sea-ice, Ocean, and Coupled Assimilation (SOCA) component in the JEDI framework. MOM6/3DVAR system assimilates hydrographic observations collected from a fleet of Hurricane Gliders, quality-controlled sea surface temperature, sea surface salinity, and Absolute Dynamic Topography observations. Preliminary results based on a two-week case study of Hurricane Isaias (July 20 - August 5, 2020) show that the 3DVAR increment and analysis fields look reasonable. Future plans include developing a marine JEDI-based weakly or fully coupled ocean data assimilation system for HAFS featuring MOM6.

Paul Mattern (UCSC) presented a **A four-dimensional ensemble optimal interpolation approach for adjoint-free data assimilation in a regional biogeochemical ocean model**. The authors argue that traditional variational data assimilation techniques like 4DVar rely on tangent linear and adjoint code, which can be difficult to create and maintain for complex biogeochemical models with more than a few dozen variables. The authors propose a four-dimensional ensemble optimal interpolation (4dEnOI) implementation that uses a small ensemble, and spatial and variable localization to create reliable flow-dependent statistics. For this purpose, a simple biogeochemical model with 4 biogeochemical variables was used as a test case, presenting similar performance to reference data assimilation system based on the 4dVar technique.

Discussion and questions for the Round Table (session 3):

a) Should we establish a common framework, based on existing infrastructure (such as OOPS and JEDI) and models (NEMO, MOM6, ROMS) to enable developing communities to easily develop coastal monitoring and forecasting for new regions?

b) How can we better crowd-source ocean observations from industry?

c) How should we integrate physics and lower-trophic-level biogeochemistry with wider biology, ecosystems, genomics…?

d) What should we be observing that we aren't now for coastal applications?

e) How do we balance the observing needs of different communities? For instance, what may be most useful for monitoring may not most improve model forecasts.

f) How do we better engage with stakeholders to as to provide products that are useful? (e.g. apps, APIs, or other deliverables)?

g) For high-resolution coastal modelling, can we provide general advice on when it's best to employ nesting, or to use boundary conditions from existing products, and when to employ data assimilation?

Other points that arose, not captured in the above:

h) There is a continuing discussion in the community over how best to update phytoplankton functional types and other biogeochemical variables when assimilating chlorophyll from ocean colour. This was raised in the context of developing assimilation for the very complex DARWIN model.

i) To elaborate on question 2. Talks showed a very successful partnership with the fishing industry in New Zealand to attach temperature sensors to fishing nets. This was on a basis of mutual benefit. Many other countries would like to emulate this, but past attempts have often been unsuccessful. Learning from where it has been successful could provide benefits to the community.

j) The issue of the impact of underwater noise from shipping on marine mammals was presented in a poster. This is something that is starting to be monitored.

k) Other posters considered operationalising port-scale models, tracking harmful algal blooms, and developing and validating new biogeochemical data assimilation schemes

2.4. Session 4 - EuroSea & OceanPredict – support for the UN Ocean Decade

Eric Chassignet (Florida State University) presented **ForeSea – The Ocean prediction Capacity of the Future**. He summarised the UN Decade vision and mission to "generate and use knowledge for the transformational action needed to achieve a healthy, safe, and resilient ocean for sustainable development by 2030 and beyond". He summarised the processes the UN Decade used to identify Decade programmes and contributions and introduced ForeSea as the endorsed UN Decade programme proposed by OceanPredict.

ForeSea's vision is for a strong international coordination and community building initiative to create the ocean prediction capacity of the future, including

- Improving the science, capacity, efficacy, use and impact of ocean prediction systems
- Building a seamless ocean information value chain, from observations to end users, for economic and societal benefit

The transformative aspect of the ForeSea programme is going to be realised through the co-creation of a framework for operational oceanography enabling scientists to collaborate on all components of the ocean information value chain in support of a sustainable operational oceanography system that is responsive to user needs. ForeSea, in collaboration with partner programmes, is planning to democratise ocean data and predictions, enabling less developed countries to access and benefit from free and accessible ocean information. It also plans to engage diverse stakeholders in the co-design processes through emerging partnerships. ForeSea plans to coordinate its plans through dedicatee projects, building on the OP task teams. In co-creating a new information platform, ForeSea not only supports its easy access but will contribute to setting standards and best practices for ocean prediction.

Giovanni Coppini (CMCC) presented **CoastPredict: Empowering coastal communities to address global challenges**. He highlighted the aim to empowering coastal communities to address global challenges. He introduced the concept of the Global Coastal Ocean and the need to view regions, coastal area, estuaries and rivers in unison as part of a large connected system. He stated the importance of the coastal ocean as part of the global carbon cycle, its biological production, the natural ecosystem variability and the role of the river. He also identified gaps and possible actions for improvements, e.g.

- Standardize the essential common variables of interest
- Define the observational, modeling and data assimilation system requirements together
- Design innovative coupled/linked models (especially for underground waters links with the sea waters)
- Assess sources of uncertainties
- Develop coastal operational oceanography

The CoastPredict mission reads as the "Transformative ocean science solutions for sustainable development, connecting people and our ocean" and its main objectives include:

1. A predicted global coastal ocean
2. The upgrade to a fit for purpose oceanographic information infrastructure
3. Co design and implementation of an integrated coastal ocean observing and forecasting system adhering to best practices and standards, designed as a global framework and implemented locally.

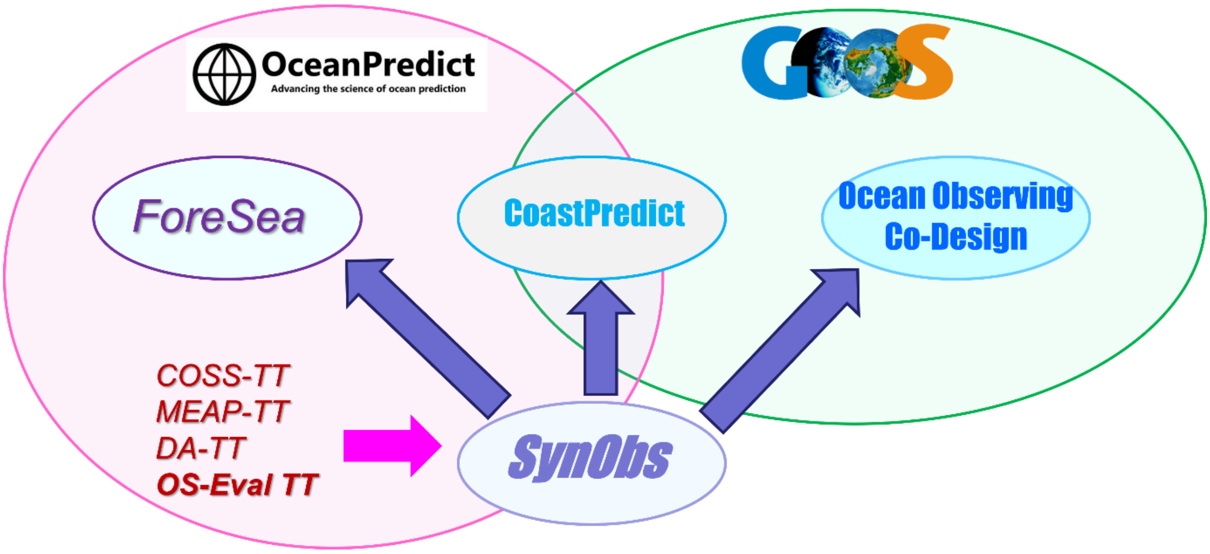
Next steps include

- The Global Coastal Ocean concept has started to be defined
- CoastPredict solutions are being devised and will be implemented worldwide

- We need to undertake these developments with the hydrological and environmental engineering community to reach the wanted SDG targets

Elisabeth Remy (Mercator Ocean International) presented **SynObs: a UN Decade project on Synergistic Observing Network for Ocean Prediction**. SynObs is a common comprehensive project supported by the three UN Decade programmes, ForeSea, CoastPredict, and Ocean Observing Co-Design *(graphic below is showing its partners and relationships within the Decade).* ForeSea and CoastPredict will collaborate with observational agencies and communities to support building a better ocean observing systems which are effective for predictions. The GOOS Decade programme Ocean Observing Co-Design (or ObsCoDe) plan to optimise the ocean observing network for various purposes.

SynObs is proposed as a UN Decade Project under the collaboration of OceanPredict task teams in generate transformative collaboration among the three UN Decade Programmes.



SynObs seeks to extract maximum benefits from the combination of various observation platforms, typically satellite and in-situ observation data, or coastal and open ocean platforms, in ocean/coastal predictions through observing system design/evaluation, and to develop assimilation methods through which synergistic effects from the combination can be drawn. It is planned to include open-ocean (global, tropical, mid-latitude, polar areas), coastal, and biogeochemical (BGC) observing systems.

SynObs will be submitted for endorsement, is now in the process of setting up its members and is exploring what partner organisation it will work with. The SynObs kick-off is planned to take place during the joint OS-Eval TT & CP-TT symposium in Tsukuba/Tokyo, 15-18 Nov 2022

Sabrina Speich (Ecole normale supérieure (ENS) – PSL) presented **Ocean Observing Co-Design: Transforming our ocean observing system assessment and design process**. She introduced the UN Decade programme on "Ocean Observing Co-Design", highlighting the programmes objective of "transforming our ocean observing system assessment and design process", by developing a more user-focused co-design process to create a truly integrated, responsive ocean observing system.

She highlighted the programme objectives and benefits, and introduced the concept of exemplars, which are anticipated to an expanding set of relevant example areas, inspired and driven by stakeholders for specific purposes of high societal relevance and need. Exemplars are expected to be dynamic, action-oriented, and interactive in nature - connecting all involved groups who are working on co-developing & co-designing a stakeholder-driven and evaluated observing system. This approach is expected to help provide a voice, visibility, and attract interest of others to support this effort and make it successful. A first set of exemplars include:

- Improving carbon data to inform climate targets, such as net zero.
- Advancing cyclone forecasting to save lives and property
- Monitoring marine heatwave impacts on biodiversity and economies
- Observing key ocean currents that drive climate and productivity
- Improving Storm Surge predictions for vulnerable communities
- Marine Life 2030: building global knowledge for local action

Next steps for the programme include Prepare Exemplar project proposals, to collaborate on a paper to present an initial summary of co-design best practices 'Co-designing Science for the Ocean We Want', to highlight the Exemplars, benefits and policy connections at the Lisbon conference and to work on ideas/priorities for additional exemplars, particularly those that move towards an integrated ocean observing system.

Adèle Révelard (SOCIB) presented **Ocean integration: how can we improve coordination between observing activities?** This presentation focused on how to improve coordination between ocean observing activities using ocean integration. The complexity of the different actors in ocean observing requires a coordinated approach to create optimal results. Ocean integration helps to optimally coordinate all these elements, so they are shaped to each other and form a coherent whole on coordinating the measurements, processing, checking and delivery of ocean observations. Successful coordination of efforts can be found for example in the establishment of the Copernicus Marine Service which was built by a large community with diverse knowledge, skills and drive, developing new systems, processes and ways of communication, supporting a complex, robust service structure.

Adèle highlighted the current challenges for ocean integration, e.g. combination of harmonized multi-platform measurements to yield sufficient vertical, horizontal and temporal resolution, to determine a multidisciplinary lists of variables and better characterize the "initial state" of oceanic forecasts. Ocean integration is seen as essential to be able to satisfy the ambitions of the UN Decade of Ocean Science and the Digital Twin of the Ocean.
Ocean integration is challenging as we are still facing finical, technical and communication issues, due to silo thinking. Ocean integration requires to transcend the traditional silos of expertise and start to build bridges to connect the silos.

One approach is not only to encourage better interaction of the involved groups but to reform the whole research assessment system by diversify research activities and develop team science & collaborations, convincing the whole community to collectively debate on how to proceed.

3. Round table

3.1. Round table panel

Sabrina Speich is Professor of Oceanography and Climate Science at the Ecole Normale Supérieure in Paris and member of the French Climate Institute Simon Laplace. She is co-chair of the ocean observations panel for climate (OOPC) and ex-officio member of GCOS. She co-chair the GOOS sponsored Ocean Observing Co-design program (ObsCoDe) at the UN Decade of Ocean Science together with David Legler from NOAA and is EuroSea WP2 co-leader together with Ananda Pascal.

Pierre-Yves Le Traon is the scientific director of Mercator Ocean International and he's in charge of program management of the Copernicus Marine Service and co-leader of the EuroSea WP4 for data assimilation simulation and forecasting together with Nadia Pinardi. He is interested in this use of in-situ and satellite observations for data assimilation systems and including their impact assessment and ocean observing design issues.

Fraser Davidson is currently the manager of the research group of Environmental Climate Change Canada for environmental and numerical prediction research, and his group researches and implements new systems for land surfaces, rivers, lakes, ocean, ice, waves and storm surge prediction, and for the operational implementation of the prediction systems his group has partnered with the Meteorological Service of Canada. Fraser co-chairs OceanPredict and spent 20 years in improving ocean prediction systems, ocean prediction applications, such as e-navigation, interface software etc. Fraser's interest for this panel discussions involves ocean prediction activity to help enable our knowledge exchange, providing benefit across the ocean information value chain.

Johannes Karstensen is a sea going physical oceanographer and scientists at GEOMAR Helmholtz Centre for Ocean Research in Kiel in Germany and is representing the co-chairs of the IOC Ocean Best Practices project (OBPS) on the panel.

3.2. Discussion topics

The discussion covered five topics:

- Ocean observations
- Ocean prediction
- Essential ocean variables (EOVs)
- Sustainability
- Ocean best practice

The purpose of this session was to dive deeper into the important aspects of these topics and how they complement what has already been discussed at the workshop in terms of the use of OSEs/OSSEs, impacts of extreme events, observing, modelling and forecasting of coastal systems, as well as how this can be taken forward under the UN Decade.

3.3. Ocean observations

How to improve both, the European and global Ocean Observing network design and governance

- **Analyse and develop a good understanding of the diverse user needs** and the value-chain that delivers information from observations to users
- **Improve and advance the integration between the observation and modelling communities**
  - on a mutual basis, including OSEs/OSSEs and other efforts from the start as an integral part of observing system design/co-design which should be planned and funded. Good examples for positive collaboration exist, e.g. AtlantOS or EuroSea, that show that when an activity is well organized and funded good progress is made.
  - Europe generally provides good example of groups already working together (e.g. Copernicus Marine, Digital twin Ocean, EMODnet, etc) to support observing system design by working closely together and trying to regularly assess the impact of observations
  - Recommendation to push for new project(s) with appropriate funding to support a step change in sustaining the observing system and organising observing system co-design on a long-term basis (incorporating serving user needs, observation/modelling community integration, including coastal processes).

How should the two communities, the observation community and the modelling community share and coordinate their work to achieve an improved and sustained ocean observing system

- **AtlantOS and EuroSea are very good examples** for how support can be directed to achieve progress. It shows that if funding is available, interconnecting and rationalising the observing system *language*, metrics and operational modelling system will drive building and running OSSEs or other evaluations of the observing system for mutual benefit. It will make partners and end users work together. However, such projects have a fixed lifespan (3 or 4 years) which limits what can be achieved long-term.
- **Share the design of OSSEs,** particularly the internal metrics used to assess the impact of the observations. Besides the improvement of forecasts or better representation of e.g. deep water masses, it is specifically important for user applications and the collaboration with end users (e.g. setting up wind farms offshore)
- **Develop a new infrastructure and capability to run OSSEs in a common framework**. This could be set up under the UN Decade umbrella and supported by the DCC (Decade Collaborative Centre) in collaboration with the UN Decade programmes (e.g. digital twin ocean) and other partners. OSEs or feedback on the impact of existing observations are already delivered by the centres contributing to Copernicus Marine.
- **Consider how blue economy or green energy companies (e.g. wind farms) use ocean information** to make their business viable as an example of how the observation community and the modelling community could collaborate better
- **Improve collaboration (between observation and modelling communities) to focus more of showing the benefit of the observing systems (use OSSEs as tools) and demonstrating its uses** for end users and sponsors (insurance industries, green energy, blue economy, policy makers, etc.) as a result of the ocean information value-chain and learn how the needs of users can be served better.
- **Consider adopting a rolling review process similar to what WMO is using** to assess current systems and services (for end users) by applying agreed performance metrics, and also taking in account the digital twin ocean concept to uniting the observations and predictions in answering to user needs and also providing feedback to the systems and services.

How to better integrate open ocean and coastal observations?

- The coastal observation community is very diverse. There are many groups dealing with a **variety of coastal systems**, and I can be an advantage for them to collaborate and identify common issues. This is already done in part in OceanPredict (via the COSS-TT) and will be addressed in CoastPredict. It will be important to highlight the **value of the observing system and work towards developing a common design**, which also would need to be adapted to the specific coast region, including identifying the key in-situ and satellite observations for constraining the coastal systems also taking into account of hydrology (rivers, etc.).
- In EuroSea the ocean has been looked at from another viewpoint (or demonstrators), focusing on coastal ocean resilience, climate and health. These demonstrators are addressed through interaction with users, whereby they are asked to provide information on local issues or indicators analysing the gaps of existing systems, and how these are related from open ocean to the local scales, also taking into account EOVs. Therefore, this discussion between open ocean and coastal ocean can also go through these indicators.
- Proposal to work towards **creating an integrated global Earth observation system** to take care of all relevant observations (atmosphere, ocean ice, wave, land, space, etc.)

3.4. Sustainability

Sustainability – how to move forward in securing the observing system long-term and understanding impacts of a degrading observing system if support is insufficient

- Current support for the **In-situ observing system** often comes from research funding serving different purposes (regional and/or national) and is **not sustained long-term**
- **Ocean Observing Co-Design (ObsCoDe)** a UN Decade programme is trying to rationalise the observing system to make it fit for purpose to respond to societal needs, involving the modelling and atmospheric community from the start (including ice, BGC, land, etc. as it evolves). The big challenge is, in the next 9 years, to set up very robust processes to build or at least start this capacity to show the funding agencies, sponsors and industry how **indispensable ocean observations are and that it is mandatory for science, the environment, the economy and society** to run a long-term sustained ocean observing system.
- Vital for success will be **effective communication**, to make sure we highlight the role of the ocean and its impact on the world and society, and that this can only be achieved through a sustained global ocean observing system underpinning ocean research, blue economy, green energy, security, etc.
- **UN Decade success** for "ocean science for sustainable development" **relies on the observing system**, but at this time it is not a fully reliable resource or a provider of ocean information long-term.
- In order to support the ocean observing system as described it is important to let the **observation and modelling community** (physics, BGC, biology, etc.) **come together to identify and agree a series of top priorities for the observing system.**
- Communication between science, society, research ministries and governments have to be improved.

- **Employ citizen science** to collect observations and to give feedback to the public on their impact, highlighting their value and benefit to the environment and society *(compare the New Zealand presentation on small obs on fishing nets and the info going back to the user).* This is not easy to do and can only evolve over time using best practice approaches. Examples of science/user interaction is done in Copernicus Marine but will need more effort to broaden this to a wider user audience.
- **Industry awareness** of ocean prediction, and specifically the importance of observation as a vital underpinning component: need to raise literacy level to make people understand how ocean prediction works and what utility it has regards decision making, etc. by providing real-time examples (e.g current or ice forecasts).
- **Considering increasing uses of the ocean observing system** to serve a wider purpose and develop stronger arguments for long-term sustainability
- Orientate information from science to users (society, industry, etc.) highlighting the improved ability of avoiding or mitigating disasters (e.g. Tsunamis, oils spills, etc.) if the right ocean observations are available

3.5. Essential Ocean Variables (EOVs)

What essential ocean variables do we really need and what best practices should be put in place to make sure that they are observed?

- Various Essential Ocean Variables (EOVs) have already been defined, but there is no full consensus on what they should be. New EOVs are anticipated in connection with BGC, ecology/biology, coastal, rivers, etc. measurements.
- There needs to be a balancing between what EOV is wanted and what is needed and what can be sustained. Also, different applications (science, industry, economy, environment, society) will need different EOVs. Also, relevant is not only which EOVs to define, but also at what frequency, at what depth and at what spatial resolution, and also how we link the global ocean observing system and central ocean variables to the coastal and local ones. It needs an ocean best practice approach and discussion between the concerned communities to discuss EOV requirements.
- Strong requirement for scientists to engage with stakeholders on the question on EOVs. This is being explored within EuroSea through specific WPs focussing on indicators. It could be helpful to consider new user linked viewpoints for EOVs for applications by focusing on points of risk or points of stress through extreme events or disasters.
- Close communication between users and scientists is vital for the development of mutual understanding of the issue and identification of requirements (very difficult without funding)
- An example of EOV implementation might be the ongoing discussions within the global climate observing system GCOS (ocean is one of three subsystems of GCOS), on defining the variables and their requirements needed for adaptation and in relation to extreme events.

3.6. Ocean prediction

How to demonstrate and support the principle that ocean prediction will benefit from an improved ocean observing system and how to show it?

- Need to **show** we have a supported structure in place, which we call the ocean information **value chain**, that provides details about the interconnectedness of the value-chain components and their interdependence. This would include also the **feedbacks and impacts of the value chain components and each other and on the societal benefit**.
- Develop an **architecture**, like the DCC, that supports the value chain components in this framework, i.e. supporting observations, predictions, services, etc. and their communication and interactions for mutual benefit, including connections with the UN Decade programmes, like ObsCoDe and CoastPredict.
- This **collaboration of systems, programmes and projects** will allow to set up experiments (OSEs or OSSEs) and intercomparison (class 4 evaluations) on a long-term basis to provide feedback on the system's performance.
- Consideration to work on **traceability** on the use and benefit of ocean observing system measurements in the forecast and prediction systems. It will be hard to set up but would be a useful tool for showing the importance of observations for the predictions. This will also allow **better quality control and performance assessments** for the forecast products.
- **Generally better coordination** and communication is needed between the prediction and observation community
- Communicate **uncertainties of the observing system** and their dependants and their dependencies and include this as a best practice activity.
- Highlight the different aspects of interaction between an observation. Observations are not only used for analyses or predictions, but also for **model and system validation and improvement**.

How does the ocean observing and forecasting systems deal with the blended maturity of its components (physics, BGC, biological, ecological…) and when is our understanding good enough of the mature aspect and we can put effort towards the less advanced aspects?

- **key challenge** for the next decade is how we move forward with the **biogeochemistry and biology** using a joint approach working together
- Need to address this aspect of **advancing capacity as an important step in improving all associated systems**, even though it adds a lot of complexity.
- demand now is for **local level** focus, both for adaptations and end use, with higher resolution and more processes monitored and forecasted
- **In-situ observations should also provide uncertainty estimates** (as satellite observations do), and provide assistance on question about their quality *(maybe the assimilation community could assess observation value by using statistics of the data assimilation system via the error covariance based on what data are assimilated and interact with the observation teams)*
- Consider **learning from the atmospheric side** in approaching new challenges avoiding mistakes, and provide comprehensive ocean information, including communicating probabilities and uncertainties, to make a product better understood
- All observations provided should be documents via **metadata** (e.g. quality information, etc.) and be supplied through certified infrastructures, including data provided via citizen science.

3.7. Ocean Best Practice

What is Ocean Best Practice and how should it be applied in ocean observing and ocean prediction?

- The IOC-OBPS is a global, sustained system comprising technological solutions and community approaches to enhance management of methods as well as support the development of ocean best practices.
- As a project IOC-OBPS is identifying the best methodologies that are repeatedly producing superior results relative to other methodologies with the same objective, which should, once agreed, being adopted and employed by multiple organizations.
- Ocean Best Practice outcomes will be provided by a group or collaboration of experts with the relevant knowledge, to be able to advice on the latest best methodologies by considering all currently used standards. This also includes regular checks on new technologies and processes to update best practice advice as it develops.
- Proper and wide-spread application of best practice methods would deliver a solid basis for comparison of output and outcomes, and will be very important for deriving uncertainty information for e.g. measurements.
- Ocean Best Practice will
    - be a binding element between different part of the ocean information value-chain
    - provide comparable methods and process for collaboration and comparisons
    - provide a useful link between observations and models
    - enhance the provision of information on observation quality
    - support assessment of impact of observations
    - help to carry out useful ocean observing system simulation experiments (OSSEs)
    - increase capacity building and the developing common metrics between the observing and prediction system communities
- Setting up best practices will pull the community together to develop best practices and also to apply them

How can Ocean Best Practice be practically exploited in a bottom-up approach, and what are exemplars of that?

- Need incentives to foster the dialogue on using best practice at home and in exchange with other communities
- Need leading figures who drive the identification and implementation of best practices from the beginning to completion

Appendix

Appendix 1: Workshop agenda

Wed, 29 June 2022 – Day 1

Times give and local times (BST)

Registration and Introduction	8:00 – 9:30		
Session 1 presentations and discussion	9:30 – 10:55	11:20 – 13:00	14:30 – 15:50
Session 2 presentations	16:26 – 17:25		
End of day 1	17:30		

Thu, 30 June 2022 – Day 2

Times give and local times (BST)

Session 2 presentations and discussion (contd.)	9:00 – 10:50	11:20 – 12:20	
Session 3 presentations and discussion	12:20 – 13:05	14:00 – 15:40	16:10 – 17:30
End of day 2	17:35		

Fri, 1 July 2022 – Day 3

Times give and local times (BST)

Session 4 presentations and discussion (contd.)	9:00 – 10:15	10:45 – 11:25
Round table discussion	11:45 – 13:00	
End of day 2	14:00	

Appendix 2: Oral presentations

Session 1 oral presentations - OSEs & OSSEs in support of observing system design

No	First name	Surname	Affiliation	Title
1.1	Joao Marcos	Azevedo Correia de Souza	MetOcean Solutions, a division of Meteorological Service of New Zealand	Assimilation of fishing vessel derived observations into an operational ocean forecast system
1.2	Peter	Oke	CSIRO	Using Argo data for ocean reanalysis: some pitfalls to avoid
1.3	Florent	Gasparin	IRD/LEGOS, Toulouse	Identifying constrained scales by ocean observations in global ocean analyses
1.4	Biswamoy	Paul	Indian National Centre for Ocean Information Services, Hyderabad, India	A study of forecast sensitivity to observations in Bay of Bengal using LETKF (mp4, recorded presentation)
1.5	Ali	Aydogdu	Fondazione CMCC	Assimilation of glider profiles in the Mediterranean Analysis and Forecasting System MedFS
1.6	Jennifer	Waters	Met Office	Assessing the impact of assimilating Total Surface Current Velocities in global ocean forecasting systems
1.7	Robert	King	Met Office	The impact of upcoming wide-swath and along-track altimeter constellations in global and regional ocean forecasting systems
1.8	Davi	Mignac Carneiro	Met Office	Improving the Met Office's Forecast Ocean Assimilation Model (FOAM) with the assimilation of satellite-derived sea-ice thickness data from CryoSat-2 and SMOS in the Arctic
1.9	Eric	Chassignet	Florida State University	Towards a next generation AMOC observing system

1.10	Bàrbara	Barcelo-Llull	IMEDEA (CSIC-UIB), Spain	Evaluating in situ sampling strategies for SWOT satellite validation
1.11	Andrew	Moore	University of California Santa Cruz	Forecast Sensitivity-based Observation Impact (FSOI) and Forecast Sensitivity to Observations (FSO) in an Analysis-Forecast System of the California Current Circulation

Session 2 oral presentations - Extreme marine events – observing, modelling, forecasting and user accessibility

No	First name	Surname	Affiliation	Title
2.1	Hyun-Sook	Kim	NOAA/AOML	Numerical study of the upper ocean response to Hurricane Laura
2.2	Matthieu	Le Henaff	University of Miami/CIMAS-NOAA/AOML	Ocean OSSEs and OSEs for hurricane applications
2.3	Emanuela	Clementi	CMCC	The September 2020 Medicane Ianos predicted by the Copernicus Mediterranean Forecasting systems
2.4	Samuel	Adiprabowo	Badan Meteorologi Klimatologi dan Geofisika	Utilization of water-level measurement and analysis under extreme conditions: Case Study Severe Tropical Cyclone Seroja
2.5	Ronan	McAdam	CMCC	Seasonal forecasting of surface and sub-surface marine heat waves: a global validation and comparison
2.6	Hugo	Dayan	Laboratoire de Météorologie Dynamique/IPSL, Ecole Normale Supérieure, CNRS, Paris, France	Marine Heat Waves in the Mediterranean Sea: an assessment from the surface to the subsurface to meet national needs
2.7	Mélanie	Juza	SOCIB	The “Sub-regional Mediterranean Marine Heat Waves” monitoring and visualization tool

2.8	Coline	Poppeschi	Ifremer, Univ. Brest, CNRS, IRD, Laboratory for Ocean Physics and Satellite remote sensing (LOPS), IUEM, 29280 Brest, France.	Coastal and regional marine heatwaves and cold-spells in the Bay of Biscay and the English Channel
2.9	Louise	Darroch	National Oceanography Centre	The use of Internet of Things sensors and ERDDAP in a nowcast hazard alerting coastal flood system

Session 3 oral presentations - Coastal Ocean: Modelling, observing system design and product utility

No	First name	Surname	Affiliation	Title
3.1	Julie	Jakoboski	MetOcean Solutions (Meteorological Service of New Zealand)	Crowd Sourcing Ocean Observations for Ocean Forecasting Data Assimilation
3.2	Nelly Florida	Riama	The Agency for Meteorology Climatology and Geophysics Republic of Indonesia	Improvement of Ocean Forecasting System for Enhancing Marine Information in Maritime Continent mp4, recorded presentation
3.3	Christopher	Stokes	Coastal Marine Applied Research, University of Plymouth.	Sources of uncertainty in coastal overtopping forecasts: observation and modelling of waves, water levels, and discharge
3.4	David	Ford	Met Office	Towards adaptive monitoring of coastal oceans integrating marine robots and operational forecasts
3.5	Emma	Reyes Reyes	SOCIB, Balearic Islands Coastal Observing and Forecasting System, Spain	European high-frequency radars as a valuable asset to validate and improve ocean prediction in coastal areas.
3.6	Xin	Li	German Federal Maritime and Hydrographic Agency (BSH)	A comparison of data assimilation experiments in an operational model system for the North and Baltic Sea

3.7	Alice	Soccodato	EMBRC	Towards an extended biological and oceanographic observatory for marine ecosystem monitoring
3.8	Yongzuo	Li	IMSG at NOAA/NWS/NCEP/EMC	Sensitivity of HAFS to MOM6 Data Assimilation initialization
3.9	Jann Paul	Mattern	University of California Santa Cruz	A four-dimensional ensemble optimal interpolation approach for adjoint-free data assimilation in a regional biogeochemical ocean model

Session 4 oral presentations - EuroSea & OceanPredict – support for the UN Ocean Decade

No	First name	Surname	Affiliation	Title
4.1	Eric	Chassignet	Florida State University	ForeSea – The Ocean prediction Capacity of the Future
4.2	Giovanni	Coppini	CMCC	CoastPredict: Empowering coastal communities to address global challenges
4.3	Elisabeth	Remy	MOI	SynObs: a UN Decade project on Synergistic Observing Network for Ocean Prediction
4.4	Sabrina	Speich	ENS – PSL / IPSL	Ocean Observing Co-Design: Transforming our ocean observing system assessment and design process
4.4	Adèle	Révelard	SOCIB	Ocean integration: how can we improve coordination between observing activities?

Appendix 3: Poster presentations

Session 1

1.1	Théo	Brivoal	Mercator Ocean International	A new kilometric resolution zoom over the North-East Atlantic based on NEMO 4.2 (IMMERSE) version
1.2	Matthew	Carr	SAEON	Operational ocean modelling within South Africa; a downscaling approach
1.3	Gianpiero	Cossarini	National Institute of Oceanography and Applied Geophysics - OGS	Assessing the impact of BGC-Argo data assimilation into the Copernicus operational model system of the Mediterranean Sea biogeochemistry
1.4	Danni	Du	University of Colorado, Boulder	Assessing the Impact of Ocean In-situ Observations on MJO Propagation across the Maritime Continent in ECMWF Subseasonal Forecasts
1.5	David	Ford	Met Office	Assimilating synthetic Biogeochemical-Argo and ocean colour observations into a global ocean model to inform observing system design
1.6	Carine	G. R. Costa	MetOcean Solutions, part of MetService New Zealand	Improving ocean forecasts with subsurface data assimilation in the northeast shelf of New Zealand
1.7	David	Gwyther	University of New South Wales	OSSEs reveal subsurface temperature observations improve estimates of circulation and heat content in a dynamic WBC
1.8	Hyun-Chul	Lee	IMSG at NOAA/NWS/NCEP/EMC, USA	An Evaluation of Impacts from Ocean Observing Systems in NCEP GODAS in the Tropical Ocean
1.9	Elisabeth	REMY	Mercator Ocean International	Leveraging the multi-system glider data assimilation experiments within EuroSea to the international level
1.10	Robert	Weller	Woods Hole Oceanographic Institution	Ocean Reference Stations: Long-term, open ocean observations of surface meteorology and air-sea fluxes are an essential component of the observing system

Session 2

2.1	Louise	Delhaye (on behalf of Matthias Baeye, RBINS)	RBINS, Belgium	Acoustic and optical turbidity response to altering particle size distribution during extreme events
2.2	Matías	Dinápoli	UMI IFAECI/CNRS-CONICET-UBA	Improving the short-range forecast of storm surges in the Southern-West Atlantic Continental Shelf using EnSRF data assimilation

2.3	Chaimaa	Jamal	Hassan II University of Casablanca, Faculty of Sciences BenSik	Spatial and temporal variability of the coastal upwelling activity of the Moroccan Atlantic coast, 1994- 2020
2.4	Diego	Pereiro	Marine Institute	An observing and modelling system to monitor and forecast extreme marine events
2.5	Oscar	Reyes-Mendoza	CONACyT-ECOSUR, Mexico	Marine Heatwaves and Marine Cold-spells on the Yucatan Shelf-break Upwelling region and its relationship with Red tide
2.6	Amr	Salama	University of Bologna, Italy.	Past and future changes in the Benguela upwelling system with global warming
2.7	Claudia G	Simionato	IRL IFAECI/CNRS-IRD-CONICET-UBA, Buenos Aires, Argentina	Development and implementation of an operational ocean sea level and waves forecasting system at the Southwestern Atlantic Continental Shelf
2.8	Anna	Teruzzi	OGS, Italy	Effectiveness of an operational forecasting system to predict anomalous 2022 water formation and intense bloom event in the southeastern Mediterranean Sea

Session 3

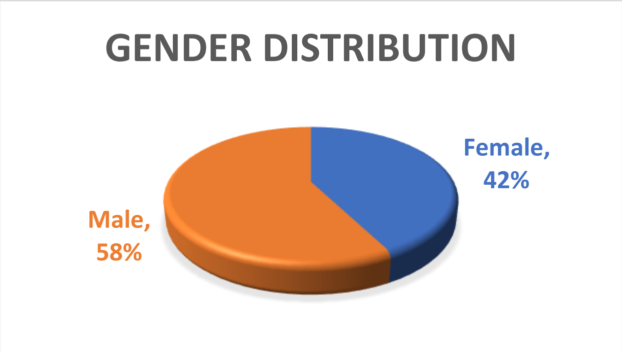
3.1	Mauro	Cirano	Federal University of Rio de Janeiro (UFRJ/REMO)	Ocean Forecast and Analysis Systems evaluation based on the NOAA AX97 High-Density XBT transect
3.2	Adam	Drozdowski	Fisheries and Oceans Canada	Progress towards operationalization of six port scale models on the east and west coast of Canada
3.3	Flávio	Martins	CIMA, University of Algarve (UAlg)	Coastal Simulation Experiments Supporting NAUTILOS New Observing Methodologies
3.4	Artash	Nath	Founder, Monitor My Ocean	Monitoring Underwater Anthropogenic Noise Levels in Global Oceans: Using COVID-19 Lockdown as Baseline
3.5	Yolanda	Sagarminaga	AZTI	Tracking HABs' origins in the eastern Cantabrian Sea with coastal models and satellite imagery
3.6	Anju	Sathyanarayanan	AWI	Influence of data assimilation on a biogeochemical ocean model for the North and Baltic Seas
3.7	Jozef	Skakala	Plymouth Marine Laboratory	Introducing ensembles to the biogeochemical component of the operational system for the North-West European Shelf

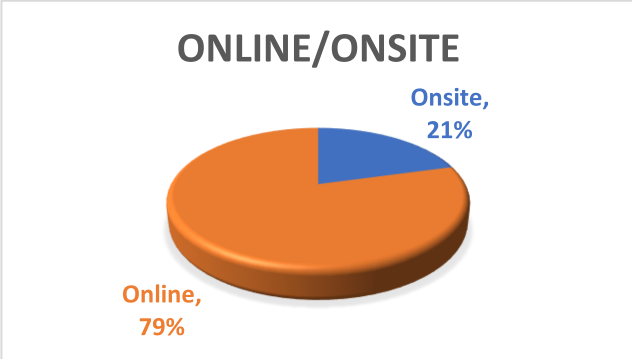
Session 4

4.1	Boyko	Doychinov	Balkan and Black Sea Business Institute	Involvement of small-scale fishermen in the process of monitoring and collecting primary data in the coastal waters of the Black Sea
4.2	Anna	Katavouta (on behalf of Jo Hopkins, NOC)	National Oceanography Centre, UK	FLAME: Future Coastal Ocean Climates
4.3	Stavriana	Neokleous	University of the Aegean	Ranking of the coastal areas of Cyprus regarding their vulnerability in pollution episodes using GIS and multiple-criteria analysis.

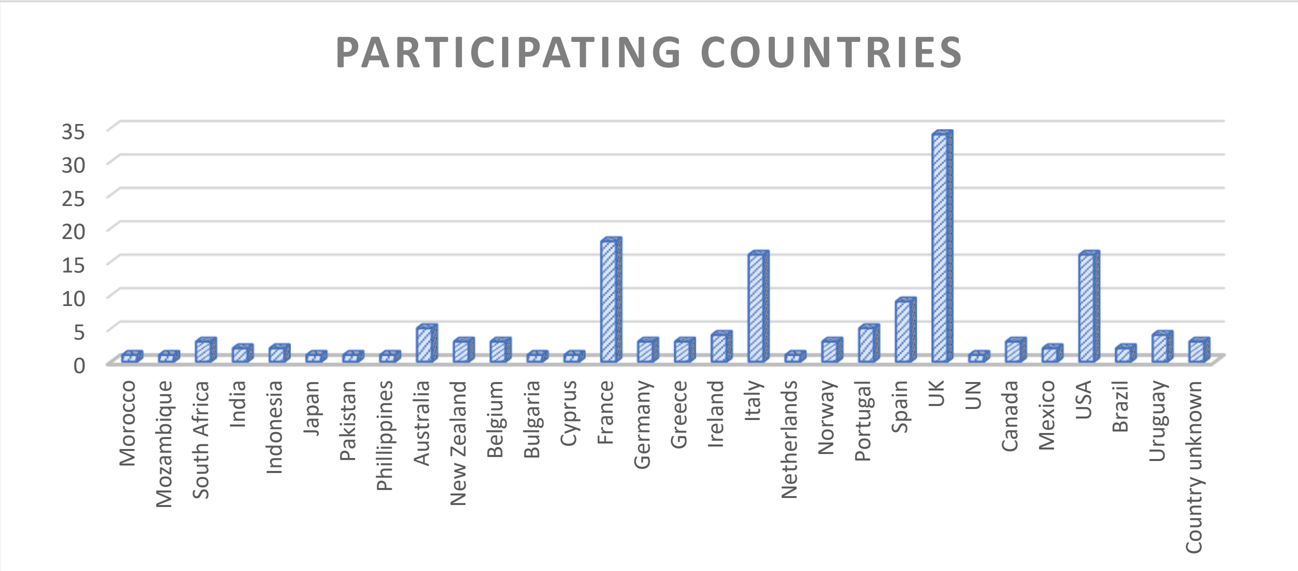
Appendix 4 – Workshop statistics

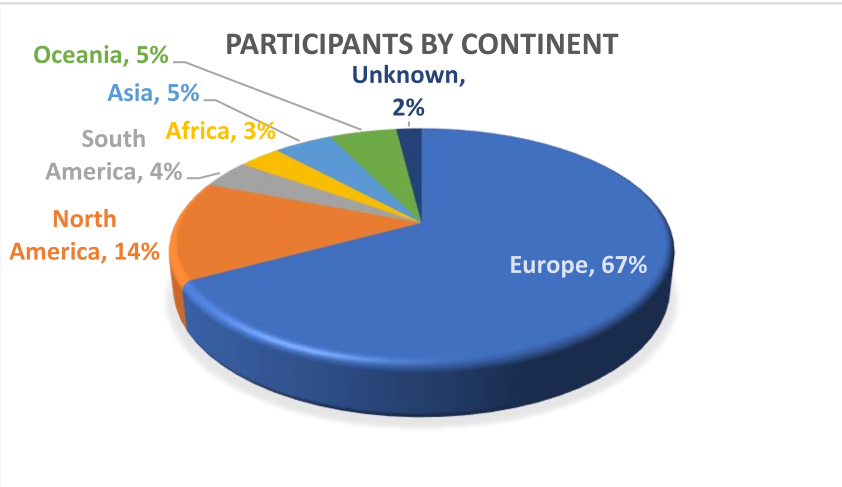
The number of actual participants was 152.



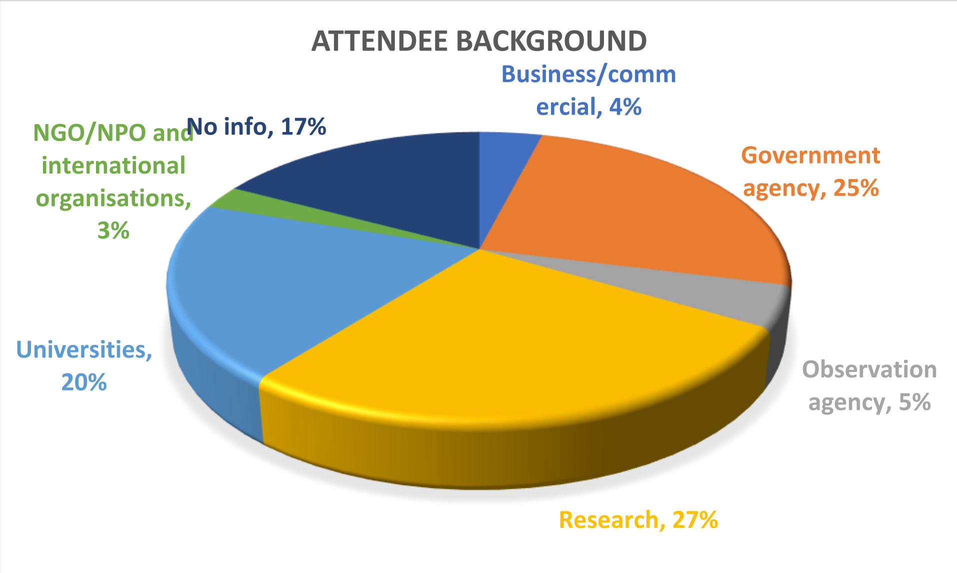


Distribution by country/ continent





Representation by organisation background



Links with EuroSea (some overlaps)