Observing System Design through Impact Studies: Developments in Ocean/coupled Model Systems

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Outline

• Ocean/coupled monitoring systems and Observing System Evaluation studies

• Examples of OS-Eval studies
  • In situ and satellite impact assessment

• Lesson learnt and recommendations
The quality of the ocean analysis and forecasts highly rely on the observations used to constrain the ocean circulation. They are also crucial for their evaluation.

- need of strengthening the link between the ocean observing community and the monitoring and forecasting centers.
A close collaboration between the ocean Monitoring and Forecasting Centers (MFC) with the data providers is crucial:

- To define suitable observation products for operational oceanography
- To ensure the best use of observation information
- To inform on the observation use and report on their impact on analysis and forecasts
- To help designing observing system evolution to improve analysis and forecasts
- To advocate for the observation network sustainability

- MFCs from CMEMS and OceanPredict are already involved with the observing community/agencies and begin to be recognized as part of the full value chain from the observations to users.
- Requirement documents on observing system evolution and data provision (level, QC, error estimate, timeliness, traceability,...) are produced: CMEMS requirements for the evolution of the Copernicus Satellite and in situ observations, Sea Surface Salinity requirements from GOV, ...
- MFCs need to be involved in evaluation of the present network and design of future / evolution of the GOOS component and products to be assimilated. This begins to be recognized as a best practice.
Ocean Predict

✓ represents a third phase of GODAE with full integration of GODAE and GOV achievements and expertise
✓ will contribute to a value chain from observations, data and information systems, predictions and scientific assessments, to end users.

The Ocean Predict Observing System Evaluation (OS-Eval) Task Team:
• Collect, synthetize and perform impact studies of GOOS and ROOS on Ocean Predict reanalysis and forecasts.
• Provide consistent and scientifically justified requirements and feedbacks to agencies in charge of Global and Regional Ocean Observing Systems.
Methods and best practices for OSEval studies

Impact assessment of the **present** observing networks in ocean analysis and forecasts

- Dedicated simulations with operational systems (OSEs: Observing System Evaluations),
- Observation sensitivity diagnostics (DFS, SRF, FSOI,...)

Impact assessment of the **future** observing networks in ocean analysis and forecasts

- Dedicated simulations with improved version of operational systems (OSSEs: Observing System Simulation Experiments);
- Design optimization

Some methods and best practices inherited from the atmospheric community.

G. Halliwell et al., 2014: Rigorous Evaluation of a Fraternal Twin Ocean OSSE System for the Open Gulf of Mexico:
[https://doi.org/10.1175/JTECH-D-13-00011.1](https://doi.org/10.1175/JTECH-D-13-00011.1)
Impact of the number of altimeters on the quality of Mercator Ocean global ocean analyses and forecasts (CNES).

Forecast skill evolution in days when assimilating 1 to 4 altimeters.

Steady improvement of forecast skill with respect to the increasing number of altimeters in the constellation.

7-day sea level forecast error reduction: 4 altimeters versus 1 altimeter assimilated

Hamon et al., J. Atmos. Tech. (2019)
Impact of a constellation of 2 wide-swath altimetry missions in a regional data assimilation system (OSSE).

(Noise level requirements were less stringent as for SWOT)

OSSE1 = 3 altimeters (SAR mode)
OSSE2 = 3 alt + 1 Wide Swath ($\text{error}_{\text{Karin}} \times 4$)
OSSE3 = 3 alt + 2 Wide Swath ($\text{error}_{\text{Karin}} \times 4$)
OSSE4 = 3 alt + 2 Wide Swath ($\text{error}_{\text{Karin}} \times 2$)

- Considering a constellation of 3 nadir (SAR) and 2 wide-swath altimeters, ocean analysis errors are reduced by up to 50% with respect to 3 nadir constellation.

Bonaduce et al., Ocean Science (2018)
A Mercator Ocean / ESA study
Impact of deep-Argo is evident on T and S in the 2000-4000m layer, the Southern Ocean remains undersampled.

Compared with Argo4000, Argo6000 significantly reduces biases in the 4000-6000m layer. (Gasparin et al., J. Climate, 2019)

Temperature and salinity profiles of error reduction in % of the DEEP exp. as compared with the BACKBONE experiment, relative to the Nature Run fields.

Gasparin et al. (2019) Requirements for an integrated in situ Atlantic Ocean Observing System from coordinated OSSEs. Frontier in Marine Sciences.
0-300m averaged RMSD of temperature (°C) between the regular ODA runs and OSE without assimilating tropical mooring buoys

Evaluation results inevitably depends on the prediction system.

- There is considerable dependency in the seasonal forecasts (mainly due to large systematic biases).
- Also, there is significant dependency in the ocean reanalysis fields (due to differences of models and data assimilation methods).
- Multi-system efforts are indispensable to get reliable evaluation.
Present and future requirements both for in-situ and satellite observations (Sentinels) have been defined. Based on impact assessment (OSE/OSSEs) and expert analyses.
OceanObs’19 Community White Paper on OS-Eval

Review papers:


- Oke et al. (2015a,b). J. of Oper. Oceanogr. (In the GODAE OceanView Special Issue.)
Recommendations for future assessment and design studies

1. **Agree on standards and best practices** on the way to perform OSEs (e.g. data denials, DFS/IC, FSOI) and OSSEs (e.g. NR and AR choices, calibration with OSSEs).

2. Define **metrics** for observing system evaluation **taking into account user & application needs** (also for designing the options to evaluate): observing systems are multi-purpose (climate, ocean services, ocean health) (GOOS).

3. Improve the robustness of the results by moderating system-dependency with **multi-system evaluation** and **re-assess regularly** the observation impact to follow the system evolutions.

Assessment of the observing networks and design studies is still challenging/at an early stage:

- in **Polar Oceans**,
- in **coastal regions** dominated by high frequency/small scale processes,
- for **BGC to ecosystem** monitoring and forecasting systems,
- in complex **coupled systems** (ocean/wave/atmosphere/ice/hydrology – BGC/ecosystem).
Key messages

- Enhanced communication and coordination between modelling/data assimilation experts and observation/network experts is essential for a proper design and interpretation of OS-Eval, especially to extract compelling messages on the ability of the ocean observing system to resolve processes having different temporal and spatial scales.

- OS-Eval (OSSE/OSE/...) require dedicated infrastructures and resources. It is essential to strengthen the capabilities of operational and climate centres to assess the impact of present and future observations to guide observing system agencies but also to improve the use of observations in models.

- OceanPredict OS-Eval TT would like to implement a standard to report on observation impacts to support decision-making related to the design of the observing system and to provide quantitative demonstrations of data impacts.

- OS-Eval activities should be consolidated. Cooperation with international partners (e.g. OceanPredict, GOOS/ROOS, WMO, IOC...) is essential.