MERCATOR OCEAN INTERNATIONAL

# How well does interoperability between observation and prediction systems function? Example satellite observations

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# Outline

Satellite Oceanography and Ocean Prediction

Use of satellite observations in models

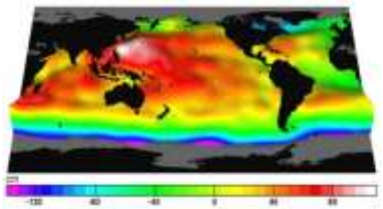
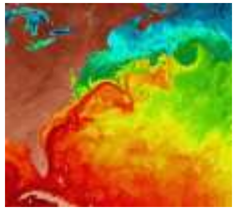
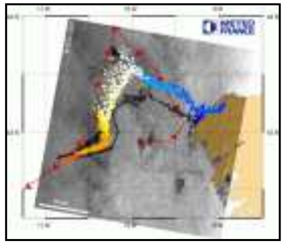
Interoperability between satellite and prediction systems

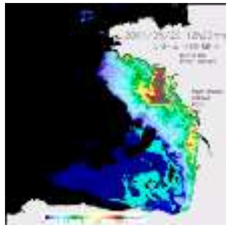
The Copernicus Marine perspective

Conclusions

## *Unique contribution of satellites*

- ❑ Provide key parameters / essential variables (sea level and ocean currents, SST, SSS, ocean colour, sea ice, waves, winds) needed to constrain ocean models through data assimilation and/or to validate them
- ❑ Global, real time and high space and time (repeat) resolution.
- ❑ Only means to observe globally the mesoscale variability
- ❑ Need to be complemented by in-situ observing system (ocean interior)



# Data assembly and data processing issues for ocean prediction

**The quantity, quality and availability of data sets and data products directly impact the quality of ocean analyses and forecasts.**

**Key satellite data processing needs for ocean prediction**

- **Real time (analyses and forecasts) and delayed mode/reprocessing (reanalyses) (incl. QC)**
- **more effective data assembly from multiple sources**
- **more timely data delivery**
- **improvements in data quality**
- **better characterization of data errors**

# Use of satellite data in models

Differences in quality real time versus delayed mode data

Reprocessing issues : different types of reprocessing (e.g. climate/non-climate). Assembling the best data sets for a reanalysis is a major and essential step.

Error characterisation : essential for data assimilation

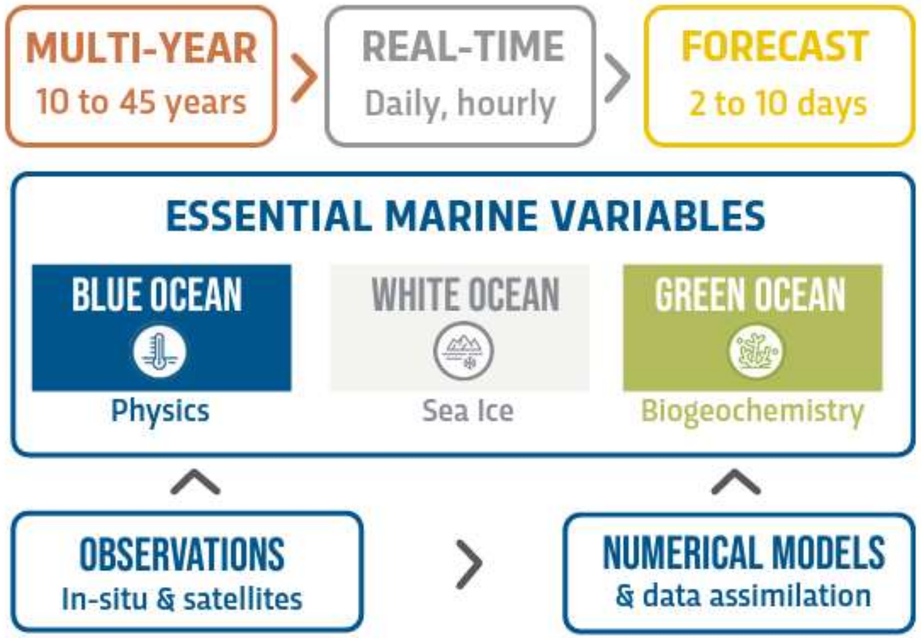
Processing steps and levels (from 1 to 4) before data assimilation

- ✓ It is <u>much</u> better <u>in theory</u> and for advanced assimilation schemes to use raw data (level 2 or in some cases level 1 when the model can provide data needed for level 1 processing). Data error structure more easily defined and less complex.
- ✓ In practice, not always true. Some high level data processing (e.g. correcting biases or large scale errors, intercalibration) is needed as it cannot be easily done within the assimilation systems.
- ✓ Examples : use of SST/SSS maps (L4), use of intercalibrated along track SSH data from altimeters (L3), use of ocean colour data rather than optical measurements (radiance), use of SSS data rather than brightness temperatures, etc…
- ✓ When feasible better to assimilate level 2 or level 3 data (or even level 1).

# Interoperability between satellite observing and ocean prediction systems: ingredients

- Operational interfaces with satellite ground segments from different satellite agencies
- Homogenization of multiple data sources, intercalibration, standardized QC (real time & delayed mode)
- Organize the feedback to satellite ground segments (data quality, processing requirements, timeliness, new products)
- Organize the feeback to satellite agencies.   Impact assessment.
- Preparing future missions :  requirements from integrated system perspectives

# Copernicus Marine Perspective




marine.copernicus.eu

# Copernicus Marine : Applications and Users

*A wide range of applications (environment, society, economy)*
*Support to EU policies (Green Deal)*

**55,000**
subscribers
(+ 20% per year)

| ENVIRONMENT | | | | SOCIETY | | | | ECONOMY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| POLAR ENVIRONMENT MONITORING | MARINE CONSERVATION & BIODIVERSITY | OCEAN HEALTH | CLIMATE & CLIMATE ADAPTATION | POLICIES & OCEAN GOVERNANCE & MITIGATION | EDUCATION, PUBLIC HEALTH & RECREATION | SCIENCE & INNOVATION | EXTREMES, HAZARDS & SAFETY | COASTAL SERVICES | MARINE FOOD | NATURAL RESOURCES & ENERGY | TRADE & MARINE NAVIGATION |
| Arctic policy, MSFD, MSP, WFD, Habitat Directive, Bird Directive, Natura 2000, the Convention on Biological Diversity, WMO/UNFCCC, IPCC, the Paris agreement / global stocktake, SDG 13, 14, 15 | | | | Arctic Policy, MSFD, MSP, WFD, IOG, The Sendai Framework for Disaster Risk Reduction, SDG 1, 2, 3, 4, 5, 6, 7, 9, 11 and 16, 17 | | | | Space policy, Flood Directive, Green Deal, Energy Policy, Air Quality Directives, SDG 8, 9, 10, and 12, 17 | | | |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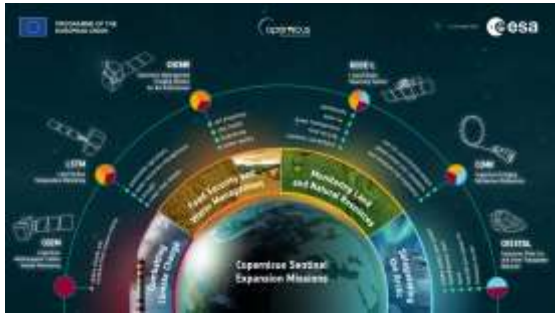
# The essential role of satellite observations in Copernicus Marine

The Copernicus Marine Service is highly dependent on satellite observations (Sentinels, contributing missions). 80% of Copernicus Marine products depends on them.

Copernicus Marine role : operational interfaces (ESA, Eumetsat), feedbacks, requirements (present & future) and advocacy

- From integration of S1, 2, 3 A&B in Copernicus 1 to S6 A&B and S1, 2, 3 C&D in Copernicus 2.
- Preparing for Sentinel Expansion Missions.
- Support the EC for NG Sentinel mission design (post 2030).



# Working with satellite agencies / Copernicus Marine

**Day to day operations. Regular interactions with ESA and EUMETSAT in charge of ground segments:**

- High level meetings to provide updates on the status of Sentinels and the Ground-Segments. This ensures an effective coordination of the data flow and a quick reaction to emerging issues.

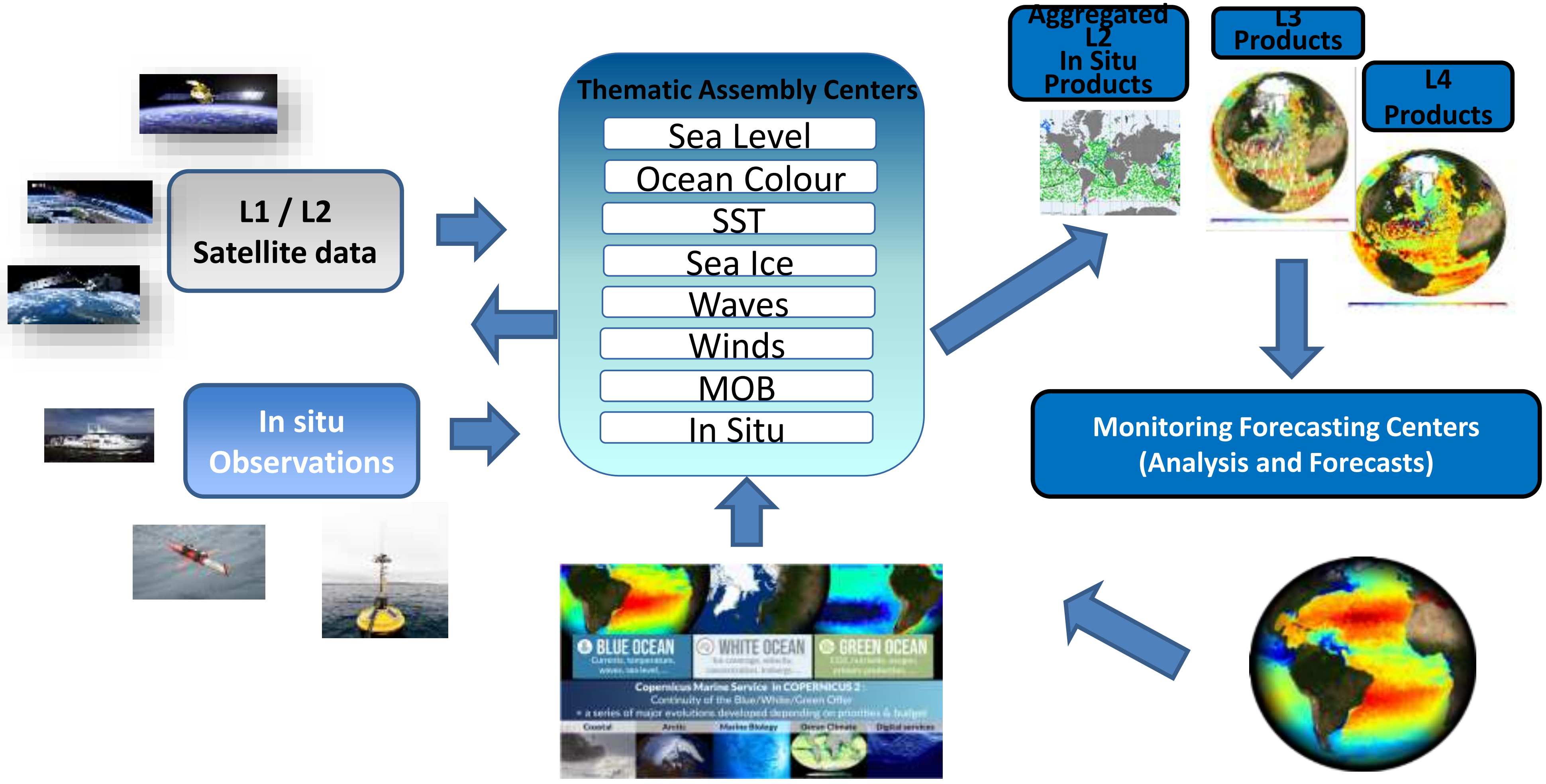
- Ad-hoc or more technical meetings are organized to allow Copernicus Marine production centers to express their needs and provide feedback on data quality and availability.

- Participation to technical Sentinels reviews and quality meetings

**Evolution of the Copernicus Space component.** MOi / Copernicus Marine role is to provide user requirements through the European Commission and interact with ESA on options and trade offs from the Copernicus Marine user perspective.

# Expert centers in charge of satellite observations

## Copernicus Marine Service Architecture : role of Thematic Assembly Centers



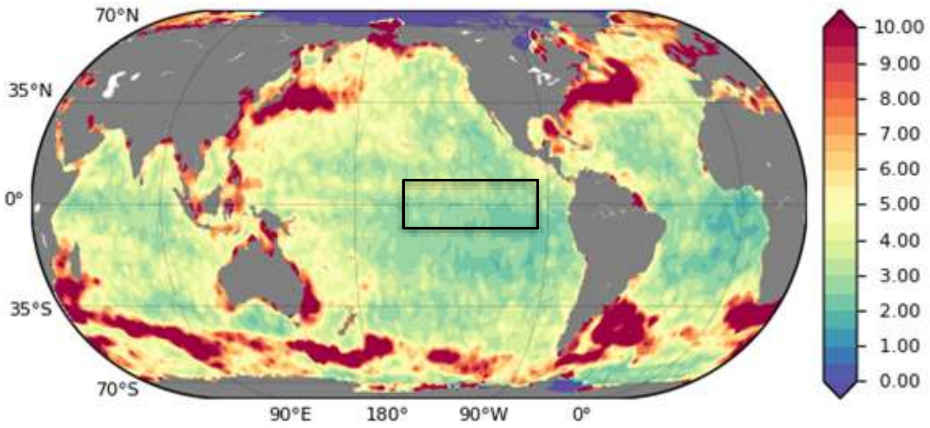
# Observation impact studies

Assessing the impact of observations assimilated in the Copernicus Marine analysis and forecasts is important to:

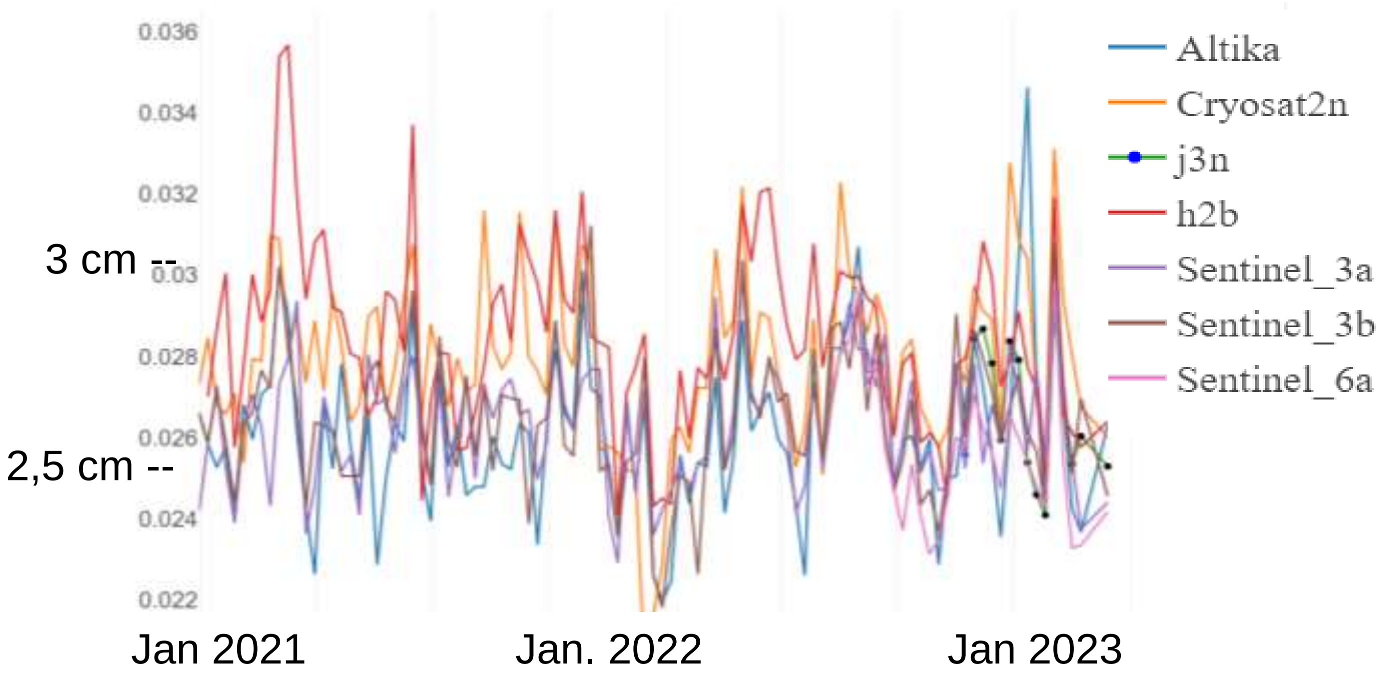
- **Understand how each type of observations are constraining the model forecasts** toward a more realistic estimate
- **Improve the use of observations** and their error specification in the DA system
- **Help designing the evolution of the observation network.**

This generally requires running specific and often heavy simulations.

# Monitoring the real time system performance in SLA




*Statistics on S3-B: Std Dev(Obs-Ana) for the global 1/12° system (Dec. 2020-Nov. 2021)*



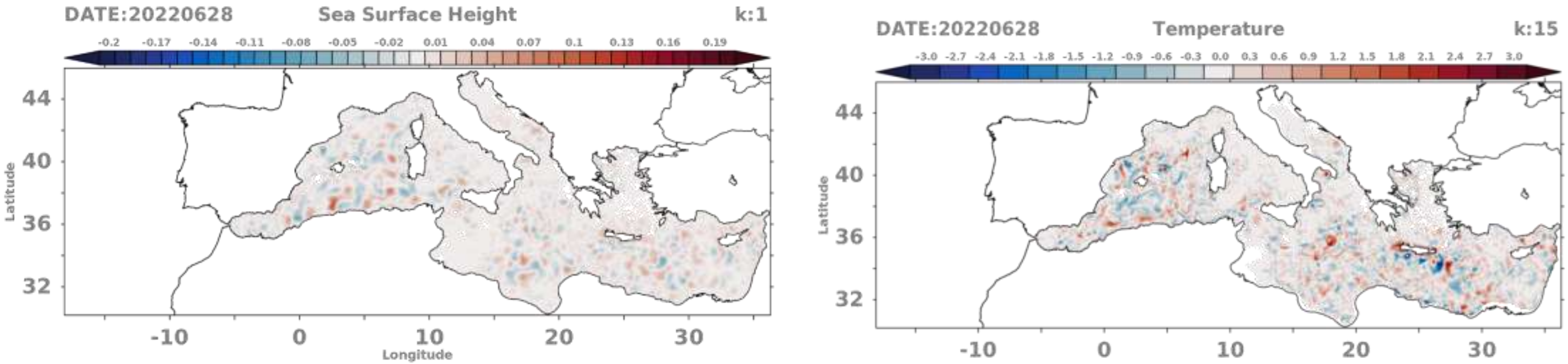

*SLA RMS misfits (Obs - Ana) in the Nino3 box*

- Largest RMS in energetic regions (WBC, ACC) dominated by meso scale activity
- In low energetic regions, the analysis error in SLA is close to the observation error,
- HY2 B et C2n has the higher RMS misfits as S6A, S3A, S3B and AltiKa has lower analysis error.

**E. Remy et al. , MOi**

# Impact of S6 on the Mediterranean Sea analysis

**E. Clementi, CMCC**




*Map of Sea Surface Height difference (in metres) and Temperature at 45 m depth on 28 June 2022 between the experiment with and without S6A assimilated*

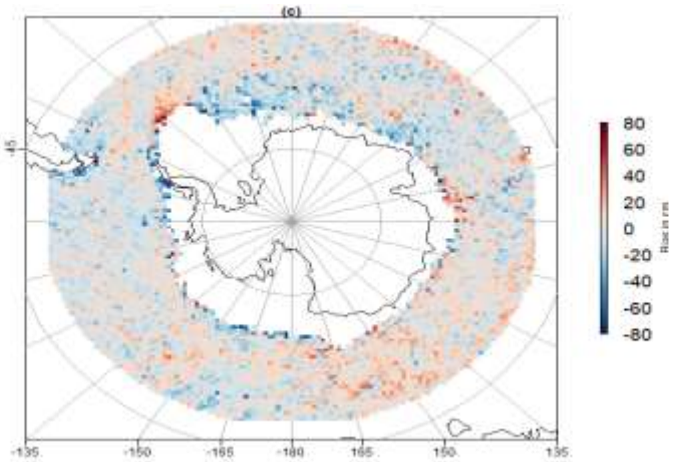
- ❑ Differences in meso-scale structures are found between the 2 simulations in SSH, associated with temperature change in the ocean interior
- ❑ Slight improvement of the SLA misfits to other altimeter observations

# Performance in Southern Ocean and complementary use of SWIM and SAR directional wave spectra

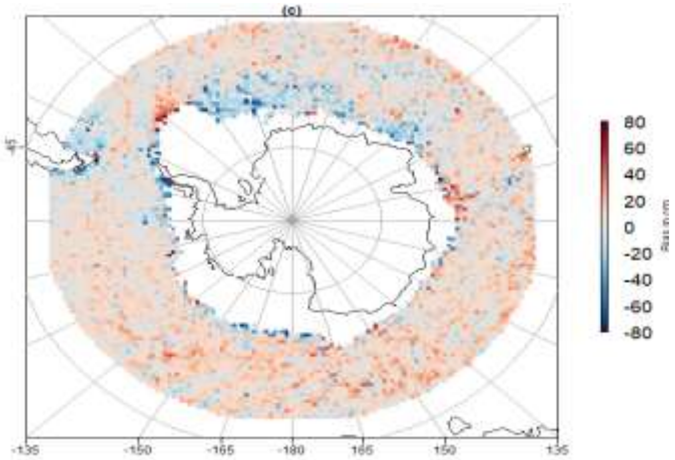
**L. Aouf, Meteo France**

Bias maps SWH (max. 80 cm)

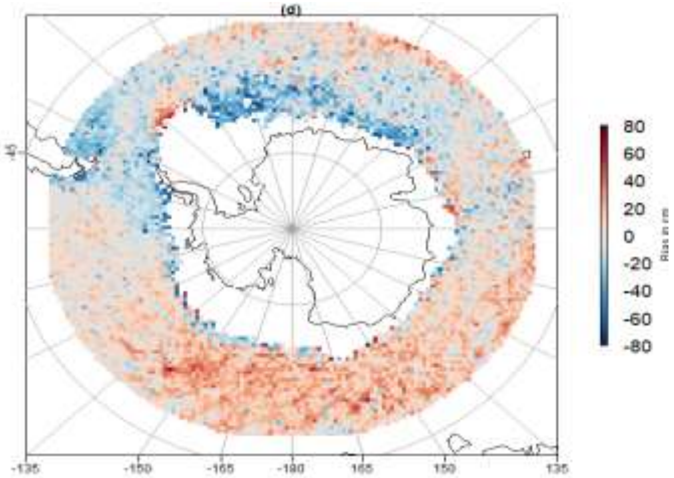
**With DA SWIM+SAR**




**With DA SWIM**



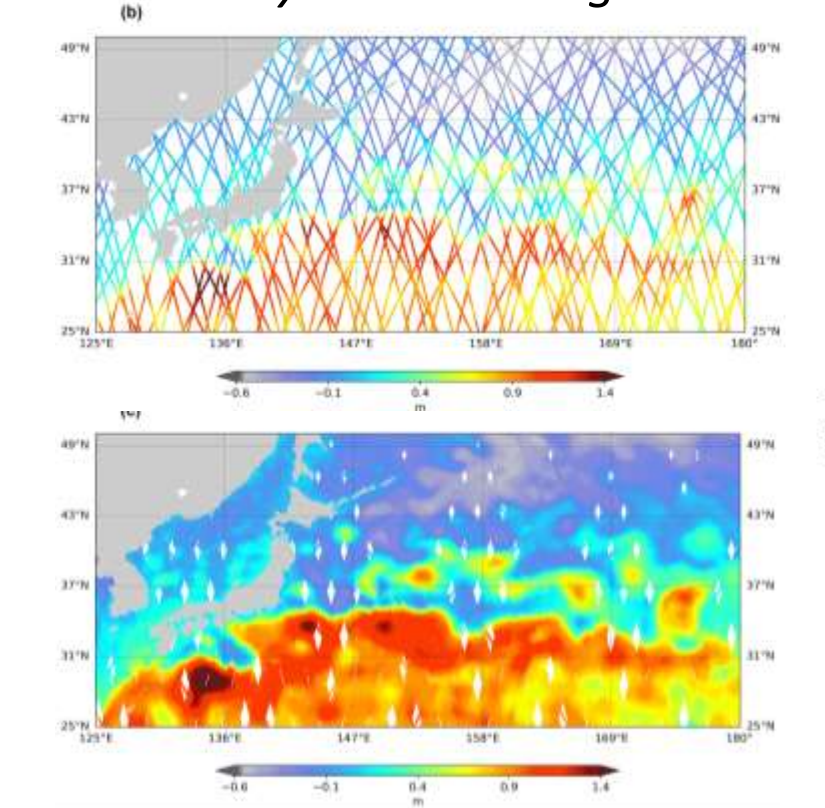

**Without DA**

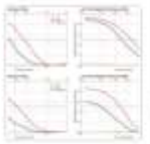



Complementary use of SAR and SWIM wave Spectra enhances SWH bias reduction

# Observing System Simulation Experiments (S3 – NG TOP0)

*7-day data coverage*



Research article

05 May 2022

Contribution of a constellation of two wide-swath altimetry missions to global ocean analysis and forecasting

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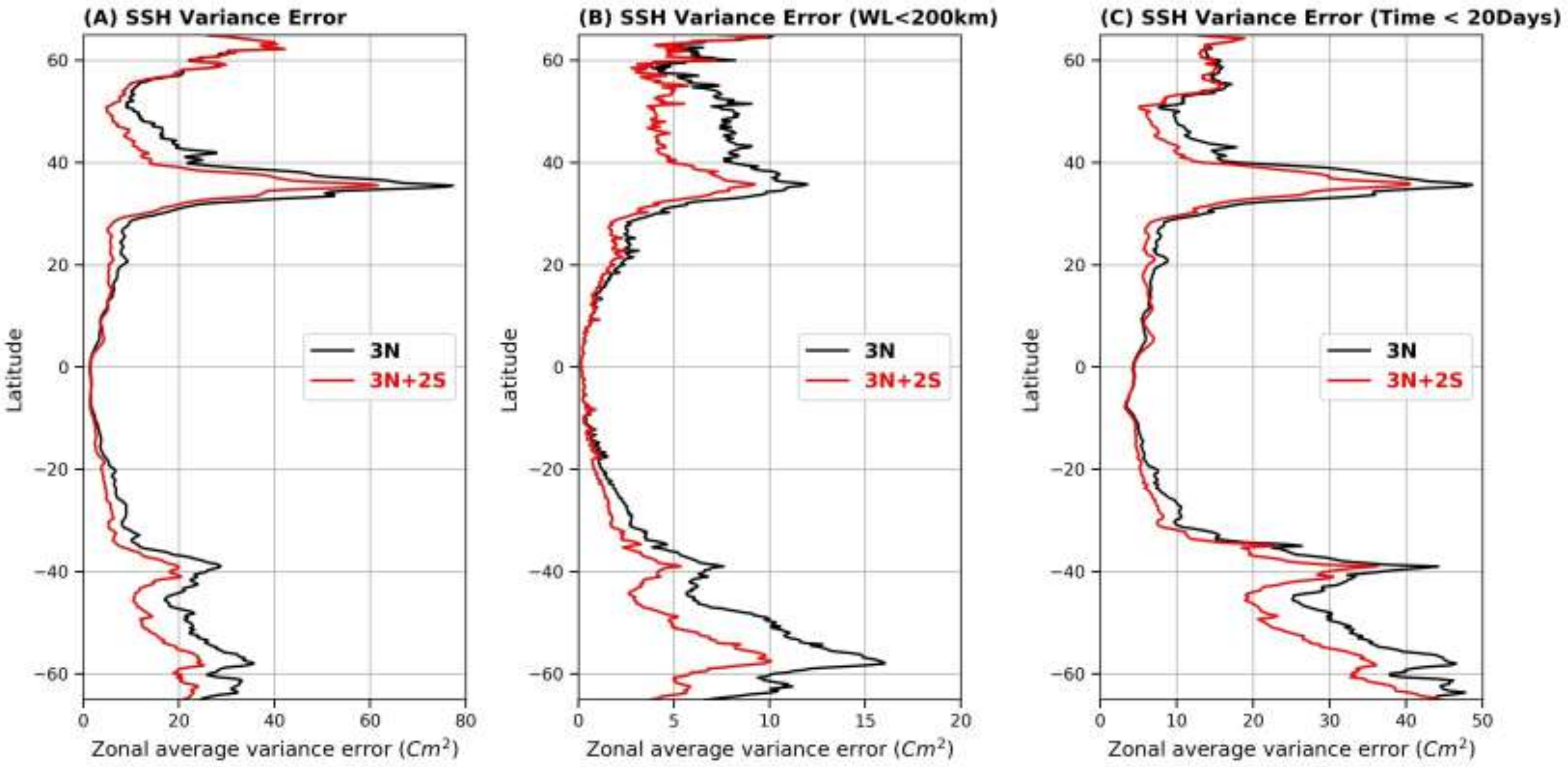
*Assimilation of simulated SSH From 3Nadirs vs 2 Wide-Swath*




*Zonal averaged error variance of SSH: (A) for full scales, (B) for scales less than **200 km** and (C) for time scales less than **20 days**; assimilation of 3Nadir (black lines) and assimilation of 3N+2Wisa-Swath (red lines). Units are $cm^2$*



**M. Benkiran et al. MOi**

# Working and communcating on requirements

Present and future requirements both for in-situ and satellite observations (Sentinels) have been defined.

Based on impact assessment (OSE/OSSEs) and expert analyses.

Network of a large number of Copernicus Marine expert centers




SYSTEMATIC REVIEW ARTICLE

Front. Mar. Sci. | doi: 10.3389/fmars.2019.00234

From observation to information and users: the Copernicus Marine Service perspective

Pierre Yves Le Traon, Antonio Reppucci, Enrique Alvarez Fanjul, Lotfi Aouf, Arno Behrens, Maria Belmonte, Abderrahim Bentamy, Laurent Bertino, Vittorio E. Brando, Matilde Kreiner, Mounir Benkiran, Bruno Buongiorno Nardelli, Thierry Carval, Stefania Ciliberti, Hervé CLAUSTRE, Emanuela Clementi, Giovanni Coppini, Gianpiero Cossarini, Marta De Alfonso Alonso-Muñoyerro, Gerald Dibarboure, Frode Dinessen, Marie Drevillon, Yann Drillet, Yannice Faugere, Vicente Fernández, Andrew Fleming, M. Isabel Garcia-Hermosa, Marcos Sotillo, Gilles Garric, Florent Gasparin, Marion Gehlen, Marilaure Grégoire, Stephanie Guinehut, Mathieu Hamon, Chris Harris, Fabrice Hernandez, Jørgen Buus-Hinkler, Jacob L. Høyer, Juha Karvonen, Susan Kay, Robert King, Thomas Lavergne, Benedicte Lemieux-Dudon, Leonardo Lima, Chongyuan Mao, Matthew J. Martin, Simona Masina, Angelique Melet, Glenn Nolan, Ananda Pascual, Jenny Pistoia, Atanas V. Palazov, Jean-Francois Piolle, Marie Isabelle Pujol, Anne-Christine Pequignet, Elisaveta Peneva, Begoña Pérez-Gómez, Loic Petit de la Villeon, Nadia Pinardi, Andrea Pisano, Sylvie Pouliquen, Rebecca A. Reid, Elisabeth REMY, Rosalia Santoleri, John Siddorn, Jun She, Joanna Staneva, Ad Stoffelen, Marina Tonani, Luc Vandenbulcke, Karina von Schuckmann, Gianluca Volpe, Cecilie Wettre and Anna Zacharioudaki

# Conclusions
# Interoperability between observation and prediction systems

- Strong links between satellite oceanography and operational oceanography since the start of global operational oceanography (GODAE – end of the 90').

- Satellite observing and ocean prediction capabilities have been co-developed => good interoperability between the two systems. Good maturity in the interactions.

- Ocean prediction system architecture requires specific functions related to satellite data acquisition (real time and delayed mode), processing/reprocessing, impact assessment:

  - ✓ Operational interfaces with satellite ground segments.

  - ✓ Regular interactions with satellite agencies and ground segments is key : real time and reprocessing.

  - ✓ Capabilities to assess the impact and support the design of future missions are required.

- Future improvements. More standardized interfaces/interactions shared at international level between the different ocean prediction systems and satellite observing agencies => OceanPredict and DCC OceanPrediction