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Use and impact assessment of observations in Operational Ocean forecasting systems

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First Data Buoy Cooperation Panel Mediterranean Training Workshop on Ocean Observations and Data Applications – 2-4 May 2023

Outline

- Ocean monitoring and forecasting systems in brief
- Use of observations by monitoring and forecasting systems
  - assimilation
  - validation
- Observation impact studies
- Conclusion
- Perspectives

Value chain from observations to ocean analysis and forecasts

Ocean observing systems → *Ocean Observation integrators* → *Data integration into model* → *Provision of Ocean analysis and forecasts*

…

Data assembly centers

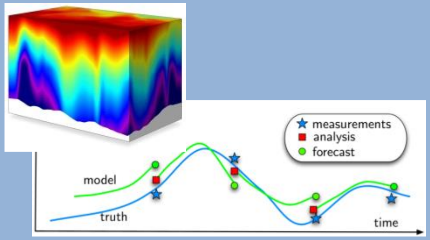
SST, SLA, Ocean Colour, Sea Ice, Wind, Wave and

SATELLITE observations

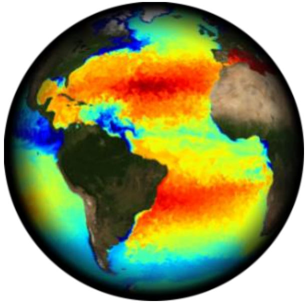
and INS TAC (Coriolis)

IN SITU observations

Global/Regional Monitoring and Forecasting Center (MOi)



Data assimilation into a **physical model at 1/12°,** coupled with a sea ice and BGC models.



Ocean, ice and BGC analysis and forecasts for the ocean

Copernicus Marine Service

Feedback from ocean monitoring centers to observing networks

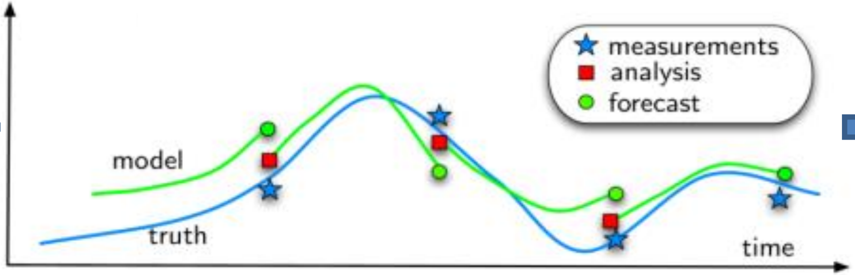
Mercator Ocean analysis systems

Marine Services are highly dependent on the satellite and in-situ observing capabilities and quality of the observations

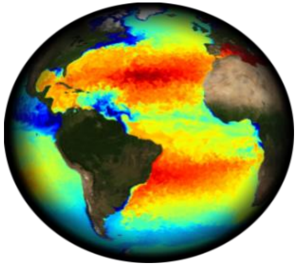
In situ observations:
- Argo T and S profiles,
- surface drifting buoys,
- coastal and tropical moorings,
- ship based observations (TSG, CTD, XBT), gliders,
- marine mammals

Satellite observations:
- Sea Level Anomaly (SLA),
- Sea Surface Temperature (SST),
- Sea Ice Concentration

Assimilation of observations into the NEMO ocean model, coupled with the PISCES BGC model and the LIM seaice model

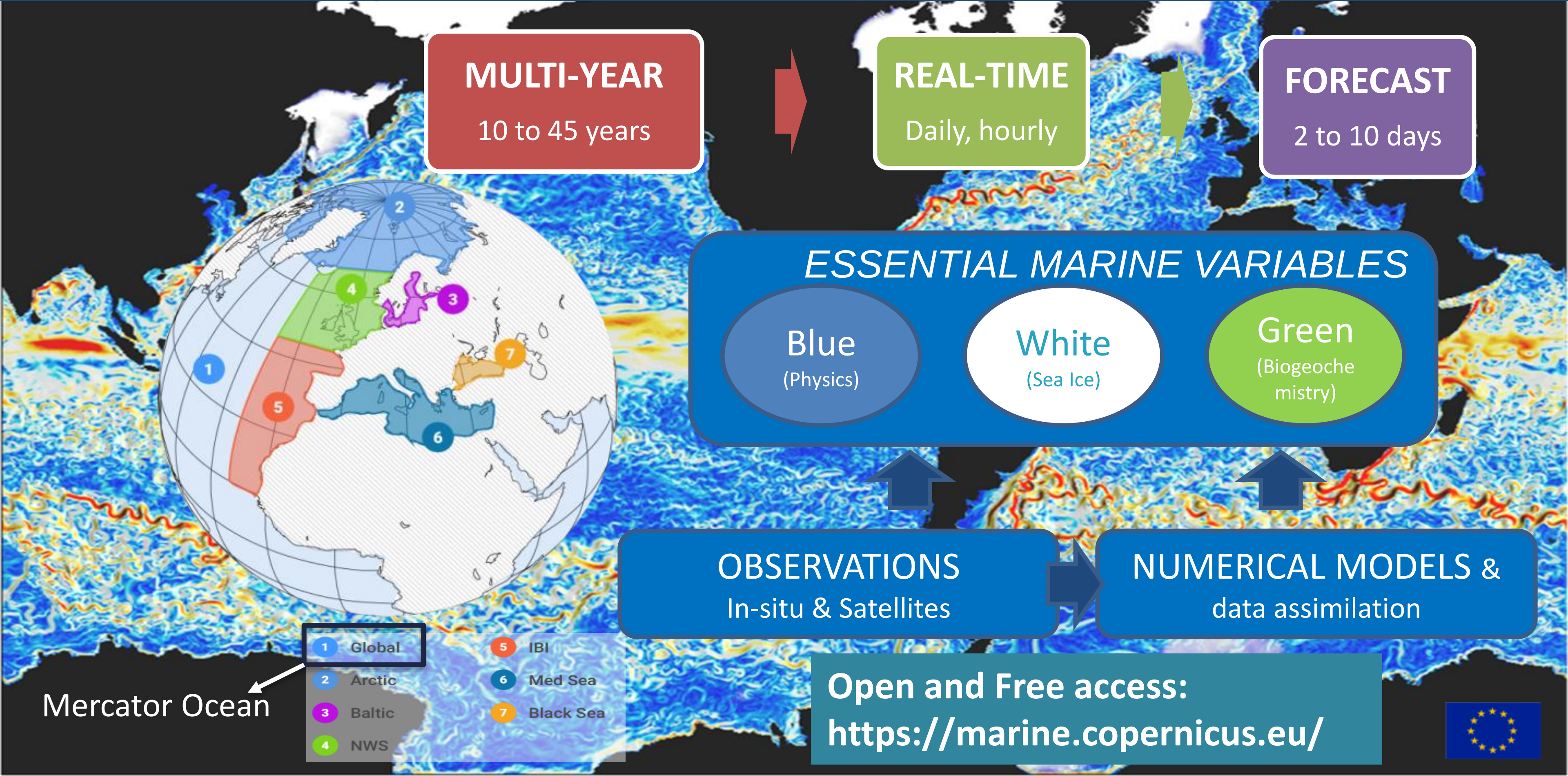


Ocean, ice and BGC analysis and forecasts for the global ocean

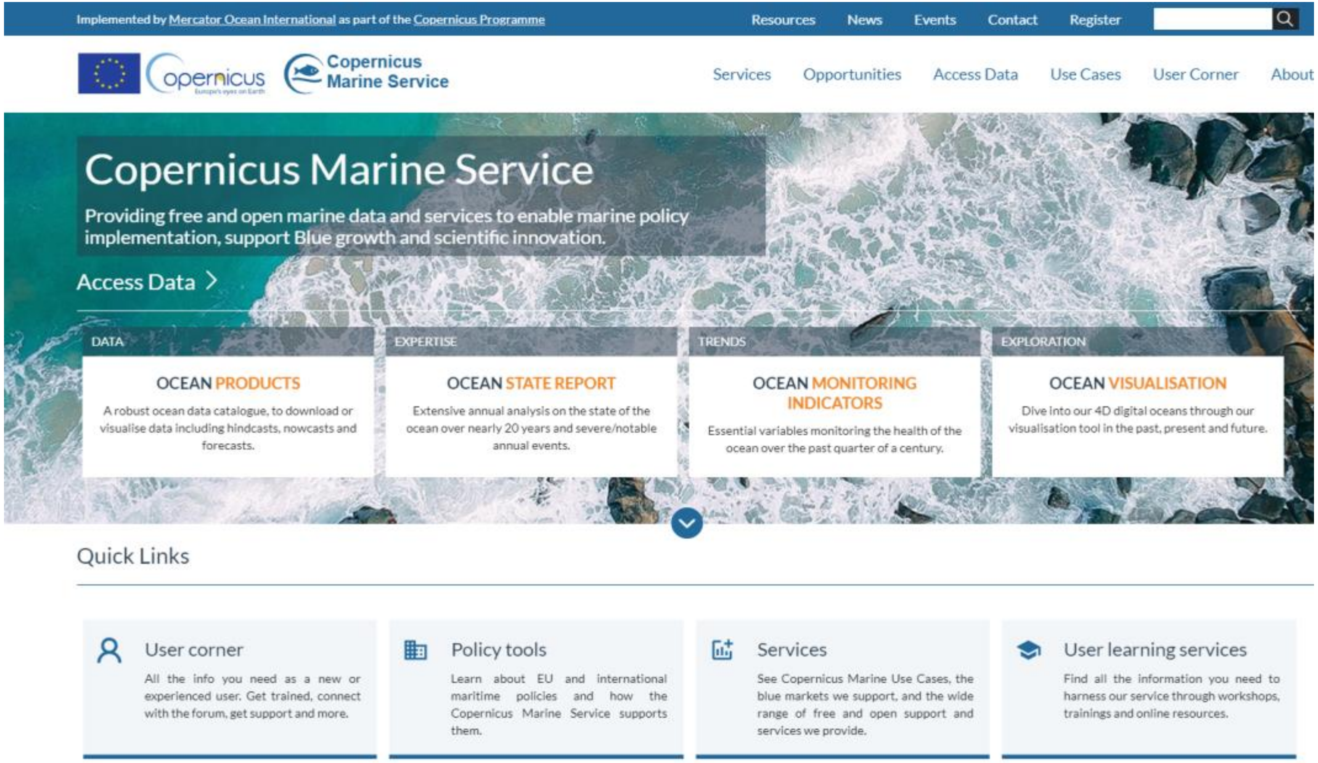


- ➢ quite sparse coverage of in situ observations except at the surface, deeper than 2000 m depth very few observations.
- ➢ satellite provide a regular, dense and global observation coverage but only of the ocean surface.

The Copernicus Marine Service: Monitoring and forecasting the ocean



Copernicus Marine Service : single access point



Online catalogue
marine.copernicus.eu

Nearly 300 scientifically qualified products & Ocean monitoring indicators

User driven

Common format
(Netcdf)

Open and Free

Applications for Operational Oceanography

End users/Applications:

Fishing, Coast Guards (Search and Rescue, Environmental Response, Operations), Environmental Consultants, Navy (Acoustics, Operations, Briefings…), Fish Management, Hydrographic Services, Offshore Resource Extraction, Navigation…

Observations for operational use in OceanPredict systems

Levels	Description
Level 0	Not used at all
Level 1	Used for validation (The system is constructed independently from the data)
Level 2	Not assimilated but used for input data (The system depends on the data), or assimilation scheme is currently being developed
Level 3	Assimilated on the research basis
Level 4	Assimilated indirectly in operation (a
Level 5	Assimilated directly in operation (Th

Center/ Institute	System Name	Drifter/ Temp.	Drifter/ Velocity	Drifter/ ocean waves	Drifter/ SLP	Ocean glider/ Temp.	Ocean glider/ Salinity	Animal borne/ Temp.	Ice buoy/ ice drift	Ice-tethered profiler/ Temp.	Ice-tethered profiler / Salinity	ALAMO	Tide Gage	Coastal Wave Recorders	Notes
JMA	MOVE (Global)	Level 5			Level 4	Level 5	Level 5	Level 5				Level 5	Level 1		TS data on GTS are used in operation.
	MOVE (Regional)	Level 5	Level 1		Level 4	Level 5	Level 5	Level 5				Level 5	Level 1		
	Wave DA Systems			Level 4	Level 4									Level 4	
Mercator Ocean	RT Global 1/12°	Level 1	Level 1			Level 5	Level 5	Level 5		Level 1	Level 1				
	Reanalysis 1/12°		Level 1			Level 5	Level 5	Level 5							
	Regional 1/36°					Level 5	Level 5						Level 1		
MET Norway	TOPAZ4 (Pan-Arctic)	Level 1	Level 1						Level 1	Level 5	Level 5				
	WAM3km														
Met Office	FOAM global and regional (1/4 and 1/12 degree)	Level 5	Level 1			Level 5	Level 5	Level 5	Level 1	Level 1	Level 1				
	FOAM shelf (1.5 km)	Level 5	Level 1			Level 5	Level 5	Level 5							

https://oceanpredict.org/science/task-team-activities/observing-system-evaluation/#section-observations

OceanPredict : an international science programme

https://oceanpredict.org/

OceanPredict
Advancing the science of ocean prediction

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About

A science network to accelerate, strengthen and increase the impact of ocean prediction

OceanPredict is a science programme for the coordination and improvement of global and regional ocean analysis and forecasting systems. It provides a platform for communication and knowledge exchange run by scientists and experts in operational oceanography from around the world to accelerate, strengthen and increase the impact of ocean prediction.

About

- History & Motivation
- Strategy
- Partners
- Organisational Structure

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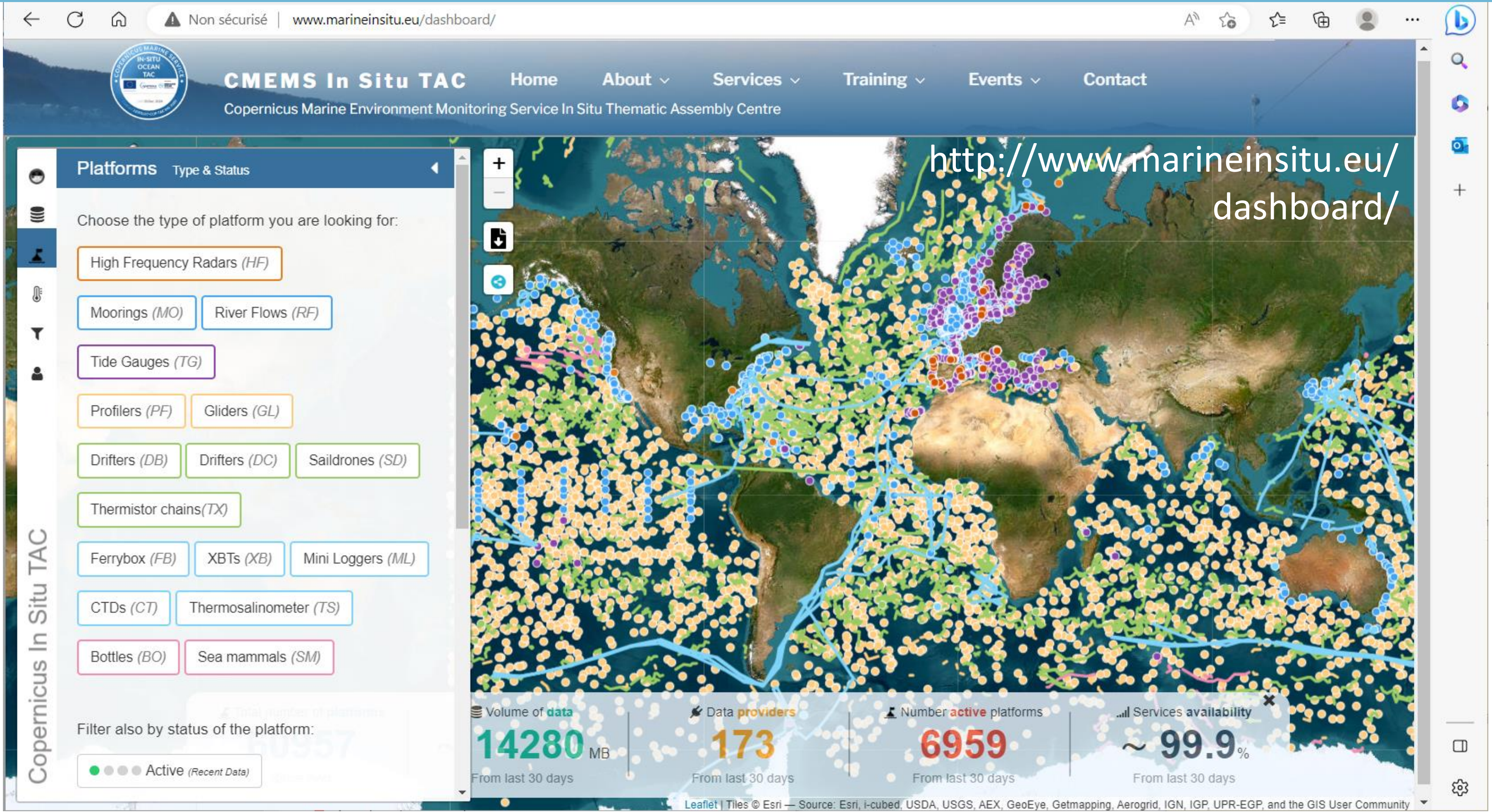
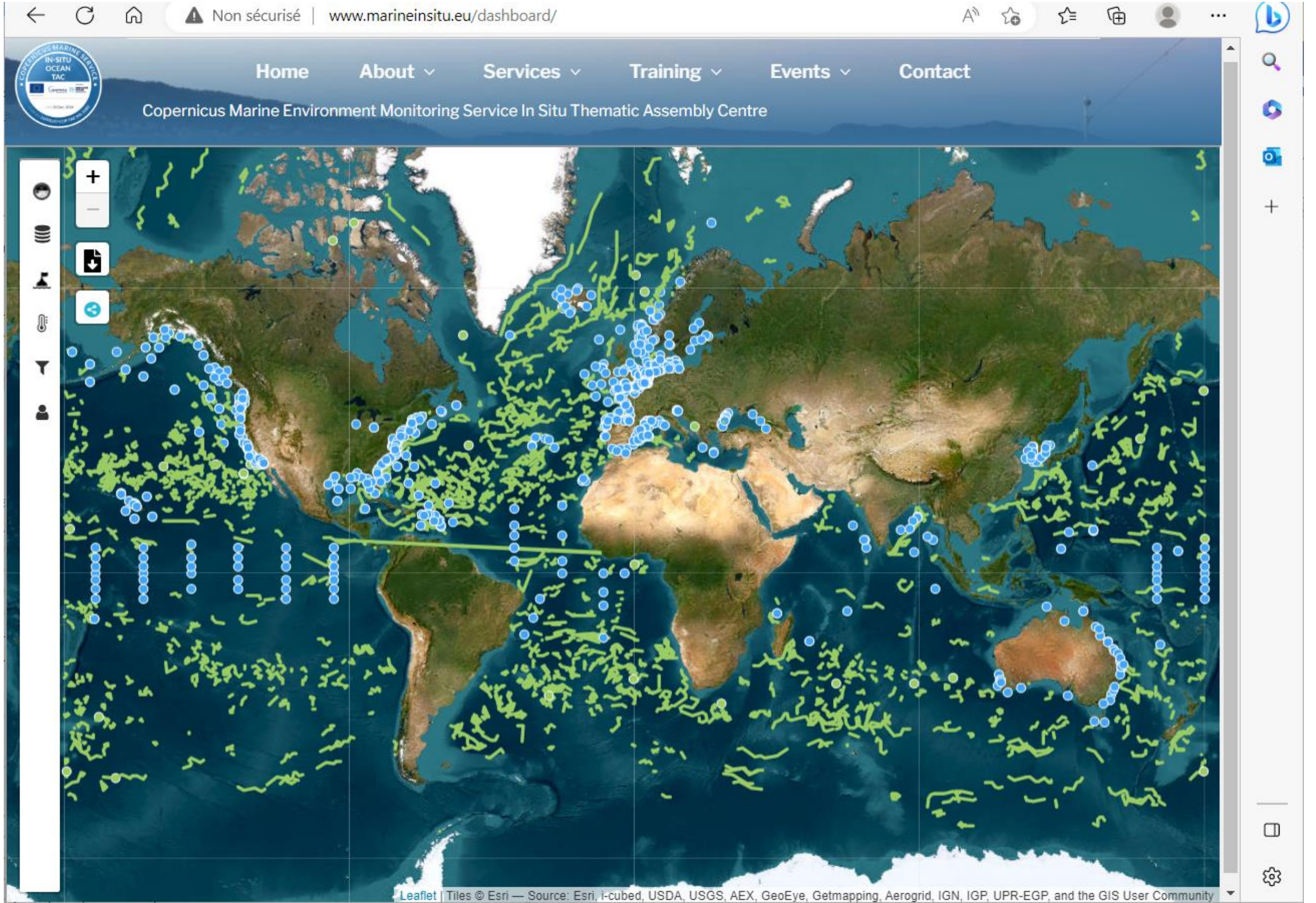
Copernicus In Situ Observation dashboard

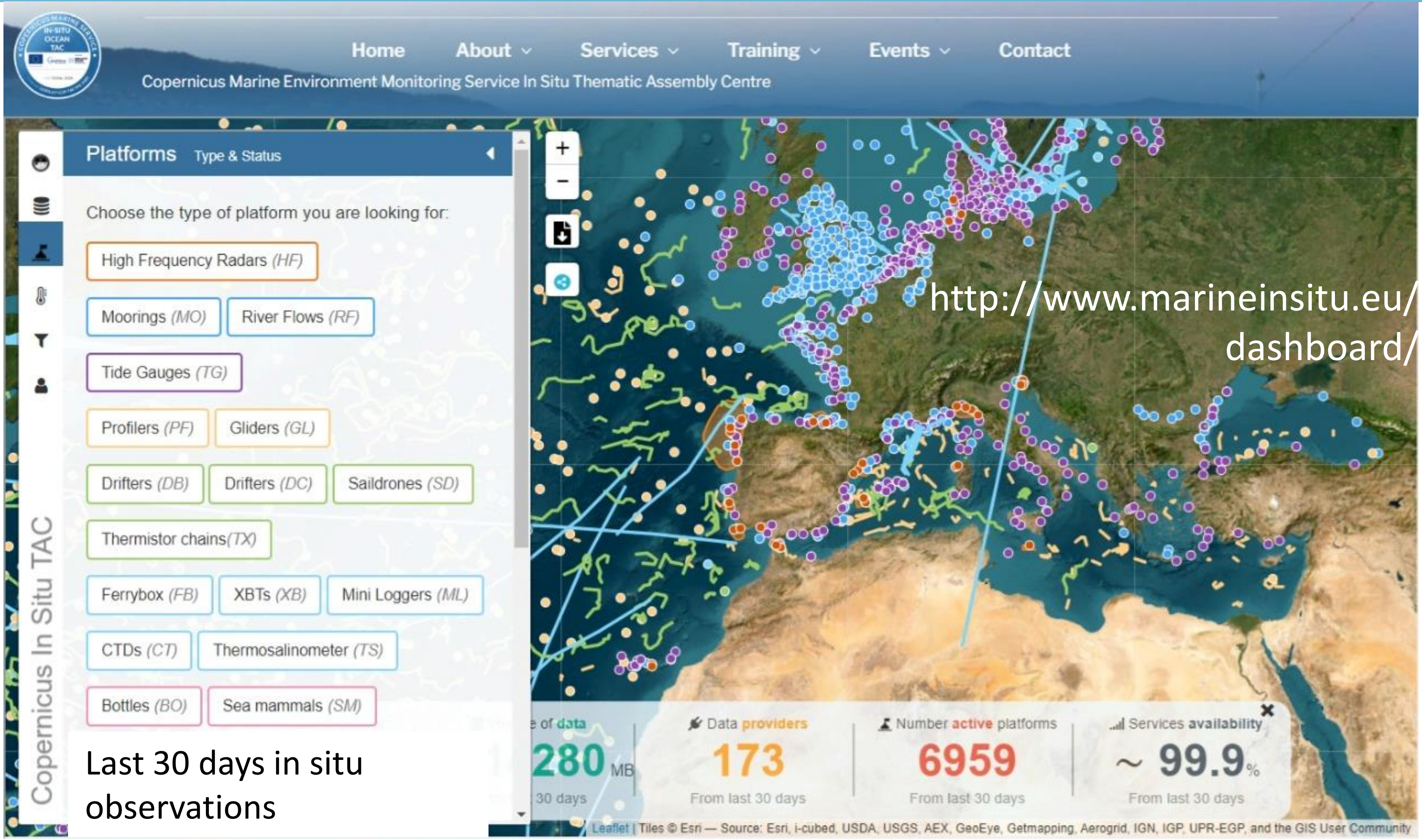


Copernicus In Situ Observation dashboard

Mooring and drifter positions over a 30 day period, in the real time Coriolis in situ database



Copernicus In Situ Observation dashboard

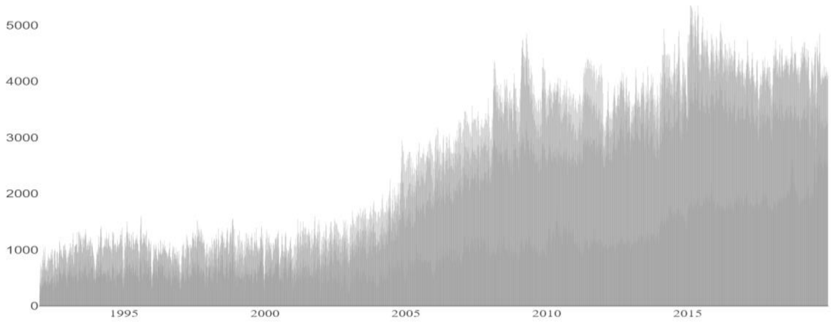


http://www.marineinsitu.eu/dashboard/

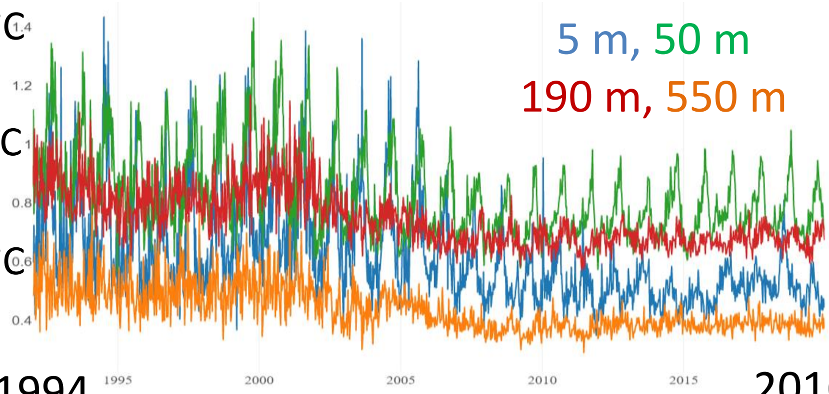
Last 30 days in situ observations

1/12° reanalysis compared to in situ Temperature observations

The accuracy of the ocean analysis and forecasts highly rely on the availability and quality of the assimilated observations.



Number of data assimilated at 5m, 50m, 200m and 500m

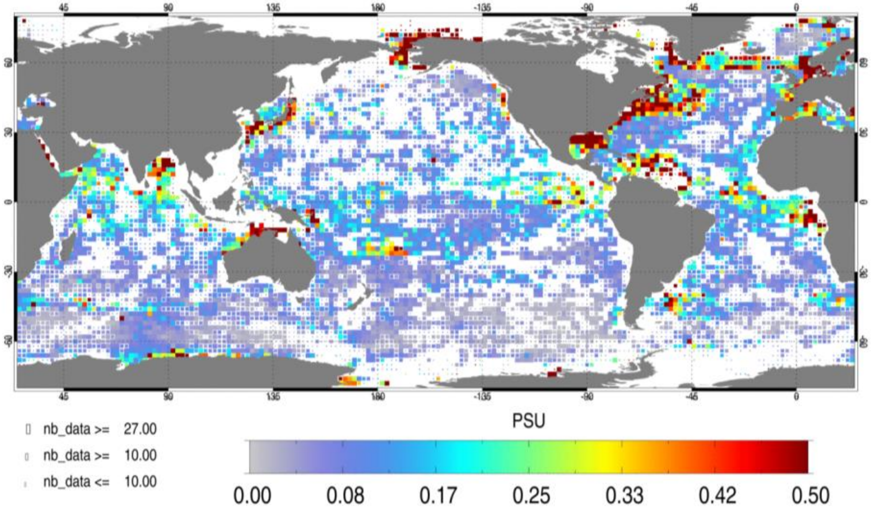


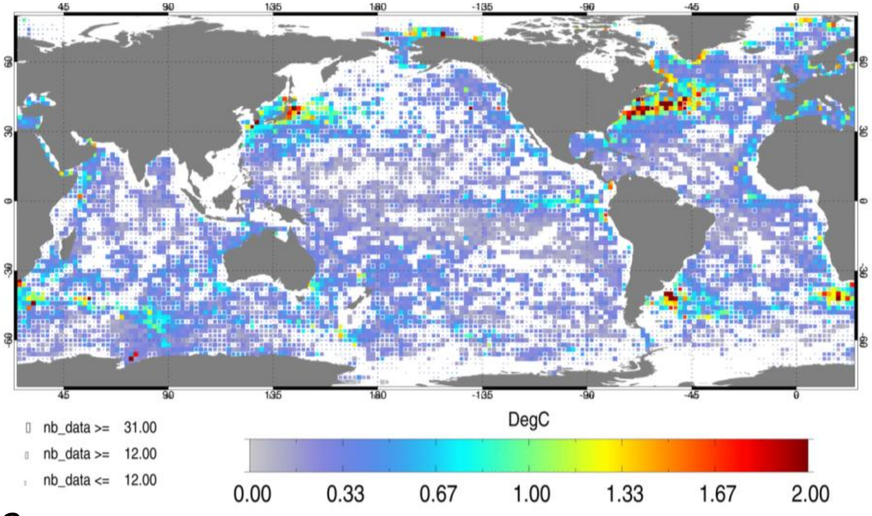
Global RMS analysis error in temperature estimated with the CORA in situ observation database.

- ➢ Clear improvement of the global 1/12° reanalysis temperature estimation following the increase of the observation number, mostly due to Argo network.

1/12° ocean real time analysis compared to in situ observations

RMS Difference between analysed and observed Salinity (0 - 5m)	*RMS Difference between analysed and observed Temperature (0 - 5m)*

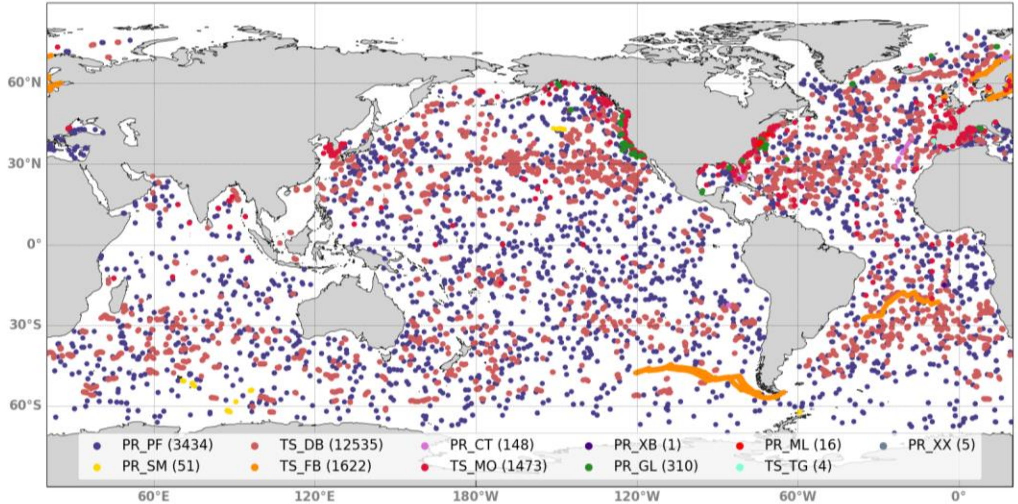




2019

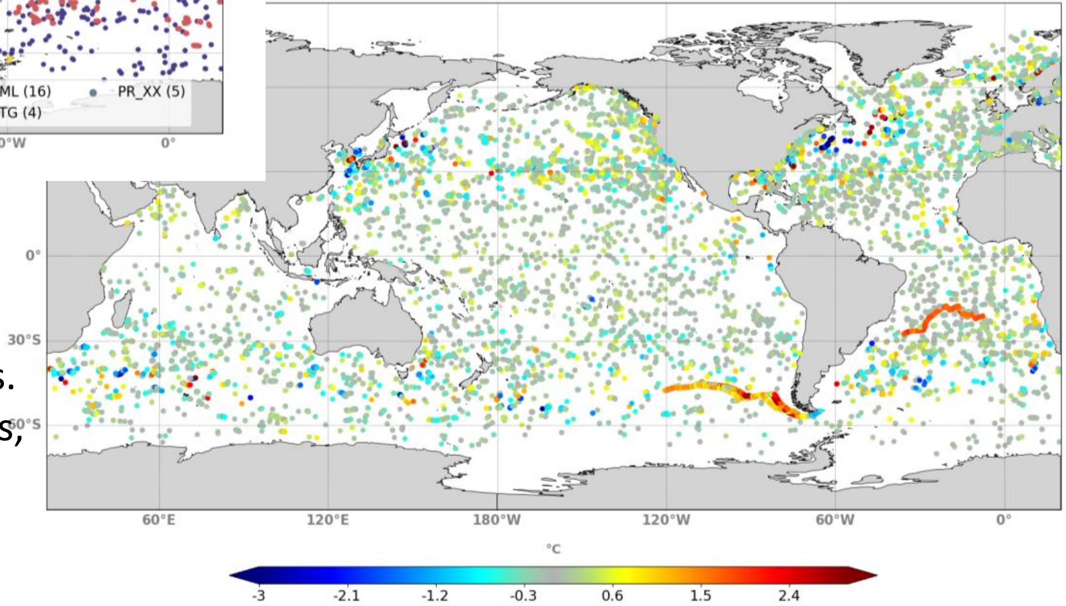
- Largest errors in salinity found at the surface in the Western Boundary Currents, the freshwater pool and regions with large influence of river runoff.
- Largest errors in temperature in WBC, tropical oceans and at the thermocline depth.

Global Ocean 1/12° analysis for the week (28 March 2023)



Location and type of assimilated surface observations (0-1m)

Temperature innovations (observation – model forecast) for surface observations

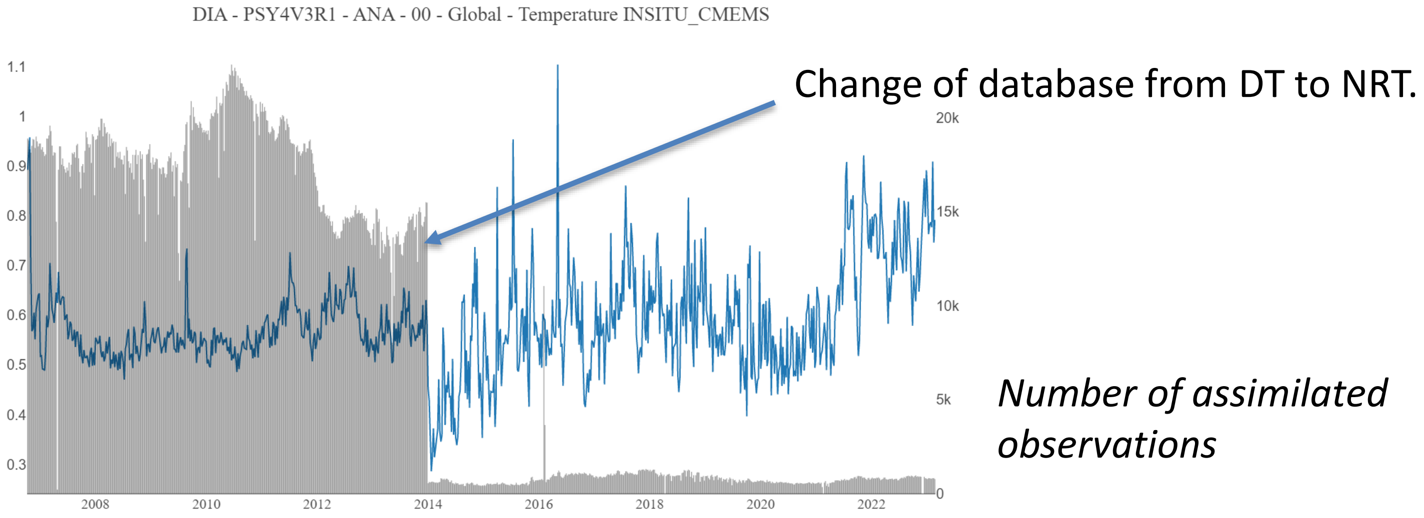


- Model misfits with drifters are coherent with the ones with Argo float observations.
- A ferry box line shows too high innovations, which failed to be rejected.

Use of QC flag in operational systems

QC flags are used to select the observations to be assimilated.
QC flags for the position, including depth/pressure, and for the observation are considered.

In the Mercator Ocean global system, only observations with QC equal to 0 or 1 are assimilated.



Temperature RMS error (0-1m)

Number of assimilated observations

For delayed time (DT) production, the CORA database is used.
For real time production, the CORIOLIS Near Real Time (NRT) database is used.

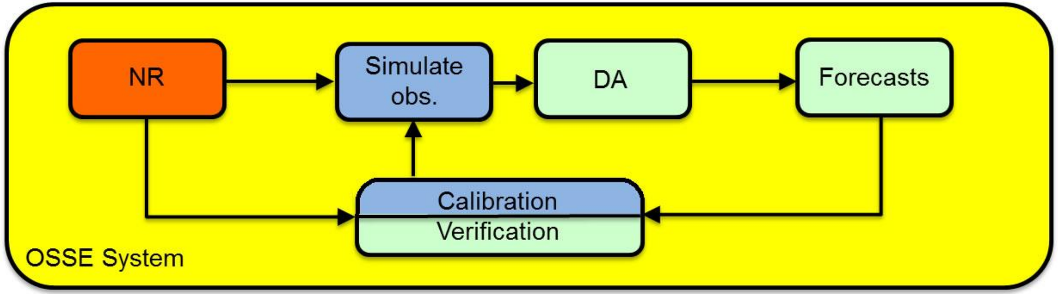
Observation impact assessment

Observation impact studies are performed at MOi and OceanPredict centers to:

- ✓ verify that observation information is « optimally » used in the analysis step and improve the assimilation components,
- ✓ quantify the impact of the observation network in ocean analyses and forecasts,
- ✓ demonstrate the value of an observation network for ocean analyses and forecasts,
- ✓ test future observing system design from an integrated system perspective involving satellite and in-situ observations and numerical models.

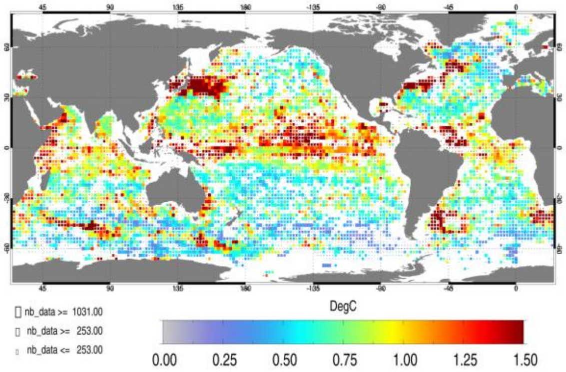
OSEs (Observing System Evaluations) => assessing the impact of existing data sets by withholding a set of observations in the analysis. Other approaches (e.g. DFS) are also used.

OSSEs (Observing System Simulation Experiments) => help designing new observing systems and perform preparatory data assimilation work.

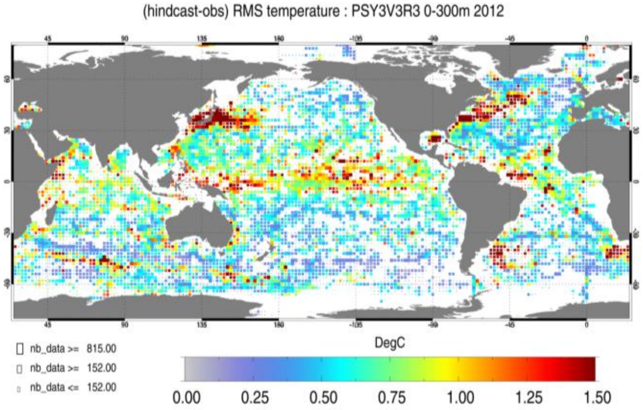


Impact of the present ARGO network on the global ¼° analysis

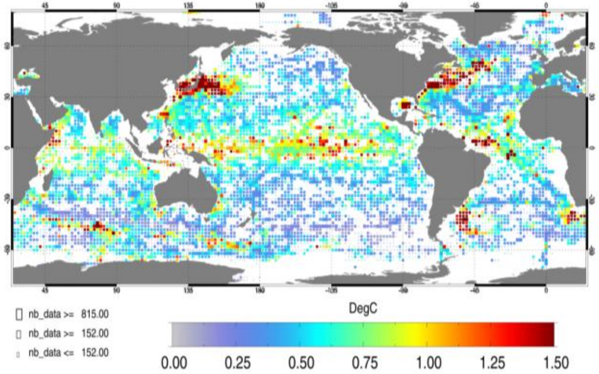
Global RMS 0-300m misfit between the *in-situ* temperature observations and OSEs analysis



Run-No Argo



Run-Argo/2



Run- All Argo

Regions of higher impact:

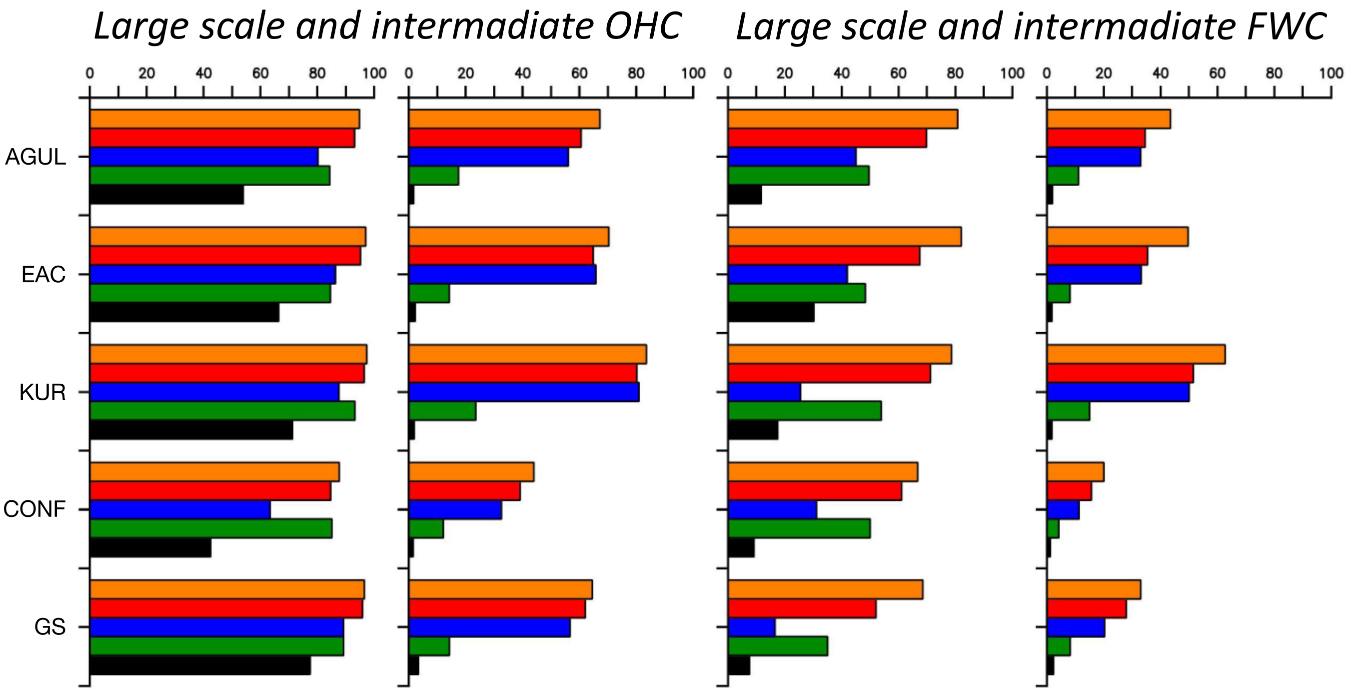
- at depth, **water masses from outflow or deep convection are better represented**,
- in the surface layers, the largest impact is found in the **tropical band and energetic ocean regions (WBC,…)**,
- keeping only half of the ARGO floats degrades significantly the analysis.

Turpin et al., 2016

Complementarity of Argo, its extension, and altimetry

% of the Nature Run variance reconstructed, area-averaged in WBC regions: 0-700 m Ocean Heat (OHC), and Freshwater Contents (OFC) in the OSSEs.

ENHANCED_AR (orange)
NOMINAL (red)
ONLYSATT (blue)
ONLYSITU (green)
FREE (black)



➢ Complementarity of in situ and satellite observations in ocean physical analysis:

In situ observations are constraining the large scale variability of the ocean interior (Ocean Heat Content (OHC) and Freshwater content (FWC), as satellite observations are constraining mostly the surface, at higher resolution. *Gasparin (2022), submitted to frontiers.*

Use of observation for validation

Observations are not only used for assimilation but are also extensively used:

- To validate model developments, sensitivity experiments (model and assimilation) and operational production,
- To provide uncertainty estimations for the delivered ocean products.

- Coastal HF radar and drifters with and without their drogue, are used to evaluate surface and 15m depth velocities with eulerian and lagrangian diagnostics.

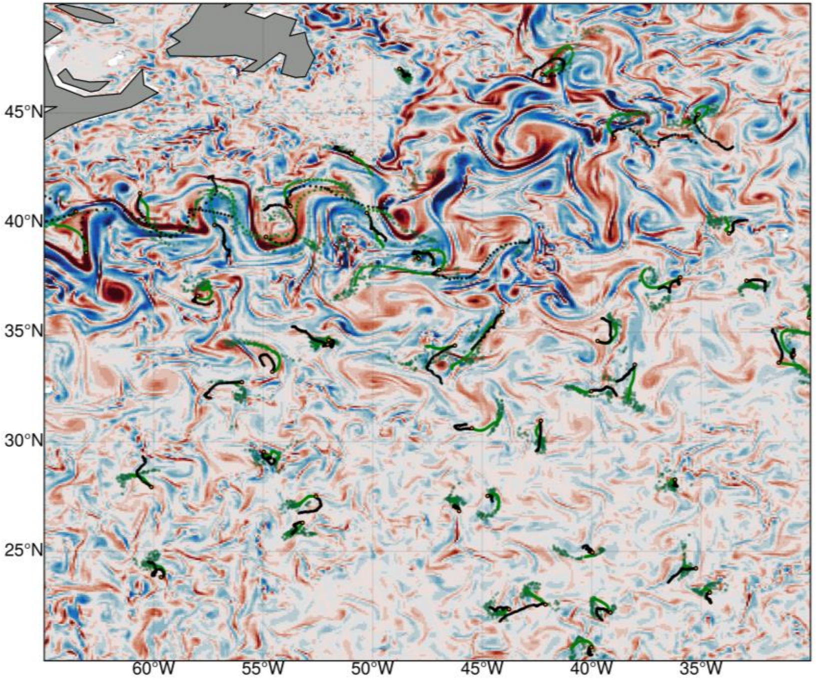
- Coastal and tropical mooring T,S and current observations are used to validate real time production but also reanalysis since they provide unique long term data record of the ocean interior.

- Tide gauges are used to evaluate sea surface height close to the coast.

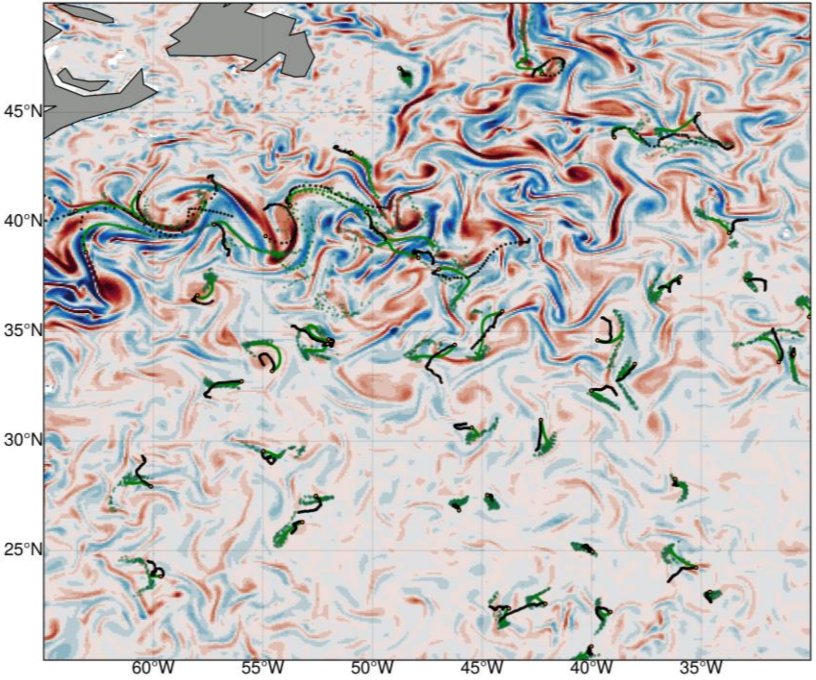
Validation of the new GLO12V4 current (15m depth)

Lagrangian evaluation: 01-02-2019 (10-day drift)

New GLO12



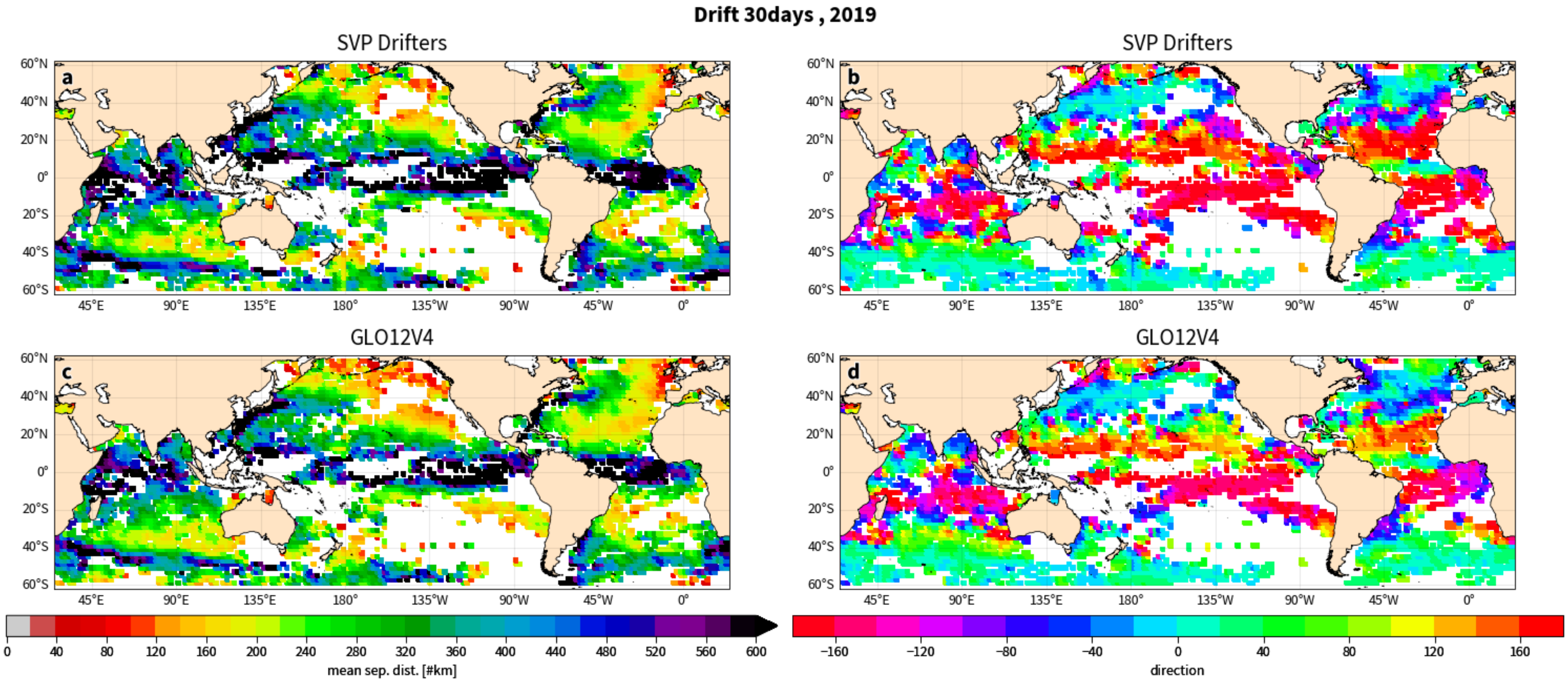
Old GLO12 (PSY4)



10 day trajectories: *SVP drifters (**black**), PSY4 (green)*

- The new GLO12 is much more energetic. Mesoscale structures better reproduced

General characteristics of the GLO12 Lagrangian flow



- ➢ large-scale characteristics of the Lagrangian transport are well represented in the global 1/12° analysis
- ➢ regional differences: larger displacement vicinity of WBC, edge of subtropical gyre,

  large directional differences in eastern NA, northern NP Gulf of Alaska, Western SA.

Conclusion

Drifters, coastal and tropical mooring physical observations are extensively used for:

- Data assimilation in real time and reanalysis systems,
- Validation of the reanalysis and real time production, model development and assimilation experiments (OSE, assimilation scheme development,…),
- Provision of accuracy number for distributed product.

➢ For an efficient data assimilation, a good knowledge of the information content of the observations and their uncertainty is required.

➢ Long term reference observation time series are critical to validate long term simulation as reanalysis.

➢ In situ observations are complementing the satellite surface observation to constrain the large scale variability of the ocean interior as satellite observation are constraining mostly the surface, at higher resolution.

Perspectives

Evolution of ocean models and observations toward higher resolution in space and time:

- Model tends to include more processes with an increased spatio/temporal resolution (inclusion of tides in global ocean model, coupling with wave/other earth system components, …) in addition to BGC/ecosystem models;
- Continuity from large scale open ocean to coastal modeling and forecasting capacity
- Increased density and higher resolution/frequency content of the observations

Challenges:

- ➢ Refinement of the Data Assimilation strategy to control a larger spectrum of scales (processes) taking into account complex error, and high density/volume of observations.
- ➢ Understand/ensure the complementarity of satellite and in situ observations to constrain the variability of the ocean interior, in the open ocean and on the coastal areas.
- ➢ Improve the dialog between modeling and observing communities to advocate for sustained, fit for purpose observing networks for operational oceanography

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Perspectives