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# The Copernicus Marine Service global ocean analysis and forecasting 1/12° high-resolution system. Recent changes and future evolution.

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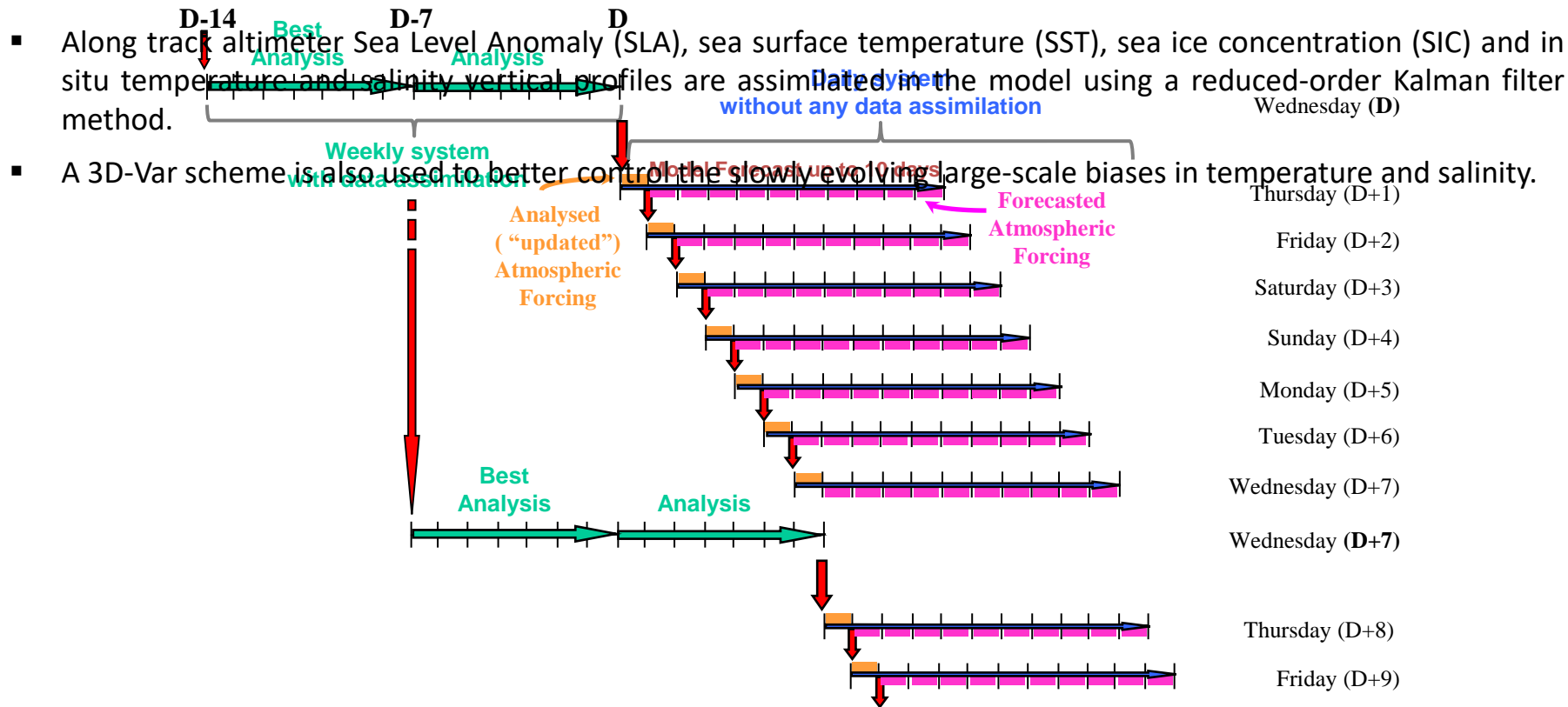
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<sup>2</sup>*CLS, Ramonville Saint Agne, France*

- Components and operational schedule for operation of the system
- Main updates of the system and performances of the new system (GLO12) compared to the previous one (PSY4)
- Some additional updates thanks to interactions with the SHOM (Hydrography and Oceanography Service of the French Navy)
- Future evolutions of the system

# Components and operational schedule of the system

Since October 2016, and in the framework of Copernicus Marine Service, Mercator Ocean delivers in real-time **weekly analyses** and **daily 10-day forecasts** with a global  $1/12^\circ$  high resolution system, which is used by a wide range of users and marine sectors.

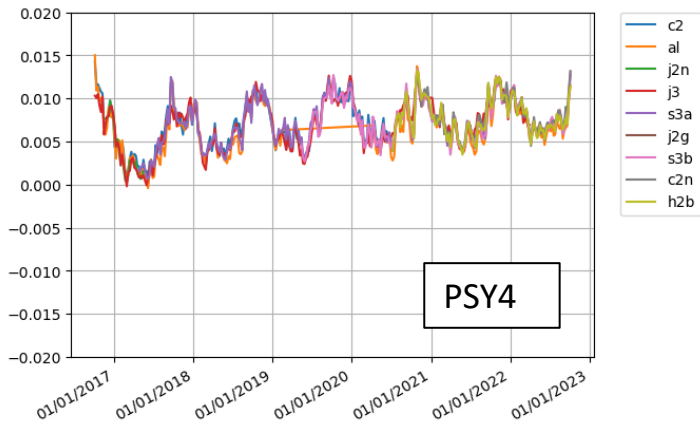


A new version of the system, called GLO12, is available since November 2022 with the following main changes and updates:

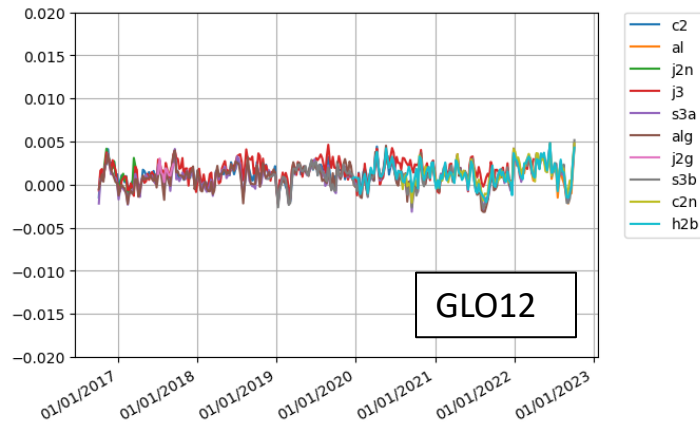
- New version of NEMO ocean and sea ice models;
- Higher spatial and temporal resolution ( $1/15^\circ$  - 1 hour) atmospheric forcing;
- Assimilation of L3 ODYSSEA SST product instead of L4 OSTIA gridded product;
- New Mean Dynamic Topography for SLA assimilation;
- Improved parametrization of the model error covariance deduced from the GLORYS12 reanalysis at  $1/12^\circ$ ;
- 4D extension of the data assimilation scheme allowing a better spatiotemporal continuity of mesoscale structures;
- Use of satellite-based monthly estimates of the Global Mean Sea Level to better constrain the ocean mass and the steric height.

SLA

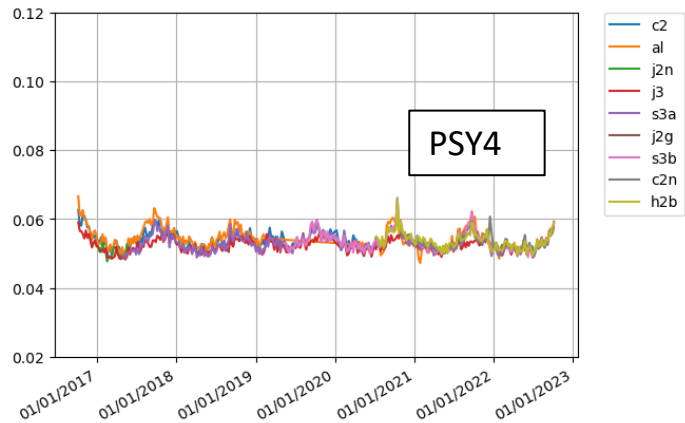
Mean bias for SLA



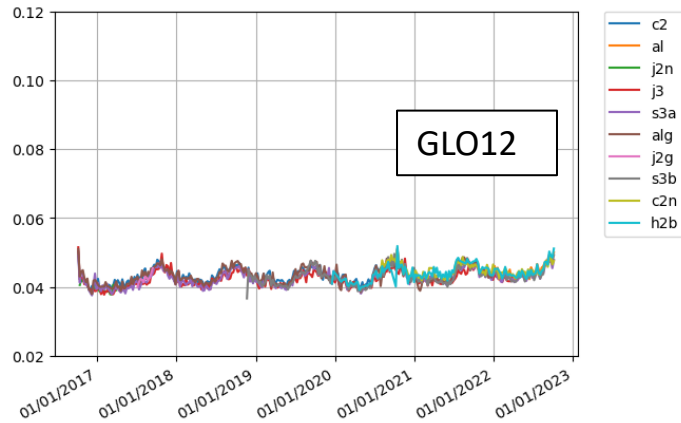
Mean bias for SLA



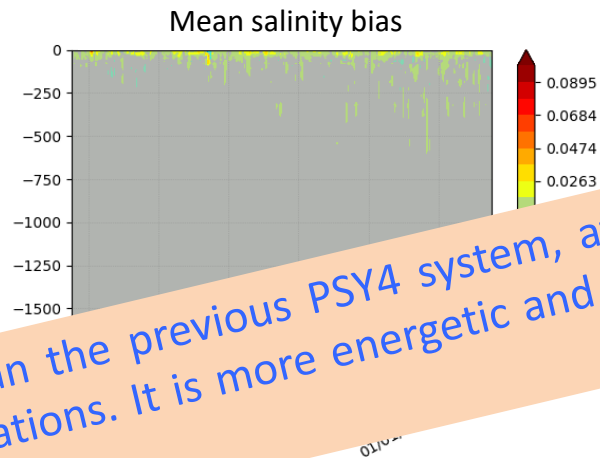
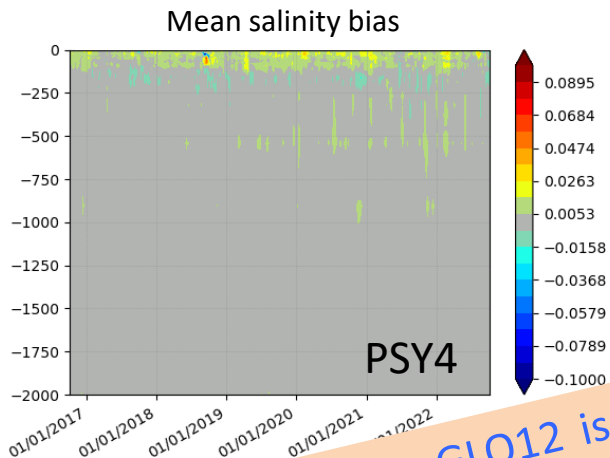
RMS error for SLA



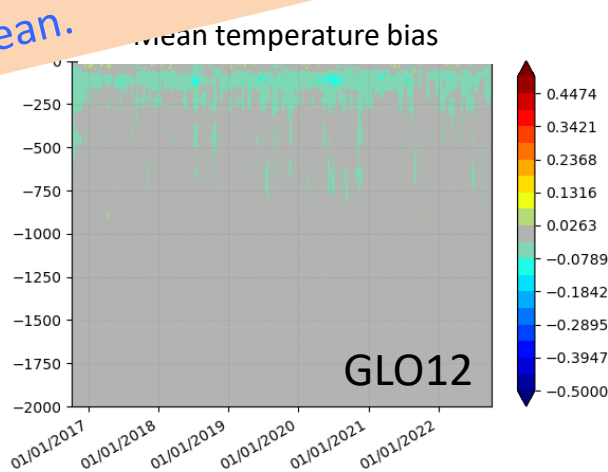
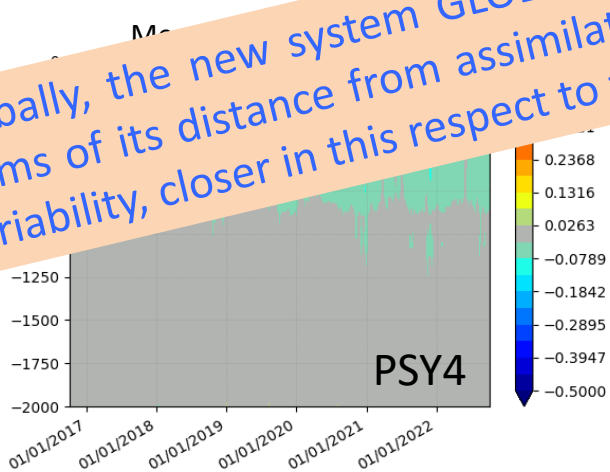
RMS error for SLA



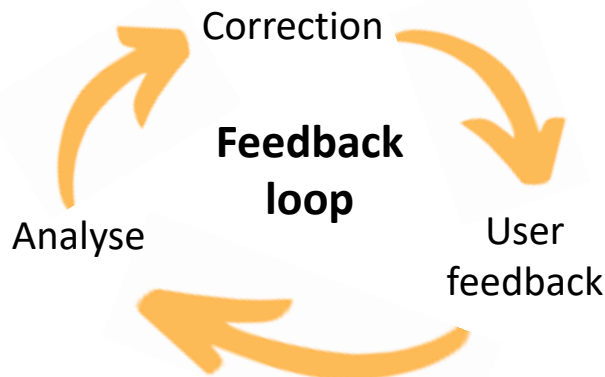
T/S *insitu*



Globally, the new system GLO12 is better than the previous PSY4 system, at least in terms of its distance from assimilated observations. It is more energetic and has more variability, closer in this respect to the real ocean.



One important thing in the context of the Copernicus Marine Service is to take into account users' feedback in order to correct any potential problems and so improve the system's behavior.

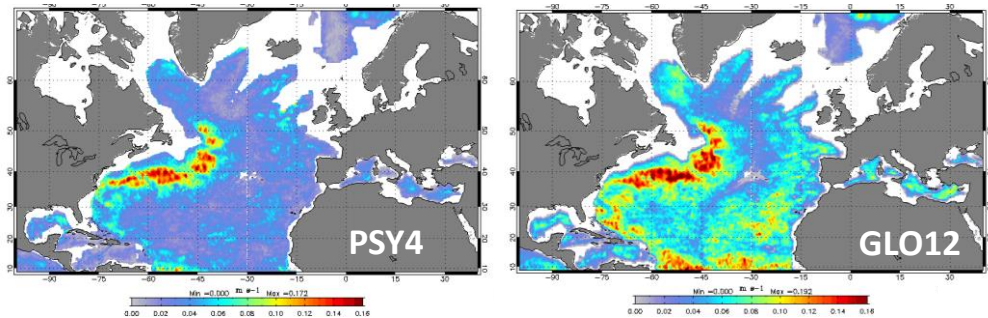


Recent interactions with the SHOM have led corrections in some components of the system in 2024.

In the GLO12 system, the model was a bit over-corrected, introducing some noise. Vertical profiles of temperature and salinity were well assimilated, but advected anarchically by an under diffusive and little too turbulent model.

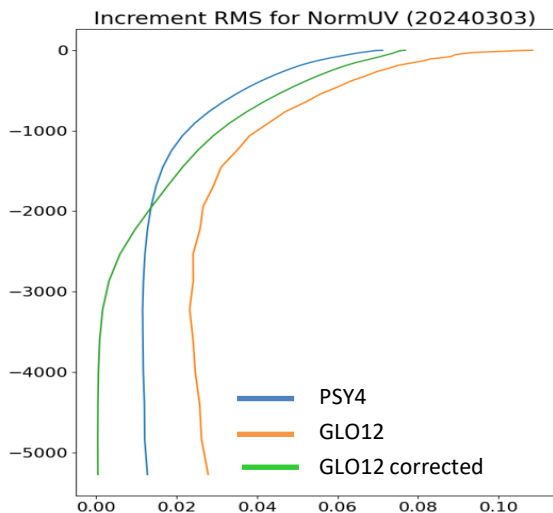
To address these issues, some additional modifications have been made to the system, involving the ocean model, SEEK (Kalman Filter) assimilation and 3D-Var bias correction.

## Standard deviation of the meridional velocity at 2200 m



The move to a new version of NEMO (**new advection scheme and time-splitting for SSH**) and the **higher-resolution/frequency atmospheric forcing** ( $1/15^\circ$  - 1h versus  $1/8^\circ$  - 3h for the previous system) result in too much energy appearing in the model.

→ Viscosity on dynamics has been increased in the ocean model.



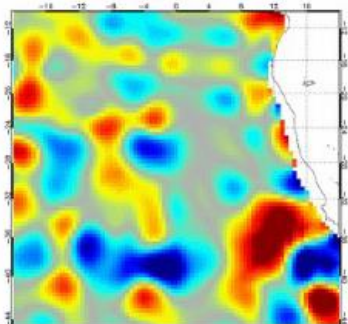
→ The intensity of the SEEK correction has also been reduced over the entire water column, and particularly velocity increments, which become very weak below 2500 m.



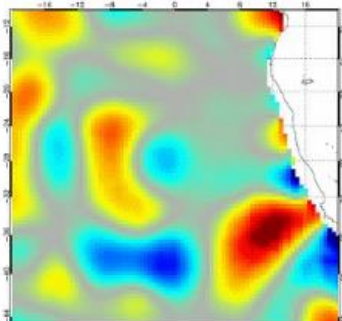
*From Eric Greiner*

The bias correction for T/S has been also significantly revised.

Old spatial scales  
(too small)

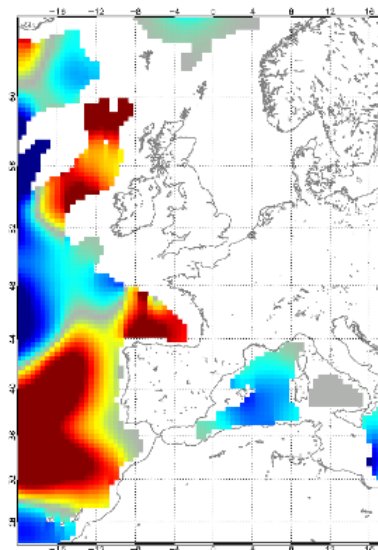


New spatial scales

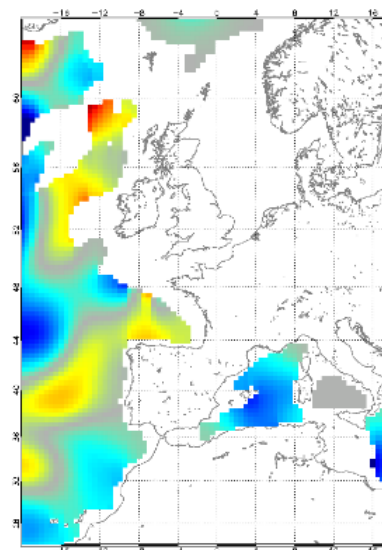


The spatial scales of the increments have been modified, as the previous scales were too small.

Old increment

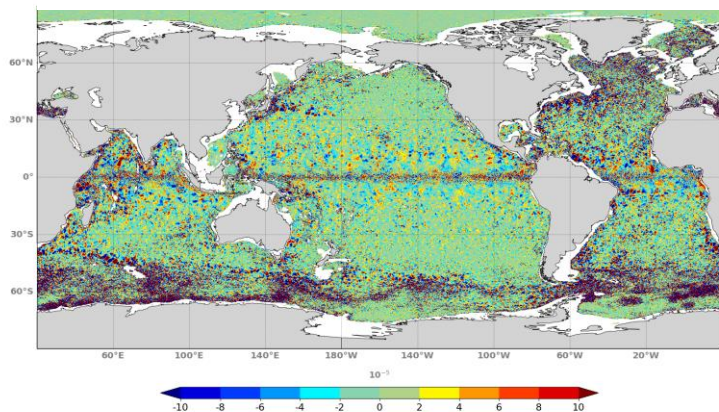


New increment

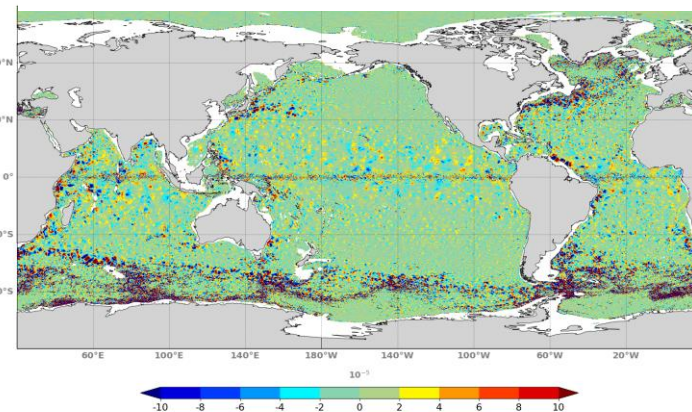


The intensity of the increments has been reduced.

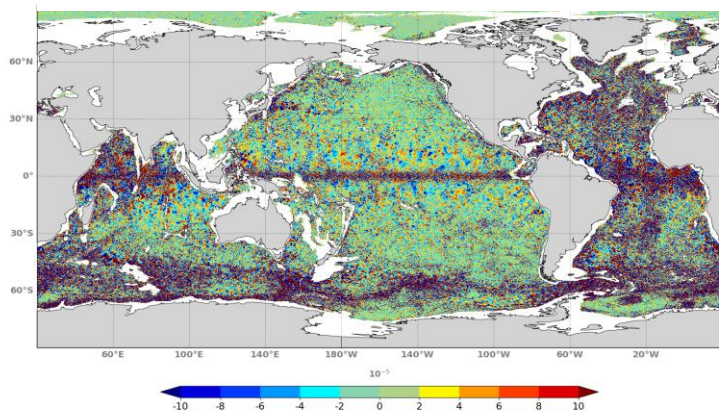
**GLO12** vertical velocity at **1000 m**



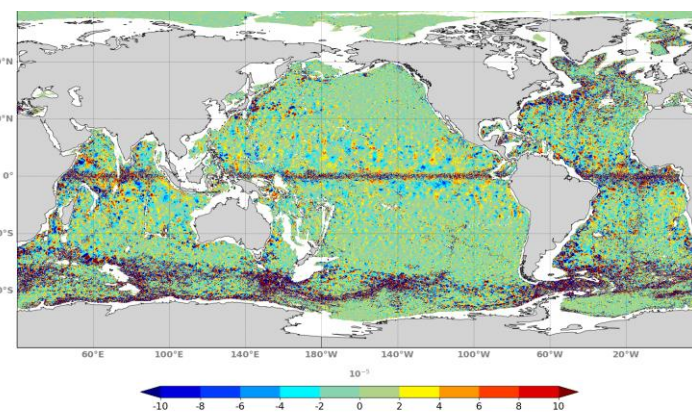
**GLO12 corrected** vertical velocity at **1000 m**



**GLO12** vertical velocity at **2300 m**



**GLO12 corrected** vertical velocity at **2300 m**



The GLO12v4 system will benefit from a few evolutions, such as the introduction of

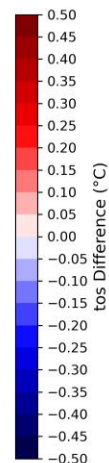
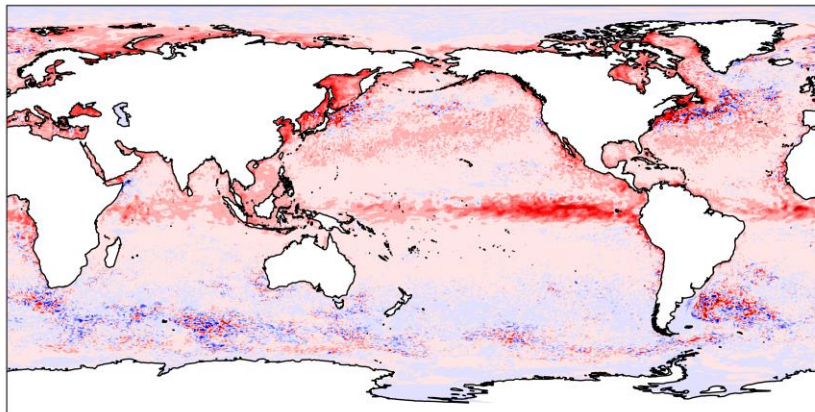
- **wave forcing**,
- **daily analysis** to improve the quality of the forecast
- the use of **ensemble-based methods** to provide forecast probabilities.

Additionally, the system will benefit from the inclusion of sea level and atmospheric pressure forcings.

All these developments have already been largely initiated in R&D mode...

The system will also benefit from the inclusion of **swOT, snow thickness and freeboard radar** data in the system if mature enough and if the data are available in real time.

Mean SST difference on 2024 : GLO4+Waves minus GLO4



From Stéphane Law Chune

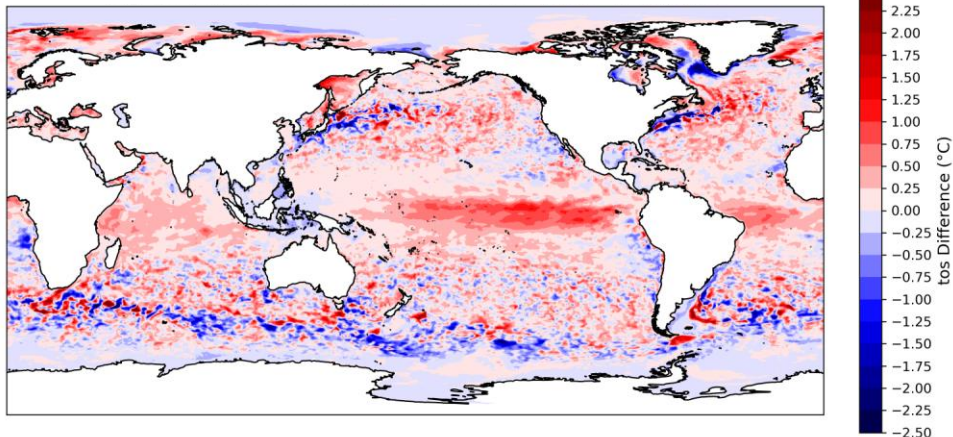
The GLO12v4 system will benefit from a few evolutions, such as the introduction of

- **wave forcing**,
- **daily analysis** to improve the quality of the forecast,
- the use of **ensemble-based methods** to provide uncertainty and forecast probabilities.

Additionally, the GLO12 model will include tidal and atmospheric pressure forcings.

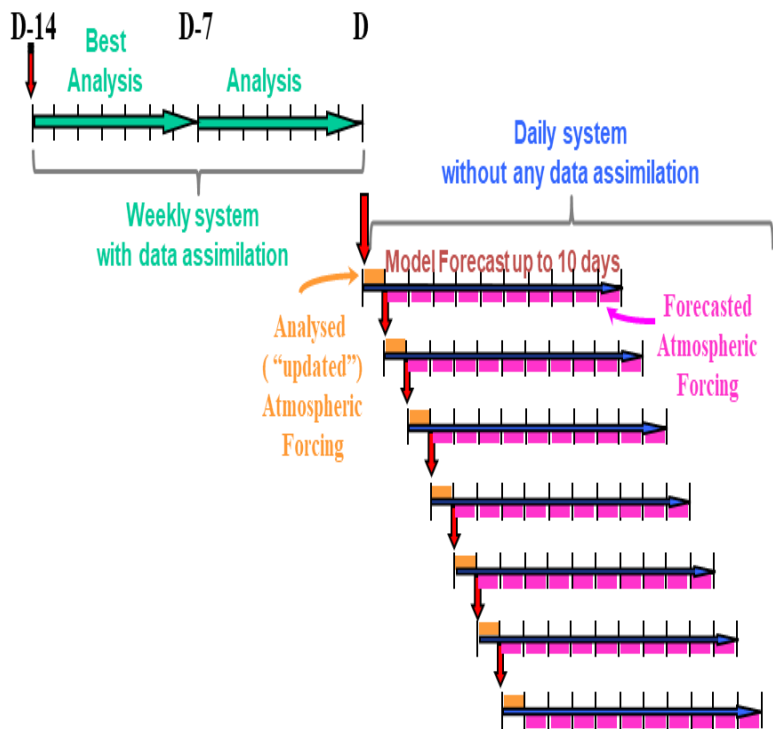
- the **assimilation of SWOT, snow thickness and freeboard radar** data in the system if mature enough and if the data are available in real time.

Mean SST difference on 2024 : GLO4 minus GLO4free

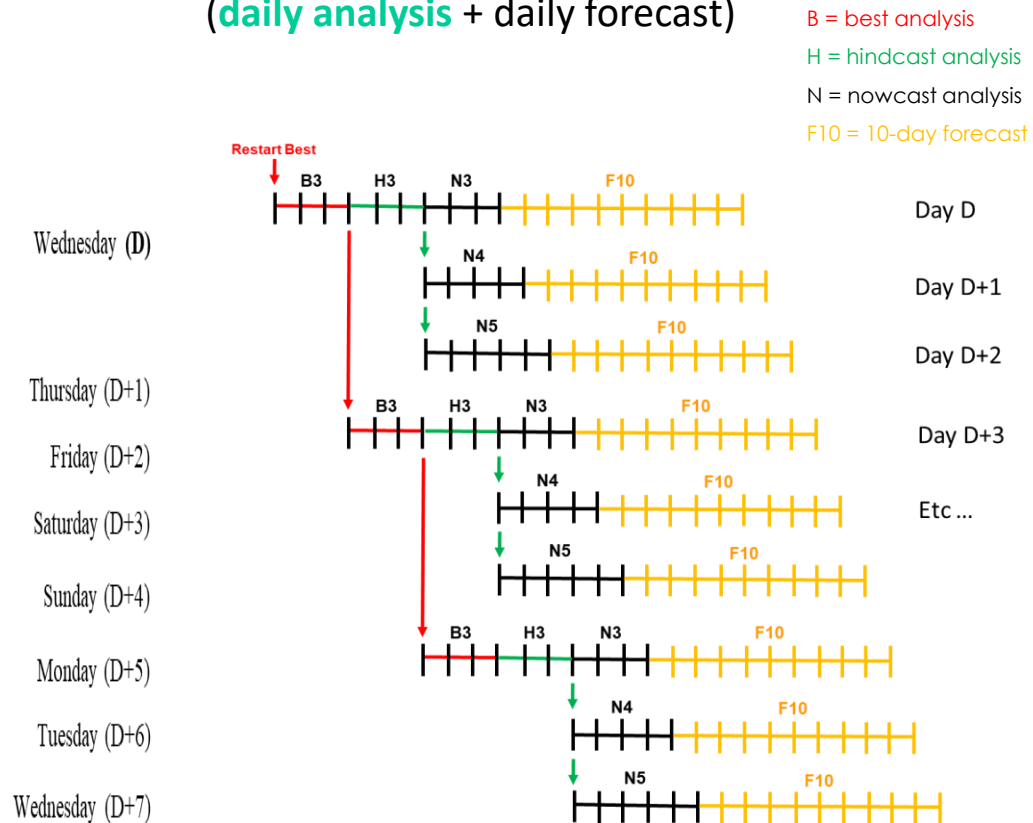


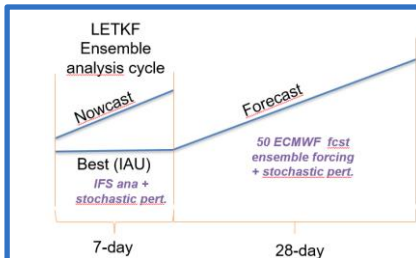


## Current scenario (weekly analysis + daily forecast)



## New scenario (daily analysis + daily forecast)



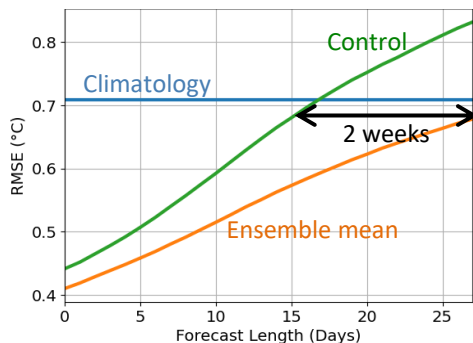


- ❑ Based on Noobs, MROA and NEMO4.2
- ❑ iORCA025-75layers / SI3 5 categories
- ❑ 50 members + Control (unperturbed + assim cov-ens)
- ❑ Assimilated observations (SST-OSTIA, In-situ, Sea Level Anomaly, SIC-OSISAF)

*From Giovanni Ruggiero*

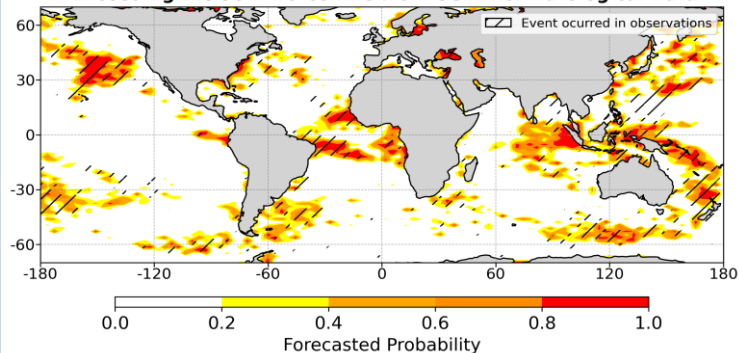
## Informative extended range forecasts

Forecast performance shown as root mean squared error (RMSE) SST-OSTIA



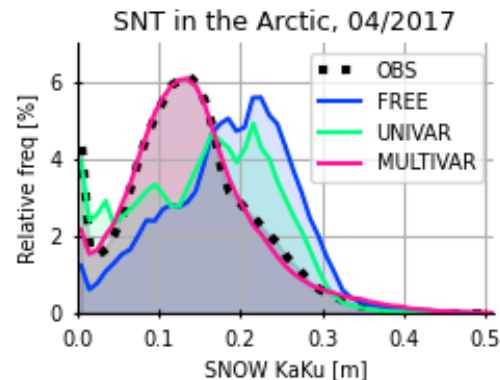
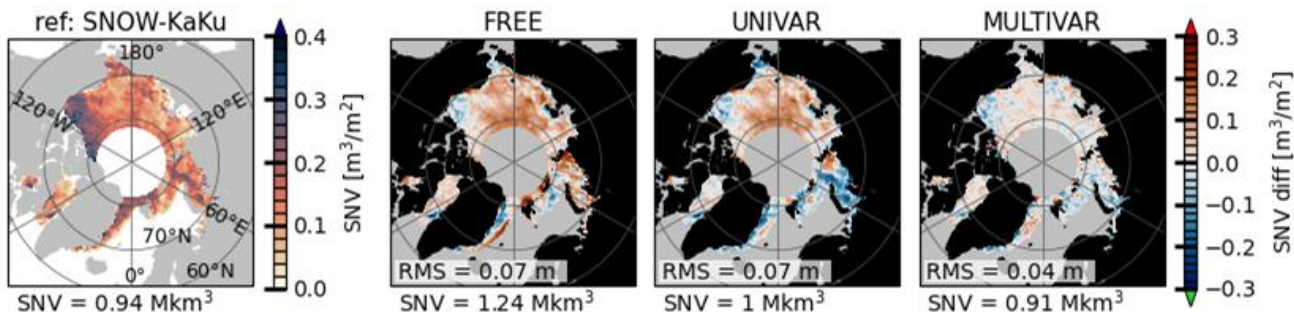
The ensemble mean extends predictability by approximately 2 weeks for SST.

Probability of Forecasted Sea Surface Temperature (SST) Exceeding the 90th Percentile from OSTIA Climatological Data

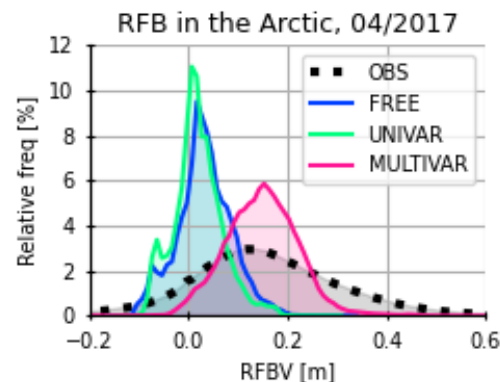
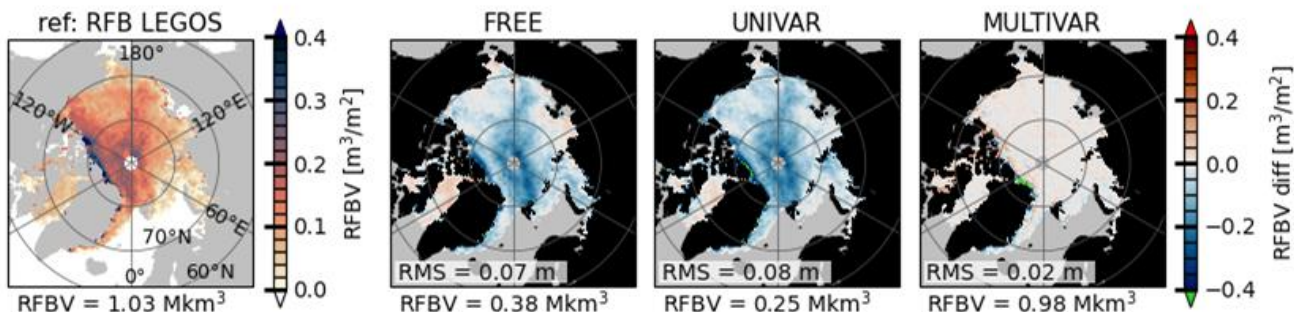


The ensemble system provides some information on the probability of events of interest for users, such as the probability of forecasted SST exceeding the 90th percentile from OSTIA climatological data. Hatched areas indicate where this event was confirmed by real-time OSTIA data.

## April 2017 Arctic snow volume differences relative to SNOW-KaKu



## April 2017 Arctic radar freeboard volume differences relative to RFB LEGOS



- **FREE** and **UNIVAR** : similar biases.
- **MULTIVAR** : the closest to the assimilated observations.