Ocean Predict

SYMPOSIUM OP'24

In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Impact of SWOT Data in a global high-resolution analysis and forecasting system

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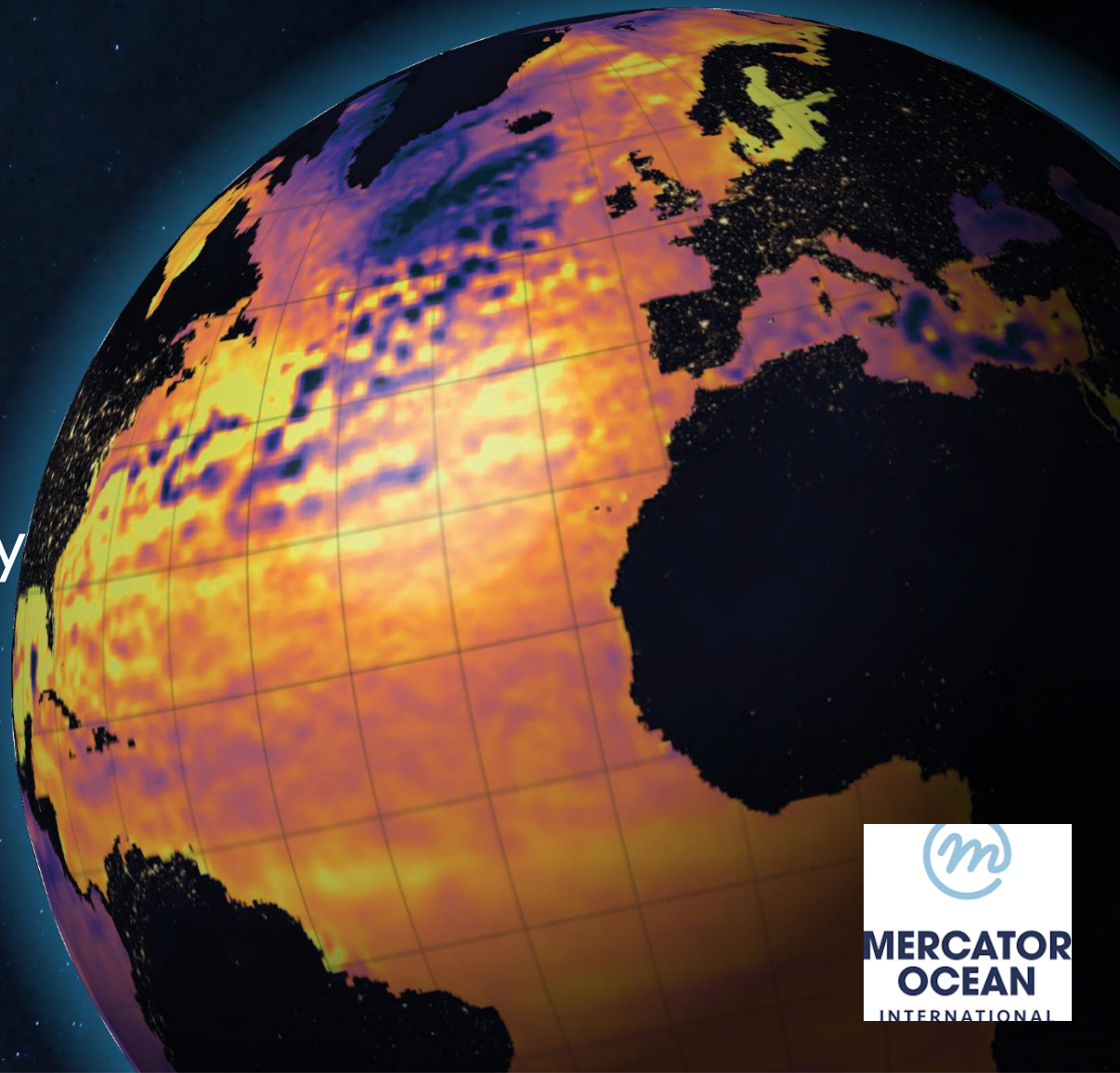

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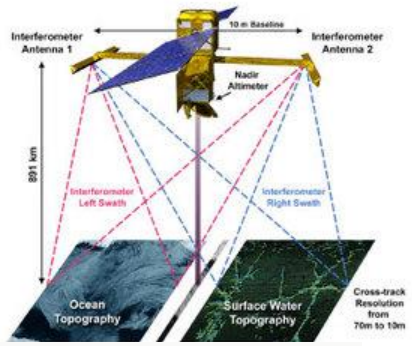
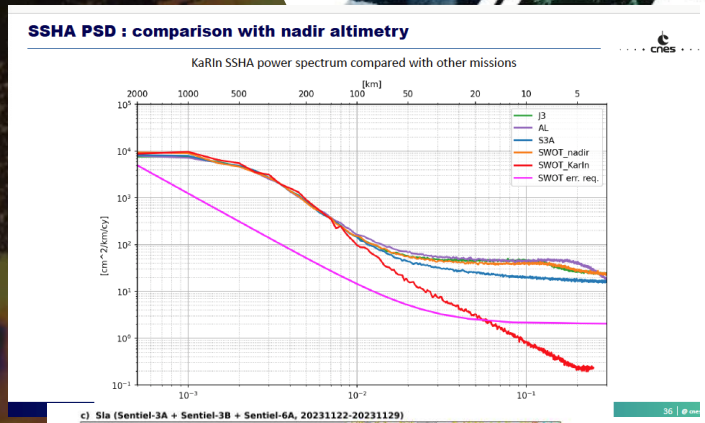
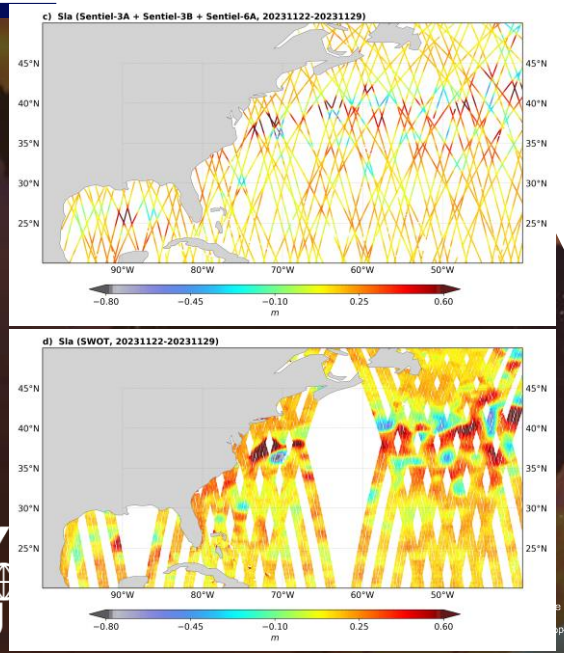
Outline







- Motivations :
  - Addition of wide swath altimetry assimilation to other data
  - Estimation of the impact of SWOT data assimilation in a global system:

- Ocean Observing System Simulation Experiments (**OSSEs**) have been performed to assess the impact of SWOT on the Mercator Ocean and Copernicus Marine Environment Monitoring Service (**CMEMS**) global, high-resolution analysis and forecasting system.

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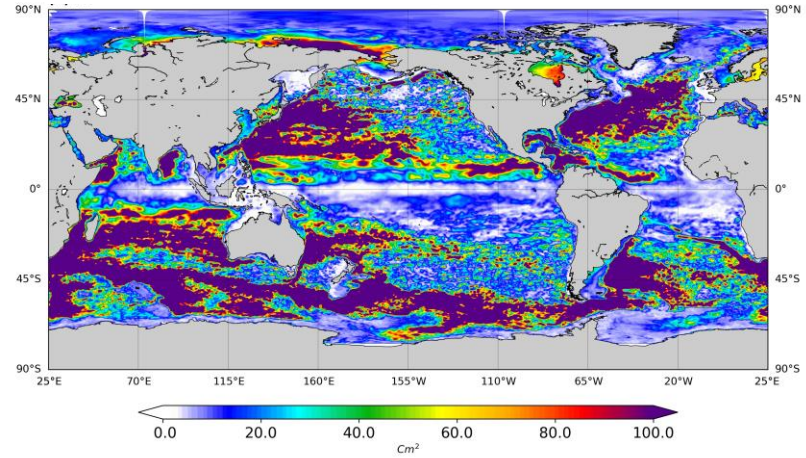
  - Impact of SWOT 1Day **Calval** Phase
  - Impact of SWOT 21Day **Science** Phase

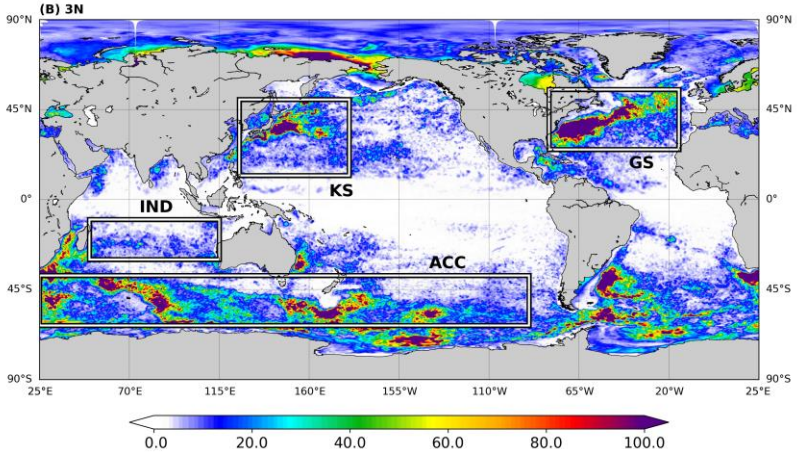
OSSE : Impact of SWOT data assimilation in the global system

SSH Variance Error : 3Nadirs vs SWOT (1-year OSSEs)

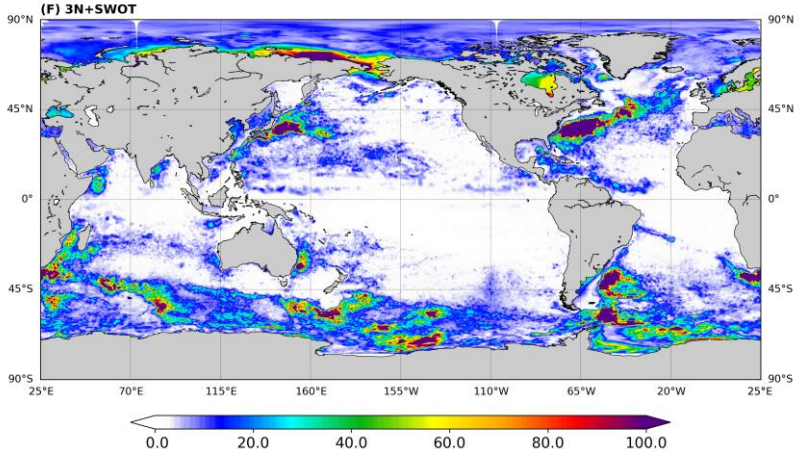
Control

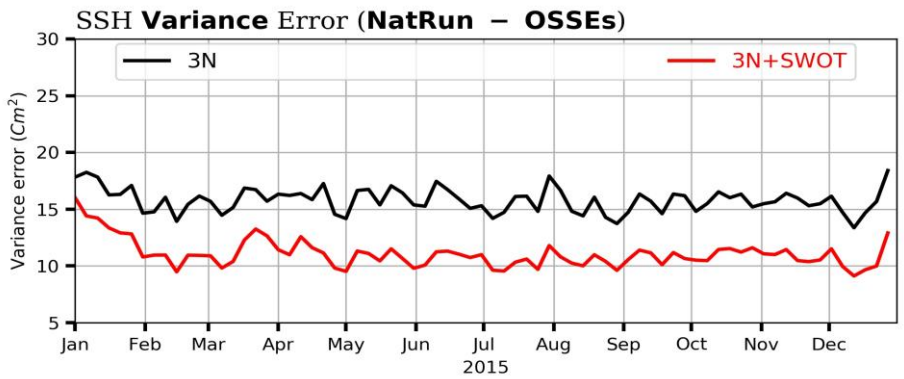


3Nadirs



3Nadirs +SWOT





3N+SWOT = 11Cm² compared to 3N =15Cm²

SSH Adding SWOT Gain : 36%

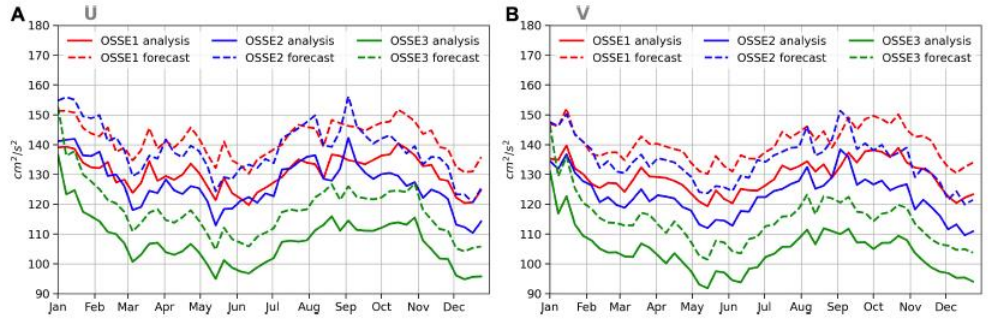


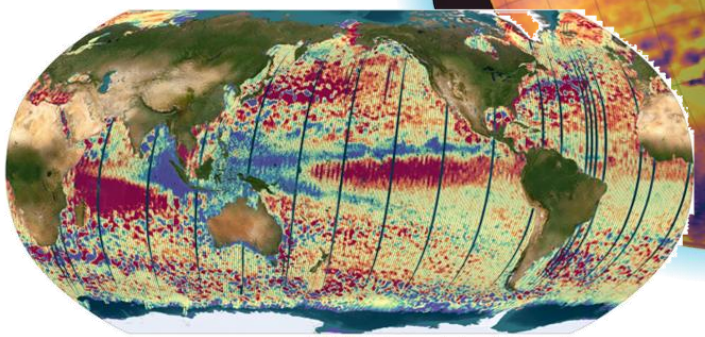
FIGURE 11 | Temporal evolution of **(A)** zonal velocity (U) and **(B)** meridional velocity (V) error variance (in cm^2/s^2) for 7-day ocean analysis (plain lines) and 7-day ocean forecast (dash lines) over the period from January 1 to December 29, 2015. The results were obtained by comparing U and V in the OSSE1 (red lines), OSSE2 (blue lines), and OSSE3 (green lines) experiments with the U and V from the NR. See **Table 2** for a description of each experiment.

OSSE1: 3Nadirs
OSSE2: SWOT
OSSE3: 3Nadirs+SWOT

(Benkiran et al. 2021 Tchonang et al., 2021).

- Velocity : Adding SWOT in the global Ocean :
  Improvement (**24% in Analysis and 23% in Forecast**

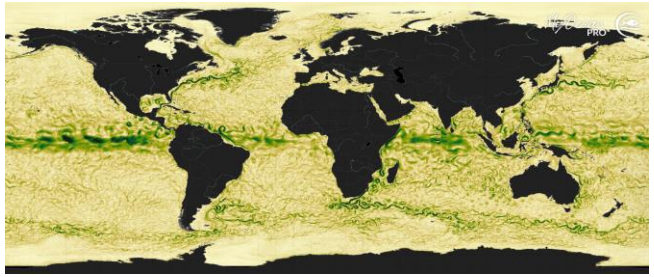
OSE SWOT : 1-day CalVal Phase and 21-day Science Phase



- SWOT Level-3 (**L3, AVISO+**) product (**version 1.0.2,** 2km resolution):

  - 1-day **CalVal** phase : 28thMarch 2023 – 10thJuly 2023
  - 21-day **Science** phase : 26th July 2023 – 29th April 2024

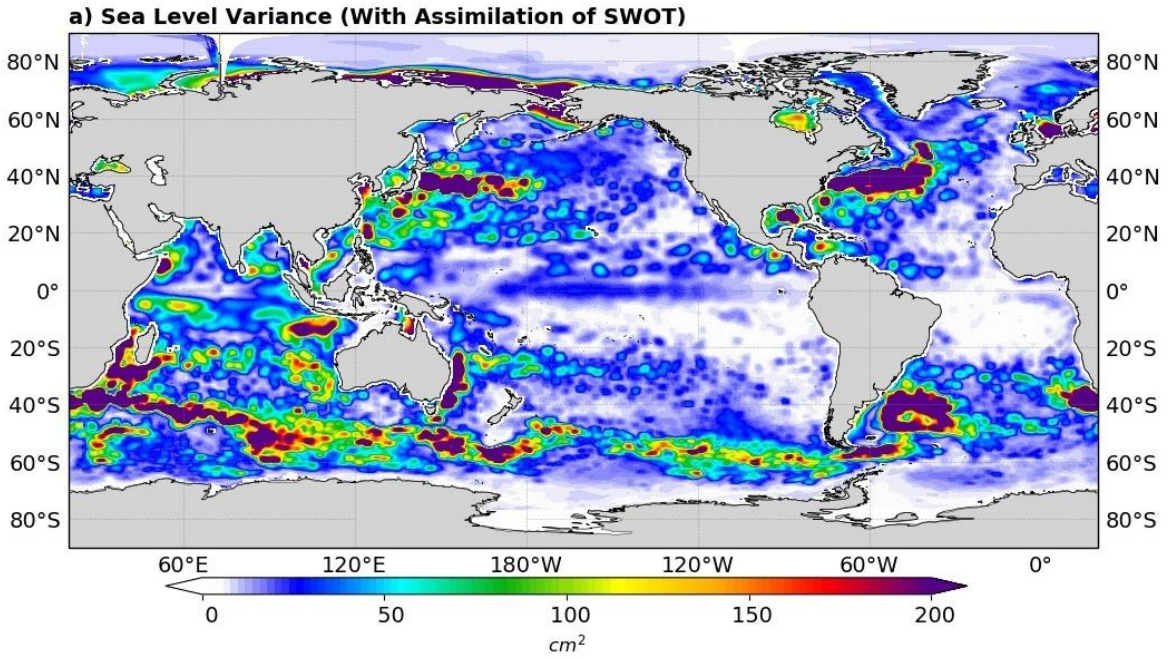
- Copernicus Marine Service global 1/12° modelling and data assimilation system
  - ✓ Model : Nucleus for European Modelling of the Ocean (NEMO)
  - ✓ Assimilation system (SAM2 (Système d'Assimilation Mercator V2))
    - Assimilation :
      - SST (ODYSSEA,1/10°)
      - In-Situ Temperature and Salinity profiles Coriolis
      - SLA: Sentinel-3A, Sentinel-3B, Sentinel-6A
      - ICE: L4 sea ice concentration (OSI SAF)
    - MSSH : HYBRID_MSSH_V5_ORCA12_r1 (cmems)
    - Validation : SLA(Jason-3, Saral/Altika, Cryosat-2, Haiyang-2B, Duacs L4) , SST(OSTIA)



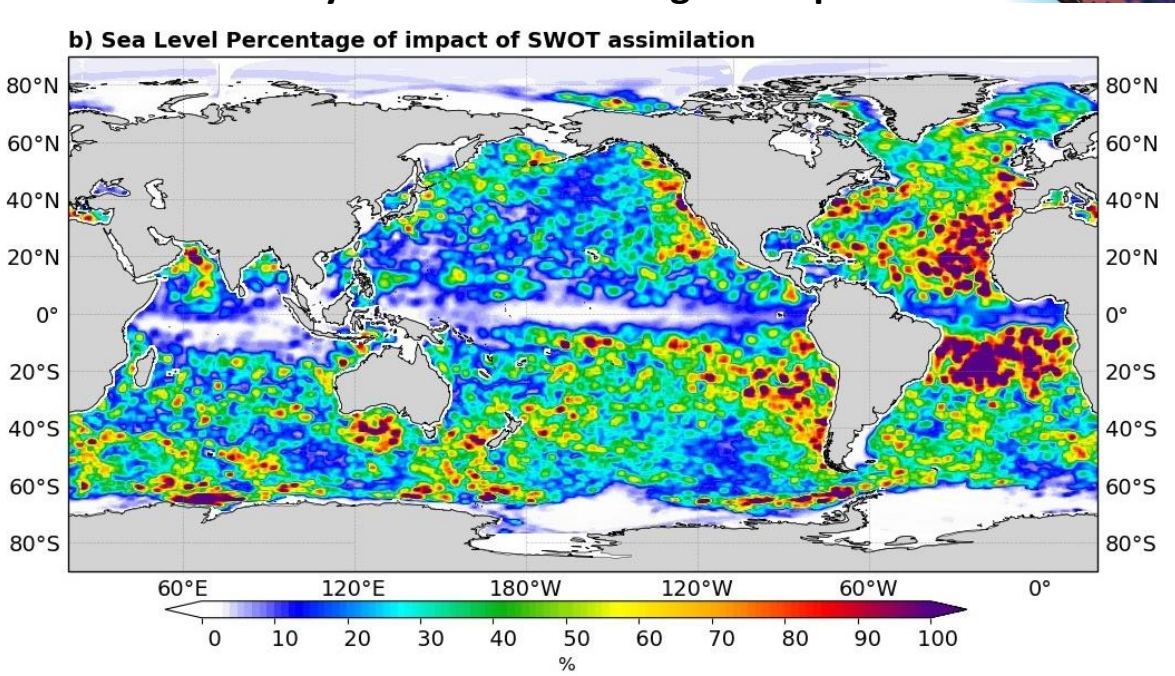
Impact of SWOT Assimilation on Model Sea Level Anomaly

Simulation (OSE): Sep 2023-March 2024

Sea Level Anomaly Variance (Assimilation of SWOT)



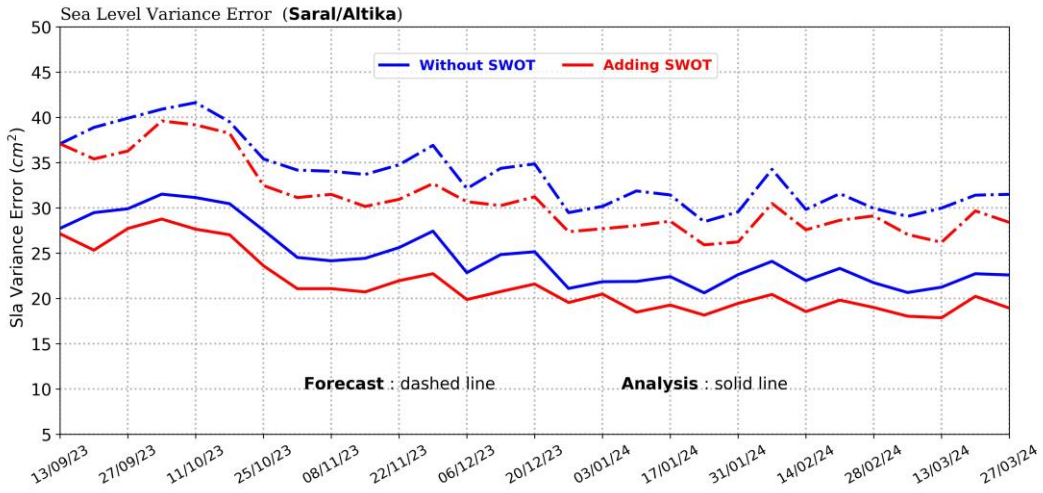
Sea Level Anomaly Variance Percentage of Impact of SWOT

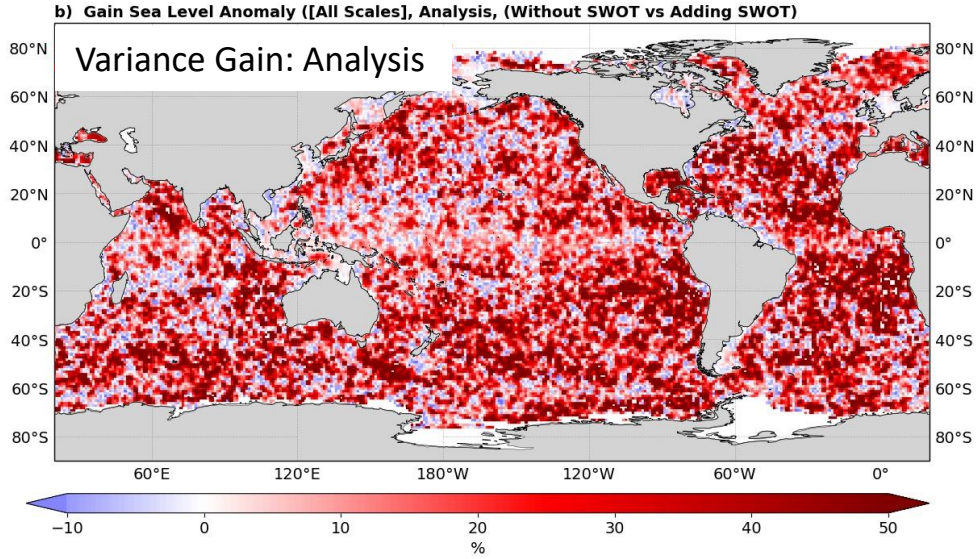


- Variance Percentage is higher in regions of low signal variability:
  SWOT provides more information than nadir altimeters.
- Low impact in the tropical band (large-scale circulation):
  Nadirs control these region well.

Impact of SWOT Assimilation on model Analysis and forecast

VarError : Variance Error (Model Error relative to the No assimilated **Saral/Altika**)



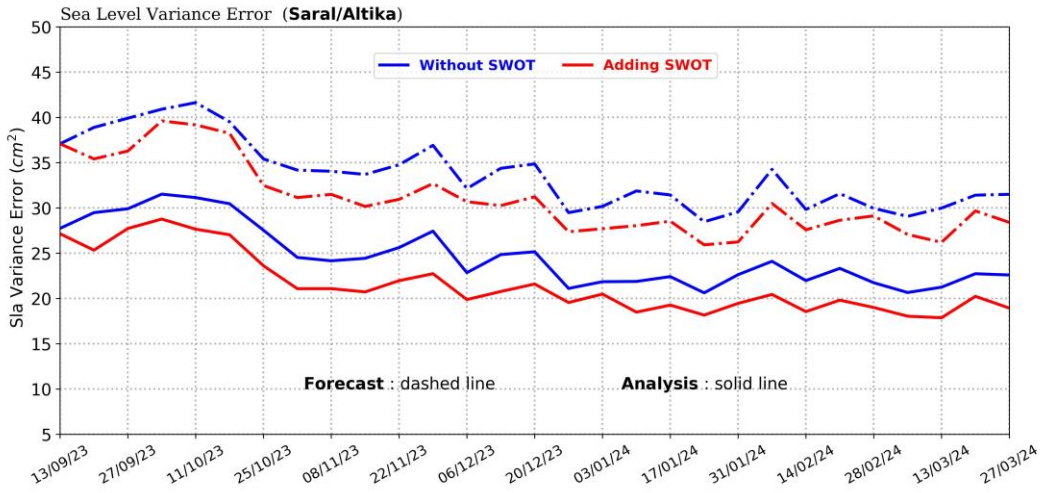


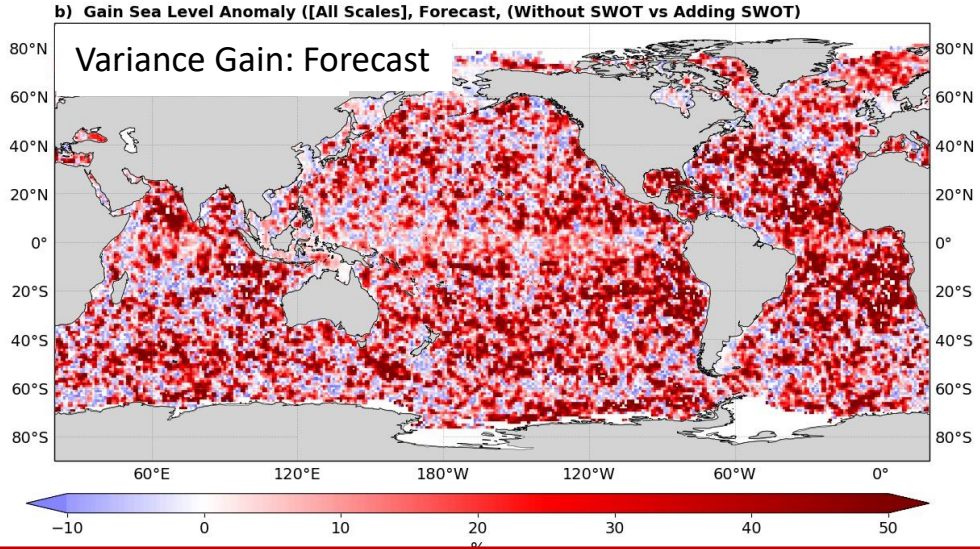
Assimilation of SWOT:

- ✓ Reduces the error compared no assimilated Saral/Altika (Forecast and Analysis)
- ✓ Gain is well distributed across the global ocean

Impact of SWOT Assimilation on model Analysis and forecast

VarError : Variance Error (Model Error relative to the No assimilated **Saral/Altika**)





Model error relative to the non assimilated Saral/Altika data

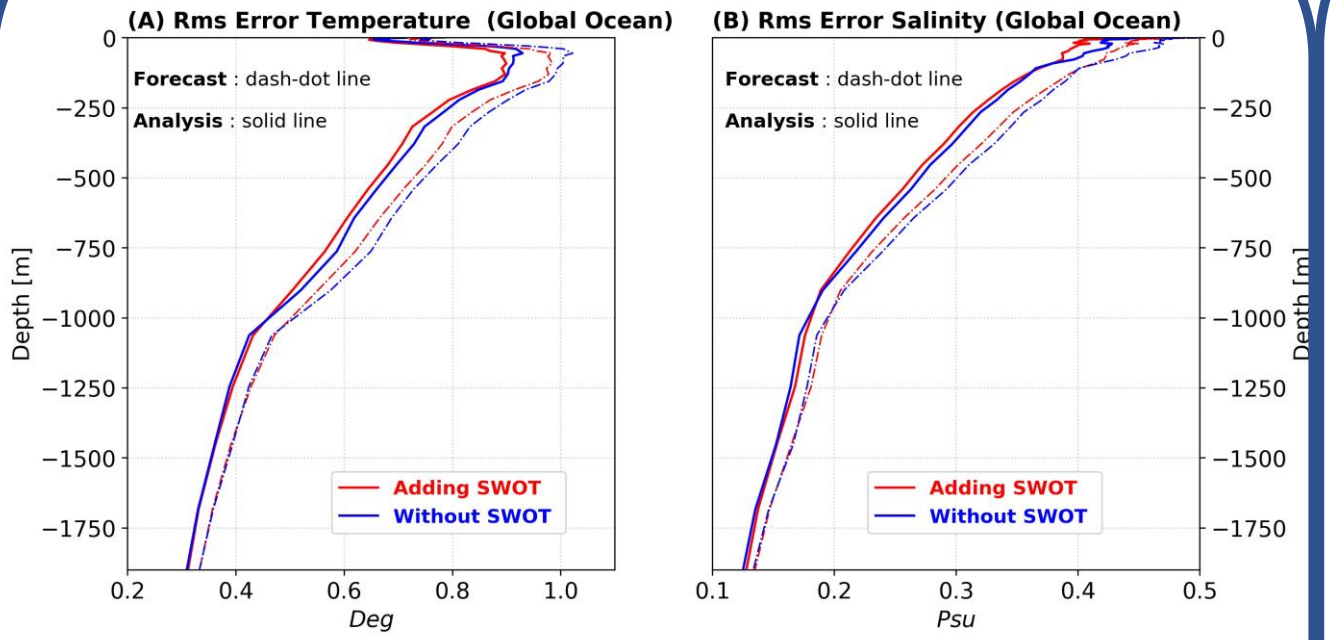
(Improvement with SWOT)

Assimilation of SWOT: more mesoscale structures every where, positive impact in all regions

	Open Ocean		Coastal region	
	Analysis	Forecast	Analysis	Forecast
Low variability	15.1%	12.9%	13.4%	10.5%
High variability	14.5%	10.6%	14.0%	10.8%

Assimilation of SWOT: Impact on Temperature , Salinity profiles and Sea Surface Temperature

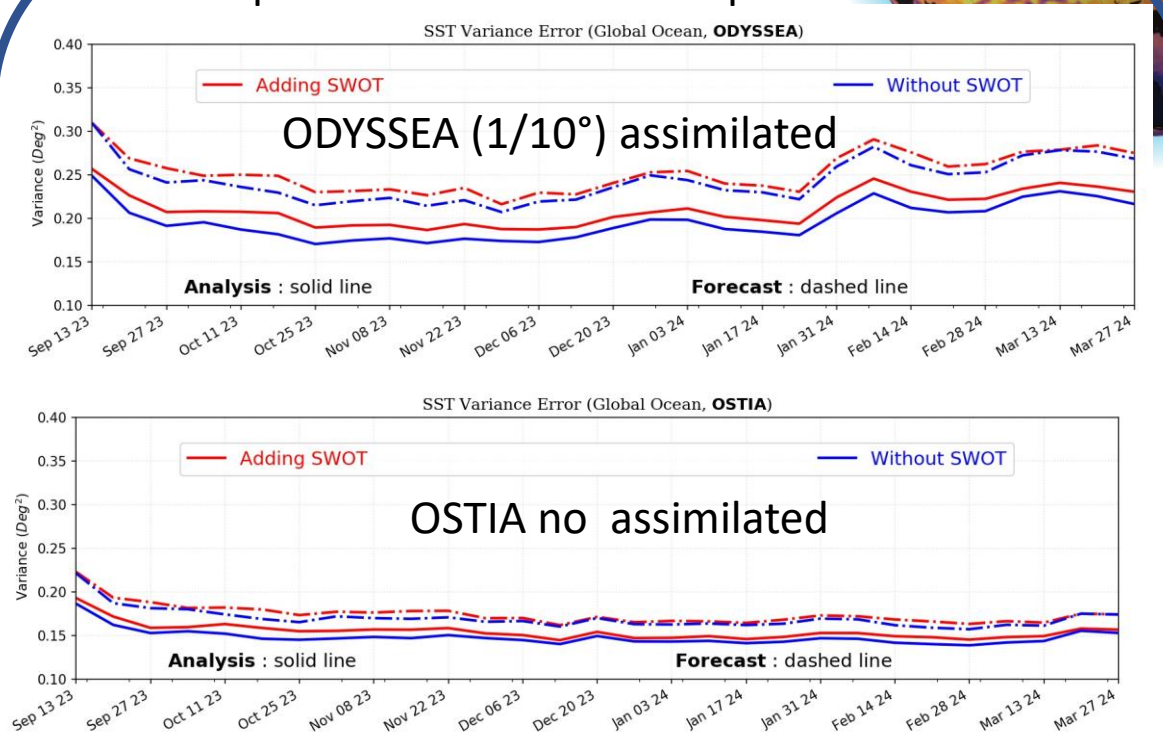
Impact on Temperature and salinity profiles



Assimilation of SWOT:

- ✓ No degradation either in Forecast or Analysis
- ✓ Reduction of error between Surface and 1000m

Impact on Sea Surface Temperature



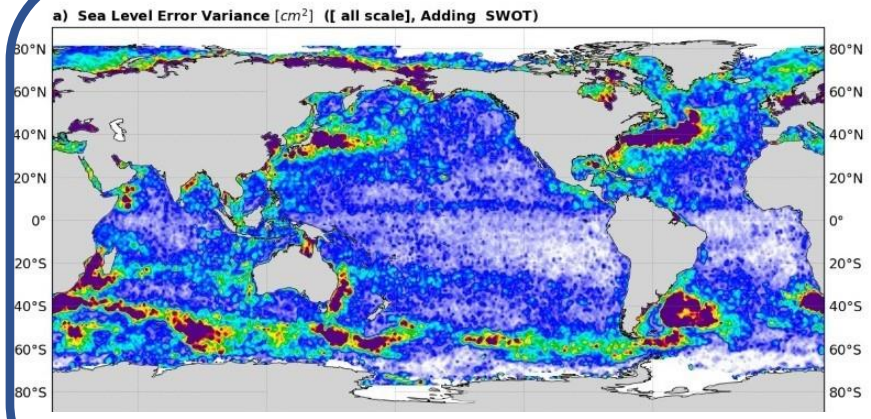
Assimilation of SWOT:

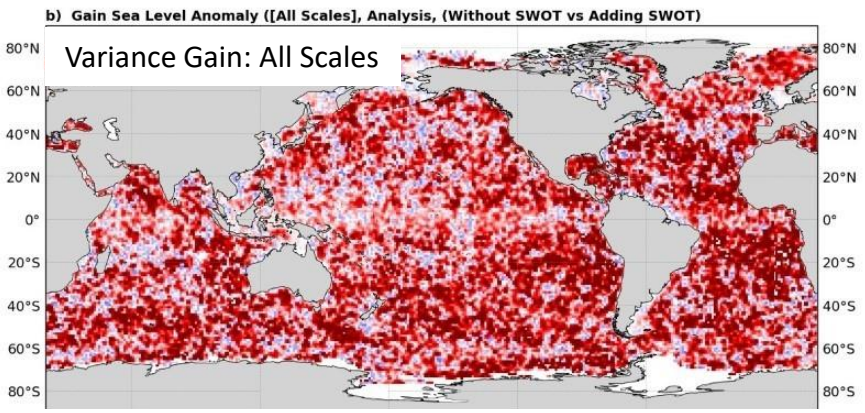
- ✓ Degradation (ODYSSEA) in Forecast (3%) and Analysis (5%):

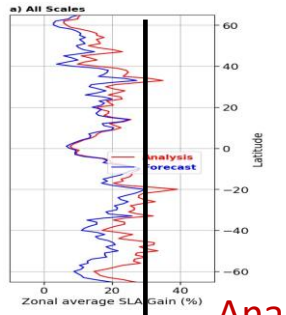
Balancing the observation weight in assimilation (+ Observation Error) between SLA and SST?

Impact of SWOT Assimilation on model Analysis

(All Scales vs 65km < Scales < 250km)







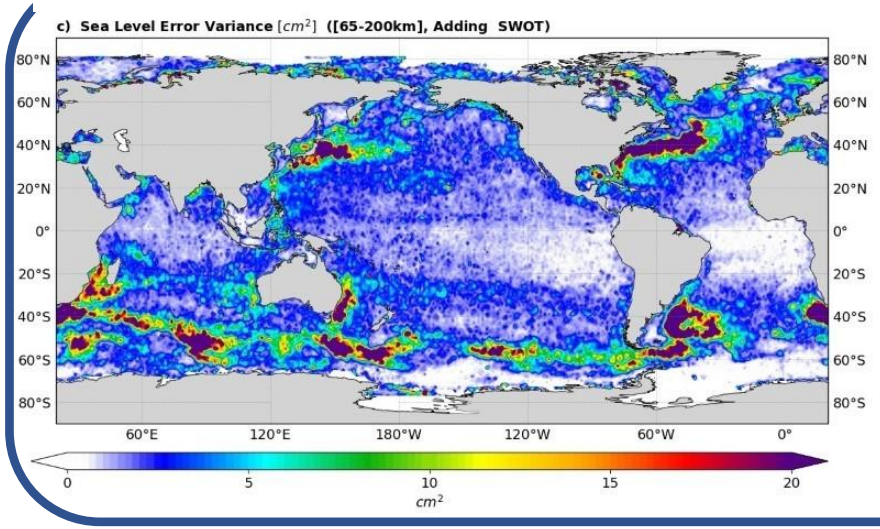
25%

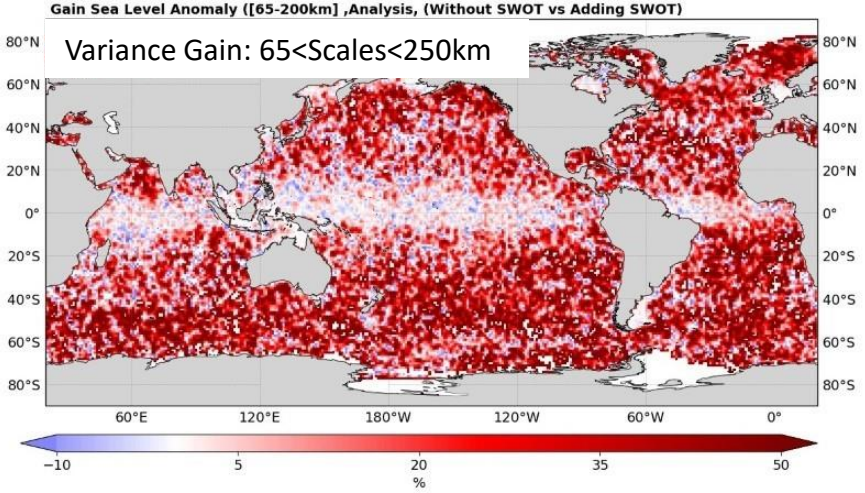
All Scales

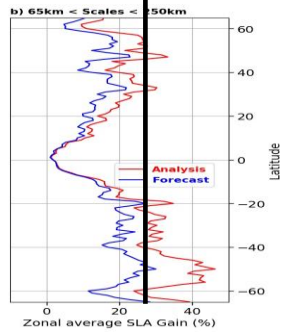
Analysis

Forecast

➢ **The Variance Gain is greater for the small scale than the large one.**





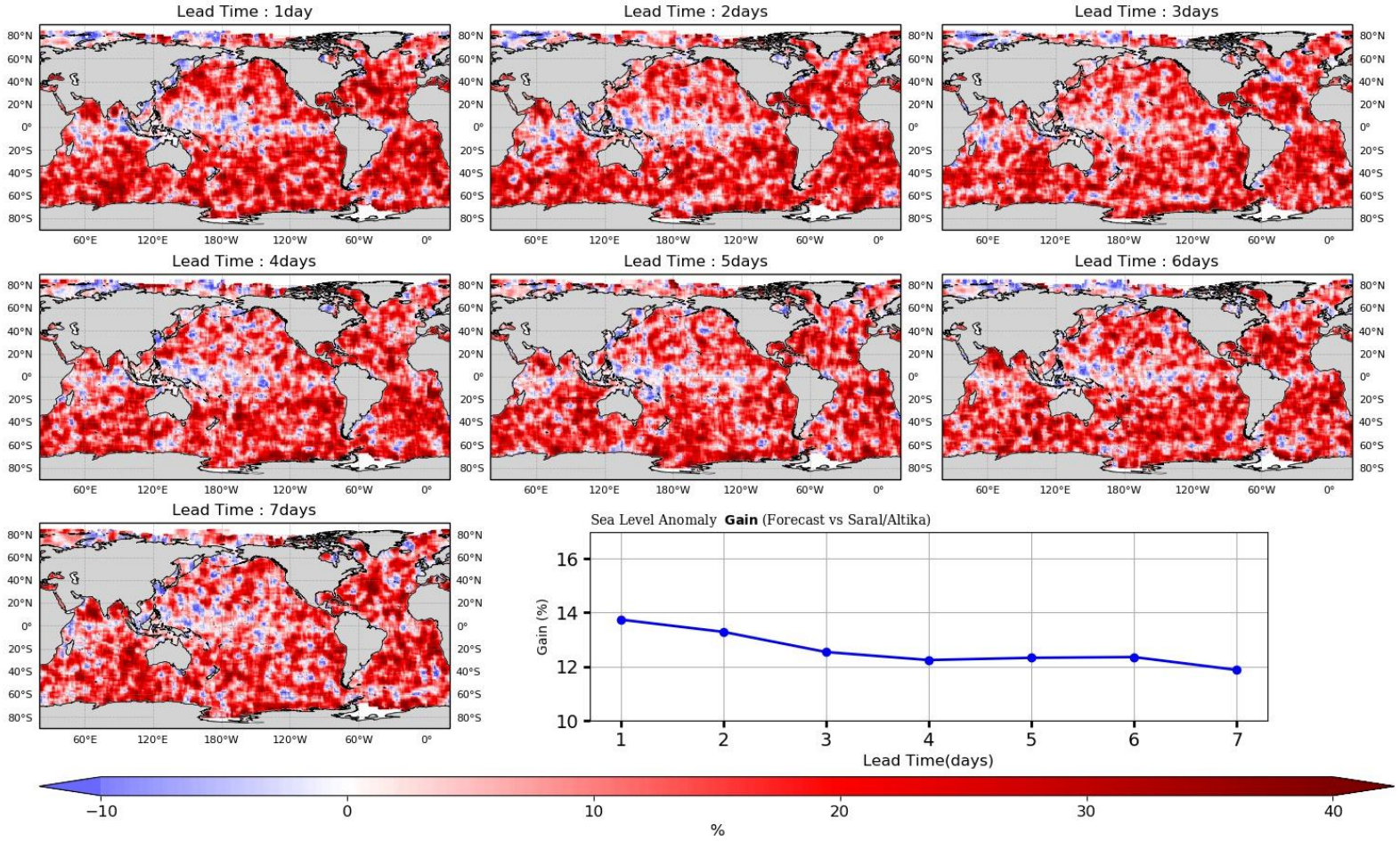


65 < Scales < 250km

Zonal average SLA Variance Gain(%)

Impact of SWOT Assimilation on model Forecast

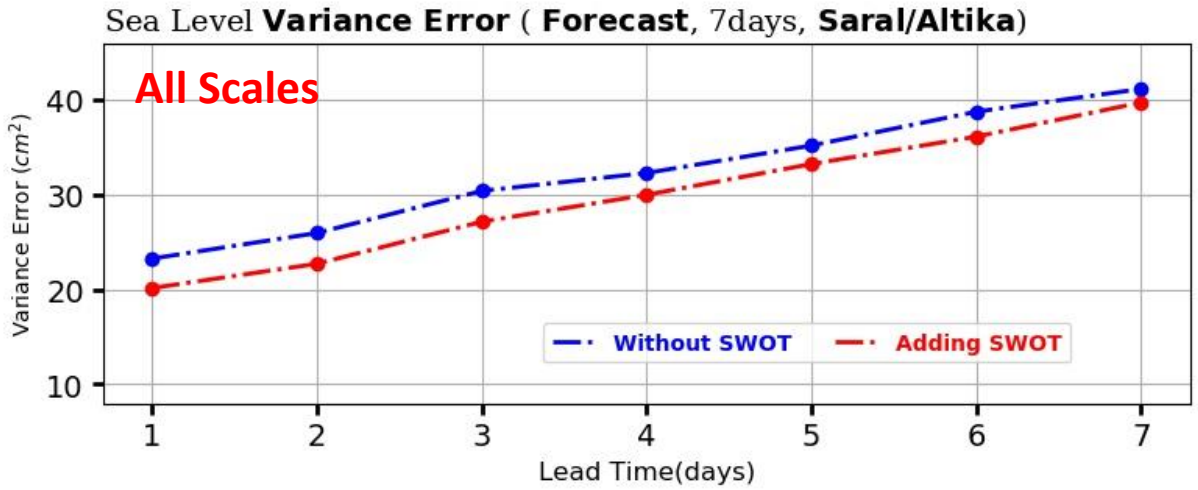
Variance Gain Sea Level Anomaly (**All scales**, OSE SWOT, Model **Forecast** vs **Saral/Altika**)
Lead times from 1-day to 7-days calculated on every 1°x1° area from Sep. 2023 to March 2024

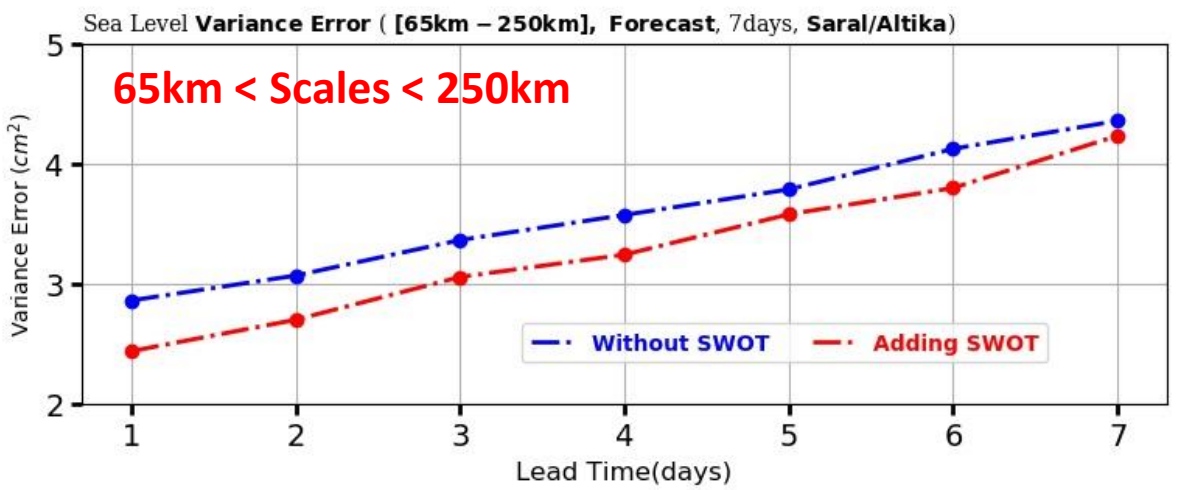


- Gain more important :
  - the mid-latitudes
  - the western currents area
  - The coastal regions.

- Decrease Gain with lead times:
  - 14% for 1-day Forecast
  - 12% for 7-days forrecast

Impact of SWOT Assimilation on model Forecast (All Scales vs 65-250km)





Sea Level Variance error for each day of forecast (1-day to 7-days, cm^2) considering the SLA on the Global Ocean, over the period from September 2023 to March 2024. Results obtained by comparing the SLA of the ocean forecast in the 3Nadirs (blue line), 3Nadirs + SWOT (red line) to the Saral/altika data.

Assimilation of SWOT:

- ✓ Gain of 1 day of forecast
- ✓ Reduction in Variance Error is more marked over the first three days on the mesoscale structures than the other scales.

Impact of SWOT Assimilation on model Forecast(6-day)

California Current (14/11/2023)

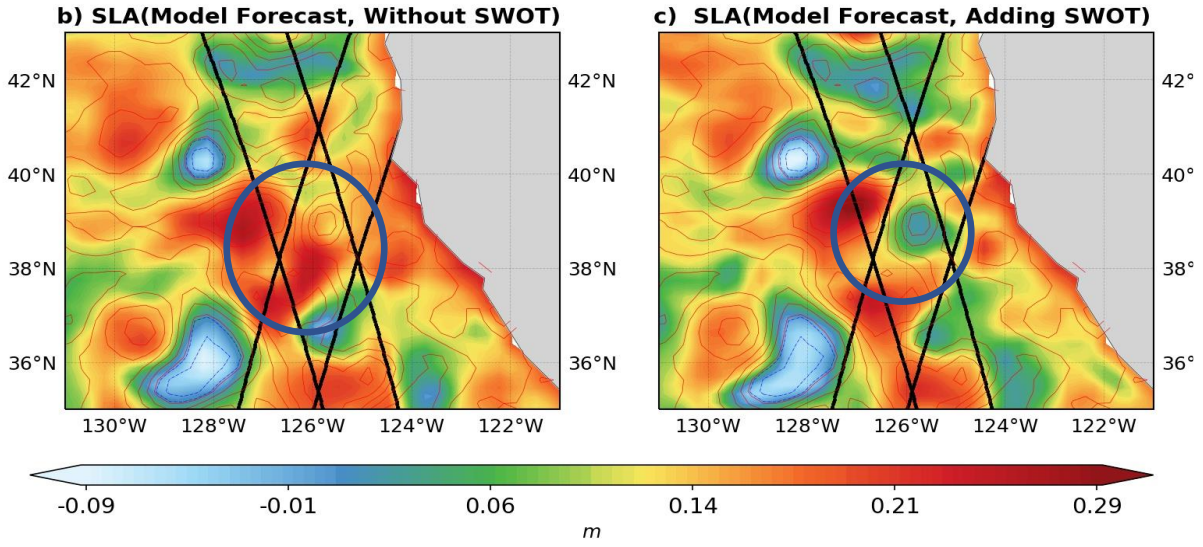
Sea Level Anomaly and model dynamic (Relative Vorticity) :

- ✓ b) SLA model forecast (without assimilation of SWOT),
- ✓ c) SLA model forecast (with assimilation of SWOT)

The contours line present the Duacs product (AVISO),

The black lines show the limits of the two SWOT swaths of the day

SLA : Model Forecast + Contour line : Duacs L4



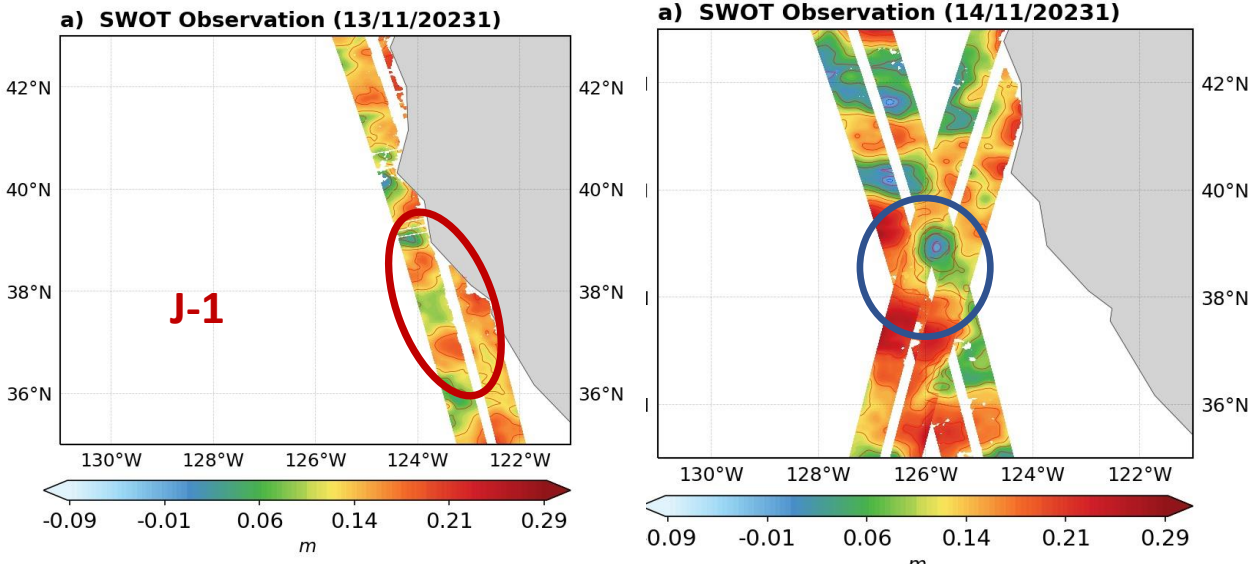
Impact of SWOT Assimilation on model Forecast(6-day)

California Current (14/11/2023)

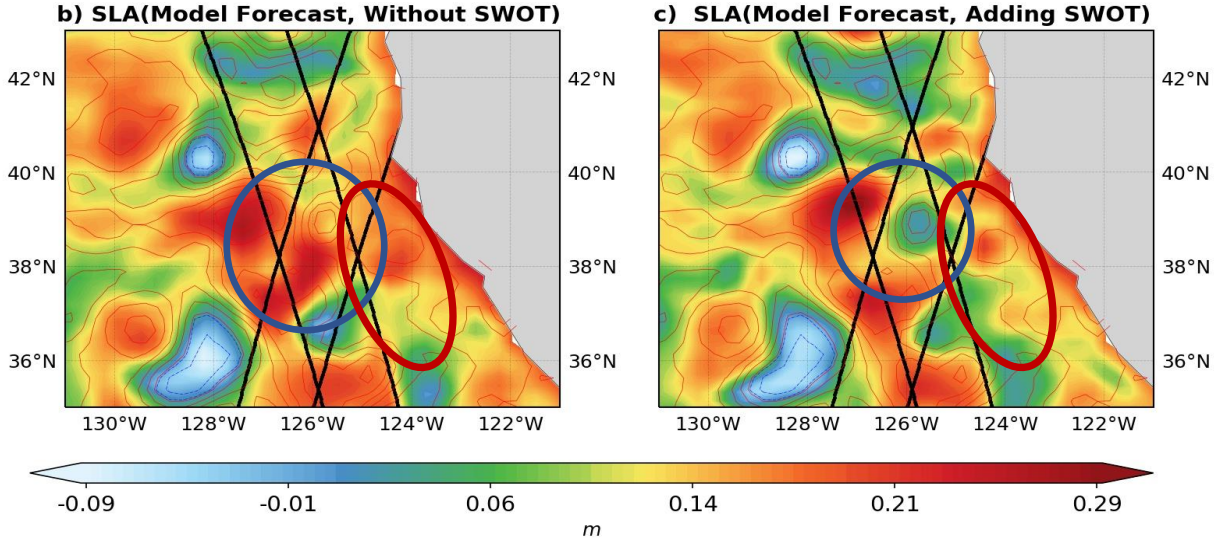
Sea Level Anomaly and model dynami

- ✓ a) SWOT Observation,
- ✓ b) SLA model forecast (without as
- ✓ c) SLA model forecast (with assim
  The contours line present the Du
- ✓ d) and e) relative vorticity without a

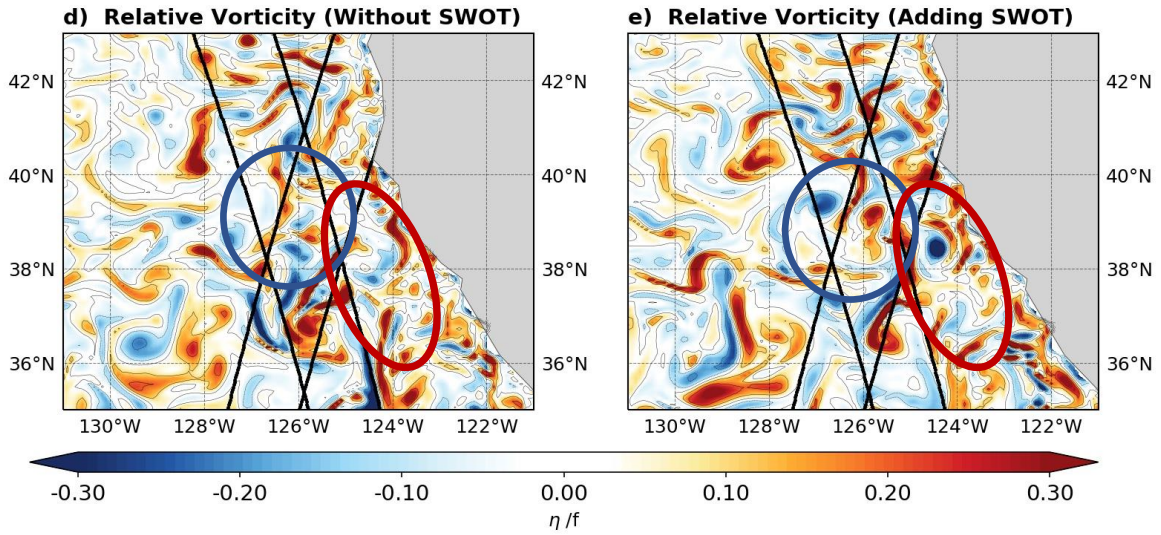
The black lines show the limits of the t



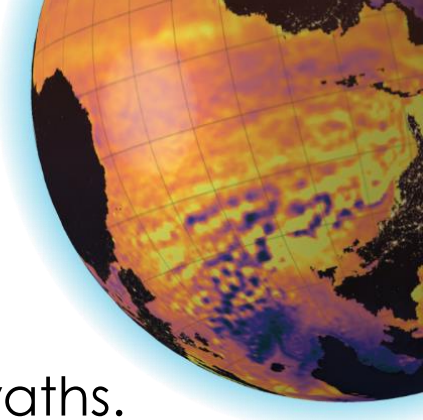
SLA : Model Forecast + Contour line : Duacs L4



Relative Vorticity : Model Forecast (14/11/2023)



Conclusions and perspectives



- **1-Day CalVal Phase :**
  - SWOT data assimilation results show already a promising improvement of the quality of ocean forecasts (gain in variance >15%).
  - The model is able to propagate this new information outside the SWOT Swaths.

- **21-Day Science Phase :**
  - The MOi/Copernicus Marine global ocean forecasting system is ready to assimilate SWOT (L3 products) data.
  - Improvement in **analysis** (~16%) and **forecast** (~13.0%) for the global system
  - A significant gain in SLA variance error for the **small scale** (65 – 250 km)

- **Perspectives and Validation :**
  - Balancing the observation weight in assimilation between SLA and SST?
  - Spectral analysis, effective resolution
  - Impact on model dynamics (horizontal and vertical Velocity)
  - Assimilation of SWOT Data with scale separation

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ADVANCING OCEAN PREDICTION
SCIENCE FOR SOCIETAL BENEFITS
Thank you!
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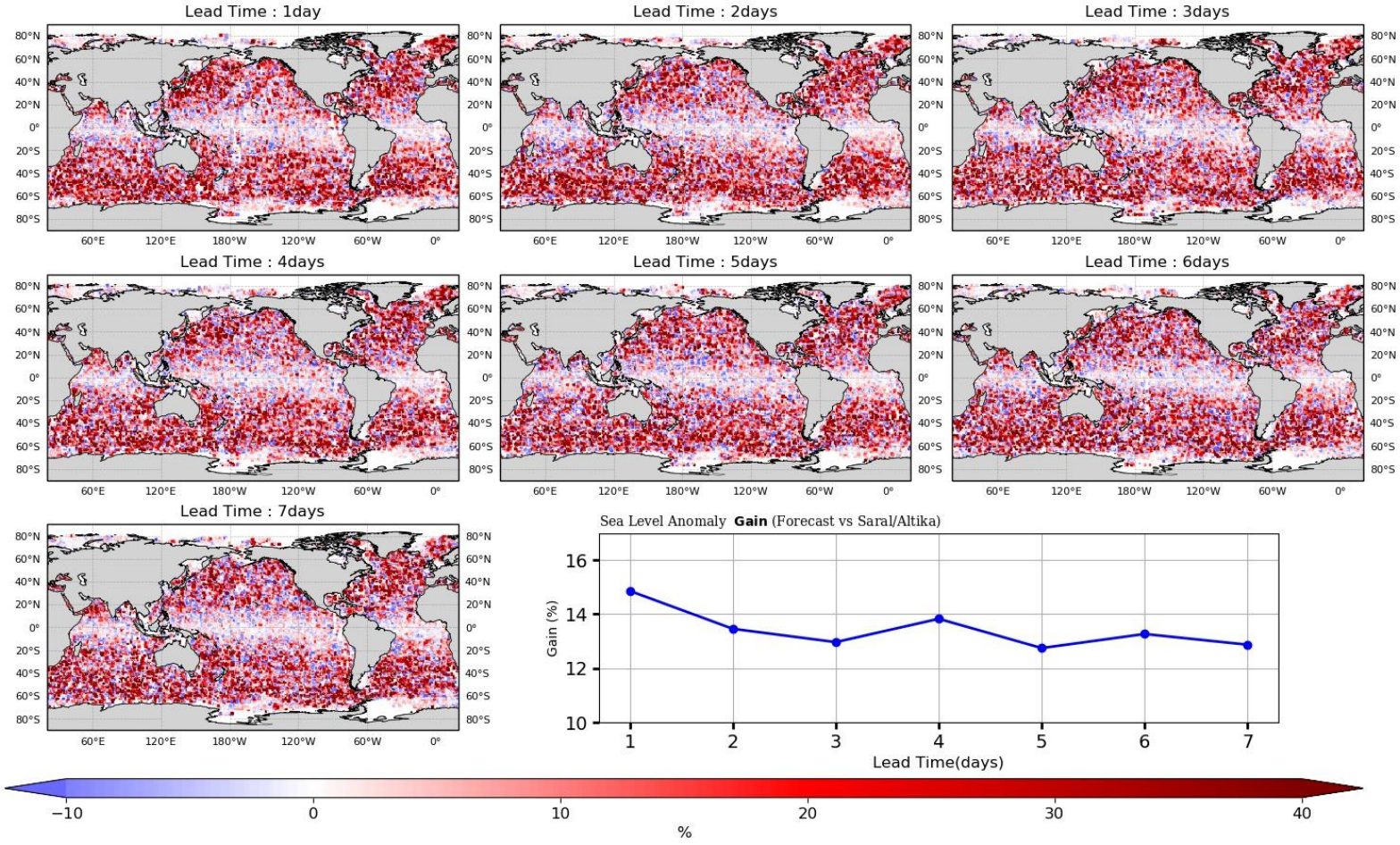
Impact of SWOT Assimilation on model Forecast

Gain Sea Level Anomaly (**65km<Scales<250km)**, OSE SWOT, Model **Forecast** vs **Saral/Altika**)