Assimilating Nadir SLA at Multiple Resolutions in the Western Mediterranean Sea

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I - Abstract

Mesoscale eddies in the Balearic Sea[a] were reproduced by integrating a high-resolution (2 km) ocean model with observations during April 2023. To assess the impact of assimilating smaller-scale features, we performed experiments assimilating Nadir SLA at 1 Hz (~7 km), 5 Hz (~1 km), and 20 Hz (~0.3 km). An Ensemble Optimal Interpolation (EnOI) scheme was used to integrate multi-platform data into an eddy-rich simulation. Model performance was evaluated using independent high-resolution SWOT observations, focusing on the representation of small-scale surface features. Results show that assimilating 20 Hz Sentinel-6A data improves the reconstruction of surface eddy patterns, highlighting the potential for further system development toward enhanced subsurface predictions.

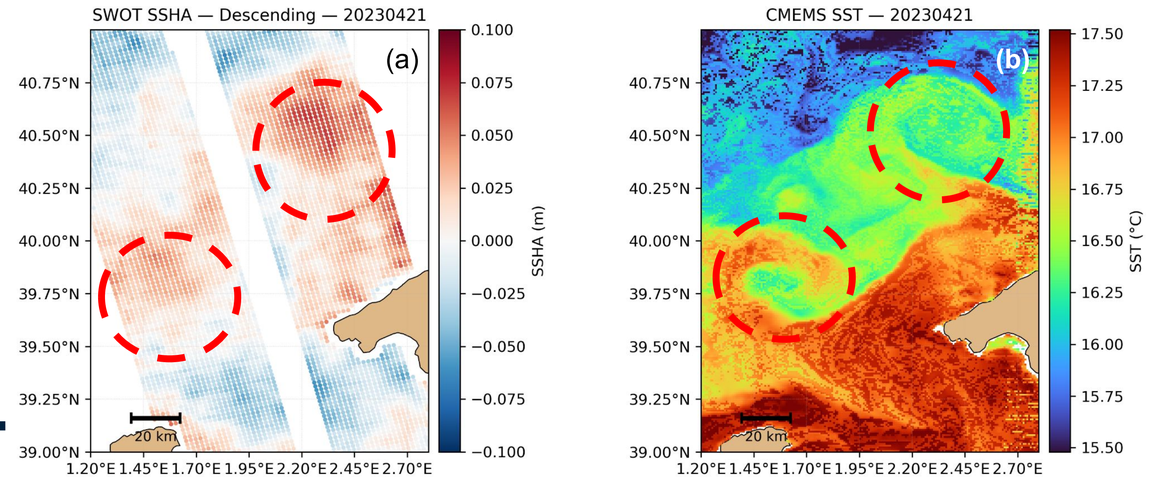
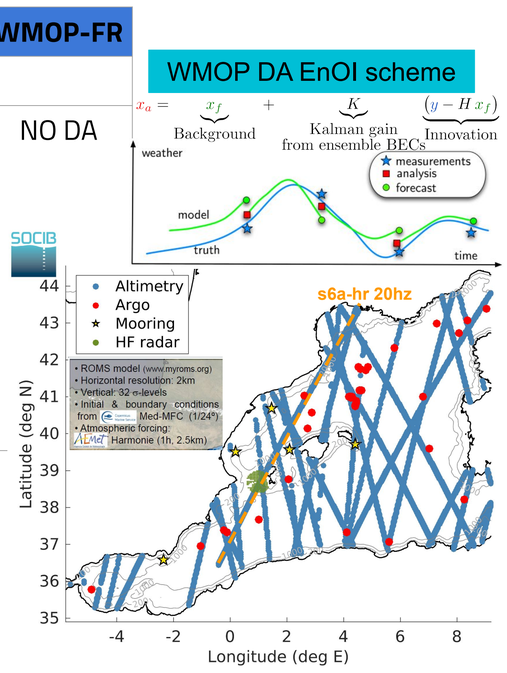


Figure 1. Maps for April 21, 2023 showing (a) SWOT sea surface height anomaly (SSHA) and (b) SST L3. Red contours mark two anticyclonic eddies observed in the Balearic Sea.

II - WMOP Data Assimilation Setup

We performed three distinct data assimilation simulations in the Western Mediterranean Operational Forecasting (WMOP)[b] system using:

WMOP-RA-1Hz	WMOP-RA-5HZ	WMOP-RA-20HZ	WMOP-FR
from 2023/04/20 to 2023/05/14			
HaiYang - h2b-l3	h2b-l3 - 1hz	h2b-l3 - 1hz	NO DA
Jason - j3n-l3	j3n-l3 -5hz	j3n-l3 - 5 hz	
Saral/Altika - al	al - 1hz	al - 1hz	
CryoSat-2 - c2n	c2n - 1hz	c2n - 1hz	
Sentinel - s3a	s3a - 5hz	s3a - 5hz	
Sentinel - s3b	s3b - 5hz	s3b - 5hz	
Sentinel - s6a-hr	s6a-hr - 5hz	s6a-hr - 20hz[c]	



The WMOP data assimilation component is based on a local multi-model EnOI scheme and integrates multi-platform observations, including satellite SLA, SST, HFR surface currents, and in-situ T/S profiles from Argo and moorings, focusing on assimilating Nadir SLA at multiple resolutions.

Figure 2. Spatial distribution of assimilated on 26 April observations in the Western Mediterranean for the analysis.

III - SWOT vs S6A-HR

Higher-frequency S6A-HR products (**20 Hz** and **5 Hz**) reproduce the amplitude and structure of the SWOT eddies signal more accurately than the **1 Hz** data. However, slight longitudinal offsets are observed in the western eddy relative to SWOT Band 1.

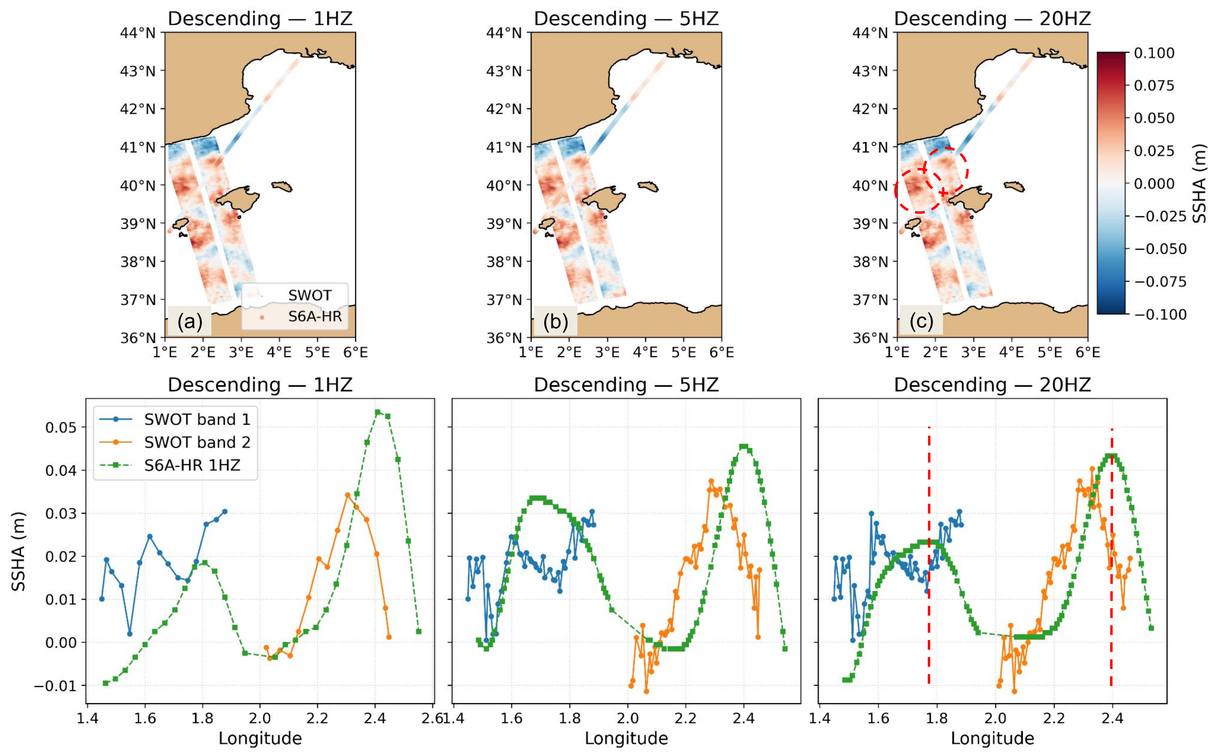


Figure 3. Comparison between SWOT and S6A-HR observations on 26 April 2023.

IV - S6A-HR vs WMOP

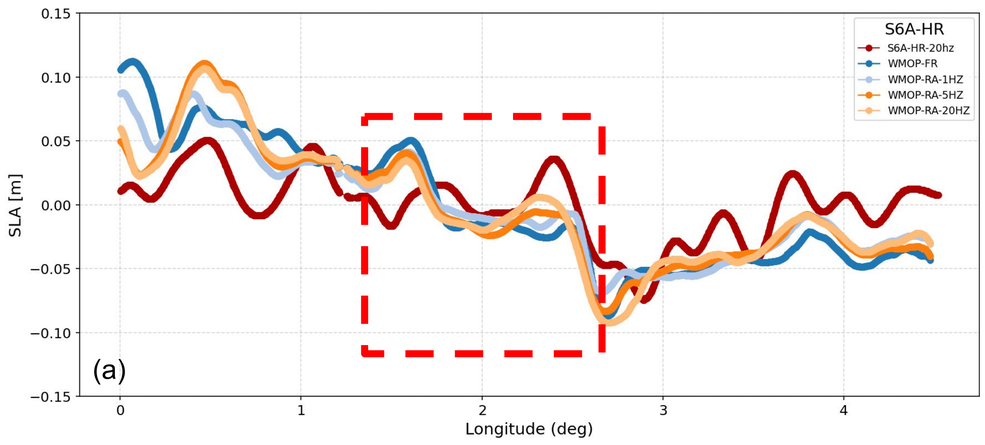
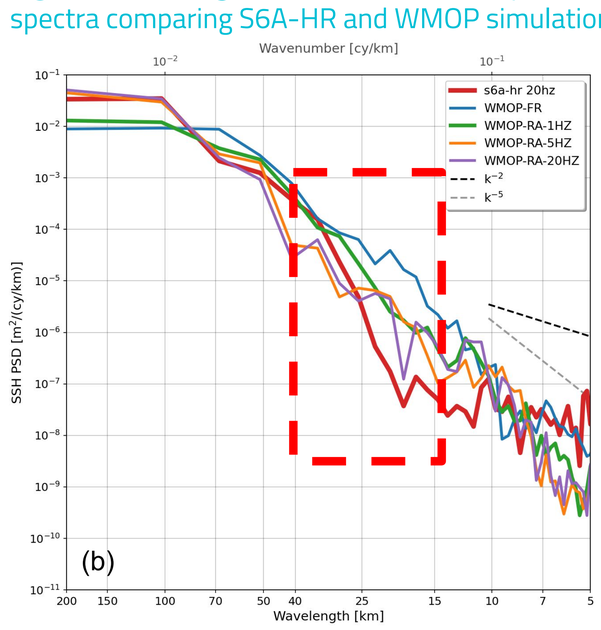


Figure 4. (a) Along-track sea level anomaly (SLA) and (b) wavenumber spectra comparing S6A-HR and WMOP simulations.



WMOP-RA **5 Hz** and **20 Hz** best match S6A-HR, capturing SLA amplitude and phase, while **1 Hz** and **FR** underestimate variability of the anticyclonic eddies.

WMOP-RA-**5 Hz** and **20 Hz** best match S6A-HR, reproducing the spectral slope (40–15 km).

WMOP-**FR** shows higher energy at wavelengths <10 km.

V - SWOT vs WMOP

All WMOP simulations reproduce the large-scale eddy structures observed by SWOT.

WMOP-RA **5 Hz** and **20 Hz** runs show the best spatial agreement, particularly around the anticyclonic eddies, with smaller SSHA differences.

In contrast, WMOP-**FR** and RA-**1Hz** underestimate eddy amplitudes and exhibit larger deviations.

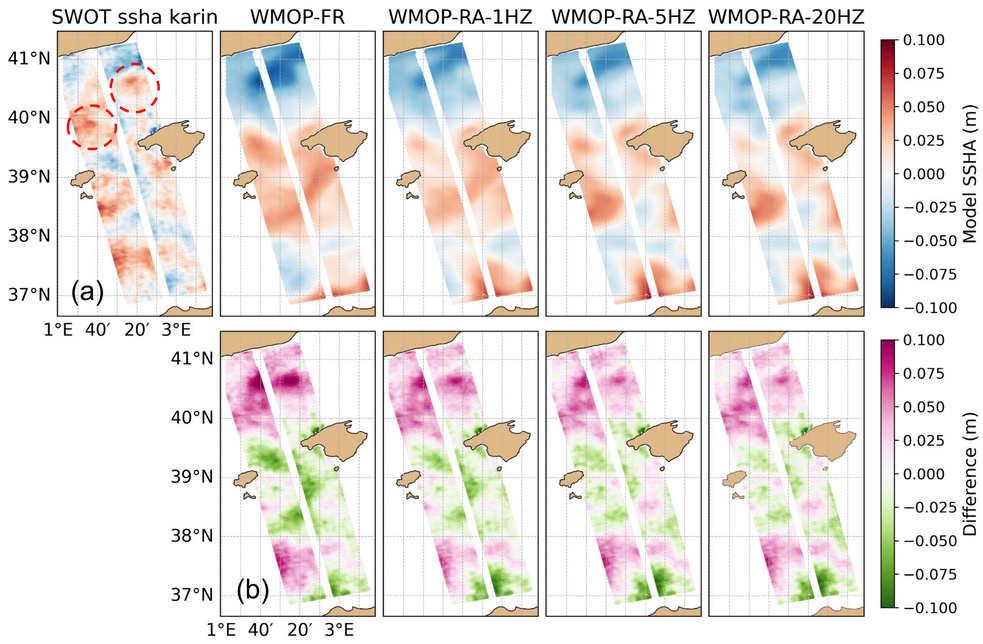
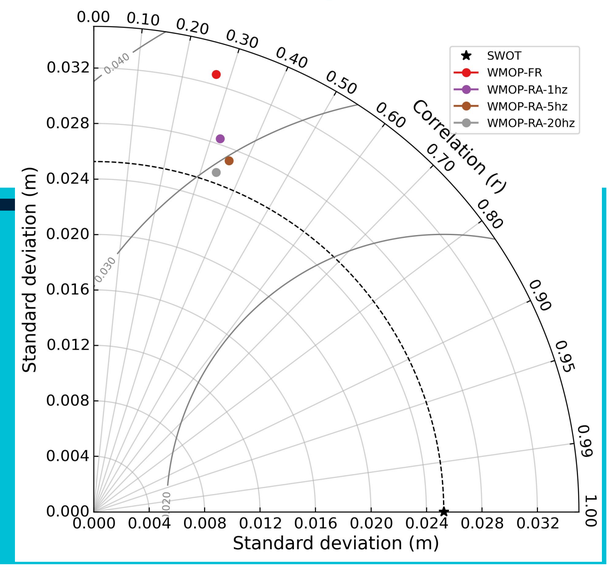


Figure 5. Comparison between SWOT and WMOP simulations on 26 April 2023. (a) Sea surface height anomaly (SSHA) from SWOT and WMOP runs.
(b) SSHA differences between SWOT and each corresponding WMOP simulation.



VI - Conclusions

Higher-frequency Sentinel-6A (**20 Hz**, **5 Hz**) products provide the best agreement with SWOT, confirming their ability to resolve mesoscale and submesoscale eddy features in the Balearic Sea.

WMOP-RA **5Hz** and **20Hz** best reproduce SWOT fields, showing highest correlations and lowest deviations, as shown in the Taylor diagram.

Assimilating high-resolution SLA improves eddy representation and supports enhanced mesoscale forecasting in the Balearic Sea.

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References:
[a]Verger-Miralles et al., 2025; [b]Hernandez-Lasheras, J. & Mourre, B. (2018); [c]Vergara, O., & Pujol, M.-I. (2025).

Acknowledgments