Design of multi-platform sampling strategies for reconstruction of fine-scale ocean currents

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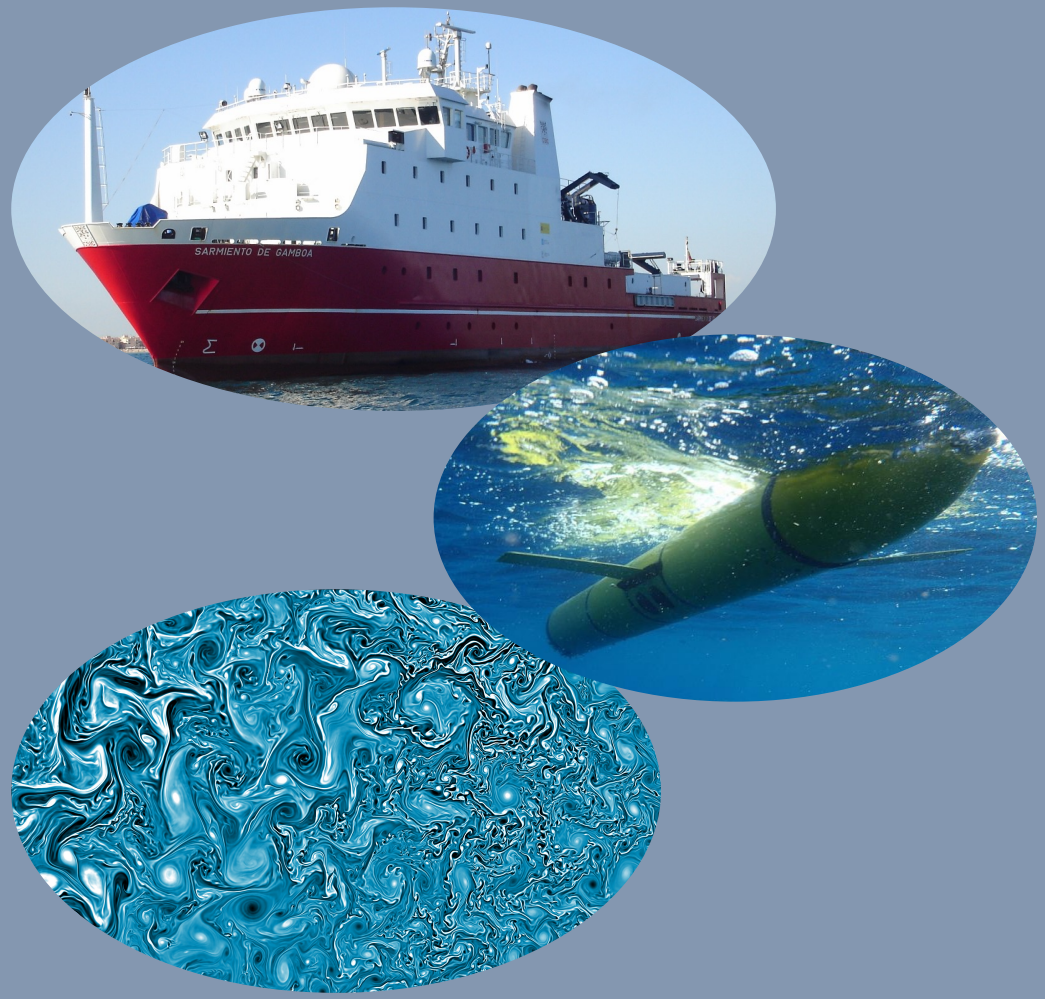
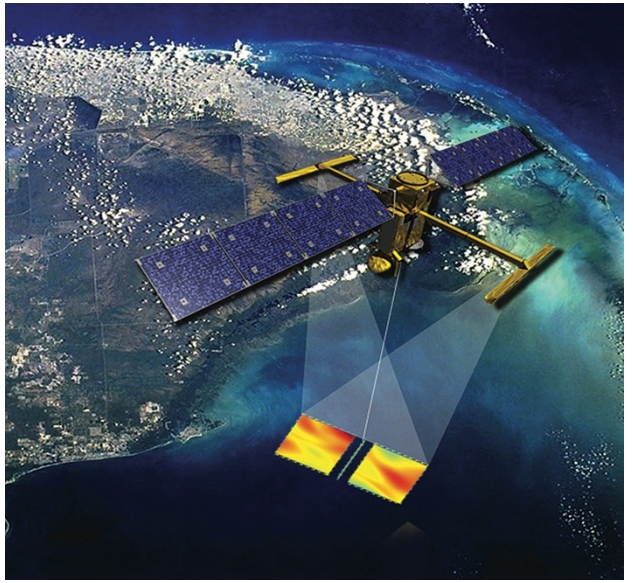


*The EuroSea project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 862626.

Context: SWOT mission validation

- The Surface Water Ocean Topography **(SWOT)** satellite mission will be a game changer in the observation of ocean circulation

2D sea surface height (SSH) maps at unprecedented spatial resolutions of 15-30 km



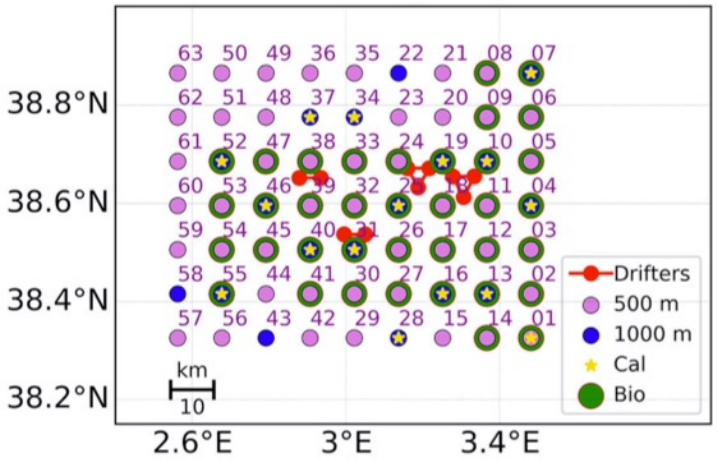
Morrow et al. EOS (2019)

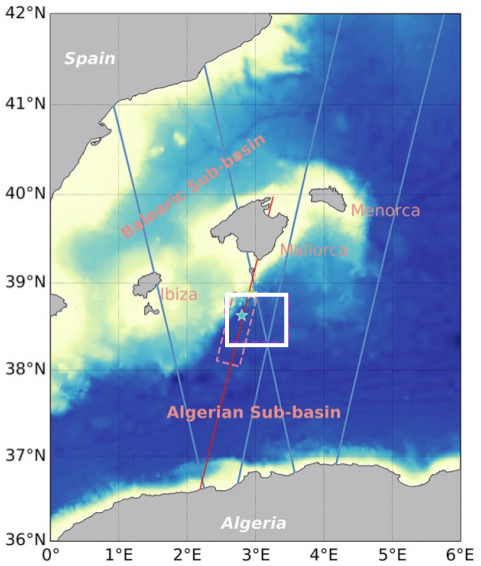
- Need to define **strategies for SWOT validation** using integrated high-resolution multi-platform observations

Context: PRE-SWOT experiment in 2018

- In preparation for SWOT validation: PRE-SWOT multi-platform experiment in 2018
  - Collect in situ data from different platforms (CTD, ADCP, drifters, water samples) to explore the 3D circulation at scales of 20 km wavelength (SWOT scales)

PRE-SWOT sampling strategy





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ORIGINAL RESEARCH

Fine-Scale Ocean Currents Derived From *in situ* Observations in Anticipation of the Upcoming SWOT Altimetric Mission

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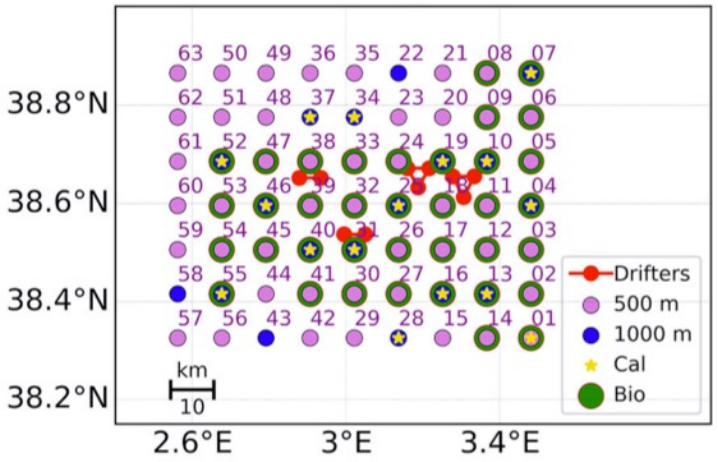
Bàrbara Barceló-Llull, Ananda Pascual, Antonio Sánchez-Román, Eugenio Cutolo, Francesco d'Ovidio, Gina Fifani, Enrico Ser-Giacomi, Simón Ruiz, Evan Mason, Fréderic Cyr, Andrea Doglioli, Baptiste Mourre, John T. Allen, Eva Alou-Font, Benjamin Casas, Lara Diaz-Barroso, Franck Dumas, Laura Gómez-Navarro and Cristian Muñoz

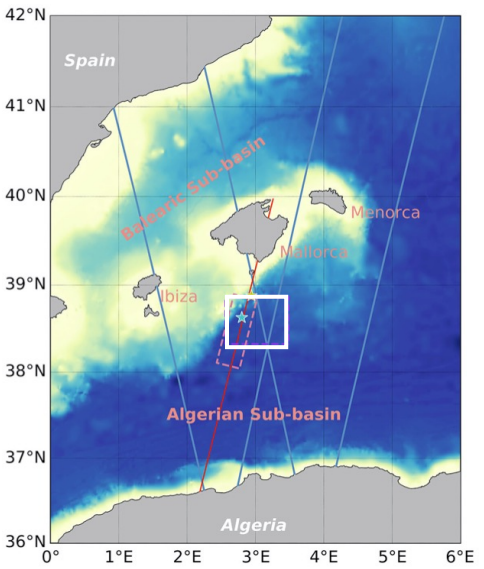
Barceló-Llull, Pascual, et al. (2021)

Context: PRE-SWOT experiment in 2018

- In preparation for SWOT validation: PRE-SWOT multi-platform experiment in 2018
  - Collect in situ data from different platforms (CTD, ADCP, drifters, water samples) to explore the 3D circulation at scales of 20 km wavelength (SWOT scales)
- Spatial optimal interpolation to reconstruct the observations of T and S
  - Widely used in field experiments (e.g., Rudnick, 1996; Pascual et al., 2004; Barceló-Llull et al., 2017; Ruiz et al., 2019)
  - It assumes quasi-synoptic observations

PRE-SWOT sampling strategy





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Fine-Scale Ocean Currents Derived From *in situ* Observations in Anticipation of the Upcoming SWOT Altimetric Mission

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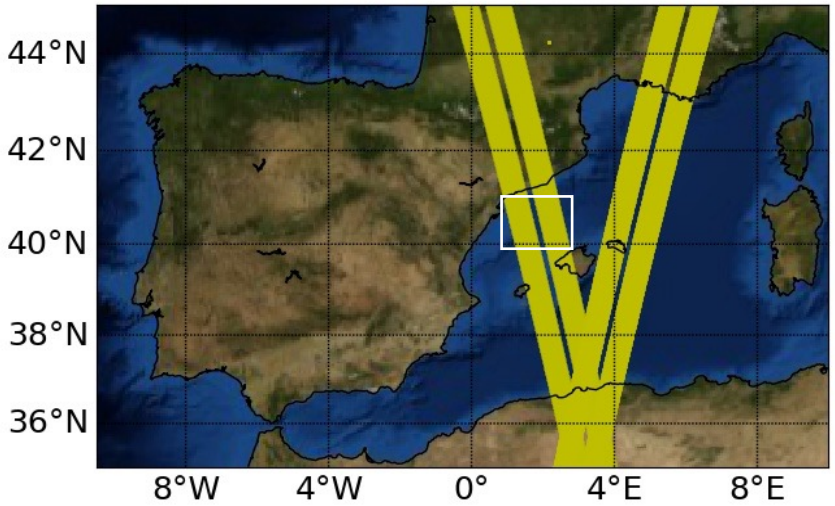
Optimizing multi-platform sampling strategies through OSSEs

Objective: Improve the design of multi-platform experiments aimed to validate SWOT observations through Observing System Simulation Experiments (OSSEs)



- Focus on SWOT scales ~20 km
- Results for the Mediterranean

Observing System Simulation Experiments

Models

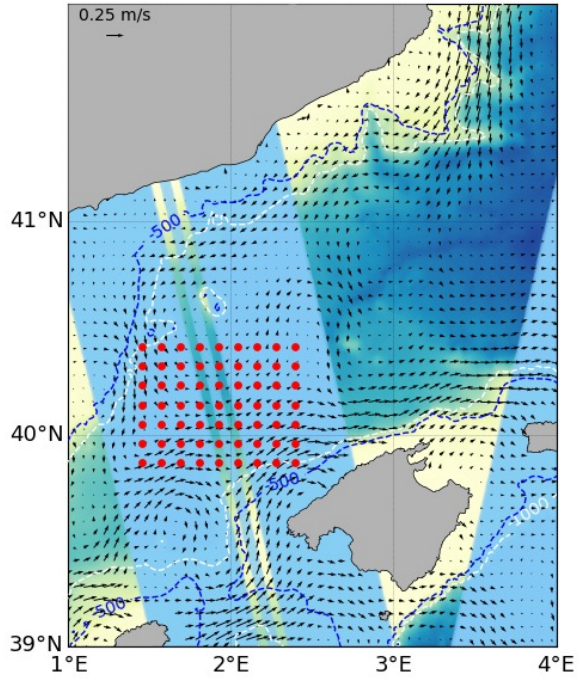
eNATL60	1.5 km, hourly *Ajayi et al. (2020)*
WMOP	2 km, daily *Mourre et al. (2018)* *Aguiar et al. (2020)*
CMEMS	4 km, daily *Escudier et al. (2020)*

- Models used to simulate CTD observations and as the “ocean truth”
- 3 models to test sensitivity

Configurations

Reference	• CTD casts • z_{max}: 1000 m • dx: 10 km • Summer
#1	z_{max}: 500 m
#2	dx: 5, 8, 12, 15 km
#3	uCTD
#4	Winter
#5	Gliders

CTD profiles of the Reference configuration



- Region of study within a swath of SWOT

More details in the Deliverable 2.1: https://doi.org/10.3289/eurosea_d2.1

Improvement of the optimal interpolation (OI) algorithm

Before reconstructing all configurations…

Drawbacks of the spatial OI used in field experiments

1) Assumption of quasi-synopticity
2) No specific date for the resulting map

Spatio-temporal OI algorithm

$$C(r,t) = e^{-\frac{r^2}{2L^2}} e^{-\left(\frac{t}{T}\right)^2}$$

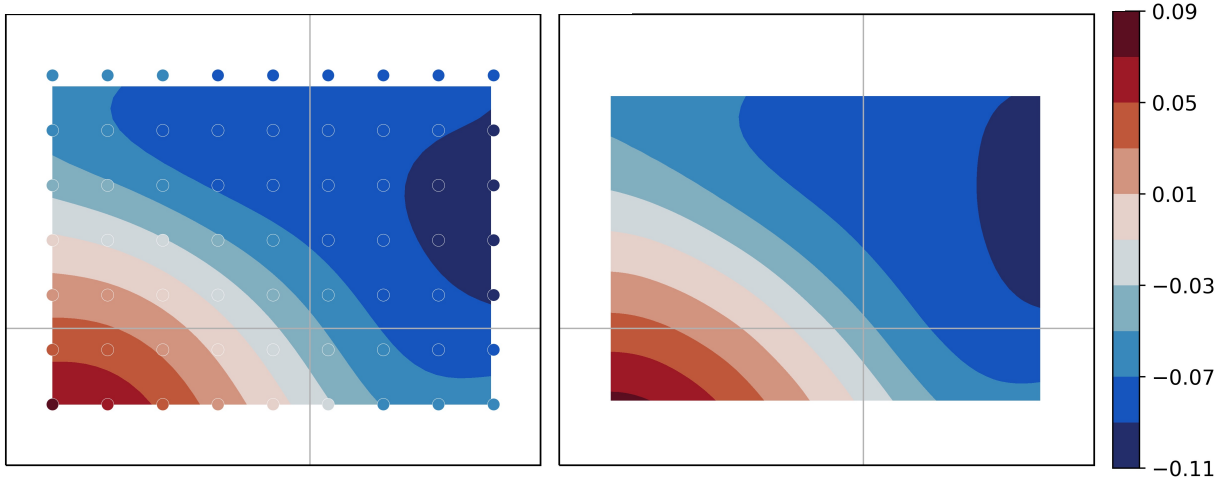
Escudier et al. (2013)

Which temporal correlation scale should we use?

Analysis of the temporal correlation scale (Lt)

Reconstructed SSH (m)
Pseudo-obs + OI map

“Ocean truth” SSH (m)



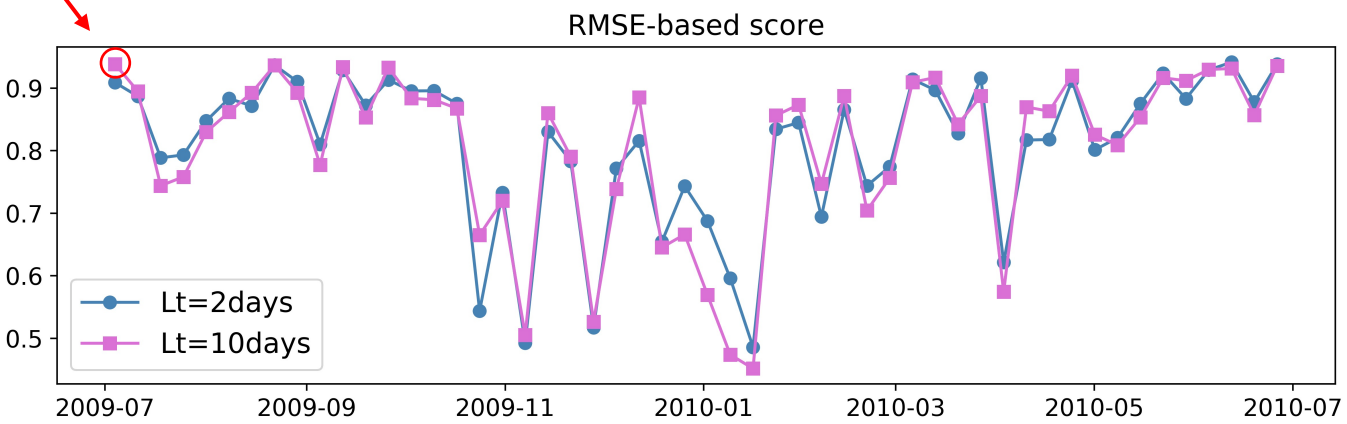
Reconstruction and “ocean truth” date: 2009-07-04 03:30
Spatio-temporal OI with **Lt = 10 days**

RMSEs = 0.94

RMSE-based score (RMSEs)

$RMSEs = 1 - [RMS(SSH_{rec} - SSH_{true})/RMS(SSH_{true})]$

1 = perfect reconstruction; 0 = bad reconstruction



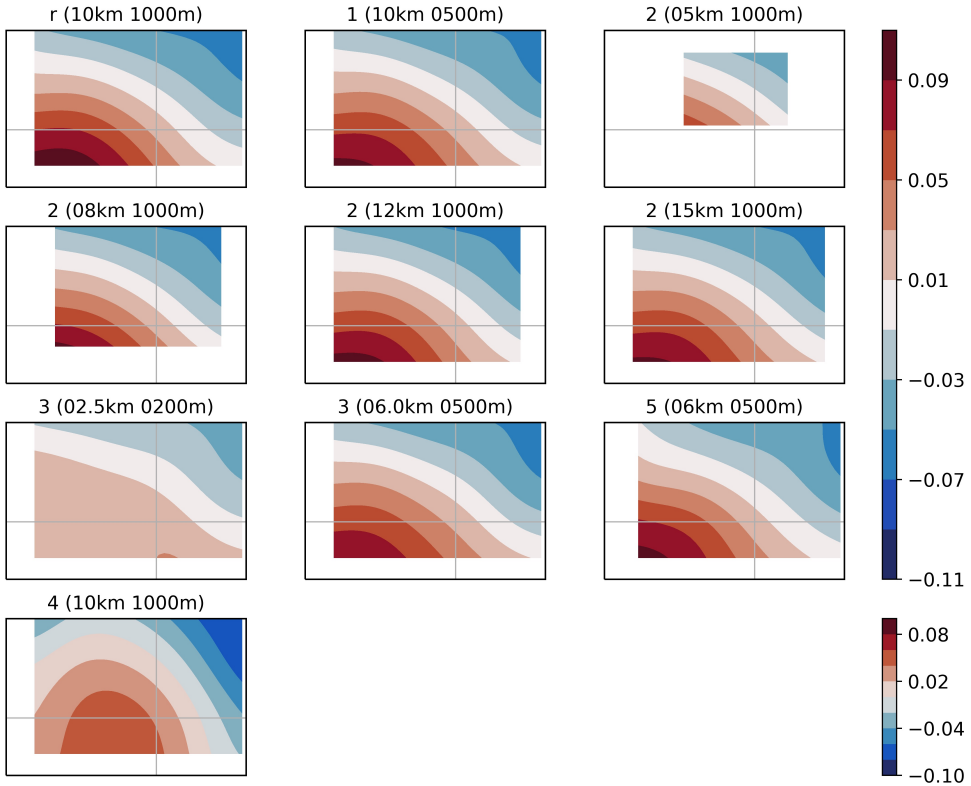
Similar RMSEs for both Lt:
we can use Lt = 10 days and consider quasi-synoptic pseudo-observations

Spatio-temporal OI reconstruction

Reconstruct all configurations with the spatio-temporal OI

1) Interpolate T and S pseudo-observations (Lx=20km, Lt=10days)
2) Calculate DH and geostrophic velocity at the ocean surface
3) Calculate the RMSEs for each configuration (and model)

Reconstructed DH anomaly (dyn m)
at the upper layer for all configurations [eNATL60]



"Ocean truth" SSH anomaly (m)
at the upper layer for all configurations [eNATL60]

Spatio-temporal OI reconstruction

Reconstruct all configurations with the spatio-temporal OI

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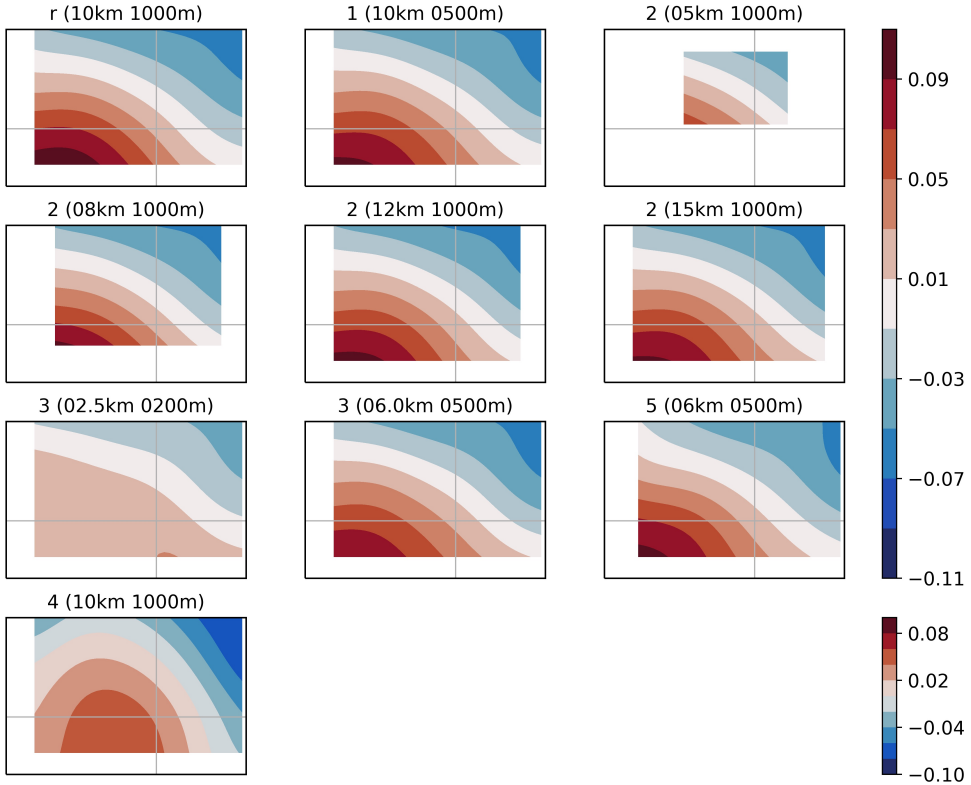

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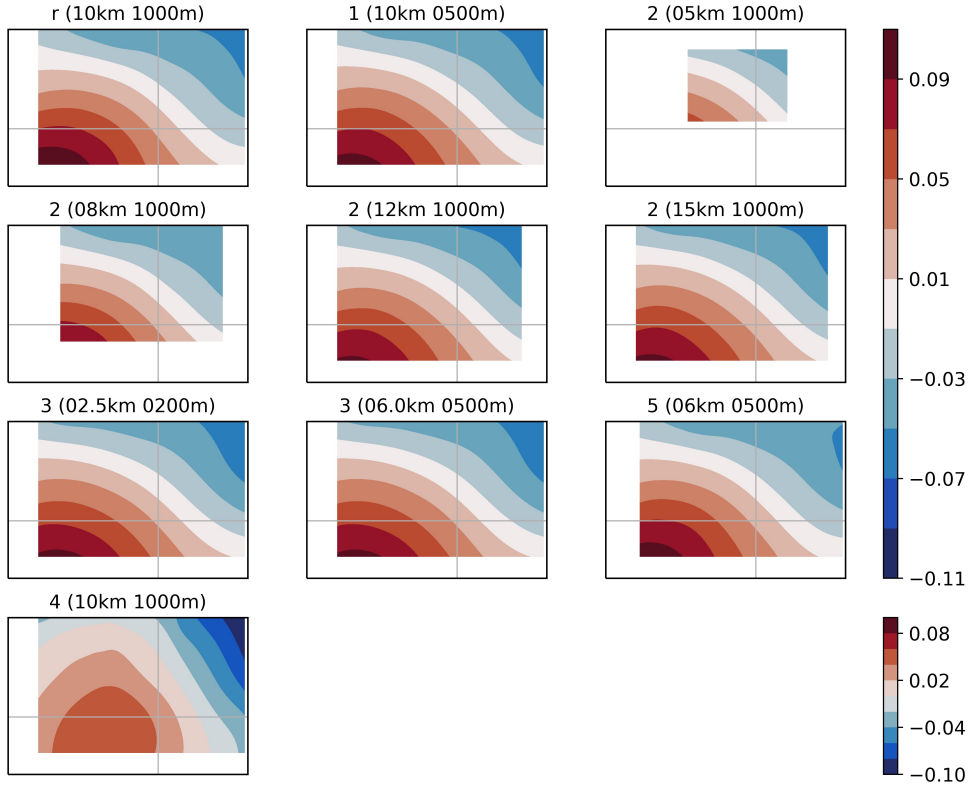

Results based on the RMSEs

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Ranking (RMSEs, conf)
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01  0.8820  Med_conf_3_dep_0500m_res_06.0km_Sep_eNATL60
02  0.8706  Med_conf_1_dep_0500m_res_10km_Sep_eNATL60
03  0.8706  Med_conf_2_dep_1000m_res_15km_Sep_WMOP
04  0.8695  Med_conf_r_dep_1000m_res_10km_Sep_eNATL60
05  0.8685  Med_conf_2_dep_1000m_res_05km_Sep_eNATL60
06  0.8662  Med_conf_2_dep_1000m_res_12km_Sep_eNATL60
07  0.8604  Med_conf_2_dep_1000m_res_12km_Sep_WMOP
08  0.8603  Med_conf_2_dep_1000m_res_15km_Sep_eNATL60
09  0.8592  Med_conf_r_dep_1000m_res_10km_Sep_WMOP
10  0.8426  Med_conf_2_dep_1000m_res_05km_Sep_WMOP
11  0.8401  Med_conf_2_dep_1000m_res_08km_Sep_WMOP
12  0.8090  Med_conf_3_dep_0500m_res_06.0km_Sep_WMOP
13  0.7934  Med_conf_1_dep_0500m_res_10km_Sep_WMOP
14  0.7910  Med_conf_5_dep_0500m_res_06km_Sep_eNATL60
15  0.7859  Med_conf_5_dep_0500m_res_06km_Sep_CMEMS
16  0.7844  Med_conf_2_dep_1000m_res_08km_Sep_eNATL60
17  0.7167  Med_conf_r_dep_1000m_res_10km_Sep_CMEMS
18  0.7050  Med_conf_2_dep_1000m_res_15km_Sep_CMEMS
19  0.6896  Med_conf_3_dep_0500m_res_06.0km_Sep_CMEMS
20  0.6626  Med_conf_2_dep_1000m_res_12km_Sep_CMEMS
21  0.6434  Med_conf_1_dep_0500m_res_10km_Sep_CMEMS
22  0.6385  Med_conf_2_dep_1000m_res_08km_Sep_CMEMS
23  0.6291  Med_conf_3_dep_0200m_res_02.5km_Sep_WMOP
24  0.5679  Med_conf_5_dep_0500m_res_06km_Sep_WMOP
25  0.4628  Med_conf_3_dep_0200m_res_02.5km_Sep_eNATL60
26  0.4597  Med_conf_2_dep_1000m_res_05km_Sep_CMEMS
27  0.4268  Med_conf_3_dep_0200m_res_02.5km_Sep_CMEMS
```

- *Which is the best configuration considering all models?*

Reference configuration

Conclusions

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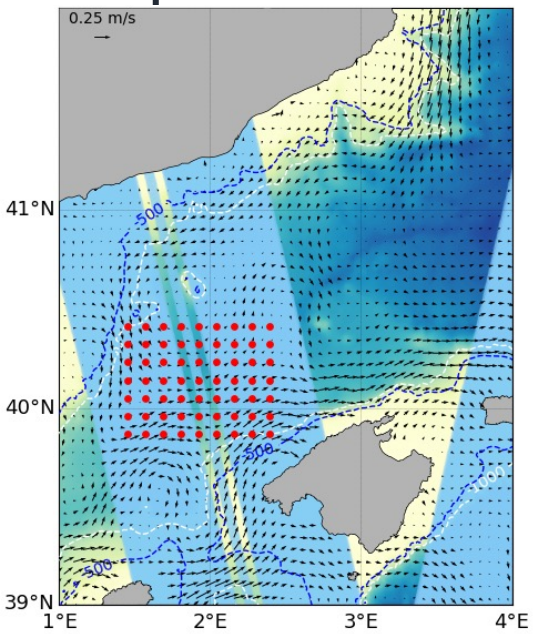
- ✓ Evaluation of different sampling strategies for SWOT validation through OSSEs using 3 models (eNATL60, WMOP, CMEMS)
- ✓ Spatio-temporal OI algorithm to reconstruct in situ observations
- ✓ Sensitivity test of the temporal correlation scale: low sensitivity for values ranging from 2 to 10 days
- ✓ Best reconstruction considering all models: reference configuration (CTD casts, dx = 10 km, z_{max} = 1000 m; similar to PRE-SWOT sampling strategy)

- ✓ Perspectives:
  - Diagnostic for other variables (surface currents, vorticity)
  - Analysis in the Atlantic
  - Diagnose the temporal variability
  - Test different methods of reconstruction: machine learning techniques (IMT-Atlantique) and model data assimilation (SOCIB)
  - Real multi-platform experiment during the SWOT fast-sampling phase in 2023 (pending funding 🤞)



Thank you!

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