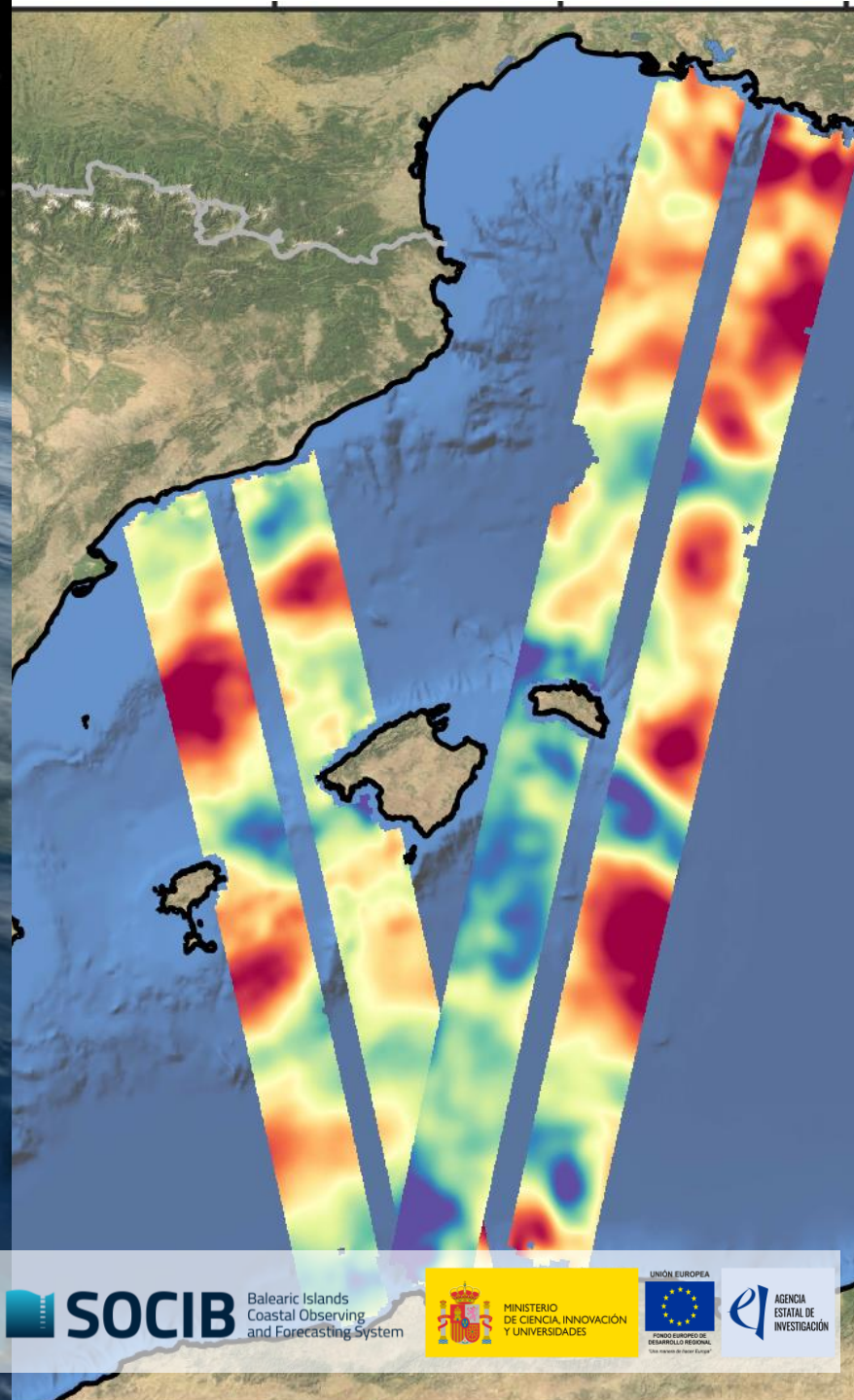
Ocean Predict Coastal Ocean and Shelf Seas Task Team
International Coordination Meeting *Brest, 17-20 June 2025*

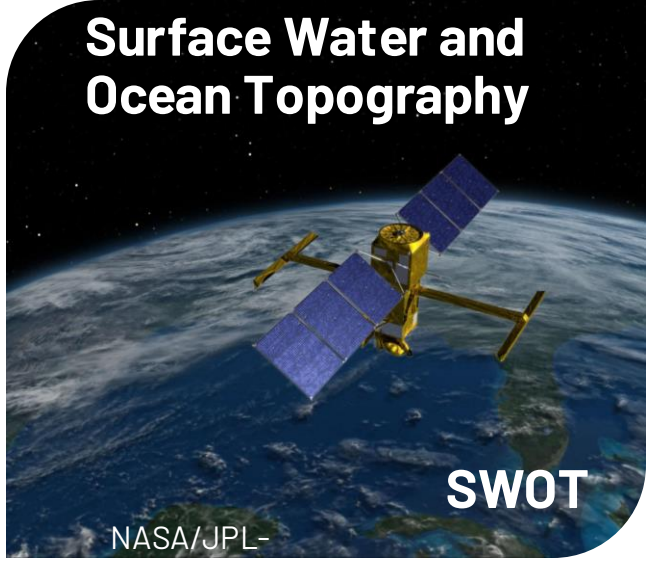
SWOT satellite sea level observations: validation and integration with high-resolution regional simulations



B. Mourre[1,2], E. Verger-Miralles[1], J.-P. Peng[1], L. Gómez-Navarro[1], M. García-Jove[2], E. Cutolo[3], B. Barceló-Llull[1], D.R. Tarry[4], N. Zarokanellos[2] and A.Pascual[1]

[1] *IMEDEA (CSIC-UIB), Spain*
[2] *SOCIB, Spain*
[3] *IMT Atlantique, France*
[4] *University of Washington, USA*

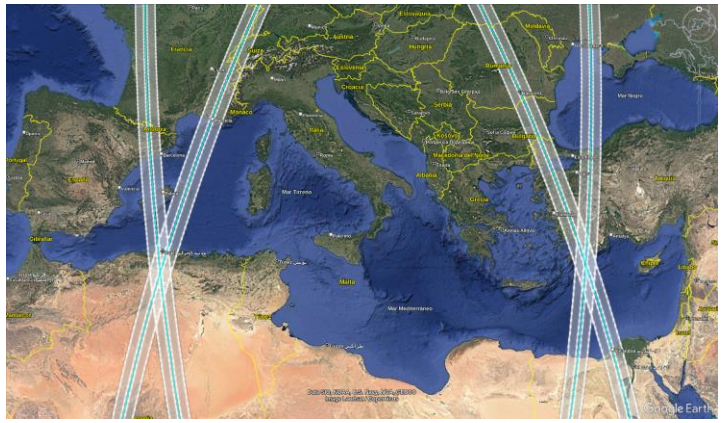
SWOT satellite



- Launched in December 2022 (NASA/CNES)
- **New interferometric technology → accurate 2-D monitoring of sea level variability at high-resolution (down to ~5km in wavelength)**

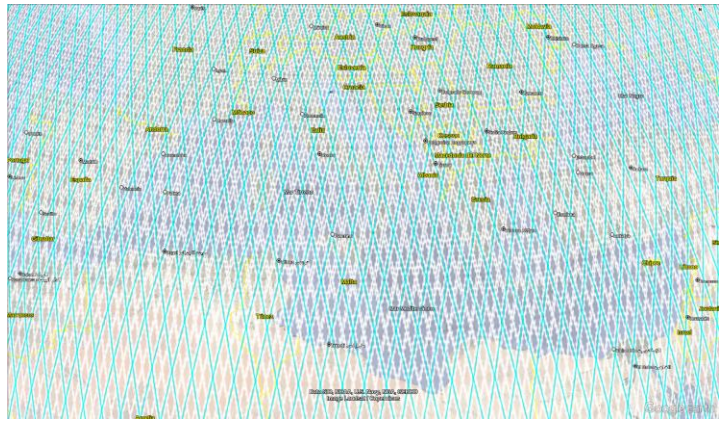
1 fast-sampling phase

- April-June 2023
- Cal/val activities
- Daily repetitivity along selected tracks



2 science phase

- From July 2023
- Covering the whole basin
- Individual tracks with a 21-day repetitivity



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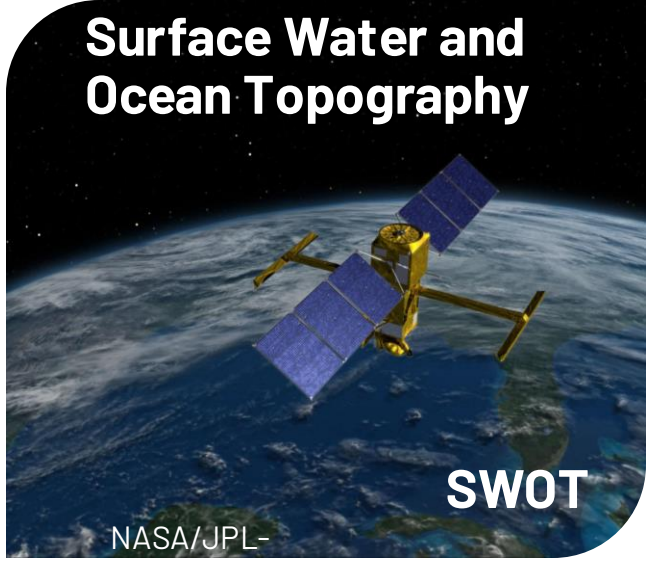

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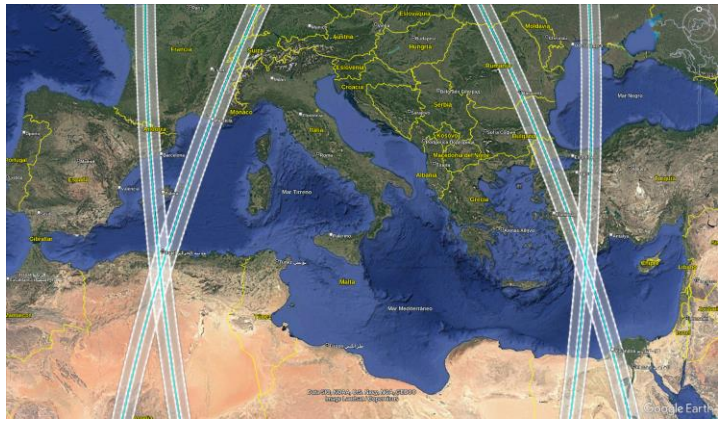

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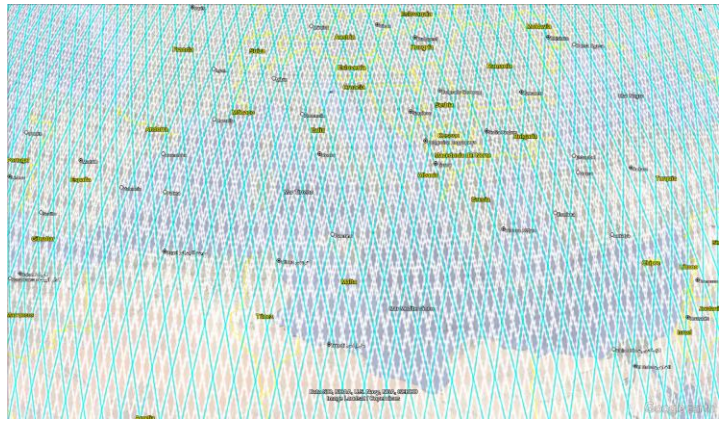
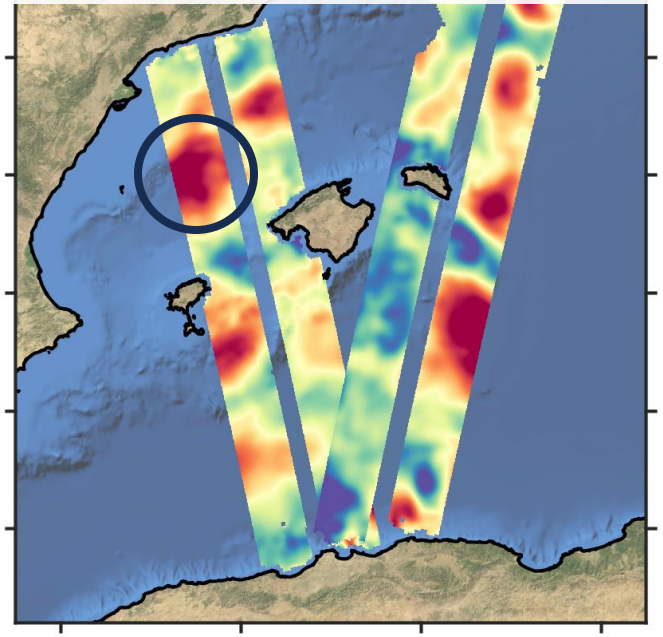


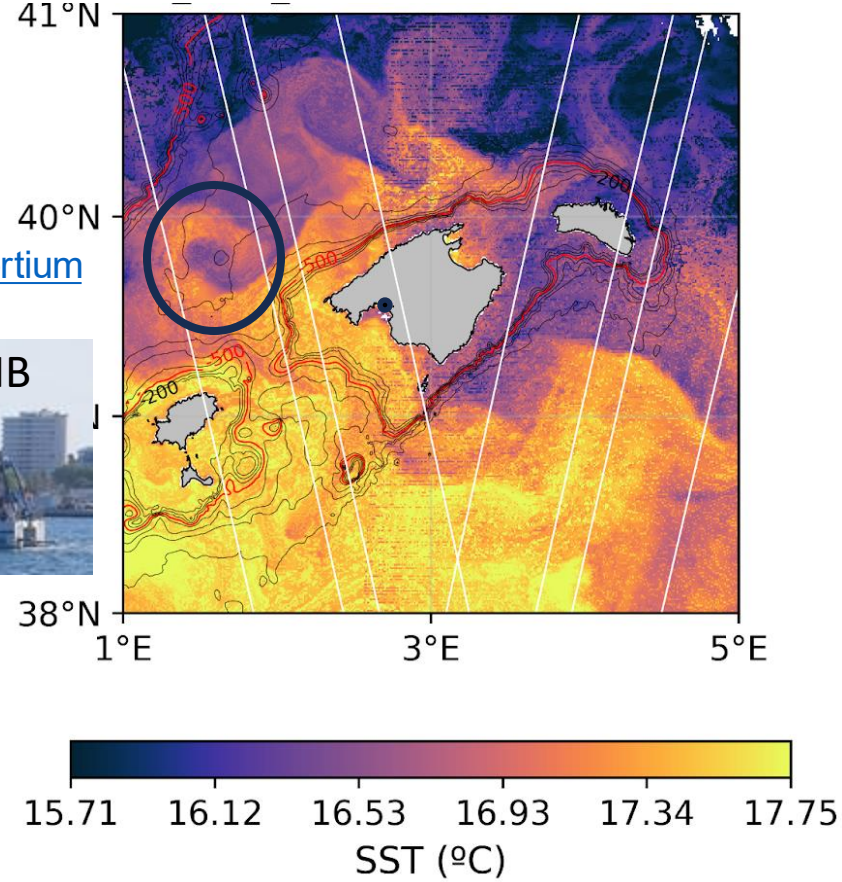
FaSt-SWOT project

Objectives

- **Validation of SWOT** satellite observations
- **Integration of SWOT** observations with in-situ measurements and high-resolution models
- Understanding the **3D dynamics** linked to **small-scale ocean features** (10-100 km)



SWOT 'Adopt-A-Crossover' Consortium



→ **In-situ sampling** of a **small-scale eddy** during the SWOT **fast sampling phase** in the Balearic Sea

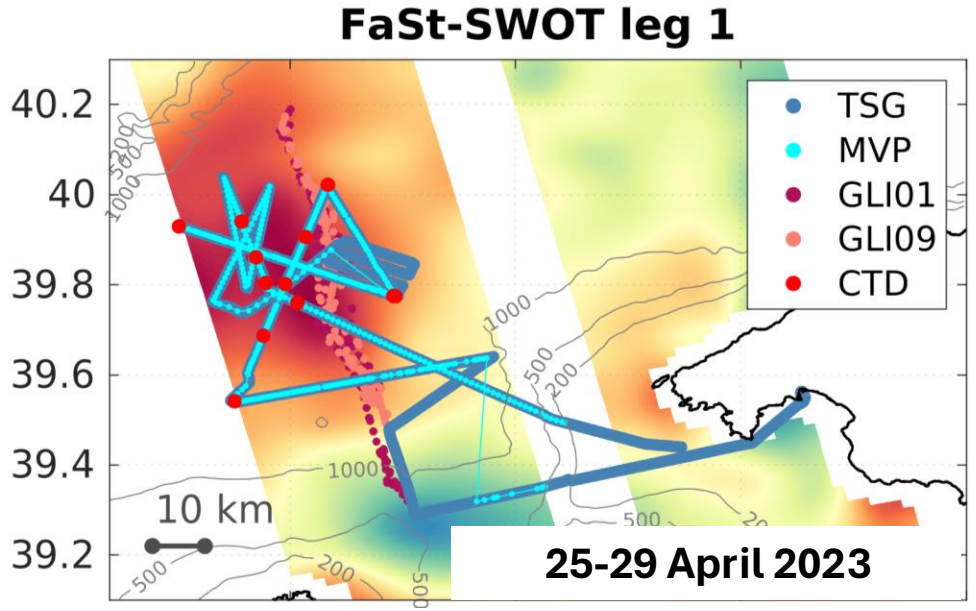
→ **Repetition of the sampling after 10 days** to track the evolution

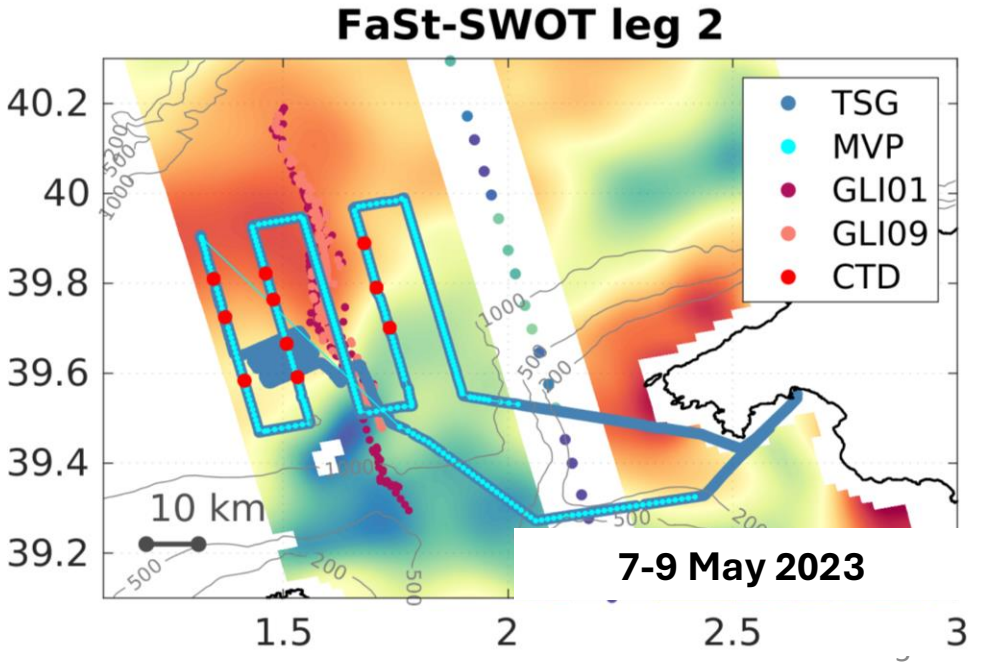
FaSt-SWOT campaigns

Pascual et al., 2023 – **CRUISE PLAN** https://doi.org/10.20350/digitalCSIC/15276
Mourre et al., 2024 - **CRUISE REPORT** https://doi.org/10.20350/digitalCSIC/16077
Mourre et al., 2024 – **RAW DATASET** https://doi.org/10.20350/DIGITALCSIC/16511

Measurements

- 2 Slocum **gliders** [0-700 m]
- Moving Vessel Profiler (**MVP**) [0-200 m]
- Vessel-mounted **ADCP** [10-200m]
- **Thermosalinograph**
- 45 surface **drifters**
- **CTD** stations [0-700m]



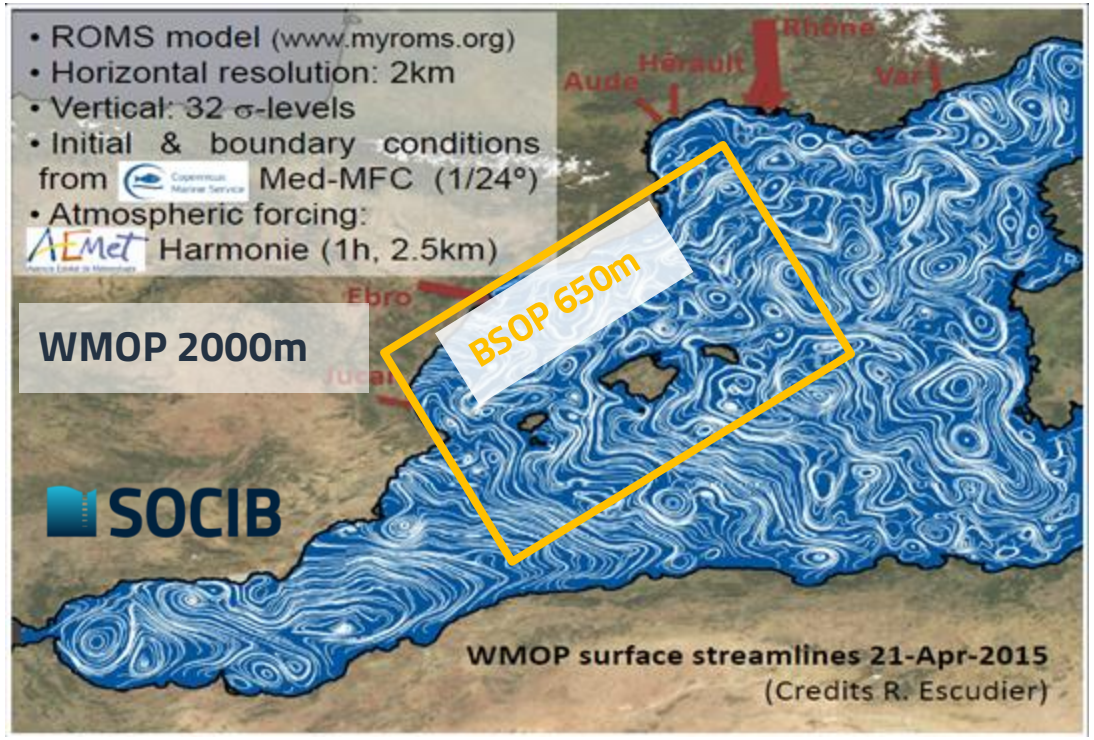


FaSt-SWOT campaigns

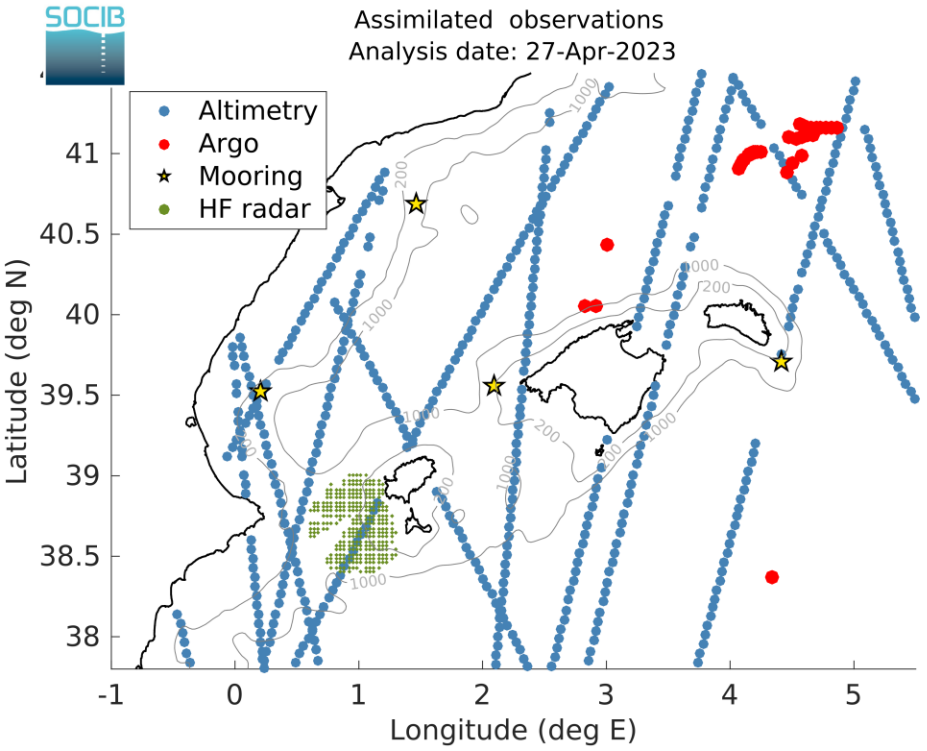
Modelling

high-resolution data-assimilative modelling from SOCIB WMOP modelling system including grid refinement

Daily data assimilation in WMOP (Multimodel Local Ensemble Optimal Interpolation):
SST, along-track SLA, Argo T-S profiles, Ibiza Channel HF radar, moorings.



- Real-time
- Reanalysis
- Free-run



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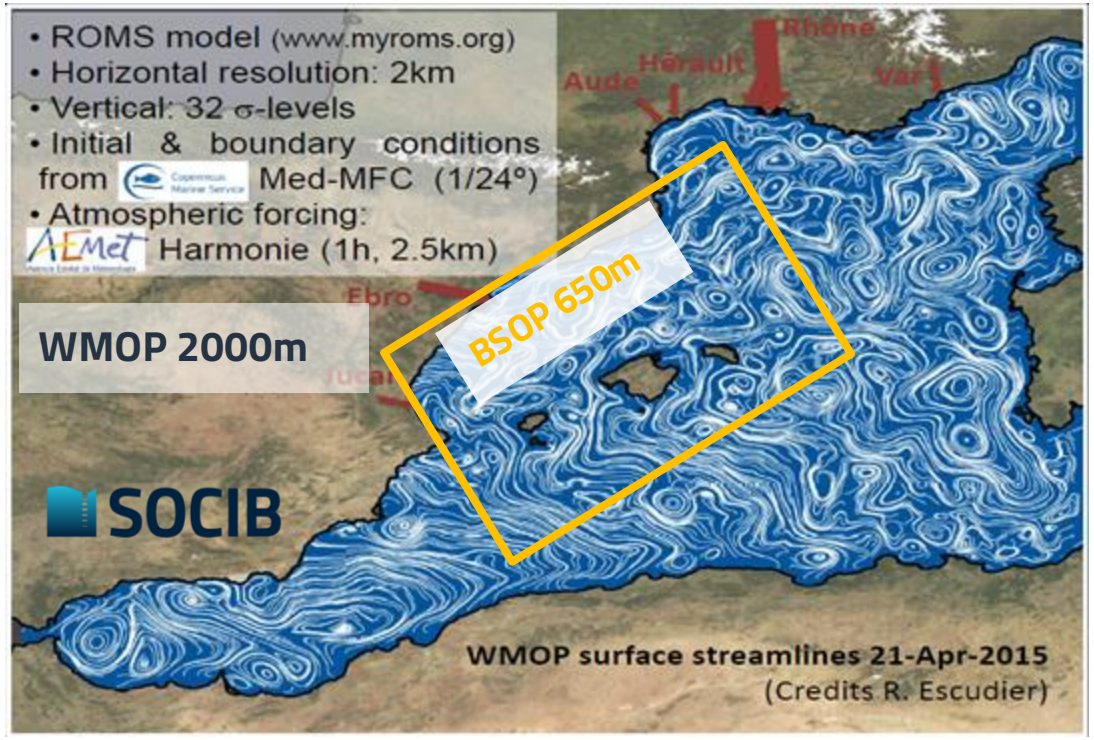

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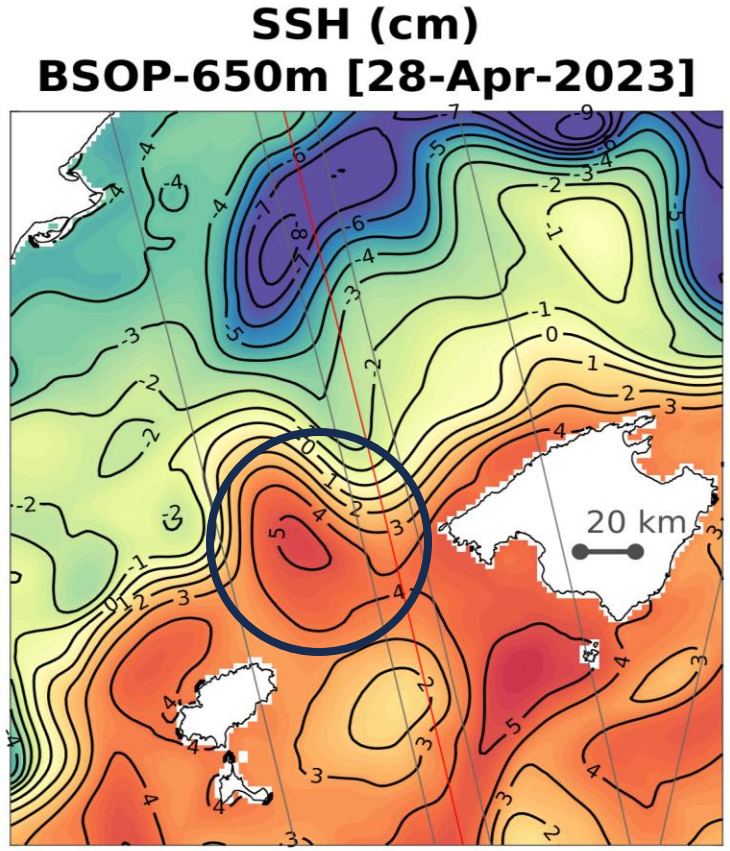
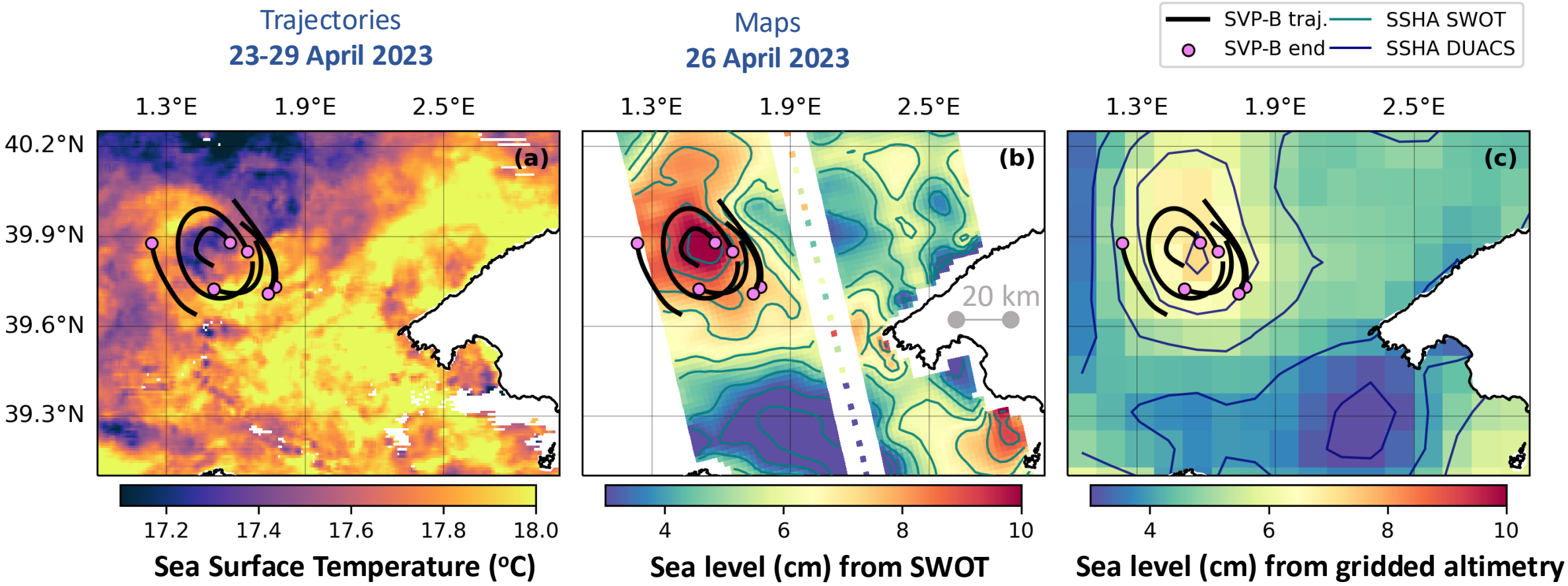


SWOT vs conventional altimetry, SST and drifters



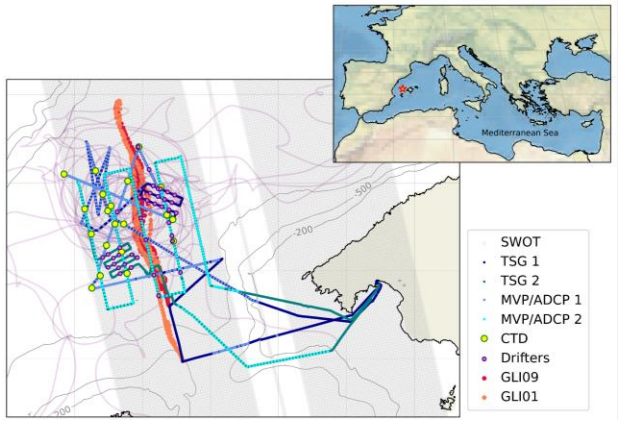
(E. Verger-Miralles)

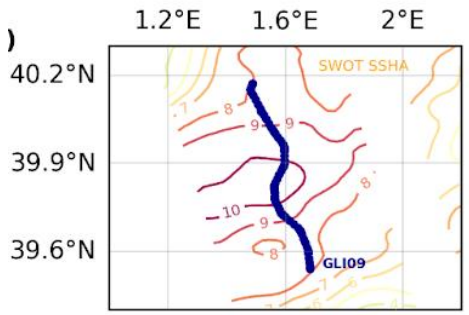
→ 6 SVP-B drifters (with drogue at 15 m) trapped in the eddy (inertial oscillations filtered here)

→ Positive SLA signal intensified in SWOT data wrt conventional gridded altimetry, with smaller-scale features

→ SWOT data consistent with SST gradients and drifter trajectories

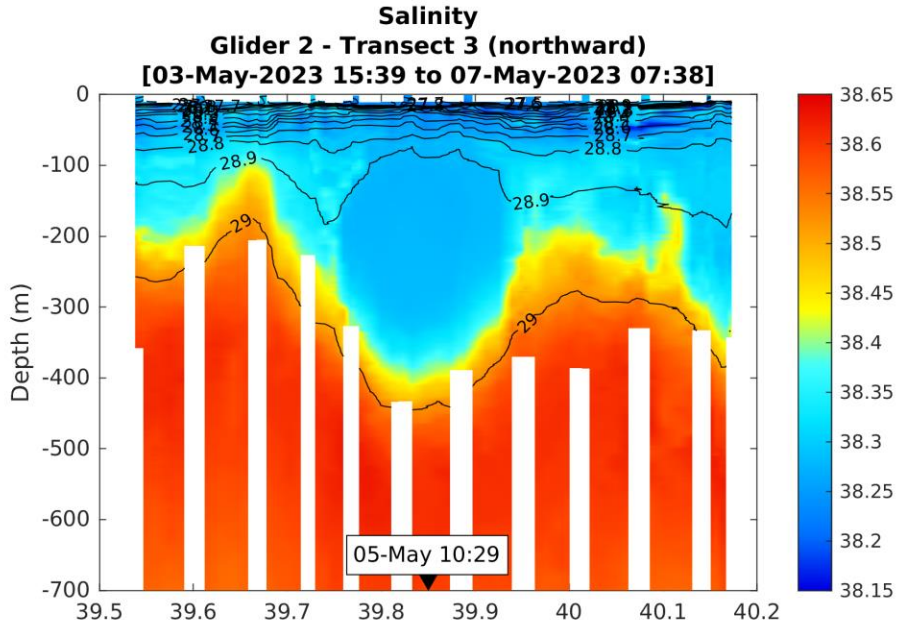
Vertical structure observed by underwater gliders

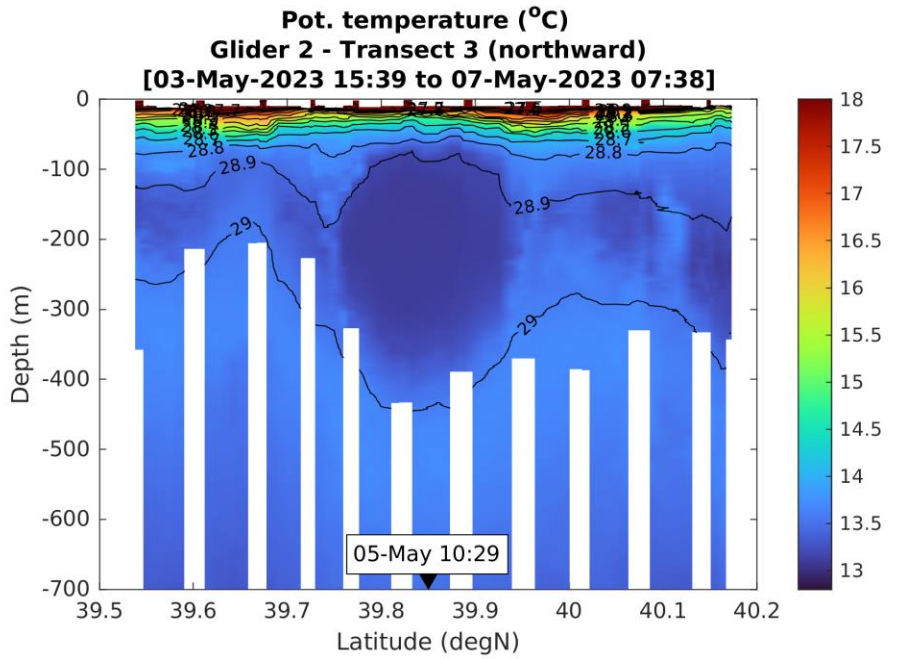




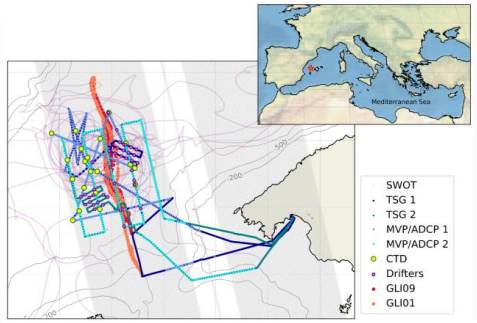
- 2 gliders on the same trajectory 24-hour apart
- Back and forth crossing of the eddy
- Total of 8 sections (~ 3.5 days each)

→ Small-scale intrathermocline eddy



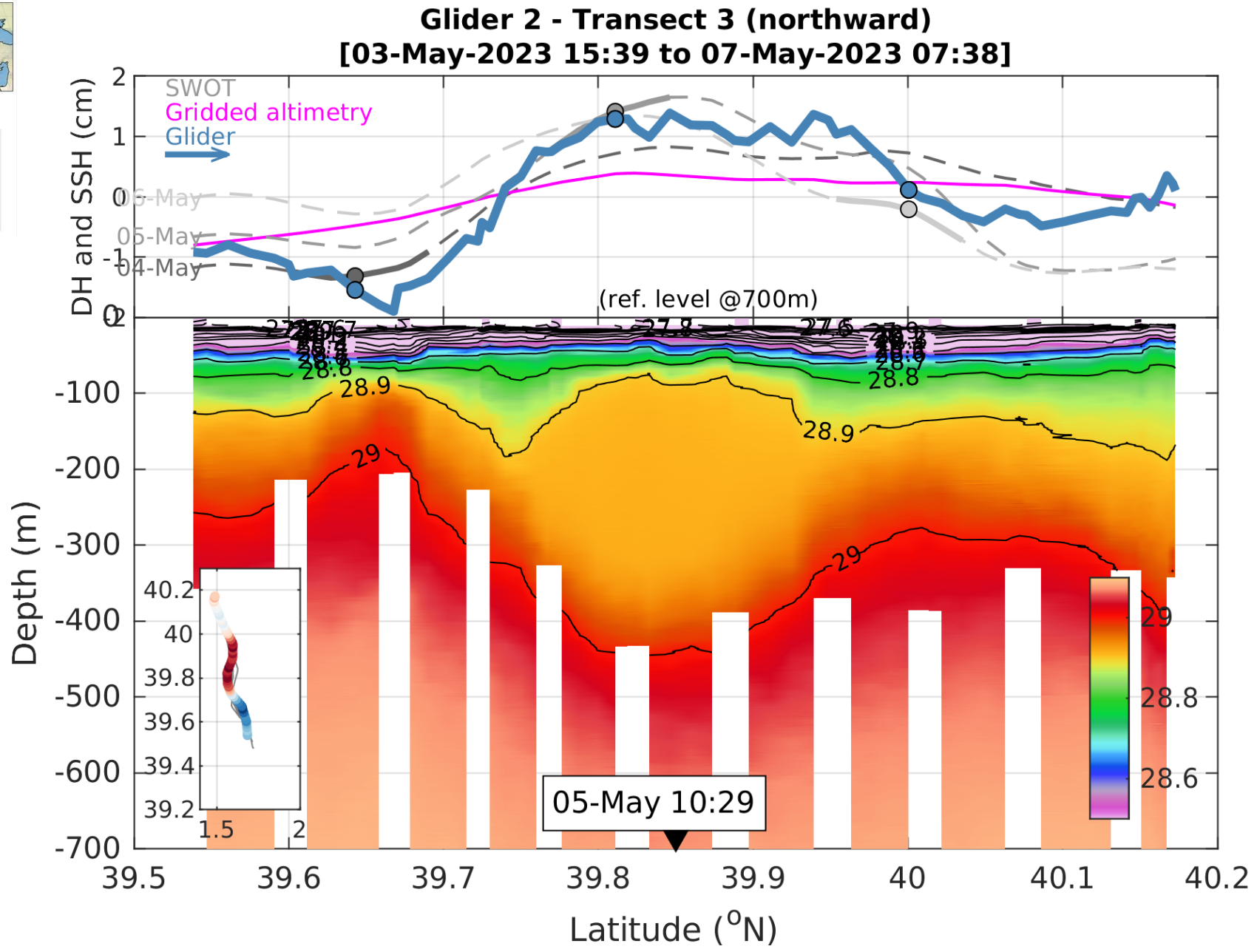


SWOT SSH vs glider dynamic height



$$DH = -\frac{1}{g}\int_{p_0}^{p_1}\frac{1}{\rho}dp$$

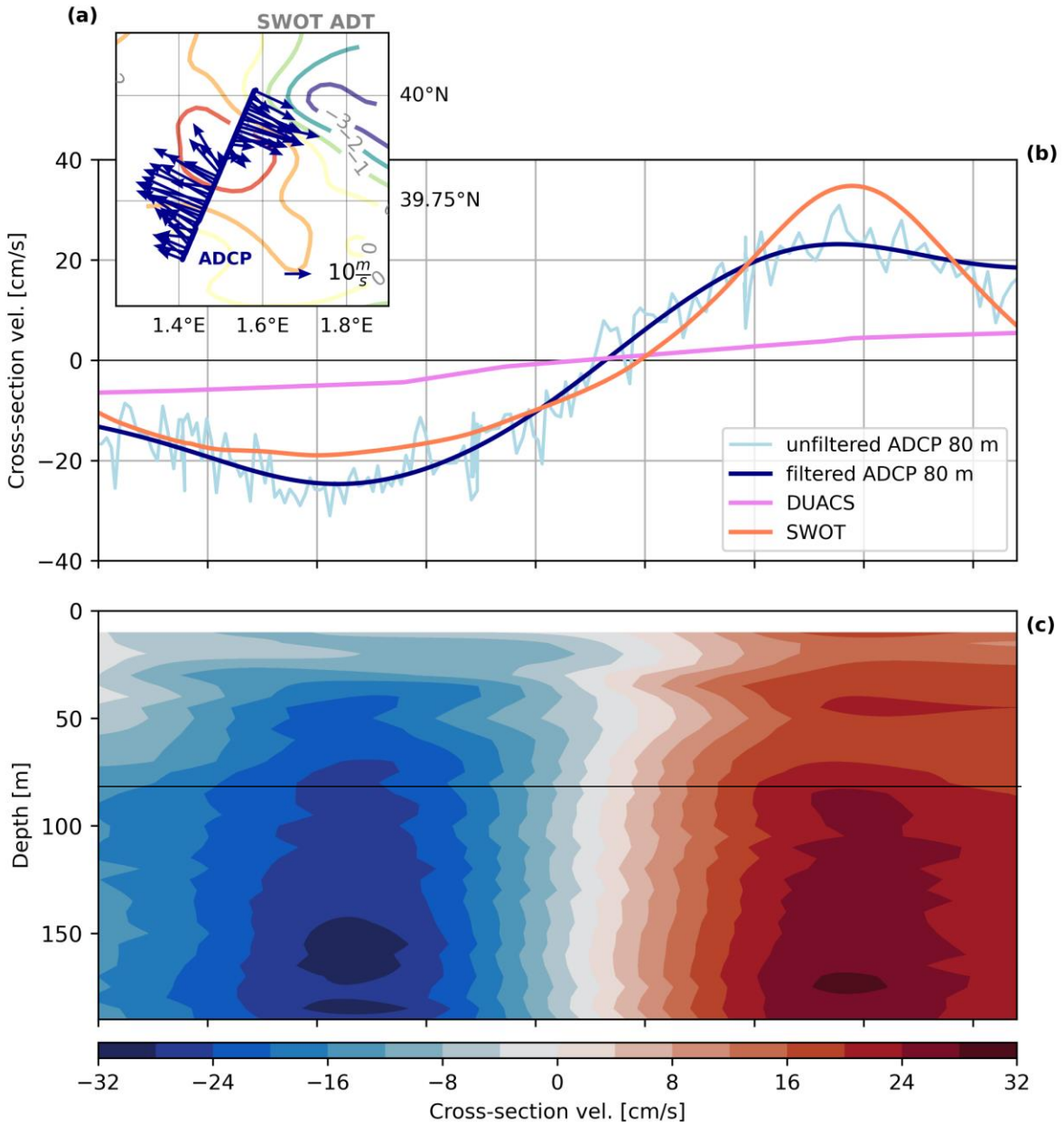
- → SWOT SSH and glider DH in good agreement
- → 33% improvement wrt conventional altimetry
- → Significant daily variability in SWOT data



SWOT-derived vs ADCP velocities

→ Very good agreement between SWOT-derived geostrophic velocities and ADCP horizontal velocities at 80 m

Cross-section velocities (cm/s)



(E. Verger-Miralles)

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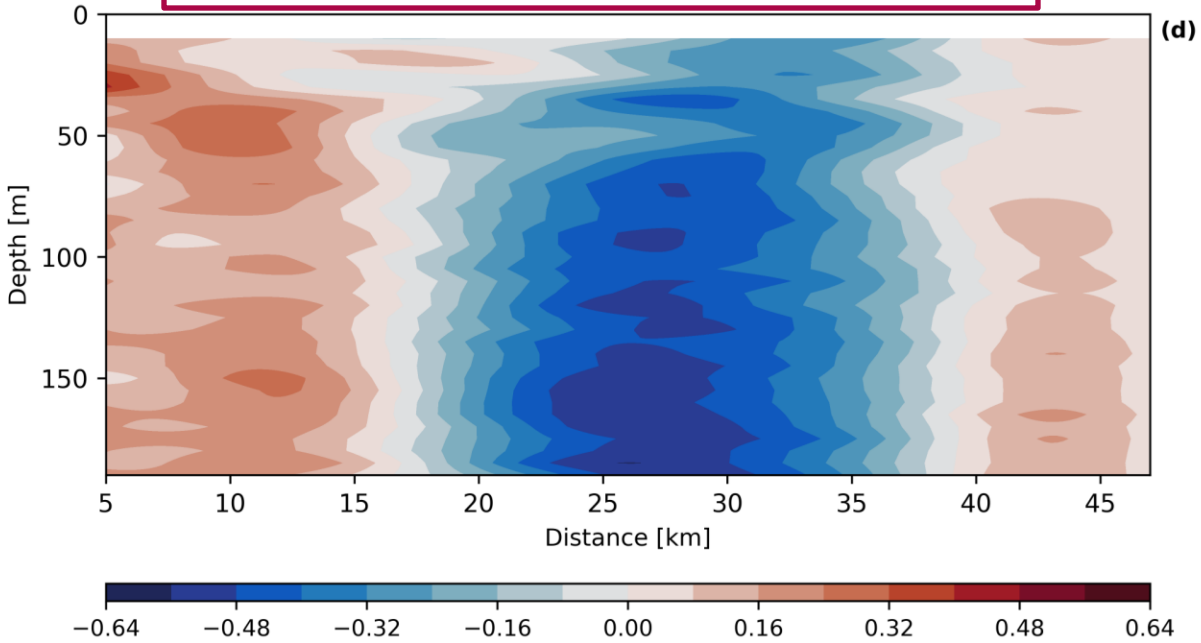
Rossby number (ζ / f)



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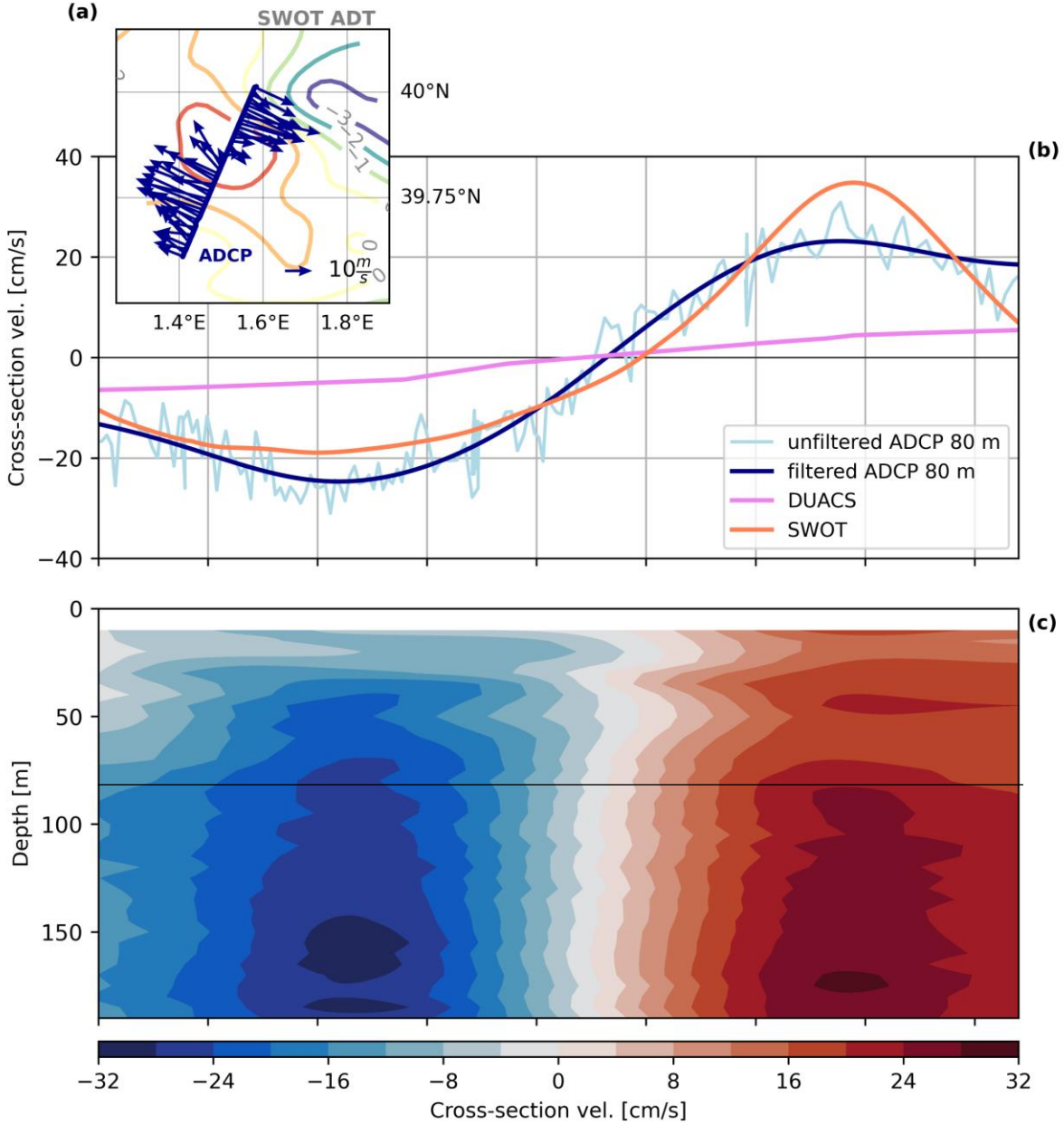
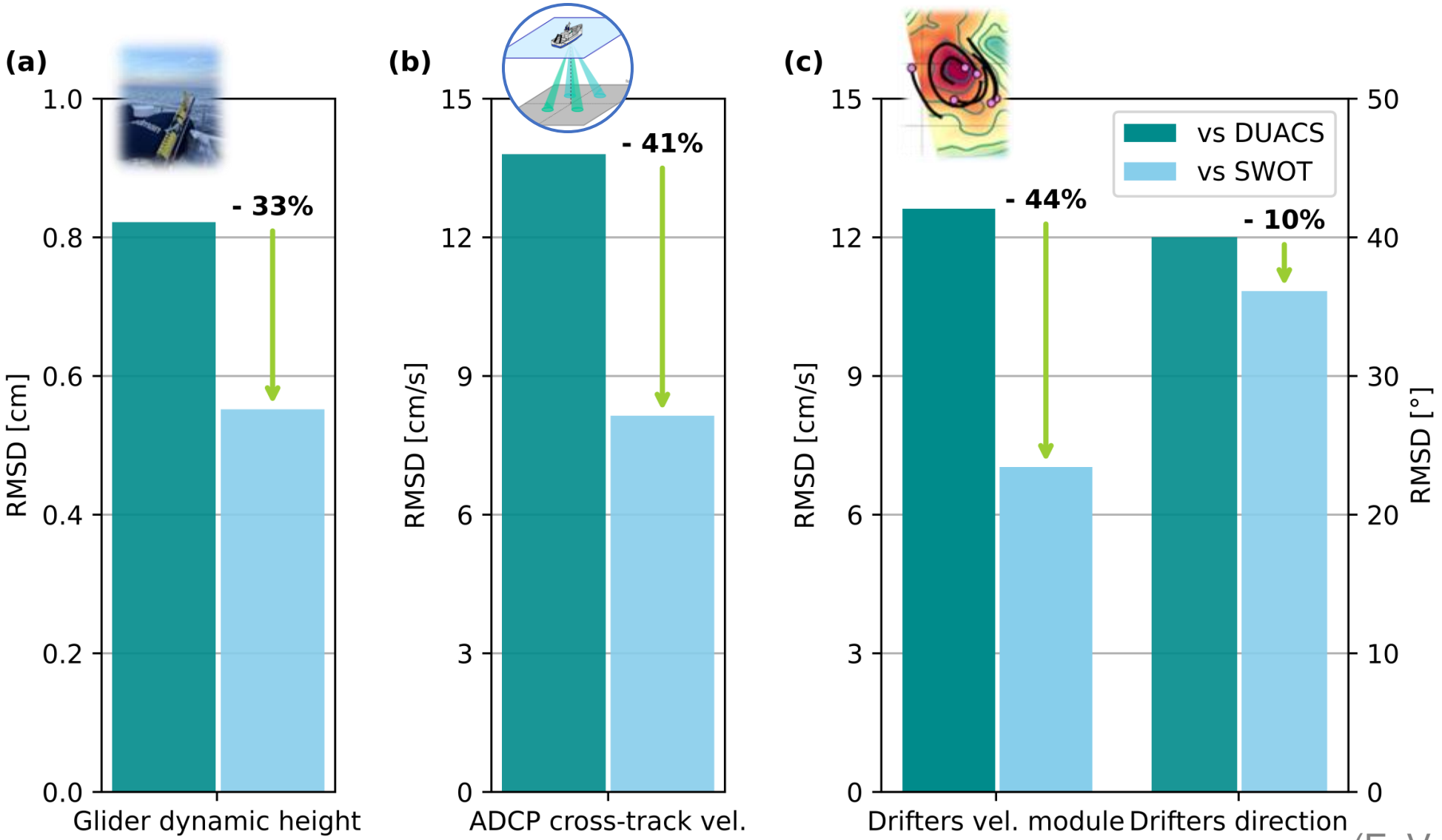


(E. Verger-Miralles)

SWOT improvement over conventional gridded altimetry

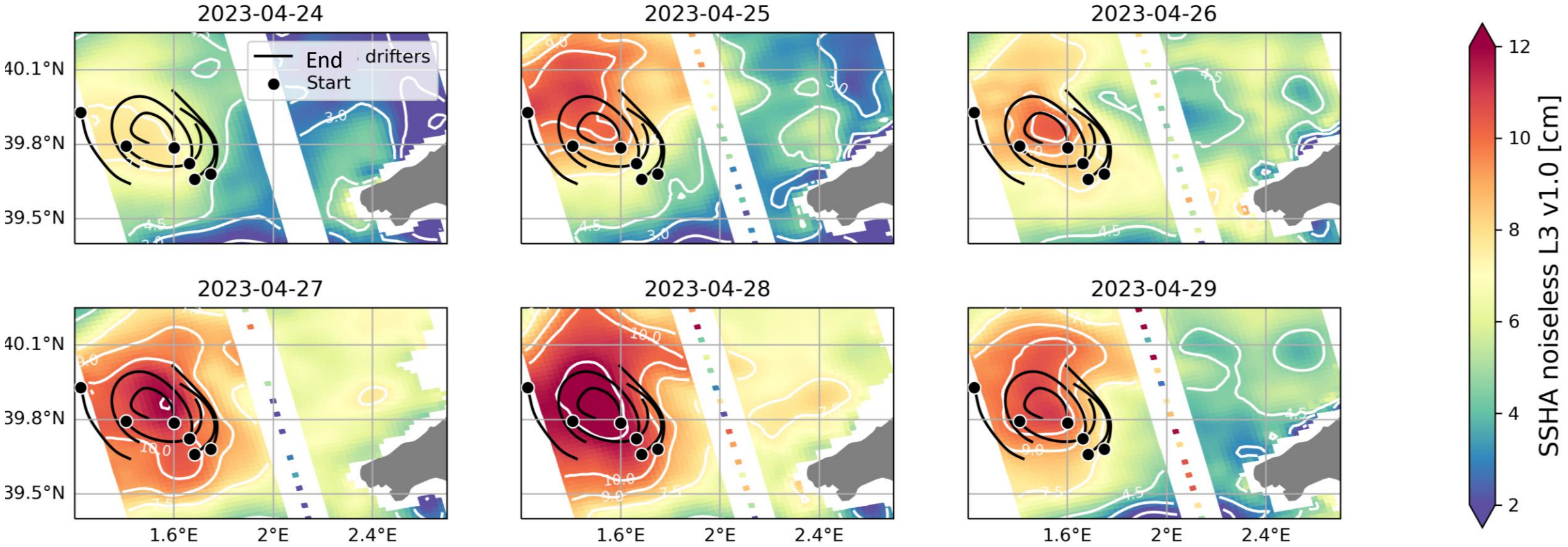


(E. Verger-Miralles)

→ Significant RMSD reduction wrt conventional altimetry maps

New insights into daily SSH variability

Sea level (cm) from SWOT



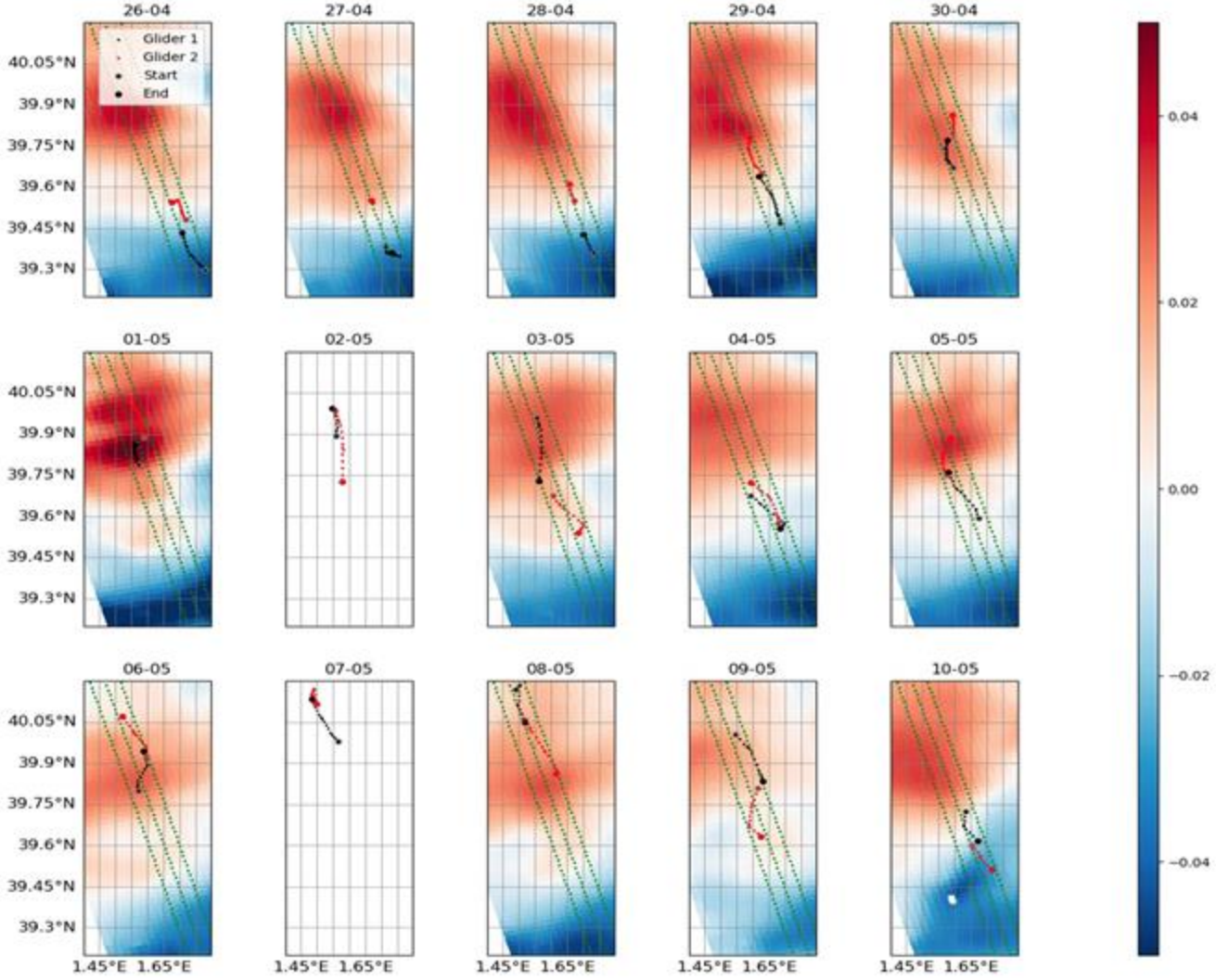
(L. Gómez-Navarro)

→ Significant daily variability

Selection of 6 **SVP-B Drifters**
25/04 – 29/04/24 (IOs filtered)

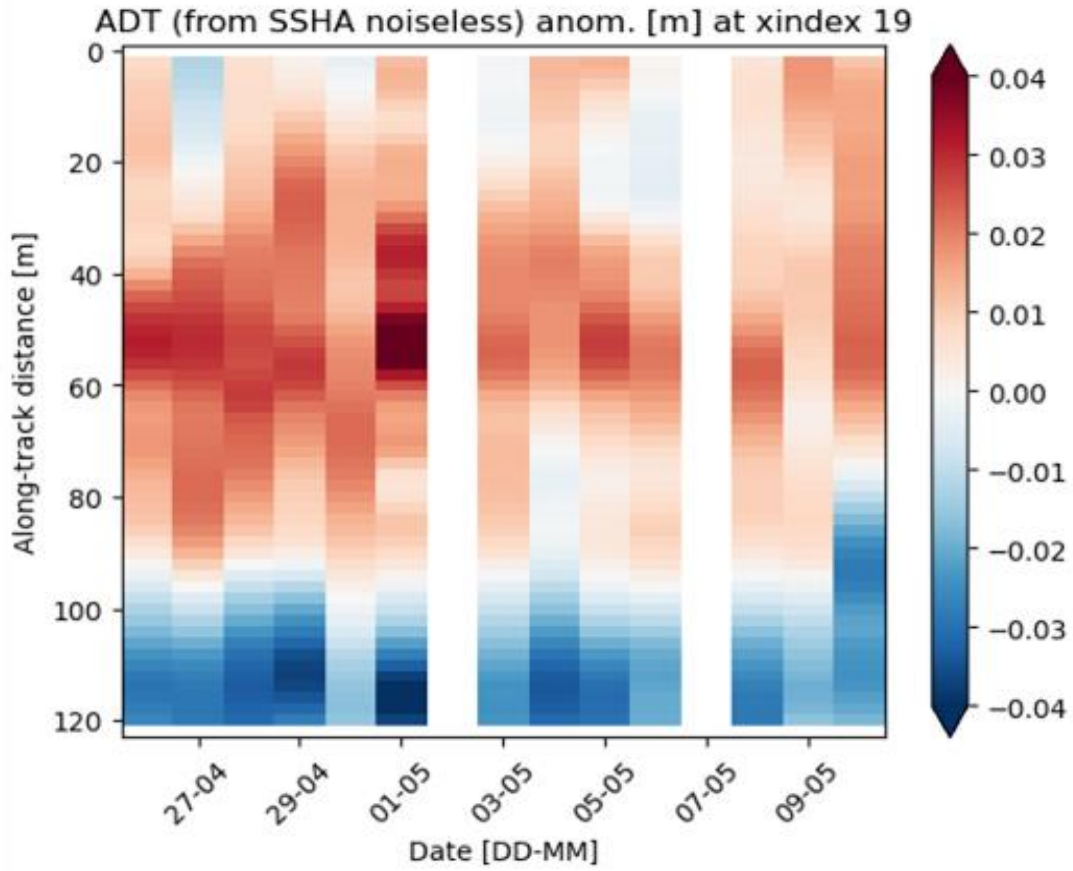
New insights into daily SSH variability

SWOT ADT maps 26 Apr to 10 May



(L. Gómez-Navarro)

Hovmoller plot along the mean glider track



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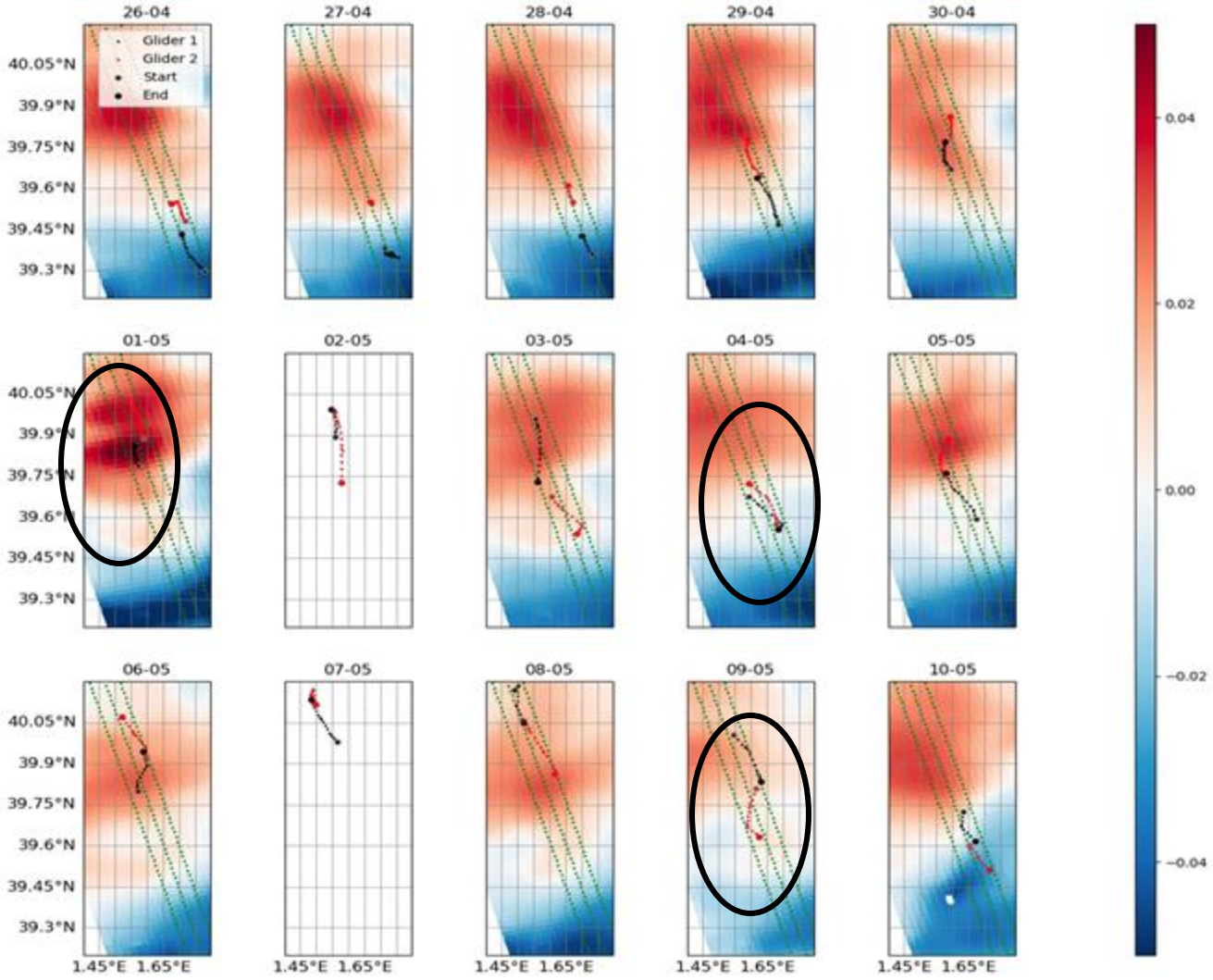

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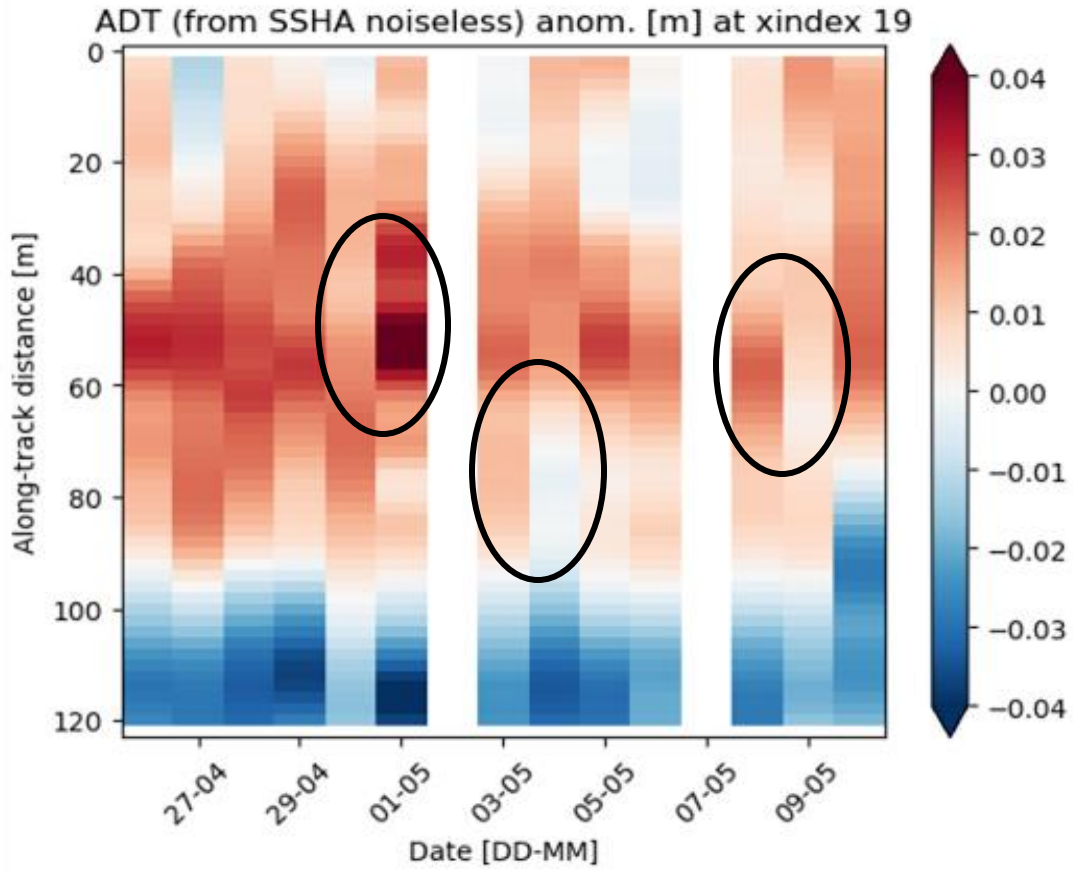

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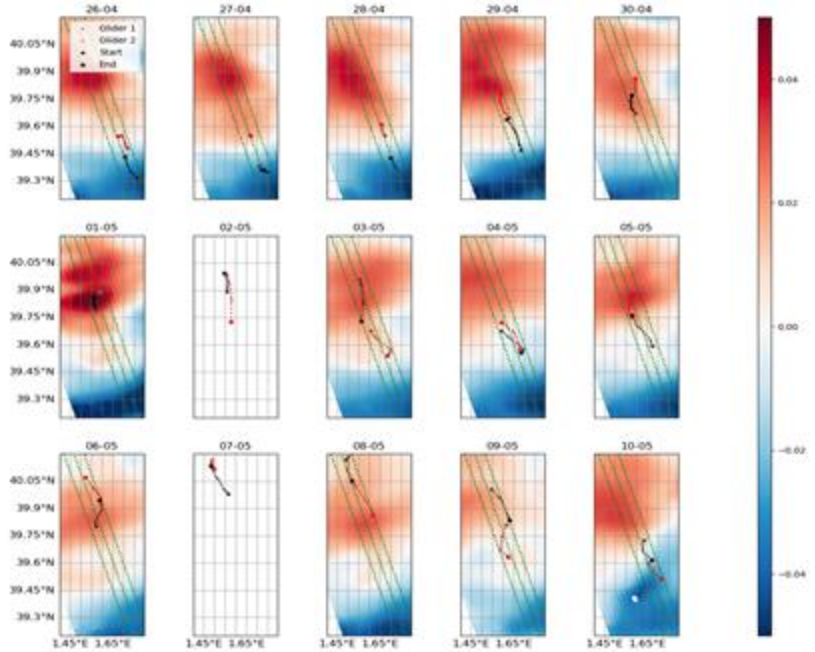
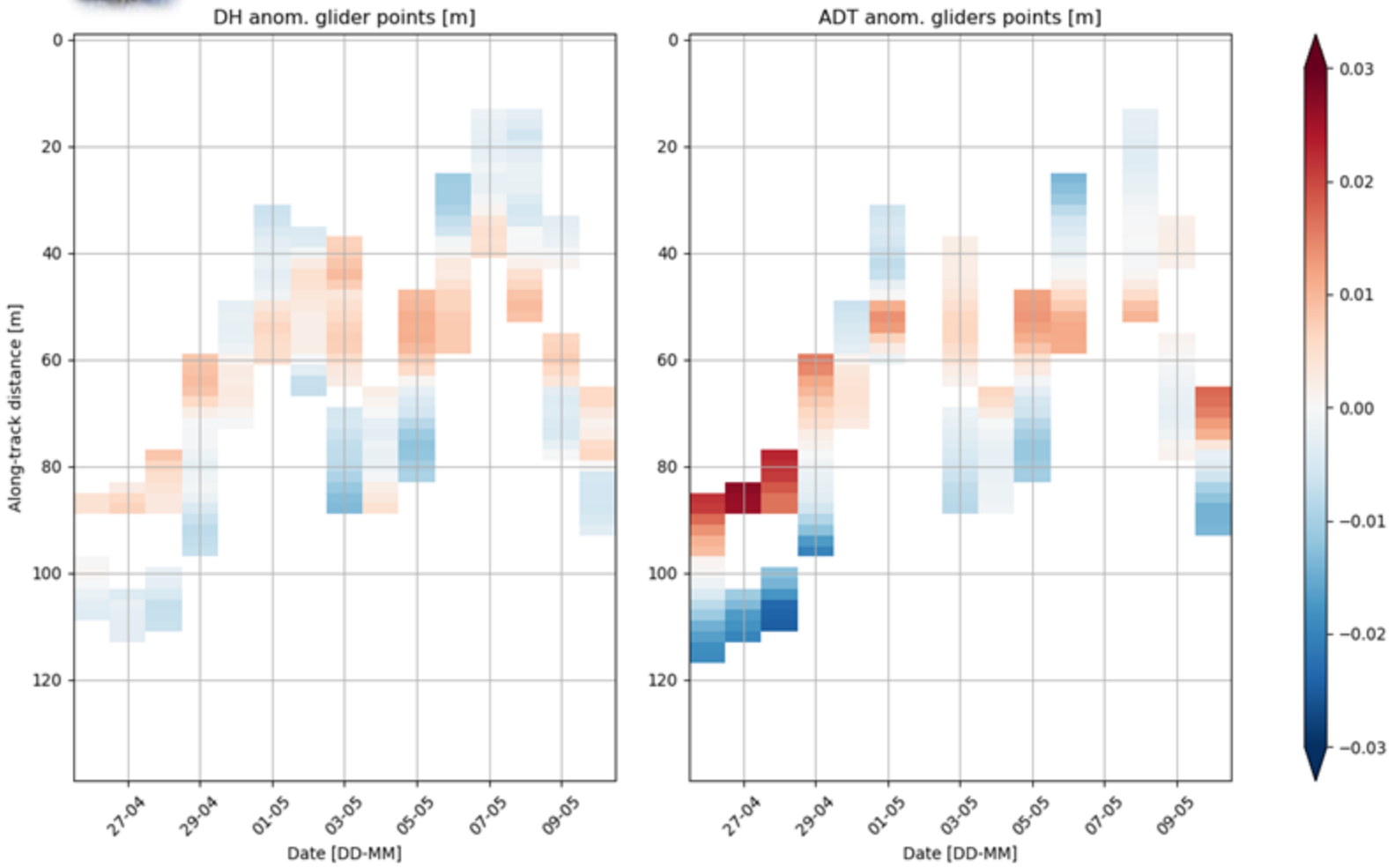


(L. Gómez-Navarro)

Glider DH

SWOT SSH



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New insights into daily SSH variability

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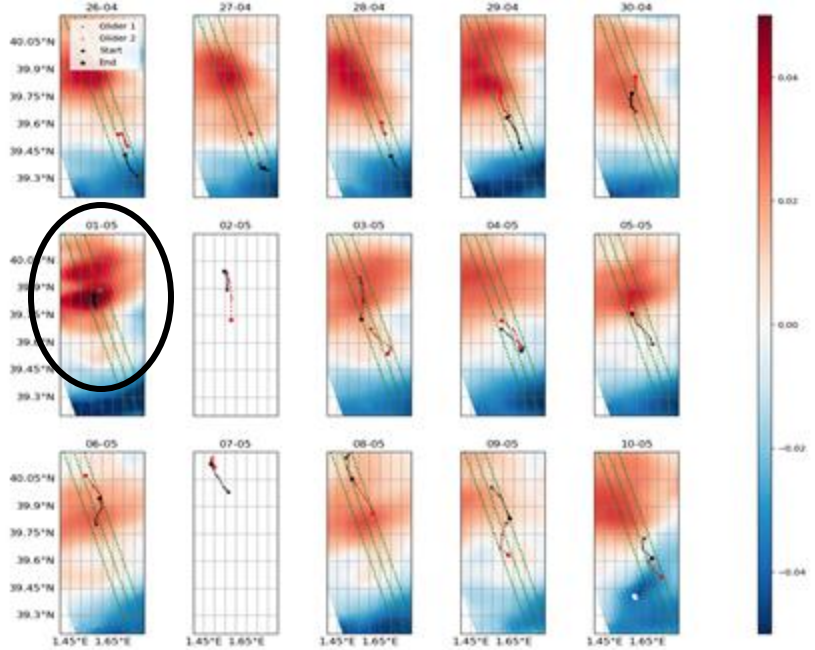

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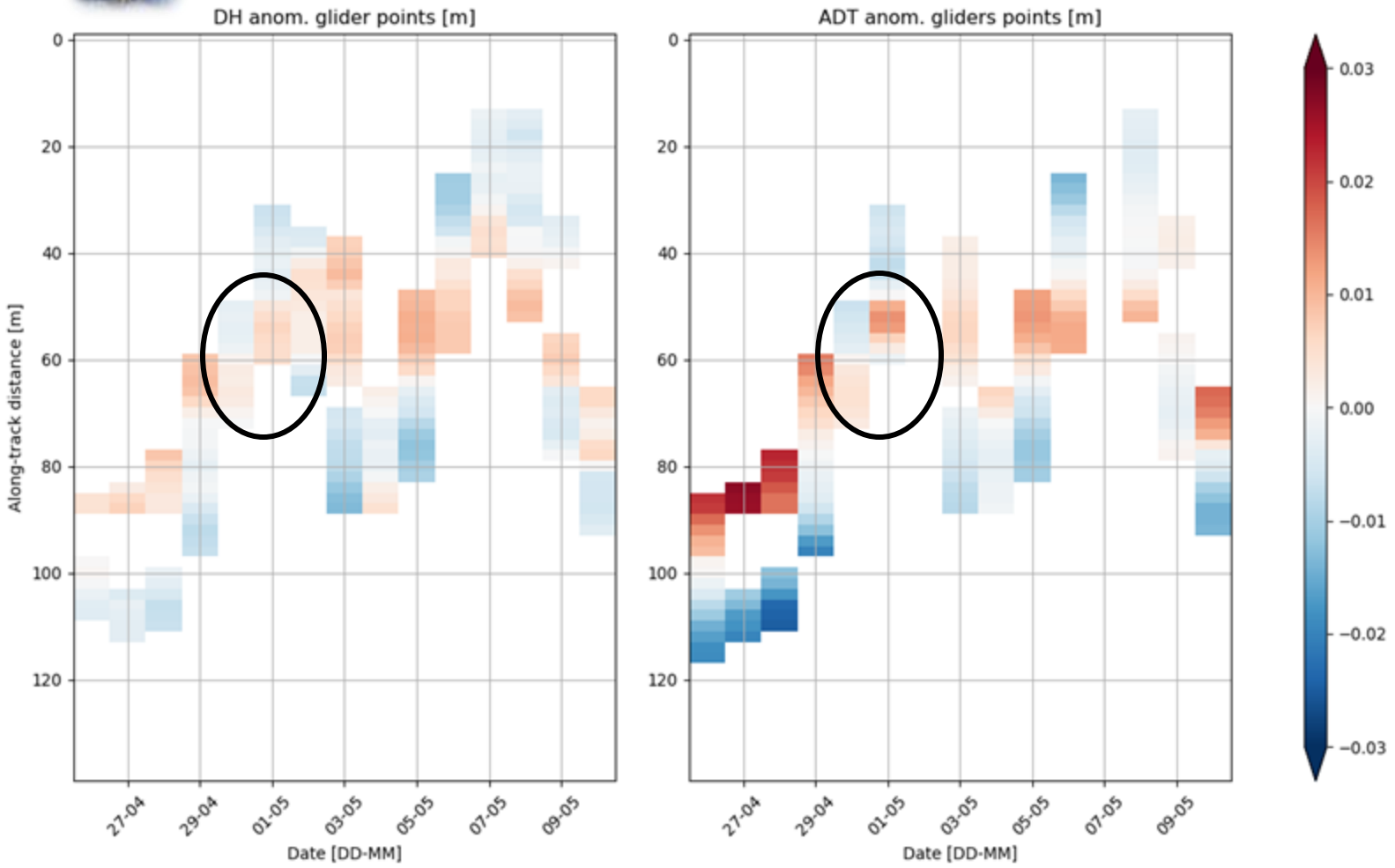
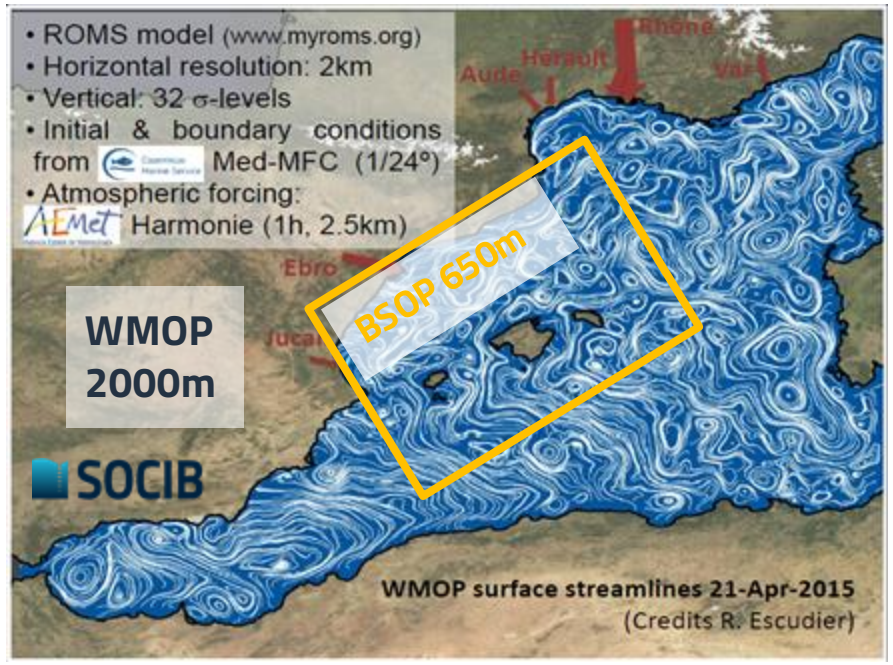


(L. Gómez-Navarro)

SWOT vs model



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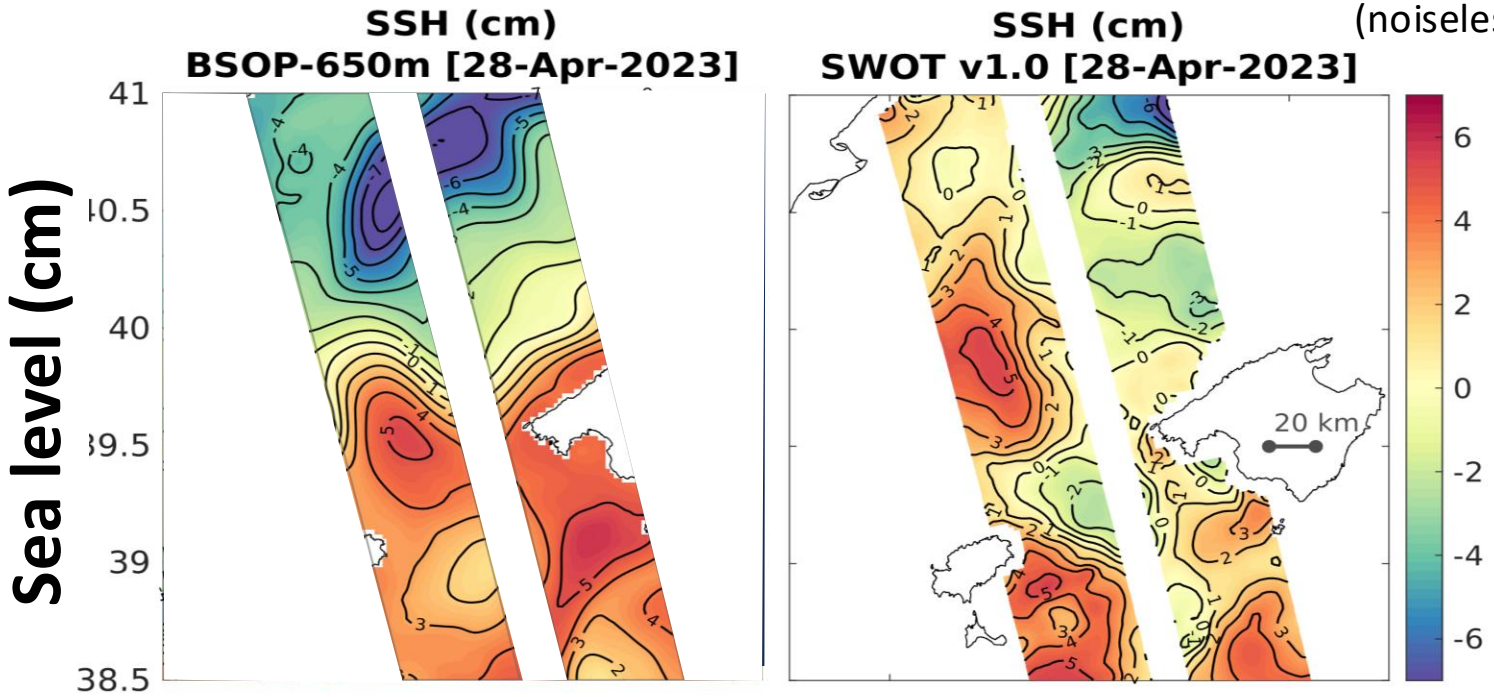
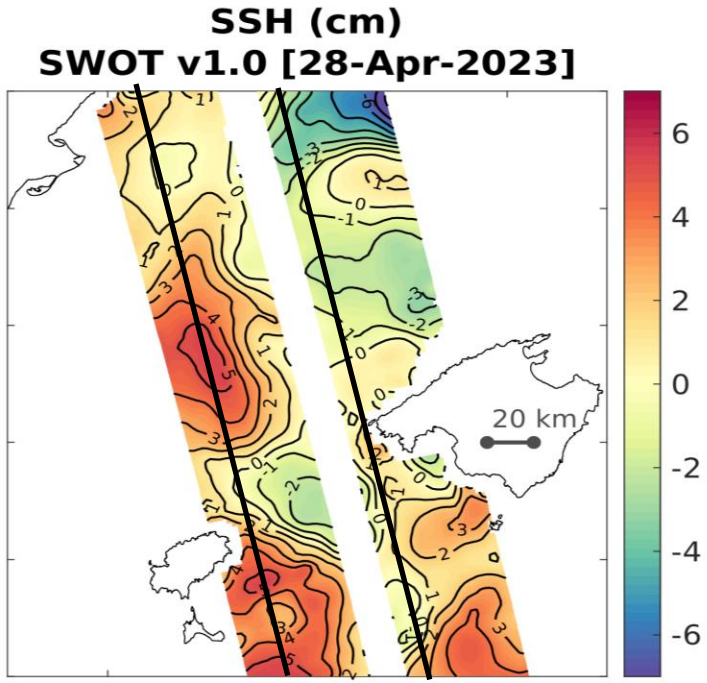
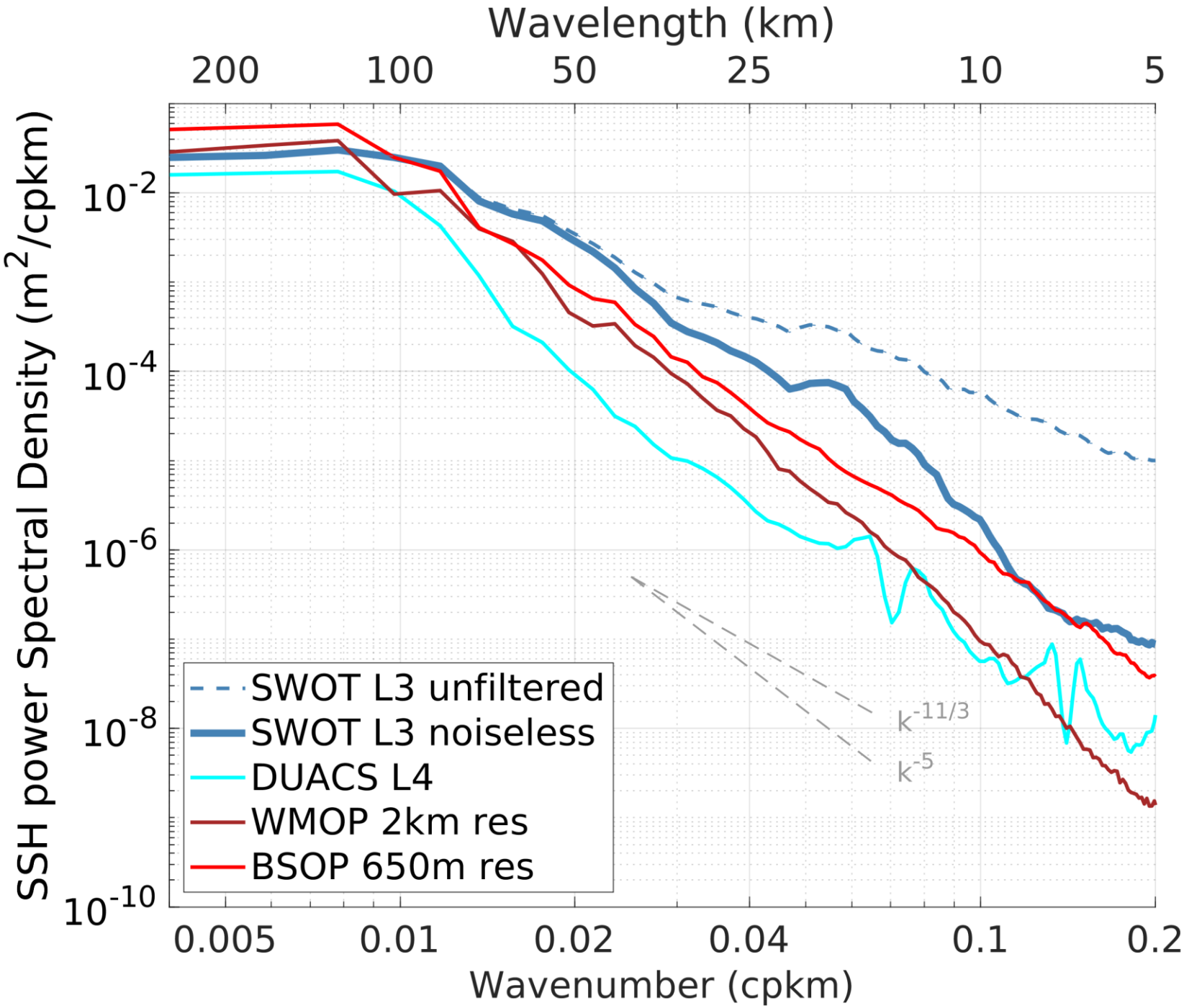
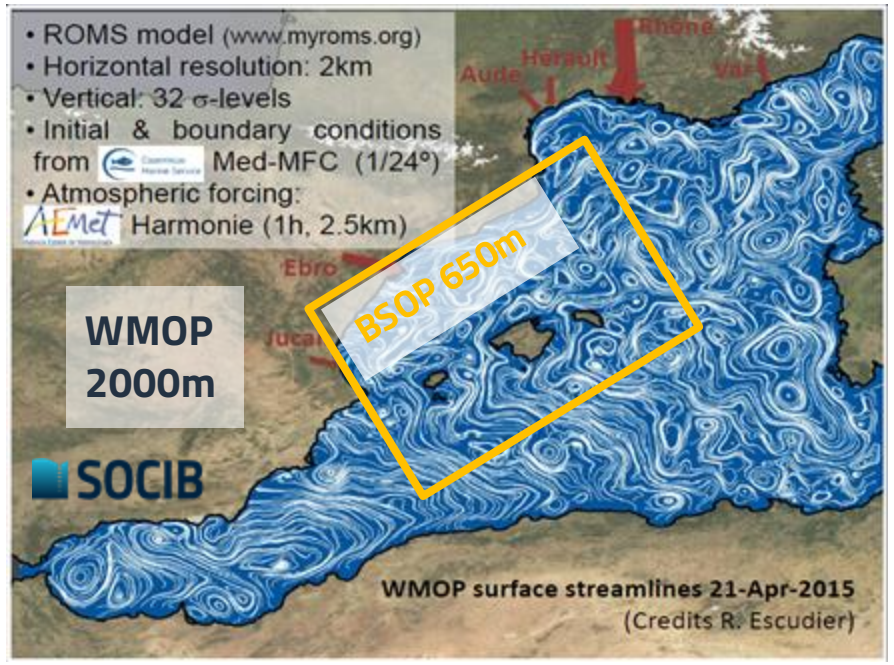
(noiseless)




SSH (cm)
SWOT v1.0 [28-Apr-2023]
20 km
6
4
2
0
-2
-4
-6


Wavelength (km)
200
100
50
25
10
5
SSH power Spectral Density (m²/cpkm)
10⁻²
10⁻⁴
10⁻⁶
10⁻⁸
10⁻¹⁰
0.005
0.01
0.02
0.04
0.1
0.2
Wavenumber (cpkm)
SWOT L3 unfiltered
SWOT L3 noiseless
DUACS L4
WMOP 2km res
BSOP 650m res
k^-11/3
k^-5

SWOT vs model



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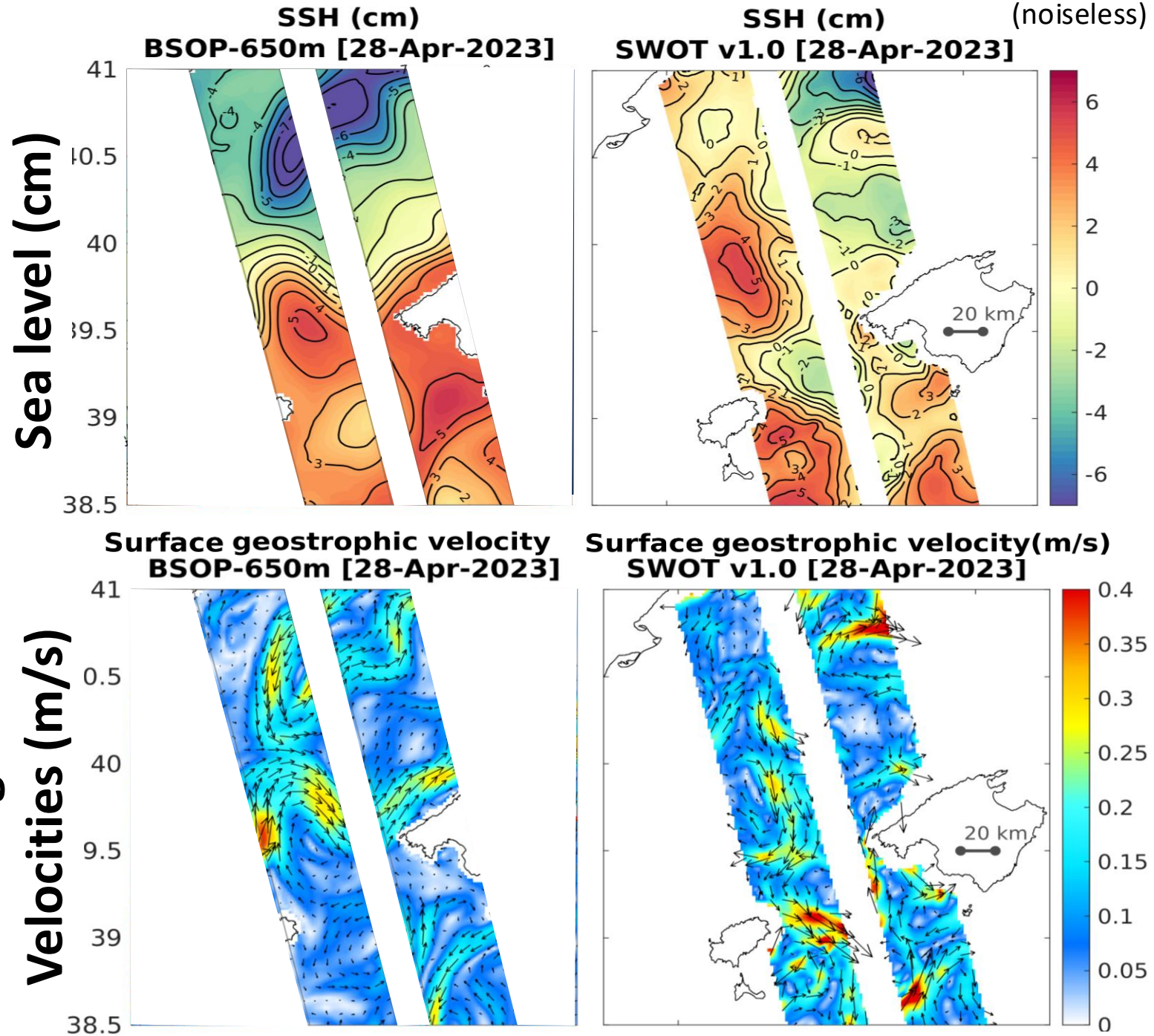

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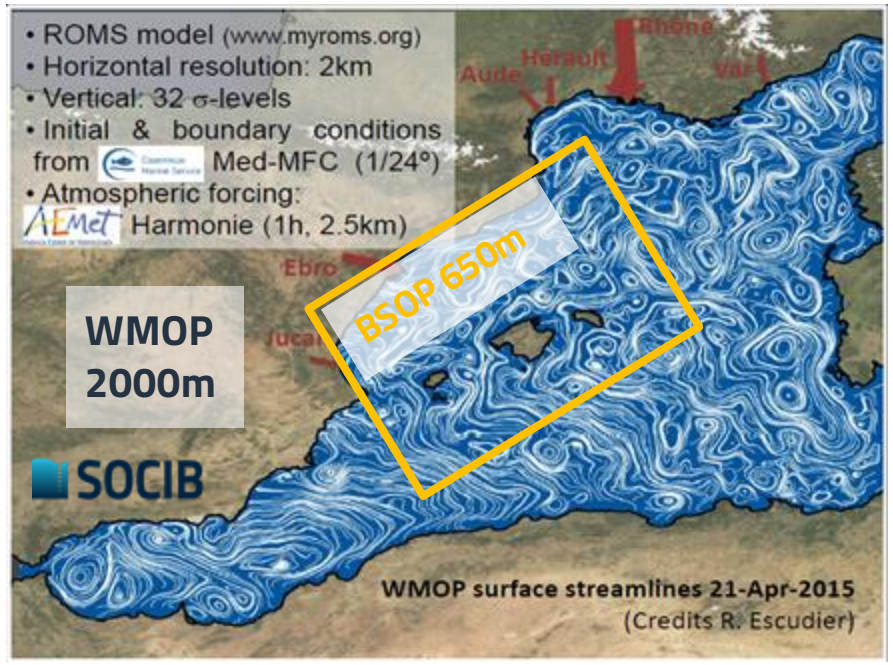

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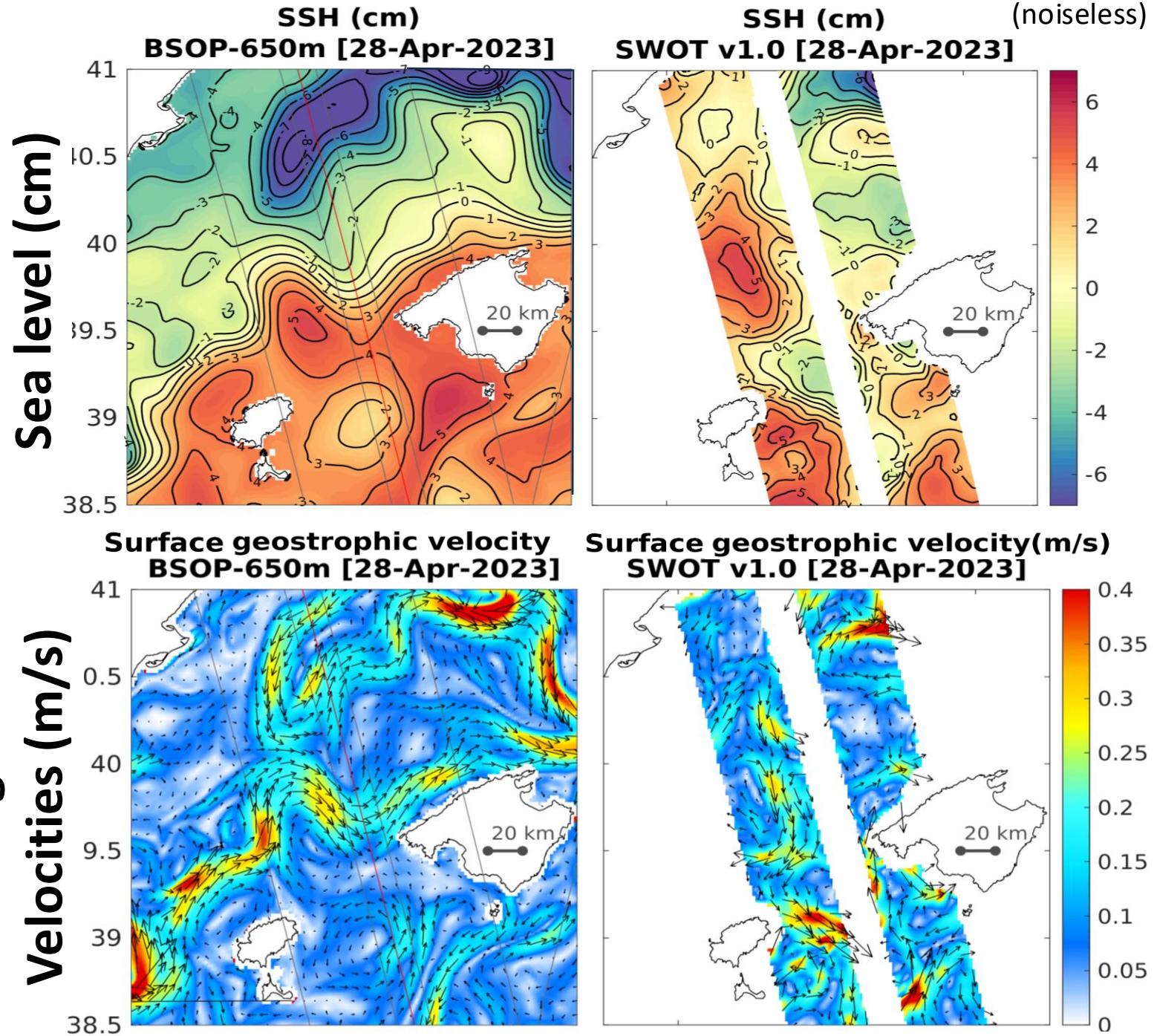

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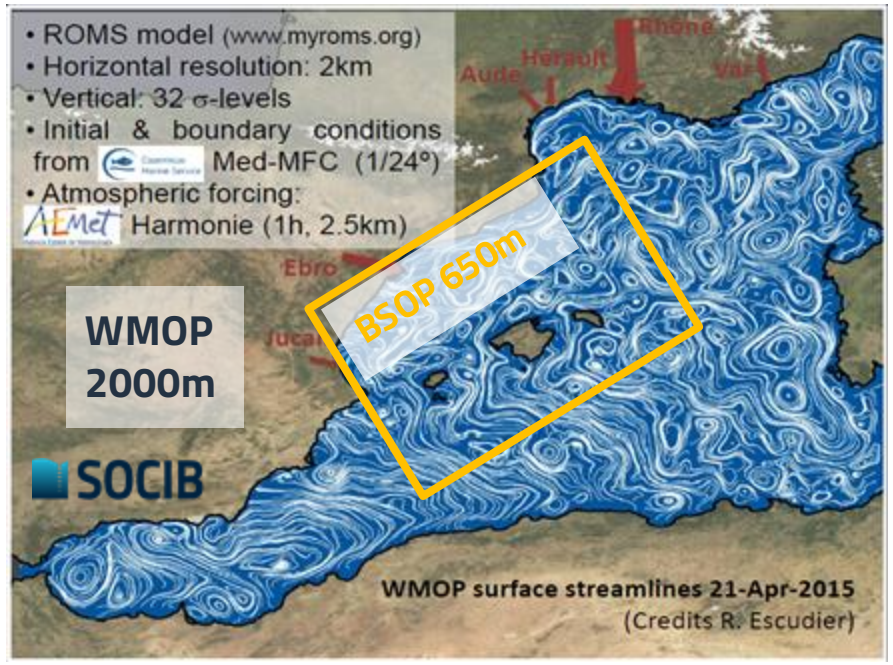

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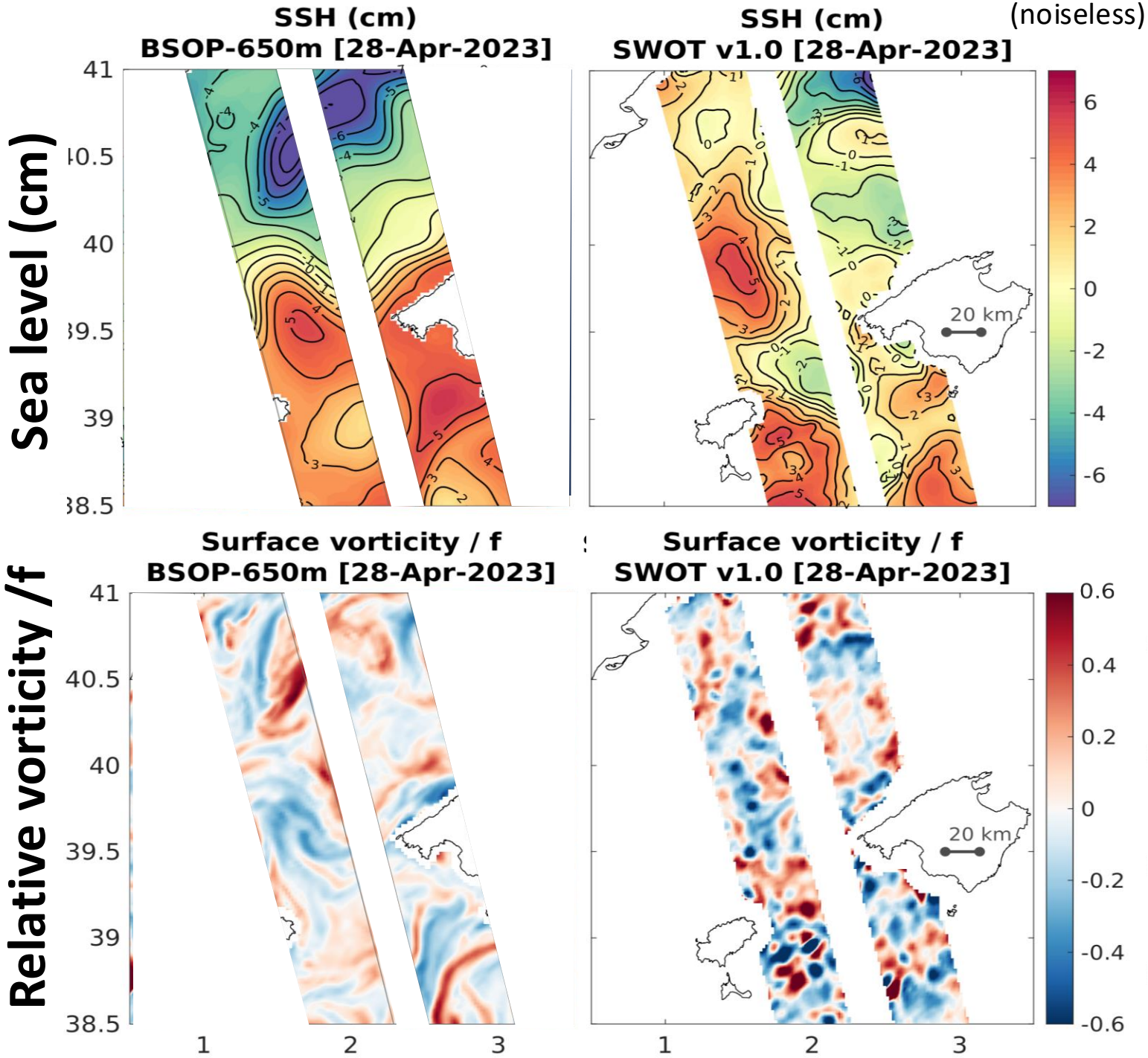
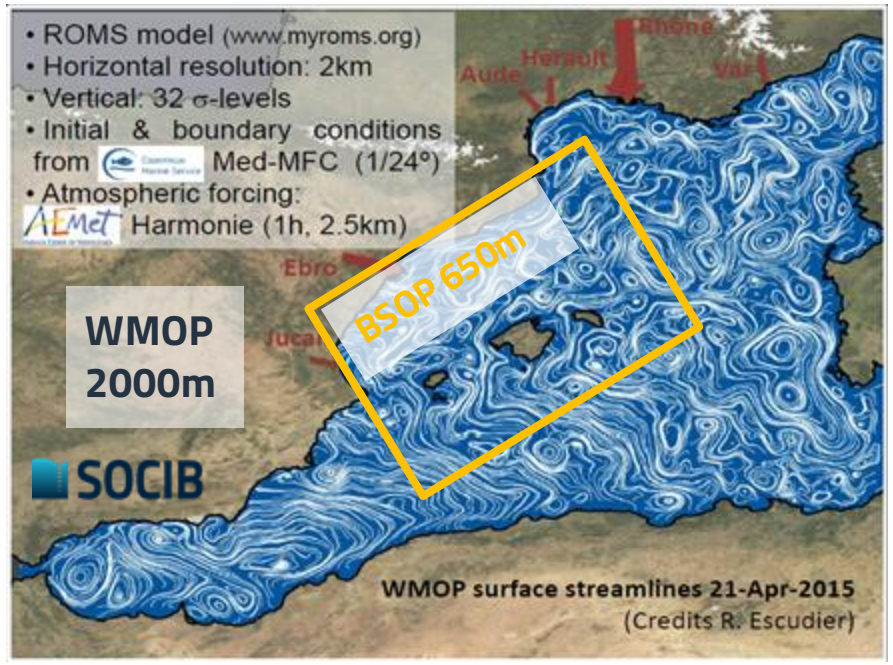
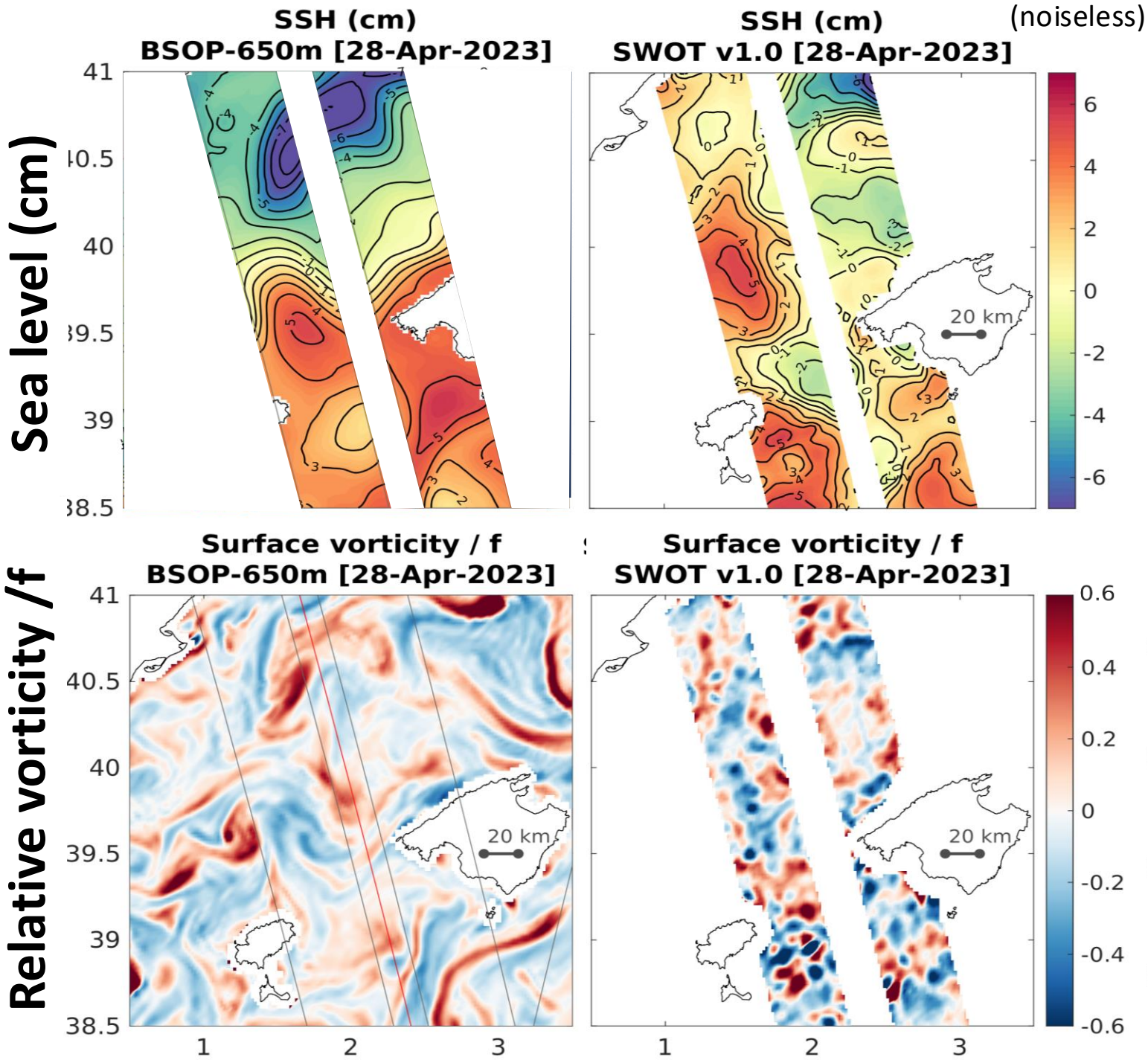


SWOT vs model

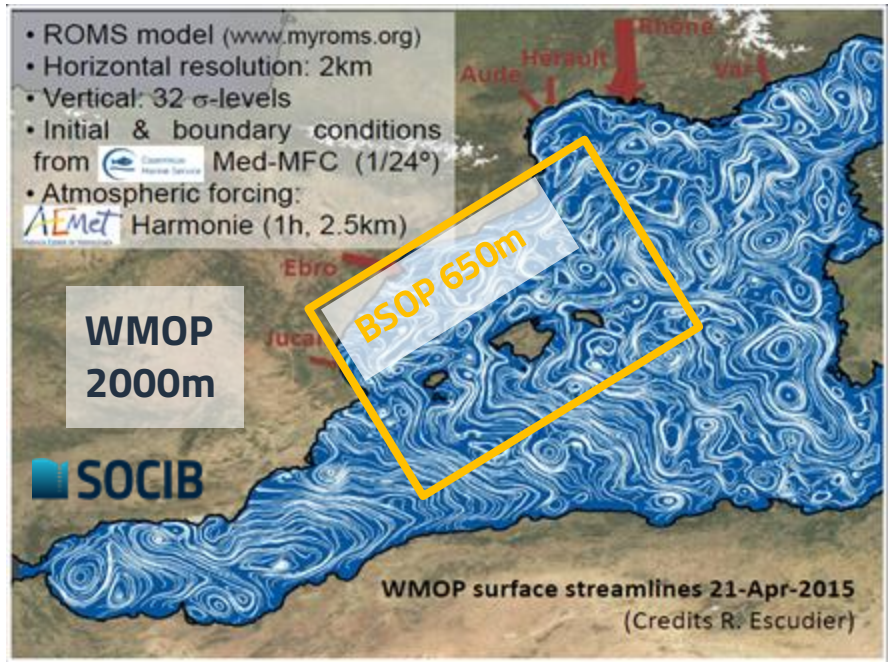


Daily data assimilation in WMOP (Multimodel Local Ensemble Optimal Interpolation):
SST, along-track SLA, Argo T-S profiles, Ibiza Channel HF radar, moorings.

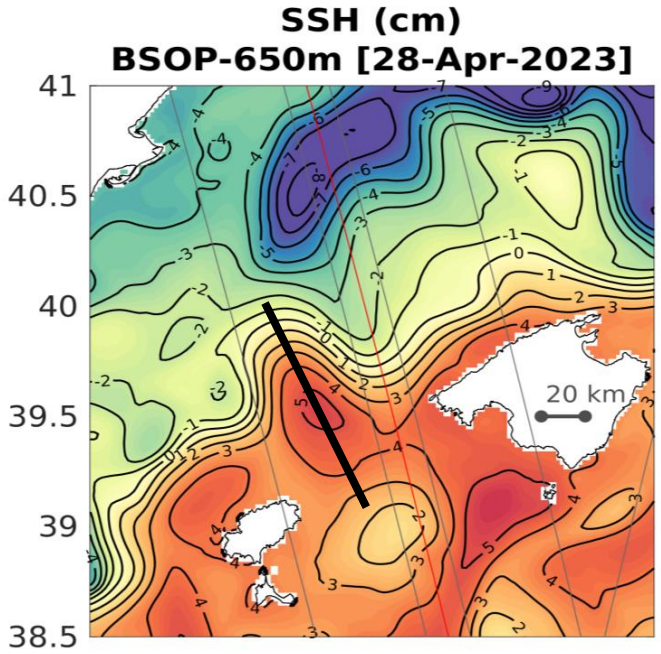
(noiseless)

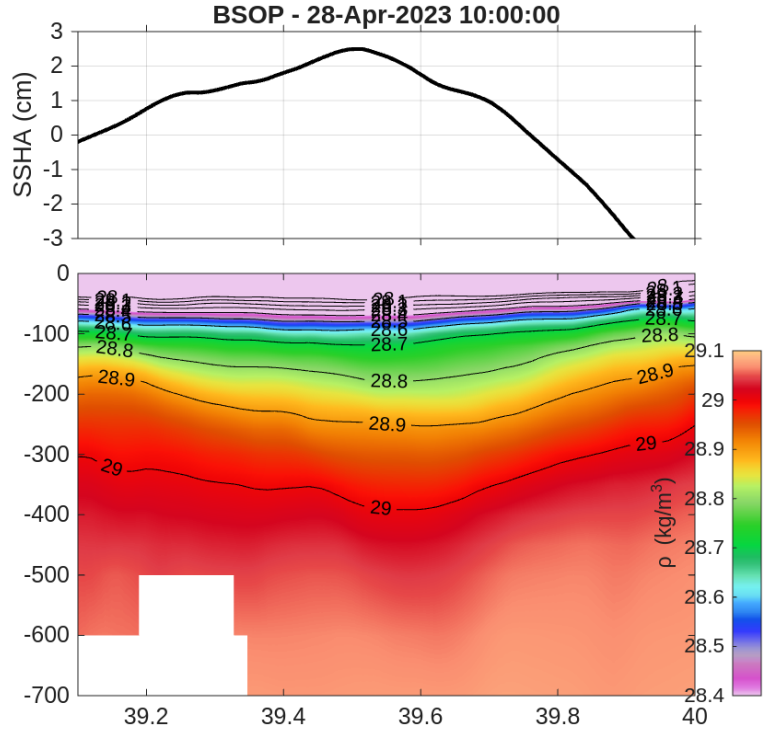


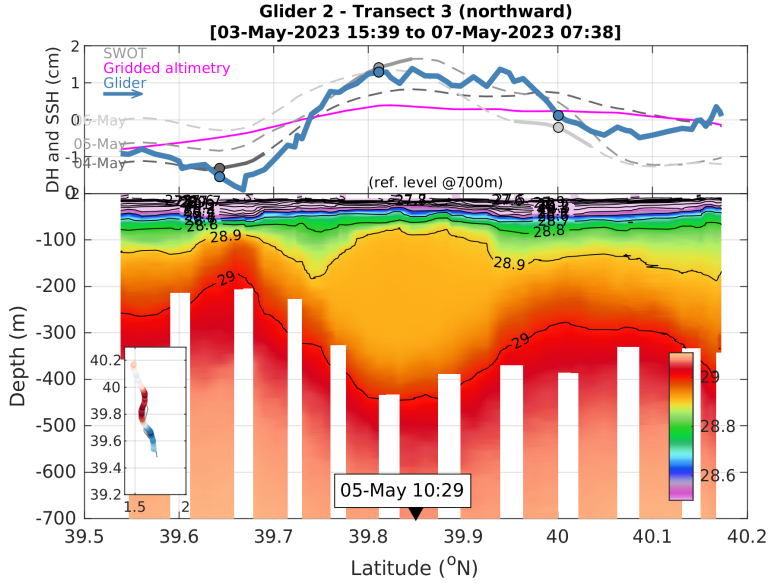
Glider vs model



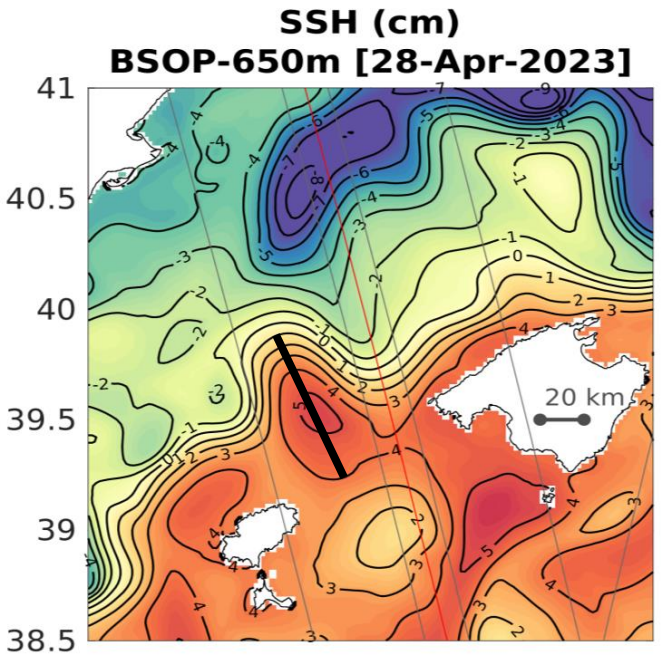
Daily data assimilation in WMOP (Multimodel Local Ensemble Optimal Interpolation):
SST, along-track SLA, Argo T-S profiles, Ibiza Channel HF radar, moorings.





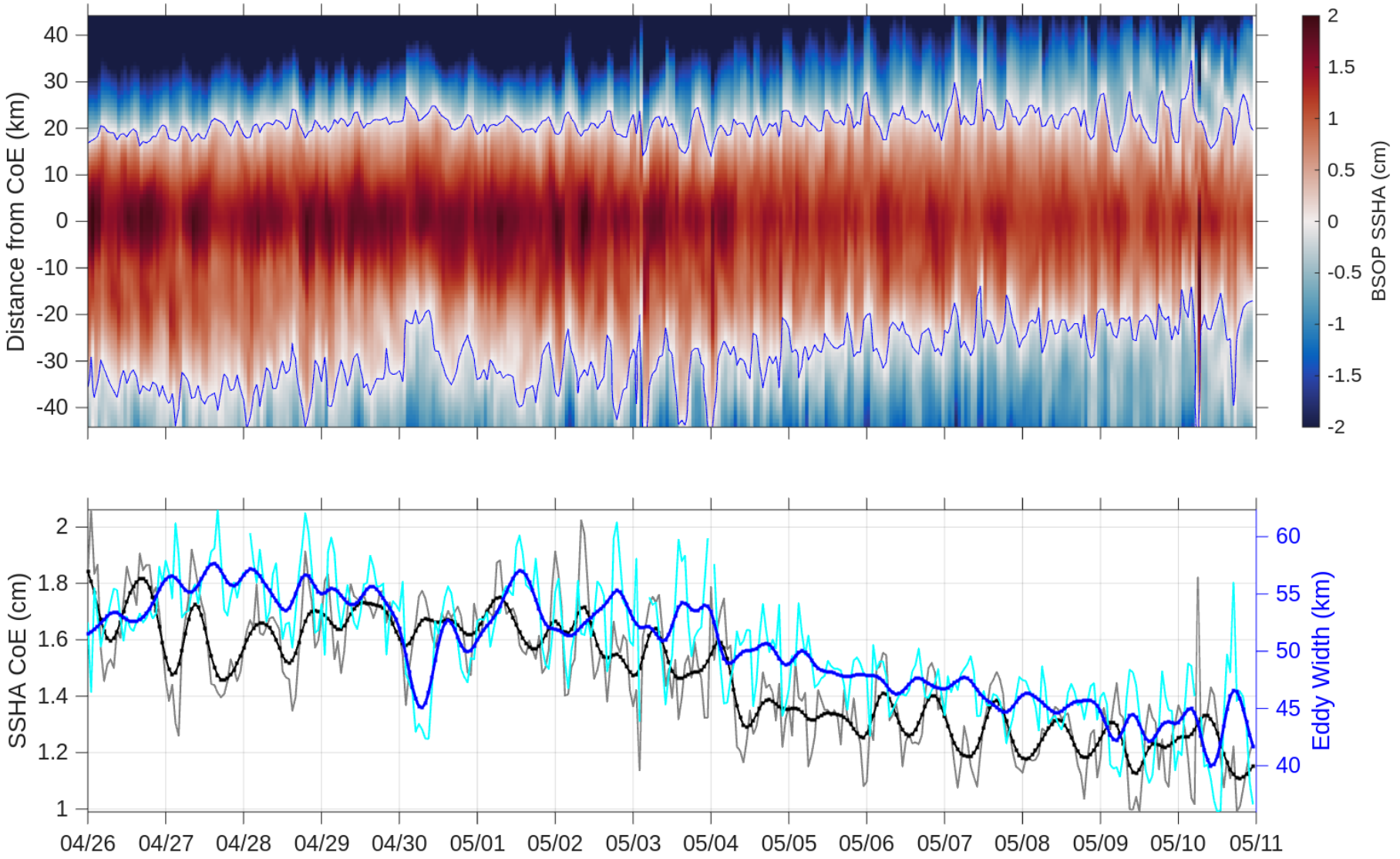


Daily SSH variability



→ Model free run 650m horizontal resolution

Model SSHA along eddy cross-section



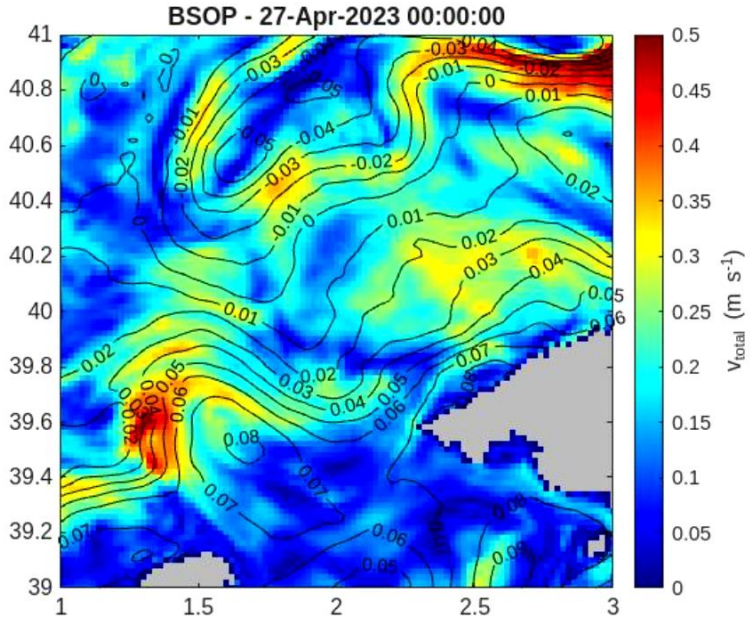
(J.-P. Peng)

Importance of ageostrophic processes

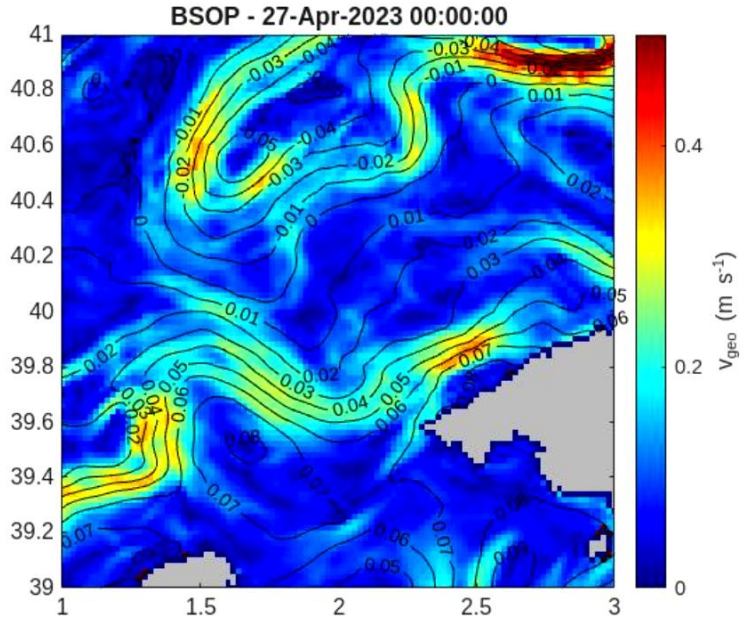
Surface velocities (m/s)

BSOP
650m res.

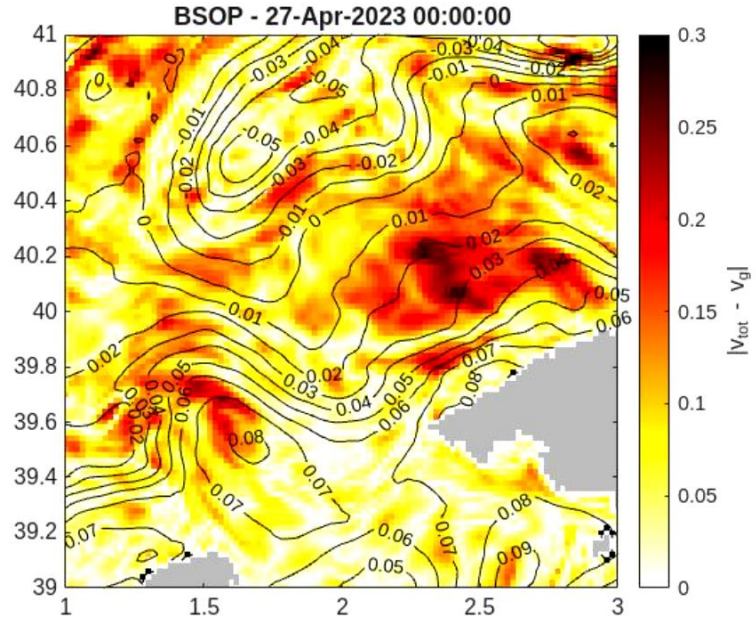
[total]



[geostrophic]



[total – geostrophic]



(J.-P. Peng)

Impact of SWOT observations through data assimilation

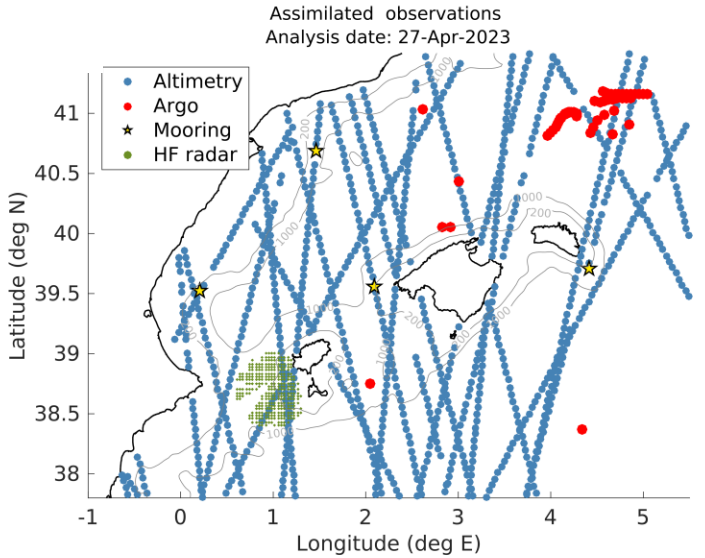
GEN = along-track SLA, SST, Argo T-S, Moorings, HF radar

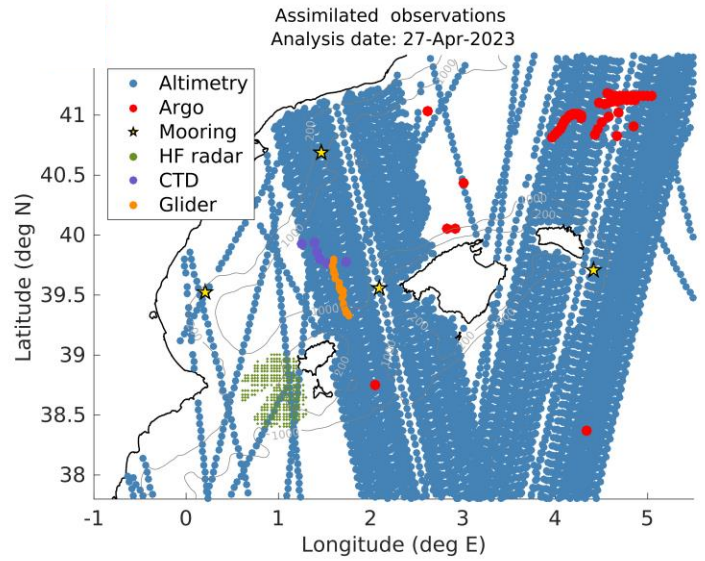
1- Assim GEN

2- Assim GEN + SWOT

3- Assim GEN + CTDs + Gliders

4- Assim GEN + CTDs + Gliders + SWOT

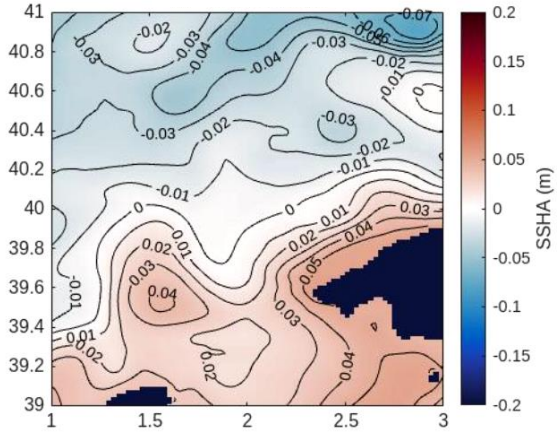




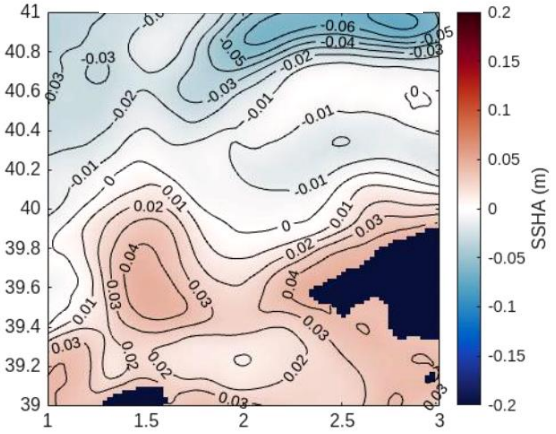
Impact of SWOT observations through data assimilation

SSH anomaly on 27-Apr-2023 12:00

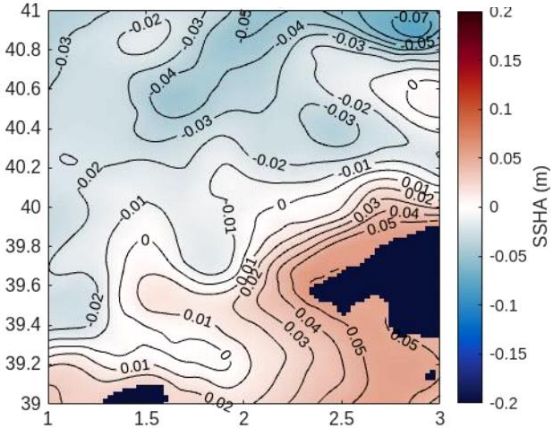
GEN



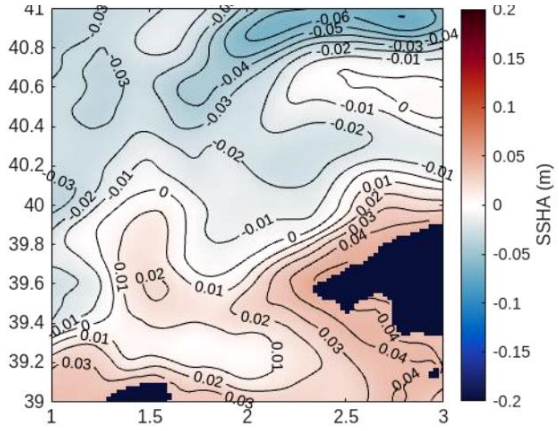
GEN + SWOT



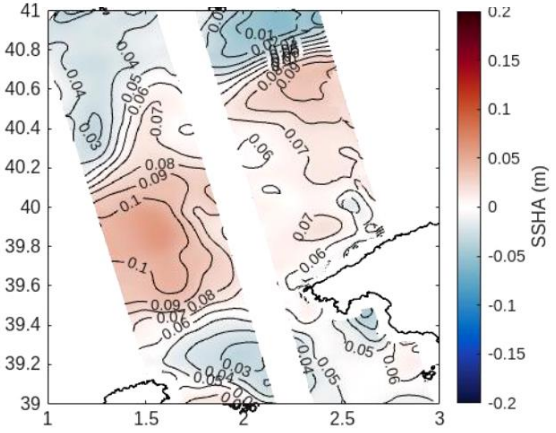
GEN + CTDs + Gliders



GEN + CTDs + Gliders + SWOT



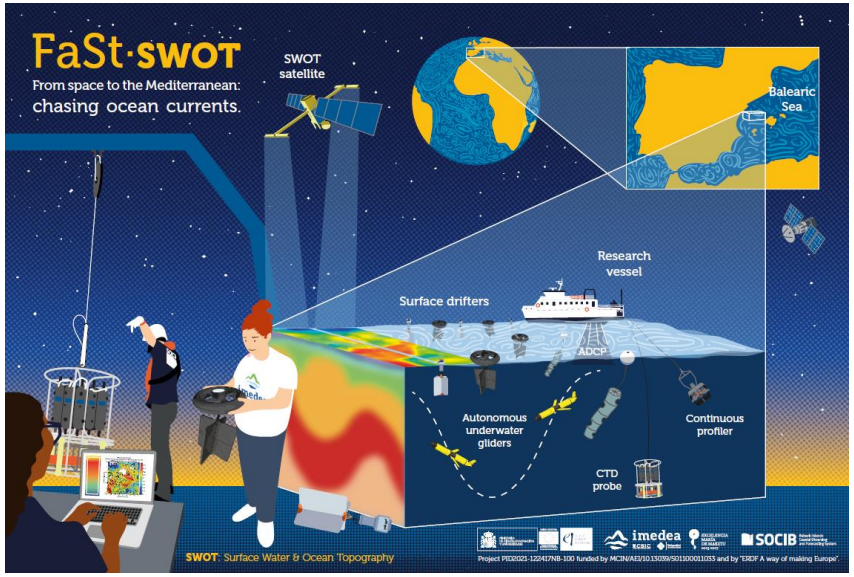
SWOT observations

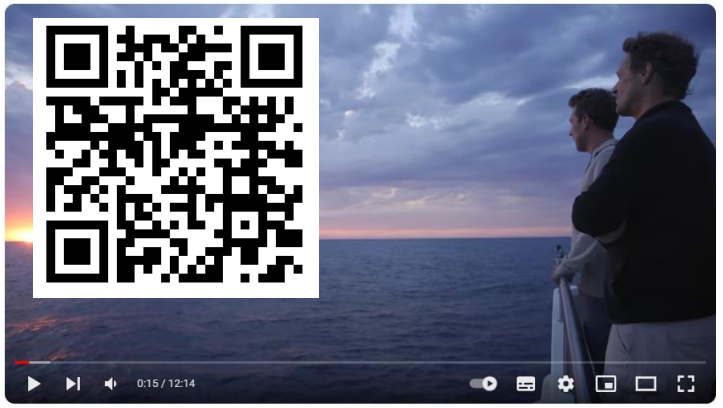


Conclusions

- New small-scale sea level observing capability provided by the SWOT satellite, with very good accuracy.
- SWOT-derived surface geostrophic currents consistent with observed currents for the small scale eddy under study.
- Daily repetitivity during the fast-sampling phase reveals significant daily SSH variability, also somehow present in glider data and model simulations.
- Ageostrophic components of surface currents significant in areas with intense SSH gradients.
- First experiments assimilating SWOT data in numerical models show qualitative improvement. Detailed analysis still needed.

Conclusions





"Del espacio al Mediterráneo: Persiguiendo corrientes marinas"

Thank you!

Verger-Miralles et al., SWOT enhances small-scale intrathermocline eddy detection in the Mediterranean Sea, Authorea Preprints 2024, ESS Open Archive, https://essopenarchive.org/doi/full/10.22541/essoar.173315547.75973902, submitted to Geophys Res Letters

Acknowledgements

PID2021-122417NB-I00 funded by MCIN/AEI/10.13039/501100011033/ FEDER, UE

CNS2023-145542 funded by MCIN/AEI/10.13039/501100011033/ NextGenerationEU/PRTR