Exploring the “small” mesoscale (10-100km) of the Mediterranean sea with the SWOT satellite

M2 project proposed by
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General context

The oceanic fine scales (1-100 km) have relatively short lifetimes (days to weeks) but crucially affect ocean physics and ecology up to the climate scale, due to the strong gradients created by their energetic dynamics. These gradients are associated with strong vertical transport connecting the ocean's upper layer to its interior. Moreover, the temporal scale associated with this horizontal and vertical dynamics is the same as that of many important oceanic processes including biogeochemical cycles, biodiversity, fish distribution, and even foraging strategies of the mega-fauna.

One of the main challenges for studying the ocean finescale circulation is its observability. Datasets unhindered by clouds able to track in space and time finescale filaments and eddies are limited to satellite altimetry. However, conventional altimetry only marginally resolves the fine scales, being limited to spatial scales larger than 70-100km. This limitation in resolution is especially problematic in basins with a small (<30km) Rossby radius like the Mediterranean sea. For these cases the existence of a “small mesoscale” regime (<70km) is suggested by model simulations and indirectly observed during clear sky conditions from sea surface temperature or ocean color images. However, the characteristics of such small scales still lack of direct observations. What is the life cycle of these features? What is their statistics? Which role do they play in the circulation or biogeochemistry of the Mediterranean compared to the larger features observed by conventional altimetry?

In order to address this and other problems associated to the limits of conventional altimetry, a novel satellite mission has been recently developed. The Nasa-Cnes Surface Water and Ocean Topography (SWOT) satellite has been launched on the 16th of December 2022. After several months of calibration and validation, SWOT started its science orbit since July 2023 providing full coverage (up to 77.6°). The main advantage of SWOT lies in its altimetric sensor of novel generation, capable of a resolution about ten times higher than conventional altimetry. These data represent a revolution, because they will open the way to the empirical and direct characterization of the geostrophic regime <70km that until now had remained invisible to conventional altimetry.

Objectives

This Master 2 project aims at providing the first observational exploration of the Mediterranean “small mesoscale” (10-100km) based on the new SWOT dataset focusing on the western basin. The choice of this region stems from two reasons. First, the Western Mediterranean sea is characterized by a Rossby radius of the order of 15-30 km, and therefore offers the ideal case study for a “small mesoscale” study. Second, this

region has been the theater of the recent BIOSWOT-Med field experiment, which targeted precisely an eddy (an anticyclone) ~30km large, visible in SWOT maps and unresolved by conventional altimetry. In this regard, the results of this Master 2 project will contribute to the BIOSWOT-Med post-cruise analysis, and help to understand how typical the small mesoscale feature sampled by BIOSWOT-Med is, and on the other hand what is its specificity.

For this study region, the specific objectives are the following:

- Estimation of the excess size of “large mesoscale” eddies rendered by conventional altimetry map and of the “small mesoscale” unresolved by traditional altimetry but present in SWOT observations. This will be achieved by comparing the surface occupied by the eddies (using the Okubo-Weiss technique) in maps from both conventional and SWOT maps, and looking respectively at positive and negative anomalies appearing in the difference between these two maps.
- A comparative study of the statistics for eddy and filament diagnostics (Lyapunov exponents, retention parameters, Okubo Weiss, kinetic energy, strain, vorticity, as well other classical quantities), comparing conventional altimetry and SWOT products.
- A determination of the differences between the basin-scale circulation patterns as derived from conventional altimetry and SWOT observations, with a focus on the surface water mass origin of the BIOSWOT-Med sampling area, on timescales consistent with the phytoplanktonic bloom development (seasonal period).

Other diagnostics that can help to unveil the contribution of SWOT to the finescale circulation of the Western Mediterranean may be proposed by student. If the time will permit, an assessment of the realism for Copernicus assimilation models available for the area will be explored as well.

Methods and working environment

The student will work on the standard DUACS maps plus the new validated SWOT L2 and L3 (Level 2 and Level 3) datasets, available through the AVISO+ provider. These L2 and L3 maps contain the along-the-swath sea surface height observations of SWOT after that a denoising and calibration procedure have been applied. A SWOT L4 product is also under validation by the SWOT project and will contain uninterrupted maps of sea surface height thanks to a dynamical interpolation technique among the SWOT swaths. If these L4 maps will be available for the beginning of next year, they will provide a good opportunity for exploring the Western Mediterranean circulation at a larger synoptic scale. The analysis will mostly concern eddy characterization using the SWOT-AdAC Lamta package (python language). The working place will be the LOCEAN laboratory, 4 place Jussieu, 75005 Paris. The duration is 6 months. The work will be in collaboration with M. Lévy (LOCEAN), L. Rousselet (LOCEAN), A. Doglioli (MIO), A. Bosse (MIO). Strong interactions with the BIOSWOT team (LOCEAN, MIO, LMD, IGE in France; Scripps Inst., CNR-ISMAR, IMEDEA abroad) and visits to MIO (Marseille) are envisaged. This subject is financed by the NASA-CNES SWOT Science Team project “SWOT-AdAC”.

Skills and know-how

The student will have:

- solid knowledge of ocean dynamics, in particular about geostrophic dynamics
- good coding skills (python)

- proficiency with the English language
- knowledge of Lagrangian methods will be an added value
- Attitude for working in collaborations, for exchanging, and for presenting scientific results.

References

d’Ovidio, F., Pascual, A., Wang, J., Doglioli, A.M., Jing, Z., Moreau, S., Grégori, G., Swart, S., Speich, S., Cyr, F., et al. (2019). Frontiers in Fine-Scale in situ Studies: Opportunities During the SWOT Fast Sampling Phase. Frontiers in Marine Science *6*, 168. 10.3389/fmars.2019.00168.

Morrow, R., Fu, L.-L., Ardhuin, F., Benkiran, M., Chapron, B., Cosme, E., d’Ovidio, F., Farrar, J.T., Gille, S.T., Lapeyre, G., et al. (2019). Global Observations of Fine-Scale Ocean Surface Topography With the Surface Water and Ocean Topography (SWOT) Mission. Frontiers in Marine Science *6*, 232. 10.3389/fmars.2019.00232.

Tzortzis, R., Doglioli, A.M., Barrillon, S., Petrenko, A.A., d’Ovidio, F., Izard, L., Thyssen, M., Pascual, A., Barceló-Llull, B., Cyr, F., et al. (2021). Impact of moderately energetic fine-scale dynamics on the phytoplankton community structure in the western Mediterranean Sea. Biogeosciences *18*, 6455–6477. 10.5194/bg-18-6455-2021.

SWOT-AdAC: visit https://www.swot-adac.org/