Evaluating SWOT assimilation in Mercator Ocean global system: insights from AdAC campaigns surface drifters

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SWOT's unprecedented high resolution provides global insights into ocean dynamics down to the submesoscale. To fully exploit this information, ocean models and data assimilation systems are required to dynamically propagate sea surface height in time, in depth, and across physical variables. The Mercator Ocean global high-resolution forecasting system will start assimilating SWOT sea level anomalies operationally by spring 2026. Ahead of this upgrade, we assess the impact of assimilating three months of daily observations from the Cal/Val phase on surface velocity fields.

Using **surface drifters** from the Adopt-A-Crossover (AdAC) Consortium, we use **Eulerian and Lagrangian metrics** to assess the accuracy of the **model surface currents** over three regions.

SWOT Cal/Val phase
- SWOT Level-3 V2.0.1
- SSHA filtered (KaRIn & Nadir)
- Daily observation
- **March 29 to July 10 2023**

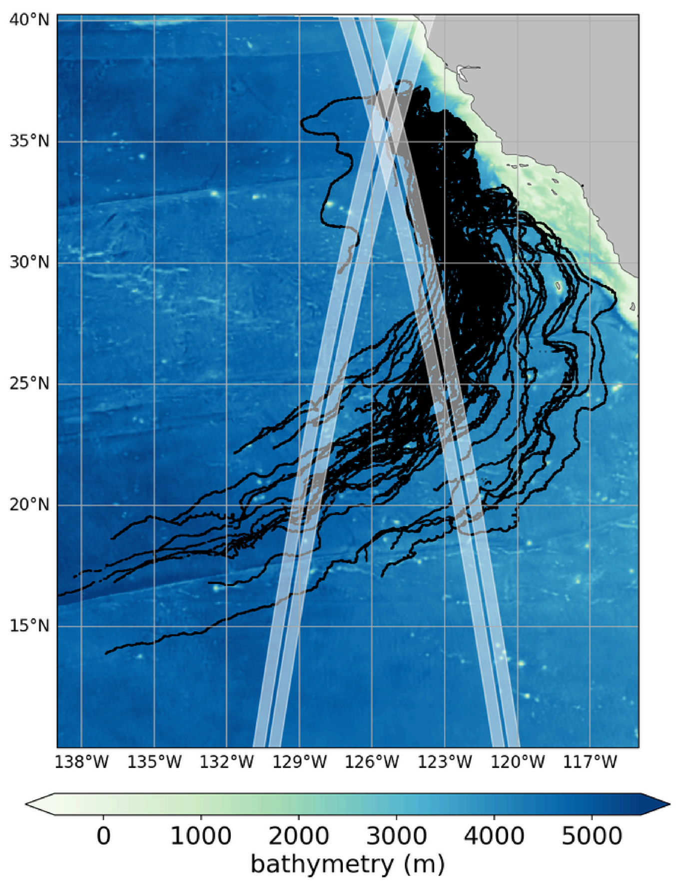
AdAC drifters
- Surface drifters, hourly measurements
- Velocities computed with a central differencing scheme applied to positions

Copernicus Marine GLO12 operational system
Global, 1/12° resolution
Assimilated data :
- SST
- T&S in situ profiles
- nadir SLA

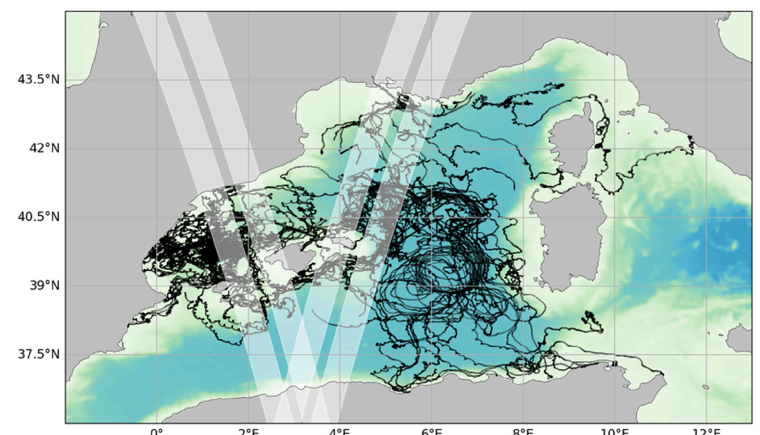
AdAC drifters → **Total U, V** *drift.*

Copernicus Marine GLO12 → *Eulerian U, V SWOT assim.* / *Eulerian U, V SWOT not assim.* + **SMOC** (stokes drift & tidal currents) → *Total U, V SWOT assim.* / *Total U, V SWOT not assim.*

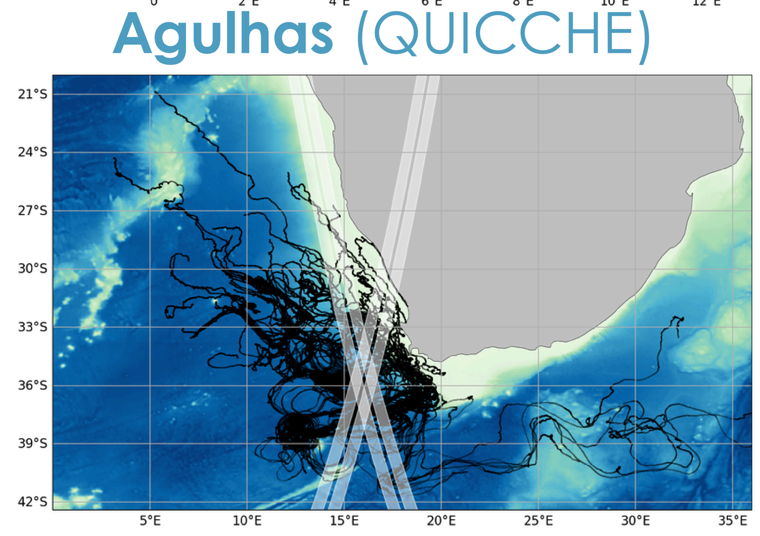
California (SMODE)



Med. Sea (C-SWOT, BioSWOT-Med, FaSt-SWOT)



Agulhas (QUICCHE)



Eulerian metrics on U & V time series

Model interpolated on drifters times and positions

- r² Pearson coefficient
- Explained variance

$$100 \times \left[1 - \frac{\sigma^2(V_{mod.} - V_{drift.})}{\sigma^2(V_{drift.})}\right]$$

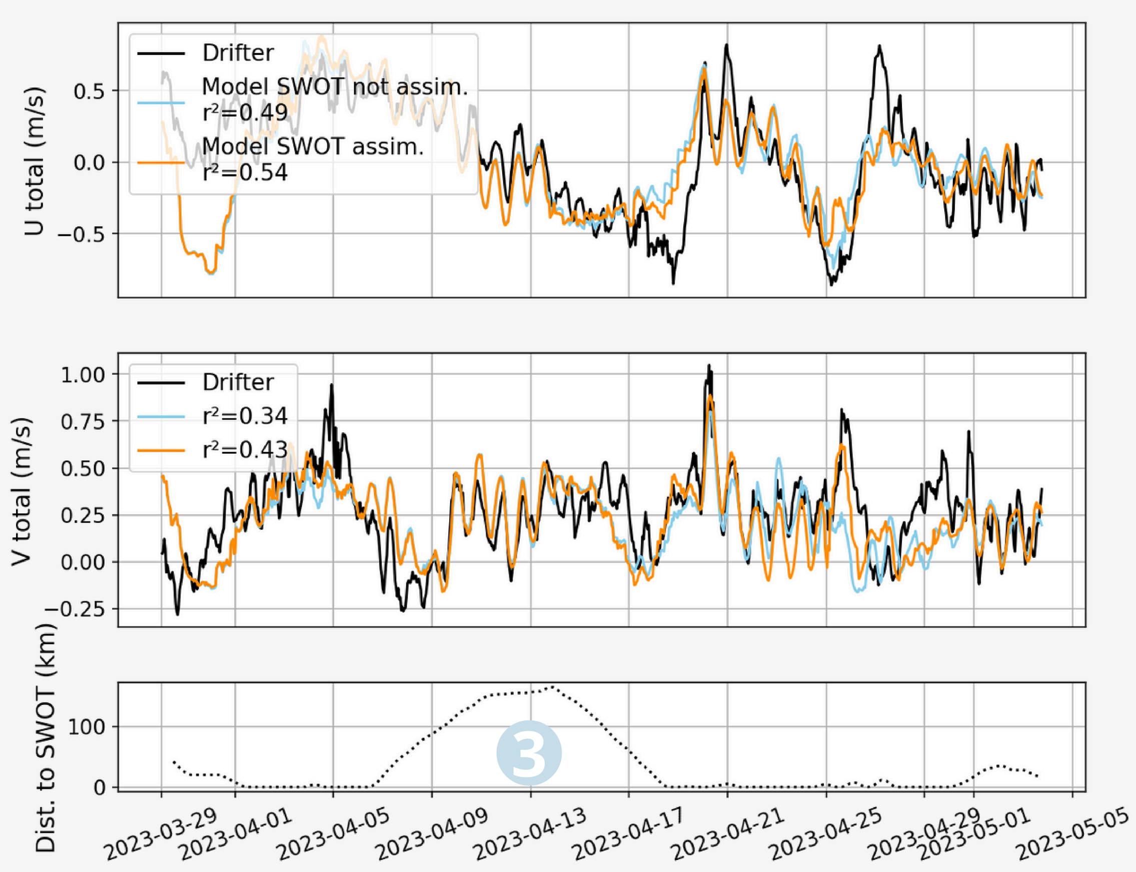
Lagrangian metrics on positions

Pseudo drifters daily sed on AdAC drifters positions with Ocean Parcels

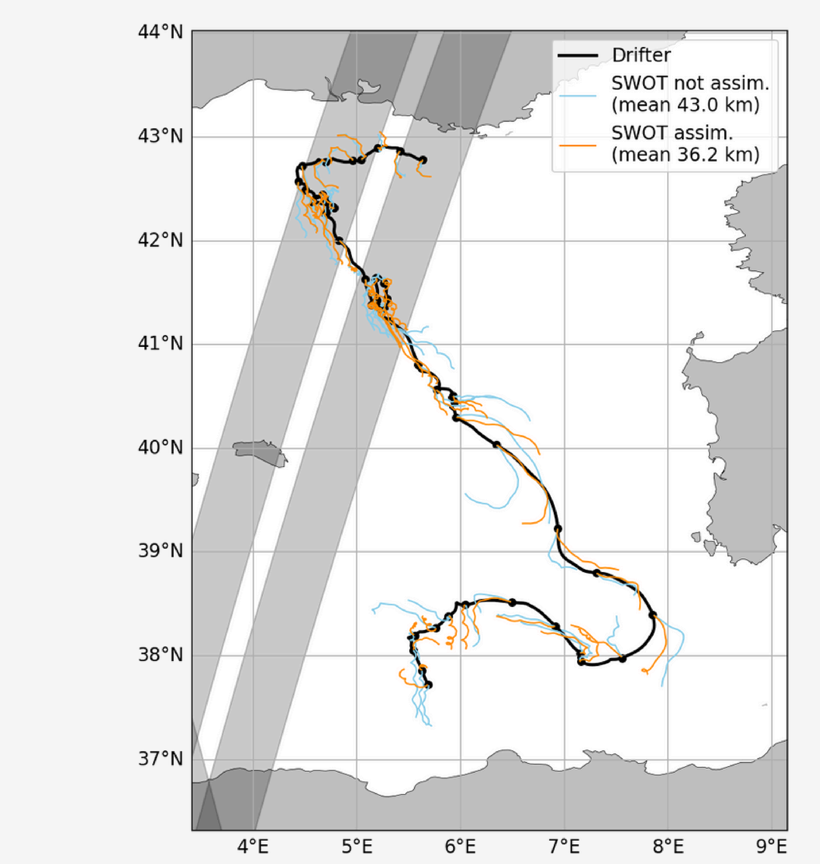
- d_3 3-day separation distance
- s_3 3-day skill score

$$s_n = \begin{cases} 1 - \frac{c}{n} & \text{if } c \le n \\ 0 & \text{if } c > n \end{cases} \qquad c_N = \frac{\sum_{j=1}^{N} d_j}{\sum_{j=1}^{N} l_j}$$

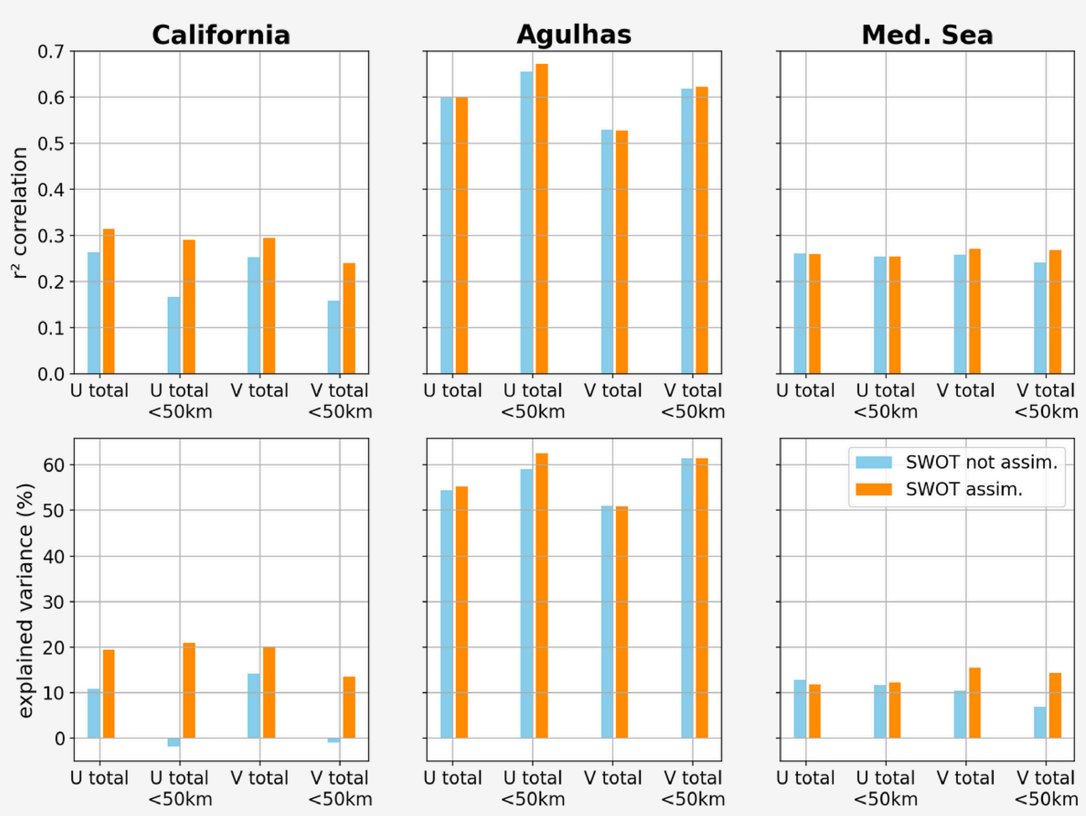
Example of Eulerian comparison for one drifter in **Agulhas**



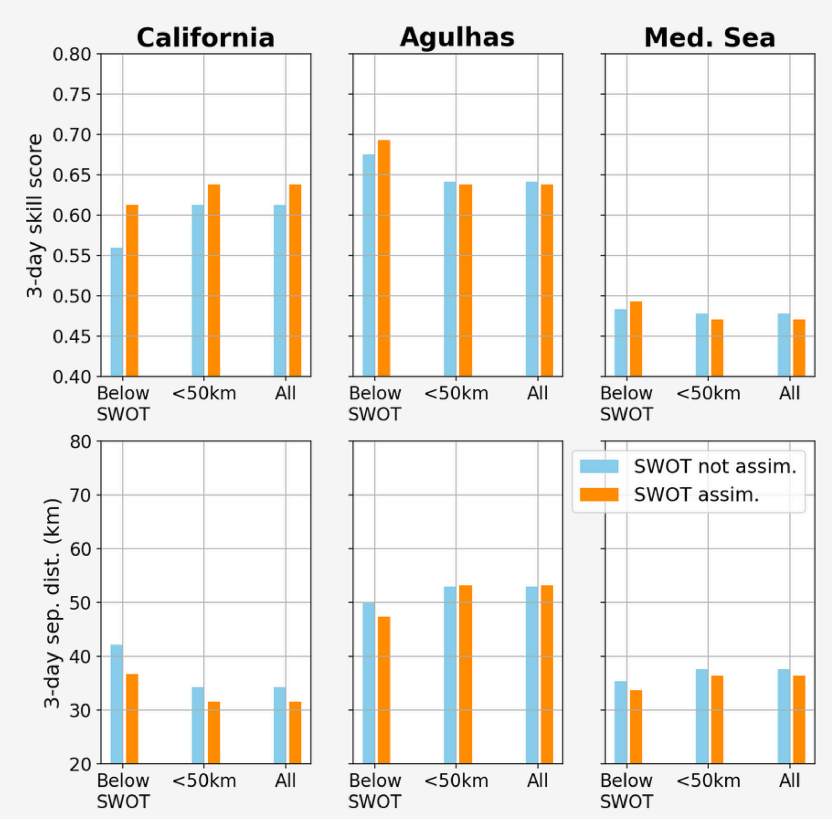
Example of Lagrangian comparison for one drifter in **Med. Sea**



Campaign averaged Eulerian results



Campaign averaged Lagrangian results



① ② ③

① Gain depends on regions' dynamics

The 3 compared regions contain very different physics.
- **Agulhas**: western boundary current dominated by large mesoscale eddies
- **California**: wind-driven eastern boundary current, narrow coastal jets, small eddies and fronts
- **Med. Sea**: frequent mesoscale activity with small Rossby radius (5–15 km), strong coastal currents and air–sea interactions

6 nadir altimeters are assimilated in both model simulations. With an effective resolution of at least 50 km, they successfully capture the largest mesoscale signals (eddies and fronts) but miss smaller-scale structures. This partly explains why surface currents show higher correlations in the Agulhas region than in Med. Sea and California.

② SWOT SLA assimilation improves both zonal and meridional surface currents

Assimilating SLA data from nadir altimeters refines model estimates of surface currents yet these improvements mostly affect the zonal component (U), due to the one-dimensional orientation of nadir tracks. Assimilating SWOT's two-dimensional, high-resolution wide-swath data **enhances both zonal and meridional currents** (U and V). The 2D capability explains the stronger improvements observed in the California region where currents are predominantly southward.

③ Better effect near the swaths

Both Eulerian and Lagrangian metrics are sensitive to the distance from SWOT swaths, due to the localized impact of assimilation. Unlike other altimetry satellites, the Cal/Val orbit provides reduced spatial coverage but high temporal frequency. While SWOT assimilation has an impact throughout the ocean, the **strongest improvements are concentrated near the swaths**.

④ Impact of SST data

The operational system assimilates high-resolution 2D sea surface temperature (SST) observations. SST assimilation better locates ocean structures in the model and affects **wind stress,** which in turn **influences surface currents**. However, satellite SST are impacted by cloud cover, so the number of assimilated observations varies from day to day. The California region shows several "white days," with very few SST observations available for assimilation due to persistent clouds. **SWOT data also have more weight** in such conditions.

SWOT is thus more likely to improve ocean dynamics in cloudy and/or windy regions, providing 2D information that complements missing SST data.

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