

# Lagrangian characterization of fine-scale processes using an array of surface drifters in the Brazil Current

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## Motivations and objectives



Figure 1. (a) CARTHE-type surface drifters. (b) SVP-type drogue.

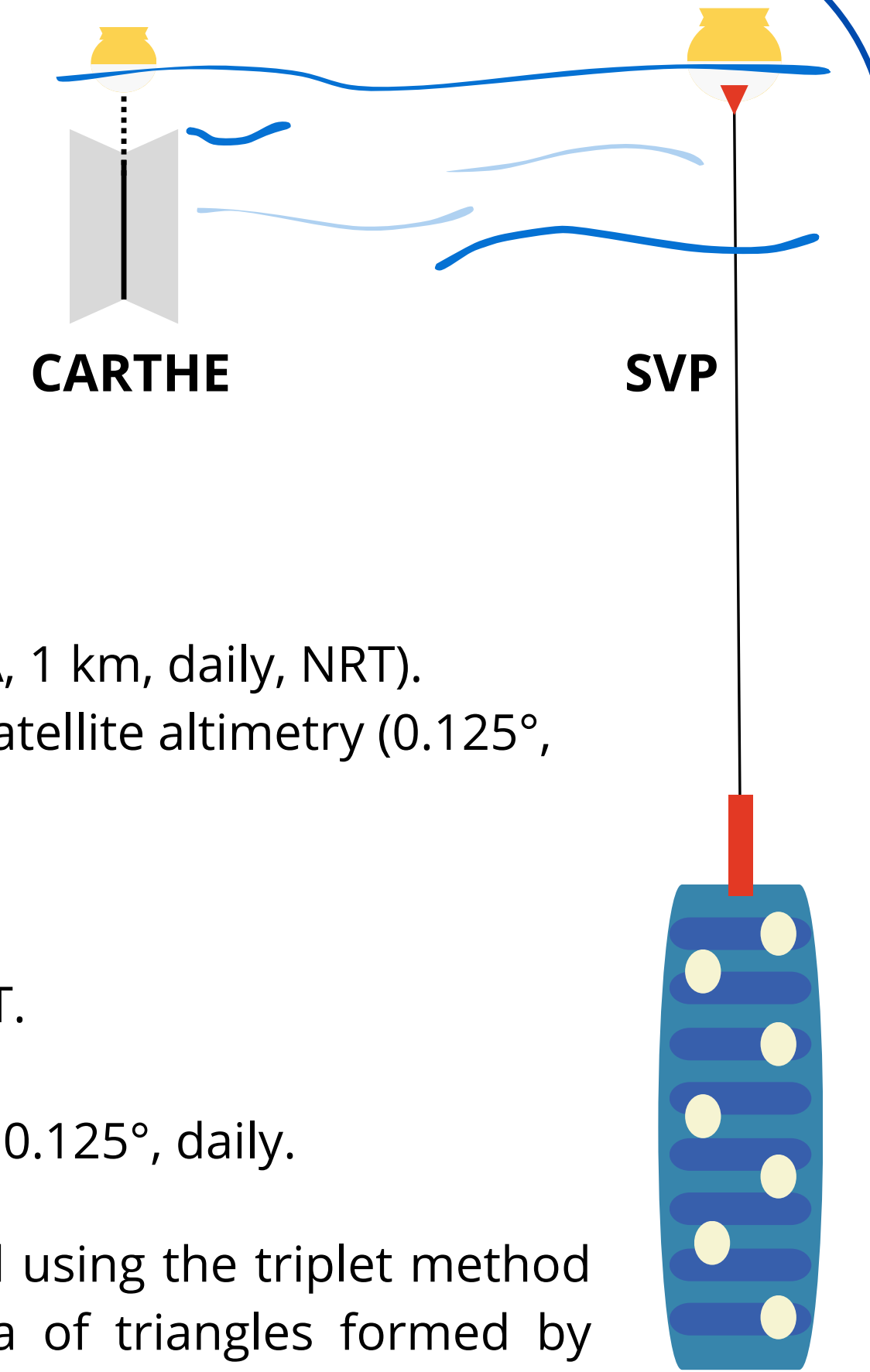
Drifting buoys provide Lagrangian measurements that follow the motion of water parcels. Their high temporal resolution allows the detection of fine-scale variability that is often unresolved by traditional in situ or satellite observations.

For this experiment, 23 drifters were deployed in a frontal area and drifted for 24 hours in Uruguayan shelf-break. The main objectives are:

- 1) Identify fine-scale features in the Southwestern Atlantic from drifter observations and assess whether satellite and model products reproduce the observed in situ patterns.
- 2) Estimate vertical velocity ( $w$ ) at two depth levels to quantify vertical transport associated with submesoscale processes.
- 3) Explore why drifters with similar initial conditions evolved differently, and determine which physical forcings dominated each trajectory.

## Data

- 24 h trajectories of two types of surface drifters
  - 5 SVP type, anchored at 15 m depth.
    - Transmitted position every 30 min
  - 18 CARTHE type, anchored at 0.5 m depth
    - Transmitted position every 10 min.
- Satellite
  - Chlorophyll-a: OLCI (Sentinel-3A, 300 m, NRT).
  - Sea Surface Temperature (SST): SLSTR (Sentinel-3A, 1 km, daily, NRT).
  - Absolute Dynamic Topography: DUACS L4 multi-satellite altimetry (0.125°, daily, NRT).
- Velocity fields for particle advection
  - MERCATOR model, 1/12°, hourly and 6-hourly, NRT.
  - Globcurrent (drifter-derived), 0.25°, hourly, NRT.
  - Altimetry-derived: DUACS multi-satellite product, 0.125°, daily.



Horizontal divergence at two depth levels was calculated using the triplet method (Berta et al., 2020), which considers the changing area of triangles formed by neighboring drifters. Vertical velocity was subsequently estimated from these divergences (Tarry et al., 2021), allowing us to infer vertical transport without explicitly solving for the full 3D velocity field.

$$\bar{\delta} := \frac{1}{A} \iint (u_x + v_y) dA \quad w(z = h_2) = - \int_{z=0}^{z=h_2} (u_x + v_y) dz.$$

## Results

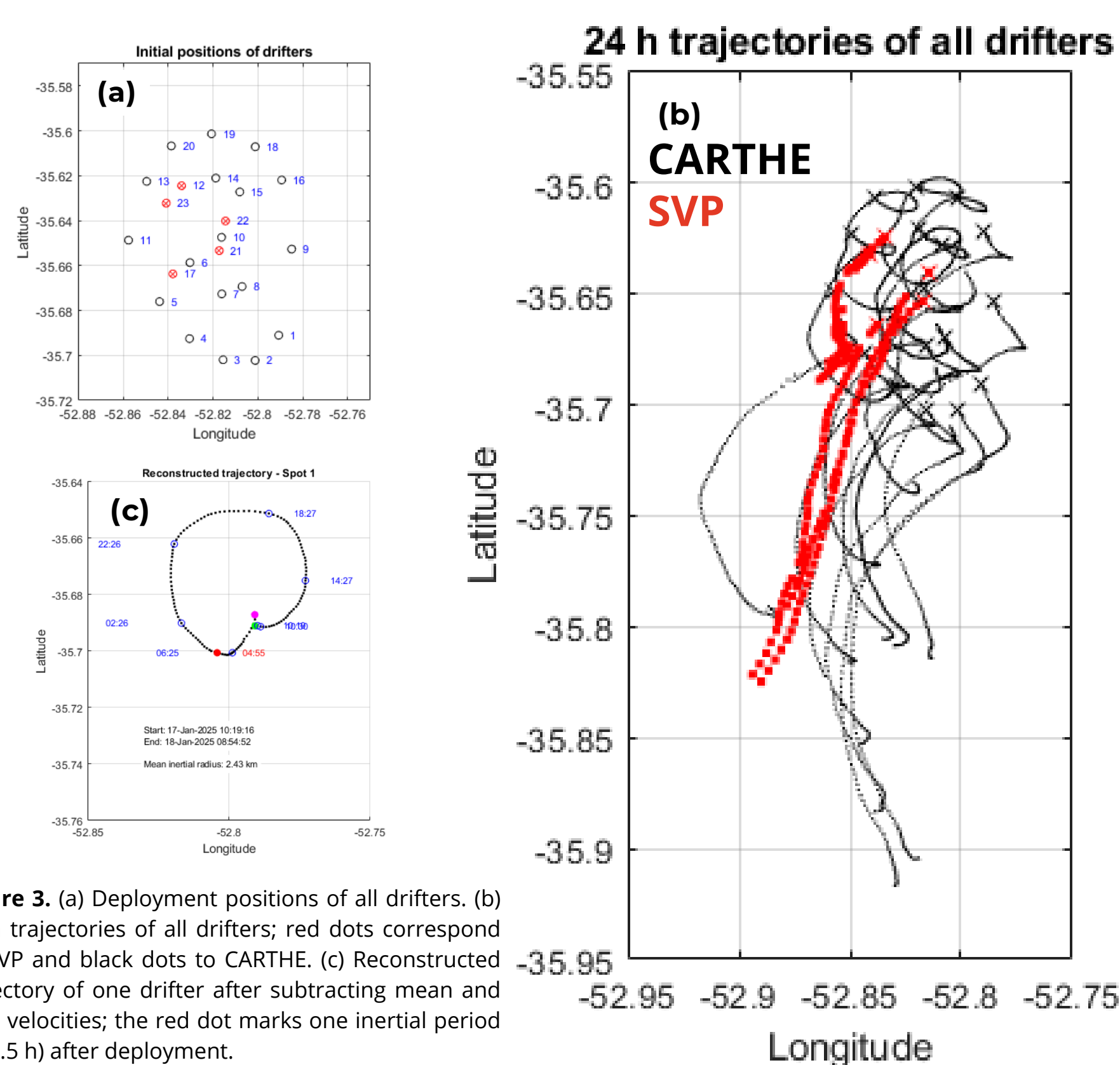


Figure 3. (a) Deployment positions of all drifters. (b) 24-h trajectories of all drifters; red dots correspond to SVP and black dots to CARTHE. (c) Reconstructed trajectory of one drifter after subtracting mean and tidal velocities; the red dot marks one inertial period (~20.5 h) after deployment.

CARTHE and SVP drifters exhibited different circulation patterns. While all drifters were advected southward by the Brazil Current, CARTHE units were more affected by tidal and inertial motions (Figure 3).

SVP drifters were primarily advected by the Brazil Current. Their trajectories run parallel to ADT contours, suggesting that currents at 15 m depth are well represented by satellite altimetry geostrophic velocities (Figure 4).

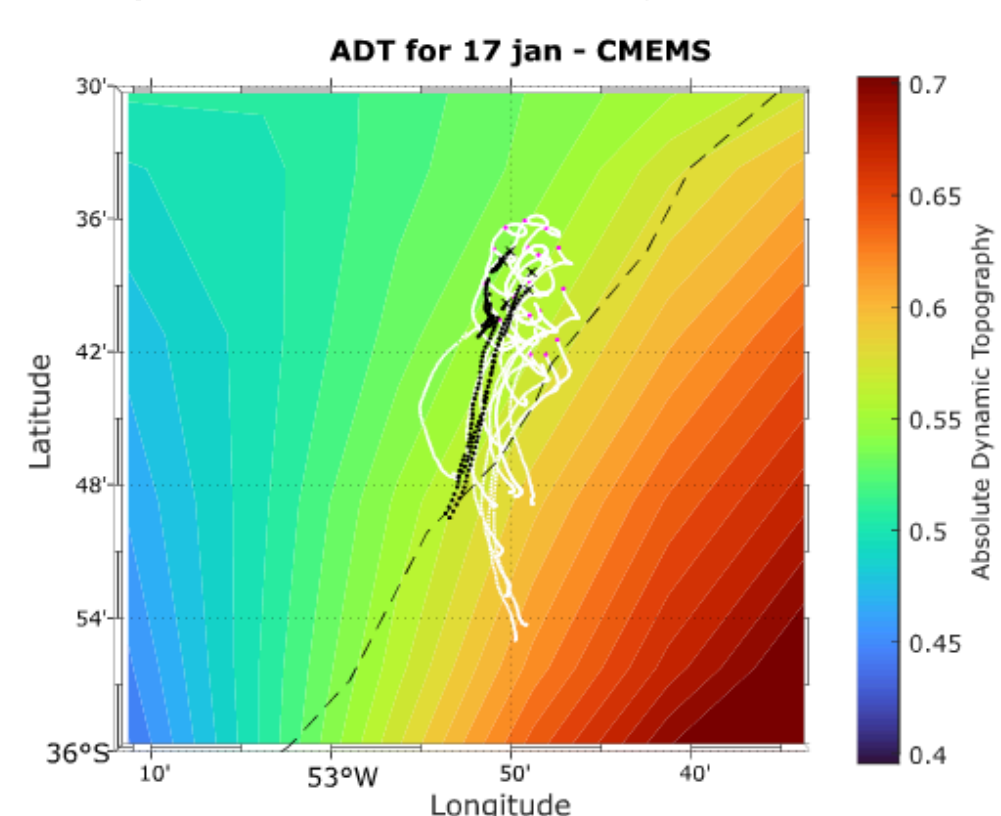


Figure 4. Absolute Dynamic Topography (ADT) for 17 January. Black dots represent SVP trajectories and white dots represent CARTHE trajectories. The dashed line marks the 200 m isobath.

Nearby CTD stations show an abrupt change in salinity and in consequence in potential density in the first 20 m. The water mass differences likely reflect the summer offshore expansion of the Río de la Plata's low-salinity plume (Guerrero et al., 2014), indicating that drifters are affected by different water masses.

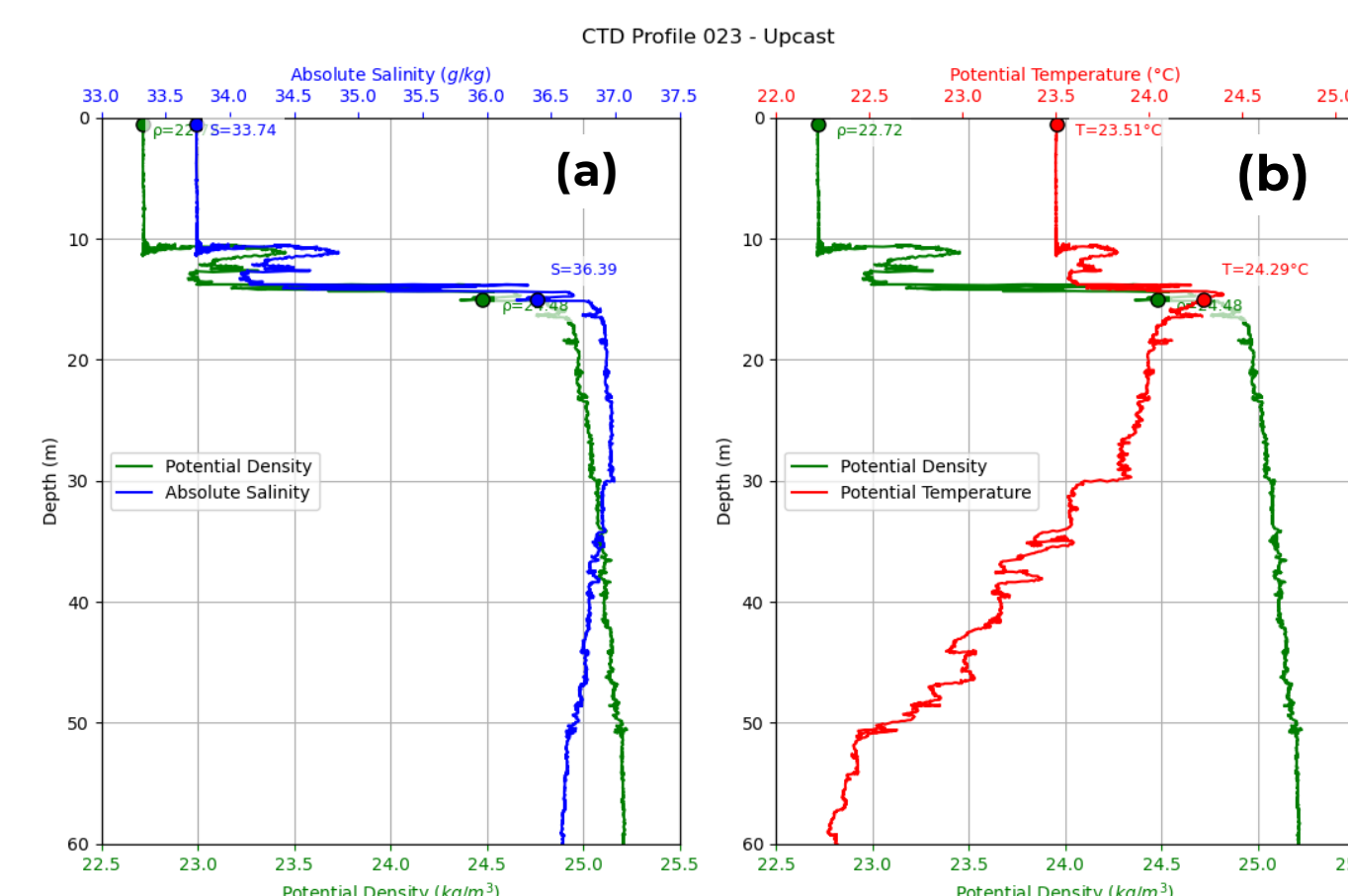


Figure 5. CTD station located near the drifter deployment area (first 60 m). (a) Absolute salinity and potential density profile, and (b) potential temperature and potential density profile. Dots indicate the values at the surface and at 15 m for each variable.

The strain-vorticity relationship reveals that SVP drifters predominantly sample organized geostrophic flows, while CARTHE drifters capture stronger ageostrophic rotational processes influenced by surface forcing.

- Record higher ageostrophic activity
- Dispersed distributions with extreme vorticity values
- Vorticity  $\approx$  or  $>$  Strain  $\rightarrow$  more rotational energy in turbulent processes
- High sensitivity to wind and surface processes
- Well-structured geostrophic flow
- Concentrated distributions of vorticity and strain
- Strain-dominated regime  $\rightarrow$  jet-like organized flow
- Lower wind influence  $\rightarrow$  better representation of subsurface dynamics

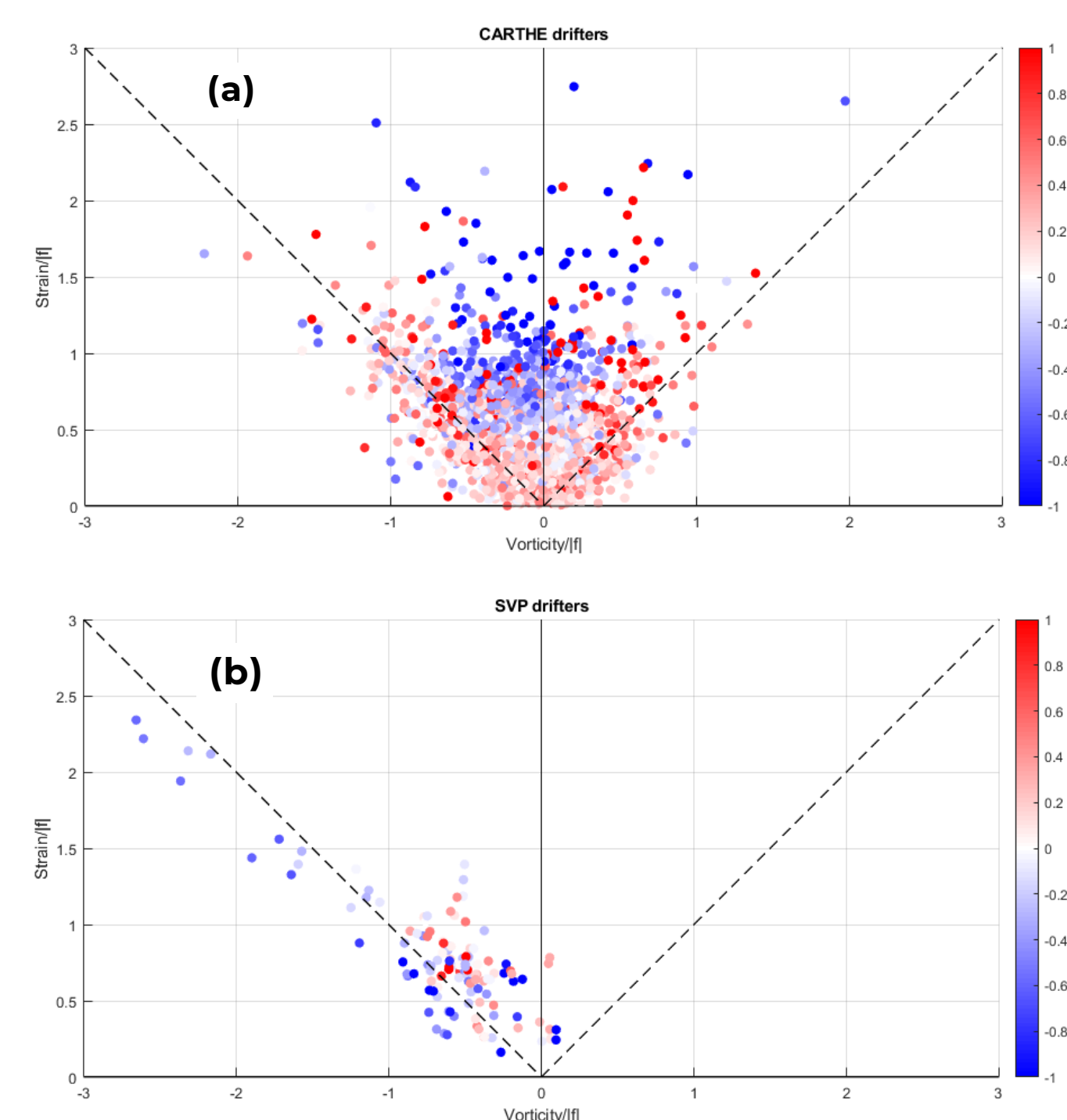


Figure 6. Scatter plots of normalized strain versus normalized vorticity. Colors are normalized divergence. Panel (a) for CARTHE drifters and (b) for SVP drifters.

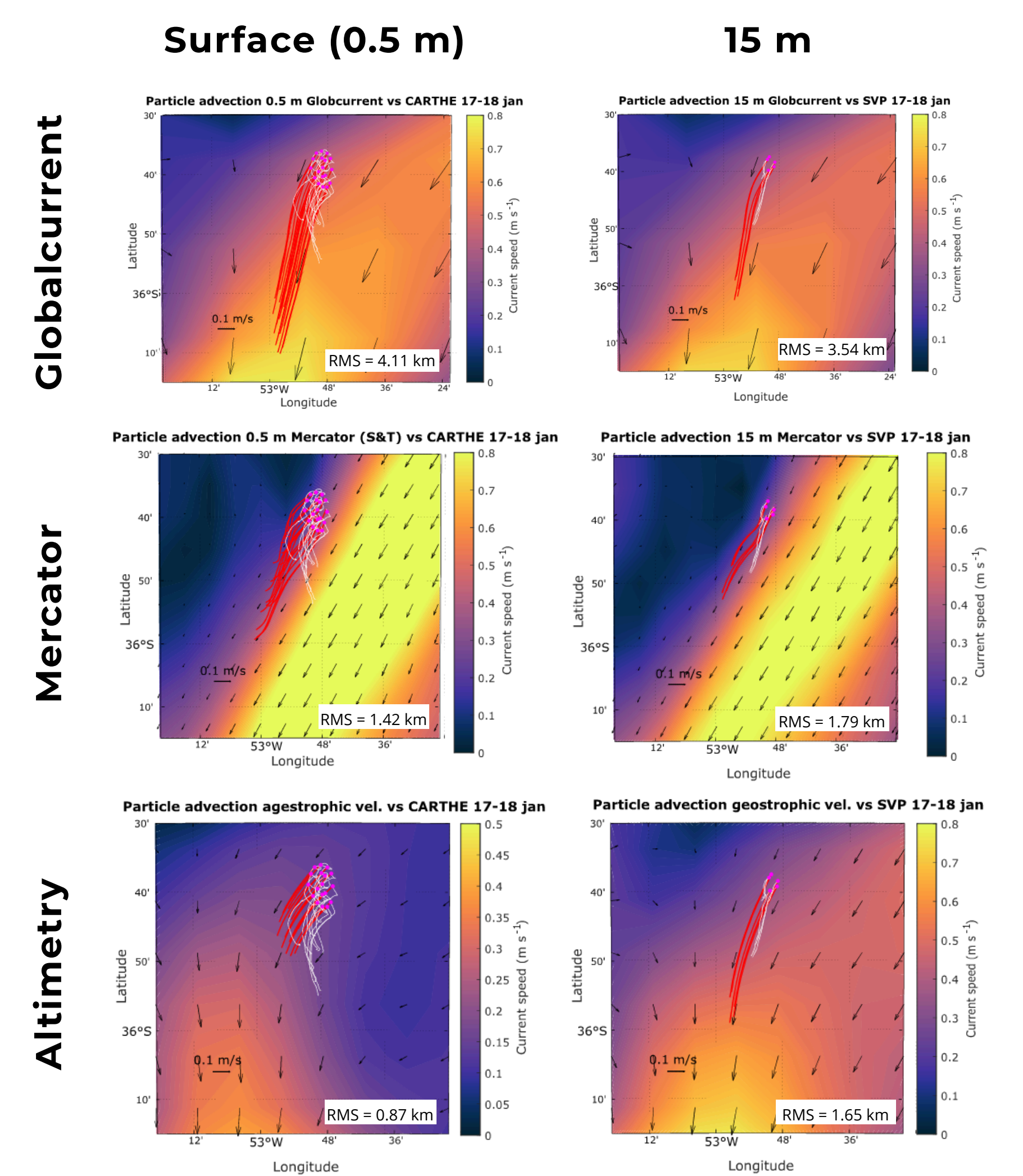


Figure 7. Virtual particle advection for the 24h drift vs real drifter trajectories

Velocity fields derived from satellite altimetry show the best agreement with the drifter trajectories. The ageostrophic velocity component provides the most accurate comparison for the surface-following CARTHE drifters. The Globcurrent product overestimates velocities at both depth levels and fails to reproduce the complex processes dominant at the surface. In contrast, the Mercator model better captures these complex effects, likely due to its inclusion of surface forcings like Stokes drift and tides.

## Conclusions

- The simultaneous deployment of SVP (15 m) and CARTHE (0.5 m) drifters in a frontal area revealed fundamentally different flow regimes: organized geostrophic currents dominate at depth, while chaotic ageostrophic processes control the immediate surface layer.
- Kinematic analysis shows SVP drifters sample strain-dominated geostrophic jets, while CARTHE drifters capture vorticity-rich ageostrophic flows, **highlighting the presence of distinct fine-scale features at different depth levels.**
- Altimetry-derived geostrophic velocities best represent the 15 m flow, while ageostrophic velocities better represent the surface dynamics. High-resolution models like Mercator successfully incorporate surface layer physics despite not having the lowest RMS error.
- Vertical transport was quantified despite limited spatial sampling. Future work will focus on optimized deployment strategies to increase data density to allow compute vertical transport.