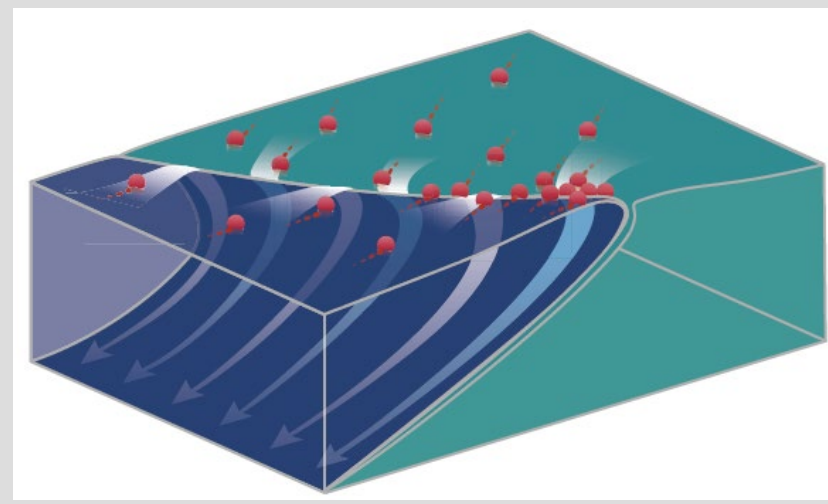


1. SUMMARY

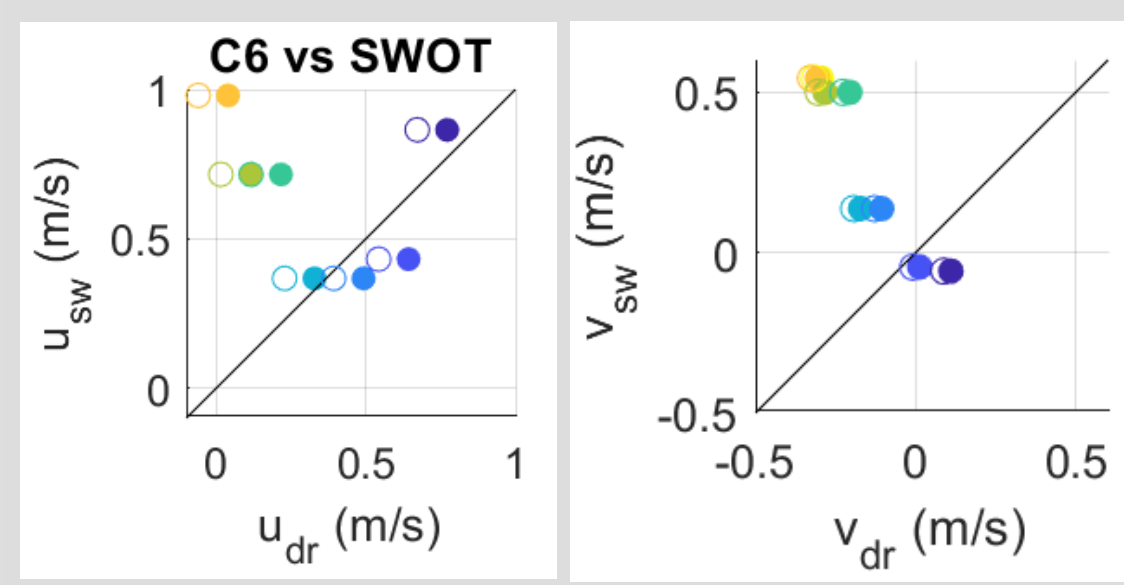
Oceanic Lagrangian Coherent Structures (LCS), such as submesoscale eddies, current convergence and frontal zones, play a key role in controlling the spatial distribution of passive tracers, biological materials and marine litter. These structures are poorly represented in circulation models and need to be better documented. Surface drifters deployed in June 2024, together with underway ADCP velocity measurements, demonstrated the existence of fine-scale current convergence structures (CCS) in the Mekong plume region. Velocity field derived from SWOT altimetry were then analysed within a Lagrangian framework to identify zones of enhanced stretching. Some of them coincide with area of buoy convergence. These results demonstrate the potential of SWOT measurements for monitoring the extent and morphology of river plumes, as well as associated frontal zones.



Schematic representation of surface current convergence and sink at the river plume boundaries (d'Asaro, 2018)

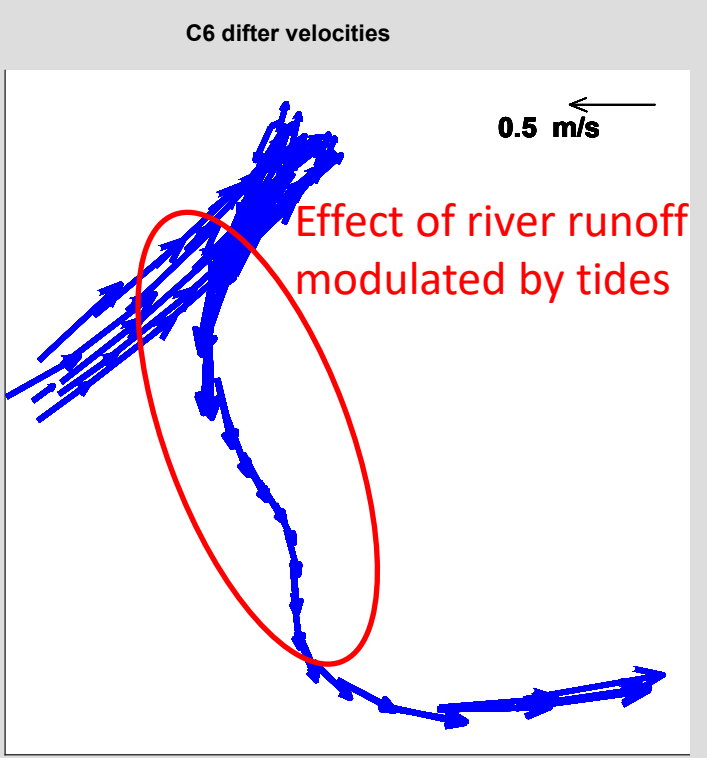
3. RESULTS

SWOT-derived versus drifter velocities (example)



Velocities from surface drifters (dots) and wind-corrected velocities (circles)

Good agreement is found within a time window ± 2 h with respect to the SWOT pass time (blue shading). Correction for wind slightly improves the agreement. The large discrepancy is likely due to river runoff, modulated by the tidal variation of sea level.



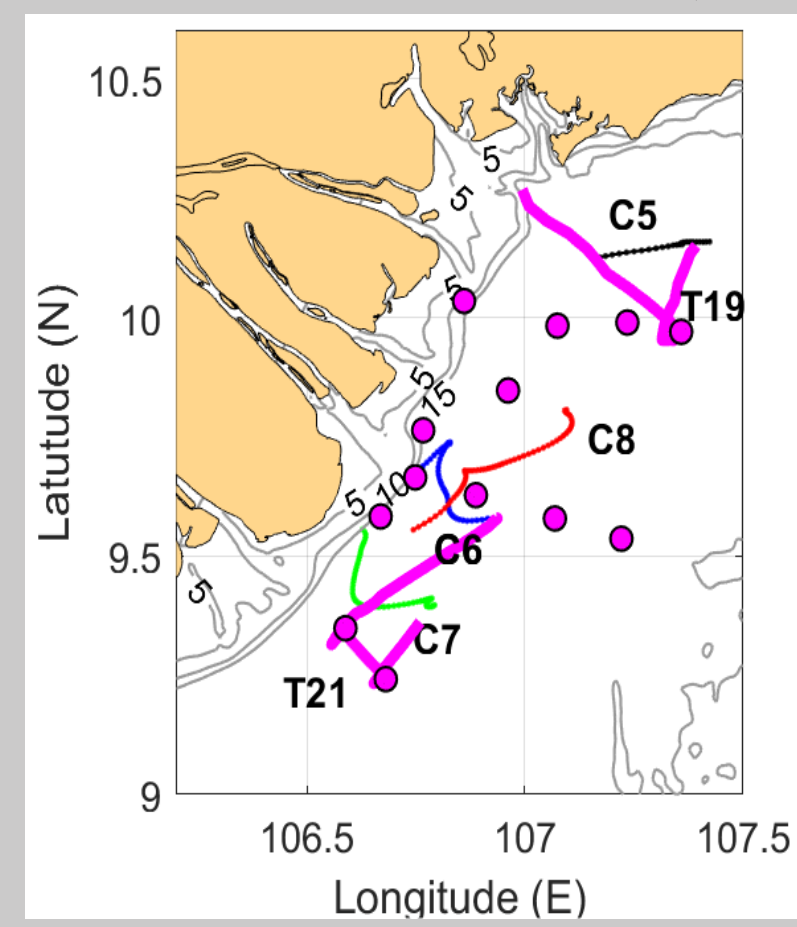
2. DATA: VELOCITIES FROM SURFACE DRIFTERS AND SWOT

VELOCITY MEASs (SURFACE BUOYS)

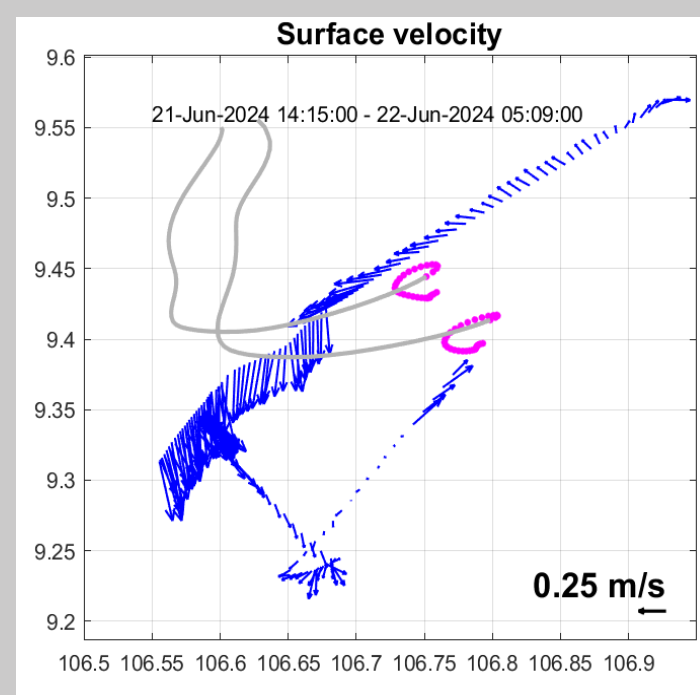
ADDITIONAL UNDERWAY VEL MEASs

COMPARISON

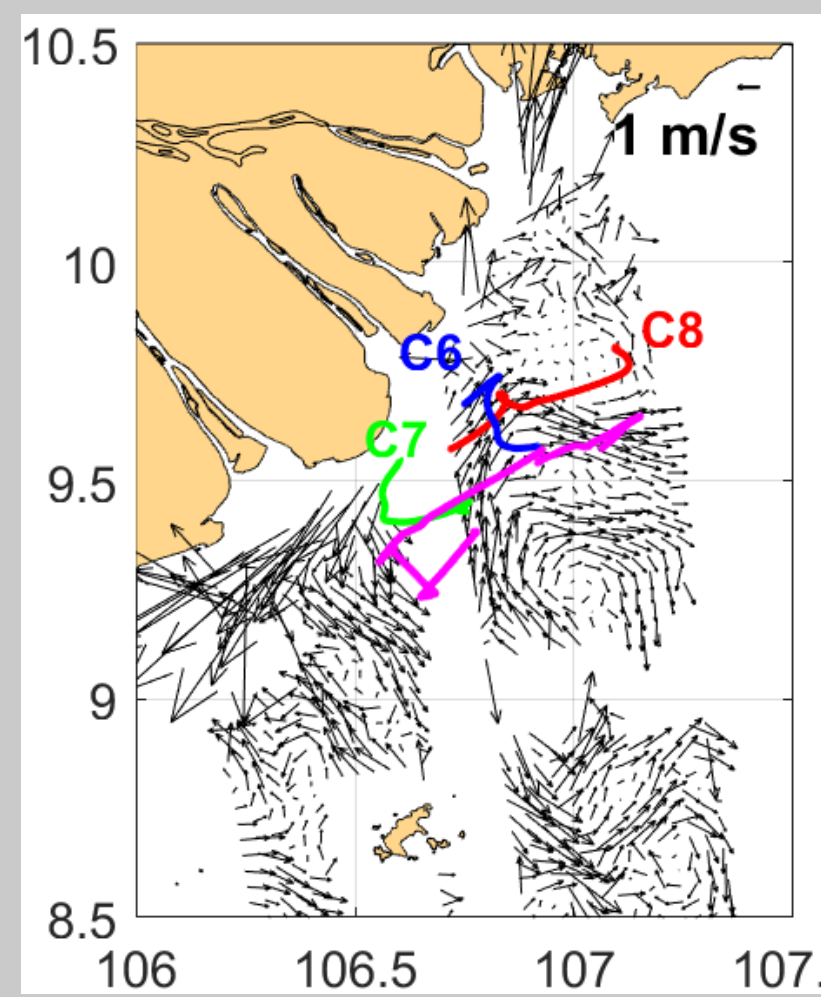
SWOT-L3-017-090 2024-06-22



CTD casts
Surface drifters
Towed ADCP

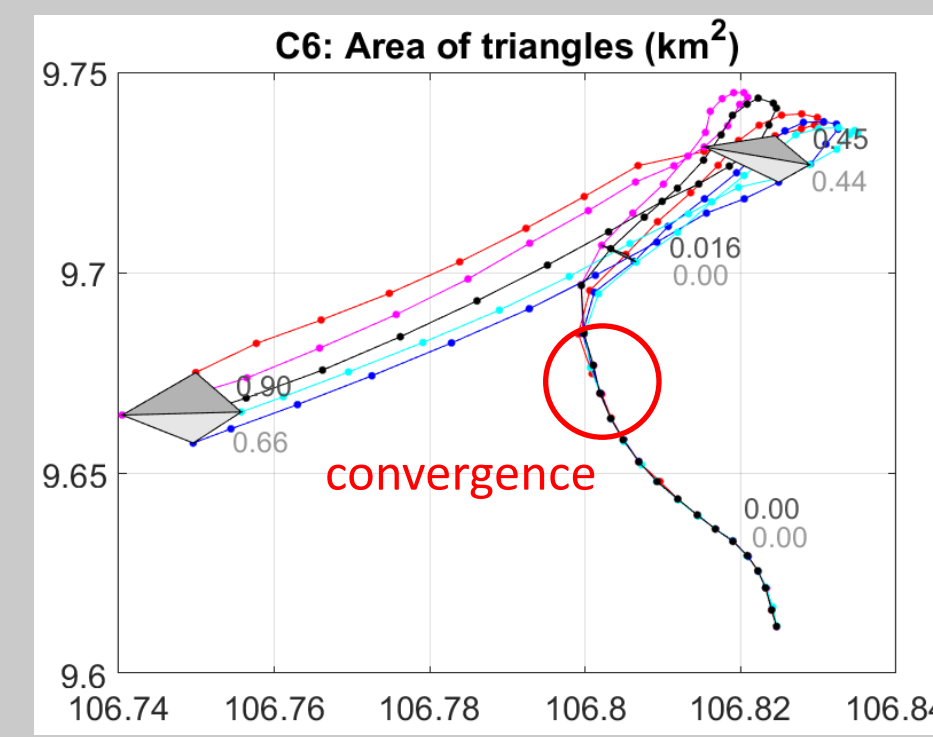


Surface velocities from transect survey

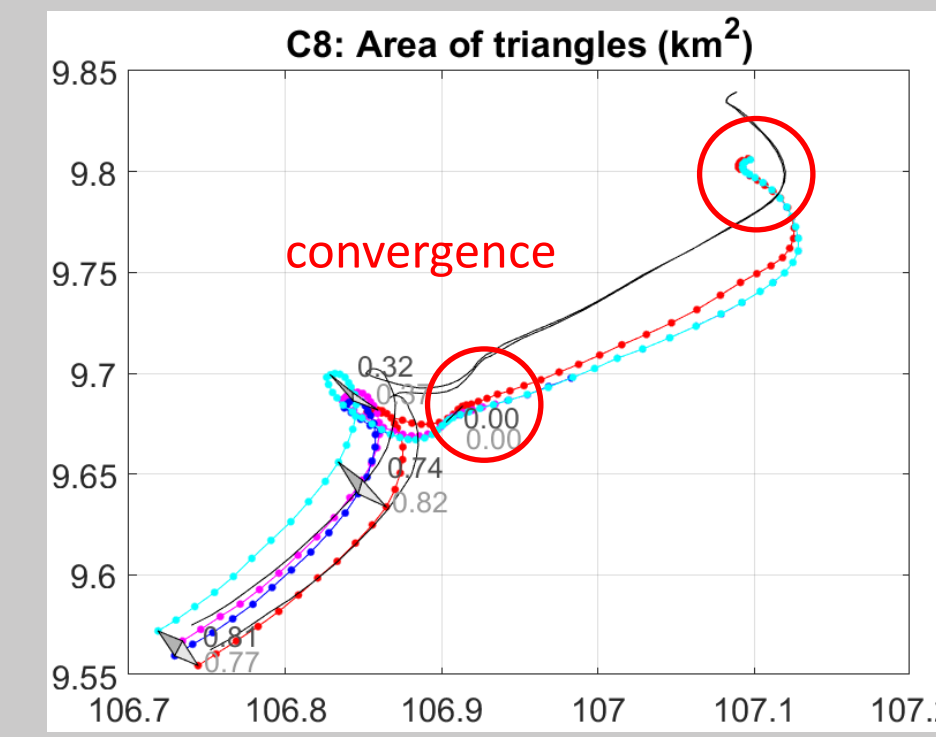


SWOT-derived velocities and the available data

CURRENT CONVERGENCE IN THE MEKONG R. PLUME (PLUME campaign, June 2024, R/V ANTEA)



Area of triangles formed by the surface buoys of clusters C7, C8



Surface buoys initially, separated by 1.5 km, have converged into 15-m and 5-m radius areas.

Buoys in C8 converged on 23-Jun 05:00 UTC.

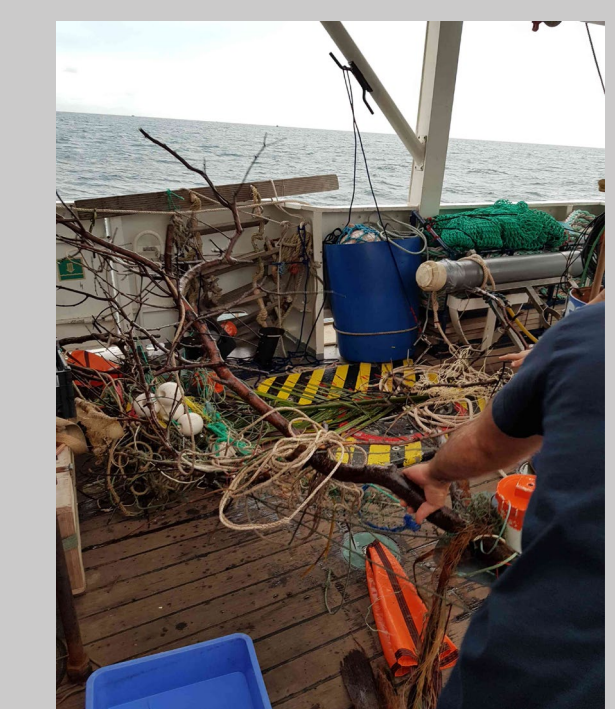
Buoys in C6 converged on 21-Jun 21:00 UTC.

A large amount of marine litter has accumulated within the current convergence zones.

These zones correspond to FSLE ridge lines derived from SWOT altimetry data.



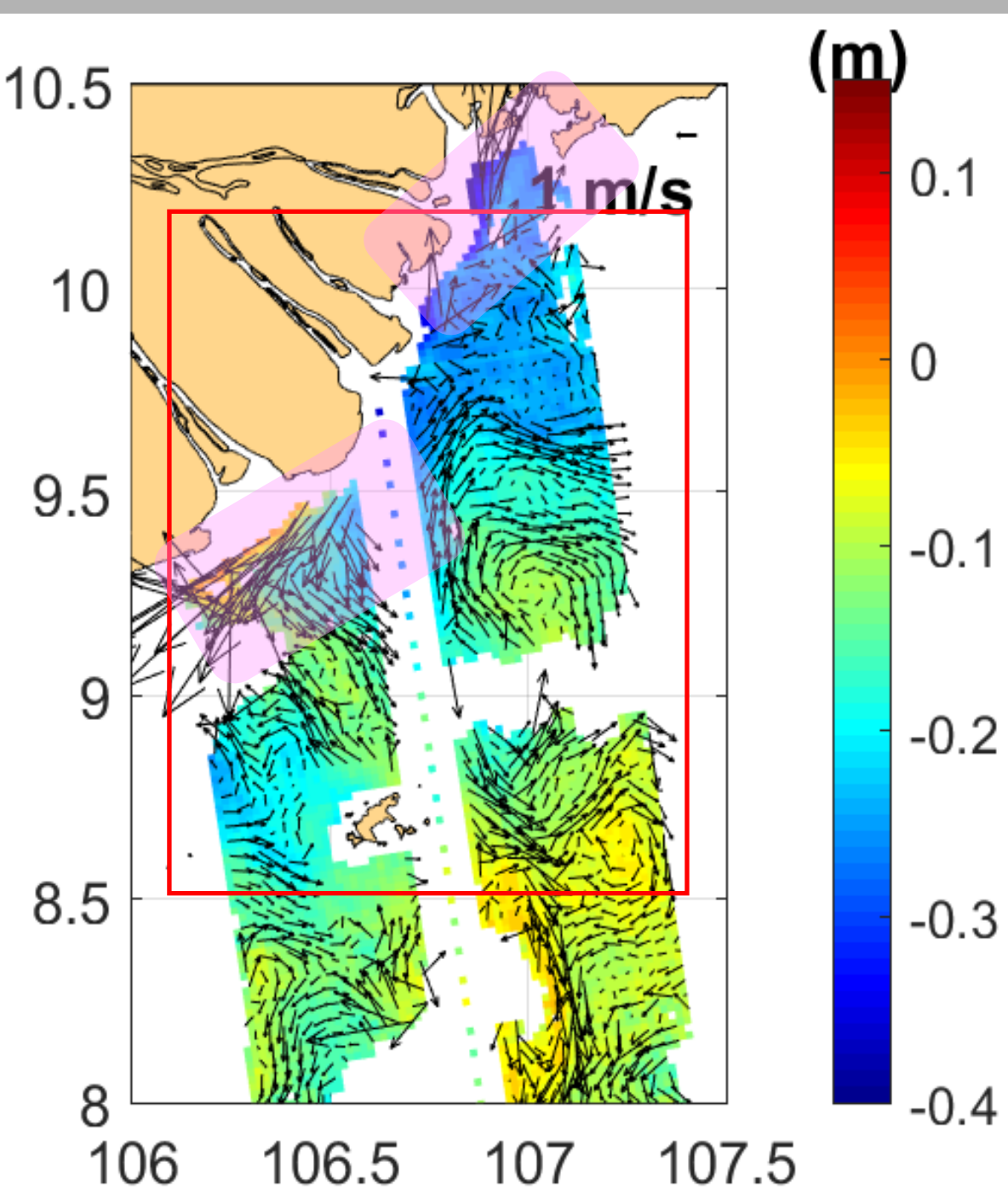
Debris at the location where buoys of cluster 6 were recovered.



Marine litter accumulated within the current convergence zones.

3. METHODS OF INVESTIGATION

Removal of outliers and variational interpolation



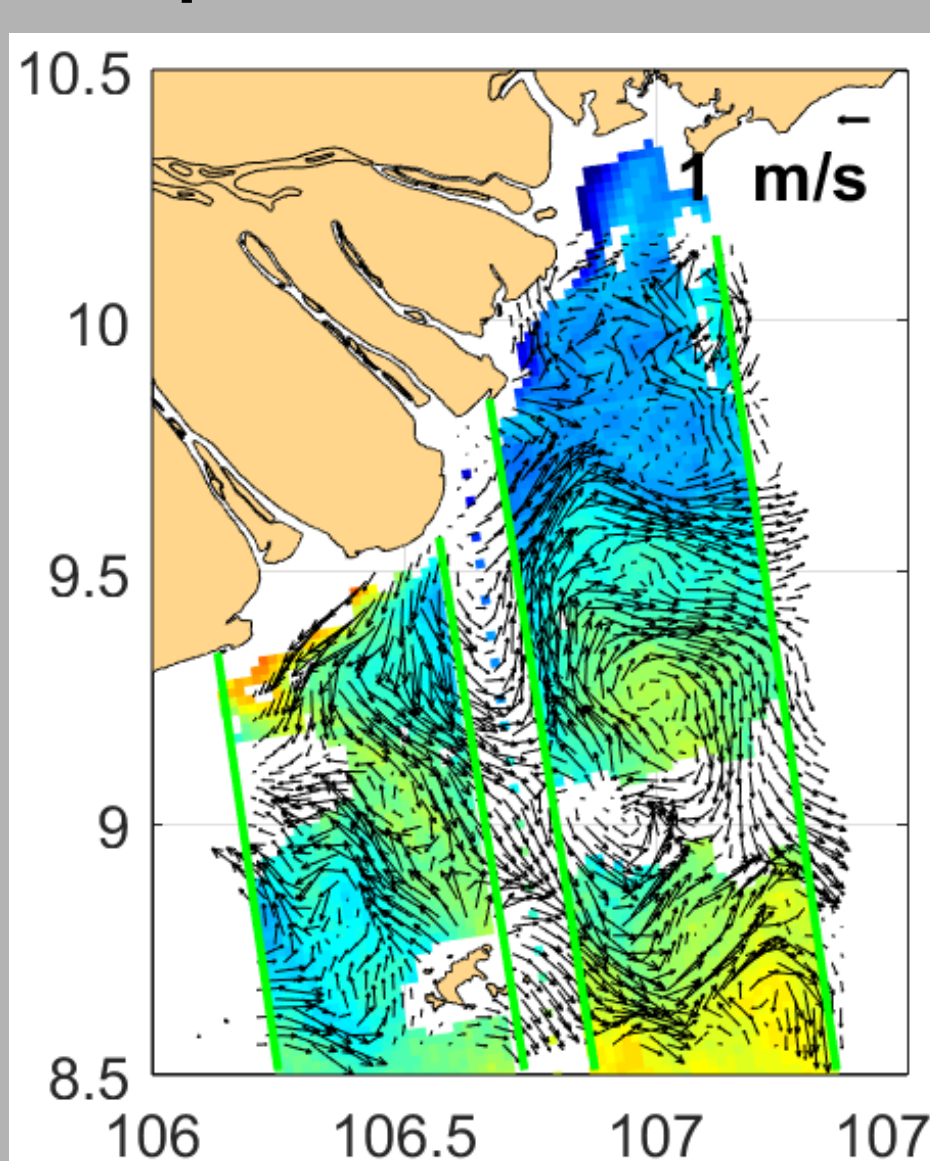
DYNAMICALLY CONSTRAINED VARIATIONAL INTERP OF VELOCITIES FROM SWOT

$$P[v] \sim \exp(-J); \quad J = J_d(v) + J_r(v) \rightarrow \min_{|v(\alpha)|=0}$$

$$J_d = \frac{1}{2} \sum_{k=1}^K \sigma^{-2} (v_k \cdot r_k - v_k^2)^2$$

$$J_r = \frac{1}{2} \int_{\Omega} [W^d(x, y)(\Delta \text{div} v)^2 + W^c(x, y)(\Delta \text{curl} v)^2] d\Omega$$

Interp. on a regular 2 km grid
Constraints: div, curl, smoothing
Relative error in obs points is 12% (very low)



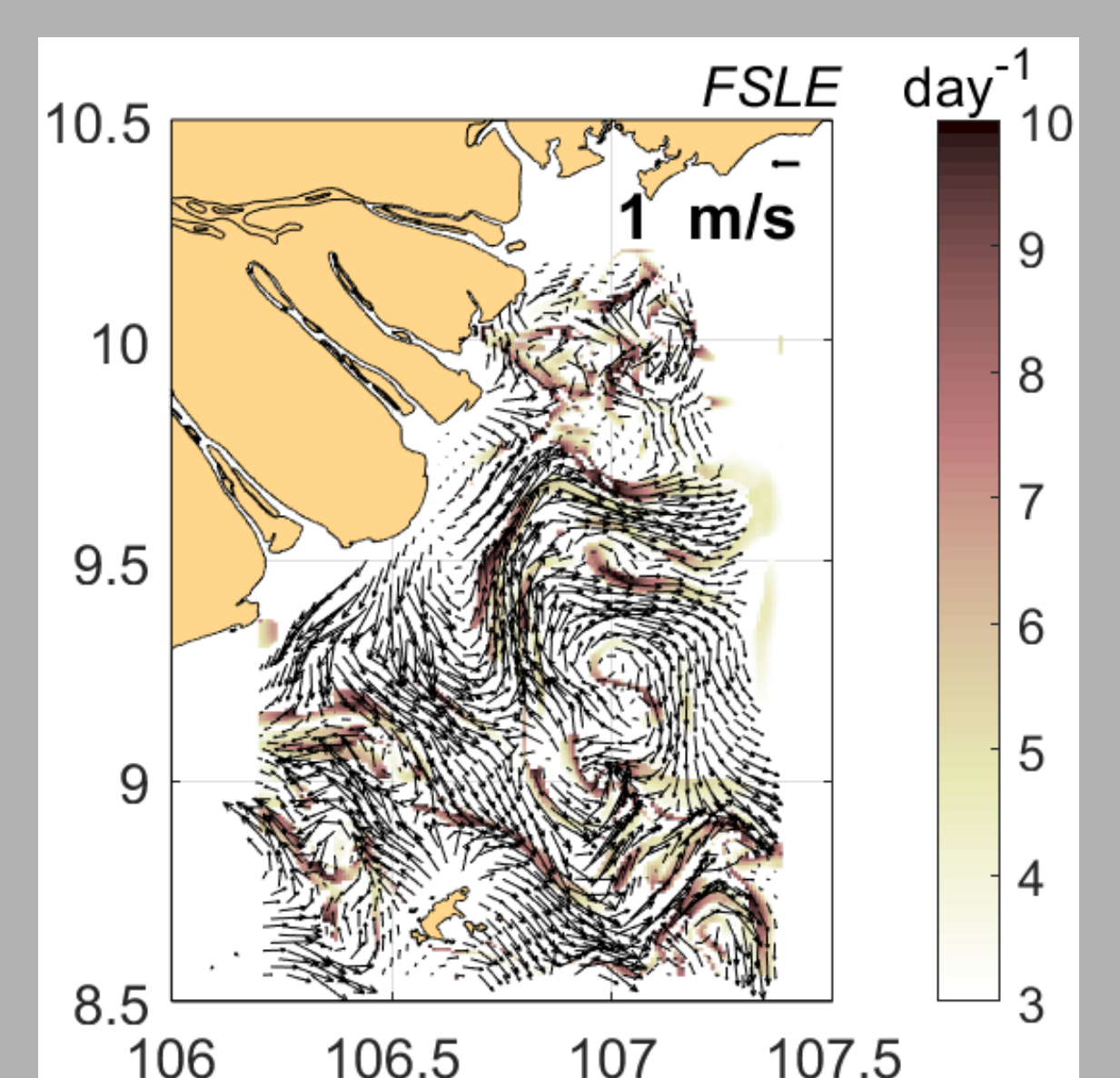
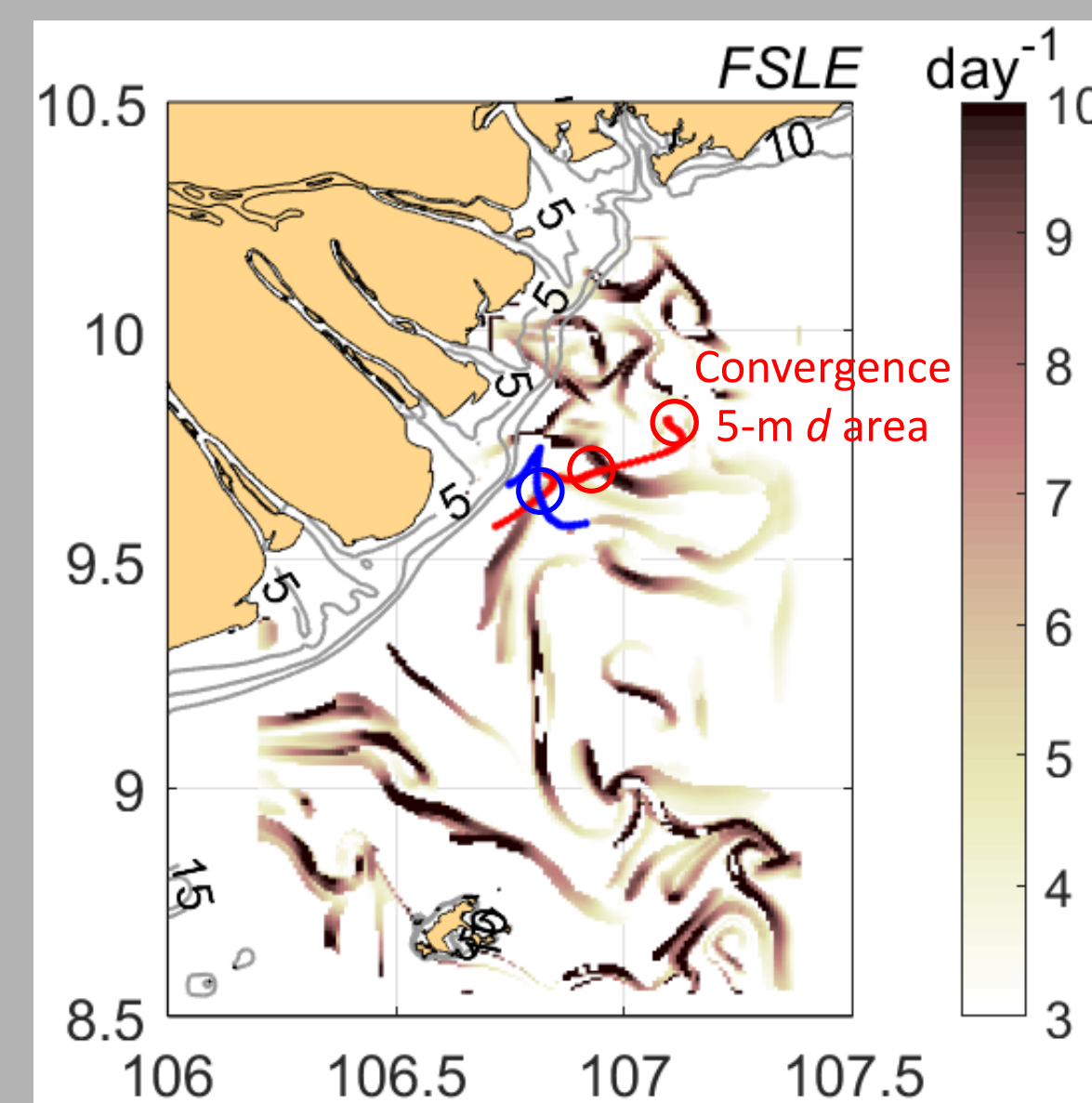
Removal of outliers (mauve shading) creates gaps, in addition to existing gaps (white space). Variational interpolation 2dVar with dynamical constraints is non-local method of int with gap filling (Yaremchuk & Sentchev, 2009). Low relative error (12%) in observation points was reached.

Validation of the interpolated field using independent velocity data

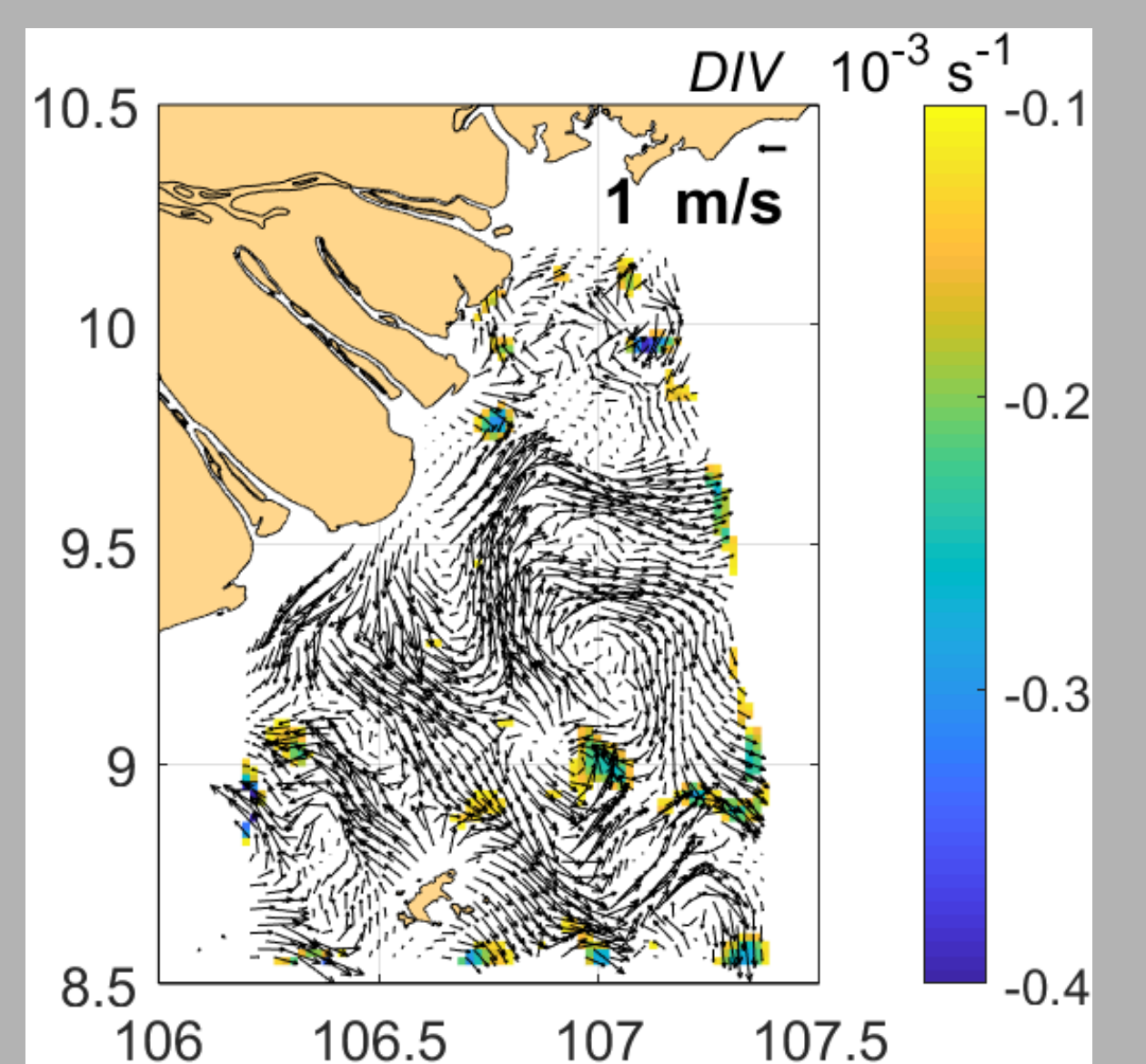
Surface drifter velocities (16 drifters in three clusters (C6, C7, C8) obtained on June 20-24 2024

Surface velocities from transect surveys (towed ADCP measurements)

FSLE RIDGE LINES FROM SWOT ALTIMETRY



Velocities derived from SWOT altimetry are used within a Lagrangian framework for particle tracking and detection of zones of enhanced stretching, characterized by large values of FSLE - ridge lines (upper figure). They indicate the locations of zones with high shear in the flow (upper right figure). Velocity field derived from SWOT altimetry are not in geostrophic balance (right figure). There are helpful for identification of zones of current convergence and high shear in the flow, which are essential for characterizing the dynamics associated with plumes and mapping the fronts delimiting them.



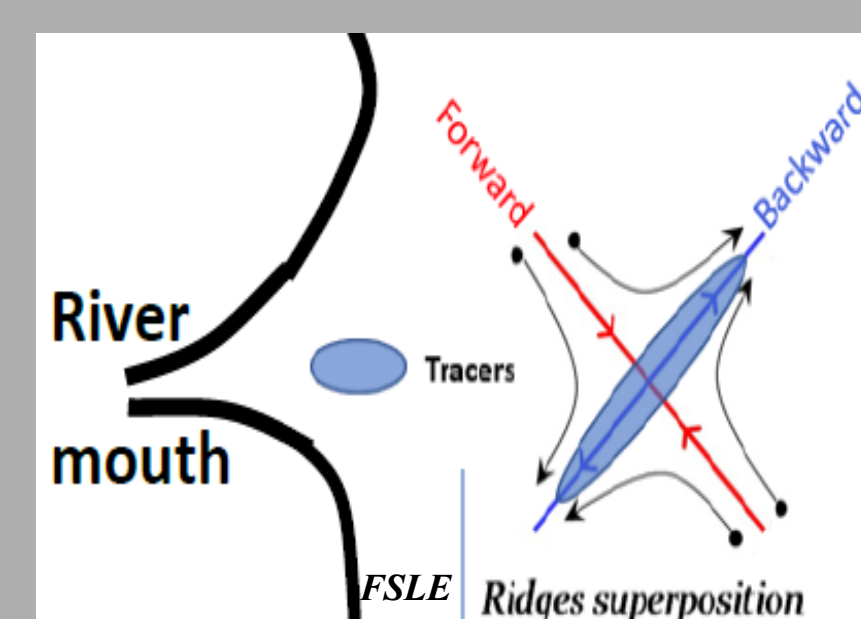
IDENTIFICATION OF LAGRANGIAN COHERENT STRUCTURES (LCS)

Finite Size Lyapunov Exponents (FSLE), λ , are a mathematical tool used to describe dispersal characteristics in a velocity field (e.g., SWOT-derived velocity). They have proven useful for identifying LCS such as fronts, zones of current convergence, which are crucial for characterizing river plume morphology and boundaries.

Neutrally buoyant particles are seeded in all grid cells of the interpolated (SWOT-derived) velocity field and advected backward in time over 48 h (the inertial period is ~ 60 h, ensuring that geostrophic adjustment is maintained). FSLE measure the separation time τ of particle pairs (shorter time - faster separation).

Large values of λ (ridge lines) indicate the location of fronts and current convergence zones.

$$\lambda(x) = \frac{1}{\tau(x)} \ln \left(\frac{\delta_f}{\delta_0} \right), \quad \delta_f = 5\delta_0$$



FSLE ridge lines indicate the location of plume boundaries and zones of intense stretching. They act as barriers controlling the distribution of materials floating at the sea surface.

4. CONCLUSIONS

Convergence zones have been identified by surface buoys, released in the Mekong River plume region. Velocity data from SWOT altimetry indicate that these zones correspond to FSLE ridge lines. The ridge lines are assumed to act as barriers limiting the offshore expansion of materials and controlling dispersal and lateral mixing. Intense stretching of materials occurs along these lines. Therefore, these Lagrangian diagnostics are useful not only for monitoring the transport and accumulation of floating materials (e.g., marine litter, oil slicks, or biological materials), but also for understanding plume dynamics and mixing within the plume body.

The convergence of real drifters within frontal zones identified from SWOT measurements indicates that, in the study region, SWOT-derived velocities at the submesoscale are not in geostrophic balance.

ACKNOWLEDGMENTS

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