Improvement of a high-resolution oceanic circulation model using Optimal Interpolation of Lagrangian drifters in the Southeast Bay of Biscay for assessing the turbulent dispersion

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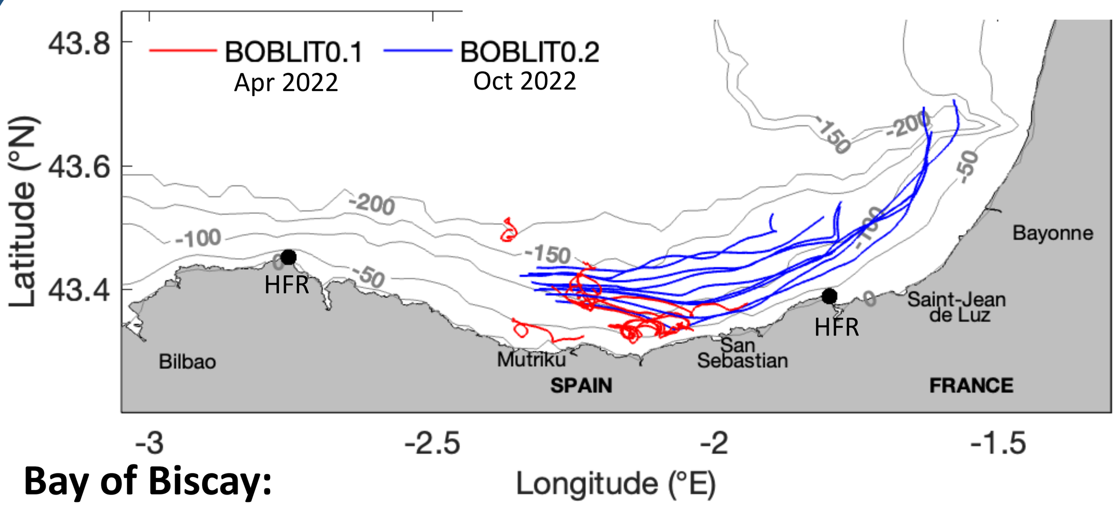
BACKGROUND

Despite a certain progress achieved recently in simulating the large-scale and mesoscale variability of oceanic currents, reconstructing small scale features of circulation, particularly the sub-mesoscale (from 1 to 10 km), remains challenging. Sub-mesoscale motions play a key role in transport and dispersion of particulate matter at sea. In the Southeast Bay of Biscay, it has been pointed to have an important role in the aggregation of marine litter along frontal lines that are visible to the naked eye: "marine litter windrows" (Ruiz et al., 2020). A method capable of improving the coastal circulation and dispersion from model outputs has been applied to this study area, where two in-situ surveys were conducted: BOBLIT0.1 and BOBLIT0.2.

MATERIALS: STUDY AREA AND DATA



Bay of Biscay:

- Iberian Poleward Current creating anticyclonic eddies
- Dynamics affected by geostrophic current, winds, inertial oscillation (~18 hours period), and tides

Modeled outputs:

U and V velocities from 3-D NEMO model in Iberia-Biscay-Ireland (IBI) . Space-time resolution: ~3.5 km - 15 min

Observations:

- 13 surface drifters with 1 m drogue deployed during 2 surveys (40 hours observations) - 15 min temporal resolution
- 2 deployment strategies: clusters (BOBLIT0.1) and grid (BOBLIT0.2)
- HF Radar from Euskoos system

METHOD: OPTIMAL INTERPOLATION

Linear combination of the weighted differences between the modeled and observed velocities (Gandin, 1963):

$$u_{OI} = u_m + \sum_{ij} BH_j^T \left(H_i B H_j^T + R_{ij}\right)^{-1} \left(H_i u_m - u_i^*\right)$$

Initial model velocity | Dynamic interpolator Combination of model and observations covariances | Interpolated differences between model and observations

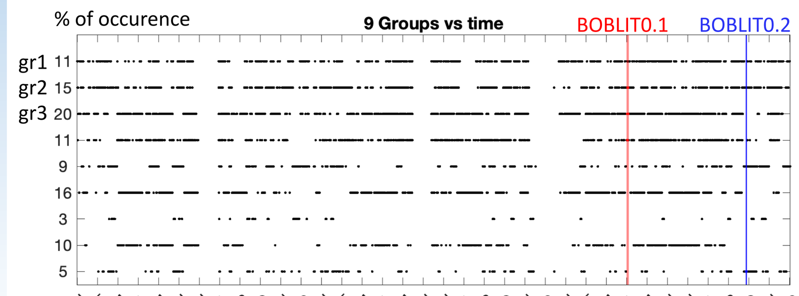
$B = \langle u_m(x,t) u_m(x',t') \rangle$ Model's space-time covariance matrix

$R_{ij} = \langle u_i^* u_j^* \rangle$ Observations' space-time covariance matrix

u_M ; u_i^* ; u_{OI} Modeled, observed and optimized velocities

H_i Projection operator

K-Means clustering method using velocities from HF Radar measurement (Solabarrieta et al., 2015) for extraction of ensemble members required for the covariance matrix calculation:

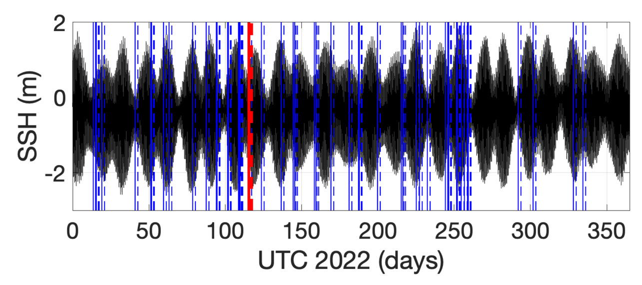


Extraction of ensemble members displaying the same groups of surface current variability in the same order of magnitude

In 2022:

→ 47 ensemble members for BOBLIT0.1

→ 49 ensemble members for BOBLIT0.2

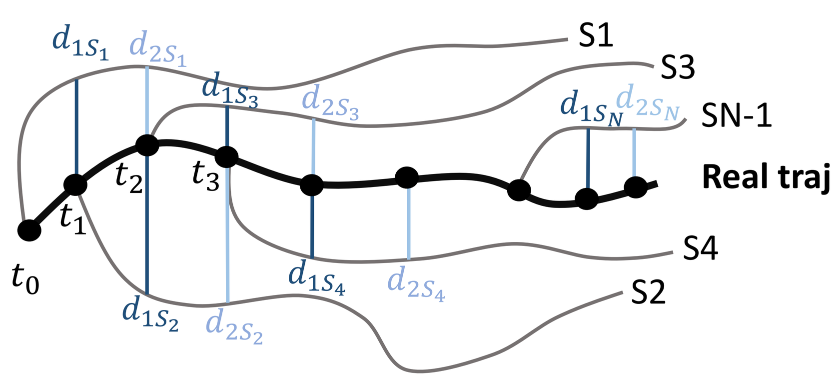


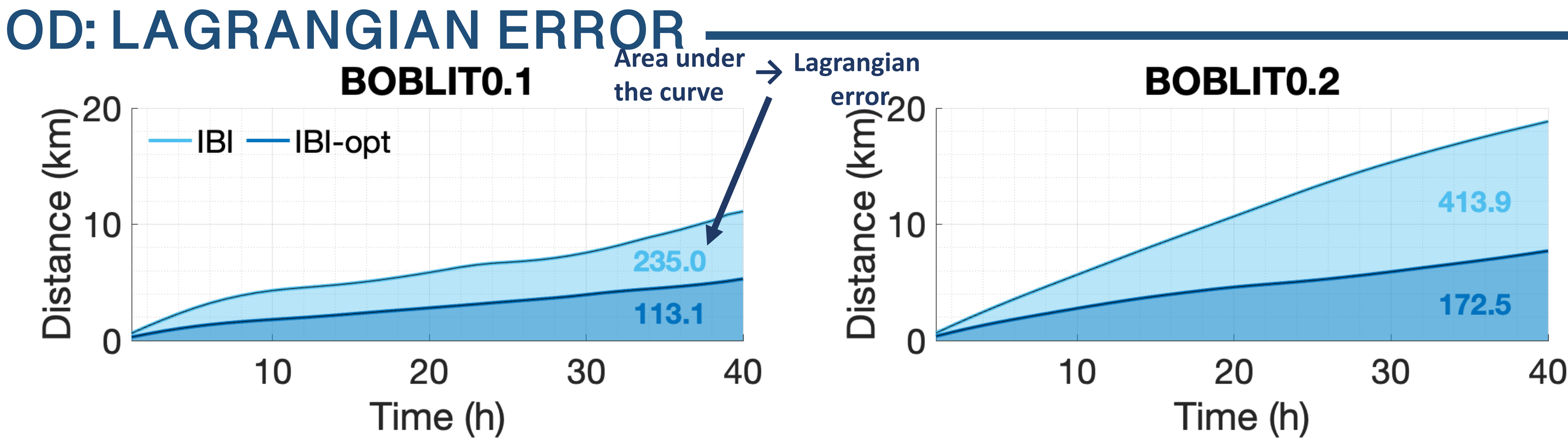
METHOD: LAGRANGIAN ERROR

$$\varepsilon_L = \left\langle \sum_n d_{nS_n} \right\rangle$$

Separation distance averaged over all the simulated trajectories

With n = 1,…,N the number of time steps/simulated trajectories.





52% reduction during BOBLIT0.1

58% reduction during BOBLIT0.2

METHOD: LAGRANGIAN ERROR

Deployment of 1500 virtual particles seeded around the deployment zone at t_0 during the 40-hours of each survey. Particles are advected using OpenDrift software in the initial and optimized model fields. Separation distance: 500m.

RESULTS: ONE-PARTICLE STATISTICS

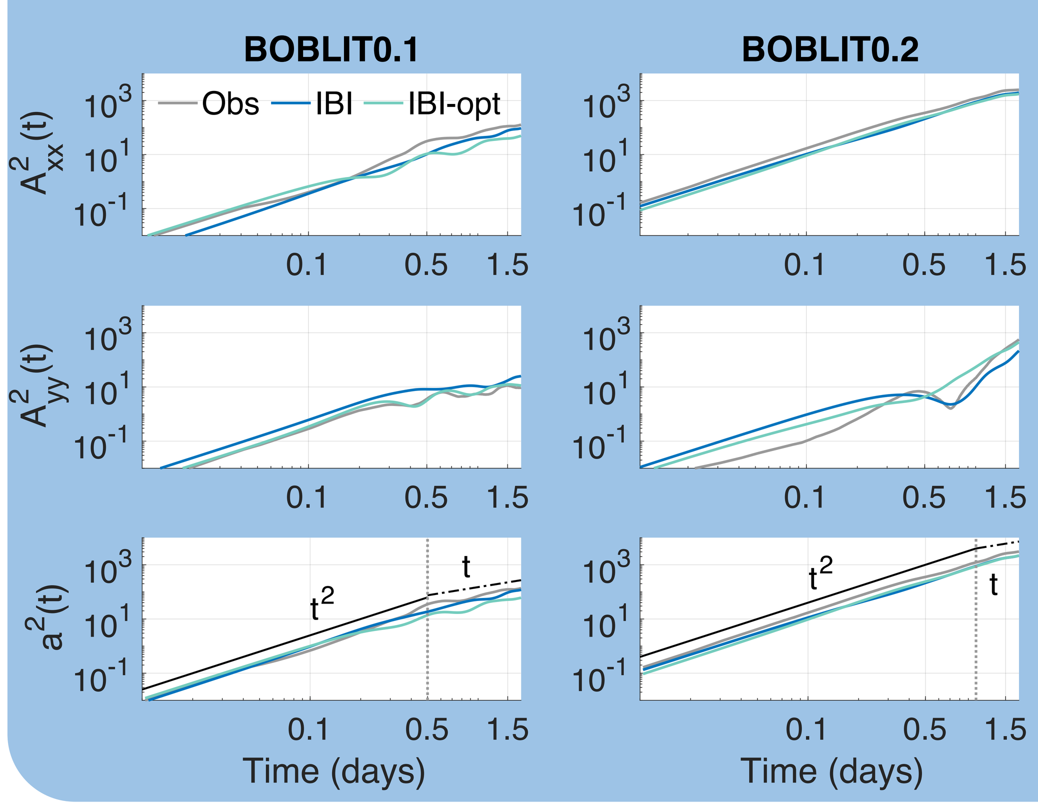
Absolute dispersion

Variance of particle spreading with respect to the mean coordinate of particles in a cluster (barycenter). Dispersion regimes are identified from the time-dependence of $a^2(t)$ (Berti et al., 2011, Enrile et al., 2019). $a^2(t) = A_{xx}^2(t) + A_{yy}^2(t)$

$$A_{ij}^2(t) = \frac{1}{M}\sum_{m=1}^{M}\{[x_i^m(t) - x_i^m(t_0)][x_j^m(t) - x_j^m(t_0)]\}$$

$\langle (a(t)^2 \rangle \sim t^2 \implies$ Ballistic regime

$\langle (a(t)^2 \rangle \sim t \implies$ Diffusive regime



- Optimization more efficient on A_{yy}^2
- 44% increase of absolute dispersion with OI during BOBLIT0.1, 15% during BOBLIT0.2.
- Conservation of the duration of dispersion regimes

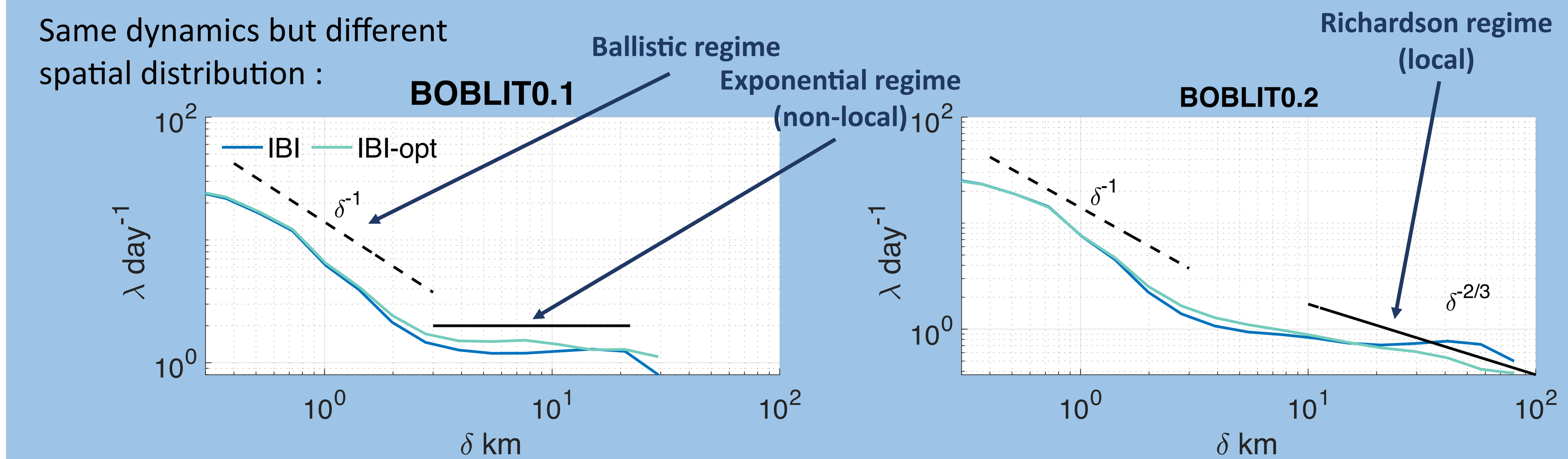
RESULTS: TWO-PARTICLES STATISTICS

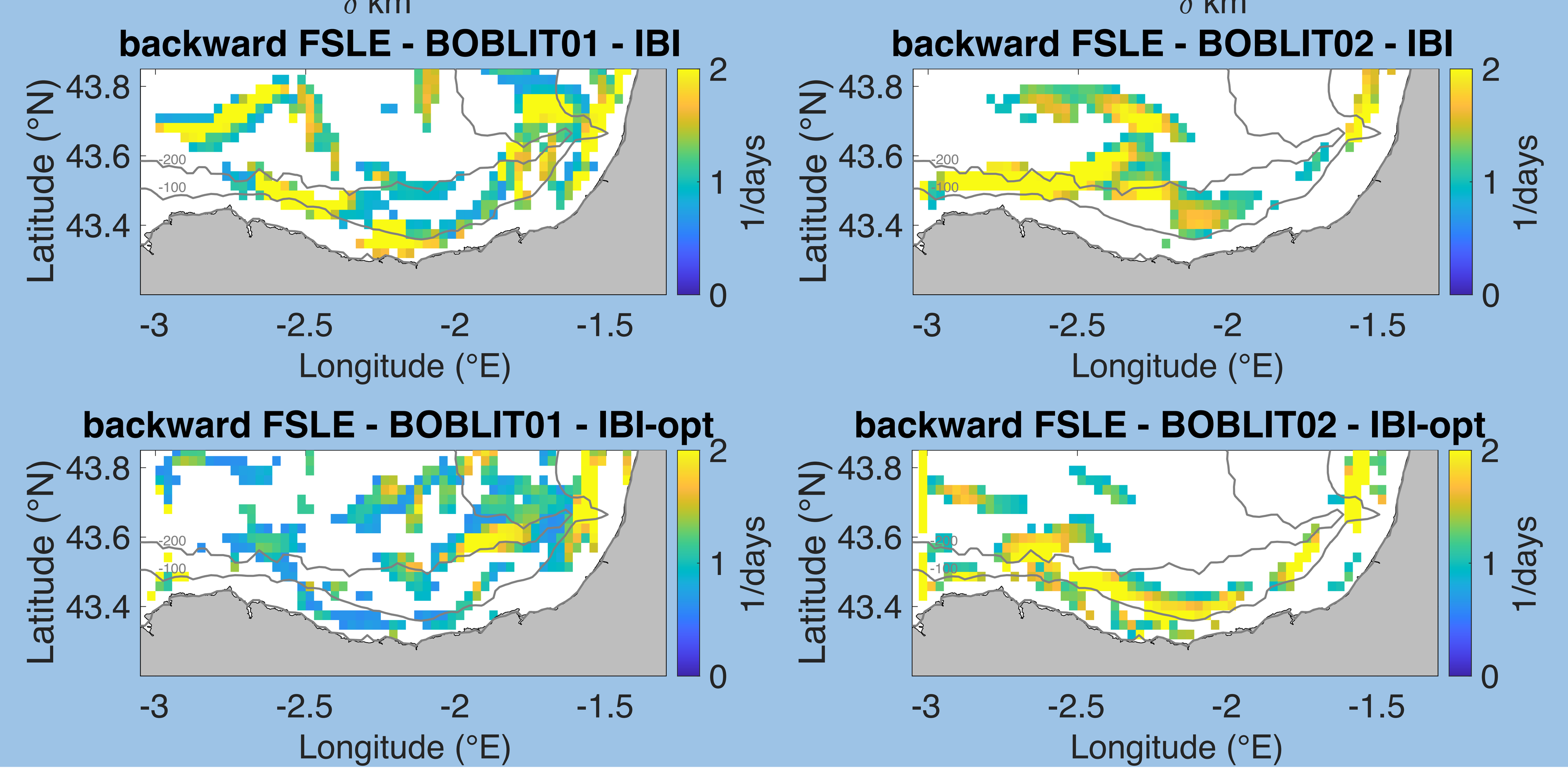
Finite Size Lyapunov Exponent (FSLE)

Quantification of the rate of divergence or convergence of close trajectories (Berti et al., 2011). Estimated by measuring the time τ, averaged over all particle pairs, needed to separate particle in a pair from a distance δ_k to a distance $\delta_k = r\,\delta_k$ with $r \geq 1$. Maximum of FSLE identify the Lagrangian Coherent Structures (d'Ovidio et al., 2004, Hernández-Carrasco et al., 2011).

$$\lambda(\delta) = \frac{\ln(r)}{\langle \tau \rangle}$$

Same dynamics but different spatial distribution :





CONCLUSIONS & FUTURE WORK

- The optimization method is efficient using drifters as observations and enables 52% reduction of Lagrangian error during BOBLIT0.1 and 58% during BOBLIT0.2.
- The use of Optimal Interpolation modifies:
  → *the rate of dispersion*
  → *the location of Lagrangian Coherent Structures*

NEXT ?

- Apply method of optimization using other dataset (HFR, other models)
- Quantification of the impact of the number of drifter accounted in the optimization method
- Quantification of the impact of ocean horizontal diffusivity (random walk)

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This study has been conducted using E.U. Copernicus Marine Service Information (surface currents: https://doi.org/10.48670/moi-00027 ; euskoos: https://doi.org/10.57762/T4WH-DQ48 ; HFR: https://doi.org/10.17882/86236).