

Lagrangian simulations of marine debris transport: a case study of the Toconao plastic pellet spill

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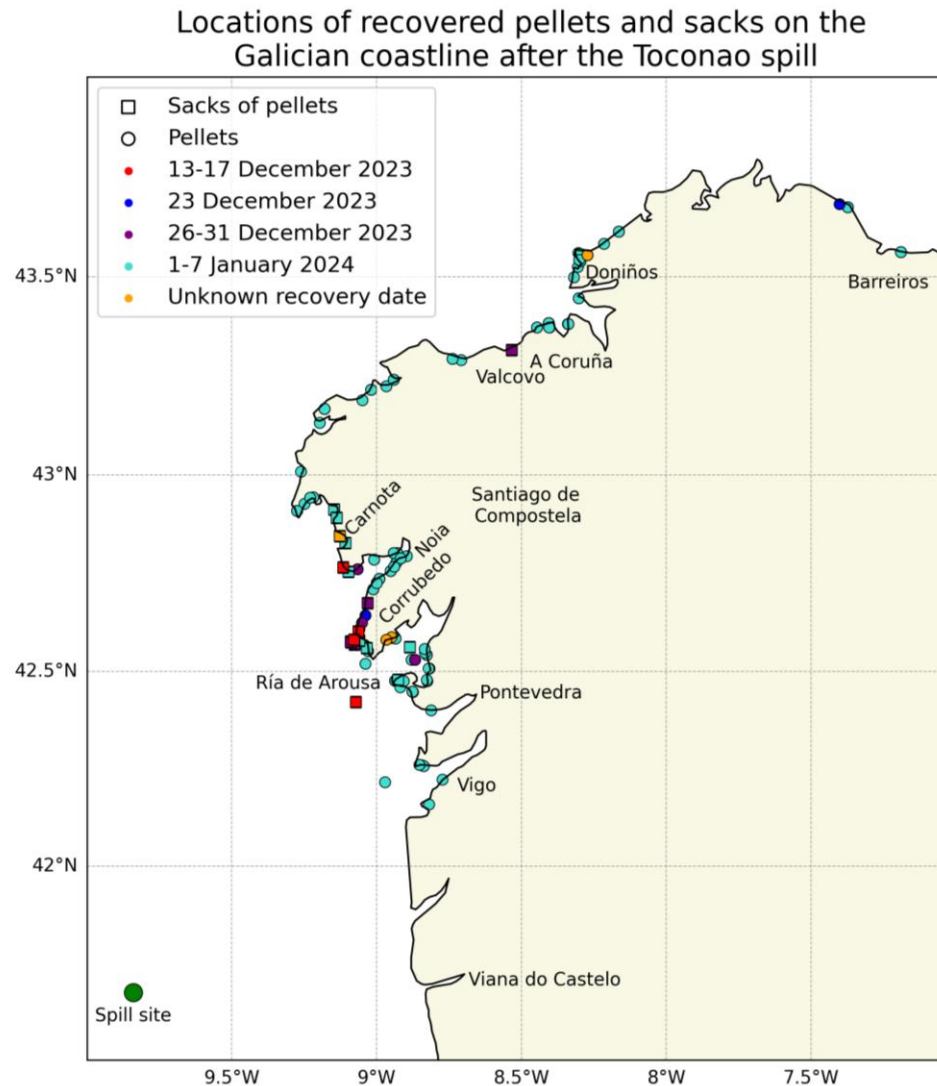
FONDO EUROPEO DE
DESARROLLO REGIONAL
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AGENCIA
ESTATAL DE
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Toconao pellet spill

- Date of the spill: December 8th 2023
- 1050 25kg sacks of pellets from the Toconao container ship
- Spill site: aprox. 80km from Viana do Castelo, Portugal
- December 13-14th 2023 first sighted sacks on the coast (Corrubedo, Galicia, Spain)



Compilation of recovery efforts data published by Noia Limpa y Unha Vez Máis and several news media (El País, El Español, elDiario.es)



Pellets on the beach (image from El Español)



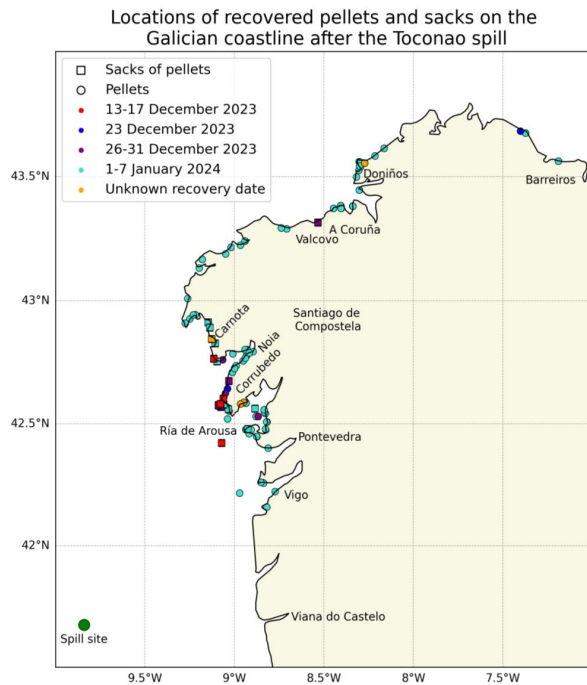
First recovered sacks of pellets in Corrubedo on December 13th 2023 (image from El Español)

Objectives of the Lagrangian simulation

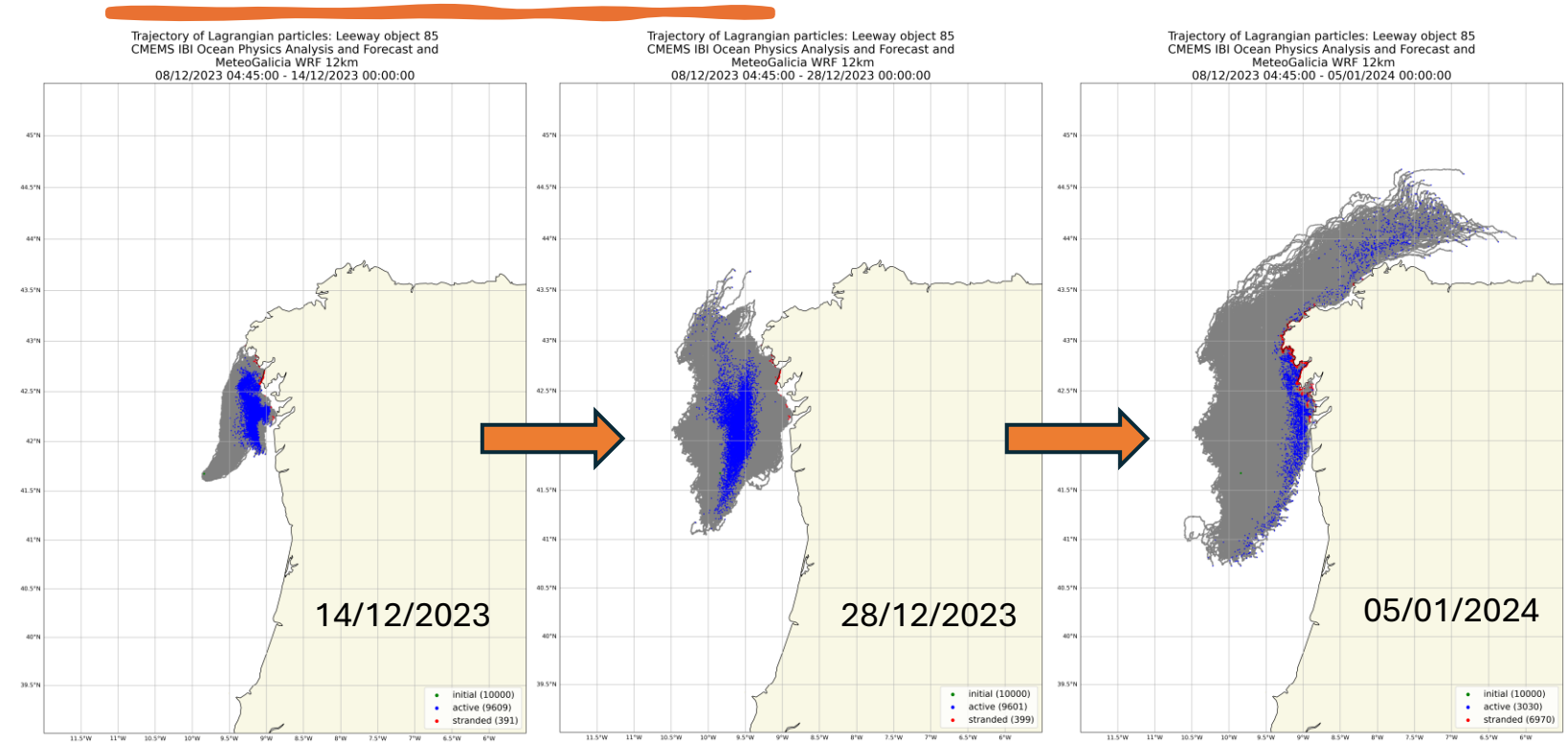
- A set of Lagrangian simulations were performed to simulate the spill using the offline trajectory model OpenDrift (<https://opendrift.github.io>)
- Sensitivity analysis of the Lagrangian model to
 - The type of particle simulated
 - The hydrodynamic and atmospheric models used as forcing
- To assess the impact of freshwater fronts using Lagrangian Coherent Structures (LCS)



Results of the Lagrangian simulations



Available data



Lagrangian simulation



Copernicus
Marine Service

IBI Ocean
product

meteogalicia

WRF 12km
wind product

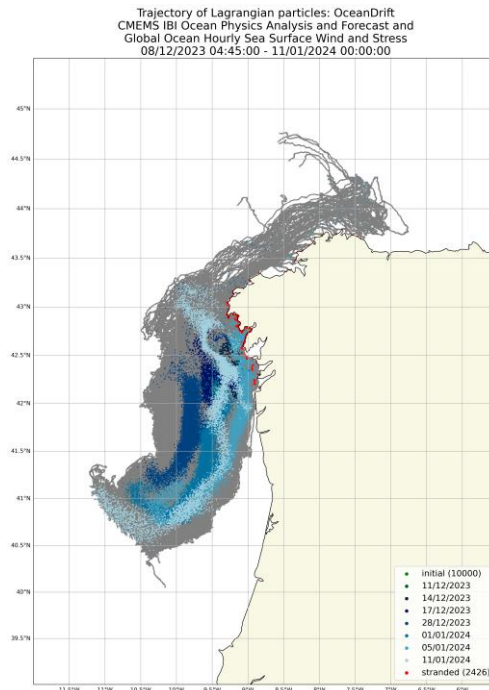


Leeway drift, small
medical waste

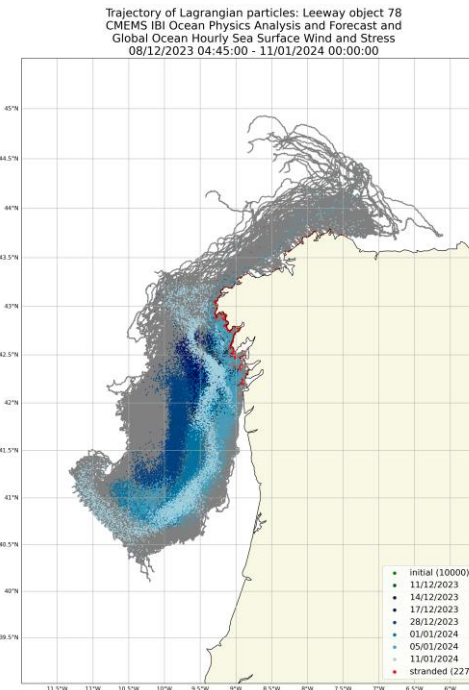
Sensitivity to object type

- initial (10000)
- 11/12/2023
- 14/12/2023
- 17/12/2023
- 28/12/2023
- 01/01/2024
- 05/01/2024
- 11/01/2024
- stranded (2426)

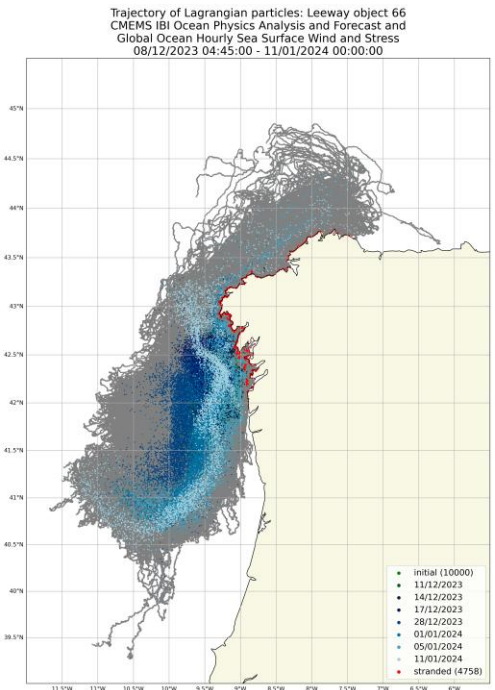
- OceanDrift: particles with a direct wind drag
- Leeway: objects with downwind and crosswind drag empirical-based coefficients
 - Object 85: Medical waste, syringes, small
 - Object 78: Sewage floatables, tampon applicator
 - Object 70: Bait/wharf box, holds a cubic metre of ice, lightly loaded
 - Object 66: Fishing vessel debris



OceanDrift



Leeway ob. 78

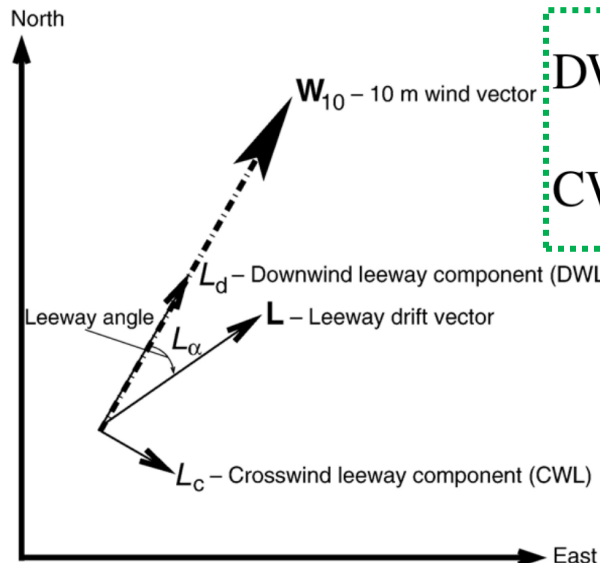


Leeway ob. 66

OceanDrift vs Leeway model

$$\frac{dx_i}{dt} = \underbrace{u_{sea}(x_i, t)}_{\text{Current horizontal advection}} + \underbrace{C_D u_{wind}(x_i, t)}_{\text{Wind drag}} + \underbrace{R(2K_h d^{-1} dt)^{1/2}}_{\text{Current horizontal dispersion (random walk)}}$$

OceanDrift: 2%



$$DWLeeway = \left(a_{dw} + \frac{\epsilon_n}{20} \right) \cdot W_{10} + b_{dw} + \frac{\epsilon_n}{2},$$

$$CWLeeway = \left(a_{cw} + \frac{\epsilon_n}{20} \right) \cdot W_{10} + b_{cw} + \frac{\epsilon_n}{2}.$$

$$\epsilon_n = rdw \cdot \epsilon$$

$$rdw \in N(0, 1)$$

Object	a_{dw}	b_{dw}	ϵ
85. Medical waste, syringes, small	1.79%	0.00 cm/s	2.40 cm/s
78. Sewage floatables, tampon applicator	1.79%	0.00 cm/s	3.10 cm/s
70. Bait/wharf box, holds a cubic metre of ice, lightly loaded	2.53%	9.01 cm/s	3.05 cm/s
66. Fishing vessel debris	1.97%	0.00 cm/s	8.30 cm/s

Sensitivity to forcing



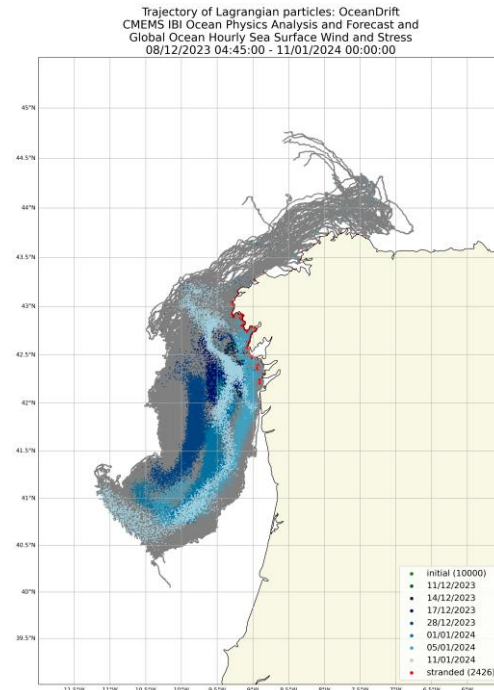
- IBI Ocean Physics Forecast and Analysis (2km)
- Global Ocean Hourly Sea Surface Wind and Stress from Scatterometer and Model (9.5km)



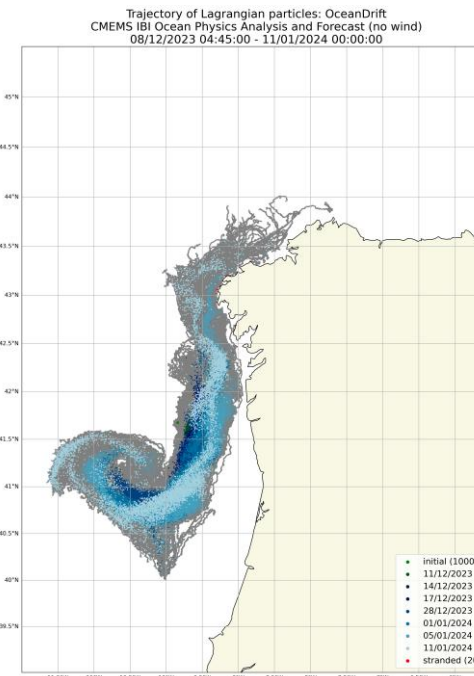
- ROMS 2km
- WRF 12km

Experiments only explain the spill if both hydrodynamic and atmospheric models are used as forcing

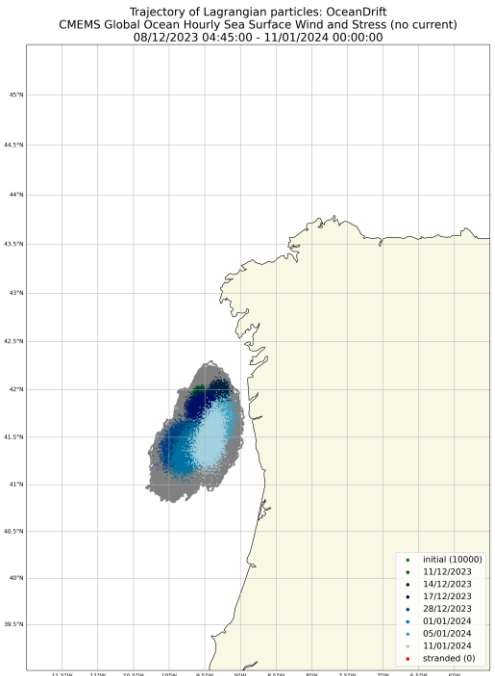
- initial (10000)
- 11/12/2023
- 14/12/2023
- 17/12/2023
- 28/12/2023
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Currents and wind

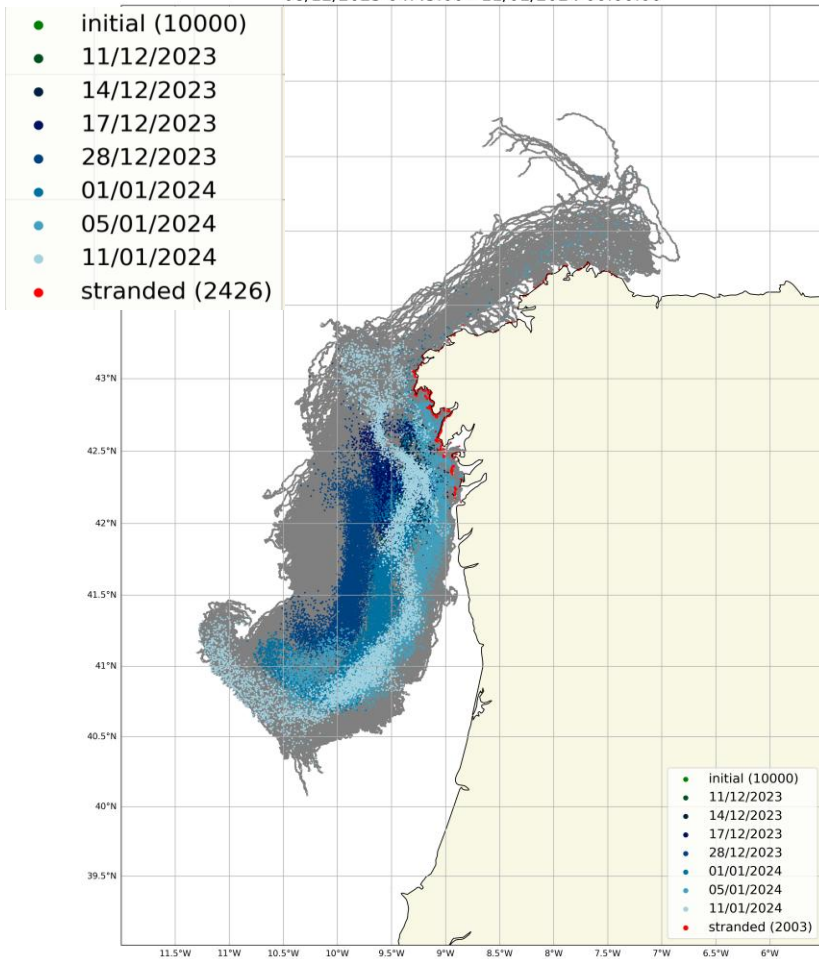


Only currents



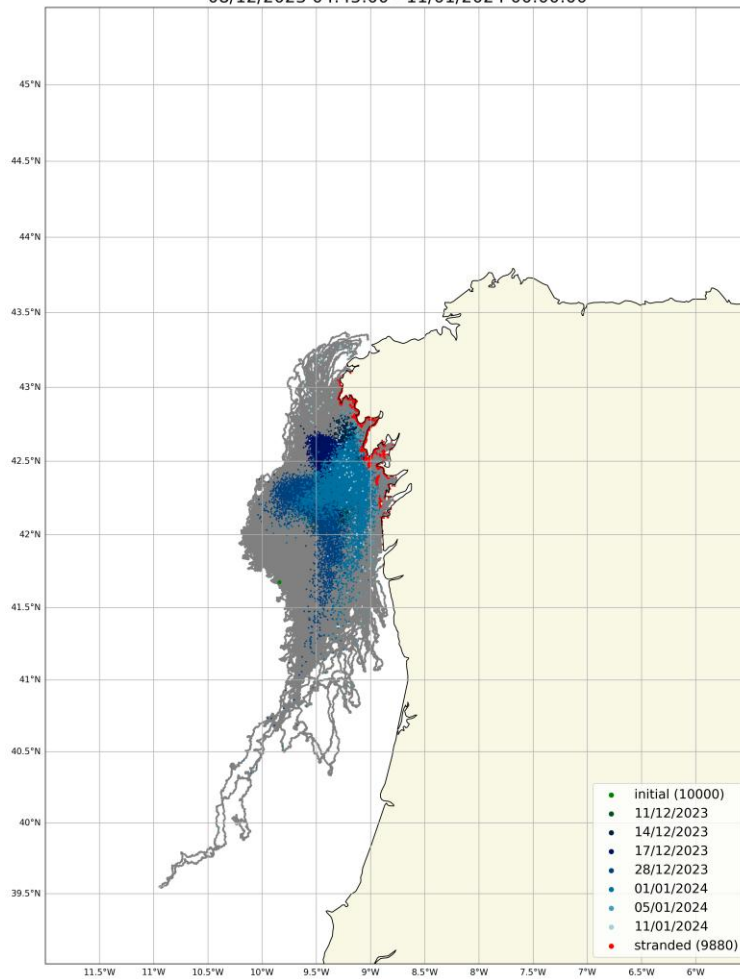
Only wind

Trajectory of Lagrangian particles: Leeway object 85
 CMEMS IBI Ocean Physics Analysis and Forecast and
 Global Ocean Hourly Sea Surface Wind and Stress
 08/12/2023 04:45:00 - 11/01/2024 00:00:00



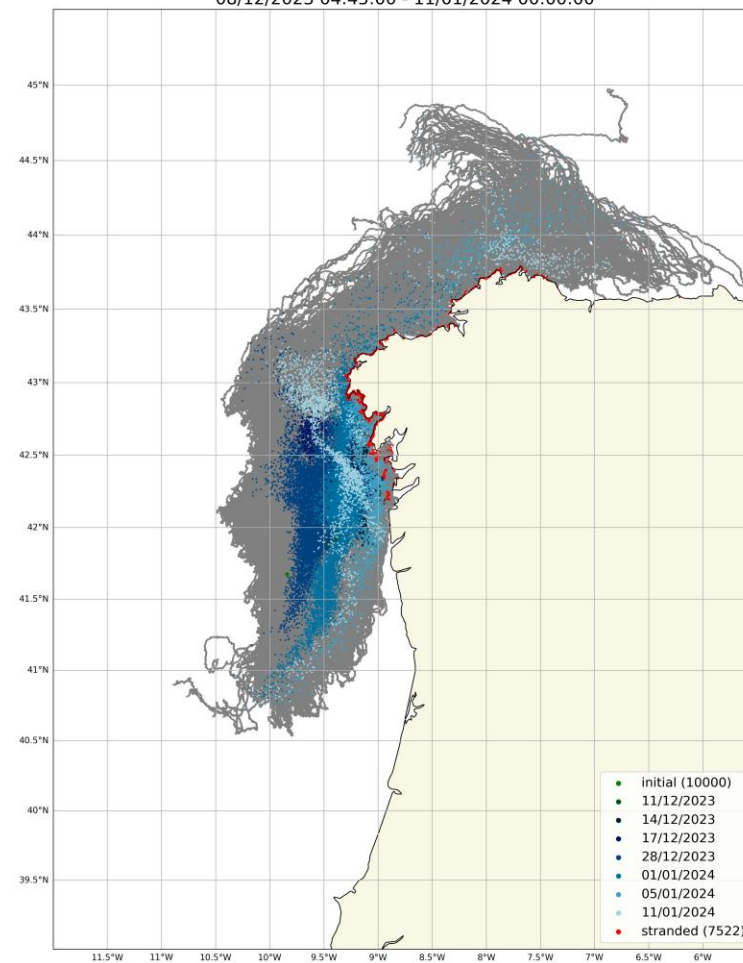
Currents and wind

Trajectory of Lagrangian particles: Leeway object 85
 MeteoGalicía ROMS raw and WRF 12km
 08/12/2023 04:45:00 - 11/01/2024 00:00:00



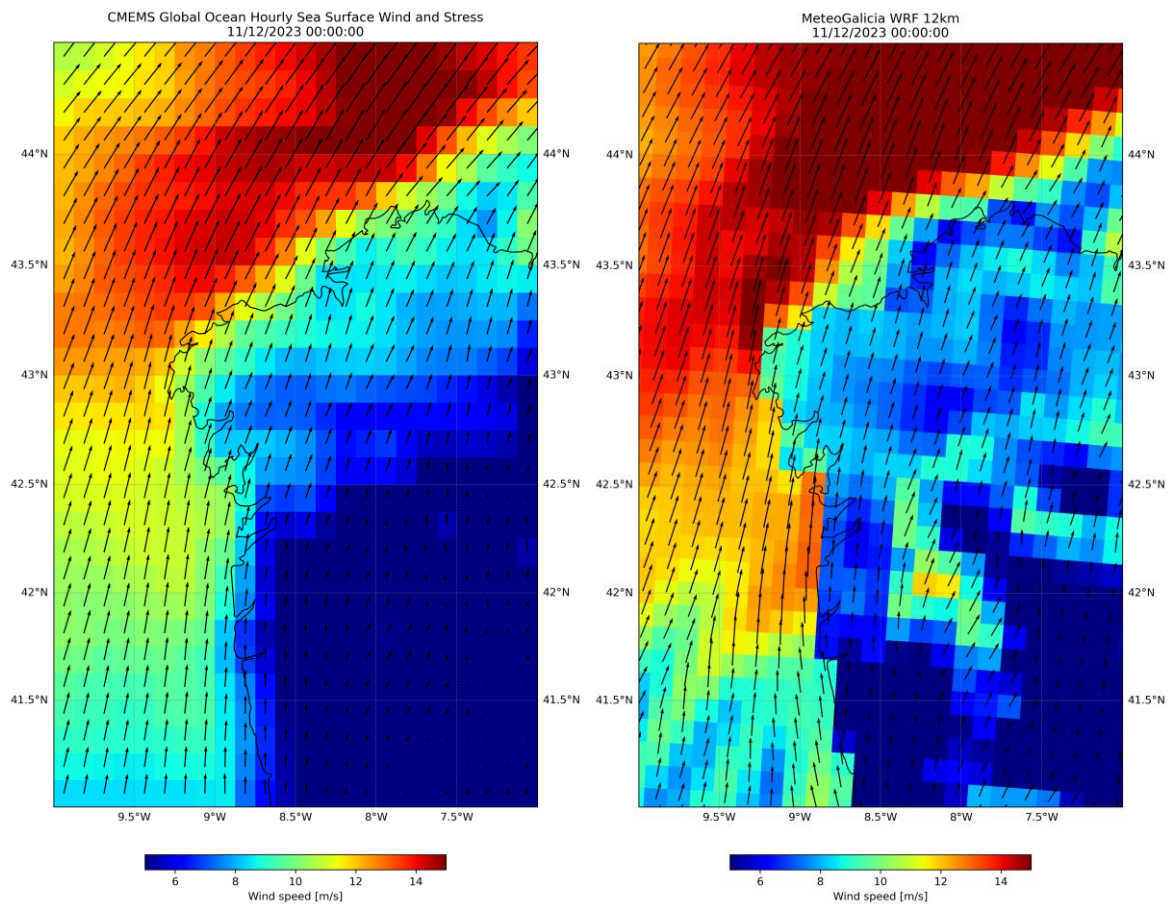
Currents and wind

Trajectory of Lagrangian particles: Leeway object 85
 CMEMS IBI Ocean Physics Analysis and Forecast and
 MeteoGalicía WRF 12km
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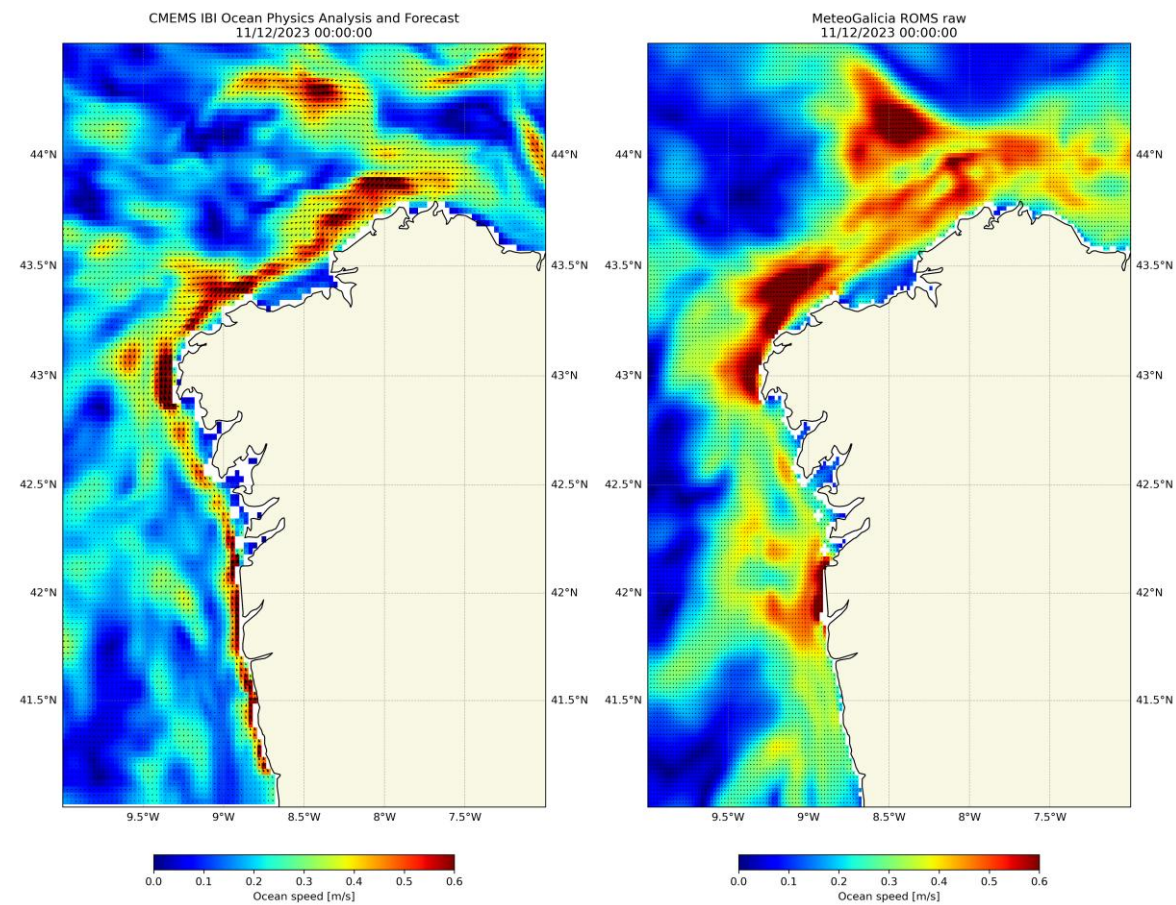
Currents

Wind



meteogalicia

Wind velocity field



meteogalicia

Current velocity field

Lagrangian Coherent Structures and freshwater fronts

- LCS are material lines that organize transport
- LCS attract (or repel) nearby fluid particles
- LCS are a tool to identify maximal attraction areas, retention zones, isolation regions, Lagrangian barriers

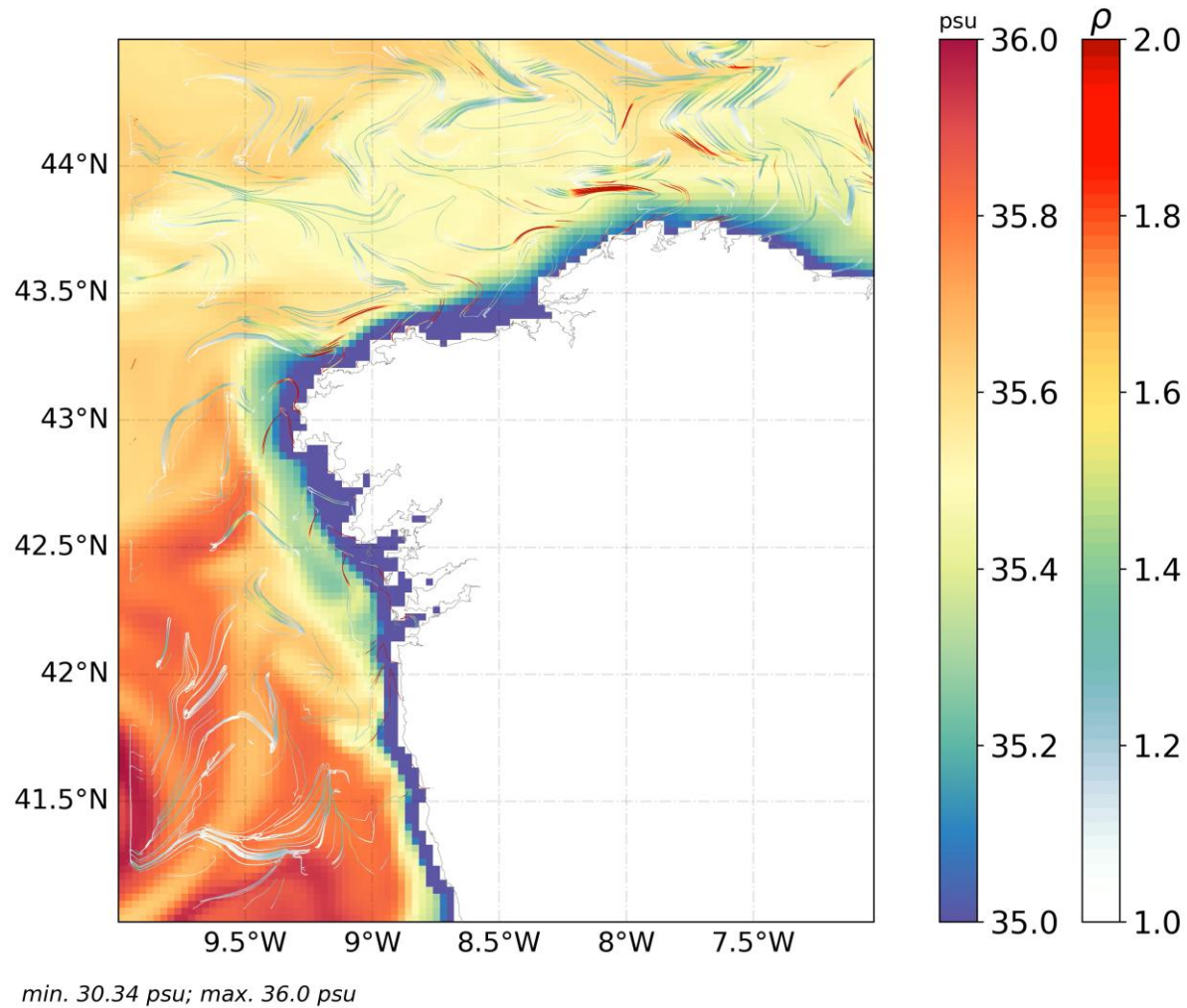
River plumes (low salinity regions originated by river runoffs) are subjected to wind events:

1. Downwelling pulse: S-SW wind confines river plumes to the coast
2. Relaxation of the wind: slight expansion of the plumes
3. Upwelling pulse: N-NE wind expands river plumes to the platform

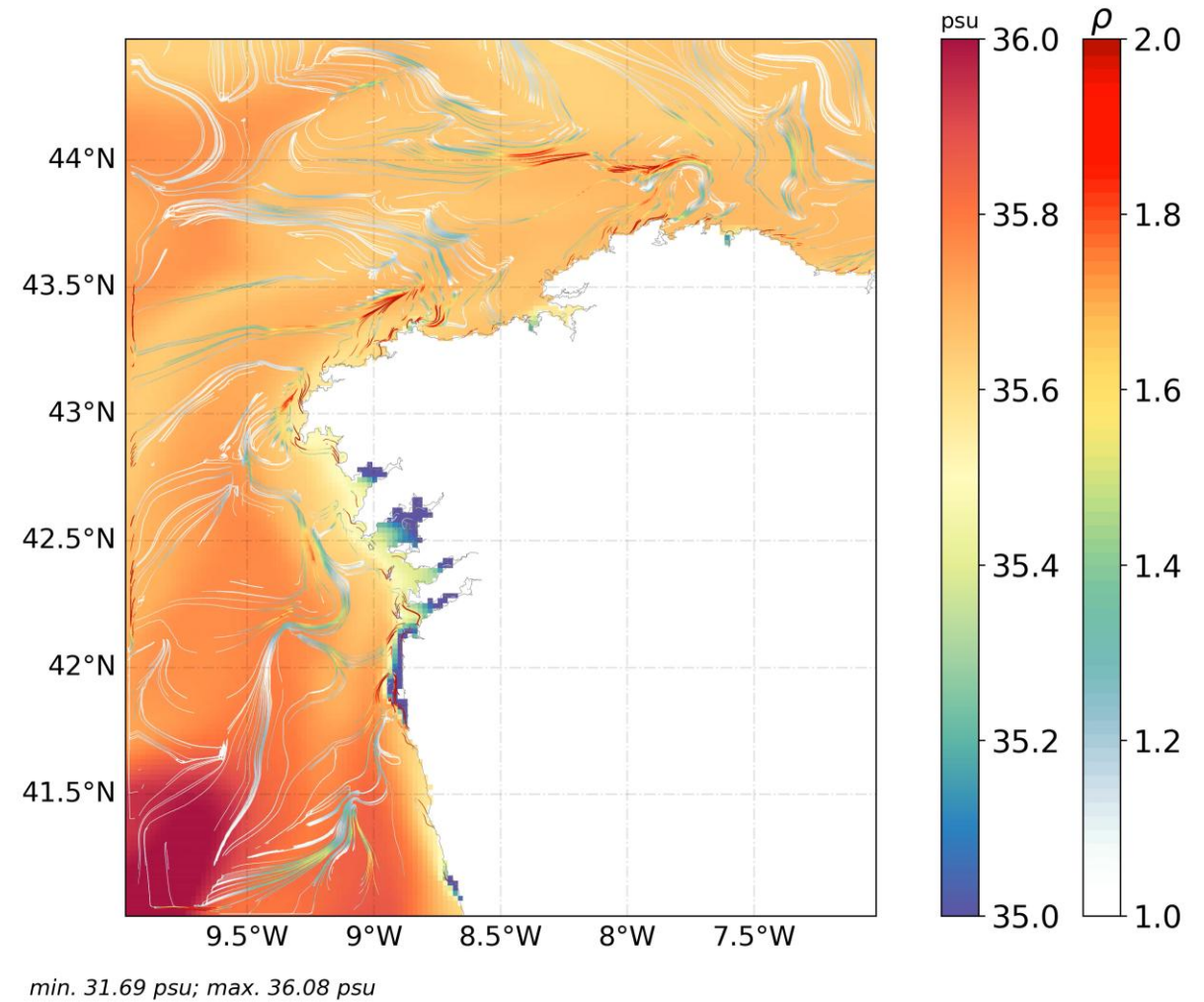
This variability strongly affects the dynamic of the Galician Rías and also drift in the ocean surface



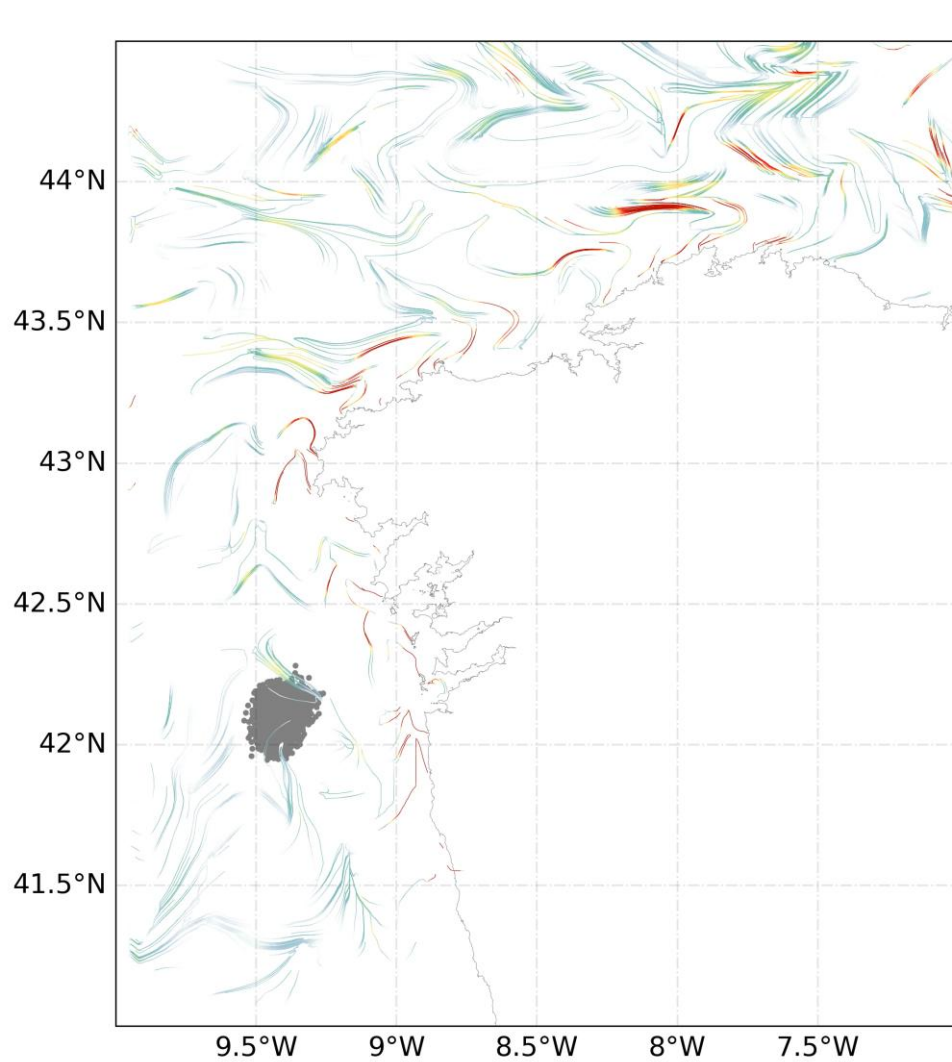
Is the presence of LCS related to freshwater fronts?



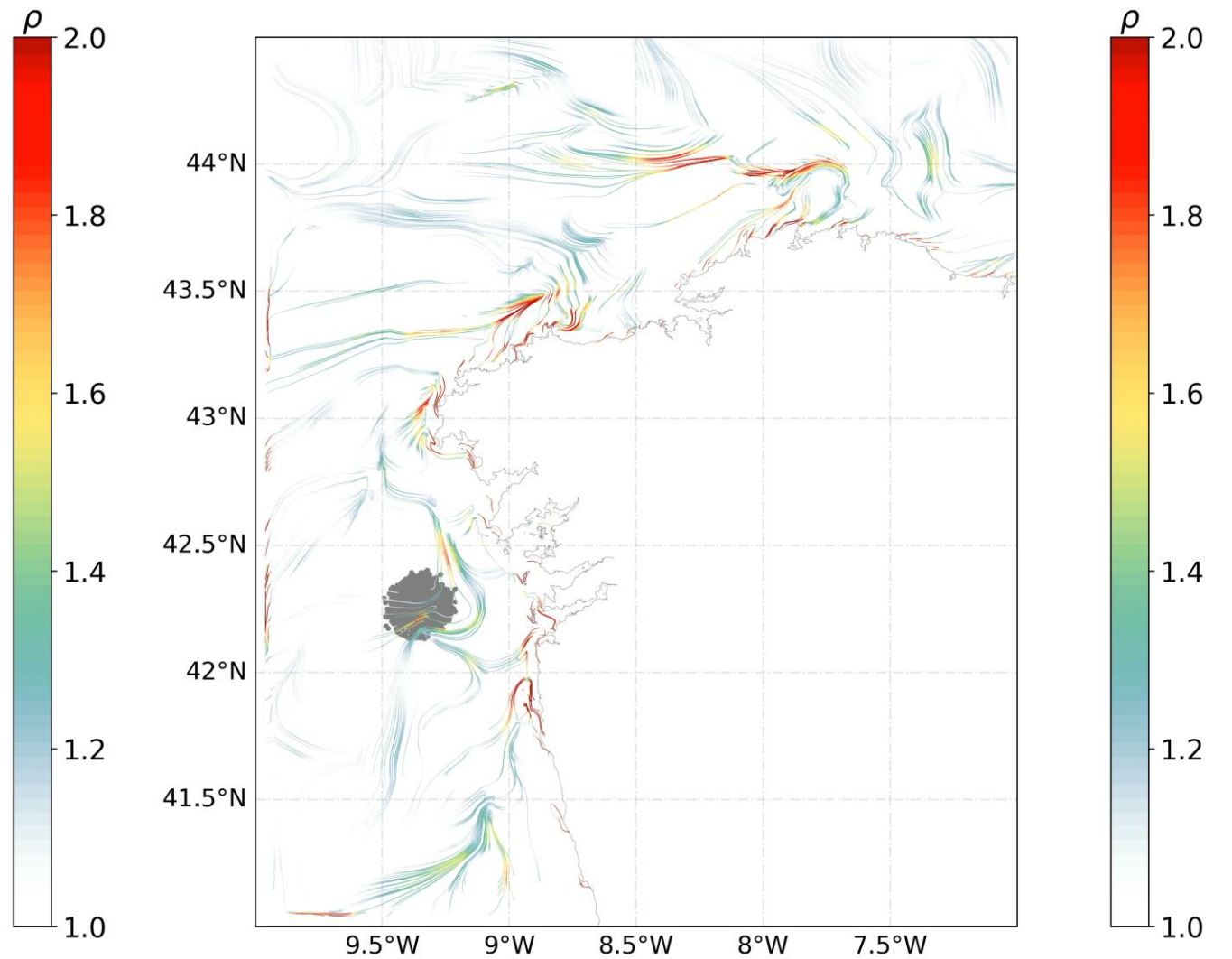
LCSs and surface salinity fields (daily mean)



LCSs and surface salinity fields (hourly)



LCSs and OceanDrift Lagrangian particles



LCSs and OceanDrift Lagrangian particles

Preliminary results: MOHID-Lagrangian

Objective: To replicate OpenDrift simulations using MOHID-Lagrangian and compare the results of both models.

Results: MOHID-Lagrangian simulations are consistent with the spatio-temporal distribution of plastic pellet arrivals on the coast



Conclusions

- Our experiments show coherence with the spill data
- Only using both hydrodynamic and atmospheric models as forcing results are explained
- The Lagrangian model is influenced by the choice of the particle type
- The Lagrangian model is influenced by the choice of forcing configuration
- LCS are useful for assess the impact of freshwater fronts in the dynamics of the Galician Rías

This contribution is part of Project DEMON (Dissipation of Energy in Ocean Models and Connectivity)



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