Assessing Wind Influence in Marine Debris Dispersal in Northwest Spain

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Table of Contents

Objectives

The arrival of plastic waste on the Galician coast leads us to set the following objectives in our work:

- Relation between extreme meteorological events and debris arrival to the coastline.
- Study of wind influence in particle motion.
- Validation of new parametrizations for particle dispersion processes.

Study Case

- Geographical region: Ría de Arousa.
- Study period: January 2019 - December 2023.
- Main debris source: Ulla river.
- Particle emission ratio according to river's flowrate.
- Division into 3 main zones: inner, intermediate and outer regions.
- Wind coefficients:

c_w	Particles
1%	Pellets, small dense plastic fragments...
3%	Bottle caps, plastic bags, mid-sized polystyrene fragments...
5%	Plastic bottles, expanded polystyrene...

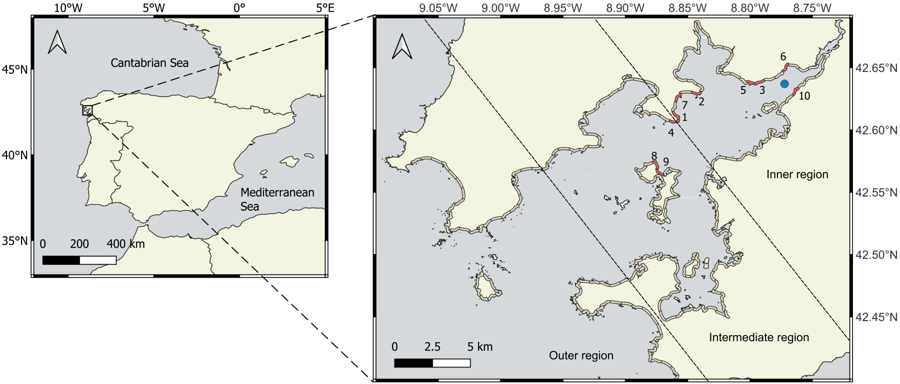
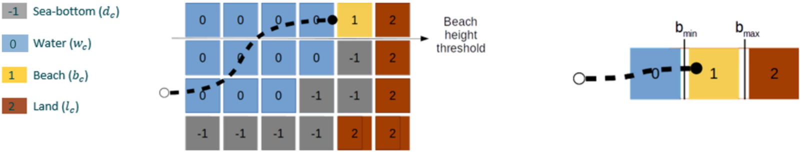


Figure: Study region to evaluate riverine (blue dot) debris dispersion in the Ría de Arousa . Dashed lines divide the Ría de Arousa into three interest regions: inner, intermediate and outer regions. The coastal segments marked in red show the most polluted beaches and correspond to: (1) Praia da Ladeira, (2) Praia Redonda, (3) Ensenada de Seveira, (4) O Chazo, (5) Praia do Lodeiro, (6) Ensenada de Rial, (7) Praia de Piñeiro, (8) Praia do Nabal, (9) Praia do Arroás and (10) Punta Remuiño.

MOHID-Lagrangian model

The **MOHID-Lagrangian** tool has been used. A high-performance Lagrangian tracer model.

- Validated beaching module [1]



- Windage module. Wind coefficient typically set between 1% and 5%.

$$\frac{dr_i}{dt} = v_i(r_i(t), t) + R\sqrt{\frac{2K_h}{\Delta t}} \quad , \qquad \text{with } v_i = v_i^h + c_w v_i^w$$

[1] Cloux et al., 2022, Science of The Total Environment; 2024, Marine Pollution Bulletin

Wind Study

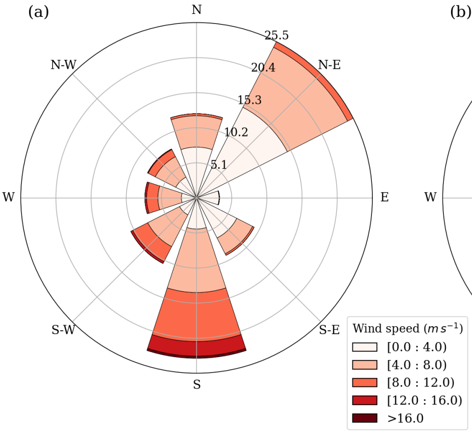


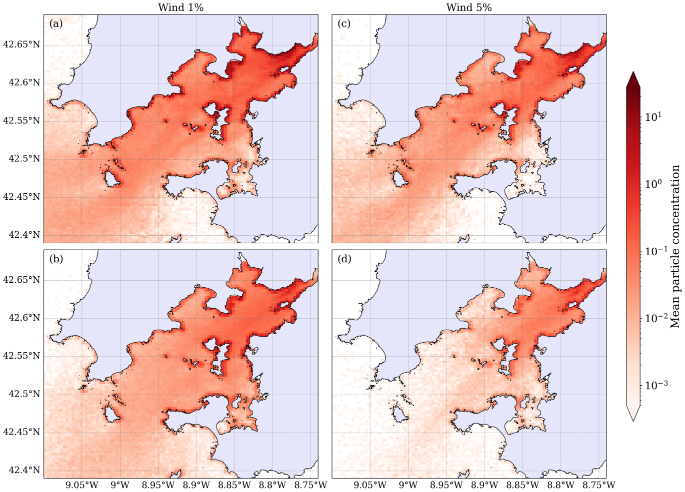
Figure: Wind directions and mean velocities for winter months (a) and summer months (b)

Results on wind influence

- Main areas of particle accumulation in water.
- Beached particle distribution along North and South sides of the Ría.
- Correlation between the river's flow rate and the number of particles.
- Main coastal accumulation zones.
- Mean residence time before beaching.

Mean particle concentration maps

Mean particle concentration distributions for **winter** (panels a and c) and **summer** (panels b and d) seasons, based on Lagrangian simulations using wind drag coefficients of 1% (left panels) and 5% (right panels).



North-South debris distribution

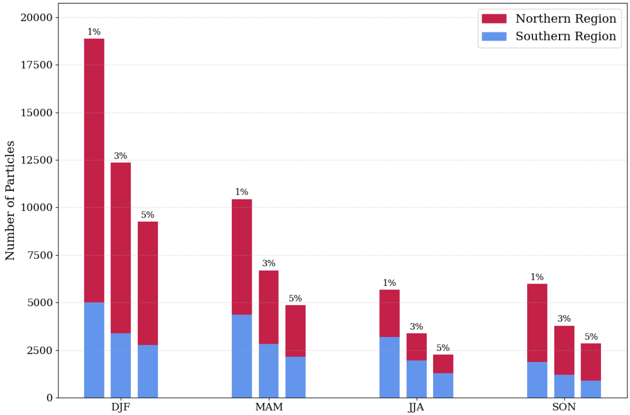
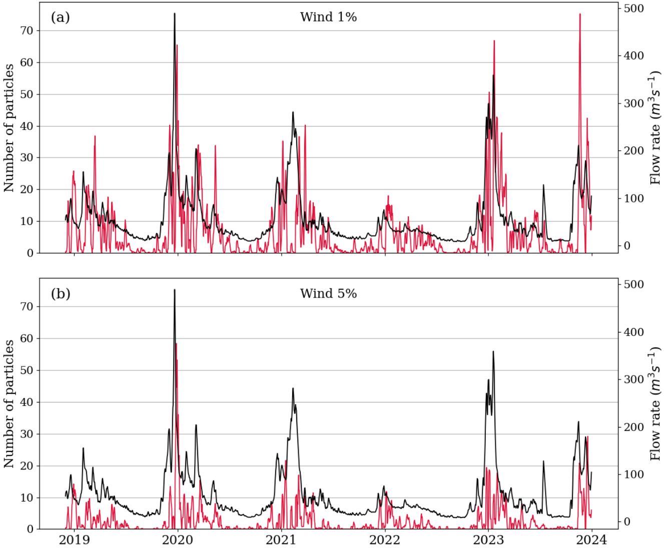


Figure: Seasonal distribution of particle accumulation in the northern and southern (blue) areas of the Ría de Arousa for three wind drag coefficients: 1%, 3%, and 5%. Concentrations are grouped by season.

River's flow rate vs. Number of particles

Daily time series of number of beached particles (red) for Praia da Ladeira and Ulla river flow rate (black). Plotted for 1% wind (a), and for 5% wind (b).



Correlations in most polluted zones

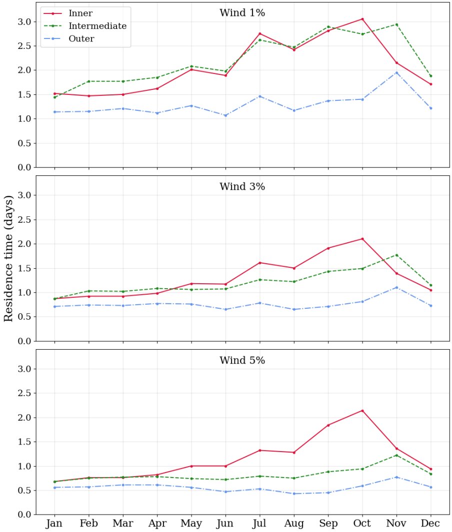
ID	Name	Council	$c_w = 1\%$	$c_w = 3\%$	$c_w = 5\%$
1	Praia da Ladeira	Boiro	0.6855	0.6972	0.6952
2	Praia Redonda	Boiro	0.6127	0.5931	0.5629
3	Ensenada de Severa	Rianxo	0.7618	0.7011	0.6472
4	O Chazo	Boiro	0.6832	0.6307	0.6140
5	Praia do Lodeiro	Rianxo	0.8131	0.7279	0.6661
6	Ensenada de Rial	Rianxo	0.6971	0.7226	0.7218
7	Praia de Piñeiro	Boiro	0.5369	0.5664	0.5969
8	Praia do Nabal	Illa de Arousa	0.6079	0.6164	0.6093
9	Praia do Arroás	Illa de Arousa	0.6676	0.6357	0.6400
10	Punta Remuiño	Vilagarcia de Arousa	0.4618	0.4366	0.4887

Table: Correlation coefficients between river discharge and particle beaching under three windage scenarios ($c_w = 1\%, 3\%, 5\%$), for the ten most polluted coastal segments in the study area, which account for around 50% of beached particles.

Residence times

Monthly residence times as a function of time for different wind cases.

Summer and autumn months show longer residence times, which can make sense, as particles are dragged to the southern side of the domain, which has more sheltered zones, and calmer waters.



Conclusions

- **Wind dominates dispersal**: Even slight wind increases (1%–5%) reduce coastal particle accumulation, shortening residence times.
- **Asymmetric retention**: Sheltered northern areas accumulate more particles, especially under weak winds and in cold months.
- **River-wind interplay**: Fluvial inputs drives near-mouth accumulation, but strong winds decouple this relationship.
- **Seasonal shifts**: Warmer months see higher southern accumulation due to hydroclimatic and circulation changes.
- **Geography matters**: Complex inner regions (bays, bathymetry) retain particles longer than exposed outer zones.

Future Work

- Acquisition and comparison of real coastal debris data in order to validate our study.
- Improve existing parametrizations such as biofouling (see Kooi et al. 2017).
- Add new parametrizations for plastic fragmentation.

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