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Fate and 3D distribution of marine litter in the western Mediterranean basin from offshore to coast

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INTRODUCTION

This study presents a methodology aimed at advancing our understanding of **plastic dispersion, accumulation and stranding within the western Mediterranean basin**. The approach is multi-scaled and employs the **Ocean General Circulation Model NEMO coupled with the Lagrangian particle tracking simulator OceanParcels** to simulate the 3D movement of plastic particles at **large, meso- and small scales**. On a large scale, the goal is to identify potential hotspots in the Mediterranean basin where plastics accumulate, strand or settle on the seafloor and link them with climate indices. Then, focusing on the mesoscale, the analysis will enable us to investigate how particles are trapped or redistributed within an ocean eddy, shedding light on transport barrier effects. Lastly, the study narrows to the small scale with the incorporation of wind and wave interactions to enhance the model accuracy and with a focus on biomedia to bridge model predictions with available observations.

I – MATERIALS AND METHODS

To model the ocean currents, this study uses the product MEDSEA_MULTIYEAR_PHY_006_004 from the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) Foundation on the Copernicus Marine Service. A **hydrodynamic model** generated by the Nucleus for European Modelling of the Ocean (**NEMO**) is coupled with a variational data assimilation scheme OceanVAR. The model **horizontal grid resolution is 1/24°** (ca. 4-5 km) with hourly ECMWF ERA5 atmospheric forcing. We then use the **daily ocean currents in the western Mediterranean basin to simulate the trajectories of plastic particles** with the Lagrangian particle tracking simulator **OceanParcels**.

The first set of simulations runs for **10 years** from 01/08/2011 to 31/07/2021.
Every day 6.10⁴ plastic particles (the size of a water particle), are numerically put on the sea surface in the entire basin (every 4-5 km) and **drift for 1 year**.
In total: 6.10⁴ particles x 3654 days of simulations **~ 2.10⁸ particles drift for 1 year**.

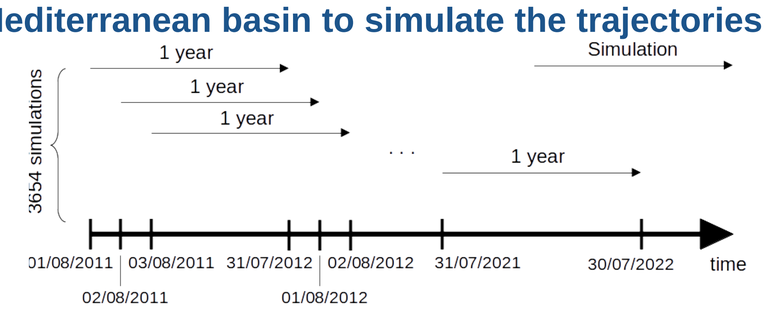

Fig 1: Schematic diagram of simulations conducted

II-A – Identify the accumulation areas: where are the potential plastic hotspots in the Mediterranean Sea?

After 3 months of drift, we record the position of the particles still drifting in the western Mediterranean basin. The final particle density d_f in each bin of the basin (~20km²) relative to the initial density d_i is calculated: $\left(\frac{d_f}{d_i}\right) - 1$

We can see a **strong seasonal variability** in the relative density.

- density has decreased: **loss**
- density is unchanged
- density has increased: **accumulation**

Hotspots:

- **North of the Balearic Islands**
- In the **North Balearic Front**
- The **Tyrrhenian Sea** and **Southeast of Corsica**
- At the start of the **Northern Current**

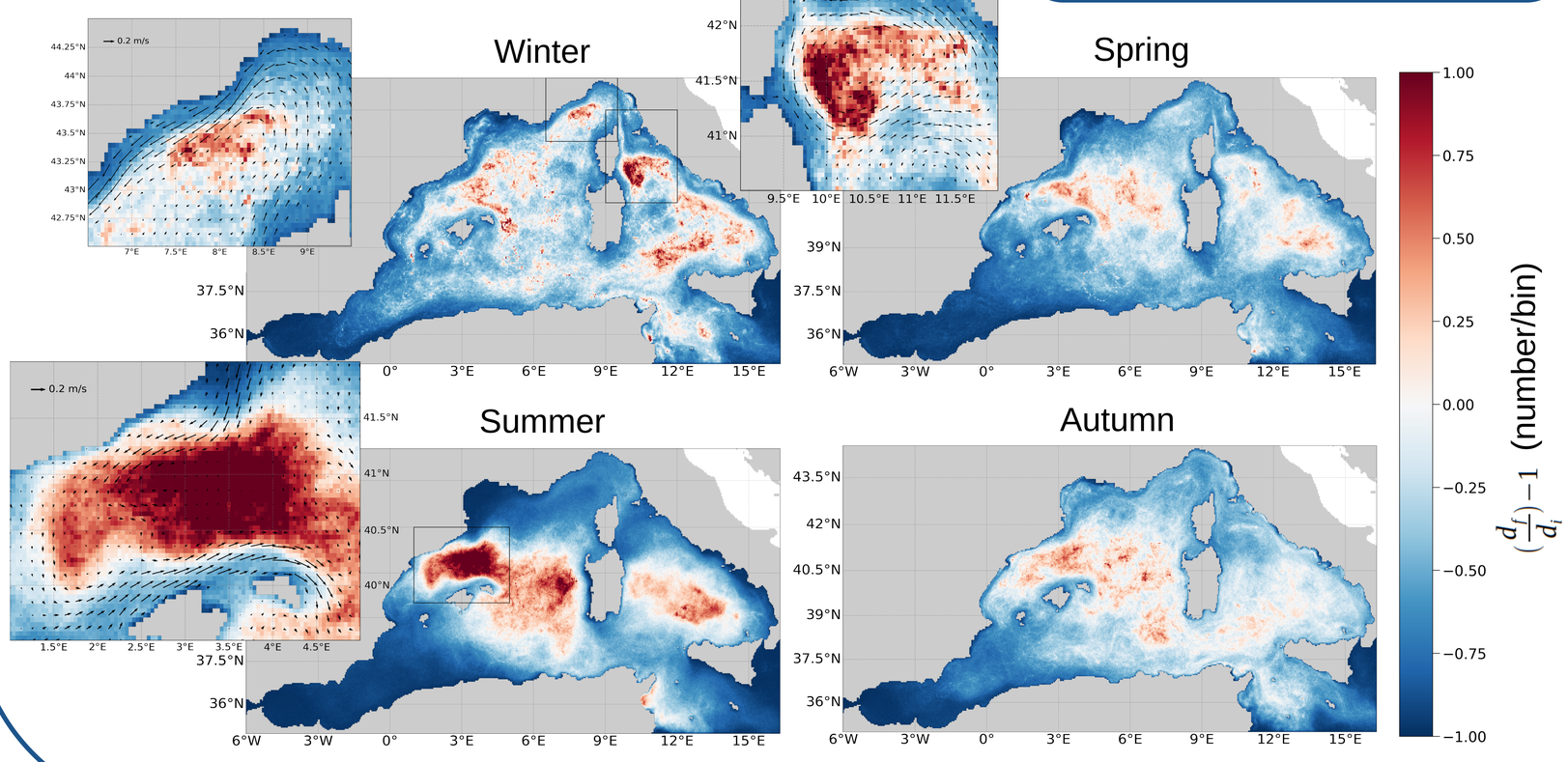

Fig 2: Relative density of drifting plastic particles after 3 months drift on the sea surface for each season

II-B – Identify the beaching zones: where does plastic strand on the coast?

When a drifting particle arrives on coastal bins, it has a great probability of stranding, it is therefore classified as beached. After 3 months, we calculate the density of beached particles in each bin (~20km²): $\mathbf{d^b_f}$

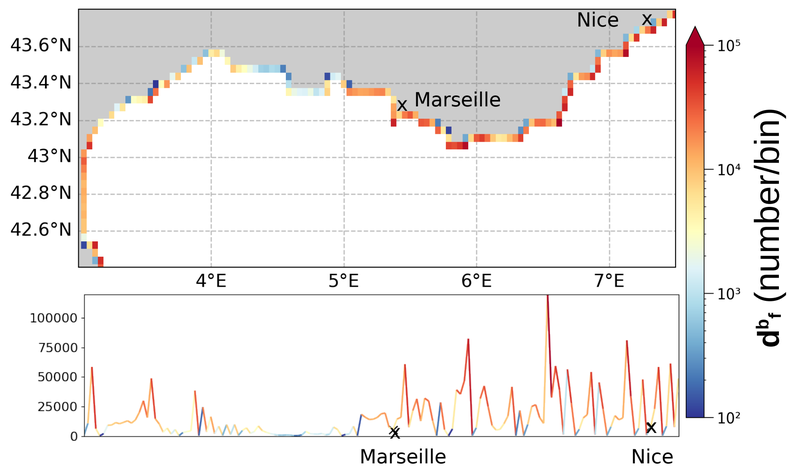

Fig 3: Density of plastic particles beached on the French coast after 3 months drift on the sea surface

On the French coast there are more particles beached between Marseille and Nice than in the Gulf of Lion.

III – Understand mesoscale processes: how is plastic redistributed within an ocean eddy?

Second simulation: Particles are deployed in an **anticyclonic ocean eddy** at the eastern side of Sardinia Island, at **4 fixed depths** (1, 30, 70 and 100m). The particles are **advected for one month with horizontal currents only, starting the 01/11/2022.**

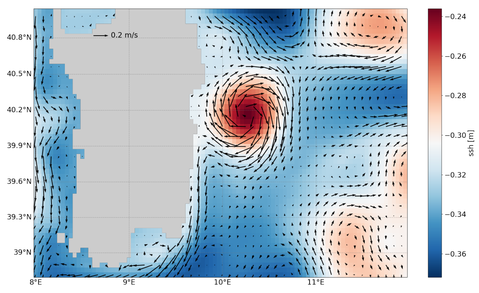

Fig 4: Location of the anticyclonic eddy with sea surface height (ssh)

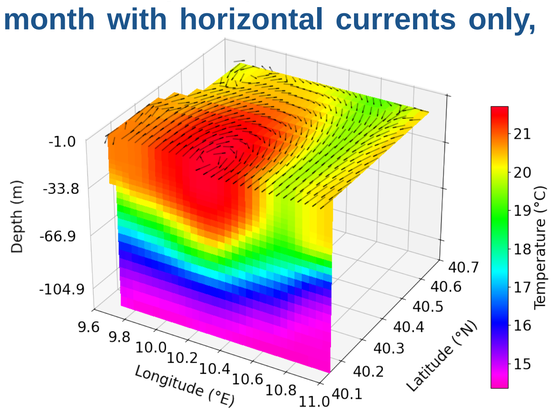

Fig 5: 3D representation of the eddy with temperature and surface currents

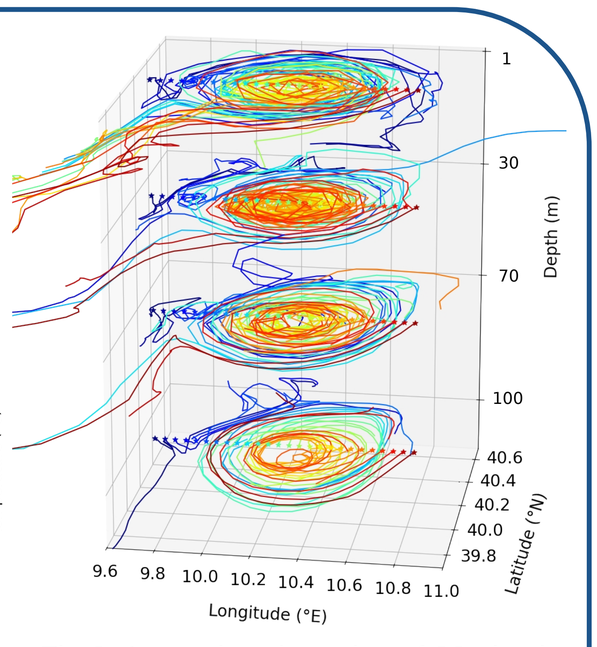

Fig 6: 1-month trajectories of 26 plastic particles at 4 depths within the eddy

Particles on the east side of the eddy (in red) concentrate in the center whereas particles on the west side (in blue) concentrate on the borders of the eddy.

PERSPECTIVES

- Analyze the results and link them with climate indices
- 3D: Introduce vertical speed to take account of the buoyancy of the plastic
- Improve model realism by adding the impact of wind and waves
- Bridge model predictions with available observations on biomedia

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