Modelling the transport of microplastic pollution across the Antarctic Circumpolar Current

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1: Background

- It is estimated that between 4.8 and 12.7 million metric tons of plastic waste enters the world's oceans each year (1).
- Despite its remote location and the presence of the fast eastward currents that make up the Antarctic Circumpolar Current (ACC), the Southern Ocean is not immune to plastic pollution, with **macroplastic pollution (>5 mm)** documented in the Southern Ocean since the 1980s (2), with **microplastic pollution (<5 mm)** also reported more recently (3).
- There are **major gaps in our understanding of the sources, fate and transport pathways** of Southern Ocean plastics (3), especially around how plastics are transported across the ACC.

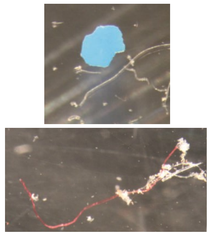

Figure 1: Microplastic found in the Southern Ocean (4).

2: Aims and Objectives

- Incorporate the effect of **underlying ocean currents**, **Stokes drift** and **sub-grid scale diffusion**, on the transport pathways of floating microplastics.
- Identify the most significant **source regions** and **crossing locations** for floating microplastics that cross the ACC.
- Assess the influence of seasons on the transport of floating microplastics across the ACC.
- Investigate if the **Southern Annular Mode (SAM)** or **El Niño–Southern Oscillation (ENSO)** may be partly responsible for interannual variation in the transport of simulated floating microplastics across the ACC.

3: Methodology

- The lagrangian particle tracking framework **OceanParcels** (5), is forced with ocean velocity fields from a Southern Ocean configuration of **NEMO-LIM3** with **1/12 degree horizontal resolution** which has been developed by the **ORCHESTRA** project (6).
- This set up has been validated though comparison with satellite derived flow fields and drifter trajectories.
- We also use Stokes drift at the sea surface data from the **WaveWatch III** model (7) and apply a uniform horizontal diffusion coefficient of 10 m^2s^{-1} to account for sub grid scale processes.
- Simulated floating microplastic particles are released every 0.2° of longitude and latitude within a 1° release zone that is a buffered distance of 0.5° from the long-term northernmost position of the northern boundary of the ACC.
- Particles are released monthly between 1990 and 2011 and advected for 5 years.

OceanParcels NEMO ORCHESTRA OCEAN • CLIMATE • CARBON

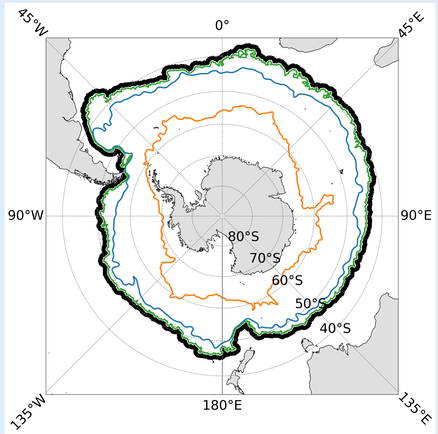

Figure 2: The long term average positions of the southern boundary (orange line) and northern boundary (blue line) of the ACC between 1990 and 2017. Also shown are the northernmost latitudinal location of the northern boundary between 1990 and 2017 (green line) and the release zone (black area).

4: Results

- After being released north of the ACC, simulated floating microplastics are **transported widely across the Southern Ocean.**
- Substantial quantities of **floating microplastics are found to cross the ACC**. Across all model runs, 29.49 % (4.82 %) of simulated floating microplastics crossed the northern boundary (southern boundary) of the ACC within 5 years of release.
- Overall, 0.91% of simulated floating microplastics hit land for the first time at a location south of 60°S and within 5 years of release. Highlighting that **floating microplastics are interacting with the coastline of Antarctica.**

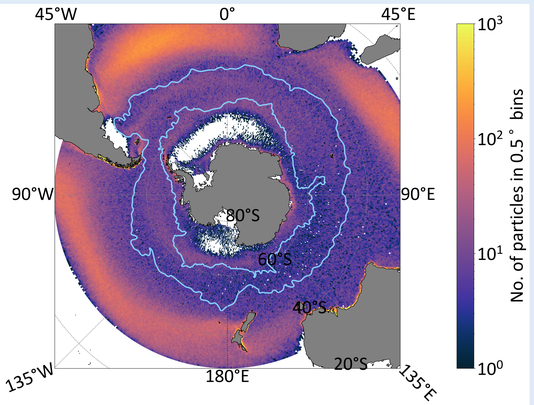

Figure 3: The final locations (binned into 0.5° bins) of simulated floating microplastics released between 1990 and 2011 and advected for 5 years.

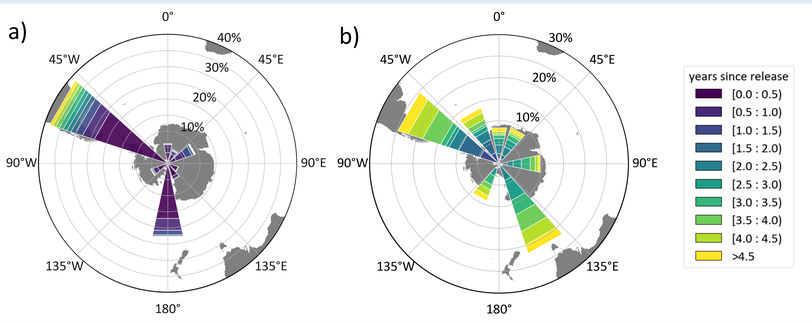

Figure 4: Windrose plots showing the percentage of particles that crossed the **a)** northern boundary and **b)** southern boundary of the ACC within 5 years of release, in 12 30° sectors. The distance each segment extends from the centre indicates the percentage of particles that crossed in that segment and colour corresponds to time since release that said simulated particles crossed the specified ACC boundary.

- We observed notable **interannual variation** in the transport of simulated floating microplastics across the northern and southern boundaries of the ACC.
- There are **significant correlations** (at different time lags) between the number of simulated floating microplastics crossing the northern / southern boundaries of ACC with SAM and ENSO indices.

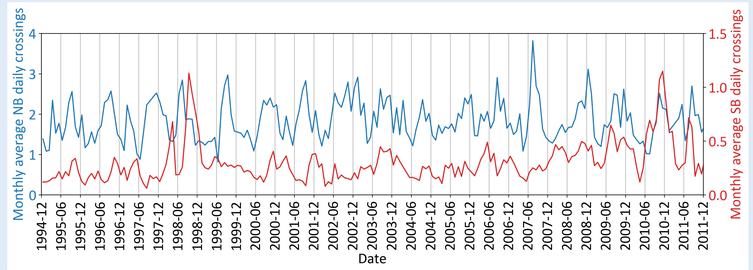

Figure 5: Monthly average daily number of simulated floating microplastics crossing the northern (blue) and southern (red) boundaries of the ACC. Average is calculated using data from 60 monthly releases of 11,139 simulated floating microplastics.

- The **Drake Passage** is a crucial region for the transport of floating microplastics across both the northern and southern boundaries of the ACC.
- In regions where the northern and southern boundary of the ACC are **topographically steered northwards**, we found higher quantities of simulated floating microplastics crossing into or out of the ACC.

5: Future work

- We are now incorporating sea ice into the model set up, which will allow us to investigate the role of sea ice in modifying the transport pathways of floating microplastics in the Southern Ocean.
- Additional work will also examine the distributions of floating microplastics released by research stations on the Antarctic coastline.

Academic Institutions
1: University of Exeter, 2: Plymouth Marine Laboratory, 3: British Antarctic Survey.

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