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Mixed up at the ocean surface: how garbage patch dynamics causes initial information to be lost in particle dispersion models

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The tracking of virtual particles has been one of the main numerical tools to understand the global dispersion of marine plastic debris in the recent literature. Used in combination with certain plastic input scenarios as initial conditions, individual particle trajectories can be computed based on ocean circulation model outputs, and final particle distributions can be compared to actual plastic measurements.

Although this method has been successful in explaining the global-scale accumulation patterns of surface micro plastic (‘garbage patches’), this does not necessarily imply that the transport pathways of individual particles are well-represented by these models. In fact, the surface ocean is a chaotic dynamical system that tends to amplify small uncertainties coming from initial conditions or numerical errors. Within this chaotic system, the garbage patches can be seen as attractors of the surface ocean, playing the role of almost stationary densities (Froyland et al. 2014). This fact, together with the inherent imprecision of plastic input scenarios and ocean circulation models make the surface ocean a mixing dynamical system: given the finite precision, the information of an initial particle location is lost over time, and the correlation between initial and final plastic distributions decays.

The presence of this mixing property is expected for the chaotic ocean surface, yet the time scales of mixing are currently not known. Nevertheless, knowledge of this time scale is important in order to not over-emphasize the role of initial conditions for particle advection modelling, and to calculate the natural threshold in the time scale over which floating material can be backtracked to determine where e.g. a piece of plastic came from.

We use two methods to analyze this mixing property: mixing entropy and the second eigenvalue of the transfer operator associated with surface ocean transport. We find a mixing time at the order of 5 years for all subtropical basins (depending on the precision of available input data), which is lower than typical simulation times for surface plastic simulations. This small time scale explains why previous studies found more or less similar distributions for different input scenarios and advection schemes (van Sebille et al. 2015). Our results have important implications for global dispersion modelling of floating materials as they demonstrate that correlations between initial and final particle distributions should not be over-interpreted, and that precise initial information is irrelevant for long-term simulations.