Local particle retention in oceanic flows from finite-scale absolute dispersion: application to the Mediterranean Sea

Ismael Hernandez-Carrasco[1] and Alejandro Orfila[1]

ihernandez@imedea.uib-csic.es

[1]Mediterranean Institute for Advanced Studies (CSIC-UIB)

Abstract

Residence time has been widely used to determine the water quality of a given marine area by computing the rate of the fluid particle interchange with surrounding waters. However its classical definition has a two-fold dependence on the initial location of the particles and on the boundaries of the analyzed region, common to all initial locations, which results in ambiguous time mixing scales. We propose a new approach based on a generalization of the original definition of the residence time, conventionally defined to provide a global quantity, toward a local measurement around localized points, that we call finite-scale escape rate (FSER). The FSER informs on the local retention properties of the flow around a point. This new definition introduces a measure of the absolute dispersion with the spatial separation as independent variable, allowing us to reveal retention structures of different sizes and their contribution to particle dispersion in geophysical flows. Computing the local escape time by a proper selection of the parameters we are able to identify flow structures and regions in the fluid flow susceptible to strongly trap drifting particles or tracers, such as biogeochemical particles, microplastics or other pollutants. We apply this new Lagrangian metric to study retention properties across the Mediterranean basin using satellite altimetry and drifter trajectories. Our findings show a high temporal variability in regional residence times (see Figure 1), characterized by a range of temporal and spatial scales from monthly to seasonal and larger. Additionally, we analyze the scale dependence of the absolute dispersion showing the different scales that contribute to the dispersion depending on the data resolution. This novel metric enables the assessment of hydrodynamical conditions with a significant impact on transported particles.

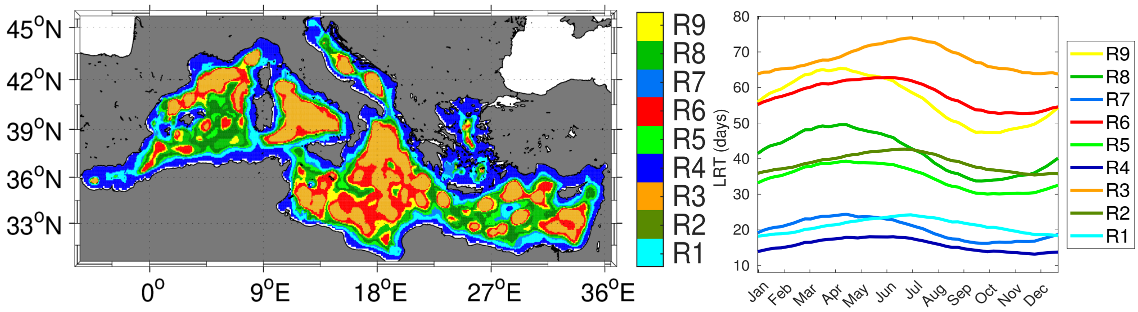

Figure 1: A neural network classification of the Mediterranean sea in coherent regions (left panel) based on the same temporal pattern of variability of local particle retention shown in the right panel.

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