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Marine ecosystem dynamics, ocean circulation and horizontal stirring

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The oceanic submeso and mesoscale circulation and its eddies, filaments, meanders play a major role in marine ecosystems dynamics from the lower trophic levels to the marine top predators. We study here the interplay between turbulence in fluid dynamics on these scales and biological activity at different trophic levels using two cases study.
The first example focuses on the four eastern boundary upwelling zones, the Canary, Benguela, California and Humboldt upwelling systems which constitute the largest contribution to the world ocean productivity. These areas are spatially heterogeneous, populated with a large variety of mesoscale and sub-mesoscale structures such as filaments, plumes and eddies, which control exchange processes between the shelf and open ocean and play a major role in modulating the biomass, rates and structure of marine ecosystems. We will present here results from a lagrangian approach based on Finite Size Lyapunov Exponents (FSLE) using altimetric and scatterometric data to estimate the spatial and temporal variations in the lateral stirring and mixing of tracers in the upper ocean within the four areas. When investigating links with chlorophyll a concentration as a proxy for biological activity in these upwelling systems, results show that surface horizontal stirring and mixing vary inversely with chlorophyll standing stocks. FSLEs lead to a clear clustering of the systems suggesting that one may use them as integrated and comparative indices for characterizing horizontal dynamical features in all eastern boundary upwellings.
Then we investigate the role of submesoscale structures in the Mozambique Channel on the distribution of a top marine predator, the Great Frigatebird. Using similar dynamical concept, the FSLE, we have identified Lagrangian Coherent Structures (LCSs) present in the surface flow in the Channel. By comparing seabirds' satellite positions with LCSs locations, we demonstrate that frigatebirds track precisely these structures in the Mozambique Channel, providing the first evidence that a top predator is able to track these FSLE ridges to locate food patches. We propose several hypotheses to understand how frigatebirds can follow these LCSs. A thorough comprehension of their foraging behaviour and movement during the breeding season is crucial not only to seabirds' ecology but also to an appropriate ecosystemic approach of fisheries in the Channel.