Tree dimensional Lagrangian structures in turbulent flows: application to oceanic processes

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Abstract

The dynamics of the ocean is characterized by multiple time and space scales of motion driven by the energy input at the large-scale ocean gyres. Water masses in the ocean move principally in the horizontal, and vertical velocities are normally negligible due to the combined effect of rotation and stratification. However, vertical motions are at the core of extremely important processes in the ocean, specially, in the vertical exchange of tracers between the stratified interior and the well-mixed superficial layers. The supply of nutrients to the usually nutrient depleted surface waters where photosynthesis and production of new organic matter occurs is one of such processes. Mesoscale motions are an important driver of these vertical exchanges and are responsible for a large supply of nutrients to the euphotic layer.

The Lagrangian perspective of ocean dynamics has benefited greatly with the adoption of several concepts and tools from dynamical systems theory. These contributions deal with the fate of individual trajectories of fluid particles and with ensembles of particles. The study of these provides a powerful insight into the transport properties of turbulent flows and how these properties affect the budget of physical and biogeochemical tracers such as carbon dioxide or oxygen in the ocean. A very useful concept is the Lagrangian coherent structure that may be defined as a region of the flow that greatly impacts the behavior of fluid masses in its vicinity. They behave as barriers or pathways to transport in the ocean and have an important effect in the turbulent fluxes of tracers. Most of the applications have been to two-dimensional settings but given the importance of vertical motions in several critical processes occurring in the ocean, the study of these structures in three dimensions is a pressing and prominent step forward in our understanding of the ocean.

In three different oceanic settings, 3D Lagrangian structures were found to determine fluid transport and consequently the exchange of physical and biogeochemical properties between distinct physical and biogeochemical regions: mesoscale eddy interior/exterior in the Benguela upwelling regions; the Peruvian OMZ core/exterior oxygenated regions and near-shore cold waters and offshore warm waters in the Iberian upwelling region.