Lagrangian predictability in weakly ageostrophic surface ocean turbulence

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Upper-ocean turbulent flows at horizontal length scales smaller than the deformation radius (the submesoscale range) depart from geostrophic equilibrium and develop important vertical velocities, which are key to marine ecology and climatic processes. Due to their small size and fast temporal evolution, these fine scales are difficult to measure from satellites and in oceanographic campaigns. New, high-resolution satellite altimetry has very recently started to reveal them. However, to compute horizontal transport properties or surface energy exchanges, it is crucial to assess how well the horizontal velocities provided by the satellite compare to actual surface currents and down to what length scale. Indeed, the satellite-derived velocities should represent the geostrophic flow component, and the impact of unresolved ageostrophic motions on transport and dispersion features needs to be assessed. In this study, we investigate ocean submesoscale turbulence from a Lagrangian point of view, relying on numerical simulations of a model including (weakly) ageostrophic motions [1,2]. The model originates from a Rossby-number expansion of the primitive equations and recovers the surface quasi-geostrophic one [3], a paradigm of submesoscale dynamics, in the limit of vanishing Rossby number. We focus on the predictability of the full Lagrangian trajectories when using a filtered flow, where ageostrophic motions are artificially removed. Specifically, we consider Lagrangian tracer dynamics for particles advected by either the total velocity field or by its geostrophic component only, to perform a systematic comparison of the flow transport properties, in terms of single and two-particle statistics. Our results indicate that, over long times, both the particle mean-square displacement and relative dispersion are only weakly affected by the ageostrophic component of the velocity field. However, advection by the geostrophic-only flow tends to overestimate the typical pair-separation rate. We then provide a characterization of the temporary particle clusters that form due to ageostrophic motions, showing that Lagrangian tracers preferentially accumulate in cyclonic frontal regions, in agreement with observations from real drifters. We further find that, while compressibility is always small in our simulations, due to the smallness of the Rossby numbers explored, the intensity of clustering can be relevant. Our analysis suggests that, in this system, clustering is essentially due to the interplay between the (small) flow compressibility and the existence of long-lived structures that trap particles, enhancing their aggregation.

Références

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