Lagrangian particle dynamics in weakly ageostrophic surface ocean turbulence

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Ocean flow features in the submesoscale range correspond to length scales of $\mathcal{O}(10)$ km or smaller and time scales of the order of a day. Recent studies have shown that such small scales can have a relevant impact on the transport and dispersion properties of Lagrangian tracer particles. Moreover, data from high-resolution general circulation models indicate that ocean submesoscales are associated with important vertical velocities, and thus should play a prominent role for climatic processes and marine ecology. However, the latter scales are difficult to measure due to their small size and fast temporal evolution. Therefore, the understanding of their dynamics still appears incomplete. In particular, a key open question concerns the characterization of the non-geostrophic flow components, which are expected to gain importance as the considered scales get smaller. We explore this question by means of numerical simulations of a model that includes ageostrophic motions associated with fronts, and that is derived as a small, but finite, Rossby number approximation of the fundamental equations of motion[1]. In the limit of vanishing Rossby number, this model describes surface quasi-geostrophic dynamics.

We focus on the effect of the ageostrophic flow on the transport and dispersion properties of Lagrangian tracer particles. Moreover, we investigate the mechanisms controlling the phenomenon of particle clustering, which was recently put in evidence by observations of surface drifter trajectories in different ocean regions. Using different statistical indicators to examine the characteristics of the turbulent flow, we aim at assessing the impact of the latter on the spatial distribution of particles. Our results show that, while over long times initially close Lagrangian trajectories separate; furthermore, the ageostrophic flow components are responsible for the temporary formation of particle clusters, and that the intensity of this phenomenon increases with the Rossby number. Moreover, we provide evidence that Lagrangian tracers preferentially accumulate in frontal regions characterized by intense strain and positive (i.e. cyclonic) vorticity, in agreement with observations and other, more realistic modeling studies[2].

These findings demonstrate that the relatively simple model we adopted captures some of the main features characterizing ocean turbulence at submesoscales, and can help shedding light on the mechanisms underlying particle clustering in this range of scales.

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[2] Vic, Hascoët, Gula, Huck and Maes, *Geophysical Research Letters* **49**, (2022).