Submesoscale Flows in the Oceanic Surface Layer

M. Jeroen Molemaker
Department of Atmospheric and Oceanic Sciences
University of California, Los Angeles

Despite the importance of submesoscale flows to climate and its prediction, and the suggested ubiquity of submesoscale flows from numerical modeling studies, the understanding of submesoscale flows is still limited. This limitation is due to the difficulty of sampling submesoscale features that exist at small length and time scales. Flows at submesocales represent ocean dynamics between boundary layer turbulence and geostrophically dominated mesoscales. This transitional regime is important from a dynamical perspective, since it represent flows in which the dominant horizontal force balance between pressure gradients and Coriolis force (geostrophic balance) is relaxed. Submesoscale flows play a crucial role in the global energy budget of the ocean circulation since they provide a pathway of energy to a forward turbulent energy cascade and dissipation scales where molecular viscosity is effective. Additionally, while mesoscale flows are dynamically restricted to two-dimensional, horizontal currents, the relaxation of geostrophic balance allows the emergence of significant vertical velocities, with strong implications for ocean-atmosphere gas exchanges and sources and sinks of biogeochemical tracers.

We aim to improve understanding of the submesocale, its dynamics and its associated effects on the lateral mixing of tracers at scales between 100m and 10km. In addition to lateral mixing of tracers, these small scale flows can also lead to significantly enhanced diapycnal mixing rates. This will enhance the interpretation of high resolution remotely sensed data products and help predict mixing rates and small scales.

Our tool of choice is the Regional Ocean Modeling System (ROMS) of which our group at UCLA is a major developer. We have developed tools that allow us to design and compute a flexible set of nested computational domains. We start with the computation of basin scale flows using realistic climatological forcing fields at the ocean surface. The resolution of the basin scale grids is O(10km), which is not sufficient to resolve the small scale features in which we are interested. A set of numerically nested solutions is computed at increasingly high resolutions.

A range of numerical solutions were obtained for the LatMix target region of the northwestern Atlantic for both summer and winter conditions. Using our computational nesting ability, numerical grids were designed to accurately compute many examples of specific submesoscale phenomena as well as statistics for the quasi-uniform turbulent regions south and east of the Gulf Stream. Using innovative LatMix observations, the models distributions of vorticity, strain, and divergence in the wintertime oceanic mixed layer were validated (Shcherbina, 2013). This implies that the modeled processes are likely to be occurring in the ocean. These include frontogenesis and frontal instability, finite-Rossby number effects (not found in a QG or SQG model), lateral mixing on submesoscale space and time scales, trapping of surface buoyant particles into convergence lines, and forward energy cascade toward dissipation and diapycnal tracer mixing. The model predicts relatively flat spectra of velocity variance in the submesoscale range which suggests a limited predictability of surface layer quantities compared to what it would be with only mesoscale eddies.