Surface semi-geostrophic dynamics in the ocean

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The surface quasi-geostrophic approximation is re-written in an oceanic context using the two-dimensional semi-geostrophic approximation. The new formulation allows to take into account the presence of out-of-balance flow features at scales comparable to or smaller than the Rossby radius of deformation and for small bulk Richardson numbers. Analytical solutions show that, while the surface quasi-geostrophic approximation tends to underestimate the buoyancy anomaly, the inclusion of finite Rossby number allows for larger values of the buoyancy
anomaly at depth. The projection of the surface semi-geostrophic solution on the first baroclinic modes is calculated. The result of the projection is a functional form that decreases with the values of the Rossby number and toward smaller scales. Solutions for constant and exponential profile for the background potential vorticity are compared. Results of the comparison show that, in agreement with the results found for balanced flows, even for large Rossby number the exponential profile for the background potential vorticity retains smaller values for the buoyancy anomaly at depth than the solution found using a constant potential
vorticity profile.