Dynamical Influences on Observation Impacts for Ocean Data Assimilation

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Abstract

The impact of observations on analysis and forecast estimates depends on several factors which include the configuration of the data systems system (e.g. assumptions made about the background error covariance and observation error covariance matrices). However, there are fundamental underlying dynamical constraints that will also control the impact of different observations even in the case of a perfect data assimilation system.

At low Rossby numbers ($R_o \ll 1$), the ocean circulation is in quasi-geostrophic balance, and the theory of geostrophic adjustment indicates that for scales of motion $\gg$ the Rossby radius of deformation, direct observations of the density field (i.e. temperature and salinity observations) will have more impact on data assimilation circulation estimates than observations of the velocity. For scales of motion $\ll$ the Rossby radius, velocity observations can be expected to have the greatest impact. For scales ~ Rossby radius, there is approximately equal partitioning of energy between potential and kinetic forms, so both observation types can be expected to contribute equally.

For nonlinear flow regimes $R_o \sim 1$ so the expectations of geostrophic adjustment theory cannot necessarily be assumed to apply. Nonetheless, for boundary currents, even though R_o maybe ~ 1, the alongshore component of the current is generally in quasi-geostrophic balance, and geostrophic adjustment theory may work reasonably well in this case for explaining the relative impact of different types of observations.

At the submesoscale $R_o = U/fL$ is also ~ 1. Such circulations are not necessarily vigorous since for typical submesoscale features with length scales $L \sim 1$ km, then at middle latitudes $R_o \sim 1$ for modest flows $U \sim 0.1$ ms^{-1}. Furthermore, submesoscale circulations are typically a mix of quasi-geostrophic and inertia-gravity wave regimes, in which case it is reasonable to ask what dynamical constraints might we expect on the relative impact of different observations in these situations based on energetic considerations?

These ideas will be explored in a nested configuration of the ROMS 4D-Var data assimilation system in the Mid-Atlantic Bight where we quantify the impact of observations from different observing platforms on different aspects of the ocean circulation. A triply nested configuration of ROMS with grid refinement employing both 1-way and 2-way nesting is used which captures a wide range of scales and dynamical regimes, ranging from the quasi-geostrophic Gulf Stream western boundary current, the associated energetic mesoscale eddy field, and the secondary and frontal instabilities that subsequently develop at the submesoscale.