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Impact of representativeness errors in an ocean application for the Back-and-Forth Nudging method

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The goal of data assimilation (DA) is to combine, in the "best" possible way, all available sources of information of a given system to reconstruct its state. The appropriate weight given to observations and models is a function of their respective errors. In the specific case of oceanographic applications, one significant source of errors is discretization as, for instance, it truncates the portion of the spectrum being explicitly resolved. Spectral differences between the observations and the model solutions represent a challenge in data assimilation because: i) The statistical properties of the representativeness errors need to be estimated, and ii) in a nonlinear system, the realism of the resolved spectra depends on the validity of the physical parameterization of the effects of the non-resolved processes. Finding appropriate strategies to deal with these two issues remains one of the major present efforts in ocean data assimilation.
In this work, we investigate the problem of assimilating data coming from an eddy resolving ocean simulation into an eddy permitting model. With such a setting, the ocean model cannot be considered as perfect because the observations contain information of a spectral band not accounted by the model, and also because it should be expected that the resolved spectral band slightly differs between the data and the model. Therefore, this experimental setting allows the presence of both errors of representativeness of observations and model errors due to unsatisfactory parameterization of diffusive/viscous processes.
This study has been conducted using an idealized simulation of a subtropical double gyre circulation (SQB gyre) using the NEMO model (Madec and the NEMO team, 2008). The observations are derived from a high resolution configuration (1/12°), while the assimilative model has a coarser (1/4°) resolution. The most significant mean difference between both free solutions is the southward displacement of the convergence zone observed in the 1/12° simulation. This difference is probably induced by interactions between small and large scales, better resolved in the higher resolution model. Similar modeling issues were reported for correctly positioning the Brazil-Malvinas confluence and the Gulf Stream separation from the coast. In both cases the differences found between model and data could be reduced thanks to an increase of the model resolution.
The data assimilation method used in our experiments is the Back and Forth Nudging (BFN, Auroux and Blum, 2005), that avoids the perfect model hypothesis by adding an additional term into the prognostic equation in order to relax the model towards the observations. We investigate the ability to reconstruct the observed time series at each observation location and correct the position of the frontal structures as well as the time persistence once the nudging term is removed with respect to the spatial and temporal observations sampling (Jason-2, and SWOT). Lastly, the advantage of the back and forth iterations is assessed by comparing the results with the pure straight nudging method for which only the forward model is used.