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Ensemble experiments to estimate model error statistics for data assimilation in a nested coastal ocean model

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The control of coastal ocean circulation using data assimilation techniques is still an open problem. This is due to the complexity of the non-linear phenomena characterizing the coastal circulation and the difficulty to acquire appropriate sets of accurate observations. In this work, we are developing a reduced order Kalman filter (a variant of the SEEK filter) to control a regional model of the bay of Biscay. The model is a HYCOM configuration between 14.80°W - 1.04°W and 43.21°N - 50.82°N with a 1/15° resolution, covering the Biscay abyssal plain and a large part of the Celtic continental shelf. It is nested in a 1/3° HYCOM configuration of the North Atlantic basin.

In order to use a Kalman filter for controlling such a complex dynamical system, it is of primary importance to identify the main sources of error and to provide an accurate parameterization of the corresponding error covariance matrices. In our system, two important sources of errors are the atmospheric forcing and the open sea boundary conditions. Firstly, the dynamics of coastal models is strongly constrained by the turbulent heat, fresh water and momentum fluxes imposed at the air/sea interface. Such fluxes are known to be affected by important errors, and the problem is amplified in coastal regions, where the atmospheric fluxes are usually derived from global reanalyses without specific tuning near the coast. Secondly, the dynamics of coastal models is also strongly dependent on the data imposed at the open boundaries. The low resolution model error feeds the high resolution model with imperfect data. Moreover, an imperfect nesting protocol can lead to inconsistency between the low resolution and the high resolution dynamics at the open/sea boundaries.

The purpose of this contribution is to address the problem of the parameterization of these two main sources of error in a low rank Kalman filter. The structure of the model

error due to the atmospheric forcing and to open sea boundary conditions is estimated from ensemble experiments. We build an ensemble of atmospheric forcings and an ensemble of boundary conditions that represent the error probability density on these two sources of information, and we fulfill an ensemble of simulations forced by these two ensembles of forcings. From the resulting ensemble of simulations, we can study the structure of the error that is generated in the system. We focus on the two first moments of the resulting error probability distribution: the mean and the covariance.

As a first result, we show that even by using zero mean error probability density on the forcing, we can obtain a biased error structure on the model state. This is the consequence of the nonlinear processes in the model, and can be of significant importance in the setup of a Kalman filter, which is not originally conceived to deal with biases. As a second result, we have computed representers associated to the resulting error covariance. The representers show the influence that an observation would have if analysed using that covariance matrix to parameterize the background error on the ocean state. The study of the representers allows us to anticipate the behavior of the assimilation system. We can evaluate in particular the impact of the vertical coordinate (z coordinate vs hybrid coordinate) on the statistical analysis, the impact of various features of the circulation on the error structure, and hence, the impact of various observation systems such as altimetry, sea surface temperature, or in situ profiles, according to their location in the open ocean or on the shelf.