Evaluating Data Assimilation Algorithms

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Data assimilation leads naturally to a Bayesian formulation in which the posterior probability distribution of the system state, given the observations, plays a central conceptual role. The aim of this paper is to use this Bayesian posterior probability distribution as a gold standard against which to evaluate various commonly used data assimilation algorithms.
A key aspect of geophysical data assimilation is the high dimensionality and low predictability of the computational model. With this in mind, yet with the goal of allowing an explicit and accurate computation of the posterior distribution, we study the 2D Navier-Stokes equations in a periodic geometry. We compute the posterior probability distribution by state-of-the-art statistical sampling techniques. The commonly used algorithms that we evaluate against this accurate gold standard, as quantified by comparing the relative error in reproducing its moments, are 4DVAR and a variety of sequential filtering approximations based on 3DVAR and on extended and ensemble Kalman filters.
The primary conclusions are that: (i) with appropriate parameter choices, approximate filters can perform well in reproducing the mean of the desired probability distribution; (ii) however they typically perform poorly when attempting to reproduce the covariance; (iii) this poor performance is compounded by the need to modify the covariance, in order to induce stability. Thus, whilst filters can be a useful tool in predicting mean behavior, they should be viewed with caution as predictors of uncertainty. These conclusions are intrinsic to the algorithms and will not change if the model complexity is increased, for example by employing a smaller viscosity, or by using a detailed NWP model.

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