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Accounting for model error in data assimilation. A deterministic formulation

Alberto Carrassi[1], Stephane Vannitsem[1]

[1]*Royal Meteorological Institute of Belgium, Bruxelles, Belgium*

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Data assimilation is confronted with the presence of model errors arising from the imperfect description of atmospheric dynamics. Due to the lack of a unique framework for the model error treatment and to the difficulty to accumulate reliable statistics, these errors are usually either ignored or modeled on the basis of simple assumptions such as white noise or first order Markov process.

By using a deterministic formulation, an approach to account for the model error in data assimilation is proposed. This deterministic perspective has been the guideline for model error treatment in sequential and variational schemes. The approach is based on a formal expression for the deterministic evolution of the model error and on the use of an approximation suitable for practical nonlinear filtering problems. The accuracy of this approximation is inherently connected to the stability property of the dynamics such as the spectrum of Lyapunov exponents. The numerical analysis is performed using low order chaotic prototypes of geophysical fluids.

First, the deterministic description of the model error evolution, incorporated into the classical extended Kalman filter equations, is used to estimate the contribution to the forecast error covariance due to model imperfections. Results reveal that substantial improvements of the filter accuracy can be gained as compared with the classical white noise assumption.

A natural step ahead implies the online estimation of the model parameters in conjunction with the system's state. The EKF in the state augmentation formulation is implemented. The dynamical evolution law for the model error allow now for the estimation of the cross covariances between errors in the state estimate and parameters, and both are efficiently evaluated online over a wide range of initial parametric error amplitude.

The extension to variational schemes is presented in the sequel. The state estimation problem requires here the model error time correlations. A straightforward way to estimate these correlations using the deterministic approach is proposed, and it is incorporated in the weak-constraint variational assimilation. Results with two simple dynamics of increased complexity suggest the potential for the successful application to more realistic situations.