Geophysical Research Abstracts
Vol. 17, EGU2015-8510, 2015
EGU General Assembly 2015

A simple new filter for nonlinear high-dimensional data assimilation

Julian Tödter (1), Paul Kirchgessner (2), and Bodo Ahrens (1)

(1) Goethe University, Institute for Atmospheric and Environmental Sciences, Frankfurt/Main, Germany (toedter@iau.uni-frankfurt.de), (2) Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Bremerhaven, Germany (paul.kirchgessner@awi.de)

The ensemble Kalman filter (EnKF) and its deterministic variants, mostly square root filters such as the ensemble transform Kalman filter (ETKF), represent a popular alternative to variational data assimilation schemes and are applied in a wide range of operational and research activities. Their forecast step employs an ensemble integration that fully respects the nonlinear nature of the analyzed system. In the analysis step, they implicitly assume the prior state and observation errors to be Gaussian. Consequently, in nonlinear systems, the analysis mean and covariance are biased, and these filters remain suboptimal. In contrast, the fully nonlinear, non-Gaussian particle filter (PF) only relies on Bayes' theorem, which guarantees an exact asymptotic behavior, but because of the so-called curse of dimensionality it is exposed to weight collapse.

This work shows how to obtain a new analysis ensemble whose mean and covariance exactly match the Bayesian estimates. This is achieved by a deterministic matrix square root transformation of the forecast ensemble, and subsequently a suitable random rotation that significantly contributes to filter stability while preserving the required second-order statistics. The forecast step remains as in the ETKF. The proposed algorithm, which is fairly easy to implement and computationally efficient, is referred to as the nonlinear ensemble transform filter (NETF).

The properties and performance of the proposed algorithm are investigated via a set of Lorenz experiments. They indicate that such a filter formulation can increase the analysis quality, even for relatively small ensemble sizes, compared to other ensemble filters in nonlinear, non-Gaussian scenarios. Furthermore, localization enhances the potential applicability of this PF-inspired scheme in larger-dimensional systems.
Finally, the novel algorithm is coupled to a large-scale ocean general circulation model. The NETF is stable, behaves reasonably and shows a good performance with a realistic ensemble size. The results confirm that, in principle, it can be applied successfully and as simple as the ETKF in high-dimensional problems without further modifications of the algorithm, even though it is only based on the particle weights. This proves that the suggested method constitutes a useful filter for nonlinear, high-dimensional data assimilation, and is able to overcome the curse of dimensionality even in deterministic systems.