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A Comparison of Different Hybrid Methods on the Lorenz 1963 Model

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Hybrid data assimilation schemes are becoming more widely used in Numerical Weather Prediction (NWP). These methods combine ideas from successful schemes such as 4DVAR and the ensemble transform Kalman filter (ETKF). The motivation behind hybrid schemes is to make use of a flow-dependent background error covariance matrix (Pb) in a variational setting. Although some of these hybrid schemes are being used operationally now, several basic questions on the reasons behind their performance are still open.

Hybrid methods mainly differ in their use of Pb. Here we study 3 formulations. The first scheme, ETKF-4DVAR, uses Pb from the ETKF and combines it (weighted) with the climatological background error covariance matrix in 4DVAR (Bclim), at the start of each assimilation window. The second scheme, 4DVAR-BEN, is similar to ETKF-4DVAR but has zero weighting on Bclim. The third scheme, 4DENVAR, uses a the 4-dimensional covariance from the ensemble that alleviates the need for the tangent-linear and adjoint model in the 4DVar.

We systematically compare the performance of ETKF-4DVAR, 4DVAR-BEN and 4DENVAR with respect to two traditional schemes (4DVAR and ETKF) on the Lorenz 1963 model. Using the analysis root mean square error (RMSE) as a metric, these schemes have been compared considering (1) assimilation window length and observation interval size, (2) ensemble size and (3) inflation of the climatological background error covariance matrix.

For short assimilation windows, hybrid schemes are shown to outperform traditional methods. As the assimilation window length increases, sequential schemes become more accurate over both traditional variational and hybrid schemes which use an adjoint model. The 4DENVAR scheme performs slightly better in most cases than the ETKF over longer assimilation windows, which suggests that replacing the adjoint model by 4D-covariances from sequential schemes can increase the accuracy of variational schemes.