Initial Trials of 4D-Ensemble-Var for Data Assimilation and Ensemble Initialization

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Hybrid data assimilation schemes augment flow-dependent ensemble covariances with extra samples from a climatological covariance. Variational hybrids combine ensemble information with the existing investment in methods such as 4-dimensional variational assimilation (4DVar) [1]. However, the perturbation-forecast and adjoint models which 4DVar uses to evolve covariances over time impose significant computational and maintenance cost, and may not scale well on future massively parallel computer systems. 4D-Ensemble-Var (4DEnVar) offers an alternative approach, in which the temporal correlations are taken from the ensemble [2,3].

This presentation will show results from early trials of 4DEnVar in the Met Office global Numerical Weather Prediction (NWP) system. For initializing a deterministic forecast, we find that 4DEnVar is superior to 3DVar and hybrid-3DVar, has similar average performance to 4DVar, but is inferior to hybrid-4DVar (the current operational system), when all are run at the same resolution. 4DEnVar performs relatively worse in the Southern Hemisphere, where reduced observation density places greater reliance on the accuracy of the ensemble covariances. However, the 4DEnVar system is a factor 3-6 cheaper than hybrid-4DVar, even though the latter has been optimized much more than the former. These cost savings could be recycled into extra resolution, extra ensemble members, and/or use of an outer loop.

The reduced cost of 4DEnVar makes it an attractive method for ensemble initialization. It has theoretical advantages over the Ensemble Transform Kalman Filter (ETKF) currently used by the Met Office, in areas such as localization, re-linearization, the use of balanced variables, and greater consistency with the way the central analysis is produced [4]. A single system serving both purposes should also reduce maintenance costs. Better ensemble perturbations may in turn benefit the hybrid data assimilation, further improving both the deterministic and ensemble forecasts. We will present the results of initial trials comparing 4DEnVar with the current ETKF in the global ensemble, including consideration of alternative inflation methods such as relaxation-to-prior-spread and additive inflation, and re-centering of the ensemble about the high-resolution deterministic analysis.

References

[1] A. M. Clayton, A. C. Lorenc, D. M. Barker. "Operational implementation of a hybrid ensemble/4D-Var global data assimilation system at the Met Office," *Q. J. R. Meteorol. Soc.*, DOI: 10.1002/qj.2054, November 2012.

[2] C. Liu, A. Xiao, B. Wang. "An Ensemble-Based Four-Dimensional Variational Data Assimilation Scheme. part II: Observing System Simulation Experiments with advanced research WRF (ARW)," *Mon. Weather Rev.*, vol. 137, no. 5, pp. 1687–1704, May 2009.

[3] M. Buehner, P. L. Houtekamer, C. Charette, H. L. Mitchell, B. He. "Intercomparison of variational data assimilation and the ensemble Kalman filter for global deterministic NWP. Part II: One-month experiments with real observations," *Mon. Weather Rev.*, vol. 138, no. 5, pp. 1567–1586, May 2010.

[4] N. E. Bowler, J. Flowerdew, S. R. Pring. "Tests of different flavours of EnKF on a simple model," *Q. J. R. Meteorol. Soc.*, DOI: 10.1002/qj.2055, December 2012.