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Evaluating the role of the EOF analysis in 4DEnVar methods

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The four-dimensional variational data assimilation (4DVar) method is one of the most popular techniques used in numerical weather prediction. Nevertheless, the needs of the adjoint model and the linearization of the forecast model largely limit the wider applications of 4DVar. 4D ensemble-variational data assimilation methods (4DEnVars) exploit the strengths of the Ensemble Kalman Filter and 4DVar, and use the ensemble trajectories to directly estimate four-dimensional background error covariance. This study evaluates the role of the empirical orthogonal function (EOF) analysis in 4DEnVars. The widely recognized 4DEnVar method DRP-4DVar (the Dimension-reduced projection 4DVar) is adopted as the representation of EOF analyses in this study. The performance of the Dimension-reduced projection 4DVar (DRP-4DVar), 4DEnVar (i.e. another traditional 4DEnVar scheme without EOF transformation) and the Ensemble Transform Kalman Filter (ETKF) was compared to demonstrate the effect of the EOF analysis in DRP-4DVar. Sensitivity experiments indicate that EOF analyses construct basis vectors in eigenvalue space and the dimension reduction in DRP-4DVar approach helps improve computational efficiency and analysis accuracy. When compared with 4DEnVar and the ETKF, the DRP-4DVar demonstrates similar analysis root-mean-square error (RMSE) to 4DEnVar, whereas surpass the ETKF by 22.3%. In addition, sensitivity experiments of DRP-4DVar on the ensemble size, the assimilation window length and the standard deviation of the initial perturbation imply that the DRP-4DVar with the optimized EOF truncation number is robust to a wide range of the parameters, but extremely low values should be avoided. The results presented here suggest the potential wide application of EOF analysis in the hybrid 4DEnVar methods.

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