Geophysical Research Abstracts
Vol. 12, EGU2010-15148, 2010
EGU General Assembly 2010

An efficient Matrix-free implementation of the Ensemble Kalman Filter

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In this work we present an efficient matrix-free implementation of the EnKF for parallel computations. The Ensemble Kalman Filter (EnKF) has increasingly become an essential tool for initializationn and calibration of numerical models. As more data becomes available for assimilation a potential bottleneck in the EnKF is the matrix inversion included in the Kalman gain matrix. The standard method applied for the matrix inversion is either LU decomposition followed by inversion, or the singular valued decomposition (SVD). Both methods exhibit a cost of $O(n^3)$, making them expensive and time consuming. Additionally there are no simple parallel implementation for these methods. In this work we propose the use of a matrix-free Krylov iterative method with a Sherman-Morrison preconditioner. The particular form of the EnKF matrices is fully exploited by the Sherman-Morrison identity. Using this advantage, a solver based on the Sherman-Morrison formulas is used as a preconditioner for the Krylov iterative method. This preconditioner significantly reduces the number of iteration needed for convergence, hence reducing the computational cost of implementing a Krylov solver. Numerical experiments with a Lorenz-96 model are presented where the computational time and accuracy of the matrix-free implementation is compared with an SVD based implementation.