A Numerical Approximation Method for Fast Computations of Matrix-Vector Products with Spatially Correlated Observation Error Statistics

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Abstract

Recent studies have shown that observations such as geostationary satellite observations and Doppler radar radial winds can exhibit strong spatial error correlations. The estimated error correlation lengthscales are found to be significantly longer than the observation-thinning distances used by many operational centres. Therefore, there is a need to include the correlated error statistics in the data assimilation procedures. However, this can potentially increase the computation costs for the matrix-vector multiplications arising in the solution of the variational minimization problem. The calculation of these matrix-vector products is perfectly parallel when observations are distributed across different processing elements (PEs) according to their geophysical locations and if their errors are assumed to be uncorrelated. However, if correlated error statistics are used, the PEs cannot complete their own tasks without excessive communications between each other. Previous studies have proposed many methods or strategies that can be used to reduce the computational cost. These include allocating observations with correlated errors into one PE and using the Cholesky decomposition, assimilating spatial difference observations, using truncated eigen-decomposition to approximate the error covariance matrix, using data compression technique to reduce the number of observations and using diffusion operators to model correlated errors. In this presentation, we will present a new numerical approximation method developed based on the fast multipole method. This method works with the domain decomposition of the observations and can compute the matrix-vector products with reduced communication costs.

Keywords: Observation error covariance matrix, spatial error correlations, fast multipole method, matrix, vector multiplications, parallelization

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