The Tensor Hybrid forecast covariance model: unifying localization and hybridization

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Abstract

The true forecast error covariance matrix P^f plays a crucial role in the accuracy of numerical weather prediction (NWP) systems. P^f is unknown, and it has to be estimated in some way. A method for this is given by the Hybrid covariance matrix. Although operationally successful, the Hybrid does not have the correct climatological mean. The coefficients in its linear combination are scalar, lacking any geographical dependence. Also, little theoretical justification was provided for its formula.

In the present work, we define P^f through a thought experiment involving an infinite number of copies of the Earth. We then implement this experiment on a computer using the Lorenz 96 model. We compute P^f at each DA cycle, showing that it is time-dependent. The set of P^f's for all DA cycles defines their climatological distribution, which we experimentally reveal (for the first time in DA research).

We then develop a general Bayesian theoretical framework for the problem of estimating P^f. In this Bayesian framework, the prior is given by the climatological distribution for P^f (its mean is the climatological covariance matrix P^c) and the likelihood function involves the ensemble covariance matrix. Within this general framework, we apply the Kalman filter to the true forecast covariance matrix estimation problem. This unifies hybridization and localization into one geographically dependent procedure, and it gives rise to new Hybrid covariance matrix models, such as the Tensor Hybrid, the reduced Tensor Hybrid and the T-matrix Hybrid. We also introduce a variant of each of these covariance models by performing a change of variables with which P^c is the identity (standardized variables). We introduce a new algorithm to make this change of variables computationally affordable. The T-matrix Hybrid in standardized variables has the correct climatological mean, and it significantly outperforms the current Hybrid in two synthetic experiments.

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