A Hybrid Variational-Ensemble Data Assimilation Method with an Implicit Optimal Hessian Preconditioning

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Hybrid variational-ensemble data assimilation has been the focus of research and applications in recent years. The advantages of hybrid methods are generally due to using an error covariance that has both full rank and flow dependence, as well as being able to account for nonlinearities of the model and observation operators. A common characteristic of hybrid methods is that nonlinearity is addressed through its variational component that typically employs an iterative minimization to numerically obtain the optimal solution. However, since variational data assimilation is searching for the solution in model or observation spaces, both of very high dimensions, the mathematically correct solution equation has to be approximated. This eventually results in numerous minimization iterations with undesirable impact on efficiency and accuracy of the analysis solution.

In this presentation we will present a new hybrid-variational data assimilation method that has a potential to overcome the above deficiencies of current hybrid methods. The reduced efficiency of iterative minimization in variational methods can be traced back to Hessian preconditioning. The approach adopted here is to develop a hybrid method that includes an optimal Hessian preconditioning based on the inverse square root of the Hessian matrix. This preconditioning method is implicit, being embedded in data assimilation algorithm.

The new hybrid method will be evaluated in the context of cloud-resolving data assimilation with the Weather Research and Forecasting (WRF) model. A special attention will be given to the interaction of hybrid error covariance and Hessian preconditioning, as well as to examining the structure of hybrid error covariance. The presentation will also address the issues relevant to future development of hybrid variational-ensemble data assimilation.