Inter-comparison of the hybrid variational-ensemble methods

*Le Duc[1], Kazuo Saito[2]

1.Department of Seamless Environmental Prediction Research, Japan Agency for Marine-Earth Science and Technology, 2.Meteorological Research Institute, Japan Meteorological Agency

Variational (VAR) and ensemble Kalman filter (EnKF) methods are two dominant approaches in data assimilation for large-scale problems. VAR estimates the mode of the posterior distribution, leading to minimize a cost function. This cost function depends on the second moment of the prior distribution which cannot be produced by VAR itself. Therefore the climatological background covariance is used instead of the true “errors of the day”. This second moment is available into EnKF by sampling the prior distribution with a number of ensemble members. However, with a limited number of ensemble members, only a subspace of the error space can be represented. This means partial “errors of the day” are considered in EnKF. To introduce “errors of the day” into assimilation as in EnKF but can still explore the full error space as in VAR, some hybrid methods have been proposed.
In a hybrid method a specific operator is taken as a linear combination from the corresponding operators in the variational part and the ensemble part. If this operator is the background covariance we have the hybrid covariance method (hybrid B). In case the Kalman gain is chosen we have the hybrid gain method (hybrid K). In some variants of the hybrid covariance method, the operators in the factor form of the background covariance can be used. That means we can take a linear combination between background variances (hybrid V) or background correlations.
In the Strategic Programs for Innovative Research (SPIRE) Field 3, besides the traditional methods like 4DVAR and EnKF, hybrid methods have been implemented in the K Computer under a unified hybrid assimilation system for the Japan Meteorological Agency (JMA) limited-area operational model NHM. The system consisted of two components: the variational one 4DVAR and the ensemble one 4D-LETKF. The variational part was adopted from the JNoVA system developed at JMA. The ensemble part was based on the NHM-LETKF system developed at JMA. There is a two-way interaction between two sub-systems.
Real observation experiments were carried out for the August in 2014. This month was characterized by abnormal rainfall over the western Japan with two tropical cyclones and several heavy rainfall events. To verify performance of three hybrid methods (Hybrid B, Hybrid V, and Hybrid K) the same 50-50 weights were used in all hybrid experiments. In addition to the hybrid experiments, JNoVA and NHM-LETKF were run over the same period. Verification shows that all hybrid methods and JNoVA outperformed NHM-LETKF. Using JNoVA as the control method, Hybrid B and Hybrid K were slightly better than JNoVA. Hybrid V can beat JNoVA at some pressure level but in general Hybrid V was slightly worse than JNoVA. Hybrid B and Hybrid K were comparable in predicting atmospheric variables. Further verification against rainfall analyses points out that Hybrid K was comparable to JNoVA, whereas Hybrid B was better than JNoVA significantly in predicting precipitation especially for rainfall thresholds greater than 20 mm.

Keywords: variational data assimilation, ensemble Kalman filter, hybrid covariance, hybrid gain

