Hybrid Data assimliation in the KIM forecasting system at KMA

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Abstract

KMA is plan to run KIM and its H4DEV data assimilation system as a real-time forecasting system in 2020. In the KIM forecasting system, the use and the increase of ensemble covariance improved the model performance, especially high latitude and specific humidity, which resulted in improving the performance of the heavy rainfall and typhoon track error on the Korean Peninsula.

1 Introduction

Data assimilation (DA) provides a best estimate of the atmospheric state (analysis) for Numerical Weather Prediction (NWP) (Daley, 1991). An accurate estimates of atmospheric variables helps the NWP model to provide valuable information, based on which socio-economic decisions are made. Therefore, in recent years, much effort has been spent in the development of data assimilation systems to replace previously used schemes. Four-dimensional variational data assimilation (4DVAR) is a successor to three-dimensional variational data assimilation (3DVAR) and has been adopted in several operational centers. The maintenance of 4DVAR system would require the development of adjoint models, which are transpositions of the linearized NWP models (Rabier et al., 2000). Therefore, the operational centers that do not run adjoint models or do develop new NWP models are in the process of developing hybrid four-dimensional ensemble variational data assimilation (Bishop and Hodyss, 2011; Buehner et al., 2015; Kleist and Ide, 2015b, Lorenc et al., 2015). In hybrid 4DEnVar (H4DEV), the ensemble trajectory describes the relationships among model variables of the NWP model, and therefore, H4DEV does not require an adjoint model. In this study, we introduce the hybrid data assimilation in the KIM forecasting system at Korea Meteorological Administration (KMA) and present the impact of the ensemble covariance in the hybrid data assimilation system.

2 Methods

The Korea Institute of Atmospheric Prediction Systems (KIAPS) has been developing a global NWP model named the Korean Integrated Model (KIM) and its DA system. KIM is nonhydrostatic global model that uses the spectral element method on cubed-sphere grid (Choi and Hong, 2016). KMA is plan to run KIM and its H4DEV data assimilation system as a real-time forecasting system in 2020.

2.1 H4DEV in the KIM forecasting system

H4DEV uses an ensemble forecast trajectory (ensemble background error covariance (BEC)) to overcome the limitation of the climatological BEC. The H4DEV in the KIM forecasting system has a formulation similar to those in Lorenc et al., (2015) and Kleist and Ide (2015b) in that an ensemble control variable, α, which serves as a weight for the linear combination of ensemble forecast perturbations to fit actual observations, was used. H4DEV requires a correlation function to constrain the ensemble control variable by imposing a specific localization on ensemble BEC (Lorenc, 2003). The Gaussian function in spectral space for the correlation function was prepared and the inverse spectral transformation was implemented with the horizontal length scale of total wave number 10 using the spherical harmonic functions defined on the cubed-sphere grid (Song and Kwon, 2015). The inverse vertical localization comes from Gaspari and Cohn's fifth-order correlation function with 0.2 hPa vertical correlation length scale in logarithmic pressure. A detail description of the H4DEV is presented in Song et al., (2017).

2.2 LETKF in the KIM forecasting system

We used the Local Ensemble Transform Kalman Filter (LETKF; Hunt et al., 2007; Shin et al., 2016) to obtain the ensemble forecast. We used the four-dimensional version of LETKF formulation and 50 ensemble members. The localization weights were given by Gaussian-like piecewise fifth-order rational function (Gaspari and Cohn, 1999) in such a way that the function drops to zero at about 1800 km for the horizontal space. The vertical resolution for conventional data was also defined by the Gaussian-like rational function, with the localization of 0.1 hPa in the unit of the logarithmic pressure for the standard deviation parameter in the function.

3 Data

The observations used in this study were conventional observations, such as, raidionsonde, pibal, wind profiler, surface, aircraft observations; Global Positioning System-Radio Occultation (GPS-RO) bending angle; satellite-derived atmospheric motion vectors; and satellite data of Advanced Microwave Sounding Unit-A (AMSU-A), Advanced Technology Microwave Sounder (ATMS), Infrared Atmospheric Interferometer (IASI), Cross-Track Infrared Sounder (CrIS). Before assimilation, these observations were preprocessed through KIAPS Package for Observation Processing (KPOP).

4 Results and Discussions

4.1 Impact of ensemble BEC

To investigate the impact of ensemble covariance, the results between H3DEV and 3DVAR are compared in the 3D data assimilation frame work. Due to deficient number of observations around the Arctic and the Anratctic, the impact of ensemble covariance was concentrated on higher latitude. The deficient observation network was compensated by the ensemble BEC. Also, the improvement in specific humidity was distinguished in the tropics and subtropics and especially in the northern hemisphere tropics.

4.2 Impact of increase of the ensemble covariance in the hybrid data assimlation

The impact of the ensemble forecast in the hybrid data assimilation was investigated by increasing of the ensemble covariance. The ensemble covariance was increased from 30% (CTL) to 70% (EXP), but that is function of the latitude. At the equator, the ratio of ensemble covariance was 70%, but towards pole, the percentage was reduced to use an ensemble covariance ratio of 30 %. To investigate the impact of the increased ratio of ensemble covariance, 5-day forecasts were made from 1 to 31 July 2019 at intervals of 12 h.

Figure 1 shows 5 day forecast RMSE of KMA, CTL and EXP experiments in the northern hemisphere. The KMA experiment means the results from a real-time operation. In the northern hemisphere, EXP improved the forecasts compared to CTL. (KMA, CTL and EXP are 34.643, 37.680, 35.723 m) although KIM showed the large error at certain data. In the other regions, EXP performed better than CTL (not shown here). For the 2-m temperature, both of KMA and KIM model simulated cold bias compared with the surface observations, but the EXP experiment simulated a smaller bias and error than KMA, which indicated that KIM had excellent performance at the surface temperature. In the rainfall, compared to CTL, EXP had similar rainfall performance at weak rainfall, but outperformed at heavy rainfall (Fig. 2). In the case of heavy rainfall and typhoon on the Korean Peninsula, EXP improved in the distribution and location of precipitation and reduced the typhoon track error. Detailed results will be presented at the conference.

4.3 Conclusions

We investigated the impact of ensemble covariance in the hybrid data assimilation by comparing between H3DEV and 3DVAR and increasing the ensemble covariance. Use of ensemble covariance improved performance at the high latitude, and the specific humidity was significantly improved. The increase of ensemble covariance in the hybrid data assimilation was contributed the improvement of the model performance, especially heavy rainfall and typhoon track error. Proven performance of the increase of the ensemble covariance, it was implemented in semi-operational KIM forecasting system at KMA. In future, KMA is plan to increase of horizontal resolution of ensemble forecast in the hybrid data assimilation to present the error of day.

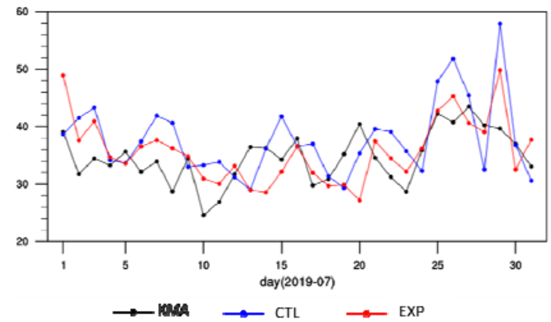

Figure 1. The 5 day forecast RMSEs of KMA (black), CTL (blue) and EXP (red) experiments for the northern hemisphere 500 hPa geopotential height (Z500; m).

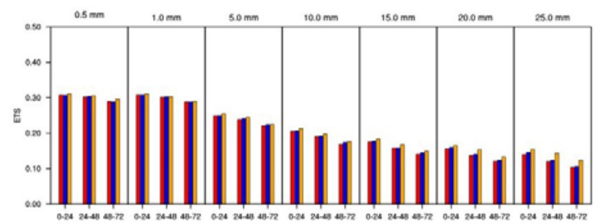

Figure 2. The Equitable Threat Score verified by CPC global rainfall data; CTL (red), EXP (blue) and KMA (yellow).

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