Introduction of a new hybrid data assimilation system for the JMA Global Spectral Model

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1. Introduction

A four-dimensional variational (4D-Var) data assimilation system has been employed in the analysis of atmospheric conditions for the JMA Global Spectral Model (GSM) since February 2005. Evolution of initial background error covariances for the assimilation window is calculated in 4D-Var, but initial background error covariances are climatological and do not represent day-to-day weather conditions. Daily forecast uncertainties can be represented via ensemble forecasting, and various operational global numerical weather prediction centers use such forecasting data for related covariances. In this context, JMA has applied its own hybrid method composed of a Local Ensemble Transform Kalman Filter (LETKF; Hunt et al. 2007) and 4D-Var within its operational system since December 2019. This report gives an overview of the hybrid system and its impacts on forecasting.

2. Specifications of the Hybrid Data Assimilation System for the GSM

JMA (2019) outlines the Agency's Global Ensemble Prediction System (GEPS) and the 4D-Var global data assimilation system. The LETKF used to make initial perturbations in the GEPS was imported into the 4D-Var global data assimilation system to construct the hybrid LETKF/4D-Var system. Three-hour ensemble forecasting initialized with the LETKF is used in 4D-Var with the extended control variable method of Lorenc (2003) to create flow-dependent background error covariances, which are blended with climatological background error covariances. Analysis from 4D-Var is used to re-center LETKF ensemble analysis. Figure 1 outlines the hybrid LETKF/4D-Var system, and Table 1 lists related specifications.

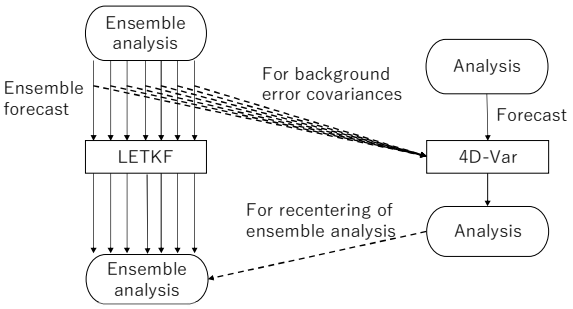

Figure 1. The hybrid LETKF/4D-Var system

Table 1. Specifications of 4D-Var in the hybrid LETKF/4D-Var system

Weighting for hybrid covariance	0.85 for climatological covariance and 0.15 for ensemble covariance under 50 hPa. They are approaching to 1 and 0 above that, respectively
Covariance inflation for ensemble covariance	Adaptive multiplicative covariance inflation (as per LETKF application). Additional covariance inflation is applied to create vertical profiles for the horizontal global mean of standard deviation from ensemble covariances consistent with those from climatological background error covariances.
Localization for ensemble covariance	Gaussian function. The localization scale for which the localization function is $1/\sqrt{e}$ is set to 800 km in the horizontal domain and 0.8 scale height in the vertical domain.
Ensemble size	50 members

3. Hybrid System Impacts on Forecasting

To verify the impacts of the hybrid LETKF/4D-Var system, a 4D-Var experiment with configuration identical to that of the operational JMA global NWP system as of October 2018 was conducted along with a hybrid LETKF/4D-Var experiment. Both covered the period from June 2 to October 11 2018, which included forecasting for tropical cyclones (TCs) from T1804 to T1825 in the western North Pacific.

Ensemble forecasting initialized with the LETKF showed the capacity for background error covariance creation dependent on day-to-day weather conditions as exemplified in Figure 2 (a) (extratropical cyclone, tropical cyclone and tropical depression) and 2 (b) (indicating a larger ensemble

spread around these phenomena than in other areas). Figure 2 (c) shows average TC position errors for the western North Pacific from both experiments. The results from the hybrid LETKF/4D-Var experiment are slightly better. Figure 3 shows the zonal mean of the improvement ratio for geopotential height forecasting from the hybrid LETKF/4D-Var experiment relative to that of the 4D-Var experiment. Improvements in geopotential height forecasting for the mid-latitudes in particular were observed in the winter hemisphere and elsewhere, as well as in the boreal winter experiment (not shown). The new system has been operated by JMA since December 2019.

References

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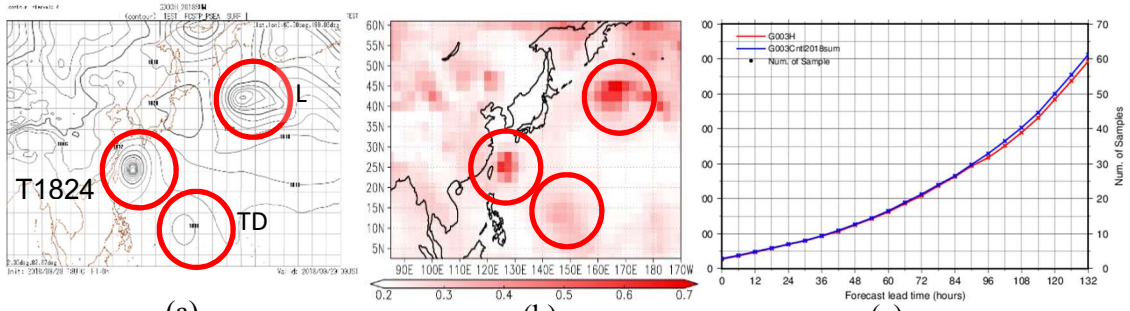

(a) (b) (c)

Figure 2. Six-hour forecasting for (a) sea-level pressure and (b) sea-level pressure spread, both from the hybrid LETKF/4D-Var experiment with initialization at 1800 UTC on 28 Sep 2018. (c) Average TC position errors for TCs from T1804 to T1825 in the western North Pacific. Blue: 4D-Var experiment; red: hybrid LETKF/4D-Var experiment

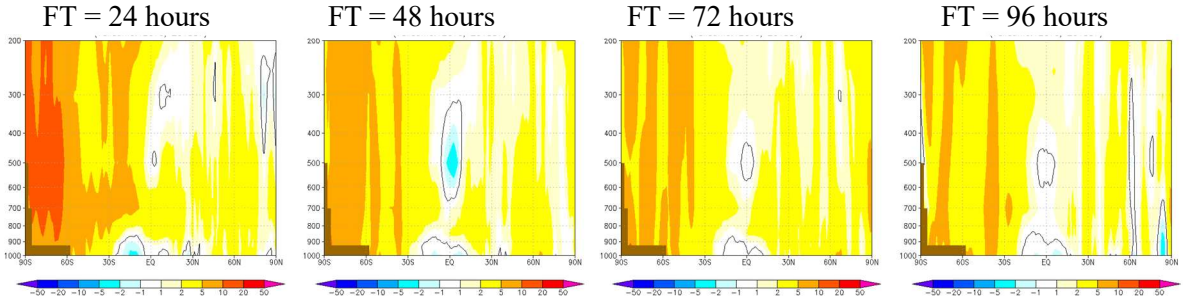

Figure 3. Zonal mean of relative improvement ratio [%] for the hybrid LETKF/4D-Var experiment against that of the 4D-Var experiment in terms of RMS error against ECMWF analysis for geopotential height forecasting. Warm colors indicate forecast error reduction. The validation period is from 1st July to 30th September 2018 (92 days).