Development of an ozone analysis system using a local ensemble transform Kalman filter at Japan Meteorological Agency

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QOS2016-113,2016

Introduction

Japan Meteorological Agency (JMA) operates a global chemistry transport model, called Meteorological Research Institute Chemistry Climate Model, version 2 (MRI-CCM2) for daily UV index forecasts. The ozone assimilation process in the model is a simple Newtonian relaxation (= Nudging method) and only total column ozone data from Ozone Monitoring Instrument (OMI) is assimilated.

To improve prediction accuracy of the model, we plan to introduce a local ensemble transform Kalman filter (LETKF) technique as a data assimilation (DA) system and assimilate Aura/Microwave Limb Sounder (MLS) observational data of ozone as well as OMI data in next few years

We present the long term (2010-2014) stability of the DA performance and the advantage of this system by comparison with the present DA process.

Methodology

Model Settings :

- Resolution: T42L64 (surface to 0.01hPa)
- Meteorological field: nudged into zonal and meridional winds (U,V) of JMA global analysis data. The relaxation time varies with each member (6-hour to 192-hour).

LETKF Settings :

- Ensemble member: 32
- Assimilation cycle: 6-hour
- DA Period : Jan 2010 - Dec 2014
- Horizontal (vertical) localization length parameter: 500km (log P=0.4)
- Adaptive covariance inflation (MAX is set to 30%)

Assimilated observational data :

- Aura/MLS (NASA, Level2 Ver 4.2) : O3 concentration data
- Aura/OMI (NASA, Level2 OMTO3.003): Total column O3 data (smoothed in a 2.5°×2.5° grid)

Result2: Evaluation using Ozonesonde

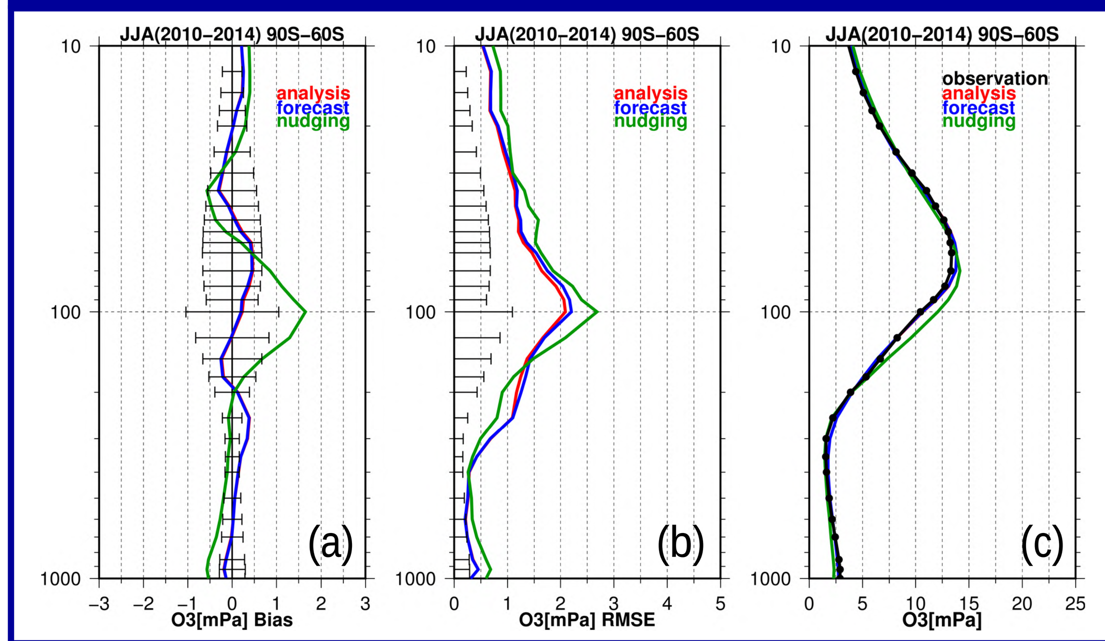
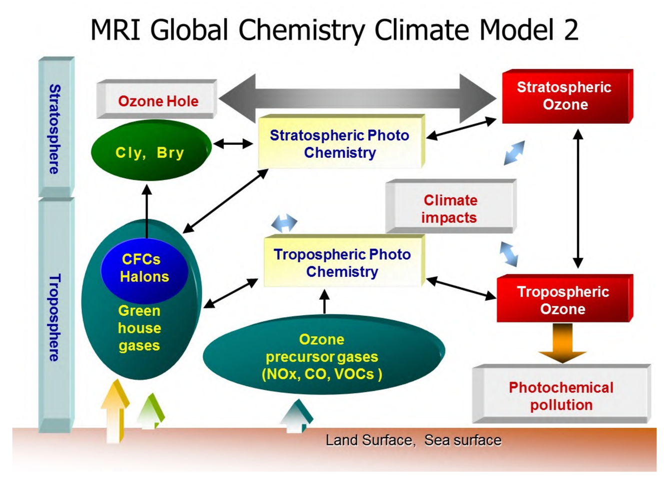
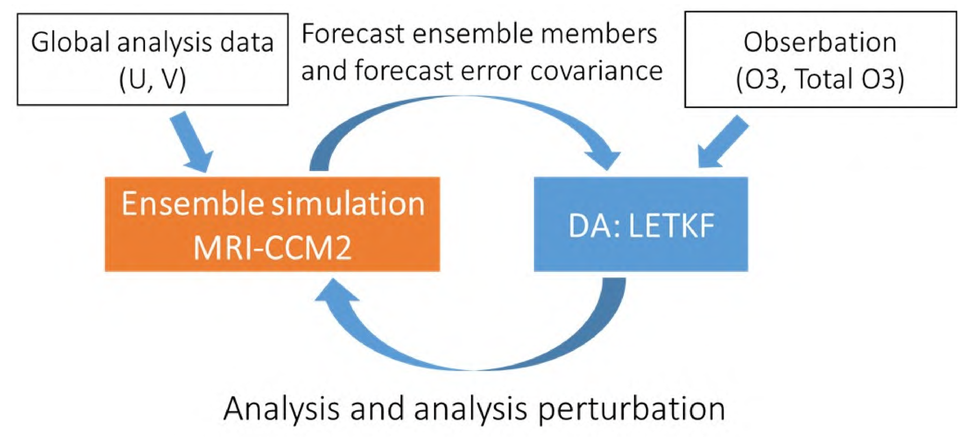


Figure4. Vertical profiles of 3 months (JJA) mean (a) O3 bias, (b) O3 RMSE and (c) O3 for the period 2010-2014 over the southern high latitude (90S–60S). Unit is mPa. The bias and RMSE were calculated against ozone sonde observations. Error bars shows the observation errors.

System

MODEL : MRI-CCM2 (Deushi and Shibata, 2011) is designed to simulate the distributions and time-evolutions of ozone and related chemical species over the troposphere and the stratosphere.





LETKF DA system : The LETKF scheme (e.g. Hunt et al., 2007) is a kind of the ensemble Kalman filter technique, in which covariance localization is applied to remove sampling errors caused by the limited ensemble size.

Result1: Data assimilation statistics

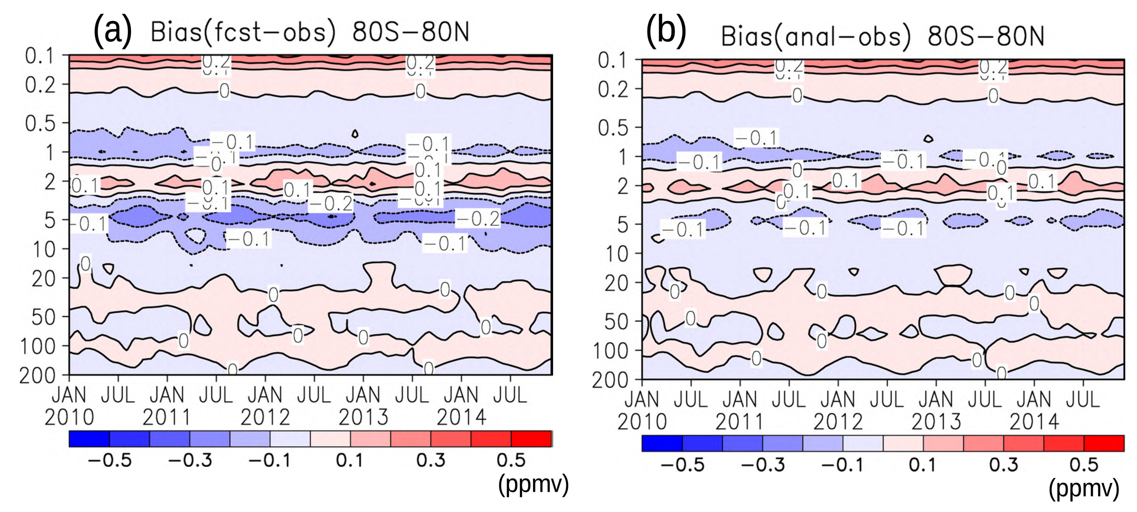


Figure1. Vertical profiles of time series of monthly mean model minus observation biases against MLS averaged over 80S-80N. (a) 6h-forecast and (b) analysis in LETKF run. Unit is ppmv.

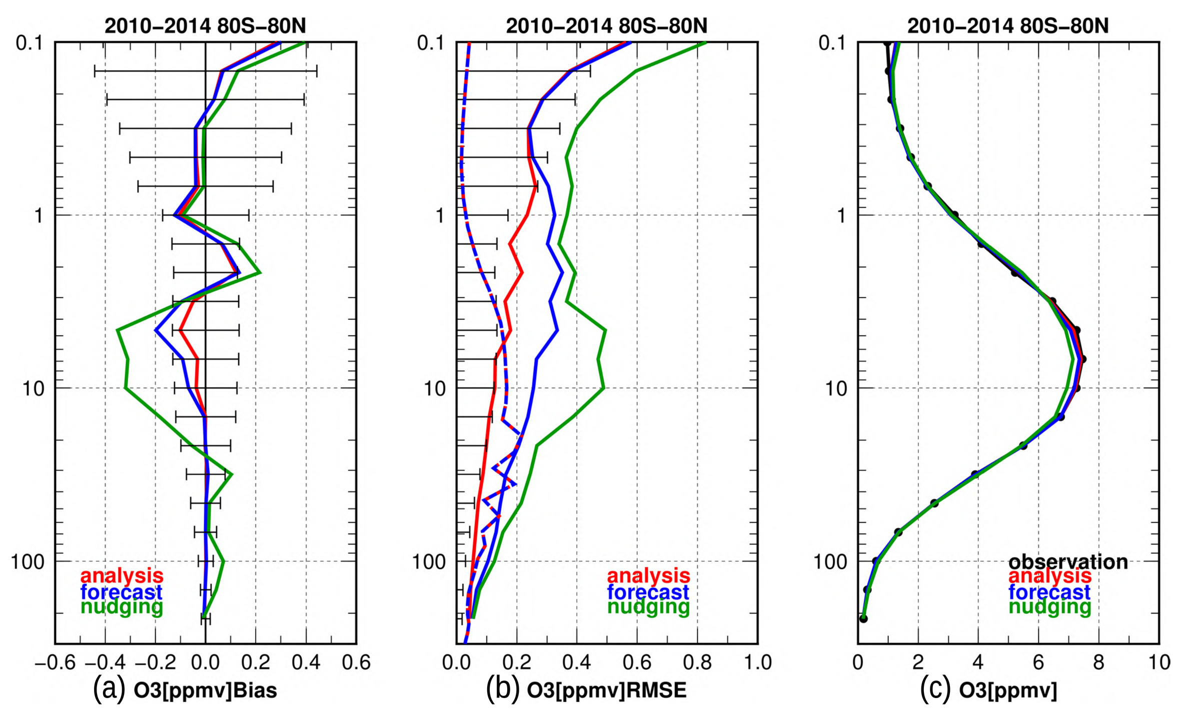


Figure3. Vertical profiles of (a) O3 bias, (b) RMSE (solid line) and spread (dotted line), (c) O3 averaged for the period 2010-2014 over 80S–80N. Error bars shows the averaged error of the assimilated MLS observations.

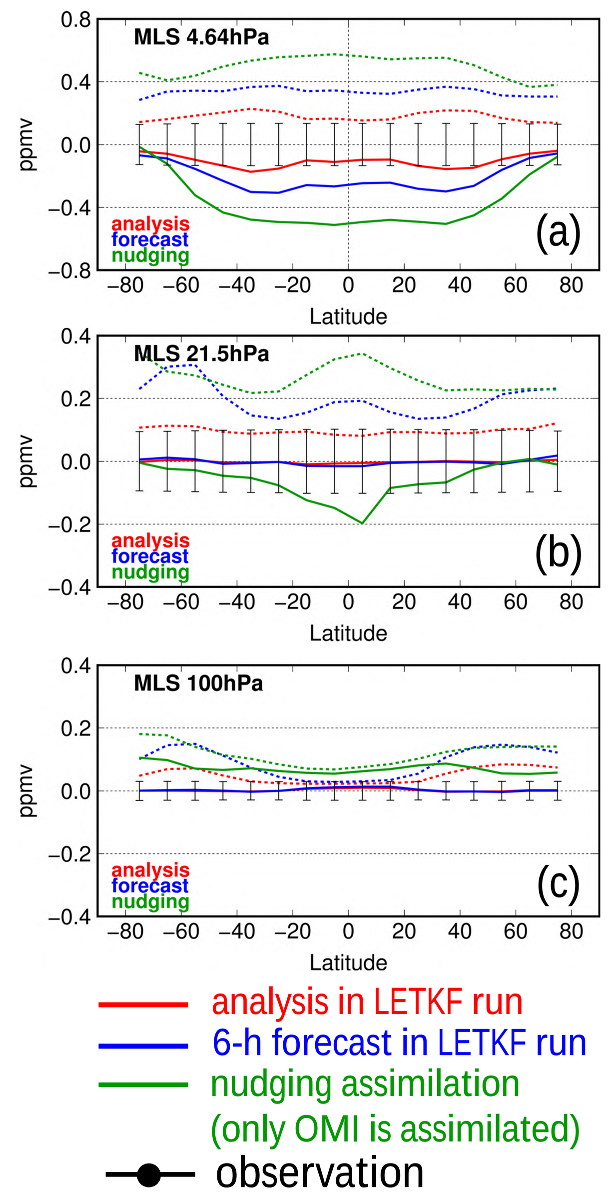


Figure2. Latitudinal distribution of the 5-year mean model minus observation biases (solid line) and RMSE (dotted line) against MLS O3 data at 4.64hPa (top), 21.5hPa (middle) and 100hPa (bottom). The error bars are the MLS errors. Unit is ppmv.

Result3: Impact of new ozone climatology on JMA NWP model

The operational numerical weather prediction model (GSM) at JMA now uses the three-dimensional monthly-mean O3 climatology (2000-2004) which was simulated by the previous version of CTM (MRI-CCM1) with nudging assimilation technique. We compare the climatological temperature response of GSM for the two O3 climatology, the present one and the one produced from the LETKF data assimilation system (2010-2014).

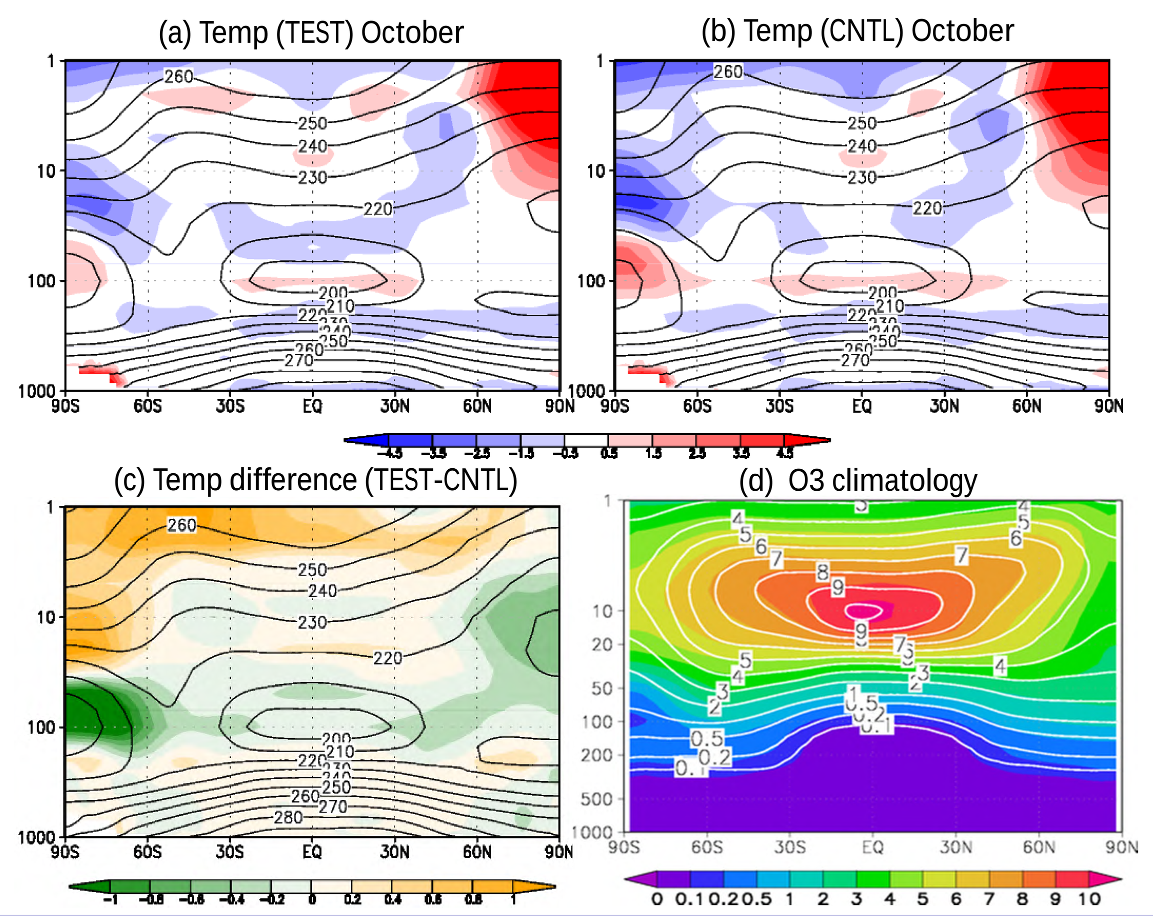


Figure5. 10-year (2002-2011) averages of zonal mean temperature forecasted by GSM in October with (a) O3 climatology specified by LETKF (TEST) and (b) the present climatology (CNTL). Unit is K. Color shaded represents the difference with that of ERA-Interim. (c) is the difference of above temperature (TEST-CNTL) and contour is the ERA-Interim climatology temperature. (d) is the latitude-pressure cross section of O3 (in ppmv) in October for the TEST version of O3 climatology (color shaded) and the present one (white line).

Conclusions and Future Plan

The LETKF data assimilation system which have the advantage of making use of different types of O3 observations at the same time improves the assimilation performance compared with the present system.

- **Result1:** The assimilation works well especially below 10hPa in the stratosphere throughout the experiment period of 5 years and the analysis ozone biases are within the MLS error bars. The long term stability of the DA performance shows a possibility of the operational use.
- **Result2:** LETKF reduces O3 bias and RMSE in the middle stratosphere in Antarctic winter comparing with the ozone sonde observations independently. But the assimilation does not work well below 100hPa, which may have a negative impact on the tropospheric O3 concentrations. The cause is under investigation.
- **Result3:** The O3 climatology specified by LETKF may have a positive impact on the temperature forecast by GSM. One experimental result in October shows that the biases of the temperature are reduced in the southern polar region, in the lower stratosphere and around at 1hPa of 90S-60N.

We plan to develop the system which perform DA in the operational CTM resolution (T106) using a forecast error covariance estimated from a low–resolution (T42) ensemble model forecast.