Simplified basic state update in the JMA global 4D-Var

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1. Introduction

Remote sensing observations are one of the main information sources in atmospheric analyses. Furthermore, cloud and rain affected remote sensing observations may bring significant improvements of analysis and forecast accuracy in near future. Nonlinearity of observation operators of these data is stronger than that of conventional direct observations. Therefore, data assimilation systems (DASs) have to treat such nonlinearity.

Analyses of the atmosphere based on variational schemes are executed with optimization algorithms using gradients of a cost function. Therefore, it is needed that nonlinearity of observation operators is weak. If tangent linear approximation of observation operators around a basic state is valid, this condition is satisfied and operational DASs are able to be stable and keep high accuracy.

In this paper, we describe results of cycle experiments of a simplified basic state update scheme.

2. Method

To update a basic state, we also need to update departure values, differences between observations and guesses, and computational costs of such update using an outer forecast model are not small. However, if we explicitly use an assumption for representative errors of observations and guesses, which is used implicitly in an incremental system, the rerun of outer model is not needed (Ishibashi 2011). Therefore, we can construct a basic state update scheme without outer model rerun, and we call this formulation a simplified basic state update.

The simplified basic state update scheme has been tested in a few single analysis and forecast experiment, and these experimental results show that the scheme can derive more information from relatively strong nonlinear observations (radiances, GPS-ROs, and humidity observations), and forecast accuracy is improved (Ishibashi 2011).

3. Experimental design

We executed two analysis and forecast cycles TEST and CNTL, here, TEST is a cycle with the simplified basic state update scheme, and CNTL with original scheme (no basic state update). The experimental system is a low resolution version of the JMA global NWP system, which has same spec with the JMA operational system except for horizontal grid resolution is about 60 km (operational is 20 km). Analyses were run from Jul 20 to Sep 9 (52 days), and 9 days forecasts are executed in August in 2009.

4. Results

First, we compare analysis fields of TEST and CNTL. Figure 1 shows differences of water vapor fields between these experiments in monthly average. We can find TEST has more precipitable water than CNTL in Tropics, and water vapor mixing ratio of TEST is larger in mid troposphere and smaller in low troposphere than those of CNTL (Figure 1(b)). Figure 1(c) shows validation of these changes using radio sonde observations as truth. We can find TEST reduces dry biases in mid troposphere and wet biases in low troposphere, therefore we can guess these changes in water vapor fields are adequate.

Secondly, we compare forecast fields of TEST and CNTL. Figure 2 shows normalized differences of root mean squared errors of forecasts between these experiments. We can find when we use radio sonde observations as truth, TEST has smaller RMSEs than CNTL in average. While, when we use initial fields as truth, TEST has larger RMSEs before 2 days in NH and SH, and almost all days in TP. To validate this contradiction in these two verifications, we show third verification, which used radiance data as truth (Figure 3). The figure shows that TEST has smaller RMSEs in average. Therefore, we can guess that the discrepancy comes from methodological problem of the verification using initial fields. Since the verification using initial fields assumes enough error growth against analysis errors, it cannot makes adequate verification when analysis biases are different in two experiments and those biases come from forecast model biases, in first few days and weak error growth area.

To see existence of forecast model bias, Figure 4 is monthly averages of 24 hours precipitation forecasts at a valid time of 24 hours and 72 hours. We find precipitation decreases when forecast time increases in tropical west pacific region. This and the dry (wet) biases in mid (low) troposphere shown in Figure 1(c), imply the forecast model cannot keep water vapor in the atmosphere, and drops them as precipitation during first few days. Therefore, we can see that this model bias makes the verification using initial fields inadequate.

However, there is another aspect of this model bias. Figure 4 shows zonal mean 24 hours precipitation of the first forecast day, we find TEST is larger precipitation. This is results of the wrong model response to the mid troposphere humidity increase in TEST, and this process may partly degrade forecast accuracy of TEST.

5. Future work

We plan two works. The first is to clarify conditions that the verification using initial fields is valid or invalid. The second is to treat forecast model biases in the DAS.

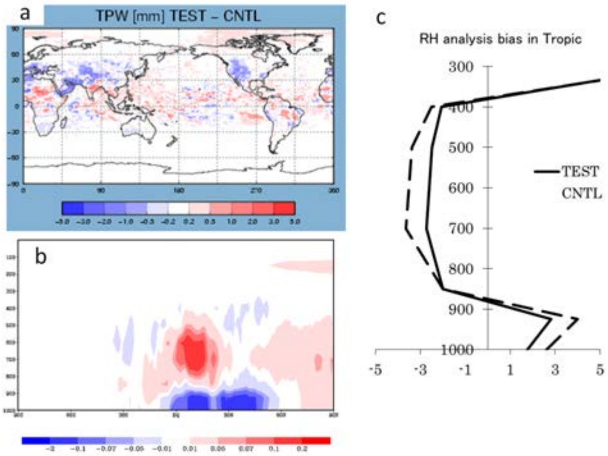

Figure 1. Analysis field differences between TEST and CNTL. The panel (a) is differences (TEST minus CNTL)of precipitable water, and the panel (b) is those of zonal mean water vapor mixing ratio, and the panel (c) is relative humidity biases against radio sonde observations.

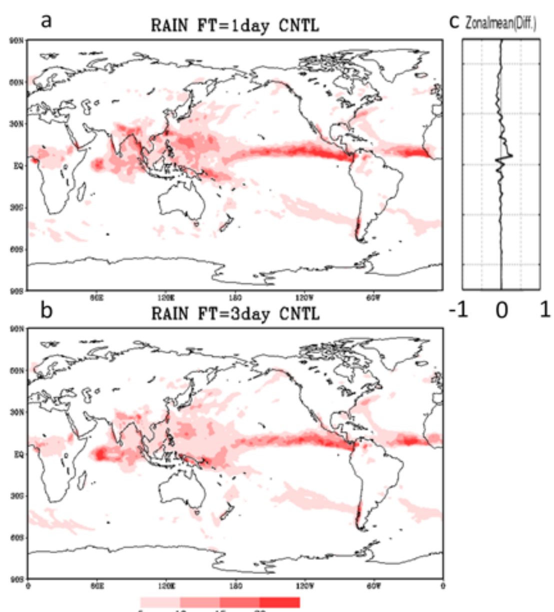

Figure 4. Rain forecast dependencies on forecast valid times and forecast rain differences. The panel (a) and (b) are 1 day precipitation at valid time of forecast day 1 and day 2, respectively. The panel (c) is differences of 1 day forecasted rain between TEST and CNTL (TEST minus CNTL).

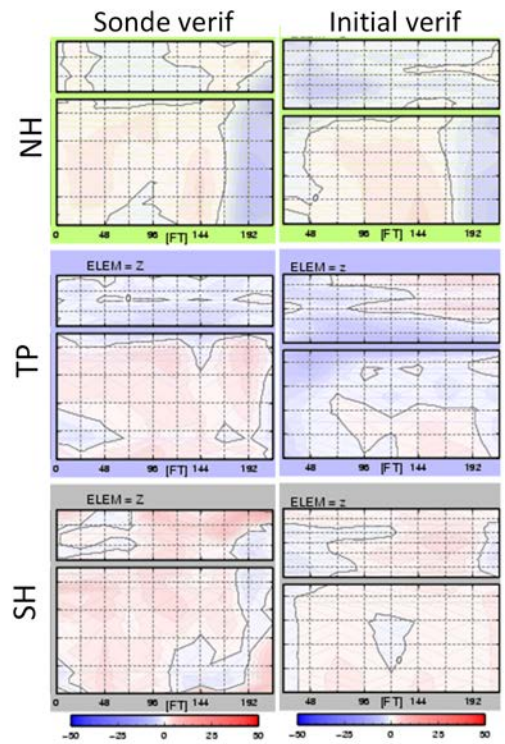

Figure 2. Differences of forecast RMSEs between TEST and CNTL (CNTL minus TEST) normalized by RMSEs. The left column is verification using radio sonde as truth, and the right using initial field for each region, the Northern hemisphere (NH), the Tropics (TP), and the Southern hemisphere (SH). TEST decrease (increase) forecast errors in red (blue) regions area. The horizontal axis is forecast times and the vertical axis is pressure height (surface to stratosphere)

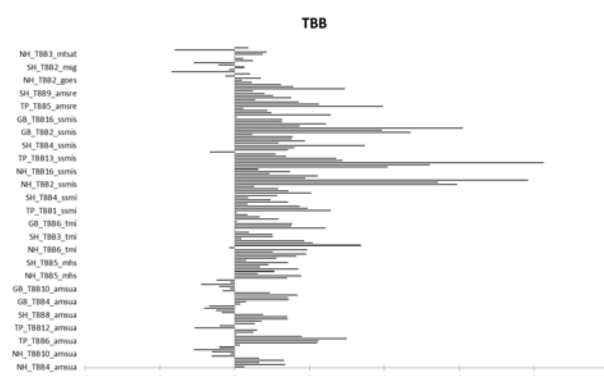

Figure 3. Differences of standard deviations of departure values of radiance data. Plus (minus) means TEST decreases (increases) errors.