# Evaluation from a Perspective of Spin-down Problem: Moistening Effect of Convective Parameterization

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## 1. INTRODUCTION

Model errors stem from various sources such as parameterization types and statistical sub-grid fluctuations, and basically grow from the initial state, leading to a systematic bias in model climatology. Accordingly, diagnostic measurement of short-range forecast errors before interacting globally with errors brought from unknown inherent predictability provides a wealth of beneficial information for the development of physics parameterization. Considering the differences between observations and short-range forecasts produced by the operational Global Spectral Model (GSM) highlights a problem referred to as spin-down – an issue associated with data assimilation (DA) cycles that involves a rapid decrease in humidity caused by strong precipitation during the short-range forecast period. It has been suggested that the problem is closely related to convective precipitation (Andersson et al. 2005). Against this background, the purpose of the present study was to investigate the performance of revised convection and cloud schemes in the GSM.

## 2. EXPERIMENTAL DESIGN

Two experiments (CNTL and TEST) were conducted to compare model performance levels. In the CNTL experiment, a low-resolution version of the operational GSM (TL319L60: 60-km horizontal resolution, 60 layers) was used. In the GSM, a convection scheme (the prognostic Arakawa-Schubert scheme with a spectral cloud ensemble) and a large-scale cloud scheme (cloud fraction is diagnosed following an assumed probability density function (PDF)) were implemented.

In the TEST experiment, a number of modifications were introduced. For the convection scheme, these were as follows: 1) the mass flux profile in the sub-cloud layers was changed in consideration of the large entrainment rate near the surface; 2) the mass flux amount was modified to vary depending on the water saturation deficit in the atmosphere; 3) the downward mass flux was reduced, starting from the Level of Free Sinking (LFS); 4) the formulation of the closure was changed from a cloud work function type to a diluting CAPE type; 5) treatment of detrained cloud water and cloud ice was modified; 6) the artificial on/off switching function for convective triggering was removed; 7) the formulation of the prognostic equation for the mass flux at the cloud base was modified; and 8) an upper limit for the cloud top was added based on calculation of the vertical velocity of an entraining parcel. For the large-scale cloud scheme, the modifications were: 1) the formulations of the PDF function were modified; and 2) the artificial threshold for low-level clouds was removed to suppress inadequate cloud data.

## 3. EVALUATION IN A 4D-VAR DA SYSTEM USING RETRIEVED GPS-PWV DATA

Retrieved GPS precipitable water vapor (PWV) data provides performance with a level of accuracy comparable to that of retrieved Sonde PWV data regardless of the presence or absence of rain areas. Moreover, ground-based GPS sites are located all over the world, providing a continuous stream of hourly data. GPS-PWV data are therefore useful in evaluating column water vapor and precipitation in light of the spin-down problem seen with the 4D-VAR DA system. The experiment results suggested that the problem was alleviated more in TEST than it was in CNTL (Figs. 1 and 2). In TEST, the mean error for 1 – 9 hour forecast PWV was lower, and the difference in the vertical profiles of water vapor from Sonde observations was also reduced, which related to better representation of the timing of precipitation occurrence for the short-range forecast period (not shown). These results mainly stem from the suppression of excessive deep convection during the period, with the second, seventh and eighth modifications to the convection scheme contributing significantly.

## 4. EVALUATION OF FORECASTS FROM 4D-VAR ANALYSIS FIELDS

The TEST forecast from the TEST analysis provided in the DA forecast cycle produced global PWV fields (Fig. 3) and lower relative humidity (RH) spin-down better than the CNTL forecast from the CNTL analysis, while RH spin-down was notable in the CNTL forecast from the TEST analysis (Fig. 4). Even if the TEST forecast starts from CNTL analysis, it does not show the same value as the TEST forecast from TEST analysis in the nine-day version. These results suggest that a consistent relationship between the initial state (analysis field) and the forecast model in the numerical weather prediction system should be elaborated. To develop moist parameterization, such evaluation in regard to the spin-down problem provides useful information for the improvement of hydrological forecasting in consideration of observed values and initial errors in the DA forecast cycle.

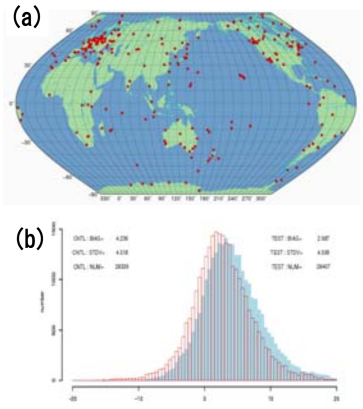


Figure 1. (a) World GPS site map (192 sites, excluding 1,200 sites in Japan), and (b) histograms of PWV O-B (GPS-PWV observations minus forecasts) for TEST (red) and CNTL (blue)

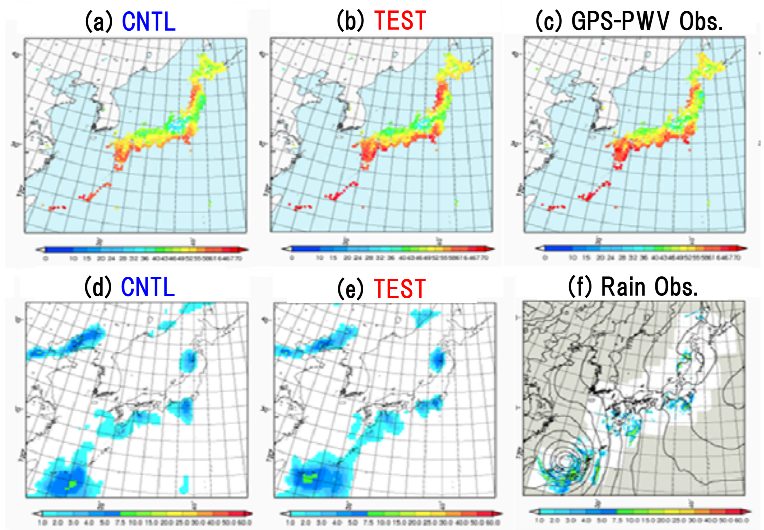


Figure 2. PWV [mm] (top) and rain [mm/hour] (bottom) for observations (c, f) and six-hour forecasts in CNTL (a, d) and TEST (b, e). The PWV observation in (c) was based on data from around 1,200 ground-based GPS sites throughout Japan. The rain observation in (d) was based on data from radar and ground observations in Japan.

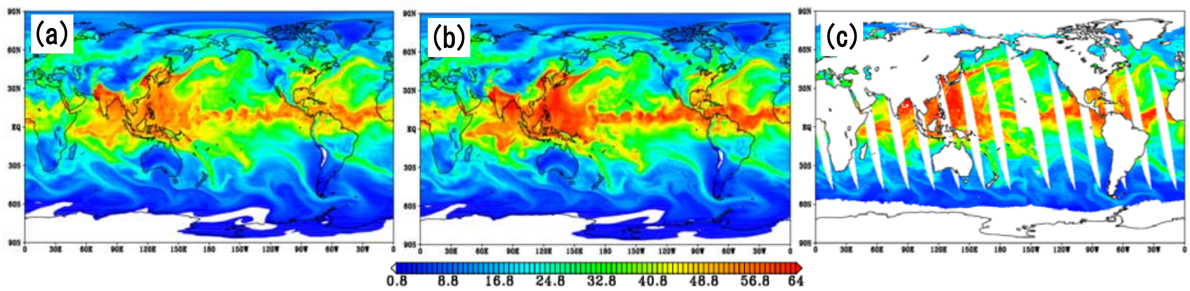


Figure 3. Global PWV fields of three-day forecasts in (a) the CNTL forecast from the CNTL analysis, (b) the TEST forecast from the TEST analysis, and (c) retrieved data from the AMSR-E satellite.

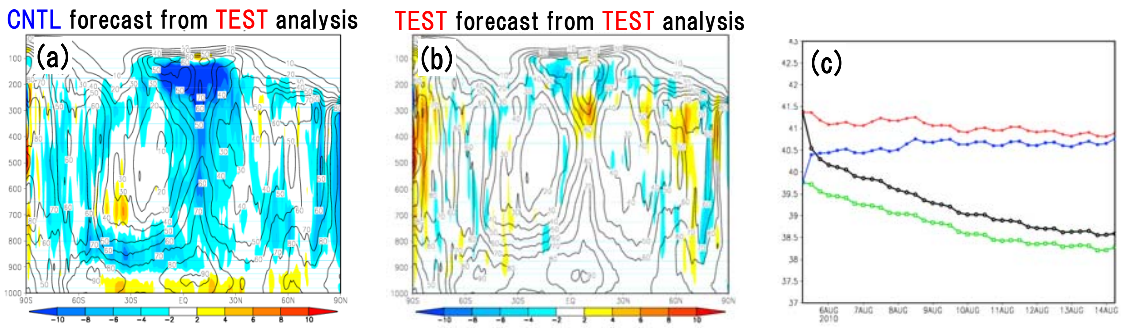


Figure 4. Zonal mean of 24-hour RH change from the initial conditions in (a) the CNTL forecast from the TEST analysis, and (b) the TEST forecast from the TEST analysis. (c) Nine-day PWV forecasts averaged over the tropics (20°S – 20°N) in the TEST forecast from the TEST analysis (red line), the CNTL forecast from the TEST analysis (black line), the TEST forecast from the CNTL analysis (blue line) and the CNTL forecast from the CNTL analysis (green line).

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