Vertical Resolution Increase of the Japan Meteorological Agency Global Spectral Model

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1. Introduction – New Version of JMA GSM is going to be in operation

Japan Meteorological Agency (JMA) is going to implement a new version of the Global Spectral Model (GSM) in a few months. This update includes (i) extending the model layers, (ii) raising the model top height (Table1 and Figure 1), (iii) implementing various improvements in the forecast model, and (iv) introducing new observations into the data assimilation system.

Motivations for increasing the number of model layers and raising model lid are as follows:

■Improving the representation of atmospheric vertical structure and the atmospheric processes

■Using satellite channels that have sensitivity for the middle atmosphere in data assimilation

■Improving accuracy of forecasts in the both troposphere and stratosphere

In this presentation, summary of upgraded GSM (Section 2 and 3) and its performance (Section 4 and 5) are presented.

Table 1. Specifications of the JMA operational medium-range deterministic NWP model (red : upgraded).

Horizontal Resolution	TL959
Vertical Levels	L60→L100
Model Top Height [hPa]	0.1→0.01
Time Step [sec]	600→400
Forecast Range [hr]	84hr(00, 06, 18UTC) 264hr(12UTC)

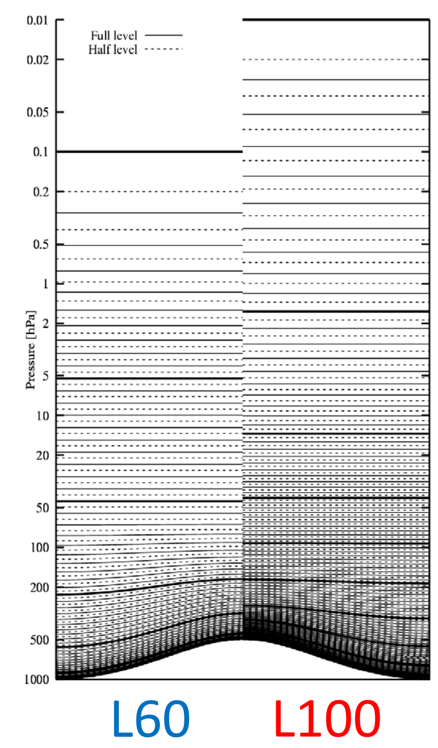

Figure 1. Vertical levels of current (left) and upgraded GSM (right).

2. Major Changes of the Forecast Model

■Introducing the Monin-Obukhov similarity theory in surface flux scheme over land

■Revising a stable boundary layer scheme

→**Improving wind fields and diurnal temperature variation in stable conditions**

■Revising albedo parameters in the desert areas (Figure 2)

→**Reducing clear sky radiation biases**

■Introducing two-stream approximation for long wave radiation scheme

→**Accelerating radiation code and improving the middle atmosphere temperature structure**

■Introducing a non-orographic gravity wave forcing scheme in the forecast model

→**Improving the middle atmosphere climate and representation of long-term oscillation in the tropical lower stratosphere such as QBO (Section 4)**

■Changing the application criteria of energy correction terms in convective parameterization

→**Improving general circulation and global precipitation distribution (Figure 3)**

■Applying 2nd-order linear horizontal diffusion in the divergence equation and adjusting 4th-order linear diffusion as a sponge layer around the model top region

→**Improving the middle atmosphere forecast accuracy**

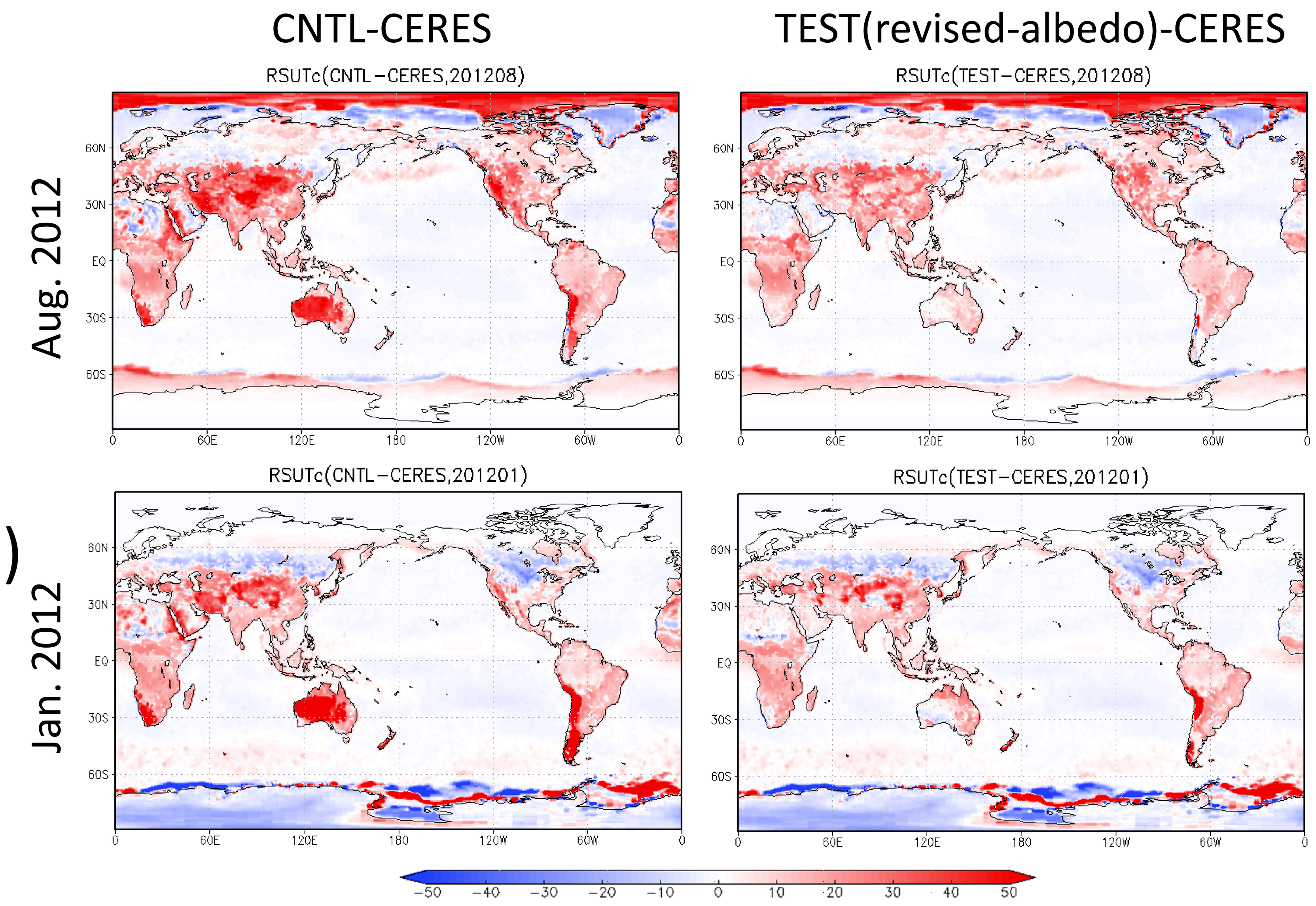

Figure 2. Monthly averaged difference of top of atmosphere clear sky upward short wave radiation fluxes [W/m^2] between GSM FT6 and CERES. (left) CNTL-CERES and (right) TEST-CERES.

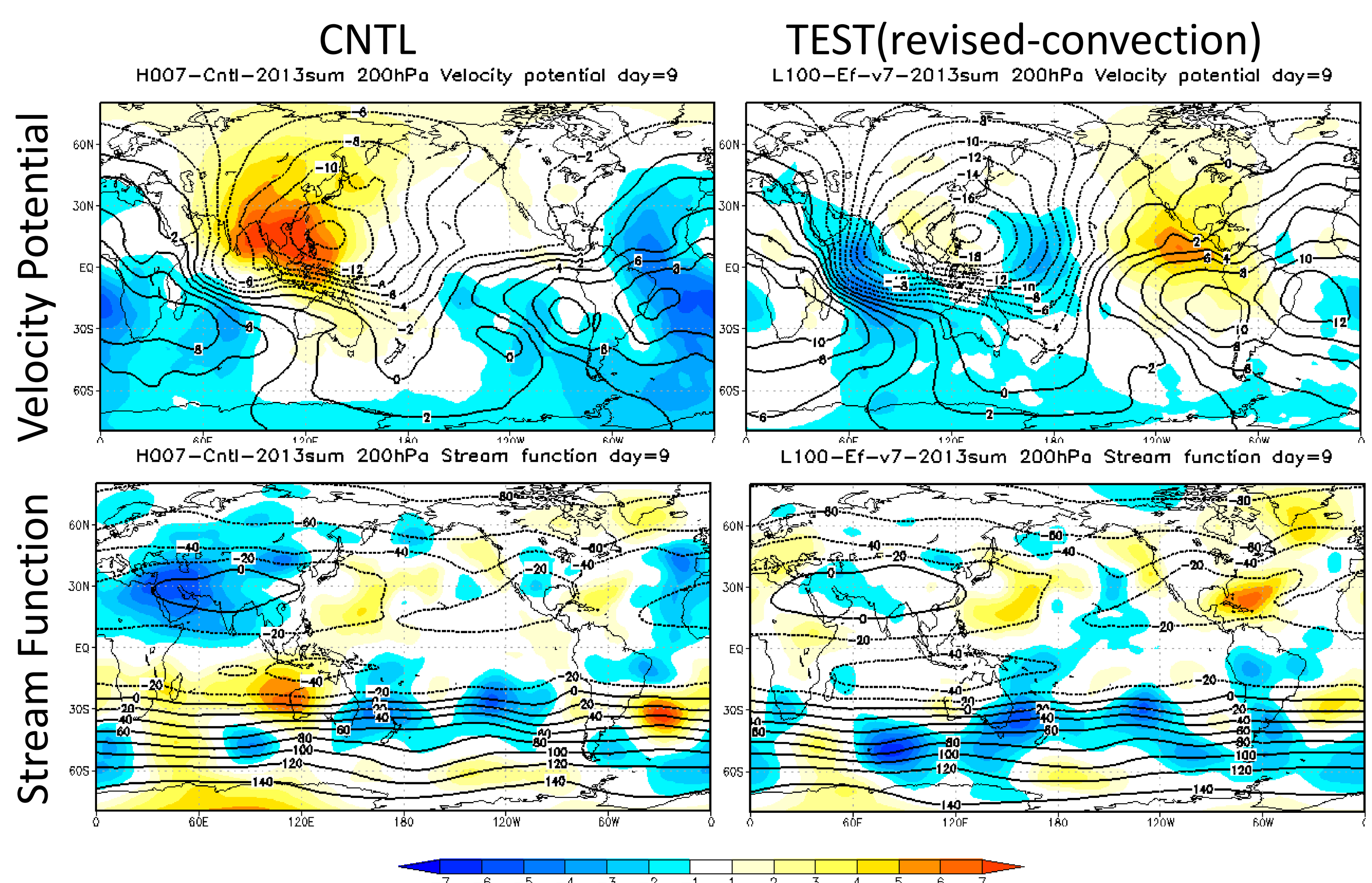

Figure 3. Velocity potential (top) and stream function (bottom) [m^2/s^2] at 200hPa. Averaging period is Jul-Aug 2013. Contours indicate day 9 forecast fields and shaded areas indicate mean error (day 9 forecast fields – analysis fields).

3. Introduction of New Observations and Revision of Data Usage in the Analysis

■Assimilating AMSU-A channel 14 (new use)

■Assimilating GNSS-RO bending angle data at the altitude up to 60km (currently, refractivity data up to 30 km) (Figure 4)

→**Correcting errors in the sparse observation data areas such as stratosphere and lower mesosphere**

■Assimilating ground-based GNSS-ZTD (Zenith Total Delay) data (new use) (Figure 5)

→**Providing accurate moisture profile of initial state over the Japan, Europe and the USA**

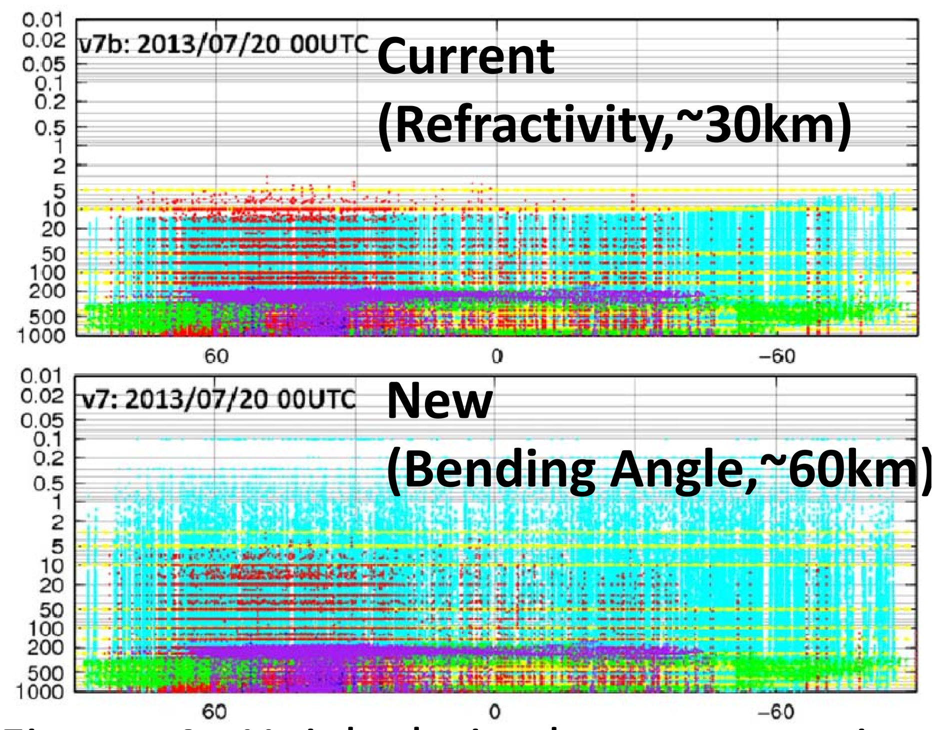

Figure 4. Height-latitude cross section of assimilated data points. (top) GNSS-RO refractivity, and (bottom) GNSS-RO bending angle. Light-cyan colored points indicate GNSS-RO data.

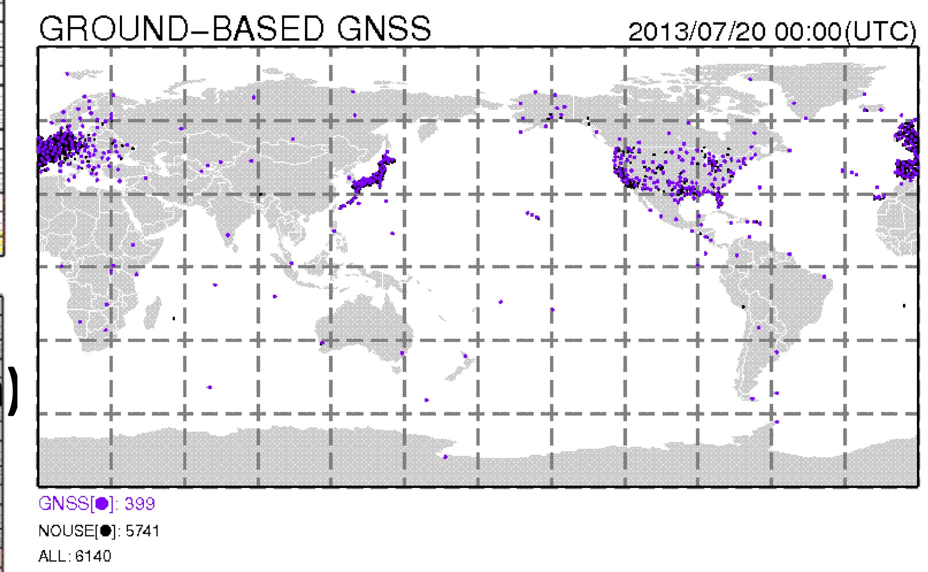

Figure 5. Data coverage of ground-based GNSS-ZTD data.

4. Improved Middle Atmosphere Climate through a Non-Orographic Gravity Wave Forcing Parameterization

To achieve better forecast performance in the middle atmosphere, a non-orographic gravity wave forcing scheme (NGF) by Scinocca (2003) is introduced and it replaces Rayleigh friction (RF) in the forecast model. A six-year integration using low horizontal resolution version (TL159L100) shows upgraded GSM successfully reproduces QBO-like periodic zonal wind oscillation in the tropical (Figure 6). However, its period is shorter and amplitude is weaker than that of ERA-Interim (Dee et al., 2011). The middle atmosphere climate of upgraded GSM shows realistic meridional temperature gradient and zonal wind structure in the middle atmosphere (Figure 7).

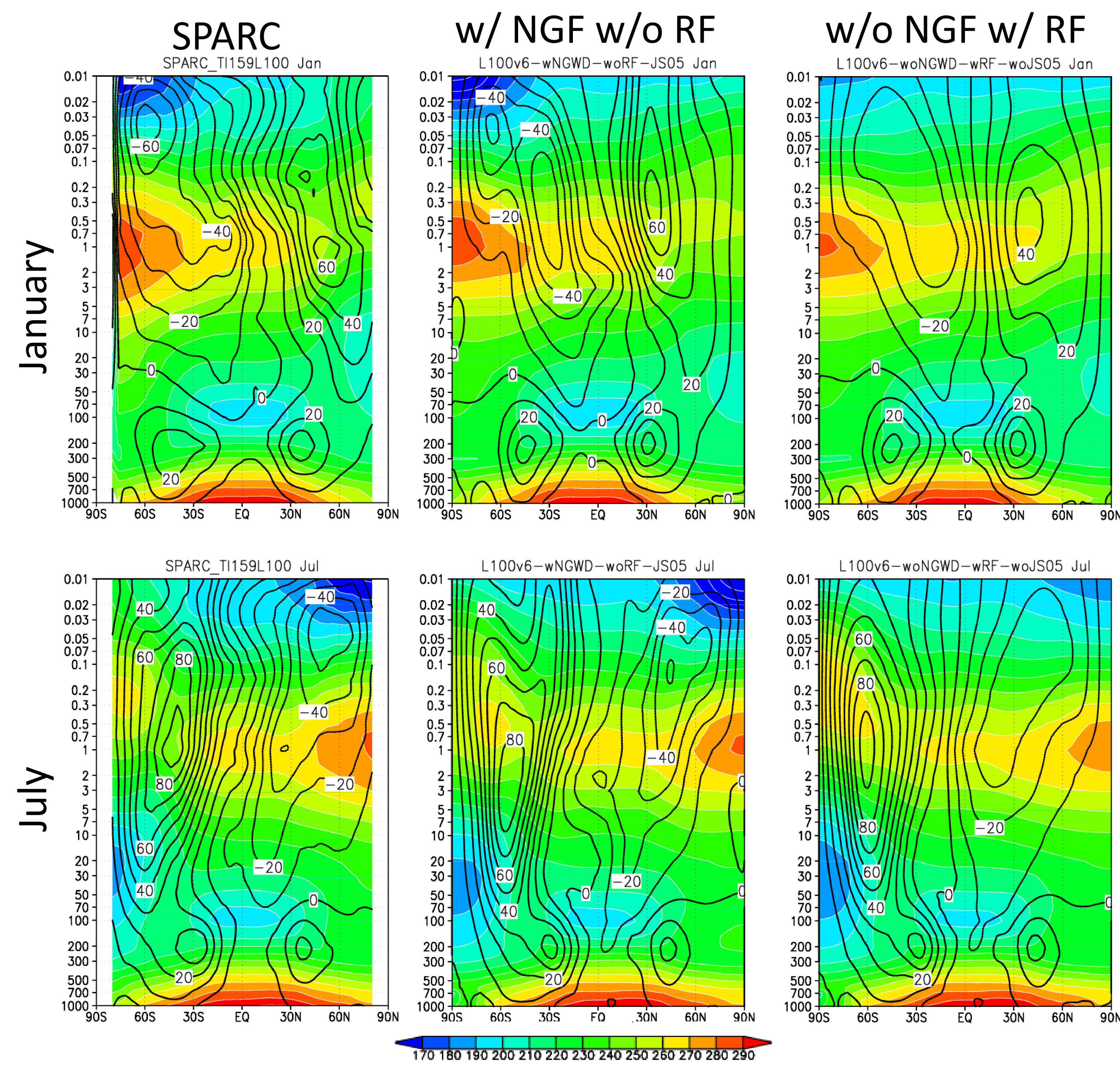

Figure 7. Zonal mean temperature (shaded) and zonal wind (contour) climatologies from TL159L100 six-year integration. January (top) and, July (bottom). (left) SPARC (Randel et al., 2004), (middle) GSM with NGF, (right) GSM with RF.

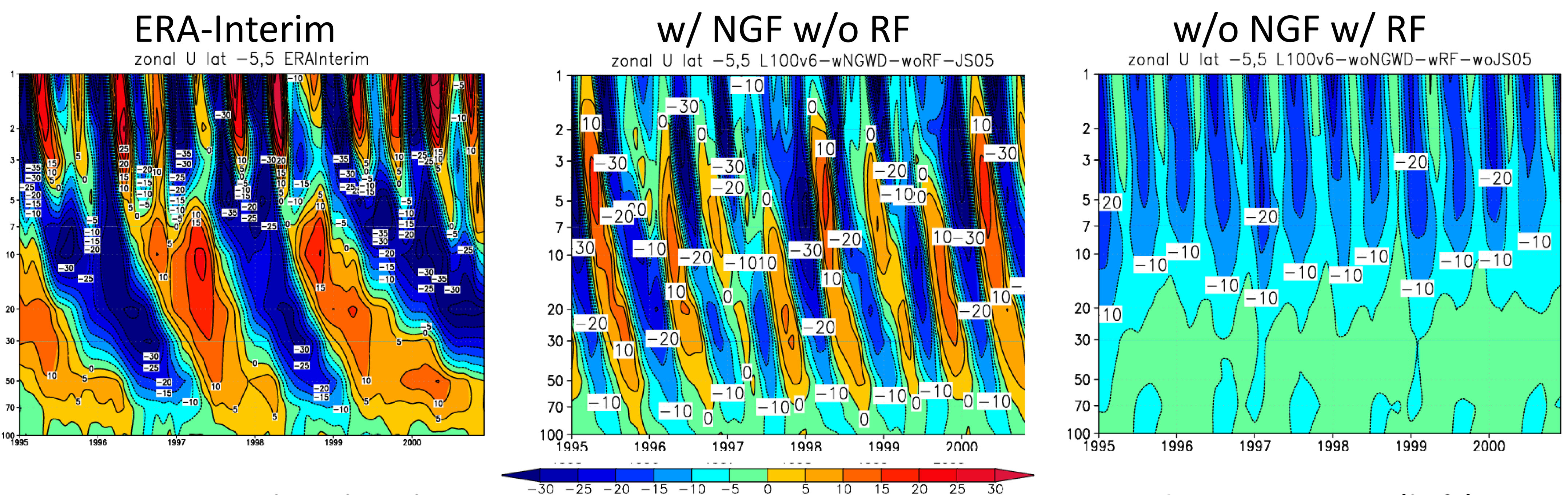

Figure 6. Time-height plots of zonally averaged zonal wind averaged over 5S-5N. (left) ERA-Interim, (middle) GSM with NGF, (right) GSM with RF.

5.Total Performance

Upper Air Verification Scores

■ In extratropics, forecast performance improves significantly.

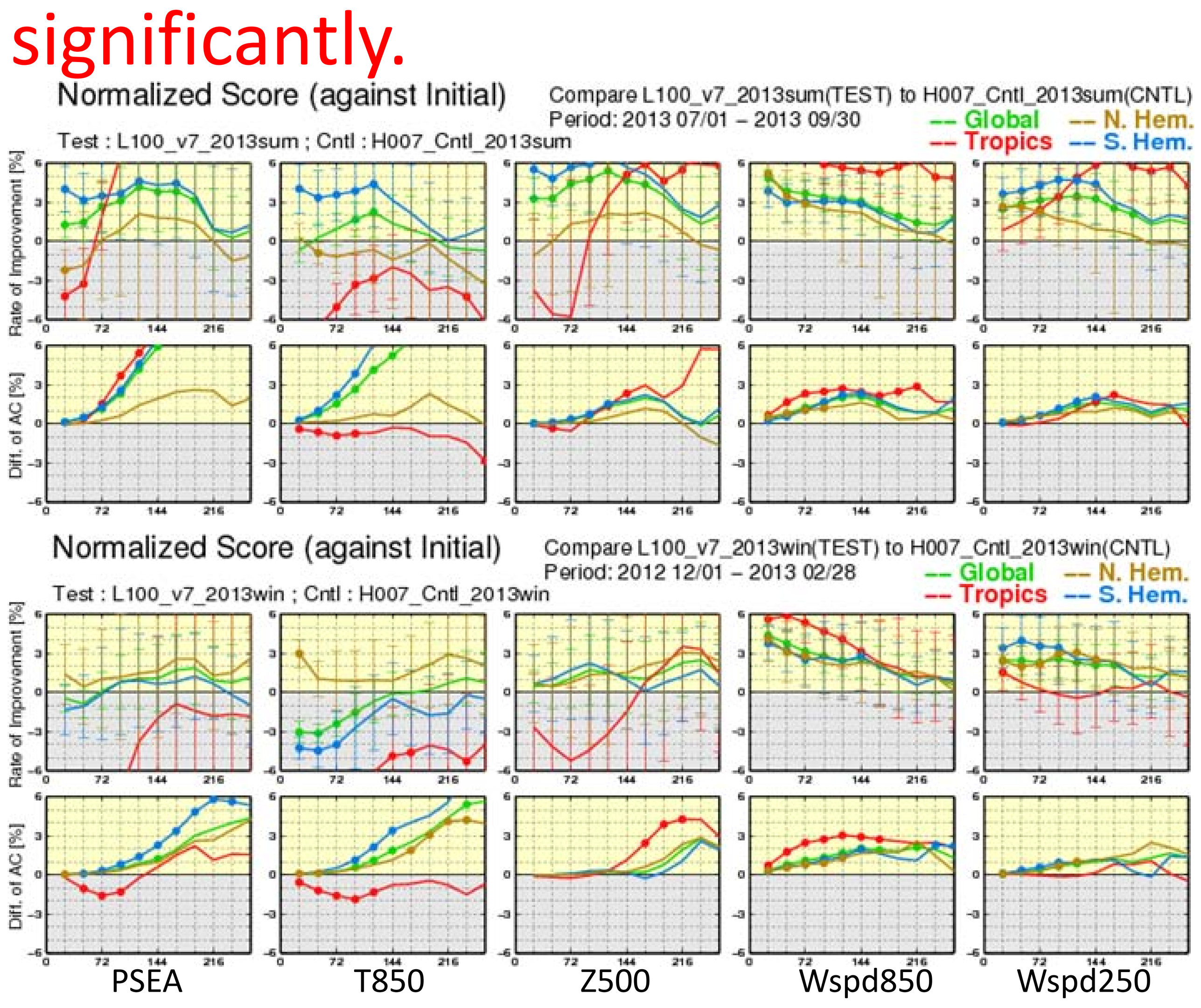

Figure 8. Comparisons of upper air verification scores against analysis between upgraded GSM and current GSM for Jun-Sep 2013 (top) and Dec-Feb 2013 (bottom). Lines over yellow (gray) background area mean upgraded GSM shows better (worse) scores than current GSM.

Tropical Cyclone Track Forecasts

■ Upgraded GSM reduces tropical cyclone track forecast errors in all regions.

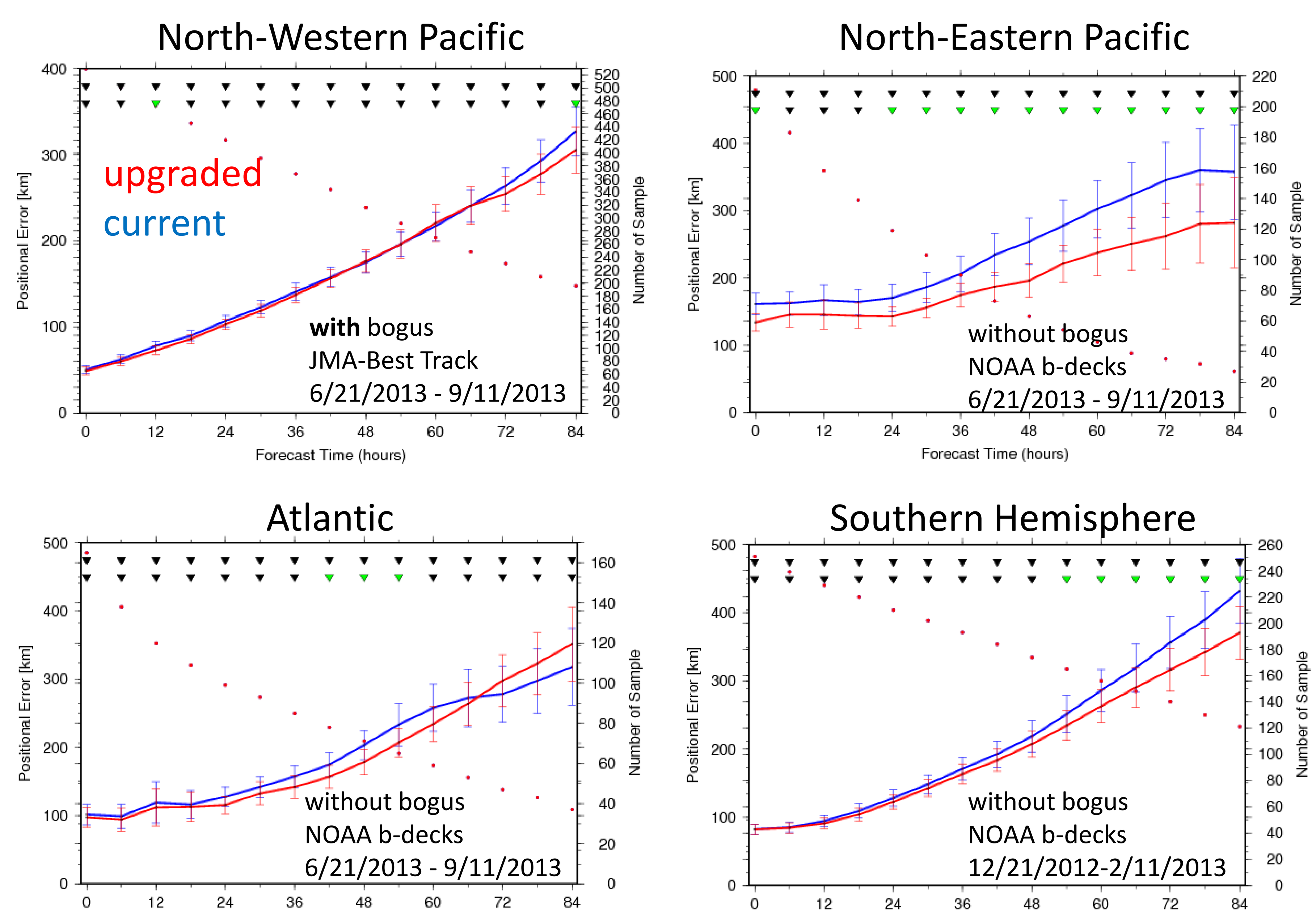

Figure 9. Tropical cyclone track forecast errors. Bogus data usage, best track data and verification periods are shown in figures.

References

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