Operational use of GOES-16 clear-sky radiance (CSR) data in JMA's global NWP system

OKABE Izumi
Numerical Prediction Division, Forecast Department, Japan Meteorological Agency
E-mail: i-okabe@met.kishou.go.jp

1. Introduction

Clear-sky radiance (CSR) data from five operational geostationary satellites (Himawari-8, two Meteosat Second-Generation (MSG) and two GOES) are utilized in JMA's global numerical weather prediction (NWP) system. With the retirement of GOES-13 (the predecessor to GOES-East, operating at a longitude of 75 degrees west) on January 8 2018, data acquisition of GOES-16 CSR was started on April 16 2018, leaving a four-month observation void in JMA. Data quality evaluation based on first-guess (FG) departure (i.e., the difference between observed and simulated brightness temperatures) statistics and assimilation experiments conducted by JMA verified the benefits of using GOES-16 CSR data, which were incorporated into the Agency's operational global NWP system on June 4 2019. This report gives an overview of GOES-16 CSR data evaluation within the JMA system.

2. GOES-16 CSR data evaluation

The 16 bands of the GOES-16 Advanced Baseline Imager (ABI) include three water-vapor (WV) bands (8, 9 and 10) with central wavelengths of 6.2, 6.9 and 7.3 micrometers, respectively. As ABI is a similar instrument to the Advanced Himawari Imager (AHI), whose CSR data are currently assimilated in JMA's NWP systems, the quality control (QC) method used for Himawari-8 was applied to GOES-16 CSR data. Since these data are produced assuming under clear-sky conditions, cloud-affected data need to be removed before assimilation. Thus, CSR data with a low clear-pixel ratio and a large standard deviation (STD) of brightness temperature in a particular segment (consisting of 32 x 32 pixels for CSR data production) are eliminated. To remove cloud-affected data, WV-band CSR data with clear-pixel ratios under 90% or STD values larger than 1 K are rejected in QC. With clear-pixel ratios for the window band (band 13) below the relevant thresholds (55, 60 and 65% for bands 8, 9 and 10, respectively), WV CSR data in the same segment are rejected.

The radiative transfer (RT) calculation developed for Himawari-8 and MSG CSR data (Okabe 2019) is applied to GOES-16 CSR data. This approach involves the use of retrieved land surface temperature rather than FG skin temperature to improve the accuracy of simulated brightness temperature, especially for surface-sensitive bands.

To evaluate the quality of GOES-16 CSR data, FG departure statistics in QC-processed data were compared to those of Himawari-8 CSR data. Passively monitored (i.e., without assimilation) GOES-16 CSR data were used for the FG departure statistics, and data from Himawari-8, two MSGs and GOES-15 CSR data including other observations were actively assimilated. Two geostationary satellites were used for CSR observation in the GOES-16 area (Meteosat-11 for the eastern part, GOES-15 for the western part). Figure 1 shows horizontal distributions of root mean squares (RMSs) of FG departures for the two satellites. The RMS of GOES-16 in the area outside overlapping with other geostationary satellites was larger than those of Himawari-8, suggesting that background quality was degraded in the CSR gap area after the retirement of GOES-13. Meanwhile, RMSs in overlapping areas were as small as those of Himawari-8, and the quality of QC-processed GOES-16 CSR data was assumed to be similar to that of Himawari-8.

3. Assimilation experiments

Assimilation experiments were conducted to determine the impact of GOES-16 CSR data on global analysis and forecasting. The control experiment (referred as CNTL) had the same configuration as the operational JMA global NWP system as of December 2018, and the test experiment (referred as TEST) was the same as CNTL except for the assimilation of three WV bands of CSR data from GOES-16. The experiments covered the periods from June 10 to October 11 2018 and from November 10 2018 to March 11 2019.

4. Impacts on analysis and forecasting

Figure 2 shows normalized changes in STD values for the FG departure between TEST and CNTL for brightness temperatures from the microwave humidity sounder (MHS) and the Advanced Microwave Sounding Unit-A (AMSU-

A), and relative humidity from radiosonde observation. Reduced STD values indicate improved FG fields, especially for water vapor. The values here are generally reduced, indicating significant MHS improvement. Figure 3 shows horizontal distributions of differences in the STD of FG departure for MHS data between TEST and CNTL, with reduced STD values observed in the GOES-16 CSR coverage area. As MHS is sensitive to WV in the middle-to-upper troposphere, this result suggests a positive impact on WV field accuracy for the FG from GOES-16 CSR assimilation. Figure 4 shows the vertical zonal mean of forecast field relative improvement for specific humidity and geopotential height (defined as the difference between the CNTL and TEST root mean square error (RMSE) divided by the RMSE of CNTL). The improvements in analysis (0-day forecasts) were retained for up to two-day forecasts for the humidity and geopotential height fields at low and mid-latitudes in the troposphere.

5. Summary

On June 4 2018, JMA began assimilating GOES-16 CSR data based on the QC method developed for Himawari-8. Evaluation showed that RMSs of FG departure for GOES-16 CSR were as small as those for Himawari-8 CSR in areas of overlap with other geostationary satellites, and the quality of GOES-16 CSR data was deemed to be similar to that of Himawari-8 data. Experiments showed a positive impact from GOES-16 CSR data assimilation on the WV field accuracy of FG in the mid-to-upper troposphere, especially in the central part of the GOES-16 observation area. The forecast fields of humidity and geopotential height were improved in forecasts of up to two days in the low- and mid-latitudes of the troposphere.

References

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Acknowledgements

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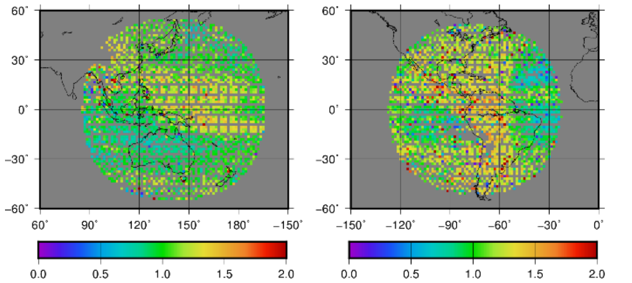

Figure 1. Root mean square of first-guess departures for Himawari-8 (assimilated, left) and GOES-16 (not assimilated, right) for August 2018 based on post-QC CSR data

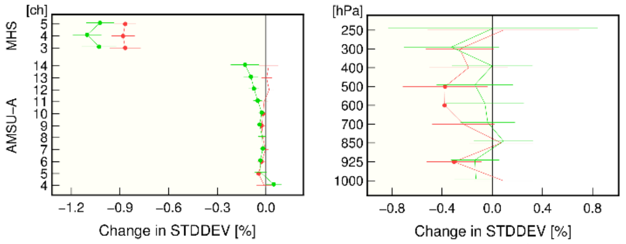

Figure 2. Normalized changes in standard deviation (STDDEV) for first-guess departures in microwave sounding data for individual channels [ch] (left) and radiosonde observation data indicating relative humidity for individual pressure heights [hPa] (right). The validation periods are from June 21 to October 11 2018 (red dots) and from November 21 2018 to March 11 2019 (green dots).

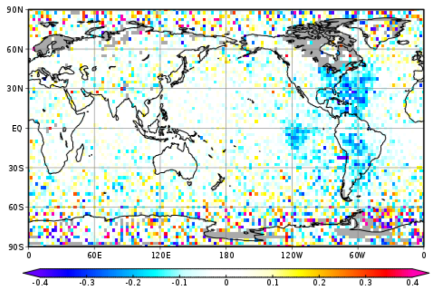

Figure 3. Normalized changes in the standard deviation of first-guess departures for MHS (channel 3) [%]. The validation period is from June 21 to October 11 2018.

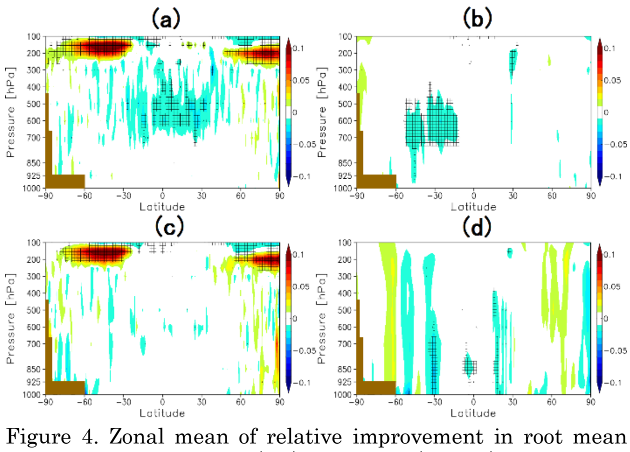

Figure 4. Zonal mean of relative improvement in root mean square errors for 0-day (top) and 2-day (bottom) forecasts for (a), (c) specific humidity and (b), (d) geopotential height based on calculation using forecasts from 12 UTC initials and ERA5 analysis for verification. The verification period is from July 1 to September 30 2018.