Assimilation of Suomi-NPP/CrIS radiances into the JMA's global NWP system

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Introduction

Hyper Spectral Infrared Sounder (HSS) radiance data from the Cross-track Infrared Sounder (CrIS) which is onboard Suomi National Polar-orbiting Partnership (NPP) spacecraft have been operationally assimilated in JMA's global Numerical Weather Prediction (NWP) system since March 2017. This report briefly describes the data quality control and impacts of assimilating the data in the system.

Quality control

CrIS instrument is a Fourier transform spectrometer with a total of 1305 infrared sounding channels covering 3 bands (i.e. the long-wave (655‑1095 cm^{-1}), mid-wave (1210‑1750 cm^{-1}), and short-wave (2155‑2550cm^{-1}) spectral range). JMA obtains CrIS 399 channel data set from NESDIS. 27 channels were selected from the long-wave temperature sounding channels for the assimilation. Figure 1 shows the weighting function of CrIS used channels. Because AQUA/AIRS and Suomi NPP/CrIS are the same satellite orbit (13:30 afternoon orbit), a data thinning is necessary for their overlap region to reduce an overfitting in the analysis. Normally, a higher priority in data thinning is assigned for CrIS because it has wider swath coverage (CrIS: 2230 km, AIRS: 1650 km). The priority in the data thinning depends on available channel numbers (clear-sky condition) and the distance between the observation and the center of the thinning grid box. CrIS data of a particular FOVs (field of view) number (FOV=1, 3, 5, 7, 9) are rejected for the assimilation. A method of cloud top estimation and cloud screening which is used for AIRS and IASI in the system (Eyre and Menzel 1989) is applied to CrIS data.

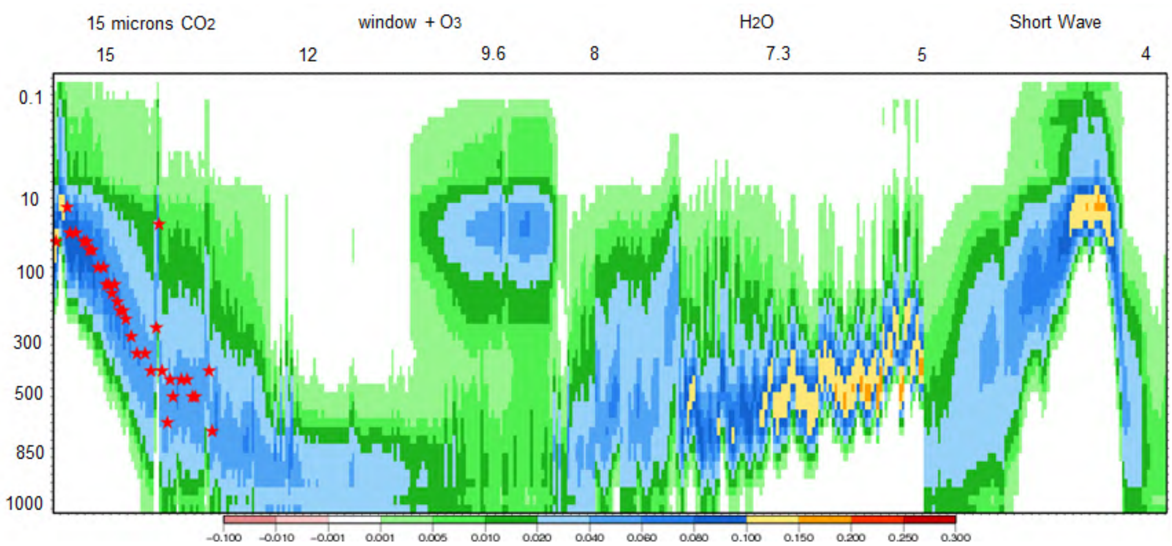

Fig 1: The weighting function of CrIS. The upper horizontal line shows wavelength and the vertical one pressure level. The color scale indicates the magnitude of the weighting function, and the red star marks show Long-wave temperature sounding 27 used channels (around 15 um) at the peak of weighting function.

Assimilation experiments

Observing system experiments were performed for a month in August 2015 and in January 2016 to evaluate the impacts of CrIS data assimilation in the global NWP system. The control experiment (CNTL) uses the same configuration as the operational system. In test experiment (TEST), CrIS data were added on top of the operational observation dataset.

As shown in Figure 2, changes in the normalized standard deviation of the first-guess departure (FG) indicate improvements of stratosphere and upper troposphere of temperature fields, especially in the Southern Hemisphere.

Figure 3 shows that the significant improvements of geopotential height forecasts in stratosphere and upper troposphere were confirmed especially in summer in the Southern Hemisphere.

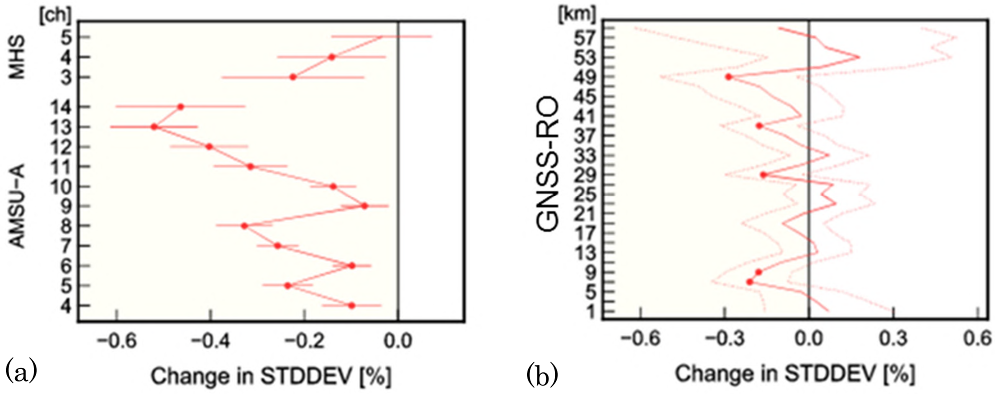

Fig 2: Normalized changes in the standard deviation of FG departures of (a) AMSU-A and MHS, (b) GNSS-RO bending angle for the experiment period. The negative value represents improvement. The horizontal axis indicates normalized standard deviation's difference. The error bar represents a 95% confidence interval, and the red dots represent statistically significant changes.

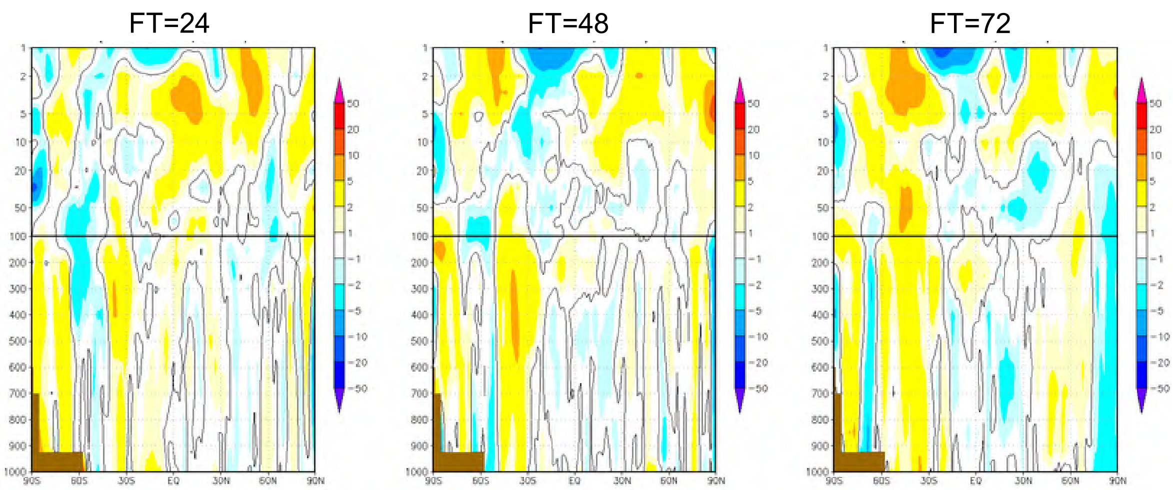

Fig 3: Improvement ratio ((CNTL-TEST) / CNTL) of zonal mean of differences in the RMS error for the forecast of geopotential height in August 2015. Positive values indicate reductions in the forecast errors. The verification was performed against own analysis.

Impact study by improving ozone analysis

The CO2 band of HSS has the channels that are some sensitive in ozone. The ozone profile of RTTOV in global analysis is given by not the climate products but JMA's chemical products. In other words, the use of better ozone profiles means the accuracy of the calculation brightness temperature is improved.

The figure 4 shows comparison of vertical ozone profiles from MLS observation, old model is blue and new one red. The improvement point of the stratosphere is to add the gas-phase reaction [ClO + OH → HCl + O2] and update the photolysis rate table significantly reduces the negative model bias of ozone in the upper stratosphere. The figure 5 shows comparison of vertical ozone partial pressure profiles from ozonesonde that is black curve at Naha in Japan. The improvement point of the troposphere is to add detailed tropospheric chemistry and this is found that vertical distributions of tropospheric ozone agree better with the observations.

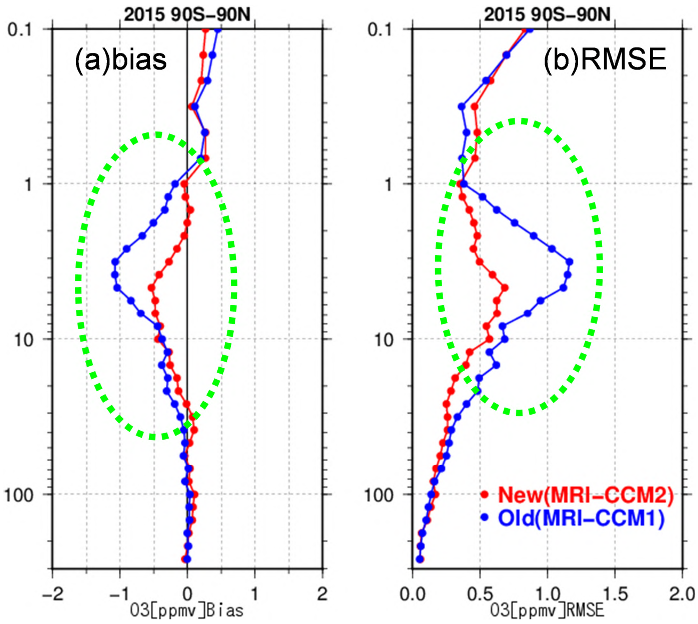

Fig 4: Comparison of vertical ozone profiles from MLS observation, old model (blue) and new model (red).
(a) Bias and (b) RMSE against MLS observations are shown in the partial volume of ozone. In the New model, green circle was shown the decrease in bias and RMSE at 10 hPa to 1 hPa.

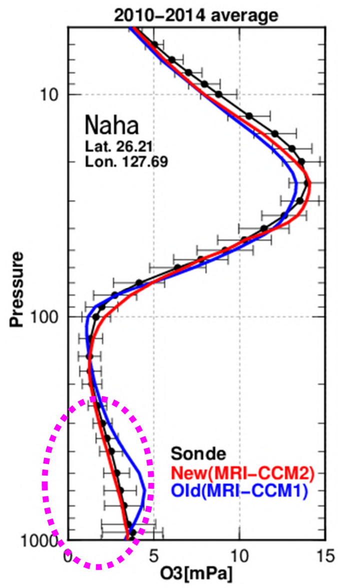

Fig 5: Comparison of vertical ozone partial pressure profiles from ozonesonde (black) at Naha. Error bars shows the standard deviations of the observations. The new ozone profile is consistent with the observation than the old one.

Observing system experiments were performed for a month in August 2015 and in January 2016 to evaluate the impacts of new ozone profiles assimilation in the global NWP system. The control experiment (CNTL) uses the same configuration as the operational system. In test experiment (TEST), new ozone profiles were replaced on the operational observation dataset. The figure 6 show changes of standard deviation of First Guess Departure, data counts and tropical cyclone track forecast errors of TEST for CNTL. FG fit to IASI is improved in the tropical region. The number of the lower layer of HSS is increased in the tropical region. A case of typhoon track prediction improved was confirmed. In my opinion, the significant improvement of lower layer temperature field may have reduced errors of typhoon track forecast.

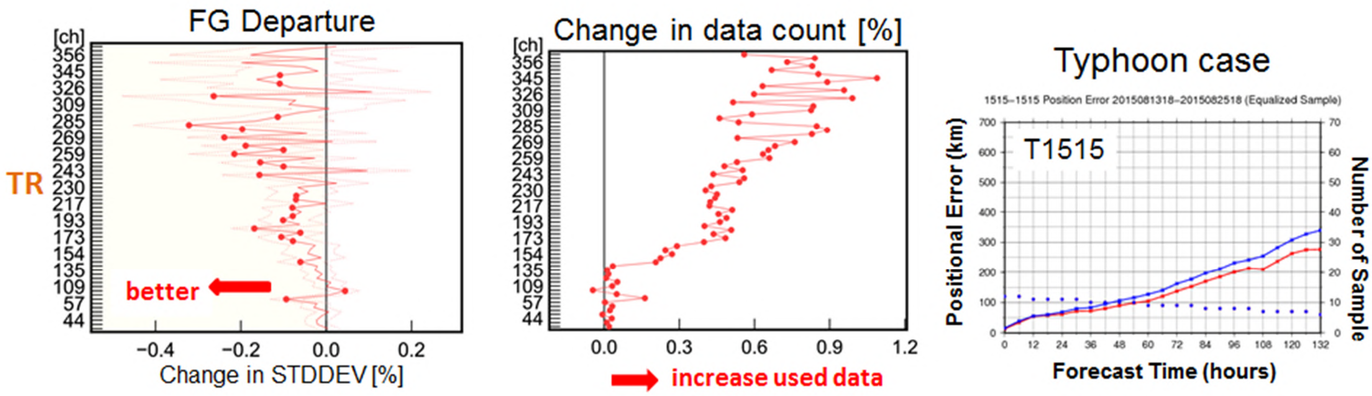

Fig 6: Left figure is normalized changes in the standard deviation of FG departures of Metop/IASI in the tropical region for the experiment period. Middle figure is changes in the data count of Metop/IASI in tropics. Right figure represents tropical cyclone track forecast errors for the northwestern pacific region with reference to JMA best-track data. The red and blue lines show track errors for the new and old models, respectively (left axis), and each point shows the number of samples (right axis).

Summary

To evaluate CrIS radiance data assimilation in JMA global system, assimilation experiments were conducted. The results showed the addition of the CrIS long-wave temperature sounding channels brought clear improvements on temperature analysis in the upper troposphere and stratosphere. Furthermore, large improvements of geopotential height forecast in the Southern Hemisphere were confirmed. Based on these findings, operational use of CrIS radiance data in JMA's global NWP system was started on 29 March 2017.

The ozone product profiles of the JMA showed improvement in stratosphere and troposphere compared to MLS and ozonesonde. Experiments were conducted using improved ozone profiles. Utilizing new ozone profiles of the JMA for HSS produced better temperature analysis. An improved TY prediction was found. In my opinion, better ozone profiles contribute to the accuracy of NWP.

References

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