Assimilation of GOES hourly AMVs in NCEP global data assimilation and forecast system

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Abstract

NESDIS has been producing GOES hourly atmospheric moisture vectors (AMVs) since 2010. NCEP made the efforts to try to assimilate GOES hourly AMVs to replace current so called three hourly AMVs. The characteristics of the "observation minus background" from GOES hourly AMVs were studied and compared with current operational GOES AMV products. The quality markers from data were also examined. Based on these studies, the strategies to assimilate GOES hourly AMVs were defined and tested in the NCEP data assimilation (GSI) and forecast system (GFS).The experiments show that The forecast impacts are neutral.

Introduction

NESDIS has been producing GOES hourly AMVs since 2010. The algorithms to produce the hourly AMVs are similar to those used to produce three hourly AMVs with a few updates such as improving height assignment over ocean when a low level temperature inversion is detected, the image scan line time defines the time for each satellite wind observation, the data is more timely and the latency is reduced about 15 to 30 minutes, the data bufr files contain the expected error (EE) and QI quality indicators. The data counts from GOES hourly AMVs is about 5 times of 3 hourly winds since more images are processed. The GOES hourly AMVs provide more information about system dynamic tendency compared with 3 hourly winds, but also poses some challenges to assimilate them such as correlated errors not only in space and also in time and also possible over fit issues. To address these issues, the data quality were examined, the relationships between quality indicators from the data provider and observation minus NCEP global forecast background (OMB) and observation minus analysis (OMA) were explored, the proper quality control strategies and observation errors were defined based on these studies. Only GOES hourly infrared (IR) and water vapor (WV) cloud top AMV data were examined in this study since only GOES 3 hourly IR and WV cloud top AMV data were assimilated in NCEP global forecast and data assimilation system. The parallel experiments were set up to test GOES hourly AMVs forecast impacts. The more details descriptions are given in the following sections.

The data and quality control schemes

Two weeks of data samples were used to examine the quality of GOES hourly AMS. The first one is to compare 3 hourly data with hourly ones. The statistics of OMB were calculated over two week period from July 11 to 25th, 2012. The OMB statistics show the quality of GOES hourly AMVs is comparable with 3 hourly GOES AMVs (figure 1, for example). The features of comparison between 3 hourly with hourly from IR and WV cloud top are similar, therefore only comparisons from IR AMVs are discussed.

Figure 1a is OMB statistics (bias, u RMS, v RMS and vector RMS) from GOES hourly IR AMVs and 1b is from statistics from GOES 3 hourly IR AMVs. Compared figures 1a and b, RMS of u, v, and vector are very similar from two data sets some differences of OMB bias are at low levels around 800mb, the bias of OMB for u component from -0.5 m/s around 800mb from GOES 3 hourly IR AMVs to close -0.15 m/s from GOES hourly IR AMVs, OMB bias improvement from GOES hourly may be from height assignment improvement over the ocean the ocean when the temperature inversion was detected.

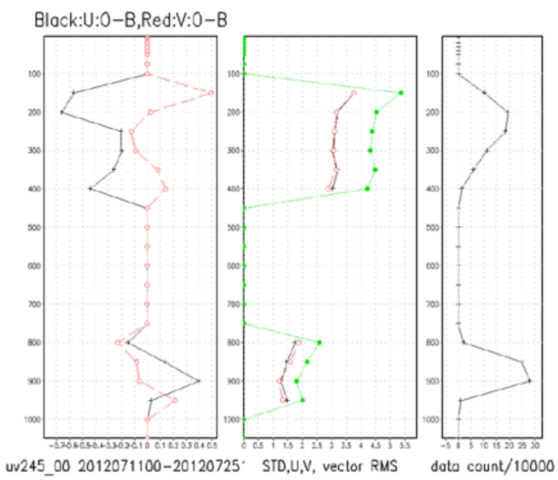

Figure 1a. O-B statistics for GOES 13 hourly AMVs. The left panel is O-B for u (black line), v (red line). The middle panel is RMS of u (black line), v (red line), vector (green line), the right panel is data count

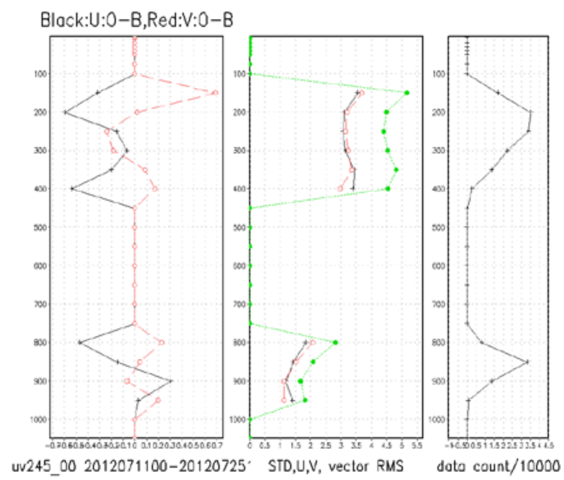

Figure 1b. O-B statistics for GOES 13 3 hourly AMVs. The left panel is O-B for u (black line), v (red line). The middle panel is RMS of u (black line), v (red line), vector (green line), the right panel is data count.

The next step is to examine whether data quality varies with relative to cycle time. The statistics of OMB show slight variability with relative cycle time, however there is no trend to larger RMS with larger relative cycle time (See Figure 2 as example). There are two quality indicators in the data set, QI with and with out forecast, expected error (EE). QI without forecast is used in the most NWP assimilation groups to filter the data. Santek et al. (Santek et al, 2012) have used normalized EE in his quality control scheme to assimilate MODIS winds. The QI and EE vs. vector RMS of OMB were examined with two week data, also the relationships between normalized vector RMS (by observation wind speed) vs. QI, and The QI and EE vs. vector RMS of OMB were examined with two week data, also the relationships between normalized vector RMS (by observation wind speed) vs. QI, and original EE values were also examined in a single cycle scattering display (see figures 3 and 4 as examples). The statistics of OMB vs. Quality indicators QI and EE show that the OMB RMS vector decrease with higher QI and lower EE values (see Figure 3 as example). The scatter plots of QI values vs. normalized RMS of OMB show the most data

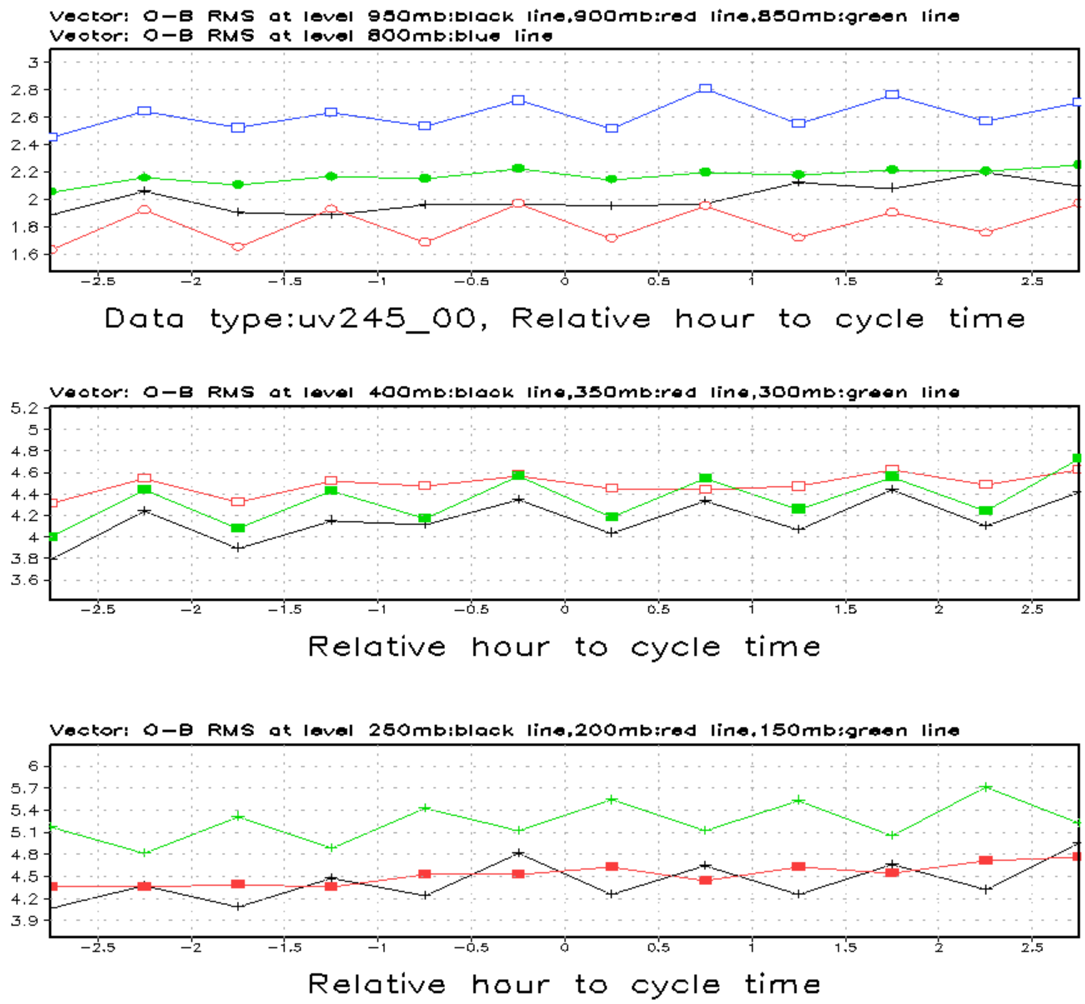

Figure 2. The vector RMS of O-B for GOES 13 IR hourly MAVs at different relative to cycle time at different levels

concentrated QI values greater than 85, also normalized RMS values scatter with large range from 0.02 to 0.37 for QI values below 85, and most normalized RMS values are between 0.025 and 0.15. The scattering plot of original EE values vs. normalized RMS show that the values of normalized RMS vary larger range with larger original values and most data concentrate at EE values less than 0.4. These plots not only show EE and QI can be used in the quality scheme also provide the information of criteria of EE and QI values for the quality control scheme. Another study was conducted to compare GOES hourly penalty with varying observation error with 3 hourly AMVs with current operational observation errors. The final quality control strategy and observation errors for GOES hourly IR and WV cloud top AMVs were determined by these studies.

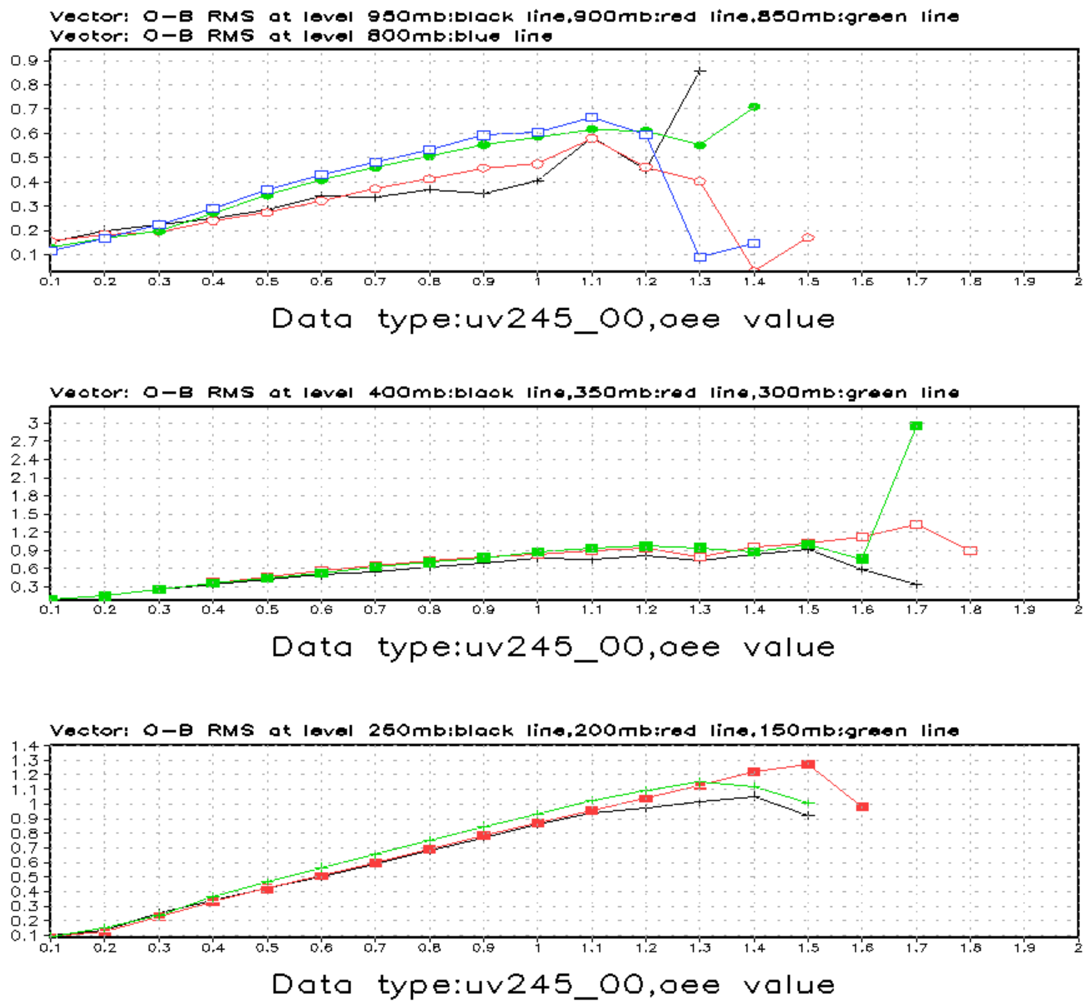

Figure 3. Normalized RMS by observed speed vs. original EE values at different heights for GOES 13 IR hourly AMV

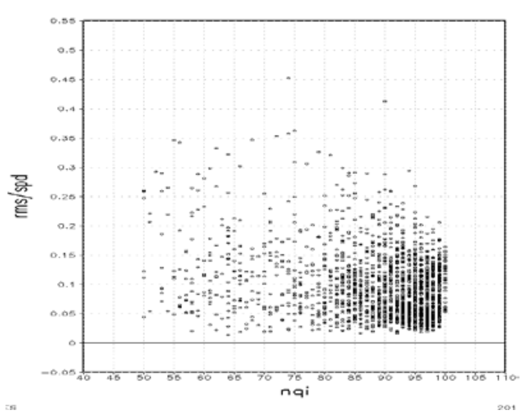

Figure 4a QI values vs. normalized O-B rms (by observed wind speed for GOES 13 hourly AMVS at 20130502

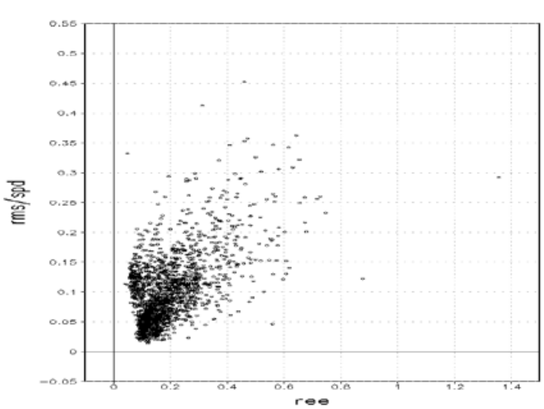

Figure 4b original EE values vs. normalized O-B rms (by observed wind observed speed for GOES 13 hourly AMVS at 20130502.

The experiments were set up to assimilate GOES hourly IR and water vapor cloud top AMVs which replace 3 hourly GOES AMVs. The experiments cover two periods: July 1st to August 15th 2012 as summer period, November 15th to December 31st 2012 as winter period. The systems for the experiments are T574L64 2013 operational NCEP global forecast system (GFS) and 2013 March GSI system. The forecast impacts and observation fits for both periods are similar. The results presented in the following section is summer period and compared with control experiment, not only GOES IR and water vapor cloud top AMVs different from control experiment, but also adding JMA profiler winds and Metsat water vapor cloud top AMVs. The individual tests for these two new winds are neutral.

The Results

The Forecast impacts of assimilation of GOES hourly IR and WV cloud top AMVs are presented as figures 5, 6, and 7. The black line and red line represent results from control run (prCrtSOx) and experiment (prda141g) respectively. The results from the experiment to assimilating GOES hourly IR and WV cloud top AMVs to replace 3 hourly IR and WV cloud top AMVs and JMA profiler winds, METSAT WV cloud top AMVs. The results from figures 5 show that there are neutral impacts on both hemispheres and tropical region. The impacts on precipitation forecast (figure 7) is slight positive, especially at 60 to 84 forecast hours but not statistically significant.

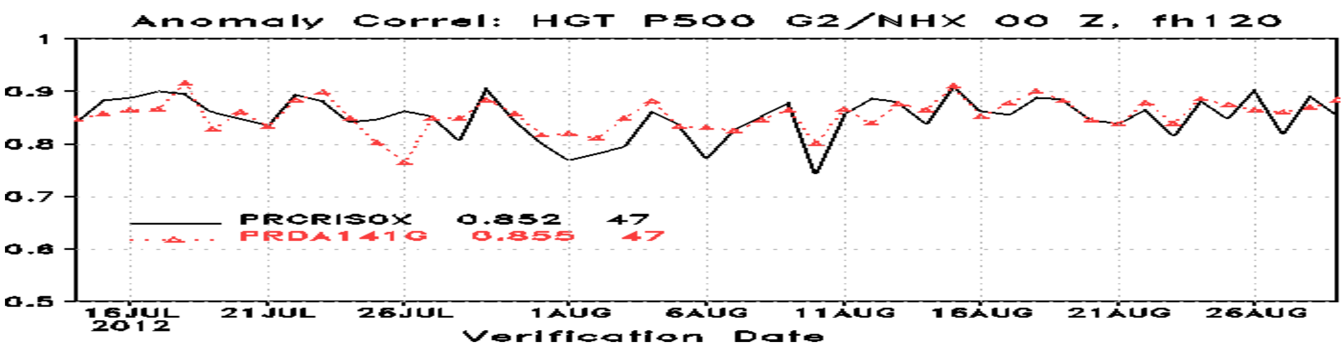

Figure 5a Time series of anomaly correlation of height at 500mb of Northern hemisphere at forecast day 5, the black line is control run, red line is for experiment

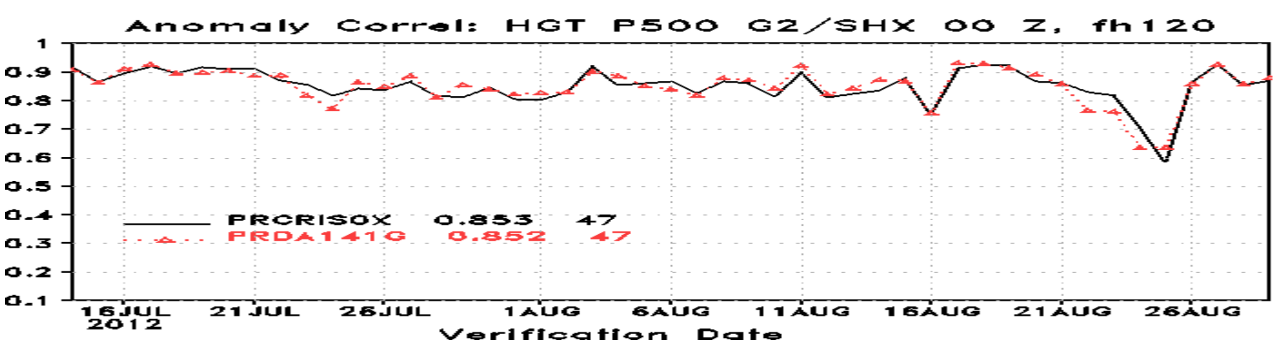

Figure 5b Time series of anomaly correlation of height at 500mb of Southern hemisphere at forecast day 5.

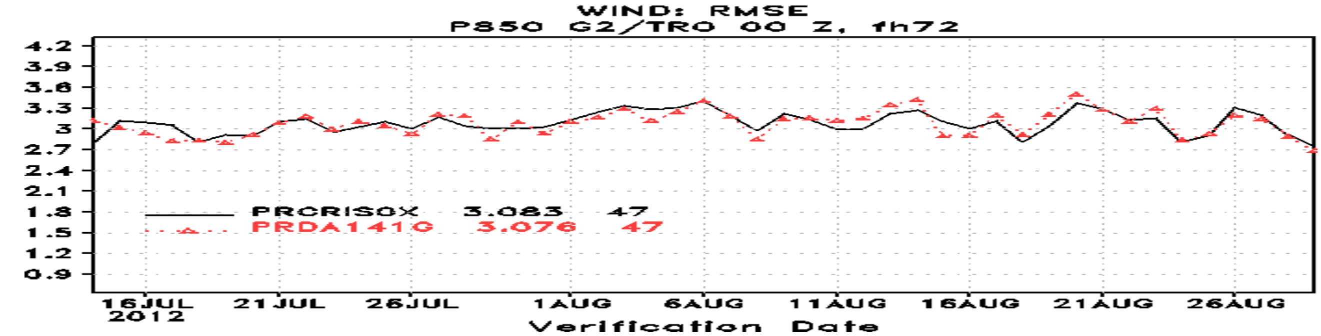

Figure 6a The time series of wind vector RMS at 850mb tropical region (20° south to 20° north) of day 3.

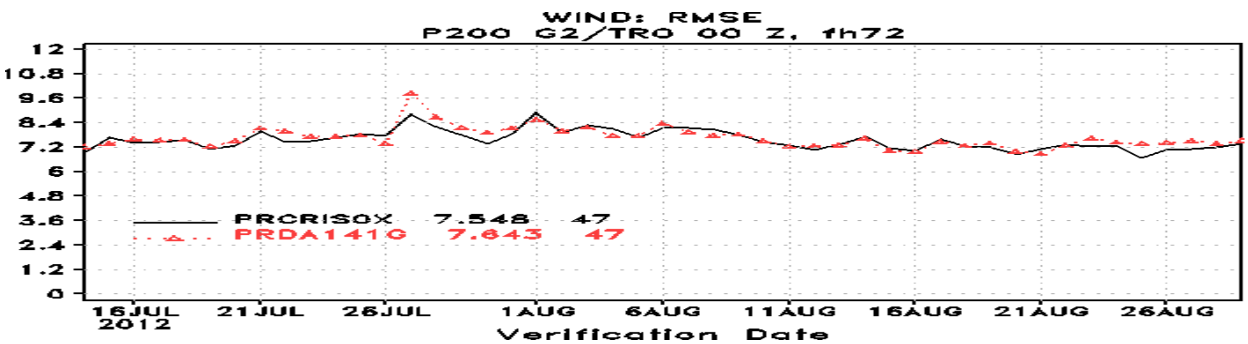

Figure 6b The time series of wind vector RMS at 200mb tropical region (20° south to 20° north) of day 3.

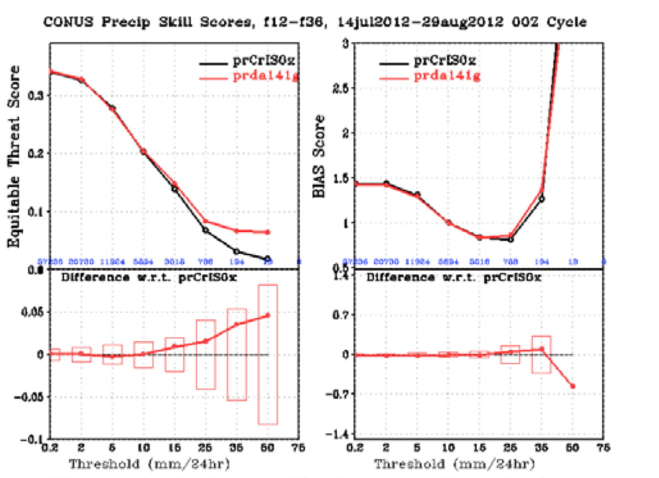

Figure 7a CONUS precipitation scores for the 12 to 36 forecast hour,, top left panel is threat scores, bottom left is threat score differences between control run and experiment, the top right panel is bias score and bottom right is bias score difference between control run and experiment.

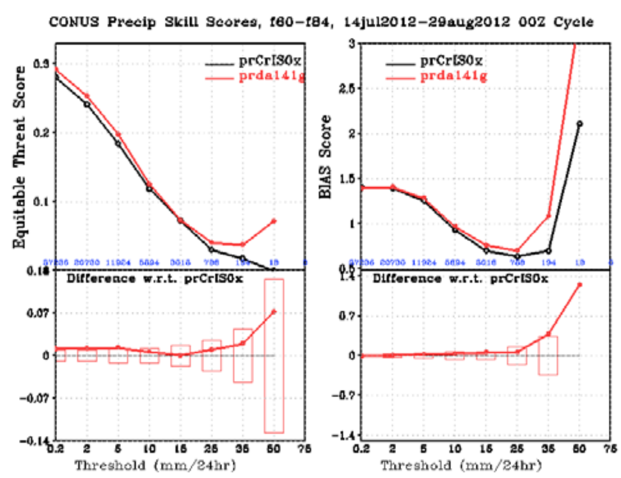

Figure 7b CONUS precipitation scores for the 60 to 84 forecast hour,, top left panel is threat scores, bottom left is threat score differences between control run and experiment, the top right panel is bias score and bottom right is bias score difference between control run and experiment.

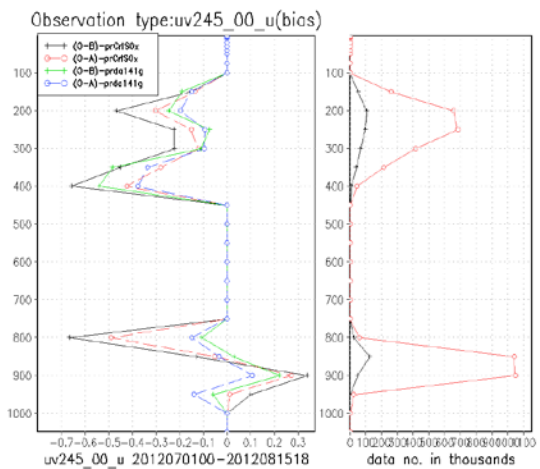

Figure 8a The vertical profile of O-B and O-A bias from control run and experiment for GOES 13 IR AMVs

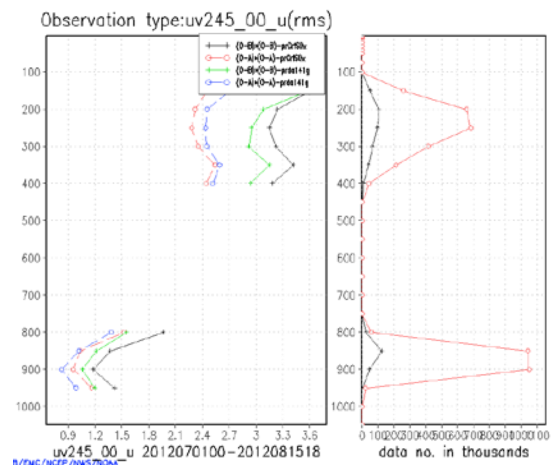

Figure The vertical profile of O-B and O-A RMS from control run and experiment for GOES 13 IR AMVs

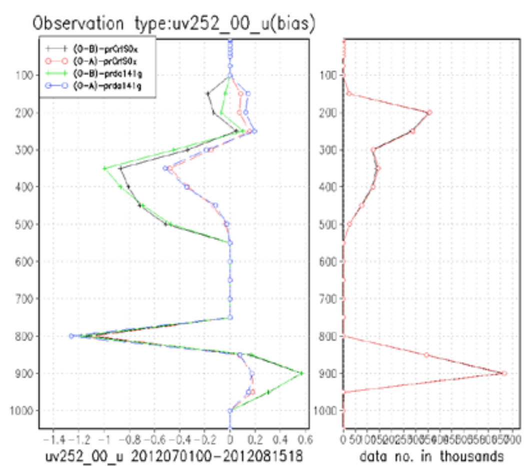

Figure 9a The vertical profile of O-B and O-A bias from control run and experiment for IR AMVs

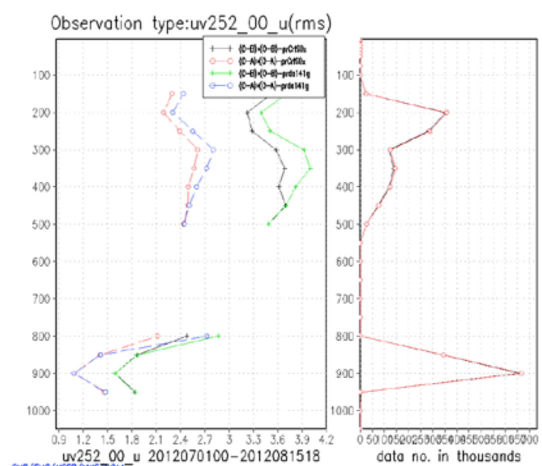

Figure The vertical profile of O-B and O-A RMS from c and experiment for GOES 13 IR AMVs

The assimilation of GOES hourly IR and WV cloud top AMVs has some impacts on observation fit on AMVS, but not other conventional data. The results of observation fits for different types of AMVs are shown in Figure 8. Assimilation of GOES hourly IR and WV cloud top, JMA profiler winds and Metsat WV cloud top AMVs improve Observation fit for GOES IR and WV cloud top AMVs as shown at figures 8a and b of GOES IR u component vertical profiles from control run and experiment. Compared with control run, the biases of OMB and OMA from experiment are smaller at both lower levels (below 800mb) and higher levels. OMB and OMA wind vector RMS are also smaller at both lower and higher levels compared with ones from control run. There are also much more data assimilated (right panel, red line for experiment). For other data types, OMA and OMB bias and vector RMS are similar from experiment and control run at lower levels, however OMB and OMA wind vector RMS increases at higher level (above 400mb) as shown Figure 9 as an example.

Summary

GOES hourly IR and WV cloud top AMVs are assimilated in NCEP global and forecast system to replace 3 hourly IR and WV cloud top AMVs. The quality control and assimilation schemes were defined after examining GOES hourly IR and WV cloud top data and comparing with GOES 3 hourly IR and WV cloud top data. The forecast impacts are neutral, the impacts on observation fits are mixing, the bias and RMS of OMB and OMA for GOES hourly IR and WV cloud top are smaller, however RMS of OMB and OMA for other AMVS larger. This may imply some inconsistences between GOES AMV products with other satellite AMV products. More studies may be needed to examine assimilation schemes such as thinning algorithm and observation errors, and quality control schemes.

Reference

Santek, D. , B. Hoover, J. Jung, S. Nebuda, Quality control of MODIS and AVHRR polar winds in the GDAs/GFS: status and plans, 10^{th} JCSDA workshop on satellite data assimilation, October 10-12, 2012, Maryland, USA