Recent Work on Satellite Atmospheric Motion Vectors in the NCEP Data Assimilation System

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Abstract

The satellite Atmospheric Motion Vectors (AMVs) quality depends partially on the reliability of the height assignment methods. Jung et al., (2010) showed that the quality of the height assignment method, used in deriving the GOES AMVs, is consistent with the RMS difference between the observation and the model background (O-B). We have focused on improving the quality control procedures for the GOES AMVs which have the poorer quality height assignment methods and have slow speed biases. In addition, the cloud top AMVs, derived from the MTSAT water vapor channel, are now being assimilated. The forecast impacts are positive and the largest where stricter quality control was applied. Improvements in the O-B and O-A statistics with conventional data are observed.

INTRODUCTION

Satellite derived AMVs have been produced since the1970s and provides valuable information to the data assimilation systems, especially in regions where conventional observations are sparse or void. However poor quality data also can harm the analysis and forecast. The uncertainty of the AMV quality is inherent in the AMV production methods: the uncertainty in the image target, tracking and height assignment method. The accuracy of height assigned to the AMV depends on the height and assignment methods. Another issue related to AMV quality is that they have a slow speed bias when compared with the 6-hour forecast and rawinsonde observations. In this study, we will focus on improving the quality control related to the AMV height with respect to the height assignment method and the slow speed bias. In addition, we will also discuss assimilation techniques used for the water vapor cloud top AMVs from the Geostationary Multi-Functional Transport Satellite (MTSAT) generated by the Japan Meteorological Agency (JMA).

The Quality Schemes

The National Environmental Satellite, Data and Information Service (NESDIS) uses several height assignment techniques in determining AMV height. For the Geostationary Operational Environmental Satellites (GOES), CO_2 ratio (CO_2), infrared window (WIN), water vapor intercept (H_2O), histogram (HIST) and cloud base are the common methods. In comparison of satellite AMVs with rawinsonde observations, NESDIS has ranked height assignment methods from best to worst as CO_2, H_2O, WIN (Jung et al, 2010). According to Jung et al. (2010), the most used height assignment method between 800mb and 600mb is WIN which suggests poor quality AMVs. Jung et al. (2010) also found those low levels AMV to have larger normalized speed and direction errors when compared with the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) first guess. Our statistics between AMVs and first guess confirm that there are large speed biases for all water vapor AMVs at the low levels(below 600mb) and all infrared AMVs at the middle levels (between 800 and 600 hPa), as shown in Figure.1. The AMV slow speed characteristics also appear in the O-B and O-A statistics from other geostationary satellites. The quality control schemes from other Numerical Weather Prediction (NWP) centers such as the European Center for Medium-range Weather Forecasts (ECMWF) and the United Kingdom Meteorological Office (UKMO) includes eliminating the winds with poor quality found in these regions. In this paper, the quality control scheme focuses on the data with large uncertainty in the height assignment and slow speed biases. Using information from our O-B and O-A statistics, Jung el al. (2010) and the quality control schemes used by other NWP centers (web sites) we filtered out AMVs below 600 hPa for derived from water vapor cloud top and between 800 and 400 hPa derived from the infrared images. We also applied an asymmetric gross check to most AMV types

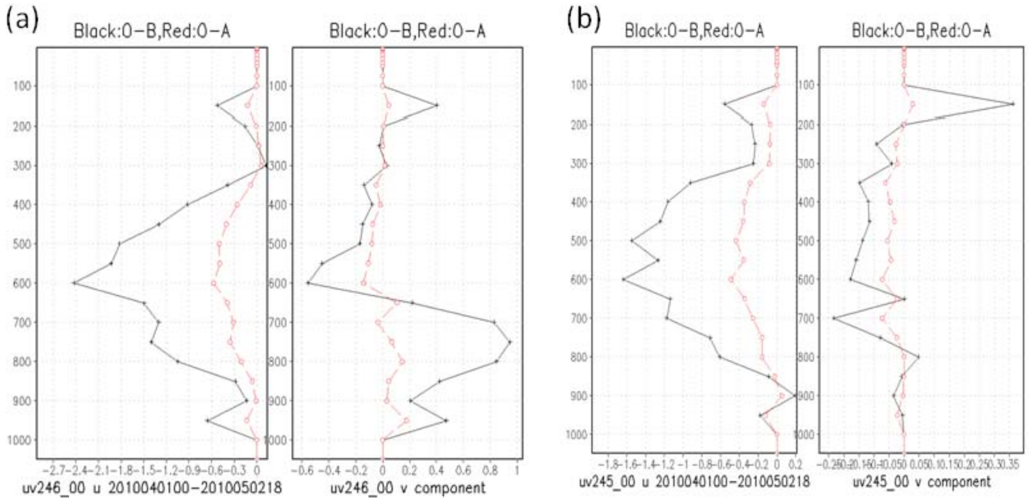

Figure 1: **The vertical profile of mean and RMS between the observation and the model background (O-B) (black) and analysis (O-A) (red) for the GOES (a) cloud top water vapor and (b) Infrared AMVs.**

The Experiment

Forecast and assimilation experiments were conducted for the period of March 22 to May 2, 2011, using NCEP GFS at T574L64, the forecast and data assimilation system is the version implemented in May 2011. The differences between the control and experiment include: the new quality control procedures for satellite AMVs, the asymmetric gross check, the assimilation of water vapor cloud top AMVs from MTSAT. In the following figures, prd11q1y represents control and satqj2 is represents the experiment with quality control package and assimilation of water vapor cloud top AMVs.

The Results

1. The impact on forecast

Figure 2 presents the forecast day 5 time series geopotential height anomaly correlation at 500mb for the Northern and Southern hemisphere verified against its own analysis. The black and red lines represent results from control and experiment respectively. This is an important index to evaluate the forecast impact at mid-latitudes. Compared with forecast impact with control run, the results from the experiment show an almost neutral impact on the mid-latitude forecast, with very slight negative impact in the Northern hemisphere and slight positive impact in the Southern hemisphere.

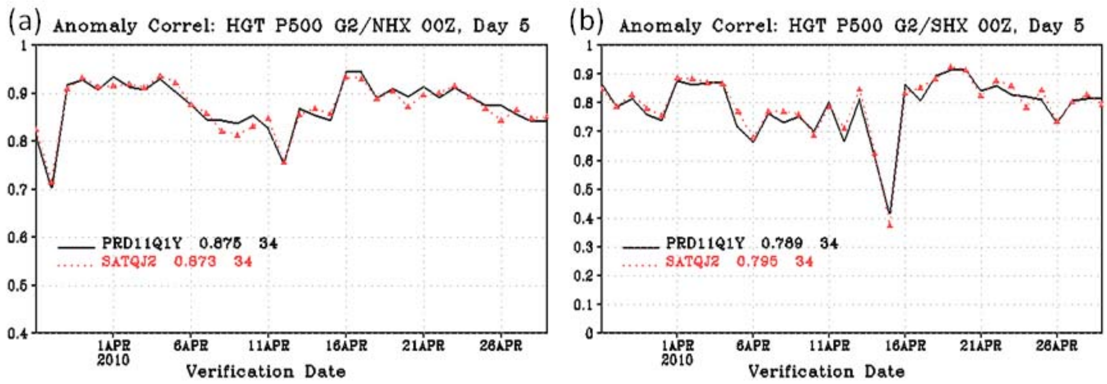

Figure 2: **The forecast day 5 anomaly correlation time series of geopotential height for the (a) Northern and (b) Southern hemisphere.**

Another important index to evaluate the forecast impact in the tropical region is wind vector root mean square (RMS) difference between the forecast and analysis. The tropical region is defined between 20^o north to 20^o south. For forecast day 3, the time series of wind vector RMS shows slightly larger RMS values for the experiment compared to the control (Figures 3a and b). However, clear improvement in the tropical regions are shown at 700 and 500 hPa (Figures 4a and b), especially at 500 hPa, where most of the new AMV quality control was applied (between 800 to 400 hPa). The consistency between improvements and data quality control may indicate the quality control scheme works.

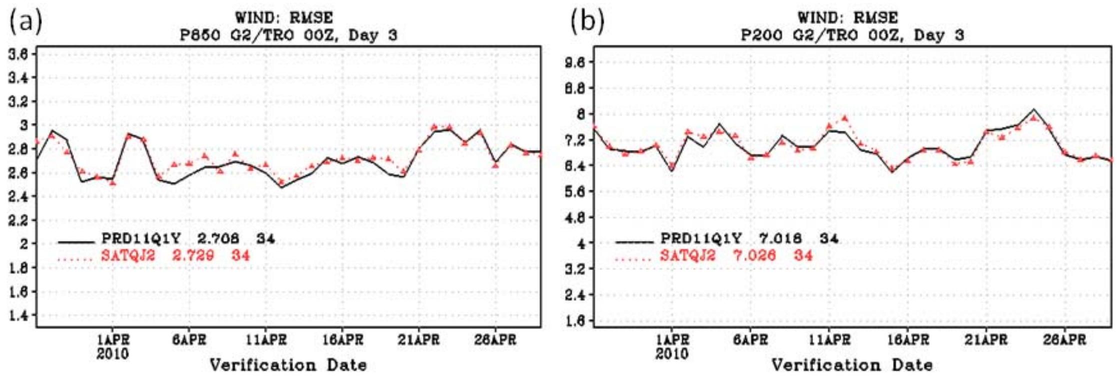

Figure 3: **The forecast day 3 vector wind RMSE time series in the tropics at (a) 850 hPa and (b) 200 hPa.**

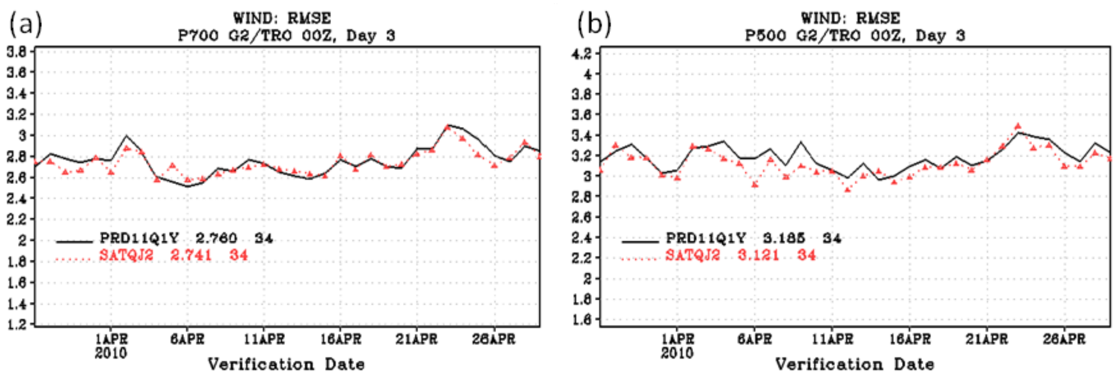

Figure 4: **The forecast day 3 vector wind RMSE time series in the tropics for (a) 700 hPa and (b) 500 hPa.**

To further examine the wind vector change, the vertical profile of mean RMS between analysis and forecast maps are presented in Figure 5 for the global average (Figure 5a) and the tropical region (20^o north- 20^o south) (Figure 5b). Generally speaking, there is overall positive impact globally from the changes made in the experiment for wind vector RMS for the experiment period at all levels, for all forecast hours. The green/red areas indicate that the RMSE difference between the forecast –

analysis of the control are greater/smaller than the RMSE difference between the forecast – analysis of the experiment respectively. For the tropical region, different forecast hours and different heights tell different stories. At lower levels (below 700 hPa) the first five days show negative impact, there is positive impact at the middle level (700 to 300 hPa) for all forecast hours, and mixed impact in the upper levels (300 to 100 hPa). Compared with green areas (positive impact) with red areas (negative impact), the overall green area is greater than red area, meaning there is more positive impact than negative impact for tropical region.

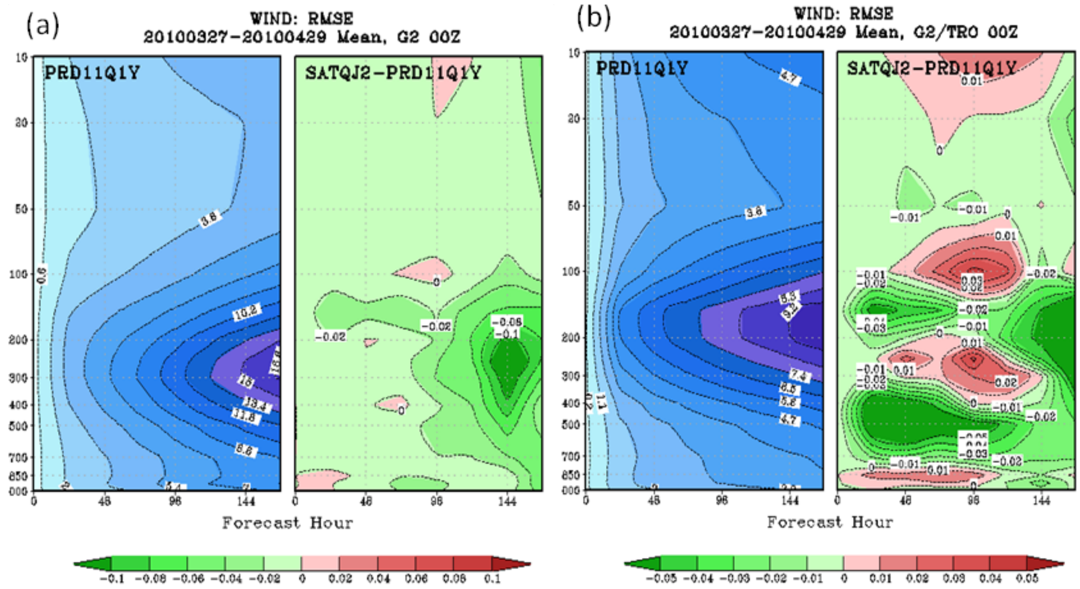

Figure 5: **The vertical profile of vector wind difference RMSE between the analysis and forecast for the (a) global mean and the (b) tropical region. The left panel is the analysis- forecast difference RMSE from the control. The right panel is the difference of the RMSE difference between the control and experiment. Green/red indicates positive/negative impact from the new quality control procedures and addition of MTSAT winds.**

2. The impact on precipitation

The impacts on the precipitation forecast mainly focus on the Continental United States (CONUS), the precipitation forecast skill include equitable threat score (ETS) and bias, whose definitions can be found in the web site http://www.emc.ncep.noaa.gov/gmb/STATS_vsdb. Generally speaking, the higher ETS value and a bias value close to 1 means better precipitation forecast skill. Figure 6 represent precipitation forecast skill for12- to 36-hour forecasts (Figure 6a), and 36- to 60-hour forecasts (Figure 6b), the top panel is ETS and bias score, the bottom panel is the statistical significance measure. The black line is result from control, red is the experiment. The results would be significant if the difference line is outside of the rectangle boxes. Figure 6 shows the experiment improved the precipitation forecast, especially for the forecast hour from 12- to 36-hours, although the difference between results from control and experiment is not statistically significant.

3. The impact on observation fits

The AMV quality control improves most O-B and O-A fits to the AMVs. Figure 7 shows an example of the vertical profile of O-B and O-A mean bias, RMS and data counts for wind direction (Figure 7a) and speed (Figure 7b) averaged over experiment period for GOES IR AMVs. The different color lines represent O-B and O-A for control and experiment as labeled in the plots. The mean bias and RMS for wind speed and direction for O-B and O-A all decrease in the experiment. The data number reduced at low and high levels is mainly from asymmetric gross check and land data which is rejected in this package. The data rejected at the middle level is because of poor height assignment quality. The improvements are also shown on observation fits on some conventional wind observations, the improvement scales are smaller than for satellite winds. Generally speaking, the O-B bias for wind

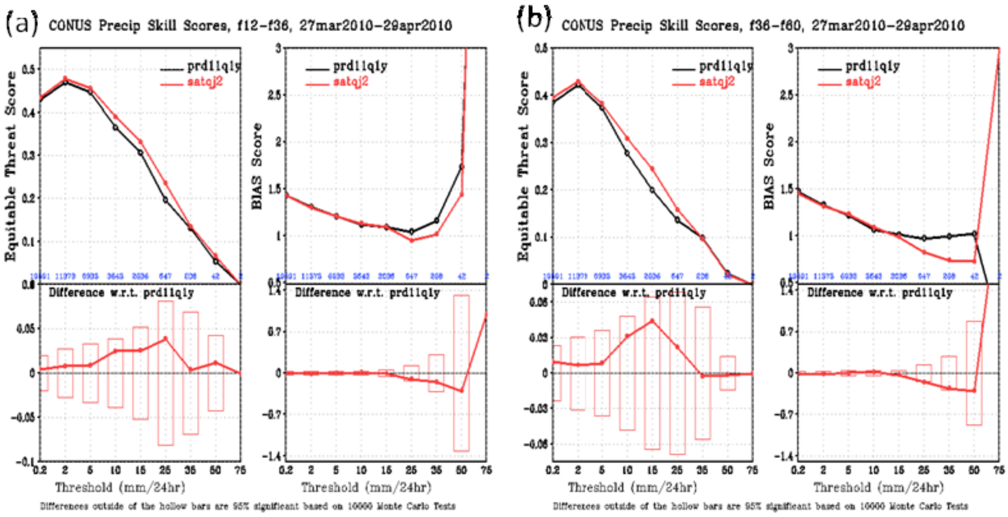

Figure 6: **CONUS precipitation forecast skill scores valid for (a) 12- to 36-hour and (b) 36- to 60-hour forecasts**

direction decreases for most conventional data while more data are assimilated (as shown in Figure 8 as an example of ranwinsonde vertical profile of O-B and O-A statistics of wind direction and speed). For the O-B of wind speed, the O-B bias decreases if O-B is positive, increases if O-B negative which implies the background wind speed increases after removing slow AMVs. There are no distinguishable differences for the RMS of wind speed and direction differences between observations and background, analysis. Another slight improvement to observation fits are rawinsonde humidity observations. The O-B bias is slight smaller for the experiment compared with control (results not shown).

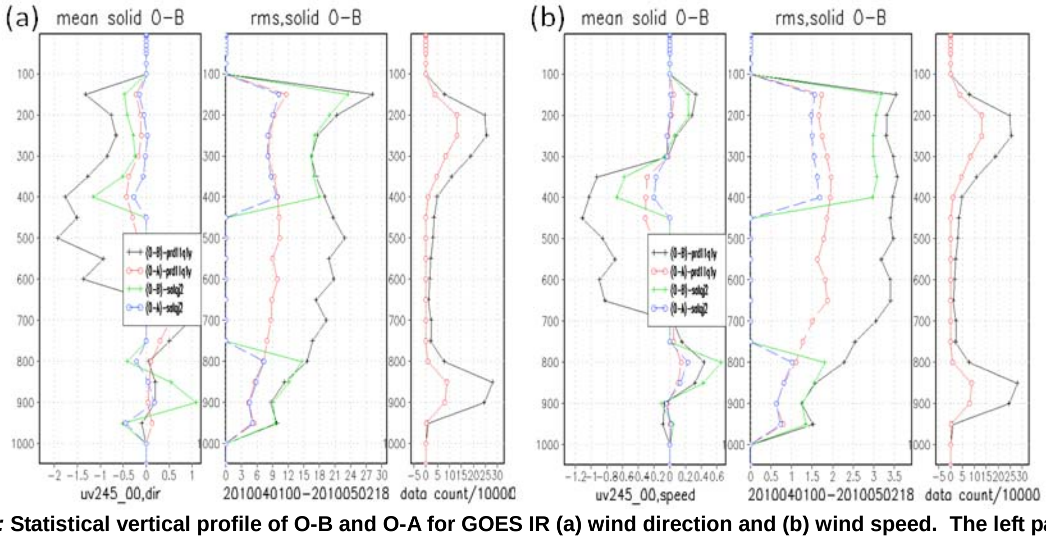

Figure 7: **Statistical vertical profile of O-B and O-A for GOES IR (a) wind direction and (b) wind speed. The left panel is bias, the middle panel is RMS and the right panel is observation counts.**

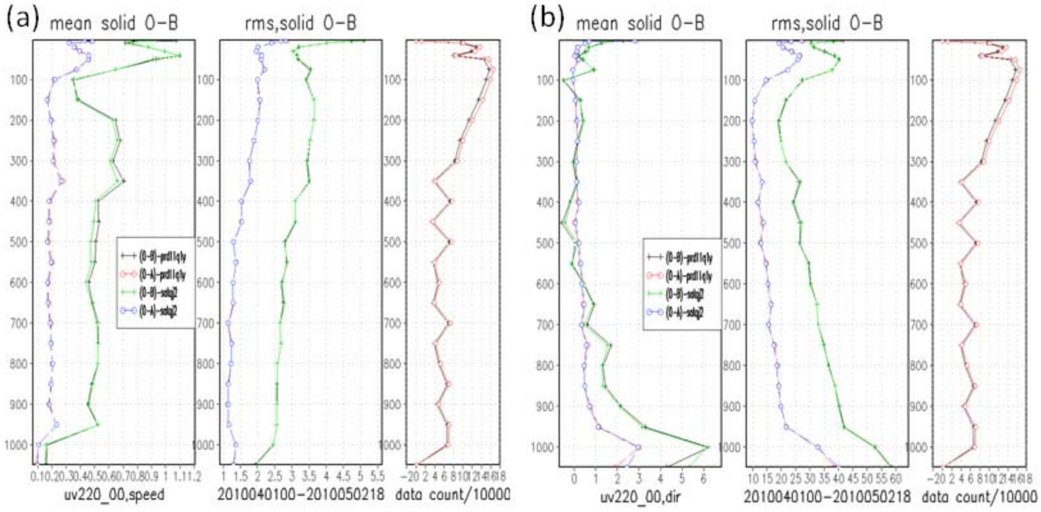

Figure 8: **Statistical vertical profile of O-B and O-A for rawinsonde (a) wind direction and (b) wind speed. The left panel is bias, the middle panel is RMS and the right panel is observation counts.**

SUMMARY

The satellite AMV quality control scheme used for this experiment was based on the statistic characteristics of differences between satellite AMVs and the NCEP global 6 hour forecast, results from Jung et al. (2010), and the quality control strategies applied at other NWP centers. The experiment results show that neutral forecast impacts at middle latitudes, positive impact wind vector RMS at tropical between 700 to 500 hPa, where lower quality data were removed. Another improvement is in the precipitation forecast, especially for the first 60 hours. The satellite AMV quality control package and assimilation of water vapor cloud top wind also improve background fit to observations including satellite AMVs and conventional wind observations. The most improvements, including bias and RMS are for satellite AMVs. The improvement for other conventional wind observations is limited for the bias of O-B and increased number of assimilated data. The background wind speed increases, compared with O-B differences from other conventional wind observations, may be because of removing slow AMVs with the asymmetric gross check.

REFERENCE

Jung, J., J. Le Marshall, J. Daniels, and L. P. Riishojgaad: Investing height assignment type error in the NCEP global forecast system. 10th International Winds Workshop, Tokyo, Japan, 22-26 February 2010.