

# MODIS POLAR WINDS ASSIMILATION EXPERIMENTS AT JMA

Masahiro Kazumori, Yoshiyuki Nakamura

Numerical Prediction Division, Japan Meteorological Agency  
1-3-4 Otemachi, Chiyoda-ku, Tokyo, 100-8122, Japan

## ABSTRACT

Since 1979, Atmospheric Motion Vectors (AMVs) from geostationary satellites have been used in the Japan Meteorological Agency (JMA) numerical weather prediction system. They provide valuable information of atmospheric motion from mid-latitudes to the tropics. However, there is little wind information at high-latitudes from the geostationary satellites and the radiosonde observations. The polar regions, therefore, have been remained as data poor regions for many years.

Recently, polar winds have been derived on a quasi-operational basis at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) of the University of Wisconsin-Madison by tracking structures in successive orbits from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua satellites. The MODIS polar winds are promising data to improve the quality of analysis in the polar region and to bring better-forecast results.

The MODIS polar winds assimilation experiments were performed for July 2003 and January 2004 using the JMA global three-dimensional variational data assimilation system (3D-VAR). Terra MODIS and Aqua MODIS polar winds in the Arctic were assimilated in the experiments. The experiments demonstrated positive impacts of the MODIS polar winds on short- and medium-range forecasts. Large improvements were found for the Northern Hemisphere in terms of geopotential height and wind fields. And improvements in typhoon track predictions were also found. Terra MODIS and Aqua MODIS polar winds in the Arctic have been operationally assimilated at JMA since 27 May 2004.

In this paper, details of the results from the assimilation experiments are described.

## 1. INTRODUCTION

The geostationary satellites have provided winds data from the tropics to mid-latitudes for global numerical weather prediction (NWP), and their winds data play a significant role to grasp the structure of wind field at global scale. While the polar region have been remained as a data poor region for long time because the observation of high latitudes is difficult for the geostationary satellites. Furthermore, radiosonde and aircraft network are sparse in the polar region.

The MODIS is an instrument aboard the Terra and Aqua polar-orbiting satellites. The MODIS measures radiances from the Earth with 36 spectral bands from Visible to Infrared bands. Since the resolution of the MODIS instruments is from 250m to 1km, cloud patterns and moisture feature are observed clearly. Recently,

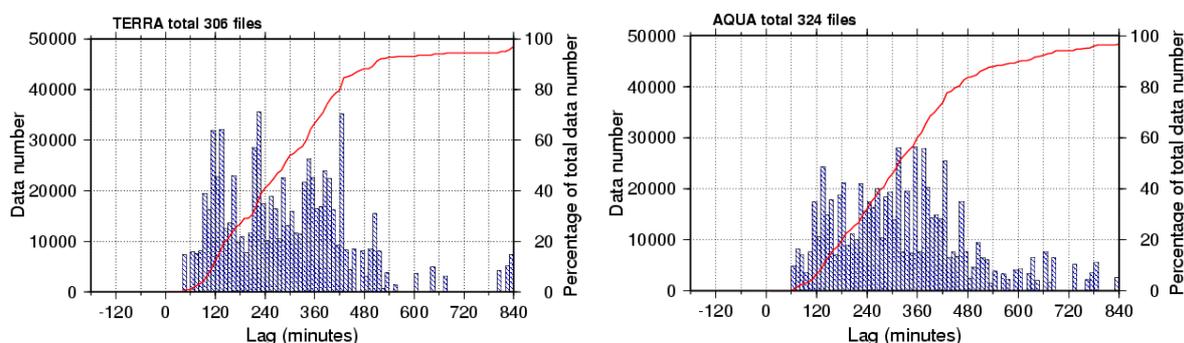
the MODIS polar winds are derived at CIMSS by tracking structures in successive swaths from the MODIS instruments (Key et al, 2003). Cloud patterns are tracked in the Infrared band (IR) and water vapour features are tracked in  $6.7 \mu\text{m}$  (WV).

ECMWF was used the Terra MODIS polar winds operationally since January 2003 (Bormann and Thepaut, 2003) and other NWP centres have performed MODIS polar winds assimilation experiments. Mostly their results showed positive impacts for NWP in the Northern Hemisphere (Cress, 2004).

Aiming to improve the forecast skill of NWP, JMA has started the acquisition of the MODIS polar winds from CIMSS since July 2003 and has investigated the quality of the MODIS polar winds.

## 2. DATA AND EXPERIMENTS

The MODIS polar winds were acquired from a CIMSS FTP server via Internet. The earliest cut off times is 440 minutes for the cycle analysis, and 150 minutes for the early analysis at JMA. 80% of the produced data are available for the cycle analysis and 20% for the early analysis. Figure 1 shows an example of number of received data as a function of time for Terra MODIS and Aqua MODIS respectively. The histogram represents the number of available data at that time and the red line represents the percentage of accumulated available data.



**Figure 1. Number of received data as a function of time for Terra MODIS (left) and Aqua MODIS (right) from 19 February 2004 to 4 March 2004.**

The MODIS polar winds assimilation experiments were carried out at JMA for July 2003 and January 2004. The Global Spectral Model (GSM) and 3D-VAR with 6-hourly analysis were used (Takeuchi, 2002). The model and analysis resolution were T213 (approximately 60km) with 40 levels in the vertical. 9-day forecasts were run from each 12UTC-initialized analysis. The MODIS polar winds were thinned to 150km resolution. No QI and RFF were used in the selection of MODIS polar winds data.

The configurations of the experiments were:

**CNTL:** Without MODIS polar winds assimilation. All other observational data were assimilated as the operational run. Terra MODIS and Aqua MODIS were monitored passively for the statistical investigation.

**TEST:** Experiments with Terra MODIS polar winds and Aqua MODIS polar winds. Except for MODIS polar winds, the TEST was the same as the CNTL. Based on the quality of MODIS polar winds, only the MODIS polar winds in the Arctic were assimilated in the TEST. And low level wind data were not used. Over ocean, IR winds data above 700hPa and WV winds data above 550hPa were used. Over land, IR and WV data above 400hPa were used. These thresholds of data selection were set based on the results of the ECMWF experiments (Bormann and Thepaut, 2003) and the data quality investigation in the CNTL as described later.

Figure 2 shows the quality of all MODIS polar winds against their first guess from the CNTL. These panels are the wind speed statistics of all MODIS polar winds. Left panels represent the BIAS against the first guess and right ones represent the Root Mean Square (RMS) error. The upper panels are Terra MODIS and the lower ones are Aqua MODIS. The statistical investigation revealed that the MODIS polar winds in the Antarctic have larger BIAS against the first guess than those of the Arctic. And the lower level MODIS polar winds have poor quality. The level with the maximum data number was around 500hPa. Figure 3 shows the

same but for the quality check passed data. As these results of statistics suggest, the data selection criteria in the preceding paragraph works effectively.

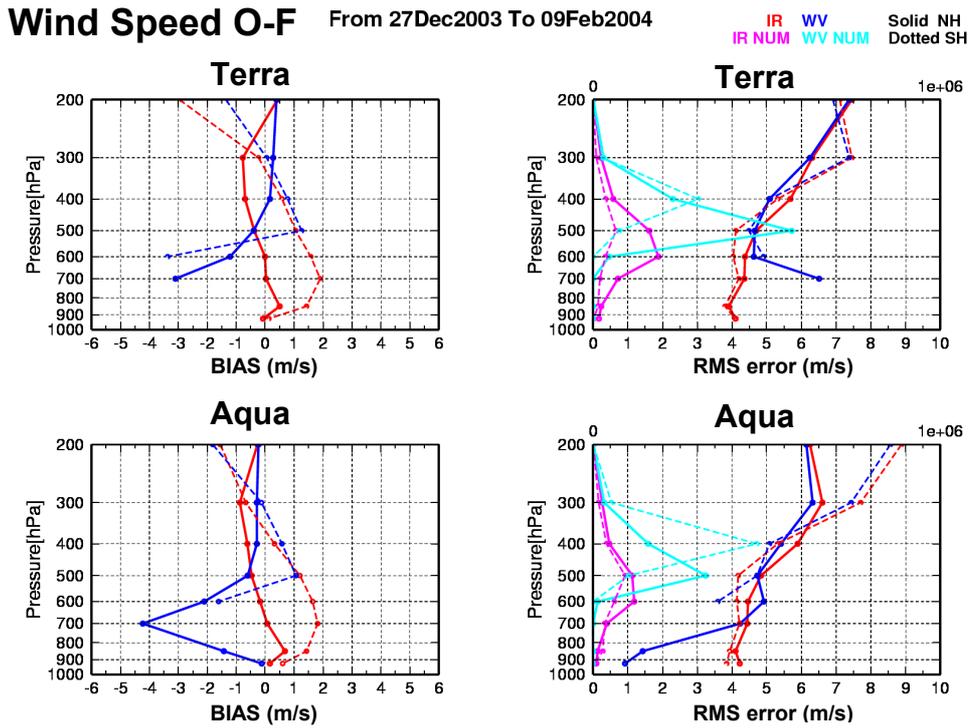


Figure 2. Statistics of wind speed against first guess for all MODIS polar winds from the CNTL. Upper panels are Terra MODIS and lower ones are Aqua MODIS. Left panels are BIAS and right ones are RMS error. Red line is IR winds and blue line is WV winds. Solid line is the Arctic and dotted line is the Antarctic. Light colour lines in the right panels show the numbers of data. The period is from 27 December 2003 to 9 February 2004.

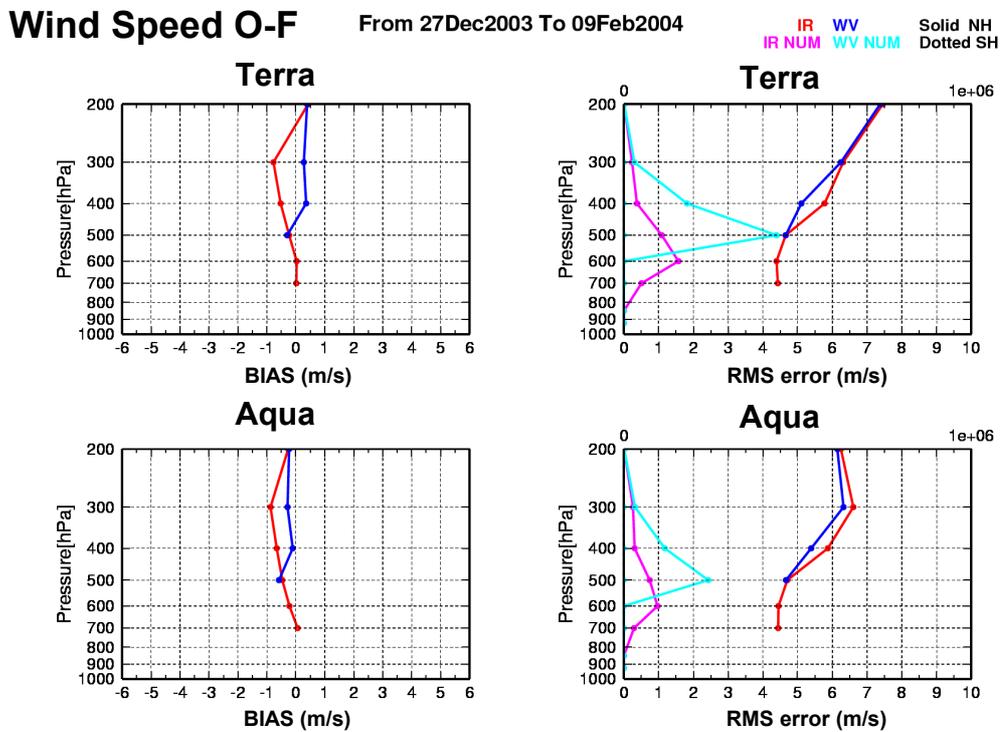


Figure 3. Same as Figure 2 but for the quality check passed data.

Figure 4 show an example of the assimilated data coverage of AMVs in the TEST and the CNTL in the Arctic. By using both Terra (morning satellite) and Aqua (afternoon satellite), MODIS polar winds filled the gap of wind data in the Arctic complementarily.

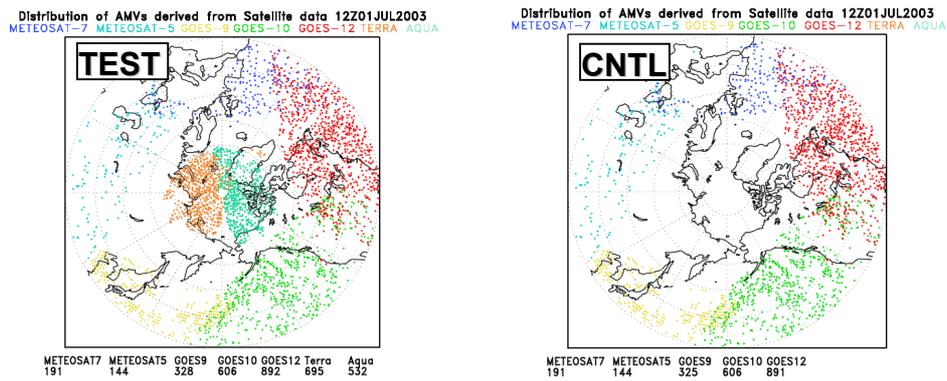


Figure 4. The example of AMVs data coverage in the TEST (left) and the CNTL (right) for the Arctic. Orange points are the Terra MODIS polar winds and the green points are Aqua MODIS polar winds. Other points are the AMVs from the geostationary satellites. These data are used in the MODIS experiments.

### 3. RESULTS

The impacts on analysis were restricted in the Arctic where the MODIS winds were assimilated. Figure 5 shows the monthly mean difference of 500hPa geopotential height between the TEST and the CNTL for analysis field and first guess field. Upper panels are the results of July 2003 and lower ones are January 2004. Left panels are the analysis field and right ones are the first guess field. The MODIS polar winds exert a similar influence on 500hPa geopotential height for both seasons. They increased the height over ocean and decreased the height on land. This feature is conspicuous in the guess fields. The same feature appeared in the temperature fields at 500hPa (not shown). Thus the effects of new observational information from MODIS polar winds were evident.

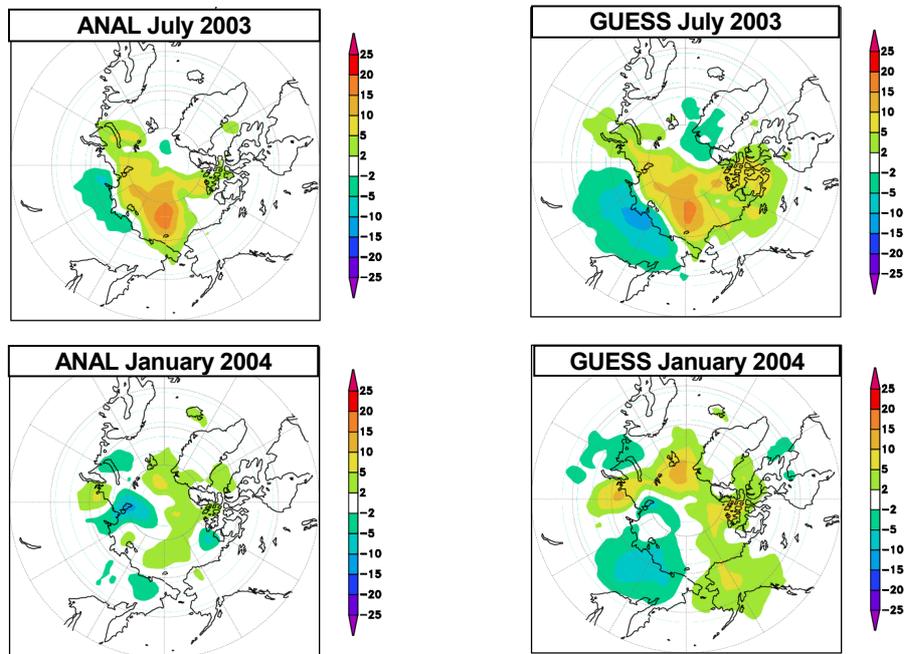
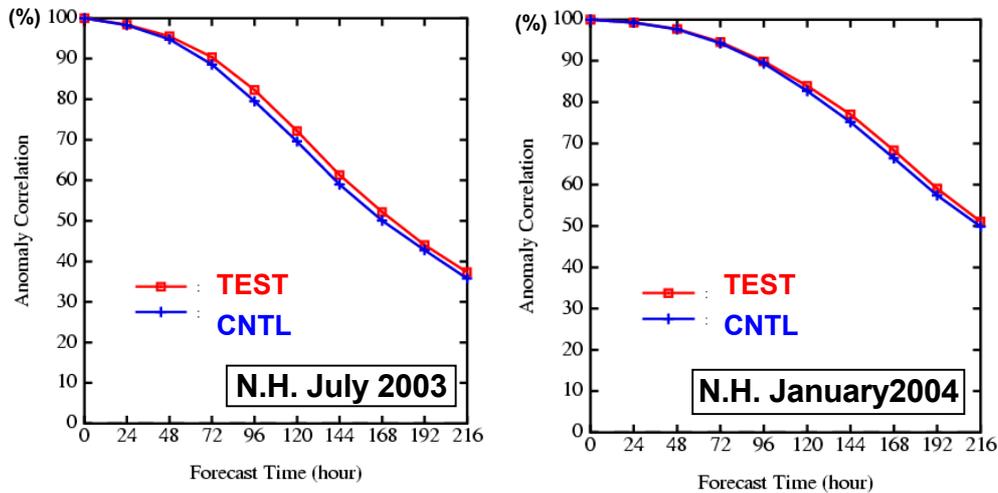
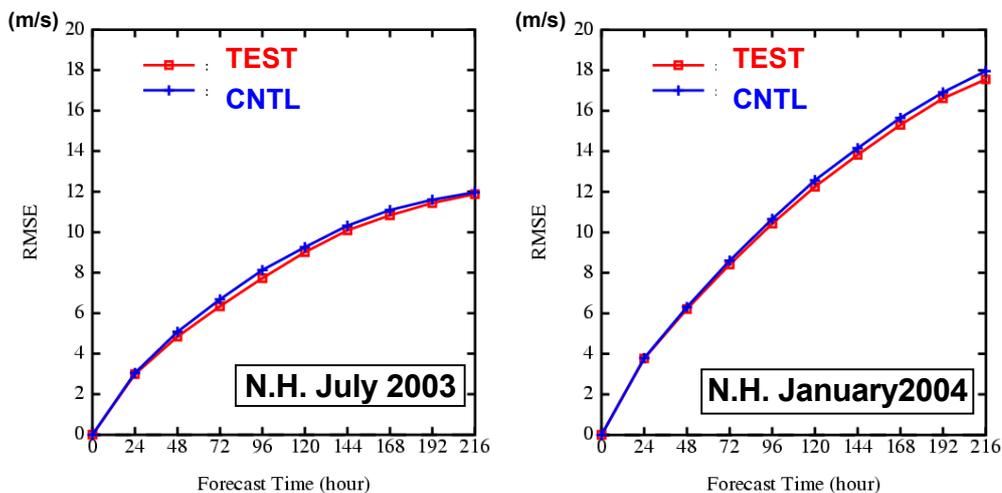


Figure 5. Monthly mean difference of 500hPa geopotential height between the TEST and the CNTL. Left panels show that of analysis field and right panels show that of first guess field. Upper panels are July 2003 and lower ones are January 2004.

As for impacts on forecast, the TEST demonstrated substantial positive impacts for the geopotential height at 500hPa in the Northern Hemisphere. Figure 6 shows the anomaly correlation as a function of forecast time for the 500hPa geopotential height forecast in the Northern Hemisphere. As for the tropics and the Southern Hemisphere, the impact was almost neutral. Figure 7 shows the RMS errors for the 500hPa wind vectors forecast for the TEST and the CNTL. The same impacts were found as the anomaly correlation for the 500hPa geopotential height.



**Figure 6. Anomaly correlation as a function of forecast time for the 500hPa geopotential height forecast in the Northern Hemisphere. Left panel shows that of July 2003 and right panel shows that of January 2004. The TEST (red) and the CNTL (blue) have been verified against their own analysis. The period is July 1-31, 2003 and January 1-31, 2004 respectively. The Northern Hemisphere is defined as the area north of 20 degrees.**



**Figure 7. Same as Figure 6 but for the RMS errors of 500hPa wind vectors.**

In general, RMS forecast error in the polar region accounts for the most part of the RMS forecast error in the Northern Hemisphere. Therefore, the MODIS winds are expected to reduce the RMS error in the Northern Hemisphere and make better effects on the forecast scores. It is important to evaluate how the RMS errors change spatially for each forecast time. Figure 8 shows monthly mean differences of RMS error between the TEST and the CNTL. The left panels are distribution of RMS error for the TEST and middle panels are that of for the CNTL. Right panels are the difference between the TEST and the CNTL. In the right panels, the negative value means positive impact. Upper panels are for 1-day forecasts and middle panels are 3-day forecasts, bottom panels are 5-day forecasts. The results were that the reduction of RMS error was large in the polar region in the short range forecast and the error reduction spread to lower latitudes with a hemisphere scale in the medium range forecast.

Upper panel in Figure 9 show the zonal mean distribution of RMS error of wind vectors at 500hPa for the TEST (red) and the CNTL (blue). Lower panel show the difference between the TEST and the CNTL. Negative difference means improvements by MODIS polar winds. Clear improvements were found at the area north of 50 degrees.

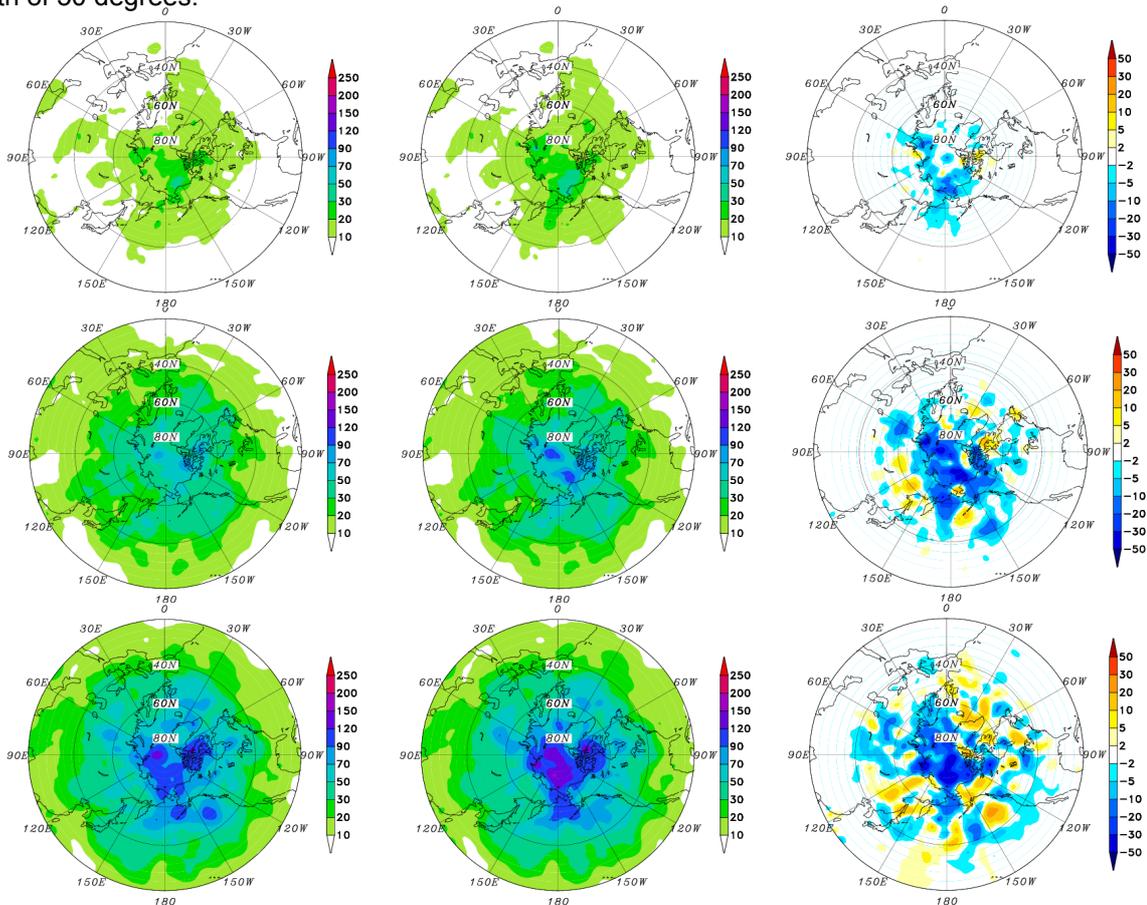


Figure 8. The distributions of RMS error at 500hPa geopotential height for the TEST (left) and the CNTL (middle) and the difference between the TEST and the CNTL (right). Upper panels are 1-day forecasts and middle panels are 3-day forecast and bottom panels are 5-day forecast.

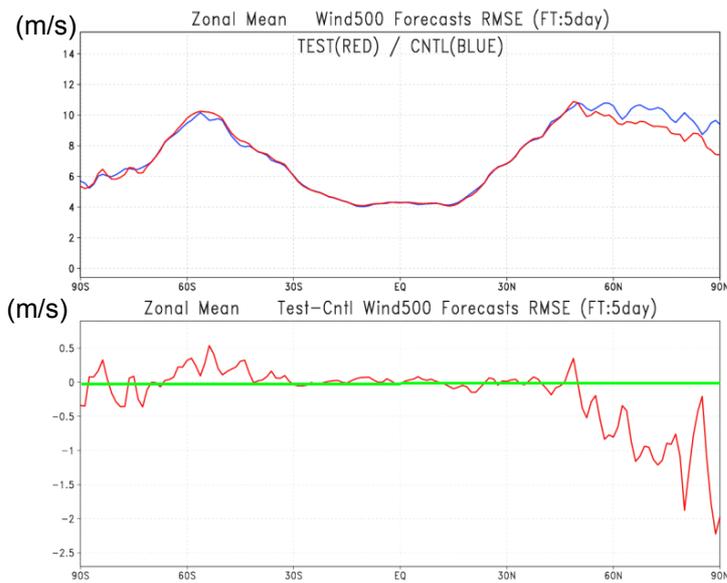
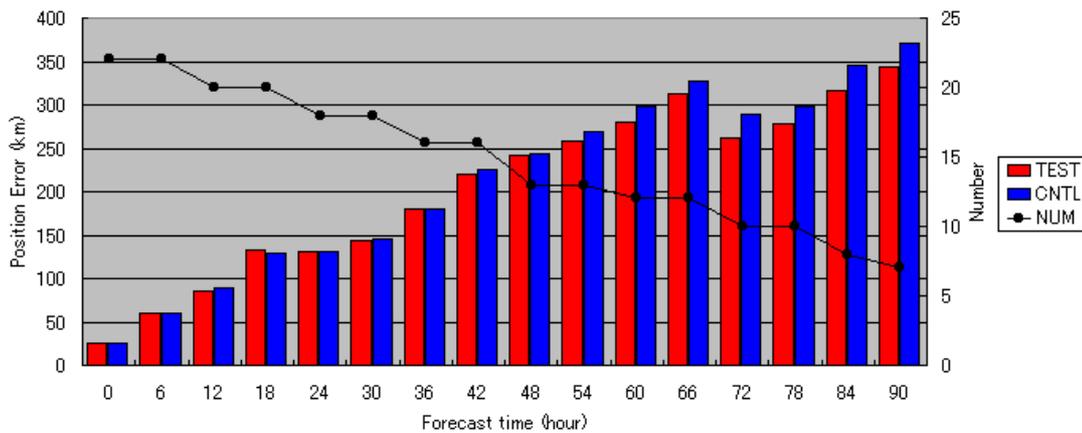


Figure 9. Zonal mean distribution of RMS error of wind vectors at 500hPa for January 2004. Upper panel is RMS error. Red line is the TEST and blue line is the CNTL. Lower panel is the difference in RMS error between the TEST and the CNTL.

Better predictions of the typhoon track were also found. The comparison of the mean positional error of typhoon track prediction between the TEST and the CNTL is shown in Figure 10. Improvements in mean positional error were seen at the later stage in the forecast time. The mean positional error was reduced by 20km after 60-hours (12 cases). It suggested that the improvement in the analysis field spread to the lower latitudes with procession of forecast time and the typhoon track prediction was improved.



**Figure 10. Comparison of mean positional error of typhoon track prediction between the TEST and the CNTL. Red bar is position error of the TEST and blue bar is that of the CNTL. Line is the number of cases.**

#### 4. SUMMARY AND FUTURE PROSPECT

The MODIS polar winds assimilation experiments were performed for July 2003 and January 2004 with the JMA GSM.

The MODIS polar winds were used in the Arctic. The MODIS polar winds complement other observations and introduce analysis increment in data sparse regions. And by using data from the two satellites, a better temporal coverage was acquired than one satellite case. Based on independent innovation statistics, the quality of the MODIS polar winds in the Northern Hemisphere was acceptable for the assimilation.

Analysis impacts of MODIS polar winds were restricted in the Arctic. Increase in 500hPa geopotential height over ocean and decrease over land were found for both July 2003 and January 2004.

As for forecast impacts, large improvements in forecast scores of geopotential height and wind fields were found. Better typhoon track predictions were also found. The MODIS polar winds revealed that the analysis in the polar region is extremely important for the forecast of mid-latitudes because the improvements in the polar region spread to mid-latitudes with the procession of forecast and that influence is on a hemisphere scale.

Based of these findings, JMA started the operational assimilation of Terra MODIS and Aqua MODIS polar winds in the Arctic on 27 May 2004.

Since November 2003, the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite Data Service (NESDIS) has produced MODIS polar winds experimentally. Some statistical investigations against first guess at JMA confirmed that MODIS polar winds produced by NOAA/NESDIS had better quality than CIMSS MODIS polar winds. The difference in the quality comes from the accuracy of height assignments. The assimilation experiment for NOAA/NESDIS MODIS polar winds is a subject for future study.

## **5. REFERENCES**

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