MODIS POLAR WINDS ASSIMILATION IMPACT STUDY WITH CMC OPERATIONAL NWP SYSTEM

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ABSTRACT

Wind observations derived from geostationary satellites imagery have been used in the Canadian Meteorological Centre (CMC) global and regional NWP systems for many years. However, because of the viewing angle, no high latitudes winds are available. The analyses in the Polar Regions suffer from the low density of conventional radiosonde or aircraft wind observations. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has adapted the wind retrieval procedure to the MODIS instrument on-board Terra and Aqua, NASA polar orbiting satellites. Early studies have shown the potential of these new observations. Recent assimilation and forecasts experiments conducted with the CMC global NWP system show an improvement in the quality of the forecasts with the inclusion of the polar wind observations in the 3D-Var assimilation. The selection and thinning procedure is similar to the one used with the geostationary satellites and is partly based on the quality indices provided with these observations. The benefit of the addition of the polar wind observations is more obvious in the polar region but extends to a certain degree to the whole hemisphere. This is especially true in the Southern Hemisphere. A new observing system experiment with no satellite winds, confirm the positive impact of this type of observations in the CMC 6-hourly 3D-Var assimilation system.

1. INTRODUCTION

Since June 2000, a series of major modifications have been implemented in the CMC global NWP system, resulting in substantial improvements to the quality of forecasts. In particular, the direct assimilation of ATOVS (AMSUA and AMSUB) radiance data, better use of wind and temperature data from automated aircraft reports, as well as a revised 3D-Var algorithm performed directly on the model η levels using temperature and surface pressure data rather than geopotential heights. Modifications to the assimilation of Atmospheric Motion Vectors (AMVs) have been presented at the last workshop, (Sarrazin and Brasnett, 2002, 6th IWW).

The CMC operational global forecast model (GEM) has a horizontal resolution of 0.9º and 28 η levels in the vertical. The analysis program is a 3D-Var assimilation program on model surfaces at a spectral resolution of T108. Background errors were obtained from the so-called 24-48h method. The quality control of observations is now a two step approach: a background check prior to the analysis and a variational QC during the analysis process itself. The CMC continuous assimilation cycle is a 6-hourly 3D-Var system.

After the workshop on MODIS polar winds, (Fairbanks, Alaska, 7-9 October 2003), the participants decided to conduct additional monitoring and assimilation trials during a common period in order to better examine the quality of MODIS polar winds. Wind datasets generated by UW-CIMSS and NOAA/NESDIS were available during MOWSAP (MODIS Winds Special Acquisition Period) from 8 November 2003 to 31 January

2004. Preliminary monitoring and assimilation results indicate more positive impacts in the CMC NWP system with the NOAA/NESDIS dataset. The focus of the present paper is the results of some recent fine tuning in assimilation experiments for AMVs and the impact of the inclusion MODIS polar winds from the NOAA/NESDIS dataset during MOWSAP in preparation for operational implementation.

2. TUNING OF AMV ASSIMILATION

This section describes a few low impact modifications to the selection and assimilation procedure of AMVs in CMC NWP system. First, until now the observation errors were specified in 2 layers only, above 500 hPa and a second layer from the surface to 500 hPa. The observations errors of AMVs are now distributed on 10 layers as shown in table 1. This modification was partly prompted by the fact that the number of MODIS polar winds peak between 400 and 500 hPa, contrarily to geostationary satellite data. The small increase in the observation errors new values has a very small positive impact in CMC NWP system but is not statistically significant.

layer	1000	850	700	500	400	300	250	200	150	100
old	2.5	2.5	2.5	2.5	5.0	5.0	5.0	5.0	5.0	5.0
new	3.0	3.0	3.5	4.5	5.0	5.5	6.0	6.0	6.0	6.0
RAOBS	1.6	1.7	1.8	2.0	2.2	2.5	2.6	2.5	2.2	2.0

Table 1: Observation errors (m/s) for AMVs, old, new and comparison with radiosondes.

The second modification is the replacement of GOES-9 satellite data from SATOBS format bulletins by data in JMA BUFR bulletins. The passive monitoring of these observations and observation minus first guess statistics as a function of QI values has shown characteristics very similar to EUMETSAT METEOSAT AMVs. For that reason, the same selection rules are applied in the thinning of the observations. Another modification is the assimilation of WV channel observations in clear air regions as well as in cloudy regions. The MOWSAP dataset did not discriminate between cloudy or clear-air WV observations. On average these modifications have little impact on the quality of the forecasts.

Finally, the quality control was modified by a tightening of the rejection rule in QC-Var, based on an increase of the a-priori probability of gross error. The number of “rejected” observations went from about 2% to 2.5% in the mid and high levels. This change in the number of rejected observations led to a small positive impact in CMC NWP system. Figure 1 shows the impact of these modifications on the quality of 6-day forecasts during MOWSAP.

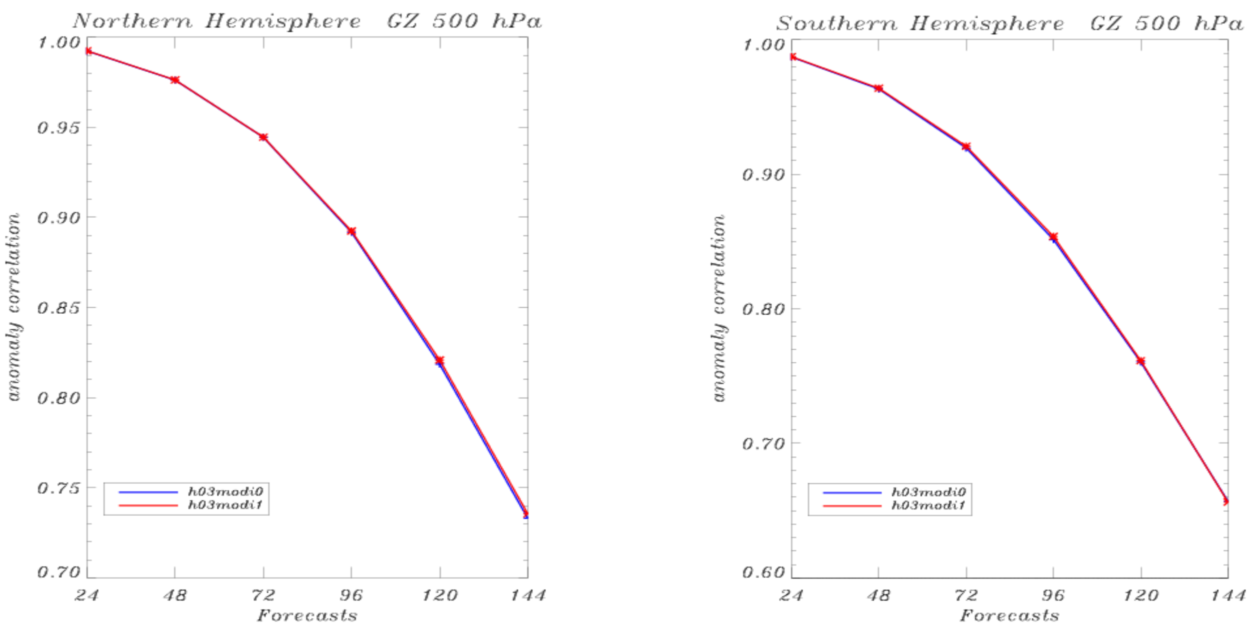

Figure 1: 500 hPa heights anomaly correlation for Northern and Southern Hemisphere (20°-90°), red line with the tuning mentioned in section 2, and the control in blue, verified against their own analyses.

3. PASSIVE MONITORING OF MODIS POLAR WINDS

The retrieval procedure of MODIS polar winds and the first assimilation trials with positive results were presented at the last workshop (David Santek et al 2002, 6th IWW). CMC has started the monitoring of these observations in 2003. During MOWSAP, the data was included in CMC observation database in near-real time, first for quality monitoring and eventually to conduct assimilation trials. The near-real time gathering of the observations may have occasionally limited the number of observations included in the trial because of the late arrival of the data.

Figure 2 shows average observation minus first-guess statistics during the passive monitoring, using the CMC operational first-guess fields. The statistics, for both IR and WV (ALL) observations, cover the whole period but only observations within 90 minutes of the time of the first-guess and between 100-700 hPa were included in the sample. MVD results are better for the Arctic than for the Antarctic. This is not necessarily a reflection of a difference in quality of the observations but also the result of different quality of CMC first-guess fields in the Antarctic region. The greater variability of the results on the border of the region is due to the lower number of observations in each box at the limit of the polar winds region. These MVD values are close to those obtained from observations of geostationary satellites. On the Arctic speed bias map we find a region with a negative bias of -1 m/s or more north of the Canadian Arctic Archipelago, but on average the bias is small. For the Antarctic, there is a positive speed bias and it seems mainly located over the continent.

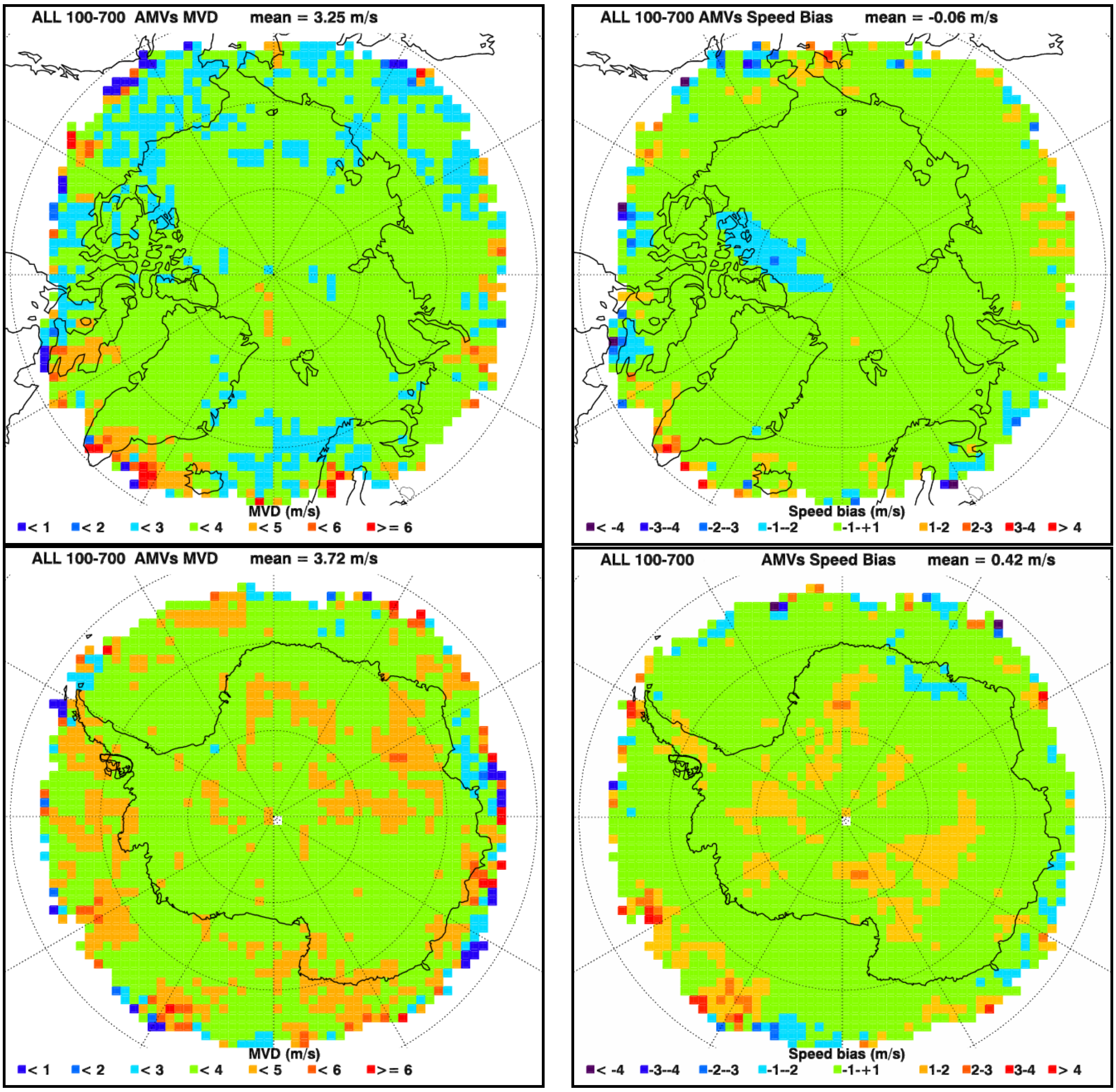

Figure 2: Passive monitoring of polar winds, observation minus first-guess statistics, MVD on the left side and speed bias right, MOWSAP period, 100-700 hPa data.

Figure 3 shows similar maps over the Antarctic but separately for WV and IR observations. As for the geostationary satellites data, the WV observations show somewhat higher MVD values than the IR observations. These larger values seem concentrated over the ocean area. It is difficult to estimate the significance of this geographical distribution of MVD and bias values with this unique sample.

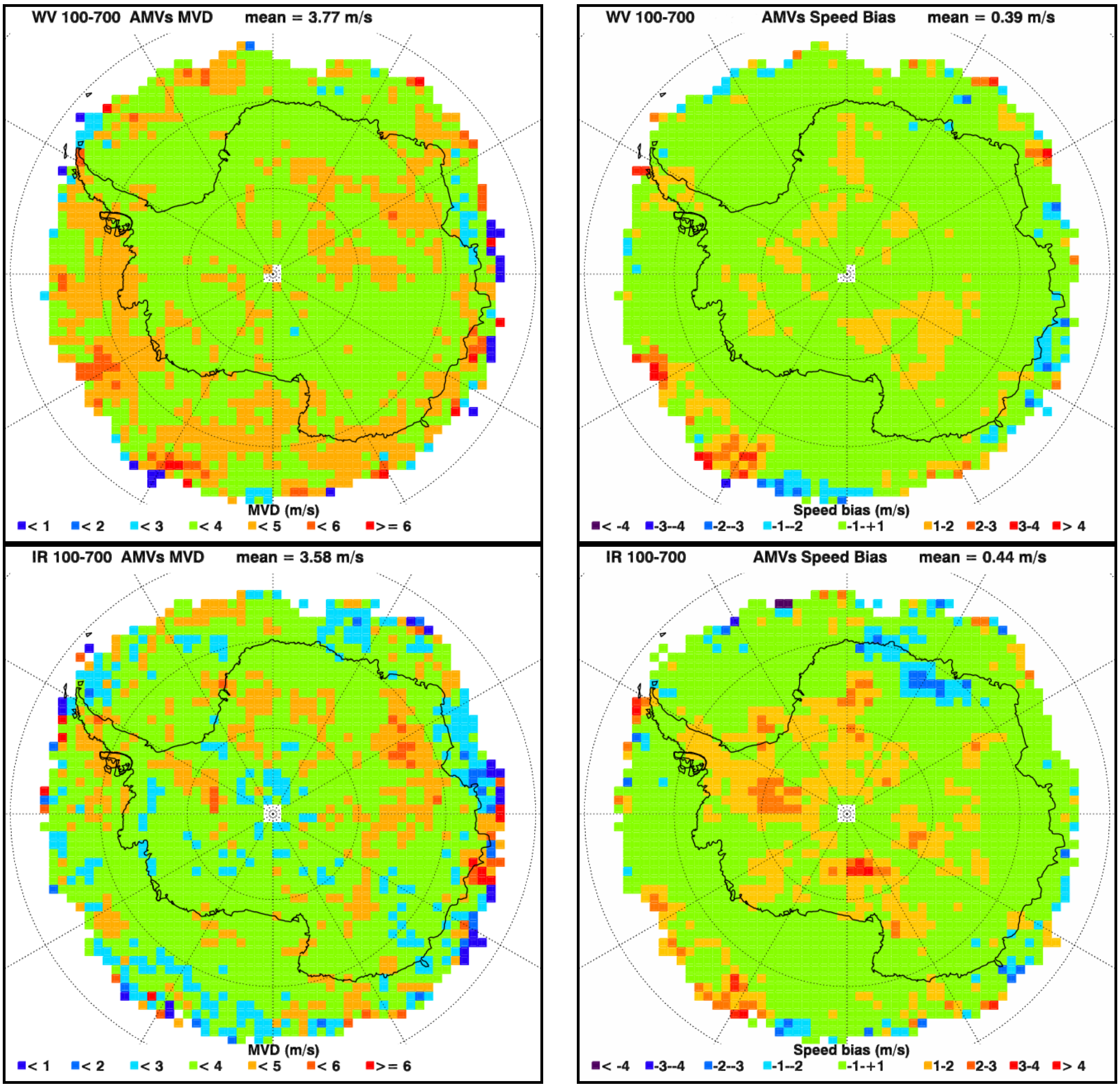

Figure 3: Passive monitoring of polar winds, observation minus first-guess statistics, MVD on the left side and speed bias right, MOWSAP period, Antarctic region WV data on top, IR below, 100-700 hPa data.

The MOWSAP dataset also includes the RFF and QI quality indices. The observation minus first-guess statistics was also examined as a function of the indices in order to evaluate their usefulness in the selection procedure. Figure 4 shows an example for WV observations during November 2003 in the Arctic region. The distribution as a function of the RFF values is very similar to the NESDIS GOES data distribution but shifted toward somewhat lower RFF values. EUMETSAT QI values show that for higher QI observations the average wind speed is also higher, giving a lower NRMSVD.

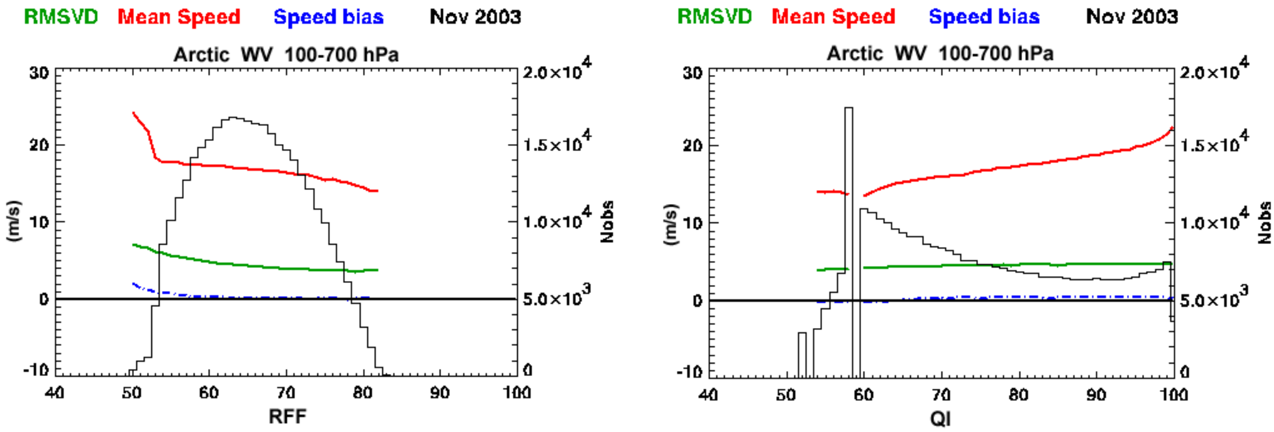

Figure 4: Observations minus first-guess statistics versus quality indices, RFF left, QI right, for November 2003 WV observations.

4. ASSIMILATION TRIAL RESULTS

The polar winds selection and assimilation procedure is similar to the one used for GOES observations, but, with a RFF threshold = 60, spatial thinning at ~180 km density, IR observations are used above 700 hPa, WV above 550 hPa, over land both above 400 hPa only, the QC is the same with background check and QC-Var. Observation errors are also the same as geostationary satellite observations. During MOWSAP, in near real-time, about 200-500 observations per analysis were selected for assimilation. Figure 5 shows the impact on the forecast quality of 6-day forecasts, run every 12 hours during MOWSAP. The impact of the addition of the MODIS polar winds is clearly more important than the previously mentioned tuning alone. Not shown here, the verifications for the high latitudes 60°-90° indicate a more significant improvement in the scores for that region alone.

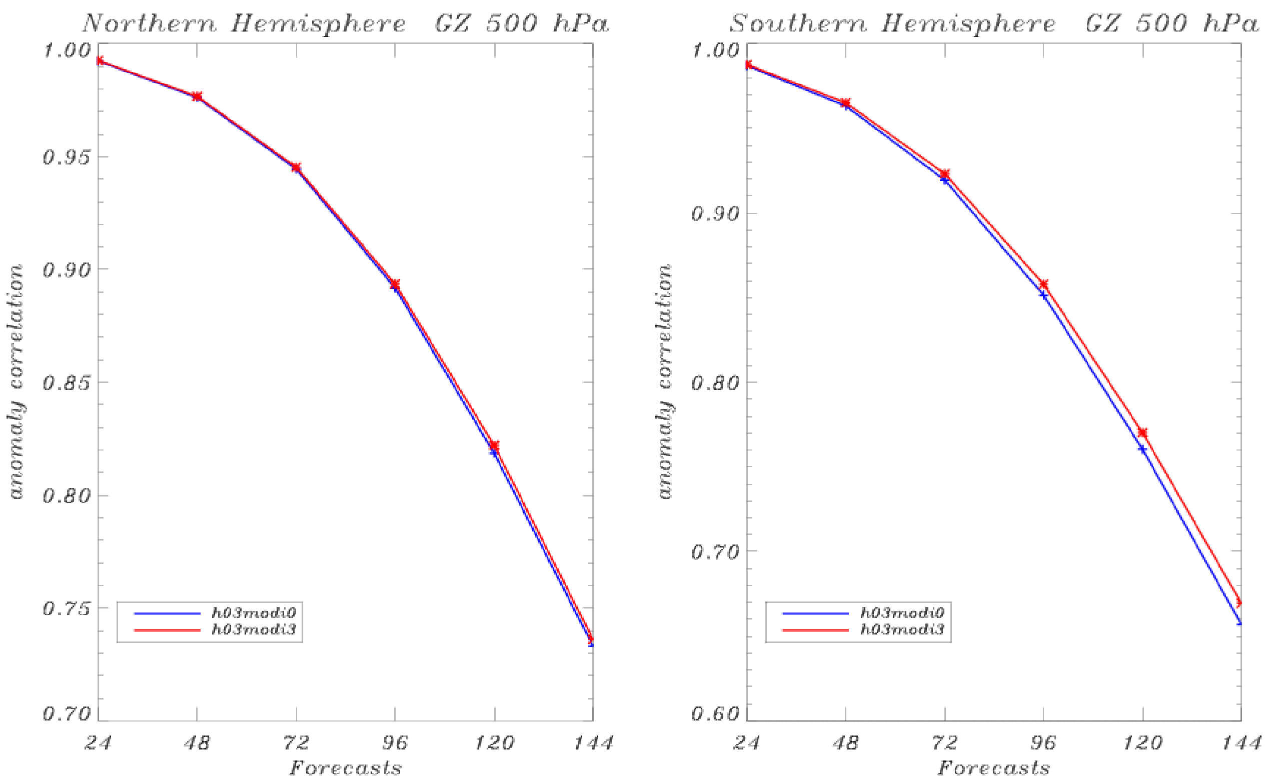

Figure 5: 500 hPa heights anomaly correlation for Northern and Southern Hemisphere (20°-90°), red line with the tuning mentioned in section 2 and the MODIS polar winds, the control in blue, verified against their own analyses.

The scores of Figure 5 show that the positive impact of the polar winds in the high latitudes is sufficient to influence the quality of the forecasts for the complete hemispheres especially in the south. The verification of the impact of the addition of the polar winds was also done by comparing with the results of the tuning alone. Figure 6 shows a map of the difference in rms of forecast errors for 24-hour forecasts. The verification is done against the analyses of the assimilation cycle containing all observations, including polar winds.

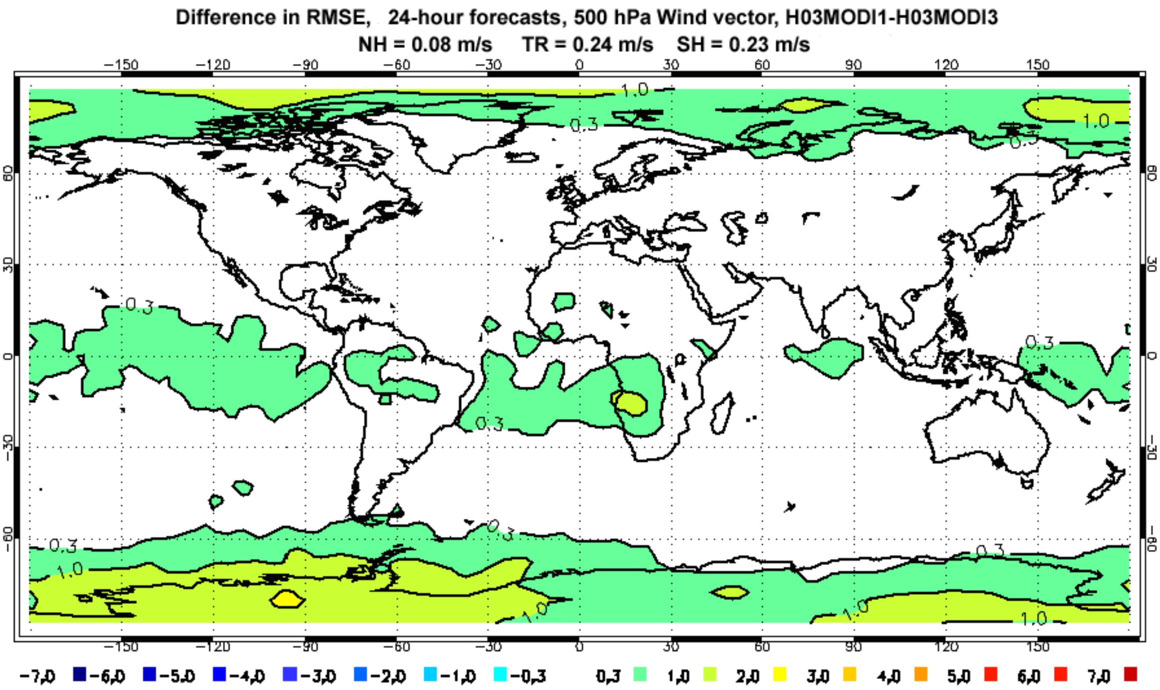

Figure 6: Map of difference of rms of forecast errors for 24-hour forecasts, experiment without polar winds minus experiment with polar winds, both verified against the analyses with all the observations.

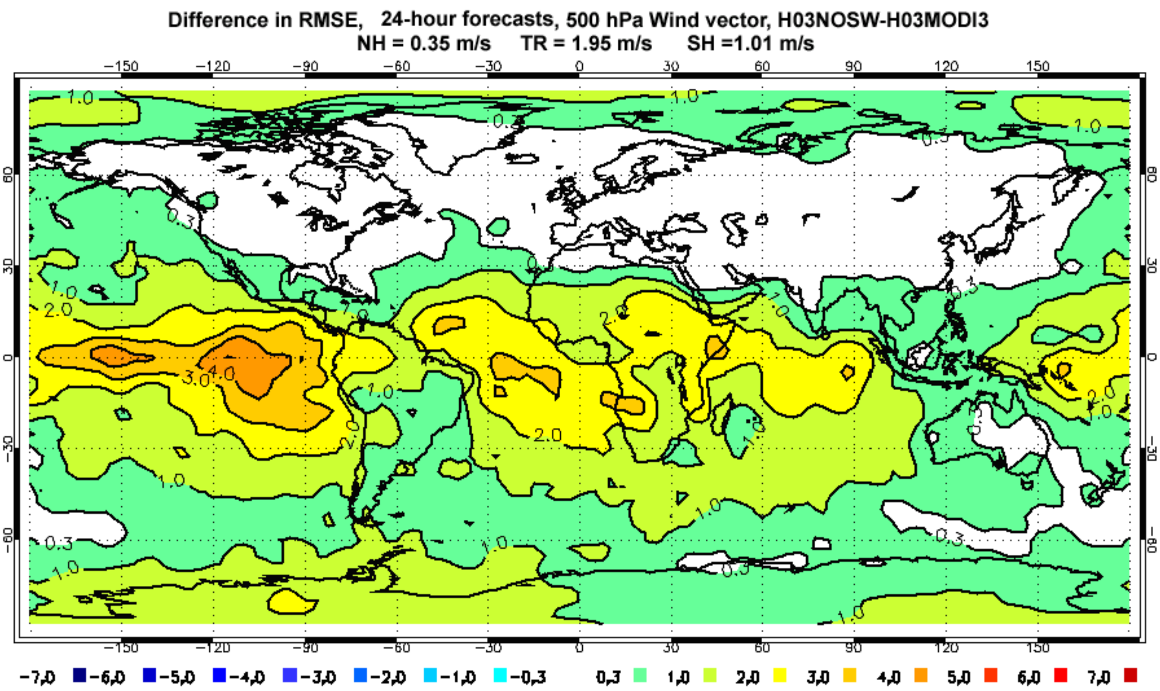

Figure 7: Map of differences of rms of forecast errors, 24-hour forecasts, without any AMVs minus with all AMVs, including polar winds, verified against the analyses with all the observations.

The positive areas indicate a higher rmse for the experiment without the polar winds, so a positive impact obtained by the addition of polar winds. Contours of more than 1 m/s reduction of rmse are obtained in the high latitudes. Over the 2½ months of the verification period, it is clear that some of the impact of the polar extended to lower latitudes. The difference of rms in the lower latitudes reach values of more than 0.3 m/s, the first contour used in Figure 6.

An experiment without any AMVs was run to confirm the usefulness of this type of observations in the current CMC NWP system. Figure 7 shows the same type of results as Figure 6 but for a comparison between the no AMVs experiment and the run with all the observations. The impact in the high latitudes is very similar, showing that it comes mainly from the polar winds. The maximum impact of AMVs is still for the oceanic areas of the low latitudes. This confirms past observing system experiments results with CMC system showing the maximum impact of the AMVs observations from the geostationary satellite in the low latitudes and the Southern Hemisphere. The minimum over the northern mid-latitudes is obviously related to the fact that no AMVs are assimilated over land in that region. Also, relative minimum in rms difference seems related to the distribution of radiosondes. For example, there is a relative minimum over Australia and may be over the area of the coast of Antarctica were the radiosondes are located. Looking at this map, one can understand that the signal of the impact of the AMVs in a NWP system can be weaker when verifying against radiosondes, at least for the short term forecasts.

Figure 8 shows the usual anomaly correlation of 500 hPa heights in 3 regions, confirming in another way that the greatest impact of AMVs is obtained for the Tropics and the Southern Hemisphere. In light of the map in Figure 7, it appears that this difference in anomaly correlation for the 3 regions is likely related to the fact that we assimilate far less AMVs observations in the Northern Hemisphere and that in regions where other winds observations are present, such as observations from radiosondes and aircrafts, the impact of the AMVs is less important.

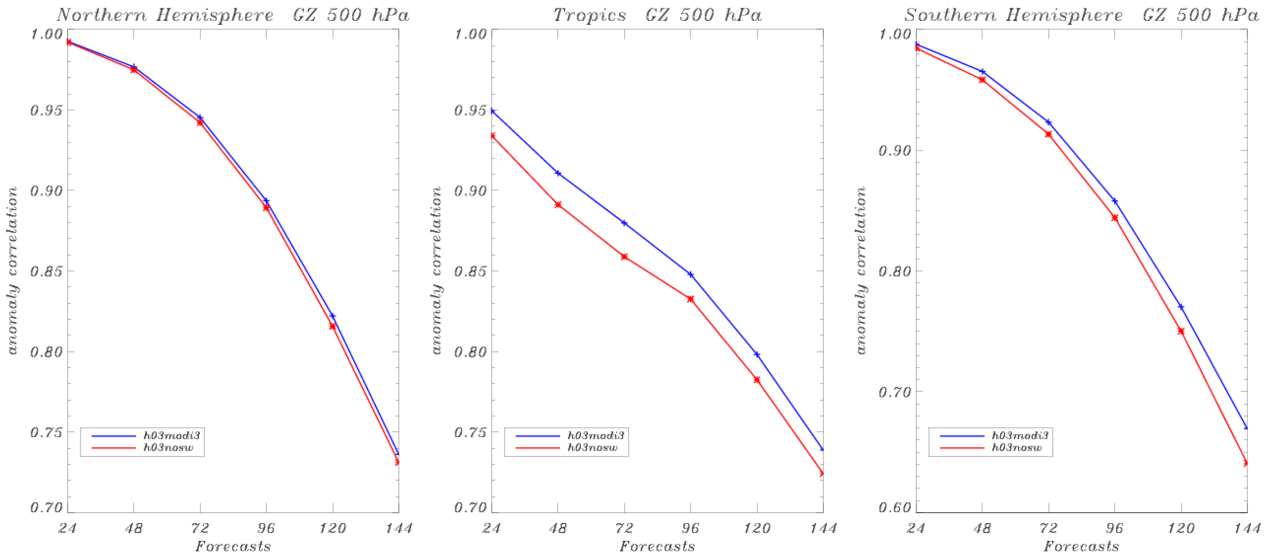

Figure 8: 500 hPa heights anomaly correlation in 3 regions, the blue line for the tuning mentioned in section 2 and the MODIS polar winds, the red line for the no AMVs experiment.

5. CONCLUSIONS

Observing System Experiments have shown that the atmospheric motion vectors from geostationary satellite used in the Canadian Meteorological Centre NWP system, have a significant impact on the quality of the forecasts. The modifications described here are being run in a parallel assimilation cycle this spring for operational implementation early in the summer 2004.

The passage to the BUFR bulletin from JMA removes the usage of SATOBS format bulletins for the AMVs assimilated at CMC. While the asymmetric condition in QC-Var does a good job in rejecting data with strong negative bias value in the jet regions it was felt that the overall percentage of rejection might not be sufficient. An increase of the a-priori probability of gross error for AMVs resulted in a tightening of the quality control and a small positive impact on the analyses and forecasts quality.

But the main improvement comes from the addition of the MODIS polar winds. The AMVs derivation technique adapted by CIMSS and run in a pre-operational setup by NOAA/NESDIS produces AMVs in the Polar Regions where there is a low density of other types of wind observations. The quality of the new observations, during the MOWSAP experiment, was good enough to produce significant improvements in the quality of CMC forecasts.

6. REFERENCES

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