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IMPACT OF NEWLY AVAILABLE TYPES OF REMOTE SENSING DATA AT MSC

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1. INTRODUCTION

The Canadian Meteorological Center (CMC) runs global and regional numerical weather models which serve as the principal guidance for most of MSC's forecast products. During the last decade the quality gain in the initial conditions of the state of the atmosphere or analysis for these models has become a critical aspect of the improvement of resulting weather forecasts. Observations of atmospheric parameters are obviously the main ingredient of a good an analysis. Satellite observations that have been for some time the greater contributor over southern hemisphere have recently become in some centers of equal or greater importance than conventional radiosonde (RAOB) data over the better sampled northern hemisphere (Kelly et al. 2003). For these reasons and also for robustness concerns a constant effort is made towards incorporating more observations and especially from satellites into the operational analysis. This paper presents the latest increment (to be implemented shortly) of CMC's assimilation system where four types of observation newly available at the center are added. New data include satellite-derived winds (SATWIND) from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument when flying over polar region onboard *Aqua* and *Terra* satellites. The *Aqua* research satellite also provides ATOVS AMSU-A radiances which are assimilated to compensate for the loss of that instrument on NOAA-17. The third type of new data is water vapor IMAGER channel radiances from GOES-12 that replace the void left by withdrawal of GOES-08. Finally wind profiles from the U.S. ground PROFILER network are added.

CMC's data assimilation system uses a variational algorithm also called 3D-var (e.g., Gauthier et al. 1999). The 3D-var allows for direct assimilation of data types, like radiances, which are indirectly linked to the forecast model variables. As one can see on the list (e.g., Table 1) of current data type and nature in use at CMC, satellite radiances are already part of the data stream. Except for the wind profiler data all new data presented here are observed with similar instrument to those already assimilated. This implementation does not contain major novelties but represent an important gain in coverage and provides improvements in the forecasts over several regions. The following four sections describe each additional data type and their potential impact on the operational analysis and forecasts. Section 6 presents the combined impact of the four types during pre-implementation tests.

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Data source	*Nature of the observation*
Radiosonde (RAOBS)	Profiles of temperature, moisture, wind and surface pressure
Surface (SYNOPS)	Temperature, moisture and surface pressure
Surface (BUOYS/DRIFTERS)	Temperature, moisture, wind and surface pressure
Aircraft (AIREP/ACARS/ AMDAR/ADS)	Temperature and wind
Cloud track motion winds (SATWIND)	Wind
NOAA/15-16-17 ATOVS AMSU-A/AMSU-B	Radiance
GOES10	Imager water vapor channel radiance

Table 1. Current data usage in CMC's analysis

2. MODIS SATWINDS

MODIS has 36 channels at wavelength which include the ones of the Imager flown onboard geostationary satellites (GOES and METEOSAT). The satellite winds are derived in a similar fashion than the ones from geostationary satellites when two subsequent MODIS swaths are overlapping in the polar areas (see Key et al. 2003 for complete description of the technique). Both infrared channels at 11 and 6.7 µm (water vapor band) tracked features are used to produce wind vectors. This is possible generally only at latitudes higher than 60 degrees.

Since SATWINDS from geostationary platforms do not extend at higher latitudes than 60 degrees, this is a welcome source of information over a data sparse area. Indeed other than a few RAOBs, the polar regions which are mainly sampled by AMSU sounders have practically very little wind information taken. An example of the coverage over South Pole for a 6 hour time period is given on Figure 1.

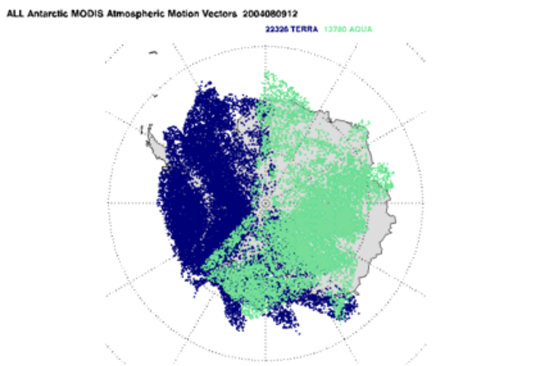

Fig. 1. Location over Antarctic of *Aqua* and *Terra* SATWINDs received during the 6 hours time window centred on 12 GMT August 9, 2004.

These data are made available through ftp from NESDIS. Although MODIS satwinds are available in real time some data do not make it in time for global model run analysis. This is will limit the impact of the data especially for the regional run as it has a relatively short cutoff time.

Before proposing an implementation of a new data source a series of test are run with the addition of the new data. Note that in this test mode the cutoff was not an issue as is was possible to run the cycle with all the available data. A test period of over a month of cycle with CMC's operational global GEM model (Côté et al. 1998a) forecasts every 12 hours (76 cases) show that in general, the MODIS winds have a slight positive impact. Despite the fact that the results for the Arctic are positive, the Northern-Hemisphere results are neutral at longer forecast range. The Antarctic and Southern-Hemisphere results are good as shown on Fig. 2 where the 500 hPa geopotential height anomaly correlation of the MODIS experiment is higher than the control.

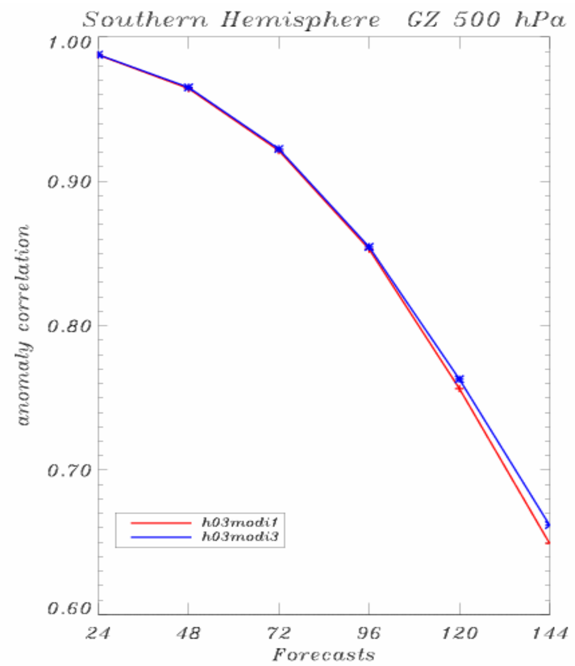

Fig. 2. Southern hemisphere anomaly correlation for the 500 hPa geopotential height forecasts against verifying analysis as function of forecast hours. Results are averages from November 8 to December 15, 2003. The experience with MODIS data is in blue and the control in red.

3. AQUA ATOVS/AMSUA

The Advance Microwave Sounding Unit (AMSUA) radiances from research AQUA platform are processed and assimilated in a similar manner than those from NOAA15, 16 and 17. NOAA NESDIS level 1b radiance data are gathered through ftp and decoded with AAPP (Advanced ATOVS Processing Package). Operational 3D-var uses RTTOV-7 radiative transfer model to simulate a radiance from the background atmospheric profiles (6 hour model forecast). The departure from the observed radiance is one of the input values to be minimized in the variational assimilation system.

Assimilated channels over land are sensible to upper troposphere temperature. Channels sensible to the surface are added over sea, as the surface emissivity is better defined, giving deeper temperature information.

The added coverage of AQUA does not compensate entirely for NOAA17 loss. Some overlapping with NOAA16 occurs (e.g., Fig. 3). Only in 4D-var will it be possible to see the full advantage of incorporating this data since it will be possible to assimilate overlapping data valid at different times on the 6 hour assimilation time widow. In the 3D-var a thinning at 250 km is performed.

A two month data assimilation cycle (December 11, 2003 to February 10, 2004) with the GEM global model launched every 12 hours with this new data was executed. A control run representing exactly the operational suite was also performed. The overall impact is positive over the northern-hemisphere and slightly negative over southern-hemisphere.

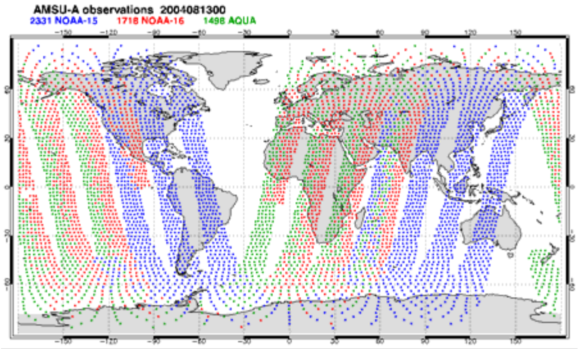

Fig. 3. An example of CMC's current AMSU-A coverage. NOAA-15 data are in blue, NOAA-16 in red and AQUA in green.

4. GOES-12 IMAGER WATER VAPOR CHANNEL

IMAGER channel 3 (6,7 μm) radiances from GOES-12 (GOES-East at longitude 75W) that replaced the decommissioned GOES-8 are added to already present GOES-10 (GOES-West at 135W) data. These radiances are mainly sensible to water vapor at 500 to 200 hPa levels. GOES data processing steps at CMC are described in detail in Garand 2003. Pixels above 60 degrees (north or south) are not considered. The forward radiative transfer model used in the assimilation is MSCFAST (e.g., Garand et al, 1999). Positive impact of assimilating channel 3 radiances from both GOES-10 and GOES-08 on the CMC moisture analysis and forecast was shown in Garand and Wagneur 2002. Gain in the quantity of precipitation forecast was also noted.

Here the impact of adding the second satellite was performed over the same two months period than for AMSU-A AQUA evaluation described above. Comparison with a control run that had only GOES-West data (like the operational run) shows no significant differences in the forecast quality when measured against the radiosonde network. This is consistent with the fact that the value of information input upstream by GOES-West can be measure with radiosondes over the continent, whereas GOES-East benefits would probably be best seen over the Atlantic Ocean. However a reduction of the 6 hour forecast moisture biases in the middle atmosphere was noted over North-America in the 6 hour forecasts, confirming the good quality of GOES-12 water vapor radiances.

5. WIND PROFILER

The NOAA Profiler Network is composed of 35 UHF radars located mainly over central US. The radars provide hourly averages of horizontal wind vector at a vertical resolution of 250 meters. This gives good additional information over radiosondes that are launched only every 12 hours.

The winds valid a central synoptic time were assimilated, and only at a third of the vertical resolution, for the same two months test period of winter 2004 described above. The impact on the forecasts of the global GEM model is slightly positive over North-America. A small systematic improvement is also noted on the 6 hours wind forecasts. It is hoped that these data will significantly help the regional model for short range forecasts on specific cases.

6. COMBINED RESULTS

Finally all four new types were added together and a two month cycle with a global forecast launched every 12 hours from December 11, 2003 to February 10, 2004. The quality gain of these 123 forecasts over the current operational system was assessed against the global RAOB network.

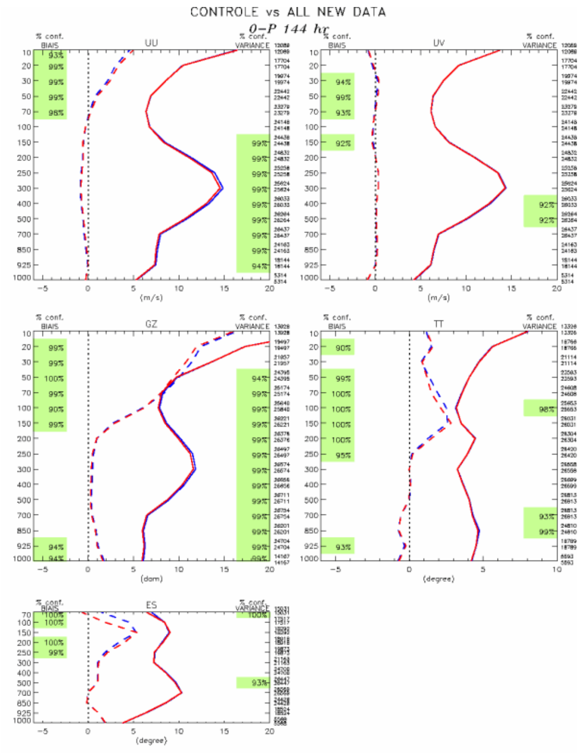

Fig. 4. Day 6 forecast root-mean-square errors (solid lines) and biases (dash lines) measured with ROABS over Northern-Hemisphere for the 123 winter 2003/04 cases. The control is in blue and the experiment is in red. The top two graphs show values for the wind components, the middle one are for the geopotential height (left) and temperature (right) and the bottom graph is for dew point departure.

The new system shows better root-mean-square errors over both northern (Fig. 4) and southern hemisphere (not shown). The gain is more perceptible at longer ranges as can be seen on the anomaly correlation comparison shown on Fig. 5. However day 8 to 10 forecasts show deterioration over the southern hemisphere. This is something to investigate although these forecasts have exceeded their usefulness with an anomaly correlation less then 60%.

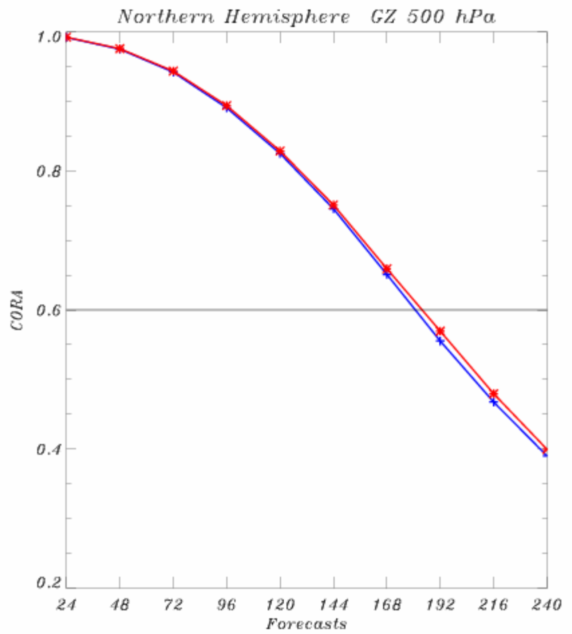

Fig. 5. Northern hemisphere anomaly correlation for the 500 hPa geopotential height forecasts against the verifying analysis as function of forecast hours. Results are averages from Dec. 11, 2003 to Feb. 10, 2004. The experience with new data set is in red and the control in blue.

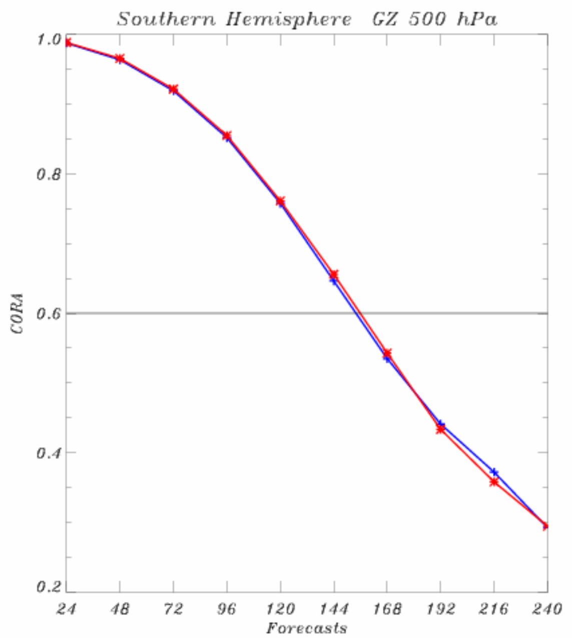

Fig. 6. Same figure than Fig. 5 but for the southern hemisphere.

On a time series of the root-mean-square of differences to the verifying analysis (see Fig. 7), one can note that the new system has a tendency to produce less busts like on January 9 and 12, 2004 over North-America for example. But even if on average the experiment outperforms the control, it is not always true as seen on January 21, where the forecast without the new data preformed better.

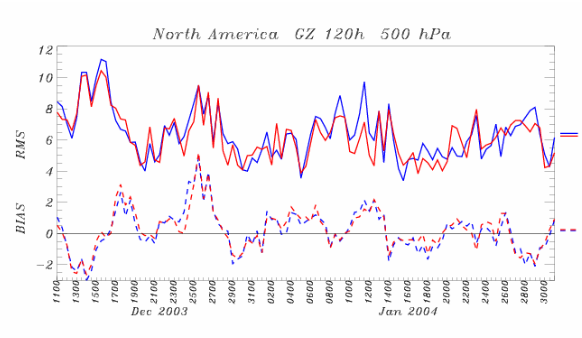

Fig. 7. December 11, 2003 to January 31, 2004 time series of root-mean-square differences (solid line) and biases (dashed line) to the verifying analysis over North-America of the five day 500 hPa geopotential height forecast. The new data set experiment is in red and the control in blue.

The quality of precipitation forecasts was also evaluated. The north-American SYNOP and the U.S. SHEF networks are used to measure the performance of each system in term of quantity of precipitation over a 24 hour period. Again a positive impact of the added information was noted as can be seen on Fig. 8. where a significant increase of the equitable threat score is noted for the low amounts categories over US with the SHEF network (12 GMT daily amounts measurements) Higher than 30 mm amount classes showed worse score but this is perhaps less significant considering the much smaller number of cases.

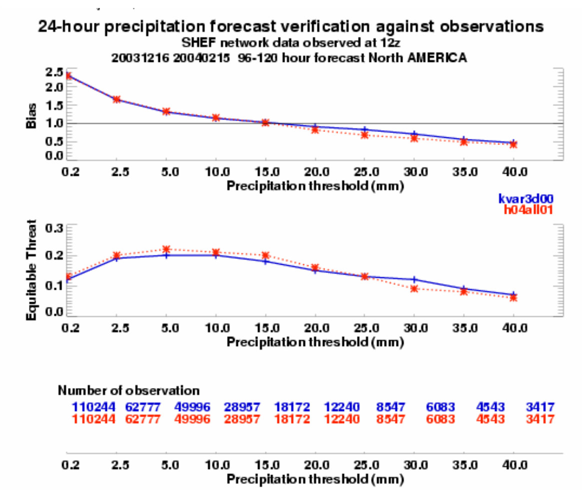

Fig. 8. Day 4 bias and equitable threat score of the 24 hours quantity of precipitation forecasted estimated with U.S. SHEF network. Numbers represent only half oh the cases from December 11, 2003 to February 10, 2004 since SHEF data are only available at 12 GMT.

7. CONCLUSION

MODIS winds, AMSUA radiances, GOES-12 water vapor radiances and U.S. profiler wind profiles were independently tested. Each component had a positive impact on the analysis or forecast of CMC's operational global model. An expected gain in the quality of the numerical weather products has been shown when four additional data types are added to global data assimilation cycle. Forecasted mass fields over the globe were improved and quantity of precipitation over northern-America was better forecasted. This gain was more evident in the four to seven days range forecast than in the first few days.

At time of writing, this upgrade of the assimilation system is in parallel suite test mode and is planned to be implemented operationally within a few weeks.

8. REFERENCES

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