ADDICTION OF AIRS, SSM/I, QUIKSCAT AND 3.9M AMV SATELLITE DATA IN MSC’S OPERATIONAL 4DVAR ASSIMILATION SYSTEM

Nicolas Wagneur, L. Garand, D. Anselmo, J. Aparicio, A. Beaulne, M. Buehner, J-M. Bélanger, G. Deblonde, J. Hallé, P. Koclas, R. Sarrazin and G. Verner

Meteorological Service of Canada, Dorval, QC

Abstract

Following the recent major implementation of a 35 km resolution global model, The Meteorological Service of Canada (MSC) operational 4Dvar assimilation system is being improved with a significant amount of new satellite observations. These include AIRS radiances from 87 channels, SSMI radiances, QuickSCAT winds and 3.9 microns Atmospheric Motion Vectors. A dynamic bias correction for all radiance data has been implemented. Some data type specific impact results are discussed but this paper focuses on the combined package impact for forecasts up to day 10.

1. CURRENT OPERATIONAL ASSIMILATION AND FORECAST SYSTEM

The Canadian Meteorological Center operates a 35 km uniform resolution global forecast model called GEM (Global Environmental Model) with 800x600 points and 58 eta levels, the uppermost one being at 10 hPa. Initial conditions are obtained through a 4DVAR global assimilation procedure performed over a 6 hour window. A global 10 day forecast is launched twice daily. The GEM model is also operationally run with in a variable resolution configuration with a 15 km uniform resolution over North America. The regional model is fed by a 3DVAR FGAT (First Guess at Appropriate Time) assimilation system with 6 hour spin-up cycle launched from global cycle every 12 hours.

The current observations assimilated from satellites are ATOVS AMSUA and AMSUB/MHS data from NOAA 15 to 18 satellites series and AMSUA from AQUA. GOES water vapor channel radiances are also assimilated which represented the only infrared data used up to now. The Atmospheric Motion Vector information deduced from visible and water vapor channel from all 5 operational geostationary are also assimilated. The so-called standard observations assimilated are from the radiosondes and surface stations, the buoys and aircraft. Winds from US profiler network are also assimilated.

2. SUMMARY OF THE NEW COMPONENTS TO BE IMPLEMENTED

- AIRS radiance data from 87 channels.
- SSM/I radiance data in addition with elimination all AMSU-A channel 3 radiances and a using new cloud mask for AMSU-B.
- Usage of NWP SAF RTTOV-8.7 radiative transfer model (RTM) including a new vertical interpolation to go from NWP model levels to RTTOV level.
- Addition of pixels with high scan angle from AMSU data.
- QuikScat oceanic surface winds obtained from KNMI.
- 3.9 micron AMV giving information on nighttime low level winds.
- Dynamical bias correction for radiance data.

These additional data from satellites represent a significant increase in data amounts assimilated. Fig. 1 illustrates the typical data amount per data types over a 6 hour assimilation window. The red color bars show the increase over the blue operational amounts. The new data represents an augmentation of about 50% from the current operational system.
Fig. 1 Comparison of current operational numbers of observations typically assimilated over a 6 hour window and the proposed increased data set.

3. AIRS

The Canadian Meteorological Center receives a subset of 281 channels from the AIRS infrared hyper spectral radiances trough a ftp file transfer from NOAA/NESDIS. A subset of 87 channel are selected for assimilation. The selection criteria include good vertical sampling of the atmosphere by the channels, low instrument noise and limited or no contribution above the NWP model top. Furthermore shortwave channel in daytime and data over land and ice are excluded. Channels weakly affected by ozone or minor gases are also discarded. Data over water rejected if surface emissivity is less than 0.9 and if NESIS noise flag is different from zero.

Then a radiance free cloud selection based on window channel and trial profile comparison is done. In presence of cloud, only radiances sensing above cloud height estimated with CO$_2$ slicing technique are kept. A linear bias correction is applied to raw data. Before assimilating the AIRS data a horizontal thinning is performed that gives a typical 250 km separation between pixels. The observation error variance is set to the total error statistic. RTTOV8 fast radiative transfer model is used as forward model or observation operator (see Garand et al. companion paper, this conference).

4. SSM/I RADIANCES

The Raw SSM/I file received trough ftp link from NOAA/NESDIS. Initial nominal resolution of the data is at 25 km. Radiances from all 7 channels onboard DMSP13 and DMSP14 satellites are assimilated. Data from DMSP15 are not assimilated due to poor quality (currently). Observations over land are removed due to complexity of surface emissivity modeling. Also data over ice and when CLW is greater than 0.01 kg/m$^2$ are excluded. Scan position and air mass correction are applied to the raw radiances. The thinning is at the scale of 200 km. As for AIRS, the observation error variance is set to the total error statistic and RTTOV$_8$ is again the RTM.
5. QUIKSCAT SURFACE WINDS

These data are represent surface (10 m) winds derived from scatterometer. These wind retrievals are provided in BUFR format at 100 km resolution from KNMI via a ftp site. The observation error is set to $1.7 \text{ m sec}^{-1}$. Only wind speeds superior to $4 \text{ m sec}^{-1}$ are assimilated. More details can be found at:

www.knmi.nl/scatterometer/publications

6. ATMOSPHERIC MOTION VECTORS FROM THE 3.9MICRON CHANNEL

Atmospheric motion vectors from the near infrared channel onboard GOES satellites are received through GTS. This gives low level winds at night that complement the day-time low-level visible cloud drift observations. The current operational system assimilates water vapor and visible channels AMV from GOES11, GOES12, METEOSAT-7, METEOSAT-9 and MTSAT-1R geostationary satellites. The processing done for the new $3.9 \mu$ channel information is similar to what is done for other channels. The horizontal thinning gives an assimilated resolution of about 150 km.

7. DYNAMIC RADIANCE BIAS CORRECTION

Up to now a static bias correction was applied to radiance observations. With this new implementation, a dynamic bias correction is applied to all radiances, updated every analysis cycle (6-h) and based on the last 15 days. Two air mass predictors are used for the microwave radiances after the scan bias has been removed. Only data over ocean are used. For the infrared, the bias correction is linear with the observation itself. All data judged suitable for assimilation are used (no mask).

8. RESULTS

Global 4D-var assimilation cycles lasting about 80 days were ran for summer and winter seasons. Global 10 day forecasts were launched twice daily from the resulting analyses. Results presented here compare the operational cycle (OPE) with the experiment cycle (NEW) that incorporated the above mentioned new satellite data and procedural changes. From these analyses, a 2 day regional forecast (and cycle with regional assimilation) was launched every 36 hours for each configuration.

Fig.2 shows for both hemispheres and both seasonal cycles the impact of the combined package from time series of 72-h 500 hPa geopotential verified against corresponding analyses. The positive impact is clear (NEW curve consistently below the OPE curve). Fig.3 are examples of verifications against radiosondes for both the global and regional models. Again the impact is systematically positive. Finally Fig. 4 presents results in terms of anomaly correlation up to day 10. The impact was more strongly positive for the winter cycle than for the summer one. As perhaps could be expected, the impact in the Southern Hemisphere is more pronounced than that seen in the Northern Hemisphere.

The impact of all individual modifications were extensively tested in both 3D-FGAT and 4D-Var experiments of at least 1 month. The combined impact on the medium-range forecasts of the proposed modifications is consistently positive in all regions at all levels and forecast times. The gain in predictability for the 5-day forecast is approximately 3-4 hours in winter 1-2 hours in summer. AIRS accounts for about half of the gain. Second in importance are the AMSU data at the edge of the scans which increased the horizontal coverage of these data significantly. The positive impact was also evidenced in the regional forecasts. Additional AIRS and AMSU channels will be used as the model lid is raised to 0.1 hPa in 2008.

ACKNOWLEDGEMENT

This work was funded in part by the Canadian Space Agency Government Related Initiatives Program.
Fig. 2 Time series comparison of 72-h 500 hPa geopotential day 3. Operational forecast (OPE) and NEW for summer and winter test periods. Note the mean RMS and bias values on the right of the figures.
Verification against Radiosondes for winter 2007

5 day global forecast – 160 cases verified over Southern Hemisphere

2 day regional forecast – 40 cases verified over North America

OPE in blue versus NEW in red

Fig. 3 Evaluation of operational and new forecast for regional 48-h forecasts (right) and 120-h (left) global forecasts over North America and Southern Hemisphere respectively. The forecasts are evaluated against observations from radiosondes. Variables are zonal wind (UU) and modulus (UV), geopotential GZ, temperature (TT) and dew point depression (ES).

Global model 500 hPa geopotential forecast anomaly correlation

156 summer cases 160 winter cases

World 500 hPa

Northern Hemispher 500 hPa

Southern Hemispher 500 hPa

Fig. 4 Comparison of 500 hPa error anomaly correlation up to day 10 for the current system OPE and the proposed one NEW. Results shown for the whole world (summer period) and each hemisphere separately for the winter cycle.