Assimilation of ATMS data at Environment Canada

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1. Introduction

ATMS is a 22- channel cross-track microwave radiometer replacing the legacy AMSU-A and AMSU-B/MHS instruments. AMSU-A data from 6 satellites and AMSU-B/MHS data from 4 satellites are currently assimilated at Environment Canada (EC). Assimilation of ATMS data from Suomi NPP will soon be added to EC's Global Deterministic Prediction System (GDPS), Regional Deterministic Prediction System (RDPS) and Global Ensemble Prediction System (GEPS). RTTOV-10 is the RTM used in these systems. Differences between ATMS and AMSU-A and AMSU-B/MHS include differences in beam width, scan swath width, number of field-of-views, and frequency/polarity for some channels. ATMS also has an additional window-surface channel (4), and 2 new 183 GHz water vapour (WV) channels (19, 21). The radiometric noise level is higher for the temperature-sounding (TS) channels compared to AMSU-A and striping noise is evident for most TS channels.

In this poster, we discuss our ATMS assimilation strategy, data preprocessing and quality control, observation errors and inter-channel error correlations. We also show some observation-minus-first-guess (obs-fg) monitoring results, including biases as a function of field-of-view. Finally, some results are shown for an ATMS data impact experiment with the GDPS.

2. Assimilation Strategy & Quality Control

We chose **assimilation strategy and quality control** that follows closely that of AMSU-A (TS channels) and AMSU-B/MHS (WV channels). For example:

- no assimilation of window channels (ATMS channels 1-4, 16)
- assimilation of non-window surface-sensitive channels over open water only (ATMS channels 5-6, 17-19)
- topography height check over land for lower-peaking tropospheric channels (7-8, 20-22)
- no assimilation of water-vapour channels in very dry conditions over land or sea-ice (channels 20-22)
- application of cloud liquid water and scattering index limits for assimilation of tropospheric channels (5-9, 17-22)
- static bias correction for 2 highest-peaking temperature-sounding channels (14, 15); dynamic correction for all other channels.

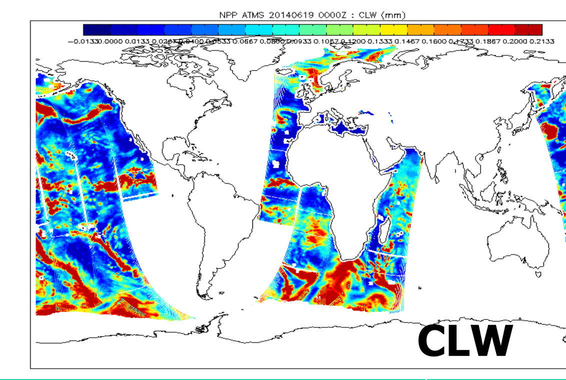
Additional processing specific to ATMS:

- Application of AAPP software package *ATMS_BEAMWIDTH* program to reduce noise level of temperature sounding channel data (Fourier technique is applied to increase effective beam width for channels 3-16 from 2.2° to AMSU-A beam width of 3.3°)
- Initial data reduction applied prior to pre-assimilation QC and final thinning to reduce preprocessing data volumes to levels comparable to other satellites (as done for AMSU-B/MHS data).
- Rejection of radiance data based on the ATMS data QC flags

In summary, assimilated ATMS channels are 5-15 (11 AMSU-A like) and 17-22 (6 MHS like) for total of 17 out of 22 channels. Data from extreme field-of-view (FOV) 1 and 96 are not assimilated due to anomalous biases (see Fig. 3).

3. Retrieval of physical parameters

For QC purposes, various parameters are retrieved from the satellite radiances for selected channels using algorithms as listed in **Table 1**.
NRL = Naval Research Laboratory (Monterey CA)
EC = Environment Canada



Parameter	Algorithm (Source)	Channels Affected
Cloud Water (CLW)	NRL	5-9, 17-22
Scattering Index (SI) (2)	NRL (Bennartz-Grody, ECMWF)	5-9, 17-22
Sea Ice	NRL	5-6, 17-19
Dryness Index (DI)	EC (adapted from QC for AMSU-B/MHS)	20-22
Mean 183 GHz	NRL (similar results to D.I.)	20-22

Table 1: QC parameters used to filter data for selected channels. **CLW** and **SI** are computed over open water only. **Mean 183 GHz** is simply the average brightness temperature for the five 183 GHz water vapour channels (18-22) and is a measure of atmospheric dryness.

4. Observation Errors

Observation errors for each channel are based on obs-fg monitoring statistics, namely the StdDev(obs-fg) computed over a fixed 10 day period. The errors specified for assimilation are the StdDev values inflated by a factor ranging from 1.4 to 3.7, with higher factors applied to the higher-peaking temperature sounding channels. Inter-channel correlations are considered. **Figure 1** shows the errors assigned to each assimilated channel as well as the associated inflation factors. **Figure 2** shows the inter-channel error correlations specified for ATMS (assimilated channels only) as determined by the Desroziers (2005) method. The higher correlations in the upper-right 5x5 corner block are for the five183 GHz water-vapour channels (ch. 18-22).

Assigned error = StdDev(obs-fg) x Inflation_Factor

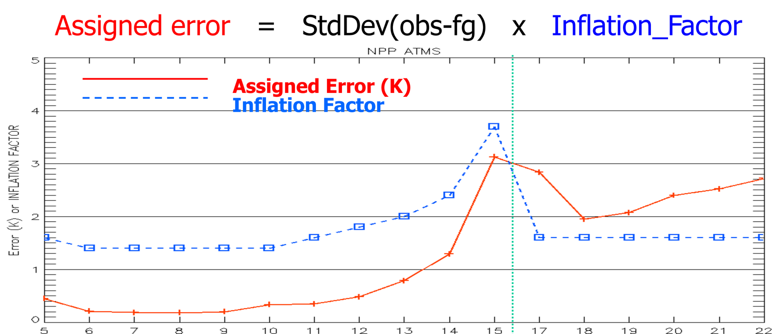


Figure 1: ATMS observation errors

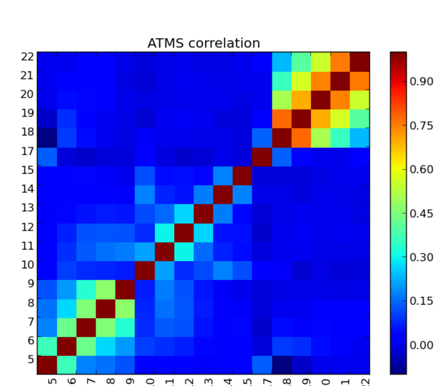


Figure 2: ATMS observation inter-channel error correlations

5. Obs-FirstGuess Monitoring

Figure 3 shows variation of mean and Std Obs-FG stats with field-of-view (FOV) for channels 6, 10, 15, 17, 20. Note the anomalous values for the Mean at extreme FOV 1 and 96 for TS channels 6, 10 and 15. This is most likely an artifact of the beam width resampling done to reduce the noise levels in TS channels 3-16 data, as it is not evident for WV channels 17-22 (which do not have beam width resampling applied).

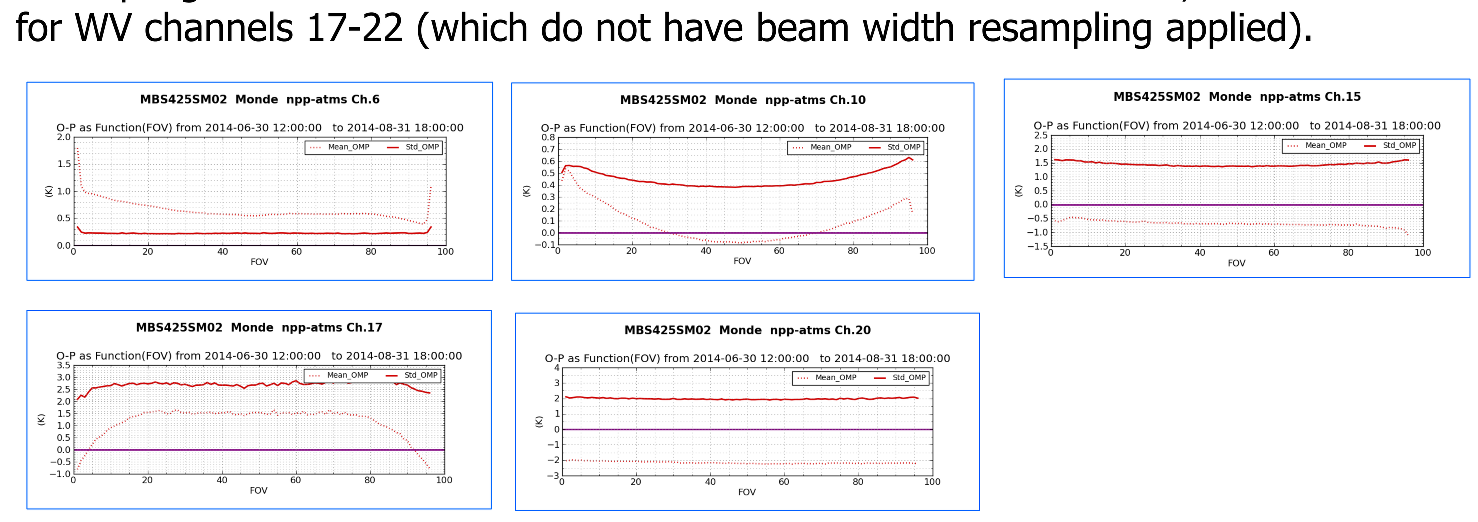


Figure 3: Mean and Std Obs-FG as a function of FOV (view angle) for selected ATMS channels

Channel 10 is unique in that the variation of bias with FOV depends on latitude, as shown in **Figure 4** and **Figure 5**., with strong variation in the tropics region and little variation in the south extra-tropics region. As a result, the dynamic bias correction system (based on global Obs-FG statistics) cannot remove all the FOV-dependency of the bias, especially in the tropics region (**Figure 6**). This kind of behaviour is not seen in any other ATMS channel or in AMSU-A/AMSU-B/MHS data. Also note the striping noise in the plots.

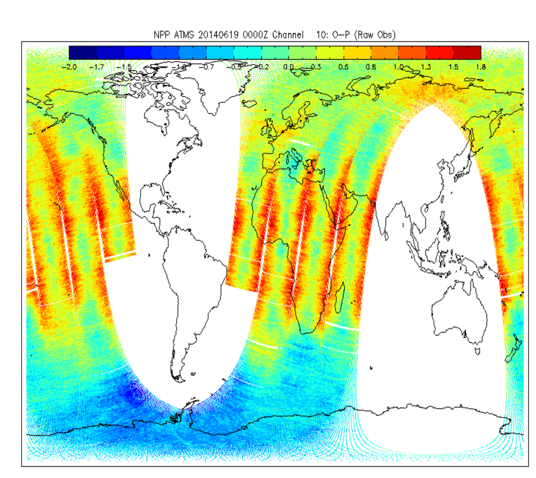


Figure 4: Obs-FG (uncorrected) for ATMS channel 10 for 00 UTC 19 June 2014.

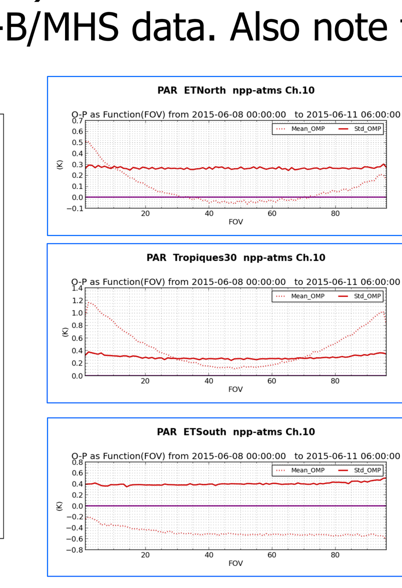


Figure 5: Obs-FG (uncorrected) stats as function of FOV for ATMS channel.

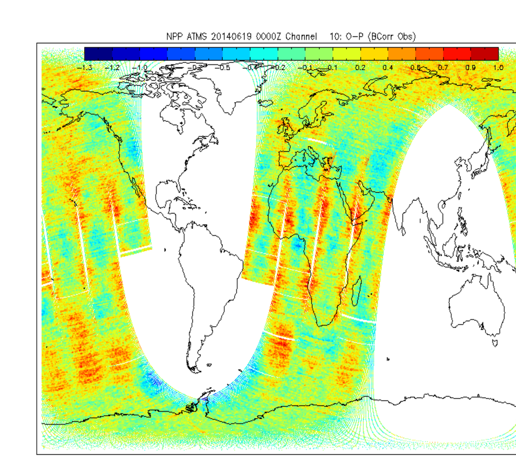


Figure 6: Obs-FG (corrected) for ATMS channel 10 for 00 UTC 19 June 2014.

NOTE: We use dynamic bias correction with standard thickness predictors based on last 7-days bias (Mean(Obs-Anal)), where Anal = 3D-Var analysis **excluding** satellite radiances. Biases and corrections are determined separately for each FOV. Variational bias correction (VarBC) is currently in development.

6. Data Impact Experiment

An assimilation cycle was performed to assess the impact of adding ATMS data to the GDPS for the period Sept 1 to October 8, 2014. Verification of temperature and RH against ERA-Interim analyses in **Figure 7** shows an overall positive impact of ATMS, especially in the South extra-tropics region. Verification against radiosondes (**Figure 8**) shows more impact for the extra-tropics North region.

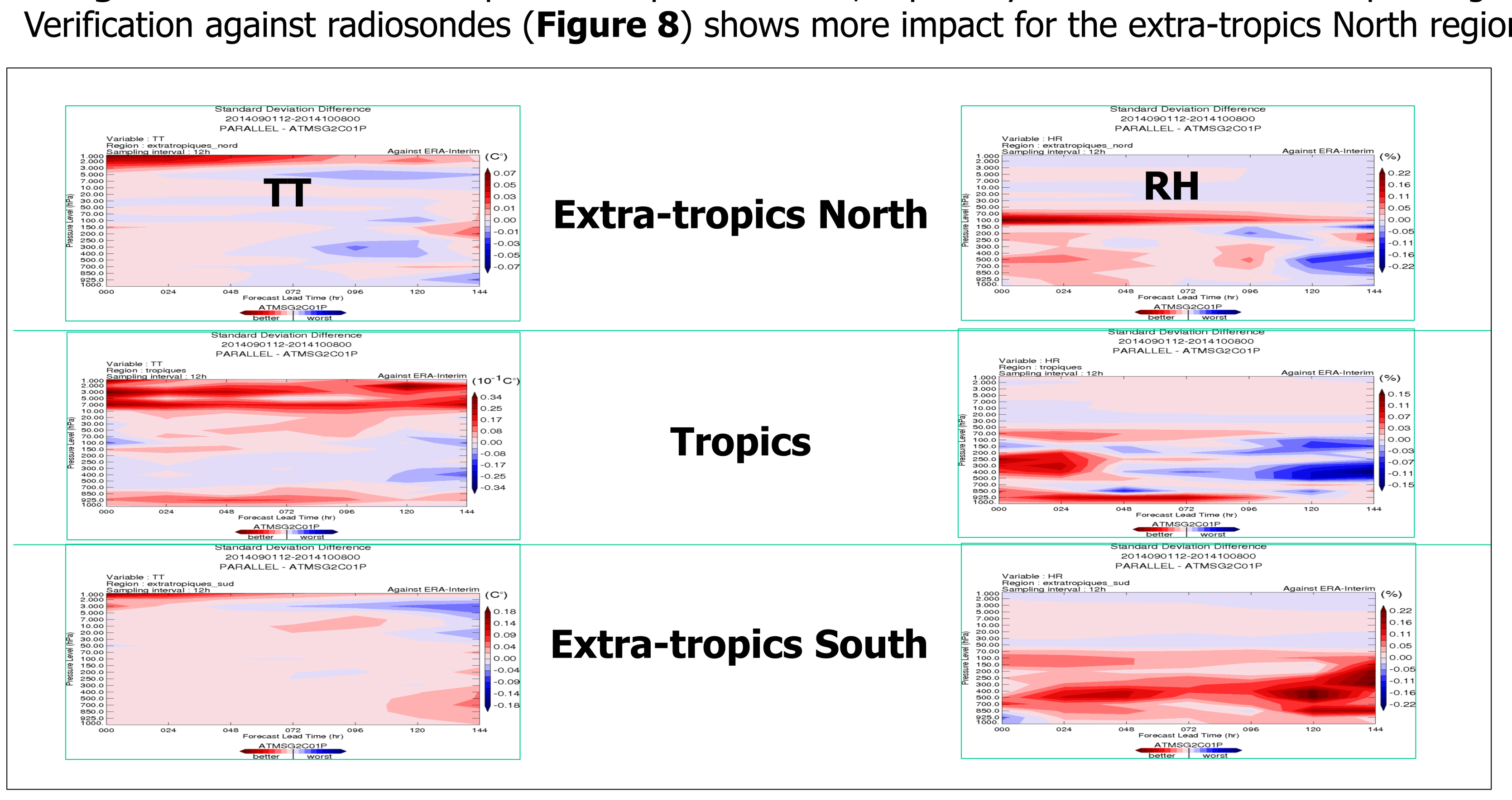


Figure 7: Verification of GDPS temperature (TT) and Relative Humidity (RH) 0-6 day forecasts against ECMWF (ERA-Interim) analyses. **Red shades** indicate a better fit to ECMWF analyses for the ATMS experiment.

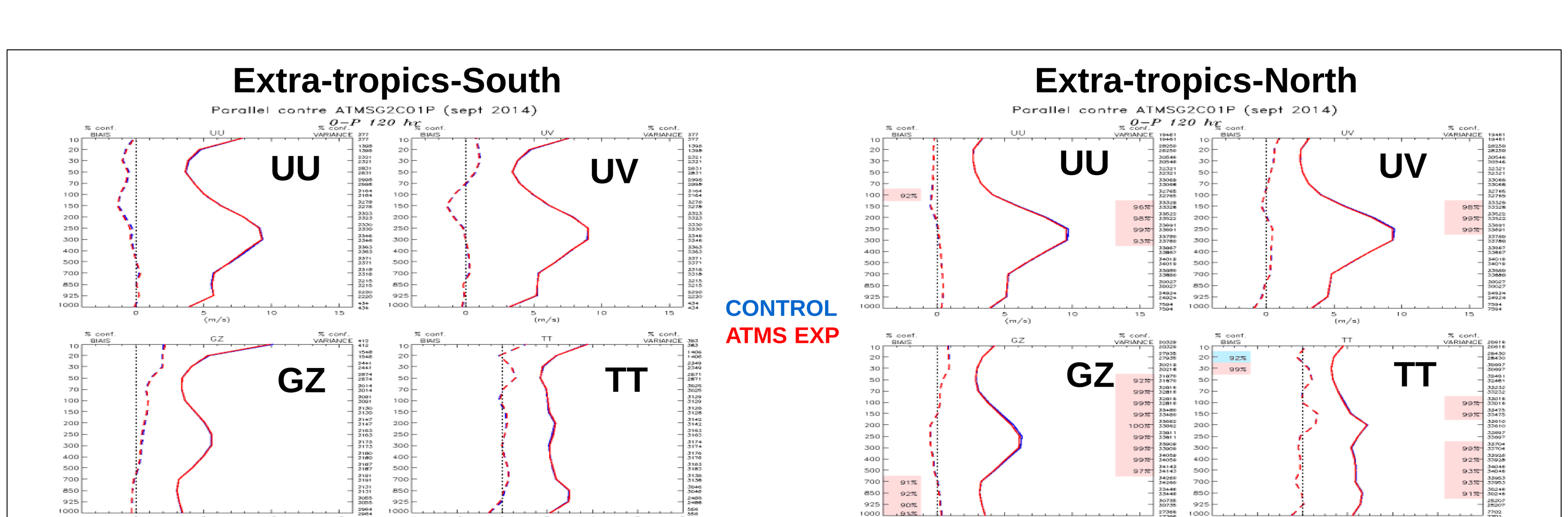


Figure 8: Verification of GDPS Day-5 temperature (TT), winds (UU,UV) and geopotential height (GZ) against radiosonde observations. **Red shaded** confidence percentages indicate ATMS experiment is better.

7. Conclusion

Assimilation of ATMS radiances will soon be implemented at Environment Canada. Inter-channel error correlations are explicitly accounted for through specification of an error correlation matrix. Quality control and data filtering is performed in a similar manner to AMSU-A and AMSU-B/MHS. Comparing ATMS radiances with 6h forecast (first-guess) radiances simulated with RTTOV-10 reveals several characteristics of the data, such as a variation of mean obs-fg (bias) with field-of-view that depends on latitude for channel 10 only and striping noise for most temperature channels.

A Global Assimilation System (GDPS) data impact study reveals a noticeable positive impact of ATMS data on forecast quality, in particular for the southern extra-tropics using ERA-interim analyses for verification. On the other hand, verification against radiosondes shows more positive impact for the northern extra-tropics. The 2 additional 183 GHz water-vapour sounding channels compared to AMSU-B/MHS may explain some of the forecast improvement to the humidity field. The positive impact is encouraging, considering the large volume of AMSU-A and AMSU-B/MHS data already assimilated.

REFERENCE: Desroziers et al., 2005: Diagnosis of observation, background and analysis-error statistics in observation space, *Q. J. R. Meteorol. Soc.*, **131**, pp. 3385–3396