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Impact of Radiance Assimilation Near the Model Lid

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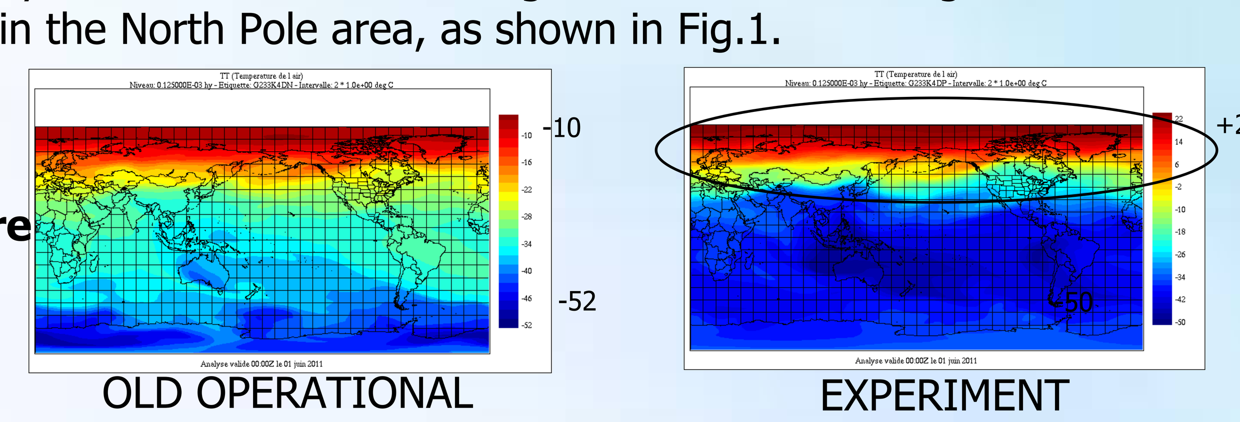
Heating problem at model lid

An assimilation cycle was run for several months in preparation for the latest operational implementation of the Environment Canada Global Deterministic Prediction System. It aborted following an unrealistic heating at the model lid (0.1 hPa), in the North Pole area, as shown in Fig.1.

➢ **Fig.1 Temperature at Level 1**

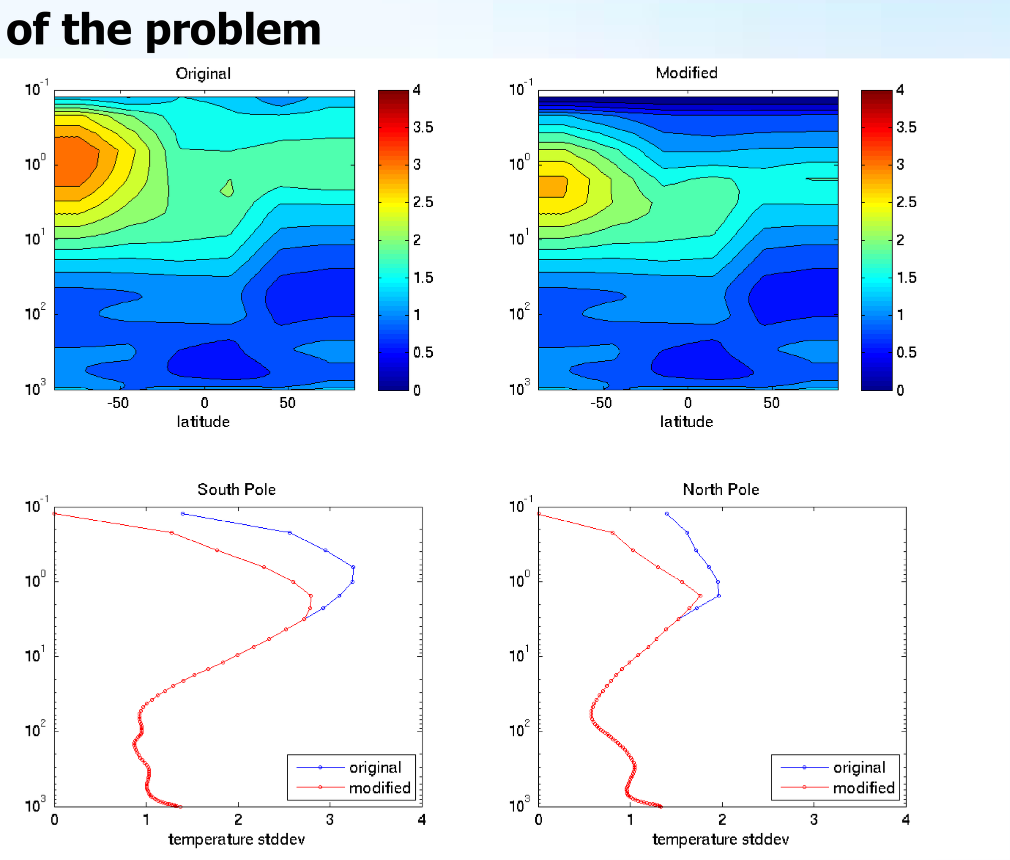


Investigations revealed that:

- The problem is related to radiance assimilation
- It disappears when either microwave (AMSU-A) or infrared (AIRS and IASI) observations are removed.
- The rate of heating increases with assimilated data density

This study investigates potential causes of the problem and presents the practical solution which was implemented.

Fig.2 Mitigation of the problem



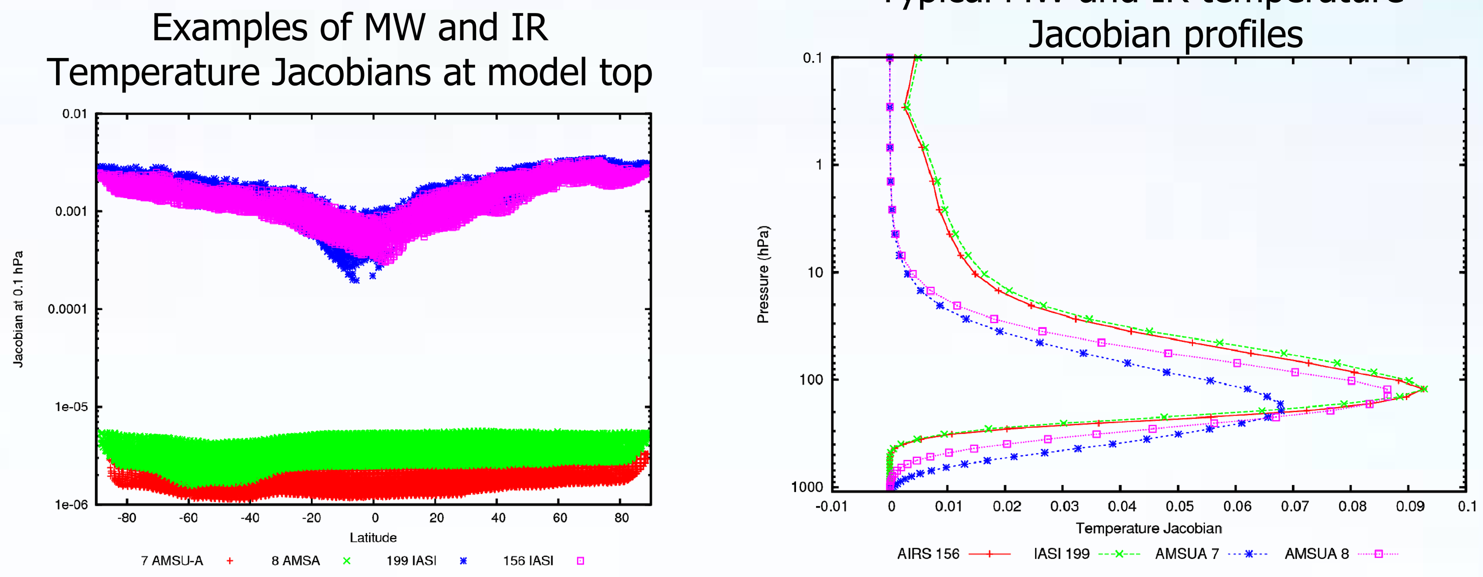
Since the problem is linked to radiances through weak sensitivity in Jacobian tails, a way to solve the problem is to not allow contribution from radiances at the model top. As shown in Fig.2, the solution which was adopted for implementation was to reduce gradually the background error, starting at about 2hPa to reach zero a the model top. Therefore data cannot participate at all to the analysis at the first level.

Alternatively, to keep the same background error as before, we can set to zero contributions from the first layers to calculations of the outgoing radiances. This can be done in the tangent linear and adjoint of the radiative transfer model RTTOV. This works well. Increments were found to be very similar to those obtained from reducing the background error if contributions from the first three levels are cut (not shown). The impact on calculated BTs is negligible.

Fig.3

Examples of MW and IR Temperature Jacobians at model top

Typical MW and IR temperature Jacobian profiles



As shown above, Jacobian tails for highest peaking infrared channels are non negligible near the top. The same is true for AMSU-A channels, especially channel 14. There are several possibilities for errors:

- Are RTTOV Jacobians accurate near the top? This can be verified from line-by-line calculations. *It is noted that tails are stronger at high latitudes, which is where the problem occurred.* No issue in Tropics.
- There is inconsistency of bias correction between MW and IR channels peaking at similar heights (right figure). One way to facilitate that consistency is to use the same bias correction predictors for both IR and MW. Currently we use 4 air mass predictors (thicknesses) for MW, and one predictor for IR (BT itself).

➢ Fig. 4a Temperature at model top showing high temperatures near North Pole area from cycle representing configuration to be implemented operationally (without the fix at top shown in Fig.2).

➢ Fig. 4b same as Fig. 4a, but resulting from a cycle using the same bias correction predictors for IR and MW radiances. That cycle also assimilated more AIRS and IASI channels. Temperature near poles are normal for August. *There is no anomalous heating at model top.*

Fig.4a

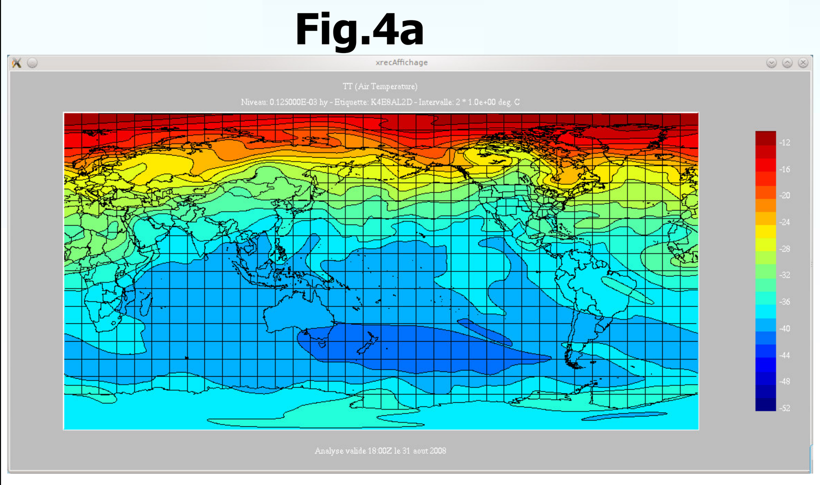
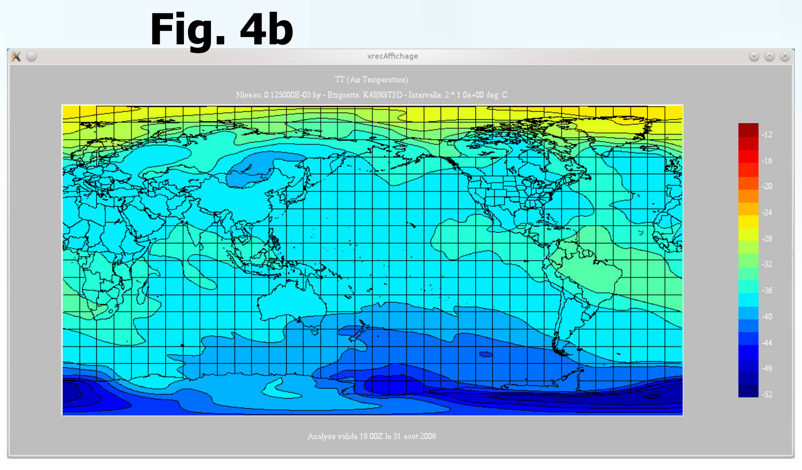


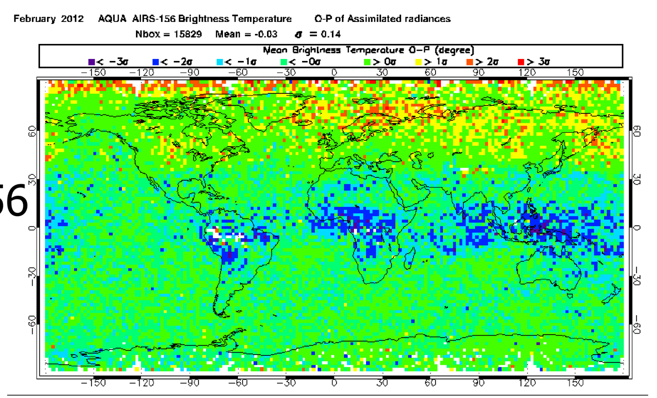
Fig. 4b



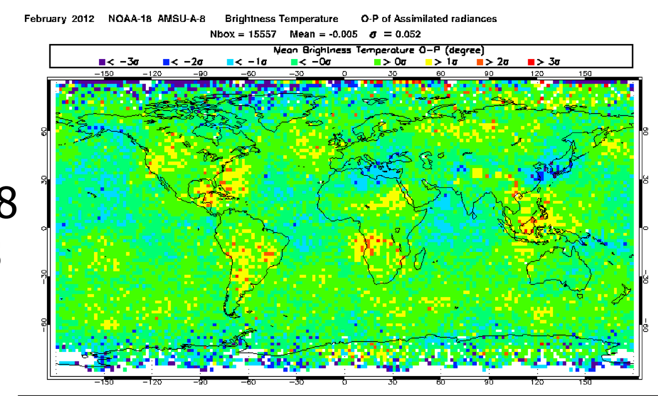
➢ It is seen that the temperature at both Poles is higher. The cycle leading to Fig.4b was redone with the exact same channels as in 4b. It was confirmed that it is the choice of bias predictors which makes the difference. However, the approach of using the same predictors for IR and WW leads to a slight negative impact in general in the mid troposphere.

Fig. 5 Feb. 2012 mean normalized O-P from assimilated radiances

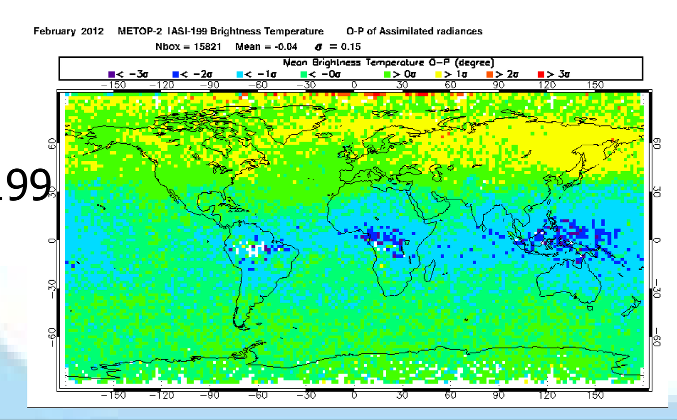
AIRS 156



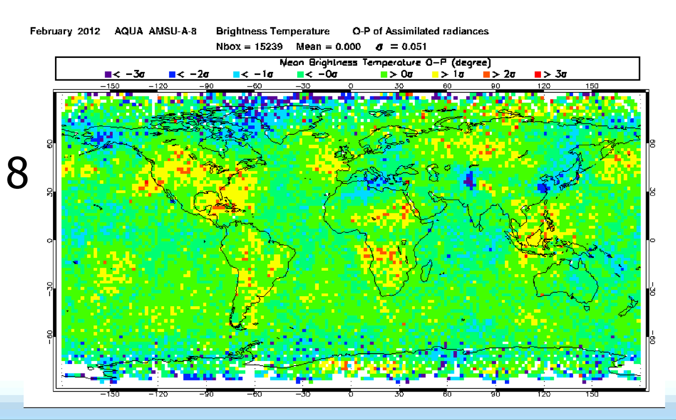
AMSU-A 8 NOAA-18



IASI 199



AMSU-A 8 AQUA



As shown in Fig. 3, AIRS-156 and IASI-199 have a very similar response function. AMSU-A-08 has also a very similar response to these two channels, peaking at same height, but its upper tail drops faster to zero. These 3 channels are sensitive to temperature only. The EC monitoring displays the mean monthly O-P representing the mean forcing. Fig.5 shows the mean (O-P) for assimilated channels in February 2012. The observation « O » is bias corrected.

It is seen that AIRS-146 and IASI-199, as expected, provide very similar forcings. Similarly AMSU-A ch 8 patterns from NOAA-18 and AQUA are very similar. However IR and MW radiances peaking at same height present significant differences of mean (O-P), notably in the Tropics and in North Pole area. In other words, there is apparent inconsistency between IR and MW forcings. It remains to be verified if the consistency significantly improves if the same predictors are used for IR and MW.

Conclusion

Anomalous heating occurred at the model lid in north polar areas linked to the increase of the density of assimilated radiances. The problem was mitigated by reducing the background error near the model top. The root cause of the problem appears to be linked to inconsistency between IR and MW bias correction approaches and the existence of non zero infrared Jacobian tails. Using the same bias correction predictors for IR and MW was shown to be beneficial. However the optimum selection of bias correction predictors for both IR and MW channels remains an issue which is currently being investigated.