Impact of Radiance Assimilation Near the Model Lid

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An assimilation cycle was run for several months in preparation for the latest operational implementation of the Environment Canada Global Deterministic Prediction System. It absorbed 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
OLD OPERATIONAL
EXPERIMENT

Investigations revealed that:
- The problem is related to radance 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

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.
- 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.3 Examples of MW and IR Temperature Jacobians at model top

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 radiance. That cycle also assimilated more AIRS and IASI channels. Temperature near poles are normal for August. There is no anomalous heating at model top.

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 channel 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.

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

AIRS 156
AMSU-A 8
NOAA-18

IASI 199
AMSU-A 8
AQUA

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.

Conclusion