Operational use of ATOVS at the Met Office

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1. Introduction

The Met Office continues to make effective use of ATOVS radiances in Numerical Weather Prediction (NWP), and this use has been extended significantly in recent years. Whilst data from the HIRS instrument are used only in the global model, extensive use is now made of AMSU-A and AMSU- B in regional and mesoscale NWP. Data is used from three satellites rather than two. In preparation for future developments research has been undertaken in a number of areas. This paper will focus on use of data over land, bias correction and the implementation of RTTOV version 7, as well as briefly discussing the impact of the third ATOVS instrument and preparations for SSMIS. Assimilation of ATOVS in regional and mesoscale NWP is discussed by Candy *et al*. (2003).

The use of ATOVS in global NWP at the Met Office has changed from that described in English *et al*. (2002) only in the addition of NOAA-17 data. The processing system is unchanged. The use of data in regional and mesoscale NWP is described in Candy *et al*. (2003).
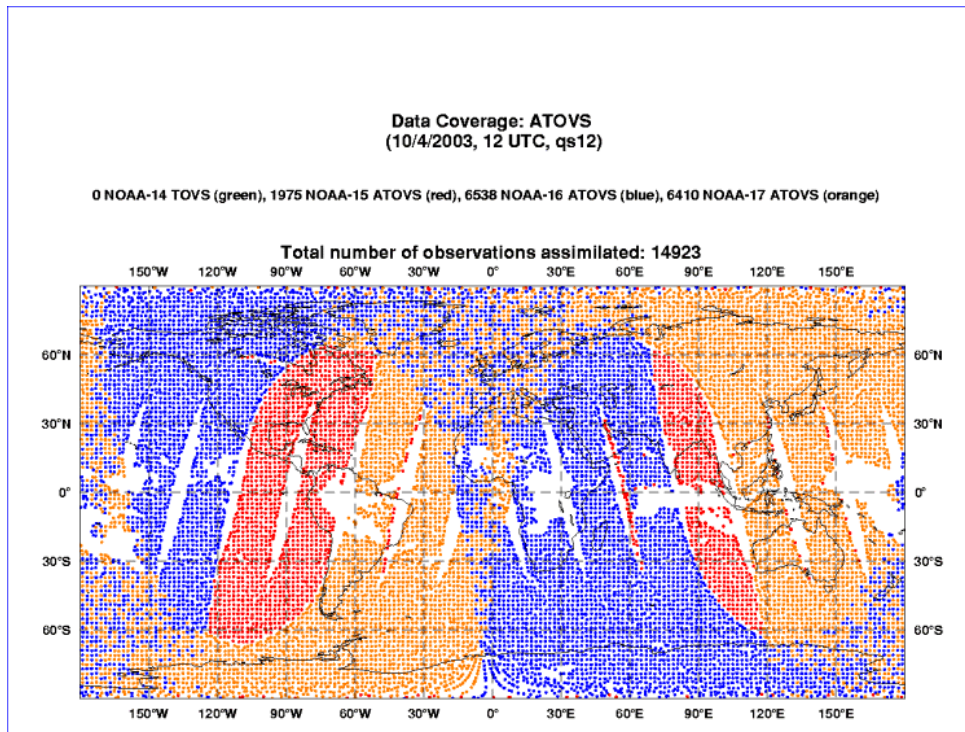

Figure 1: Data coverage for NOAA-15, 16 and 17 level 1D radiances in the Met Office global model stratospheric version for 10 April 2003, 09:00 to 15:00 UTC.

2.   Impact of NOAA-17

NOAA-17 ATOVS was introduced operationally on 1st October 2002, just 3 months after launch. This gave complete global coverage in a six hour data assimilation window for the first time (Figure 1). The quality of the data was initially slightly lower than NOAA-15 and NOAA-16 data due to a misalignment of the HIRS. This was corrected in operational Met Office processing in February 2003. The impact of NOAA-17 was nonetheless found to be significantly positive. In the southern hemisphere key fields such as mean sea level pressure and 500 hPa geopotential height have RMS error compared to observations 1-3 % lower. Verification against NOAA-16 radiances at very short range showed RMS errors lower by 1-5% in the troposphere for temperature sounding radiances, but 5-10% lower in the stratosphere and for humidity sounding radiances (Figure 2). The impact of removing NOAA-15 from a three satellite system was found to be roughly twice as large as removing NOAA-17, despite the loss of HIRS and several AMSU channels on NOAA-15. This difference was attributed to the HIRS misalignment error on NOAA-17.
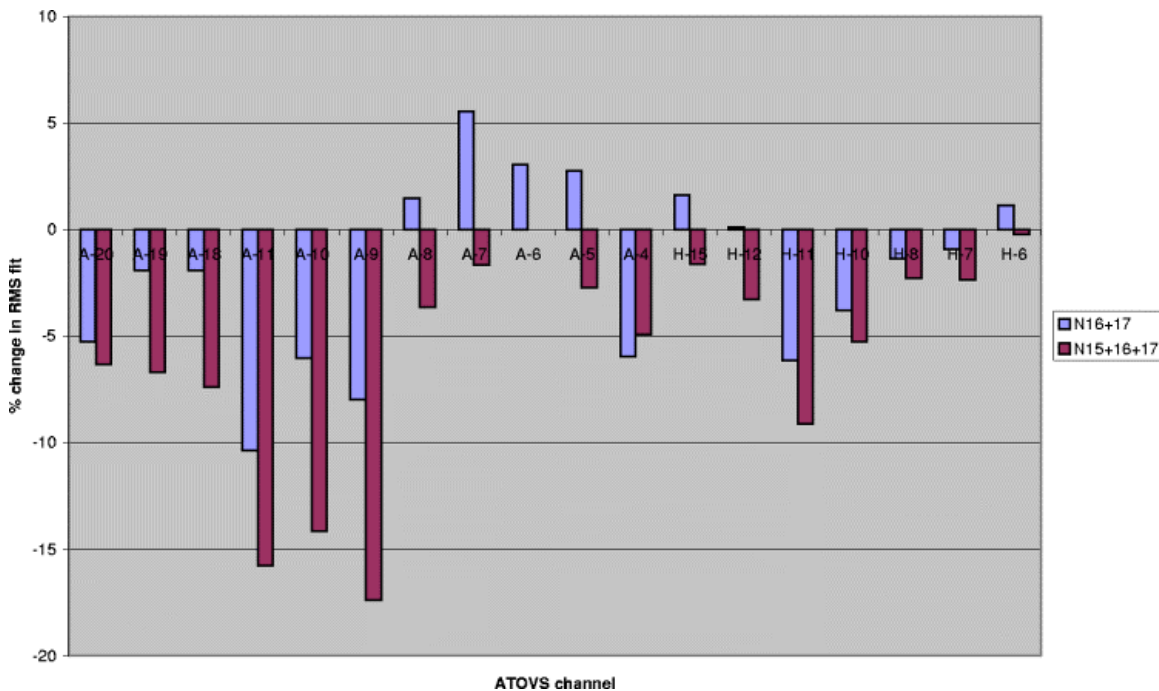

Figure 2: Percentage change in RMS of observed minus background radiances for NOAA-16 for (left to right) AMSU channels 20-18, 11-4 and HIRS channels 15, 12-10, 8, -6 when assimilating NOAA-16 and 17 or NOAA-15, 16 and 17 against a baseline run assimilating NOAA-15 and 16, (15 August – 24 September 2002).

3.   Research topics
3.1   Assimilation of ATOVS over land

A system was developed to use emissivities from the atlas of Prigent *et al.* (1997). Despite some initially encouraging results (English, Poulsen and Smith 2000) it was found that the fit of calculated brightness temperatures from the background was not improved compared to using an emissivity of 0.95. Furthermore the model function proposed in English, Poulsen and Smith (2000) was unable to fit the observed brightness temperatures over snow covered surfaces. It is accepted that for many surfaces the variation of emissivity was less than the errors in estimating

the AMSU emissivities from the atlas. The exceptions are the effect of surface water variations, snow cover, ice sheets and deserts. Water fraction from permanent water features (lakes, rivers) can be predicted more accurately from a high resolution surface type atlas. Transient water features are not represented in the emissivity atlas or a surface type atlas. Snow cover and type is also transient in nature (brightness temperature at 89 GHz can vary by over 100 K during the diurnal cycle due to the thawing and re-freezing of the ice crust (Matzler, pers. comm.). This may mean that an emissivity atlas is most helpful over deserts and ice sheets.

3.2   Use of RTTOV version 7

RTTOV-7 offers improved accuracy for several ATOVS channels, especially water vapour channels, compared to previous versions (Saunders *et al.* 2002). More instruments are supported, the model offers new and improved surface emissivity models for both microwave and infrared instruments, the cloud liquid water profile is included and there is a better treatment of ozone. An update to the status of RTTOV is provided in a paper in these proceedings by Saunders *et al.* (2003). However the model was also significantly more expensive to run, mostly because of the increased number of predictors for water vapour and ozone. At the Met Office the replacement of RTTOV-5 by RTTOV-7 was also complicated by a switch from the RTTOV-5 levels (40 levels) to RTTOV-7 levels (43 levels), as RTTOV-7 no longer supports the 40 level scheme..
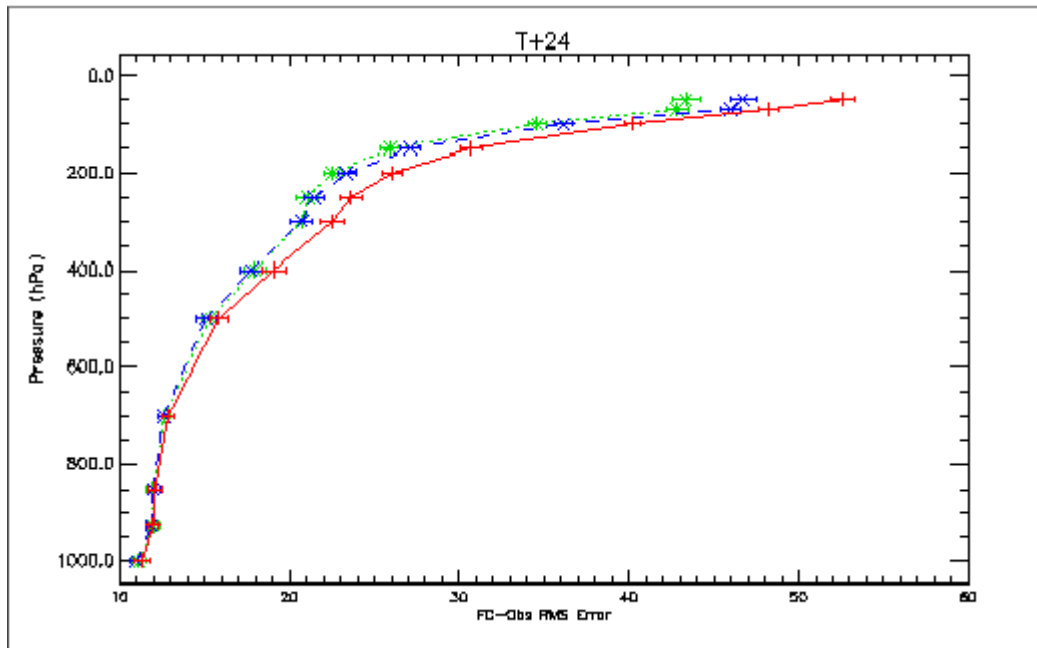

Figure 3: Verification of 500 hPa geopotential height in the region 20 S to 90 S assimilating ATOVS using RTTOV-5 (red line), RTTOV-7 with "passive" bias corrections (blue line) and RTTOV-7 with revised bias corrections (green line).

Trials of RTTOV-7 identified a small bug which was important for data assimilation, but otherwise not apparent, relating to the stratospheric water vapour Jacobians (see Figure 2 of Saunders *et al.* 2003). The trials also showed the importance of retuning bias corrections and any background dependent cloud checks for a new model. When these issues were satisfactorily dealt with RTTOV-7 was able to demonstrate a small positive impact, most notably in the tropics and southern hemisphere. The impact on 500 hPa geopotential height is shown in Figure 3. It was found best to generate initial bias corrections for RTTOV-7 by using RTTOV-5 for assimilation,

but calculating brightness temperatures using RTTOV-7 to generate the bias corrections. In this way RTTOV-7 bias corrections were generated which kept the mean analysis state consistent with that achieved using RTTOV-5. Then the cycle was repeated generating a new set of bias corrections using RTTOV-7 for assimilation with the bias corrections from the "passive" run. This technique allowed the creation of a robust set of bias corrections for use with RTTOV-7

3.3   Model predictor bias correction

Harris and Kelly (2002) showed that use of bias correction predictors based on NWP fields (e.g. 200-50 hPa thickness) had advantages over the use of observation predictors (Eyre 1992). Following Harris and Kelly (2002) a range of possible model predictors was evaluated (layer thicknesses, background BTs, skin temperature, total column water vapour, lapse rate) and trials have been run using two options: Experiment 1) Two mean layer thicknesses (200-50 hPa and 850 to 300 hPa) and calculated BT from background; Experiment 2) Two mean layer thicknesses only. The impact compared to a control using the Eyre (1992) method with AMSU channels 5 and 9 as predictors was neutral in the extra-tropics, but there was a slight increase in tropical moisture. New runs using only two thicknesses gave similar results. However the new scheme also allows use of data where observation based predictors do not work. In particular over Antarctica, Greenland and parts of Africa. Modest positive impact from using these additional observations has been found for geopotential height at medium range (forecast range day four and beyond) at altitudes corresponding to pressures less than 600 hPa.

3.4   Preparation for SSMIS

The Defense Meteorological Satellite Program (DMSP) F16 satellite carrying the first Special Sensor Microwave Imager Sounder (SSMIS) was launched on 18 October 2003. Simulated test data for SSMIS has been provided by NRL/FNMOC and this has been processed successfully. A total water control variable, defined simply as the addition of all moist variables will be used within the 1D-var preprocessing scheme (see Deblonde and English 2003 and English and Weng 2002). Not all SSMIS channel fields of view are collocated. In this sense SSMIS can be considered to comprise four instruments. One with imaging channels like SSM/I, one with temperature sounding channels for the troposphere and stratosphere like AMSU-A and SSM/T, the third with humidity sounding channels like AMSU-B, MHS and SSM/T2 and the last a completely new mesospheric sounder. The AMSU-A, AMSU-B and SSM/I like channels are being processed and will be assimilated on their original grids. The mesospheric sounder, which provides information well above the top of the current Met Office NWP model, is not used. Furthermore use of this latter instrument requires a sophisticated treatment of Zeeman line splitting. SSMIS sounding channels over-sample with short integration times. Therefore individual measurements will be noisy, and some averaging is desirable. After initial implementation of data on the original grid a system will be developed with super-obbing and/or re-mapping.

4. Conclusions

ATOVS radiances continue to be very important for global NWP. Improvements continue to be made to the assimilation, of which the most notable at the Met Office since ITSC-12 was the implementation of NOAA-17 ATOVS. Progress continues to made in others areas with improvements likely to result soon from implementation of a new bias correction scheme, RTTOV-7 and use of ATOVS over existing data voids (e.g. Antarctica). The advent of SSMIS will improve robustness by increasing the number of operational sounding instruments of AMSU quality to four. Evidence at ECMWF (Kelly,

pers. comm.) using Aqua AMSU-A data suggests further benefit can be achieved from a fourth satellite. Work is in hand to use the Aqua data at the Met Office.

References

Candy B.C., English S.J., Renshaw, R.J. Macpherson, B. 2003. Use of AMSU in the UK mesoscale model. *Proceedings of the XIIIth International TOVS Stidy Conference, St. Adele, Canada*, 29 October – 4 November 2003.

Deblonde, G. and English, S.J. 2003 One-dimensional variational retrievals from SSMIS simulated Observations, *In press*. *J. Appl. Meteorol.*

English, S.J., Poulsen, C. and Smith, A.J. 2000. Forward modeling for liquid water cloud and land surface emissivity. *ECWMF/EUMETSAT workshop on use of ATOVS data for NWP assimilation, 2-5 November 1999*, 91-96.

English, S.J., Hilton, F., Jones, D.C., Smith, A.J. and Whyte, K.W, 2002. ATOVS and SSM/I assimilation at the Met Office. *Proceedings of the XIIth International TOVS Stidy Conference, Lorne, Australia,* 28 February – 5 March 2002.

English, S.J. and Weng, F. 2002 Methods for processing cloudy AMSU observations. *Proceedings of the XIIth International TOVS Study Conference, Lorne, Australia.*

Eyre, J.R. 1992. A bias correction scheme for simulated TOVS brightness temperatures *ECMWF Tech. Memo.* **186**.

Harris, B.A. and Kelly,2002: G. A satellite radiance-bias correction scheme for data assimilation. *Q. J. Royal Meteorol. Soc*., **127**, 1127, 1453-1468.

Prigent, C., Rossow, W.B and Matthews, E. 1997. Microwave land surface emissivities estimated from SSM/I observations. *Journal of Geophysical Research (Atmospheres)*, **102 (D18)**, 21867-21890.

Saunders, R.W., Matricardi, M., Brunel, P., English, S.J. and Deblonde, G. 2002. RTTOV-7: a satellite radiance simulation for the new millennium. *Proceedings of the XIIth International TOVS Study Conference, Lorne, Australia,* 28 February – 5 March 2002.

Saunders, R.W., English S.J. Rayer P.J., Francis P., Hilton F., Matricardi M., Chevallier F., Brunel P. 2003. Status of RTTOV-7 and plans for RTTOV-8. *Proceedings of the XIIIth International TOVS Stidy Conference, St. Adele, Canada*, 29 October – 4 November 2003.