An Update on the Operational Use of Satellite Sounding Data at the Met Office

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Abstract

Since ITSC-18 in March 2012 the Met Office have implemented three major upgrades to the operational global model, all of these involving changes in the way satellite radiance data are used. These upgrades have included the assimilation of data from the Suomi-NPP ATMS and CrIS instruments, both of which have shown benefit in the Met Office system. Other changes have included: the treatment of inter-channel error correlations for IASI; the introduction of a variable observation error model for ATOVS surface sensitive channels; and the introduction of RTTOV-9. In addition, data from MetOp-B ATOVS and IASI were introduced in January and February 2013 respectively following successful evaluations of data quality.

1. Introduction

The Met Office currently run a global model with forecast / analysis resolutions of 25km / 60km. The model has 70 levels in the vertical with a model top at ~0.01 hPa. In July 2014 the model will be upgraded to 17km / 40km for forecast and analysis resolutions respectively. Other models include a variable resolution (1.5km – 4km) model over the UK domain. Key features of the data assimilation systems are - the use of incremental 4D-Var (Rawlins, 2007) and the use of a 1D-Var pre-processor for all radiance data types. The 1D-Var pre-processor is used for general quality control and to generate *pre-analyses* of variables which are required for the assimilation of radiances, but which are not analysed in the main assimilation. These variables include skin temperature and emissivity for observations over land, and cloud variables (cloud top pressure and cloud fraction) for cloud affected infrared radiances.

The main upgrades to the Met Office system during the period March 2012 (ITSC-18) until March 2014 (ITSC-19) are described in Section 2 below.

2. Current use of Microwave data

2.1. Use of ATOVS data

The use of ATOVS data is summarised in Figures 1-3 below, showing the satellites used, coverage in each 6-hour assimilation window, and the observation errors assumed for each channel respectively.

	AMSU-A	AMSU-B / MHS	HIRS
MetOp-A	4-6, 8-14	3-5	4-7,11,12,15
MetOp-B	4-14	3-5	4-7,11,12,15
NOAA-19	4-7, 9-14	3-5	---
NOAA-18	4-14	3-5	---
NOAA-15	5,7-10,12	---	---

Figure 1: ATOVS instruments and channels assimilated in the current (March 2014) Met Office operational global model. [*Note: MetOp-A AMSUA-8 was withdrawn in May 2014.*]

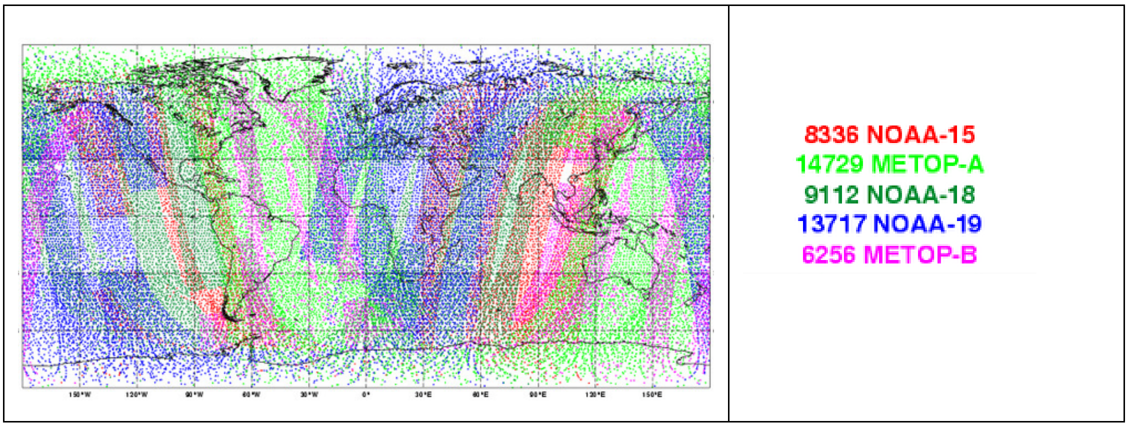

Figure 2: Coverage provided by the ATOVS instruments in a 6 hour assimilation window. Also shown is the number of observations assimilated in each 6 hour period.

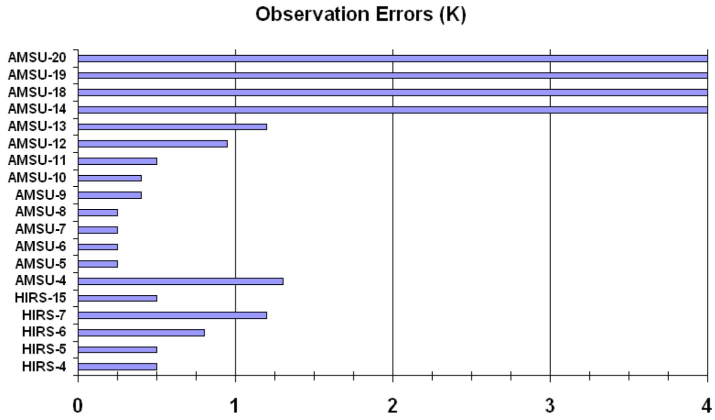

Figure 3: Observation errors assumed for the ATOVS channels. These are the errors assumed *prior to* the upgrade to the *variable observation error model* in January 2013 (AMSU-A channel 4 and 5 and HIRS channels 6 and 7).

Data from ATOVS on MetOp-B was introduced in January 2013 following successful data evaluation between launch (September 2012) and January 2013. AMSU-A channels 1 and 2 were withdrawn from operations in January 2013 (*parallel suite* 31, PS31) as investigations showed that AMSU-1 and -2 were responsible for generating large and unrealistic analysis increments near the Antarctic ice edge. Data denial experiments also showed a benefit from withdrawing these channels.

2.2. Introduction of Suomi-NPP ATMS data

ATMS data quality was assessed and found to be generally good. A detailed report on this assessment can be found in Doherty *et al* (2013). One issue which emerged in this assessment is the presence of cross scan striping effects for ATMS, illustrated for channel 8 in Figure 4 below.

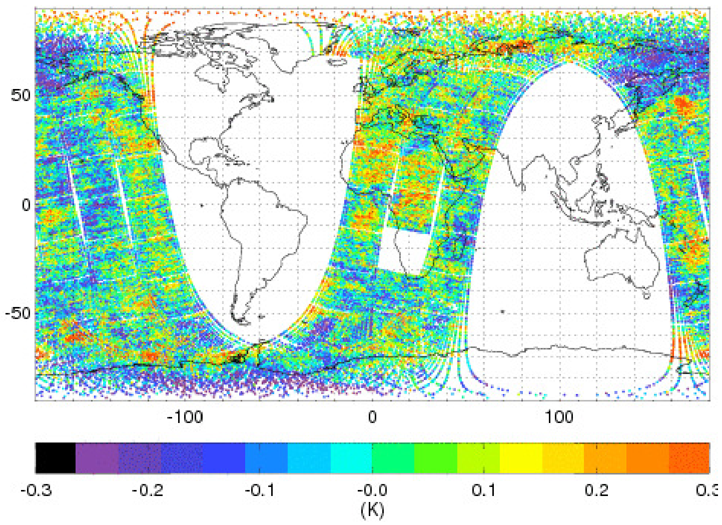

Figure 4: ATMS channel 8 (54.94 GHz) first guess departures, illustrating striping effects due to 1/f noise. See Doherty *et al* 2013.

Assimilation experiments showed ATMS provided benefit in the Met Office system (see Figure 5), reducing SH RMSE errors by 1-2% for PMSL and 500 hPa geopotential height. In the initial implementation observation errors were set at 0.35K for channels 6-15 and 4K for channels 18-22.

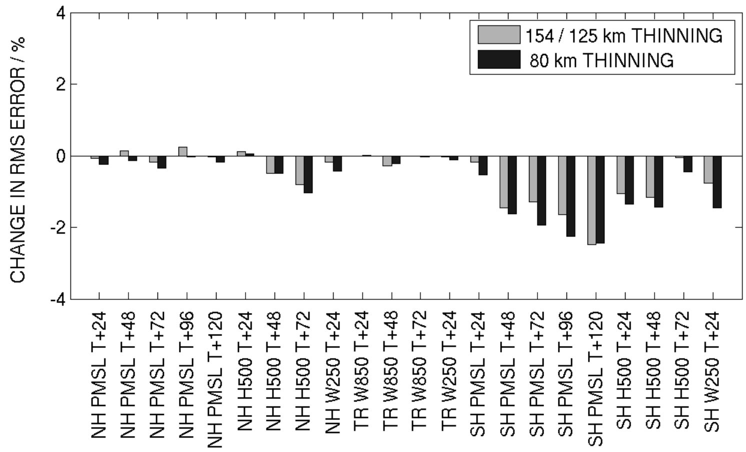

Figure 5: ATMS forecast verification when ATMS introduced into a full observing system.

3. Current Use of IR data

3.1. AIRS and IASI / Inter-channel error correlations

Infrared sounding data from AIRS, IASI (and now CrIS, see 3.2 below) are assimilated in the Met Office global model. AIRS warmest field of view data is used. Cloud top pressure and cloud fraction are diagnosed in a 1D-Var pre-processing step and 141 / 46 channels are used over sea / land. Observation errors are currently set to 1K / 4K / 1K for temperature / humidity / window channels respectively. For IASI 1 pixel is selected from 4 using the most homogeneous field of view determined using AVHRR. Surface emissivity and skin temperature are analysed, as well as cloud parameters as for AIRS. 138 /131 channels are used over sea / land and, until January 2013, observation errors were set at 0.5 / 4.0 / 1.0 K for temperature / humidity / window channels respectively.

Following the PS31 upgrade revised R matrices were used for IASI which used diagnosed inter-channel error correlations diagnosed from the method of Desroziers (see Weston *et al* 2013 for more details). Figure 6 shows the pre-PS31 observation errors assumed for IASI as well as the diagnosed errors and reconditioned errors that were implemented in operations.

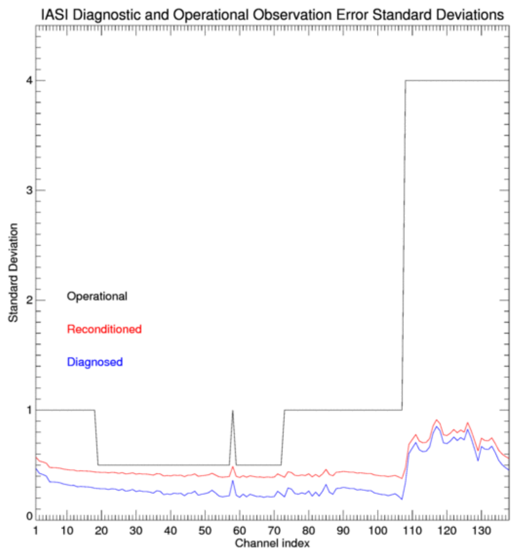

Figure 6: Pre-PS31 observation errors for IASI (black), diagnosed errors (using the Desroziers method, blue) and reconditioned errors (red) implemented at PS31 for IASI.

3.2. Introduction of Suomi-NPP CrIS data

A data quality assessment showed data from CrIS to be of excellent quality. Standard deviations of innovations compared well with those from IASI and AIRS (see Figure 7 below), indicating excellent NEΔT and bias characteristics.

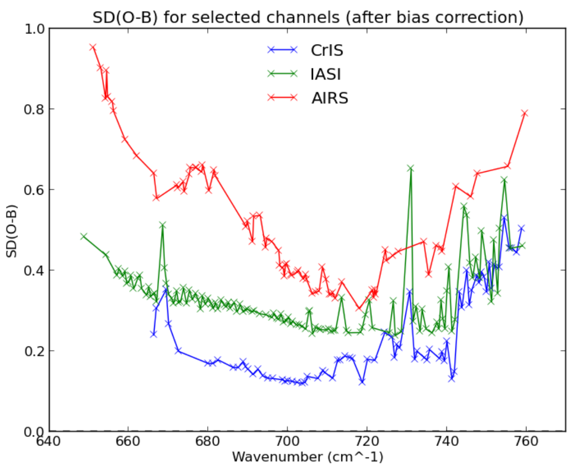

Figure 7: Standard deviations (SD) of innovations (O-B) for CrIS temperature sounding channels, compared with comparable values from IASI and AIRS.

Several configurations were tested in which channel selections and observation errors were varied (see Smith *et al*, 2014). All configurations gave modest positive impact. The configuration implemented was the most aggressive tested in terms of observation errors and channel selections. In this configuration observation errors were set to 2× the standard deviation of the (O-B) values, resulting in R values of, typically, approximately

0.3K for the upper tropospheric and lower stratospheric temperature sounding channels. Figure 8 below shows the verification results for two configurations tested.

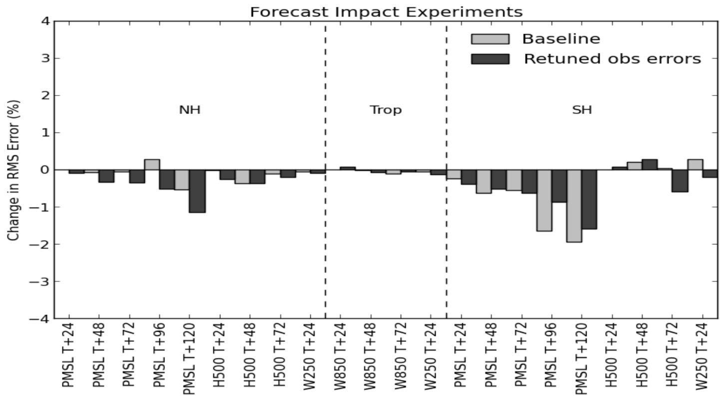

Figure 8: Forecast verification for CrIS assimilation experiments, showing results for conservative observation errors (0.5K, 1-2K, 4K for lower atmospheric T-sounding, other T-sounding and water vapour sounding channel respectively), and retuned errors (**R**=2×STD(O-B)). See Smith *et al*, 2014.

3.3. Introduction of MetOp-B IASI

Following a detailed evaluation of MetOp-B IASI (see Cameron et al , 2013a, b) the data was introduced into operations in February 2013. The results of pre-operational tests are shown in Figure 9 below.

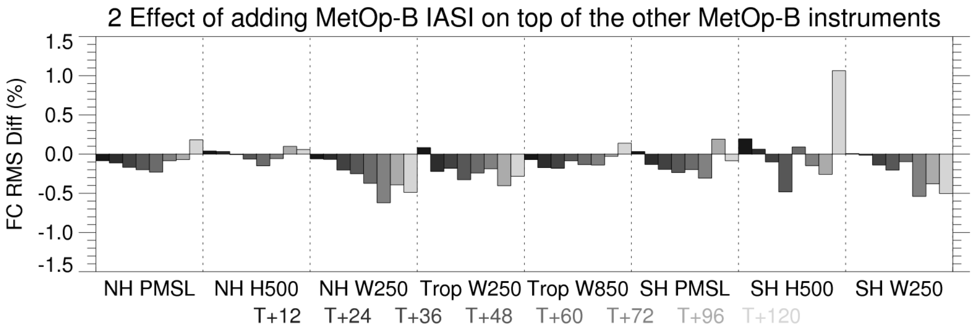

Figure 9: Forecast verification for the introduction of MetOp-B IASI in a full system. Verification is relative to observations. Changes in RMSE shown for forecast day 1 to day 5 in NH, Tropics and SH. See Cameron *et al*, 2013

4. References

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