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Evaluation of FY-3B data and an assessment of passband shifts in AMSU-A and MSU during the period 1978 – 2012

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Evaluation of FY-3B data and an assessment of passband shifts in AMSU-A and MSU during the period 1978 – 2012

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Introduction

The first of a series of eight polar-orbiting Chinese meteorological satellites, FY-3A, was launched successfully on 28th May 2008. FY-3A carries a payload of eleven sensors, including a suite of three infrared/microwave temperature and humidity sounders (IRAS, MWTS and MWHS similar in specification to HIRS, MSU and AMSU-B/MHS respectively) as well as a microwave imager (MWRI, similar in specification to AMSR-E). A second mission carrying the same payload of instruments (FY-3B) was launched into an afternoon orbit on 5th November 2010.

Previous investigations, performed during NWPSAF VS Missions, on the FY-3A MWTS instrument revealed two significant biases which were characterised and corrected [1]. The resulting data was shown to be of similar quality to AMSU-A instruments and delivered modest positive impact on ECMWF forecasts [2].

The aims of this NWP-SAF visiting scientist mission were to perform a similar analysis on the FY-3B instruments and to apply the methods developed in characterising the FY-3A MWTS to existing operational AMSU-A instruments – in order to refine bias correction methods, and to inform the specification of future microwave sounding instruments.

The specific objectives of the mission were to:

- Perform initial evaluation of FY-3B data, if launch is successful (Oct / Nov 2010) and data becomes available.
- Establish operational monitoring for FY-3B.
- Analyse *on-orbit* pass-band parameters for existing constellation of ATOVS and SSMIS sensors, using tools developed for the FY-3A MWTS and, if time permits, extend the analysis to the MSU series.
- Perform a detailed evaluation of FY-3A infrared (IRAS) and microwave temperature and humidity sounders (MWTS and MWHS) and imager (MWRI).

Summary of progress

Two Technical Memoranda are in preparation covering; (i) An assessment of pass band shifts in all MSU and AMSU-A instruments during 1978-2012; and (ii) An initial evaluation of FY-3B data. A summary of the main results and a few key figures are included here:

Pass band shifts in existing operational AMSU-A instruments

Using the methods developed in [1] a detailed analysis of pass band centre frequency shifts in AMSU-As on-board: NOAA-15,-16,-18,-19, MetOp-A and EOS-Aqua was carried out. The analysis was repeated for two new sets of spectroscopic parameters for the O_2 60 GHz band [3, 4], and for four independent NWP models (ECMWF, NCEP, UKMO and CMA). The results are summarised in Figure 1 below which shows the analysis obtained from the four centre analysis (for AMSU-A channels 6-11).

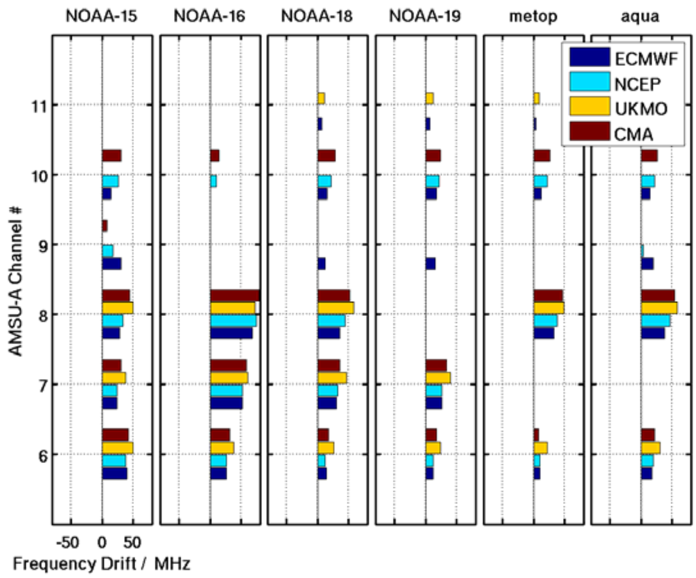


Figure 1: Analysed frequency drifts from 4 NWP centres, for all operational AMSU-A instruments. Analysis for channels 6-11 is shown.

The analysis was restricted to channels 6-14. Several conclusions were drawn from this analysis:

- Large shifts, of order 10's MHz, are evident on most AMSU-As for channels 6-8. Simulations using these shifts significantly reduced the variance of first guess departure fields and in many cases reduced the magnitude of the mean first guess departures. It can be concluded that most of the *air-mass biases* currently corrected using a *Harris and Kelly* predictor scheme, a variational scheme , or a *gamma correction* scheme are most likely due to drift in instrument pass bands.

- The shifts analysed for channels 9-14 are generally much smaller, at < 10MHz, and result in less significant reductions in the variance of the first guess departures. This 6-8 / 9-14 split in the stability of the channels is explained by the use of a *phase-locked loop* (PLL) around the Gunn diode local oscillator (LO) which locks the LO to a highly stable reference crystal oscillator and ensures sufficient stability for the narrowest channels which sound the upper stratosphere.

- New O_2 spectroscopy (Tretyakov (2005), Makharov (2011)) had a relatively small impact on the analysed pass band shifts for channels 6-8 – supporting the conclusion that the large analysed shifts are realistic. For channel 10, there was a reduction in the magnitude of the analysed shift, consistent with the spectroscopy being more accurate, and the true shifts for channel 10 being very small due to the phase locking of the oscillator.

- The results were broadly consistent for the analysis using atmospheric fields from four NWP centres – supporting the conclusion that the analysed large shifts are real and not an artefact of particular NWP model biases.

Pass band shifts for MSU and AMSU-A over the period 1978-2012.

The analysis was extended to cover the MSU and AMSU-A series of instruments, commencing with the TIROS-N MSU instrument launched in 1978. The analysis used analysis fields from ERA-Interim and pass

band shifts were analysed for each instrument from a single 12 hour assimilation cycle on the 15th of each month over the life of the satellite.
As an example a summary plot for the pass band analysis of AMSU-A channel 6 is shown in Figure 3 and for MSU channel 3 in Figure 4.

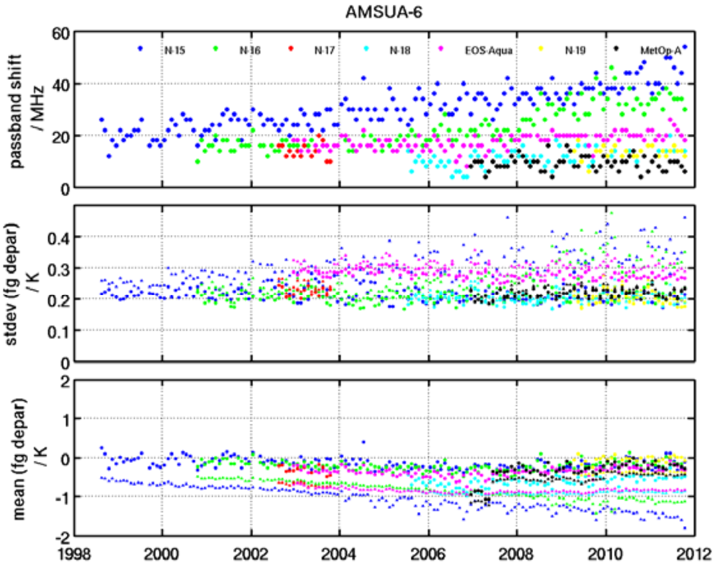


Figure 2: Pass band shift analysis for AMSU-A Channel 6, for NOAA-15, -16, -17, -18, -19, MetOp-A and EOS Aqua.

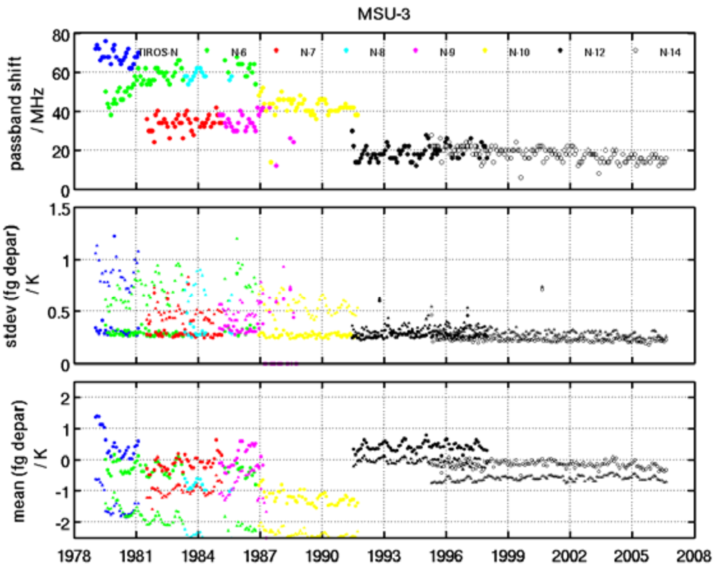


Figure 3: Pass band shift analysis for MSU Channel 3, for TIROS-N, NOAA-6, -7, -8, -9, -10, -12, -14.

The main conclusions to be drawn from this analysis so far are:

- Many of the AMSU-A instruments exhibit large shifts from launch for channels 6-8 and, by inference, channels 3-5 as well. For some instruments the shifts remain stable over the life of the satellite, whereas for others the LO centre frequencies drift with time (*eg.* NOAA-15 channel 6 and NOAA-16 channels 6-8).

- The more recent instruments, NOAA-19 and MetOp-A, exhibit smaller shifts at launch which may reflect improved LO performance or improved pre-launch characterisation.

- For NOAA-15 Channel 6, withdrawn from ECMWF operations in February 2005 due to concerns about degrading data quality, evidence suggests that a correction to the pass band centre frequency renders the data of usable quality.

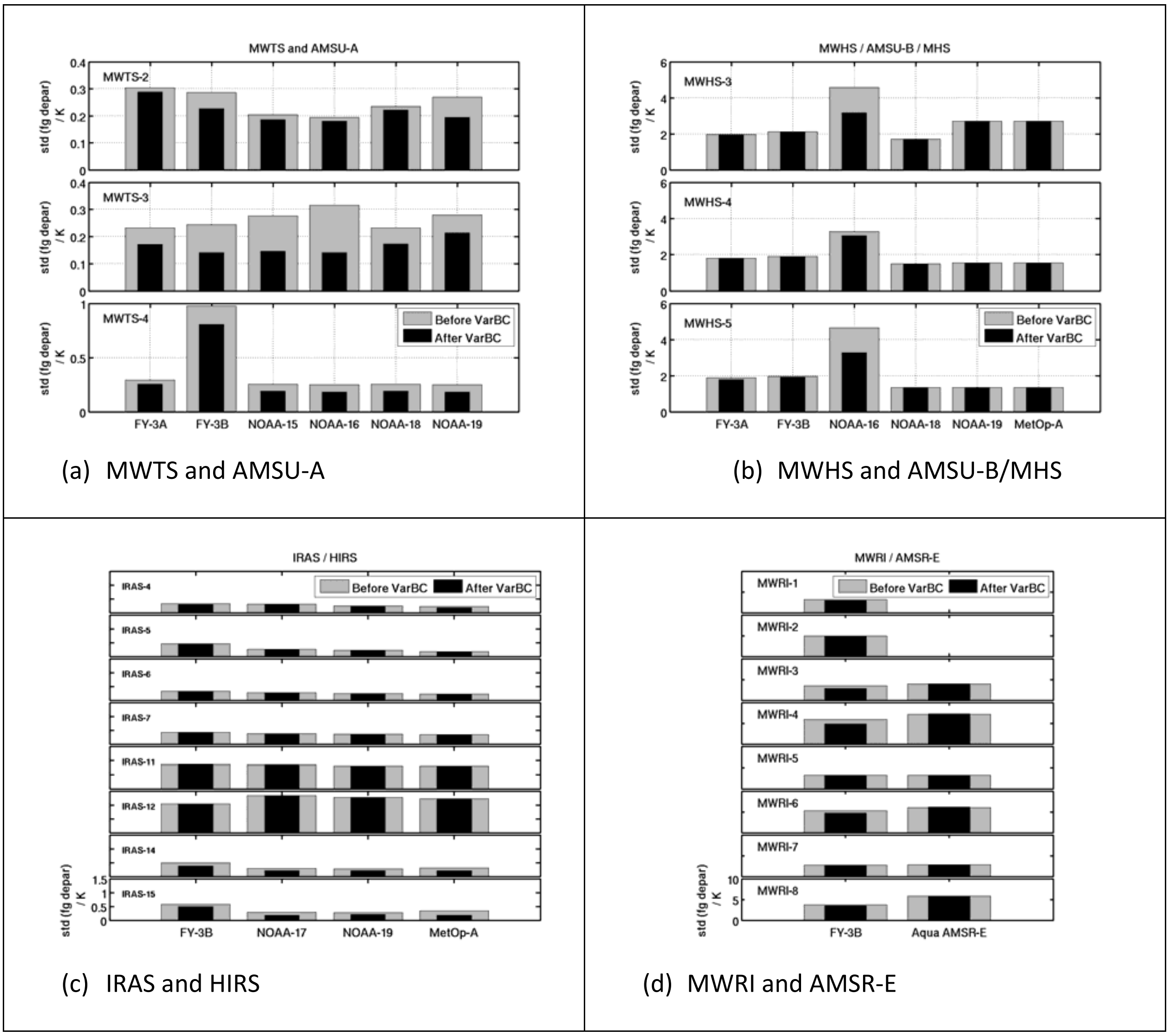
- For MSU, the shifts at the start of the earlier missions were very large, of up to 70 MHz and many remain stable. Over time the shifts evident at launch decrease in magnitude for successive instruments – and may reflect an improvement in LO technology and/or improved pre-launch characterisation.

- MSU channels 3 and 4 were analysed. For channel 3 the mean first guess departures are usually reduced in magnitude through use of the new pass band centre frequencies. For MSU-4 the picture is less clear – with derived pass band shifts showing much larger variability in time and the improvements in first guess departures being less significant.

This analysis is expected to lead to improved bias correction of AMSU-A data, and assimilation experiments are underway to test the performance of using RT coefficients based on improved pass band centre frequencies. Initial indications (6 weeks verified to date) show that the passband shifted coefficients give measurable benefits over variational bias correction (VarBC) alone – or VarBC coupled with a *gamma correction*. Forecast improvements of ~1% in RMSE for geopotential for pressure levels from 850-200 hPa are observed. New coefficient files are expected to lead to reduced biases in data used for reanalysis, thereby reducing intersatellite biases and improving confidence in climate trends derived from the data.
Uncorrected pass band shifts result in complex bias fields that are manifested as cross scan biases as well as apparent *air mass*, or latitudinally dependent, biases. The correction of these biases present challenges for the use of the data in NWP data assimilation systems, but also in the use of the data for reanalysis and in climate trend studies. In this context the benefit of improved LO stability, achieved through phase locking, should be considered by satellite agencies.
Time did not permit a similar analysis for the temperature sounding channels of SSMIS.

Assessment of FY-3B Data

Data from the FY-3B MWTS, MWHS, MWRI and IRAS were assessed, based on a sample of the data covering 1st June -30th September 2011. The data quality is assessed relative to FY-3A and equivalent AMSU-A/-B, MHS, HIRS and AMSR-E channels in Figure 4(a-d) below:



(a) MWTS and AMSU-A

(b) MWHS and AMSU-B/MHS

(c) IRAS and HIRS

(d) MWRI and AMSR-E

Figure 4: A comparison of data quality (standard deviation of first guess departures) for the FY-3B instrument compared with equivalent channels and instruments.

The following conclusions can be drawn at this stage:

- For FY-3B MWTS the data for channels 2 and 3 is comparable to data from operational FY-3A MWTS and equivalent AMSU-A channels, however for channel 4 the data is significantly worse. This was tracked to a problem in the gain computation for this channel. Several anomalies in the gain time series have been corrected using a piecewise spline interpolation method. At the junctions between these splines discontinuities are evident which result in errors in the computed brightness temperatures at these points in the orbit.

- The FY-3B MWHS matches the performance of FY-3A MWHS and is close to the performance of AMSU-B /MHS equivalents.

- The FY-3B IRAS performs well, with departure statistics for the key sounding channels (4-7, 11, 12, 14, 15) close to the HIRS equivalents.

- The FY-3B MWRI compares well with AMSR-E and as the only microwave imager in an afternoon orbit - is potentially an important contribution to the global observing system.

Observing system experiments are underway which add the FY-3B instruments, both individually and collectively, to an ECMWF full system. Early indications are that the overall impact is neutral. Details will be presented in subsequent Technical Memos and publications. Operational monitoring of the FY-3B data awaits the establishment of an operational stream of FY-3B data which is planned for Spring/Summer 2012.

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