An assessment of the characteristics of SSMIS from F-16 to F-18

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During 2010 the data from the latest Special Sensor Microwave Imager/Sounder (SSMIS) instrument onboard the U.S. Defense Military Satellite Program (DMSP) F-18 satellite were made available to Numerical Weather Prediction (NWP) Centres. Assimilating the new data into the Met Office's global NWP model is expected to improve the current data coverage, as well as enhance the NWP system's future robustness. However, the F-18 instrument has been found to suffer from a distinct ascending and descending systematic bias.

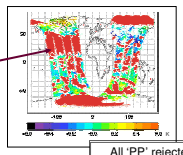
The bias characteristics of the SSMIS data streams from the F-16, F-17 and F-18 satellites have been investigated with respect to the Met Office's global forecast NWP model. The influence of the new ascending/descending (asc/dsc) bias predictor (being introduced in order to mitigate the strong bias present in the F-18 data), is presented.

Characteristics of the various 'flavours' of SSMIS data

At the Met Office we currently assimilate SSMIS data from the F-16 instrument that is pre-processed using our original *in-house* SSMIS 'PP' pre-processing software[1]. In preparation for switching to use SSMIS data pre-processed using the Unified Pre-Processor (UPP) at the Naval Research Laboratory, the characteristics of our operational 'PP' data are compared with that of the 'UPP'. The nature of the F-17 and F-18 data are also shown below.

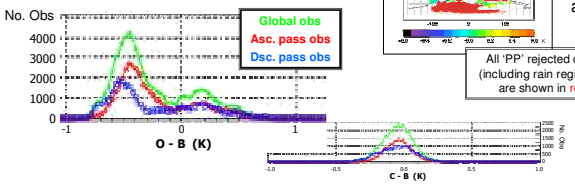
F-16 'PP'

As part of the SSMIS 'PP' pre-processing, observations contaminated by solar intrusion are flagged and later rejected, as here.



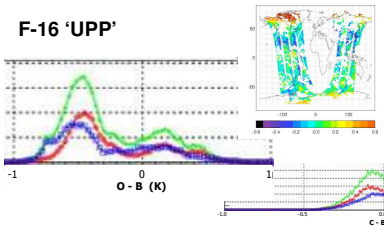
All 'PP' rejected obs (including rain regions) are shown in red

Consequently, only ~50% of the observations are typically accepted by the assimilation system.



The characteristics of our operational 'PP' data were found to be very similar to that of the 'UPP' data, as can be seen when comparing histograms of observations – background (O-B) departures.

F-16 'UPP'



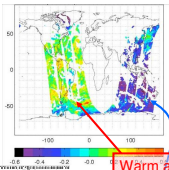
SSMIS data pre-processing using the UPP in which additional corrections are applied, enables observations in the solar intrusion regions to be utilized, thus providing better data coverage.

This data is averaged using the 'SSMIS Averaging Module'[2].

A note about the plots..
We currently assimilate temperature (Ch. 2-7, 23-24), moisture (Ch. 9-16) and UAS (Ch. 21,22) sounding channels, but the temperature channels are more noticeably influenced by the biases, and so the results from Channel 5, typical of the temperature sounding channels, are used to illustrate the findings from this work.
The histograms plotted are for observed-background (O-B) and bias corrected-background (C-B) departures for the QU00 14 March 2011, cycle. Global maps of the C-B departures are also included.

The channels exhibit similar behaviour in each instrument, although in F-18 there is a distinct separation between the ascending and descending passes. The O-B bias structures' are effectively mitigated (except in F-18) when the Harris and Kelly[3] bias correction scheme is applied, with the corrected observation – background (C-B) departures, now resembling Gaussian distributions.

In F-18, the separation of the ascending and descending nodes is quite distinct, and is ~0.7K. This does not result from a cross-scan bias dependence, but from an asc/dsc bias. This can be clearly seen in the global map of the C-B departures, as well as the histograms, with the descending pass being distinctly cooler than the model background.

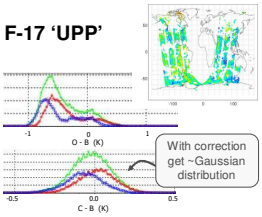


In general, the maximum difference occurs near the equator

Warm ascending pass

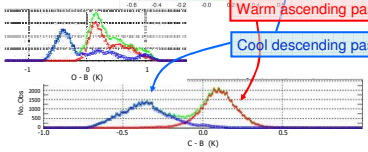
Cool descending pass

F-17 'UPP'



With correction get ~Gaussian distribution

F-18 'UPP'



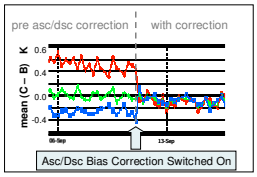
Although not particularly apparent, the F-16 instrument is also known to suffer from a similar issue, although to a much lesser degree, with the bias being ~0.2K in magnitude.

Introducing a new predictor

In order to compensate for the ascending/descending bias, a new bias predictor was developed whereby application of a co-sinusoidal predictor was found to most effectively reduce the departures. When implemented, the predictor is scaled accordingly and subtracted from the observed radiances, thus removing the ascending/descending bias.

$$Predictor = pass.\cos(L)$$

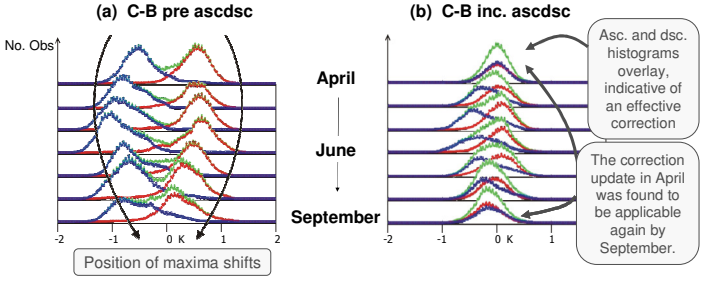
L is the latitude
$pass$ +1 if ascending
or -1 if descending
(we use the ephemeris latitude information)



When switched on, the predictor was found, as a first order correction, to be very effective.
However, the effectiveness of the correction was found to lessen with time...

A seasonal dependence?

Monitoring of the F-18 UPP data over a six month period revealed that the magnitude of the bias varied throughout the season, such that it was most significant around the summer solstice. The position of maximum bias was also observed to deviate from the equator.



Plots show daily histograms of C-B departures recorded at 28 day intervals for data (a) corrected using the standard method, and (b) with the new predictor.

An amendment to the predictor…

Simply adding an additional phase term, φ into the predictor enabled the position of the maxima to be varied, so that seasonal variation could be corrected for upon a bias update.

Thus: $$Predictor = pass.\cos(L - \varphi)$$

This is implemented as a two-part predictor in order to conform to the Harris and Kelly scheme. Thus:

$$Predictor_A = pass.\cos(L)$$
$$Predictor_B = \sin(L)$$

Assimilating the data

Preliminary NWP trials have been run to assess the impact of assimilating the new data into the Met Office model. Given the need to use the asc/dsc bias predictor in order to assimilate the F-18 data, and that F-16 was also found to benefit from the correction, the 'ascdsc' predictor was used to correct all the SSMIS data assimilated in the trials undertaken. Interestingly, both instruments are found to provide slight positive impact when used independently, yet neutral benefit is realised when they are simultaneously included in the assimilation.

Satellite data used in trial (All obs corrected using 'ascdsc' predictor)	NWP Index v. Obs.	NWP Index v. Analysis
F-16 UPP	+0.21	+0.27
F-18 UPP	+0.21	+0.27
F-16 and F-18 UPP	+0.03	+0.08

The table presents trial results for the month period of December 2010. The NWP Index results (calculated as in (4)) are relative to that of our current operational model (using SSMIS F16 'PP' data).

A second season of testing is being undertaken with the aim of operationally assimilating the F-18 data.

(1) A Preprocessor for SSMIS Radiances Scientific Description, NWPSAF MO UD 014, available from www.nwpsaf.org
(2) SSMIS UPP Averaging Module Technical Document, NWPSAF MO UD 025, available from www.nwpsaf.org
(3) Harris and Kelly, 2001, QJRMS 127, p.1453
(4) Global NWP Index documentation, Met Office 2010, http://www.wmo.int/pages/prog/www/DPFS/Meetings/CG-FV_Montreal2011/Doc4-6-Annex_Global_index_documentation_2010-2.pdf

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