

Effect of Predictor Choice on the AIRS Bias Correction at the Met Office

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Abstract

Based on the Harris and Kelly (2001) bias correction scheme used at ECMWF and the Bureau of Meteorology, a bias correction code was set up at the Met Office to apply to a given set of channels from the AIRS instrument on the AQUA satellite. Using a choice of five bias predictors, scan only and four air-mass predictors based on background fields, various combinations of predictors were applied to a large subset of AIRS channels in order to determine the optimal set of predictors for the subset. For this particular subset, it was found that the optimal predictors were the two air-mass predictors, 850-300 hPa and 200-50hPa thickness.

1. Introduction

The Atmospheric Infrared Sounder (AIRS) is a high resolution spectrometer with 2378 channels in the range of $640 - 2700 \text{ cm}^{-1}$ in the infra-red spectrum. The instrument is onboard the NASA AQUA earth observing satellite launched on 4 May 2002. The Met Office receives a subset of brightness temperatures of 324 channels, in near real time from NOAA/NESDIS. It has also developed a cloud detection scheme Takeuchi (2003) as part of a pre-processing scheme. The radiance profiles determined to be 'clear' are then passed to a 1DVAR quality control phase. Those profiles that pass the 1DVAR quality control are then to be passed to the VAR assimilation system.

When any radiance is used in a variational retrieval system, a bias correction needs to be applied, see Eyre(1992). Section 2 details the bias correction scheme used for the AIRS radiances, and is mainly based on the and Harris and Kelly(2001) method which uses background fields as air-mass predictors for the bias correction. Section 3 details the dataset that was used, which was mainly from April 2003, and a small subset from March 2003. The results obtained from using various combinations of bias predictors for both the small subset and the larger subset are presented in Section 4. Section 5 gives a summary of the work performed and some areas of further work.

2. The Bias Correction Scheme

The bias correction scheme, based on Harris and Kelly (2001), uses a constant global scan bias for each channel, and a set of air-mass predictors which may be chosen in advance. Those that were available for selection were

- 1) **Thick850** 850-300 hPa Thickness.
- 2) **Thick200** 200-50 hPa Thickness.
- 3) **T_Skin** Surface Skin Temperature.
- 4) **Not Used**
- 5) **BriTemp** Calculated radiance for the given channel.

Predictor 4 was reserved for total column water vapour, but was unavailable in the initial experimental bias correction dataset.

This bias correction method attempts to remove both locally and globally, the bias in observed minus background radiance (O-B), for a large sample of radiance observations. Once the scan bias has been removed, it is straightforward to show mathematically, that the predictors with the highest correlation to (O-B), will be those which are most effective at removing the bias. This is mathematically equivalent to those predictors which reduce the standard deviation in (O-B) by the largest amount.

3. The Datasets

A large dependent sample was used, in this case for the April dataset, to calculate the scan bias and the coefficients of the chosen predictors. Only sea points (not including sea-ice) were used. Also, when calculating the coefficients, the goal of reducing the bias both locally and globally, is achieved by thinning the data so that roughly equal numbers of observations for each air-mass type is used. This is analogous to choosing a uniform spread when performing a one-dimensional line-of-best-fit regression. This ensures that a clump of data does not dominate the regression and cause a bad fit to data from under-represented areas. A slightly smaller dataset was used in the limited March analysis.

	90S-60S	60S-30S	30S-30N	30N-60N	60N-90N	Global
Total	3935	50468	158164	20222	2073	234862
Thinned	3935	5873	5811	9157	2073	26849

Table 1. The AIRS dataset used for April 2003.

The data is passed through a set of routines adapted from ECMWF and Bureau of Meteorology software which has its own internal quality control.. The scan bias coefficients may be either computed separately or within the regression step for the air-mass coefficients. In both cases the results appeared identical. In all subsequent calculations, the scan bias coefficients were computed within the regression. It is possible to restrict the calculation to scan only, which gave another basis for comparison when attempting to find the best predictor combination.

4. Results

Firstly, something must be said about the numbering conventions used in this paper for AIRS channel numbers. The conventions are the index number 1-324 in the NESDIS dataset, the AIRS channel number 1-2378, and the wavenumber (cm^{-1}). The convention used will be, for example, 77(174)[699.668], where 77 is the index in 1-324, 174 is the index in 1-2378, and 699.668cm^{-1} is the wavenumber.

a) March results using small channel subset.

Initially only five channels were studied. These were chosen on the basis that they corresponded to channels which had weighting functions which reached to the lower troposphere or the surface. The idea was to investigate the skill of either the T_{Skin} or the Thick850 predictors.

Index	73	77	85	100	140
Channel	169	174	190	227	914
Wavenumber	698.276	699.668	704.162	714.782	965.842

Table 2. The initial five AIRS channels chosen from March 2003 data.

The bias correction scheme was run for various combinations of predictors ranging from scan only to the full set of (1235) predictors. After the coefficients have been calculated, the bias correction is applied back to the full unthinned dataset. For each of the channels, the global standard deviation for each of the predictor combinations is compared to the standard deviation of the uncorrected bias.

In a simple one dimensional linear regression, the variance of the corrected departures is reduced by a factor of $(1-r^2)$ where r is the correlation of the single predictor with the predictant. Similarly, in a multi-dimensional case, it can be shown that the combination of predictors which gives the greatest reduction in standard deviation has the most skill, and should apart from sampling issues, give the greatest reduction in bias. Figure 1 shows the reduction in standard deviation for the sample channels for various predictor combinations.

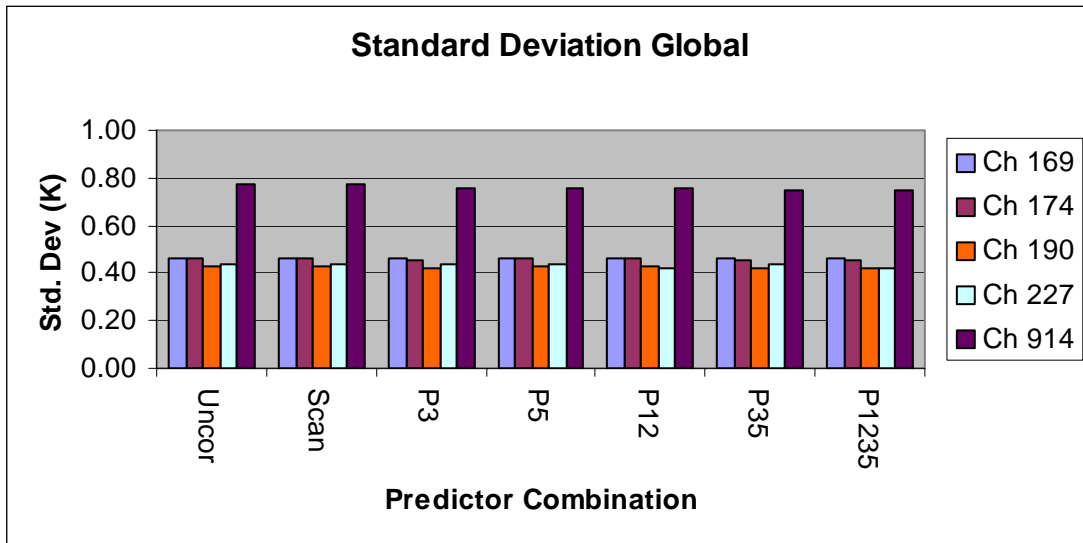


Fig 1 The global standard deviation for the initial five AIRS channels.

It can be seen that scan only has very little skill. More surprisingly, P12 also shows very little skill except for Ch 227. It is possible to compute the correlation between the temperature at various levels and the (O-B) departure. For any temperature level above 900hPa the correlation is very low. This could possibly be due to the skill of the RTTOV-7 forward model. For some channels there is more skill for different predictor combinations. For example, P3 has more skill than P5 for Ch 174. However, the combination P35 has more skill for Ch 914 than each predictor separately. In total, the combination P1235 does best, but the combination P35 appears to encompass most bias, except for Ch 227 where P12 does show some skill. However, this is only an example of global skill, and is skewed towards the tropics as the full unthinned dataset is used.

What is required is a method to determine the local skill of the predictor combination against the uncorrected bias. From the large dataset, the (un)corrected values of (O-B) are computed, and the results analysed using a Cressman analysis technique onto a 160 x 320 grid. The results are then plotted using IDL to produce a latitude-longitude plot of the biases. Using Ch 169, the mean bias was plotted for uncorrected bias, which includes a mean offset in Fig 2(a). The mean offset is absorbed into the scan bias in Fig 2(b). Figure 2(c) shows the reduction in bias if the P12 combination is used for this channel. Predictors P3 and P5 alone, are shown in Fig 2(d) and 2(e) respectively. Finally P35 is shown in Fig 2(f). The combination P1235 was not substantially different to P12 or P35.

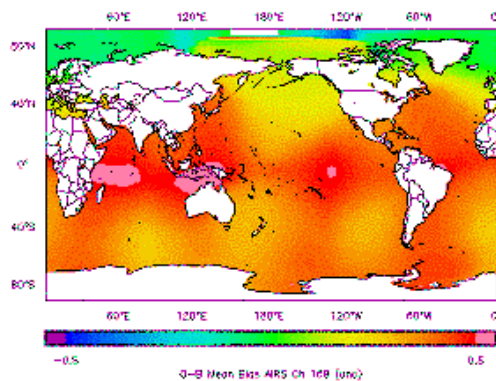


Fig 2(a) Uncorrected bias for Ch 169.

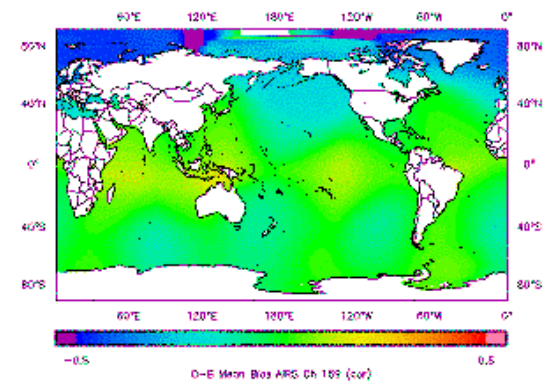


Fig 2(b) Scan bias only for Ch 169.

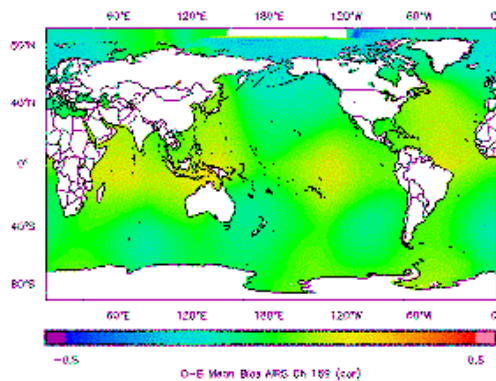


Fig 2(c) Predictors P12 for Ch 169.

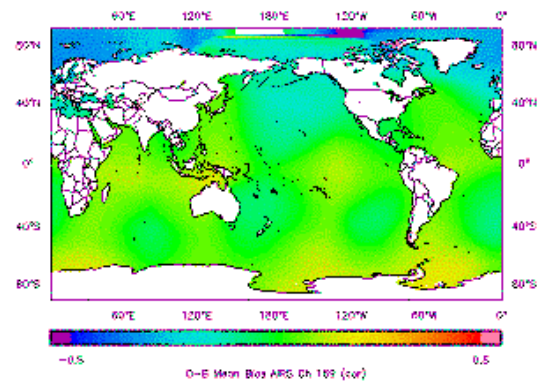


Fig 2(d) Predictor P3 for Ch 169.

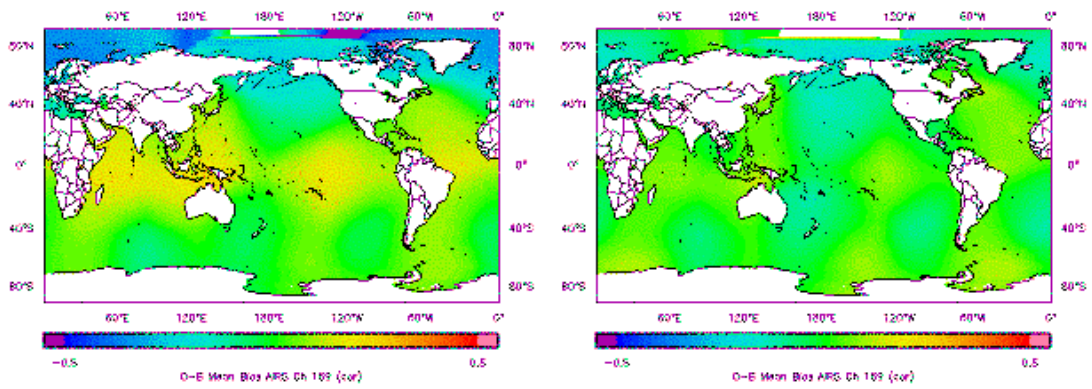


Fig 2(e) Predictor P5 for Ch 169.

Fig 2(f) Predictors P35 for Ch 169.

For these plots, it is clear that the scan bias alone is insufficient to produce a good reduction in bias over a wide area. It appears P12, P3 or P35 (and P1235) produce a good reduction, but P5 by itself is also insufficient.

A dataset from January/February 2003 was studied in much greater detail. The details of numbers of data from various latitude bands is shown in Table 3 below.

	90S-60S	60S-30S	30S-30N	30N-60N	60N-90N	Global
Total	4189	48994	133838	15940	624	203585
Thinned	4189	5951	5144	6867	624	22775

Table 3 The dataset used for Jan/Feb 2003.

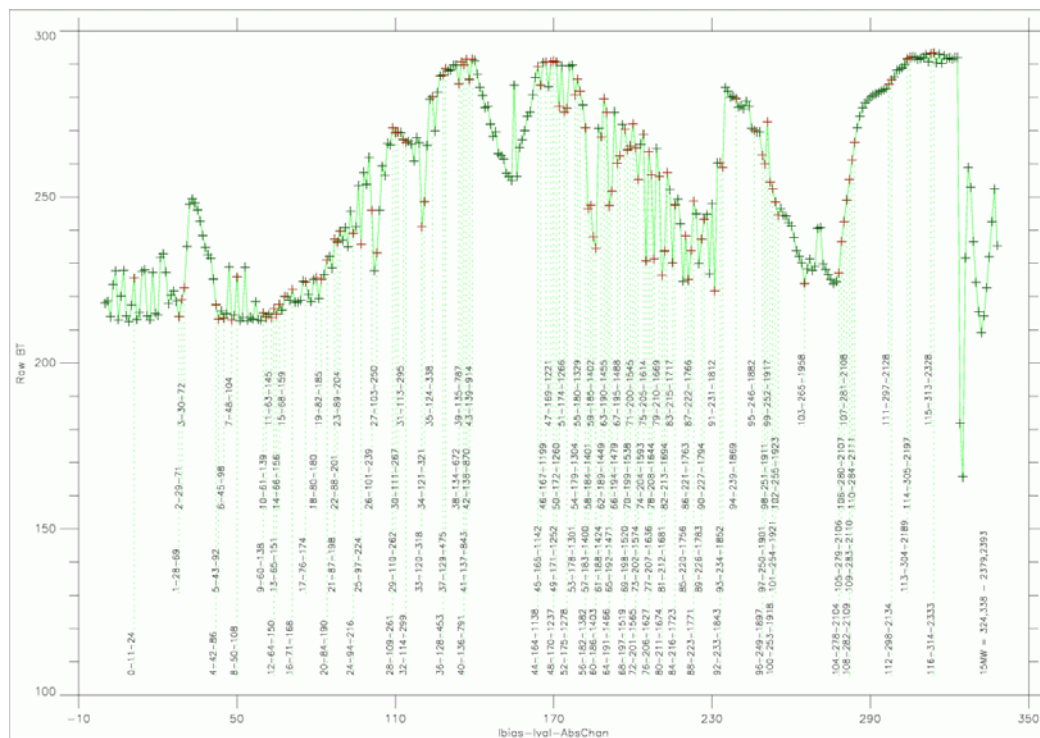


Figure 3 The subset of channels used in Jan/Feb 2003 study.

A much larger subset of channels was chosen for this study, the details of which are shown in Figure 3.

After the scan bias was applied to the above channels, various combinations of predictors were used, and a statistical technique was used to facilitate the viewing of the mean and standard deviation over latitude bands. The idea was to take an RMS mean of the bias and standard deviation of the unthinned dataset over each latitude band, and to plot the results against channel number.

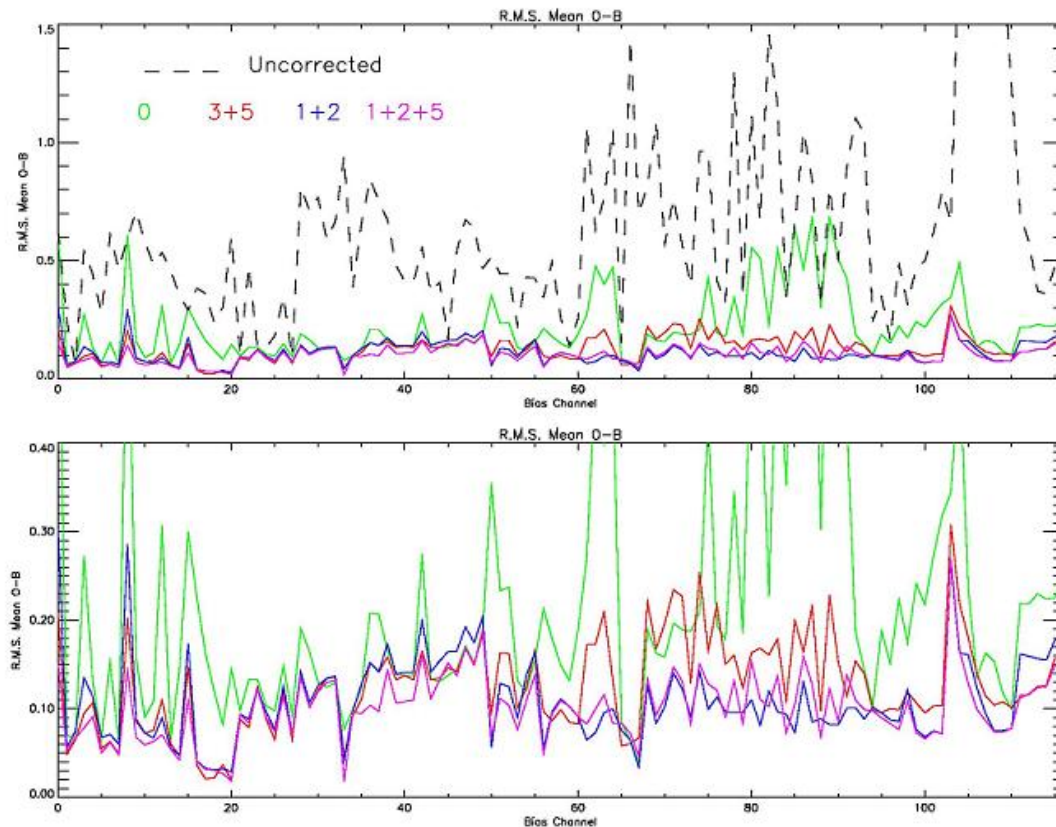


Fig 4 RMS bias by channel number (lower rescaled to exclude uncorrected mean).

Figure 4 shows the RMS bias for a much larger subset of channels. It shows some interesting features not seen in the smaller original subsets. Going to a much larger range of channels, appears to show that the predictor sets P12 and P125 produce the a much better overall reduction in bias then using scan only or using the P35 combination. Also, since the data is expected to be used over land, it is considered desirable to not use the possibly inaccurate skin temperature predictor. Experiments have been performed using the P12 and P125 combinations and can be found in Collard *et. al.* (2003).

5. Conclusions

Of all the combinations of bias predictors used, it is suggested that the combination of the two air-mass predictors (P12) would be the best and simplest combination, after a scan correction has been applied. Of course, many other considerations affect the results, such as the cloud clearing scheme and the interaction with sea-ice. With the datasets given, data assimilation trials are underway to see how

the AIRS data, with this type of bias correction, can impact on forecast performance. (see paper by Collard *et. al.* (2003) for more details in this proceedings).

6. References

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