The effect of variable O_3 and CO_2 on the bias of AIRS observations

James Cameron, Stephen English, Fiona Hilton, Ed Pavelin

Introduction

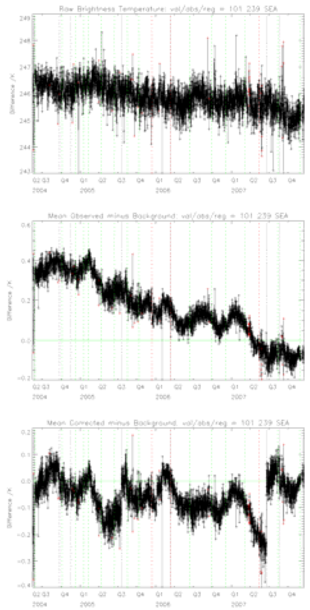
The bias of AIRS observations relative to observations simulated from the Met Office global model show shifts, seasonal variations and an on-going trend. Some of these changes are due to model upgrades, but others are due to variable gases and in particular O_3 and CO_2. The bias variations that are observed are presented and discussed.

Observed changes in the bias of AIRS observations

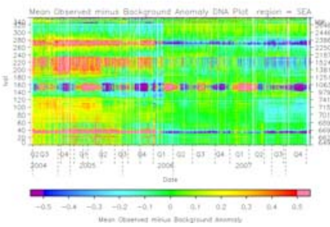
The bias of a number of AIRS channels used by the Met Office for operational data assimilation were observed to drift by as much as 0.2K from the beginning of April to the middle of June 2007. The scale and rapidity of this change lead to a review of the bias of AIRS observations with respect to observations modelled from the Met Office's 6 hour forecast field (the background).

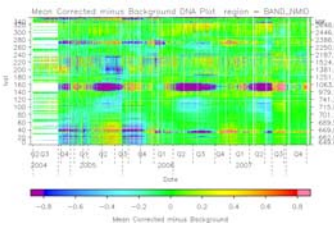
The plots to the right show the average raw, observed minus background (O-B) and bias corrected minus background (C-B) brightness temperatures for AIRS channel 239, which peaks at about 520 hPa. The average is calculated over all cloud-free observations over the sea for each 6 hour data assimilation time window. The red and green vertical dashes indicate parallel suite changes. Parallel suites 9, 10 and 15 (PS9, PS10, PS15) are shown in red. Before PS9 the AIRS central field of view data set was used along with a 38 level model (AIRS/38-level). After PS10, the AIRS warmest field of view data set was used with a 50 level model (AIRSWF/50-level). No AIRS data was assimilated between PS9 and PS10. PS15 is highlighted as there was a particularly large change in the AIRS biases with the introduction of this parallel suite. The black horizontal dashes indicate updates to the bias correction that was applied.

A downward trend is visible in both the raw and observed minus background plots. The bias correction is repeatedly correcting this trend. The rapid change in spring 2007 is visible.



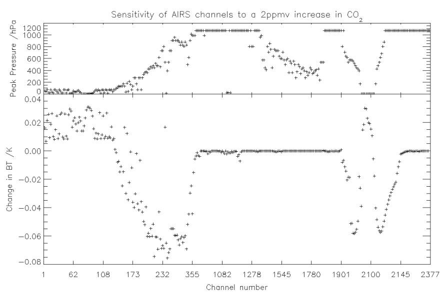
The left-hand plot below shows the O-B variations for all AIRS channels, with the mean O-B for each channel subtracted. The right-hand plot shows the C-B variations for observations between 20 and 70 degrees North. The y-axis is an index to the 324 AIRS channels received by the Met Office followed by the 15 AMSU-A channels. Numerous features are visible in these plots. Starting from the lowest channel indices, it can be seen that the move from a 38 to a 50 level model considerably improved the bias of the highest peaking channels. The sudden change in bias of some of the high peaking sounding channels associated with the introduction of PS15 is visible. Channels with indices in the range 141-163 are in the 9.6 micron ozone band. A climatological total column ozone is used in the forward model. Most of the channels in the range 90-126 are weakly sensitive to ozone and it can be seen that their bias follows that of the main ozone band.





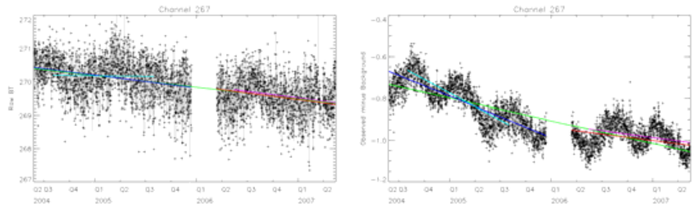
Sensitivity of AIRS to CO_2

This plot shows the change in the brightness temperature of AIRS channels associated with a 2ppmv increase in CO_2 (a reasonable figure for the annual increase in CO_2). The brightness temperatures were simulated using RTTOV9 for a standard tropical profile viewed at 20° off nadir. For the most strongly affected channels, the change is a decrease of about 0.07K.

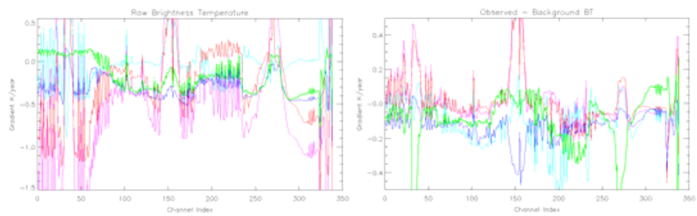


Straight line fits to the bias trends

Linear least-squares fits were applied to the raw and observed minus background brightness temperatures. The green line shows the fit to all data, the blue line the fit to all AIRS/38-level data, the red line the fit to all AIRSWF/50-level data, the cyan line from 1 Aug 2004 to 1 Aug 2005, and the magenta line from 15 May 2006 to 15 May 2007. The rationale for fitting the AIRS/38-level and AIRSWF/50-level separately is that there is a discontinuity between the two time periods for high-peaking and surface channels. A straight line is a particularly bad model for the variations of O-B for the ozone and water vapour channels!

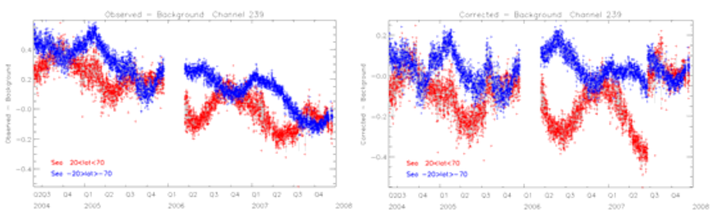


The plots below show the fitted gradients in Kelvin per year for all channels. The gradient of O-B for long-wave CO_2 sounding channels is about 0.1K/year as seen from the green line (all data) in the O-B plot, ignoring high-peaking channels and channels near the surface. The gradient of O-B for sounding channels appears to be less for AIRSWF/50-level than for AIRS/38-level, but this is probably just a result of the time-series being too short to get an accurate fit. The trend in water vapour seems to be quite negative although the effects of data selection and model changes make the result subject to some doubt. There is wild disagreement in the gradient of raw brightness temperature for different time periods for almost all the channels. The size of the gradient of the green line in raw brightness temperature can be alarmingly high, especially for the temperature sounding channels where it is in the region of 0.35 K/year! This is probably just a consequence of the large uncertainty in the fit and the large variation of the gradient depending on the time period chosen gives some evidence for this.

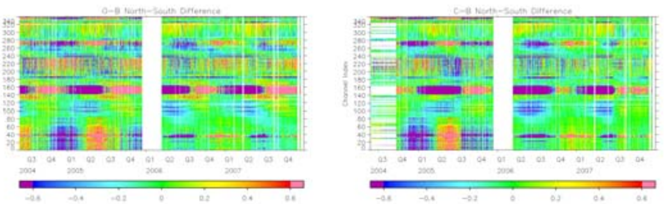


Difference between Northern and Southern Hemispheres

As well as having a seasonal cycle and an annual trend, CO_2 is thought to have significant spatial variations, including a difference between the Northern and Southern Hemispheres. The plots below show the behaviour of observed minus background and corrected minus background for the latitude bands 20-70º North and 20-70º South.



Differencing the two latitude bands for all channels results in the plots below. The most striking feature in the long-wave CO_2 temperature sounding channels is the variation due to ozone.



Conclusions

The bias of AIRS observations with respect to the Met Office global model shows an annual trend that is broadly consistent with the annual increase in CO_2. CO_2 is known to have a seasonal cycle and spatial variations that will also give rise to biases. However, the most prominent feature in the bias of long-wave CO_2 sounding channels appears to be due to poorly modelled ozone. Improving the treatment of ozone should therefore take precedence over attempting to model the variations in CO_2.

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: 01392 885680 Fax: 01392 885681
Email: james.cameron@metoffice.gov.uk