Met Office

The residual bias of AIRS observations after bias correction.

Technical Report No. 547

26th July 2010

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Abstract

The residual bias of AIRS observations after bias correction has been studied for cloud-free AIRS data over the sea, spanning the period 1 September 2007 to 15 July 2008. Uncorrected biases have been identified arising from undetected cloud and the use of an inaccurate climatological ozone. There is also a bias affecting the highest peaking channels near the poles and an unidentified bias affecting short-wavelength channels near land masses.

The bias affecting the highest peaking channels may have already been reduced by the raising of the model top. It may be further reduced in the future through the use of RTTOV coefficients with more levels. The biases arising from undetected cloud may have been addressed, at least to some extent, through the introduction of cloudy radiance assimilation. The most serious outstanding issue is likely to be the biases due to the inaccurate climatological ozone. Eliminating this bias should improve the accuracy of the analysis and could potentially allow the use of lower observation errors. It is recommended that an effective total column ozone be retrieved in the OPS and used as a fixed parameter in VAR. After a period of time in operations or running parallel to operations the scale of the remaining systematic errors should be reassessed.

Date	Version	Action/comment
05/07/2010	0.1	First version.
08/07/2010	0.2	Amended following comments from Brett Candy.
22/07/2010	0.3	Minor editing after attending the report writing course.
26/07/2010	1.0	Approved by John Eyre with minor corrections.

1 Introduction

Data assimilation systems are usually designed to assimilate unbiased data. Since there is often a systematic bias between satellite radiances and observations simulated from the forecast background, a bias correction scheme is normally employed. At the Met Office, the bias correction scheme is based on the method of Harris and Kelly [3]. There is a constant global scan bias for each channel and the 850-300 hPa thickness and 200-50 hPa thickness are used as air-mass predictors.

The residual bias after bias correction has been studied in order to assess how well the bias correction is performing and to try to identify areas where systematic errors might be reduced. Lower systematic errors may enable the use of lower observation errors, leading to a more complete use of the information provided by high spectral resolution infrared sounders.

2 Assessment of the residual bias

To assess the scale of the residual bias after bias correction, bias-corrected AIRS innovations were averaged on a geographical grid for each month spanning the period 1 September 2007 until 15 July 2008. During this time period, only cloud-free observations were being assimilated, and so only cloud-free data over the sea were included in the average innovation calculations. The cloud detection scheme is based on the method of English et al. [1][2]. The monthly averages were computed from the 16th of one month to the 15th of the next since the coefficients used to calculate the climatological ozone change on the 16th of each month. The size of the grid boxes used for averaging were 15 degrees in longitude and 10 degrees in latitude. Data from short-wavelength channels were only included in the average for observations made at night. The resulting residual bias maps for 9 AIRS channels are shown in figures 1–9. Grid box averages containing fewer than 500 entries are not shown and were not used in subsequent calculations.

Figure 1 shows the residual bias of the highest peaking, long wavelength AIRS channel in the 324 channel set. This channel has large uncorrected biases near the poles. Figure 2 shows the residual bias of AIRS channel 201, a long-wavelength temperature sounding channel peaking at around 400 hPa. This channel has very little sensitivity to ozone. The most prominent residual bias is around Southeast Asia, which is almost certainly due to undetected cloud. The channel most sensitive to ozone in the long-wavelength temperature sounding band is channel 257, shown in figure 3. The biases in this channel should be compared with those in channel 1092, see figure 5. Channel 1092 is the channel most strongly sensitive to ozone in the 324 channel set. There is a very clear correlation between the residual biases of these two channels. Channel 257 is not used for temperature sounding because of the large ozone-related bias. The most ozone sensitive channel that is used in the current channel selection is channel 305, see figure 4. Although the bias is not as large as in channel 257 it is still very significant. The strong correlation of the bias with channel 1092 is clear, although there is also some evidence of cloud contamination that correlates with the bias in channel 201. Figures 6 and 7 show the residual bias for mid-tropospheric and high-peaking water vapour channels respectively. The high peaking channel shows evidence of an uncorrected bias in the tropics. The residual bias for channel 1917, a short-wavelength temperature sounding channel, is shown in figure 8. This channel again shows some evidence of cloud contamination, particularly around Southeast Asia. Figure 9 shows the residual bias for channel 2128. As well as the bias due to undetected cloud there also appears to be a warm bias close to land masses. The cause of this warm bias is not known.

It has been seen that many of the channels share bias characteristics. Figure 10 shows the covariance and correlation of the residual biases. These correlations were calculated by looping over all grid points and every monthly average. There are clear, strong covariances between the very high peaking channels around channel index 34. The correlation of the bias appears to be more uniform amongst these high peaking channels, even where the covariance is relatively low. The characteristic pattern of ozone sensitivity is quite clear in the covariance of channels around channel index 110. Figure 12 shows the distinctive pattern of ozone sensitivity in red. As with the high peaking channels, the correlation seems more uniform and widespread. Some of the covariance and correlation will arise from matching cloud contamination. The strongly ozone sensitive channels around channel index 155 form a large block of correlation, as do the water vapour channels around index 220. The correlations around channel index 250 probably arise mostly from cloud contamination. Next comes a block of correlation from channels that violate the assumption of local thermodynamic equilibrium, around channel index 270. The channels around channel index 300 also form a large block of covariance and correlation. The anomalous warm bias surrounding land masses will be contributing to the correlation between these channels. Selecting 161 of the better modelled channels gives the covariance and correlation matrix shown in figure 11. Many of the large covariances have been avoided, although there are still very significant blocks of correlation.

Figure 13 shows the R.M.S. of the residual biases for the AIRS 324 channel set and 15 AMSU-A channels. The AMSU-A channels are shown with channel indices 325–339. The 161 channels used in figure 11 are marked with crosses and the 9 channels shown in figures 1–9 are highlighted by dashed magenta lines and squares. The influence of ozone bias is clearly visible in figure 13 in the channel index range 90–120. Compare this pattern with the red line in figure 12.

3 Discussion

Where biases arise from forward modelling errors such as unmodelled cloud or inaccurate climatological ozone, they will reduce the accuracy of the analysis. Biases may also arise from systematic errors in the forecast background. In this case, assimilating observations may help improve the analysis, but will not necessarily help the forecast. If the forecast model is unable to sustain the new, more realistic structure, it may quickly relax back to a more stable running configuration. Systematic errors will have a particularly large effect on the analysis when similar biases occur in multiple channels whose errors are assumed to be independent.

The best solution to the problem of systematic errors is to remove them at source, either by fixing the forecast model or forward model. In the case of the biases seen in the highest peaking channels, such as in figure 1, it is possible that the raising of the model top has already reduced or eliminated this effect. The bias might be further reduced in the future by using RTTOV coefficients with more levels. The correlations caused by undetected cloud may have already been addressed through the assimilation of cloud-affected radiances [4]. Perhaps the most serious outstanding systematic error is that arising from the inaccurate climatological ozone. It affects the long-wavelength temperature sounding channels and impacts enough channels to make it difficult to avoid. As has been shown in figures 3 to 5 the pattern of bias in the sounding channels is similar to those in the main ozone band. It is therefore reasonable to suppose that if an effective total column ozone were fitted using channels in the strong ozone band it would significantly reduce the bias of channels in the temperature sounding band. In the longer term it is possible that ozone may become a prognostic variable, which should greatly reduce the systematic error for ozone sensitive channels.

The analysis here was done using cloud-free observations over the sea from the ASCII files produced by the old AIRS OPS code. It should be possible to repeat this analysis using SatRad Mstat files as these already record the average bias-corrected innovations on a geographical grid similar to those in figures 1–9. The only slight disadvantage of data processed by SatRad is that only channels that are used in the 1D-Var have bias corrections. Despite this minor difference, it would be interesting to repeat this analysis using data from SatRad after fitting cloud parameters and adjusting the total column ozone to see how far the systematic errors are reduced.

4 Conclusions and recommendations

A simple method for studying the residual systematic error after bias correction has been applied to AIRS observations. Biases have been observed arising from undetected cloud and inaccurate climatological ozone. There is also a bias affecting high peaking channels near the poles and short-wavelength channels near land masses. The bias of the very highest peaking channels may have already been reduced by the raising of the model top and may be further reduced in the future by the introduction of RTTOV coefficients with more levels. The biases arising from cloud may have been addressed, at least to some extent, through the introduction of cloudy radiance assimilation. The outstanding, unaddressed source of bias that may be having a negative effect on temperature sounding is from the use of inaccurate climatological ozone. As it may still be some time before ozone becomes a prognostic variable, it is recommended that an effective total column ozone be retrieved in the OPS. This should substantially reduce the bias of ozone sensitive channels in the long wavelength temperature sounding band. After a period of time in operations, or running in parallel to operations, the scale of any remaining systematic error in the channels used could be reassessed using data from SatRad Mstat files.

References

[1] Collard, A. Assimilation of AIRS Observations at the Met Office. ECMWF Workshop on Assimilation of high spectral resolution sounders in NWP, 2004.

[2] English, S., Eyre, J., and Smith, J. A cloud-detection scheme for use with satellite sounding radiances in the context of data assimilation for numerical weather prediction. *Q. J. R. Meteorol. Soc.*, 125:2359–2378, 1999.

[3] Harris, B. and Kelly, G. A satellite radiance bias correction scheme for data assimilation. *Q. J. R. Meteorol. Soc.*, 127:1453–1468, 2001.

[4] Pavelin, E., English, S., and Eyre, J. The assimilation of cloud-affected infrared satellite radiances for numerical weather prediction. *Q. J. R. Meteorol. Soc.*, 134:737–749, 2008.

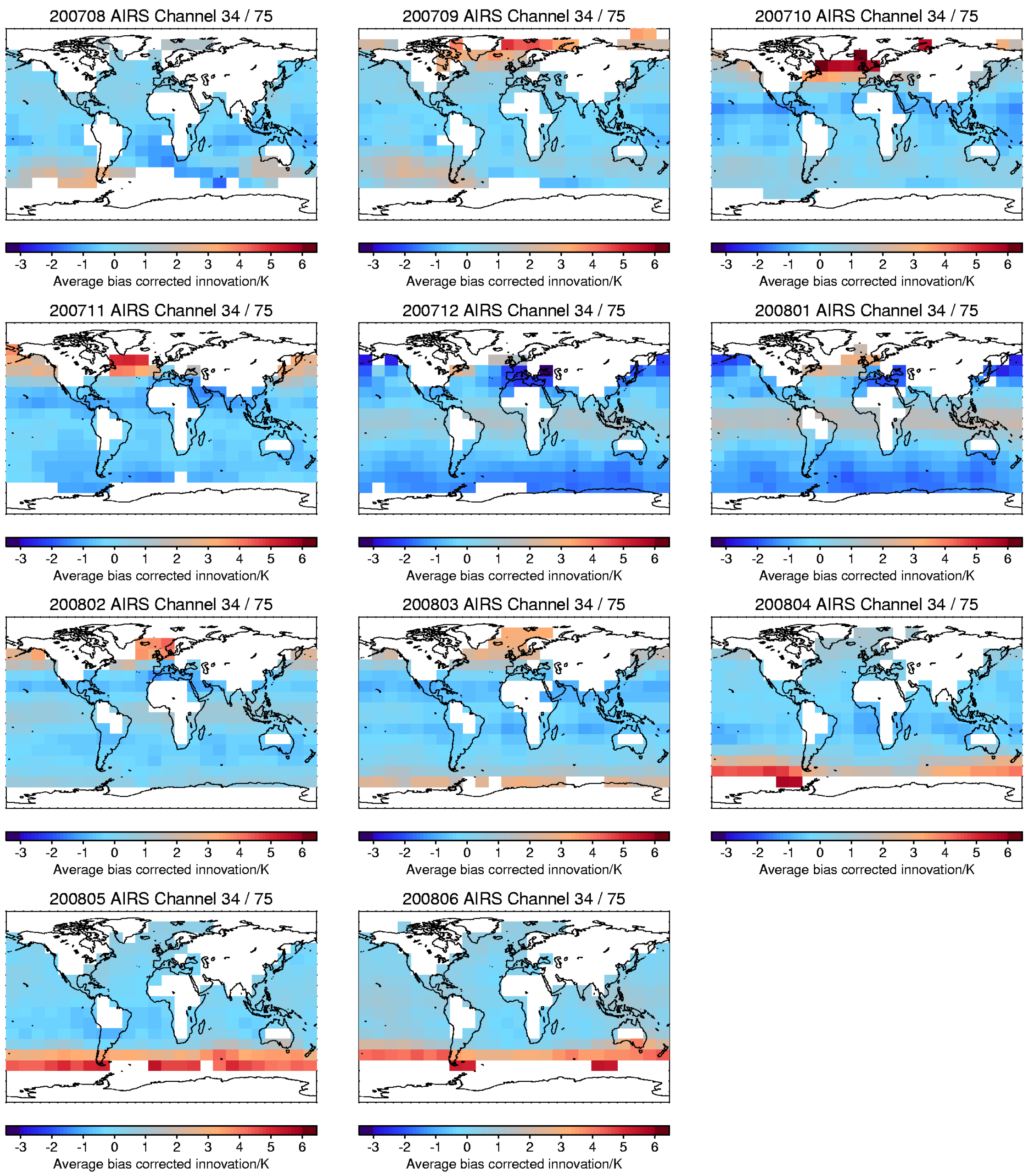

Figure 1: Maps of average bias corrected innovation for AIRS channel 75. This is a very high peaking channel in the CO_2 Q-branch.

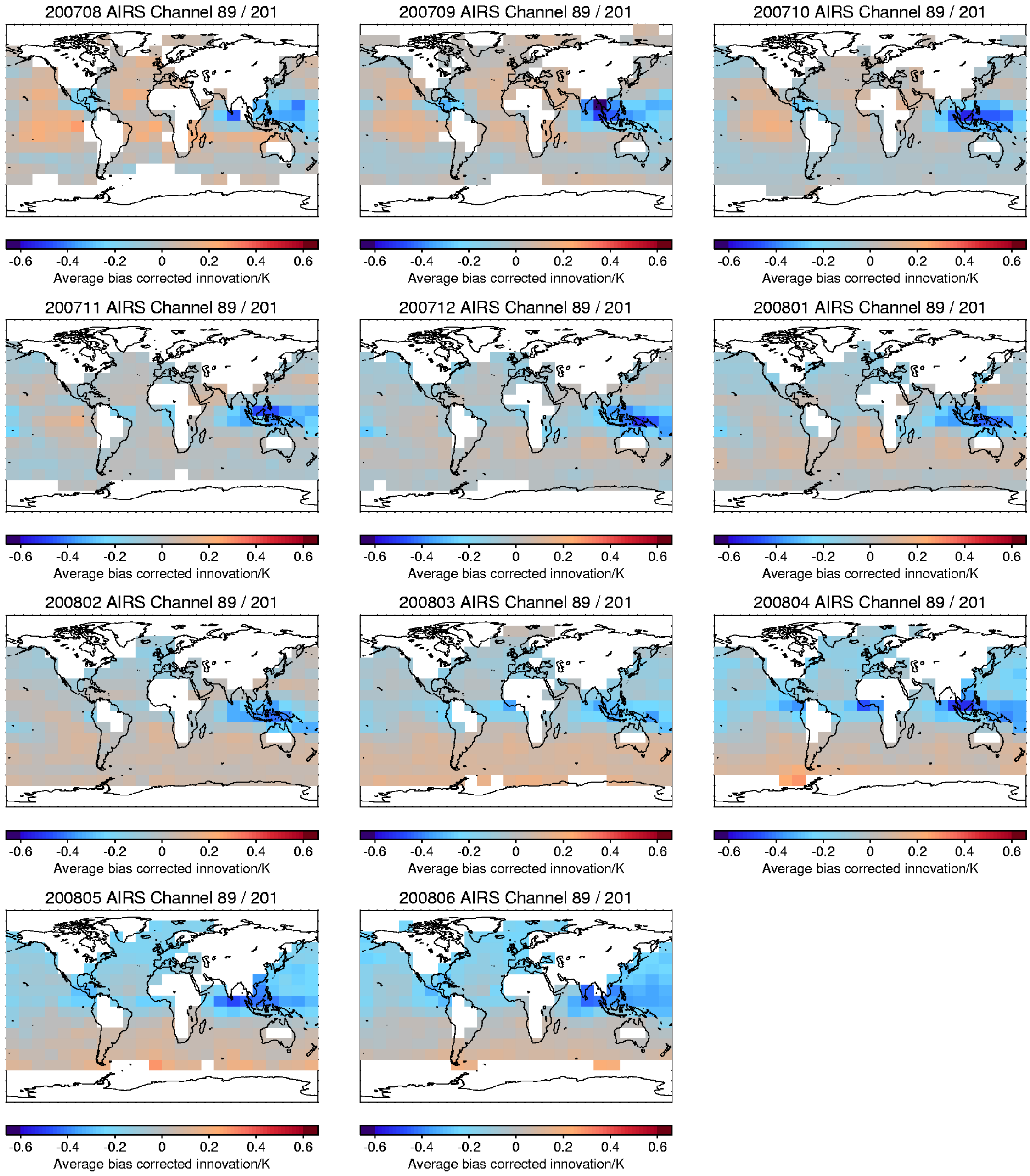

Figure 2: Maps of average bias corrected innovation for AIRS channel 201. This is a temperature sounding channel peaking around 400 hPa.

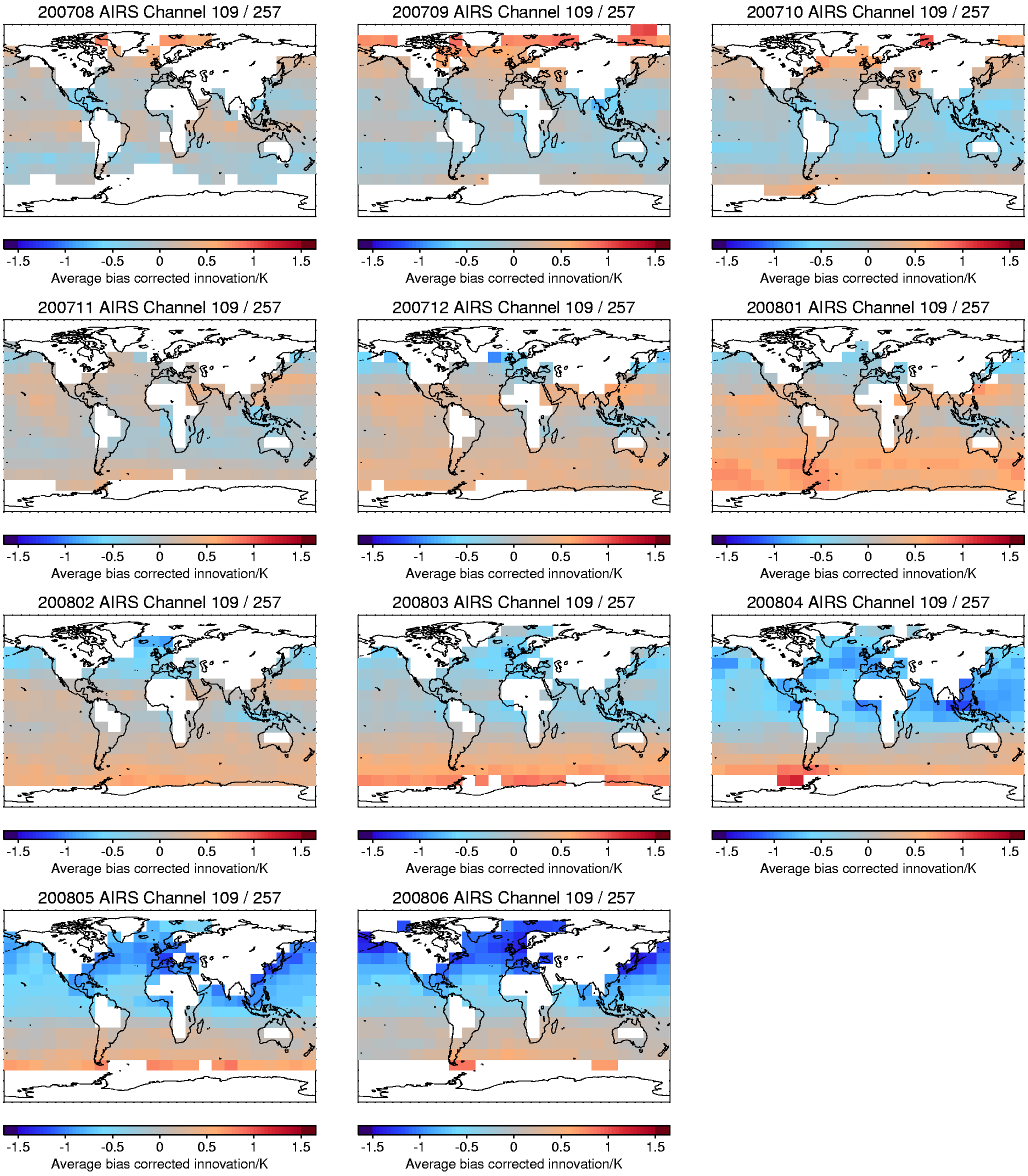

Figure 3: Maps of average bias corrected innovation for AIRS channel 257. This is a temperature sounding channel peaking around 800 hPa and modestly sensitive to ozone.

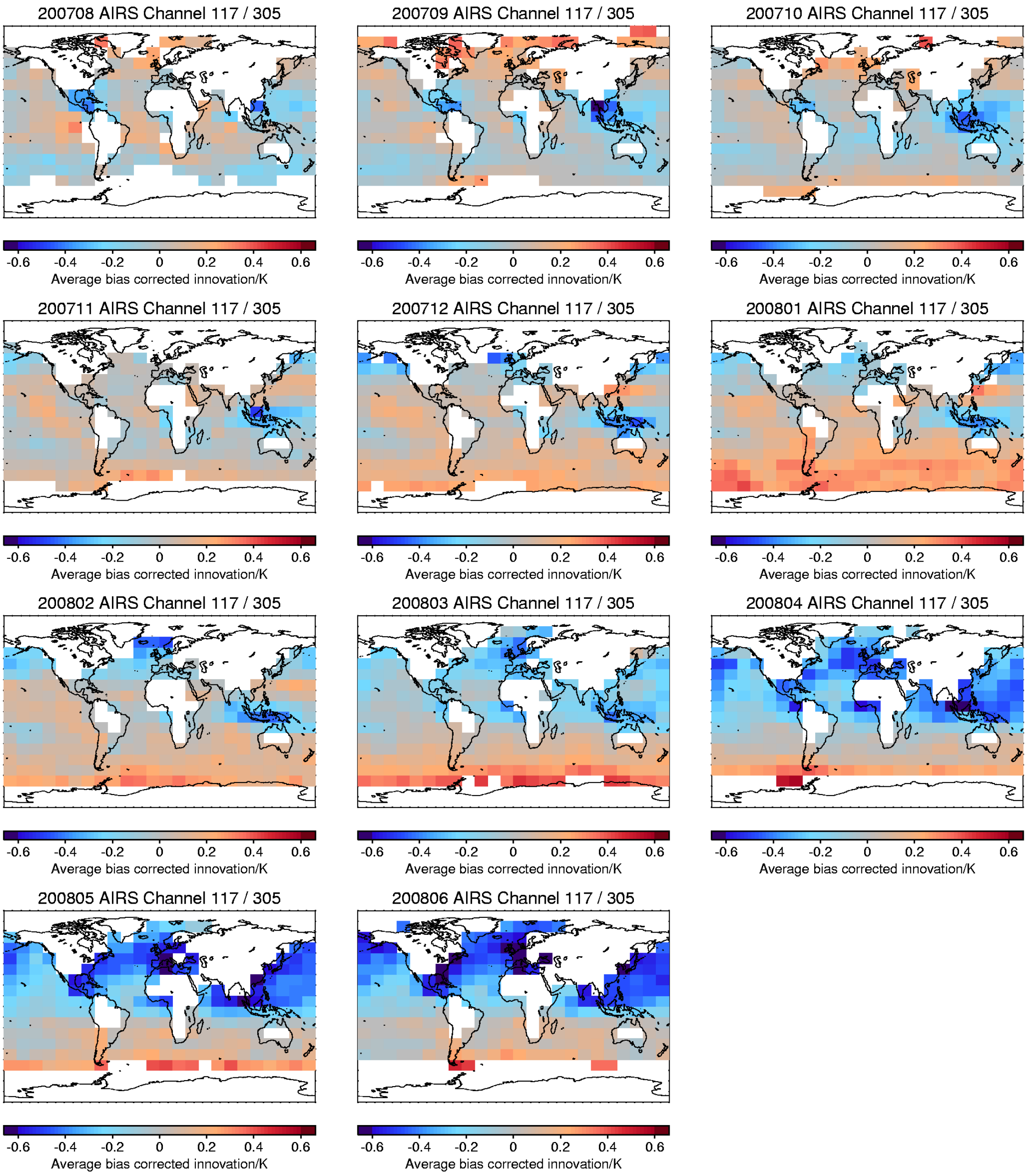

Figure 4: Maps of average bias corrected innovation for AIRS channel 305. This is a temperature sounding channel peaking around 800 hPa. This is the most ozone sensitive channel used in the current channel selection.

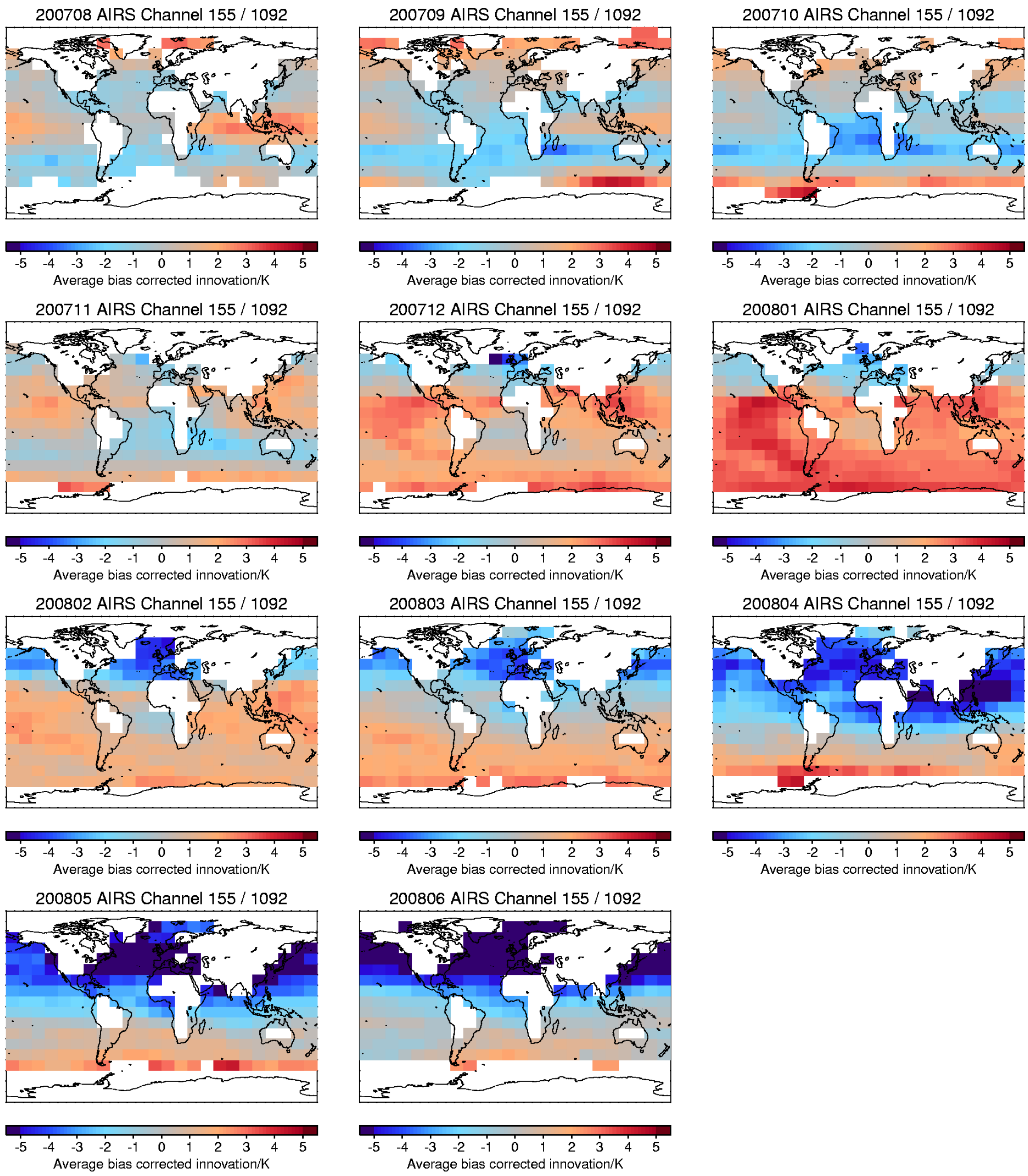

Figure 5: Maps of average bias corrected innovation for AIRS channel 1092. This is the most ozone sensitive channel in the 324 channel set.

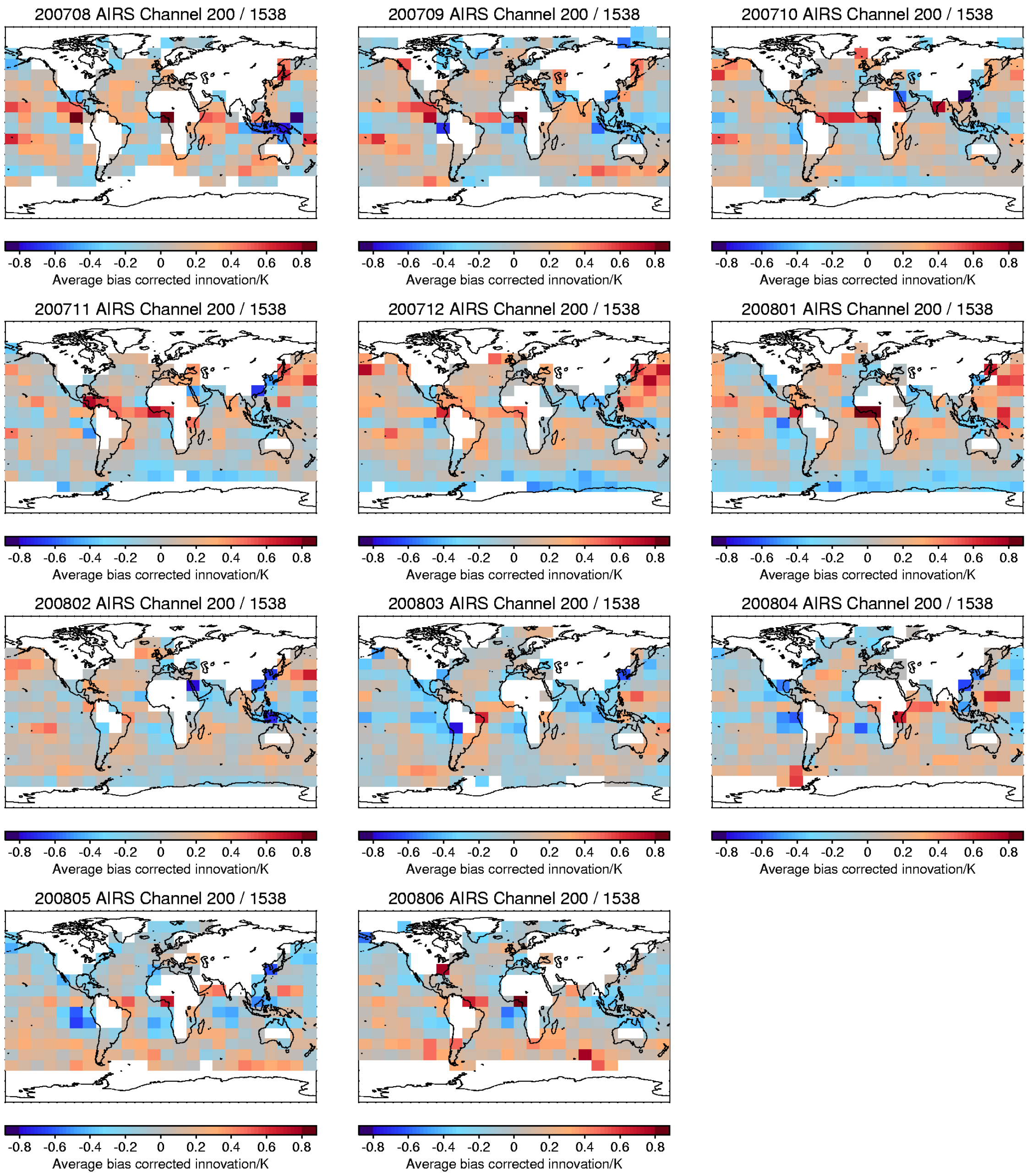

Figure 6: Maps of average bias corrected innovation for AIRS channel 1538. This is a mid-tropospheric water vapour channel.

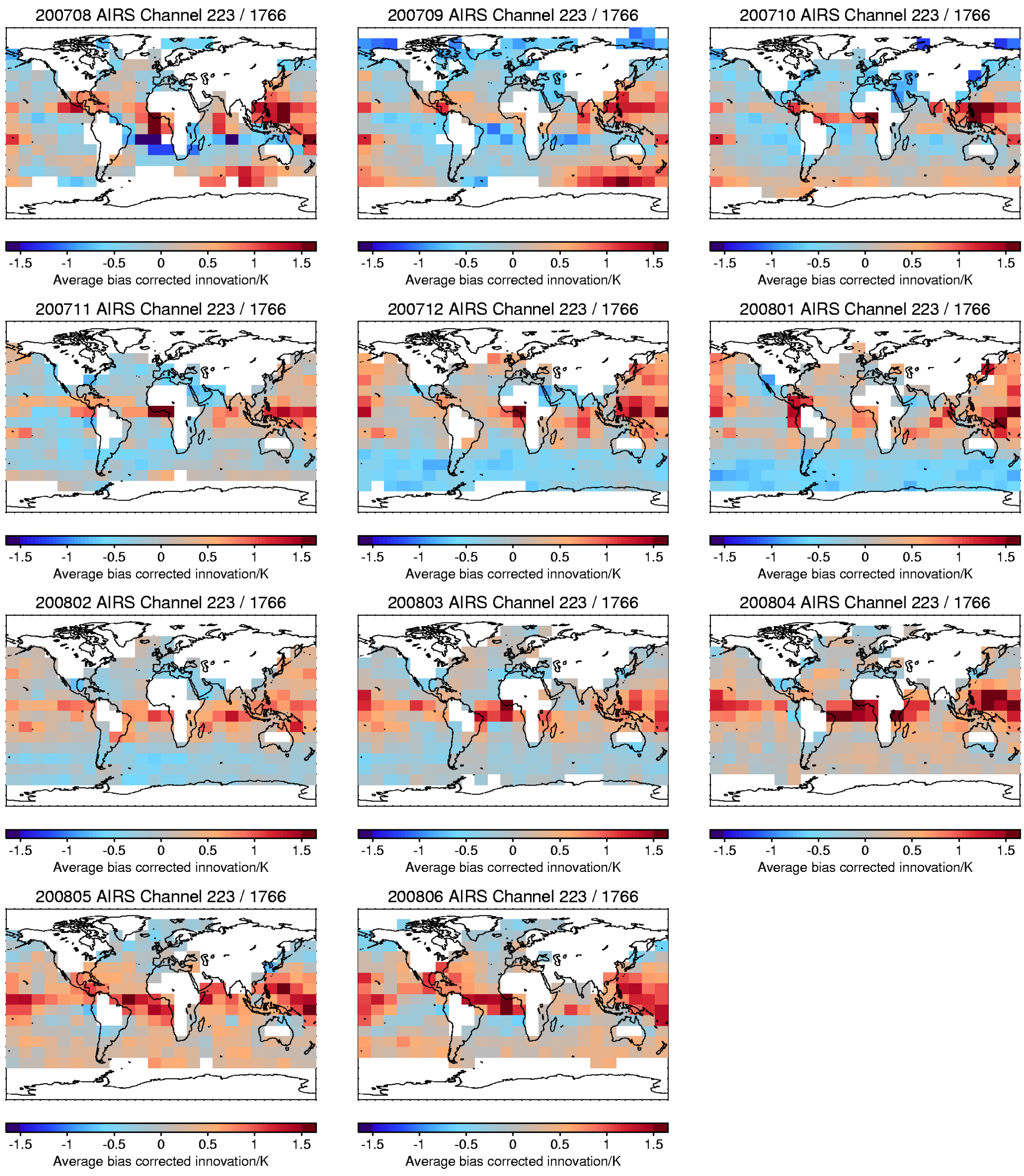

Figure 7: Maps of average bias corrected innovation for AIRS channel 1766. This is a high-peaking water vapour channel.

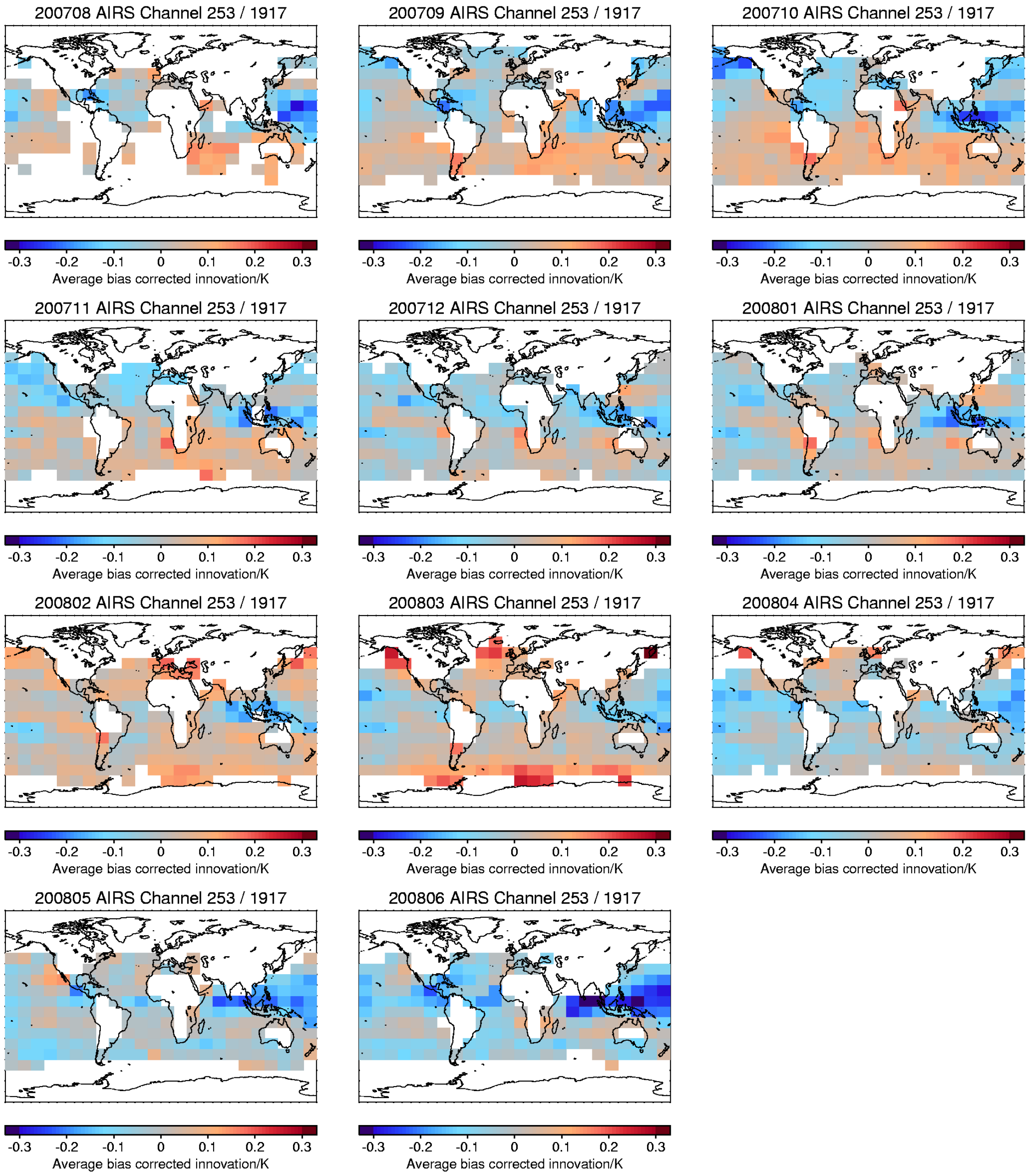

Figure 8: Maps of average bias corrected innovation for AIRS channel 1917. This is a short-wavelength CO_2 channel peaking around 700 hPa.

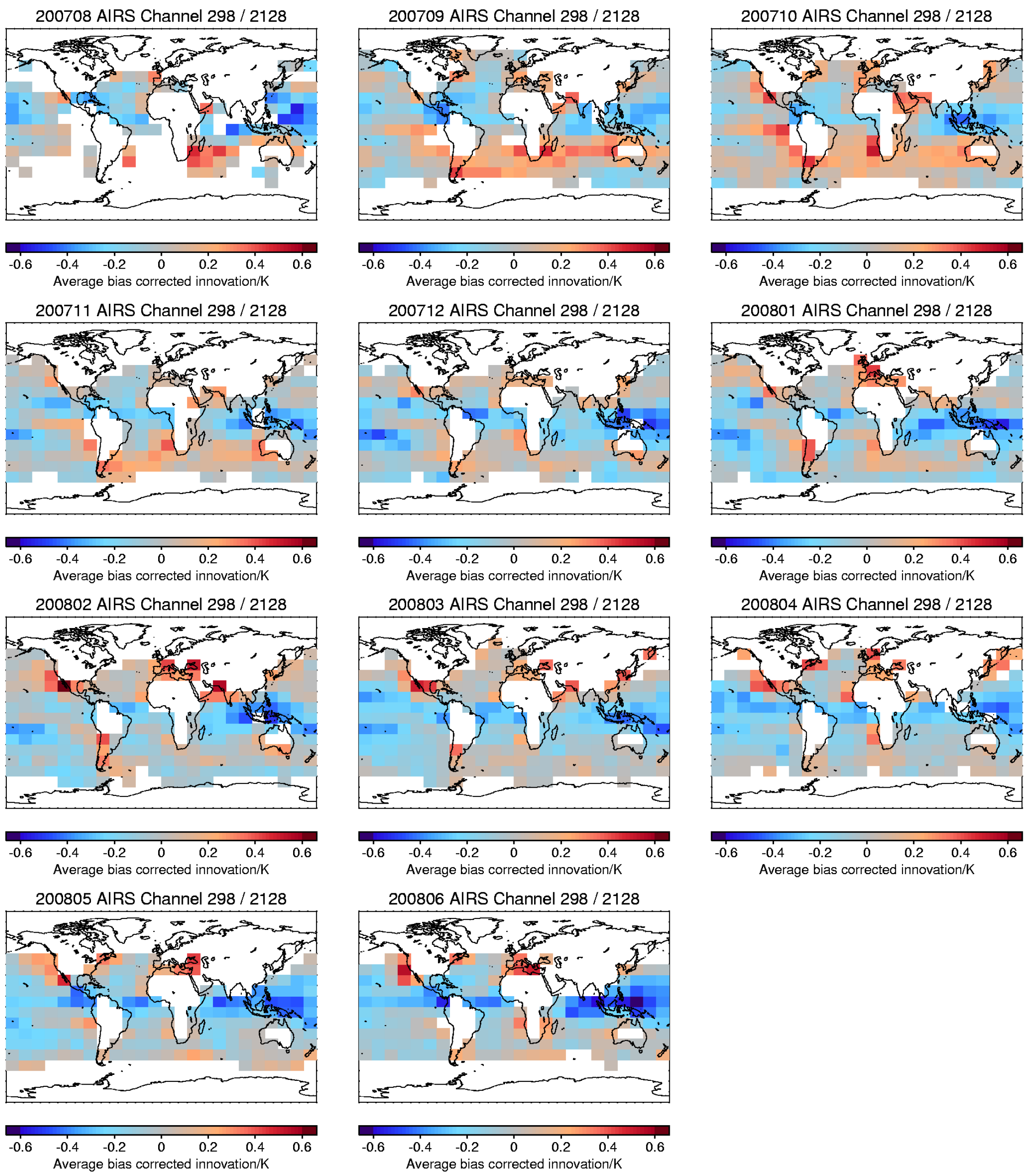

Figure 9: Maps of average bias corrected innovation for AIRS channel 2128. This is a short-wavelength CO_2 channel peaking around 900 hPa.

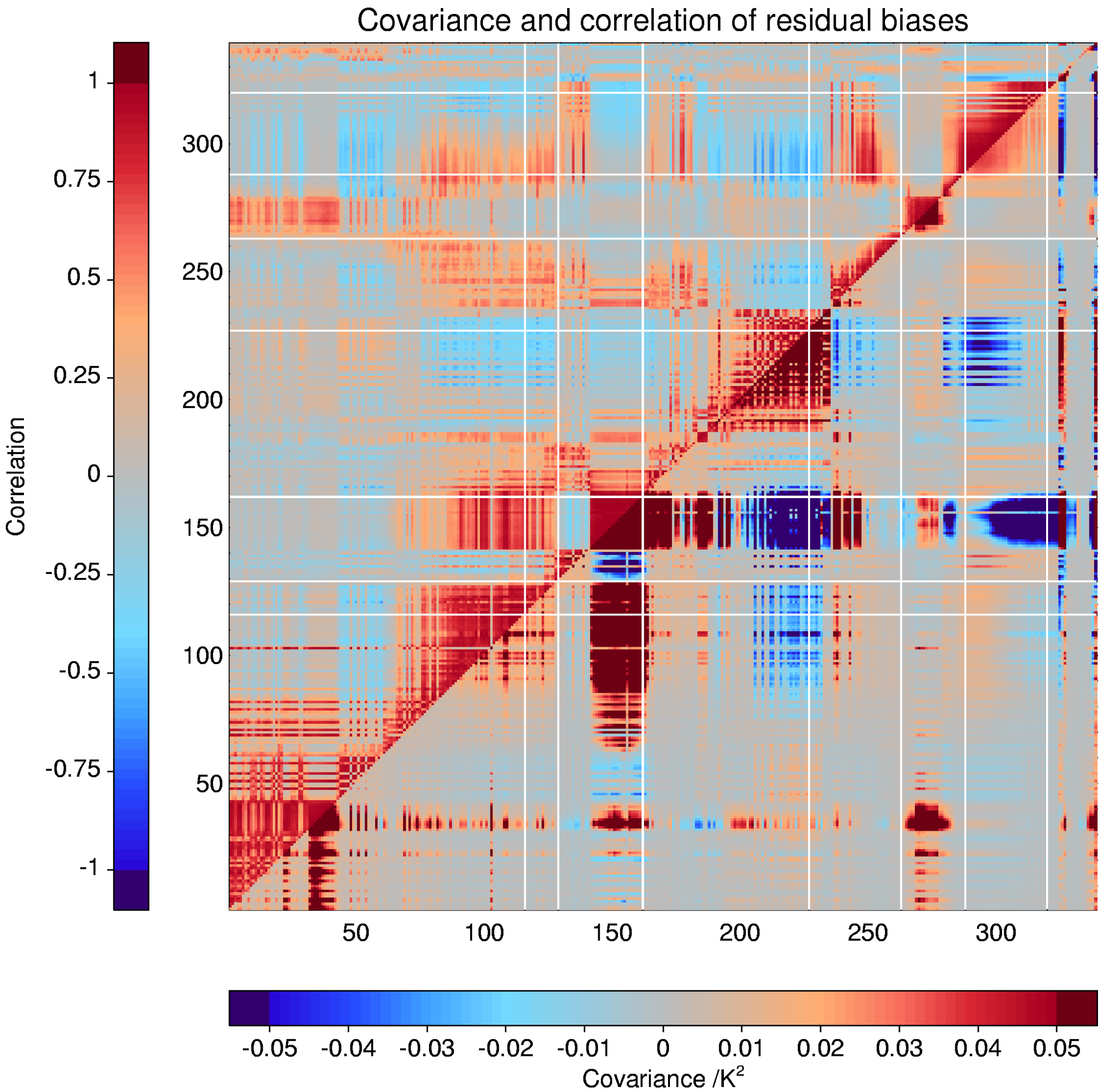

Figure 10: The covariance and correlation of average bias corrected innovation for all channels in the 324 channel set. The 15 AMSU-A channels are shown in the positions 325–339.

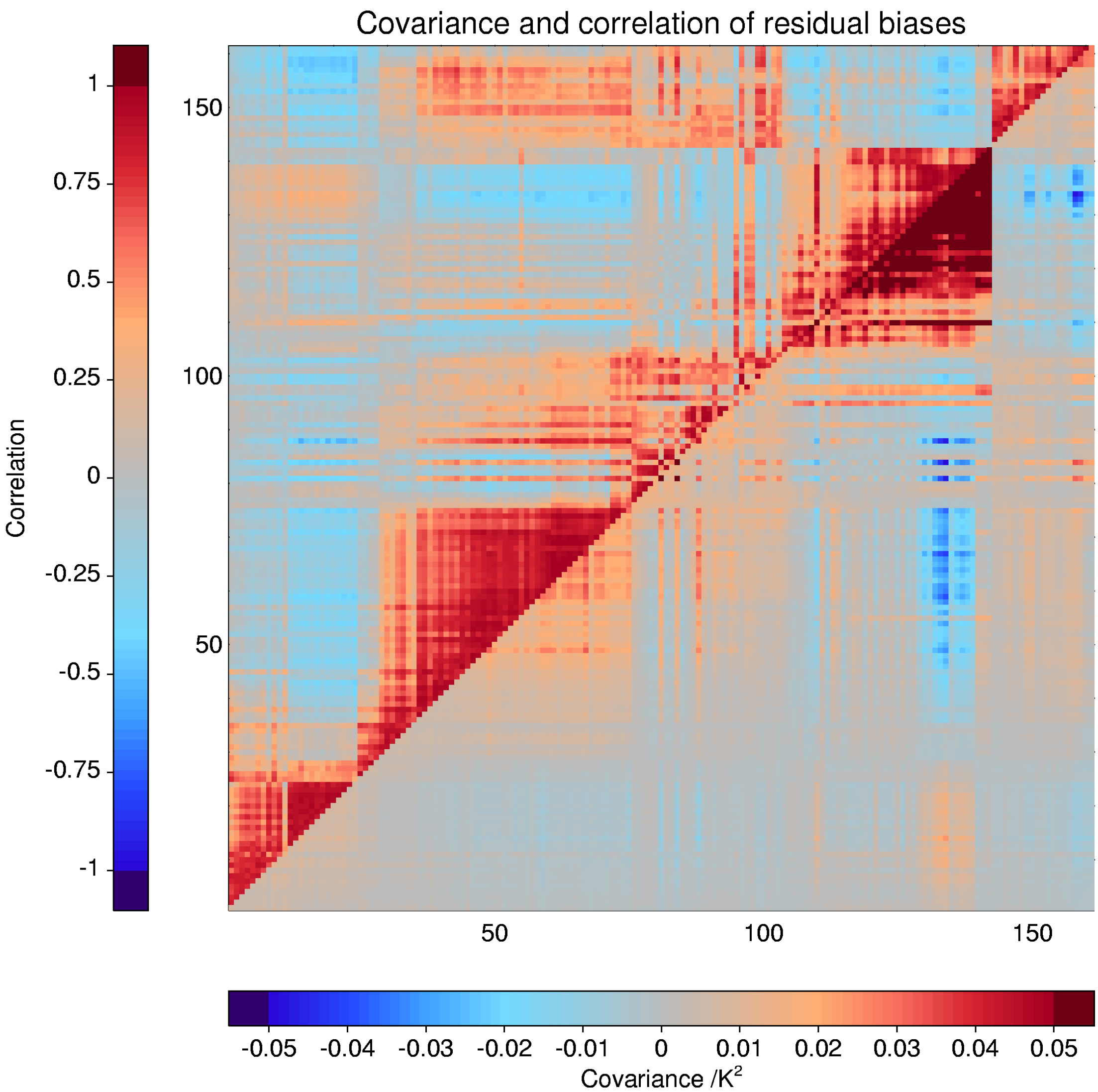

Figure 11: The covariance and correlation of average bias corrected innovation for a subset of 161 well modelled channels.

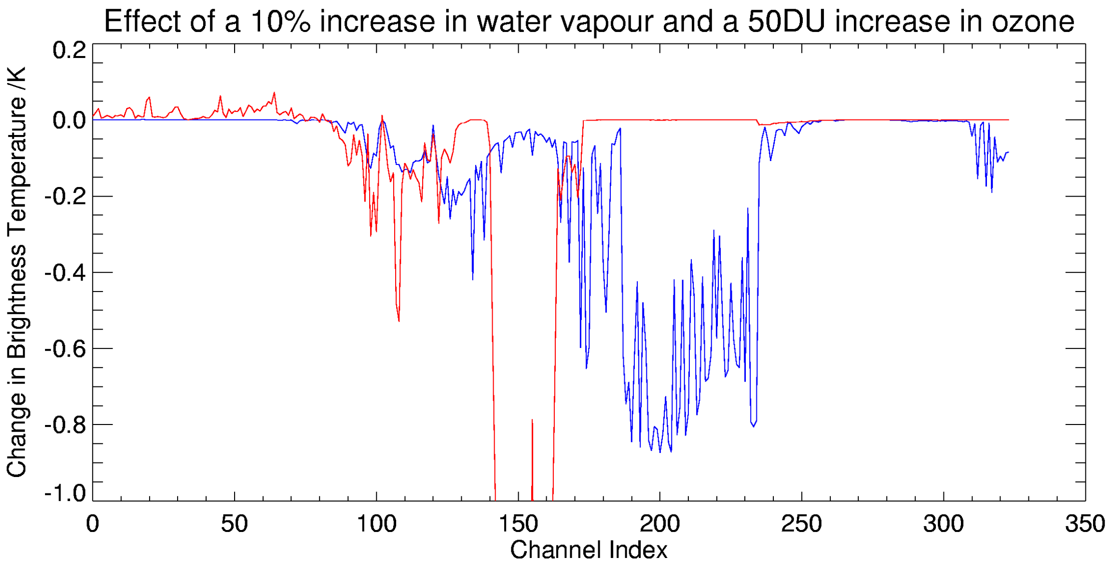

Figure 12: The change in brightness temperature from a 10% increase in water vapour (blue) and a 50 DU increase in ozone (red), as simulated using RTTOV and the A.F.G.L. U.S. standard atmosphere.

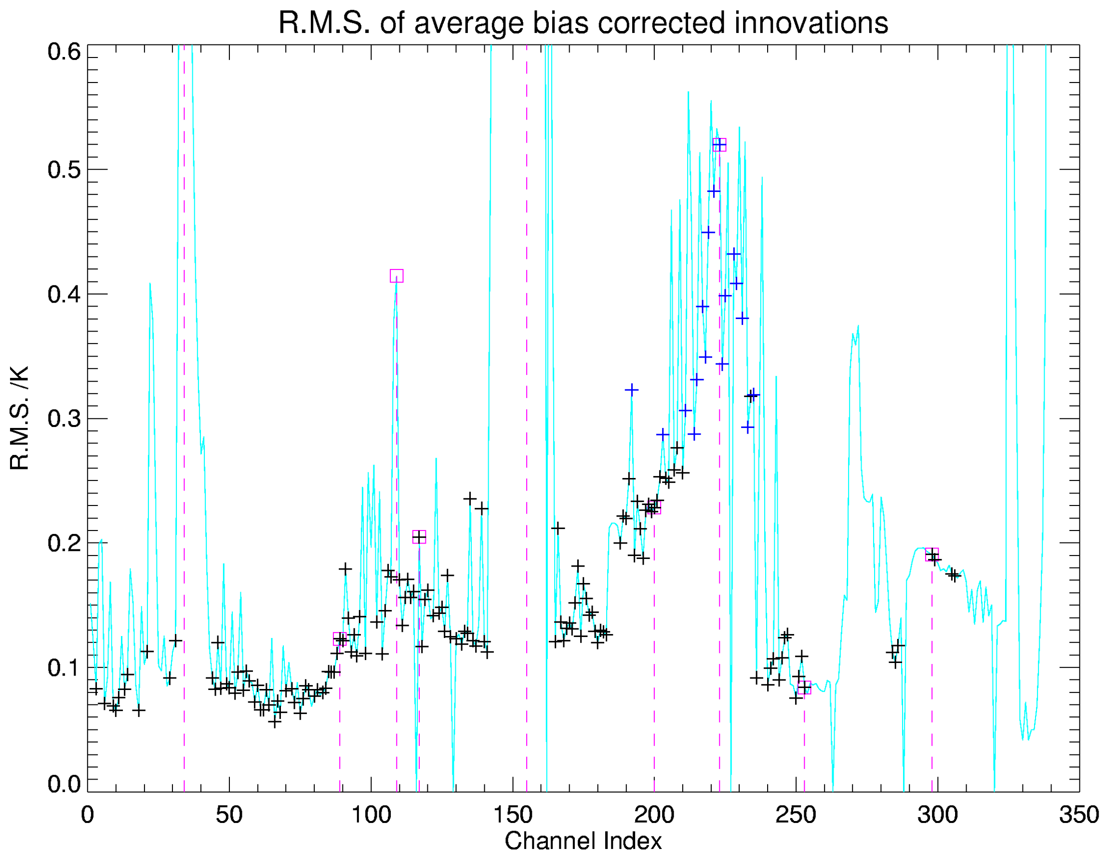

Figure 13: The R.M.S. of the average bias corrected innovations. The crosses show the positions of 161 well modelled channels, including some higher peaking water vapour channels in blue. The magenta dashed lines and squares show the locations of the channels featured in figures 1–9.

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