ENVISAT GROUND SEGMENT

AATSR TECHNICAL NOTE

LATITUDE DEPENDENT BIAS CORRECTION

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1. LATITUDE DEPENDENT BIAS CORRECTION

1.1 Introduction

The retrieval of Sea Surface temperature from AATSR measurements is based on the use of linear retrieval coefficients as described in the AATSR Product Handbook. The coefficients used for dual view SST retrievals were derived using the aerosol robust treatment described by Merchant et al (1999), and are global; that it to say, the same coefficients are used at all latitudes. Thus although the mean retrieval error averaged over the ensemble of atmospheric profiles is zero, if the retrieval error is plotted as a function of the latitude of the profile a characteristic variation can be seen.

The effect is particularly pronounced in the '4-channel' retrievals that use only the dual view 11 and 12 micron channels. It is much weaker in the '6-channel' retrievals that also use the 3.7 micron data in both views (Fig. 1). As a result there is a latitude-dependent bias between the retrievals that use the 3.7 micron channel and those that do not.

Since the 3.7 micron channel data are not used during the day, because of the possibility of contamination by scattered solar radiation at this wavelength, it is important to establish the relationship between the two retrievals, and to derive a correction that can be applied to the 4 channel SST retrievals to bring them into line with the 6 channel retrievals.

This note presents a derivation of the latitude dependent correction, and provides a tabular correction that can be applied off-line to the sea surface temperatures retrieved using the four channel algorithm.

Two sets of retrieval coefficients have been used operationally for AATSR product generation. The pre-launch coefficients were used operationally until December 2005. These were based on the same spectroscopic model that has previously been used for ATSR-2 processing. Subsequently a new set of coefficients was derived using more up-to-date radiative transfer modelling based on the HITRAN 2000 molecular spectroscopy data base, and these have been used from December 2005. The correction presented here is based on the latter set.

1.2 Derivation of the correction

The SST retrieval coefficients for AATSR were determined using a set of 1290 atmospheric profiles based on ECMWF operational data from 1995. This profile set was sampled at intervals of 15 degrees in latitude, and so although the latitude dependence is clearly visible in these data, the sampling in latitude is insufficient for a useful operational correction.

To determine the latitude correction a profile set more closely sampled in latitude is required. C.J. Merchant (private communication) has supplied a profile set sampled at 5 degrees in latitude. This profile set contains 4528 profiles derived from ECMWF re-analysis fields from 1990. To derive the latitude correction, the operational retrieval coefficients have been applied to the brightness temperatures derived from this profile set. In order to ensure that the derivation is self-consistent, the same version of the radiative transfer model was used as was used in the derivation of the operational coefficients themselves. Initial calculations used the pre-launch coefficients, but the calculations were then repeated using the current operational coefficients.

The dual view retrieval coefficients were applied to the model infrared brightness temperatures for 4-channel and 6-channel retrievals at both the swath centre and swath edge. Thus, for each profile k a retrieved sea surface temperature $T(k)$ has been derived. From this the retrieval error

$$\Delta T_k = T_0(k) - T(k) \qquad (1)$$

has been calculated using both the 4 and 6 channel retrieval algorithms, where $T_0(k)$ is the actual surface temperature from the ECMWF analysis corresponding to profile k. ΔT_k thus represents the correction to be added to the retrieved temperature to give the true SST. Note that the coefficients used for the present calculations are those for the averaged SST retrieval; equivalent calculations for the gridded SST retrieval are not reported here.

To determine the latitude dependent bias, the retrieval errors were averaged over the profiles at each latitude separately. This analysis yields the retrieval bias as a function of latitude. Fig. 1 shows the results based on the pre-launch coefficients at the swath centre. The solid and dashed curves show the bias for the 4 and 6 channel retrievals respectively. Clearly the latitude variation of the six-channel retrieval is marginal, but the four-channel retrieval shows a characteristic variation of approximately 0.1 K amplitude.

The difference between the retrievals, after smoothing, is shown as the dot-dashed curve in Fig. 1. This is

$$\Delta\overline{T}_{k,4} - \Delta\overline{T}_{k,6} = \overline{T}_0(\varphi) - \overline{T}_4(\varphi) - \left\{\overline{T}_0(\varphi) - \overline{T}_6(\varphi)\right\} = \overline{T}_6(\varphi) - \overline{T}_4(\varphi), \tag{2}$$

where the bar denotes the average over all values of k at latitude φ, and the subscripts 4 and 6 denote the 4 and 6 channel retrievals respectively. This is the quantity that must be added to the 4-channel retrieval to give the 6-channel retrieval, and represents the required correction.

The retrievals show a substantial spike at 80 S. latitude. Investigation shows that this spike is derived from a single invalid profile that falls on the Ross Ice Shelf. Clearly it is not appropriate to include this datum in the correction. The difference in Fig. 1 shows the correction after removing this point and applying a simple Hanning filter to smooth the data. The resultant curve represents the correction that is to be added to the 4-channel (daytime) retrieval to align it with the 6-channel (night-time) retrieval.

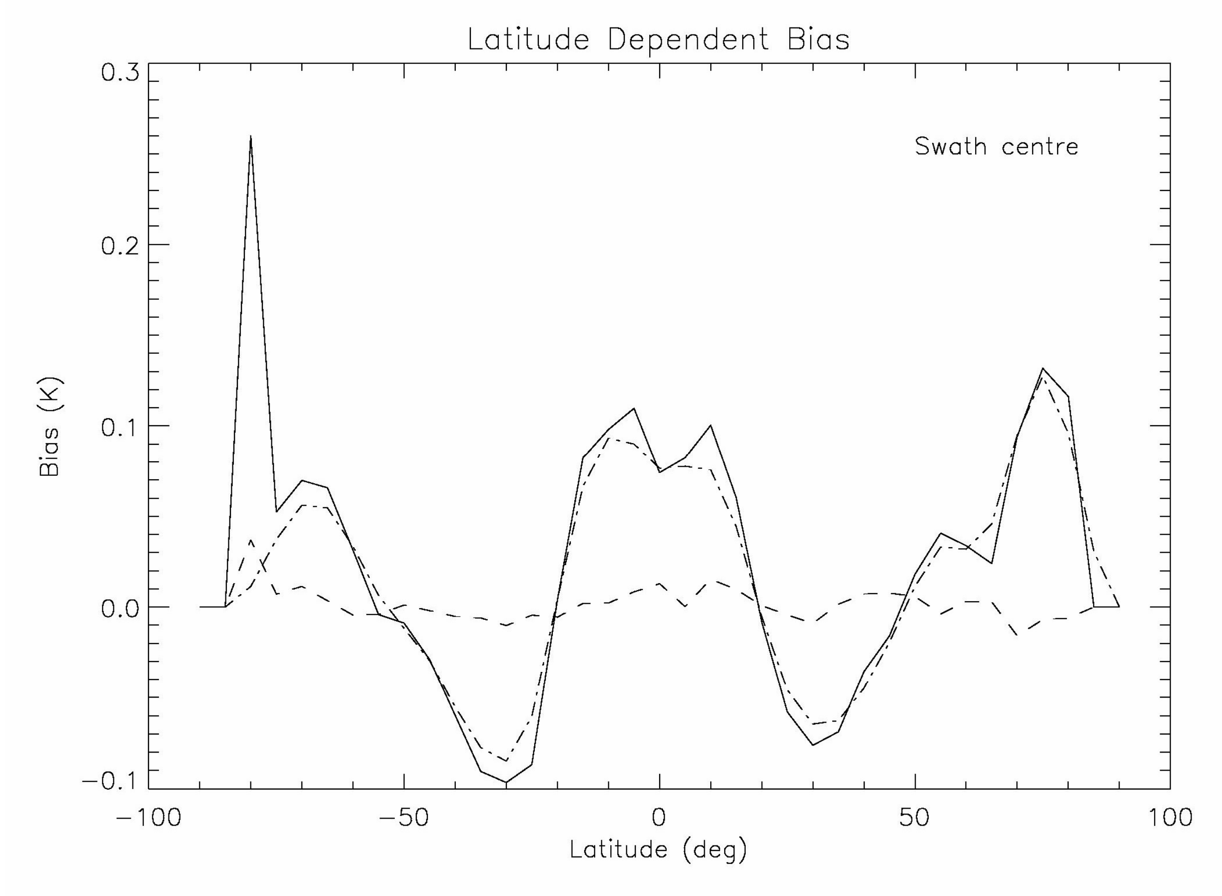

Fig. 1: Latitude dependent bias at the swath centre calculated using the pre-launch coefficients and spectroscopy. Solid curve: 4-channel retrieval; Dashed curve: 6-channel retrieval; Dot-dash curve: smoothed difference 4-channel – 6-channel.

If the calculation is repeated using the swath edge coefficients, the results differ very little from those for the swath centre shown in Fig. 1. It is thus sufficient to use a single correction for all pixels regardless of their position in the swath. Similarly the latitude dependence is not sensitive to the set of coefficients used in its derivation, provided that the coefficients are consistent with the model brightness temperatures to which they are applied (otherwise a global bias will be introduced). Thus the curve derived for the new coefficients can also be used for the historic data processed with the pre-launch coefficients.

The correction itself is shown in Table 1.

Table 1: Smoothed Latitude Dependent Correction based on the HITRAN 2000 spectroscopy and coefficients.

Latitude (deg)	Smoothed correction (K)
-90.000	0.000
-85.000	0.000
-80.000	0.008
-75.000	0.030
-70.000	0.052
-65.000	0.056
-60.000	0.038
-55.000	0.009
-50.000	-0.012
-45.000	-0.033
-40.000	-0.062
-35.000	-0.087
-30.000	-0.094
-25.000	-0.067
-20.000	0.004
-15.000	0.071
-10.000	0.100
-5.000	0.096
0.000	0.082
5.000	0.084
10.000	0.080
15.000	0.046
20.000	-0.007
25.000	-0.051
30.000	-0.072
35.000	-0.072
40.000	-0.054
45.000	-0.028
50.000	0.006
55.000	0.030
60.000	0.030
65.000	0.045
70.000	0.095
75.000	0.126
80.000	0.092
85.000	0.029
90.000	0.000

1.3 Application of the correction

1.3.1 Application to Averaged SST

The correction shown in Table 1 was calculated using the retrieval coefficients for averaged SST, and is intended to be used to correct the averaged dual view SST values from the Averaged Surface Temperature (AST) product ATS_AR__2P.

The correction was calculated using the revised HITRAN 2000 retrieval coefficients; however, repeating the derivation with the pre-launch coefficients yields essentially the same correction, so the correction in Table 1 can be applied to products using either set.

The correction should not be applied to sea surface temperatures retrieved using the nadir-only algorithms. The nadir-only retrieval coefficients are not global. Different coefficients are defined for the three different latitude zones as described elsewhere, and therefore the correction for global coefficients does not apply.

The correction should be applied to dual view SST values where the 3.7 micron data has not been used in the retrieval. This includes all daytime retrievals, but may also include night-time retrievals if for any reason the 3.7 micron data has not been used. Whether or not the 3.7 micron data has been used can be determined from the AST confidence word.

Table 2 shows the structure of the AST confidence word for Sea MDS.

Table 2: The AST Confidence Word for sea MDS. Bits are numbered from LSB bit 0.

Bit	Meaning if set.
0	Nadir-only SST retrieval used 3.7 micron channel
1	Dual-view SST retrieval used 3.7 micron channel
2	Nadir view contains day-time data
3	Forward view contains day-time data
4 - 31	Unused

For each SST data record bit 1 of the confidence word should be inspected. If it is set, no correction is required. If it is clear, the correction derived from Table 1 should be added to the mean dual view SST value.

The following is the procedure to determine the correction for the case of the half-degree and 10 arc minute cell MDS.

Step 1. Extract the cell latitude from the MDS record

The cell latitude refers to the lower left, or south-west, corner of the cell. For maximum accuracy, correct the latitude to refer to the centre of the cell by adding one-half of the cell dimension. This is 0.0833 degrees for a 10 arc minute cell or 0.25 degrees for a half-degree cell. Denote the resulting latitude by φ.

Step 2. Interpolate latitude dependent correction

Using the corrected latitude φ just found as the argument, interpolate in Table 1 with respect to latitude to find the temperature correction. In the first column of Table 1 identify the interval in which the corrected latitude φ falls. If the tabular values defining the interval are φ_j and φ_{j+1} and if the corresponding temperature corrections in the second column of the table are δT_j and δT_{j+1}, the interpolated correction is given by

$$\delta T = \delta T_j + (\varphi - \varphi_j)\frac{(\delta T_{j+1} - \delta T_j)}{(\varphi_{j+1} - \varphi_j)} \quad (3)$$

Step 3. Apply the correction

Add the temperature correction to the dual view SST, ensuring that consistent units are used. The units of Table 1 are K, but the SST in the product is provided as a short integer in units of 0.01 K. If SST_{dual} represents the 4-channel dual view SST taken from the product MDS, in units of 0.01K, the corrected SST in K is

$$SST_{corrected} = SST_{dual} \times 0.01 + \delta T \qquad (4)$$

A similar approach can be taken with the 50 /17 km MDS. In this case however it is more difficult to correct the latitude to the centre of the cell, and this step should be omitted. The maximum error is 0.003 K.

1.3.2 Application to full resolution SST

Although the correction was derived for use with averaged SST values, it can also be applied to gridded SSTs from the full resolution product ATS_NR__2P, with errors up to 0.03K. In this case the correction should be applied to those dual view SST retrievals for which the 3.7 micron channel was not used. Whether the 3.7 micron channel was used or not can be determined from the GST confidence word. If the pixel is not cloudy (refer to the relevant bits of the confidence word), then the correction should be applied to the dual view SST if bit 4 is clear (meaning the pixel is over sea) and bit 3 is clear (so the retrieval did not use the 3.7 micron channel). For reference, the structure of the confidence word is shown in Table 3.

Table 3: The least significant bits of the GST Confidence Word. Bits are numbered from LSB bit 0.

Bit	Meaning if set
0	Nadir-only SST is valid
1	Nadir-only SST retrieval includes 3.7 micron channel
2	Dual-view SST is valid
3	Dual-view SST retrieval includes 3.7 micron channel
4	Pixel is over land
4	Pixel is over land
5	Nadir-view pixel is cloudy
6	Nadir-view pixel has blanking pulse
7	Nadir-view pixel is cosmetic fill
8	Forward-view pixel is cloudy
9	Forward-view pixel has blanking pulse
10	Forward-view pixel is cosmetic fill
11	One or both views flagged cloudy by 1.6 micron test (daytime only)
12	Cloud flagged by 11 micron/12 micron nadir -forward test
13	One or both views flagged cloudy by infra-red histogram test
14 - 15	Topographic variance flags for LST retrieval

In this case the procedure is the same as that described above, except that the pixel latitude is substituted for φ in Step 2. Thus:

Step 1. Extract the cell latitude from the geolocation ADS record

Extract the relevant tie point latitudes from the geolocation ADS and interpolate to the position of the pixel. The procedure for the interpolation of pixel geolocation can be found in the AATSR Technical Note entitled 'Interpolation of Pixel Geolocation in AATSR Full Resolution Products' referenced in Section 2.12.1.3.1 of the AATSR handbook. Denote the resulting pixel latitude by φ.

Step 2. Interpolate latitude dependent correction

Using the interpolated latitude φ just found as the argument, interpolate in Table 1 with respect to latitude to find the temperature correction. In the first column of Table 1 identify the interval in which the corrected latitude φ falls. If the tabular values defining the interval are φ_j and φ_{j+1} and if the corresponding temperature corrections in the second column of the table are δT_j and δT_{j+1}, the interpolated correction is given by Equation (3):

$$\delta T = \delta T_j + (\varphi - \varphi_j)\frac{(\delta T_{j+1} - \delta T_j)}{(\varphi_{j+1} - \varphi_j)}$$

Step 3. Apply the correction

Add the temperature correction to the dual view SST, ensuring that consistent units are used. The units of Table 1 are K, but the SST in the product is provided as a short integer in units of 0.01 K. If SST_{dual} represents the 4-channel dual view SST taken from the product MDS, in units of 0.01K, the corrected SST in K is

$$SST_{corrected} = SST_{dual} \times 0.01 + \delta T$$

2. REFERENCE

C.J. Merchant, A.R Harris, M.J. Murray and A.M. Zavody. Towards the elimination of bias in satellite retrievals of sea surface temperature. 1 Theory, modelling and interalgorithm comparison. Journal of Geophysical Research, 104 (C10), 23,565 - 23,578, 1999.