Empirical Nonlinearity Correction for 12um Channel

Dave Smith

Change Record

Issue	Date	Affected Pages	Changes
1.0	16-Sep-2013	All	Initial Release
1.1	27-Feb-2014	3 6 6-8	Additional References Provided Introduction updated Algorithm reformulated for consistency with ARB paper

1 Documents

1.1 Applicable Documents

No.	Title	Reference
AD1	AATSR 12 Micron Anomaly Review Board Final Report	IDEAS-VEG-OQC-REP-1274

1.2 Reference Documents

No.	Title	Reference
RD1	ISO Guide to Expression of Uncertainty in Measurement	GUM:1995
RD2	Detector Temperature Dependence of the 12micron Channel Filter Profile and its Impact on the ATSR-1 Calibration – A.R.Birks	ATSR Technical Note
RD3	ENVISAT AATSR Instrument Performance - End of Mission Report	PO-RP-RAL-AT-0621

2 Terms, Definitions and Abbreviations

2.1 Terms and Definitions

The following definitions are obtained from ISO Guide to Expression of Uncertainty in Measurement 1995 (GUM) [RD1].

Accuracy is defined as the difference between a result obtained and the 'true' value.

Calibration is the process of quantitatively defining the system response to known, controlled system inputs.

Precision is defined as the difference between one result and the mean of several results obtained by the same method, i.e. reproducibility (includes random errors only).

Traceability is the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.

Uncertainty parameter associated with the result of a measurement that characterises the dispersion of the value that could reasonably be attributed to the measurand.

> **Type A evaluation (of uncertainty)**
> method of evaluation of uncertainty by the statistical analysis of series of observations. This is usually given by the standard deviation of a number of measurements of a random variable.
>
> **Type B evaluation (of uncertainty)**
> method of evaluation of uncertainty by means other than the statistical analysis of series of observations. This is usually based on existing knowledge, for example data provided in calibration and other certificates or an estimation of the uncertainty based on previous experience.

Validation is the process of assessing by independent means the quality of the data products derived from the system outputs.

2.2 Acronyms

ARB	Anomaly Review Board
ATSR	Along-Track Scanning Radiometer
BB	Black-Body
IR	Infrared
LUT	Look-Up-Table
LWIR	Long Wave Infra-Red
MCT	Mercury Cadmium Telluride

MIRI	Mid InfraRed Instrument
MWIR	Medium Wave Infrared
NCR	Non Conformance Report
NIR	Near Infra-Red
NL	Non-Linearity
RAL	Rutherford Appleton Laboratory
S/C	Spacecraft
tbc	to be confirmed
tbd	to be defined
TIR	Thermal IR
w.r.t.	with respect to

3 Introduction

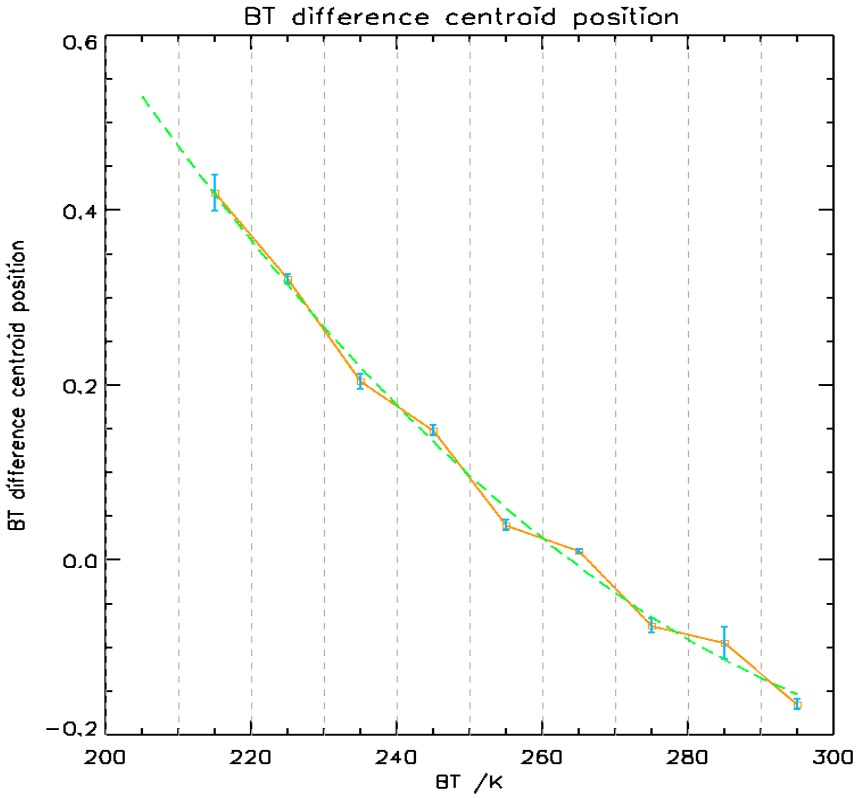

Figure 1: Summary of the analysis of IASI-AATSR intercomparisons.

An investigation into the anomaly of the AATSR 12um channel calibration [AD1] found that comparisons between AATSR and IASI showed temperature dependent differences varying from 0.4K for cold scene temperatures to -0.2K for hot scenes (Figure 1). The ARB concluded that the most likely explanation was the combination of two factors.

1. Changes after launch rendering the non-linearity corrections to the data inappropriate. This effect produces biases that are more pronounced at low scene temperatures.

2. An apparent error in the wavelength calibration of the 12 μm channel. This is of the order of 50 nm. This effect produces biases that are more pronounced at higher scene temperatures.

The ARB recommended improving the AATSR data by taking into account the non-linearity error and spectral response shifts. At the time of writing a detailed investigation is on-going to determine a solution that could be implemented in the AATSR 4th reprocessing.

As an interim solution we propose an empirical non-linearity correction to the measured brightness temperatures in the L1b products.

4 Generation of Table

We assume the BT bias as a function of scene brightness temperature due to errors in non-linearity correction has the form [RD2]

$$\Delta BT = a(T - T_1)(T - T_2)$$

T_1 and T_2 are the temperatures of the two on-board blackbody temperatures where ΔBT = 0. The blackbody temperatures during the AATSR mission remained very stable with mean values at T_1 = 263K and T_2 = 302K [RD3].

Using these fixed points and the low temperature measurements from the IASI-AATSR intercomparisons we can derive the coefficient *a*, so ΔBT becomes

$$\Delta BT = \Delta BT_0 \frac{(T - T_1)(T - T_2)}{(T_0 - T_1)(T_0 - T_2)}$$

From Figure 1 we obtain ΔBT_0 = 0.425 for a scene brightness temperature T_0 of 215K. Note that we assume that the differences at low scene temperatures are not strongly influenced by spectral response errors.

We then use the function and coefficients to generate the table in Appendix A as shown in Figure 2.

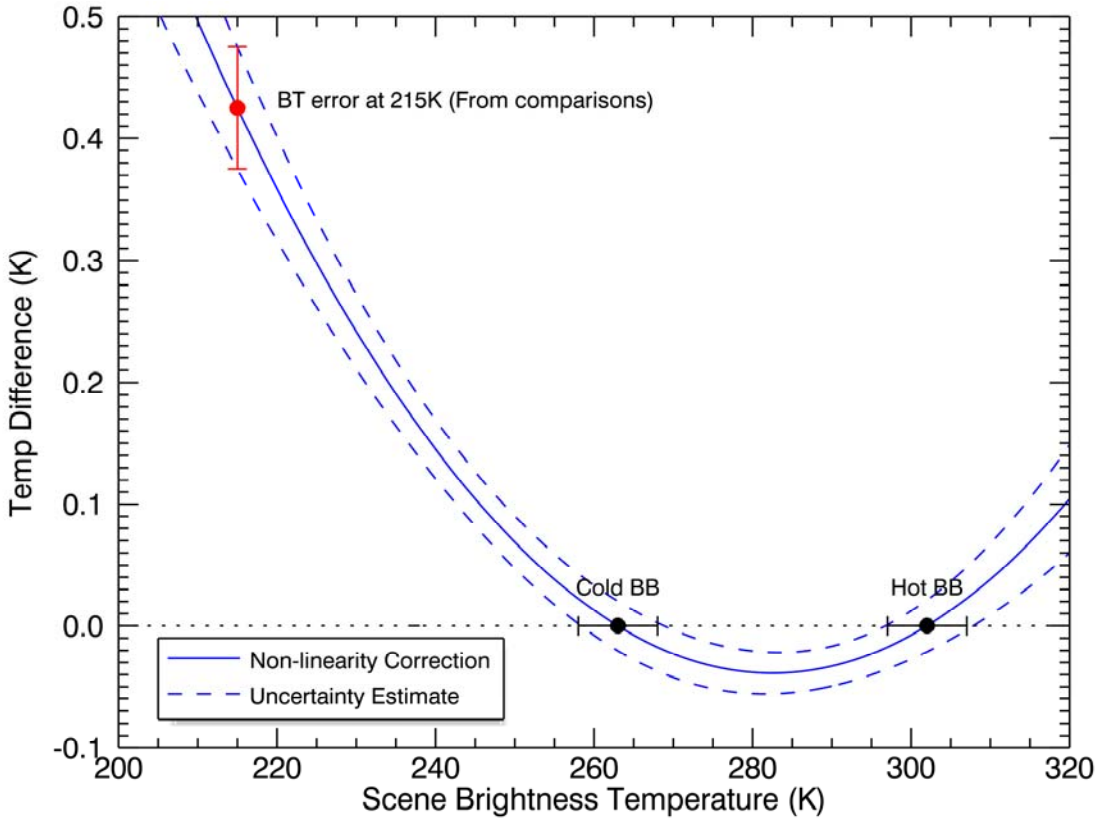

Figure2: Non-linearity correction for AATSR 12um channel.

An uncertainty estimate is provided by differentiating the function with respect to ΔBT_0, T_1 and T_2 to obtain

$$(u\Delta BT)^2 = (u\Delta BT(\Delta BT_0))^2 + (u\Delta BT(T_1))^2 + (u\Delta BT(T_2))^2$$

Where

$$u\Delta BT(\Delta BT_0) = \frac{(T - T_1)(T - T_2)}{(T_0 - T_1)(T_0 - T_2)} u\Delta BT_0$$

$$u\Delta BT(T_1) = \frac{(T - T_2)(T - T_0)}{(T_2 - T_0)(T_0 - T_1)^2} uT_1$$

$$u\Delta BT(T_2) = \frac{(T - T_1)(T - T_0)}{(T_1 - T_0)(T_0 - T_2)^2} uT_2$$

Here we assume worst case errors of ±0.05K.for ΔBT_0 and ±5K for the blackbody temperatures T_1 and T_2. The latter is based on the long term trends of the on-board blackbody temperatures [RD3]. This results a range of uncertainty in ΔBT from ±0.02K to ±0.08K depending on scene temperature. Note that these uncertainty estimates assume that the radiometric gain of the instrument has remained stable throughout the mission.

5 Use of Table

The non-linearity correction table provides a first order adjustment to 12um brightness temperatures in the L1b product. The adjusted brightness temperature is given by

$$BT'_{scene} = BT_{scene} - \Delta BT(T_{scene})$$

$\Delta BT(T_{scene})$ is obtained by linear interpolation of the correction table.

Caveat emptor! The adjustment does not constitute a fully robust correction to the radiometric calibration since it is dependent on a stable instrument configuration. The correction does not account for variations in optical throughput or thermal behaviour that have occurred during the instrument lifetime.

Appendix A - Nonlinearity Correction Table

Temperature (K)	Correction (K)	Uncertainty Estimate (K)
200.000	0.654	0.079
201.000	0.637	0.077
202.000	0.621	0.075
203.000	0.605	0.073
204.000	0.588	0.070
205.000	0.573	0.068
206.000	0.557	0.066
207.000	0.541	0.064
208.000	0.526	0.062
209.000	0.511	0.061
210.000	0.496	0.059
211.000	0.482	0.057
212.000	0.467	0.055
213.000	0.453	0.053
214.000	0.439	0.052
215.000	0.425	0.050
216.000	0.411	0.048
217.000	0.398	0.047
218.000	0.385	0.045
219.000	0.372	0.044
220.000	0.359	0.042
221.000	0.346	0.041
222.000	0.334	0.040
223.000	0.322	0.038
224.000	0.310	0.037
225.000	0.298	0.036
226.000	0.286	0.035
227.000	0.275	0.034
228.000	0.264	0.033
229.000	0.253	0.032
230.000	0.242	0.031
231.000	0.231	0.030
232.000	0.221	0.029
233.000	0.211	0.028
234.000	0.201	0.027
235.000	0.191	0.027
236.000	0.181	0.026
237.000	0.172	0.026
238.000	0.163	0.025
239.000	0.154	0.025
240.000	0.145	0.024
241.000	0.137	0.024
242.000	0.128	0.023
243.000	0.120	0.023
244.000	0.112	0.023
245.000	0.104	0.022
246.000	0.097	0.022
247.000	0.090	0.022
248.000	0.082	0.022
249.000	0.076	0.022
250.000	0.069	0.021
251.000	0.062	0.021
252.000	0.056	0.021
253.000	0.050	0.021
254.000	0.044	0.021
255.000	0.038	0.021
256.000	0.033	0.021
257.000	0.027	0.021
258.000	0.022	0.021
259.000	0.018	0.021
260.000	0.013	0.021
261.000	0.008	0.020
262.000	0.004	0.020

Temperature (K)	Correction (K)	Uncertainty Estimate (K)
263.000	0.000	0.020
264.000	-0.004	0.020
265.000	-0.008	0.020
266.000	-0.011	0.020
267.000	-0.014	0.020
268.000	-0.017	0.020
269.000	-0.020	0.020
270.000	-0.023	0.019
271.000	-0.025	0.019
272.000	-0.027	0.019
273.000	-0.030	0.019
274.000	-0.031	0.019
275.000	-0.033	0.019
276.000	-0.034	0.018
277.000	-0.036	0.018
278.000	-0.037	0.018
279.000	-0.037	0.018
280.000	-0.038	0.018
281.000	-0.038	0.017
282.000	-0.039	0.017
283.000	-0.039	0.017
284.000	-0.038	0.017
285.000	-0.038	0.017
286.000	-0.037	0.017
287.000	-0.037	0.017
288.000	-0.036	0.016
289.000	-0.034	0.016
290.000	-0.033	0.016
291.000	-0.031	0.016
292.000	-0.030	0.017
293.000	-0.027	0.017
294.000	-0.025	0.017
295.000	-0.023	0.017
296.000	-0.020	0.018
297.000	-0.017	0.018
298.000	-0.014	0.019
299.000	-0.011	0.019
300.000	-0.008	0.020
301.000	-0.004	0.020
302.000	0.000	0.021
303.000	0.004	0.022
304.000	0.008	0.023
305.000	0.013	0.024
306.000	0.018	0.025
307.000	0.022	0.026
308.000	0.027	0.027
309.000	0.033	0.028
310.000	0.038	0.029
311.000	0.044	0.031
312.000	0.050	0.032
313.000	0.056	0.033
314.000	0.062	0.035
315.000	0.069	0.036
316.000	0.076	0.038
317.000	0.082	0.039
318.000	0.090	0.041
319.000	0.097	0.043
320.000	0.104	0.044