Update on AATSR Visible Channel Long Term Trends

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Abstract

Studies of the long term stability of the AATSR visible channel calibration have shown that the drift does not follow a linear trend. The implications for ground data processing are that the visible channel reflectances for scenes after December 2004 will be too low by as much as 10%, in particular for the 0.56μm channel. A further correction is therefore needed to compensate for the deviation from the expected trend. Inspection of the data suggests that the calibration drift may be due to the gradual build up of a thin contaminant film on the optical surfaces of the visible calibration system, rather than by the gradual degradation of the exposed optics. A simple thin film model has been applied to the data that appears to confirm this hypothesis. A new drift correction based on this model is proposed, and a guide to applying the new correction is given in the Appendix.

1 Introduction

Data from desert and ice targets have been used to monitor the long term stability of the AATSR VNIR channels over the period from October 2002 to December 2004 [Smith 2006]. The basic assumption is that certain geographic regions, in particular the Sahara and Arabian deserts, are stable over many years due to the extremely low rain fall and sparse population. In addition, the large spatial uniformity of the sites makes them suitable for comparisons with similar instruments such as MERIS.

The data shown in Figure 1 suggests that the long-term drift in the visible channel calibration is linear and is due to the gradual degradation of the optical surfaces in the VISCAL system. The drift could be expressed as a simple function of time $D = exp(k*t)$ where k is the drift rate and t is the time. The drift rates for the AATSR visible channels as shown in Table 1 were typically below 5% and comparable with those for the corresponding channels on ATSR-2.

Table 1 – AATSR visible channel drift rates

Wavelength	Drift Rate
1.6μm	0.002
0.87μm	0.013
0.66μm	0.021
0.56μm	0.034

From December 2005, this drift correction model using the measured drift rates has been routinely applied to the visible calibration tables.

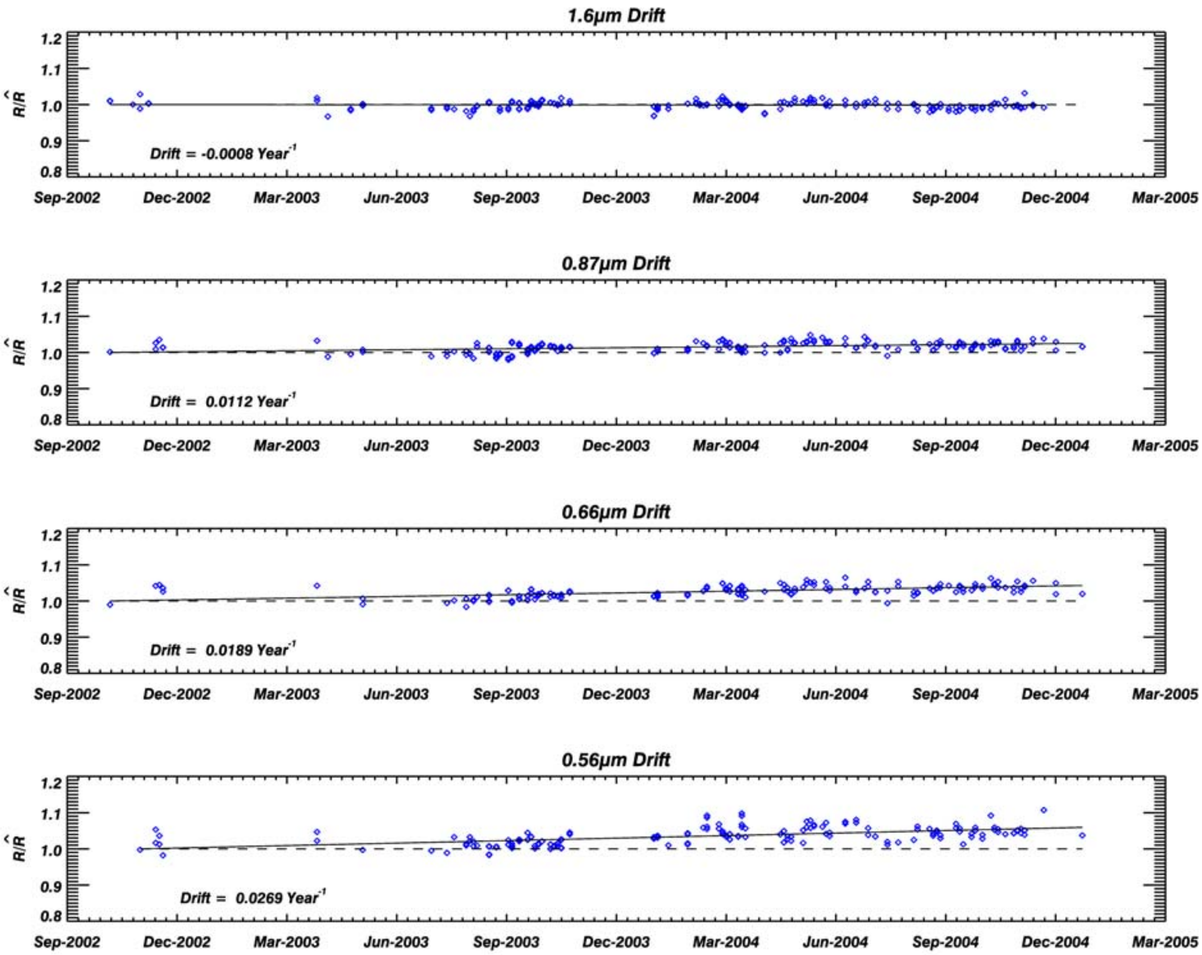

Figure 1 - Time series of the AATSR reflectances *R*, normalised to a Bidirectional Reflectance Distribution Function, $\hat{R}$ over the Arabia1 site**.** Here the BRDF is obtained by fitting to the AATSR TOA reflectances as a function of scattering angle.

2 Post 2004 Trends

Another of the basic assumptions was that the long term drift would continue to follow the same trend, as it had done for ATSR-2. Marc Bouvet however, reported at the MAVT workshop in March 2006 that when compared against MERIS, the 0.56µm channel was showing some anomalous behaviour after 2004, Figure 2. Similar behaviour has also observed in data for the Greenland Ice Cap, Figure 3, where the 0.56µm channel was not drifting according to the exponential decay model.

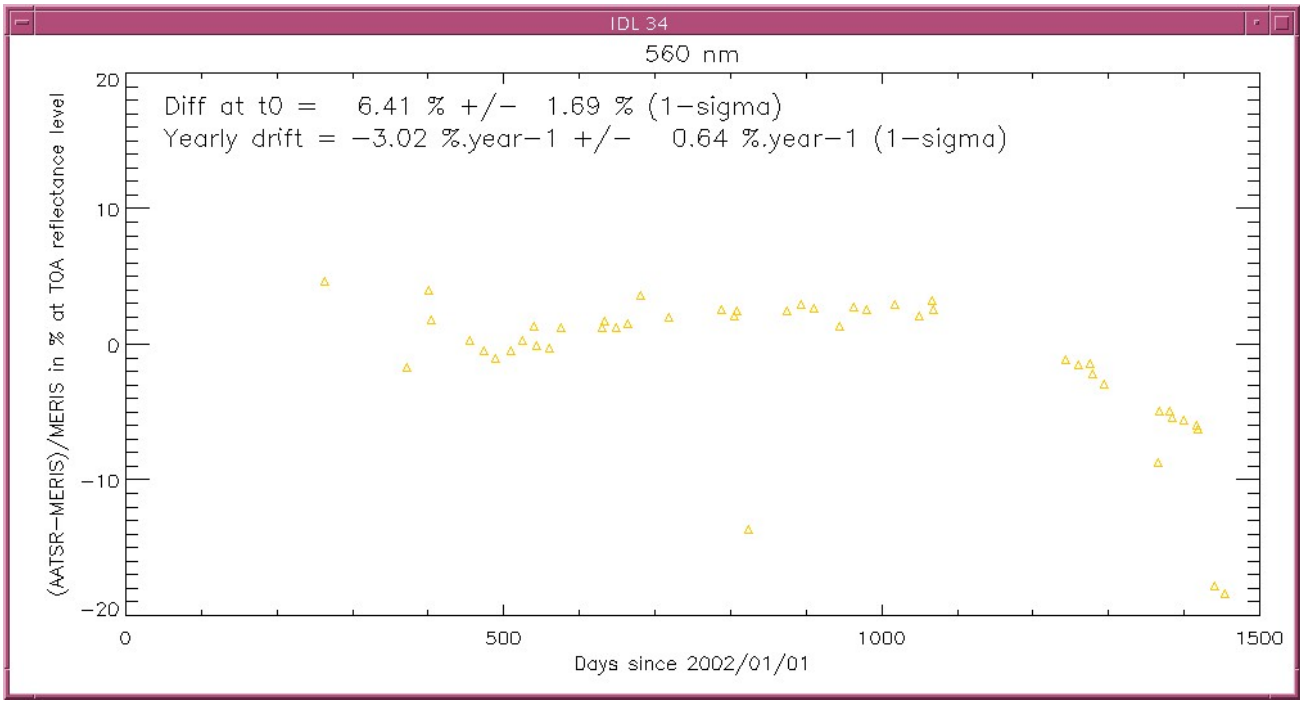

Figure 2: Normalised difference of AATSR and MERIS 0.56um TOA reflectances over the Salar de Uyuni salt plain in Bolivia (Bouvet 2006).

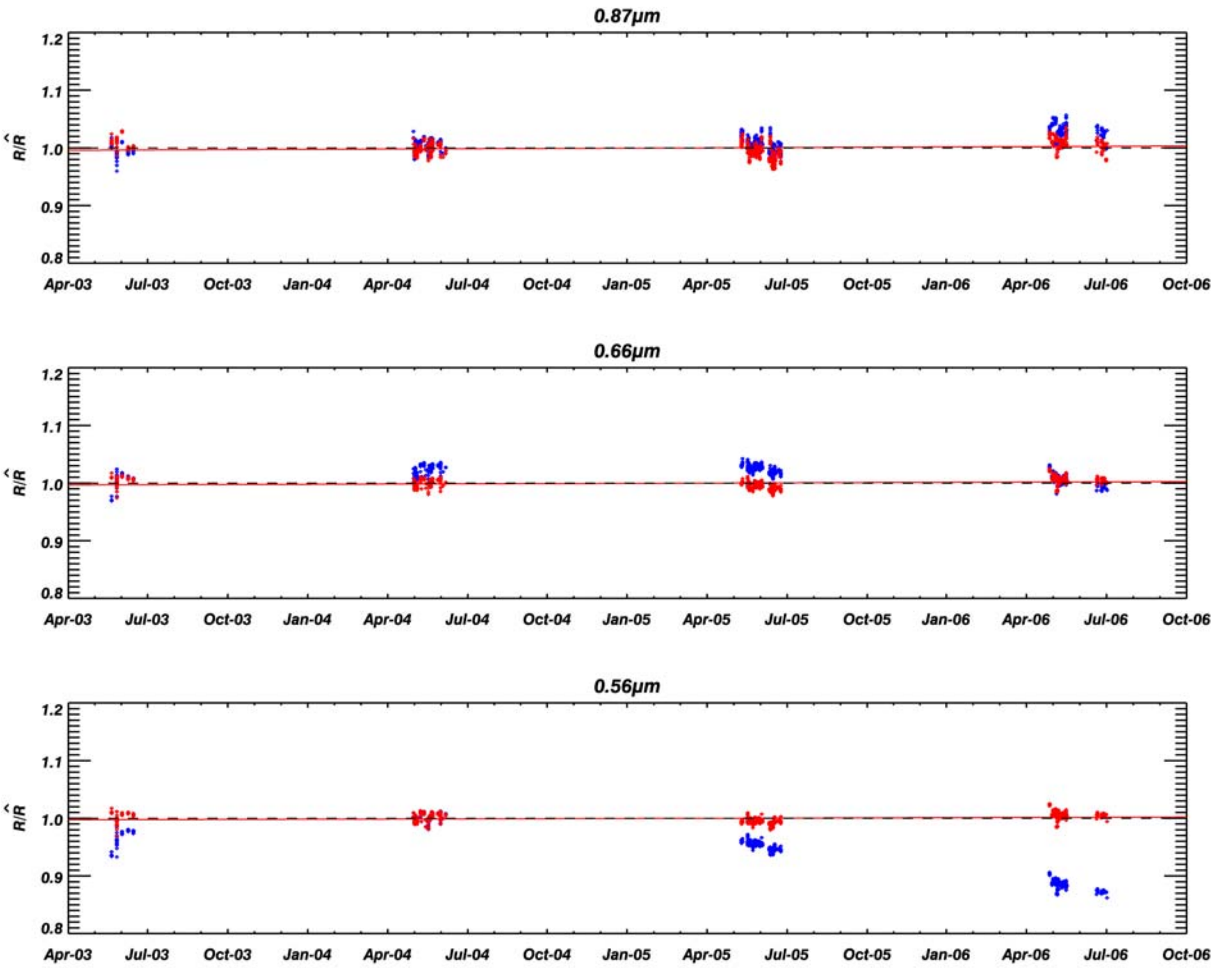

Figure 3: Comparison of AATSR and MERIS drifts using data from the Greenland ice-cap. Here the BRDF, has been obtained by least squares fit of MERIS reflectance vs. cosine solar zenith angle.

At the time of writing, it was suggested that there had been a change in the drift rate for the 0.56µm channel that had not been picked up by the desert trend analysis owing to the limited time range of the analysis, and further investigation was needed to confirm this.

Data for the Sudan1, Algeria, and Lybia1 and Arabian sites have since been processed to include data up to October 2006. The data for all sites have confirmed the earlier results and show that the 0.56µm trend has changed significantly. Figure 4, shows the time series of the normalised AATSR reflectances over the Sudan1 site, without the long term drift correction. The plots show that for the period up to December 2004, all channels show an almost linear drift. However, the trend in the 0.56µm channel reverses from about December 2004 and follows a new trend. This means that the current drift correction no longer applies. A similar reversal can be observed in the 0.67µm channel from around May 2006. Similar behaviour was observed from the data for the other targets.

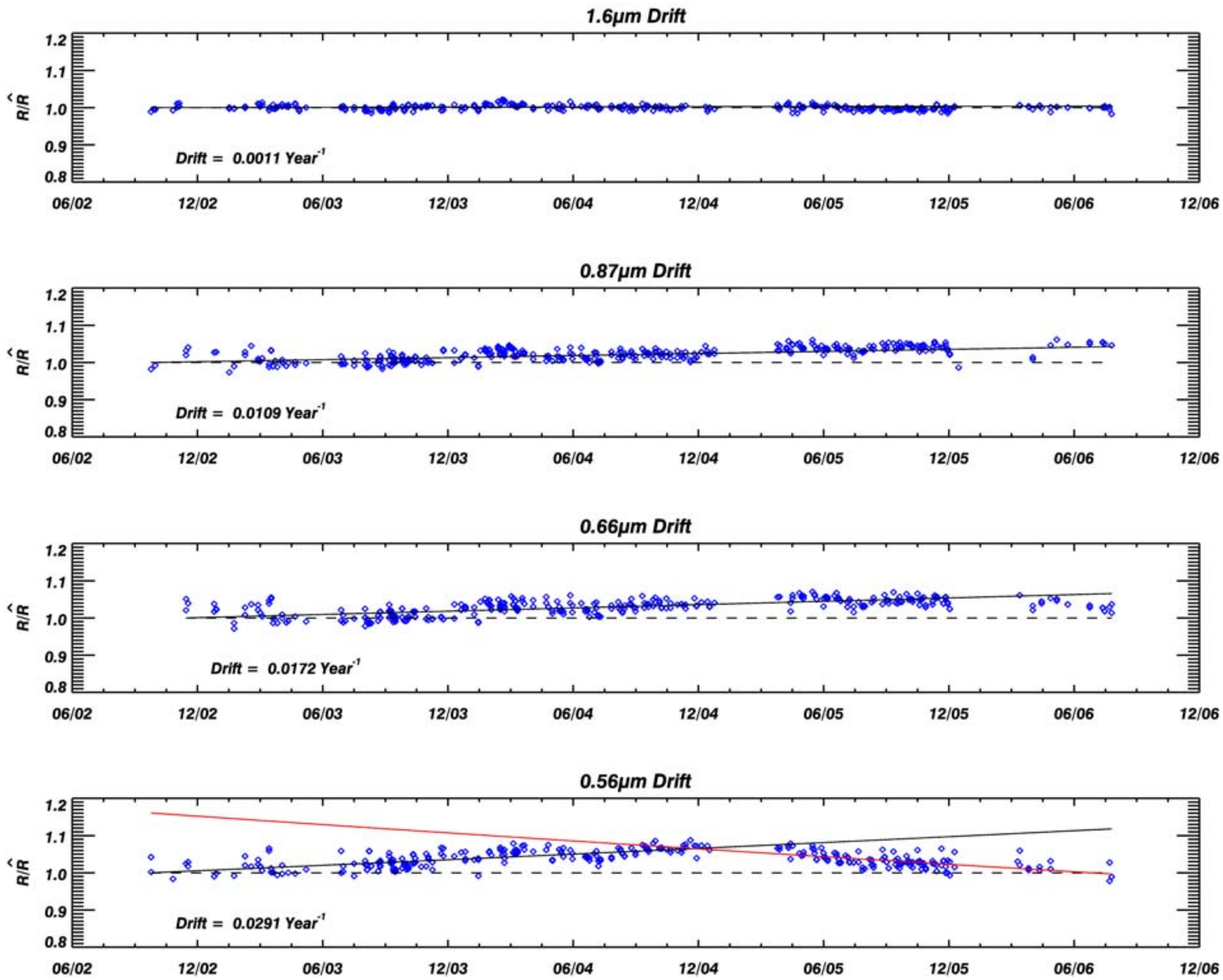

Figure 4: Time series of the AATSR reflectances *R*, normalised to a Bidirectional Reflectance Distribution Function, $\hat{R}$ for the Sudan1 site over the time period up to 2006, showing the change in direction of the 0.56µm drift.

3 Thin Film Model

The results clearly show that the assumed exponential decay model for the AATSR drift is no longer valid. The general assumption had been that the optical surfaces were gradually degrading as a consequence of being exposed to the harsh space environment. While this may be true in part, this would not explain the reversal seen in the 0.56µm channel. An alternative explanation could be that the long-term trend is instead caused by the gradual build up of a thin contamination film on the optical surfaces of the VISCAL system. A similar effect was present in the uncalibrated visible channel signals from ATSR-2 where the build up of water ice contamination on the cold relay lens between the IR and VIS FPAs produces an interference effect. The result is a periodic oscillation in the uncalibrated visible channel response, Figure 5.

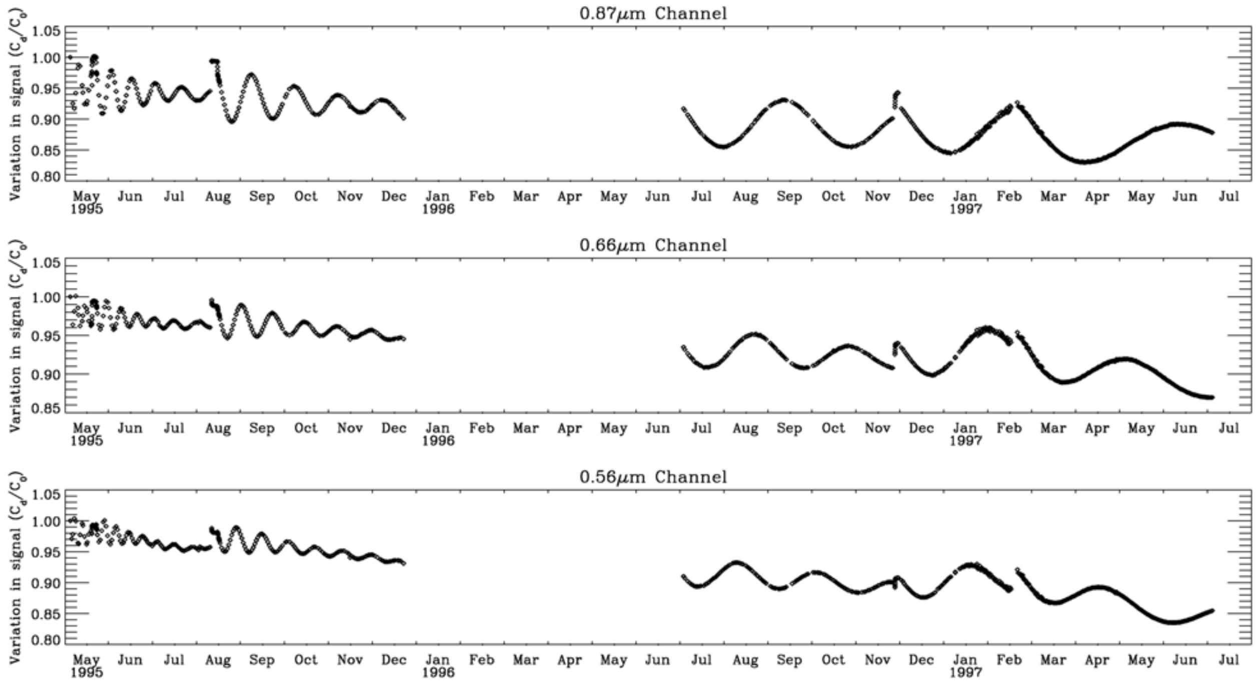

Figure 5: Variation in ATSR-2 visible channel gains during the first two years of the ERS-2 mission.

The effect is illustrated by applying the following model. The intensity, *I(t),* of the transmitted beam through a uniform film of thickness x is given by:

$$I(t) = I_0 \frac{\left(1-r^2\right)^2}{1-2r^2\cos^2\delta + r^4}$$

where I_0 is the intensity of the incoming beam,
r = reflectance of the film
δ= is the phase angle = $2\pi nx/\lambda$
λ = channel wavelength in microns
and n = refractive index of film

This results in an oscillation in the signal intensity as the layer depth increases with maxima at x= nλ/2, nλ, 3nλ/2…and minima at nλ/4, 3nλ/4, 5nλ/4...

Assuming that the film is building up on one of the optical elements in the VISCAL system (UV window, Russian opal or relay mirrors), the normalised signal is modified by $1/I(t)$. Using the above model we can define a new drift function of the form:

$$D(t) = 1.0 + A\sin^2\left(2\pi nx' t/\lambda\right)$$

where A is the amplitude of the modulation, x' is the deposition rate of the film in μm per day and t is the time since the start of the mission.

This function produced a good result when fitting to the data for Sudan1, Figure 6 and also for Greenland, Figure 7.

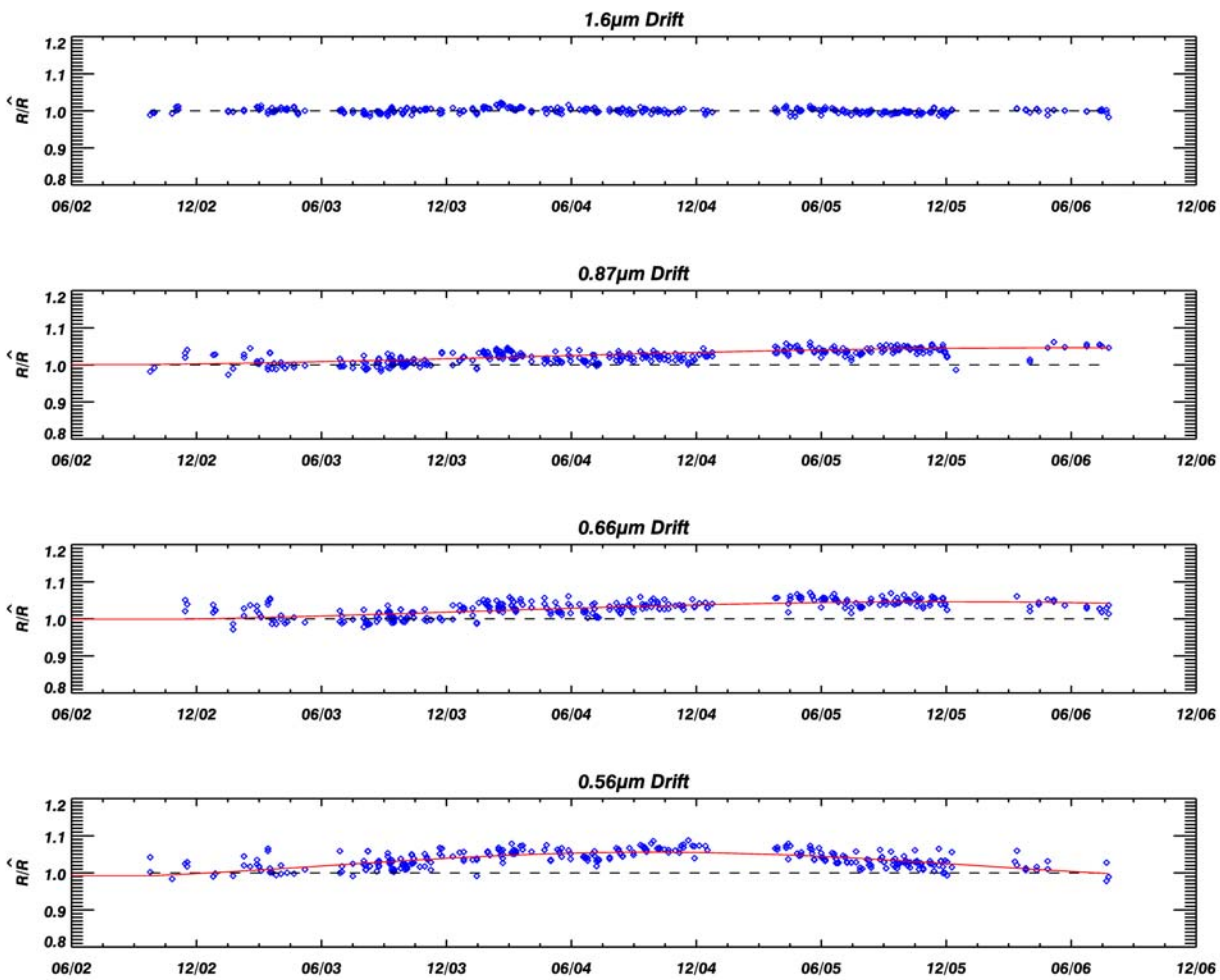

Figure 6: Results of fitting thin film interference model to normalised radiances for SUDAN1 test site. Note that the previous long term drift correction has been first removed from the L1B radiances (i.e. data are uncorrected before fitting)

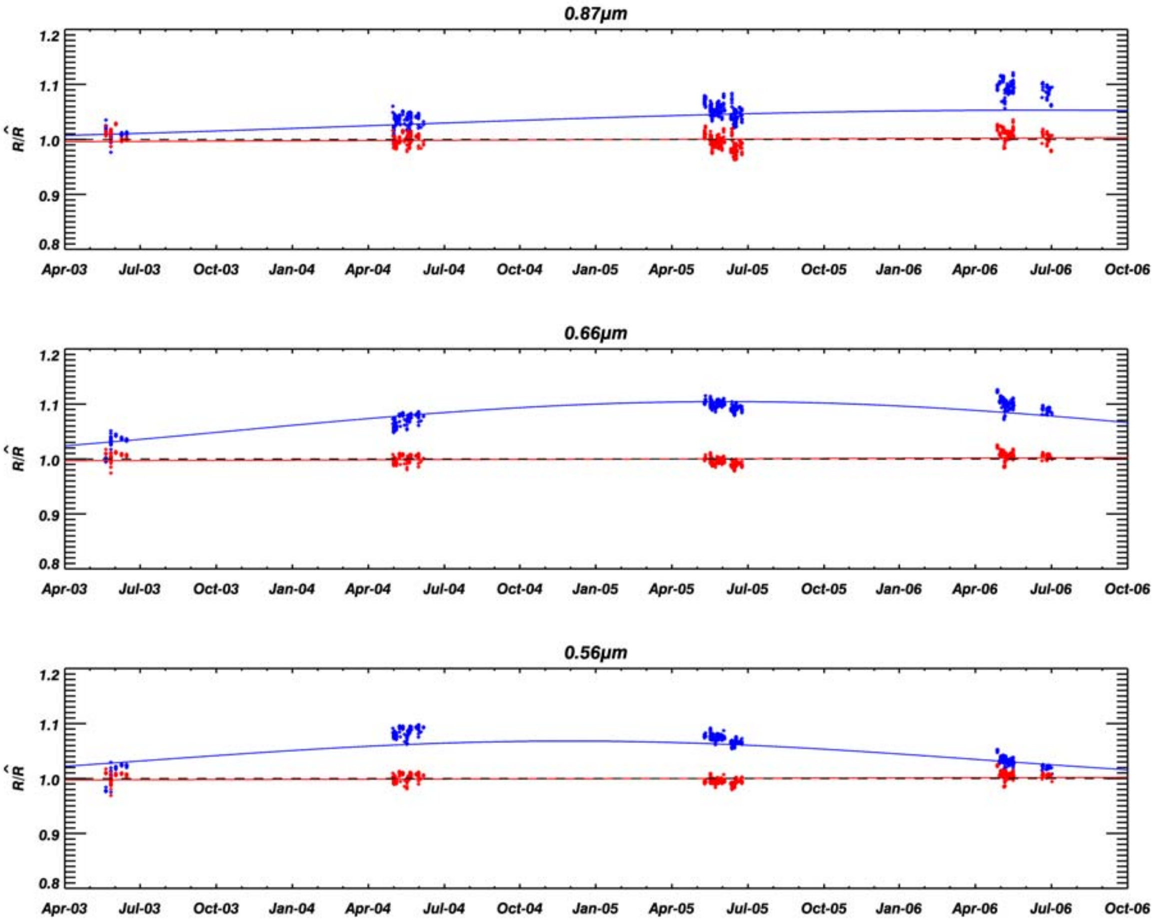

Figure 7: Comparison of AATSR and MERIS drifts using data from the Greenland ice-cap after removing the exponential long term drift correction. A thin film interference model has been fitted to the AATSR measurements.

The model has been applied to all sites where a long term archive has been built up through the visible calibration studies.

Table 2: Coefficients for thin film model obtained from fit to desert sites.

	0.87µm		0.67µm		0.555µm	
	nx'	A	nx'	A	nx'	A
Sudan1	1.3912E-04	0.041	1.2959E-04	0.050	1.3793E-04	0.087
Arabia 1	1.3323E-04	0.034	1.3997E-04	0.020	1.3793E-04	0.087
Algeria 3	1.2111E-04	0.033	1.1314E-04	0.036	1.3977E-04	0.080
Lybia 1	1.3399E-04	0.044	1.2825E-04	0.065	1.4725E-04	0.095
Greenland	1.3793E-04	0.054	1.3793E-04	0.107	1.3793E-04	0.069
Average	**1.3308E-04**	**0.041**	**1.2978E-04**	**0.056**	**1.4016E-04**	**0.083**
Stdev	7.631E-06	0.005	1.105E-05	0.019	4.438E-06	0.006
% Uncertainty	5.73%	13.03%	8.51%	34.19%	3.17%	7.51%

Although the model gave reasonably good fits to the measurements, it was necessary to constrain the starting values to avoid aliasing. This is most likely because the measurements have not yet completed a full cycle, especially the 0.87µm and 0.67µm channels where the trends are only just beginning to turn over. Also, the 0.56µm trend appears to have reached a minimum and should start to turn, if the model is correct. Unfortunately this will only be confirmed once data for several more months of data have been processed and analysed.

4 Conclusions

We have a possible explanation for the behaviour seen in the long term stability of the AATSR visible channels (0.87µm, 0.67µm and 0.56µm channels only). A correction to the existing VC1 files or L1B data is possible using the following approach:

1. Remove any previous drift correction if present from the AATSR visible channel slopes or L1B reflectances
2. Calculate new drift correction factor using thin film model.
3. Apply new drift correction factor to visible channel signals or L1B data.

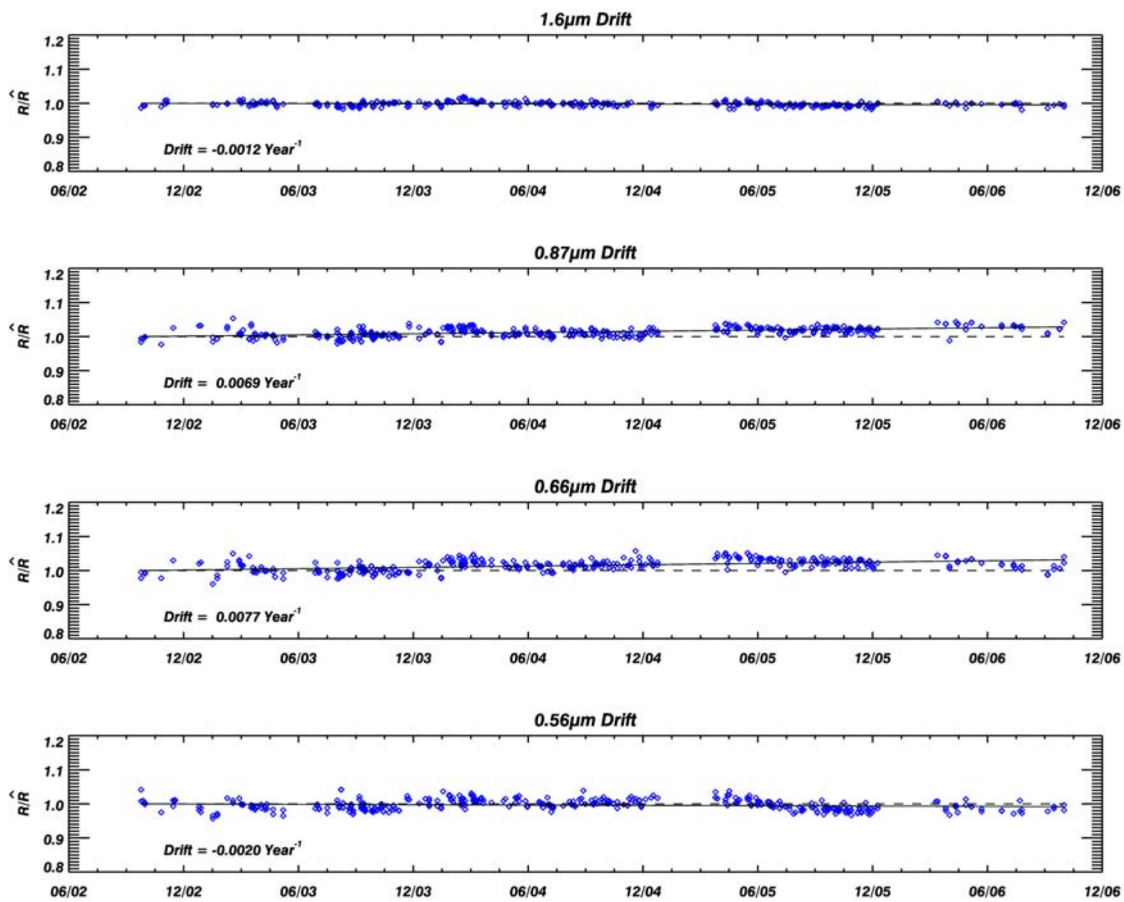

Figure 8: Time series of the normalised AATSR reflectances over the Sudan1 site corrected using a thin film interference drift model.

The resulting time series shown in Figure 8 for the Sudan-1 site, not surprisingly shows a significant improvement from the data shown in Figure 4. Applying the model to the data for Greenland does appear to reduce the overall drift in the 0.56µm channel, although the drift is not completely removed from the 0.87µm and 0.67µm channels, Figure 9. Further analysis is still required to understand the differences between the desert targets and ice targets such as Greenland.

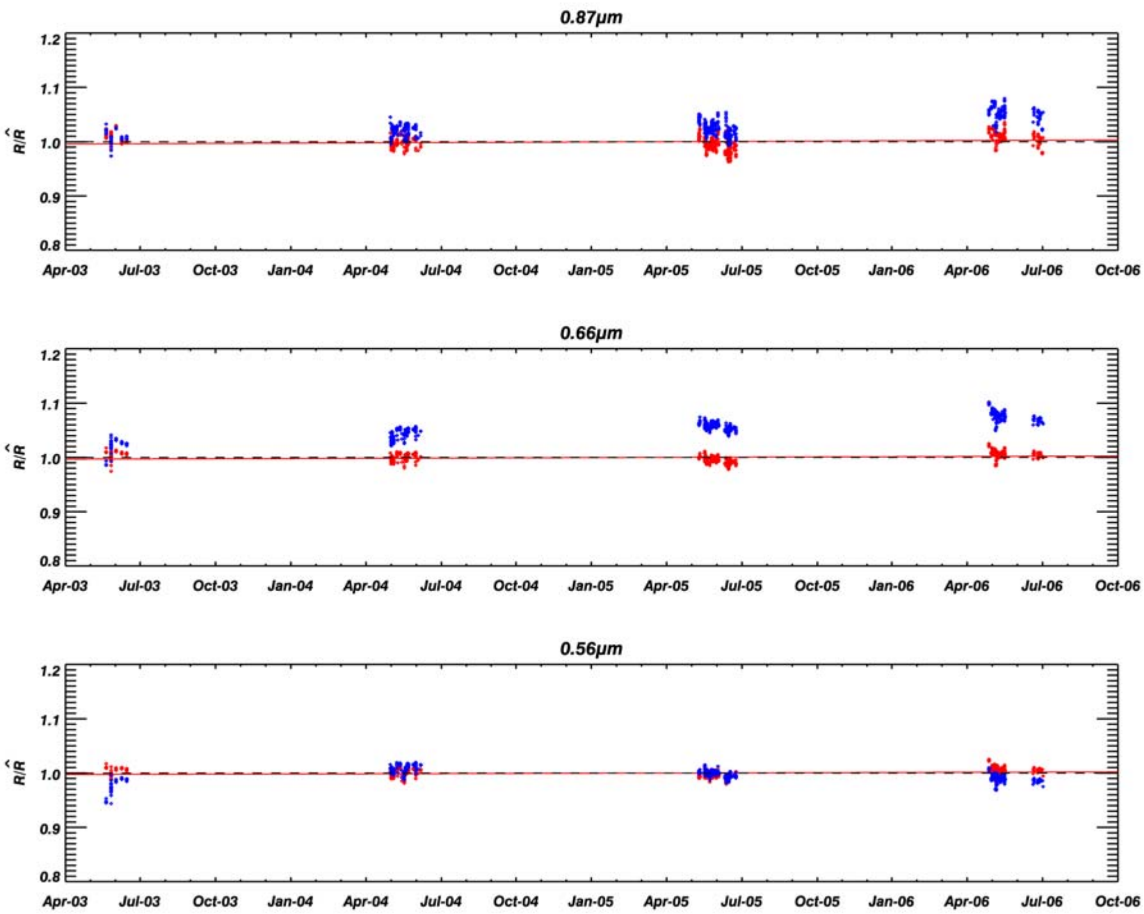

Figure 9: AATSR normalised radiances corrected for long term drift using the thin film model, compared against coincident measurements obtained from MERIS data, for the Greenland site.

5 References

D.L. Smith, 2005, “Visible Channel Long Term Drift Analysis Using Desert Targets”, AATSR Report PO-TN-RAL-AT-0542

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H.Cosnefroy, M. Leroy and X. Briottet, ‘Selection and Characterisation of Saharan and Aarabian Desert Sites for the Calibration of Optical Sensors’, Remote Sens. Environ. 58, 101-114, (1996)

Appendix – User Guide to Applying New Drift Correction

The procedure described below assumes that the user already has the capability to read in AATSR L1B products into tools such as BEAM or IDL.

Note: the first NRT product processed with the new drift correction was for orbit 25142. The following procedure details the approach required for consolidated (offline) data. Depending upon when the product was acquired by AATSR, different treatment will be required:

1. If the product was acquired after 20:14:15 on 18^{th} of December 2006 (I.e. the start time of the validity period of the first VC1 file supplied containing the new correction) then no action is necessary since the new drift correction should already be implemented.

2. If the product was acquired after December 2005 but before 20:14:15 on 18^{th} of December 2006 then it is necessary to remove the previous drift correction for the 0.87um, 0.67um and 0.56um channels as follows:

   *OLD_DRIFT = EXP(DRIFT_RATE*NUMBER_OF_DAYS_SINCE_LAUNCH)*

   *UNCORRECTED_REFLECTANCE = L1B_REFLECTANCE*OLD_DRIFT*

   The *DRIFT_RATE* per day is given in the table below:

Table A – AATSR rates for exponential drift model

Wavelength	Drift Rate
0.87µm	3.5617E-5
0.66µm	5.7459E-5
0.56µm	9.3087E-5

   Note that the 1.6µm channel should not be changed.

3. If the image was generated before December 2005 then there is no previous correction so the new correction should be applied without additional treatment.

The new drift correction should be applied to all uncorrected data (i.e. data from before 20:14:15 on 18 December 2006, and with any previous correction removed) for the 0.87um, 0.67um and 0.56um channels as follows:

*NEW_DRIFT = 1.0 + A*SIN(B*NUMBER_OF_DAYS_SINCE _LAUNCH)^2*

CORRECTED_REFLECTANCE = UNCORRECTED_REFLECTANCE/NEW_DRIFT

The coefficients A and B are given in the table below, where A is the amplitude, and B = nx'/λ is the drift rate per day.

Table B – Coefficients for thin film drift model

Wavelength	A	B
0.87µm	0.041	9.6111E-4
0.66µm	0.056	1.2374E-3
0.56µm	0.083	1.5868E-3