Visible Channel Long Term Drift Analysis Using Desert Targets

D.L. Smith

Abstract

The stability of AATSR visible channel calibrations have been measured using data from stable desert targets. The calibration drift rates obtained from the time-series are less than 3.5% per year and comparable to those measured for ATSR-2. Application of the drift correction to AATSR L1B images is discussed.

1 Introduction

The AATSR visible channel images are calibrated using data from the VISCAL on board visible calibration subsystem. As with most optical systems, the optical surfaces will degrade with time due to exposure to the space environment, in particular UV radiation. A broadband photodiode mounted in the system provides a basic level of monitoring, although this does not give the specific degradation rates for each visible channel.

The technique adopted for ATSR-2 was to measure the drifts using top-of-atmosphere (TOA) reflectance measurements from desert and ice targets (Smith, Mutlow and Rao 2002), the supposition being that over a time scale of several years the sites are radiometrically stable because they are arid with little or no vegetation, and are largely unaffected by human activity. Although some variations do occur, such as clouds, dust etc… the effects can be accounted for. The test sites used are also spatially uniform over a large area and are therefore suitable for sensors having a relatively large footprint such as ATSR.

The same methodology has been applied for the AATSR visible channels as described in this technical note. The sites used in this work, listed in Table 1, are a subset of sites identified by Cosnefroy and co-workers (1996) having long term stability and high spatial uniformity.

Table 1: Coordinates of desert targets used in this analysis

	Lat center (°)	Long center(°)	lat-min	Lat_max	long_min	Long_max
Algeria3	30.32	7.66	29.82	30.82	7.16	8.16
Algeria5	31.02	2.23	30.52	31.52	1.73	2.73
Arabia1	18.88	46.76	18.38	19.38	46.26	47.26
Libya1	24.42	13.35	23.92	24.92	12.85	13.85
Libya2	25.05	20.48	24.55	25.55	19.98	20.98
Sudan	21.74	28.22	21.24	22.24	27.72	28.72
Sonora	31.8	-113.86	31.54	32.06	-114.18	-113.54

2 Data Processing

AATSR L1B images containing the test area are first checked for the presence of clouds or dust. Clouds will generally have a higher reflectance than the underlying scene, while the reflectance of wet sand will be lower. Frequent dust storms will generally lower the measured top-of the atmosphere albedo when the surface reflectance is high. In addition, because of the spatial uniformity of the sites chosen, clouds,

wet sand and dust will increase the noise in the top-of-atmosphere radiances measured over an area. All three phenomena will produce a lower brightness temperature than for clear desert.

To test for clouds each image was split into 4km x 4km regions and the ranges (max-min) of the 0.87µm and 1.6µm reflectances, and 11µm and 12µm brightness temperatures, of each region were calculated (ΔR0.87µm, ΔR1.6µm, ΔT11µm and ΔT12µm). Image regions were declared as cloudy pixels if ΔR0.87µm/ Δ0.87µm>0.1. ΔR1.6µm/ Δ1.6µm>0.1, Δ T11µm/T11µm > 0.01 and ΔT12µm/T12µm > 0.01. The spatial test worked well for cumulus, cirrus, localised dust storms and wet sand, but was less effective at detecting large areas of stratus. To account for this, a test was also performed on the brightness temperature distribution of the image. For a mainly cloud free image, a desert scene will have a relatively narrow temperature distribution, having a width typically < 25ºC. Here pixels with brightness temperatures below the main peak are rejected as cloudy. If the width of the main temperature distribution is >25ºC it is probable that the scene is predominantly cloudy and therefore all the data were rejected. For the analysis presented here only scenes that are cloud free over whole region were used.

After rejecting cloudy data, the spatially averaged top-of-atmosphere reflectances were calculated for each site and recorded.

In order to obtain the long-term drift it is necessary first to determine the surface BRDF. The TOA reflectances will mainly be a function of the surface BRDF, $\hat{R}(\theta, \theta_0, \varphi, \varphi_0)$, and the calibration drift, D(t), which are independent functions since the surface is assumed to be radiometrically stable. So the measured scene reflectance can be expressed as

$$R_{scene} = \hat{R}(\theta, \theta_0, \varphi-, \varphi_0)D(t)$$

$\theta, \theta_0, \varphi-, \varphi_0$ are the satellite and solar zenith and azimuth angles respectively. For ATSR-2 it was possible to treat the BRDF as a simple function of the scattering angle, γ,

$$\hat{R} = a_0 + a_1\gamma + a_2\gamma^2$$

where

$$-\cos(180 - \gamma) = \cos\theta \cos\theta_0 \, \theta \cos\theta_0 + \sin\theta \sin\theta_0 \, \theta_0 \cos(\varphi - \varphi_0)$$

The function was fitted to nadir and along track data separately. The measured top-of-the-atmosphere reflectances were then normalised to the anisotropy function [i.e., $R/\hat{R} = D(t)$] and plotted as a time series as in Figure 1. The drift rate, k, was then obtained by fitting the function $D = exp(k*t)$ to the time series. Further iterations of the procedure could be performed to improve the fit of the BRDF although this proved to be unnecessary because of the small drift rates observed.

3 Results

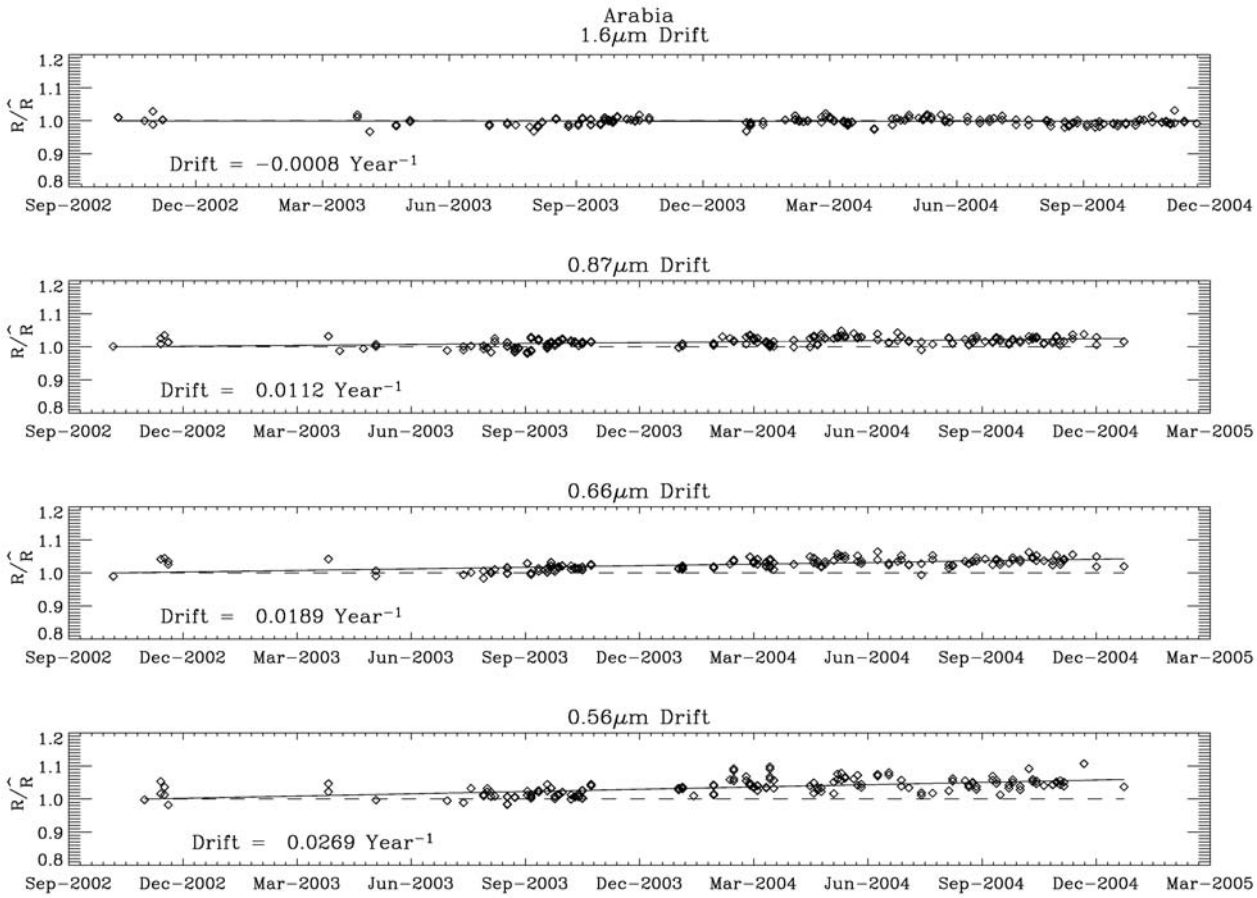

Figure 1: Time series of the normalised AATSR reflectances over the Arabia1 site.

Table 2: AATSR visible channel drift rates in % per year measured over desert targets.

	1.6um	0.87um	0.67um	0.56um	Date Range	
Algeria3	0.7	1.6	1.8	3.3	Oct-02	Dec-04
Algeria5	0.3	1.6	3.0	3.2	Oct-02	Dec-04
Libya1	-0.1	0.9	2.2	4.5	Oct-02	Dec-04
Libya2	0.1	0.5	1.2	3.6	Oct-02	Dec-04
Sudan1	0.4	1.4	1.9	2.6	Oct-02	Dec-04
Arabia1	-0.2	1.1	1.9	2.7	Oct-02	Dec-04
Sonora	-0.1	1.6	2.3	4.0	Oct-02	Dec-04
Average	**0.2**	**1.3**	**2.1**	**3.4**		
Std Dev.	**0.3**	**0.4**	**0.6**	**0.7**		
ATSR-2	0.3	1.1	1.1	1.6	May-95	Jan-00
Std Dev.	0.1	0.3	0.2	0.2		

Time series of the normalised TOA reflectance have been generated for each site to obtain the drift rates given in Table 2. A typical example for the Araba1 site shows that the drift increases towards the shorter wavelengths, Figure 2. This is to be expected as the effect of UV radiation on the white diffuser is to produce a yellowing and was also observed on ATSR-2. The drift rates measured for all sites are consistent with the average.

In comparison, the drifts for AATSR are higher than for ATSR-2 although the measurements for the latter were taken over a much longer timescale. The difference in timescale may also explain the difference in the measurement errors. Continuing the AATSR drift measurements over a longer timescale should reduce these.

It should also be noted that with no on-board calibration, the drift rates would be much higher (7-15% per year depending on wavelength) due to the degradation of the full optical chain.

4 Conclusions

The long term drift rates of the AATSR visible channels have been measured for the period from October 2002 to December 2004.

Table 3

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

For existing AATSR images, a simple correction can be applied by multiplying the reflectance by the drift function

$$D = \exp(-kt/365)$$

where t is the number of days since launch on 01-Mar-2002, and k is the drift rate per year for each channel as given in Table 3.

Future processing and reprocessing should include this drift correction. Ideally this would require a modification to the processing system to apply the drift directly using coefficients contained in a modified GC1 file. However, this is unlikely to be implemented in a reasonable time scale as it has not already been factored into the processing scheme and will require significant effort.

Alternatively the correction can be applied by modification to the VC1 files using a simple batch file. All new VC1 files could be generated using the existing processing tools and then modified with the same batch routine. This should be done at the earliest opportunity.

In the case of all existing VC1 files, the correction should be applied retrospectively in readiness for the reprocessing scheduled for early 2006.

The only problem to address is one of configuration control and providing the right level of information to users. Although modifying the VC1 files is relatively straightforward, the data products will contain no direct indication to users that a correction has been applied. The approach taken is a matter for the QWG to discuss and agree.

5 References

D.L. Smith and C.T. Mutlow and C.R.N. Rao “Calibration Monitoring of the Visible and Near-Infrared Channels of Along-Track Scanning Radiometer-2 (ATSR-2) using Stable Terrestrial Sites”,Applied Optics, 41 no 3, 515-523(2002)

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