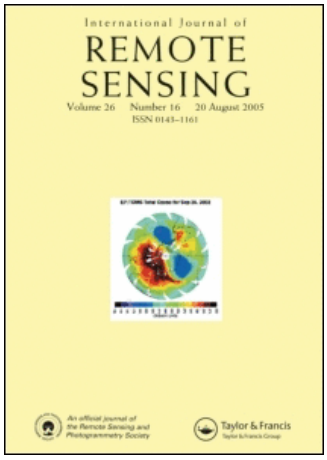

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Updated calibration coefficients for NOAA-14 AVHRR Channels 1 and 2

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Abstract. New calibration coefficients for channels 1 and 2 of NOAA-14 AVHRR are presented. Observations from the radiometrically stable permanent ice sheet of central Antarctica for the period from launch through January 2001 are used to evaluate the accuracy of published calibration coefficients. The rate of sensor degradation in channels 1 and 2 is found to change after January 1998. The new calibration coefficients more accurately characterize sensor performance to date.

1. Introduction

The NOAA-14 satellite, launched in December 1994, carried the Advanced Very High Resolution Radiometer (AVHRR), but no onboard calibration source for channel 1, at 0.64 μm, and channel 2, at 0.84 μm. The sensitivities of these channels are known to degrade with time (Rao and Chen 1995) and calibration coefficients that characterize sensor degradation have been published (Rao and Chen 1996, Tahnk and Coakley 2001a). NOAA regularly upgrades the calibration coefficients imbedded in the NOAA-14 Level 1b data stream. Tahnk and Coakley (2001a) used the interior zones of the permanent ice sheet of Antarctica as a radiometrically stable target to evaluate the accuracy of the published and imbedded calibration coefficients. They derived improved calibration equations based on data for the period from launch to January 1998. In this study, the analysis period is extended to include Antarctic data from January 1999–2000, and from Greenland for May and June 1998–2000. The details of the analysis technique are given in Tahnk and Coakley (2001a).

The study was motivated by an analysis of aerosol optical depths over the Indian Ocean for the five years 1996–2000 (Tahnk and Coakley 2001b). Using the previously published coefficients (Tahnk and Coakley 2001a), optical depths for 2000 were markedly different than in previous years. The change in optical depths prompted a re-examination of the calibration coefficients.

2. Analysis

NOAA-14 AVHRR Global Area Coverage (GAC) measurements (Kidwell 1994) are collected and analysed for the interior zone of the permanent ice sheet on a daily basis for the month of January 1996–2001 for Antarctica, and for May and June 1995–2000 for Greenland. The GAC AVHRR 4-km data are divided into 17 scan

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line by 17 scan spot arrays covering approximately 68 km^2 subregions at nadir. An index of spatial uniformity, N, for the radiances in channels 1–4, is calculated (equation (4) in Tahnk and Coakley, 2001a) for each 68 km^2 subregion and used to minimize cloud contamination.

Loeb (1997) developed calibration curves for the permanent ice sheets using NOAA-9 AVHRR channel 1 and 2 reflectances. The NOAA-9 AVHRR reflectances were linked to other calibration sources and thus serve as a reference (Rao and Chen 1996). The reflectances for the Antarctic ice sheet are given by

$$R_1 = 74.25 + 0.8953\theta_o 0.01233\theta_0^2 \tag{1a}$$

$$R = 60.29 + 0.8305\theta - 0.00915_0^2 \tag{1b}$$

where R_1, R_2 = channel reflectance (in %); θ_o = solar zenith angle (in degrees). (1a) and (1b) are restricted to solar zenith angles between 63° and 80°.

Since launch, the calibration coefficients imbedded in the Level 1(b) data stream have undergone several changes. For the period 1994–1996, the reflectances were given by

$$R_1 = 0.1115C_{10}^1 - 4.5715 \tag{2a}$$

$$R_2 = 0.1337C_{10}^1 - 5.4827 \tag{2b}$$

where R_1, R_2 = channel reflectance (in %); C_{10}^1, C_{10}^2 = channel 10-bit raw pixel count.

For the most recent upgrade, Rao and Chen (private communication) used a desert reference and 1996–1998 data. The revised calibration equations for the period December 1998 to present are given by

$$R_1 = (0.0000135d + 0.111) \times (C_{10}^1 - 41) \tag{3a}$$

$$R_2 = (0.0000133d + 0.134) \times (C_{10}^2 - 41) \tag{3b}$$

where d is day since launch (30 December 1994: $d = 0$), and 41 is the 10-bit raw pixel count for the deep space offset in channels 1 and 2.

Tahnk and Coakley (2001a) developed new calibration coefficients for NOAA-14 AVHRR using the NOAA-9 AVHRR reflectances for Antarctica given by (1a) and (1b). Based on observed NOAA-14 AVHRR reflectances for 1996–1998, the coefficients are given by

$$R_1 = (0.0001195d + 0.1146) \times (C_{10}^1 - 41) \tag{4a}$$

$$R_2 = (0.00000513\,5d + 0.1432) \times (C_{10}^2 - 41) \tag{4b}$$

3. Results

When observations from Antarctica for the period January 1999–2001 were included in the analysis, it was apparent that there was a change in sensor degradation after January 1998. Figure 1 shows the change in the count-to-reflectance 'slope' with time for channel 1 and 2 reflectances, when data from all 6 years are included in the analysis. The dotted line represents the 'slope' from (4a) and (4b), and the dashed line represents the 'slope' imbedded in the NOAA-14 AVHRR Level 1b data stream since December 1998 as given by (3a) and (3b). The rate of degradation in both channels appears to change after 1999, with a decrease in degradation rate in channel 1 and a sharp increase in channel 2.

New calibration coefficients are developed from the 6 years of data for Antarctica using (1a) and (1b) as a reference. The new coefficients are as follows:

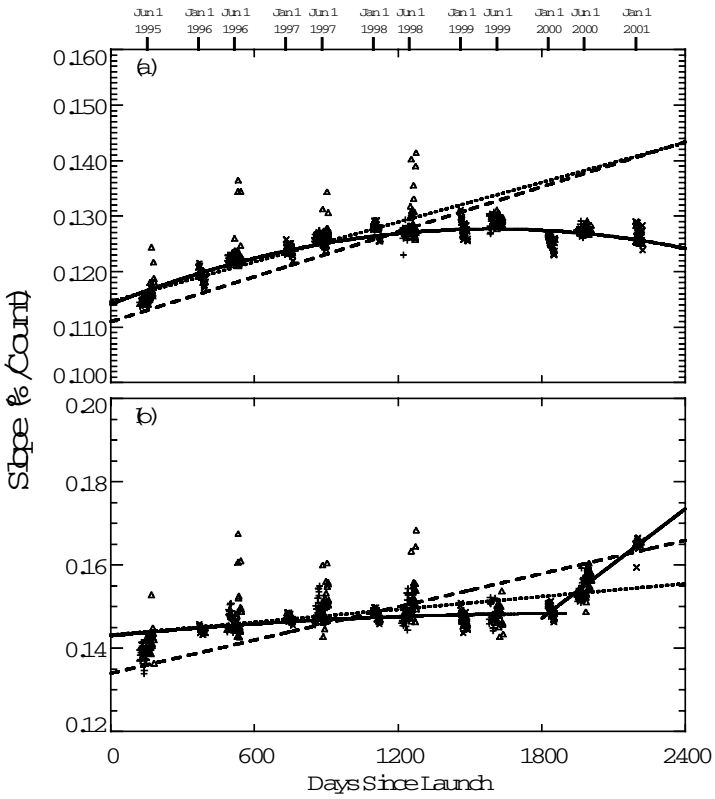

Figure 1. Change in slope with time for (*a*) channel 1, and (*b*) channel 2 of NOAA-14 AVHRR. Plotted symbols represent daily mean 'slopes' for NOA-14 passes from May (+) and June (△) over Greenland for the period 1995–2000, and January (×) over Antarctica for the period 1996–2001. The solid line represents the 'slope' from (5*a*) and (5*b*), the dotted line represents the 'slope' from (4*a*) and (4*b*), and the dashed line represents the 'slope' imbedded in the NOAA-14 AVHRR Level 1b data stream since December 1998 as given by (3*a*) and (3*b*).

For channel 1,

$$R_1 = (-5.35829 \times 10^{-9}\, d^2 + 1.70469 \times 10^{-5}\, d + 0.11414) \times (C_{10}^1 - 41) \qquad (5a)$$

and for Channel 2, from launch to 1 January 2000,

$$R_2 = (-1.46883 \times 10^{-9}\, d^2 + 5.59073 \times 10^{-6}\, d + 0.14302) \times (C_{10}^2 - 41) \qquad (5b)$$

after 1 January 2000,

$$R_2 = (4.38569 \times 10^{-5}\, d + 0.06829) \times (C_{10}^2 - 41) \qquad (5c)$$

The solid line in figure 1 represents the 'slope' from (5*a*) and (5*b*).

Figure 2 shows reflectances for January 1996–2001 for channels 1 and 2 as a function of solar zenith angle for sub-regions where the spatial uniformity index, $N < 0.6\%$. The reflectances are obtained using the calibration formulae given by (5*a*) and (5*b*). Superimposed on the observations are the NOAA-9 AVHRR reference calibration curves (1a) and (1b). The channel 1 and 2 reflectances appear to be well calibrated when compared with the NOAA-9 AVHRR reflectance standard. Note

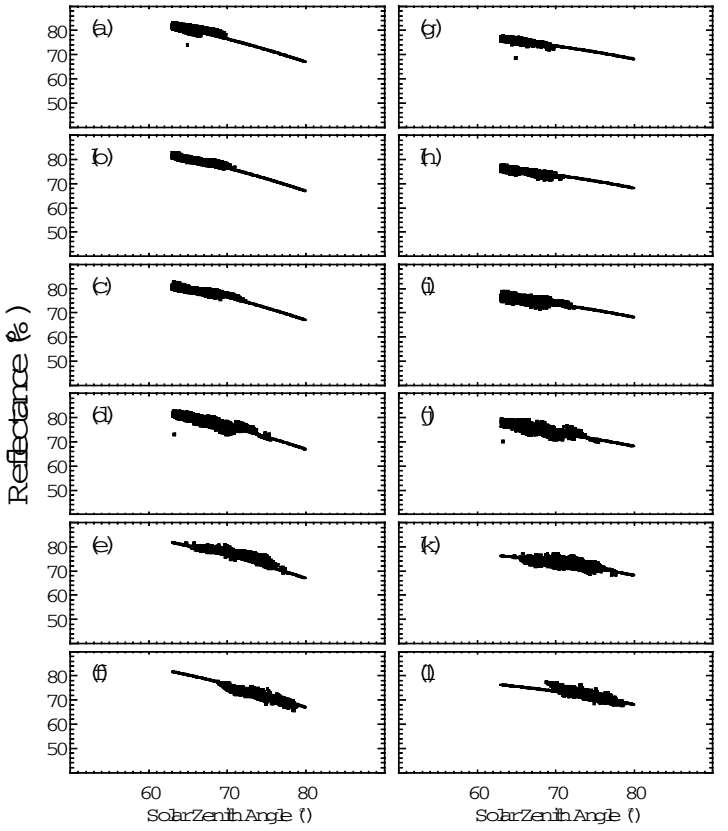

Figure 2. NOAA-14 AVHRR Channel 1 and 2 reflectances and solar zenith angles for 17 pixel × 17 pixel sub-regions with spatial uniformity index, $N < 0.6\%$ in January 1996–2001 for Antarctica. Parts (*a*)–(*f*) represent observations for Channel 1, and parts (*g*)–(*l*) for Channel 2. The solid line represents the NOAA-9 AVHRR calibration reference for Antarctica, from Loeb (1997). The NOAA-14 AVHRR reflectances are obtained using (5*a*) and (5*b*).

the steady progression of solar zenith angle towards higher values as the satellite orbit drifts over time.

Observations over the interior zone of the Greenland ice sheet were used to determine the accuracy of (5*a*) and (5*b*). Daily mean 'slopes' for NOAA-14 AVHRR passes from May and June over Greenland for the period 1995–2000 are included in figure 1. Though the scatter in 'slopes' for Greenland suggests some target variability, the calibration coefficients derived in this study appear to provide stable reflectances for both channels.

4. Summary

Observations from the radiometrically stable permanent ice sheet of central Antarctica are used to evaluate the accuracy of the calibration coefficients previously reported by Tahnk and Coakley (2001a). The rate of sensor degradation in channels 1 and 2 is found to change after January 1998. Using Antarctic observations from January 1996–2001, new calibration coefficients are derived for the period from launch to present. The derived calibration formulae are tested using the central

Greenland ice sheet and proved to adequately account for sensor degradation. It is recommended that (5*a*) and (5*b*) be used to calibrate reflectances from launch to present for NOAA-14 AVHRR channels 1 and 2.

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