CERES TRMM-PFM-VIRS Edition2A SSF
Aerosol Properties - Accuracy and Validation

Data Set Caution: The CERES Team recomends that data users not use Edition2A aerosols. The dependent-channel algorithm used to process CERES TRMM Edition 2A and VIRSonly SSF was found to propagate the under-corrected residual of the thermal leak correction from channel 2 into a well-behaved channel 1. The 25th CERES Science Team Meeting (Brussels, Jan 2002) recommended that in future processing the independent-channel algorithm be re-instated to avoid this propagation. Also, part of the data are corrupted with a software bug that uses CERES relative azimuth instead of VIRS in aerosol retrievals. Questions about Edition2A aerosols may be sent to Alex.Ignatov@noaa.gov.

Introduction

Aerosol optical depths, τ , are being retrieved from calibrated reflectances in channels 1 (0.63 µm) and 2 (1.6 µm) of the Visible Infrared Scanner (VIRS) onboard the Tropical Rainfall Measuring Mission (TRMM) satellite, launched in 1997. The parts of these algorithms unique to the τ retrieval are:

- The need to correct the channel 2 reflectance for a leak of thermal radiation at 5.2 µm, referred to as the "dark albedo" correction.
- Most cloud mask conditions are acceptable for aerosol retrieval: weak-cloud (with 3.7 µm albedo < 3%), strong-clear, weak-clear, aerosol-clear, glint-clear, and smoke-clear.
- All aerosol cases have to pass a 2x2 adjacent pixel uniformity test with VIRS channel 1 reflectance ($R_{1,max}$ - $R_{1,min}$ less than 0.3%).

The change in the aerosol product on SSF Edition2A, as compared to Edition1, stems from

1. introducing a new retrieval algorithm, referred to as the 3rd generation algorithm; and
2. Barnes' thermal leak adjustment (see below).

3rd Generation Algorithm

The 3rd generation algorithm first estimates a retrieval aerosol model from VIRS channels 1 (0.63 µm) and 2 (1.61 µm) assuming a bi-lognormal aerosol size distribution (for the modal radii and widths of the modes, and complex index of refraction, see Higurashi and Nakajima 1999), and solving for the ratio of the modes. The retrieval model is then used to estimate τ_1 and τ_2 in the two channels. These two parameters are stored on SSF as SSF-73 and SSF-74 respectively. Occasionally, the 3rd generation algorithm fails (e.g. when aerosol optical depth is too small to estimate the retrieval model reliably). Then the algorithm backs up to the 2nd generation type (independent-channel, prescribed aerosol model) retrievals (Stowe et al. 1997; Ignatov and Stowe 2000, 2001). Look-up tables of cloud-free reflectances, used for the retrievals, have been pre-computed from the 6S radiative transfer code as a function of τ, and illumination/viewing geometry for a plane parallel atmosphere, bounded by a bi-directional wind-driven (currently, wind speed of 1 m/s is assumed) ocean surface. The retrieval algorithm will be documented in a paper currently in preparation (in the meantime, more detailed information can be obtained from the author of the algorithm, A.Ignatov at Alex.Ignatov@noaa.gov). The calibration and cloud masking algorithms are described in detail in Cloud properties - Accuracy and Validation.

To avoid problems with the spherical atmosphere and specular reflection from the ocean surface, the retrievals are restricted to the following geometrical limits: solar zenith angles less than 70°, relative azimuth angle between 90° and 180°, and glint angle (angle between reflected ray and specular ray for a flat ocean) greater than 40°. (Later analysis by Ignatov and Stowe 2001 suggests that range of sun angles beyond 60° should also be excluded). The VIRS visible and near IR pixel level reflectances are mapped into the CERES Single Scanner Footprint (SSF), and their mean value is computed and saved as an Aerosol A supplement. (See SSF Collection Guide.) This value is used, with the associated geometrical parameters stored on the SSF, to estimate τ_1 and τ_2, which are also stored on the SSF. The Angstrom exponent, α , is estimated as:

$$\alpha = - \ln(\tau_1 / \tau_2) / \ln(0.63 / 1.61)$$

Effective radius, R_{eff}, is estimated as a function of α:

$$R_{eff}=10^{**}(0.637303 - 2.293543^*\alpha + 0.868814^*\alpha^2 - 0.170881^*\alpha^3)$$

Mixing ratio of the two log-normal modes, η , is estimated from Table 1

Table 1: Table for conversion R_{eff} to η

R_{eff}	0.13840	0.16369	0.38848	1.39359	2.22320	2.37058
LOG10(η)	-5	-4	-3	-2	-1	0

Thermal Leak at 1.6 µm

Thermal Leak Correction Algorithm

As mentioned earlier, the channel 2 albedo requires a correction for thermal emission at 5.2 µm. It is termed the "dark albedo" correction because it is quantified as a reflectance equivalent to the infrared radiance observed at night, and it is applied in the daytime. It was developed from one orbit of VIRS pixel level data on May 1, 1998 using regression analysis relating this dark albedo to the thermal radiances in channels 4 (10.8 µm) and 5 (11.9 µm), and view zenith angle, and documented in Ignatov and Stowe (2000). (See also Cloud Properties - Accuracy and Validation.)

Checks of the Thermal Leak Correction Algorithm

To determine the stability of this correction over the entire eight month record of TRMM/CERES SSF, hour = 2 of ValidationR4 SSF nighttime data from the first day of each month were processed. The dark albedo is computed from channel 2 radiance and subtracted from the dark albedo estimated by the regression formula. If the correction is working as expected from the May 1st analysis (Ignatov and Stowe 2000), a histogram of these differences should be centered about 0.0% with extremes less than 0.2% (albedo units; this is equivalent to a $\delta\tau_2$ ~0.04). It was found that for May - August Edition1 data, this was indeed the observed behavior of the dark albedo correction. However, from January - April, the distribution of Edition1 dark albedo residual was centered about -0.2% with extremes from -0.4% to 0.0%. This is consistent with the considerable number of negative τ_2 retrievals observed from consistency analyses. (See Cautions and Helpful Hints.)

Barnes' Adjustment to the Thermal Leak Correction Algorithm

The above analyses thus suggest that the thermal leak component itself is unstable. (It is not clear at this moment if this may have implications in the instability of the reflected component in Channel 2). VIRS calibration was ruled out as a cause, as it has been extensively studied by others on the CERES science team. (See Cloud Properties - Accuracy and Validation.) Additional analysis suggested that additional adjustment term (hereafter called Barnes' adjustment) be added based on detector temperature readings.

When the channel 2 detector temperature exceeds a threshold of 113 K, a radiance adjustment is applied. The adjustment, provided by Barnes, is

$$L2 = L2 + 0.0023879 * B4 - 0.4972,$$

where L2 is the measured VIRS channel 2 radiance and B4 is the channel 4 brightness temperature. The magnitude of the adjustment is -0.02 W m^{-2} sr^{-1} μm^{-1} at a temperature of 200 K and 0.3 W m^{-2} sr^{-1} μm^{-1} at a temperature of 330 K. Note that in Edition2A, channel 2 readings are first adjusted using the Barnes' adjustment, then corrected for thermal leak using the Ignatov and Stowe (2000) algorithm. Although the Barnes' adjustment reduces the occurrence of negative radiances, preliminary analysis shows that there are still periods (e.g. Feb. 04-12, 1998) when the adjusted and corrected radiances in channel 2 are unstable or low. This observation needs further checking.

Validation Study Results And Data Accuracy

Evaluation of the TRMM SSF Edition2A data set is expected to be complete in Spring 2002. At that time, this section and the Validation Study Results section, which follows, will be updated.

Validation Approach

Until the SSF Edition2A data set is evaluated, Edition1 is the most current and complete SSF data set available for analysis. The only quantitative evaluation done with CERES SSF values of aerosol optical depths, τ_1 and τ_2, has been with the TRMM Edition1 SSF version of the data, as reported at the 24th CERES science team meeting. This was done for all Edition1 SSF data from 1998 using the NASA Aerosol Robotic Network (AERONET) system of scanning sky radiometer/sun-photometer instruments and their estimates of τ as ground truth (N=104 daily match-ups were found). With such a small sample it is only possible to assess the performance on a global basis (ensemble of all AERONET sites) of the algorithm, rather than a regional one (at each AERONET location).

Validation Results

Table 2 shows the systematic errors (differences) predicted for the Edition1 SSF parameters "Total aerosol A optical depth - visible", τ_1, and "Total aerosol A optical depth - near IR", τ_2, values at extreme and mean values of optical depth, as derived from linear regression relationships, using τ_1 and τ_2 estimates from Aerosol Robotic Network (AERONET) data as ground truth (Zhao et al. 2001). The standard error of regression is also interpreted to represent the random error of the VIRS retrievals. Table 2 shows that on average, the τ_1 values are biased high by about 0.07 relative to AERONET, with random error of about 0.11. For τ_2, it is high by 0.04, with random error of 0.07.

Table 2: Systematic and Random Errors for VIRS Edition1 SSF

		Systematic Error in τ				
VIRS Channel	**µm**	**Minimum**	**Mean**	**Maximum**	**Random Error**	**Samples**
#1 (τ_1)	0.63	+0.12 at 0.0	+0.07 at 0.17	-0.14 at 1.00	+/- 0.11	104
#2 (τ_2)	1.61	+0.07 at 0.0	+0.04 at 0.09	-0.36 at 1.00	+/- 0.07	104

Word of Caution

One must note that error predictions are essentially worst case, as they do not account for any error coming from the AERONET observations themselves, or for the departure of the ocean/atmosphere system at these island locations from that of the deep ocean, as assumed in the retrieval model. Also, the match-up procedure itself may introduce errors. None-the-less, we offer Table 2 as a VERY PRELIMINARY assessment of the performance of the TRMM Edition1 SSF τ_1 and τ_2 parameters. It will be finalized once the Edition2A SSF data are processed.

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