CERES TRMM-PFM-VIRS Edition2B SSF
Aerosol Properties - Accuracy and Validation

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:

- Most (but not all) cloud-free 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. In addition, all aerosol cases have to pass a 2x2 adjacent pixel uniformity test with VIRS channel 1 reflectance: $R_{1,max} - R_{1,min} < 0.3\%$.
- Ch2 reflectance needs to be corrected for a leak of thermal radiation at 5.2 µm. Two corrections have been made in the past:
  1. Ignatov-Stowe (2000) (implemented with Edition1), and
  2. Ignatov-Stowe (2000) with Barnes-Stowe (2001) adjustment (implemented with Edition2).
- A dependent-channel algorithm ("3rd generation") was introduced with Edition2A (on Edition1, independent-channel "2nd generation" algorithm was run based on Dave radiative transfer model). Analyses of τ_2 suggest that it remains to be strongly contaminated by the residual of the thermal leak corrections. The 25th CERES STM (Brussels, Jan 2002) recommended to
  1. switch back to independent-channel algorithm, and
  2. make one more attempt to improve quality of Ch2.
- An improved independent-channel algorithm has been implemented with Edition2B. It is the one used with Advanced Very High Resolution Radiometer (AVHRR) data in NOAA/NESDIS operations. The algorithm uses pre-computed look-up tables from the 6S radiative transfer code to relate cloud-free reflectances in the VIRS channels 1 and 2 to AOD and illumination/viewing geometry. Atmosphere is considered plane parallel, bounded by a rough ocean surface with wind speed of 1 m/s (Ignatov and Stowe 2002a). Consistency checks of aerosol retrievals from AVHRR using this algorithm are reported by Ignatov and Nalli (2002). The calibration and cloud masking algorithms are described in detail in other sections of this quality summary.
- τ_2 on Edition2B still has thermal leak problem. An improved thermal leak correction is currently being developed, and will be implemented in a future edition of this data set.
- 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° (we do not recommend using data with sun angle greater than 60°, due to pronounced bias in this range of sun angle as reported by Ignatov and Nalli 2002, and Ignatov and Stowe 2002a), satellite viewing zenith angles less than 60°, relative azimuth angle between 90 and 180°, and glint angle (angle between reflected ray and specular ray for a flat ocean) greater than 40°.
- The τ_1 and τ_2 pixel level retrievals are mapped into the CERES Single Scanner Footprint (SSF) and their mean value is computed. In addition to many other VIRS and CERES parameters on the SSF (see SSF Collection Guide), the mean of the VIRS pixel level radiances used to compute the AOD value is also saved. This value can be used, with the associated geometrical parameters stored on the SSF, to test improvements to t using other retrieval algorithms.

Thermal Leak Correction

Ch2 requires a correction for thermal emission at 5.2 µm. It is derived from radiance observed at night, and applied in the daytime.

Ignatov-Stowe (2000) Thermal Leak Correction Algorithm

This correction 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 (Ignatov and Stowe 2000). (See also Cloud Properties - Accuracy and Validation.) To determine the stability of this correction over the entire eight month record of TRMM/CERES SSF, hour = 2 of SSF/Edition1 nighttime data from the first day of each month were processed. Residual of the correction was estimated as the difference between the observed nighttime radiance in Ch2 radiance and that estimated by the Ignatov-Stowe (2000) regression formula. If the correction is working as expected, a histogram of these differences should be centered about 0 with extremes less than 0.2% (albedo units; this is equivalent to a τ_2~0.03). It was found that for May - August 1998, this was indeed the observed behavior of the dark albedo correction. However, from January - April 1998, 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. (W. Miller, personal communication.)

Barnes-Stowe (2001) Adjustment to the Ignatov-Stowe (2000) 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 Ch2). 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-Stowe (2001) adjustment) be added based on detector temperature readings. When temperature is above 113K, this term is calculated as a function of channels 4 and 5 readings. When temperature is below 113K, no adjustment is needed. (Note that in Edition2, Ch2 readings are first adjusted using the Barnes-Stowe (2001) algorithm, then corrected for thermal leak using the Ignatov-Stowe (2000) algorithm). Analyses of 8-month record of τ_2 by W.Miller suggests that the residual of Barnes-Stowe adjustment remains highly unstable in time.

New thermal leak correction algorithm under development

The 25th CERES science team meeting recommended that new analyses are undertaken to improve accuracy of Ch2. Currently these analyses are underway. The correction will be peer-reviewed, and implemented in a future edition of this data set.

Validation Study Results And Data Accuracy

Evaluation of the TRMM SSF Edition2B data set is expected to be complete in 2002. At that time, this section and the Validation Study Results section, which follows, will be updated.

Validation Approach

Until the SSF Edition2B data set is evaluated, Edition2A is the most current and complete SSF data set available for analysis. A quantitative evaluation was done with CERES SSF values ofτ_1 and τ_2 for both Edition1 and Edition2A (Zhao et al., 2002). 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). Considing the possible thermal contamination in the Edition2A data, we apply the independent retrieval algorithm to the Edition2A match-up points to simulate expected Edition2B results since the radiance used in the Edition2A and Edition2B are the same.

Validation Results

Table 1 shows the systematic errors (differences) predicted by the "simulated Edition2B" SSF parameters "Total aerosol A optical depth - visible", τ_1 , and "Total aerosol A optical depth - near IR", τ_2, values at "extreme" (zero and one) 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. 2002). The standard error of regression is also interpreted to represent the random error of the VIRS retrievals. Table 1 shows that on average, the τ_1 values are biased high by about 0.01 relative to AERONET, with random error of s_1 = 0.09. For τ_2, it is biased high by 0.002, with random error of s_2 = 0.04. The aerosol model needs to be adjusted in both VIRS channels, to reduce the remaining systematic error, especially at the large τ. Or, alternatively, cloud contamination should be reduced.

Table 1: Systematic and Random Errors for "simulated Edition2B" SSF

		Systematic Error in τ				
VIRS Channel	**µm**	**Minimum**	**Mean**	**Maximum**	**Random Error**	**Samples**
#1 (τ_1)	0.63	+0.07 at 0.0	+0.005 at 0.17	-0.28 at 1.00	+/- 0.09	104
#2 (τ_2)	1.61	+0.04 at 0.0	+0.002 at 0.08	-0.65 at 1.00	+/- 0.04	104

Word of Caution

At large τ, VIRS retrievals may be biased low, due to either biased aerosol retrieval model, or due to the residual cloud in the CERES FOV. One must note that error predictions are essentially worst case. 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 1 as an assessment of the performance of the "simulated Edition2B" SSF τ_1 and τ_2 parameters. It will be finalized after the Edition2B SSF data are processed.

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