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TWO MODIS AEROSOL PRODUCTS OVER OCEAN ON THE TERRA AND AQUA CERES SSF DATASETS

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Introduction

Terra and *Aqua* carry 4 CERES (Clouds and the Earth's Radiant Energy System) and 2 MODIS (Moderate Resolution Imaging Spectrora-diometer) instruments. CERES science team combines their data on the SSF (Single Scanner Footprint) dataset. Over ocean, two aerosol products are reported. The primary *M-product* is derived from multi-spectral (0.55-2.1 μm) MOD04 generated by the MODIS aerosol group and re-mapped into CERES footprints. The secondary (AVHRR-like) *A-product* is generated at LaRC using a different cloud screening, and applying NESDIS' single-channel aerosol algorithm to radiances in two MODIS bands: 1 (0.65 μm; τ_{A1}) and 6 (2.1 μm; τ_{A2}). A-product is useful to place 20+ yr AVHRR & 6+ yr VIRS aerosol records into more accurate M-context, and to assess multi-channel MODIS improvements.

Objective

1) Document two aerosol products on *Terra/Aqua* CERES SSFs
2) Compare using two weeks of *Terra* data

Data

- *Terra* CERES SSF (Edition 1A)
- 2 weeks of global data (15-21 Dec 2000 and 1-7 Jun 2001)
- A-AODs (τ_{A1}, τ_{A2}) and their M-counterparts (τ_{M1}, τ_{M2})
- Angstrom exponents derived from τ's: $\alpha=-\ln(\tau_1/\tau_2)/\ln(\lambda_1/\lambda_2)$

Terra/Aqua Orbits and Local Obs Times

Nominal local Equator crossing times for *Terra* and *Aqua*: EXT~1030 and ~1330. Due to systematic change in local observation time (LT) with latitude, and due to MODIS cross-scan mode, the actual LT for aerosol retrievals varies. Also, the LT differs for the M- and A-products, primarily due to different glint screening (40°-cone angle around glint point is excluded from both products, plus the solar side of the orbit from the A-product). In this study, *Terra* M- and A-data are used.

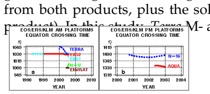

Fig.1. Actual *Terra* (nominal 1030) and *Aqua* (1330) EXT.

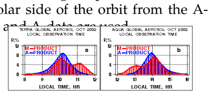

Fig.2. Local times at which actual aerosol retrievals are made.

Specifics of MODIS Radiances/Aerosols

MODIS has 7 solar reflectance bands from 0.47-2.11 μm; 6 are used in the M- and 2 in the A-retrievals. (For cloud screening, more bands are used.) The M-algorithm fits a 3-parameter model (radii of the 2 modes, and mixing ratio) to radiances in 6 bands. The A-algorithm estimates 2 τ using single-channel LUTs (i.e., assuming fixed aerosol microphysics). MODIS radiances are truncated, and so are the retrieved M-AODs.

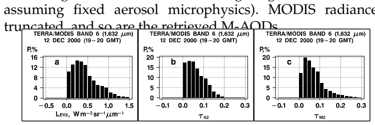

Fig.3. Truncation an (a) MODIS radiances and resulting truncation in (b) A- and (c) M-retrievals.

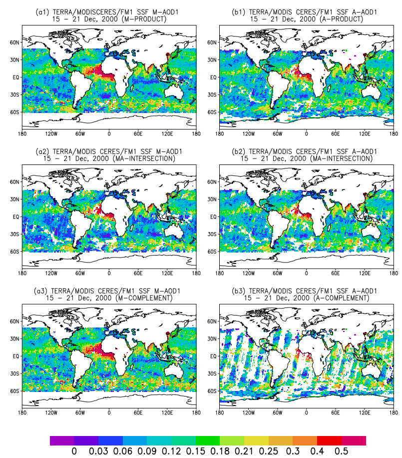

Fig.4. Mapping (left) τ_{1M}- and (right) τ_{1A}-products for different sub-samples of data: (1) full products [M≡(M⊗A)⊕(M⊖A) and A≡(M⊗A)⊕(A⊖M)]; (2) MA-intersection [M⊗A]; and (3) M- and A-supplements [M⊖A and A⊖M].

Definition of Sub-samples

Union sample (M⊕A): CERES FOVs in which either M- or A- product is available. *Intersection* sample (M⊗A): both M- and A-aerosols available.

Supplements (M⊖A, A⊖M): one product is available but the other is not.

M-product: M≡(M⊗A)⊕(M⊖A).

A-product: A≡(M⊗A)⊕(A⊖M).

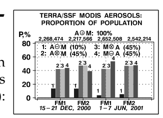

Fig.5. Count of CERES footprints with valid aerosol retrievals in different sub-samples. The *intersection* sub-sample (clusters 2-3) accounts for ~45% of the *union* sample. The *A-supplement* (cluster 1) accounts for ~10%. The *M-supplement* (cluster 4), accounts for ~45% footprints.

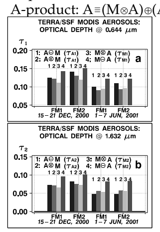

Fig.6. Average τ-retrievals in different sub-samples.

τ-statistics in samples

Fig.6 shows statistical summary of retrievals in different sub-samples. Aerosol-algorithm induced τ-differences (clusters 2-3 in the *intersection* sample) are much smaller than sampling-induced differences (cluster 4 stands apart from clusters 2-3). Geographical domain is close for all sub-samples and cannot explain τ-differences. Retrieval conditions differ. Also note that τ in Jun 2001 is smaller than in Dec 2000.

M- and A-*products*

Show much similarity. Differences are due to:

(1) Different sampling (cloud and glint screening)
(2) Different aerosol algorithms (including treatment of aerosol microphysics, Rayleigh scattering, gaseous absorption, surface reflectance, Radiative Transfer Model, and inversion methods)
(3) Different propagation of data errors (resulting from sensor cal and other radiometric uncertainties.)

MA-*intersection*

In order to highlight aerosol algorithm induced differences, the *MA-intersection* sub-sample was formed. It includes only those CERES footprints in which both M- and A-retrievals are available and therefore sampling differences are minimized (but not removed completely). Agreement between the τ_M and τ_A is closer in the *intersection* sub-sample compared to the *products* samples above.

M- and A-*supplements*

The *supplements* (sub-samples in which one product is available but the other is not; note that areas may look overlapped due to7-day temporal averaging) highlight sampling-induced differences. The τ_M -τ_A differences are larger here than in the *products* (top), and much larger than in the *intersection*. Thus it is concluded that the major differences between the M- and A-products on CERES SSF are caused by differences in sampling (in particular cloud clearing).

Aerosol/Cloud Correlations

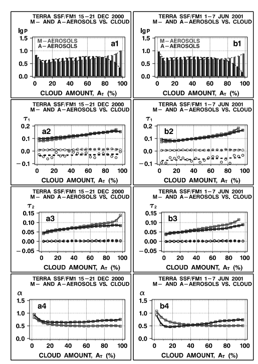

Fig.7. (1) Histograms of cloud amount A_T (ΔA_T= 5%), and (2-4) aerosol retrieval trends for (a) December 2000, and (b) June 2001. In Dec 2000, the average cloud amount is 58% in the M-product and 48% in the A-product. In Jun 2001, A_T=53% and 43% in the M- and A-products, respectively. (Note that cloud amount used here was defined by the CERES team cloud mask algorithm).

Aerosol retrievals are made from cloud-free MODIS pixels within a CERES FOV. Cloudy pixels are used to calculate the total cloud amount in CERES footprint, A_T. The M-product has a larger fraction of CERES FOVs with high A_T>80%. Both M- and A-products correlate with A_T. The average cloud fractions in the M-product are 58% in Dec 2000 and 53% in Jun 2001. In the A-product, the respective A_T are 48% and 43%.

Conclusion

Two aerosol products over ocean are available on the *Terra* and *Aqua* CERES SSF datasets. Cloud screening and aerosol algorithms differ significantly, causing sampling and τ-differences. To estimate their relative effect, special sub-samples have been constructed and analyzed.

The aerosol-algorithm induced differences (evaluated using the *intersection* sub-sample) cause differences of $\Delta\tau_1$~(4±5)×10^{-3}, $\Delta\tau_2$~(3±1)×10^{-3}, and Δα~0.1±0.1. These differences appear to be sun-angle and scan-position dependent, and may reach Δτ~0.04.

Sampling differences are almost an order of magnitude larger: Δτ~(0.030±0.03). Analyses suggests that different cloud screening is most likely the cause. Different domains of scattering angle may also contribute to the observed differences.

Plans

In-depth checks of M- and A-products on *Aqua* and *Terra* CERES SSF for self- and cross-consistency.

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Acknowledgments

The MOD04 algorithms were developed in late 1990s by the international team of scientists (NASA/GSFC, US, and Lab. D'Optique Atmospherique, Univ. of Lille, France) under leadership of Y.Kaufman. The A-product retrievals were initiated in late 1980s by N.Rao (deceased) and L.Stowe (retired) at NOAA/NESDIS following the pioneering ideas by M.Griggs proposed in mid-1970s. The A-product has been enhanced and applied to other sensor data (TRMM VIRS and *Terra/Aqua* MODIS) under the CERES project. Thanks to J.Xiong, W.Barnes, B.Guenther (NASA/GSFC-MCST), C.Moeller (Univ. Wisconsin, Madison), K.Thome (Univ of Arizona), C.Cao and J.Sullivan (NOAA/NESDIS) for helpful discussions of the MODIS radiometric issues. Advice from R.Hucek, S.Mattoo, A.Chu, R.Levy, R.-R.Li, V.Chiang, G.Fireman (NASA/GSFC), Q.Trepte, R.Arduini (NASA/LaRC) is appreciated. This work was funded under NASA/CERES, NOAA/NASA/DOD Integrated Program Office, NOAA/NESDIS Ocean Remote Sensing, and Joint Center for Satellite Data Assimilation Programs. We thank S.Mango (IPO), W.Pichel and E.Bayler (NESDIS) for support and encouragement. The *Terra* CERES SSF data used in this study were obtained from the Atmospheric Sciences Data Center at NASA Langley Research Center. The views, opinions, and findings contained in this report are those of the authors and should not be construed as an official NOAA or U.S. Government position, policy, or decision.

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