MODIS Semi-Annual Report, December 1999

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This reports covers the **aerosol ocean** and **aerosol land** algorithm, and our involvement in the **NIR water vapor**, **cirrus** and the **fire** algorithms.

Main topics addressed in this period:

AEROSOL OVER LAND

1. Development of new methods for remote sensing of aerosol absorption. (*Kaufman, Tanre, Dubovik, Remer and Karnieli*); and a new dust climatology (Tanre et al.)
2. Analysis of spectral properties of land across a transition from desert to vegetation. (*Wald, Remer, Kleidman*)
3. Analysis of data from Mexican smokes events. (*Remer).*
4. Examination of viewing angle dependence of aerosol optical depth retrieval over land (*Li, Kaufman, Chu*)

AEROSOL OVER OCEAN

5. Analysis of the SeaWiFS chlorophyll measurements and radiative transfer look-up tables of dust and sea salt aerosols. (*Levy, Kaufman, Tanre, Fraser)*
6. Study of the TARFOX MAS-derived aerosol properties. (*Levy, Mattoo, Tanre*)
7. Analysis of the SeaWifs measurements during EOPACE-Duck Field Experiment. (*Levy, Kaufman, Remer*)

WATER VAPOR & FIRE

8. Study of total precipitable water over ocean glint. (*Kleidman, Kaufman, Gao*)
9. Comparison and validation of MODIS fire detection algorithm (*Ichoku, Kaufman*)

ALGORITHM ENHANCEMENT & DEVELOPMENT

10. Delivery of MODIS PGE04 algorithms including aerosol (over land and ocean), water vapor, and water vapor correction. (*Chu, Mattoo)*
11. Implementation of dust and smoke aerosol determination criteria. (*Chu, Kaufman*)
12. Tests and diagnostics of PGE04 MODIS algorithms on Windhoek under MODIS operational environment. (*Chu, Mattoo*)
13. Algorithm development of aerosol single scattering albedo. (*Chu, Kaufman*)
14. Development of dust/cloud separation algorithm. (*Ichoku, Kaufman, Remer*)

OTHER TOPICS

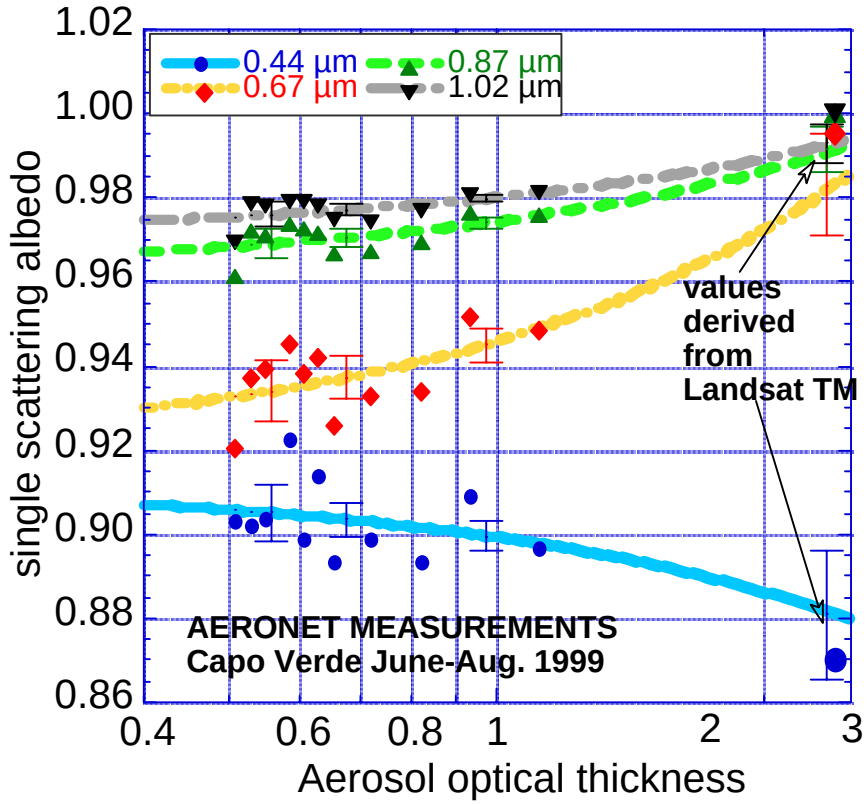
15. Revision of MODIS Atmosphere QA Plan. (*Chu, Kaufman, Remer*)
16. Application of the MODIS aerosol, water vapor, and cloud mask algorithms to all SCAR-B and TARFOX MAS data. (*Li, Remer, Kaufman*)
17. Trajectory analysis of using NCEP wind data for aerosol transport study in Egypt Africa. (*Ichoku, Li, Remer, Kaufman)*
18. Development of MODIS aerosol subsetting and visualization software. (*Ichoku, Remer, Chu*)
19. ASD measurements of surface properties over land and ocean *(Levy, Remer, Kleidman, Ichoku, Mattoo*)
20. Use of global transport models to estimate the limitations of MODIS estimates of aerosol forcing. (*Remer, Kaufman, Levin*)
23. Study of snow detection using 0.66 and 2.1 μm channels (*Kleidman, Kaufman*)
24. Participation in Dead Sea Haze Experiment (*Kleidman, Kaufman*)
25. Paper acceptance/submission/preparation. (*Kaufman, Remer, Kleidman, Ichoku, Chu, Levy*)
26. Meeting & workshop. (*Kaufman, Remer, Chu, Mattoo, Li, Kleidman, levy, Ichoku*)

OTHER TOPICS

1. Work with MODIS data!!!!!
2. Develop routine evaluation stratgy with the data
3. Compare analysis of Landsat 7 with MODIS on 20 cases
4. Develop new experimental algorithms for the aerosol single scattering albedo and others

1. Development of a new method for remote sensing of aerosol absorption

The ability of dust to absorb solar radiation and heat the atmosphere is one of the main uncertainties in climate modeling and the prediction of climate change. Dust absorption is not well known due to limitations of *in situ* measurements. In this paper we report two new independent remote sensing techniques that provide sensitive measurements of dust absorption. One uses satellite spectral measurements, the second ground based sky measurements. Both techniques demonstrate that Saharan dust absorption of solar radiation is several times smaller than the current international standards and, therefore, dust cooling of the earth system in the solar spectrum is 40% stronger than recent calculations indicate. Using AERONET data and satellite inversions a new dust climatology was derived. Paper was submitted to the dust special issue (Tanre et al.)



This figure shows that the inversion of the AERONET data for the aerosol single scattering albedo if extrapolated to high optical thicknesses, fits the satellite retrievals. We hope to have many such cases from MODIS

2. Analysis of spectral properties of land across a transition from desert to vegetation

Representative target spectra selection based on video imagery have been chosen. Analysis for the effect of the surface spectral properties on the MODIS column water vapor and aerosol optical depth completed. A paper was submitted by Remer et al and two papers are in preparation (Karnieli et al. and Wald et al.).

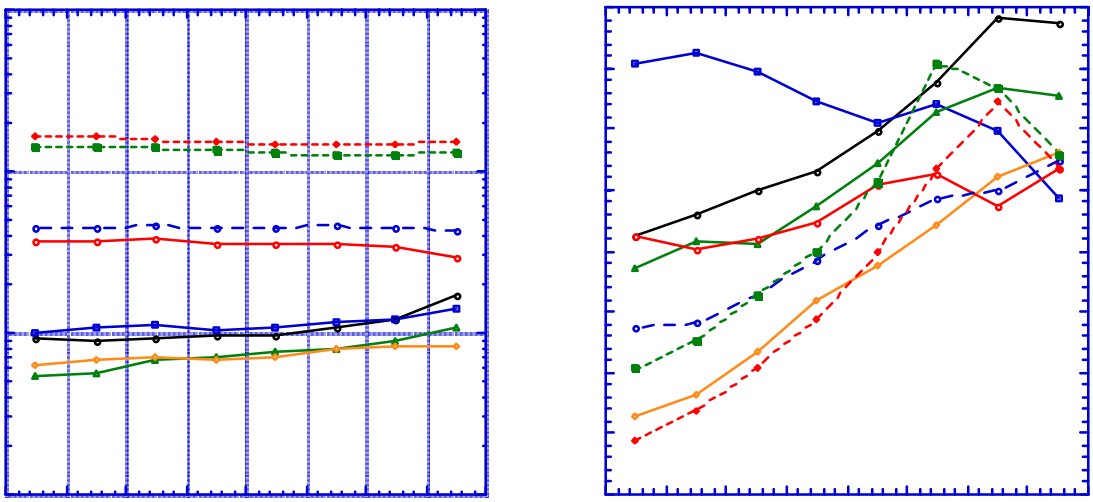
3. Analysis of data from Mexican smoke event

Our measurements of the smoke from the Southern Mexico and Central American biomass burning episode were mostly made after the wind shift carried the fresh smoke westward over the Pacific Ocean. This gave us the opportunity to observe the aging of the older residual smoke over a wide regional area. The smoke particles of the older Mexican smoke tended to be a larger size than the average smoke particles observed in previous campaigns in

South America and Africa. The effect on the phase function is relatively small, introducing manageable errors to the MODIS retrieval algorithms and increasing the aerosol radiative forcing by only 10%. A paper was submitted for publication by Remer et al.

4. Examination of viewing angle dependence of aerosol optical depth retrieved over land

The viewing angle dependence of aerosol retrieval is examined near the principal plane (azimuth less than 20 deg) using MAS-derived optical thickness from SCAR-B measurements. Noticeably the viewing angle dependence is more pronounced for optical depth < 0.3, which is not surprised because of the uncertainties in surface reflectance. It is still well within the expected uncertainty of ±0.05. For optical thickness > 0.3, the viewing angle dependence becomes relatively small. The bi-directional reflectance distribution function (BRDF) may contribute to the uncertainties in surface reflectance but is not taken into account, so are the inhomogeneity of aerosol distribution and surface types and reflectance.



Using large assemble of data from SCAR-B, this figure shows that despite the strong variability of the surface angular properties (right) the retrieved aerosol optical thickness does not depend on the view angle (left) more than ±0.03.

5. Analysis of SeaWiFS chlorophyll measurements and radiative transfer look-up tables of dust and sea salt aerosols

Chlorophyll concentrations show stronger absorption with decreasing wavelength from 0.86 to 0.41 μm, which closely correlates with dust absorption in the near-UV wavelength. As a result, the aerosol and chlorophyll signals can't be easily separated for all aerosol optical depths. For larger aerosol depths, the retrieval of aerosol properties can only be done if the aerosol type is known. Eigenvalue analysis applied to chlorophyll observation shows that 85% (out of 791 chlorophyll observations) of chlorophyll signals can be modeled by the first eigenvector except at 0.55 μm.

6. Study of TARFOX MAS-derived aerosol properties.

Overall the study shows that the retrievals obtained using a new look-up table are similar to those with an old look-up table. In other words, no systematic bias are found from the change of old to new tables. However, individual pixels or scans may look quite different. The largest changes are found in retrieved aerosol effective radius (up to 0.1 μm). We can also conclude that adding a small mode "dust-type" particle, while maybe physically relevant, caused bad retrievals. The discontinuity of aerosol retrieval is found due to the selection of aerosol models.

7. Analysis SeaWifs overpass measurements during EOPACE-Duck Field Experiment

Several SeaWifs images are analyzed in terms of reflectance, aerosol optical depth, and chlorophyll for the EOPACE-Duck field experiment in the North Carolina coast from February 18 to March 15, 1999. It is planned to analyze ground observations from radiometers, Micropulse lidar and CIMEL Sun photometer, along with overpass satellite measurements and downward-looking sunphotometer onboard a small airplane.

8. Study of total precipitable water over ocean glint

Over ocean glint, good agreement is found for total precipitable water derived using 2-channel ratio method from MAS measurements and the results from LASE measurements collected during TARFOX experiment. It concludes that we can derive total precipitable water over ocean glint region (due to specular reflection) within the accuracy of 10-20%. A paper "Remote Sensing of Total Precipitable Water Vapor in the Near-IR Over Ocean Glint" is submitted to GRL.

9. Comparison and validation of MODIS fire detection algorithm

Detailed analysis and validation of MODIS fire detection algorithm are performed using AVHRR images in the fire season May-October 1995. Errors are found and corrected in various fire detection codes from IGBP (International Geosphere and Biosphere Program), ESA (European Space Agency) and CCRS (Canada Center for Remote Sensing) during the inter-comparison effort. In conclusion, MODIS fire algorithm is too conservative to catch small-scale fires, it however catches 80% energy released from fires. The conservative approach is chosen to avoid false fire detection.

10. Delivery of MODIS PGE04 algorithms including aerosol, water vapor, and water vapor correction

The new MODIS PGE04 (version 2.4.0) algorithms including aerosol, water vapor and water vapor correction was delivered in September 29, 1999 for the integration into the MODIS data production stream. For aerosol algorithm over land and ocean, the enhancements are the use of new look-up tables of dust, the derivation of reflected and transmitted fluxes, and the lessons learned from MODAPS X-day, Y-day, and N-day processing. Updated QA flags and metadata are also included, as well as the new parameters of scattering angle and optical thickness at 0.55 μm in levels 2 and 3 products. Water vapor correction due to aerosol is included in the PGE04 algorithm. The correction factor is documented in the level 2 product.

11. Implementation of new dust and smoke aerosol determination criteria

With the hybrid phase function constructed assuming 80% spherical and 20% non-spherical particles (based upon the ratios of non-spherical and spherical phase functions from M. Mishchenko et al. [1997]), the application to SCAR-B AVIRIS data shows much clear separation of smoke and dust in the path radiance ratio. It allows better identification of aerosol types. The separation zone is set to allow the uncertainties due to refractive index, aerosol absorption, and size distribution. This new criteria is implemented into MOD04 aerosol algorithm.

12. Tests and diagnostics of PGE04 MODIS algorithms on Windhoeck under MODIS operational processing environment

The PGE04 algorithms have been tested on Windhoek (MODIS atmosphere group designated computing facility) under the MODIS operational processing environment after the delivery to MODIS SDST. Several quick fixes are required due to Forcheck errors and for the compliance with ECS requirements. The NCEP data of total precipitable water, total ozone, and surface temperature are

changed to "necessary requirement" in production rule. Redelivery is made after the fixes of the problems.

13. Algorithm development of aerosol single scattering albedo

Single scattering albedo is a critical parameter in the retrieval of aerosol properties for aerosol radiative forcing. Different aerosol shows a different single scattering albedo, which is also spectrally dependent. The derivation of the single scattering albedo operationally will improve not only the aerosol retrieval and reduce the uncertainties but also the understanding of aerosol direct and indirect aerosol forcing. Different methods (land/water contrast, spectral contrast and haze/clear contrast) will be employed to derive the single scattering albedo globally. Preliminary analysis is underway using the SCAR-B MAS measurements.

14. Development of dust/cloud separation algorithm

Landsat-5 TM (1987 & 1997) and TARFOX MAS (1996) data are used to test the dust/cloud separation scheme over ocean surface. The scheme uses 1×1 km grid box of the measurements of 2.1 μm reflectance and 11 μm brightness temperature. The scatter plots of the quantity (mean/standard deviation) of the TM image in Western Africa coast (1987) and the MAS image in TARFOX (1996) show similar pattern of clear separation between dust and clouds, whereas less clear separation is found in TM image (1997) in the coast of California around St. Nicholas Island. The reason is not known. The investigation of the spectral variation in reflectance (in terms of aerosol, clouds, and ocean surface) is underway.

15. Revision of MODIS Atmosphere QA Plan (version 2.0)

The MODIS Atmosphere QA Plan is revised to include more detailed post-processing QA procedures, including visualization software, statistical analysis report (i.e., time series, histogram), ancillary data (GOES, AVHRR, MISR, POLDER, OCTS, TOMS, etc.), and finally the update of science QA flag. The QA network systems are defined to include GDAAC, MODAPS, and Windhoek (MODIS atmosphere computing facility) with clear responsibilities of personnel in each group. Possible QA scenarios are also included.

16. Application of the MODIS aerosol, water vapor and cloud mask algorithms to all SCAR-B and TARFOX MAS data

The MODIS aerosol, water vapor and cloud mask algorithms are applied to all SCAR-B and TARFOX MAS data. Consistent statistics are derived in SCAR-B

that smoke aerosol and water vapor show virtually no correlation in both forest and cerrado region, regardless of higher aerosol optical depth retrieved in the forest than that in the cerrado. In TARFOX, the MAS-derived optical thickness is much lower compared to that in SCAR-B but with the accuracy better than expected. Sun glint contamination is still a problem to be solved. This is an effort to fully evaluate the MODIS aerosol algorithms over land and ocean.

17. Trajectory analysis of using NCEP wind data for aerosol transport study in Egypt Africa

Trajectory model (code 916) is used to analyze the aerosol transport according to NCEP wind data in 1998 in Egypt, Africa. The Microtop II sunphotometer was used to measure the aerosol optical thickness at Alexandra, Egypt. High aerosol optical thickness (>0.5) are found due to Kamaseen dust storms originated in Spring (March-April) in Sahara desert and low aerosol optical (<0.06) thickness are found due to air pollution in Western Europe. Altitude dependence is found in terms of aerosol types (dust, sulfate, and mixed) as a result of the back trajectory analysis. Angstrom coefficient (derived based upon wavelengths ?) is used to distinguish the aerosol types. The larger the aerosol particle, the smaller the Angstrom coefficient, and vise versa.

18. Development of MODIS aerosol visualization software

The MODIS after-launch visualization software is under development for visualization and validation purposes. The preliminary application has been successfully applied to L2 aerosol product during MODIS N-day and X-day tests. Enhancement and improvement of the software continue to include capabilities of linking of L3 global map to L2 granules and the subsetting of ground validation sites. Aerosol properties retrieved from MODIS measurements and AERONET ground-based sunphotometer aerosol optical thickness data are grouped into a user-friendly database. Global maps and statistical results are to be produced daily, weekly and monthly.

19. ASD measurements of surface properties over land and ocean

Several airborne measurements of using ASD instrument onboard a small 4-seater airplane are collected over Maryland, Florida and California. The purpose is to acquire measurements of surface properties under clear (cloud-free and aerosol-free) condition. ASD instrument provides the measurements in the solar spectrum from 0.4 to 2.2 μm.

20. Use of global transport models to estimate the limitations of MODIS estimates of aerosol forcing

We intend to combine the results of global transport models with AERONET data and MODIS data in order to make the best estimate of global aerosol radiative forcing both the direct and indirect effects. As a pilot study, we asked the question of how much of the global radiative forcing occurs in regions where the aerosol optical thickness is large enough to be retrieved from MODIS with sufficient accuracy. To do this study we used the model results of Tegen et al. (1997) and ISCCP climatology. The model data severely underestimated aerosol optical thickness in smoke regions close to the sources when validated by AERONET data. The model data was then adjusted to agree with AERONET. The results show that MODIS will be able to see most of the direct forcing, but perhaps only 50% of the indirect forcing. An interesting byproduct of this analysis indicates that on a global basis cloud fraction is inversely correlated with aerosol, which suggests that estimates of indirect forcing may be too high. Further studies using this model and others are planned.

23. Study of snow detection using 0.66 and 2.1 μm channels

Preliminary study of determination of fractional snow cover using the reflectance ratio of 0.66 to 2.1 μm is underway. A carefully mapped TM snow scene is being used to develop and test the algorithm. The relationship between 0.66 and 2.1 μm is used to identify snow pixels and distinguish them from vegetation. The algorithm is expect to be able to detect subpixel snow of several percents. In the process we discovered that MODIS snow algorithm is insensitive to snow contamination when trying to identify snow free pixels.

24. Participation in Dead Sea Haze Experiment in Israel

The deployment of sunphotometer was made in October 1999 to observe sulfate aerosol due to urban pollution. Participation in the Dead Sea Haze experiment in Israel is to set up and maintain a sunphotometer. Variable aerosol types were observed dependent upon the season. The mixture of different aerosols, such as sulfate and dust, are often seen in this region. The data collected will be used to analyze the aerosol properties and to improve the MODIS aerosol algorithm.

25. Paper acceptance/submission/preparation

Chu, D. A., Y. J. Kaufman, D. Tanré, B. N. Holben, R. R. Li, Smoke optical properties derived from airborne measurements in Brazil, in preparation to submit to JGR.

Kaufman, Y. J., A. Karnieli and D. Tanré, Detection of dust over the desert by EOS-MODIS. *IEEE TGARS accepted.*

Kaufman, Y. J., D. Tanré, O. Dubovik, A. Karnieli, and L.A. Remer, 1998: Satellite and Ground-based Radiometers Reveal Much Lower Dust Absorption of Sunlight than Used

in Climate Models, submitted to Science Jan 2000
Kaufman, Y.J. , D. Tanré and L. A. Remer New Frontiers in Remote Sensing of Aerosols and Their Radiative Forcing of Climate, in Frontiers in Research of Climate Change, Kiehl and Ramanathan Editors.
King, M. D., Y. J. Kaufman, D. Tanré, and T. Nakajima, 1998: Remote sensing of tropospheric aerosols from space: past, present and future. *Bull. of Meteor. Soc*.. **80**, 2229-2259, 1999
Kleidman, R. G., Yoram J. Kaufman, Lorraine A. Remer, Richard A. Ferrare and Bo-Cai Gao , Remote Sensing Of Total Precipitable Water Vapor In The Near-IR Over Ocean Glint, submitted to GRL
Li, Z., Y. J. Kaufman, C. Ichoku, R. Fraser, A. Trishchenko, L. Giglio, J. Jin, 2000, A review of satellite fire detection algorithms: Principles, limitations, and recommendations, *Rem. Sens. Environ*., A special issue on GOFC-FIRE, Submitted.
Remer, L.A., A.E. Wald, Y.J.Kaufman, Angular and seasonal variation of surface reflectance ratios: Application to the remote sensing of aerosol over land. *IEEE Transactions on Geoscience and Remote Sensing*, submitted.
Sabbah I., Charles Ichoku, Yoram Kaufman, and Lorraine Remer, Climatology of desert dust spectral optical thickness and precipitable water vapor over Egypt in 1998, submitted to JGR.
Tanre, D., Y. J. Kaufman, B.N. Holben, B. Chatenet, A. Karnieli,F. Lavenu, L. Blarel, O. Dubovik, L.A. Remer, A. Smirnov: Climatology of dust aerosol size distribution and optical properties derived from remotely sensed data in the solar spectrum, JGR dust special issue subitted Dec 99.

26. Conference/workshop

GOFC (Global Observation of Forest Cover) Fire monitoring workshop in Ispra, Italy, from November 1-7, 1999 (*Ichoku*)

MODIS Atmosphere Group meeting, Goddard Space Flight Center, Greenbelt, November 14, 1999. (*Remer, Chu, Mattoo, Li, Levy, Ichoku*)

American Geophysical Union Fall Meeting, San Francisco, California, December 13-17,1999. (*Kaufman, Remer, Levy*)

AAAR Oct. 1999 Takoma Washington, tutorial on remote sensing of aerosol and its radiative forcing. (Kaufman)

Guenther conference on Atmospheric Chemistry, Oct. 1999 Israel: : Re-evaluation of dust absorption and radiative forcing of climate using satellite and ground based remote sensing. (Kaufman).

Workshop on Frontiers in the science of climate modeling, Scripps, Oct., 1999: Measurements of Aerosols from Space. (Kaufman)

Kyoto workshop on aerosol and clouds, Dec, 1999: Remote sensing of aerosol direct radiative forcing at the top and bottom of the atmosphere using MODIS and AERONET. (Kaufman, Remer)