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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 a new method for remote sensing of aerosol absorption. (*Kaufman, Tanre, Remer*)
2. Analysis of spectral properties of land in Maryland and across a transition from desert to vegetation in Israel. (*Remer, Kleidman*)
3. Analysis of effect of heavy smoke on aerosol radiative forcing using SCAR-C AVIRIS data. (*Kaufman, Li)*
4. Analysis of data from Mexican smoke event. (*Remer*)
5. Test of the criteria of dust and smoke aerosol determination scheme using SCAR-B AVIRIS data. (*Chu, Kaufman*)

AEROSOL OVER OCEAN

6. Analysis of TARFOX data over ocean. (*Tanre, Remer, Mattoo, Kaufman)*
7. Analysis of SeaWiFS chlorophyll measurements and radiative transfer look-up tables of dust and sea salt aerosols (*Levy, Kaufman, Tanre, Fraser)*

WATER VAPOR

8. Analysis of water vapor retrievals on SCAR-B AVIRIS data using different pairs of MODIS channels. (*Chu, Kaufman*)
9. Study of total precipitable water over ocean glint. (*Kleidman, Kaufman*)

ALGORITHM ENHANCEMENT & DEVELOPMENT

10. Implementation and integration of cirrus detection / removal scheme into MODIS aerosol / water vapor PGE. (*Chu, Kaufman, Gao*)

11. Enhancement of MODIS aerosol algorithm over land and ocean. (*Chu, Mattoo*)
12. Test and diagnostics of MODIS aerosol algorithm on windhoek under MODIS operational environment. (*Chu, Mattoo*)
13. Algorithm development of the derivation of single scattering albedo of aerosols. (*Chu, Kaufman*)

OTHER TOPICS

14. Application of MODIS aerosol, water vapor and cloud mask algorithms to SCAR-B MAS data. (*Li, Mattoo, Remer*)
15. Application of cirrus cloud detection / removal scheme to AVIRIS images. (*Li, Gao, Kaufman)*
16. Calibration of hand-held Microtops II sunphotometers. (*Ichoku, Kaufman, Levy, Remer*)
17. Development of MODIS aerosol visualization software. (*Ichoku, Remer, Chu, Kaufman*)
18. Use of global transport models to estimate the limitations of MODIS estimates of aerosol forcing. (*Remer, Kaufman, Levin*)
19. Paper submission / acceptance. (*Kaufman, Remer*)
21. Meeting / workshop. (*Kaufman, Remer, Chu, Mattoo, Li, Kleidman, levy, Ichoku*)

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

Simultaneous spaceborne and ground-based solar radiation measurements create a powerful novel tool to determine absorption of solar radiation by dust. Absorption is a key component of the dust radiative forcing of climate at the top of the atmosphere. It affects the temperature profile and cloud formation. We use Landsat spaceborne measurements at 0.47 to 2.2 μm over Senegal with ground based sunphotometers to find that Saharan dust absorption of solar radiation is two to four times smaller than in models. Though dust absorbs in the blue, the absorption for wavelengths > 0.6 μm is 0 to 1% (±0.5%) of the total light extinction, much smaller than the 10-35% in present models. The new finding increases by 50% recently estimated solar radiative forcing by dust at the top of the atmosphere, and decreases the estimated dust heating of the lower troposphere. Dust transported from Asia shows slightly higher absorption (0-7%) probably due to the presence of black carbon from populated regions. A paper was submitted to JGR.

2. Analysis of spectral properties of land in Maryland and across a transition from desert to vegetation in Israel

We analyze low flying aircraft spectral data for the impact of surface spectral properties on the aerosol and water vapor algorithms. A paper is in preparation for the data from Maryland that shows that the remote sensing of aerosol from MODIS is tested positively against this data set, except for specular reflection over the land. We shall have to correct the land aerosol algorithm to eliminated specular reflection zone in a similar way to what we do over the oceans. Arnon Karnieli from the Israeli Desert Inst. works with us in the analysis of the Israeli spectral data. We anticipate to generate a web page with all the data for the public and to write a paper that tests the impact of surface properties on the MODIS aerosol and water vapor algorithms.

3. Analysis of effect of heavy smoke on aerosol radiative forcing using SCAR-C AVIRIS data

Several heavy smoke scenarios in SCAR-C AVIRIS database were further analyzed for different solar zenith angles, in order to test the sensitivity of solar fluxes reflected by the smoke to space to illumination conditions. The data set is used to estimate the ability of MODIS to estimate directly the smoke direct forcing of climate.

4. 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%.

5. Test of the criteria of dust and smoke aerosol determination scheme using SCAR-B AVIRIS data

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 resulting from M. Mishchenko et al. [1997]), the application to SCAR-B AVIRIS data shows clear separation of smoke and dust in the path radiance ratio. The separation zone is set to allow the uncertainties due to refractive index, aerosol absorption and size distribution.

6. Analysis of TARFOX data over ocean

A complete set of TARFOX images has been analyzed to test the MODIS aerosol algorithm over ocean. The retrievals shows good

comparison with in-situ measurements, in particular, for effective particle size. The test of glint angles indicates the current limit of glint angle should be changed from 30° to 40° to improve the retrieval. QA flag of glint angle between 40 and 50 is added to indicate the range. A few shortcomings of subroutines were also corrected. A paper was published in JGR.

7. 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. Eigenvalue analysis applied to chlorophyll observations shows that 85% (out of 791 chlorophyll observations) of chlorophyll spectral signal can be modeled by the first eigenvector. But this eigenvector has the same spectral properties as the difference between dust and salt. So for moderate optical thickness there seems to be no way to distinguish between dust and salt in the presence of unknown chlorophyll. Same may be true for measuring chlorophyll in the presence of uncertianty in the dust/salt relative concentrations. A paper is being written on the subject.

8. Analysis of water vapor retrievals on SCAR-B AVIRIS data using different pairs of MODIS channels.

Different MODIS water vapor absorption channels have been tested for the derivation of column water vapor from SCAR-B AVIRIS data using a 2-channel ratio method. Because of surface reflectance varying with wavelength, the closest pair of water vapor absorption and window channels (0.86 and 0.91 μm) has shown to be most accurate to derive column water vapor, which leads to the selection of the radiometer channel at 0.91 μm to measure the column water vapor for a Triana instrument. The linear interpolation of surface reflectance values from two adjacent window channels using a 3-

channel ratio method overestimates the water vapor retrievals because of iron absorption in the soil in Brazil.

9. Study of total precipitable water 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 over ocean glint collected during TARFOX experiment. It indicates that we can also derive total precipitable water over ocean glint region within the accuracy of 10-20%. A paper "Remote Sensing Of Total Precipitable Water Vapor In The Near-IR Over Ocean Glint" is in progress to submit to GRL.

10. Implementation and integration of cirrus detection/removal scheme into MODIS aerosol/water vapor PGE

The detection and removal of cirrus clouds are important for aerosol retrieval since cirrus clouds contribute to the signal received by the satellite. By removing cirrus path radiance before aerosol retrieval, we can reduce the uncertainties in the aerosol properties retrieved. The spectral variation of cirrus clouds from visible to near-IR (0.4 to 2.1 μm) needs to take into account. The modified cirrus detection / removal scheme will calculate cirrus clouds path radiance at 1.6 and 2.1 μm wavelength, in addition to that in the visible wavelength for aerosol retrieval over ocean. Over land, it is now only applicable to the visible wavelength because of the complex underlying surface features.

11. Enhancement of MODIS aerosol algorithm over land and ocean

Dust look-up tables using new dust model are generated for aerosol retrievals over land and ocean. The new dust model is based upon more realistic aerosol size distribution, nonsphericity of dust particles and dust absorption. Other enhancements include aerosol type

determination using path radiance ratio over land and changes of quality control flags and metadata over ocean.

12. Diagnostics and test of MODIS aerosol algorithm on windhoeck under MODIS operational data processing environment

PGE04 has been successfully tested on Windhoek (MODIS atmosphere group designated computing facility for data processing and new algorithm development) under MODIS operational data processing environment. Several significant problems has been encountered due to the incompatibilities of toolkits (PGS, MAPI, HDF) and shared codes. It is a good exercise to move the algorithm development from current DEC to SGI computing environment, compatible to MODAPS (MODIS Data Processing System).

13. Algorithm development of the derivation of aerosol single scattering albedo

Aerosol single scattering albedo, a measure of aerosol absorption, is a critical optical parameter in assessment of the impact of aerosol on climate change and in the retrieval of aerosol from MODIS. The single scattering albedo varies from one aerosol type to another and is also spectrally dependent. To derive the single scattering albedo operationally will improve significantly the aerosol retrieval and reduce the uncertainties. Different methods (land / water contrast, spectral contrast and haze / clear contrast) will be employed to derive the single scattering albedo globally, in a new post launch algorithm.

14. Application of MODIS aerosol, water vapor and cloud mask algorithms to SCAR-B MAS data

The application of MODIS aerosol and water vapor algorithms to SCAR-B MAS data has focused on the cloudy scenes of September 4 and 11, 1995. Consistent statistics are derived - 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. This is an effort to fully evaluate the MODIS algorithms and will continue until the launch of MODIS on EOS-Terra satellite.

15. Application of cirrus cloud detection/removal scheme to AVIRIS images

The application of MODIS cirrus detection/removal algorithm to AVIRIS images shows promising results over land and ocean using 1.38 μm channel. In addition to visible wavelength, the correction of cirrus effect at 1.64 and 2.13 μm is also studied. As expected, the cirrus effect at these two wavelengths is found to be smaller than that in the visible. The cirrus correction is important to improve vegetation index, water-leaving radiance and the retrieval of aerosol optical thickness. By removing cirrus cloud, low clouds can be seen, which is useful for aerosol-cloud interaction study.

16. Calibration of hand-held Microtops II sunphotometers

Microtops II sunphotometers are used by us to supplement the AERONET network with MODIS validation when needed and on an "emergency basis", if problems with the algorithm are detected. Calibration of hand-held Microtops II sunphotometers is completed. Anomalies in 0.94 μm water vapor are found due to incorrect calibration of aerosol properties derived from adjacent aerosol channels, which results in false correlation between water vapor and dust aerosol as observed in Alexandria Egypt. Long-term calibration is planned for the use of the Microtops II sunphotometers in Egypt and Israel.

17. Development of MODIS aerosol visualization software

The after-launch visualization software is developed for visualization and validation purposes. The preliminary application of the software to MODIS N-day and X-day tests is successful for L2 aerosol product. Enhancement and improvement of the software will continue to include L3 global maps and the flexibility of selecting different

validation sites over ocean and land. 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 going to be produced daily, weekly and monthly.

18. 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. This may explain why we are not heading towards an ice age despite the theoretically strong aerosol effect. Further studies using this model and others are planned.

19. Paper submission/acceptance

Tanré, D., L.R. Remer, Y.J. Kaufman, P.V. Hobbs, J.M. Livingston, P.B. Russel, A. Smirnov, 1999: Retrieval of Aerosol Optical Thickness and Size Distribution Over Ocean from the MODIS Airborne Simulator during Tarfox, J. Geophys. Res, 104, 2261-2278.

Remer LA, Kaufman YJ, Holben BN, 1999: Interannual variation of ambient aerosol characteristics on the east coast of the United States J. Geophys. Res, 104, 2223-2231.

Kaufman Y. J., and V. Ramanathan, State of the art check-up of planet Earth at the turn of the millennium. Revised to *BAMS, June 1999* .

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

King, M. D., Y. J. Kaufman, D. Tanré, and T. Nakajima, Remote sensing of tropospheric aerosols from space: past, present and future. *Bull. of Meteor. Soc.*. revised to BAMS. June 1999

Kaufman, Y. J., D. Tanré, A. Karnieli, and L.A. Remer, 1999: Re-evaluation of dust absorption and radiative forcing of climate using satellite and ground based remote sensing. Submitted to JGR.

Alpert, P., J. Herman, Y. J. Kaufman, I. Carmona, 1999: Dust forcing of climate inferred from correlation between TOMS aerosol index and atmospheric model errors. Atmospheric Res. revised.

22. Meeting/workshop

1. International Conference and Workshops ALPS99, Meribel, France, January 18 - 22, 1999. (*Kaufman, Remer, Chu*)
2. QA telecon on the metadata update tools, March 9, 1999. (*Chu*)
3. MODIS Science team meeting, University of Maryland, College Park / Goddard Space Flight Center, Greenbelt, May 4 - 6, 1999. (*Kaufman, Remer, Chu, Mattoo, Li, Levy, Ichoku*)