MODIS Semi-annual Report
MOD06 Optical and Microphysical Retrievals
July-December 2001

Michael D. King[1] and Steven Platnick[1,2]
[1] Goddard Space Flight Center, Greenbelt, MD
[2] University of Maryland Baltimore County, Baltimore, MD

and

G. T. Arnold, M. A. Gray, C. K. Gatebe, P. A. Hubanks, J. Y. Li, E. G. Moody, J. Riedi

Abstract

Major efforts over the past six months included: (i) introduction of two new components into the Level-2 cloud retrieval algorithm: an atmospheric correction algorithm for absorbing gas species, and a new spectral surface albedo map using MODIS land products, (ii) analysis of MODIS L2 cloud retrieval algorithm and ancillary data sources, including comparisons between NCEP and DAO analyses and subsequent impacts on the cloud retrieval algorithm, (iii) participation in the CLAMS field experiment in July-August 2001, (iv) analysis of data obtained during the SAFARI 2000 dry season campaign in southern Africa, (v) continued analysis of MAS and CAR data from the arctic FIRE-ACE experiment, and (vi) planning efforts for the upcoming CRYSTAL-FACE experiment in July 2002.

New personnel

Jerome Riedi arrived December 1, 2001 for a postdoctoral position through GEST. He will focus on aspects related to remote sensing of cloud thermodynamic phase with MODIS. Specifically, he is expected to work on the so-called decision tree logic and improve the cloud phase inference used in the cloud retrievals. The 1.6 µm and 2.1 µm bands will be investigated in conjunction with results of the IR bi-spectral technique from Baum et al. (also in MOD06). These SWIR bands contain information on cloud thermodynamic phase due to differential absorption properties of liquid water and ice in the near-infrared spectra region. It is expected that additional information from these bands will improve daytime retrievals of cloud phase, which in turn will improve the overall MODIS cloud properties retrievals accuracy.

I. Task Objectives

With the use of related airborne instrumentation, such as the MODIS Airborne Simulator (MAS) and Cloud Absorption Radiometer (CAR), our primary objective is to extend and expand algorithms for retrieving the optical thickness, effective radius, and water path of liquid and ice clouds using radiation measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS). The secondary objective is to obtain an enhanced knowledge of surface angular and spectral properties that can be inferred from airborne directional radiance measurements.

II. Work Accomplished

a. MODIS Data Analysis, Code and Related Software Development

MOD06 Level-2 cloud retrieval code

Two new updates were included in the latest MOD06 cloud retrieval delivery and are now part of the production code. Eric Moody added a new surface albedo map (based on Land IGBP ecosystem classifications and the Land spectral albedo product, as described in the previous report). Jason Li completed implementation of an atmospheric correction algorithm for absorbing gas species spectral transmittances, including analysis of the impact of different ancillary data sets (see below).

Ancillary processing package (Jason Li):

Code Update:

Major effort was put into updating MOD06OD ancillary data programs taking advantage of advanced Fortran 90 language features. The entire MOD06OD ancillary data package has been repackaged using F90 modules and data structures. All code has been checked, tested, and made available for inclusion into production. An added benefit is the increase efficiency after the repackaging process.

DAO vs. NCEP:

The impact of these two ancillary sources for moisture and temperature fields on the cloud retrieval algorithm was investigated. Larger than expected differences in surface temperature fields were found when two model results were compared. Figure 1a is one example out of the 60 pairs of comparisons completed for November 2000 to December 2001, mainly in the late fall/early winter season. Both models seem to agree well over the ocean, with problems occurring over land. For example, DAO surface temperature is much too warm over the west coast of the United States, southern edge of the Amazon in South America, and much of the African and Asian continent, while being too cold over the poles and parts of Australia. The NCEP GDA1 analysis product contains a blend of observations from the previous 6 hours while DAO surface temperatures are instantaneous values. However, the large discrepancies in surface temperature cannot be explained by this incompatibility. After discussing the findings with DAO scientists, it turns out that this is a known problem with the current DAO GEOS-3 model. The future GEOS-4 model (in the pipeline) is expected to fix the surface temperature problem.

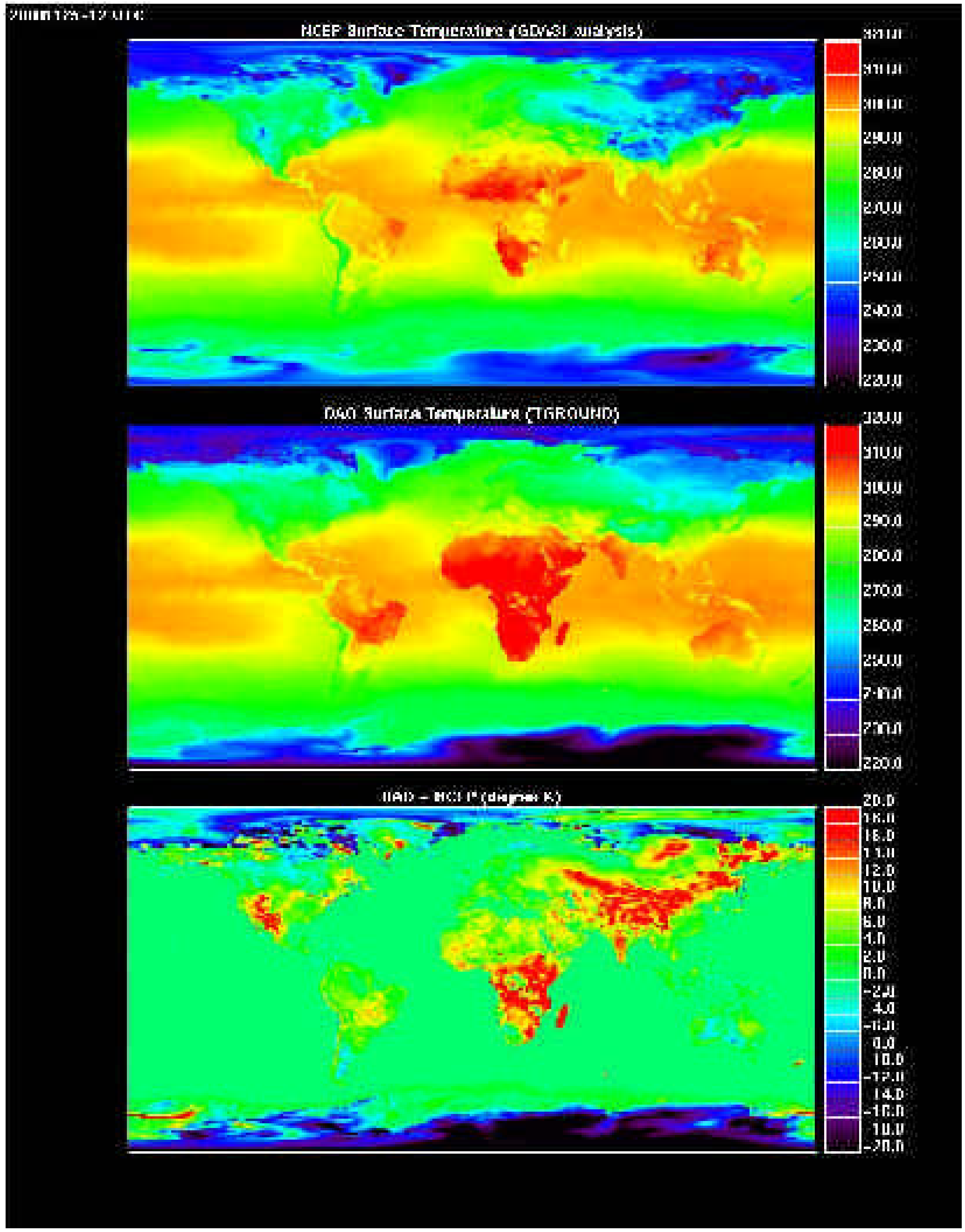

Fig. 1a. Surface temperature comparison between DAO and NCEP Global Assimilation Models at 12 UTC, November 25, 2000..

In general, moisture comparisons between two models fare better. For a given pressure altitude (fixed at 800 hPa globally for this comparison work), we compute integrated precipitable water amount from this altitude all the way to top of the atmosphere (TOA). Results are presented in Fig. 1b. It is evident that NCEP and DAO match well as far as moisture pattern and features go. Although there

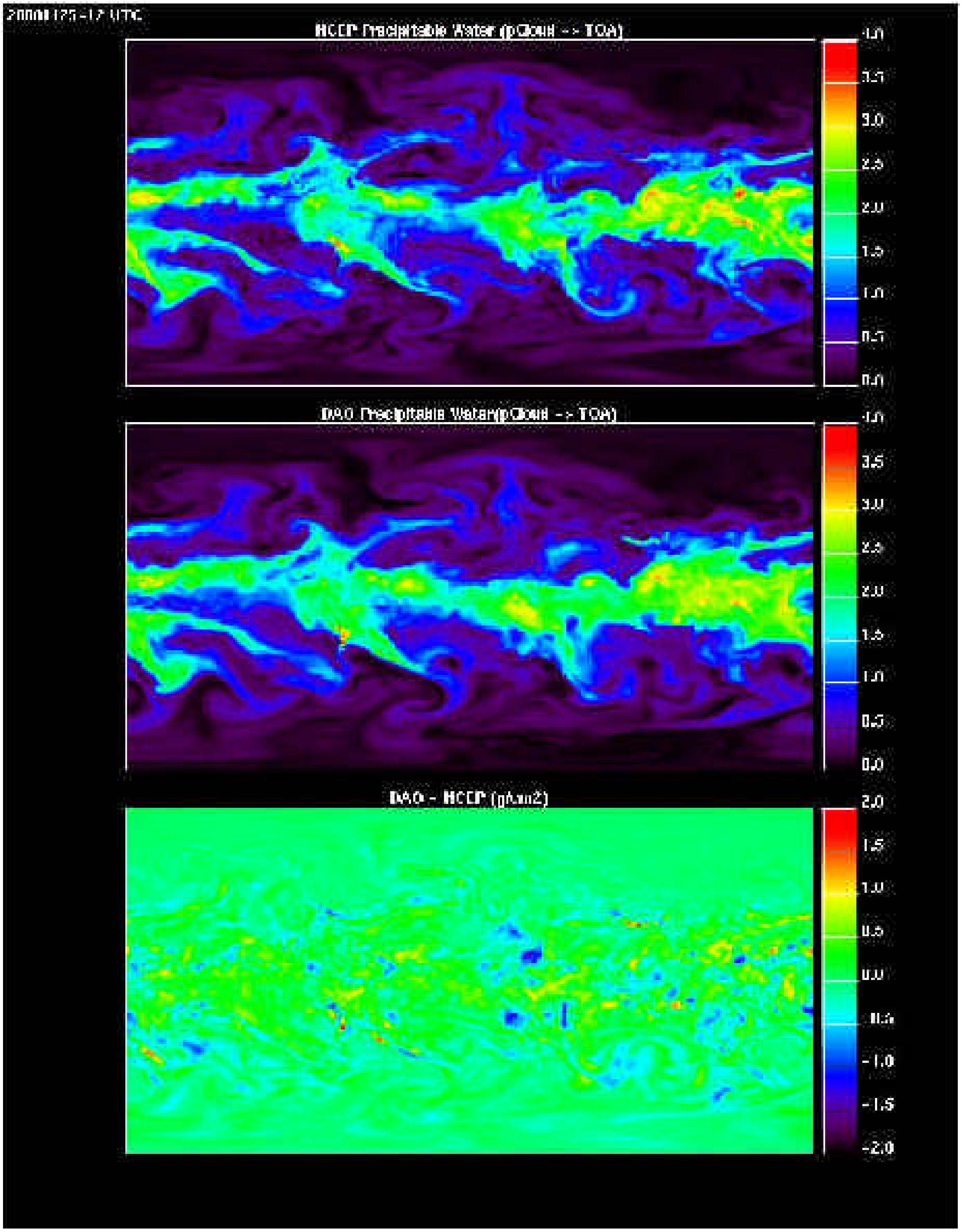

Fig. 1b. Precipitable water (850 mb to TOA) comparison between DAO and NCEP Global Assimilation Models at 12 UTC, November 25, 2000.

are magnitude differences, no clear coherent pattern emerges from the limited number of comparisons made thus far.

Another way to look at the differences is to examine the vertical structure shown

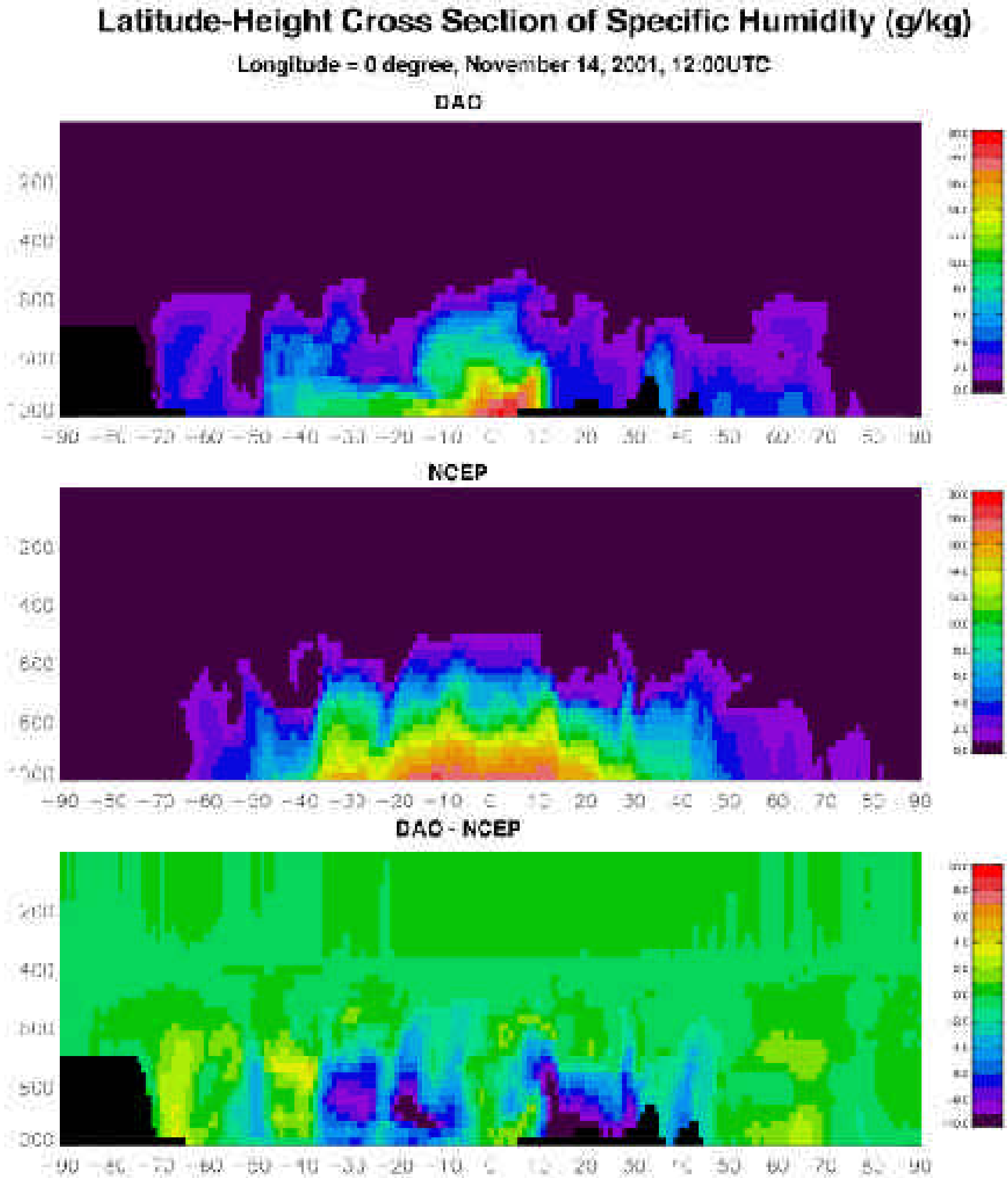

Fig. 2. Comparisons of DAO and NCEP specific humidity in a Latitude-Height cross-section.

in Fig. 2. Note that NCEP shows symmetric features around the tropics, whereas DAO does not. It is unclear what the correct moisture field is. DAO scientists claim their moisture values are more realistic because they assimilate SSM/I observations.

The moisture/temperature ancillary data are used to perform atmospheric corrections in the cloud retrieval algorithm. After atmospheric correction, the cloud top reflectance values in each band will increase, resulting in smaller values of the cloud particle radius and/or larger optical thickness. A case study was conducted to qualitatively assess the impact of this atmospheric correction on our cloud optical property retrievals. The MODIS RGB composite of 15:35 UTC, May 6, 2001 granule (cf. Fig. 3) shows the cloud coverage along the Peruvian coast. This is a good case in that both ice and water clouds are present at various altitudes, and underlying surfaces are uniform (either ocean or evergreen forests). Based on meteorological observations at Lima, Peru, the total column precipitable water amount was about 4 cm, enough water vapor absorption to make a significant difference in the cloud optical property retrievals.

To retrieve cloud properties over the land, the 0.65 and 2.1 µm bands are primarily used while over the ocean the 0.86 and 2.1 µm bands are used. The transmittance for these bands depends on the amount of absorbing gases (mainly water vapor) along the viewing path. In turn, for the water vapor, the quantity of in-

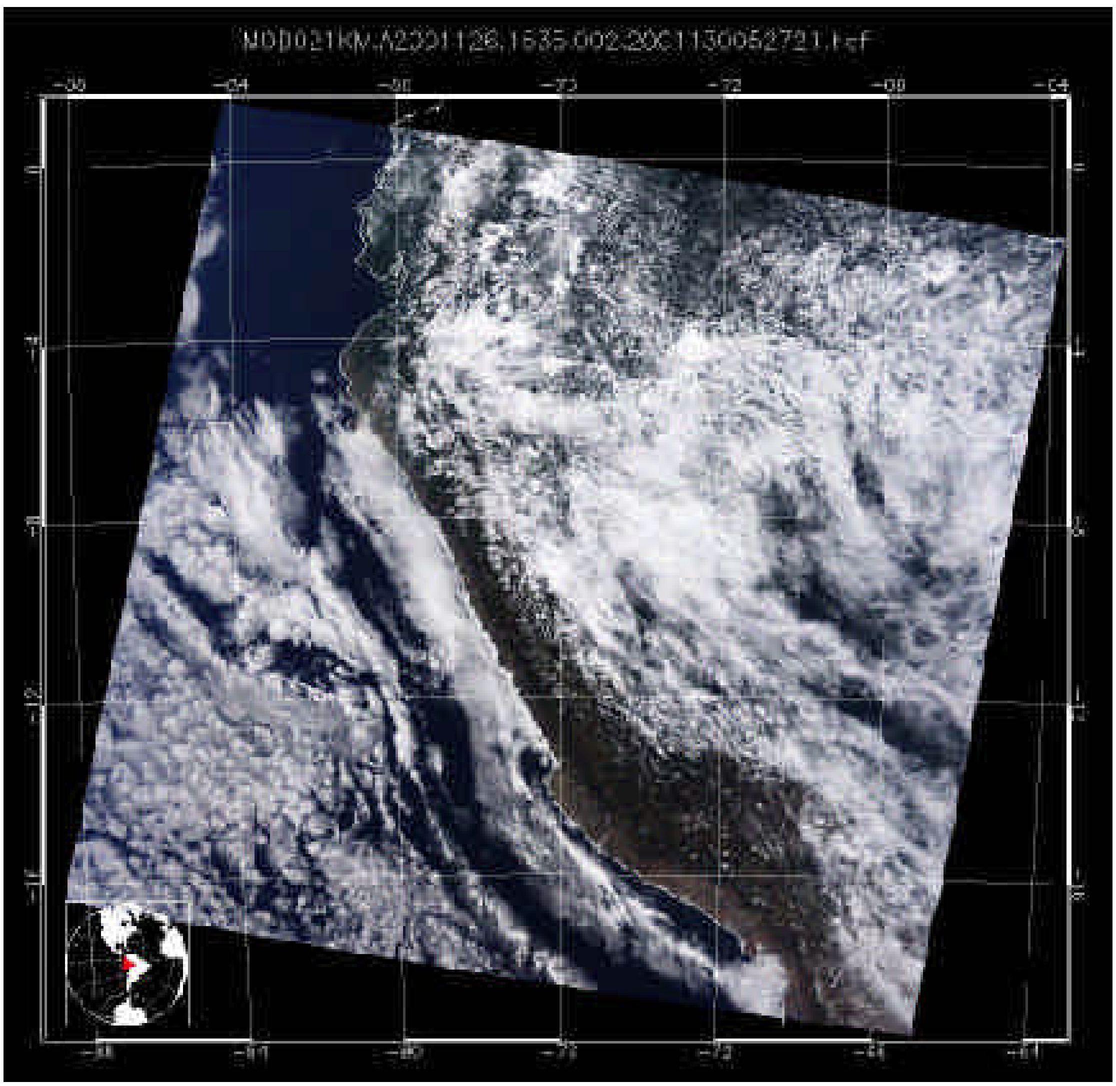

Fig. 3. MODIS RGB composite image of May 6th, 2001 granule.

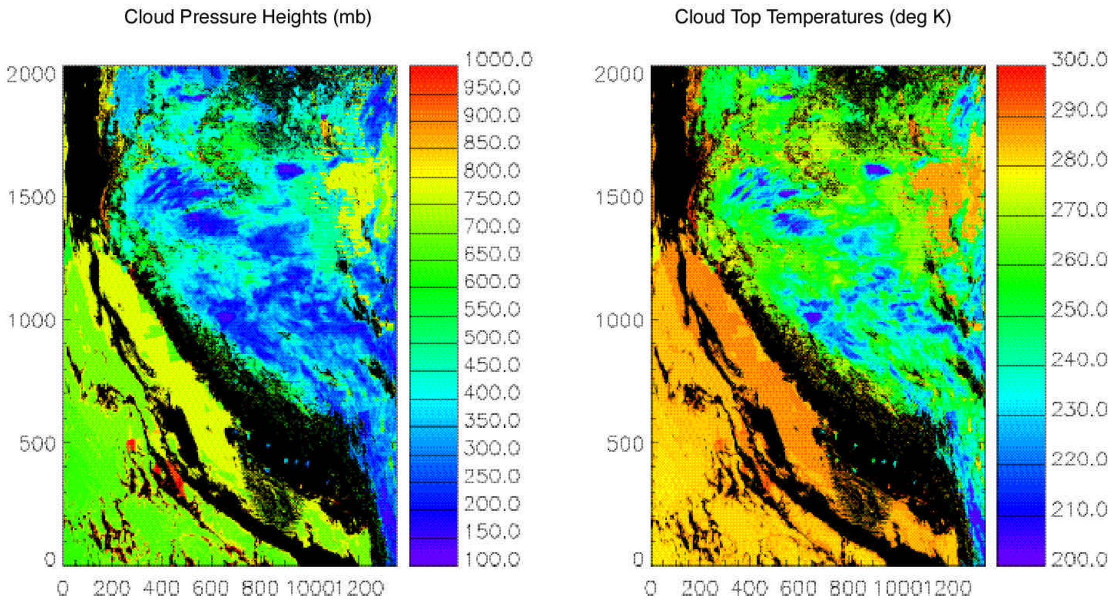

Fig. 4. Cloud top properties (pressure height and temperature) provided by MOD06CT product.

terest is the above-cloud precipitable water amount that is a function of cloud top height (derived from MOD06 cloud top properties, Fig. 4), viewing geometry and vertical distributions of moisture in the atmosphere (Fig. 5). Using the above-cloud integrated water amount, two way transmittance values are obtained from a pre-computed look-up table. It is this atmospheric-corrected reflectance that is used by the retrieval algorithm. The differences in cloud optical thickness and effective radius retrievals between atmospheric corrected and non-corrected runs are shown in Fig. 6. For water clouds over the ocean, effective particle radius is on the order of low teens before a correction. After the atmospheric correction, sizes decreased by 1 to 2 µm, while optical thicknesses are unaffected. Clouds over land are predominantly ice and at higher altitudes. Their effective particle radius remains largely unchanged after correction, but optical thicknesses increase by an appreciable amount (up to about 5).

Miscellaneous L2 items (Eric Moody):

1. An investigation into the possible use of Elevated and Heavy Aerosol flags found in the cloud mask.
2. An investigation into the possible use of Wisconsin's IR Cloud Phase product to supplement the decision tree.
3. Several retrieval issues were identified as critical science problems, and strategies were formulated for investigating possible causes and solutions. Identification of these issues resulted from examining images of golden day granules (see Visualization section), and includes the following:

   - Small cloud optical thickness, large effective particle radius retrievals
   - Large effective particle radius retrievals in SAFARI validation granules

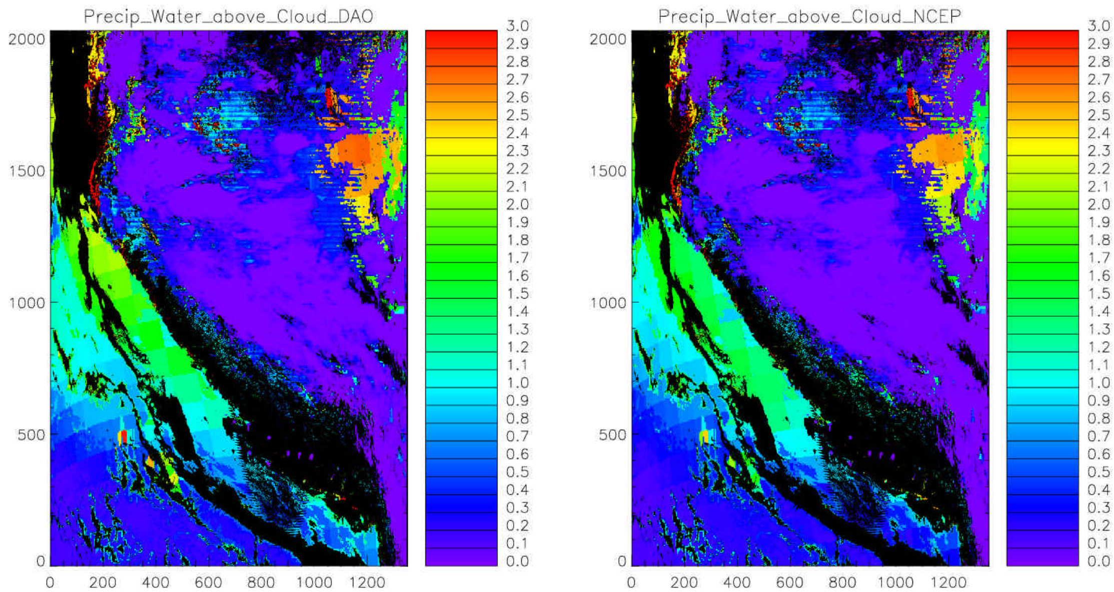

Fig. 5. Integrated precipitable water from cloud top to TOA, computed using both DAO and NCEP ancillary inputs.

- Warm clouds being inferred as ice clouds.
- Failed 3.7 µm retrievals for ice clouds.
- Identified that there are non-science trends in cloud optical thickness and effective radius in our global retrievals.

4. Several scripts and codes were developed to assist in investigating and veri-

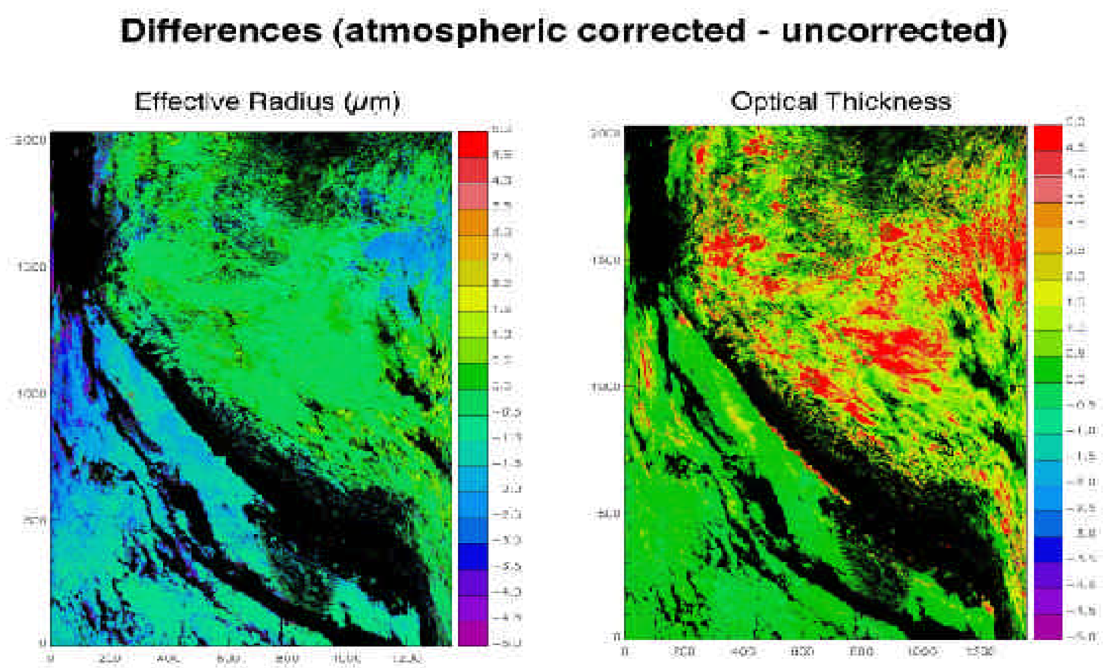

Fig. 6. Difference in cloud retrieval results: with and without atmospheric correction.

fying these problems. Specifically, codes were developed to:

- Investigate effects of atmospheric and Raleigh corrections.
- Reprocess granules, ignoring the Cloud Mask's sun glint flag.
- Compute retrieval parameter statistics for a selected box within a granule.
- Generate HDF files for use with a retrieval sensitivity study.

Analysis:

Mark Gray, Eric Moody, Steven Platnick, and Michael King continued to examine MODIS Level 2 cloud optical thickness and effective radius retrievals, including golden day visualizations created by Moody (currently for October 1, 2001 and July 18, 2002). Moody created thumbnails of selected MOD06 products plus the cloud mask that were posted to a web site (Hubanks) and made available to the MOD06 team. These have been useful for indicating inconsistencies between products and in finding artifacts.

Data Processing Review Team:

A MODIS Data Processing Review Team (MDPRT) report was circulated in December that detailed recommendations for the processing of Aqua Level-2 and Level-3 data products. In response, a group of Atmosphere Team Discipline team developers created a document listing some of our recommendations. Two main issues required a response from the Atmosphere team:

1. Creation of a consolidated MODIS product for the outside community that can be used as an interim processing for Aqua.
2. Creation of an easily reprocessible subset product for algorithm testing and validation prior to major reprocessing efforts.

The team responded with the following recommendations, in brief:

1. Create a unified MODIS-Atmosphere product that would be a set of perhaps 10 atmosphere scientific data sets (SDSs) chosen for their interest and value to the general community. These SDSs would be generated from MODIS Level-2 algorithms and processed to Level-3 using a filespec modified to produce a small number of statistical parameters.

2. The MODIS Atmosphere product would be produced on a system independent of Land and Ocean data product processing. This unified Atmosphere product (or part of it) would be combined with MODIS Land and Ocean products generated for the same grid and time periods to generate a MODIS Core Product.

To provide a Fast Reprocessing System for algorithm testing, it was proposed to use MODIS Atmosphere Level-2 and -3 algorithms as they stand and produce data for just one orbit processed for a year, effectively cutting the data quantity and processing time down to 1/16th of the full processing load. This 'testbed' for MODIS Atmosphere products would operate independent of Land and Ocean product testing.

<u>MOD08 Level-3 atmosphere code</u> (Paul Hubanks)

Changes were made to the Fortran 77 and/or Fortran 90 software, CDL file specifications, and corresponding HDF structure files for the MOD08 (MODIS Atmosphere Joint Product) Tile, Daily, Eight-Day, and Monthly. Specific changes include:

1. Modifying the histogram and joint histogram intervals for several cloud products

2. Testing all changes performed, and preparing complete delivery packages (Fortran and Fortran 90 software, test populated HDF files, HDF Structure files, CDL file spec files, History files, Readme files, and PACKINGLIST files) for four PGE's (PGE56, 57, 69, 70) that correspond to the MOD08 Daily, Monthly, Tile, and Eight-Day, respectively.

3. Delivering the updated packages (PGEs) to the MODIS Science Data Support Team (SDST) for integration into MODAPS

<u>MODIS Atmosphere Web Site Development</u> (Paul Hubanks)

Paul Hubanks updated and added numerous items on the MODIS Atmosphere web site. A sampling of some of this work includes:

1. Developing and implementing (algorithm change) history web pages for various MODIS Atmosphere products.

2. Continuing to populate the global L3 product browse image archive library. The L3 products include the daily global (MOD08_D3), eight-day global (MOD08_E3), and monthly global (MOD08_M3) products. For each product file, over 800 images that reflect the most highly used statistics, on both an equal-area and equal angle grid, are available for viewing. During the past year, over 400,000 images have been created and are available for viewing through the web site interface.

3. Continuing to optimize many of the SDS parameter specific fixed scales used to display the MOD08_D3, MOD08_E3, and MOD08_M3 browse images. The scales were adjusted to enhance detail in the images. Some of the adjustments became necessary after science algorithms were modified to reduce the range of data in the images (e.g., Cloud Effective Radius).

4. Several new tools were added to the TOOLS page. For example, a new granule locator tool, which will locate granules based on the granule

metadata files produced by MODAPS.

5. Numerous new QuickTime animations of MODIS-Atmosphere products, as well as several new PowerPoint presentations from a number of group members were added.

6. Completed the modification of the high-res L3 image display scripts to handle the new size thumbnail images. Created thumbnail and full resolution browse images for all available high-resolution L3 (MOD08D3H) data files and upload to web site. Over 18,000 images have been produced and uploaded in the past year; and are available for viewing though the web site interface

7. Added SDS parameter definitions (and derivation information) to the Format & Content page for the MOD08_D3 Atmosphere Data Product. This information is useful for those needing additional details on the derivation of particular L3 parameters.

8. Added color bars and scales to all QuickTime animations displayed on the web site.

9. Added the SDS Cloud Phase Infrared Histogram Counts (for day, night, and combined) to the L3 browse display system for all provisional (V3) data days.

10. Added an Instrument Status and a Platform Status page to the News section.

11. Redesigned the Validation page dividing the content into four sections: 1.) Known Problems (Summary), 2.) Presentations, 3.) Field Experiments, and 4.) Correlative Data.

12. The Known Problems content, covering all MODIS-Atmosphere products, was updated.

13. Added a detailed, color-coded MODIS-Atmosphere Products Processing and Availability Calendar. This calendar received numerous positive comments.

14. Developed a new L2 granule web-based display system. Selected L2 granule images, along with a L1B composite image and ecosystem map, are organized by orbit (daytime / descending orbits only). The location of each orbit is marked by a red highlight on a global orbit track thumbnail image at the top of each page. There is a full set of 15 descending orbit pages available for viewing.

MODIS product visualizations and other software tools

Paul Hubanks developed a new joint histogram display tool that was developed and served from the MODIS-Atmosphere web site, including: 1) An IDL tool that creates 3-D “lego” plots of any joint histogram SDS (masked for ocean or land) from MOD08 HDF products. 2) An IDL tool that creates zonal average plots of any simple statistical SDS parameter (masked for ocean or land) from MOD08 HDF products. A number of these plots were used in group presentations. Paul also developed a new high-contrast rainbow color scale for MODIS Atmosphere browse imagery that is now being used in all web site images. This new scale was also used on images in several PowerPoint presentations and in images created for the MODIS brochure.

Eric Moody’s visualization efforts included:

- Evaluating several commercial 3D visualization software packages to be used as an alternative to Mike Manyin’s in-house software package. A package called 3D Toolkit was selected for visualizations of Rotating Globe imagery.
- Creating scripts and code to visualize various granule level parameters, both in geolocated and un-geolocated formats. Parameters include Albedo, Ancillary, Ecosystem, Level-1B, and Level-2 data, as well as bit flags of the Cloud Mask and Level-2 QA.
- Writing scripts to run the geolocated and un-geolocated codes to produce images for a whole day’s worth of data.
- Creating code to visualize cloud optical thickness using two separate color schemes to differentiate ice and water phases within the image.
- Modifying the high-resolution Level-3 visualization scripts so that images mirror the official product’s website images.
- Documenting and packaging unmapped and mapped visualization codes for distribution.
- Developing scripts to produce selected unmapped images for daytime granules from a “golden day”.

MODIS brochures

Paul Hubanks created a number of optimized images for use in the MODIS brochure, and updated the EOS Data Products Handbook for MODIS-Atmosphere related products.

b. MODIS-related Instrument Efforts

Cloud Absorption Radiometer (CAR)

1. CLAMS

Level-1A data have been processed and quick looks for all flights have been posted to the CAR web site. Documentation of CAR measurements during CLAMS has been completed and posted to the CAR web site as well.

2. CAR Data processing

Calibration, *SAFARI*: Tom Arnold assisted Charles Gatebe in analysis of the SAFARI 2000 CAR calibration. He analyzed validity of the pre-deployment calibration, and also application of the change in calibration (noted from pre-deployment to post-deployment) to actual SAFARI data. Resolution of these issues led to final SAFARI 2000 CAR calibration. Appropriate processing files were then updated with the new calibration information and) all SAFARI 2000 CAR Level-1B data were reprocessed. CLAMS: CAR data for CLAMS 2001 were collected during July and August. Subsequently data were processed to Level-1A. Preliminary CAR calibration analysis was conducted (with C. Gatebe) and then data were processed to Level-1B for all CLAMS flights.

BRDF roll correction software: Applied roll correction to CAR CLAMS 2001 data (correction is much different than that for SAFARI data due to the active roll compensation scheme used during CLAMS). Correction software was first designed to apply corrections to CAR Level-1B (HDF) data but was then modified to adjust the Level-1A data. Software reads the input file of scan line numbers and corresponding "horizon" location information to determine where and how much to correct for roll errors. Developing input file is quite labor intensive (data must be examined using image display software and in some cases reviewed line by line). Input file for Flight 1870 has been developed and tested successfully. Input files will need to be developed for all CLAMS flights.

BRDF processing: CAR bidirectional reflectance distribution function (BRDF) processing software was upgraded to improve efficiency and for automation. Initial BRDF processing, for quality assurance, is always conducted one case at a time. However once BRDF circle locations and times have been defined, multiple reprocessing of BRDFs (say for a calibration change) can now be accomplished in a single step.

All CAR SAFARI 2000 and CLAMS 2001 BRDF cases were identified, processed, and plotted using non-pitch corrected data. Output files from specific BRDF cases were generated and sent to the MISR research group for comparison. Subsequently BRDF processing software was modified to include the pitch correction (a non-trivial modification) and all SAFARI 2000 BRDF cases were then reprocessed. Comparative analysis of pitch and non-pitch corrected BRDFs show only minor differences in computed hemispherical albedo values, but improved polar plots, particularly those with sunglint features. Eight particular SAFARI BRDF cases have been selected and have been more intensively analyzed and will be used in a paper by C. Gatebe.

During testing of the BRDF code (being modified for pitch correction), data values in the interpolated 'near nadir' data region of the BRDF plots were found to be anomalously low. After extensive investigation, the source of the problem was determined to be instrumental. The radiance level of pixels of about the last 15 or so pixels of each CAR scan drop off significantly, regardless of view mode. The cause of this problem has not yet been determined. However for the BRDF analysis, due to the pitch of the aircraft, the zenith angle of the approximately last 25 pixels in a given CAR scan is nearly constant (though view azimuth angle changes). Thus not using the last 15 pixels eliminates the suspect data without significant data loss for the BRDF. All SAFARI and CLAMS 2001 data is affected by this problem (it has not been observed in any previous data sets).

Another significant problem encountered in the SAFARI and CLAMS BRDF data (particularly for CLAMS data) was various navigation data errors. Navigation errors cause errors in CAR scan angle data and complicate the BRDF polar plotting. In some cases the navigation data problems were serious enough to require previous BRDF software (which is not dependent on the navigation data – and thus does not include any pitch angle correction) for BRDF analysis. A program was written and run to summarize navigation related problems for the CLAMS CAR data.

3. CAR web site

Paul Hubanks continued the redesign and re-engineering of the Cloud Absorption Radiometer (CAR) web site. Work included:

A. Creating a CLAMS 2001 campaign page, as well as comprehensive mission pages for all CLAMS flights. Each mission page contains: coincident MODIS and GOES-8 satellite imagery, CAR quicklook images (thumbnail and full-resolution versions), digital photographs taken from aircraft vantage, flight logs, flight track maps, and a meteorological summary. Received numerous positive comments on the redesign.

B. Creating a SAFARI-2000 campaign page, as well as comprehensive mission pages for numerous SAFARI-2000 flights. Each completed mission page contains: coincident MODIS (or NOAA-14) and Meteosat-7 satellite imagery, CAR quicklook images, digital photographs taken from aircraft vantage, flight logs, flight track maps, and a meteorological summary.

<u>MODIS Airborne Simulator (MAS)</u>

Mark Gray and Eric Moody are developing MAS versions of the MODIS cloud retrieval code, including use of the latest routines developed for MODIS version 3 algorithms. The new MAS code will include HDF output of retrieval results, ancillary data including the cloud mask, geolocation, and QA information. Development is expected to be completed in February 2002.

Eric Moody developed a code that converts the binary MAS Cloud Mask file into an HDF file, and worked on development of MAS HDF output routines ready for integration into the final code.

c. MODIS-related Field Campaign and Validation Efforts

SAFARI 2000

Steve Platnick and Tom Arnold worked with in situ cloud data received from the University of Washington CV-580 and UK Meteorological Research Flight C-130 during validation efforts off the coast of Namibia. A comparison of the in situ data with MODIS retrievals has been completed (using the latest algorithm updates) by Eric Moody and Steve Platnick. Comparison with MAS retrievals is pending. This work marks the first validation effort for the MODIS cloud retrieval product. Michael King and Steve Platnick discussed collaborative efforts on cloud property and aerosol interactions with SAFARI scientists during the SAFARI 2000 First Data Workshop, Siavonga, Zambia, August 28-31, 2001. An overview of the MODIS SAFARI retrievals was presented at the Fall AGU Meeting by Steve Platnick. Paul Hubanks resolved outstanding issues with the Goddard DAAC on archiving and distributing MAS data collected during the SAFARI 2000 Field Campaign.

Tom Arnold analyzed MODIS Airborne Simulator (MAS) data acquired on September 7, 2000 over a prescribed burn of the Timbavati Private Game Reserve, South Africa. The ER-2 made 3 consecutive passes over the fire. RGB imagery (2.2, 0.87, and 0.47 µm) for each case was remapped then co-located. Imagery was then overlaid in a PowerPoint presentation to show the sequence of fire. Tom Arnold significantly modified IDL code that compares three different methods of determining cloud phase from MAS data. Code no longer requires any manual pre-analysis and can read from any MAS HDF dataset.

Charles Gatebe, Tom Arnold, and Jason Li worked on various aspects of the CAR SAFARI data, including calibration and generation of Level 1B data.

CLAMS (Chesapeake Lighthouse and Aircraft Measurements for Satellites)

Charles Gatebe participated in the CLAMS Field Experiment based at Wallops Flight Facility, July 10 – August 3, 2001. Several CAR measurements of ocean BRDF over and near Chesapeake Lighthouse and over the Great Dismal Swamp were made. Quick looks for all flights were posted to the CAR web site along with documentation of CAR measurements.

CRYSTAL-FACE

Michael King and Steve Platnick were funded for the participation in the NASA CRYSTAL-FACE field campaign planned for southern Florida during July 2002. Participation includes use of the MAS instrument flown on the NASA ER-2, membership in the CRYSTAL-FACE management team, and ER-2 flight scientist duties. Jerome Riedi was funded to fly the CNES Airborne POLDER (POLDER (POLarization and Directionality of the Earth Reflectances) instrument on the Proteus aircraft during CRYSTAL-FACE. POLDER will provide directional and polarimetric observations useful for inferring cloud phase, particle habit, and bidirectional reflectance patterns. Further, simultaneous observations of POLDER and MAS during CRYSTAL-FACE will provide valuable dataset to help in designing new synergistic algorithms with MODIS/Aqua and PARASOL during the A-Train time frame.

The field campaign will examine the life cycle of strong convective systems and resulting anvils, providing an excellent opportunity for validation of MODIS ice cloud retrievals. The campaign supports 6 aircraft, 2 ground stations, and various modeling efforts. It is supported by the NASA Radiation Sciences Program.

d. MODIS-related Services

Meetings

1. Steve Platnick attended the Global Change Open Science Conference, 10-13 July 2001, Amsterdam, Netherlands.

2. Steve Platnick attended the Scientific Assembly of IAMAS, 18 July 2001, Innsbruck, Austria.

3. Michael King attended the International Geoscience and Remote Sensing Symposium, 9-13 July 2001, Sydney, Australia.

4. Michael King attended the 3rd International Workshop on Aerosol-Cloud Radiation Interaction, 22-27 July 2001, Chongqing China.

5. Michael King and Steve Platnick attended the SAFARI 2000 First Data Workshop, Siavonga, Zambia, 28-31 August 2001.

6. Michael King attended the AMS 11th Conference on Satellite Meteorology and Oceanography, 15-17 October 2001, Madison, WI.

7. Michael King, Steve Platnick, and Charles Gatebe attended the AGU Fall Meeting, 10-14 December 2001, San Francisco, CA.

8. Michael King regularly attended weekly MODIS Technical Team meetings.

9. Steve Platnick regularly attended weekly MODIS Sensor Working Group meet-

ings.

10. Eric Moody, Mark Gray, and Paul Hubanks attended weekly MODIS Atmosphere Data Processing meetings.

11. Michael King organized the MODIS Atmosphere Discipline Team Meeting at Linthicum, MD, 17 December 2001; Steve Platnick, Charles Gatebe, Mark Gray, Eric Moody, and Paul Hubanks attended.

12. Michael King, Steve Platnick, Charles Gatebe, Mark Gray, Eric Moody, and Paul Hubanks attended the MODIS Science Team Meeting in Linthicum, MD, 18-19 December 2001.

13. Steve Platnick, Michael King, Jerome Riedi, and Eric Moody attended the CRYSTAL-FACE Science Team Meeting in Lanham, MD, 30 January - 1 February 2002.

<u>Presentations</u>

1. Platnick, S., M. D. King, S. A. Ackerman, W. P. Menzel, B. A. Baum, and R. Pincus, *Multispectral Cloud Retrievals from MODIS*. Presented at the 8th Scientific Assembly of IAMAS, <u>invited talk</u>, 18 July 2001, Innsbruck, Austria.

2. Platnick, S., M. D. King, G. T. Arnold, M. Gray, E. Moody, J. Y. Li, S. Ackerman, *Satellite and Airborne Retrievals of Cloud Properties during SAFARI*. Poster, presented at the Global Change Open Science Conference, 10-13 July 2001, Amsterdam, Netherlands.

3. Platnick, S., S. Ahmad, M. D. King, W. P. Menzel, S. Ackerman, Y. Kaufman, D. Tanré, L. Remer, and B. C. Gao, Remote Sensing of Cloud, Aerosol, and Water Vapor Properties from MODIS. Poster, presented at the Global Change Open Science Conference, 10-13 July 2001, Amsterdam, Netherlands.

4. King, M. D., S. Platnick, D. A. Chu, and E. G. Moody, Remote Sensing of Cloud, Aerosol, and Land Properties from MODIS: Applications to the East Asia Region. Presented at the 3rd International Workshop on Aerosol-Cloud Radiation Interaction, <u>invited talk</u>, 22-27 July 2001, Chongqing, China.

5. Dubovik, O., B. N. Holben, Y. J. Kaufman, T. F. Eck, A. Smirnov, M. D. King, D. Tanré and I. Slutsker, 2001: Absorption of key aerosol types observed in worldwide locations. Presented at the Chapman Conference on Atmospheric Absorption of Solar Radiation, Estes Park, CO.

6. King, M. D., and S. Platnick, Overview of NASA ER-2 Operations during SAFARI 200*0*, <u>invited talk</u>, SAFARI 2000 Science Team Meeting, 28-31 August 2002, Siavonga, Zambia.

7. Platnick, S., M. D. King, P. V. Hobbs, S. Osborne, S. Piketh, R. Bruintjes, R. Swap, Cloud and Radiation Studies during SAFARI 2000. Poster, presented at the SAFARI 2000 Science Team Meeting, 28-31 August 2002, Siavonga, Zambia.

8. Gatebe, C. K., M. D. King, G. T. Arnold, and J. Y. Li, *Airborne Spectral Measurements of Surface-Atmosphere Anisotropy for Skukuza and Mongu Sites.* Poster, presented at the SAFARI 2000 Science Team Meeting, 28-31 August 2002, Siavonga, Zambia.

9. Annegarn, H. J., R. J. Swap, J. T. Suttles, J. L. Privette, M. D. King, S. J. Piketh, P. V. Hobbs, S. Platnick, A. Queface, T. Freiman, B. N. Holben, S. C. Tsay, J. D. Spinhirne, S. L. Nasiri, P. B. Russell, R. A. Kahn, Y. J. Kaufman and L. A. Remer, Ground, airborne and satellite observations of the "River of Smoke" biomass burning plume over southern Africa during SAFARI 2000. Presented at the Conference on Regional Haze and Global Radiation Balance—Aerosols, Measurements and Models: Closure, Reconciliation and Evaluation, October 2001, Bend, OR,.

10. King, M. D., S. Platnick, W. P. Menzel, Y. J. Kaufman, S. Ackerman, D. Tanré and B. C. Gao, 2001: Remote sensing of cloud, aerosol, and water vapor properties from MODIS, invited talk, AMS 11th Conference on Satellite Meteorology and Oceanography, 15-18 October 2002, Madison, WI.

11. Smith, W. L., T. Charlock, B. Wielicki, R. Kahn, J. Martins, L. Remer, C. K. Gatebe, P. V. Hobbs, J. Redemann, L. Remer and K. Rutledge, The Chesapeake Lighthouse and Aircraft Measurements for Satellite (CLAMS) Campaign: Experiment Overview. Presented at the AMS 11th Conference on Satellite Meteorology and Oceanography, 15-18 October 2002, Madison, Wisconsin.

12. Platnick, S., M. D. King, P. V. Hobbs, S. Osborne, S. Piketh, R. Bruintjes, R. Swap, Cloud and Radiation Studies during SAFARI 2000. Presented at the AGU Fall Meeting, invited talk, 10-14 December 2001, San Francisco, CA.

13. Gatebe, C. K., M. D. King, G. T. Arnold, and J. Y. Li, Airborne Spectral Measurements of Surface Atmosphere Anisotropy for Several Surfaces and Ecosystem over Southern Africa. Poster, presented at the AGU Fall Meeting, 10-14 December 2001, San Francisco, CA.

14. Conel, J. E., W. A. Abdou, S. H. Pilorz, D. J. Diner, J. L. Privette, C. K. Gatebe, B. L. Holben, T. Eck, and M. D. King, Intercomparison of AirMISR, CAR, and MISR Observations of Bidirectional Reflectance Factor, Mongu Tower, Zambia, during SAFARI 2000 Dry Season Campaign. Presented at the AGU Fall Meeting, 10-14 December 2001, San Francisco, CA.

15. Abdou, W. A., M. C. Helmlinger, D. J. Diner, J. E. Conel, S. H. Pilorz, J. V. Martonchik, R. A. Kahn, J. L. Privette, C. K. Gatebe and M. D. King, *Sua Pan* Bidirectional Reflectance: A validation Experiment of the Multi-angle Imaging SpectroRadiometer (MISR) during SAFARI 2000. Presented at the AGU Fall

Meeting, 10-14 December 2001, San Francisco, CA.

16. Smith, W. L., T. Charlock, B. Wielicki, R. Kahn, J. Martins, L. Remer, C. K. Gatebe, P. V. Hobbs, G. Purgold, J. Redemann, and K. Rutledge, The Chesapeake Lighthouse and Aircraft Measurements for Satellite (CLAMS) Campaign: Experiment Overview. Presented at the AGU Fall Meeting, 10-14 December 2001, San Francisco, CA.

17. King, M. D., S. Platnick, M. A. Gray, E. G. Moody, *Cloud Optical & Microphysical Properties*. Presented at the MODIS Science Team Meeting, 18 December 2001, Linthicum MD.

18. Gatebe, C. K., Overview of CAR Measurements during CLAMS. Presented at the MODIS Science Team Meeting, 18 December 2001, Linthicum MD.

19. Steve Platnick, ER-2: objectives, capabilities, instruments. Presented at the CRYSTAL-FACE Science Team Meeting, 30 January 2002, Lanham MD.

III. Data/Analysis/Interpretation

a. FIRE-ACE

Further analysis is awaiting completion of the MAS version of the MODIS cloud retrieval code.

b. SAFARI analysis of Namibian marine stratocumulus

Several flight days were deemed suitable for cloud retrieval case studies after discussions during the SAFARI 2000 science team meetings held at GSFC on 30-31 May 2001, and in Siavonga, Zambia in August 2001. MODIS retrievals for these selected days have been run using the latest production code and compared with in situ cloud data from the University of Washington CV-580 and UK Met Office C-130.

Initial comparisons suggest that MODIS optical thickness retrievals are in reasonable agreement with in situ inferences, while effective radius retrievals appear to be biased high by several micrometers. The cause for the size discrepancies is being investigated. Pending MAS retrievals should help clarify the cause. A summary of droplet size validations during the SAFARI campaign are shown in Fig. 7. Also shown are the range of droplet sizes retrieved in previous campaigns or satellite studies in other marine stratocumulus regimes (California, Arctic) and in the California Central Valley. Cloud droplet effective radius off Namibia is generally seen to be at the low end of the size range, perhaps indicating elevated Cloud Condensation Nuclei in the boundary layer during cloud formation.

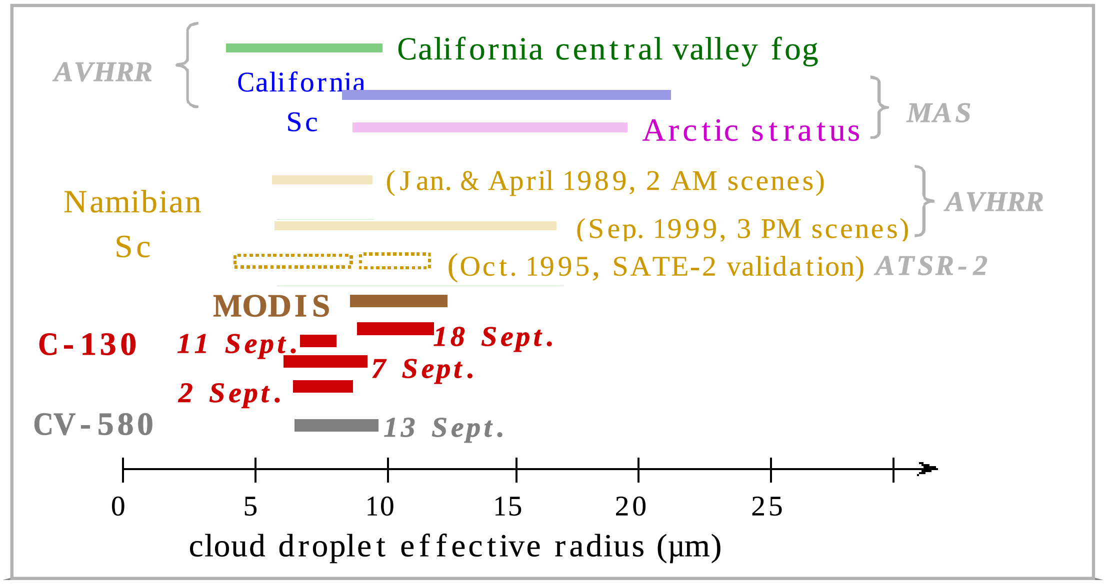

Fig. 7. Comparison of in situ and MODIS-derived estimates of effective particle radius of stratus clouds off the coasts of Namibia and California.

c. CAR analysis

Charles Gatebe, Oleg Dubovik, Michael King, and Si-Chee Tsay are developing a new inversion scheme to simultaneously retrieve aerosol optical properties and surface BRDF. These will be applied to data previously obtained over the Brazilian Cerrado, oceanic regions (TARFOX, SCAR-A, CLAMS), desert areas (Kuwait Oil Fire Experiment), and observations over southern Africa during SAFARI 2000.

IV. Problems/Corrective Actions and Status

The main emphasis over this reporting period was to begin addressing higher order algorithm concerns and implementation of algorithm improvements.

<u>Retrieval frequency distribution</u>: It was found that histograms of optical thickness and effective radius retrievals, plotted with a large number of small-sized bins, show a nonphysical reduction in the frequency of optical thickness retrievals at a value of about 13 and 7 for water and ice clouds, respectively. A reduction in effective radius in some bins is also noted. Though this is not thought to impact L3 statistics, the cause is being investigated.

<u>Large effective radius retrievals associated with small optical thickness retrievals in ocean water clouds</u>: Appears to be related to sub-pixel cloud variability. Action: work on development of a 1 km and 250 m spatial variability test to assist in indicating sub-pixel clouds.

Lack of cloud mask "confidence" in sun glint regions resulting in fewer retrievals: Action: explore use of spatial variability test in discriminating glint from clouds.

Thermodynamic Phase: Inferences based on the MOD06 decision tree (phase derived from individual cloud mask tests) not always consistent with other methods (e.g., MOD06 IR phase test from Bryan Baum and Steve Ackerman, cloud top temperature from Paul Menzel). Action: investigate incorporating this additional MOD06 information into the phase determination logic. Refine decision tree logic as needed.

Conflicts between the use of the NISE data set and IGBP ecosystem: It was found that regions of coastal Greenland (especially along the Northeast) were flagged as being clear of snow in the NISE data set in July, but are assumed in the IGBP ecosystem classification to be permanent snow/ice. In the logic of the retrieval code, this means that the surface albedo of such pixels are given values associated with snow/ice even though they may be considered snow-free by NISE. Action: need to either improve ecosystems assignments in this region, or don't retrieve in cases of such NISE/IGBP inconsistencies.

Failed retrievals of cloud effective radius at 3.7 µm for ice clouds: Cause: unknown.

V. Anticipated Future Actions

1. Monitor performance of the cloud retrieval code in production.

2. Continue to compare cloud particle size retrievals using the three different SWIR/MWIR bands (at 1.6, 2.1, 3.7 µm).

3. Update reflectance libraries as needed.

4. Duplicate additions/corrections/features of the MODIS code in the MAS version of the cloud retrieval code.

5. Evaluate anomalous non-monotonic behavior of diffusion domain parameters in reflectance libraries and implement a correction.

6. Continued analysis of SAFARI 2000 dry season campaign (August-September 2000), and FIRE-ACE (May-June 1998) data sets. Prepare for July 2002 CRYSTAL-FACE field campaign.

7. Present status and examples of MODIS cloud products at scientific conferences and meetings.

VI. Publications

a. Published

1. Platnick, S., J. Y. Li, M. D. King, H. Gerber, and P. V. Hobbs, 2001: A solar reflectance method for retrieving cloud optical thickness and droplet size over snow and ice surfaces. J. Geophys. Res., **106**, 15,185-15,199.

2. Marchand, R. T., T. P. Ackerman, M. D. King, C. Moroney and J. P. Muller, 2001: Multiangle observations of arctic stratus clouds. J. Geophys. Res., **106**, 15201–15214.

3. Gatebe, C. K., P. D. Tyson, H. J. Annegarn, G. Helas, A. M. Kinyua, and S. Piketh, 2001: Characterization and transport of aerosols over equatorial eastern Africa. Global Biogeochem. Cycles, **15**, 663-672.

4. Dubovik, O., B. N. Holben, T. F. Eck, A. Smirnov, Y. J. Kaufman, M. D. King, D. Tanré and I. Slutsker, 2002: Variability of absorption and optical properties of key aerosol types observed in worldwide locations. J. Atmos. Sci., **59**, 590–608.

b. Accepted

4. Arnold, G. T., S. C. Tsay, M. D. King, J. Y. Li and P. F. Soulen, 2001: Airborne spectral measurements of surface-atmosphere anisotropy for Arctic sea ice and tundra. Int. J. Remote Sens., in press.

5. King, M. D., and D. D. Herring, 2002: Overview of research satellites for atmospheric sciences, 1978-present. Encyclopedia of Atmospheric Sciences, J. R. Holton, J. A. Pyle, and J. A. Curry, Eds., Academic Press, in press.

VII. Awards

1. Michael King received the William Nordberg Memorial Award for Earth Sciences, the highest award of the Goddard Space Flight Center for Achievement in research in Earth systems science, ‘in recognition of your exceptional scientific leadership of the NASA Earth Observing System during the last eight years, while leading outstanding experimental and theoretical research in atmospheric aerosol, clouds, and radiation.’

2. Michael King received the NASA Outstanding Leadership Medal ‘in recognition of your exceptional leadership of the NASA Earth Observing System (EOS) during the last eight years while maintaining outstanding contributions to the sciences of atmospheric radiation and remote sensing.’

3. Steve Platnick received the NASA GSFC Code 910 *Best Senior Author Publication Award* on July 17, 2001.

VIII. Web sites

The Cloud Retrieval Group, MODIS Atmosphere, MAS, and CAR web sites can be found at:

ltpwww.gsfc.nasa.gov/crg
modis-atmos.gsfc.nasa.gov
ltpwww.gsfc.nasa.gov/MAS
car.gsfc.nasa.gov