

**MODIS Semi-annual Report
MOD06 Optical and Microphysical Retrievals
January-June 2003**

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and

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Abstract

Major efforts over the past six months included: (1) submission of MOD06 Optical and Microphysical Retrieval recompetition proposal, (2) delivery of a MODIS Atmosphere Level-3 update, (3) delivery of the MODIS Atmosphere's new combined Level-2 product, (4) development of an above-cloud precipitable water research algorithm and a multi-layer cloud detection algorithm, (5) continued development of a Fortran 90 version of the retrieval code for use with MAS as well as operational MODIS processing, (6) preliminary analysis of CRYSTAL-FACE field experiment in July 2002, (7) continued analysis of data obtained during the SAFARI 2000 dry season campaign in southern Africa, and the Arctic FIRE-ACE experiment.

Personnel changes

Jay Dinsick left the group in June for an IT position with a private company supporting the Department of Education.

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. NASA re-competition NRA

King (PI) and Platnick submitted a recompetition proposal for continued support for the four main tasks currently being carried by the group: the MOD06 cloud retrieval product (currently supporting or partially supporting Mark Gray, Eric

Moody, Gala Wind, Brad Wind), the MODIS Atmosphere's Level-3 product (Paul Hubanks), the MODIS Atmosphere's web site (Hubanks), and the MODIS Atmosphere's combined Level-2 product (B. Wind).

King and/or Platnick were on a large number of other science data and analysis proposals.

B. Hardware

A new 8-processor SGI Origin 300, with 4 GB of memory and 2 TB of hard disk storage, was purchased and installed in June. The machine (*Amarula*) is located adjacent to the MODIS Atmosphere team machine (*Windhoek*) and shares disks with that system. For the last several years, *Windhoek* has been oversubscribed, impacting algorithm testing and development. *Amarula* is intended for cloud retrieval group activities only.

C. MODIS Code and Related Software Development

1. MOD06 Level-2 cloud retrieval code

An overview paper on the collection 004 cloud products was published in the TGRS Aqua special issue (Platnick et al.).

a. Collection 004 retrieval code - fixes and enhancements

A history file documenting changes to the production software and indicating retrieval impact has been linked to the atmosphere web site for MOD06/MYD06 optical, microphysical products as well as other atmosphere products (see products, availability calendar). No updates to the collection 004 software were made during this 6-month period, though much work has taken place offline in re-writing vast portions of the production code, converting old Fortran 77 routines to Fortran 90. Once thoroughly tested and uploaded, the scientific results will not change due to this change alone, but the PGE will process about 4 times faster on average.

b. Alternative retrieval code available for testing and development

Steve Platnick has begun working on development of a set of MAS ice cloud libraries for use in MODIS and MAS retrievals. A water cloud library and retrieval code had previously been implemented for MODIS by Gala Wind.

c. Ancillary surface albedo maps (E. Moody)

Eric Moody has worked with colleagues at Boston University (Alan Strahler, Crystal Schaaf, and Feng Gao) and NASA GSFC (Steve Platnick and Michael

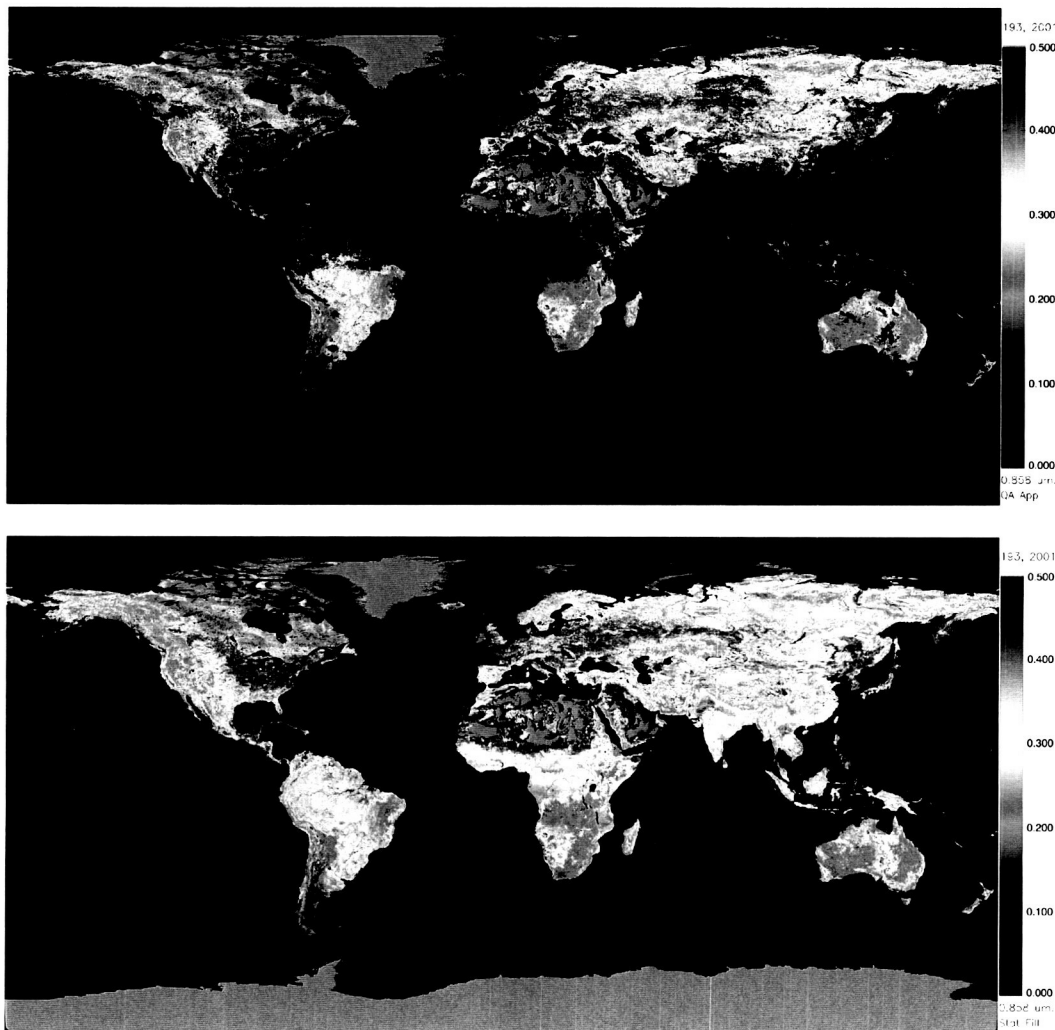


Figure 1. Example of a complete albedo map from July 2001 for the MODIS 0.86 μm band. The top image is the official MODIS product after QA has been applied, where missing data arise from persistent cloudiness and snow during this time period. The bottom image is the complete map after missing data have been filled in with the statistical replacement methodology.

operational code, PW is derived from the cloud-top property product and NCEP GDAS moisture profiles. The method has had difficulty with low warm clouds where both the cloud top pressure ($p_c > 600$ mb) and moisture profiles are often problematic. Steve Platnick and Gala Wind have developed and tested a PW algorithm using the MODIS 0.94 μm band, in a manner similar to the Gao product but with allowances for pressure-broadening effects versus cloud-top height. In addition, the window IR brightness temperature can be atmospherically corrected to obtain cloud-top temperature; pressure can then be approximated from the GDAS temperature profile. Currently, the algorithm requires a dark surface (e.g., ocean). An example image is shown in Fig. 2.

Gala Wind and Steve Platnick have developed a multi-layer cloud detection algorithm that has been tested over a variety of surfaces (land, ocean, sea ice,

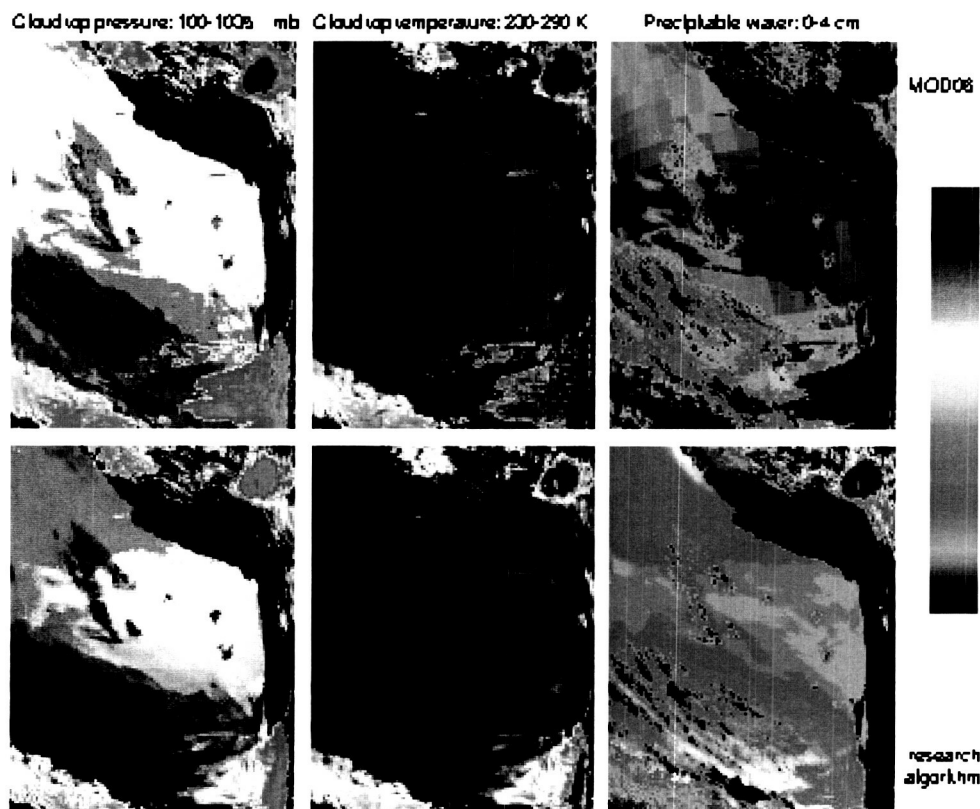


Figure 2. Example above-cloud precipitable water retrievals (right column) using the $0.94 \mu\text{m}$ band (bottom row), compared with the operational MOD06 result (top row) for a scene off the coast of Peru and Chile (July 18, 2001, 1530 UTC). Cloud top temperature and pressure from MOD06 are also shown on the top row. Cloud top temperature using the $0.94 \mu\text{m}$ precipitable water retrieval to correct for $11 \mu\text{m}$ band atmospheric absorption and emission, is shown in the middle column, bottom row; the corresponding cloud top pressure incorporating NCEP GDAS profiles is shown in the left column, bottom row. In general, over the low marine stratocumulus clouds, the research algorithm increases above-cloud moisture as well as cloud top pressure and temperature.

snow). The algorithm has two parts. First it determines above-cloud PW differences between the operational MOD06 calculation (described above) and the new $0.94 \mu\text{m}$ algorithm; the difference is normalized by the column PW as given by GDAS and a threshold is chosen. A large normalized ΔPW typically indicates a multi-layer/phase cloud situation (cirrus overlying a water cloud) where the MOD06 retrieved the scene as if it was composed of a single layer ice cloud, but where a water cloud signature was likely seen in the VIS/SWIR bands used in the retrieval. A second test looks at disagreements between the MOD06 bispectral IR cloud phase algorithm (8.5 and $11 \mu\text{m}$, Baum et al.) and the cloud retrieval phase (includes SWIR tests and cloud mask test results). A disagreement typically indicates a multi-layer cloud situation where the MOD06 retrieved the scene as if it was composed of a single layer water cloud, but where IR bands detected an ice cloud signature. The multi-layer/phase detection method doesn't require additional radiative transfer libraries. An example image is shown in Fig. 3.

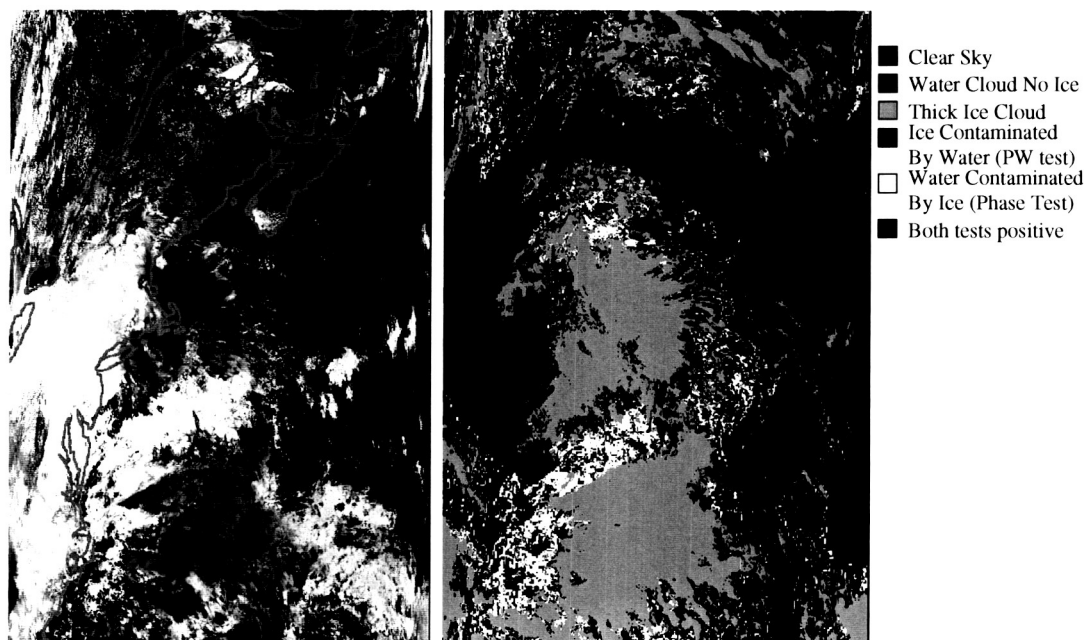


Figure 3. Results from the multilayer cloud detection algorithm for a North Atlantic granule on June 18, 2003, 1530 UTC. An RGB image (bands 7,6,4) is shown in the left panel (blue indicates likely ice cloud, and white indicates likely water cloud). The red, white, and blue colors of the right panel indicate multilevel cloud phase contamination as described in the caption; brown and green colors indicated cloud scenes where only a single phase is detected.

Brad Wind implemented a research Fortran 90 code that reads the operational MODIS cloud libraries. This capability will be used for, among other purposes, sensitivity studies of the impact of surface albedo on the MOD06 cloud retrieval products.

f. Miscellaneous Level-2 analysis

A comparison of the MODIS cloud mask product and GLAS data from March 2003 is being done for both Terra and Aqua coincident overpasses (M. Gray, A. Mahesh). Figure 4 shows an example of such a comparison for a small part of the Aqua orbit with overlaid GLAS coincidences for a scene near the Antarctic Peninsula. Note the good agreement between the MODIS-derived cloud occurrence (from the MODIS cloud mask identification) and that inferred from the GLAS lidar.

2. MOD08 Level-3 joint atmosphere code (Paul Hubanks)

An overview paper on the collection 004 MODIS Atmosphere's Level-3 products was published in the TGRS Aqua special issue (King et al.). Paul Hubanks worked on two sets of modified Level-3 software deliveries over the last six months.

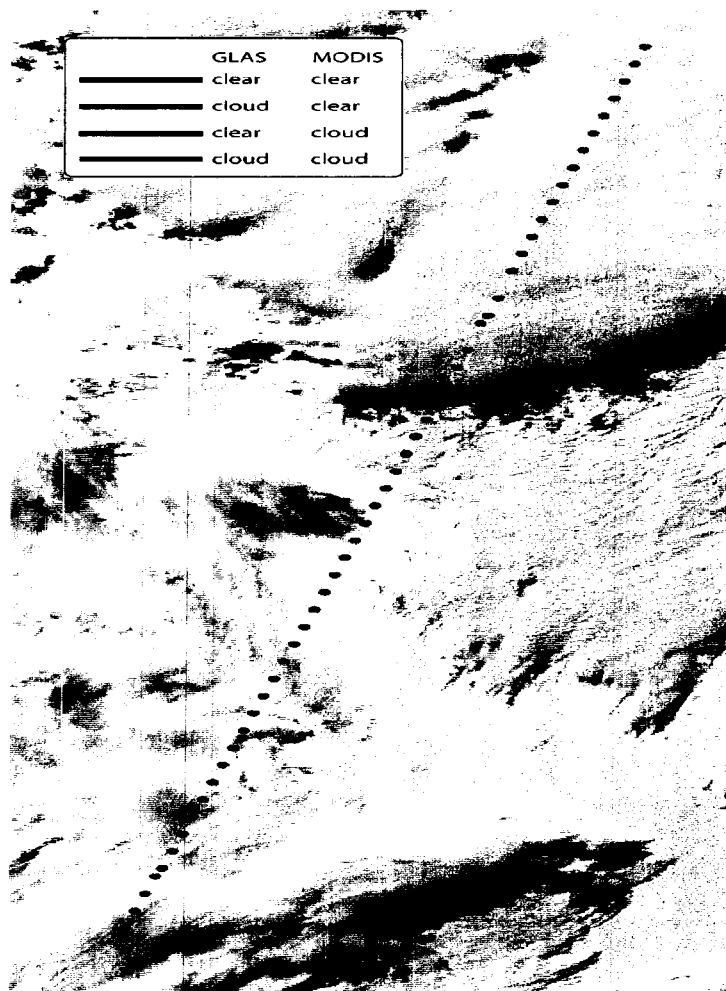


Figure 4. Comparison of MODIS-derived cloud occurrence from the operational cloud mask in comparison with coincident GLAS-derived cloud occurrence for a section of an orbit near the Antarctic Peninsula.

Delivery #1 has been completed. In this delivery, Paul corrected, tested, and delivered the entire suite of MODIS Atmosphere L3 program executables (PGEs): PGE56, 57, 69, and 70. The key updates were: (i) fix the problem with the Cloud Fraction computation in the daily Level-3 (L3) software and rename these parameters to alleviate confusion from users, (ii) fix the problem with the pixel count weighting of the MOD06_L2 optical property derived parameters for the statistics derived within the eight-day and monthly L3 software, and (iii) change the multiday weighting scheme from confidence histogram weighting to pixel count weighted for all Water Vapor (05_L2) and Atmosphere Profile (07_L2) parameters.

Delivery #2 modifications have been initiated. Paul has begun work on modifying the entire suite of MODIS Atmosphere L3 program executables (PGEs): PGE56, 57, 69, and 70 in order to implement changes requested by the Aerosol Team (Kaufman, Remer et. al). The key update was to implement a new multi-

day weighting scheme that combines pixel count weighting with a pixel count screen (if fewer than six L2 pixels populated a L3 grid cell, then set that grid cell to missing). Other changes are related to reconciling planned 04_L2 changes (SDS name changes, etc) with L3.

3. *MODIS Atmosphere Web Site*

A new server (Apple) was purchased to host the MODIS Atmosphere web site. The machine arrived in early June, and with help from Bill Ridgway and Mark Gray became active several weeks later. Jay Dinsick assisted in getting web scripts working on the new MODIS atmosphere server, along with Bill Ridgway and Brad Wind. Paul Hubanks performed a number of tests with the new server to ensure that several MS Windows applications could upload files to the Apple web server. All tests were successful.

Paul Hubanks continued to update the MODIS Atmosphere web site. Recent work has included:

- Completed a new MODIS Data Products Calendar that gives an overview of the PGE version and validation level of MODIS data available for each monthly period. The calendar also includes PGE pop-up windows that detail the changes made to all the MODIS Atmosphere science algorithms in a color-coded, impact-level format (modisatmos.gsfc.nasa.gov/products_calendar.html).
- Made numerous updates to the MODIS-Atmosphere web site, including weekly updates to the MODIS Data Products Calendar, new reference sections for Yoram Kaufman and Bo-Cai Gao, and updates to the correlative data page in the validation section. Also added MODIS and MAS versions of the 'cloud mask test' and 'final phase determination' flowcharts.
- Completed work on the web site compliance checklist required for site registration that includes Section 508 compliance for the MODIS-Atmosphere and CAR web sites. The sites were registered on March 31, 2003.
- Developed a new color bar display scheme for the L3 imagery on the MODIS-Atmosphere web site. The scheme includes new color assignments that show where image data falls outside the color bar range. Two versions were initially developed. A complete set of monthly images was run with each scheme in order to get critical feedback from the team. After approval of one of the schemes, the full set of Collection 004 monthly imagery covering 20 months for two platforms was rerun and posted on the web site.
- Updated the daily and eight day product image creation scripts with the new color bar display scheme for the L3 imagery on the MODIS-Atmosphere web site. The scheme includes new color assignments that show where image data falls outside the color bar range (greater than/equal to the top scale

value or less than/equal to the bottom scale value). Also updated the daily, eight day, and monthly product image creation scripts to match the new set of SDSs (some parameters were dropped, some parameters were added, and some parameters had their SDS names changed). Also tweaked several of the scale limits to improve the image detail.

- Updated the daily, eight day, and monthly java display scripts for use on the MODIS Atmosphere web site. These were adjusted to display the new set of SDSs in the recently delivered (updated) L3 PGE suite.

4. *MODIS product visualizations and other software tools*

A high-resolution, zoom-capable version of the group's standard IDL mapped visualization software was implemented by Mark Gray.

C. MODIS-related Instrument Efforts

1. *Cloud Absorption Radiometer (CAR)*

a. Aerosol, BRDF inversion studies

Oleg Dubovik, Code 923, Alex Sinyuk, Code 916, and Charles Gatebe, Code 913 have been working to modify the AERONET inversion algorithm to invert combined CAR/AERONET multi-spectral and multi-angular radiance measurements. The new algorithm has been successfully adapted to the CAR geometry and spectral range. The new algorithm is able to include a description of the surface bidirectional reflectance function and allows directional radiance measurements at several vertical levels. Using SAFARI 2000 CAR data over Mongu, the new algorithm has enabled retrieval of both detailed surface properties and aerosol optical properties above and below the aircraft at discrete spectral wavelengths in the ultraviolet, visible, and near-infrared window regions of the solar electromagnetic spectrum.

Charles Gatebe has been collaborating with Alexei Lyapustin, Code 920, and Eric Vermote, Code 922, in developing a well-calibrated and atmospherically corrected dataset on the bidirectional reflectance characteristics of the ocean.

b. CAR web site

Paul Hubanks continued work on and maintenance of the Cloud Absorption Radiometer (CAR) web site. No major activities to report.

2. *MODIS Airborne Simulator (MAS)*

Mark Gray continued development of a MAS version of the MODIS cloud retrieval code, including use of the latest routines developed for MODIS collection 004 algorithms. Tom Arnold led the effort on a MODIS-like cloud mask and thermodynamic phase algorithm implementation for MAS. The initial version of

this MAS code is being tested on SAFARI 2000, FIRE-ACE, and CRYSTAL-FACE data sets as described in those sections.

A MAS instrument workshop was held at GSFC in May 2003 (attend by MAS users and NASA Ames Airborne Sensor Facility personnel) to assess instrument characterization and performance over the previous year and discuss future efforts.

Using the Platnick research retrieval code (running on both MODIS and MAS data), G. Wind continued with MODIS/MAS relative calibration analysis for simultaneous observations during SAFARI 2000 and CRYSTAL-FACE. SAFARI 2000 data show a significant high bias reflectance in port 1. However it is difficult to make any definite conclusions about those data, due to lack of data for high reflectance scenes (e.g., thick clouds). CRYSTAL-FACE data don't seem to show any major differences between port 1 MAS reflectances and those from both MODIS Terra and Aqua instruments, however port 2 reflectances (e.g., 2.1 μm band) appear to be biased high in MAS.

3. *SMART suite of instruments*

Paul Hubanks completed a redesign of the SMART web site for Si-Chee Tsay.

D. MODIS-related Field Campaign and Validation Efforts

1. CRYSTAL-FACE

The NASA CRYSTAL-FACE field campaign during July 2002 sought to understand the life cycle and radiative properties of anvil cirrus and involved six aircraft, 2 ground sites, and several hundred scientists. It served as the first MODIS validation activity for ice cloud optical and microphysical retrievals.

The initial work with the CRYSTAL-FACE MAS data set focused on assessment of the cloud mask and thermodynamic phase algorithms (Tom Arnold). After completion of the following modifications, the entire CRYSTAL-FACE MAS dataset was reprocessed and imagery was placed on-line.

- Analysis of CRYSTAL-FACE MAS cloud mask data showed the cloud mask was occasionally detecting significant areas of ice surface over the ocean ecosystem in and around Florida. This problem was traced to the use of the 'clear sky' ice/snow surface detection algorithm that uses the 1.6 μm channel employed by MODIS. It has now been turned off for CRYSTAL-FACE MAS processing.
- Modifications were also made to the MAS thermodynamic phase imagery software to make it more consistent with similar MODIS software, and to interface with scripts written to process many CRYSTAL-FACE data segments in a production mode.

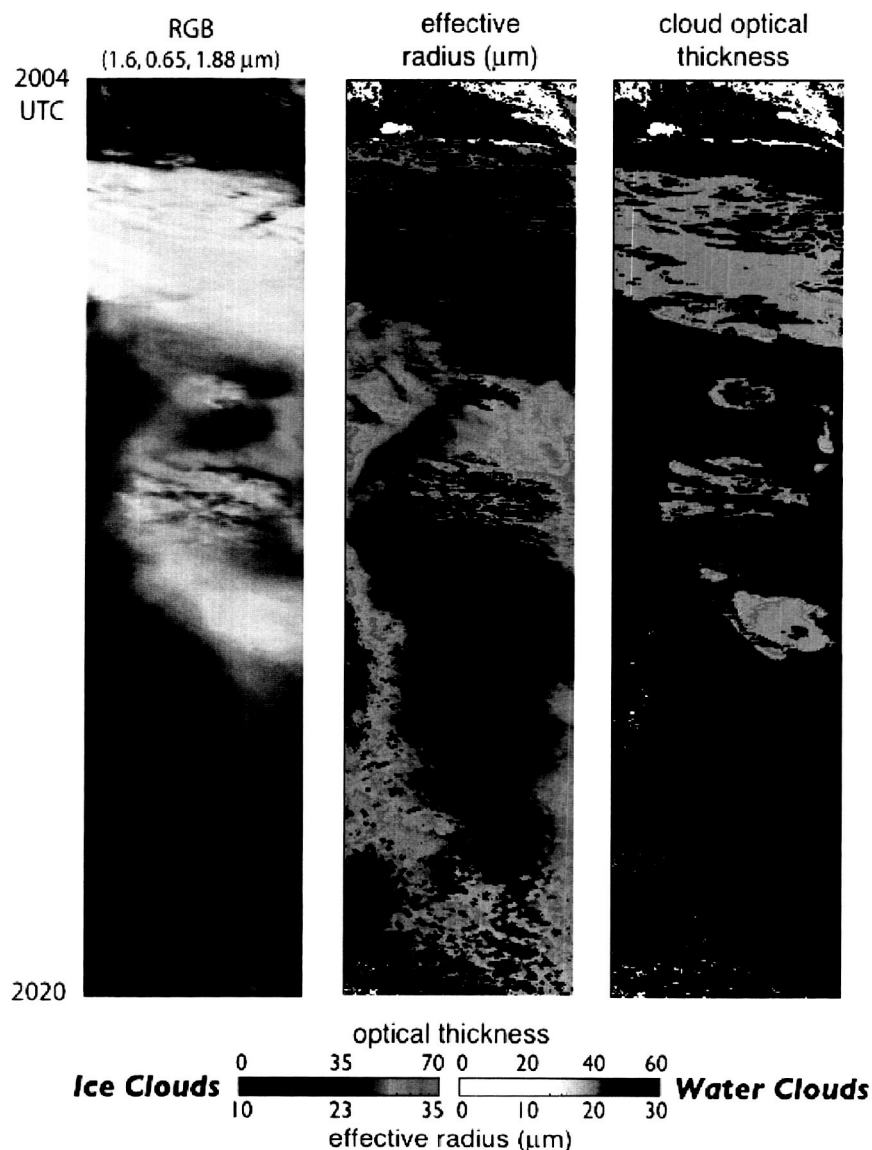


Figure 5. A CRYSTAL-FACE MAS retrieval from July 23, 2002. Convective cores (larger optical thickness) in the middle and top of the image are correlated with small particle sizes. Failed retrievals (black regions) in the optically thick parts of the cloud correspond to reflectances outside the library space.

Mark Gray developed a Fortran 90 version of the MODIS retrieval code for use in processing MAS. A number of selected flight tracks of MAS data from the CRYSTAL-FACE were processed with the MAS cloud mask, thermodynamic phase, and optical thickness and particle code. Resultant imagery was then distributed to various CRYSTAL-FACE scientists for presentation at Feb. CRYSTAL-FACE science meeting and follow-up efforts. An example retrieval is shown in Fig. 5.

MODIS Terra and Aqua granules over the operations area have also been analyzed and presented at the CRYSTAL-FACE Science Team meeting in Salt Lake

City and at the European Geophysical Society meeting in Nice, France.

2. SAFARI 2000

All SAFARI granules (over southern African and the SAFARI 2000 operations period) were to have been reprocessed using collection 004 MOD35 and MOD06 operational code, but with the sunglint logic disabled (so as to acquire more Namibian coastal clouds in the sunglint region). These data sets were analyzed by Paul Hubanks with the Level-3 high resolution code and unexpectedly found to be virtually identical to MODAPS results over the ocean. It turned out that the sunglint logic had not been disabled and therefore three SAFARI ocean granules will have to be re-run again with the sunglint logic disabled (Gray).

The Level-3 analysis will be combined with MODIS/MAS Level-2 cloud retrievals and validation for a journal submission.

3. FIRE-ACE

Tom Arnold worked on fine-tuning the MAS cloud mask and thermodynamic phase algorithms for use with FIRE-ACE data. One of the outcomes was the decision to use the 3.9 μm band rather than the 3.7 μm band in polar region processing, to be commensurate with the MODIS algorithm.

Due to a number of changes made to the cloud mask and phase determination software, cloud mask and phase imagery was reprocessed for the June 4, 1998 flight track discussed in the submitted paper by King et al. (submitted to *J. Atmos. Sci.*, 2003). Overall changes to the image were minor (most of the “undecided” phase data was classified as water. Very thin marine stratus cloud (over sea ice and near cloud edge) sometimes gets classified as ice.

FIRE-ACE MAS liquid water and ice cloud retrievals have been completed after development of a Fortran 90 version of the MODIS cloud retrieval code by M. Gray.

An example retrieval from the King et al. paper is shown in Fig 6.

4. CLAMS

Additional roll correction was done on the CLAMS 2001 CAR dataset by Tom Arnold, including one flight that had not been previously processed. Roll correction for CLAMS is now considered complete (though there are still a few segments on various flights that have not been corrected – but are considered to be too complex to be worth the time necessary to correct them). All CLAMS 2001 CAR BRDF data have been reprocessed using roll corrected data, an updated calibration, and revised solar irradiance values.

Charles Gatebe and others are working on two publications for the CLAMS spe-

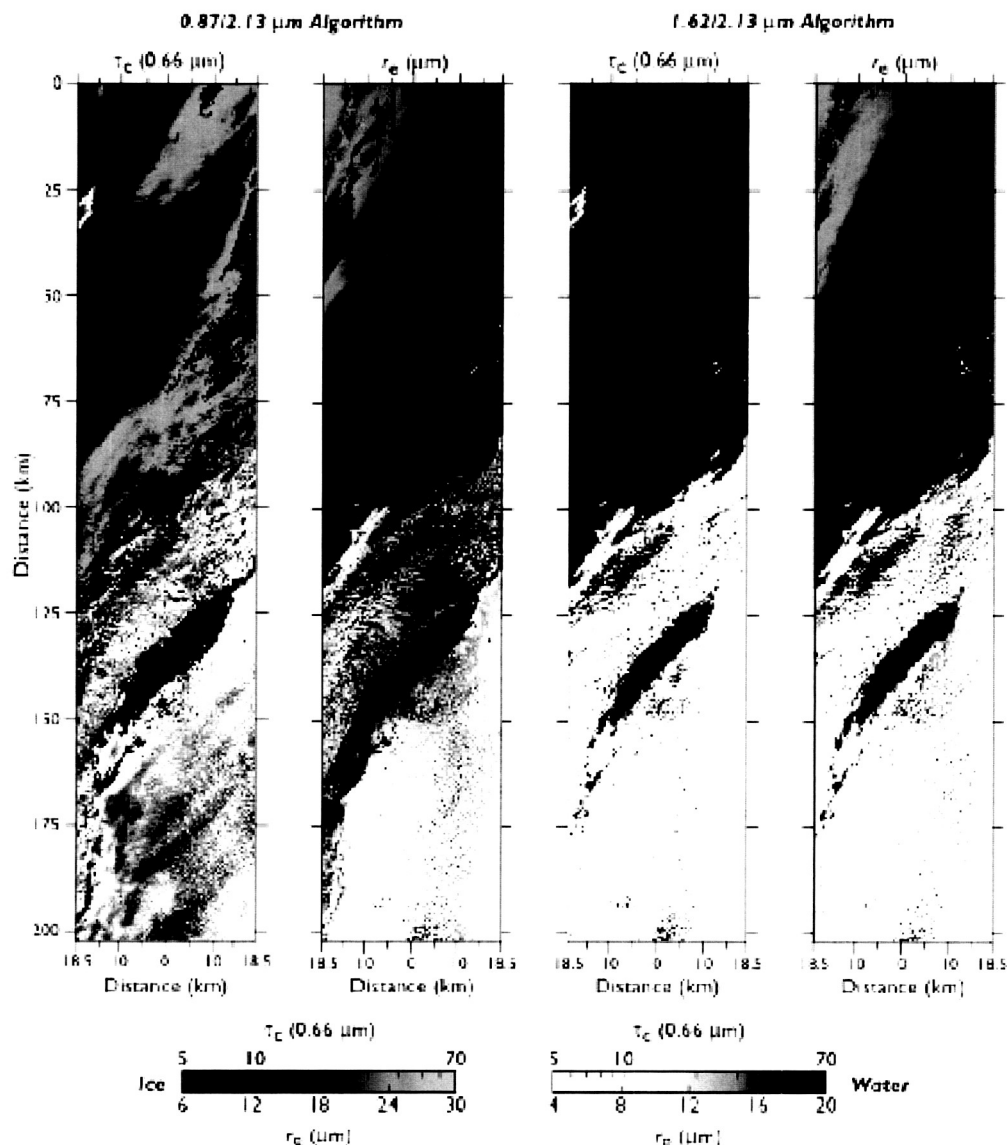


Figure 6. FIRE-ACE MAS retrievals for stratiform water and ice cloud over an ice surface (north of Barrow AK). Two versions (different band combinations) of the retrieval algorithm are shown.

cial issue based on CAR ocean BRDF measurements during the CLAMS field experiment. Tom Arnold, Oleg Dubovik and Charles Gatebe discovered a problem with aircraft navigation data for CAR during SAFARI 2000 where the azimuthal plane is shifted $>10^\circ$. A fix is being worked.

III. Anticipated Future Actions

1. The group will continue to monitor performance of the cloud retrieval code in production.
2. Continue with the analysis, development, and refinement of fill methodology for the value-added surface albedo product (E. Moody).

3. Continue development of a MODIS/MAS retrieval code. Include $0.94\ \mu\text{m}$ above-cloud water vapor retrieval for low-cloud temperature and pressure height (M. Gray).
4. Continue evaluating and write-up papers describing above-cloud water vapor retrieval and multi-layer/phase detection algorithm (G. Wind, S. Platnick).
5. Continued analysis of SAFARI 2000 dry season (August-September 2000), FIRE-ACE (May-June 1998), and CRYSTAL-FACE (July 2002) field campaigns.
6. Continue work on development of a new inversion scheme to simultaneously retrieve aerosol optical properties and surface BRDF with CAR measurements.
7. Evaluate anomalous non-monotonic behavior of diffusion domain parameters in reflectance libraries and implement a correction.

IV. Publications

A. Published

1. King, M. D., W. P. Menzel, Y. J. Kaufman, D. Tanré, B. C. Gao, S. Platnick, S. A. Ackerman, L. A. Remer, R. Pincus, and P. A. Hubanks, 2003: Cloud and aerosol properties, precipitable water, and profiles of temperature and humidity from MODIS. *IEEE Trans. Geosci. Remote Sens.*, **41**, 442–458.
2. Platnick, S., M. D. King, S. A. Ackerman, W. P. Menzel, B. A. Baum, J. C. Riédi, and R. A. Frey, 2003: The MODIS cloud products: Algorithms and examples from Terra. *IEEE Trans. Geosci. Remote Sens.*, **41**, 459–473.
3. Gatebe, C. K., M. D. King, S. Platnick, G. T. Arnold, E. F. Vermote, and B. Schmid, 2003: Airborne spectral measurements of surface-atmosphere anisotropy for several surfaces and ecosystems over southern Africa. *J. Geophys. Res.*, **108**, 8489, doi:10.1029/2002JD002397.
4. King, M. D., S. Platnick, C. C. Moeller, H. E. Revercomb and D. A. Chu, 2003: Remote sensing of smoke, land and clouds from the NASA ER-2 during SAFARI 2000. *J. Geophys. Res.*, **108**, 8502, doi:10.1029/2002JD003207.
5. Swap, R. J., H. J. Annegarn, J. T. Suttles, M. D. King, S. Platnick, J. L. Privette and R. J. Scholes, 2003: Africa burning: A thematic analysis of the Southern African Regional Science Initiative (SAFARI 2000). *J. Geophys. Res.*, **108**, 8465, doi:10.1029/2003JD003747.

B. Submitted

1. King, M. D., S. Platnick, P. Yang, G. T. Arnold, M. A. Gray, J. C. Riédi, S. A. Ackerman and K. N. Liou, 2004: Remote sensing of liquid water and ice cloud optical thickness, and effective radius in the arctic: Application of airborne multispectral MAS data. Submitted to *J. Atmos. Sci.*
2. Pinker, R. T., H. Wang, M. D. King, and S. Platnick, 2003: A first view of global radiative fluxes from MODIS. Submitted to *GEWEX News*.

V. MODIS-related Services, Presentations, and Meetings

A. Science meetings attended and presentations

1. King and Platnick attended the CRYSTAL-FACE Science Team Meeting in Salt Lake City UT, February 23-27, 2003, giving talks on "MODIS cloud optical and microphysical properties during CRYSTAL-FACE" and "MAS retrievals of cloud thermodynamic phase, optical thickness, and particle size during CRYSTAL-FACE", respectively.
2. Platnick attended the CloudSat Science Team Meeting in Broomfield CO, March 4-7, 2003.
3. King, Platnick, Arnold, Dinsick, Gray, Moody, B. Wind, and G. Wind attended the MODIS Atmosphere Team Meeting in St. Michaels MD, March 17-19, 2003. The meeting was organized by M. D. King.
4. King, Platnick, Arnold, et al. attended the MAS Instrument Workshop, GSFC, May 20-21, 2003.
5. Platnick organized a cloud mask workshop for the Aqua Science Working Group meeting held at GSFC May 28-29, 2003.
6. Moody, E. G.: Tools for visualizing and utilizing MODIS data. AERONET user seminar, NASA Goddard Space Flight Center, Greenbelt, MD, January 16, 2003.
7. Moody, E. G., M. D. King, S. Platnick, C. B. Schaaf, F. Gao, Xiaoyang Zhang: Value-added white- and black-sky surface albedo product derived from Terra MODIS data. Boston University Department Seminar. Boston, MA, January 31, 2003.
8. Moody, E. G., M. D. King, S. Platnick, C. B. Schaaf, F. Gao: Value-added white- and black-sky surface albedo product derived from Terra MODIS data. NASA GSFC Brown Bag Lunch Seminar, Greenbelt, MD, February 12, 2003.
9. Moody, E. G., M. D. King, S. Platnick, C. B. Schaaf, F. Gao, Value-added albedo and ecosystem products derived from MODIS data. MODIS Atmos-

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