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INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC PROFILES WITH MODIS

SEMI-ANNUAL REPORT FOR JUL-DEC 1996

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ABSTRACT

The second half of 1996 was spent completing the Version 1 science software deliveries. All five production code packages were transferred to the Science Data Support Team (SDST) for integration into the Distributed Active Archive Center (DAAC). Preparation for Version 2 software began with the UW hosting an atmosphere discipline group programmers meeting in November. Considerable effort went into evaluating the infrared calibration of MODIS with the MODIS Characterization Support Team (MCST), including hosting an August audit of the calibration algorithm. All UW Algorithm Theoretical Basis Documents (ATBD's) were updated and reviewed in November. Selected MAS data sets from the SUCCESS field experiment were processed; early science results have identified wave clouds with very large spectral signatures in the infrared. Preparations began for the WINter Cloud Experiment (WINCE), whose main objective is to improve cloud detection in winter environments.

TASK OBJECTIVES

Software Development

All five UW science production software packages (cloud mask, cloud top properties, cloud phase, atmospheric profiles, and ancillary data) have been delivered to SDST. All algorithms will continue be tested using MAS data segments from both the SUCCESS and WINCE experiments and the evolution of the algorithms will be tracked in the Version 2 deliveries in 1997.

ATBD Evolution

All UW ATBD's (cloud mask ATBD-MOD-06, cloud top properties and cloud phase ATBD-MOD-04, and atmospheric profiles ATBD-MOD-07) have been updated to reflect the current production software algorithms and reviewed by the EOS ATBD panel in November. Incorporation of the suggestions and feedback from the November review is being pursued.

MODIS Infrared Calibration

MODIS infrared spectral response and channel to channel crosstalk data from SBRS is being investigated and effects on calibration and derived products is being characterized. Simulations using MAS data are revealing alarming impacts; UW is participating in the Thermal Infrared Task Force to suggest possible corrections. The MCST theoretical development of the thermal IR calibration algorithm has produced a mature version and the start of software coding has been encouraged.

WORK ACCOMPLISHED

MODIS Software Development and Lessons Learned from Version 1

The Version 1 production software packages were delivered to the SDST, which included code for thermodynamic cloud phase, cloud top properties and atmospheric profiles. These were accepted by configuration management after testing at GSFC. The completion of the UW Version 1 production code is the culmination of a long progression of development involving everything from toolkit installations to visualization tools.

For the Beta atmospheric profiles software delivery, a physical algorithm was used as an engineering test that required considerable CPU time. For Version 1, a more computationally efficient algorithm was implemented using previously determined statistical relationships between observed (or modeled) radiances and the corresponding atmospheric profiles. This method is often used to generate a first-guess for a physical retrieval algorithm, as is done in the International TOVS Processing Package. The statistical regression algorithm has the advantage of computational speed, numerical stability, and simplicity. However it does not account for the physical properties of the Radiative Transfer Equation. We intend to deliver a physical retrieval algorithm as a post-launch algorithm, while our at-launch algorithm will be of the statistical kind described in detail in the updated MODIS Atmospheric Profiles ATBD. (An example of statistical and physical retrievals from HIRS is shown in Figure 1).

UW developed several easy-to-use IDL tools which are helpful in visualizing MODIS data. They were released to the public via the World Wide Web and include:

- Satellite image resampling onto a map projection,
- Point-and-click interface for reading SDS data from HDF files,
- Point-and-click interface for reading a binary image,
- Multiple image frames.

These tools are compatible with IDL 4.0.1 and are available for download at http://cimss.ssec.wisc.edu/~gumley under 'IDL Local Resources'.

The MODIS Atmosphere Group at their meeting at Chincoteague, Virginia on July 17-18 decided to draft a letter to SDST outlining their experience with the Version 1 software deliveries, and to strongly suggest ways of improving the Version 2 software development. In summary, it was recommended that the following key aspects of Version 2 development be frozen on December 1, 1996:

- Requirements for Version 2 software delivery,
- Simulated input datasets (including Level 1B, geolocation, and ancillary data),
- MAPI, PGS, and HDF toolkit versions,
- Output product file specifications.

Consensus was that this strategy would enable the highest quality software to be developed in the time available. Improving the science in the algorithms is the highest priority for the Version 2 delivery, and the majority of resources and time must be used meet this goal. Implementing the strategy described above offers the best opportunity.

HDF Cloud Mask Code

A new version of the MAS (MODIS Airborne Simulator) cloud mask has been written. It uses MAS radiance data input in HDF format, rather than McIDAS Digital Areas or simple binary "flat files". Also, the HDF data sets contain more ancillary data than previously. There are now two identical versions of the cloud mask software (one at UW and another at GSFC) which will process both the UW McIDAS MAS and the DAAC HDF archived MAS data formats.

Example Level 3 Products

Several example Level 3 products were constructed from the CHAPS (**C**ollocated **HIRS** and **A**VHRR **P**roduct**S**) data set. CHAPS data have many of the characteristics anticipated in MODIS data; they are global, contain many derived products as well as ancillary data, and use radiance data at more than one spatial resolution. Examples of global monthly mean and global eight-day mean gridded equal-area and equal-angle products at 0.5 degree spatial resolution were created in HDF format.

MODIS Atmosphere Group Programmers Meeting

The UW hosted a meeting to address concerns of the Atmosphere Discipline Group on 12-13 November. Programmer representatives of the Principal Investigators attended. Several decisions concerning Version 2 software were made.

1) It was decided that atmospheric products will include an HDF SDS byte consisting of a Q/A field which follows the structure of the first byte of the cloud mask product for each spatial element. A second byte of Q/A data will describe the quality of the product; the first 4 bits in a standard structure and the second to be product dependent.

2) It was recommended that geolocation information be included in each product file to facilitate easy visualization and to accommodate multi-pixel resolution.

3) It was decided that an SDS attribute 'Source" be added to the product files to define a variable origin. This will help to discern which product parameters are actual MODIS outputs from those which are used for validation or debugging.

4) Options were discussed for combining products which are produced by different executables into a single product file. The most promising method, which was outlined by Rich Hucek, involves the creation of a main program, which will treat each different executable as a subroutine. The advantage to this procedure is that you open files only once, and create common metadata at the same time.

5) The MODIS Level 3 programmer, Ms. Xu Liang, discussed problems relating to the collation of Level 2 products and computation of Level 3 output products. Fourteen orbits of CHAPS data (time period of one day) will serve as example data for use in algorithm development.

Synthetic Data Set

Building on previous work which resampled MAS data to resemble MODIS 250, 500, and 1000 meter bands, work commenced on resampling a SUCCESS dataset to this MODIS-like format. For simplicity, this dataset will be stored in flat binary format, along with the corresponding geolocation and cloud mask data files. This dataset should be ready for release by the end of January 1997. It's primary purpose will be to aid in UW algorithm development, however other it will also be available to MODIS team members.

Post Launch Checkout Scenarios for the TLCF

UW drafted a strategy for efficient utilization of the MODIS Team Leader Computing Facility (TLCF) during the period immediately following MODIS launch. During this time, MODIS algorithm developers will need to respond rapidly to improvements in MODIS calibration and geolocation, to rapidly update algorithms to account for in-flight instrument performance, and improve their algorithms using the latest versions of 'up-stream' products. Here, 'rapid' refers to a time scale of hours, not days. The TLCF is tasked to support MODIS algorithm development, so it offers the prospect of providing rapid algorithm development. The UW draft was distributed to the Atmosphere Group and to SDST at the fall 1996 MODIS Science Team Meeting. It outlined a plan for how the TLCF resources will be used in the post-launch checkout time frame, including what type of processing will be done, and what MODIS test data will be available. It also outlined a system for configuration control of software that allows rapid algorithm development in the post-launch checkout time frame, but still enables tracking of software history. Copies of this document are available upon request.

Shadow Detection

A first attempt has been made to detect cloud shadows using MAS multi-spectral radiance data. Reflectances from the 1.62, 0.88, and 0.66 µm channels are used in a simple thresholding scheme to determine the presence of shadows over land surfaces. It is anticipated that modifications will be needed as MAS data from more land surface types becomes available.

MODIS IR Calibration and Performance Testing

At the MODIS calibration workshop held in Madison, WI on 28-29 August, MCST presented the MODIS IR calibration algorithm and thermal vacuum test data issues were discussed. Some details that emerged were: (a) linear versus non-linear application of the calibration algorithm will be determined for each detector (instead of each band); (b) no image restoration should be applied in the IR; (c) blackbody thermistor processing will be done in two steps; first screening for bad data in each thermistor, and then screening for bad thermistors; (d) blackbody emissivity will be characterized and set pre-launch; any necessary postlaunch adjustments will focus on the BB temperature; (e) several elements in the cavity will be included in the background radiation term (Lo) so that their radiation can be correlated with possible calibration errors postlaunch; (f) the algorithm will maintain an option for a floating detector patch temperature.

Further discussion lead to the following conclusions: Testing of the algorithm with data from the EM and PFM tests must begin as soon as possible. Software coding of the IR calibration algorithm should begin as soon as possible, in parallel with the testing of the algorithm with vacuum test data. The effects of the longwave infrared channel crosstalk must be characterized as completely as possible by SBRS, particularly the spatial weighting effects versus the spectral response effects. The importance of the spacecraft maneuver to view space must be stressed to the SWAMP scientist; the IR calibration is relying heavily on the data from this maneuver to characterize IR calibration dependence on scan angle.

During the September Santa Barbara Remote Sensing (SBRS) Quarterly Review and the October MODIS Calibration Workshop and Science Team meetings (attended by Chris Moeller, Dan LaPorte, and Paul Menzel), SBRS presented MODIS PFM (with EM electronics) performance test data. Performance anomalies and uncertainty in MODIS Long Wave Infrared (LWIR) bands 31-36 due to LWIR crosstalk and poor RSR characterization cause MODIS LWIR calibration errors in excess of 1°C. This exceeds the error tolerance of MODIS Cloud Properties, Atmospheric Profiles, and Cloud Mask Products leaving these algorithms somewhere between challenged and broken. SBRS agreed to collect a new set of system LWIR ambient RSR data with improvements in S/N and sampling interval, as well as collect system spatial measurements in the LWIR bands. The new LWIR RSR measurements were collected in early December and have been reviewed at UW. The quality of the measurements is much improved. UW has participated in the atmospheric correction of these measurements by creating FASCODE forward model atmospheric corrections. A 5 nanometer spectral shift to longer wavelengths has been identified in the band 35 RSR data (Figure 2), which causes about a 0.25°C change in the band 35 calibration. Other LWIR bands do not contain isolated spectral features that help to identify spectral shifts in the RSR data, however it is assumed that all bands measured with the same grating will exhibit the same spectral shifts. Information on which gratings used for the RSR measurements of each LWIR band is being sought.

Simulations of the estimated 5% crosstalk from MODIS band 31 into band 35 using MAS data show strong impact on band 35 temperatures (up to 10°C); band 31 surface radiation is affecting the band 35 atmospheric radiances. The 6 field of view offset of the stray band 31 radiation also causes a "ghosting" in the simulated band 35 image, especially where there are contrasting features, such as cloud over land. SBRS has collected spatial data to characterize the crosstalk. While the spatial position of the leak seems to be fairly well understood, the amplitude of the leak is still a subject of investigation because the spectral shape of the 2700K ScMA source has not been corrected out of the NFR data set. Tests to correct the simulated band 35 images for the crosstalk effects have begun. Due to schedule pressures and the incomplete understanding of the crosstalk phenomenon, it appears likely that PFM will be launched with this phenomenon. However, it has been strongly encouraged that the underlying physical mechanism of the leak on PFM be understood and that it be eliminated on FM-1.

MAS Infrared Calibration

MAS spectral characterization has been measured at the Ames Research Center (ARC) calibration facility September 23,24. Measurement highlights include: (a) FTIR reference detector was installed and measurements were made for MAS Ports 2, 3, & 4. (b) The spectral leaks in Bands 38, 39, 40, & 41 were quantified. (c) The effect of water vapor on the spectral shape of bands 37 through 41 was removed. (d) The effect of CO_2 on the spectral shape of bands 34,49 & 50 was removed. (e) A procedure for rapid measurements of spectral band shape was implemented so that ports 2, 3, & 4 can be measured in less than 3 hours.

During a July visit to BOMEM in Quebec, Dan LaPorte suggested that BOMEM develop a larger source for the MB100 used at the ARC calibration facility. This would cause the source to effectively overfill the MAS aperture during spectral response measurement, eliminating a source of uncertainty in the spectral measurement. BOMEM has agreed to develop and ship a larger replacement source to ARC.

MAS post processed spectral response data were reviewed for application to the SCAR-B MAS data set (from August 95). Using atmospheric window spectral channels, a comparison between July 95 and October 95 spectral measurements showed a spectral shift in Port 1 (VIS,NIR) of about .002 microns, in Port 2 (SWIR) about .006 microns, in Port 3 (MWIR) about .035 microns, and in Port 4 (LWIR) about .015 microns. All shifts were to shorter wavelengths. These shifts represent 5%, 12%, 23%, and 3% of the typical spectral bandpass in Ports 1-4 respectively. This comparison was used to characterize the MAS spectral performance during SCAR-B. The updated MAS spectral response has been delivered by ARC to the GSFC DAAC for SCAR-B data set processing.

MAS HDF infrared radiances (produced at GSFC DAAC) and University Wisconsin MAS McIDAS radiances were found to differ during comparison testing. The difference was traced to a coding error in the GSFC processing software and has been rectified for Version 6 processing. Additionally, Wisconsin Planck function conversion software has been delivered and incorporated into MAS HDF processing. Planck function correction coefficients have been added to the HDF output format and spectral response function data is being made available to users through the MAS homepage at GSFC. Routine MAS calibration comparisons between GSFC and UW are now recommended as a standard procedure to minimize infrared calibration disparities in the future.

MAS blackbody effective emissivity estimates and their impact on IR calibration were presented in the EOS conference at the SPIE annual meeting held in August. Results of that work show that MAS infrared calibration biases (compared to HIS instrument) are less than 1°C for LWIR channels and show minimal dependence on scene temperature. Further comparisons of MAS calibrated radiances with HIS radiances are planned on future ER2 deployments.

MAS spectral measurements made at Ames Research Center's calibration facility are being used to specify the MAS SUCCESS spectral calibration. Measurements were collected in March (pre-deployment) and June (post-deployment). Atmospheric window bands have been post-processed and compared. These comparisons indicate a spectral shift of about .03 and .06 microns in Ports 3 and 4 respectively over the duration of the SUCCESS field program. This is equivalent to about a 1.5°C and 0.5°C calibration uncertainty for bands 32 (3.9 micron) and 45 (11 micron) respectively. The characterization of the spectral shift over time will be investigated by comparing MAS and HIS data throughout the SUCCESS experiment. Atmospheric correction of the spectral measurements has been completed for Port 2 bands; atmospheric correction using FASCODE convolutions to spectral measurement shape functions is planned for Ports 3 and 4.

<u>Aerosol Detection</u>

Hourly multi-spectral GOES-8 data were collected over the eastern US and the Atlantic Ocean during the TARFOX field campaign (10-31 July 1996). The GOES satellite database for this study extends from 10 to 60°N and from 20 to 100°W. During ER-2 flights half-hourly GOES imagery were collected. These data will be used in conjunction with SCAR-B GOES, ancillary aircraft, and ground measurements to document the spatial and temporal distribution of aerosols over the Atlantic Basin. This work is part of a collaborative effort led by Mr. Brent Holben (NASA/GSFC) to characterize aerosol forcing over the Atlantic Basin associated with three major aerosol components in this region: urban/sulfate, Saharan dust, and biomass burning.

EOS Validation Plan

The atmosphere discipline group developed a science data validation plan as a subset of the EOS project validation plan, where contributions were integrated by Dr. Michael King. The overall validation approach relies heavily on the sources of the data that were used in the algorithm development, which consisted primarily of the MAS, and the HIS, a 2 km resolution nadir-viewing Michelson interferometer with 0.5 cm^{-1} spectral resolution from 4 to 15 microns.

Several field programs offer opportunities for pre-launch and post-launch MODIS validation through collection and analysis of observations obtained from the MODIS Airborne Simulator and High-spectral resolution Interferometer Sounder (HIS). These field campaigns, principal focus, and UW MODIS atmosphere group participants, include:

Mission	***Dates***	***Responsible Team Members***	***Primary Purpose***
SUCCESS	April-May 1996	Steve Ackerman, Si-Chee Tsay, Paul Menzel	cirrus cloud properties
FIRE III	May-June 1998	Michael King, Si-Chee Tsay, Steve Platnick, Steve Ackerman	arctic stratus clouds over sea ice
MODIS-specific validation campaigns			
WINCE	January 1997	Paul Menzel, Steve Ackerman, Dorothy Hall	cloud detection and properties over snow/ ice covered surfaces
ARM-1	October 1998	Paul Menzel, Steve Ackerman	periodic flights over the Oklahoma ARM site with MAS & HIS
MOBY	January 1999	Paul Menzel, Steve Ackerman	cirrus clouds and atmospheric corrections over the ocean

Mission	***Dates***	***Responsible Team Members***	***Primary Purpose***
ARM-2	April-May 1999	Paul Menzel, Steve Ackerman	periodic flights over the Oklahoma ARM site with MAS & HIS
Gulf of Mexico	January 2000	Paul Menzel, Chris Moeller	clear sky and cirrus clouds, including sediment outflow from river estuaries

In addition to these ER-2 field campaigns, which often include the Cloud Lidar System (CLS) for verifying cloud top altitude and multi-layer clouds, the University of Washington C-131A, with the Cloud Absorption Radiometer (CAR) and extensive in situ cloud microphysics (liquid water content, effective radius, cloud drop size distribution), aerosol properties (size distribution, scattering and absorption coefficients), and meteorological sensors, will be used as required.

In addition to these airborne campaigns in which MODIS team members are directly planning to participate, we expect to make use of selected ground-based networks as follows:

Network	*Location*	*Responsible Team Members*	*Primary Purpose*
ARM	Oklahoma, North Slope of Alaska, Western Tropical Pacific	Paul Menzel, Si-Chee Tsay	cloud base height (micropulse lidar), temperature and moisture profiles, sky radiance (visible and IR)

The ground-based measurements will be obtained on a continuous basis as well as during intensive field experiments.

Several field campaigns are planned with the ER-2 aircraft carrying the MAS and HIS over various scenes and ecosystems. In addition to the major national and international activities outlined above, we envision the following focused and short field deployments: (1) A ground campaign with the ER-2 over the ARM CART site in Oklahoma would entail post-launch deployment of the MAS and HIS on the ER-2 aircraft to coincide with a MODIS overflight and to collect simultaneous ground-based class-sondes, AERI (a ground-based Michelson interferometer), tower measurements of temperature and moisture at various elevations, microwave moisture measurements, lidar and radar cloud observations, and whole sky camera images. (2) Ground campaigns with all sky cameras (from the University of Chicago, Dr. Ted Fujita) would include observations in both winter and summer in the upper Midwest.

Comparisons with products from other platforms are also planned. Cloud masks will be compared with those from AVHRR and HIRS/2 data, and ASTER and MISR (also on the AM-1 platform). The CERES cloud mask makes use of MODIS data (on AM-1) and is essentially the same algorithm as MODIS, so no independent verification is thereby possible. Atmospheric profiles will be compared with those from HIRS, GOES, and AIRS/AMSU/HSB (also on the PM-1 platform). Cloud properties will be intercompared with those derived from HIRS, CERES, and MISR (cloud top altitude), as well as from in situ aircraft (see below). Precipitable water vapor measurements will be compared to (i) radiosonde measurements over the continents, (ii) model output obtained as part of the EOS data assimilation interdisciplinary science team (Dr. Richard Rood, principal investigator), and (iii) periodic differential absorption lidar measurements from the ER-2 aircraft (LASE; Dr. Ed Browell). Timing, coverage and resolution will vary from one instrument to another; for example with ASTER, comparisons will be possible for selected swaths (60 km wide with 30 m resolution) that are available for different (and selected) ecosystems no more than once every 16 days.

A consolidation of ER-2 field programs for EOS validation has been requested by Dave Starr. Proposed scheduling by the MODIS Atmosphere discipline group for ER-2 deployments in fiscal years 1997-2001 was reviewed. Suggested modifications were forwarded to Michael King for assimilation into the MODIS Atmosphere's group validation plan and are reflected in the charts above. Modifications include eliminating one field campaign of FIRE III in FY 1998, moving the ARM-1 deployment from FY1998 to FY1999, and delaying the MOBY overflights until January 1999.

<u>MODIS ATBD Review</u>

UW (Steve Ackerman, Paul Menzel, and Liam Gumley) presented the algorithms for cloud mask, cloud top properties, and atmospheric profiles on 20 November to the review panel. Overall the algorithms were well received. Several suggestions were noted. (1) The CO2 slicing algorithm for deriving cloud top pressure and emissivity should account for the modest (5%) differences in the emissivity of one CO2 channel from the next. (2) Diffraction should be accounted for in the cloud mask as well as the atmospheric profiles in attempts to identify clear sky versus cloud obstructed fields of view. (3) Buoyant energy should be considered as an indicator of atmospheric stability in addition of lifted index. (4) There should be more coordination of validation experiments for all the instruments. UW is looking into implementing all of these suggestions.

<u>Preparation for the WINter Cloud Experiment (WINCE)</u>

Preparations are underway for the January/February 1997 WINCE field program to be based in Madison, WI. WINCE will assess cloud and snow detection in winter background conditions (snow, ice) in support of MODIS data products (MODIS Cloud Mask, Cloud Top Properties, Snow Mask). The experiment will be conducted using NASA's ER-2 aircraft with a payload including MAS, HIS, MIR, CLS, TSCC, and the RC-10 camera system. A field site visit by Gary Shelton (NASA HQ) in September confirmed the utility of Truax Field for supporting the ER-2 aircraft operations. MAS will provide multispectral observations of clouds and snow background conditions; CLS will provide cloud detection validation; HIS will provide IR calibration validation as well as spectral data for atmospheric profiling and cloud studies, while MIR collects microwave observations useful for defining snow background. Data collection will take place over the upper Midwest, New England, and Southern Canada in both day and nighttime conditions. Scenes will include clear-sky, cirrus, and scattered cloud over snow and water (Lakes Michigan and Superior) backgrounds. In addition, underflights of the Japanese ADEOS satellite (POLDER, IMG, OCTS instruments) will be attempted. Several ground-based instruments will be overflown, including the uplooking AERI instrument, the uplooking HSRL lidar, atmospheric and surface flux measuring instruments. Classondes will also be launched in coordination with ER-2 overpasses of the University Wisconsin. In situ snow characteristics will be measured by Dr. Dorothy Hall of GSFC in support of her MODIS Snow Mask product. A total of about 10 flights are anticipated during the 3 week program beginning Jan 24.

DATA ANALYSIS

HIRS Cloud Climatology

Seven years of HIRS data have now been processed using the CO_2 slicing cloud top property algorithm. Over the globe, cirrus clouds are now observed at about 40% of the time. Figure 3 shows the monthly trends for ISCCP and this HIRS work from 1983 through 1996 of total cloud cover (which remains roughly constant in both) and ISCCP cirrus and HIRS thin cirrus and thin plus thick cirrus (all increase about 1% per year). While the detection of thin clouds separates the ISCCP and HIRS plots, the trends are the same; there is an increasing amount of semi-transparent clouds in the atmosphere. It is noteworthy, that the dominance of northern hemisphere winter cloudiness shows up more clearly in the annual variations of the HIRS total cloud cover. Also, it seems that the HIRS detection of cirrus peaked in 1994 and is beginning to come down somewhat.

GOES Biomass Burning Program

In work supported by separate NASA and NOAA contracts, GOES-8 data sets were collected in real time over North and South America during the past burning season including diurnal (3-hourly) GOES-8 multispectral data from the 1996 biomass burning season in South America (June-October). The data is being processed with the GOES-8 ABBA to continue monitoring trends in biomass burning and to catalogue the extent and transport of associated aerosols. Half-hourly GOES-8 data as well as diurnal NLDN lightning data were collected during the first two weeks of September over the continental US. A series of 1-minute multispectral super rapid scan GOES-9 data were collected over the Western US on 16 August and 5 September 1996. These data sets will aid in the development of an operational GOES-8/9 ABBA for the continental US.

A new version of the GOES-8 ABBA (version 1.1) is now in place. It includes a number of modifications to the original version (version 1.0) which was operational during the SCAR-B field program. Version 1.1 now incorporates albedos calculated from the visible data to screen for sub-pixel and semi-transparent cloud contamination, to prevent solar reflectance in the 4 µm band resulting in false positive fire identification. Version 1.1 uses a variable offset to the 4 and 11 µm bands based on the difference between the fire pixel albedo and the background albedo to correct for the attenuation due to the non-opaque clouds. This variable offset comes from a regression analysis of the difference between the observed and background albedos and observed brightness temperatures for non-fire pixels. Version 1.1 uses an improved technique to account for GOES-8 oversampling in the East/West direction by first identifying all possible fire pixels; if fires are located in adjacent pixels, only the fire pixel with the highest signature is retained. This assures that a single fire occurrence is not counted more than once. Other modifications include an expanded surface vegetation classification scheme and associated 4 and 11 μm emissivity factors; NCEP model estimates of total precipitable water used for atmospheric attenuation corrections; and an adjustment to account for diffraction in the 4 and 11 μm infrared windows.

Diurnal multispectral GOES-8 data collected during the 1995 SCAR-B field program were reprocessed with version 1.1 of the GOES-8 ABBA. The results clearly indicate a strong diurnal signature in biomass burning activities with peak burning at 1745 UTC. The number of saturated and processed fires at this time were on average 10 to 20 % less than those reported during SCAR-B. On days with significant sub-pixel cloud contamination, the number of fires reported was cut in half. Subpixel solar reflectivity contamination near local noon (1445 UTC) still results in many false GOES-8 fire observations. This problem will be addressed in version 2.0 of the GOES-8 ABBA. Fire size estimates for the SCAR-B data set as determined by the GOES-8 ABBA (version 1.1) have changed substantially from the values reported during SCAR-B. With the inclusion of a diffraction correction and a variable offset for cloud contamination, fire estimates for the SCAR-B data are on average 60% smaller than originally reported. An analysis of the distribution of burning by ecosystem type throughout the study region indicates that over 97% of the fires occurred in 10 ecosystems, although the majority of the fires were located in seasonal tropical broadleaf (40%), savanna grasslands (29%), and mild/warm/hot grass or shrub (16%).

Validation of the GOES-8 ABBA (version 1.1) was attempted with one of the prescribed burns initiated by the USFS during SCAR-B in Rondonia. On 4 September 1995 roughly three to 4 acres of forest in the state of Rondonia (9.2S,63.2W) were ignited near 1:00 pm local time (Darold Ward, Ron Babbitt personal communication) and burned for several hours. The fire was observed in the GOES-8 4 μm data from 1715 UTC until approximately 1945 UTC. A faint signal was observed after this time. Table 1 provides a summary of the observed GOES-8 4 and 11 μm observations and GOES-8 ABBA (version 1.1) estimates of subpixel fire size and temperature. The GOES-8 results at 1715, 1815 and 1945 UTC are within the ground truth estimates of fire size and temperature. At 1845 UTC the GOES-8 ABBA attempted to correct for cloud contamination as observed by the increase in albedo and decrease in the LWIR brightness temperature, but the correction was not sufficient, and the fire was not processed. At 1915 UTC, although the fire was identified by the GOES-8 ABBA (version 1.1), it was not processed due to an elevated albedo of .28. Although limited in scope, this validation example suggests that the changes incorporated in the GOES-8 ABBA (version 1.1) produce results which are in line with ground truth.

Table 1. GOES-8 observations of the prescribed SCAR-B burn on 4 September 1995.

Time (UTC)	GOES-8 Observations 4 μm T_{obs} (K)	11 μm T_{obs}(K)	Albedo	GOES-8 ABBA Fire estimates Area (Acres)	T (K)
1715	323.4	301.6	.16	2.0	815
1745	NA	NA	NA		
1815	326.4	301.8	.17	3.5	758
1845	326.4	297.8	.23	INP	INP
1915	328.9	299.4	.28	INP	INP
1945	320.0	299.1	.20	3.5	711

NA indicates Not Available
INP indicates the fire was identified, but not processed

SUCCESS Field Program Results

Data from the 18 MAS missions during the SUCCESS field experiment is proving to be of excellent quality. Figure 4 is an example of a contrail captured in three MAS channels. Note how the contrail is barely visible in the .66 micron image, and yet appears bright (reflective) in the 1.88 micron channel and cold (dark) in the 11 micron channel image. Investigations to date have focused primarily on cloud studies (microphysical properties, cloud top pressure and emissivity). MAS 8 micron minus 11 micron brightness temperature differences have been investigated as a function of scene temperature for a MAS wave cloud scene near Denver, CO on 2 May 1996. The "arching" nature of the data is predicted by microphysical modeling using ice particles. The modeled radiances for an effective ice particle size of 5 microns show good agreement with the MAS radiances over the wave cloud scene. DC-8 based in situ measurements in this wave cloud show a predominance of 5-6 micron sized ice particles, in close agreement with the MAS results. An abstract has been submitted to the 1997 conference on Atmospheric Effects of Aviation (AEAP) on this topic.

CO_2 cloud top heights are being investigated using MAS data with validation from the CLS (lidar) data. Two different approaches are being utilized in the cloud heights algorithm, the first utilizing brightness temperature gradient across a target box, while the second relies on an estimate of clear air radiance from the MAS data. Thin cirrus scenes from the 26 April 1996 ER-2 flight are used. Results (Figure 5) show MAS cloud top heights are lower for both approaches than those given by CLS data, possibly because atmospheric conditions may not be well characterized. Of the two approaches, gradient method cloud heights exhibit more noise than clear air radiance cloud heights. This is probably due to increased sensitivity to instrument noise in the gradient approach; when the brightness temperature gradient in the target box is small (e.g. uniform cloudy target box), then the resulting cloud height is influenced by radiometric noise. Clear air radiance results are more uniform spatially and show trends that agree with the CLS cloud heights. Very thin cirrus scenes from 19.72 hrs to 19.76 hrs are not detected by the MAS CO_2 slicing algorithm. Further investigation into MAS CO_2 cloud heights is planned. Regarding cloud microphysical properties, anomolously large MAS T_{11}-T_{12} and T_8-T_{11} brightness temperature differences have been found in wave cloud and aircraft contrail scenes. Theory suggests large brightness temperature differences occur when effective cloud particle size is small; the MAS observations parallel the theory. These observations suggest an importance of small particle size clouds to earth system radiative budget studies.

Seven separate MAS SUCCESS scenes have been chosen to serve as a UW MODIS product test data set. The scenes were chosen to represent different cloud, atmosphere and surface regimes. The scene dates and times along with the scene characteristics are listed in Table 2.

Table 2: MAS scenes selected for MODIS UW algorithm end-to-end testing using SUCCESS experiment data.

Date	Time	Scene Characteristics
April 9	16:20 - 16:24	Clear sky over ocean.
April 13	18:28 - 18:32	Clear sky over land (CART site).
April 15	19:24 - 19:28	Scattered cumulus over land (CART site).
April 26	19:57 - 20:01	Thin cirrus over land; coordinated with NOAA-14 overpass.
May 2	20:24 - 20:28	Thin cirrus and wave clouds over land. Narrow contrail present.
May 2	21:18 - 21:22	Cumulus and cirrus over land. Some snow cover present.
May 12	21:38 - 21:42	Cirrus and stratus cloud over water. Numerous contrails. Sunglint down middle of track.

Each 4 minute data segment will be processed end-to-end by all UW data production software packages (cloud mask, cloud phase, cloud top properties and atmospheric profiles) adjusted to use MAS data formats. To date, the cloud mask and cloud phase runs (using the cloud mask product as input) have been completed. An example cloud mask and IR phase product from the April 15 flight segment is presented in Figure 6.

PAPERS

Menzel, W.P., and E.M. Prins, 1996: Monitoring biomass burning and aerosol loading and transport utilizing multispectral GOES-8 data. Paper presented at the 1996

International Symposium on Optical Science, Engineering, and Instrumentation, Denver, CO, August 4-9, 1996.

Moeller, C. C., P. S. Grant, D. D. LaPorte, L. E. Gumley, P. Hajek, W. P. Menzel, J. S. Myers, and S. White, 1996: Blackbody emissivity considerations for radiometric calibration of the MODIS Airborne Simulator (MAS) thermal channels. Presented at the Earth Observing System Conference of the SPIE Annual Meeting, August 4-9, Denver, Colorado. Proceedings pending.

W. P. Menzel, D. P. Wylie and K. I. Strabala, 1996: Seven years of global cirrus cloud statistics using HIRS. Presented at the International Radiation Symposium, August 19-24, Fairbanks, Alaska.

Ackerman, S. A., 1996: Monitoring the Antarctic radiation inversion using satellite measurements at 11 and 6.7 μm. Presented at the International Radiation Symposium, August 19-24, Fairbanks Alaska.

Smith, W. L., S. A. Ackerman, H. Revercomb, H. Huang, W. Feltz, L. Gumley, A. Collard and J. Spinhirne, 1996: High spectral resolution infrared remote sensing - Spectral infrared radiative absorption properties of nearly invisible high altitude ice crystal clouds. Presented at the International Radiation Symposium, August 19-24, Fairbanks Alaska.

H. E. Revercomb, M. J. Lynch, K. I. Strabala, L. E. Gumley and P. F. Van Delst: Land surface temperature and emissivity estimation with high spectral/high spatial resolution sensors. Presented at the International Land Surface Temperature Workshop, September 16-20, at the University of California - Santa Barbara.

Prins, E.M. and W.P. Menzel, 1996: The GOES-8 Automated Biomass Burning Algorithm (ABBA): Introducing new capabilities for monitoring diurnal fire activity in the Western Hemisphere. International Forest Fire News, edited by J.G. Goldammer, vol. 15, pp 49-52. United Nations ECE/FAO, Geneva.

Prins, E.M., W.P. Menzel, and D.E. Ward, 1996: GOES-8 ABBA Diurnal Fire Monitoring During SCAR-B. Paper presented at the 1996 SCAR-B Symposium, Fortaleza, Brazil, November 4-8, 1996.

L. E. Gumley, C. C. Moeller, S. A. Ackerman, W. L. Smith, 1996: Remote Sensing Observations from the NASA ER-2 during SUCCESS. Paper submitted to the Third International Airborne Remote Sensing Conference and Exhibition to be held in Copenhagen, Denmark July 1-10, 1997.

Strabala, K. S., S. A. Ackerman, C. C. Moeller, L. E. Gumley, R. A. Frey, J. Y. Li and W. P. Menzel, 1996: Cloud Properties Determined from MODIS Airborne Simulator (MAS)

SUCCESS Observations. Paper submitted to the Third International Airborne Remote Sensing Conference and Exhibition to be held in Copenhagen, Denmark July 1-10, 1997.

MEETINGS

Dan LaPorte worked with BOMEM personnel in Quebec to develop a larger source for the MB100 to improve MAS spectral calibration in July.

Paul Menzel, Steve Ackerman, Liam Gumley, Chris Moeller and Merv Lynch attend the Atmosphere Group Discipline Meeting at Chincoteague, Virginia on July 17 and 18.

Paul Menzel, Steve Ackerman and Kathy Strabala attended a cloud mask meeting hosted by Bryan Baum of LaRC on July 19.

Paul Menzel and Steve Ackerman were presenters at the International Radiation Symposium in Fairbanks, Alaska on August 19-24.

Elaine Prins attended the Multi-sensor Early Warning Fire Assessment Workshop (24-25 August, 1996) at the NOAA National Geophysical Data Center in Boulder, Colorado. She presented an overview of the UW-Madison CIMSS GOES fire detection program.

The UW hosted the infrared calibration audit for the MCST August 29 and 30.

Kathy Strabala attended the Science Advisory Panel Meeting held at GSFC on September 4 and 5. P. Menzel attended on the second day.

Mervyn Lynch was a presenter at the International Land Surface Temperature Workshop held at the University of California - Santa Barbara on September 16 - 20.

Chris Moeller attended the SBRS quarterly review meeting at GSFC on September 18 and 19.

Dan LaPorte assisted with MAS Spectral Calibration work at Ames Research Center September 23 and 24.

Dan LaPorte, Chris Moeller and Merv Lynch participated in a 4 hour telecom chaired by MCST personnel concerning MODIS Proto-flight test results on September 23.

Paul Menzel, Dan LaPorte and Chris Moeller attended the MCST Calibration Workshop held at the University of Maryland Conference Center on October 8.

Liam Gumley and Kathy Strabala chaired the MODIS Algorithm Developers Meeting at the University of Maryland Conference Center on October 9.

Paul Menzel, Steve Ackerman, Dan LaPorte, Chris Moeller, Kathy Strabala and Liam Gumley attend the MODIS Science Team Meeting held at the University of Maryland Conference Center on October 9-11.

Chris Moeller gave a presentation on MAS cloud observations during SUCCESS to the SUCCESS Science meeting in Boulder, CO October 24-25.

Elaine Prins attended the SCAR-B Symposium in Fortaleza, Brazil on 4-8 November, 1996. She presented a paper summarizing UW-Madison CIMSS activities during the SCAR-B program and revised GOES-8 ABBA (version 1.1) SCAR-B results.

Dan LaPorte assisted with MAS spectral calibration measurements at Ames Research Center November 8-9.

UW hosted the atmosphere discipline group programmers meeting on November 12 - 13.

Paul Menzel, Steve Ackerman and Liam Gumley attended the ATBD panel review November 19 - 20.

Paul Menzel, Steve Ackerman and Liam Gumley attended the atmosphere group discipline group meeting at GSFC on November 22.

Steve Ackerman attended the snow and ice workshop hosted by Dr. Dorothy Hall at GSFC on November 24 - 26.

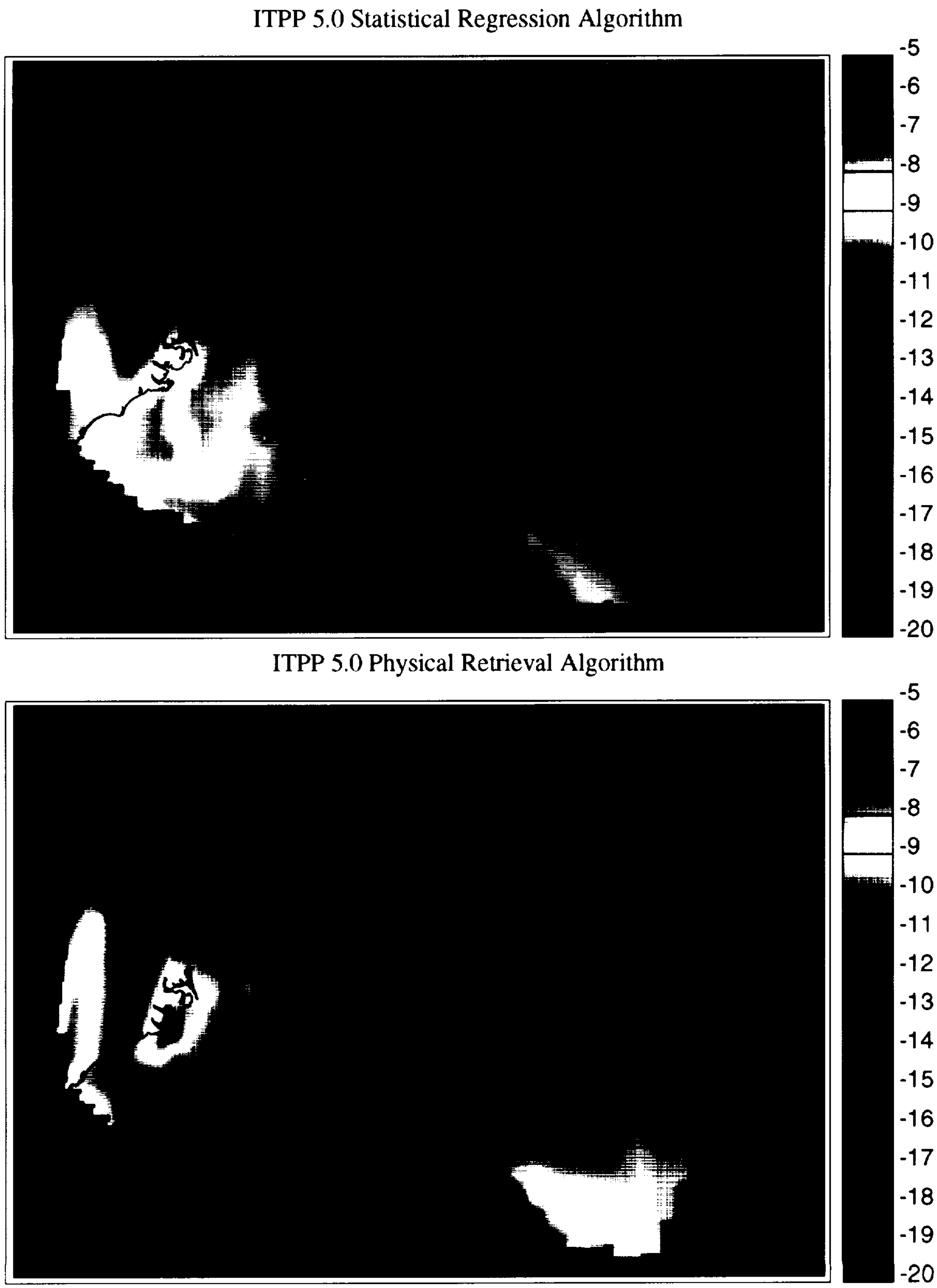

Figure 1: NOAA-12 95/05/15 1210-1214 UTC 500 hPa temperature (degrees C).

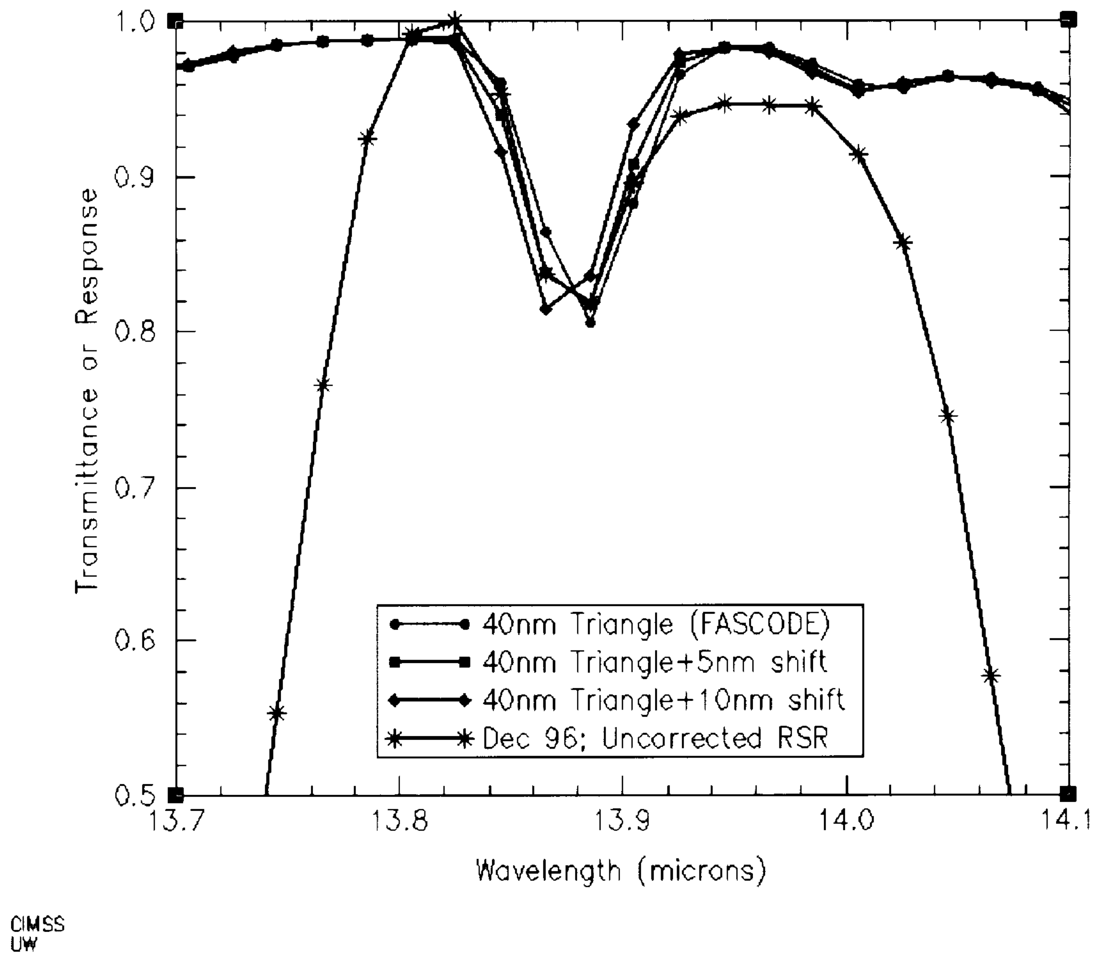

Figure 2. MODIS RSR for band 35 channel 5 (blue) with FASCODE convolution (40nm triangular bandpass) atmospheric correction for ambient data collection conditions. Shifting the spectral position of the RSR data by 5nm produces a match of the RSR data with the FASCODE convolution.

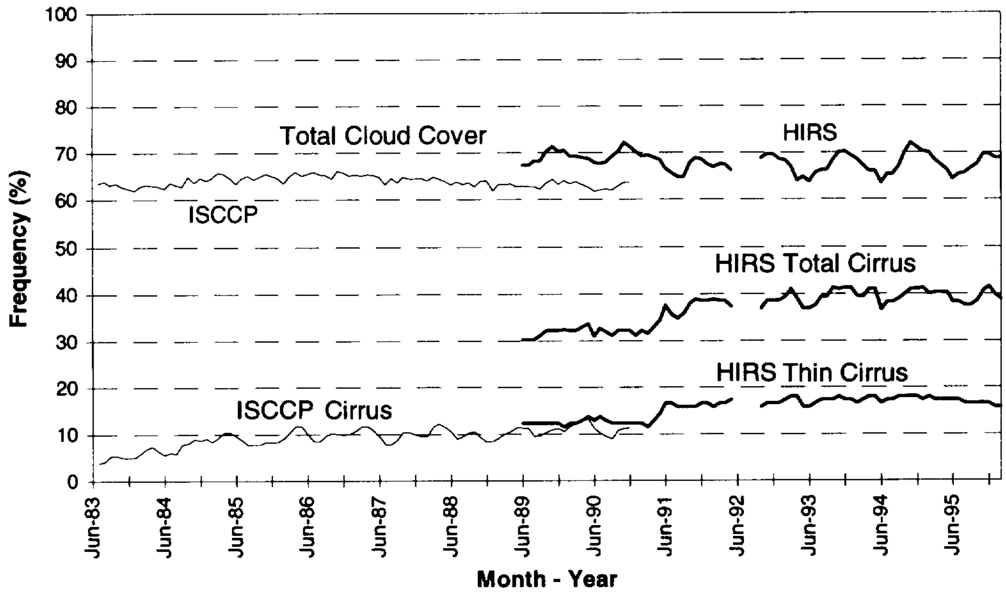

Figure 3. Monthly trends for ISCCP total cloud cover and cirrus (thin lines) and HIRS total cloud cover, thin cirrus, and thin plus thick cirrus (thick lines) from 1983 through 1996.

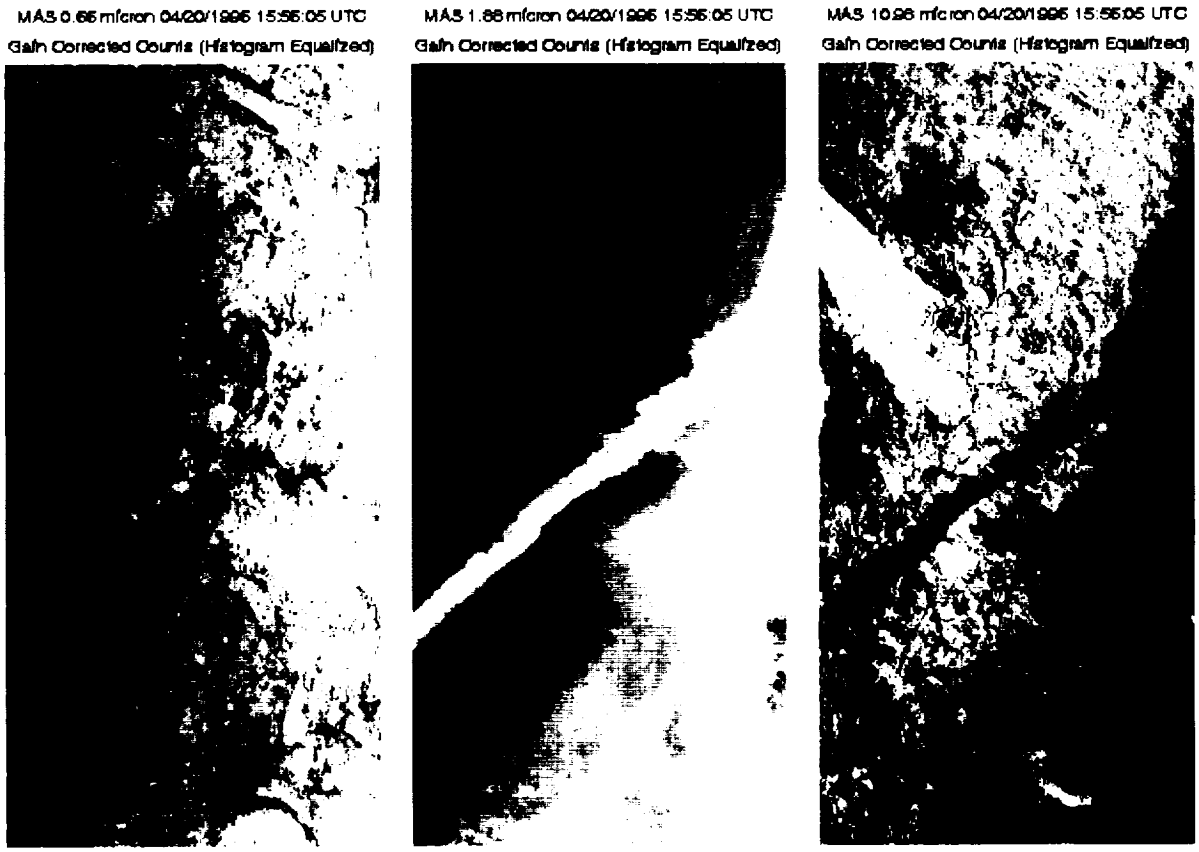

Figure 4. Three spectral images observed by the MAS instrument 20 April 1996. Note the contrail which appears bright (reflective) in the 1.88 micron image and cold (dark) in the 11 micron image, but appears very faint in the .66 micron image.

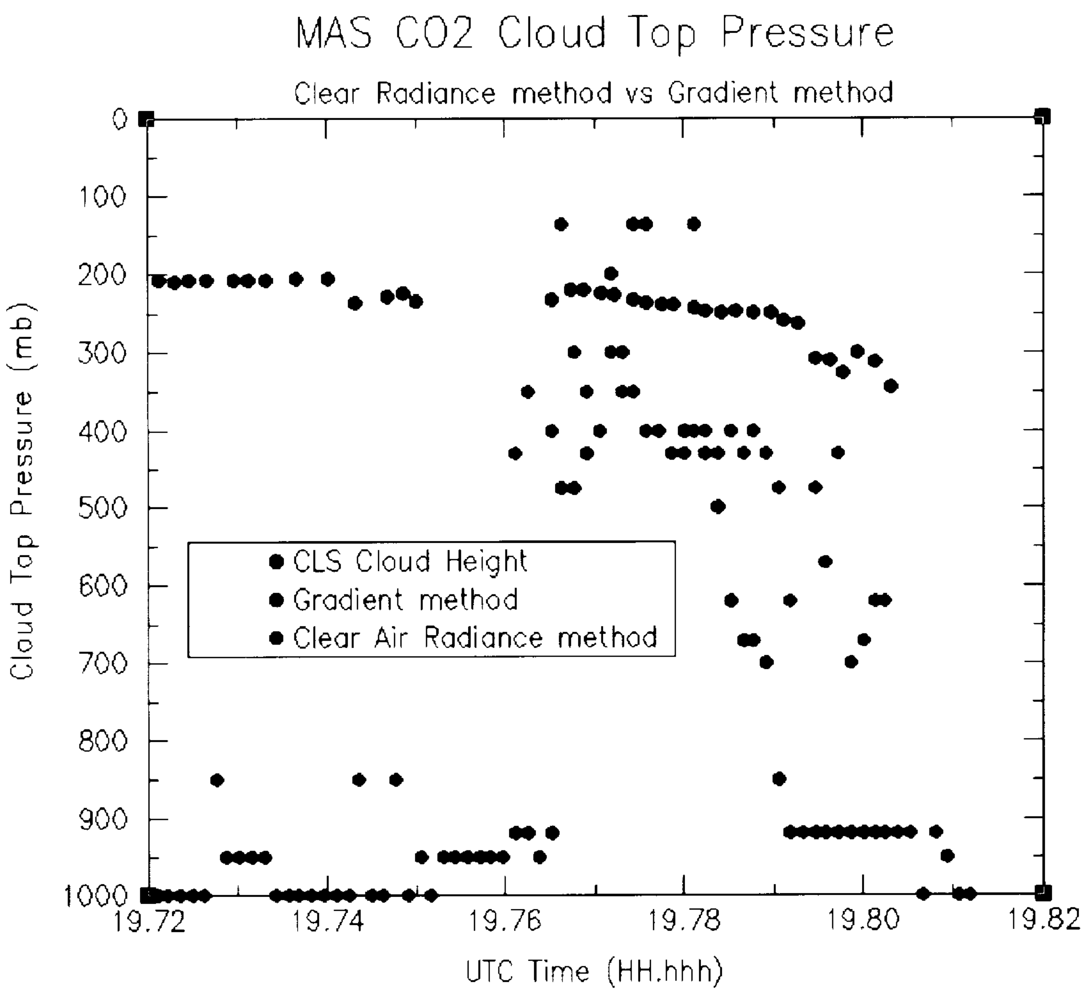

Figure 5. MAS CO_2 cloud top pressure estimates on April 26, 1996 over Kansas. Cloud top pressure from CLS lidar also shown as validation. MAS CO2 algorithm tracks relative variation of cloud top pressure. Very thin cirrus cloud is unresolved in MAS data before 19.76 UTC.

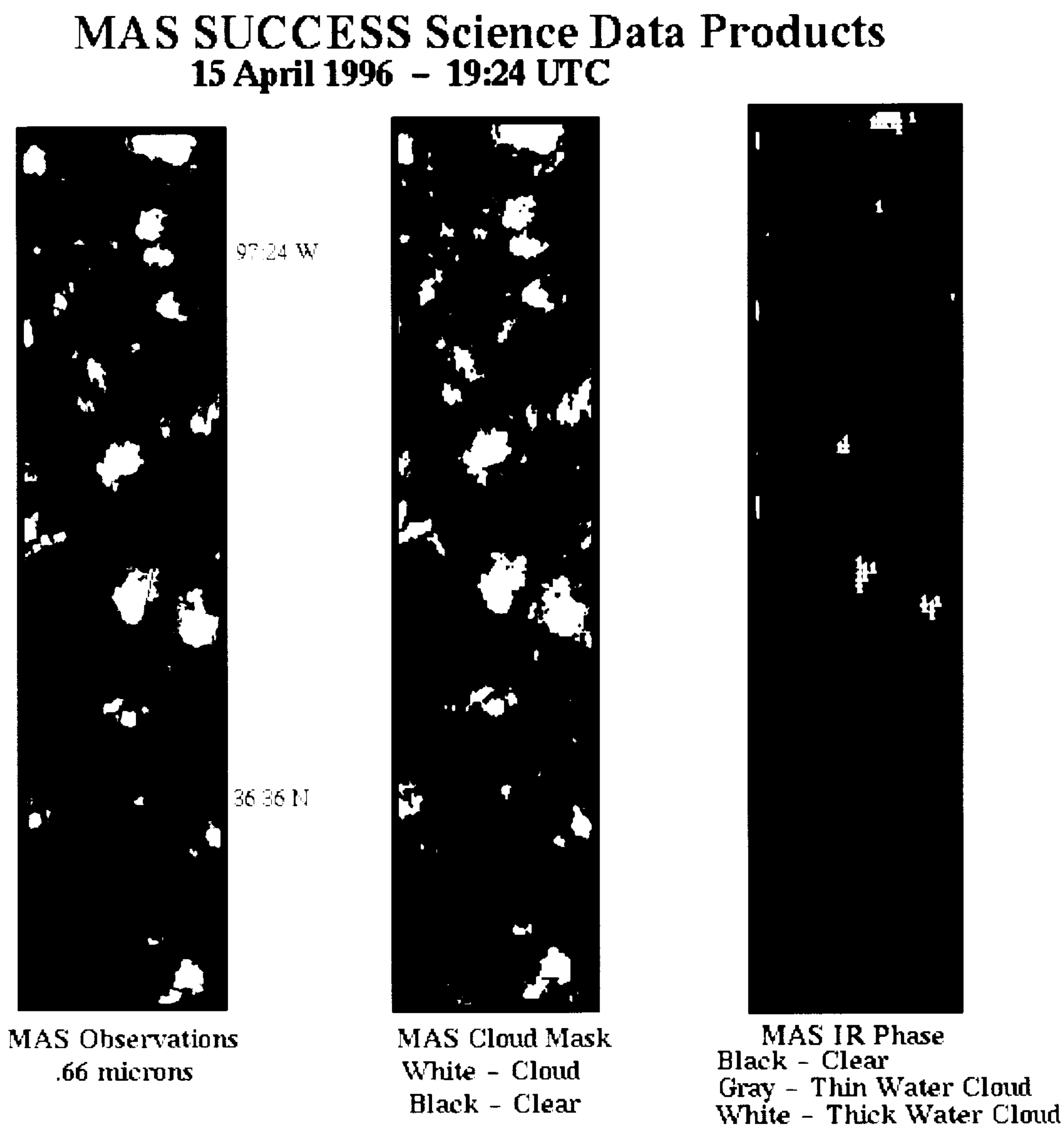

Figure 6. Example of MODIS algorithm tests using MAS data. The left scene is actual visible channel observations while the center and right panels are products. The IR phase product uses the cloud mask as an input.