INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC STABILITY WITH MODIS

QUARTERLY REPORT FOR JAN - MAR 1994

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NEAR TERM OBJECTIVES

First Software Delivery. The cloud algorithms outlined in the ATBDs on Cloud Properties, Atmospheric Profiles, and Cloud Mask will continue to be prepared with benchmark data sets (from HIRS, AVHRR, and MAS) and delivered to SDST in 1994. Transfer of all related subroutines from the McIDAS RISC environment to SDST will be completed. Algorithm execution on the SDST system will remain a large task, since there are known problems related to support software (UW use s McIDAS support software to preprocess and file data; SDST does not).

Cloud Mask ATBD. The MODIS Cloud Mask ATBD (version 1) will evolve after peer review in May 1994. Input from MODIS Science Team members will be incorporated.

Algorithm Definition. Processing and cloud algorithm testing will continue using the MAS (MODIS Airborne Simulator) data gathered during the FIRE (First ISCCP Regional Experiment) in Nov - Dec 1991, TOGA-COARE (Tropical Ocean Global Atmosphere - Coupled Ocean Atmosphere Response Experiment) in Jan - Feb 1993, and SCAR-A (Smoke, Clouds, Aerosol, and Radiation - America) experiment in July 1993. Algorithms for atmospheric total column amount (ozone, precipitable water vapor, and stability) and profiles (temperature and moisture) will be developed using the HIRS (High resolution Infrared Radiation Sounder) data from these field experiments and beyond.

Global Cloud Study. Pre-MODIS cloud studies will continue via the global cloud census with HIRS data now in its fifth year.

Definition of MODIS Infrared Calibration. The calibration of the MODIS infrared channels continues to demand attention. Adequate testing of the MODIS instrument before launch must be assured so that infrared calibration accounts for detector non-linear response, stray radiation, and angle dependence of background radiation. Plans for post-launch validation using the MAS and HIS (High-resolution Interferometer Sounder) instruments will be refined.

MODIS Instrument Review. Tradeoffs between product accuracy and MODIS infrared calibration and spectral selection will continue to demand attention. Simulations of MODIS products with MAS and HIRS data should continue to guide instrument developers.

WORK ACCOMPLISHED

Cloud Mask ATBD Submitted. The Algorithm Theoretical Basis Document on "Discriminating Clear Sky from Cloud with MODIS" was finished for April 1994 submission. It was written in collaboration with members of the CERES Science Team. The MODIS cloud mask will indicate whether a given field of view has an unobstructed view of the earth surface and additionally whether that clear view is affected by cloud shadows. The cloud mask will be generated at the three resolutions of the MODIS data (250 meter, 500 meter, and 1000 meter). Input to the cloud mask algorithms is assumed to be calibrated and navigated level 1B data; additionally, the MODIS data is assumed to be meeting specification so that no accommodation for striping is being made. The cloud mask will be determined for good data only (ie. fields of view where the data in the cloud mask channels 1, 2, 6, 8, 19, 22, 26, 27, 29, 31, 32, and 35 have radiometric integrity); incomplete or bad data will create holes in the cloud mask.

The MODIS cloud mask algorithm will benefit from previous work to characterize global cloud cover. The International Satellite Cloud Climatology Project (ISCCP) has developed cloud detection schemes using visible and infrared window radiances. The NOAA Cloud Advanced Very High Resolution Radiometer (CLAVR) algorithm uses the five visible and infrared channels of the AVHRR for cloud detection using spectral and spatial variability tests. CO_2 Slicing characterizes global high cloud cover, including thin cirrus, using infrared radiances in the carbon dioxide sensitive portion of the spectrum. Additionally, spatial coherence of infrared radiances in cloudy and clear skies has been used successfully in regional cloud studies.

Cloud Detection with the 1.38 micron Channel. MODIS channel 26 (1.38 micron) uses reflectance thresholds to detect thin cirrus in the upper troposphere. Strong atmospheric water vapor absorption in this spectral region effectively obscures the earth's surface while high cloud reflectance is essentially unattenuated because of the paucity of water vapor high in the troposphere. MAS 1.8 8 micron data and Lowtran calculations have been used to investigate the performance of the MODIS 1.38 micron channel. These data indicate that over the majority of the earth (exceptions being high latitude dry zones and high terrain regions) the 1.38 micron reflectance signal will not be contaminated by surface reflectance. Cloud/no cloud and thin/thick cloud reflectance thresholds will be employed to isolate the thin cirrus. This test will be applied in the Cloud Mask only during daytime conditions.

MAS Cloud Investigations. Investigation of cloud parameters with MAS data continues. The 11 micron atmospheric correction has been modified to use a T11-T12 brightness temperature difference from MAS clear scene data. MAS-specific coefficients in this relationship were generated using MAS radiance simulations of TOGA-COARE radiosonde data. A MAS-specific relationship between precipitable water and the T11-T12 difference has also been developed from simulations for cases where the sea surface in the target domain is entirely obscured by cloud. These modifications improve the estimate of the IR cloud/no cloud threshold temperature, enhancing detection of low cloud and thin cirrus (non-unity emissivity) in the IR channel. Other modifications under consideration are to correct cloud top temperature for emissivity effects using an emissivity estimate either from visible cloud albedo or from the CO2 technique, and separating ice and water clouds in relating visible cloud albedo to visible cloud optical depth and IR cloud optical depth. The goal of this effort is to explore how best to use MAS multispectral data collectively for determining cloud parameters in preparation for MODIS data collection.

TOGA-COARE Activities. The NASA TOGA-COARE Science Data Workshop II in March was attended by Chris Moeller. Discussions centered on identification of specific data sets for case study, interaction between the radiation and convective science working groups, updates of data processing plans by individual P.I.s, and a publication plan. A four page summary of the MAS data plan for TOGA-COARE cloud studies was submitted by Moeller and Menzel for inclusion in a work shop proceedings document. MAS quick-look imagery of radiation group priority days was used to aid in detailed selection of priority days/times. The following days/times (UTC) were chosen for priority study by the radiation group:

1)	Jan 17-18	(flt 93054)	2330-0015	thin cirrus
2)	Feb 31-01	(flt 93058)	2300-0000	thin cirrus
3)	Feb 20-21	(flt 93065)	2105-2130	microphysics
			2357-0053	thick cirrus
4)	Feb 23-24	(flt 93067)	2244-0030	mixed clouds; microphysics; profiling
5)	Jan 11-12	(flt 93053)	0245-0345	clear and thin tropopause cirrus
6)	Jan 18-19	(flt 93055)	0230-0400	transit cirrus; microphysics
7)	Feb 08-09	(flt 93062)	at end of flt	cirrus

Individual discussions were held with representatives of other TOGA-COARE datasets, including in situ microphysical data and ER-2 and DC-8 lidar data. These data will be useful with MAS data for MODIS cloud studies of cloud particle phase, cloud height and emissivity, and cloud parameters. Specific dates/times of possible combined data sets are under consideration. Interest in MAS radiance data has been expressed by the convective science group for estimating cloud top temperature of convective cells and combining with microwave observations on the ER-2.

Tri-spectral Cloud Phase Algorithm. Kathleen Strabala continued work on the three channel (8, 11 and 12 micron) brightness temperature difference technique for discerning cloud phase. The technique has been applied to MAS straight line flight tracks from the TOGA-COARE data sets of 18 January, and 26 January 1993. A close examination of the output phase discrimination from the automated software has brought out a few concerns which must be addressed. First, better precipitable water (PW) to brightness temperature difference clear sky regressions need to be determined for MAS data. Simulations of TOGA-COARE MAS brightness temperatures from radiosondes versus the integrated PW values differ from regressions currently used (developed from global HIRS/AHVRR processing using adjusted intercepts to account for bandwidth differences). Reasons for the regression differences are currently under investigation. Direct comparisons are difficult due to a lack of clear scenes and coincident radiosondes, but will continue to be sought using 12 January 1993 data. Second, mixed phase scene identification needs to be improved. The current technique is consistently accurate at detecting single phase cloud scenes; however, the unity slope mi xed phase envelope in the scatter diagram of the 8-11 versus 11-12 micron brightness temperature difference can encompass obvious single phase scenes. This occurs most often when there are two distinct single cloud layers/phases in the same large box of data being processed. A more complex maximum likelihood estimator may aid in solving this problem. Third, the accuracy of the tri-spec tral technique needs to be assessed by comparing with in situ microphysical observations. Data processing plans were presented at the March 1994 NASA TOGA-COARE workshop for the DC-8 microphysical data set collected during TOGA-COARE. Dr. Rudolf Pueschel (NASA/ARC) will process state parameters and one minute averages of microphysical data (including derived particle phase) from the data set this summer. These in situ observations will serve as a verification data set for MAS cloud particle phase determinations.

Aerosol Detection. The results from the infrared detection of Mount Pinatubo aerosols by HIRS 8 and 11 micron brightness temperature differences were presented by Steve Ackerman at the AMS conference in January. The results are currently in review for publication.

Biomass Burning and SCAR Activities. In cooperation with the biomass burning aerosol work funded under a separate NASA contract NAGW-3804, Elaine Prins is in the process of developing and implementing an algorithm to document daily biomass burning activity in South America and catalogue the extent and transpor t of aerosols associated with burning throughout the region utilizing GOES VAS visible and IR data (3.9 um, 11.2 um, and 12.7 um). Preliminary efforts have focused on GOES VAS data from 24-29 August, 1988 which documents one of the most extensive examples of smoke/aerosol transport ever recorded in South America. The imagery from these days provides a unique blend of transport regimes and cloud types (including semi-transparent cirrus and low-level stratus). This data set is ideal for developing and testing a robust algorithm capable of distinguishing haze associated with biomass burning activities from other multi -level clouds and low level moisture. In our previous work, smoke/aerosol transport regimes in South America were inferred by manually tracking smoke/haze tracers in a series of 3 half-hourly GOES visible and IR images. This process is extremely time consuming and inefficient. We hope to automate this procedu re by adapting current automated GOES VAS cloud motion vector software. Preliminary investigations suggest that the automated software is capable of tracking smoke/haze as well as clouds. Results are expected to improve with the addition of a first guess field provided by NMC Global GTS upper air and surface meteorological data.

Once the algorithm is in place we plan on processing the entire burn season for 1988 (July-September). The 1988 GOES VAS data set will cover the entire continent of South America and the Atlantic Ocean, allowing us to monitor the burning at its source and subsequent transport throughout South America and out over the Atlantic Ocean. The GOES VAS data archive for the times we requested during the 1988 burning season in South America is over 90% complete and should provide a realistic picture of biomass burning and associated aerosol transport for an entire burning season. We are also ordering NMC Global GTS upper air and surface meteorological data for the same time period to initialize and verify cloud/smoke drift winds produced with the GOES VAS data.

HIRS Cloud Climatology. The HIRS cloud climatology has been updated through the summer of 1993. Results indicate that the probability of cirrus has not decreased, but has remained in the mid 40th percentile range since the summer of 1991. The increase in high transmissive cloud has been at the expense of lowopaque cloud. The climatology is currently being brought up to date through the winter of 1993/94.

MAS/HIS/AVHRR Intercomparisons. Steve Ackerman is investigating negative 11-12 micron brightness temperature differences observed in AVHRR and MAS imagery. Negative values have previously been attributed to calibration uncertainty because they are inconsistent with the bulk absorption properties of ice and wate r (which indicate greater absorption at 12 microns). However, occurrence in independent remote sensing instruments has renewed interest in the topic. Negative differences are found predominantly over very cold scenes (high, thick clouds); they have also been observed with MAS data over uniform water cloud sce nes. Negative values as large as -3 K for ice cloud and -1 K for water cloud indicate their occurrence is not due to truncation error in MAS data.

To further the investigation, radiances from the High-resolution Interferometer Sounder (HIS) were used to simulate AVHRR, HIRS, and MAS observations under cloud conditions which produce negative differences. The HIS high spectral resolution (1 cm-1), and calibration accuracy (1 K) enables accurate simulation of brightness temperatures when coupled with spectral response function data for each instrument. Results of simulations using several days of HIS data collected during CAPE, FIRE and STORMFEST showed no negative differences over scenes that produced negative differences in MAS and AVHRR data. Although these results are somewhat discouraging, MAS simulations from radiosonde data did reveal different signals for ice and water cloud (the 11 minus 12 micron differences were not the same) when atmospheric absorption effects were removed. This suggests that the negative differences are at least partially due to the microphysical properties of the clouds. These results will be presented in a poster session next June at the 7th Conference on Satellite Meteorology and Oceanography held in Monterey, California. Investigations into the cause of the negative differences will continue.

Scientist Computer Facility Enhancement. Software additions to the RISC6000 model 370 workstation have continued. This workstation is now the primary MAS data processing/analysis/application environment. Recently, the ability to create navigated MAS images on the workstation was added. This tool, along with the future addition of an external tape drive (Exabyte or DAT) on the workstation will make it possible to access MAS data without need of the mainframe (IBM 4381) intermediary, saving on mainframe CPU charges, improving turnaround time, and increasing flexibility in staging MAS data.

MAS Processing. A dialogue between UW and SDST concerning streamlining MAS data processing is in progress. Currently, UW and SDST process MAS data into different resultant data formats; UW MAS data into McIDAS compatible files and SDST MAS data into HDF files. This dual processing is necessary to maintain full utility and compatibility of MAS data for each center. However, common ground is being sought to reduce data processing requirements at UW. A plan has been initiated to provide UW with MAS HDF file compatible software. This provides a link for UW to convert HDF files to McIDAS compatible format. While UW research and application projects will continue to require MAS data processing at UW, it is believed that this software exchange will result in some saving of processing requirements at UW in the future.

PROBLEMS

Data Format. Solutions are still being sought for the problem of data type incompatibility between the McIDAS (Man computer Interactive Data Access System) environment and the HDF format which is used by the SDST. The problem will become more serious with time, as all our developmental software relies heavily on unique McIDAS data formats and calling routines. This issue will be addressed at the upcoming MODIS Science Team Meeting in May.

PUBLICATIONS

Ackerman, S. A., and K. I. Strabala, 1994: Satellite remote sensing of H2SO4 aerosol using the 8-12 micron window region: application to Mount Pinatubo. submitted to Jour. Geo. Rev.

Prins, E. P. and W. P. Menzel, 1994: Trends in South American Biomass Burning Detected with the GOES-VAS from 1983-1991. accepted by Jour. Geo. Rev.

Wylie, D. P., W. P. Menzel, H. M. Woolf, and K. I. Strabala, 1993: Four Years of Global Cirrus Cloud Statistics using HIRS. accepted by Jour. Clim.

Strabala, K. I., S. A. Ackerman, and W. P. Menzel, 1992: Cloud Properties Inferred from 8-12 micron Data. Jour. Appl. Meteor., 33, 212-229.

MEETINGS

Paul Menzel attended a SDST meeting in Jan 1994 to reaffirm the initial set of measurements required to characterize the infrared calibration of the MODIS.

UW hosted the meeting of the MODIS Cloud Mask Team on 28 Feb and 1 Mar to discuss possible algorithms for cloud masking the MODIS data and to organize the writing of the ATBD.

Chris Moeller attended the NASA TOGA-COARE Workshop II in Mar 1994 to represent MAS data interests and to continue collaborative efforts with members of the science working groups.