INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC STABILITY WITH MODIS

SEMI-ANNUAL REPORT FOR JUL - DEC 1992

Paul Menzel
NOAA/NESDIS at the University of Wisconsin

Contract NAS5-31367

TASK OBJECTIVES

Getting MAS Ready for TOGA COARE. The MAS (MODIS Airborne Simulator) will be reconfigured to include longwave CO2 channels (out to 13.9 microns) for cloud investigations. Improved noise performance will be realized with lens replacement and insertion of a cold filter. UW will provide on site support for TOGA-COARE (Tropical Ocean Global Atmosphere - Coupled Ocean Atmosphere Response Experiment) in Townsville 6 Jan to 4 Feb 1993.

Algorithm Definition. Using the MAS and HIRS (High resolution Infrared Radiation Sounder) data from FIRE in Nov-Dec 1991 and TOGA COARE in Jan Feb 1993, the algorithms for specifying cloud parameters (temperature, phase, height, and amount) and total ozone column will continue to be investigated. The appropriate adjustments for signal noise, spatial resolution, and spectral resolution will be determined. Situations of single layer thin cloud, two layer clouds with thin over thick, mixed layers of ice and water clouds, over land, and over ocean will be studied with the MAS and HIRS data and the best MODIS algorithms will be inferred within the next year.

MODIS Instrument Review. The calibration and spectral selection of the MODIS infrared channels will continue to demand attention. Simulations of the impact of spectral channel changes on the cloud parameter derivation should continue to guide instrument developers.

WORK ACCOMPLISHED

MAS Prepared for TOGA-COARE. Replacement of the lens for the longwave port was accomplished at Daedalus; the instrument testing at NASA Ames Research Center showed considerably improved inflight NEDT (noise equivalent temperatures) for the longwave channels. Viewing ocean off the California coast on 9 December, NEDTs of 1.3, 5.1, .3, .4, 2.0, and .6 C for 3.7, 13.9, 8.6, 11.0, 13.2, and 12.0 micron channels respectively were found. This compares to previous NEDTs (viewing a similar scene) of .9, 7.8, .4, .6, 4.2, and 1.0 C respectively. Further, a 1.83 micron channel was added to enhance the detection of very thin cirrus; the reflected signal in this channel has been found to originate primarily from the upper half of the troposphere and thus shows high clouds to good advantage. The TOGA-COARE configuration will be vis and near IR at .66, .86, 1.64, 1.83, and 2.13 microns and IR at 3.7, 13.9, 8.6, 11.0, 13.2, and 12.0 microns (the last four IR channels are coming in at ten bits). A transmittance model using the spectral response functions of the TOGA-COARE MAS configuration was developed and sample transmittances were calculated for a variety of atmospheric conditions. Software which will be used to evaluate MAS performance during TOGA-COARE was installed and tested on the Ames Rsearch Center PC-McIDAS terminal (which will be shipped to Australia for the deployment).

Tri-spectral Algorithm Developed and Published. The relationship between cloud parameters (type, amount, and phase) and the three infrared channels at 8, 11 and 12 microns was refined in several case studies using MAS, HIS (High resolution Interferometer Sounder), AVHRR (Advanced Very High Resolution Radiometer), and HIRS data. A technical paper describing this work was submitted for publication in November.

CO2 Slicing Tested in Two Layer Clouds. Development of a two cloud layer CO2 slicing algorithm continued with testing on HIRS data. The initial algorithm was adjusted and several case studies were processed to confirm meteorological consistency. Verification with lidar data was begun.

MAS Radiance Validation. Software was set up to simulate MAS spectral channels with HIS radiance data. The software convolves HIS measured radiances with MAS spectral response functions to produce MAS channel radiances. Simulated radiances using MAS TOGA/COARE channels are being compared to radiances from AVHRR, HIRS, and VAS.

MODIS Algorithms Listed. A short list of algorithms and products from the atmosphere group was generated. Algorithm dependency in MODIS level-2 processing was reviewed. Feedback was given to the Science Data Support Team (SDST). The cloud top pressure, cloud effective amount, and cloud top temperature are all products from the same algorithm and hence have been newly referenced as cloud top properties. For several products (cloud top properties, atmospheric stability, total ozone, and total precipitiable water vapor), an initial guess of the temperature and moisture profile will come from the operational National Meteorological Center global models, but data from AIRS as available will also be used. These products do not depend on AIRS data as input, but they are enhanced by use of the AIRS data.

SCAR Planned. With Yoram Kaufman, plans were set for a preliminary Smoke, Clouds, and Radiation (SCAR) experiment in Jul-Aug 1993 over the eastern United States. The MAS will be flown in coordination with AVIRIS on the ER-2 out of Wallops Island, VA to collect radiance measurements over thin cirrus clouds and aerosol haze. International participation is planned with a second and main SCAR experiment in Brazil in 1994.

DATA\ANALYSIS

Tri-spectral Algorithm Development. In the last six months, information on the relationship between cloud parameters and the three infrared channels at 8, 11 and 12 microns was implemented in a simple automated cloud classification technique. The following paragraphs summarize the main points presented in a paper on this work.

(1) Large positive brightness temperature differences of 8 minus 11 micron data indicate cloud (probably cirrus), while near zero or negative differences indicate clear regions. This is true because particle absorption is a minimum and water vapor absorption is a relative maximum between 8 and 9 micron, while the converse is true between 11 and 12 micron. The exact clear/cloud threshold value will depend upon the amount of water vapor in the atmosphere and the proximity of the 8 and 11 micron bands to water vapor lines.

(2) Cloud phase can be determined by plotting 8 minus 11 micron versus 11 minus 12 micron brightness temperature differences. Water and ice cloud tend to separate in this format due to different single scattering properties. Ice and water single scattering properties differ most near 12 micron. This results in a steeper variance of the absorption coefficient from 11 to 12 micron for water cloud than 8 to 11 micron, with the reverse holding true for ice cloud. This tri-spectral technique was demonstrated with MAS data.

(3) Using high spectral resolution HIS data, the tri-spectral technique was shown to be relatively insensitive to bandwidth and band center selection for the 8 micron band. It shows good results using 8 micron bandwidths as broad as 0.8 micron. It is also effective across a large section of the 8 micron spectral region. Thus 8 micron band selection is adjustable for cloud detection and can be based on other applications.

(4) The tri-spectral method applied to operational polar orbiting HIRS data has difficulty delineating cloud phase; large footprint sizes (greater than 20 km) detect too many non-uniform cloud scenes which lead to blurring of the distinct cloud parameter thresholds seen in 2km MAS data (50 m data averaged to 2 km). The technique was found to be applicable to HIRS data that had been screened for non-uniform cloud scenes.

(5) An algorithm for identifying cloud properties was developed using thresholds of MAS brightness temperatures from a cloud scene on 5 December 1991 including a variety of clouds. The algorithm proceeds as follows. Clear and opaque cloud are distinguished

from mixed and thin cloud when the 8 micron radiance standard deviation is less than 0.5 K. Clear is then defined by 8 minus 11 micron brightness temperature differences of less that 0.5 K and 11 minus 12 micron differences of less than 3 K. If the clear requirements are not met, 11 micron brightness temperatures less than 277 K are used to distinguish thick water cloud from thick ice cloud. Further the brightness temperature difference scatter diagram (8-11 versus 11-12) shows ice cloud above the unity slope divison line passing through the origin and water cloud below. Because mixed layer, mixed phase clouds exhibit characteristics of both ice and water clouds, the scatter points tend to fall on or near unity slope. Therefore, once the 8 micron standard deviation has been established as being greater than 0.5, mixed phase cloud fall within 0.3 K of this line and have 8 minus 11 micron brightness temperature difference greater than 1.25 K. Lastly, those cloud pixels not meeting the mixed cloud scene requirements are thin ice cloud provided the difference between the 8 minus 11 micron versus the 11 minus 12 micron brightness temperature difference is greater than 0.3 K (above the unity slope on the scatter diagram) or non-opaque water cloud if the difference is less than 0.3 K (below the unity slope).

(6) This tri-spectral thresholding technique was tested on a different cloud scene including multi-layer, multi-phase clouds with scattered clear areas. Results were encouraging. Each 10 x 10 pixel area was coded according to the described algorithm. The results (see attached figure) capture the general features of the image with ice cloud (codes 4 and 2) dominating the upper right portion, and water cloud and clear (codes 1, 5, and 0) across the bottom quarter. The transition zone is fairly well identified by the mixed phase code 3 placed around the edges of the main cirrus shield, extending along the left upper edge of the image. The pixels coded 0 follow the general pattern of the warmest brightness temperatures apparent from the image in the lower right hand corner; however, they appear to underestimate the number of cloud free pixels. Likewise, areas that appear to be clear in the figure, are generally coded 1 or 5 across the remainder of the lower portion of the image. This is due to the fact that the algorithm based the clear/cloudy threshold on data from the 5 December 1991 flight over the Gulf, and applied it to a data set from a different day and a different region. A more rigorous technique, such as one which uses a clustering technique, will be able to delineate the clear region more accurately for each day, without relying on a previously determined threshold.

In summary, the opportunities for global cloud delineation with MODIS appear excellent. The tri-spectral technique seems appropriate and will be complemented by CO2 slicing (Menzel et al. 1992) to characterize cloud height and amount. The spectral selection, the spatial resolution, and the global coverage are all well suited for significant advances.

Developing a Two Cloud Layer CO2 Slicing Algorithm. Work has progressed on determining cloud parameters in two layers of clouds. In a radiative model formulation the cloud amount and height for each layer is solved from radiance observations in the infrared window and the CO2 channels over clear and two layer cloud scene. The initial version of the two layer CO2 slicing algorithm used 14.0 and 11.0 radiances to determine a table of possible upper and lower cloud pressures and amounts, and it used the 13.4 micron channel to pick to best solution. Results from this version of the algorithm showed a tendency for the two cloud layers to be within 100 hPa of one another. The algorithm was adjusted to overcome these difficulties. The current version of the algorithm uses the 13.3 and 11.0 micron radiances to suggest possible solutions, and it uses radiances from all 5 channels (14.2 to 11.0 microns) to select the best solution. Only solutions with the two cloud pressures 200 hPa apart are accepted; otherwise we revert to the one layer CO2 solution. In addition the upper cloud layer is assumed to have less cloud amount than the lower cloud layer (thin over thick). Initial results look good. Several case studies have been investigated; verification has begun using lidar data and cloud layers with partial overlap (observations of cloud A and cloud B have single layer and double layer radiances).

ANTICIPATED FUTURE ACTIONS

Algorithm Definition. An initial version of the operational MODIS Airborne Simulator (MAS) cloud parameter code will be transfered to the Science Data Support Team and science documentation will be provided.

MAS/HIS Intercomparisons. The collocated HIS (High resolution Interferometer Sounder) data will be used for intercalibration of the two instruments (MAS and HIS) and for studying the spectral sensitivity of the cloud parameter algorithms.

Investigating CO2 Slicing in Two Cloud Layers. The CO2 slicing algorithm will continue to serve as a test bed for modifcations that will accomodate both single and multiple cloud layers. Several case studies of HIRS and HIS datya will be processed to converge on the best version of the algorithm. After verification, a global HIRS data set will be processed with one and two layer CO2 algorithms.

Cloud Investigations with MAS during TOGE-COARE. UW and GSFC members of the Atmospheres Group will be supporting MAS flights out of Townsville, Australia for six weeks in Jan and Feb 1993 as part of TOGA-COARE (Tropical Ocean Global Atmosphere/Coupled Ocean-Atmosphere Response Experiment). Data sets with a variety of cloud configurations will be processed to investigate tri-spectral cloud defintion and CO2 slicing cloud parameter determination.

PROBLEMS/CORRECTIVE ACTIONS

Access to the MODIS Team Members data base that includes spectral response information (from John Barker) and the day one products files (from Al Fleig) has improved considerably. However not all information is readily available to us yet. Efforts continue to make this a smooth information flow in both directions.

Telemail communications have mostly been reliable, with some notable exceptions (eg. reporting hardware plans for the next two years). If the issue is important enough, a fax message should supplement email to assure receipt of message and a timely reply.

PUBLICATIONS

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

Nieman, S. A., J. Schmetz, and W. P. Menzel, 1992: A Comparison of Several Techniques to Assign Heights to Cloud Tracers. submitted to Jour. Appl. Meteor.

Moeller, C. C., O. K. Huh, H. H. Roberts, L. E. Gumley, and W. P. Menzel, 1992: Response of the Louisiana coastal environments to a cold front passage. accepted by Jour. of Coastal Research.

Moeller, C. C., W. P. Menzel, and K. I. Strabala, 1992: High Resolution Depiction of Atmospheric and Surface Variation from combined MAMS and VAS Radiances. accepted by Int. Jour. of Remote Sensing.

Kaufman, Y. J., A. Setzer, D. Ward, D. Tanre, B. N. Holben, V. W. J. H. Kirchhoff, W. P. Menzel, M. C. Pereira, and R. Rasmussen, 1992: Biomass Burning Airborne and Spaceborne Experiment in the Amazonas (BASE-A). Jour. Geo. Res., Vol 97, No. D13, 14581-14599.

Figure of automated cloud coding using MAS tri-spectral threshold technique. 0 indicates clear, 1 thick water cloud, 2 thick ice cloud, 3 mixed phase cloud, 4 thin ice cloud, and 5 water cloud with emissivity les than one.