

[Investigation of cloud properties and atmospheric stability with MODIS]

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Quarterly Activities Report for January - March 1993

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#### NEAR TERM OBJECTIVES

Preparing for pre-SCAR. The MAS (MODIS Airborne Simulator) will be deployed from June-August 1993 from Wallops Island, VA during the first Smoke, Cloud, and Radiation (SCAR) experiment. Efforts will be continued to improve the noise performance of the MAS in the longwave (beyond 13.0 microns) channels. UW will provide on site support for pre-SCAR for three weeks.

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 (mask, 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. A first draft of the Algorithm Theoretical Basis Document will be completed.

Cloud Mask Input. Based on MAS, HIRS, and GOES cloud investigations, suggestions for infrared screening for clouds will be forwarded to the MODIS Calibration Support Team.

Definition of MODIS Infrared Calibration. 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.

#### ACCOMPLISHMENTS

MAS Data Flights during TOGA. Chris Moeller and Paul Menzel were on site in Townsville, Australia to support MAS deployments in January and early February. The MAS flew successful data missions on the ER-2 on February 1, 4, 7, 8, 10, 21, 22 and 23. Data collection included thick and thin cirrus,

multilayer clouds, convective cumulus, and scenes over tropical storm Oliver. MAS data sets from Jan 18, 19, 26, and Feb 1 have been received at UW. Inflight NEdT (noise equivalent temperatures) from Jan 26 data were .78, .24, .32, .51, 1.76, and 4.51 for the 3.7, 8.6, 11.0, 12.0, 13.2, and 13.9 micron channels respectively, verifying that the instrument was performing as expected during the deployment. MAS 1.83 micron data (cirrus detection) show a high inverse correlation with the MAS 11 micron data over clouds. This indicates the 1.83 micron data is doing a good job of discriminating high cirrus. MAS visible (.66 micron) and 11 micron data show, as expected, a much poorer correlation. Interesting segments of the data have been selected and segmented into straight line flight tracks, navigated, and archived.

MAS TOGA/COARE Cloud Catalogue. Efforts are underway to catalogue the cloud observations in the MAS TOGA/COARE data. The catalogue will include low, middle, high and total cloud fraction, cloud top height and temperature, albedo, connectivity, and multilayering. Software used for a GOES bi-spectral cloud classification is being adapted to the MAS data. A visible and IR window combination will be used initially with additional MAS channels added to the algorithm as deemed useful (e.g. longwave and shortwave infrared window comparison). This work will help define an appropriate infrared cloud masking algorithm for the MODIS Calibration Support Team.

MAS Data Flights during CEPEX. The MAS flew 11 successful data missions on the NASA ER-2 in March (3, 9, 12, 15, 16, 17, 21, 23, 25, 28, 31). For these missions MAS was configured with an ozone channel, CO<sub>2</sub> channels for cloud height, cloud particle phase channels, and cirrus detection channels (1.83 or 1.88 microns). The data set has many cloud scenes (optically thick and thin, singlelayer and multilayer) for CO<sub>2</sub> cloud height and trispectral studies. Thin cirrus scenes will be of particular interest for algorithm development; clear scenes will also be used to evaluate instrument performance.

MAS Processing on McIDAS-X RISC Environment. Chris Moeller is moving algorithms for processing MAS data from the McIDAS mainframe to the McIDAS-X RISC environment. MAS calibration and navigation software are currently in place on the RISC. The transfer of existing MAS applications software to the RISC will continue over the next quarter. This move will save considerably in mainframe CPU charges over the next 12 months.

Tri-spectral Studies with TOGA MAS Data. Kathy Strabala continued working on using the tri-spectral technique to delineate cloud properties

with TOGA data from 26 January 1993 and 18 January 1993. The work has focused on a very cold topped cumulonimbus scene surrounded by what appears to be lower water cloud and clear areas. Preliminary results indicate that simple thresholding of temperature differences ( $8\mu\text{m}$ - $11\mu\text{m}$ ,  $11\mu\text{m}$ - $12\mu\text{m}$ ), which is the basis of the technique, must be adjusted for tropical atmospheres. A clustering analysis was added as a means of improving the identification of cloud properties based on similar groupings of points in a scatter diagram of these brightness temperature differences. Clustering can aid considerably in the identification of clear regions, whose position in the diagram can vary depending on atmospheric conditions and thus cannot be identified solely by thresholding techniques. A third dimension, such as the normalized  $11\mu\text{m}$  brightness temperature, may be added to the clustering analysis to further define cloud properties. Cloud scenes with varying cloud emissivities, phase and total cloud amount have been investigated resulting in similar patterns in the  $8$ - $11$  micron versus  $11$ - $12$  micron scatter diagrams as those seen in investigations from 1991 MAS FIRE data. Additionally, a scene with two water cloud layers showed up as two distinct features in the scatter diagram.

**Resolution and Cloud Detection.** MAS data from 18 January 1993 is being processed at varying resolutions (50m, 100m, 250m, 500m, 1km, 4km, 20km) to investigate the effects of sensor resolution on cirrus cloud detection. Early results for a few thin cirrus scenes are indicating that the percentage of fofs considered to be cloudy are not appreciably different for 4km resolution data than for 50m resolution data. Further investigation focused on a very cold topped cumulonimbus scene from 26 January 1993. As in the case with cirrus clouds, the percentage of cloud fofs is found not to be greatly affected when the data is averaged from 50m to 4km.

**Two Layer CO<sub>2</sub> Slicing.** The two layer CO<sub>2</sub> slicing algorithm has been adjusted to highlight thin cirrus over lower thick cloud. The heights and emissivities for the two cloud layers are being estimated simultaneously from CO<sub>2</sub> radiance observations. Several days of global HIRS data were processed and the differences between the one cloud layer and the two cloud layer CO<sub>2</sub> slicing statistics were reviewed. Thin cirrus over lower thick cloud is readily distinguished in the two layer CO<sub>2</sub> technique; the two layer solution is superior to a one layer solution in semi-transparent cloudy fofs 15 to 35% of the time. This is consistent with earlier work comparing ground and satellite observations which indicated that, when clouds are seen, multiple cloud layers exist roughly half of the time. Jason Li is attempting validation of two layer CO<sub>2</sub> heights with HIS data



(convolved spectrally to match the HIRS channels) and lidar data (from Jim Spinhirne) acquired on 24 November 1991 during FIRE.

HIRS Global Cloud Statistics. Over the past three years, Don Wylie and Paul Menzel have tracked trends in global upper tropospheric semi-transparent cirrus cloud cover using NOAA polar orbiting HIRS multispectral infrared data. Cloud occurrence, height, and amount have been determined with the CO<sub>2</sub> slicing technique since June 1989. Results indicate that there is a global preponderance of semi-transparent high clouds, presumed to be cirrus; 40% on the average for the three years covered by June 1989 to May 1992. The changes in cirrus cloud cover from year 1 to year 2 were insignificant, but the changes from year 2 to year 3 (the first year since the Pinatubo eruption) were very noticeable. Opaque cloud cover reduced by 7% globally, while cirrus cloud cover (most of it having effective emissivity less than 0.50) increased by 9%. The fourth year of HIRS global cloud statistics has also been completed; the elevated incidence of cirrus has continued into the second post Pinatubo year. A paper is in preparation on this work.

MODIS Calibration. An initial set of measurements required to characterize the infrared calibration of the MODIS was presented at the Calibration Team Meeting. The ground testing must provide the following information: (1) spectral response for each IR detector/spectral channel combination, (2) calibration tests with several instrument thermal configurations, (3) stray radiation as a function of view angle, and (4) non linear response and measurement repeatability. This data will be used to calculate  $R=a+bC+qC^2$  for each thermal configuration for each detector for each spectral channel. In the process there will be an attempt to characterize changes in the nonlinearity of the calibration equation as a function of instrument temperature ( $q(T)$ ) and to correlate with fore optics temperatures. The cal algorithm mean and RMS errors with respect to the external target will also be calculated as a measure of cal performance. With enough data available, half the data will be used to specify the cal algorithm and the other half will be used to determine cal performance.

#### ANTICIPATED ACTIVITIES DURING THE NEXT QUARTER

SCAR Planning. Planning for the SCAR experiment in 1993 will commence with meetings at GSFC in April 1993. Coordination with investigators using the AVIRIS will be accomplished. Flights from Wallops will start in June.

Publication on HIRS Global Cloud Climatology. A draft of the four year HIRS cloud results will be drafted and submitted to the Journal of Climate.

Draft of Initial Cloud Mask Algorithms. Infrared detection of clouds at single pixel resolution will be investigated and algorithms suggested.

PROBLEMS/CORRECTIVE ACTION

None to report.