INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC STABILITY WITH MODIS

QUARTERLY REPORT FOR JAN-MAR 1995

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ABSTRACT

In the past three months several milestones were accomplished. The MODIS Airborne Simulator (MAS) was flown in a 50 channel configuration and the data were calibrated and validated. Considerable progress was made toward producing a cloud mask data set using AVHRR local area coverage over a variety of surface and cloud scenes (to complement the global oceans only data set completed last year); delivery is expected next quarter. Software testing with portions of the EOS SDP Toolkit was successfully completed. Plans for SCAR-B matured and the UW support was better defined; GOES-8 SCAR-C data was processed and presented at the biomass burning conference. The CO_2 cloud algorithm was compared to other algorithms that differ in their construction of clear radiance fields. The HIRS global cloud climatology was completed for six years.

TASK OBJECTIVES

Software Delivery. Software packages must evolve to improved algorithms using SDP toolkit standards and benchmark data sets must be developed with simulated MODIS data as well as HIRS and MAS data. Additionally for the cloud mask, several data sets in different land/ocean and winter/summer regimes will be developed with AVHRR and MAS data. Delivery of a cloud mask over land with AVHRR/HIRS data will be forthcoming in the second quarter of 1995; high resolution cloud masks from January 1995 MAS data will be available in the second half of 1995.

ATBDs. The MODIS Cloud Mask, Atmospheric Profiles, and Cloud Properties ATBDs will continue to be revised as work progresses.

Algorithm Definition. Processing and testing of the cloud parameter algorithms (mask, temperature, phase, height, and amount) will continue using the MAS (MODIS Airborne Simulator) data at UW. Algorithms for atmospheric total column amount (ozone, precipitable water vapor, and stability) and profiles (temperature and moisture) will be developed using the GOES-8 and HIRS data from the field experiment completed with the MAS and the High resolution Interferometer Sounder (HIS) in January 1995.

Global Cloud Study. Pre-MODIS global cloud studies continue with HIRS data. Six years have been processed to date.

MODIS Infrared Calibration. The approach of validating MODIS radiances using the MAS and HIS instruments will be further studied using the data from the January field experiment. UW will continue to participate in calibration plans so that the MODIS infrared channels are adequately tested before launch to characterize detector non-linear response, stray radiation, angle dependence of background radiation, and scan mirror emissivity effects.

WORK ACCOMPLISHED

MAS Jan 95 Data Flights

The MODIS Airborne Simulator (MAS) and the High spectral resolution Interferometer Sounder (HIS) were deployed together on NASAÕs high altitude ER-2 aircraft during the month of January. Mission objectives included data collection for MODIS activities in cloud mask development, radiometric calibration algorithm development, cloud property studies, and SST validation. On site MAS flight support was provided by Paul Menzel, Chris Moeller, and Liam Gumley. MAS and HIS flew 8 missions together (including ferry to Houston) as outlined in Table 1. Data scenes include deep water Gulf of Mexico (night and daytime), coastal waters, land scenes, moisture gradients, and thin cloud to deep convective cloud. On two missions, the research vessel R/V Pelican was overflown in the Gulf of Mexico. R/V Pelican made in situ measurements of radiometric sea surface temperature and downwelling atmospheric radiance with the AERI instrument, bulk sea surface temperature, atmospheric profile (class-sonde), and surface meteorological parameters. A second AERI instrument was deployed at the CART site in Oklahoma and was overflown on two flights.

GOES-8 imager and sounder data were collected to correspond with the deployment of the R/V Pelican in the gulf and associated ER-2 aircraft flights. Diurnal hourly GOES-8 sounder data were collected throughout the field experiment (5 January 1995 - 19 January 1995, 24 January 1995). GOES-8 imager data were obtained every fifteen minutes during selected ER-2 flights and diurnally throughout the R/V Pelican deployment. Elaine Prins and Kathy Strabala provided support at Madison to make the GOES data gathering possible.

The MAS data set quality is very good. Noise estimates for the thermal bands (26-50) are shown in Table 2. This deployment was the first for MAS with the new 50 channel digitizing system. While some data loss (<10%) and other minor problems are attributable to the newness of the data collection system, the improvements of 50 channel data collection, 16 bit precision, and reduced noise (factor of 4 improvement) meet expectations. Corrections to firmware problems in the data system have been suggested and Ames Research Center has implemented them.

MAS Infrared Calibration.

HIS radiances from Jan 16 1995 have been integrated over the MAS spectral response functions (from Stennis Space Center, Aug 1994) and compared to MAS collocated observations over the Gulf of Mexico. Comparisons for thermal channels 31 - 50 are shown in Table 3. It has become evident in this investigation that the August 1994 MAS spectral response function measurements performed at Stennis contain a signal of residual atmospheric absorption (CO_2 and H_2O), causing the HIS integrated temperatures to be overestimated. This is pronounced in channels 34, 35, 49, and 50, which are all very sensitive to atmospheric CO_2 absorption. The bias is fairly constant (~ 1°C) in the longwave infrared atmospheric window channels (44 - 47), which are largely unaffected by residual atmospheric absorption. Preliminary investigations indicate that an emissivity correction of .02 to .03 would account for the 1°C longwave window bias. Laboratory measurements of MAS blackbody emissivity are under consideration. An effort is underway to remove residual absorption effects from the August 1994 spectral response measurements.

Cloud Mask Test Data Sets

The initial global ocean cloud mask test data set was delivered to the SDST for distribution in January. This data set includes both AVHRR GAC and HIRS orbit files, a resultant cloud mask file and a version of the Wisconsin Toolkit which allows these data sets to be displayed alone or together. In addition, a more complete file containing collocated radiances, brightness temperatures and cloud mask test results in binary form was also delivered. Data set distribution is being managed by Rich Hucek of the SDST, rhucek@modis-xl.gsfc.nasa.gov.

A significant effort is underway to develop and deliver an AVHRR LAC cloud mask. Investigations focus on defining thresholds based on a section of orbit over North America from 5 December 1991. A variety of surface and cloud scenes are present and supporting data collected during the FIRE experiment can be used for validation. All tests outlined in the Cloud Mask ATBD which can be applied to the AVHRR 5 channel data are being included. Confidence flags will be output for each initial individual test, with the value depending on the proximity of a test result to a given threshold. The resulting cloud mask will be structured close to that proposed as the final MODIS cloud mask product. Once this test AVHRR LAC set is processed, the mask will be applied to other scenes of varying ecosystem, season and time, for use in further threshold definition.

Tri-spectral Cloud Phase Algorithm

The availability of TOGA/COARE DC-8 lidar data has made it possible to choose potential flight segments where microphysical data were collected for comparison with coincident MAS infrared data collected on stacked ER-2 flights. The data set will be used as validation of the tri-spectral (8 minus 11 versus 11 minus 12 micron) brightness temperature difference method of

cloud phase determination. A flight segment with close ER-2 and DC-8 coordination, where the DC-8 was collecting microphysical data at cloud top, is optimal for the comparison. The most promising segments appear to be 04:00 - 05:00 UTC, 18 January 1993 and several portions of the 23-34 February 1993 MAS flight.

CO_2 slicing Cloud Products Comparison

A comparison between two implementations of the CO_2 slicing algorithm has been completed. The Menzel/Wylie algorithm has been in continuous operation for six years. The CHAPS (Collocated HIRS and AVHRR Products) algorithm also employs the CO_2 slicing method and was run for three separate months during July 1993, January 1994, and July 1994. Both methods use HIRS radiance data as input and, with a few exceptions, are very similar. CHAPS uses HIRS data with a viewing zenith angle cutoff at approximately 30 degrees, while the Menzel/Wylie method samples every third line and element and stops at 10 degrees. The CHAPS algorithm calculates clear sky reference radiances from global models with radiance bias adjustments, whereas Menzel/Wylie find clear fields of view using a threshold method and then interpolate. A monthly, global, oceanic comparison for January 1994 showed very similar results. Due to the use of higher spatial resolution AVHRR data to aid in clear sky discrimination, CHAPS found about 6% more low-level clouds and 2% less clear sky. Menzel/Wylie found about 4.5% more clouds at 500 mb and above.

HIRS Cloud Climatology

Six boreal summers and winters of cloud statistics have now been processed using the CO2 algorithm applied to HIRS data. The six year averages continue to show a global preponderance of transmissive high clouds; 42% for summer and 45% for winter. Both the latest summer (June - August 1994) and winter (December 1994 - February 1995) statistics show an increase in lower emissivity high clouds at the expense of low opaque clouds. This increase has been consistent since the summer of 1991. An investigation into the relationship between commercial air traffic increase and this steady semi-transparent cirrus increase has begun.

NOAA 14 has been added to the ongoing HIRS data processing of cloud parameters. Initial inspection shows no change in the quality of the cloud products.

Software Development

A significant effort this quarter has been directed towards the development of a new version of the MODIS atmospheric profiles heritage code, the International TOVS Processing Package (Version 5.0). While this code is primarily a research tool for the TOVS community, several aspects of the software development are pertinent to our MODIS efforts. First, the atmospheric profile retrieval algorithm used in ITPP 5.0 forms the basis for the MODIS algorithm. The physics of the problem and the means of solution are very similar. Second, portions of the ITPP software will be used directly in the MODIS software. Experience gained in polishing and

testing of heritage source code will be applicable to MODIS. Third, by maintaining support for ITPP, we are maintaining links with the research community who will be users of MODIS atmospheric profile data, and who can provide useful input on the direction of our algorithm development. After the code was compiled on four systems (IBM RS/6000 Unix, Silicon Graphics, Hewlett-Packard, and Sun Unix workstations), a test data set was used to exercise the software with five different input cases. Atmospheric profile retrieval results were screened to identify different results on different systems. Ignoring differences due to the specific arithmetic operations used by the IBM (64 bit rather than 32 bit), exact agreement was found between the SGI, HP, and Sun versions, and slight differences (>0.01K) were found in less than 1% of the profiles when comparing the IBM results to the other platforms. It was found that compiler optimization options can affect the results, so compiler options were chosen for each platform which gave the best agreement while maintaining acceptable performance. The final release of ITPP 5.0 is now pending on the incorporation of updated transmittance models.

Version 3 of the EOS SDP Toolkit was obtained from the ECS project and installed on MODIS1 (the UW IBM RS/6000). Conversations with the MODIS SDST indicated that the highest priority mandated Toolkit functions were the file open/close routines, which all MODIS science software must use. In order to verify that we could integrate these routines into our FORTRAN heritage code, the PGS Toolkit file open/close routines were tested to ensure that they would function correctly in our software development environment. A FORTRAN wrapper was written for both open and close routines, in a way that closely resembles the normal FORTRAN open/close syntax. The rationale was to minimize the impact of the Toolkit calls on our existing software. The wrapper open/close routines were successfully tested on MODIS1, and we expect to make use of them in our next MODIS software delivery. Some problems were noted with the ease of Toolkit installation, and will be checked again with the newly released Toolkit V4.0.

Software has been developed which converts HIRS/2 and AVHRR Local Area Coverage (LAC) 1b data into a format compatible with the McIDAS (Man-computer Interactive Data Access System). This allows fully calibrated and navigated historical 1b data to be quickly and easily displayed, which in turn leads to more efficient data analysis and quicker development of other new software, such as the AVHRR (LAC) cloud mask.

SCAR

Plans for SCAR-B are maturing. UW will provide daily synoptic meteorological summaries and forecasts based on GOES-8 satellite imagery and NMC model output during the field experiment. The GOES-8 Automated Biomass Burning Algorithm (developed under separate NASA funding (NAGW-3804) for the 1995 biomass burning season in South America) will be operational throughout the field experiment providing information on fire size estimates and locations (lat/lon coordinates) for the region extending from 40 to 70¡W and from the equator to 40¡S. Multispectral GOES-8 visible and IR data will be used to catalogue the presence and transport of smoke/aerosol associated with biomass burning (based on half-hourly imagery collected from 13:00 through 14:30 UTC). Daily summary satellite images depicting the

synoptic situation, fire locations and aerosol transport regimes will be made available to the mission scientists in Brazil as GIF files via the Internet (WWW). An accompanying file will provide approximate lat/lon coordinates for fires as detected by the GOES-8 ABBA.

GOES-8 data collected during SCAR-C show the enhanced ability of the GOES-8 instrument to detect small fires in North America and provide information concerning diurnal variability and fire intensity. A trial version of the GOES-8 ABBA was implemented to estimate diurnal variability in the target temperatures and fire sizes for the Quinault, ITT, and Simpson fires which were ignited by the USFS on 21 September 1994 in the state of Washington. The results for the Quinault fire were compared with ground truth observations provided by Roger Ottmar of the USFS. The Quinault fire was ignited by the USFS at approximately 1810 UTC, was flaming over 31 acres by 1830 UTC, was smoldering over 41 acres by 1920 UTC, and was assumed expired by 2000 UTC. Due to Internet difficulties, GOES-8 data were not available prior to 1945 UTC. At 1945 UTC the GOES-8 ABBA estimated the fire size at 34 acres burning at an average temperature of 472 K. Ground truth estimates indicate that approximately 28 acres were smoldering at this time. At 2015 UTC the GOES-8 imagery corroborates the USFS evaluation that the fire is no longer actively burning. However at 2045 UTC it reappears in the GOES-8 image and remains until 2215 UTC. It is not clear if the fire intensified during this time or if the GOES-8 data is responding to other factors.

At the SCAR-C Science Team meeting in Williamsburg on Monday, 13 March 1995 the attendees decided to focus the initial analysis efforts on the prescribed burns in Washington and Oregon (Quinault, ITT, Simpson, and Creamery burns) and the wildfires in Northern California and Idaho. In order to produce a complete time series analysis of the Quinault fire as observed by the GOES-8 ABBA, additional data has been ordered from the archive to fill in the data gap prior to 1945 UTC on 21 September 1994. Similar analyses will be performed for the ITT and Simpson prescribed fires and the Creamery Burn which was set by the USFS on 22 September 1994.

Meetings

Paul Menzel presented the paper ÒMonitoring Biomass Burning With the Next Generation of Geostationary SatellitesÓ and Elaine Prins presented a paper on the ÒInvestigation of Biomass Burning and Aerosol Loading and Transport in South America Utilizing Geostationary Satellite DataÓ at the Chapman Conference on Biomass Burning and Global Change in Williamsburg, Virginia, March 13-17, 1995.

Elaine Prins attended the SCAR-C Science Team Meeting on Monday, March 13 in Williamsburg, VA.

Dan Laporte attended a MAT meeting and gave a presentation on MAS calibration in early March 1995.

Table 1. MAS/HIS Flights January 5-24, 1995

DATE	ER-2 Flt#	ER-2 Payload	Mission Location	Mission Objective
1/05	95041	M/H	Ferry to Houston.	Oklahoma CART site; clear/cloud over various land types
1/06	95042	M	Gulf coast	thin cirrus to deep convective squall line; EDOP
1/07	95043	M/H	Louisiana	Clear sky over land; photo mapping mission
1/08	95044	M/H	Louisiana coast	Clear sky coastal waters, geomorphology
1/11	95045	M/H	Gulf of Mexico	Clear sky GOES-8 Calibration underflight
1/13	95046	M/H	Gulf coast	thin cirrus to deep convection; EDOP
1/15	95047	M/H	Gulf buoy 42019	Clear pre-dawn/daylight GOES-8 underflight coordinated with R/V Pelican
1/16	95048	M/H	Gulf buoy 42002	Clear sky GOES-8 underflight coordinated with R/V Pelican
1/19	95049	M/H	CART site, OKLA	Clear sky overflight of uplooking AERI mid-tropospheric water vapor dry slot
1/24	95051	M	Louisiana coast	Clear sky coastal waters, geomorphology

Table 2. MAS noise estimates from the Gulf of Mexico data on Jan 16, 1995. R is radiance (mW/m2/ster/cm^{-1}), T is scene brightness temperature, NEdR is noise equivalent radiance, NEdT is noise equivalent temperature, signal to noise (S/N) is R/NEdR.

Ch	λ_b	R	NEdR	T	NEdT	S/N
26	2.96	0.216e-1	0.123e-1	291.44	9.78	1.8
27	3.12	0.341e-1	0.137e-1	284.24	7.05	2.5
28	3.26	0.622e-1	0.105e-1	284.28	3.09	5.9
29	3.44	0.153	0.977e-2	290.91	1.28	15.7
30	3.57	0.275	0.925e-2	292.69	0.72	29.7
31	3.74	0.458	0.965e-2	292.85	0.47	47.5
32	3.89	0.644	0.103e-1	291.80	0.37	62.5
33	4.06	0.834	0.107e-1	288.63	0.30	77.9
34	4.16	0.242	0.102e-1	257.05	0.81	23.7
35	4.40	0.117	0.122e-1	233.59	1.74	9.6
36	4.51	1.098	0.130e-1	272.37	0.28	84.5
37	4.65	2.767	0.144e-1	288.53	0.14	192.2
38	4.82	3.434	0.164e-1	285.51	0.13	209.4
39	4.99	4.279	0.186e-1	285.58	0.12	230.1
40	5.14	4.279	0.204e-1	280.19	0.14	209.7
41	5.28	4.217	0.270e-1	274.51	0.18	156.2
42	8.54	59.86	0.166	292.08	0.14	360.6
43	9.70	74.85	0.165	287.18	0.12	453.6
44	10.48	98.04	0.147	294.11	0.09	666.9
45	10.98	105.97	0.164	294.14	0.10	646.2
46	11.93	118.25	0.313	293.58	0.19	377.8
47	12.80	120.93	0.757	290.90	0.46	159.8
48	13.19	111.44	0.769	282.86	0.49	144.9
49	13.66	77.23	1.672	256.46	1.32	46.2
50	14.13	48.10	1.923	228.76	2.00	25.0

Table 3 MAS measurements compared with HIS radiance measurements integrated over the MAS spectral response functions. ÔVarÕ is the data variance of each instrument.

Channel	λ_b	T(MAS)	Var	T(HIS)	Var	ΔT
31	3.74	293.4	0.5	290.9	68.2	2.5
32	3.89	292.3	0.5	293.3	10.5	-1.0
33	4.06	289.1	0.4	291.1	0.8	-2.1
34	4.16	257.3	0.2	283.4	0.6	-26.1
35	4.40	233.8	0.1	238.0	7.8	-4.3
36	4.51	272.7	0.1	270.1	0.4	2.5
37	4.65	289.1	0.4	289.6	0.5	-0.5
38	4.82	286.1	0.3	287.1	0.4	-1.0
42	8.54	292.7	0.6	292.1	0.6	0.6
43	9.70	287.5	0.6	285.1	0.7	2.4
44	10.48	294.8	0.7	293.8	0.7	1.0
45	10.98	294.9	0.7	293.9	0.7	1.0
46	11.93	294.3	0.7	293.2	0.7	1.2
47	12.80	291.5	0.5	290.5	0.5	1.0
48	13.19	284.1	2.3	282.6	0.3	1.6
49	13.66	256.0	0.7	259.8	0.1	-3.8
50	14.13	229.1	0.2	234.0	0.1	-4.9