INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC STABILITY WITH MODIS

SEMI-ANNUAL REPORT FOR JAN-JUN 1995

Paul Menzel
NOAA/NESDIS at the University of Wisconsin

Contract NAS5-31367

ABSTRACT

In the past six months several milestones were accomplished. The MODIS Airborne Simulator (MAS) was flown in a 50 channel configuration for the first time in January 1995 and the data were calibrated and validated; in the same field campaign the approach for validating MODIS radiances using the MAS and High resolution Interferometer Sounder (HIS) instruments was successfully tested on GOES-8. Cloud masks for two scenes (one winter and the other summer) of AVHRR local area coverage from the Gulf of Mexico to Canada were processed and forwarded to the SDST for MODIS Science Team investigation; a variety of surface and cloud scenes were evident. Beta software preparations continued with incorporation of the EOS SDP Toolkit. SCAR-C data was processed and presented at the biomass burning conference. Preparations for SCAR-B accelerated with generation of a home page for access to real time satellite data related to biomass burning; this will be available to the scientists in Brazil via internet on the World Wide Web. 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. The MODIS Science Team Meeting was attended by five of the UW scientists.

TASK OBJECTIVES

Software Development

Work continues on evolving the three software packages (cloud mask, cloud top properties, and atmospheric profiles) from AVHRR, HIRS, and MAS data to MODIS data. Beta 3 software will be delivered to the SDST by the end of third quarter 1995. For the cloud mask, several data sets in different land/ocean and winter/summer regimes continue to be developed with AVHRR and MAS data. A cloud mask over land with AVHRR/HIRS data was delivered in the second quarter of 1995. High resolution cloud masks using MAS 50 channel data over different atmospheric and surface regimes are being processed; a tropical data set from the Gulf of Mexico experiment (6 and 13 January 1995) and an Arctic data set from BOREAS (21 April 1995) will be forwarded to the SDST within the next quarter.

Evolving the ATBDs

The UW ATBDs will be revised to include information from the continuing MAS, AVHRR, HIRS, and GOES cloud investigations. Another version of the ATBDs will be drafted in late 1995.

Algorithm Definition

Processing and testing of the cloud parameter algorithms (mask, temperature, phase, height, and amount) will continue using the MAS 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 HIS in January.

Global Cloud Study

Pre-MODIS cloud studies will continue via the global cloud census with HIRS data now in its sixth year.

MODIS Infrared Calibration

Postlaunch procedures for validating MODIS radiances will continue to be refined; an initial demonstration with GOES-8 using underflights of the MAS and HIS was successful in January. Prelaunch calibration of the MODIS infrared channels requires considerable testing to characterize detector to detector and band to band cross talk, detector non-linear response, stray radiation, scan mirror emissivity variations with angle and wavelength, angle dependence of background radiation, and other effects. The Engineering Model thermal vacuum tests have answered some questions but raised many more.

WORK ACCOMPLISHED

Software Delivery

MODIS cloud mask Beta 3 (MOD35) software was delivered to the SDST in July. MAS data archived at the GSFC DAAC in the MAST configuration (11 channels) were used to enable HDF routines in the software. The output is in the 32 bit binary flag format described in the cloud mask ATBD.

Earlier in the last six months, UW delivered two cloud mask data sets to SDST for distribution.

An initial global ocean cloud mask test data set was delivered in January. This data set includes AVHRR GAC and HIRS orbit files, an associated cloud mask file, and the

Wisconsin Toolkit to display the data and mask individually or together. In addition, a more complete file containing collocated radiances, brightness temperatures and cloud mask test results in binary format was also included.

A second cloud mask test data set consisting of two AVHRR LAC low/mid latitude North American scenes was delivered to the SDST in June. The scenes include a variety of cloud and background surfaces. Sun glint, spring vegetation, tropical convection, and boundary layer cumulus are all captured in the December 1991 and April 1989 data sets. As with the GAC data set, data and the associated cloud mask (confidence level and individual cloud test results) can be viewed by the Wisconsin Toolkit. The final 32 bit cloud mask binary file is also included, along with a FORTRAN program to read it.

January 95 MAS Data

MAS and HIS were deployed together on NASA's high altitude ER-2 aircraft in January 1995. 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 Chris Moeller, Liam Gumley, and Paul Menzel. MAS and HIS flew 8 missions together (see Table 1) gathering data over 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 ER-2 flew over the research vessel R/V Pelican which was making 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 (results of SST validation are being published in Smith et al, 1995). A second AERI instrument at the CART site in Oklahoma was also 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 the 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 supported the GOES data gathering in Madison.

SCAR-B Activities

MAS thermal channel radiometric calibration is being re-evaluated in preparation for the SCAR-B MAS field program in Brasilia beginning 14 August 1995. The effort is focused on characterizing maximum radiance, radiometric sensitivity and noise (NEdR), and absolute calibration (especially at high temperatures) for fire detection channels at 3.75, 3.90, 11.0, and 12.0 microns. The 3.9 micron channel provides the best fire temperature information with saturation temperature at about 500 K. Radiometric background and atmospheric moisture corrections are being made using the 3.7, 11, and 12 micron channels. Sufficient precision (12 bit) from the 50 channel digitizing system is available to maintain high radiometric sensitivity over the large radiance interval between background and fire scene radiances. Findings from ongoing investigations of MAS blackbody emissivity and calibration non-linearities are being incorporated into an improved absolute calibration algorithm to be available for processing SCAR-B data.

During the SCAR-B field program, UW will provide the mission scientists with GOES-8 satellite imagery, GOES ABBA fire products, meteorological observations, and NMC model output via the UW SSEC SCAR-B web site. The SCAR-B web site was successfully demonstrated at IBAMA on 29 June 1995 via the Internet. This interactive tool allows scientists to access meteorological information as well as satellite imagery and satellite derived fire products from the Mission Operations Center at IBAMA. The UW SCAR-B home page directs the user to select from three primary menus (Figure 1): GOES-8 imagery loops, GOES-8 ABBA products, and the McWEB forecasting tool.

The GOES-8 imagery loop web page allows the user to view a series of 3-hourly 4 and 11 micron images of South America and the Atlantic Ocean collected over the past 24 hours. A loop of daytime visible imagery is also available.

The GOES-8 ABBA products web page (Figure 2) consists of plots of fire locations at peak burning times (11:45, 14:45, 17:45, 20:45 UTC) as detected with the GOES-8 ABBA for the region extending from approximately 40 to 70°W and from the equator to 30°S. A text summary of the diurnal ABBA observations will be made available daily at 00 UTC. This page also contains a morning GOES-8 visible image depicting the areal extent of smoke/aerosol coverage based on visible and infrared imagery collected at 11:45 UTC and half-hourly imagery collected from 13:00 through 14:30 UTC.

The McWEB forecasting tool consists of a series of interactive web pages that allow the user to plot meteorological data (surface and upper air observations as well as NMC model output fields) alone or over the latest visible or infrared GOES-8 satellite image. Data can be plotted over a reduced resolution image of the entire region for synoptic scale analyses. For mesoscale analyses, the user can select a specific location to view a full-resolution image centered on the selected site. The McWEB forecasting tool enables the user to plot a variety of parameters including: sun photometer site identifiers; surface visibility; surface and upper air (10 pressure levels) station plots; and MRF model output (analysis, 12, 24, 36 and 48 hour forecasts) of heights, vorticity, temperatures, isotachs, and streamlines at four distinct pressure levels, as well as 1000-500 mb thicknesses.

<u>Split Window Cloud Studies</u>

MAS, HIS, GOES-8 and AVHRR data are being used to investigate occurrences of negative difference 11 micron brightness temperature (BT11) minus 12 micron brightness temperature (BT12) over cold cloud scenes. These observations run counter to known bulk absorption properties of ice cloud particles. In the past, these occurrences have been attributed to radiometric calibration error. Using collocated data from ER-2 flights in Jan

1995, a direct comparison of MAS BT11-BT12 and HIS BT11-BT12 (integrated over MAS spectral response function) has been made. The MAS data show many occurrences of negative differences over mixed mature convective and thick cirrus scenes. The collocated HIS data, an excellently calibrated source, however does not show negative differences. This suggests that MAS calibration error may indeed be playing a significant role in negative difference occurrences. Many negative difference occurrences have also been found in 13 January 1995 GOES-8 imager and sounder data as well as AVHRR data. The predominance of these observations were found in the rapid convective growth region on the southern edge of a Gulf Coast squall line. Very few negative differences were found in mature cold cloud scenes. The GOES-8 and AVHRR negative difference observations have the interesting characteristic of being located in explosive convective growth surrounded by small clear air regions. Negative differences are found both near cloud edge and in cloud filled scenes of the new growth convection. Unfortunately the ER-2 aircraft, positioned further to the north on January 13, did not fly over these same scenes. MAS thermal channel calibration studies will be applied to adjust MAS scene radiances for onboard blackbody emissivity characteristics. A re-evaluation of the MAS BT11-BT12 differences will then be made.

AVHRR, HIRS, and GOES Cloud Studies

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.

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.

John Dostalek, a Masters student, is finishing his thesis work studying the sensitivity of CO_2 cloud studies to spacing and resolution of the measurements using GOES-8 10 km data. For scenes with mixed cloud types, the clear sky detection is reduced by 12% as the resolution degrades from 10 to 100 km; detection of thin, thick, and opaque cloud each increase by about 4%. As the spacing of 10 km observations changes from contiguous to 100 km, the clear sky detection does not vary more than 1 %; the distribution of cloud properties (height and amount) do not vary appreciable either. These results will be factored into the approach for characterizing global cloud cover with MODIS.

Tri-spectral Cloud Phase Algorithm

The availability of TOGA/COARE DC-8 lidar data has made it possible to choose flight segments where microphysical data as well as ER-2 MAS infrared data were collected on stacked DC-8 and ER-2 flight tracks. The data sets will be used to validate the tri-spectral (8 minus 11 versus 11 minus 12 micron) brightness temperature difference method of cloud phase determination. Promising segments appear to be 04:00 - 05:00 UTC on 18 January 1993 and several portions of the 23-24 February 1993 MAS flight.

Standards Waiver and Ancillary Data Tools

A standards waiver was granted to the UW for the use of Integer*2 type declarations for Beta 3 software deliveries. Use of this declaration in future deliveries is still under discussion. Integer*2 type variables are required by the Wisconsin Toolkit to access ancillary data. Since neither MODIS or the project have such tools currently available, there continues to be a need for the standards waiver. Lengthy discussions on this topic have taken place for two years; details on the necessary tools have been sent to EOS ancillary data and SDST personnel. Resolution is pending.

DATA ANALYSIS

MAS Noise Analysis and Infrared Calibration

The quality of the 50 channel MAS data is very good. Noise estimates for the thermal bands (26-50) are shown in Table 2. The January flights over the Gulf of Mexico were the first for MAS with the new 50 channel digitizing system. The improvements of 50 channel data collection, 16 bit precision, and reduced noise (factor of 4 improvement) meet expectations. Some data loss (<10%) and other minor problems occurred as the data collection system was still under checkout; Ames Research Center have corrected known problems. King et al (1995) detail the MAS configuration and early results.

HIS radiances from 16 January 1995 have been integrated over the MAS spectral response functions (measured by Stennis Space Center in August 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 that the Stennis spectral response function measurements of MAS contain 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. Removing the atmospheric absorption is hindered since reference detector and ambient condition measurements are not available in the Stennis data set. The bias is fairly constant (~ 1°C) in the longwave infrared atmospheric windows (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. A laboratory data set using the well-calibrated Advanced Kinetics Extended Area Blackbody Source has been generated at Ames Research Center to investigate MAS blackbody emissivity. Laboratory measurement of MAS blackbody reflectance is also under consideration. Plans are being made to re-measure the MAS spectral characteristics under highly controlled laboratory conditions at Ames in the next quarter.

SCAR-C

Analyses of 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. Several prescribed burns were initiated on 21 September 1994 in Washington in association with the Smoke Clouds and Radiation (SCAR-C) experiment, including the Quinault fire (48 acres, 47:19 °N, 124:16°W),), the Simpson fire (95 acres, 47:12 °N, 123:30 °W), and the ITT fire (97 acres, 47:08°N, 123:38 °W). The Quinault fire consisted of approximately 5000 tons of red cedar debris ignited by the U. S. Forest Service (USFS) at approximately 1810 UTC. Updated information from the USFS indicates that over 21 acres were flaming at 1830 UTC; approximately 30 acres remained in the smoldering phase at 20:15 UTC; and less than 10 acres were smoldering at 22:00 UTC. The first available GOES-8 short-wave window image at 1945 UTC clearly shows burning at Quinault corresponding to peak heat release rates computed by the USFS. At 2015 UTC the GOES-8 did not detect elevated 4 μm brightness temperatures for the Quinault site; however at 2045 UTC the fire reappears in the GOES-8 image and remains until 2215 UTC (See Figure 3). The GOES ABBA estimates of area burning and average fire temperature are compared with the ground estimates of flaming and smoldering acres in Table 4. Since the ABBA infers uniform background radiance from neighboring clear sky pixels, these estimates are somewhat hindered by the coastal location of Quinault, where background radiation for each GOES-8 fire pixel comes from a combination of ocean and land. The relatively good agreement between GOES-8 and ground truth estimates is very encouraging; the estimate of the size of the fires is within 20% on the average at any given time. GOES-8 also shows the enhanced capability over GOES-7 which did not detect the fire after 2045 UTC. These results are written up in Menzel and Prins (1995).

MAS Cloud Mask Data Set

An initial MAS cloud mask algorithm has been developed for both 11 channel (Monterey Area Ship Tracks) MAST and 50 channel Gulf of Mexico configurations. Dual development was necessary for several reasons. The 11 channel data includes many of the spectral bandwidths needed for the threshold tests as outlined in the cloud mask ATBD, is in HDF format for easier integration into the SDST processing strings, and has good visible calibration. The 50 channel MAS data includes nearly all of the spectral bandwidths outlined in the cloud mask ATBD, is quickly calibrated and navigated with in-house processing capabilities at Wisconsin, and is readily inspected and processed with the Wisconsin toolkit capabilities.

Threshold cloud detection tests on both data sets show the advantages of using multi-spectral tests. Figure 4 is an example from the 50 channel MAS flight of 6 January 1995 over the Gulf of Mexico. The two top left panels are the .66 micron and the 11 micron images. Note the variety of cloud types present. The next five panels are cloud mask results from individual tests; IR window, split window, reflectance ratio, SWIR minus LWIR, and visible reflectance. White indicates that the test found cloud and black indicates otherwise. Each test is effective at picking out certain cloud types, yet none is effective at detecting all cloud types. The final panel is the resultant cloud mask image; darker shade indicates reasonable probability of clear sky (2-sigma or less than 66%) and the lighter shade indicates high probability of cloud (3-sigma or greater than 99%).

A MAST flight track from 13 June 1994 was chosen to test the 11 channel cloud mask. The code to process the data as well as the cloud mask results were delivered to the SDST as the MODIS cloud mask Beta-3 software delivery. The algorithm builds upon the AVHRR LAC processing software, but also includes other spectral tests including the tri-spectral brightness temperature difference tests and the 1.88 micron high cloud test. Results are output into the 32 bit structure as defined in the cloud mask ATBD.

AVHRR Cloud Mask Data Set

The proposed multi-spectral technique and the final cloud mask product format has evolved over the past six months. A summary of the cloud mask, information on how to access the data, and an AVHRR LAC example are presented below.

The MODIS cloud mask will indicate whether a given view of the earth is unobstructed by clouds. In addition, the mask will assess if a clear view is affected by cloud shadows. The cloud mask will be generated at 250 and 1000 meter resolutions and assigns, based on a series of cloud detection tests, clear sky confidence levels to each pixel (e.g., 99%, 95%, 66% and less than 1% probability of clear). The MODIS cloud algorithm benefits from previous work (e.g. ISCCP, CLAVR, APOLLO and SERCAA) to characterize global cloud cover; however, much work remains to develop and implement the algorithms before launch. Some of the approaches to cloud detection (see the Cloud Mask ATBD) are being developed with current satellite observations, while others require modeling efforts and regional observations with the MAS.

In the process of developing the cloud mask algorithm, various data sets are being made available to the MODIS Science Team members (see Table 5). Potential users of the MODIS cloud mask are encouraged to make careful assessments of the cloud mask test data sets (e.g., are too many or too few pixels flagged as cloudy). Quick look images of the raw data and the cloud mask are available on the World Wide Web (http://cloud.ssec.wisc.edu/modis/cldmsk/cldmask.html) to aid in the selection of individual case studies. The data sets, description of the cloud mask, and programs to read the cloud masked images are available via ftp from the SDST at ltpftp.gsfc.nasa.gov, in the /pub/projects/modis/CloudMask directory. A software package (MERLIN) to display the data is available from the SDST or on the MERLIN home page on the web (http://ssec/software/merlin.html).

An example of a cloud mask image generated from an AVHRR LAC is enclosed (Figure 5) as well as the channel 2 image for reference. The color code for the cloud mask image is:

Green	> 99 probability of clear
Blue	> 95% probability of clear
Navy	> 66% probability of clear
Red	> 33% probability of clear
Gray	> 5% probability of clear
Yellow	> 1% probability of clear
White	< 1% probability of clear

The cloud mask image is the final product of a series of spectral tests. Individual test results are also available; one can decode the 32 bit cloud mask data file or use MERLIN to view an actual cloud masked image from the provided data sets. The current version of the cloud mask uses a 1 km resolution land/water file available from the USGS homepage (http://sun1.cr.usgs.gov/landdaac/1KM/1kmhomepage.html). A 10 minute ecosystem map has been included in the cloud mask algorithm, although its use is currently limited.

PAPERS

King, M. D., W. P. Menzel, P. S. Grant, J. S. Myers, G. T. Arnold, S. Platnick, L. E. Gumley, S. Tsay, C. C. Moeller, M. Fitzgerald, K. S. Brown, and F. Osterwisch, 1995: Airborne scanning spectrometer for remote sensing of cloud, aerosol, water vapor and surface properties. Submitted to Jour. Atmos. and Oceanic Tech.

Smith, W. L., R. O. Knuteson, H. E. Revercomb, W. Feltz, H. B. Howell, W. P. Menzel, N. Nalli, O. Brown, J. Brown, P. Minnett, and W. McKeown, 1995: Observations of the

infrared radiative properties of the ocean - Implications for the measurement of sea surface temperature via satellite remote sensing. Accepted by Bull. Amer. Meteor. Soc.

Menzel, W. P. and E. M. Prins, 1995: Monitoring Biomass Burning With the New Generation of Geostationary Satellites. Submitted for publication in the Proceedings of the AGU Chapman Conference on Biomass Burning and Global Change, Williamsburg, Virginia, March 13-17.

Prins, E. M. and W. P. Menzel, 1995: Investigation of Biomass Burning and Aerosol Loading and Transport Utilizing Geostationary Satellite Data. Submitted for publication in the Proceedings of the AGU Chapman Conference on Biomass Burning and Global Change, Williamsburg, Virginia, March 13-17.

MEETINGS

Paul Menzel attended the Investigators Working Group held in Santa Fe, NM on 27-29 June 1995.

Dan LaPorte attended the review of the Engineering Model Thermal Vacuum Test data held in Santa Barbara in June 1995.

Steve Ackerman, Elaine Prins, Kathy Strabala, Dan LaPorte, and Paul Menzel attended the MODIS Science Team Meeting in Greenbelt, MD on 3-5 May 1995. Menzel and LaPorte also attended the Calibration Team Meeting on 2 May 1995.

Steve Ackerman attended the CERES Science Team meeting at Langley Research Center in April 1995.

Paul Menzel presented the paper "Monitoring Biomass Burning With the Next Generation of Geostationary Satellites" and Elaine Prins presented a paper on the "Investigation of Biomass Burning and Aerosol Loading and Transport in South America Utilizing Geostationary Satellite Data" 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. λ is wavelength in microns, 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. 'Var' 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

Table 4. GOES-8 and ground estimates of the intensity and extent of the Quinault, WA controlled burn on 21 September 1994. Note that 1 acre equals .004 km^2. Ground data courtesy of Roger Ottmar of the U. S. Forest Service Seattle Forestry Science Laboratory .

Times (UTC)	Ground Observations Flaming (Acres)	Smoldering (Acres)	GOES-8 Estimates Total Area (Acres)	Temperature (°K)
1800	0	0	NA	NA
1815	2	0	NA	NA
1830	21	0	NA	NA
1845	23	7	NA	NA
1900	22	12	NA	NA
1915	21	21	NA	NA
1932	15	24	NA	NA
1945	15	21	40	602
2000	7	26	NA	NA
2015		29	No elevated signal in G-8 data	
2030		23	NA	NA
2045		20	27	626
2100		18	NA	NA
2115		18	16	597
2132		13	17	586
2145		11	NA	NA
2200		10	NA	NA
2215		8	Fire barely detectable in G-8 data	
2230		7	NA	NA
2245		6	Fire not detected in G-8 data	
2300		5	Fire not detected in G-8 data	

NA indicates Not Available

Table 5. CIMSS MODIS Cloud Mask Test Examples

The data sets currently being used to develop the MODIS cloud mask are listed below as well as brief descriptions of the advantages and disadvantages of each.

Data Set	Advantages	Disadvantages
AVHRR LAC	Similar spatial resolution Readily available	5 Channels No global coverage
AVHRR GAC	Global coverage Readily available	5 Channels 4 km footprint
HIRS/AVHRR	Many MODIS like channels Collocation of smaller footprints pixels within larger footprint	Large HIRS/2 fov Gaps between HIRS
MAS (11 channel digitizer)	High spatial resolution Similar MODIS bandwidths	No global coverage Only 11 channels
MAS (50 channels)	Most MODIS like data set High spatial resolution	No global coverage

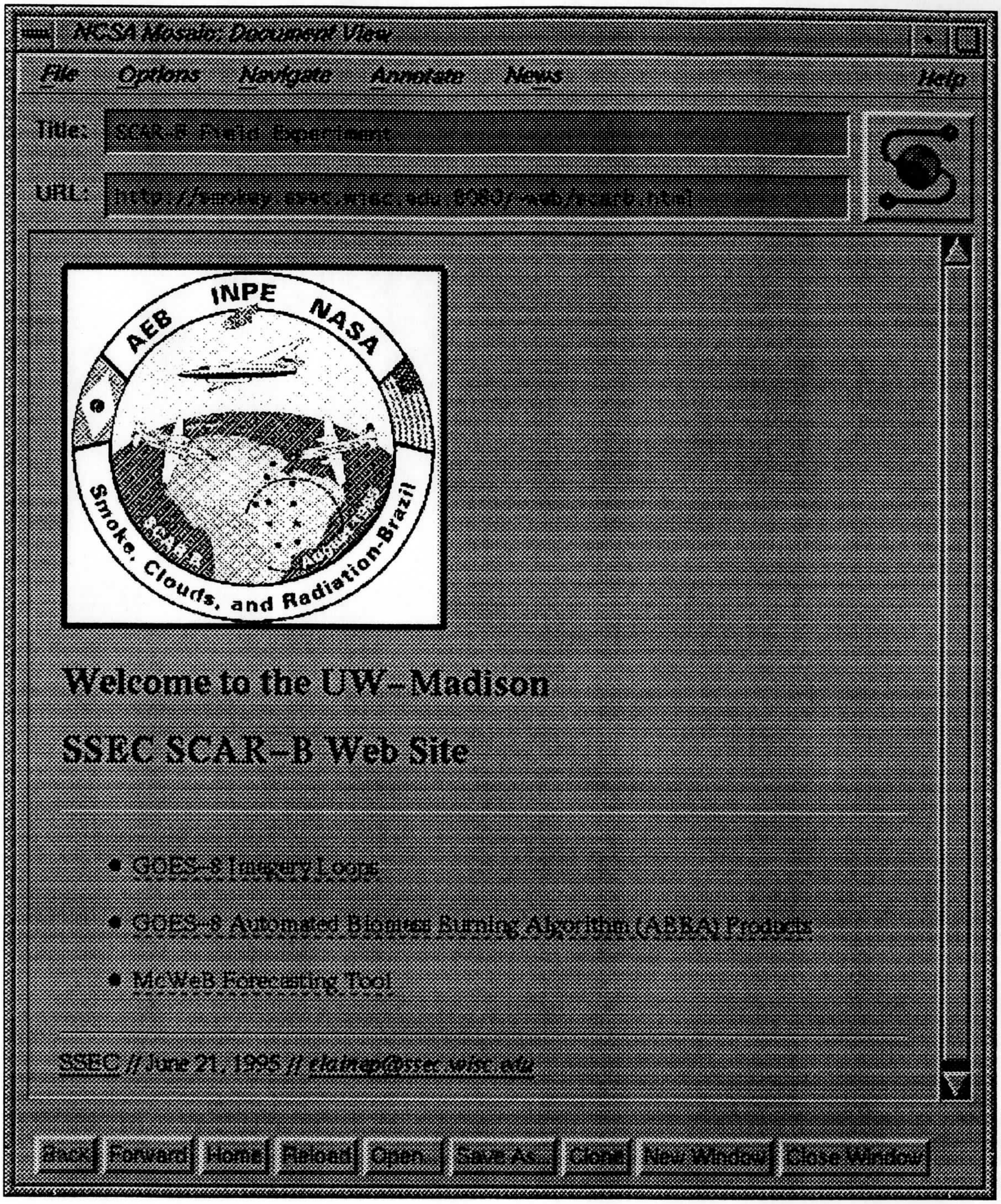

Figure 1. SCAR-B Web Home Page

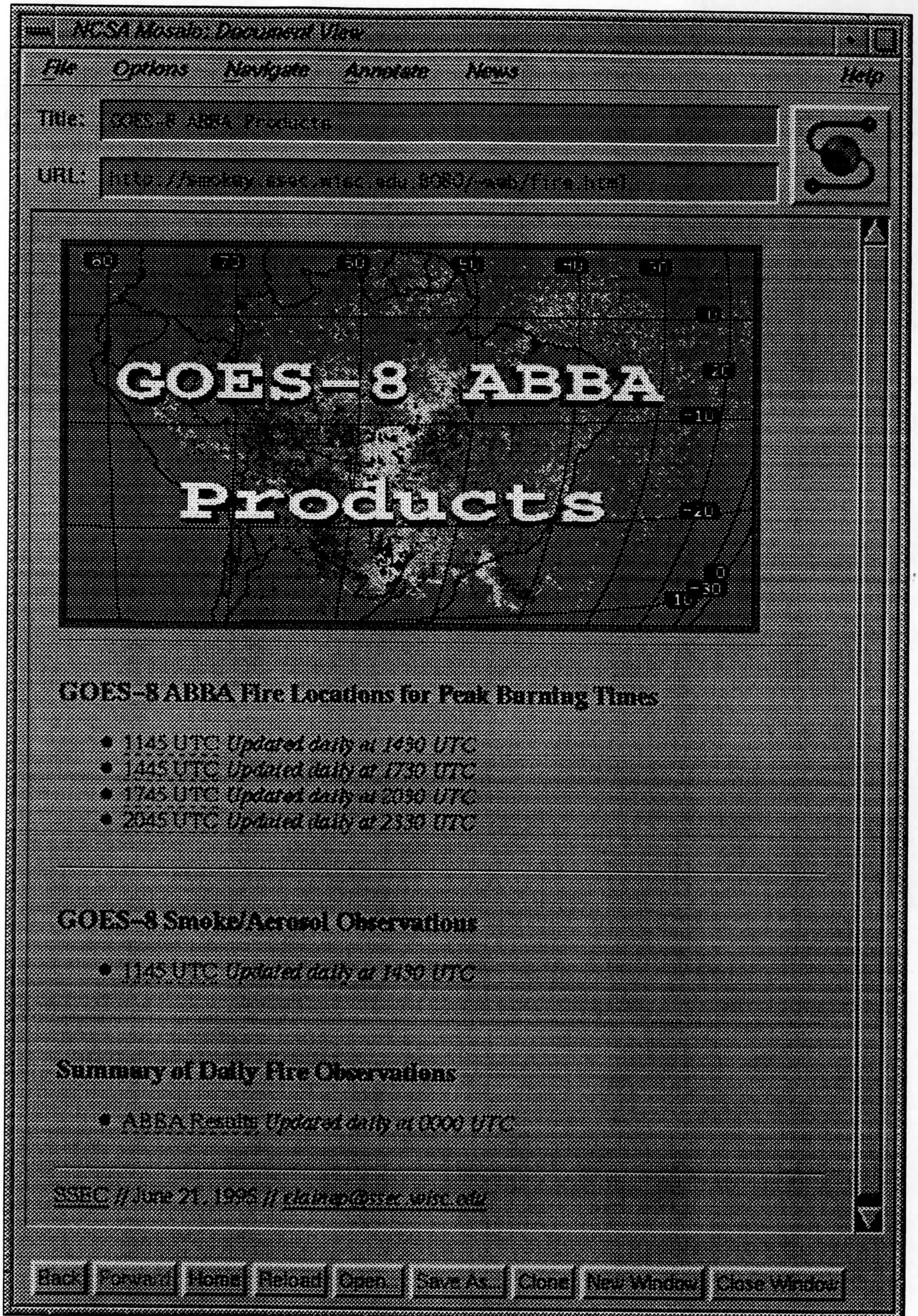

Figure 2. ABBA Products on SCAR-B Web Home Page

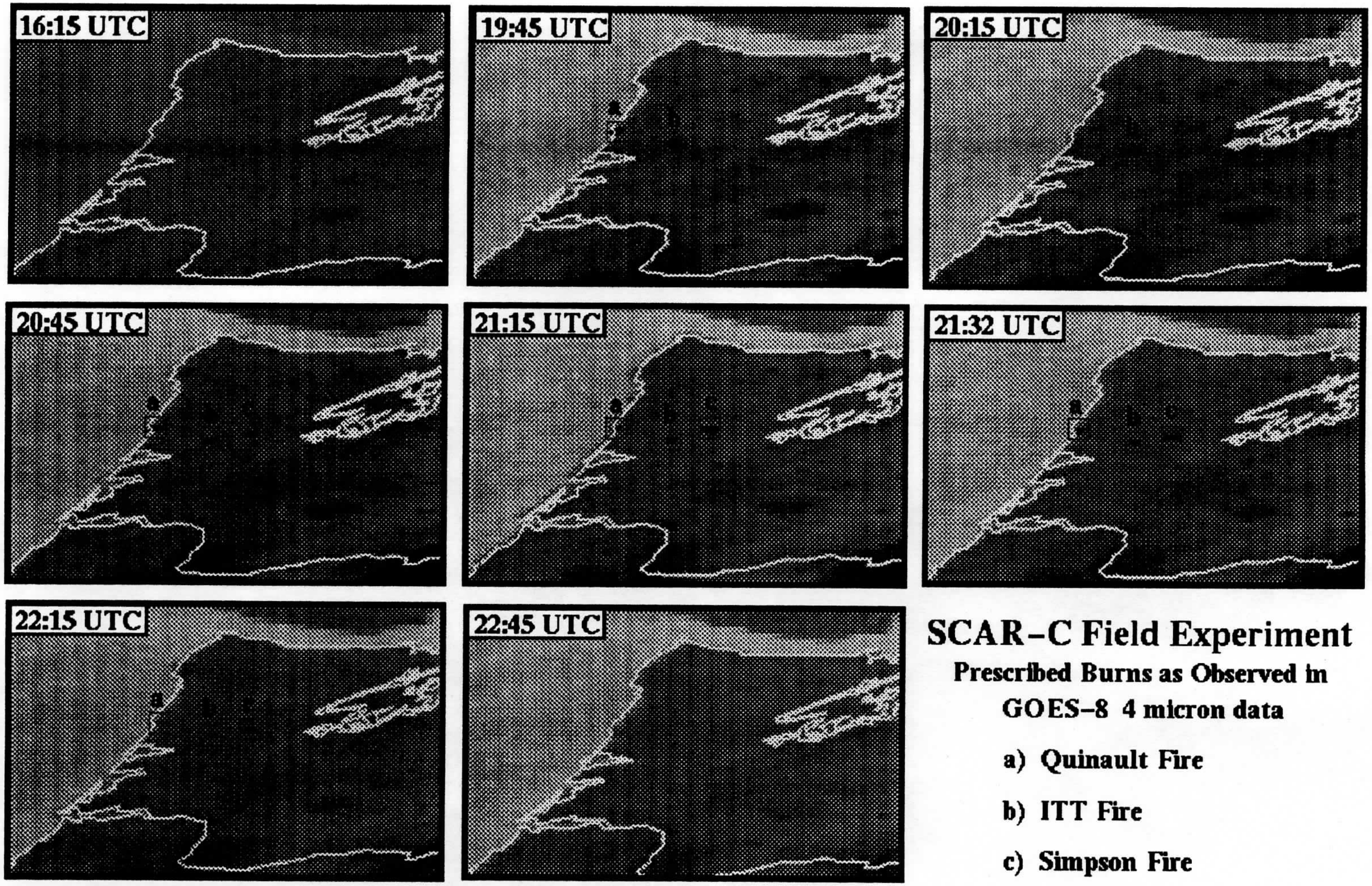

Figure 3. SCAR-C prescribed burns as detected by GOES-8.

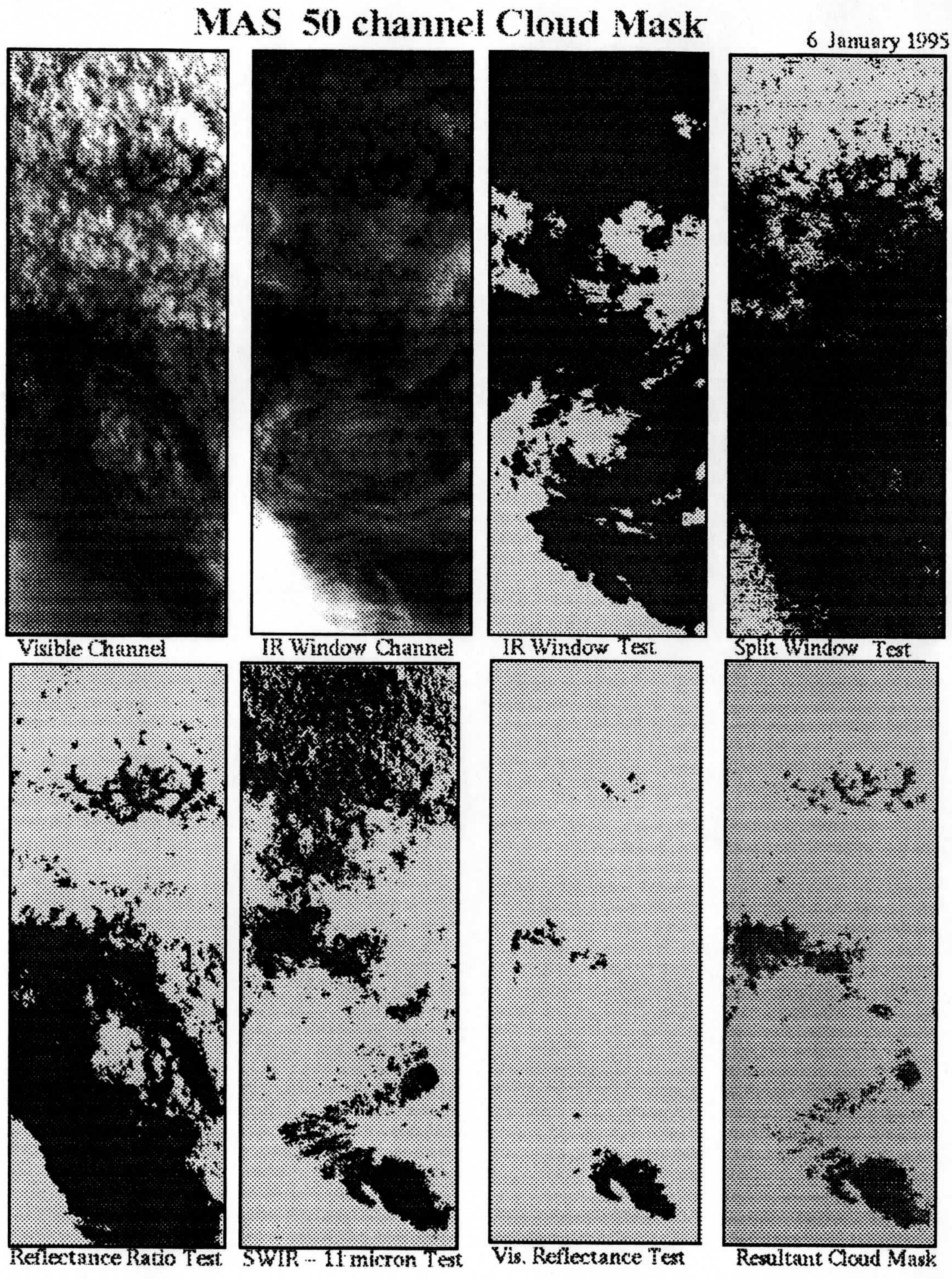

Figure 4. Example of MAS 50 channel multi-spectral cloud mask. The top left two panels are reference visible and infrared images. The next five panels (left to right, top to bottom) are results from individual tests, where dark indicates clear (test passed) and light indicates cloud (test failed). The final panel (bottom right) is the resultant cloud mask, which is a combination of all individual tests. A given field of view has a probability of being clear of < 66% if dark or < 1 % if light.

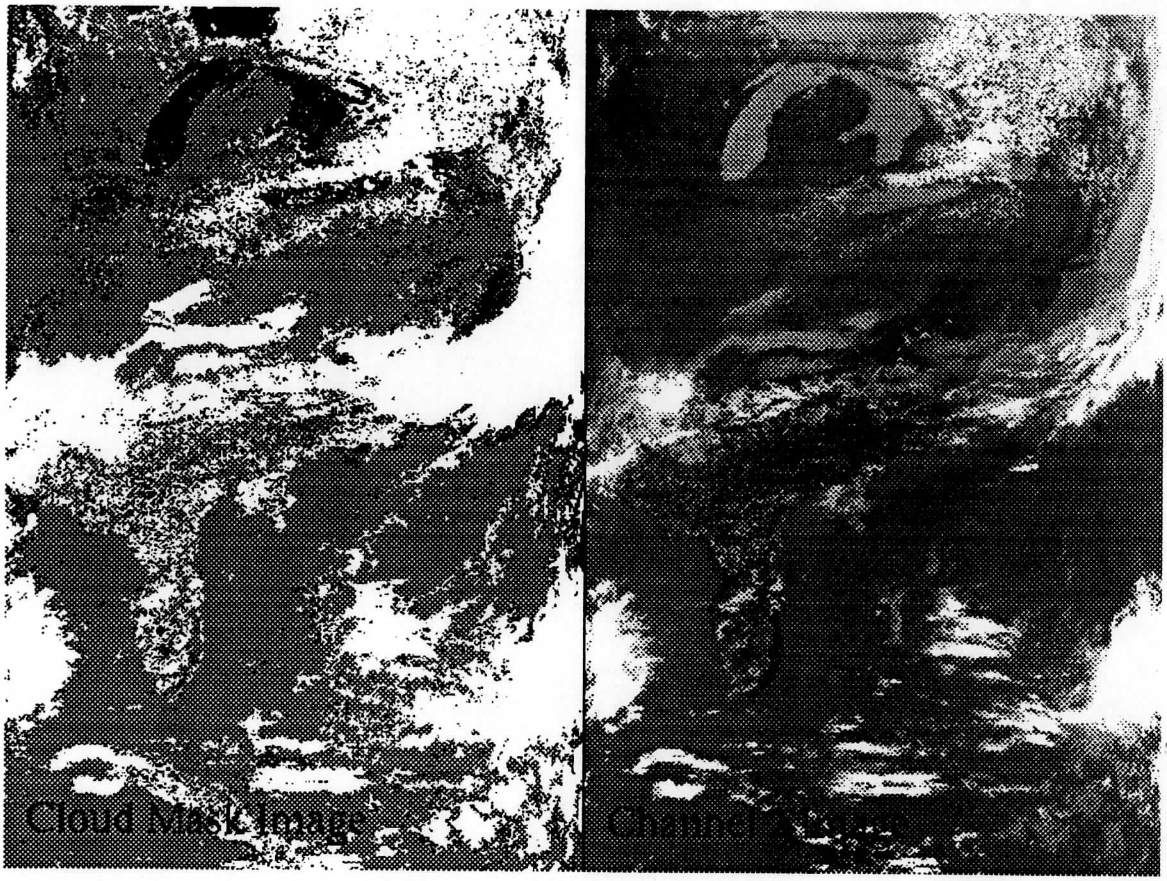

Figure 5. AVHRR LAC cloud mask and associated visible image.