INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC STABILITY WITH MODIS

QUARTERLY REPORT FOR JAN-MAR 1996

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ABSTRACT

In the last three months, preparation for Version 1 software deliveries began in earnest, with all Level 2 production code expected to be transferred to the SDST for integration in the next quarter. A simulated MODIS test data set with good radiometric integrity was produced using MAS data for a clear ocean scene. Plans were laid out for validating and testing the MODIS calibration techniques; these plans were further refined during a UW calibration meeting with Jerry Godden and Dan Knowles of the MCST.

TASK OBJECTIVES

Software Development

Cloud mask, cloud top property and atmospheric profiles science production software continue to evolve. The software which generates the cloud mask product (MOD35) is receiving the most attention; it is used as input by many other processes. It will be delivered in April, with all three Level 2 software packages delivered by the end of second quarter 1996.

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 third quarter 1996.

Global Cloud Study

Pre-MODIS cloud studies will continue via the global cloud census with HIRS data now in its seventh year. Research this quarter will focus on the affect of heavily traveled jetway contrails on the probability of detecting cirrus cloud.

MODIS Infrared Calibration

Plans have been outlined for development and testing of the MODIS calibration schemes. These plans include testing the IR calibration ATBD with GOES data as well as MODIS vacuum test data.

WORK ACCOMPLISHED

MODIS Software Development

Several steps were taken toward completion of the V1 cloud and atmospheric properties production Level 2 and Level 3 software due second and third quarters of 1996:

(1) Software was developed to ingest and resample National Center for Environmental Prediction (NCEP) global analysis data to MODIS Level-1B granule resolution. Data samples were obtained from the NCEP anonymous FTP site at nic.fb4.noaa.gov for this purpose. The data products obtained were

- Global Aviation Model, 1x1 degree, 0 and 12 UTC analysis, daily (GRIB format)
- Reynolds Optimum Interpolation SST, 1x1 degree, weekly (ASCII format)
- TOVS Total Ozone, 1x1 degree, daily (GRIB format)

The Global Aviation Model was selected because it was the only 1x1 degree resolution dataset found which contained all the desired parameters. FORTRAN code was then developed for the following tasks:

- Convert GRIB global data to FORTRAN unformatted sequential (tool obtained from NCEP)
- Convert FORTRAN unformatted sequential global data to HDF SDS
- Interpolate HDF SDS global data to MODIS geolocation lat/lons

These FORTRAN tools will be delivered to GSFC as part of the Version 1 delivery. The output dataset contains the following parameters at MODIS Level-1B granule resolution:

temperature (K) at 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 70, 50, 30, 20, 10 hPa
water vapor mixing ratio (g/kg) at 1000, 925, 850, 700, 500, 400, 300 hPa
surface temperature (K)
surface pressure reduced to mean sea level (hPa)
precipitable water (kq/m^2)
surface wind u component (m/s)
surface wind v component (m/s)
sea ice concentration (fraction)
sea surface temperature (K)
total ozone (Dobsons)

Capabilities which will be added in the future include interpolation in time between input datasets, and quality control of the input data.

(2) All required MODIS tools were implemented. These included the MODIS Application Programmer Interface (MAPI) and the Science Data Processing (SDP) Toolkit.

(3) A new simulated granule with "flat" clouds and the associated geolocation parameters were transferred from GSFC to the Wisconsin SCF. The L1B reader provided by SDST was successfully used, with small modifications, to access reflectances and radiances from the simulated granule. A geolocation reader was also written to access the accompanying latitude and longitude and geometric parameters.

(4) The Process Control File (PCF) was redesigned to allow access to the correct Version 1 input and output data sets.

(5) Several improvements have been made to the cloud mask processing software since the Beta version. The software has been streamlined, documented and updated to produce a 48 bit cloud mask product. The use of the Olson World Ecosystem Map allows more surface type processing paths to be defined, including deserts. A simple snow background test has been included, along with a thin cirrus test. Tests on individual 250 m pixels have been added. NCEP ancillary data are now read as inputs. Clear radiance maps are now generated for the infrared window channel (11 micron, channel 31) and the four CO_2 channels (13.3 - 14.1, channels 32-36). The CO_2 channel clear radiance maps are created for the cloud top properties production software.

(4) The output cloud mask HDF file was updated to conform with file specifications. The file contains the results in the updated 48 bit cloud mask format.

<u>MAS Cloud Mask Code Converted to non-McIDAS Format</u>

An updated and revised version of the fifty channel MAS cloud mask code has been made available. The new version does not require the McIDAS software package or input data in McIDAS formats. MAS radiance and earth location data from January 13, 1995 were converted from McIDAS Digital Area format into simple binary direct access files. The software was revised accordingly and updated to accommodate recent changes in the cloud mask algorithm. The code was transferred to GSFC for use by the cloud retrieval group.

<u>MAS Infrared Calibration</u>

Santa Barbara Remote Sensing (SBRS) has been asked to assist in the design of new inflight MAS blackbodies by Ames Research Center (ARC) and the UW. It is expected that SBRS will not be able to provide the new black bodies at a cost that is appropriate for an aircraft mission. If this is the case, then ARC will use the MODIS instrument blackbody technologies, shape, anodizing, painting and polishing techniques developed by SBRS to build and install the new MAS blackbodies.

Dan LaPorte visited ARC in March to assist in the MAS spectral calibration. The BOMEM interferometer was to be used in characterizing MAS thermal channels before the SUCCESS mission. The interferometer was not used due to the late arrival of the MAS to Ames by Daedalus.

<u>MODIS IR Calibration</u>

On 14 March 1996, Dan Knowles and Gerry Godden visited UW to discuss the MODIS IR calibration algorithm. Several issues were discussed and the following key points emerged.

(1) Smooth changes in the calibration equation are absolutely necessary so that they reflect what is really happening in the MODIS instrument. This will most likely require averaging blackbody views (keeping 1/f noise in mind). The calibration of adjacent granules must be related.

(2) A linear form of the quadratic calibration equations will be the automatic default for those spectral bands with negligible non-linearity.

(3) The form of the calibration equation R = f(V, V2) is largely equivalent to V = f(R, R2).

(4) Changes of the calibration algorithm as a function of scan angle are adequately determined with linear rather than quadratic interpolation.

(5) Anticipated striping in the ten detector for one spectral band images will require considerable attention. Some destriping approaches need to be investigated.

UW accepted several actions that are being pursued. They are to study the mathematical stability of the calibration equations with synthetic MODIS values and also inflight GOES-8 data. Plans include checking the validity of the numerous algorithms in the ATBD, examining the stability and uniqueness of the solution for calibration coefficients derived from the ATBD approach, and defining possible simplifications of the ATBD approach which are more intuitive and somewhat more conventional. Early results should be available in the second quarter of 1996. In addition, with the visit of Dr. Mervyn Lynch from Curtin Univertsity of Technology, UW is exploring opportunities and plans for MODIS southern hemisphere validation.

MAS SCAR-B Fire Scene Calibration

A linear calibration was finalized for the MAS 1.6 and 2.1 micron channels and delivered to GSFC (Yoram Kaufman's group). Emissivity of source blackbody in the near infrared spectral region was treated as unit. The calibration does not include an adjustment to the calibration slope based on instrument operating temperature. Previous work at GSFC has shown near infrared MAS channel calibration to be a function of instrument operating temperature. This adjustment will be generated at GSFC. The calibration is valid for MAS SCAR-B data and will be used at GSFC to estimate fire temperature from MAS near infrared data.

GOES Fire and Smoke/Aerosol Detection

The SCAR-B data is being processed for fire activity and aerosol transport; completion of the data processing is anticipated before the September meeting in Natal, Brazil. Elaine Prins attended a SCAR-B workshop in March 1996 and discussed plans with the USFS to intercompare the GOES-8 biomass burning estimates with data from three controlled burns in Rondonia.

Satellite Conference Presentations

The MAS 50 channel cloud mask algorithm and MAS, GOES-8, HIS, and AVHRR data split window studies were presented as posters at the 8th Conference on Satellite Meteorology and Oceanography in January. Cloud masks for varying MAS scenes were produced and displayed as preparation for the MODIS day-1 cloud mask product. Differences between MAS, HIS, GOES-8 and AVHRR T11-T12 were investigated and displayed in regions where negative values were found.

Preparation for SUCCESS Field Program

The MAS instrument will be flown on the ER-2 aircraft during the SUCCESS field experiment conducted out of Salina, KS from April 8 to May 10, 1996. Mission objectives include observations of persistent and non-persistent aircraft contrails, cirrus clouds, mountain lee wave clouds, and convective cloud. Software is being developed to create science products in near real time in the field. MODIS cloud properties algorithms have been exported to a portable environment and will be run in the field to evaluate scientific value of the data sets. MAS fast transmittance model coefficients were generated for use in cloud heights processing. An SGI workstation is being provided by GSFC to facilitate processing of MAS raw data and production of MAS archive products for the SUCCESS Data Exchange Archive ("browse" imagery and nadir temperature data). MAS science and mission planning on the ER-2 will be supported in the field by Steve Ackerman, Chris Moeller, Liam Gumley, and Kathy Strabala.

DATA ANALYSIS

Simulation of MODIS Level-1B Data using the MODIS Airborne Simulator

In support of MODIS algorithm development at UW-Madison, MODIS Level-1B data was simulated using data acquired by the MODIS Airborne Simulator. The motivation for this effort was the need for a locally developed dataset with good radiometric integrity that shows realistic scene variation. Goals of this effort include:

- Best possible spectral approximation of MODIS bands, given the available MAS bands,
- Use of real data where possible, and modeled data only where absolutely necessary,
- Approximating the co-registration of MODIS bands (but not the spatial resolution),
- Creating output data (Level-1B and geolocation) in HDF SDS format.

These goals have been met in Version 1.0 of the simulation for the simplest kind of MAS scene: open ocean with cloud-free skies. No limb or atmospheric corrections were applied. The MAS data were acquired on 16 January 1995 over the Gulf of Mexico during the OTIS experiment. The original unresampled MAS data contained 4000 scanlines, starting at 15:55:33 UTC and ending at 16:06:14 UTC. The direction of flight was approximately due East.

The MAS pixels (50 meter IFOV at nadir) were resampled to coarser spatial resolution to mimic the way that MODIS 250 meter pixels are registered to MODIS 500 meter and 1000 meter pixels. Here the objective was to mimic the MODIS relative band-to-band registration, ***not*** the absolute spatial resolution of MODIS. Put simply, the MAS 50 meter IFOV (at nadir) pixel was treated as being equivalent to the MODIS 250 meter pixel, and the MAS 50 meter pixels were sampled using weighting functions to create the relative equivalent of MODIS 500 meter and 1000 meter bands. In order to remove a 33% along track oversampling in the full resolution MAS data, every other MAS scanline was removed.

The MAS bands selected to simulate MODIS bands are shown in Table 1. MAS spectral responses were compared to MODIS spectral responses to find the best spectral agreement. 'Good' or 'OK' matches were found for 25 of the 36 MODIS bands. 'Good' refers to matches where a large portion of the MAS band and corresponding MODIS band spectral responses overlapped. 'OK' refers to matches where some spectral response overlap was found, and the MAS and MODIS bands were in similar absorption regions of the spectrum. The remaining 10 MODIS bands were simulated using either the radiance from the closest (in wavelength) MODIS band for visible/near-IR bands, or a forward model calculation for IR bands. MODIS bands 27, 28, and 30 were simulated using a locally developed fast IR transmittance model. Temperature and moisture profile data for input to the fast model were obtained from a CLASS sonde launched at 15:05 UTC on 16 January 1995 by the R.V. Pelican, which was located approximately at the center of the

MAS scene in support of the OTIS experiment. The ocean surface was assumed to be at a uniform surface temperature of 298 K with unit emissivity. Scan angle effects were included in the simulation. A sample of the MODIS simulation of bands 28-36 by MAS data is provided in Figure 1.

The simulated MODIS Level-1B data were stored in HDF3.3r4 SDS form, using exactly the same variable and attribute names as were used in the MODIS Level-1B simulated data sets produced by SDST for the MODIS Software Beta delivery in October 1995. In the UW-produced data files, the global attributes 'CoreMetadata' and 'ProductMetadata' were not included. All units and scaling factors are identical to those used in the SDST produced datasets.

MAS Infrared Calibration

MAS spectral response has been characterized for all 50 MAS bands using July 1995 laboratory measurements. Central wavenumber and monochromaticity coefficients have been computed for all IR channels and made available to the MAS GSFC DAAC. Before delivery, the post processed spectral response data were compared to additional spectral measurements made in October 1995. A shift (~.05 micron) in Port 3 (SWIR) spectral response was noted. Port 4 showed good agreement. The spectral shift may be due to weakness in the dewar mounting of Port 3. This is under investigation at Ames Research Center (ARC). With a fully operational spectral calibration facility at ARC, spectral response of MAS bands will be characterized regularly; typically before field campaigns and after MAS hardware maintenance/modifications. As such, updated MAS spectral bandpass data will be available on a much improved temporal basis, resulting in improved absolute calibration of MAS.

MAS blackbody effective emissivity estimates have been completed for the MAS infrared bands 26-50 (Figure 2) and delivered to the GSFC DAAC for incorporation into MAS Level 1B processing. The data analysis included effects of atmospheric attenuation (external source to instrument detector and onboard blackbody source to instrument detector) and non-unit source emissivity in the ambient laboratory measurement conditions. Strong absorption in CO_2 and H_2O sensitive channels was removed by smoothing the emissivity estimates (as a function of wavelength) with regression. The final effective emissivity estimates generally agree with the spectral shape of direct reflectance measurements (collected Feb 1996) of the MAS blackbodies. Uncertainty in the absolute value of the direct reflectance measurements (not atmospherically corrected) precludes absolute value comparisons.

PAPERS

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Prins, E.M., and W.P. Menzel, 1996a: Monitoring fire activity in the western hemisphere with the new generation of geostationary satellites. Presented at the 22nd Conference on Agricultural and Forest Meteorology with Symposium on Fire and Forest Meteorology, Jan. 28 - Feb. 2, Atlanta, GA, AMS, pp 272-275.

Prins, E.M., and W.P. Menzel, 1996b: Monitoring biomass burning and aerosol loading and transport from a geostationary satellite perspective. Presented at the Seventh Symposium on Global Change Studies, Jan. 28 - Feb. 2, Atlanta, GA, AMS.

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, 1996: Observations of the infrared radiative properties of the ocean - Implications for the measurement of sea surface temperature via satellite remote sensing. Bull. Amer. Meteor. Soc., 77, 41-50

MEETINGS

Paul Menzel, Chris Moeller, Elaine Prins and Kathy Strabala were presenters at the Eighth Conference on Satellite Meteorology and Oceanography, held Jan 28 - Feb 2 in Atlanta, Georgia.

Steve Ackerman attended a SUCCESS planning meeting to finalize plans for the experiment and to review and prioritize the mission and flight plans in light of meteorological expectations and available resources, 14-16 February at NASA Langley Research Center.

Kathy Strabala attended the Science Advisory Panel meeting at GSFC 27-28 February.

The UW hosted the follow-up MODIS IR calibration audit meeting in Madison on 13 March 1996.

Elaine Prins attended the SCAR-B workshop in Williamsburg, VA on 20 - 22 March.

Dan LaPorte assisted Ames Research Center in spectral calibration of the MAS in March.

Table 1: MAS and MODIS Spectral Band Equivalence

MAS	MODIS	λ_{MODIS}	Comments
2	1	0.64	OK match, MAS longer λ, small absorption
7	2	0.86	OK match, MAS longer λ, MODIS more absorption
1	3	0.47	No MAS equivalent, use MAS λ 0.55, minimal absorption in both
1	4	0.56	Good match, MAS shorter λ, minimal absorption
10	5	1.24	No MAS equivalent, use MAS λ 1.65, small absorption in both
10	6	1.64	OK match, MAS shorter λ, small absorption
21	7	2.13	OK match, MAS longer λ, MODIS broader, absorption in both
1	8	0.41	No MAS equivalent, use MAS λ 0.55, minimal absorption in both
1	9	0.44	No MAS equivalent, use MAS λ 0.55, minimal absorption in both
1	10	0.48	No MAS equivalent, use MAS λ 0.55, minimal absorption in both
1	11	0.53	OK match, MAS broader, MAS longer λ, minimal absorption
1	12	0.55	Good match, MAS shorter λ, minimal absorption
2	13	0.66	OK match, MAS broader and shorter λ, MAS more absorption
2	14	0.67	OK match, MAS broader and shorter λ, MAS more absorption
4	15	0.74	OK match, MAS broader and shorter λ, MAS more absorption
7	16	0.86	Good match, MAS broader, MAS more absorption
8	17	0.90	Good match, significant absorption in both
9	18	0.93	OK match, MAS broader, significant absorption in both
9	19	0.94	OK match, MODIS broader, significant absorption in both
31	20	3.75	Good Match
32	21,22	3.95	OK match, MAS shorter λ, no spectral features
33	23	4.05	OK match, MAS more absorption
36	24	4.46	OK match, MODIS more absorption
36	25	4.51	Good Match, MAS has twice the bandwidth
15	26	1.38	No MAS equivalent, use MAS λ 1.88
–	27	6.7	No MAS counterpart - simulated using MODIS fast model
–	28	7.3	No MAS counterpart - simulated using MODIS fast model
42	29	8.55	Good Match
–	30	9.73	No MAS equivalent, simulated using MODIS fast model
45	31	11.0	Good Match
46	32	12.0	Good Match
48	33	13.3	OK match, MODIS more absorption
49	34	13.6	OK match, MAS more absorption
49,50	35	13.9	No MAS equivalent, use average of MAS bands 49 and 50
50	36	14.2	OK match

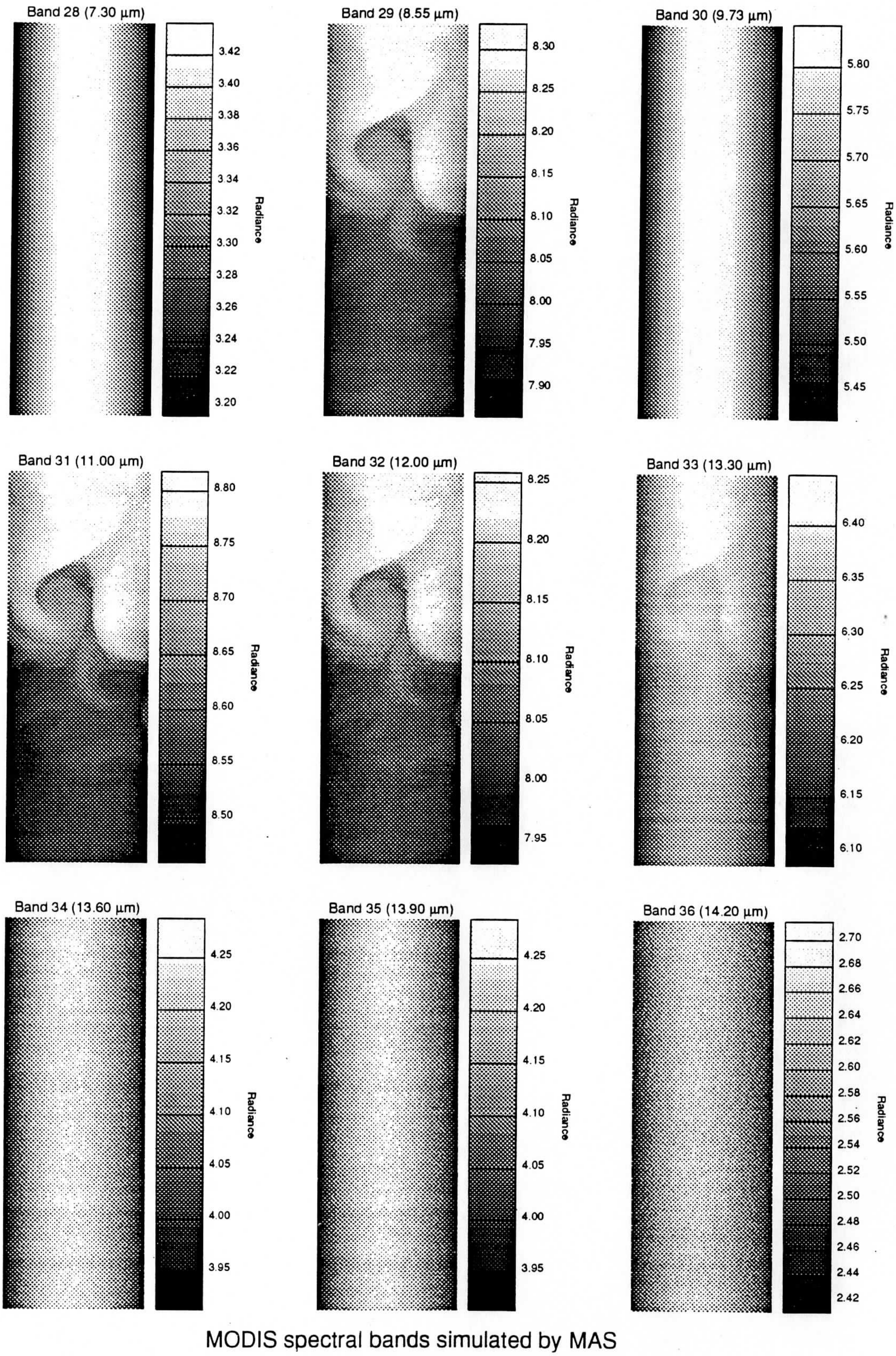

Figure 1: MODIS bands simulated by MAS

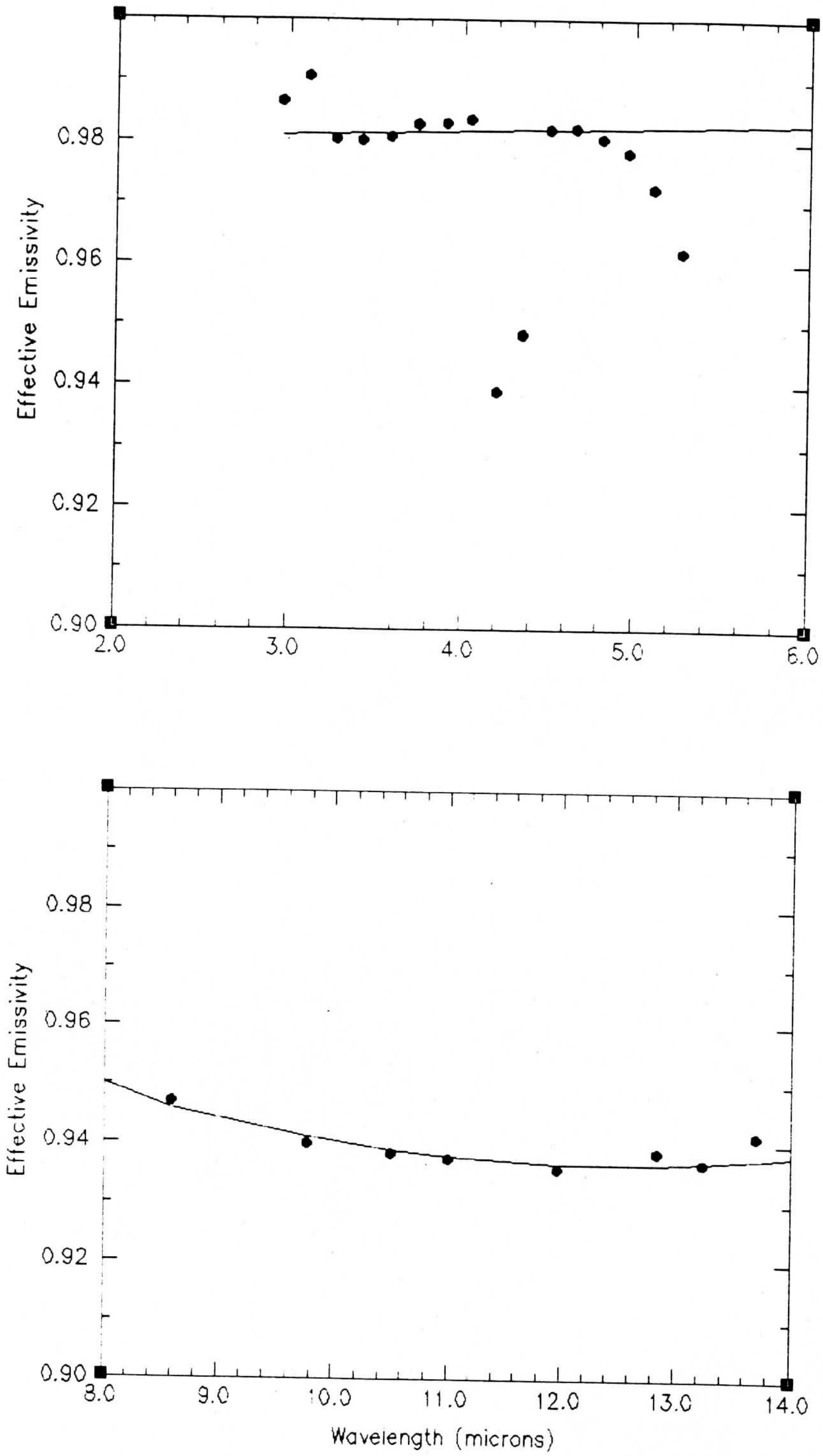

Figure 2. MAS onboard calibration blackbody effective emissivity estimates for SWIR (top) and LWIR (bottom). Selected data fit shown as solid line.