INVESTIGATION OF CLOUD PROPERTIES AND ATMOSPHERIC PROFILES WITH MODIS

SEMI-ANNUAL REPORT FOR JANUARY – JUNE 2002

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ABSTRACT

In the last six months, UW continued to adjust the operational algorithms for cloud mask, cloud top properties, and atmospheric profiles to accommodate the characteristics of the MODIS data (calibration, striping, noise, and cross-talk), to validate of the MOD35, MOD 06, and MOD 07 products, and to prepare for processing Aqua data. Weather forecast impact at the DAO from 25 days of polar winds were found to be significantly positive and preparations for near real time routine processing were begun. Comparison of MODIS and HIRS global cloud top properties continued; differences in the processing schemes were mitigated to secure better comparisons. The International MODIS and AIRS Processing Package added cloud mask and cloud top property software as well as access to ancillary data from the last six days.

TASK OBJECTIVES

MODIS Infrared Calibration

Investigations of Terra MODIS L1B performance continued. A comparison with ER-2 based SHIS showed that most MODIS Thermal IR bands are within the prelaunch accuracy specification. The correction of Terra MODIS band 26 (1.38 μm) radiances for striping and out-of-band influences continued. Coefficients for the correction algorithm were delivered to MCST for inclusion in MODIS L1B production.

MODIS Cloud Mask (MOD35)

Science upgrades continued on the MODIS cloud mask algorithm during the first half of 2002. Two updates were submitted to the Goddard DAAC during the past six months. The first (v3.1.1) was primarily to permit processing of Aqua data; code modifications or additions included response functions for the Aqua instrument, separate cloud test thresholds files for Terra and Aqua, separate metadata configuration files, as well as several minor bug fixes. The second (v4.0.0) was made in anticipation of "Collection 4" reprocessing of Terra MODIS data and included significant science updates regarding sun glint tests, clear sky restoral, thin cirrus tests, adjusted NDVI tests, polar night adjustments

MODIS Cloud Top Properties (MOD06)

Comparison of MODIS and HIRS cloud top properties continued. Bigger differences were found over land than water. Results for one day between 20 – 60 N indicated that (a) MODIS has more high clouds and less clear sky than HIRS over land; in particular MODIS has more high thick, middle thick, and low opaque and less middle opaque clouds than HIRS over land; (b) MODIS has about the same cloud cover over water; in particular MODIS has less high thin and more high thick clouds than HIRS over water. Comparisons are being extended to more data sets.

MODIS Infrared Total Precipitable Water Product (MOD 07)

A new version of the MODIS Atmospheric Temperature and Moisture Profile Retrieval Algorithm (MOD07_L2 v3.1.0) was delivered to the Goddard Distributed Active Archive Center (GDAAC) and was included in operational processing on May 1, 2002. Significant modifications have been made to the MOD07_L2 algorithm for the v3.1.0 delivery. The new version also includes updates for TERRA/AQUA compatibility.

Polar Winds

The case study data set of MODIS polar winds covering both poles were extended to 25 days. The Data Assimilation Office (DAO) and the European Centre for Medium Range Weather Forecasting (ECMWF) found significant positive impact on model forecasts. Efforts are underway to produce MODIS water vapor winds in near real time for further model impact tests in more seasons.

MODIS Direct Broadcast Software

Direct broadcast versions of the MODIS cloud mask (MOD35) and cloud top properties and cloud phase (MOD06CT) algorithms were released on 1 May 2002 via ftp at: ftp://origin.ssec.wisc.edu/pub/IMAPP/MODIS/Level-2/v1.1/. The release versions are compatible with the MODIS production cloud mask version 3.1.1 which was delivered to the Distributed Active Archive Center (DAAC) at Goddard Space Flight Center on 25 February 2002and production cloud top property and cloud phase version 3.1.0. delivered on 15 March 2002. An ftp site has been set up which contains the current and previous 6 days of ancillary data required to run both the cloud mask and cloud top property and cloud phase algorithms allowing the direct broadcast community to one-stop shop for all the ancillary data that they will need to run the algorithms.

WORK ACCOMPLISHED

MODIS Infrared Calibration and Evaluation of On-Orbit Performance

The MODIS TIR band calibration has been assessed using SAFARI-2000 data from 11 September 2000. A non-linear coefficient for the S-HIS (on the NASA ER-2) calibration has been updated, based on S-HIS measurements of LN2 and ice bath sources in the laboratory. The MODIS data uses Collect 3 calibration. The MODIS L1B residuals, in brightness temperature units, are shown in Figure CCM1 and given in Table CCM1. The residuals in the MODIS LWIR split window (bands 31 and 32) are near zero and within the prelaunch specification for the nadir views of September 11. Also, bands 31 and 32 exhibit very similar residuals, suggesting that the split window difference is also very accurate. The scene temperature for the split window is close to the nominal MODIS onboard blackbody temperature (290 K). The MWIR window band (20, 22, 23) residuals are also very near or within specification. Sunglint in the data region may be influencing the MWIR band residuals by causing a scene temperature increase in the 7 to 18 minutes between the ER-2 and MODIS data collection. The scene temperature change over 10 minutes is expected to be small (< 1 K) but is difficult to quantify (function of sea state and time difference between S-HIS and MODIS). The MWIR residuals suggest that known electrical crosstalk in MODIS SWIR reflectance bands 5, 6, 7, and 26 and MWIR bands has only modest impact on the MWIR band residuals for the flat thermal, low reflectance data scenes used in this analysis. This may be a result of the low, uniform signal of the ocean surface in the SWIR reflectance bands.

Table CCM1. MODIS detector and mirror side averaged TIR band residuals for 11 September 2000 based on comparisons to S-HIS data. The residual of each band is based on the average of 287 MODIS footprints and 869 S-HIS footprints in the common data region. Band 30 is not provided due to uncertainty in ozone profile. Band 26 is a reflectance band. Residuals that are within the pre-launch accuracy specification are shown in bold.

MODIS Band Number	Center Wavelength (μm)	Observed MODIS average scene temperature (K)	Simulated MODIS average scene temperature (K)	Altitude Correction (K)	Average MODIS Residual (K)	MODIS Accuracy Spec. (+/- K)
20	3.788	291.48	290.99	-0.02	0.51	0.18
21	3.992	289.51	288.87	-0.03	**0.67**	3.00
22	3.971	289.34	289.03	-0.02	0.33	0.25
23	4.057	287.39	287.28	-0.05	**0.16**	0.25
24	4.473	257.39	256.85	0.01	0.53	0.19
25	4.545	273.55	273.69	-0.18	**0.04**	0.24
27	6.765	248.52	248.60	0.11	**-0.19**	0.27
28	7.337	268.44	268.71	0.02	**-0.29**	0.32
29	8.524	286.04	286.62	-0.28	**-0.30**	0.53
31	11.014	287.58	287.67	0.00	**-0.09**	0.34
32	12.018	287.41	287.41	-0.02	**-0.02**	0.37
33	13.361	272.30	273.08	-0.64	**-0.14**	0.61
34	13.679	261.21	260.80	-0.57	0.98	0.58
35	13.911	252.22	250.22	0.22	1.78	0.55
36	14.194	233.84	229.55	2.06	2.23	0.47

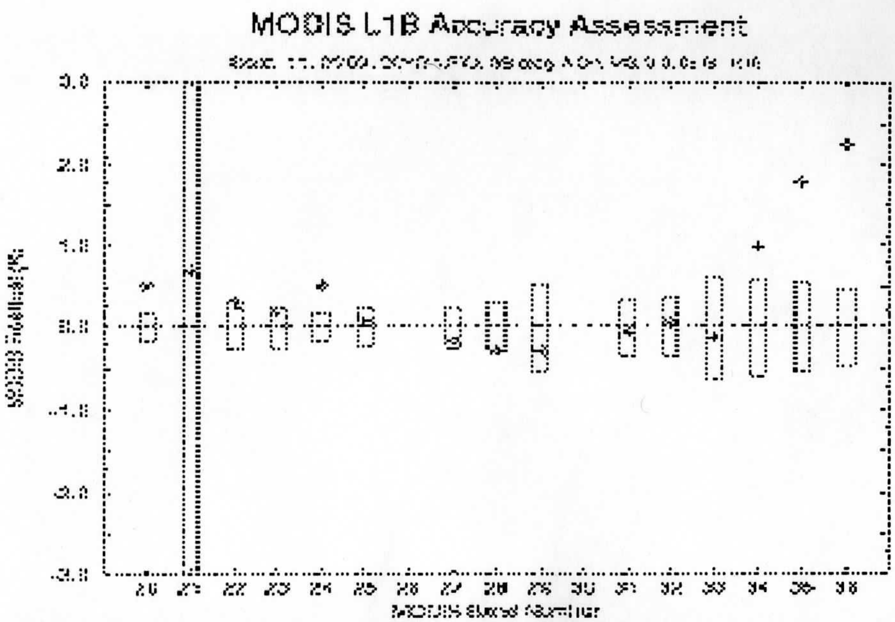


Figure CCM1: MODIS TIR band average residuals (star symbols) with prelaunch accuracy specification envelope for each band defined by the vertical boxes. MODIS band 30 is not shown. Most MODIS bands show residuals of less than 0.5 K, within or near the MODIS specification. The upper tropospheric CO_2 bands 34 - 36 have large residuals; these bands may be influenced by undocumented uncertainty in the altitude correction. The residuals of the MWIR bands 20 - 23 may be influenced by undocumented sunglint present in the data scenes (S-HIS data collection preceded MODIS by seven to eighteen minutes).

MODIS band 27 and 28 (mid-tropospheric water vapor bands) residuals are within specification. These bands are both affected by detector striping (not shown) which is included in the averaged residual of Figure CCM1. Band 29 (8.5 µm; low level water vapor) is also within specification in this evaluation. The nonlinear component of the S-HIS calibration in this spectral region has recently been re-evaluated. Early MODIS band 29 residuals (Moeller et al. 2001) based on S-HIS comparisons now appear to have overestimated the residual of band 29. Additionally, Wan et al. (2002) found band 29 to be within specification using ground based observations in a dry atmosphere.

The LWIR CO_2 sensitive bands 33 – 36 exhibit increasingly positive residual with wavelength and appear to be out of specification for bands 34 - 36. These bands are affected by optical crosstalk from band 31 (in the 11 µm region). There is an impact of 3 K or more on clear scene calibrated brightness temperatures on bands 35 and 36. A correction is applied in the MODIS L1B processing algorithm. Typical scene temperatures in bands 34 - 36 are 30 to 70 K below the MODIS 290 K onboard blackbody operating temperature, increasing the potential impact of any calibration slope error. The ER2 altitude correction applied in the analysis must also be considered as a possible source of the large residuals in these bands. Based on an unvalidated characterization of the atmosphere, it may include undocumented error, especially for band 36 whose altitude correction is large. This issue and the systematic behavior of the band 33 –36 residuals raise questions regarding the evaluation for these bands. It is noteworthy however that these residuals are similar to preliminary residuals obtained from TX-2001, using MAS and S-HIS data from the 1 April 2001 underflight of MODIS over the Gulf of Mexico. A paper on this topic is under review for inclusion in the JGR SAFARI-2000 Special Issue.

Coefficients to correct MODIS Band 26 (1.38um) earth scene radiances for striping and anomalous earth surface features have been developed and delivered to MCST for implementation in Terra MODIS L1B processing. The coefficients will be available for use in processing the Terra MODIS Collect 4 data set. Separate coefficients were developed for MODIS A-side 1, B-side, and A-side 2 operational configurations. The coefficients demonstrate dependence on the MODIS configuration (Figure CCM2). Testing the correction algorithm has shown that surface land features and striping are largely removed from the band 26 imagery (Figure CCM3), in agreement with forward model simulations. The corrected radiances in tropical regions become slightly negative in many cases; however, this is not unexpected as random noise in band 26 is capable of driving a low signal negative. High contrast zones such as coastlines also exhibit a weakness in the correction procedure; this is likely due to an additional optical crosstalk from band 6 into band 26. Since the impact is low, this will remain uncorrected. Early review of Aqua MODIS data shows similar behavior in band 26, suggesting that a similar correction may be useful when processing Aqua MODIS data to L1B.

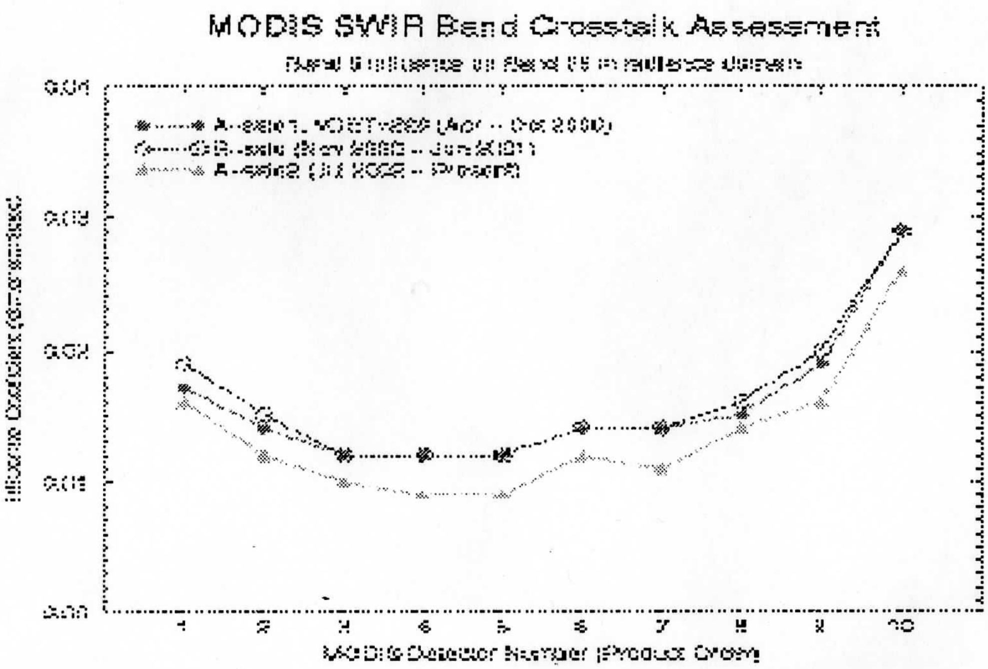


Figure CCM2: MODIS Band 26 correction coefficients for A-side, B-side, and A-side 2 configurations. A-side and B-side coefficients are very similar; however A-side 2 shows dependence on the configuration. The coefficients are detector dependent within each configuration to reduce detector striping.

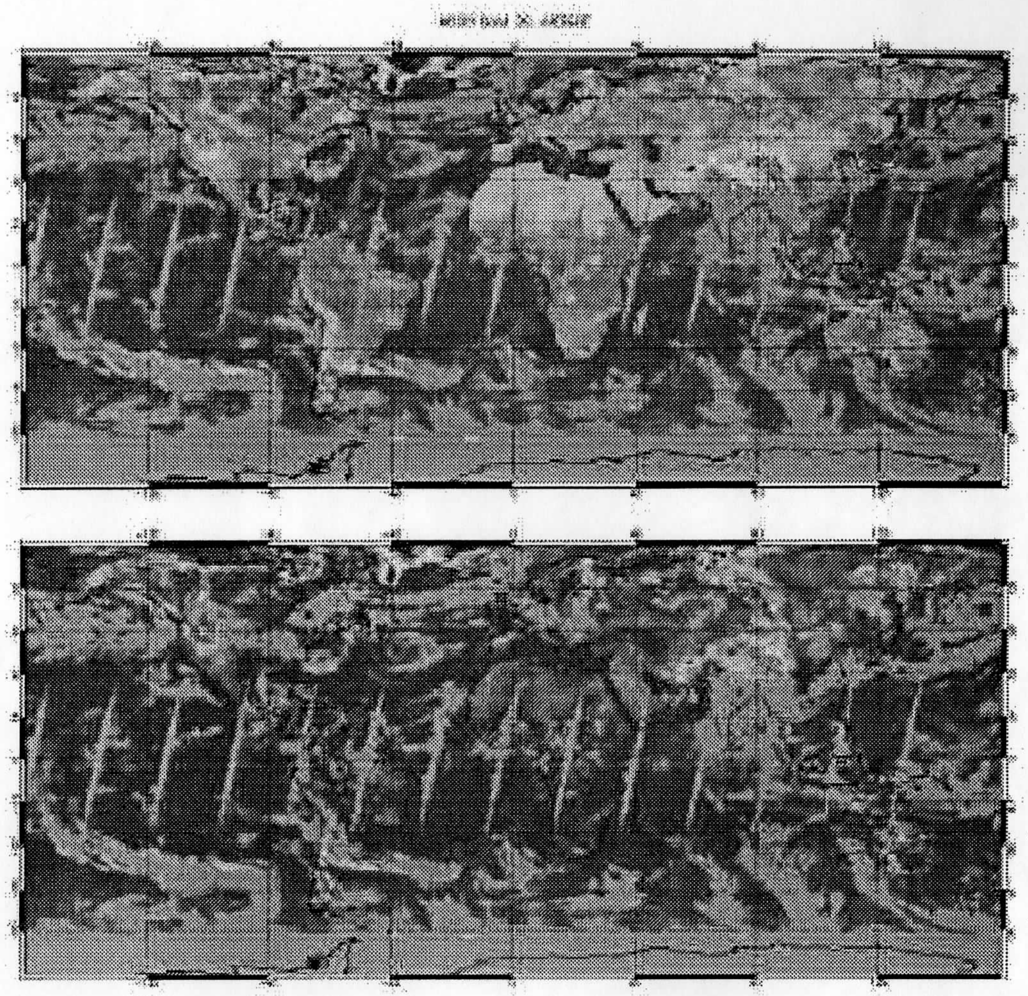


Figure CCM3: MODIS Band 26 global average clear sky radiance maps for uncorrected (top) and corrected (bottom) band 26 radiances. Uncorrected radiances show effects of land surface reflectance; much of this is removed in the corrected band 26 data, improving the contrast between thin cirrus cloud and the low reflectance clear sky background. Regions with small atmospheric water vapor (e.g. Greenland, Himalayan and Andes Mountains) show up as high reflectance features due to surface reflectance reaching the top of atmosphere in the absence of cloud. Gray areas are zones of cloudiness or no data coverage.

A review of MODIS A2 and A0 calibration coefficients for the thermal bands suggests that A0 be set to zero for calibrating Terra MODIS bands 33 – 36. Time series behavior of the postlaunch A0 term for these bands illustrates the difficulty in basing a determination on in-orbit data. The A0 term will be set to zero for reprocessing Terra MODIS band 33 – 36 data into Collect 4. This will bring the in-orbit calibration of these bands close to prelaunch calibration. The in-orbit behavior of A0 and A2 for other TIR bands has been reviewed without clear indication of necessary action; however, some evidence suggests that the water vapor sensitive bands 27 and 28 might benefit from setting A0 to a constant non-zero quantity for all detectors. This item continues to be a subject of investigation for Terra MODIS and will be for Aqua MODIS as well.

MAS IR Calibration Studies

An investigation is underway to identify degrees of freedom in the MAS spectral performance when being evaluated in the ARC calibration laboratory and during flight. The activity centers on the production of a ray trace model for the Bomem interferometer measurement through the MAS aperture to the MAS detectors. Dan LaPorte and consultant Richard Cline visited ARC in May to size the ray trace model task and collect information on the MAS and Bomem hardware setup in the laboratory. The ray trace model will reveal the sensitivity of the spectral characterization to hardware alignment both exterior and interior to the MAS instrument. Modifications to the MAS optical system design and the spectral characterization facility setup at ARC may be suggested by this investigation. The ray trace model will be produced by consultant Richard Cline in Phase 1 of the effort. This model will be transferred to ARC for use in sensitivity testing. The objective of Phase 1 is to attain robust reproducible spectral characterization of MAS using the Bomem hardware in the laboratory. The Phase 2 objective is to stabilize MAS spectral peformance inflight; Phase 2 actions will be based upon results of Phase 1. A goal has been set to complete Phase 1 by November 2002.

ER-2 MODIS Validation Activities

Plans are being finalized for the NASA ER-2 deployment to San Antonio, TX for the TX-2002 field program. Science flights during the deployment are scheduled to take place from 20 November through 11 December 2002. The ER-2 will carry the MAS, S-HIS, and CPL instruments along with the usual camera systems. Underflights of Terra and Aqua are planned. The Terra underflights will focus on validating MODIS Cloud products using MAS and the CPL data sets. Underflights of Aqua will focus on evaluating AIRS and MODIS early L1B data sets using MAS and S-HIS (CPL for validating clear sky conditions). The ARM SGP site, the Gulf of Mexico, and the Louisiana coast are targets of interest in all cases with either Terra or Aqua overhead. Six to eight science flights are anticipated.

A flight request has been submitted to NASA for ER-2 flight hours in FY2003 describing a unified effort (NASA, IPO, Aviation Safety) to deploy the ER-2 from Hawaii in February. 2003 for flights over the Pacific Ocean. Areas of interest include Aqua performance evaluation (AIRS and MODIS), GLAS (on IceSAT) validation, proto-typical hyperspectral aviation weather product development for the Aviation Safety program, THORpex (The Observing System Research and Predictability Experiment), Marine Ocean Buoy validation of visible near IR radiances, and Terra science product validation (tropical cirrus cloud heights and emissivity, multilayer cloud phase). Additional aircraft (Gulfstream IV and DC-8) and the deployment of a high altitude drifting gondola with dropsondes are under consideration. ER-2 instrumentation includes MAS, NAST, CPL, dropsondes, and possibly the LaRC Ozone probe. A total of 75 ER-2 flight hours have been requested.

Cloud Mask (MOD35)

Two updates to the cloud mask processing software were submitted to the Goddard DAAC during the past six months. The reason for the first (v3.1.1) was primarily to permit processing of Aqua data. Code modifications or additions included response functions for the Aqua instrument, separate cloud test thresholds files for Terra and Aqua, separate metadata configuration files, as well as fixes for several minor problems. The second update (v4.0.0) was made in anticipation of "Collection 4" reprocessing of Terra MODIS data and included significant science updates. The following paragraphs outline the major changes.

Sun-glint Processing

A change was made to the NIR (band 2) reflectance test. Previously, one reflectance threshold was used for the entire geometric sun-glint region and was somewhat higher than the one used in other areas. The new method is to calculate a threshold as a linear function of sun-glint angle in three separate ranges (three slopes). The ranges are from 0-10, 10-20, and 20-36 degrees (see Figure RAF1). The reflectance thresholds are 5.5%, 7.5%, and 10.5% at 36, 20, and 10 degrees, respectively. The slope of the line for the 0-10 degree segment is 0.0, thus the value of the fourth anchor point is also 10.5%.

In addition, a new clear-sky restoral test was added where the ratio of band 17/18 reflectance is utilized to discriminate between low clouds and water surfaces. The new thresholds reflect growing experience with sun-glint contaminated reflectances but also that the region of "severe" sun-glint (0-10 degrees) is still problematic and needs more work. The new tests remove most of the false "confident cloud" and reduce the amount of "uncertain" designations in areas that are clear, but many cases of "uncertain" remain in cloudy situations. Users should still treat uncertain pixels as cloudy. An example of the improvement is shown in Figure RAF3a and RAF3b.

Clear-sky Restoral Test for Land Surfaces

Previously, several tests were named "final confidence confirmation tests". This has caused some confusion and therefore we have decided to use the term "clear sky restoral test" which we hope is somewhat more descriptive. This is the term used by Stowe et. al. for similar processes in the CLAVR algorithm. A new clear sky restoral test has been added for all land surfaces. A clear-sky confidence of 0.96 (probably clear) will be assigned if thresholds are met for three tests: 3.9-11 _m and 3.75-3.9 _m brightness temperature differences, and a 1.24/0.55 reflectance ratio test. Values of these must be <15K, <11K and >2.0 (desert) or >3.0 (other land surfaces), respectively. This assumes, as before, that no IR or 1.38 _m test has found evidence of cloud and that the previously implemented clear-sky restoral test (11 _m brightness temperature threshold) has not been satisfied. Figure RAF2 shows an example from North Africa.

Adjusted NDVI thresholds for Coastal Clear-sky Restoral Test

The clear-sky NDVI threshold for coastal land surfaces was changed from 0.3 to 0.4 to avoid false "confident clear" designations.

Adjusted Thin Cirrus Thresholds for Corrected Band 26 Reflectance Data

In anticipation of corrected Terra 1.38 _m reflectance data, thresholds for the thin cirrus test were modified. The upper reflectance limit is set to the same value as the 0.5 confidence threshold for the 1.38 _m high cloud test (reported in bit 16 of the cloud mask), thus creating a smooth transition from "thicker" to "thinner" cirrus clouds. The lower reflectance limits for thin cirrus are set as follows: 0.5% for water, 1.25% for land, and 3.0% for snow-covered surfaces. The test will not be performed in Antarctica or in elevations exceeding 2000 meters. Users should remember that this test is independent of the overall confidence of clear sky reported by the cloud mask and by itself, cannot indicate the presence of *only* thin cirrus. Reflectance from other cloud types will sometimes meet the thresholds, increasingly in dryer atmospheres. This flag may be used to increase confidence that a pixel declared clear is also free of thin cirrus. However, in a great majority of cases, when the cloud mask reports a clear sky confidence > 0.95 *and* the thin cirrus flag is "on", the only cloud type found will be cirrus.

Polar Night

A new clear-sky restoral test was added for polar night conditions. A pixel is reported clear if the 13-11 _m brightness temperature difference is > 3.0 K. The 11 - 3.9 _m brightness temperature difference test has been modified to make the test threshold dependent on the 11 _m scene brightness temperature. The thresholds are as follows: -0.9 K and 0.5 K for 11 _m scene brightness temperatures <235K and >265K, respectively, with threshold values varying linearly between -0.9 and 0.5 K for scene temperatures between 235K and 265K.

Additional Cloud Mask Changes

Additional cloud mask science updates are planned for mid-July, 2002 (proposed v4.1.0). The broad outlines of the changes may be listed in this document as work has proceeded on them during the current reporting period.

The modifications are in the nighttime cloud detection algorithm, for both land and water. A new formulation of the 3.9 - 11 _m brightness temperature difference (BTD) low cloud test over land surfaces is planned where the new cloud test thresholds are a function of the 11 - 12 _m BTD. This test improves discrimination between low clouds and clear-sky, especially in very humid regions like the Amazon Basin. A new cloud test, 7.3 - 11 _m BTD, is introduced to detect mid-level clouds over land at night. It will be applied conservatively, however, as this difference varies widely with atmospheric water vapor loading. Clouds in middle levels of the atmosphere (240-260K) are often difficult to detect using only IR "window" spectral measurements and without the aid of solar illumination. An 11 _m clear-sky restoral test will be implemented for nighttime land surfaces similar to the one for daytime, although using slightly lowered thresholds.

Additional clear-sky MODIS IR radiances and reflectances will be recorded for later analysis. Currently, measurements from eight bands (1, 6, 26, 31, and 33-36) are stored in granule based clear radiance files (MODCSR_G). This will be expanded to include all bands except 8-16 (ocean color bands).

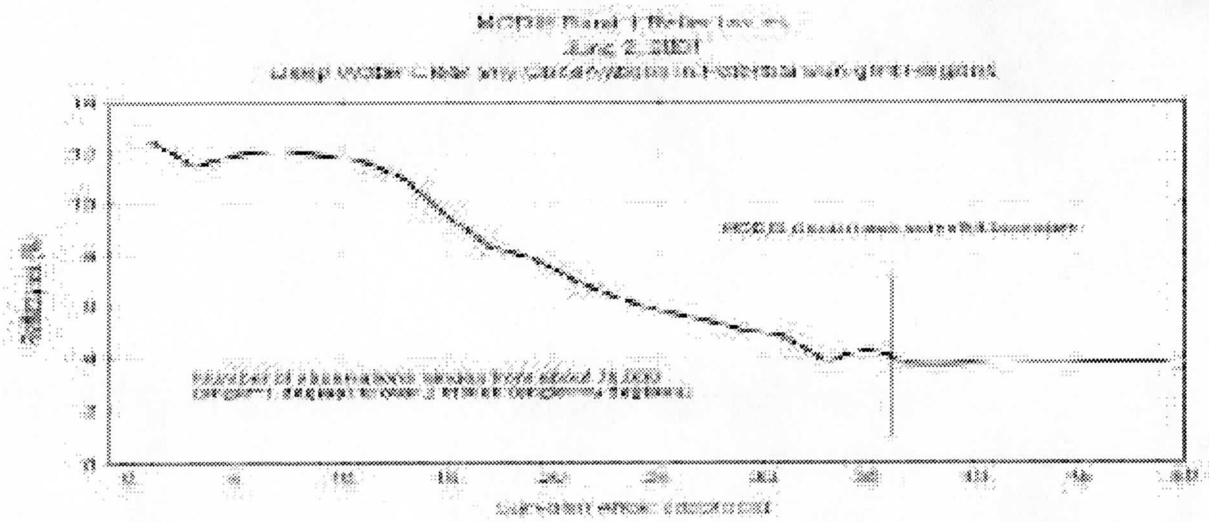


Figure RAF1. MODIS band 1 (0.66 _m) reflectance as a function of sun-glint angle. Cloud test thresholds were defined separately for 0-10, 10 -20, and 20-26 degrees.

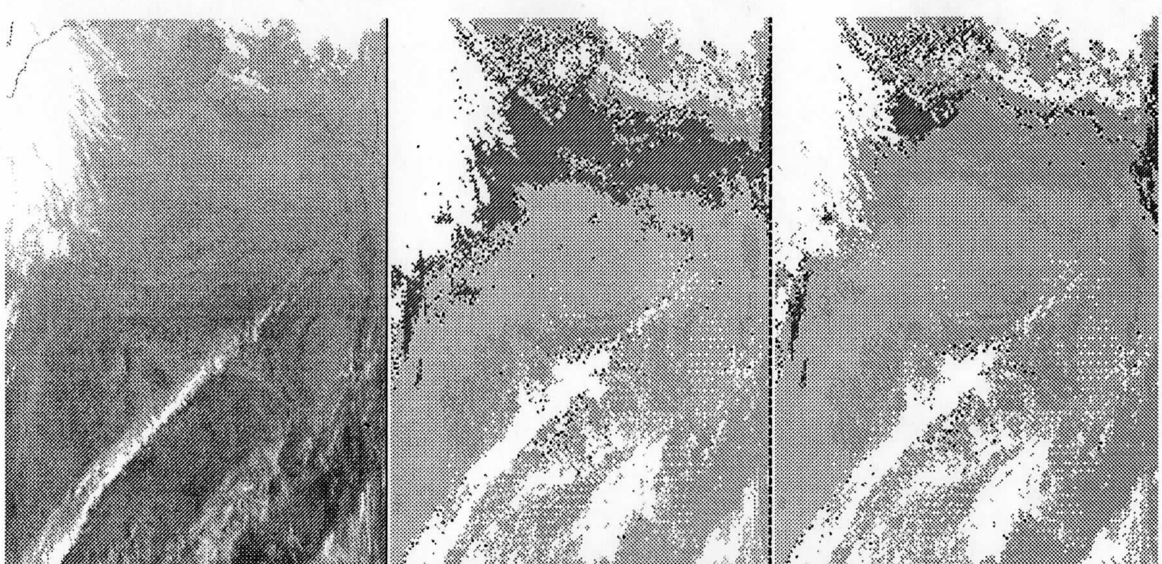
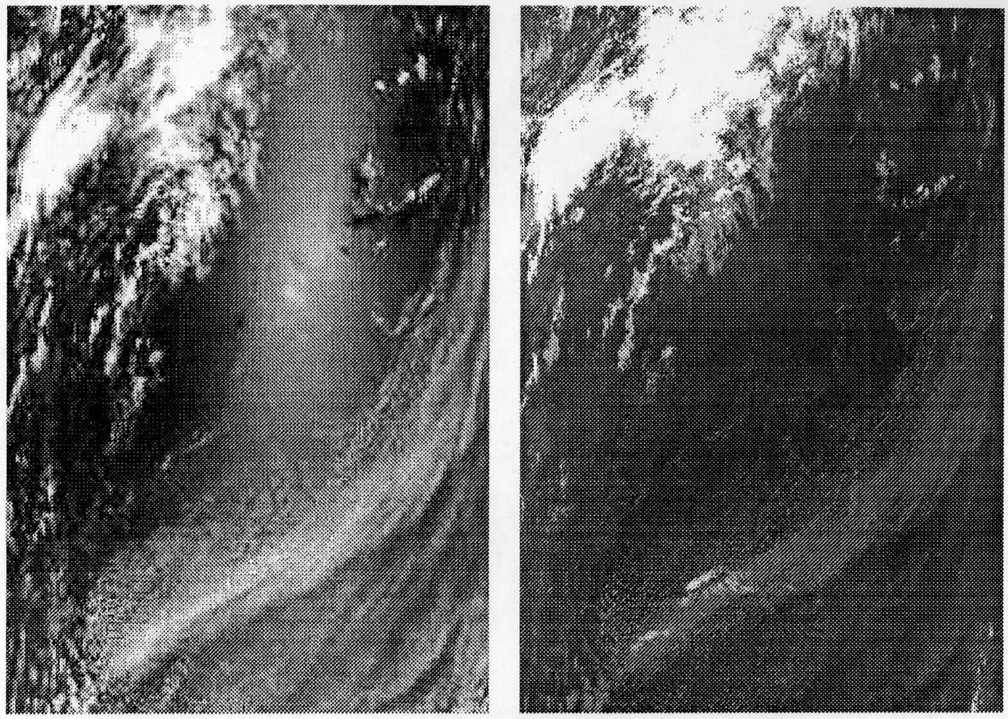
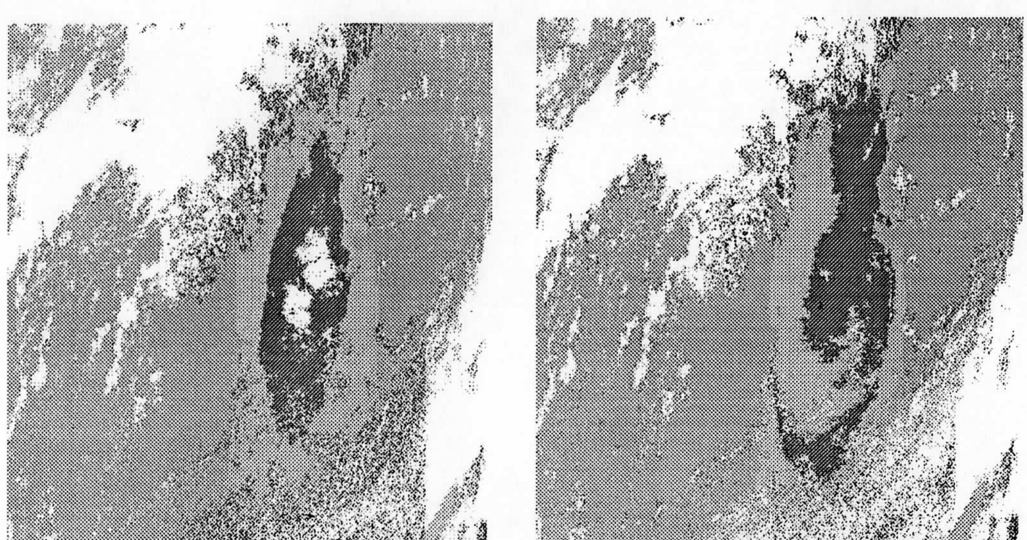


Figure RAF2: MODIS data (11 micron left, old cloud mask center, and new cloud mask right) over Northern Africa from 10:25 UTC 22 December 2000 where green is confident clear, cyan probably clear, red uncertain and white is cloudy. New cloud mask includes clear sky restoral threshold tests for 3.9-11 _m, 3.75-3.9 _m brightness temperature differences, and a 1.24/0.55 reflectance ratio test.



MODIS Band 2 MODIS Band 31

Figure RAF3a. MODIS observations from a sun-glint region in the North Atlantic at 13:15 UTC on 4 June 2001.



FigureRAF3b. Corresponding cloud mask results - left, v3.1.0, right v4.1.0. Green is confident clear, cyan probably clear, red uncertain and white is cloudy.

Cloud Shadows

Recent progress has been made towards the detection of cloud shadows over land. This has been a topic of interest by the land community that has until recently met with little progress. The work was performed by Denis Grljusic, a student from the Philipps University in Marburg, Germany, who worked closely with various members of the UW MODIS team during the months of June-July 2002. Basically, the effort involves the comparison between MODIS measured reflectances with those from a clear-sky reflectance map. If the reflectance from the field of view is considerably lower than that suggested by the clear sky map, it is flagged as containing potential cloud shadow. This simple approach uses clear-sky reflectance maps generated by the MODIS team at UW. These global maps are generated using an 8-day clear-sky collation process, but are generated at 25-km spatial resolution. These reflectance maps proved sufficient to make progress towards reliable detection of cloud shadows. The method will soon be implemented on the MODIS direct broadcast data routinely collected at the University of Wisconsin and the results will be made available to the land community for discussion. When the algorithm becomes more mature, it will be implemented operationally at the NASA Goddard Space Flight Center.

Comparison of MODIS, HIRS, and MISR Cloud Products (MOD 06)

Comparison of MODIS and HIRS brightness temperatures

MODIS global mean brightness temperature were compared to those from HIRS (see Figure HZ1) in the CO_2 bands on 3 June 2001. The brightness temperatures of MODIS and HIRS are typically within 3 K for all bands at all latitudes. The 13.3 _m brightness temperatures differ by 5 K in the 30 S latitude region. As no attempt was made to correct for spectral response differences in MODIS and HIRS, the results are considered to be reasonable.

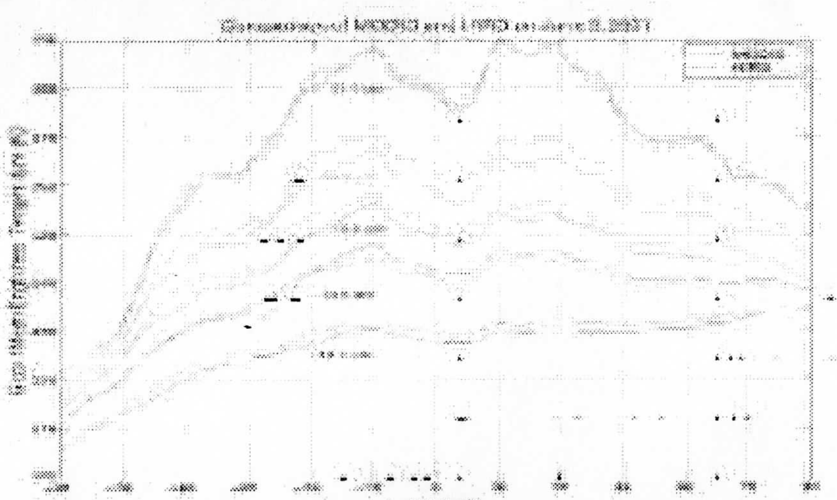


Figure HZ1: Comparison of global mean brightness temperature on 3 June 2001 between MODIS and HIRS in CO_2 bands.

Comparison of MODIS and HIRS cloud products

Comparison of MODIS and HIRS CO_2 slicing cloud products for one day between 20 – 60 N indicated that (a) MODIS has more high clouds and less clear sky than HIRS over land; in particular MODIS has more high thick, middle thick, and low opaque and less middle opaque clouds than HIRS over land; (b) MODIS has about the same cloud cover over water; in particular MODIS has less high thin and more high thick clouds than HIRS over water. Figure HZ2 shows the difference for daytime over water surface on 20 ~ 60 North latitude. Comparisons are being extended to more data sets and differences in processing algorithms are being mitigated. Differences in the MODIS and HIRS approaches include product resolution (5 km vs 20 km), cloud identification (MODIS cloud mask versus split window comparison with surface temperature), clear sky radiance estimation (forward calculation from the GDAS versus interpolation from nearby clear fields of view), and radiance bias correction (none for MODIS).

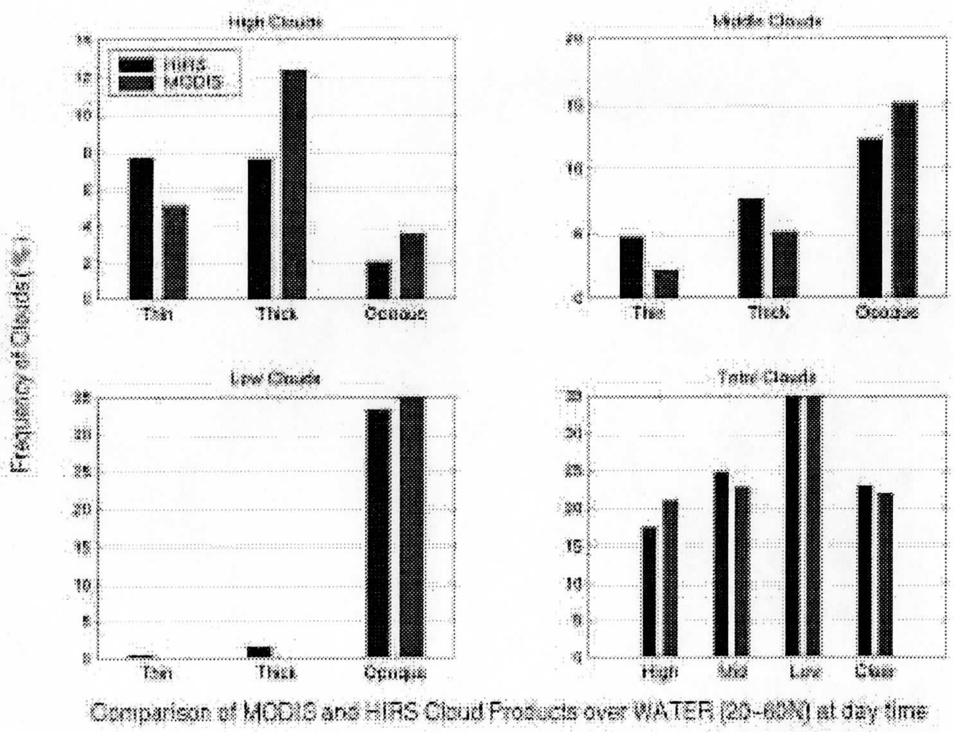


Figure HZ2: Comparison of 3 June 2001 MODIS and HIRS cloud products over water surface in 20 to 60 N at daytime.

Comparison of MODIS CO_2 slicing and MISR stereo cloud top heights

The comparison between MISR and MODIS CTH was accomplished for two cases over the UK on 1 April 2001 and 3 May 2001 (Figure HZ3). For easy comparison with MISR cloud top heights, MODIS cloud top pressures in hPa were converted to cloud top heights in km.

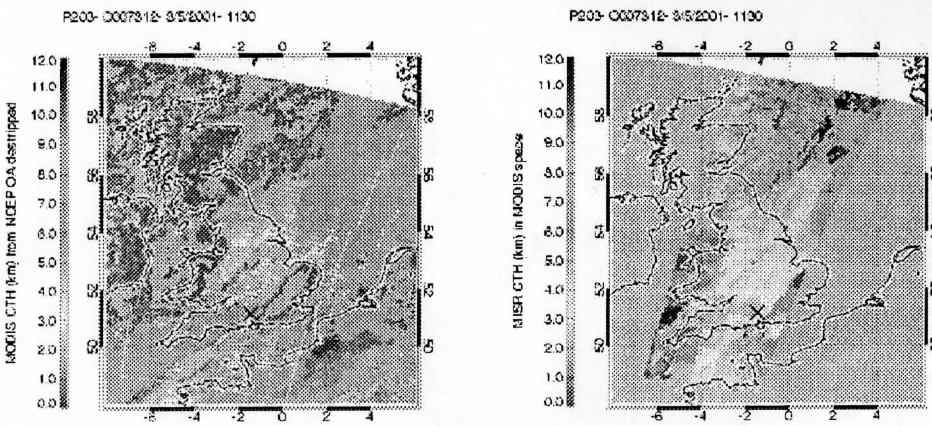


Figure HZ3a: MODIS Cloud Top Heights on 3 May 2001 (left) and MISR CTH projected onto the MODIS lat-lon grid (right)

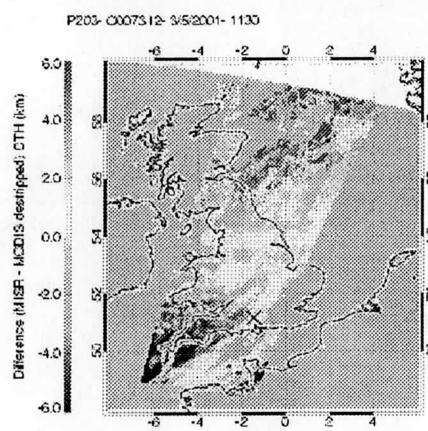


Figure HZ3b: MISR minus MODIS CTH for 3 May 2001.

MISR heights are largely below MODIS in the large area in the southwestern part of the path because MISR may not be detecting the highest layer in multi-layer cloud conditions. In the area where MISR sees clouds higher than MODIS, it might be either that MODIS missed the thin clouds or MISR overestimated the cloud top heights.

<u>Validation of MODIS instrument stability in comparison with CERES</u>

An objective analysis of the stability of MODIS and CERES radinces was undertaken. The most relevant MODIS narrowband information to the CERES broadband shortwave fluxes includes:

1. a visible channel, which indicates cloud optical thickness,
2. a near infrared channel, which indicates effective cloud particle sizes,

3. a longwave window channel for cloud temperature.

Figure HZ4a shows that the planetary albedo for deep convective cloud systems (Tc<205K) derived from narrowband to broadband conversion with MODIS data matches the albedo derived from CERES broadband observations on Terra. The peak values are all around 0.75 in Figure HZ4b indicates that MODIS narrowband instruments are stable.

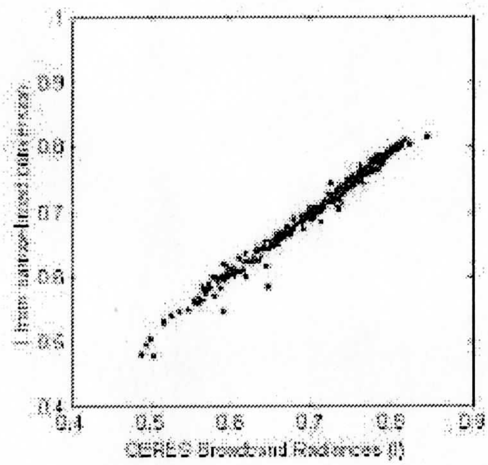


Figure HZ4a: Planetary albedo comparison of MODIS narrowband–broadband conversion versus CERES data from TERRA.

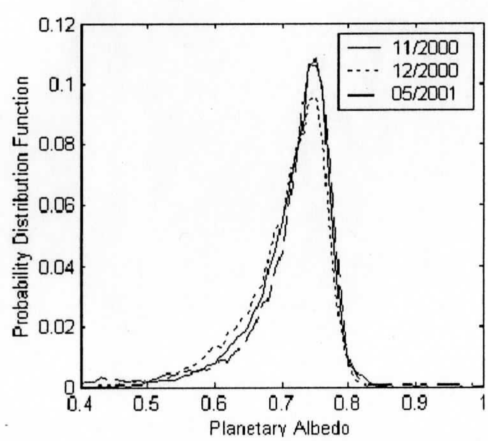


Figure HZ4b. Albedo probability distribution functions from MODIS to broadband conversion

MODIS Infrared Total Precipitable Water Product (MOD 07)

A new version of the MODIS Atmospheric Temperature and Moisture Profile Retrieval Algorithm (MOD07_L2 v3.1.0) was delivered to the Goddard Distributed Active Archive Center (GDAAC) and was included in operational processing on 1 May 2002. Significant modifications have been made to the MOD07_L2 algorithm for the v3.1.0

delivery. In addition to the algorithm changes summarized below, the new version includes updates for TERRA/AQUA compatibility.

Predictors used in statistical regression algorithm

The previous MOD07_L2 algorithm used the brightness temperatures from individual MODIS bands 24, 25 and 27-36 as predictors for the statistical regression algorithm. However, this set of predictors led to difficulty in desert retrievals. The emissivity at the 4.5 µm spectral region (bands 24 and 25) may be as low as 30-40% for desert minerals. Because emissivities this low are not included in the training data set, the IR 4.4 µm and 4.5 µm (bands 24 and 25) were not accurately represented and the MODIS retrievals were excessively moist in the desert regions. To remedy this problem, the difference between these two bands is used as a single predictor instead of using bands 24 and 25 independently; this subtraction removes most of the surface emissivity signal in the regression equation. This change led to improvements over many desert areas, including north Africa, North America, Saudi Arabia, and central Asia. Figure SWS1 shows a comparison of the old and the new algorithm over the deserts in north Africa.

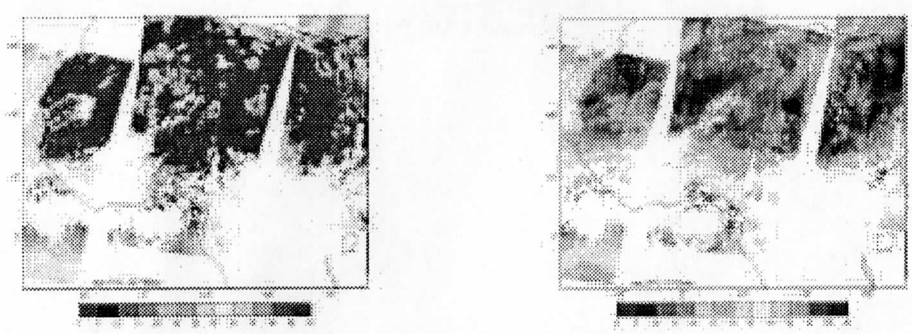


Figure SWS1: Comparison between TPW (mm) from the MODIS MOD07 previous algorithm v3.0 (left), MODIS MOD07 new algorithm v3.1.0 (right), for the north African deserts on June 2, 2001 at 0830-1155 UTC.

Training Data Set

The NOAA-88b data set contains 7547 globally distributed clear sky radiosonde observations and surface data from 1988. Profiles of temperature, moisture, and ozone and surface data from this data set were used to compute the regression coefficients for the MODIS statistical retrieval. To limit the retrievals to training data with physical relevance to the observed conditions, the NOAA-88b data was partitioned into seven zones based on the 11µm brightness temperatures (BT11) calculated from the profiles. The seven zones are BT11 $<$ 245, 245-269, 269-285, 285-294, 294-300, 300-310, and $>$ 310°K. When each statistical retrieval is performed, it uses only the subset of the training data corresponding to the relevant BT11 interval.

After partitioning, there was insufficient training data in the NOAA-88b data set for the very warm surfaces (the last two zones, BT11 $>$ 300 °K). To address this problem, new radiosonde data from the north African desert regions for January – December 2001 were added to the training data set. 900 new radiosondes, spread equally through the twelve months, met the criteria of relative humidity < 90% at each level and physically reasonable behavior up to 100hPa; profiles of temperature and moisture from these radiosondes were added to the NOAA-88b data set.

Partitioning BT11 into seven zones and adding training data improves the MODIS TPW retrievals; one example is presented in Figure SWS2. The area in Kansas and Oklahoma that shows the most improvement has a warm BT11 that falls within the highest two classes (BT11 > 300°K). This is consistent with results of other cases; the most significant improvements occurred for scenes with BT11 in the two highest classes.

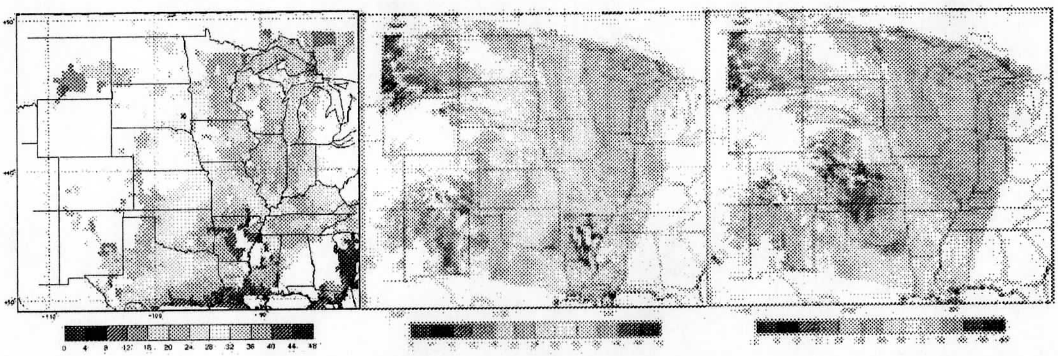


Figure SWS2. Total precipitable water (mm) from August 20, 2001 retrieved from GOES-8 (left), new operational MODIS (center), and MODIS without the 11mm brightness temperature zones (right). The MODIS granule began at 1735 UTC and GOES at 1800 UTC.

Radiance bias correction

Radiance bias calculations are routinely computed for the SGP ARM-CART site for clear scenes with MODIS sensor zenith angle less than 35°. Observed MODIS radiances, averaged from a 5x5 field-of-view area, were compared with those computed by the same transmittance model used in the algorithm. The calculations of radiances were performed using the 101-level PFAAST model, with temperature and moisture profile input from National Center for Environmental Prediction's Global Data Analysis System (NCEP-GDAS) global analysis data. Skin temperature and emissivity estimates came from regression with MODIS radiances. To establish credibility for the regression-derived skin temperature input, actual observed skin temperature from a ground-based downward-looking infrared thermometer (IRT) that measures the radiating temperature of the ground surface (http://www.arm.gov/docs/instruments/static/irt.html) was also used. Figure SWS3 shows that, on average over 60 clear-sky day and night cases from April 2001 to June 2002, the biases computed using the regression-based skin temperature differ very little from those computed using the IRT skin temperature. Most CART site MODIS radiance biases (observed minus calculated BT) shown in Figure SWS3 are positive, indicating that, on average, the observed MODIS brightness temperatures are warmer than those predicted by the model.

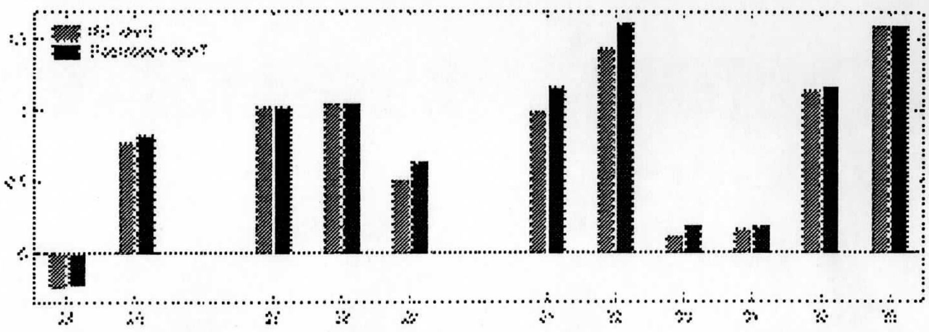


Figure SWS3: Average (Observed-Calculated) brightness temperature for MODIS IR bands 24, 25, 27-29, and 31-36 from 60 clear sky cases at the SGP ARM-CART site from April 2001 to June 2002. Red bars indicate radiance calculations used skin temperature observed by the IRT; regression-derived skin temperature was used for the calculated radiances in the blue bars. No bias is computed for band 30 because of insufficient ozone observations for input to the forward model.

A comparison of MODIS products at the SGP ARM-CART site with and without the bias correction (not shown) confirms a significant improvement with the bias corrections. The RMS for the CART site MWR minus MODIS decreased from 4.9 mm to 3.6 mm when the bias corrections were applied. The improvements were primarily apparent for moist cases where the bias correction helped to correct a dry bias. Because the MODIS retrieval algorithm is applied globally, the biases computed at the SGP ARM-CART site are not appropriate for application at other latitudes and for other ecosystem types. Thus, biases have been computed for other regions of the globe; however, they are less well validated. Future versions of the algorithm will include a more advanced global bias scheme that uses a regression based on air-mass predictors (atmospheric layer thickness, surface skin temperature, and TPW) such as that employed on the TIROS Operational Vertical Sounder (TOVS) (Eyre 1992; Harris and Kelly, 2001).

To compute the global radiance biases, observed MODIS brightness temperatures were compared with calculated brightness for 270 clear-sky scenes from 2 – 5 June 2001 with MODIS viewing zenith angle < 30°. Calculations of brightness temperatures were performed as outlined above with skin temperature estimated from regression of MODIS radiances. As there are known difficulties in retrieving skin temperature and emissivity over the desert, these cases were excluded from the global averages. The global biases are separated into twelve groups: six latitude zones: north tropical (latitude 0° to +30°), south tropical (0 ° to -30°), north mid-latitude (+30° to +50°), south mid-latitude (-30° to -50°), north polar (50° to 90°), south polar (-50° to -90°), each for land and ocean. The average global biases for north mid-latitude land agree fairly well with the CART site biases; the RMS of the MODIS-MWR TPW for 60 cases increased only 0.2 mm when using the global north mid-latitude biases instead of the CART site biases.

The radiance bias corrections applied in the operational MODIS atmospheric retrieval algorithm will need to be updated regularly to account for adjustments in the instrument calibration and improvements in the forward model. In addition, the bias values may vary seasonally so the bias corrections calculated from four days in June may need to be updated.

Other changes

A new variable, direct retrieval of total precipitable water vapor, has been added to the MOD07_L2 products. The original total precipitable water vapor ("Water_Vapor" variable) is integrated from profiles retrieved from a statistical regression. For the new variable, "Water_Vapor_Direct," the training data profiles are integrated and this information is added to the regression coefficients. Total precipitable water is then retrieved directly.

The TPW physical retrieval algorithm has been developed at UW-Madison CIMSS and applied to our local version of the MOD07_L2 retrieval algorithm for testing and research purposes. It requires more computation time to run so will not be included in the operational MOD07_L2 algorithm; however, there are plans to include it in the MODIS IMAPP direct broadcast processing package.

New estimates of instrument noise have been included in the MOD07_L2 algorithm. The previous algorithm used pre-launch estimates of NEdT and assumed a constant reference brightness temperature over all bands to convert to NEdR. The new algorithm includes the instrument specified reference brightness temperatures for each band and includes new post-launch estimates of instrument noise.

The first 10 radiance pixels in each scan line are not included in the retrieval in the new algorithm. An error introduced in the radiances by a cross-talk correction causes a variation in the total precipitable water values for the first two 5x5 retrievals for many granules.

Evaluation of MOD07 L2 products in v3.1.0

Atmospheric retrievals from MODIS and other observing systems have been compared at three spatial scales: a) a fixed point with ground-based measurements (SGP ARM-CART), b) the continental scale with GOES sounder products, and c) the global scale with retrievals from the Special Sensor Microwave/Imager (SSM/I) and Total Ozone Mapping Spectrometer (TOMS).

Comparison with ARM-CART observations

Specialized instrumentation at the Southern Great Plains (SGP) Atmospheric Radiation Measurement-Cloud and Radiation Testbed (ARM-CART) in Oklahoma facilitates comparisons of MODIS atmospheric products with other observations collocated in time and space. Terra passes over the SGP CART daily between 0415-0515 UTC and 1700-1800 UTC. Radiosondes are launched three times each day at approximately 0530, 1730, and 2330 UTC. Observations of total column moisture are made by the microwave water radiometer (MWR) every 40-60 seconds. An additional comparison is possible with the GOES-8 sounder (Menzel and Purdom 1994; Menzel et al. 1998) that retrieves TPW hourly.

MODIS retrieved products were compared for 64 clear-sky cases from April 2001 to June 2002. The data was reprocessed at CIMSS with the new algorithm. Manual inspection of visible and infrared images excluded any scenes with the possibility of cloud contamination. MODIS sensor zenith angle was less than 50° to the CART site for all cases. TPW from MODIS regression retrievals, the GOES-8 sounder, radiosondes, and the MWR are compared in Figure SWS4. MODIS shows general agreement with the MWR for these cases; GOES-8 sounder and radiosondes show better agreement with the MWR. The RMS difference between MODIS and MWR TPW collocated in time and space is 3.6 mm for regression retrievals, compared with 1.78 mm and 1.16 mm for GOES-8 and radiosondes, respectively. For dry atmospheres, MODIS consistently overestimates the total column moisture; the average TPW bias (MODIS minus MWR) is approximately 3 mm for the 26 dry cases with MWR TPW less than 10 mm.

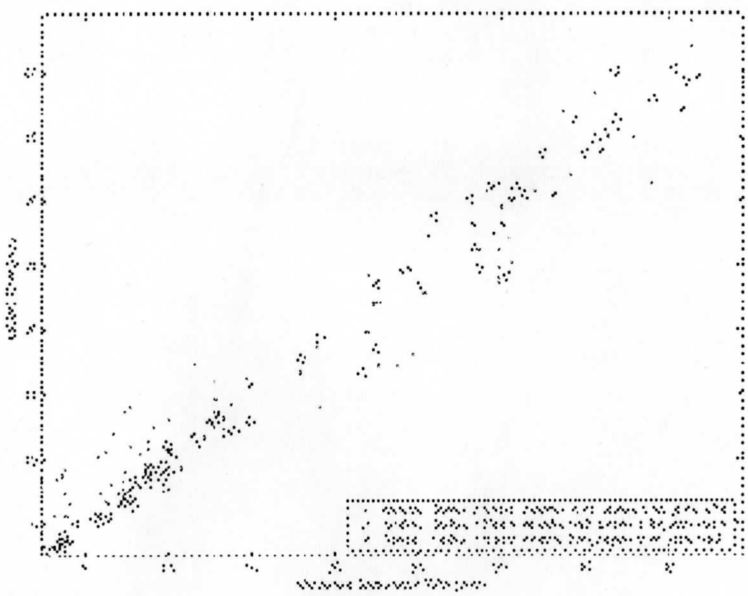


Figure SWS4: Comparison of TPW from MODIS regression (red dot), GOES-8 (blue diamonds), and radiosonde (black cross) with the SGP ARM-CART microwave radiometer (MWR) in millimeters. 64 cases from April 2001 to June 2002 are shown in the comparison.

Continental-Scale Comparisons between MODIS and GOES TPW

On the continental-scale, MODIS TPW was compared to GOES-8 and GOES-10 sounder retrievals of TPW over the continental United States and Mexico. GOES TPW has been well validated (Schmit et al. 2002). GOES has a resolution at the sub-satellite point of 10 km and uses radiances measured from a 3 by 3 field of view area (approximately 30 km resolution) to retrieve one atmospheric profile, while MODIS has nadir resolution of 1 km and uses a 5 by 5 field of view area (5 km resolution). Unlike the MODIS retrieval, GOES hourly radiance measurements are supplemented with hourly surface temperature and moisture observations as additional information in the GOES retrieval. MODIS and

GOES retrieval procedures also use different first guess profiles; GOES uses a numerical model forecast, while MODIS uses the previously described regression retrieval.

Figure SWS5 compares MODIS TPW to TPW retrieved by the GOES-8 and GOES-10 sounders over North America for 02 June 2001 during the day and at night. The two show fairly good agreement except the MODIS TPW retrieved by regression is drier than GOES over Oklahoma, Arkansas, and the Gulf of Mexico. TPW retrieved by physical retrieval shows better agreement with GOES in these areas.

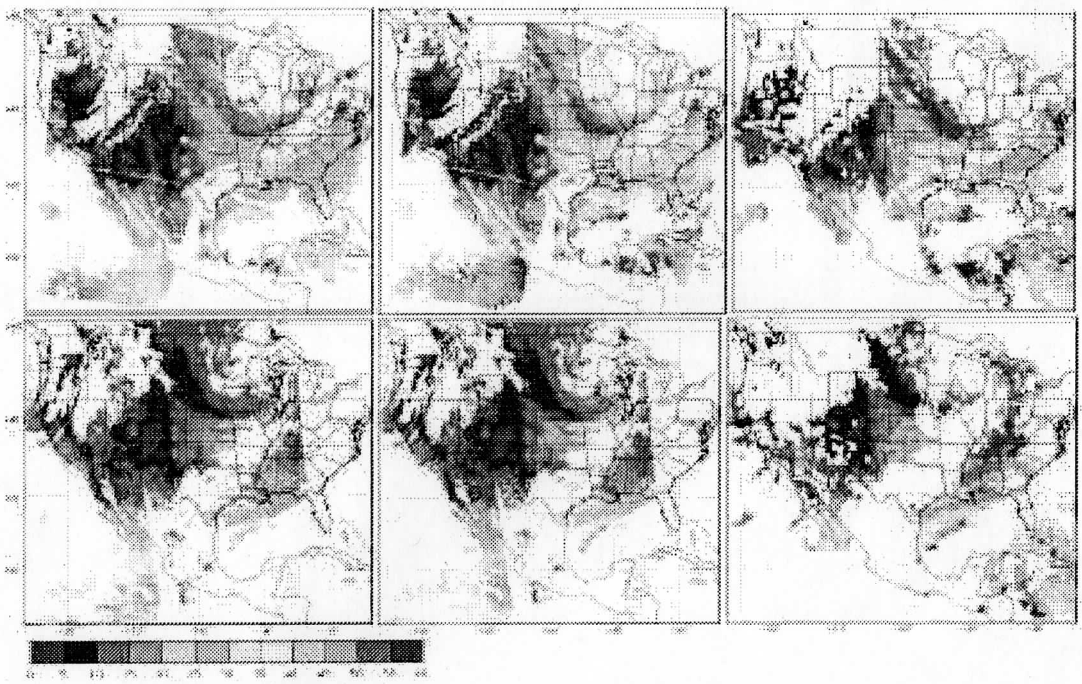


Figure SWS5. Total precipitable water (mm) for 02 June 2001 over North America retrieved by MODIS regression (left), MODIS physical (center), and GOES-8 and GOES-10 (combined, right). The top column shows daytime retrievals (4 MODIS granules from 1640, 1645, 1820, 1825 UTC; GOES at 1800UTC), and the bottom column nighttime (MODIS 0435, 0440, 0445, 0615, 0620 UTC; GOES 06 UTC).

Global comparisons of MODIS products with SSMI and TOMS

Global TPW from MODIS atmospheric retrievals is compared with TPW from the Defense Meteorological Satellite Program (DMSP) SSM/I (Alishouse, 1990; Ferraro, 1996; Wentz, 1997) for 22 May 2002 in Figure SWS6.

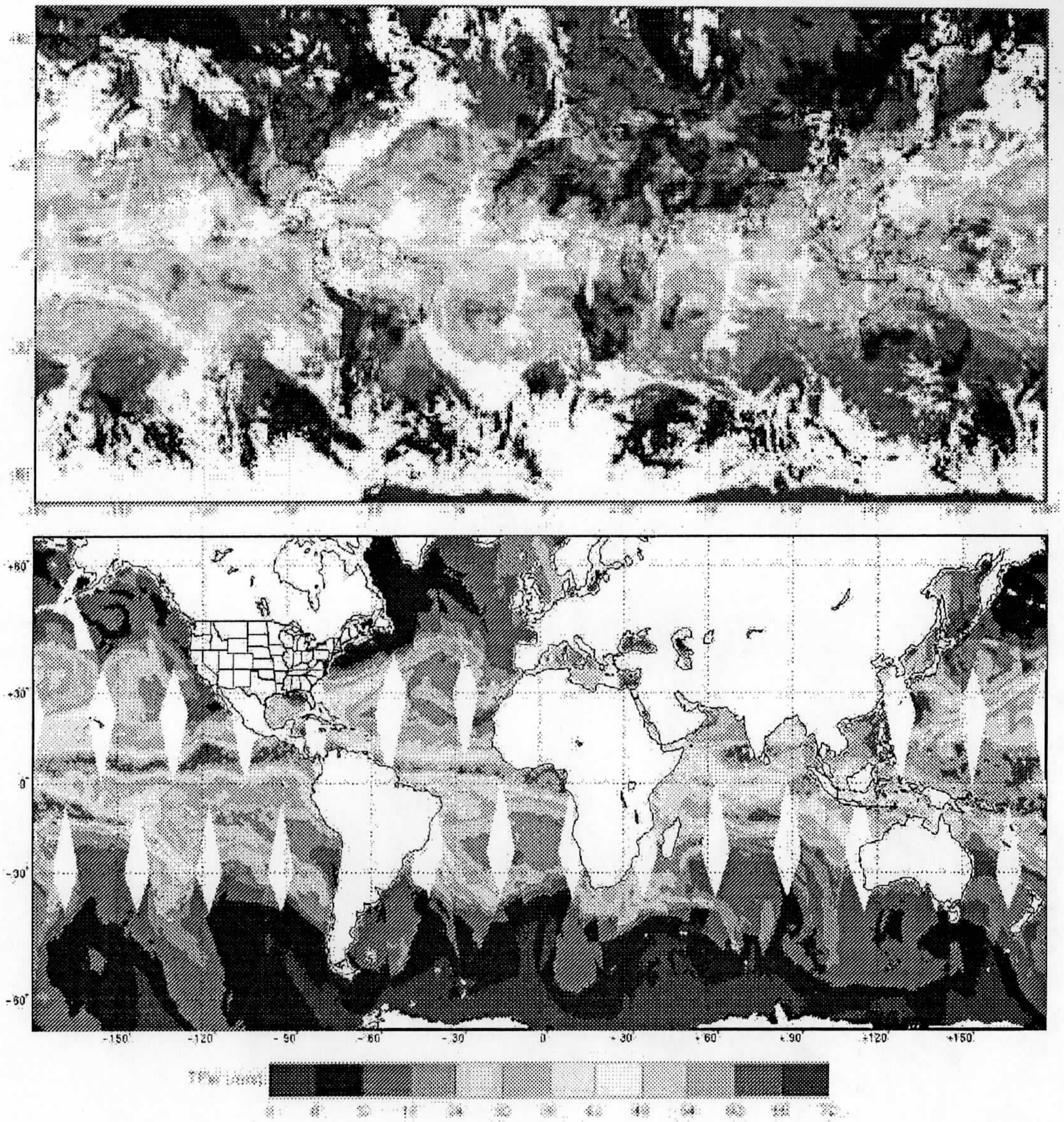


Figure SWS6. MODIS TPW (mm, upper panel) and SSM/I f-14 TPW (mm, lower panel) distribution on 22 May 2002. Retrievals from ascending and descending passes were averaged to obtain these values. The color scale is the same for both MODIS and SSM/I and is shown below the two images. SSM/I data were obtained through http://www.ssmi.com. MODIS data was degraded to 25 km resolution from the original 5 km resolution for this figure.

The SSM/I (resolution 12.5 km) retrieves products for clear or cloudy skies over ocean only, and uses the 22 and 37 GHz microwave channels. MODIS and SSM/I show similar patterns of TPW distribution and similar magnitudes, however MODIS retrievals are somewhat less moist over tropical oceans. Some of the differences can be attributed to the fact that MODIS does not retrieve cloudy pixels and, thus, does not capture the moist environment around clouds. This can affect the results even where MODIS retrievals were performed since the retrieval only requires that 5 of the 25 pixels in a 5x5 MODIS field-of-view area be clear. The remaining cloudy pixels are excluded, however the retrieval is still performed using only the clear pixels. Other differences may be attributed to the time differences between the two satellite overpasses.

MODIS total column ozone retrievals are compared with ozone from the NASA/GSFC Total Ozone Mapping Spectrometer (TOMS) (Bowman and Krueger 1985; McPeters et al. 1996, 1998) ozone measurements from the Earth Probe (EP) satellite for 22 May 2002 in Figure SWS7. The general distribution of ozone from TOMS is similar to that from MODIS. In order to predict the evolution of ozone on time scales of a few days to a week, reliable measurements of ozone distribution are needed. However, the TOMS instrument measures backscattered ultraviolet solar radiation and cannot provide measurements at night. High spatial resolution IR radiance measurements at 9.6µm from MODIS allow ozone estimates during both day and night.

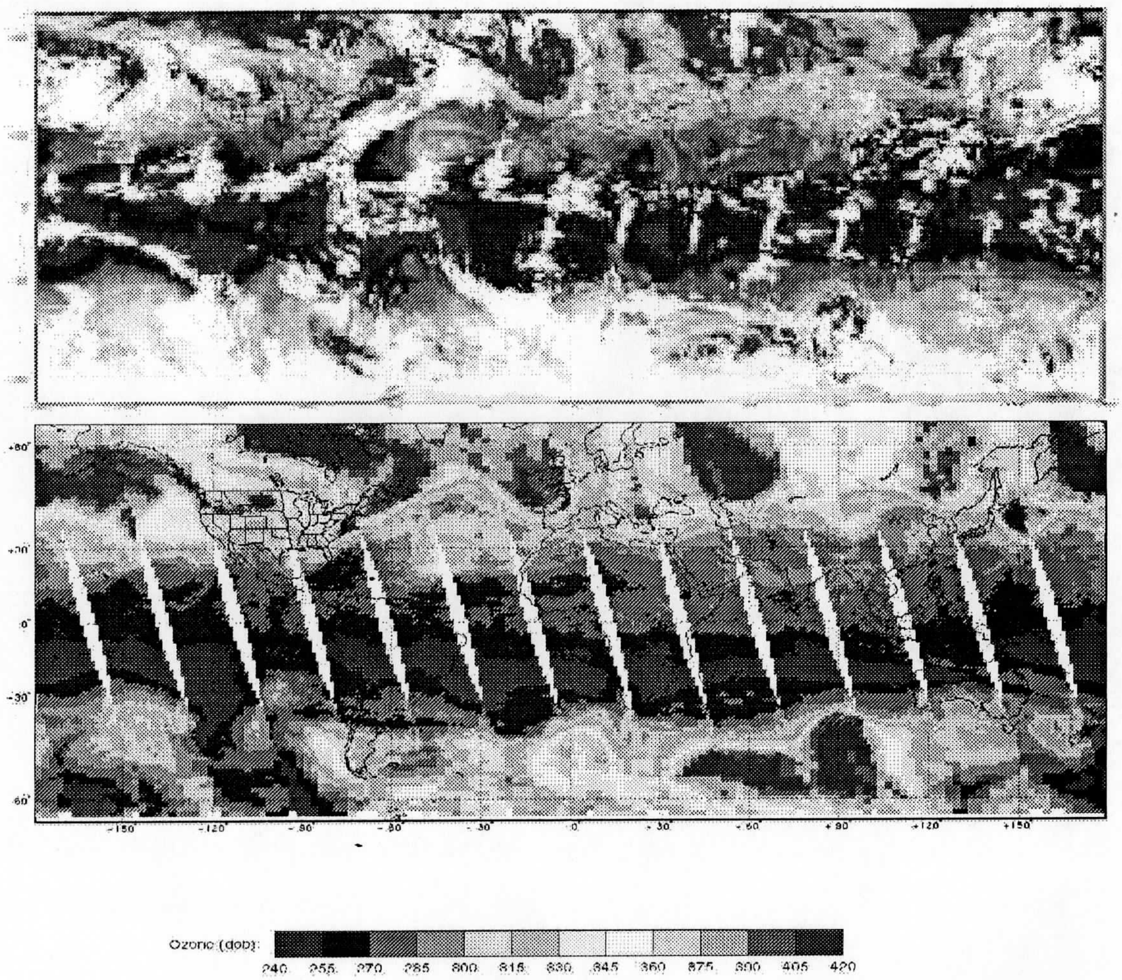


Figure SWS7. Total column ozone (Dobson units) for 02 June 2001 for MODIS (top) and TOMS (bottom). TOMS data was obtained from http://toms.gsfc.nasa.gov/ozone/ozone.html.

References for TPW work

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Bowman, K.P. and A.J. Krueger, 1985: A global climatology of total ozone from the Nimbus-7 Total Ozone Mapping Spectrometer", J. Geophys. Res., 90, 7967-7976. Eyre, J.R., 1992: A bias correction scheme for simulated TOVS brightness temperatures. *ECMWF Technical Memorandum 186*. 28 pp.

Ferraro, R.R., F. Weng, N.C. Grody, and A. Basist, 1996: An eight year (1987 - 94) climatology of rainfall, clouds, water vapor, snowcover, and sea-ice derived from SSM/I measurements. Bull. of Amer. Meteor. Soc., 77, 891 - 905.

Harris, B. A., and G. Kelly, 2001: A satellite radiance bias correction scheme for radiance assimilation. *Quart. J. Roy. Meteor. Soc.*, 127, 1453-1468.

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Schmit, T. J., Feltz, W. F., Menzel, W. P., Jung, J., Noel, A. P., Heil, J. N., Nelson, J. P., and G.S.Wade, 2002: Validation and Use of GOES Sounder Moisture Information. *Wea. Forecasting,* **17,** 139-154.

Wentz F. J. 1997, "A well-calibrated ocean algorithm for SSM/I", J. Geophys. Res., Vol. 102, No. C4, pg. 8703-8718.

Polar Water Vapor Winds

The MODIS water vapor winds were tested in the next-generation assimilation system of the NASA Data Assimilation Office. This a global three-dimensional system based on the flux-form semi-Lagrangian general circulation model of Lin and Rood (1998), coupled with the Physical-space Statistical Analysis System (PSAS; Cohn et al., 1998). The PSAS algorithm solves the Kalman Filter analysis equation globally, in the same way that a 3D variational algorithm does, but calculations are carried out in observation space rather than in spectral space. The model resolution is 1.0 x 1.25 degrees latitude/longitude with 55 vertical levels. Analysis increments are calculated at 2.0 x 2.5 degrees for 25 levels. The MODIS winds were thinned to a 0.5 by 0.5 degree resolution; winds were not otherwise excluded from the experiments.

First, a control experiment was performed for the MODIS test period including all the standard observations available for operational NWP purposes, but excluding the MODIS winds. At each analysis time and observation location the observation-minus-6-hour forecast residuals (OMF) were calculated. Next, an assimilation that included the MODIS winds was performed and the OMF residual was again calculated. This residual is calculated before the analysis is performed, so it is essentially a diagnostic of the consistency between the analysis background (the 6-hour forecast) and the observations. The OMF residual for the assimilation that includes the MODIS winds was significantly smaller than in the control assimilation, especially at 500 hPa. This demonstrates that the observations are consistent with the dynamics of the model, and that the MODIS winds contain information that can be ingested and retained by the assimilation system. As a result, the short-range forecast becomes more consistent with the observations at the new analysis time.

Five-day forecasts were then run from the 0Z analyses on every other day of both the MODIS assimilation and the control assimilation. This was done for water vapor winds, IR winds, and for all MODIS winds together. The combined IR and water vapor winds experiment is discussed here. The DAO forecast was verified against operational ECMWF analyses.

Figure JRK1 shows the 500 hPa forecast score (anomaly correlation) as a function of forecast day for the Arctic and Antarctic, both defined as the area poleward of 60^{o} latitude. Forecasts from the MODIS winds assimilation scored significantly higher than the control experiment in the Arctic, and marginally higher in the Antarctic. Due to the lack of observations over Antarctica, the Southern Hemisphere result may therefore be less meaningful than the Northern Hemisphere result. For the extratropics of each hemisphere (not shown), the MODIS winds improved the forecast skill in the Northern Hemisphere while the Southern Hemisphere impact was neutral to slightly positive. Again, errors in vector height assignment may explain the smaller impact in the Southern Hemisphere.

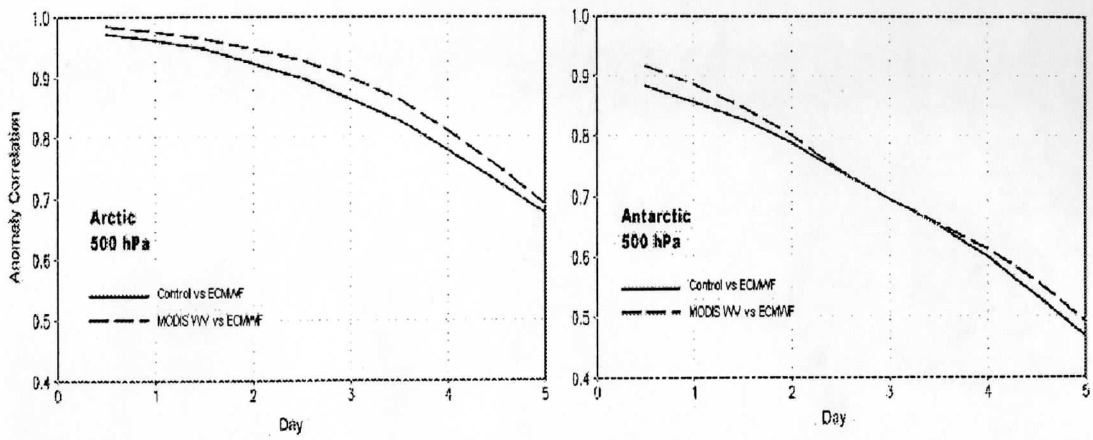

Figure JRK1: Anomaly correlation as a function of forecast range for the 500 hPa geopotential height forecast over the Arctic (left) and Antarctic (right) from the DAO model impact study. The MODIS experiment (dashed) and the control experiment (solid) have each been verified against ECMWF analyses. The study period is March 5-29, 2001. The Arctic and Antarctic are defined as the area poleward of 60° latitude.

References for DAO Polar Winds Study

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Lin, S.-J., and R. B. Rood, 1998, A flux-form semi-Lagrangian general circulation model with a Lagrangian control volume vertical coordinate, The Rossby-100 Symposium, Stockholm, Sweden.

International MODIS/AIRS Processing Package (IMAPP) Science Products Software Release

Direct broadcast versions of the MODIS cloud mask (MOD35) and cloud top properties and cloud phase (MOD06CT) algorithms were released on 1 May 2002. These products have been running real-time as part of the Wisconsin operational direct broadcast processing since March. The direct broadcast code and production scripts were developed from the official Goddard approved production software. The code was rewritten to remove dependencies on all toolkits except NCSA HDF4, simplified and streamlined and tested on 5 different unix platforms. The output was compared with operational products using the same inputs and code released via ftp at: ftp://origin.ssec.wisc.edu/pub/IMAPP/MODIS/Level-2/v1.1/. The release versions are compatible with the MODIS production cloud mask version 3.1.1 which was delivered to the Distributed Active Archive Center (DAAC) at Goddard Space Flight Center on 25 February 2002and production cloud top property and cloud phase version 3.1.0. delivered on 15 March 2002.

In addition, an ftp site has been set up which contains the current and previous 6 days of ancillary data required to run both the cloud mask and cloud top property and cloud phase algorithms. This will allow the direct broadcast community to one-stop shop for all the ancillary data that they will need to run the algorithms. The files included at the site are:

(1) Near Real-Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent (NISE) file from the National Snow and Ice Data Center (NSIDC) in Colorado for providing help in identifying cloud mask snow backgrounds.

(2) Daily SSMI sea ice concentration from the National Center for Environmental Prediction (NCEP). This provides help in identifying cloud mask sea ice backgrounds.

(3) 6 hourly Global Data Assimilation System T126 resolution profiles of temperature and moisture analyses from NCEP. These profiles are required in order to run the CO2 slicing portion of the cloud top properties and cloud phase algorithm.

Permission was granted by the NISE provider to release their product on our site. The other two NCEP data sets are also freely available through the public ftp ncep site; no permissions were required. Users can access the direct broadcast ancillary data at: ftp://terra.ssec.wisc.edu/pub/terra/ancillary/ .

In an attempt to simplify the direct broadcast version of the products, some differences do exist when compared with the operational products. The cloud mask direct broadcast output file differs from the operational MOD35 output file in that:

1) It is a byte formatted flat binary file instead of HDF. No toolkits are required to open or extract data from the file.

2) There are two .img and two .hdr files representing the operational MOD35 HDF Cloud_Mask and Quality_Assurance SDS's.

3) There are no geolocation or solar and viewing geometry parameters included as part of the Direct Broadcast product.

The cloud top properties direct broadcast output file differs from the operational MOD06 output file in that:

1) It is a 4 byte float binary flat file instead of HDF. All parameters (bands) are of type 4 byte float. No toolkits are required to open and read the files.

2) There are two .img and two .hdr files representing the 48 operational MOD06 HDF SDS's listed below, and the MOD06 HDF SDS Quality_Assurance_5km.

3) There are no geolocation or solar and viewing geometry parameters included as part of the Direct Broadcast product.

4) The output product consists of 48 band interleaved parameters instead of individual HDF file SDS's.

5) The output product does not include several operational MOD06 SDS's which are not part of the MOD06 CT executable. These are:

Effective_Particle_Radius
Cloud_Optical_Thickness
Effective_Radius_Difference
Water_Path
Cirrus_Reflectance
Cirrus_Reflectance_Flag
Cloud_Mask_5km
Cloud_Mask_1km
Quality_Assurance_1km

6) The Quality_Assurance_5km array indices are ordered differently. The DB mod06qa.img order is (element,line,qa_byte), while the DAAC operational HDF SDS is ordered (qa_byte,element,line). The array order was changed to be compatible with the cloud mask byte order.

An example cloud mask and cloud top properties and cloud phase product created from the UW automated direct broadcast processing script is displayed in Figure KIS1. The left panel is a true color image (bands 1,4,3) of a Terra/MODIS overpass collected on 13 April 2002. The 1 km image shows a large deck of clouds of varying thickness (brightness) and composition (clearly defined edges and fuzzy edges) covering a large portion of the land and water. The middle panel is the output MODIS cloud mask product probability of clear bits (2 and 3.) The final panel is the cloud phase results from the direct broadcast MOD06 product. It uses the cloud mask as input to determine when there are enough cloudy pixels to perform a retrieval. As is the case for most algorithms which utilize the cloud mask to determine when to run, the division of probably clear and uncertain is used as a cutoff (cloud and uncertain – cloud, clear and probably clear – clear.)

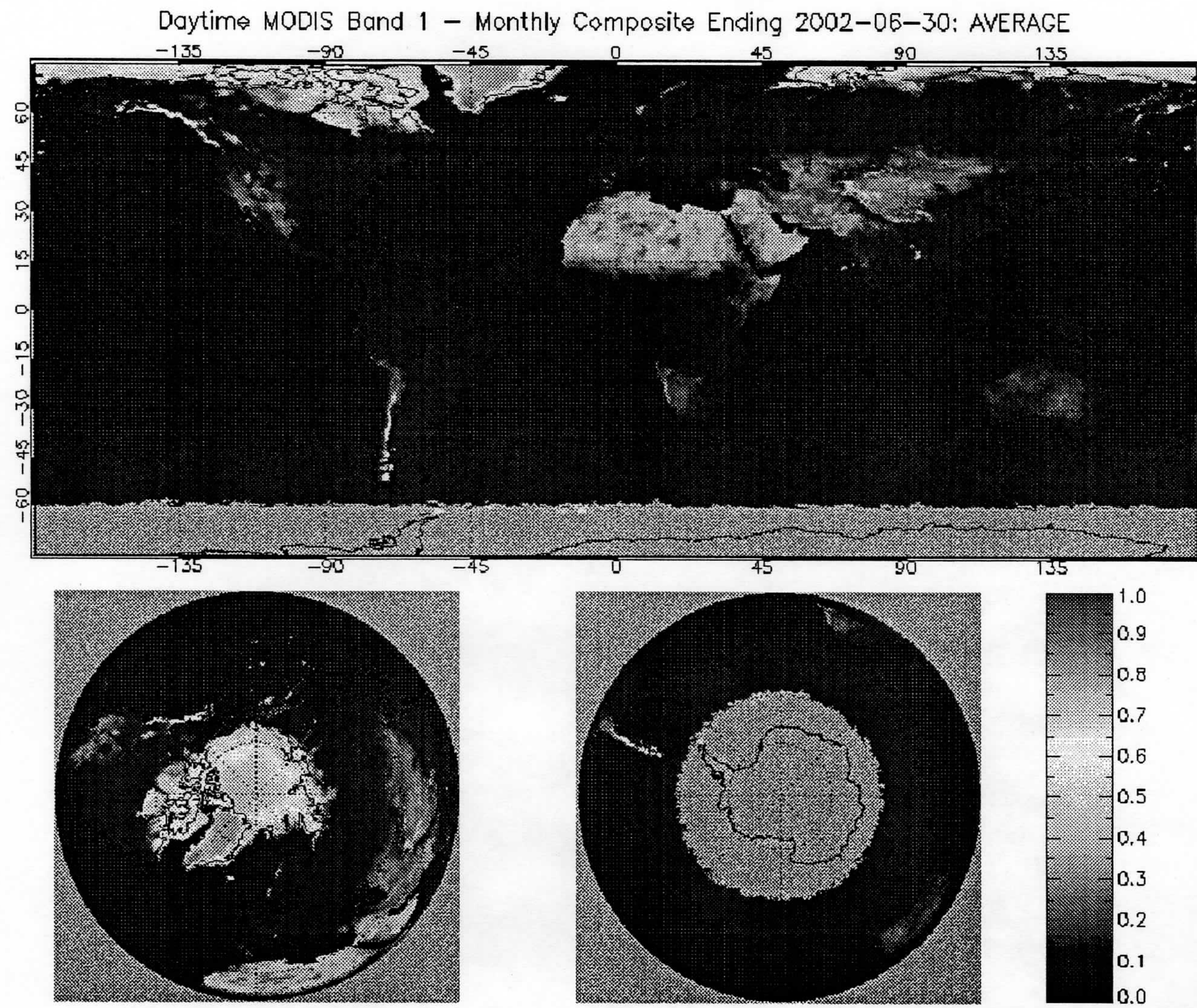

Figure KIS2a. Global clear sky reflectance composite for the month of June, 2002 for MODIS band 1 (.66 micron.) The reflectance values were stored and averaged based upon a designation of clear by the MODIS cloud mask (MOD35).

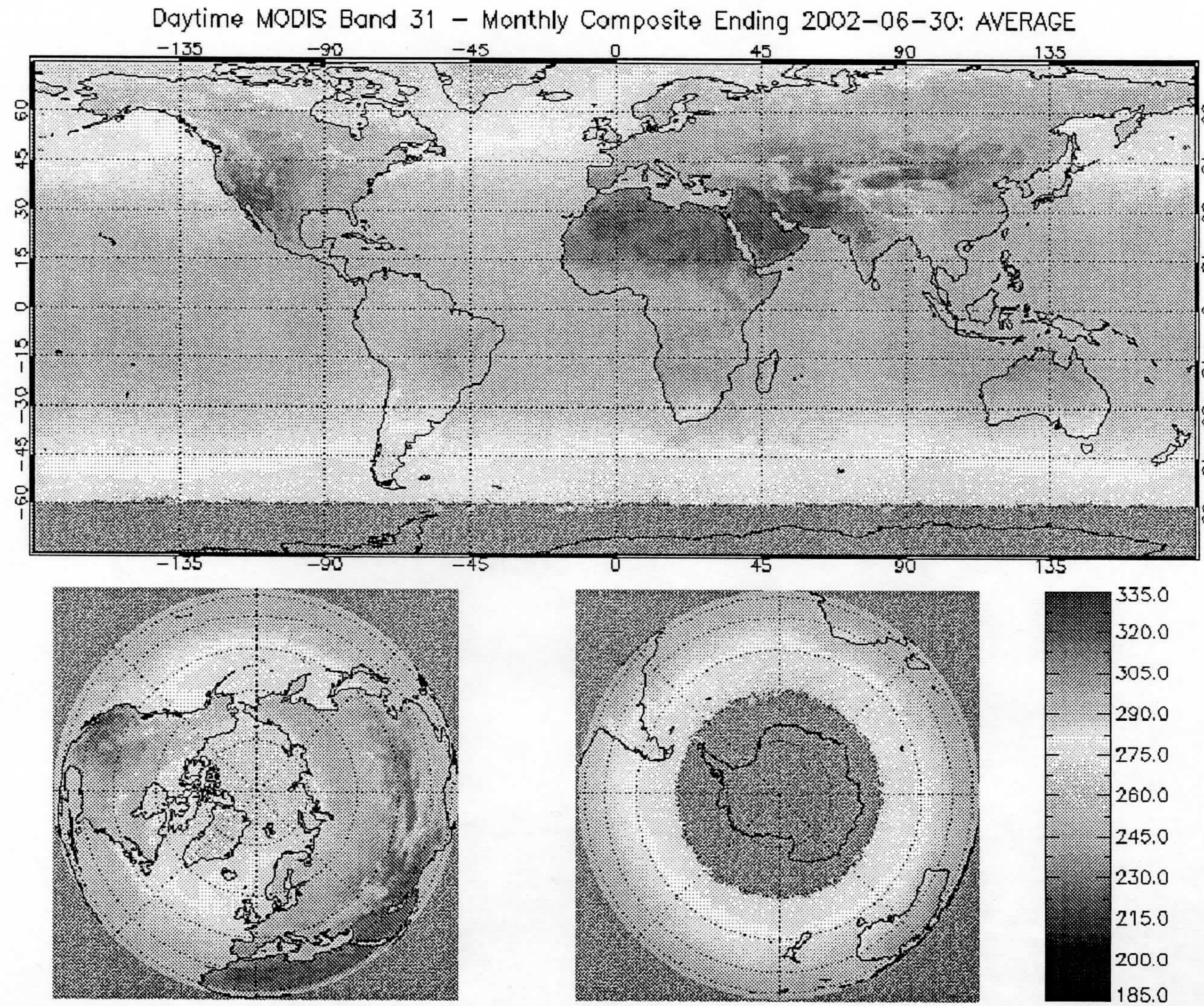

Figure KIS2b. Global clear sky brightness temperature composite for the month of June, 2002 for MODIS band 31 (11 micron). The brightness temperature values were stored and averaged based upon a designation of clear by the MODIS cloud mask (MOD35.)

Clear Sky Reflectance and Brightness Temperature File Generation

Global composites of clear sky reflectance and brightness temperature are being created for eight MODIS spectral bands based upon cloud mask data. Clear sky statistics files are created as part of the MOD35 cloud mask executable at 25 km resolution. The files store the average reflectance or brightness temperature of clear sky as determined by the cloud mask, the sum, maximum, minimum and total number of observations for each grid box within the granule. The files are routinely copied from the DAAC to UW via subscription. An automated process has been put in place which composites the files on a daily, eight day and monthly basis. Bands 1 (.66 micron), 6 (1.6 micron), 26 (1.38 micron), 31 (11 micon) and bands 33-36 (four CO_2 13 micron bands) were initially selected for testing the clear sky compositing routines.

The creation of these files is expected to serve serveral purposes:

1) They are a cloud mask validation tool. They help to quickly identify regions where the cloud mask is not performing optimally. For instance, if the Band 31 minimum image shows anomalously cold values in a region, it is likely that there is cloud contamination.
2) They can serve as a background reflectance and brightness temperature tool. This will aid in the detection of shadows and cloud detection in regions of persistent overcast. Reflectance and brightness temperatures can be compared with those of the clear sky composites.
3) The 13 micron band composites can be used as bias corrections for the cloud top property retrievals of MOD06.
4) Reflectance and temperature properties of the earth and atmosphere can be monitored. These files will help in tracking changes in the surface and atmospheric characteristics from season to season and year to year.

A preliminary web page has been created which displays loops of the latest 8 day and monthly composites. The URL is: http://cimss.ssec.wisc.edu/modis/csr8day/. An example of a monthly composite of band 1 (.66 micron) and band 31 (11 micron) is displayed in Figures KIS2a and KIS2b.

Nighttime MODIS Cloud Mask Statistics

Cloud mask statistics are being generated on MODIS direct broadcast nighttime passes with a goal of improving the nighttime cloud mask algorithm. Relationships between individual spectral tests results within the cloud mask algorithm as well as between individual tests and the resultant cloud mask category are being collected and studied.

One area of concern with the nighttime algorithm is that it tends to detect too many clouds over the ocean. Initial inspection of the cloud mask statistics indicate a dependence of the nighttime ocean algorithm on the spatial variability test. As Table 1 shows, the spatial variability contributes the most information to a final mask result of "cloudy" or "undecided" over a region in the Gulf of Mexico. The spatial variability test finds cloud 68% of the time. Looking at the remainder of tests, none find cloud more than 18% of the time. This may lead to removal of the spatial variability test in the nighttime ocean algorithm.

Table KIS1. Percentage of time an individual test result finds cloud compared with the final cloud mask category for a 2x2 degree lat/lon box over the Gulf of Mexico. The number is divided by the total number of pixels that a cloud mask has been determined in this region, 185,383.

	Clear	Probably Clear	Undecided	Cloudy
11um Test	0.00	0.00	0.00	0.10
CO2 Test	0.00	0.00	0.00	0.05
H20 Test	0.00	0.00	0.00	0.03
IRDIF Test	0.00	0.00	0.00	0.18
4-11 Test	0.00	0.00	0.00	0.01
Spatial Variability Test	0.00	0.00	0.03	0.65

MEETINGS / CONFERENCES

Chris Moeller attended the AGU Spring 2002 meeting in Washington DC May 28 – 31 and presented a poster titled "Reducing Striping and Near Field Response Influence in the MODIS 1.38 μm Cirrus Detection Band."

Paul Menzel and Steve Ackerman gave a series of lectures on Remote Sensing that featured MODIS data in Rome, Italy from 17 – 26 June 2002 at the invitation of the Italian National Research Center.

Bryan Baum and Hong Zhang attended the International Geoscience and Remote Sensing Symposium (IGARSS) 2002, June 24-28, Toronto Canada.

PAPERS

Moeller, C. C., H. E. Revercomb, S. A. Ackerman, W. P. Menzel, and R. O. Knuteson: Evaluation of MODIS thermal IR band L1B radiances during SAFARI-2000, accepted for the - JGR Special Issue on SAFARI-2000.

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King, M. D., W. P.Menzel, Y. J. Kaufman, D. Tanré, B.-C. Gao, S. Platnick, S. A. Ackerman, L. A. Remer, R. Pincus, and P. A. Hubanks, 2002: "Cloud, Aerosol and Water Vapor Properties from MODIS: Preliminary Results from Terra. Submitted to IEEE Transactions on Geoscience and Remote Sensing, Aqua Special Issue.

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Li, J., Z. Yang, H.-L. Huang, W. P. Menzel, R. A. Frey, and S. A Ackerman, 2002: High spatial resolution surface and cloud type classification from MODIS multi-spectral band measurements. Accepted by Jour. Appl. Meteor.