Atmosphere Discipline Group Meeting
Monday, December 17, 2001
BWI Marriott Hotel

Michael King, Atmosphere Discipline Group Leader, convened the meeting, and outlined the agenda. The first presentations would be on the status of data processing; the next presentations would be on science results, followed by presentations on validation activities. The meeting would wrap up with a discussion of the results of the MODIS Data Processing Review Team.

Data Processing

MODAPS Status

Bill Ridgway summarized MODIS data processing status. Despite initial delays, , the initiative to process / reprocess a consistent year of L2 and above data should be complete by mid-January. Production of L1B ramped up in the September-October 2001 time frame to almost 3x, forcing MODAPS to catch up. This catch up has been difficult, because the data volumes for all products are quite large (for 3x, 2470 GB / day); however, in August the system began to improve, and the forward stream is now close to real time. It is undecided what reprocessing will be undertaken once this goal is complete in January. MODAPS has to augment its SGIs with additional Linux systems, and the new PGEs would need to be revalidated for equivalency with Linux compilers. Distribution issues include downtime of the ordering GUI, limits on large orders, the HDF-EOS format, and software inflexibility. However, subsetting is now available to reduce file sizes, and the atmosphere facility is still subsetting some data and sending them out, although ftp is not working perfectly.

MODIS Data Processing Review Team

Vince Salomonson, MODIS Team Leader, summarized the results of the MDPRT. The review was initiated in response to a sense that the community was disappointed with the availability of products, and that more was expected from us than we were providing, including validated as opposed to provisional data products.

He convened an internal Tiger Team that fed a report to the MODIS Data Processing Review Team (MDPRT). The recommendations of the team recognized the great effort already made, but they did have suggestions:

- Produce a reduced-resolution, interdisciplinary core data set of not more than 10 products at a common space-time grid to promote a wider use of data by the community,
- Minimize complexity of interface between MODAPS and DAAC,
- Identify a person to work with the Team Leader to conduct an end-to-end analysis of the systems and to ensure discipline within the system.

- Produce core products only for Aqua until Terra products are stabilized.
- Guard against requirements creep, review carefully all new requirements and thoroughly test code changes.

Salomonson suggested that the discipline teams think about the common grid data file. Yoram Kaufman wondered if it was 10 parameters or 10 products, and felt that there needed to be a limit on parameters as well to achieve the simplicity recommended by the MDPRT. He also suggested that perhaps we should solicit input from the community. Salomonson said that if the science team could agree, then we could get an external panel to "bless" it for us, and if they could not agree, a panel could perhaps help resolve any issues.

Steve Platnick commented that the Team should be proud of what it has already accomplished. King agreed, noting that other instruments don't even have a calibrated sensor. Terra initiated this terminology in an effort to be scientifically honest, and it is being used against us. Further it is confounding to be pushed for validated products when funding for validation activities isn't being made available.

PGE Status

Rich Hucek presented on current PGE framework and the status of Aqua PGEs. All code delivered for the Consistent Year underwent some degree of modification, with the exception of the cloud mask. Changes included both science and metadata, and also to make the code Linux or Aqua compatible. Several updates are planned after the end of the Consistent Year:

- Cloud mask. Improvements of shallow water identification, and better use of Band 2 saturated data.
- Cirrus detection. Improvements for water vapor transmittance above cirrus using a single slope approach.
- Aerosol product. Improvements to eliminate cirrus over ocean and other things. A second update will handle dust non-sphericity better.
- Atmospheric profiles. Updates for regression coefficients and Aqua compatibility.
- Cloud properties. Updates expected.

With respect to Aqua processing, metadata is in place, and there will be a single code version for both instruments, and University of Wisconsin is developing this. Delivery is expected in the first week of February 2002. A dry run test of 8 hours of processing was successful and products were inserted at the DAAC.

There is work underway to port all L2 code to Linux. The Science Data Support Team (SDST) has asked the Science Computing Facilities to have PGEs Linux-ready by the end of January. Hucek says that SDST has offered the use of their Linux boxes for testing for those who do not have their own machines.

Cloud Mask

Code Improvements

Chris Moeller presented on the status of the MODIS instrument and impacts to the cloud mask. Among the major issues were striping and elevated background signal in Band 26 (1.38 μm), SWIR electronic cross-talk, and thermal IR band striping. Their correction for Band 26 striping uses Band 5 to correct the striping, using detector-specific corrections, and it greatly improves the sensitivity, reducing the threshold for confident cloud detection to about 0.01, whereas before it was about .035.

The striping in the long-wave IR is irregular in along- and cross-track directions and is more difficult to correct than the regular striping in Band 26. He thinks it is noisy detectors. Band 35 has regular striping probably due to mirror side effects, and detector normalization will probably be successful. Liam Gumley developed a detector-dependent, empirical correction that removes 70-80%, but the last percentage will be very difficult to remove. In addition, the corrections are time dependent—the ones for June 2001 do not work for December 2000. He expects similar problems on Aqua, but there is no proof of that yet. King said it might be good to have the MODIS Characterization Support team incorporate these corrections into the L1B, but Kaufman indicated that if MCST changed the channel, it would require the aerosol group to change its code. They have found the ratio of Band 26: Band 5 to be a useful way to distinguish cirrus and non-cirrus; there is a definite threshold at 0.03.

Previously, the thermal infrared water vapor retrieval had too much water over deserts, due to high reflectance in some shortwave channels. They are now using differences in signals instead of absolute values. Compared to AMSU these corrections seem to be working well. Values are still a little too moist as compared to CART sites, but the major problem is fixed.

Many of the issues raised at the cloud mask meeting have been addressed. The 250 m cloud mask is much better over ice and deserts. Cloud shadows have not been addressed, and are anticipated to be very difficult. The main goal for spring is working on the nighttime cloud mask.

Science Analysis

Looking at a variable called the spectral greenhouse parameter, Steve Ackerman demonstrated using MODIS data that a general trend is that as SST increases, water vapor and the spectral greenhouse parameter increase. We have never been able to measure the parameter at really warm or really cold temperatures before , but MODIS provides new opportunities. With MODIS, we do see that increases in SST cause increases in the spectral greenhouse parameter, as expected. But at very high SST, the values actually drop. Also at colder regions, the slope of the increase in the parameter is much steeper than at other temperatures. An interesting feature is that at high temperature, the cloud mask classification of “uncertain” is more like clear sky, and at cold temperatures, it is more like cloudy.

Science Analysis of MODIS Data

Surface Albedos and Distribution of Global Ecosystem Types

Eric Moody presented the use of ecosystem classifications and MODIS-derived surface albedos in the retrievals of cloud optical properties. The original approach used IGBP land cover classification as a surrogate for albedo. There were three main issues with those data: they were broad-banded, they lacked seasonal variation, and they were coarse resolution. They have adapted the retrievals to use MODIS ecosystem classification and the white sky albedo at specific wavelengths. As those data sets become more complete, the cloud product should improve as well.

This approach is valid if we see expected northern and southern hemisphere differences, if we have sufficient samples for each ecosystem type, and ecosystem and albedo correlate. Moody computed statistics for albedos at different wavelengths at various latitude belts, and initial results were good.
A model was developed that had latitude belt for north and south (30° and above), a tropical region that doesn't change seasonally, and a transition region. One point of discussion was whether open shrublands should be grouped as savannas in the ecosystem classification scheme, and that may not be optimal.

Their analysis of the applied model shows that albedo means for different wavelengths and seasons are within 7%, which is good. The results show that they can improve spatial and temporal resolution by using the MODIS ecosystem classification and albedos, and that when necessary they can use ecosystem classification as a surrogate for albedo. In the future, they plan to use the full year of data to improve albedo and ecosystem, work on global albedo maps, and continue working on "ecosystem as albedo" surrogate. Moody cautioned against using this in a real-time manner because the approach uses a L3 land product, which often lags our L2 production. Moody indicated noise analysis hadn't been conducted yet, and will be difficult as no real comparison data sets exist.

Atmospheric Correction of MODIS Visible and SWIR Bands: Applications to Cloud Optical Property Retrievals

Jason Li talked about correction of the visible and shortwave infrared bands for transmission and thermal effects. The determination of optical thickness and effective radius is an inverse problem. If these are known, you can predict what an observer of the cloud might see with respect to radiances, but we have the inverse--we have the radiance observation, and want to know the parameters of the cloud.

Reflectance of a nonabsorbing band is a function of optical thickness, but of an absorbing band is primarily a function of effective radius. The MODIS cloud detection must be corrected for the atmospheric conditions between MODIS and

the cloud, with the observed values being less than the actual cloud reflectance because of attenuation by the atmosphere. Most of the absorption is by water vapor, and some by CO_2 and ozone. For their correction, they parameterize the water vapor from the cloud top to the top of the atmosphere (TOA). We also include moisture-weighted, mean column air temperature from cloud top to the TOA and surface temperature.

They also need two-way transmittance, and to get from one-way transmittance to two-way, they say that two-way is equivalent to one-way at a slant path-adjusted angle. Uncertainties include refraction, the fact that they are not using 3-D geometry (they take a vertical profile and scale accordingly), and variations in the structures of moisture profiles.

Li summarized a case study from off the coast of Peru that they used to test their approach. The region included ocean, a narrow strip of grass, and an evergreen forest. Low-level clouds were detected over ocean, and over land there were some high clouds. The uncorrected algorithm showed no difference in clouds over land, while the corrected showed various levels of cloud. Also, there was only a few µm difference between the effective radius retrieved over land versus ocean. Optical thickness and effective radius correlate well.

One important point is that using NCEP model input versus DAO for precipitable water and temperature produces very different results, and users should be aware of this. Gao suggested that another approach to correction would be to use the ratio of MODIS bands 0.94 to 0.86µm.

Improvements to MODIS Near-IR Water Vapor and Cirrus Algorithms

Bo-Cai Gao presented on improvements to MODIS Near IR water vapor product. The algorithms use the 0.94, 0.86 and 1.2 µm channels. Gao began with examples of regional water vapor over Spain and Morocco, which exhibited the expected trend: moving from the interior toward the coast, water vapor increases. Last year, they reported a 20% upward bias in water vapor, which they suspected was due to incorrect line parameters being compiled on HITRAN 96. That suspicion was confirmed when in early spring of this year, the new HITRAN code was released, and it included an increase of about 20%. Gao reported that validation from December 2000 using microradiometers showed reasonable results. However, Rich Ferarre thinks the values are still 10% high compared to ARM sites.

Gao showed several examples of global water vapor images from 2000; these global images show good results that are consistent with seasonal global trends. For example, in January, water vapor is low over America, and higher over the southern hemisphere. In July, it is higher over the U.S. and sub-Saharan Africa. In Asia, there is a sharp water vapor boundary between wetter India and the drier Tibetan plateau.

Several examples of cirrus detection indicate that the 1.38-µm channel detects well even when clouds are sub-visible, such as over the Antarctic. Scatter plots of 0.66 versus 1.38 µm for sub-setted images show a slope around 0.5-0.7. They use that slope to determine the absorption above the cirrus cloud and then interpolate for detection in the 1.38-µm channel. The approach divides the apparent 1.38-µm radiance by the slope of the scatter plot. To do this, they assume that at 1.38 µm they do not see any surface reflectance. Comparison of MODIS to CERES albedo shows that there are certain cloud types that are not being seen, which may be because MODIS is only seeing the top of stratus clouds not the bottom.

Gao reported that to improve separation of dust versus cirrus, they have used an approach based on height in the atmosphere of each. Cirrus is around 8 km; dust is 3 or 4 km. Plotting apparent reflectance as a function of wavelength, and looking at the ratio of 1.38 µm and 1.24 µm can improve aerosol greatly.

Correlative Measurements of Use in Data Validation

Cloud Property Comparisons with ARM Data

Gerald Mace presented validation activities for the cloud property product using comparisons with ARM Data. His team worked with four ARM sites: one in Oklahoma, two sites in the tropical western pacific, and one in Alaska. They have a cloud radar as the centerpiece and other remote sensing devices. These devices run continuously. Monthly cloud fractions from each site are available for many months. They have developed a WWW browse utility that allows users to grab ARM data that correspond to Terra overpasses. You can select a day and get information on various parameters, like reflectivity, cloud conditions, and histograms of MOD06 cloud properties. You can also get digital files in a common time grid.

Mace summarized several case studies. November 30, 2000, was a cirrus cloud event. Thin cirrus is not captured as well, but visible clouds performed well. Comparisons of reflectivity and radiance from MODIS and the radar showed that ice-water path, size, and optical depth all compare reasonably well. A case from March 22, 2001, showed that a lot of thin cirrus is being excluded from the algorithm due to issues with the cloud mask. Ice water path measurements correlate well, but effective radius was not as good in this case as the November case. Optical depth is high on MODIS compared to radar. In many cases, optical depth is being retrieved very well, but there are definitely some outliers in which MODIS is much higher than radar. Regional cloud property comparison (using a 250-km box) shows much larger radius measurements from MODIS compared to the radar.

Mace reported that they will be using MODIS Aqua cloud mask on CloudSat, and that they will be submitting all data to the DAAC at the end of March 2002, when the project ends.

King recommended they be careful when they move on to Alaska data because the team introduced a correction that dealt with a big problem with arctic cloud retrievals. Platnick asked that Mace inform them which version of the cloud mask was being used for the case studies.

Ground-based Arctic Cloud Properties for Comparisons to CERES, MODIS, and MISR

Paquita Zuidema from NOAA Environmental Technology Laboratory presented validation activities in the Arctic and described the data sets that are available for comparisons. The group is collecting a multi-year data set with cloud radar, microwave radiometer, and IR spectral radiometer. They have developed good GUIs to allow classification by subjective assessment and cloud microphysics. Arctic data often show low-level liquid clouds. Two liquid water retrievals have been developed: simple regression, and one that uses liquid water path to constrain the regression. Regressions are in line with aircraft data. Ice cloud retrievals use a simple regression approach and another approach that uses infrared radiometer data. A new one is being developed that uses reflectivity and velocity.

Recent work includes using explicit microphysics to come up with top of the atmosphere and surface cloud forcings and net heating rates in the atmosphere. Taniel Uttal is thinking of constructing a radar proxy of the lidar backscatter cross section with cumulative optical depth from top to bottom to correlate better with satellite. On the to-do list, they plan to add net cdf files and gifs to the data available via their web site, and comparison of their results with Mace's. They also want to expand to SGP and TWP sites, as well as some use of aircraft data. They have not conducted any MODIS comparisons to date, but they are very interested in making the data set more satellite friendly.

MODIS Aerosol and Water Vapor Validation using ARM SGP data

Lorraine Remer gave a talk in place of Dave Whiteman and Rich Ferrare on validation of aerosol optical thickness (AOT) and water vapor using ARM SGP sites using data from March 2000 through September 2001. They take a radius of 25 km around the site and average that to use in their comparisons.

Aerosol optical thickness (AOT) at the CART site is generally low. The comparisons show good general agreement at 470 nm, with an upward bias that is still within MODIS uncertainty, but comparisons are not as good at 660 nm. The lidar and Cimel AOT agree well, and can be confidently used for comparisons. They can't use CARL data alone without Cimel to validate MODIS because of extrapolation at short wavelengths. Plots of absolute differences of retrievals as a function of date showed a drop in the differences approaching October, giving the impression that things had settled down, but then they began to deviate again and settle down again. The relative differences decrease with

increasing optical thickness. As one would expect, MODIS retrieves more poorly at low signal levels.

With respect to water vapor, MODIS was compared to CARL profiles and radiometer data. There seems to be a great improvement with time in the near-IR product. The bias has decreased significantly starting in November 2000. MODIS water vapor is about 5-15% higher than SGP MWR and Cimel. Lidar compares better than AERONET with respect to water vapor. Daytime retrievals are better than night. MODIS is about 2 mm wetter than CARL. Results from CARL show diurnal variability: higher extinction concentrated over smaller vertical extent at night. Water vapor has less diurnal change than aerosol.

Finally, there is an experiment planned for looking at diffuse flux closures, CCN relationships at surface and cloud base, and also to investigate how the aerosol humidification factor varies with altitude. Ferrare thinks this will be a good validation activity for Terra and Aqua.

In summary, the low range of AOT available at the SGP site hampers full validation. MODIS at 470 nm is 30-40% higher for all AOT, but only 10-20% higher for AOT greater than 0.1. AOT at 660 nm is not well correlated to SGP for low AOT. Neither band shows a temporal trend. Comparisons show that results generally fall within uncertainties. For water vapor, bias dropped from 30-40% to 10% after November 1, and day time retrievals are better than night.

CLAMS: Chesapeake Lighthouse and Aircraft Measurements for Satellites

Remer summarized the results of CLAMS. There were five aircraft involved, but no lidar data because the CPL on the ER-2 aircraft didn't work. Originally intended to be a validation experiment, the mission became more of a developmental experiment. The MODIS aerosol group was interested in using the experiment to develop new algorithms and improvements, looking at issues such as light absorption, glint mask, aerosol retrieval over sun glint, spatial variability, and water vapor.

Among the most important outcomes for them was the testing of what they are calling the COBRA concept, which involves using data from the glint area of a scan to measure aerosol absorption effects and from non-glint areas for scattering effects. The CLAMS geometry allowed for collection of tracks that encompassed both glint and non-glint areas, and these were overlapped to get retrievals. The University of Washington's CV-580 creates a vertical profile and measures a scattering coefficient for each of four layers having different scattering and absorption properties.

They also hoped to re-examine how the present algorithm handles glint. They are missing a good portion of ocean retrieval because of the static glint mask that cuts off at 40° angles. Remer summarized a preliminary approach to creating a dynamic glint mask.

Charles Gatebe also presented his work during CLAMS for cloud optical property retrieval validation, particularly for validation of radiometry of the Cloud Absorption Radiometer (CAR). The CAR has 14 spectral bands ranging from 0.34 to 2.29 μm. There are nine channels at 16 bits, and it has a 3% calibration accuracy. They took BRDF measurements at a variety of places, including the Great Dismal Swamp and several buoys. They got several days of good BRDF: July 10^{th}, 17^{th}, 23^{rd}, and 26^{th}. Spatial resolution was between 10 and 270 m. They think they will be able to provide very good data on BRDF to the aerosol group over glint area. Looking a pre- and post-CLAMS, the digital counts are very consistent. Their results are very good. They got 40 hours of data, and took measurements for 15 total sites, 8 of which were uncontaminated by cloud. Radiometric calibration is complete and looks good. Angular sensitivity measurements are complete; a signal drop was discovered for large CAR view angles and further investigations are planned. More info is available on the web at car.gsfc.nasa.gov/data_clams.

Dust Characteristics at ACE-Asia Source Regions

Si-Chee Tsay presented his validation work for dust properties near source regions during ACE-Asia. The significance of dust movement and desertification is great. Forty percent of the world's population is in Asia, and 25% are in China. They have only 8% of the world's farmland, however, and current estimates are that 2,460 km^2 of China's land becomes desertified each year.

The data collected were from March 24-May 10, 2001. Dust storms were found to be coincident with cold air outbreaks, with about 35% coming from Siberia, and 45% coming from the northwest. He is most interested in the storms that make their way into the jet stream and reach the U.S. This past year the Taklimakan Desert was very active, with lots of dust transported across the ocean.

Preliminary data analysis showed good correlation between physical observations and models, but the models always have too much Saharan dust in them. Micrographs show dust is predominantly silicates, with clay, carbonate, feldspars, and gypsums. A time series of dust events shows that frequency and severity of events has increased in the last few years. Tsay also reported that they are planning to use cruise data from the Yangzte River to understand radiative forcing from anthropogenic aerosols in the region. He concluded by saying that they have many data sets available for physical meteorology, chemistry, and oceanography studies.

Concluding Discussion

King reported that there is a special issue of *IEEE Transactions on Geoscience and Remote Sensing* for Aqua, and they are expecting two papers from the Atmosphere group. One is a MODIS atmosphere overview, and the second is going to be on the cloud product itself. He may be contacting various team members for input. These are due by April 2. There will be a special issue of *JGR*

on SAFARI 2000 as well, with papers due by March 15. IEEE can't restrict submissions, and anyone can submit.

The group discussed the MODIS Data Processing Review Team recommendation of a reduced-resolution, interdisciplinary set of products that can be produced on a common grid, and can be processed and reprocessed quickly. King said that he could envision a reduced L3 that has a subset of certain SDSs or means like cloud or aerosol. This could be useful to the community in terms of file size, etc. But he didn't feel that the architecture for the product was at all clear. Mark Gray said that he and Ridgway think that what is being requested is highly efficient products. King said he could also see the group doing something like a sub-sample of every 10 km or something.

Ridgway said that we could adapt some L3 PGEs to fit this bill, but the objective was to create something that would slice off certain products that could be produced separately from all the rest. As for the common grid, land may want 5-10 km. King indicated that that resolution doesn't solve the problem of high volumes. If we produce this product set at the end of the chain, that doesn't really solve our problems. Ridgway thought the MDPRT believed that we could sub-sample L1B right away and work from the coarser resolution.

Kaufman thought this was a good idea and that it sounded to him like we would have to come up with our first guess of how we should do it, and then get feedback from the community. Ridgway said that the dual goal of having something that is easy to *use* and easy to *make* might be difficult to achieve. Gray felt that some algorithms—e.g. those that use the 250 m data—would be fundamentally changed by using 1 km only and would require completely different PGEs.

Ridgway added that the last point made in the report was that they thought that prior to any big reprocessing effort, we should undertake a limited production over a spatial or temporal subset so that trends or other science issues would be found with this smaller sample. He felt that the only way to satisfy the core product set requirement is to develop a new PGE that draws on existing algorithms at an early stage. All disciplines would need to develop these new PGEs.

Liam Gumley said that it is really hard to think about doing things differently without ground rules, e.g., a rule that said we would process only in order, or that any algorithms that can't run in ten minutes wouldn't be considered. So we need to come up with some rules or a goal, like we want it to be able to be downloaded in a day. Gumley also said that we could agree to doing the common grid with the other disciplines, but that we want a separate string for all other products. King said we really have a separate string with the atmosphere facility except for the push of L1B. Gatebe suggested that each discipline could do its own reduced set. Gumley asked if it would be good to get some written thoughts on the MDPRT's recommendations, and King said it would and encouraged the group to prepare any thoughts or ideas on the matter.

King reminded the group that in January there will be another Terra data products review at NASA HQ, and they are very interested in when products will be validated. Platnick said that he thinks the whole use of the *validated* terminology is a legacy with which we will burden heritage missions. He thinks the whole terminology has little use.