# Atmosphere Discipline Workshop
# Monday, July 22, 2002
# Greenbelt Marriott Hotel

**Status of IR Calibration of Aqua**

Chris Moeller began by saying that Aqua MODIS is definitely an improved instrument over Terra MODIS. The performance issue on Band 26 in Terra MODIS (which will be corrected in Collection 4) is not an issue on Aqua MODIS. The S/MWIR electronic cross-talk ongoing issue on Terra MODIS has been improved, but not eliminated, on Aqua MODIS. The PC LWIR band optical leak that was corrected in L1B of Terra was fixed during Aqua's pre-launch. The detector striping that exists in several of Terra's thermal bands has been improved on Aqua. The thermal leak that was effectively corrected on Terra will have an improved correction on Aqua (to be delivered). The SWIR band sub-sample departure on Terra is not correctable on-orbit, but is much improved on Aqua. Noisy detectors on Terra have been much improved on Aqua. The saturation in Band 2 in Terra is slightly worse on Aqua (because of a lower saturation level). The Scan Mirror reflectance vs. angle of incidence ongoing issue on Terra has been much improved on Aqua (with good pre-launch characterization). Meanwhile, there are no dead detectors on Terra, but Band 6 on Aqua is dead, and Band 5 has one dead detector.

Aqua is currently using pre-launch calibration, but they will be updated with on-orbit calibration in an upcoming LUT. Co-registration between focal planes seems stable, and the cold-to-warm focal plane offset is about 0.3 km. The pre-launch calibration on Bands 31 and 32 is essentially invalid, so they are proceeding with linear calibration until the LUT is updated. The cold-to-warm focal planes are affected; there are tiny differences in data that vary with the instrument's temperature. Warm is registered to within 1 km, cold to within 0.1km.

Moeller showed pictures of Band 26 electronic crosstalk, noting that only some detectors seem to be affected on this band. Band 5 has a little bit of the same thing, but less on Aqua than on Terra. Band 7 also shows shadows on Terra, but looks very clean on Aqua. The differences are showing at very high contrast scenes, such as Baja California. Band 26 seems to look better on Terra than on Aqua, but they will be able to apply a correction. Bands 20 and 22 show similar features. The cross track fields of view are creating the electronic crosstalk.

Looking at the Moon allows one to see the PC LWIR Optical Leak's spatial effects. Moeller showed an image of Baja California that shows Band 31 leaking into Band 35 and noted that the effect is more pronounced on Terra than it is on Aqua. He said that they haven't applied any correction to the Aqua data, and they think that the problem has been gotten rid of.

The MODIS Scan Mirror RVS shows much improved characterization on Aqua. The symmetry on Terra's mirror is not bad, but is spot-on on Aqua (Band 35). Terra's Band 36 is having a problem, but on Aqua is fine. Moeller said that this is proof that Aqua's scan mirror has been characterized very well.

There is no significant improvement of Aqua MODIS' Band 26 performance. There is a lot of striping in Aqua's data, and there is not a whole lot of difference when compared to Terra. To remove the problem on Terra, they corrected it by using the Average Clear Sky Reflectance with the clouds removed. After the correction, they can make the continents go away, and Moeller thinks that they can make the same thing happen with Aqua.

Moeller said that they don't expect any improvement on Aqua's Band 6. They are starting to think about surrogate bands. Eleven out of Aqua's 20 detectors are dead, so they don't expect to get much out of the band.

Striping has been reduced on Aqua; Band 33 is cleaner, and while Band 34 on Terra has some noise that they are having trouble removing, it looks great on Aqua. Band 35's mirror side striping is much less on Aqua than on Terra. Detector 6 has a lot of striping on Terra, and while there is none on Aqua, there is a lot of noise. The severe striping and noise on Terra's Band 27 were reduced on Aqua, and the same for Band 28. Band 29 shows striping on both Aqua and Terra. Ultimately, Bands 31 and 32 will be very similar on Terra and Aqua.

The SWIR band sub-sample performance is much improved; Aqua and Terra have only a couple of count differences.

**New TPW Algorithm**

Dr. Paul Menzel began by showing a graph of Earth emitted spectra overlaid on Planck function envelopes. He then showed the equation for Total Water Vapor Retrieval as inferred from MODIS IR Radiances and noted the necessity for a radiative transfer model calculation of MODIS IR radiances.

Dr. Menzel reported that the UW group has been working on mitigating problems in the MODIS TPW algorithm. They have changed predictors for Bands 24 and 25 brightness temperatures to their BT difference to remove surface effects; the old algorithm had 12 predictors, whereas the new algorithm has 11. They have separated training into seven regression BT zones to include a broader range of moisture regimes, and they have implemented global radiance bias corrections. They have also applied post-launch NEdT in place of pre-launch. The new algorithm was submitted in the first quarter of this year.

Dr. Menzel showed a visual of the average brightness temperatures for MODIS Bands 24, 25, 27-29 and 31-36 from 60 clear sky cases at the ARM-CART site from April 2001 to June 2002. Radiance calculations show significant radiance biases, though most are not that large. Global characterization of the biases was accomplished for four days in June 2001. They are separated into twelve groups with six latitude zones each for both land and ocean. The bias values may vary seasonally so the June bias corrections may need to be updated. Dr. Menzel said that MODIS is within 3.5 mm of "truth" globally day and night.

Dr. Menzel showed a number of comparisons of MODIS TPW to other instruments. The comparison between GOES (8 & 10 combined) and MODIS (regression and physical) demonstrated that MODIS is giving better coverage. Dr. Menzel noted that the direct broadcast package will be capable of performing physical (in addition to regression based) retrievals. The comparison between MODIS and SSM/I showed that MODIS is doing better at detecting moisture over land, though there are holes due to clouds. The comparison between MODIS and TOMS total column O3 showed that there are differences, but the MODIS product is good for atmosphere corrections. Dr. Menzel said that the absolute values are within 30 Dobson units of the "truth."

In conclusion, Dr. Menzel said that a lot of good work has been done, and that the MODIS TPW is a good product. The worst conditions are dry and Polar Regions, but they are working on that. The goal for the product is 2.5 mm rms.

**Possibilities for Detecting Cloud Overlap**

Dr. Bryan Baum explained that cloud shadows cause problems for land surface algorithms by reducing mean clear-sky radiance/reflectance values by up to an order of magnitude and cause retrieval errors over clear-sky lands. His group is using clear sky reflectance maps to filter clear sky pixels that contain cloud shadows, and they are also trying to improve subsequent clear-sky reflectance maps. He noted that they are not trying to detect cloud shadows on clouds themselves, only on land surfaces.

Their algorithm reduces reflectance at cloud shadow pixels, lowers reflectance values for shadow pixels in comparison to clear-sky values, and raises the possibility of using a clear-sky map as a database for detecting areas with reduced reflectance. They do a pixel-by-pixel comparison that is in essence a simple threshold algorithm. The algorithm seems to be able to discriminate between shadow pixels and clear sky very well. Dr. Baum showed an example of Mauritania that has very high reflectance levels, and using the algorithm, shadows came out very well in the image. He said that they are getting most of the shadows, but not all due to some problematic areas. This algorithm is very helpful when combined with cloud-mask. The technique is very straightforward, and can pick up some effective shadows even when most of the area is covered by clouds. It is also able to pick up cloud shadows when the clouds aren't visible.

In conclusion, Dr. Baum said that their initial attempt to detect cloud shadows by comparing images with clear-sky composites is encouraging. Some problems are the spatial resolution of the clear-sky map, setting the threshold, the land-water mask, and the cloud mask. Dr. Baum said that they will make some improvements to the algorithm, such as ensuring that shadows are next to clouds and finding missing cloud shadows by pixel walking.

**Progress in Detecting Cloud Shadows**

Dr. Bryan Baum explained that the big picture is that there are places on Earth where super-cooled waters occur in both the day and the night, and he and the team think that the data from those places is actually false because of overlapped clouds. Their technique worked on the assumption that there are at most two cloud layers in the data array. For a 200x200 pixel (1km), they would identify clear pixels from the MODIS cloud mask; identify unambiguous ice and water pixels from 8.5- and 11-µm bispectral cloud phase technique; classify unambiguous ice and water pixels as belonging to the higher or lower cloud layer; and classify the remaining pixels as overlap. Because they could only go through the data one pixel at a time, they decided to come up with this approach.

Now they are starting to stagger the arrays so that the pixels get analyzed more than once, up to 4 times, and are starting to get coding of pixels towards the edges of scenes, which gives more surety. When they go over the pixels with even more passes, they get higher and higher resolutions and can get a bitmap image of potential overlap. Dr. Baum noted that the algorithm has not yet been coded into Fortran, and is currently based on a Matlab COTS product. Dr. Baum said that they plan on applying the algorithm to daytime MODIS direct broadcast data for both Terra and Aqua, and once the method becomes more settled, it will be adapted for an operational environment.

**Comparison Between MODIS C02-slicing and MISR Stereo Cloud-Top Heights Over the British Isles**

Dr. Catherine Naud said that she and her group want to understand what biases and artefacts exist in the MISR 2TC Stereo and MODIS MOD06 CO2-Slicing Cloud Top Heights (CTH). They studied two different scenes over the British Isles on April 1 and March 3, 2001.

Because MISR and MODIS data are given at different resolutions, they projected MISR CTHs on the MODIS latitude and longitude grid to allow for pixel-by-pixel comparison. For April 1, 2001, the difference between the two on a pixel-by-pixel basis shows that MISR CTHs are higher in the northeast corner of the scene, while MODIS CO2-slicing CTHs are higher in the southwest. Dr. Naud said that they ignored low clouds because they may not actually be clouds, but rather may be high land. She said that the difference between MISR and MODIS CTH is not correlated to the spectral bands used for MODIS $CO_2$ slicing. In the northeast area, the MISR CTH retrieval detects much more clouds than does MODIS cloud mask (with a 99% certainty of clear areas). She speculated that the differences may be due to thin clouds not detected by MODIS. In the southwest areas, she suggested that the differences are due to MISR not detecting the highest cloud in a multilayer cloud situation. She added that the May 3, 2001 case shows a better agreement between the two instruments, though there are still areas with big differences similar to April 1, 2001.

In conclusion, Dr. Naud said that MISR CTH is greater than MODIS CTH usually for high thin clouds, and it may be that MISR is more sensitive to low optical depths. Where MODIS CTH is greater than MISR CTH, they found that MISR does not refer to high clouds in multi-layer cloud conditions, because there are contrast problem between the AF/AA and AN MISR cameras currently used in the algorithm and also the MISR stereo retrieval algorithm has been tuned to detect the reflecting layer reference altitude, i.e. it gives the CTH of the brightest layer. She said that future work will include investigating the possibility of using these discrepancies to detect multilevel cloud cases, quantifying the limit of MISR and MODIS sensitivity to thin clouds, testing performance using a new UCL matcher (M4) and assessing whether CF/DF (off nadir) cameras improve MISR CTH retrieval for multi-layer conditions.

**Aerosol and Cirrus**

Dr. Vanderlei Martins said that he and the team recognized the need for a cloud mask for aerosol retrievals over the Ocean using MOD36. They have produced an operational aerosol cloud-mask over the ocean, and will introduce improvements in next version. The mask is affected by spatial variability. They throw away the 25 % darkest and brightest pixels for every 10x10 km selection to get rid of contamination without biasing the average. There are a couple of papers coming out that will discuss results of studies.

While comparing land and water images, Dr. Vanderlei explained that the mask separates clouds very well, though the separation for cirrus is not as good. They have also found much more variability over land. Cloud contamination would cause them to lose several cases of aerosol retrieval. He noted that spatial variability for clouds makes no difference, but for aerosols there is a better separation between 1km and 500m resolutions. They chose a threshold that allows the highest retrievals of aerosols and is a good separation from clouds. They are also able to check cloud mass as a function of aerosol radius.

In the next delivery, there will be some changes to fix leftover cloud contamination, and they will start using the 1.38-µm channel to better identify cirrus clouds. The will start using a sediment mask and will introduce a high visible threshold to distinguish thick clouds from dust. They will be better able to process cloud edges and neighbor pixels using a spatial variability of 3x3 km and moving the box every 500 m. They will be able to recall high AOT dust cases with high spatial variability or slight cloud contamination by using a ratio of 0.47/0.66 <-0.75. Dr. Martins noted that sometimes the 1km resolution is better than the 500 m resolution for separation, but it also loses some cases. Faster processing treats cloud edges randomly and screens out more cloud-free pixels (1.5 km boxes). However, the 500 km processing time not overwhelming, treats cloud edges adequately, and throws away fewer cases. Sun glint would cause high uncertainty levels, but retrievals using very thick aerosols give more data. The surface effect is minimized for high optical thickness.

**NPP Status**

Dr. Robert Murphy began by explaining that NPP is a “bridging mission” that provides for the continuation of measurement series initiated with EOS Terra and Aqua for NASA’s global change research, specifically in climate change, the global carbon cycle, and the global water cycle. Further, NPP provides risk-reduction for the NPOESS mission, which will continue those measurements into the indefinite future, and that NPP is a joint program of NASA and the Integrated Program Office (IPO). The mission of NPOESS is fourfold: to provide a national, operational, polar-orbiting environmental capability; to achieve National Performance Review savings by converging DoD and NOAA polar satellite programs; to incorporate new technologies from NASA and others; and to incorporate, where appropriate, international cooperation, specifically from EUMETSAT.

Near the nominal end of the EOS/Terra mission (~2006), there will be a gap until the start of NPOESS, which will be filled by NPP. NPP will include the VIIRS, CRiS, and ATMS sensors, plus perhaps one or two instruments of opportunity. He briefly explained the individual products and which channels will provide them. Dr. Murphy explained what led to the design of VIIRS (and its similarity to MODIS) as well as that the purpose of VIIRS is to gather global observations of land, ocean, and atmosphere parameters at high temporal resolution (daily). He noted it uses a rotating telescope design similar to SeaWiFS, and that new baffling has been added around the blackbody and behind the telescope to reduce stray light. VIIRS will have 22 bands, two nested spatial resolutions, and 8 or 16 detectors per scan. Some bands will have dual gain and all will have constrained pixel growth with increasing scan angle. There have been some recent design changes - the new baffling will minimize stray light much better than MODIS and SeaWiFS, the solar diffuser (SD) and solar diffuser stability monitor (SDSM) will be evolutionary from MODIS, and they are planning to use 2$^{nd}$ order calibration polynomials for all bands. The V-groove blackbody (BB) and the characterization testing will be similar to MODIS. Some issues that Dr. Murphy highlighted are the vendor's difficulties with active fire characterization for very large or hot fires; the 645 nm band was recently widened to 80 nm to accommodate greater dynamic range (avoid saturated pixels for the imagery product); the 751 nm band center wavelength was changed to 746 nm, the NASA geolocation requirements (200 m at 3 sigma) are not an IPO requirement; and consideration is being given to adding a 6.7 micron band for water vapor for FM3 and beyond.

Dr. Murphy said that the NRA for an initial science team to evaluate the vendor's science algorithms is expected soon, and a second science team selection to develop/enhance products will be made closer to the launch of NPP.

**Observations of Three-Dimensional Radiative Effects in MODIS Cloud Optical Thickness Retrievals**

Dr. Alexander Marshak began with an explanation of 3D radiative effects. He said that they have to take into account the effects of neighboring pixels and sub-pixels variability on the retrieval errors. He pointed out that at high resolutions, diffusion smoothes the images. They can estimate where a scale break actually happens; it depends on cloud thickness and can range from a few hundred meters to a kilometer. For oblique sun angles, the clouds appear too thick and the forward reflection is too low.

Dr. Marshak explained that 3D effects are studied using theoretical simulation of horizontally inhomogeneous clouds and application of 3D radiative transfer; statistical analyses of satellite data and products; and using a combination of both. His group has been using all three methods.

Their use of “realistic” stochastic cloud models in theoretical simulations allows them to estimate the distribution and uncertainty of retrieval. This leads them to the question of how often 3D effects influence MODIS cloud products (optical thickness, particle effective radius, and cloud water path). Comparing optical thicknesses of illuminated and shadowed pixels, they have found strong statistically asymmetry; 3D radiative effects “make” illuminated pixels optically thicker than shadowed ones. They also questioned the influence on cloud water paths, and found much stronger asymmetry in optical depth than in effective radius. Additionally, they found that retrievals at different viewing angles are affected by 3D cloud structure. Finally, to estimate the smoothing effects of diffusion, Dr. Marshak showed wavenumber spectra of different MODIS data and compared them with MISR data.

In conclusion, Dr. Marshak said that statistical symmetry/asymmetry is a powerful tool for validation of 3D radiative effects ~~of~~ on MODIS products. Accounting for 3D effects substantially improves our understanding of the uncertainties in MODIS retrievals. Their estimates show that in at least 10% of 50x50 $km^2$ areas the mean optical thickness is biased by more than 10% and standard deviation by more than 20%.

**Discussion Summary**

Aqua Cloud Mask

A few thresholds need to be adjusted, and the poor quality of 1.6 (?) will have to be substituted for, likely with 2.1. There will be only one major change, and it may be available by the end of August.

8 Day Clear Sky Radiance Composites

This is an issue that needs to be looked at for the forward stream as well as reprocessing.

Radiance Bias Adjustment for MODIS IR

This is a serious issue. Adjustment should be done for every area, though it is not being done currently because data flow is not the way they want it. It needs a sequential order of processing, and the forward stream is more important to start with than reprocessing. Terra has been fairly stable, so sequencing is easier, but Aqua is not easy. This impacts timeliness if we are worried about processing sequentially. It adds a three-day delay, but that is not a concern except for polar winds. Alcott has a plan that was never implemented, so it needs to be reviewed, but we could start working on it. This is a stumbling block for some products. Oceans may be doing something similar, so we could check with them to see how they're handling the issue.

HITRAN Update

An older version of HITRAN has problems, so everyone should make sure they are using the up to date version.

Monitoring Level 3 Products

Everyone should be monitoring the L3 products. There ought to be some habit of looking at them, possibly involving a checklist. Everyone needs to self-regulate on this. One idea might be to do animations to find glaring problems.

Other Topics

There are total of five papers for the special Aqua issue, and there is a special section in GRL that will have an atmospheres paper. A review paper is close to being accepted by Nature, and it should by out by April. Also, there will be a few Atmospheres people giving talks at special conference in Italy.

Everyone needs to be ready to process Aqua data, and we need to think about quality control. The biggest concerns for Atmospheres products on Aqua are the .3km Near IR Water Vapor Offset and Band 6. The cloud optical properties algorithm is pretty dependent on Band 6, so that needs to be taken care of.

ATBDs are important to keep updated. If changes are made to the algorithms, the ATBDs should reflect those changes. Realistically, everyone should be done by the end of September.

We need to make a list of diurnal studies to do with Terra and Aqua together. One concern is in getting diurnal signature, and seeing the differences in fire detection between Aqua and Terra. It would be nice to have a list of what to look at and to have a year of data for comparison.

We need a plan for getting Terra and Aqua Polar winds. It is currently a data problem. We could do it in parallel with no technical difficulties, though there is a problem in loop intervals.

**Action Items**

1.0 Gary Alcott to supply plan for MODIS IR Radiance Bias Adjustment sequential order processing.