MODIS Science Team Meeting

October 31 – November 2, 2006

Inn and Conference Center

University of Maryland University College

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First Plenary Session

Opening Remarks

Vincent V. Salomonson, MODIS Science Team Leader

Salomonson welcomed everyone to the meeting and provided a brief overview of the status of the MODIS mission. Both Terra MODIS and Aqua MODIS are working well. Data processing is moving forward. Salomonson will soon need semi-annual reports from the MODIS Science Team along with feedback about proposals to extend Terra and Aqua mission operations.

Salomonson reviewed the agenda for the meeting.

The MODIS Program Overview, the View from Headquarters

Paula Bontempi, NASA Headquarters MODIS Program Scientist

Bontempi provided an update of happenings at NASA headquarters HQ that are relevant to the MODIS science team. Mary Cleave is still the Associate Administrator of Science Mission Directorate. Brian Cramer is the acting director of Earth Science Division. Earth science is still split into research and applied sciences. Martin Frederick is acting as the head of applied sciences until the position is filled. Bontempi reviewed the status of the budget for fiscal year 2007. There will be reductions to the mission science, but Bontempi had no further details at this point. Science team member are currently on incremental funding after reductions in the 2006 budget. Contact Shannell Cardwell with questions. FY07 may exercise the fourth year team lead option and there may be some cuts.

In terms of the EOS recompete, a March amendment reduced funding from 30 million to 25 million. Proposals submitted for the EOS recompete are being reviewed in January and February 2007. Bontempi acknowledged that renewal dates fall between May and July and will work to avoid gaps in funding. Of the three categories, science data analysis had the most proposals submitted.

Both Terra and Aqua are up for renewal. Chuck Holmes will be involved in mission extension review process.

In last meeting, we talked about future research. Our primary goal is still to reap the full scientific benefits of MODIS, Terra, Aqua, and EOS. One of the ways to do that is to make and/or keep data products. We are also developing new data products to enable important new scientific and applied uses. The final goal is to use MODIS data products to create a new scientific understanding of Earth and to find new applications. The NASA mission has shifted slightly. The strategic goal number three includes science. A subgoal is to use Earth-orbiting satellites to understand climate, climate change, and natural hazards.

NASA is in process of advanced planning at the directorate. NASA has been tasked to develop a full 10-year science plan by the end of 2006. The plan will be delivered in December. As part of advanced planning, the Earth Science division looked at its portfolio and came up with a roadmap detailing what needs to be done next. There are six focus areas in Earth Science, and two of these are under advanced planning: carbon cycle and ecosystems and atmospheric composition. Once the plan has been established, the focus areas will go back and revisit their roadmaps every couple of years to access if the direction is still right for science. Bontempi spoke of progress in moving towards measurement teams. The oceans team is doing well. The land team has made significant progress, and the atmosphere team has a tight, focused community. Don Anderson is still running modeling analysis and prediction program, which will improve modeling at NASA.

On a larger scale, the NASA/NOAA/USGS-initiated decadal survey being conducted by the National Adademies will be delivered in January 2007. How do we reconcile what we do next with all of these various plans? NASA will reconcile decadal survey and science roadmap and use that to develop a funding roadmap. In the next few years, there will be opportunities to propose new missions. One science focus now is developing new products.

Among the issues facing the MODIS Science Team is creating more interdisciplinary products. Algorithm developers should address deficiencies and work to represent a broader community. Algorithm PIs need to provide compelling justification for the importance and utility of algorithm improvements. Bontempi also spoke of the need to develop a better process for ATBD development and review. As the MODIS mission moves forward, a ramp down of MCST is scheduled under the philosophy that the mission is established and will need less calibration. Members of the audience suggested that this planned ramp down should be reconsidered as the aging instruments may require more of the MSCT rather than less.

Another issue facing the MODIS Science Team is ATBD review. It's been at least 10 years since last ATBD review. Do we need to review improvements and new products? Bontempi suggested that the science team prioritize data products in relation to each other and relative to the needs that each serves. Bontempi welcomes suggestions on how best to proceed with such a review.

Measurement streams and science teams continue to evolve. The ultimate goal is to focus on Earth system data records. The terrestrial community has written a series of white papers about which data products should be candidates for Earth system data records. Bontempi suggested that the other communities do the same. Science guidance is necessary for the development of Earth system data records. Should we do Aqua and Terra science meetings instead of instrument meetings?

Progress and Status of MODIS Atmospheres Products and Processing

Michael D. King, NASA Goddard Space Flight Center and MODIS Atmospheres Discipline Group Leader

King's presentation described the status of the MODIS atmosphere products, focusing on collection 5 Level 3 products. King showed examples from collection 5 and described changes from previous collections. The MODIS atmosphere team produces daily, weekly and monthly products with all products in a single file. Starting with Collection 5, atmosphere products use internal hdf compression in all files, thus decreasing the file size for easier download and distribution. Product Quality Assurance (QA) statistics are on the web. Some properties were added or changed in Collection 5. Cloud fraction day and night results are now very similar, where night cloud fraction was high over oceans in previous collections. One significant climate question had been what is the impact of cloudiness in the morning versus the afternoon? From July 2002 to 2004, global cloud fraction was not that different between Terra (morning) and Aqua (afternoon) on average. King compared cloud top properties for Collection 4 and 5. Cloud top height is up a little over land. In terms of cloud optical thickness, liquid water clouds are higher over continents than over oceans. Ice clouds have higher optical thickness. The color bar for Collection 5 products has been changed to make values easier to read. In the monthly mean cloud effective radius product, ice cloud particles are larger than liquid water cloud particles, and are better behaved in Polar regions of both Hemispheres. A new property in Collection 5 is the cloud effective radius uncertainty. Another new property in Collection 5 is the assessment of multilayer clouds. King observed that this property could be profitably compared with CALIPSO and CloudSat data.

There have been substantial changes in the computation of the fine mode fraction in aerosol optical thickness over both ocean and land, although there is no significant difference in ocean aerosol optical thickness between Collections 4 and 5. Over land, however, there is a reduction in aerosol optical thickness over high latitudes where snow contamination has been eliminated. Ocean and land aerosol optical thickness matches much better in Collection 5. The fine mode fraction over land has improved dramatically, and the fine mode fraction over ocean saw a significant decrease as well, when compared to Collection 4.

The modeling and science community are interested in the "Deep Blue" algorithm that now gives MODIS aerosol results over relatively bright land areas where previous efforts were not successful. The Deep Blue algorithm will be a part of Collection 5 to be delivered in January 2007. The Deep Blue algorithm has been tested using SeaWiFS data as well. A new paper compares the use of the Deep Blue algorithm in observing Asian dust storms using MODIS and SeaWiFS with results obtained with the MODIS and MISR operational algorithms.

The monthly mean precipitable water product is being produced with both near-infrared and thermal infrared bands. Collection 5 results show that the thermal infrared technique yields larger amounts of column water vapor than the near-infrared method. Monthly mean temperature profile and global temperature profiles as derived from MODIS data should be compared with AIRS data.

Level 3 global browse images are available on the web for several products. Several resources are available on modis-atmos.gsfc.nasa.gov. Collection 5 enhancements and reprocessing are complete for Aqua. Terra should be complete by early January 2007. Data are available on the Level-1 and Atmospheres Archive and Distribution System (LAADS) at ladsweb.nascom.nasa.gov.

Progress and Status of Ocean Color, SST products from MODIS, SeaWiFS, etc.

Charles McClain, NASA Goddard Space Flight Center and MODIS Ocean Group Leader

McClain reported that the ocean science group has taken on new responsibilities. The group now supports SeaWiFS, MODIS Aqua ocean color and SST, MODIS Terra ocean color and SST, NPP/VIRRS ocean color and SST, aquarius, historical data, glory data system development, and future mission concept development. New mission concepts include OCEaNs.

Since the last science team meeting, the ocean team has improved chlorophyll observations in coastal regions by incorporating high resolution land bands and SWIR bands. This also improved the analysis of turbid regions. The data were released in SeaDAS. The ocean science team started working with Chesapeake Bay Project to insert satellite data into the assessment of the bay's health. The emphasis is on chlorophyll products. Aeronet data have been incorporated for satellite product quality evaluation. The ocean team also incorporated an NO2 absorption correction algorithm to improve coastal data. Near shore NO2 levels can be high, and this affects data quality. The team is now working on developing a multi-sensor data set with GOME, Sciamachy, and OMI time series.

The ocean team is reprocessing CZCS and OCTS data sets and updating to current algorithms. A detailed description of these efforts is on the ocean color web site. McClain also reported that the ocean team has been working with the VIIRS ocean team to do EDU testing and data analysis. The MCST team did a terrific job analyzing the VIIRS data in partnership with the ocean team. McClain reported that work on processing MODIS Terra data for ocean color has started with a focus on the most recent two years. Terra data are being processed because the team wants as many fully capable sensors on orbit as possible as the VIIRS launch is pushed further out. Evaluation products are looking good.

SeaWiFS is still working well and getting global data. The primary high resolution data set is coming through NOAA. SeaWiFS has no orbit maintenance on mission, so it has drifted to an afternoon orbit. As a result, the thermal environment is different, and this changed the sensor sensitivity. SeaWiFS recently lost a GPS receiver and switched to a backup. At nine years, the sensor is still in good shape, but it is showing signs of wear and tear.

Work towards including Terra MODIS data in the ocean color data set is moving forward with level 1 processing of data collected between January 2005 and the present. Evaluations of Terra data show some mirror side differences from Aqua data because of polarization. The pattern of differences shifts seasonally. McClain said work over the next few months will focus on resolving the differences between Aqua and Terra.

OceanColorWeb provides a variety of services. SeaDAS is constantly being enhanced.

Looking forward, the focus for the next few months will be on improving the data quality of Terra, revisiting the aerosol model suite, looking at the MODIS cloud mask for SST and possibly ocean color, working on refining SST products, reevaluating standard products, and thinking about reprocessing. The MODIS ocean team will work with the community to determine what kind of changes will be made for reprocessing.

Progress and Status of MODIS Land Products and Collection 5

Chris Justice, Land Discipline Chairman, University of Maryland

An international workshop was recently held in Montana, hosted by Steve Running of the land team, focusing on the current status of global vegetation monitoring. The use of MODIS data for land studies has exceeded even our most optimistic expectations and has been an unprecedented success for NASA's terrestrial program. Justice showed an example video to illustrate the broad visibility of MODIS data. A national weather report in South Africa routinely includes MODIS fire distribution maps and MODIS imagery. Established users are getting more sophisticated in their use of the data, as new users continue to discover MODIS. The number of user inquiries about the land products is increasing and is placing an additional burden on the team. The number of practical applications of the data to societal benefit are growing and make a practical and real contribution to the international GEOSS. Many operational users are concerned about operational continuity of the data flow, which needs to be considered by the Senior Review.

Preparing for Collection 5 has been a major effort for the MODIS land community. Justice reported that extensive testing was done, and for this reason, the release date has slipped. The science testing included seven major tests and 50 smaller tests which took longer than anticipated. Collection 5 processing started in June, and Terra reprocessing is now progressing. The change-over from Collection 4 to Collection 5 for forward processing will occur on January 1 allowing a full calendar year of data to be available under Collection 4 for 2006. The Collection 5 changes were driven by science improvements. Testing was done in a more organized way than previously with global tests and time-series tests. Global tests were produced for 16-day data periods in 2003. Time series tests for distributed locations included data from a full year. Problems with the code that emerged during testing were fixed, and all changes have been posted on the web site. Land data evaluation also improved the time series. Changes in Collection 5 include improved surface reflectance and an improved daytime/nighttime land surface temperature product. Artifacts that existed in Collection 4 land surface temperature products were removed. Additional Collection 5 changes include an improved resolution albedo product, a regional tuning of the vegetation continuous fields product, a five-year product of vegetation change for the Amazon and the global burned area product. Collection 5 reduced all product sizes significantly. The land team is now planning a user outreach workshop for Collection 5 in January at the University of Maryland.

The MODIS data are extending into a significant time-series. Compilation and analyses of various Level 4 data have been completed including, a mean annual GPP, the global NPP time series, a VCC five year change for some parts of the world, an ET six year product from Collection 4, including the anomaly product, and an LST product time-series. The majority of the land products are validated to Stage 2 but the need for validation continues. In particular, Justice reiterated the need to continue to link to data from in-situ networks and especially international observation networks. The team is concerned that the validation capabilities developed for MODIS are extended to the VIIRS. The land team is working through the various international coordinating groups on observations to demonstrate the contribution from the MODIS land data. More information about validation is on the EOS Land Validation web site.

Overview of MODIS Direct Broadcast accomplishments and status

Patrick Coronado, Goddard Space Flight Center

The direct readout lab at Goddard is the implementation arm of direct broadcast at NASA. The goal of the lab is to maximize the utility and transportability of Earth science data and to get the data to the end user and product producers as quickly as possible. The lab also enforces standards to provide a means by which people can collaborate. The direct readout lab provides a good interface for science data products and visualizations. Current activities are focused on improving direct readout tools and technology. The Science Processing Algorithm is at the core of direct broadcast data. Users often find it difficult to go from hdf to geotiff, but the direct readout lab now has a tool that will allow users to do that. Some of the tools that support real time processing are similar across instruments, but the processing algorithm differs for each. HDF to geotiff is important because the direct broadcast community would like to use GIS. The H2G tool allows the generation of some products. The lab provides a common interface for algorithms to ensure

continuity from mission to mission or from algorithm to algorithm. There are specific algorithms that are taken from the science team and put into production. In 2006, the lab released some reprocessing algorithms, added geolocation and projection data to some things, and tested the MODIS products that use the new SPA wrapper. A number of software downloads occurred during the year, indicating a number of new DB stations.

Direct broadcast is also valuable from the university perspective. One of the driving forces behind direct readout is the utility of NASA data in the outside world (outside of NASA). Direct broadcast data are useful in ice monitoring, fire monitoring, weather forecasting, and other applications that require real time data. Ice monitoring uses 250 meter true color images. The NOAA Coast Watch uses MODIS operationally to monitor ice and snow over the Great Lakes. The Canadian Ice Service uses MODIS data operationally for ice monitoring. The Russians have a network of loosely connected direct readout stations that provide a variety of products for ice monitoring. The Sentinel system in Australia monitors fire hotspots with MODIS direct broadcast in near real time. Sentinel also derives burn scar and smoke cloud fraction from direct broadcast data. CONAE also monitors fires in South America. Direct broadcast data are useful to weather forecasters at the National Weather Service and elsewhere. The data are most valuable to forecasters when delivered in real time, but currently have a 35-40 minute latency. In particular, MODIS polar wind data allows feature tracking of various things including polar wind vectors. This has had a demonstrated positive impact on forecasts. In summary, the reduction in latency offered by direct broadcast is essential for many applications.

MODIS data have been in use for some time in every continent. There are a significant number of stations, and the number of stations expanding. One of the reasons for increased usage has been open access to data, an open data format, and availability of free software. Support for direct broadcast from the NOAA integrated program office will continue into NPP/NPOESS era.

Status NPP and NPOESS, VIIRS

Jim Gleason

Nunn-McCurdy certification is over. In the Nunn-McCurdy process, if an item is going over budget, it is subject to review. Over 6-8 months, NPP and NPOESS were reviewed in detail, and the programs were recertified with some changes. The process was analogous to the EOS rebaselining. After Nunn-McCurdy, the number of spacecraft in the NPOESS mission was reduced to six, none of which will have a morning orbit. EUMETSAT will provide mid-morning coverage. For NPP, operational data continuity was the primary driving factor in the Nunn-McCurdy analysis. Some instruments were cancelled or descoped, and some instruments were taken off the manifest. The spacecraft will remain intact so that instruments can be added later if funding is found. The current launch date is September 2009. Orbit configuration changed so that one satellite has a late afternoon (5:30 p.m.) orbit, and one satellite with one optional satellite will have an early afternoon orbit (1:30 p.m.). There is no mid-morning orbit planned. NPP is not considered operational, but it is a "backup" operational satellite. The CMIS which would have combined the capabilities of AMSR and SeaWinds in a single instrument, has been descoped. The requirements for ocean data didn't go away, so follow-on instruments can be expected. The SESS (the space environment suite) was also descoped. Copies of the current space environment monitoring suite will fly instead. The list of demanifested instruments includes: TSIS, ERBS, Alt, APS, full SESS, and OMPS Limb. VIRRS still flies on all platforms, so MODIS-type imagery will be available into the future. NPP lost the OMPS Limb.

Gleason gave an overview of the instruments and where they are on the spacecraft. The program has been running on two one-year contracts. The contracts are about to be renegotiated, so some things will change. The ATMS is essentially done. Flight assembly for the ozone instrument (OMPS) is underway. The OMPS instruments shifted, and the shift may have impacted the wavelength detection calibration. The OMPS Limb was removed, and it is on the shelf. The CTIS had been going well, but it recently had a complete mechanical failure during testing. The frame broke during testing. On VIIRS, the EDU thermal backtesting is complete. The testing identified three mechanical issues, and testing is ongoing. The band to band registration shifts with temperature, and the line-spread function changes with temperature. Detector cross talk is a concern across the board. Is the problem electrical or optical? The signal from one pixel bleeds into

other pixels. VIIRS flight model one is the last thing out the door in Santa Barbara. FM-2 will be assembled in El Segundo.

Gleason advised the MODIS Science Team to incorporate MCST data in proposals to show NASA headquarters that it is necessary.

The Senior HQ Review/Mission Extension Process

S. Volz, NASA Headquarters

The senior review in 2004 was a process adopted from the space science process to evaluate missions that are in extended mission phase. There was an attempt to prioritize science returns from different missions. The first review in April 2005 recommended the termination of UARS, ERBS, and SAGE III. Nearly all space missions are in the review process. In Earth science side, nearly every mission will be part of the senior review this year except for Aura and CALIPSO. Senior reviews are held every two years. The review will establish the budget for fiscal years 2008 and 2009. The Earth science missions are getting older and the number in operation will be dropping. The senior review process will look at mission operations and data handling of older satellites. The 2005 review was the first for Earth science missions. The individual missions responded well to the call for proposals. The 2005 review showed that operation utility should be a part of the review process. Volz asked the science team if reviews should be held every two years or if it would be better to hold reviews every three years to match research cycles. The review should contain information about the models used to anticipate improvements and should identify scientific criteria by which the mission should be reviewed. The review needs to address operational considerations and integrate data from various instruments.

The next senior review is in the spring of 2007. Volz will issue the call for proposals, which will be followed by an internal review. The senior review panel will be drawn from outside of NASA. The chair will be from the 2005 review panel, but the other panel members will be new and will be drawn from all research areas. The panel gives findings to the division directorate, and these findings inform the final decision. The primary criteria for the 2007 review will still be scientific relevance. For more information, refer to http://science.hq. nasa.gov/strategy/past.html. Secondary criteria include efficiency and cost effectivity, risk management, multiple instrument and satellite utility of data products, quality and timeliness of baseline data products, and education and public outreach. The applications division may be involved in assessing operational uses. The schedule for the 2007 review is as follows: the draft letter for proposals will be sent out by end of November 2006; the final call for proposals will be issued in mid-December 2006. There are many ways to evaluate mission performance, and the current thinking is to review mission operations, execution, and completed mission science, core science, and extended science. Possible proposal outcomes include compelling science, great proposal; compelling science, average proposal; excellent science, average proposal; modest science, not well presented, termination proposed. Among the current Earth science missions, there are no obvious candidates for termination.

MODIS Land Bands for Ocean Remote Sensing: Application to Chesapeake Bay

B. Franz, et al., NASA/GSFC/SAIC

Franz provided an overview of efforts to use MODIS land bands for ocean applications. There have been many investigations into using the land bands for coastal studies since the launch of Terra. Franz, et al., are gathering the results of these investigations in a format that can be distributed to the ocean community for evaluation through SeaDAS. Bands 1-7 are of interest for coastal studies. SWIR bands are used for aerosols, and the other channels overlap the ocean bands, but have a higher resolution. The 645 band is useful for sediment and turbidity. These bands also have a higher saturation than the ocean bands, which allows measurements of chlorophyll concentration in blooms, bottom reflectance and stray light. Relative to the ocean bands, the typical ocean radiance is half the saturation radiance. Characterization and calibration factors included: relative spectral response functions, polarization sensitivities, relative detector and sub-sampling striping, and vicarious calibration to MOBY. Franz reported dealing with multi-

resolution problems by taking advantage of aggregation in standard L1 B products or using a standard interpolation. Chlorophyll products are now produced in both 1 km and 500 meter. The water-leaving radiance product is available at 250 meters. There is a 20-year record of in situ chlorophyll measurements of the Chesapeake Bay which can be compared to satellite data. In such a comparison, the SWIR bands have a significantly better match to in situ measurements. Work is also going forward to match Aeronet observations to satellite data. Aeronet observations may be used to develop better aerosol models or regional aerosol models that would improve measurements of the Chesapeake Bay. An aeronet site was placed on Smith Island in the middle of the bay. Franz reported developing processing capabilities to include higher resolution land/cloud bands in ocean remote sensing. The software and tools are in SeaDAS to encourage further evaluation. More information is available on the Ocean Color web site. In the future, Franz wants to develop more applicable aerosol models, incorporate MODIS-derived water-vapor concentrations for improved water-vapor correction, assist NOAA Coast Watch to implement operational MODIS data in monitoring the Chesapeake Bay, and develop high-resolution Level-3 products.

Interrogating MODIS/AIRS data using HYDRA

P. Menzel, University of Wisconsin

HYDRA is free ware that can be downloaded from http://www.ssec.wisc.edu/hydra. HYDRA is the HYperspectral viewer for Development of Research Applications, and was developed to ingest many different satellite products. The program was developed with MODIS data, and data from many other satellites or sensors have since been added.

Hydra is free software, mainly being used in education mode, but is also useful in data analysis. It runs on most machines, but requires 512 MB of memory and 32 MB graphics card. HYDRA will be around five years from now.

Once the program is running, it displays a window that contains a stretched version of the globe. Once data are loaded, the data granule is displayed with some geographical data (coastlines). Interrogating the data opens the multi-channel viewer. For each pixel, Hydra can display all MODIS bands with exact reflectance values at 1 km resolution. Hydra allows users to zoom to single pixel resolution to interrogate clouds, ocean or land in that pixel. The multichannel viewer offers various options: RGB, transect on image, capture display, show spectra, etc. Transect displays values from the HDF file in pixels contained in the line.

To compare IR and NIR cloud detection, the user can create a difference viewer with the multichannel viewer. Hydra can generate scatter plots with any channel combination for the x and y axes. Circling the values in the scatter plot highlights the locations on the image. By the same token, highlighting a part of the image sets a box around the corresponding values in the scatter plot. Hydra also contains a pseudo-vegetation image and can play off the level 2 products.

Hydra can do the same things with AIRS data. A user can zoom into different parts of the spectra, zoom into values, or take differences between different channels of AIRS. Hydra can display the retrieval products. Hydra can also co-locate MODIS and AIRS data and display spectra simultaneously. Calipso data can also be loaded and located onto a MODIS granule so that a user can compare Calipso backscatter and MODIS visible bands. For more information about Hydra, see http://www.ssec.wisc.edu/hydra. Data used in Hydra can be downloaded from Rapidfire, the DAAC or LAADS web.

Report on Global Vegetation Workshop in Montana/August 7-10

S. Running, University of Montana

Since the focus at NASA headquarters is shifting from missions to measurements, the Global Vegetation Workshop held last summer also had that focus. Previous meetings had focused on MODIS, but this meeting targeted vegetation products and not other MODIS products. Of all vegetation data sets, there are two generated from multiple sensors: the vegetation index and leaf area index. Each data product is processed differently and thus gives different values, so intercomparisons are necessary. The most advanced intercomparison presented at the meeting looked at leaf area index comparison. This type of

comparison is something that needs to be done more. The presenter(s) developed a procedure that looked at leaf area index from ground data, high resolution imagery like Landsat, and moderate resolution data (MODIS and other) to compare leaf area index at three levels of resolution. This is a template of the type of validation procedures that will need to be done going forward. It provides a good look at error and uncertainty.

New MODIS BRDF products are providing continuity. Another application presented at the meeting was ecological forecasting, something that NASA HQ is specifically looking for. Ecological forecasting starts with observed meteorology, and grids surface observations to observed meteorology to drive a model to predict future conditions. A local model of nowcasting is being done in California to get a daily evapotranspiration map of the state. This is being done on the fly every day.

Alfredo Huete showed a new study that reinterpreted how the Amazon rainforest works. Productivity in the Amazon is highest during the dry season when there is more sunlight. This is backwards from what ecologist had always thought.

Continuity was an important topic in the meeting. If we are to detect change, we need a continuous data set. The Goddard team is looking to build a continuous data set of NDVI with AVHRR, MODIS, NPP and NPOESS. They are using an array of field data sets to validate the NDVI data set. More information is on the LTDR web site.

NOAA is reprocessing the GVI data set to make a time series. The difference between an environmental data record and climate data record is continuous reprocessing. Reprocessing is needed for continuity.

The six year global MODIS evapotranspiration data set is now available. It allows us to look at ET anomalies to see where the global land water balance is changing. Flux tower data sets are being used to validate the evapotransipiration data set.

Another new idea presented at global vegetation workshop was the composited land surface temperature global product. It is on the cover of the October 24 issue of EOS with an article titled "Where's the hottest place on Earth?" Scientifically, you this ratio can be used in land cover change detection. It creates a disturbance index and can map burn areas.

The workshop involved about 160 people from 12 countries. The satellite systems have matured enough that better international coordination is needed. The science team needs to coordinate and intercompare data products from multiple sources. Aeronet and flux net are two globally distributed field networks that are invaluable for global vegetation. These field networks are necessary for the validation of global products. Data use policies from foreign organizations aren't the same. We need access to foreign data as easily as they can access MODIS data.

A more organized calibration, validation and feedback process is needed for product processing. In particular, validation and intercomparison activities need to feed back into product generation. This is difficult for MODIS alone, and will be even more difficult if several sensors are being coordinated. It will require more international coordination than ever before. Aeronet and flux net will be required for validation.

The continuity question keeps coming up. How do you keep continuity going? As we see the focus on measurements moving forward, we need to make decisions about which products move forward and which remain research products.

Running reports that the biggest issues with land cover are field validation and continuity. LIDAR will hopefully provide the new data needed for carbon cycle science. With the biophysical variables, we're not ready to provide continuity from MODIS to VIIRS, but that is where the science needs to go over the next five years. The leaf area index is used in global models for which continuity is necessary. The fire products need to be validated in the field.

An animation of land plus ocean NPP for the past five years is now available. It is valuable as a teaching tool to show the dynamics of the whole Earth in a way we couldn't before.

Keeling said it was difficult to keep funding going for the Mauna Loa data set. We will have to keep fighting for funding every year as well.

Lunch Plenary Speaker (Day 2)

NASA Earth Science Overview

Jack Kaye, NASA Headquarters

NASA mission and vision statements are new. The new mission statement is to pioneer the future in space exploration, scientific discovery, and aeronautics research. In the new strategic plan, goal 3 incorporates the science program and includes all four divisions in science mission directorate. The goal for Earth science under that has subgoals for mission areas. It contains a set of deliverables for the next 10 years. NASA Earth Science supports multiple presidential initiatives, including the climate change science program, earth observations, and ocean action plan. Congressional direction links NASA and NOAA. NASA is part of the NPOESS program, which is important part of future. Earth-Sun research is part of an end-to-end program of sciences for society. Earth science has a tie to applications and society for the public good unlike other areas in Science Mission Directorate. Earth science at NASA is built around contributing to national efforts, whereas other science areas are determining direction on their own. Headquarters is now working toward a new science plan and decadal survey. The Science organization needs to develop a plan to incorporate the NASA plan. Congress also mandated a science plan through 2016 to make sure science is funded. One part of the plan is explain missions that we have, why they are important, and then list new priorities and rationale. Priorities are NPOESS, Landsat data continuity, ocean surface topography mission, etc… The plan must show what can be done with the budget we expect to have.

Kaye provided a summary of flight program in place now and stated the need to establish what new missions are needed for each focus area. NASA requested an Earth sciences decadal survey for the first time. The survey will bring Earth science into line with other divisions who have had to do decadal surveys. The interim report was released in 2005 and made several recommendations. NASA's response will be limited by its budget. The report suggested that NASA evaluate plans for transferring needed capabilities from cancelled missions to NPOESS. NPOESS has a key role to play in continuing current measurements. There is a need to assess what climate data records will be lost because of the cancellation of instruments on NPOESS, including the loss of imagery in the mid-morning orbit.

Atmosphere Breakout Session (Day One)

Looking Forward: Using MODIS for Aerosol Science over the Next Three Years

Lorraine Remer, NASA - Goddard Space Flight Center

Lorraine Remer discussed the plans for future improvements to the MODIS aerosol algorithm. The collection 5 algorithm has been delivered. No change seen in the AOD and the fine mode fraction is better but still does not agree with AERONET. Improvements also seen in AOD retrievals over land. Future algorithm refinements will focus on developing an urban vs non-urban product, finer spatial resolution (3 km), using POLDER data to address non-spherical particle issues, and investigate the elevated reflectance in the vicinity of clouds. Determination of causes for this elevated reflectance near cloud edges (real or instrument artifact) could yield important results for cloud-aerosol interaction. Aerosol absorption is another issue to be investigated.

Dust Aerosol Radiative Effects from Terra and Aqua

Thomas Jones, University of Alabama

Thomas Jones presented results of a study of the radiative effects of dust aerosols, using Saharan dust transported over the Atlantic as the test domain. CERES and MODIS data were used to determine SW and LW fluxes, dust aerosol AOT and fine mode fraction for cloud free pixels. The dust radiative effect (DRE) is calculated by subtracting fluxes containing aerosols to a background clear-sky flux and then scaled by the ratio of dust AOT to total AOT. It was found that dust aerosols have a measurable impact on SW and LW fluxes with the LW warming offsetting the SW cooling by ~15%. A comparison of DRE for MODIS Terra and Aqua displayed only small differences.

Aerosol Retrievals Using Airborne LIDAR and MODIS Measurements

Richard Ferrare, NASA – Langley Research Center

Richard Ferrare discussed the use of combined airborne lidar and MODIS to provide information regarding the vertical distribution of aerosol properties (i.e. size, fine mode fraction). For the TRACE-P and INTEX-NA campaigns the MODIS data helped to constrain the lidar retrievals of aerosol extinction profiles and backscatter and extinction color ratios. A combination of lidar and MODIS observations were used to derive fine mode fraction and effective radius over oceans. Good agreement was found with extinction and fine mode fraction for AOT > 0.15.

Evaluation of Global Biomass Burning Carbon Emission Estimates Using Fire Radiative Power and Aerosol Products from MODIS

Eric Vermote, University of Maryland College Park

Eric Vermote's talk centered on an alternative approach to derive biomass burning emission estimates from satellite measurements of fire radiative energy and aerosols. Uncertainties in emission estimates arise from limitations on the derivation/parameterization of the factors included in the emission calculation. Correlations between MODIS fire radiative power and emissions showed strong correlations for Southern Hemisphere Africa and weak correlations for Europe, North America and Austrailia. Land cover type and time of day factors were investigated as causes for these differences. A global alternative approach for fire emission estimates was discussed.

Aerosol Remote Sensing in the Vicinity of Clouds

Jens Redemann, Bay Area Environmental Research Institute

Jens Redemann presented an update on SWIR AOD validation and variability between level-2 retrievals, including an investigation of aerosols near cloud edges using MODIS data and aerosol retrievals from AATS onboard an aircraft during a field campaign off the coast of northern California. It was found that in nearly 75% of cases there is an increase of 5-25% in AOD in the closest 2-km near clouds with a concurrent increase in MODIS reflectance near cloud edge. Possible causes of the near-cloud increase in reflectance include 3-D radiative effects but also the increased aerosol concentration or size as indicated by theory and the AATS observations. Further observations and analysis is planned.

Atmosphere Breakout Session (Day Two)

MODIS Infrared Cloud Phase and Ice Radiative Transfer Code

Bryan Baum, University of Wisconsin – Madison

Bryan Baum discussed a MODIS Simulator Radiative Transfer Package in development. Numerous updates and improvements have been implemented in the Simulator. With the launch of CALIPSO and the deployment of HSRL, there is now independent cloud phase data that can be used to intercompare with MODIS. Case studies of comparisons were shown.

Location of Stratocumulus Cloud-Top Heights in the Presence of Strong Inversions

Harshvardhan, Purdue University

Harshvardhan investigated the deficiencies of MODIS cloud top height products when strong inversions are present. For low clouds, the algorithm assigning the cloud top pressure to window brightness temperature tends to choose the higher altitude solution when the temperature profile has a strong inversion. Ancillary information in the form of near-infrared water vapor column amount above cloud top can be used to choose the appropriate solution if more than one solution has been provided. Although this problem can be detected when studying granule level data, there is harm in letting it percolate up to spatially and temporally averaged information provided to climate modelers and the general public.

Overestimation of Cloud Cover in the MODIS Cloud Product

James Coakley, Oregon State University

James Coakley used aggregated 250-m imagery to assess the accuracy of MODIS cloud properties derived using partly cloudy pixel retrievals from 1-km imagery. It was found that the MODIS 250-m cloud mask severely overestimates the fractional cloud cover – with the cloud mask appearing to identify as overcast pixels all those with a cloud fraction > 0.5. Some consequences of these biased cloud products are that for partly cloudy pixels (MOD06) the altitude variations are inconsistent with those derived from CALIPSO; droplet radius increases with decreasing altitude, implying very small droplet concentrations in thin clouds; and droplet radii are much larger and optical depths much smaller than those for overcast pixels. Further work is ongoing to include the 500-m data and high resolution ASTER data.

Cloud Susceptibility from MODIS Level-3 Daily Cloud Products

Lazaros Oreopoulos, University of Maryland Baltimore County

Lazaros Oreopoulos presented results from a study of cloud susceptibility derived from MODIS. Susceptibility is a useful concept for identifying regions prone to significant IAE radiative perturbations not only due to their proximity to pollution sources, but also due to the nature of the prevailing clouds under current climate conditions; it therefore provides an additional constraint in cloud modeling studies. A global picture of liquid cloud susceptibility can be obtained from MODIS in a straightforward manner with the aid of some RT modeling. Significant seasonal variations of susceptibility was observed, consistent with seasonal shifts in cloud patterns and properties. As expected, marine clouds are more susceptible than continental clouds and morning-afternoon susceptibility differences are relatively small. The current distribution of liquid cloud optical thickness and effective radius, as observed from MODIS, yields ~1.5 Wm-2 IAE for a uniform 10% increase in CDNC under constant LWC conditions.

Radiative Forcing of Tropical Ice Clouds Using the MODIS/AIRS Products and Modeling Capabilities

Ping Yang, Texas A&M University

Ping Yang discussed a new parameterization scheme for ice cloud properties as applied to shortwave and longwave radiative forcing model calculations. A sensitivity study investigated the effect of the single scattering properties of ice particles with different shapes and of the bulk optical properties of ice clouds on radiative forcing. An ice cloud climatology was derived from 3 years of MODIS Aqua observations and used to estimate the radiative forcing of ice clouds. Variations in forcing with season, latitude zone, and underlying surface (land vs ocean) were studied. A comparison between Collection 4 and Collection 5 MODIS ice cloud properties showed greater radiative forcing for Collection 5.

How 3D Science Can Help to Correctly Interpret MODIS Data for Better Understanding of Aerosol-Cloud Interactions

Alexander Marshak, NASA - Goddard Space Flight Center

Alexander Marshak addressed the impact of 3-D cloud effects on aerosol and cloud properties as derived from satellite remote sensing observations. When studying aerosol-cloud interactions in a cumulus cloud environment, 3-D cloud effects cannot be ignored. 3-D effects can cause an overestimation of AOT and cloud droplet size. A case study of cloudy scene observations over Brazil was shown. Contributors to the 3-D effect are Rayleigh scattering, aerosol amount, surface reflectance, cloud optical thickness and distance from the cloud. It was found that 3-D cloud enhancements depend only weakly on AOT, molecular scattering is the key source of enhancement, retrieved AOT can be corrected for 3-D effects, and retrieved cloud properties depend on the geometry of the observations.

MODIS/CALIPSO Comparisons

Steve Ackerman, University of Wisconsin – Madison

Steve Ackerman presented a first look at comparisons of cloud detection and cloud top height between MODIS and CALIPSO. In general, the global comparisons of cloud detection were very good and consistent with expectations of ~80% agreement. An issue of mismatch was found for cases of low-level clouds: CALIPSO identified as cloudy, MODIS as clear. The cloud top height for cirrus determined by MODIS and CALIPSO agreed well. The CALIPSO low-cloud/MODIS clear differences are actively being investigated.

Aqua MODIS and PARASOL Observations of Cloud Properties

Jerome Riedi, Universite des Sciences et Technologies de Lille

Jerome Riedi discussed the contributions of POLDER/Parasol to the A-Train constellation of satellites, in particular the benefits of multi-angle observations as applied to retrieval of cloud properties such as spherical albedo. MODIS data used to compute a POLDER sub-pixel variability metric for determinations of cloud phase/structure. Applications of the multi-angle observations for aerosol properties retrieval also presented. A preliminary comparison of Parasol and CALIOP Cloud Top Pressure showed a lot of scatter.

Recent SMART-COMMIT Observations of Smoke and Dust Aerosols

Si-Chee Tsay, NASA - Goddard Space Flight Center

Si-Chee Tsay reported on a just completed field deployment of the SMART-COMMIT ground based mobile observatory as part of the NASA African Monsoon Multidisciplinary Activities (NAMMA) campaign on 8/15 – 9/15 2006. The deployment to the Sal, Cape Verde, was for the purpose of studying the Saharan Air Layer. Specifically, SMART-COMMIT provided measurements of: dust (aloft) and cirrus properties, surface aerosol properties, boundary-layer atmospheric parameters and radiative forcing approximations. Examples of data collected and early results were presented.

Application of an On-Line Relational Database for Comparison of MODIS Collection 5 Cloud Properties to Ground-Based Measurements

Jay Mace, University of Utah

Jay Mace focused on the validation of MODIS cloud products against ARM and other surface measurements using thousands of overpasses. A major milestone was developing a database and web analysis system containing ARM measurements of cloud occurrence, cloud properties, radiative fluxes, etc. He was easily able to add MODIS overpass data from LADS due to readily available online C5 data.

Mace showed the MODIS vs ARM Ice Water Path and total optical thickness for filtered subsets of cases. The scatter plots quickly identified biases in Cloud Top Temperature and Pressure comparisons. Mace expects the system to be a great validation tool for anyone to use (it's web-based). Mace noted that Cloudsat and Calipso are better suited to cloud top property validation due to top-down look and a large number of measurements. Mace also noted that as with MODIS data, ARM data are also in the process of better validation

Questions:
- Can we get cloud phase info at ARM sites? Yes using Raman LIDAR depolarization data.
- Lots of kudos on development of this system!

Retrieving Water Leaving Radiance from MODIS Land and Ocean Color Channels

Bo-Cai Gao, Naval Research Laboratory

Gao focused on ways to get better estimates for spectral water-leaving radiance by accounting for Rayleigh, aerosol, wind-induced white-caps and other effects. Gao noted that there is a well-known problem in selecting the correct aerosol model using ratio of .865/.75 micron bands. Air and ocean effects (dust vs turbidity) can't be separated unless you use channels with wavelengths longer than .8 microns. He showed examples of aerosol retrievals over turbid water and other retrievals over shallow water with sandy bottoms.

Using hyperspectral atmospheric correction, Gao developed a very large reflectance table with 14 wavelengths, many aerosol models, and sun/view angles that can be used to process one MODIS scene in about 10 minutes. This approach is able to recover water-leaving radiance over turbid or sandy bottom regions, also where ocean color bands are saturating

Gao plans to include NO2 and other gas absorption in the future and will update for VIIRS channels

Simultaneous Retrieval of Aerosol and Chlorophyll from MODIS Radiances

Clark Weaver, UMCP, GSFC

Weaver described an approach that uses radiances from 7 MODIS bands from .412 to 2.1 microns with these ingredients:

- ? Iterate forward radiative transfer model against MODIS radiances
- ? GOCART used for aerosol optical depth first guess
- ? 3D ocean boigeochem model used for chlorophyll first guess
- ? Ocean wind speeds from GMAO assimilation
- ? Herman RT model to estimate reflectance from incident fluxes and chlorophyll

The iteration tries to estimate contributions of different aerosol types: sulfate, sea salt, dust along with chlorophyll amounts. He showed scatter plot comparisons of retrievals against Ocean Color standard chlorophyll products and MODIS standard AOT products. Weaver found that matching all band radiances requires absorbing aerosols.

Questions:
Remer: How to separate dust and chlorophyll absorption in blue spectrum? Not yet resolved.
Stamnes: Comment that this is too much of a black box to draw conclusions from radiative transfer model.

Light Reflection Off Water Waves: Mimicking Sunglint Under Controlled Laboratory Conditions

Knut Stamnes, Stevens Institute of Technology

Stamnes noted that Wiscombe suggested work to better understand sunglint and its dependence on surface waves. The experimental setup included a 20m wave tank, light source, and polarization measurement apparatus. Stamnes measured BDRF and the polarization signature simultaneously with wave surface elevation. He investigated gravity glints and capillary glints in order to better link wave surface statistics and measured polarized BDRFs.

Question: Expect any differences with larger/wider tanks having fully 2D wave surfaces? Yes, but too early to estimate. We're doing the obvious first steps.

MODIS Data used by National Weather Service Forecasters

Jordan Gerth, CIMSS, University of Wisconsin

Gerth discussed how the AWIPS system is used to bring together model, satellite, local radar, etc. The NWS makes use of the following MODIS direct-broadcast products for both eastern and western US: 11/3.9 micron fog, total precipitable water, cloud phase, snow/ice, cloud top temperature, and SST. The challenge is to work with the older NWS computer hardware and low bandwidth which are bad for delivering high resolution imagery. The strengths of the initiative with NWS include ties between researchers and NWS field offices, high resolution, better quality products for NWS use, and total water vapor available to diagnose the potential for possible heavy precipitation.

Questions:

Can standard atmosphere products be used? Requires Direct Broadcast to get images delivered in 1-2 hours.

Does the fog assessment get widespread use? Yes, the fog product seems to offer unique capability.

Positive Impact of MODIS Cloud Mask on SST Comparisons with Microwave Retrievals

Corey Calvert, CIMSS, University of Wisconsin

Calvert reported that the goal is to evaluate the global performance of the MODIS cloud mask over water. The approach uses the difference [MODIS IR SST - MW SST] as a cloud contamination signature, particularly the combined TMI/AMSR-E Microwave SST product vs Aqua/Terra MODIS daytime/nighttime SST. Calvert showed histograms of SST differences from global ocean studies. He conducted separate analyses for selected latitude bands: tropics, mid-latitude, etc, Terra vs Aqua, and daytime vs nighttime. In a one-month April study, he found a cold bias of MODIS SST that reveals some cloud contamination. In separating the analysis for each of the four cloud mask categories, he found the greatest error in the "probably cloudy" category. Aqua and Terra were generally consistent. Calvert plans to extend the analysis from April to other seasons.

Six-Years of Global Aerosol Distribution from MODIS and GOCART

Mian Chin, Goddard Space Flight Center

Chin described the GOCART model that includes source emission, chemistry, transport, and removal to get mass loading residual. It must also be coupled to a model for "efficiency" of sources. Chin showed AOT estimates from MODIS, MISR, GOCART as time series since Feb 2000 and noted that AERONET measures AOT directly at point sites, mostly over land. Chin also noted that AOT is an indirectly determined parameter for both transport models and satellite retrieval algorithms. Chin showed a series of case study inter-comparisons and conclusions derived from the comparisons. The September 2000 C4 data for African smoke outbreak revealed that MODIS measurements were too high over North America, and GOCART was lower than MODIS over the southern oceans. The April 2001 C4 data for the Asian dust "perfect storm" showed that MISR measurements are too low over Asia. The boreal fire incident in July 2004 showed that GOCART emission/injection is too low, MISR has excessive AOT over Greenland, and MODIS is too high over North America.

The general conclusion about MODIS was that the C4 land AOT is 30-60% high (vs AERONET) and MODIS C5 AOT is much better, with only a 15% difference (still high). Generally, GOCART has less overall bias, but greater scatter vs. AERONET. Future model improvements might consider a data-fusion approach using MODIS over ocean + MISR over land. Better model source estimates are still needed. In addition to AOT, GOCART also needs vertical distribution, aerosol composition, hydroscopic take up, etc. It might be possible to combine CALIPSO vertical data, AOT from OMI, and field measurements of chemical composition.

Question: Could one simulate MODIS retrievals using model + cloud contamination? Clouds pose a difficult problem.

Using MODIS Aerosol Data to Constrain GISS GCM Aerosol Climatology

Andrew Lacis, GISS

Licis noted that generally, modelers have tried to get higher AOT to match MODIS, while simultaneously, MODIS C5 reduces the AOT to match models and aeronet. He found that MODIS C5 AOT over land has been reduced with respect to C4 from a global mean of .3 to .2. One should not expect MODIS to do much better without a polarimeter on board.

MODIS C5 over ocean now seems more consistent between Terra and Aqua, which is good news for modelers. After changes to the GISS GCM, the GCM aerosol over land is now a bit high, while the GCM angstrom exponent is now a bit low.

Lacis showed a regional comparison of GCM vs. Aqua C5 AOT and angstrom exponents. A difficult challenge is over the South Ocean where comparisons with 90% cloud cover show poor correlation. Generally, GCM seasonal variability of aerosol types is better than absolute AOT.

Questions:

Noted that field campaigns are showing Terra does better on angstrom coefficients.
Why not just use MODIS? --want to be able to model prior decades with different emissions.

GlobeGrid: Advanced Analysis Area Selection Tool for Gridded Products

Gala Wind, Science Systems & Applications (SSAI) at GSFC

The goal of GlobeGrid was to develop an application to allow the definition of non-rectangular regions for analysis. The tool generates mask or pattern files that can be saved and then shared among applications and users. For example, you might mask "New York + Massachusetts" together for analysis. The GUI zooms to multiple resolutions to allow for complicated patterns to be entered. One can then operate on data while masking out regions you don't want with fill values

Need for and Plans for Collection 6

Paul Menzel, NOAA/NESDIS, University of Wisconsin

Menzel noted that MODIS reprocessing to date has been essential. Cloudsat and Calipso will be an opportunity for even better algorithms.

Menzel presented a list of desirable MOD35 changes for Collection 6. He asked for additional suggestions. He also outlined plans for improving MOD06CT cloud top properties by using new cloud phase and cloud overlap information. He expected improvements to MOD07 total water (IR) after combined retrieval studies with AIRS. He requested thoughts from others about changes they would like to make and what kind of schedule is possible for Collection 6.

Discussions on Mission Extension Proposals: Need for MODIS on Terra and Aqua

Michael King, NASA Goddard Space Flight Center

Notes were taken by Paul Menzel...

Ocean Breakout Session (Day One)

Program Update
Paula Bontempi

Bontempi went over the objectives of the meeting, provided a brief program update, and talked about VIIRS, data merging, pigment processing, future planning for Round Robins, science data analysis PIs, progress on actions from the NASA data product workshop, other thoughts on vicarious calibration, discussion and future activities.

The FY07 budget hasn't been announced yet. Ocean science team members are on incremental funding from cuts in 06. Budget information will come in March or April 2007. Shannell Cardwell is the contracts person.

Calibration is still a big topic. MOBY is scheduled to end in March 2007. It's a primary source of sensor calibration and evaluation data. This puts ocean data in danger in terms of blue water calibration, which affects MODIS ocean color. The science team needs to draft a plan of what to do in the future. The future ocean color calibration system design and implementation will be funded through ROSES.

Calibration round-robins continue. A large scale optical closure field campaign called SORTIE has been funded. It will be conducted at MOBY and off the coast of California. A comprehensive plan for calibration is needed. The plan should fit the programmatic advance plan, which is community-based. Volunteers are welcome.

Field data collection has continued to drop since December 2003. Giulietta Fargion is collecting field data, and IOCCG is a means for international coordination. All solicitations now say that all data are subject to NASA data policy. Data submitted within one year of collection are embargoed for one year. Data are also to be submitted to OBPG SeaBASS.

For EOS follow on call for proposals, 322 proposals were received. Panels will begin in January and decisions will probably go out in April. Funding should be in place by the time renewal dates role around.

Tomorrow morning, we will hear about data merging and assimilation. What data format should be provided in climate records? Observational researchers may need a different type of data than the modeling community.

Bontempi asked the ocean team to notify her of interesting results, publications, and news-worthy findings for outreach. Outreach is important for the funding profile.

A merged land and ocean productivity algorithm is now available.

NPP VIIRS
Wayne Esaias

NPOESS preparatory project is a risk reduction activity for NPOESS. NPP is a NASA mission, the objectives of which are data continuity and climate data records. NPP can not be used in formal NPOESS system level requirements. The VIIRS engineering development unit is a risk reduction for NPP and NPOESS. All requirements are defined as worst case, end of life scenarios. The EDU is completely built. The thermal vacuum testing is complete, but more characterization tests are being done. The EDU design is primarily flight-like, but differences affect oceans. The differences are in the cooled focal plane read out designs, dewar configuration and slower focus length. The EDU is being tested for proof of concept. In terms of on-board calibration, the solar diffuser and sd stability monitor for reflective bands were tested. The performance was generally as expected with some differences. Three anomaly reports will be issued for LSF/IFOV (line spread function/instanteous field of view), BBR (band to band registration) and Cross-talk. The IFOV line spread function changes, and there is concern about how much the pixel changes. The M-band effects are smaller because of the lower spatial resolution. The band to band registration issue,

EDU had larger than expected BBR shifts. Dewar redesign should make FU1 performance better. How do you test for cross talk? The cross talk for any pixel has to be less than a count. The difficulty is understanding what the total impact is, so the magnitude of the effect hasn't been determined. There is some concern about how good the test fixtures are. For this reason, polarization was not measured on the EDU. NASA wants to capture all data for FU-1 testing. Data are ITAR restricted. The recommendations that came out of the tests will be discussed at cal/val working group meeting in November. The government team and the data analysis working group are trying to assess cross talk and its potential impact on science data.

Instrument concerns for ocean color data are evaluated weekly. They include cross talk, within band and total band spectral response, polarization, radiometric stability, reflectivity vs. scan, radiometric characterization, stray light, system level calibration verification, SDR look-up table verification. Other spacecraft issues include 1394 interface, cryoradiator performance, and EMI/EMC.

Software and validation are also concerns. The product evaluation analysis tool element (PEATE) was given good marks. PEATE is an evaluation effort, not for climate data record production. A validation plan needed. Draft validation plans have been written, but a final plan has not been developed. NGST is responsible to IPO for cal/val, but it is unlikely that the validation plan will be as extensive as needed for a climate data record. An individual has been hired to look at calibration for ocean color and atmospheric correction. The ocean science team should collaborate with this individual.

SST Update

Peter Minnett

Minnett reported on efforts to maintain the SST algorithm by comparing MODIS SST measurements with surface-based measurements that are of higher quality than MODIS. The comparison will show where the algorithm performs well and where it does not, so it can be improved. In the evaluation, it is important to know how accurate the reference field, in-situ measurements, is so that errors in measurements aren't attributed to MODIS.

MODIS GHRSST is intended to do this. The project matches in-situ measurements with MODIS data. In situ measurements are obtained primarily from ship-based radiometers such as M-AERI, which is the reference standard for satellite sst in general. M-AERI has been deployed on 23 independent ships since 1996. The instrument contains two large black bodies that are well-monitored. Uncertainties are in the range of 20 millikelvin. The blackbodies are characterized in terms of NIST standards, thus meeting the standard for a climate data record. M-AERI is currently on Explorer of the Seas, which crosses the Gulf Stream twice every two weeks. M-AERI was also put on research cruises to fill out areas not covered by Explorer. The research cruises covered the tropics and the Arctic, very sensitive climate regions. In addition to M-AERI, GHRSST also uses ISAR, an autonomous IR radiometer. Additional data come from drifting buoys, which take temperature measurements at one meter depth, not the surface temperature measured by satellite. This makes them inferior to other measurement, but the quantity is good. There are a large number of match-ups with Aqua. In the time series for the Terra MODIS mission, collection 5 has little seasonal bias and little difference between mirror sides. Matching to M-AERI data shows that the satellite is going a very good job of measuring skin temperature.

Cloudy areas create validation problems, so GHRSST is trying indirect validations using microwave SSTs. Work is going forward on validating AMSR-E SST data to use as a transfer validation between M-AERI and MODIS. M-AERI and AMSR match nearly 100% of the time, and then can match MODIS and AMSR.

In summary, version 5 coefficients removed seasonal bias trends and terra mirror side trends. SST 4 is less affected by dust aerosols and water vapor. MODIS SSTs are of climate quality. There is no real evidence that Terra ssts are of worse quality than aqua ssts.

Looking forward, the GHRSST program is pre-operational, but it is likely that it will become an operation product. It's likely that by the time VIIRS is flying, MODIS may not be operational. GHRSST may need to rely on M-AERI or other instruments to determine the overlap with VIIRS SST.

Ocean Breakout Session (Day Two)

UCSB Data Merging

Stephane Maritorena

Why do ocean color data merging? There are several simultaneous global ocean color missions, and there are several versions of the same product. You have to pick a sensor to get the product, but ideally, the product would be unified from multiple sensors. The resulting product would have lower uncertainties. Data merging is not easy. Sensors are not equal, there are large volumes of data, and the merging procedure can't create artifacts. There are several data merging initiatives. One is the ocean color time series project, a NASA REASoN project. The project is using the GSM01 merging model to merge data. The model uses a 9 km grid for all data sets available. For the chlorophyll product, merging is being done with daily level 3 data and 8-day, weekly, and monthly composites. There are no discontinuities in the merged product, but there are problems in the backscattering product. There is noise in the backscattering product with SeaWiFS and MERIS, but not in Aqua data. Data merging expands daily coverage. For validation, the project matched the merged product with NOMAD and SeaBASS data. The project is also comparing individual sensor products with merged products. Merged data are available on the OPenDAP server: http://dap.oceancolor.ucsb.edu/cgi-bin/nhp-dods/data/oceancolor or ftp web site, ftp://ftp.oceancolor.usbc.edu/pub/org/oceancolor/REASoN. In the future, the project will be making 3-4 day composites, merging Terra data, doing more validation, improving the user interface, and making data available through Giovani.

Data Merging/REASoN CAN

Watson Gregg

The Ocean Color Time Series Project goal is to provide a seamless time series that could be a climate data record. The time series started in 1978 and goes to the present with a 9-year gap. A consistent ocean color time series requires similar calibration. The Giovani web site will have data records for OCTS, SeaWiFS and Aqua. In the global annual mean chlorophyll product, bias is introduced when you merge Aqua and SeaWiFS. Gregg is using a model to remove the bias, which seems to work.

Can the CZCS provide a climate data record? The sensor has major deficiencies: a low signal to noise ratio, only 4 useful bands, a lack of navigation and polarization data, bias introduced by El Chichon aerosols and mission events, anomalous behavior, and sampling problems.

How do you calibrate historical and future sensors while maintaining consistency? Something beside in situ comparisons is required to constrain global mean estimates. Is it acceptable to have two data streams? How much consistency can we achieved without resorting to post-processing methods?

CZCS and OCTS Processing

Charles McClain

CZCS and OCTS data sets have been reprocessed and are available on the ocean color site with documentation about reprocessing methods. McClain applied vicarious calibration techniques and atmospheric correction and bio-optical algorithms used for SeaWiFS and MODIS to CZCS and OCTS data. With CZCS data, McClain eliminated duplicate scenes and subscenes and choose "best data." The entire mission was renavigated using ephemeris from Nimbus-7/SMMR. McClain revisited the sensor degradation and did vicarious calibration using current processing algorithms and models. The CZCS has potential for polarization sensitivity so that there are regional and seasonal artifacts in the data field. In the Balls Brothers final report, system-level tests show the greatest polarization sensitivity at 443 nm, 2-3% for 0 & +/-10 degree tilt. No information was provided on the polarization phase function, so the polarization

sensitivity of instrument isn't known. Events in the mission history also impact data. These include heating of sensor, volcanic eruptions, and El Nino. The instrument covered coastal regions. Holes in SeaWiFS are usually because of clouds. There is a large variation in global coverage. CZCS data were calibrated with BATS and compared with SeaWiFS.

Stratospheric aerosols from the El Chichon eruption had a non-negligible effect on data. An analysis of aerosols predicts that the effect should be evident in radiances. CZCS shows extreme seasonal differences at 443 nm.

CZCS global coverage is inadequate for global climate record data sets. Cholorphyll data do match well with models. OCTS has limited pre-launch characterization. The OCTS calibration table has a period where calibration adjustment was needed. Also the sensor was heated in Jan. or Feb. 1997, which caused some degradation. Globally, SeaWiFS and OCTS water leaving radiances are close except at high latitudes. Lack of radiometric validation data makes quantification of data difficult. OCTS and POLDER have simultaneous records.

For now, McClain is standing down from further analysis to focus on Terra.

Pigment Processing Update

Laurie VanHeukelem

VanHeukelem described the procedures for evaluating field samples for pigments at the Hornpoint Laboratory. After arriving at the lab, samples are placed in -25 degree C freezer. The lab extracts and injects 38 samples a day. The chromatogram is inspected on screen. As of 10/30/06, 15% of samples had been analyzed in 17% of the contract time, putting the lab on target its goal. G. Fargion will notify PIs of sample shipment dates. Samples that are at lab will be completed by December. Quality assurance procedures at Hornpoint include method validation, accuracy in Round-Robins, and continuous quality assessment. During the method validation stage, VanHeukelem looks at the peak symmetry, resolution between the peaks, quantification in the presence of interferences, linear dynamic range, LOD and LOQ, accuracy and precision, and spiked recovery. Van Heukelem reports that it has been valuable to participate in NASA Round Robins. In SeaHARRE reports, every lab has a chapter that describes their method. The reference values for natural samples are based on average consensus concentrations. Accuracy is calculated as the percent difference from consensus, but it is necessary to make sure all participating labs are quality assured. The average calibration accuracy with standards was 7 percent; Hornpoint was 1 percent. The other aspect of quality assurance is to monitor the performance of the method during the analysis of samples. This limits uncertainties and mistakes, identifies the range within which quality control measurements should fall, and identifies if corrective action is needed. Reports are given to PIs in a spreadsheet that the PI has previously prepared. Pigments not found and those with a SNR of 4 are given a concentration of .001. Hornpoint also provides a graph of effective LOQ. HPL sample codes are given for each sample. A "0.5" is added to samples that were injected twice, once at the beginning of the day, and once at the end to test uncertainty throughout day. Pigment ratios are also reported in the spreadsheet because it could be a quality assurance tool. Hornpoint also checks quality with an inter-method comparison.

Historical Pigment Processing Update

Chuck Trees

HPLC phytoplankton pigment measurements show biases for monovinyl and divinyl chl a and b. Issues were identified in CHORS lab samples. Only three compounds affected by C8 method. The CHORS lab had been using the C18 method, and had low uncertainties. With MODIS, the lab moved to the C8 method. There are two differences between two processes. The CHORS lab couldn't duplicate low uncertainty with C8 method, the choice method. Because of problems with the C8 method, the lab analyzed samples with both methods and saw a difference for diviinyl chl a, monovinyl chl a and chl b. A poster was presented at the February ocean sciences meeting. In March, SH3 results were made available showing the bias in the

C8 method. The bias is log linear and predictable. Only monovinyl chlorophyll a, and divinyl chlorophylls a and b showed bias. SH3 samples and standards were analyzed in August and September 2005. The SH3 field samples showed a similar bias. The uncertainty in the results for the C8 method was not random but followed a log-linear bias. The problem with the C8 method occurred throughout the MODIS pigment data processing period.

In the future, the CHORS lab plans to do a comparison of duplicate HPLC samples processed by Horn Point that can be used to evaluate the consistency of the bias for other waters and depths. The lab will conduct an independent review of the possible reasons for the bias, as well as verify the approach proposed by CHORS to determine bias consistency and correction factors for the 3 compounds.

Data Product Workshop Overview

Paula Bontempi

A NASA workshop titled "Supporting in situ and space based measurements" was held a few weeks ago. There were a range of participants from government, universities and the international community. Before the end of the meeting, participants wrote a draft report. The questions and properties addressed were based on the ocean program advanced plan. The four questions address ocean ecosystms and biodiviersity, carbon, marine habitat, and hazards. Carbon missions were considered by the group, both current and planned, in terms of observational requirements and strategies. What measurements do we need? What can be measured with current instruments? What is the observational strategy? What needs to be developed? Participants created a revised straw man list grouped by time frames in 5 year increments. Recommendations were to: collect a_cdom with all chlorophyll samples; collect species counts with HPLC pigments, collect AOPs and IOPs into the UV, and submit all data to SeaBAS. The straw man parameter list included chlorophyll a, PP, POC, PIC, DOC, carbon export, TSM and TOM, T, S, oxygen, PAR, PFTs, DIC, land-ocean exchange, beam-c particles, PSD, nutrients, and non-living particulates. These things should be measured by a broader community, not just NASA. The participants then broke into 3 groups.

The AIP and IOP Measurements group recommended that apparent and inherent optical properties be measured in the 300-400 nm range, vertical profiles be measured, protocols be updated, and that NASA organize a workshop on backscattering instruments and measurement protocols. Operational definitions of the absorption terms and backscattering should be revisited. The group recommended that IOPs and AOPs be measured.

The primary production group wanted to see improvements to modeling production. Field observations should aim to measure all of the presented properties simultaneously.

The parameters for characterizing standing stocks of seawater constituents including particle functional types group considered a number of particles. They recommended that the concept of phytoplankton functional types be broaden to include particle functional types. The IOCCG working group will provide a useful synthesis of concepts. The status of the measurement techniques and protocols was discussed. The group did not recommend that information about phytoplankton functional types be included in the NASA database.

A short report of the meeting should be available next week for the community to review.

Protocols/Upcoming Round Robins

Stan Hooker

The cal/val plan acknowledges the importance of protocols and outlines where we want to see protocols resurrected. A primary core scientist is assigned to each task. The basic premise of round robins is that all participants use a validated method, each of which is equally capable of estimating a true result for each "sample." What happens when basic premise, that method is valid, fails? Accuracy and precision are necessary for round robins. The types of round robins held in the past covered optical calibrations and data analysis. The SIRREX round robins brought uncertainties in the traceability of spectral lamp irradiance and

sphere radiance down. The DARR analysis showed differences in methods for determining in-water primary optical properties. The Sea-HARRE intercomparisons made precision an accessible variable as long as duplicates are used. In terms of accuracy, the results are more complicated. There is a significant decrease in uncertainties associated with the QA methods. Hooker discussed the CHORS results in SeaHARRE-3. Standards were distributed with round robins to be used as part of the quality assurance process. CHORS executed two methods based on C8 and C18 columns, both of which have significant deficiencies. Poor precision results on SeaHARRE-3 are from the CHORS C18 method. When the problem was identified with the CHORS analysis, duplicates were used in testing.

In the validation approach from mixed standards, the primary source of uncertainty is the improper handling and storage of field samples. The analysis found that a good lab analyzing bad samples is better than a bad lab analyzing good samples. Sample handling is important. Hooker is in the process of executing SeaHARRE-4 with a focus on coastal waters. He listed the labs participating in SeaHARRE-4, which demonstrated the strong effort made to increase international participation and include labs that use different methods. All labs do HPLC and one other measurement.

Calcite

Barney Balch

PIC is a primarily affects backscattering. There has been renewed interest in the PIC product because of ocean acidification. A decrease in ocean pH is expected in the next 50 years, so solubility will drop, starting at high latitudes. The PIC algorithm is a merged 2-3 band algorithm. The 2-band algorithm is a look-up table. If you underestimate chlorophyll, you overestimate calcium carbonate, and vice versa. The merged algorithm rarely requires the 3 band algorithm, which comes in at a certain radiance level. In the Gulf of Maine, Balch made many measurements of particulate inorganic carbon with backscattering. Binning could reduce the variance. Applying the product using SeaWiFS and Aqua data gives consistent results. The 2-3 band algorithms are basically backscattering algorithms. Satellite backscattering tends to overestimate PIC. In 2004 and 2005, Balch participated in cruises in the mid-Atlantic, which offered an unprecedented examination of backscattering. Cruises represent 100+ days at sea. Results for pigments, IOPs, PICs, and other data were submitted to NASA. The AMT-17 cruise, which went directly over a large cocco bloom, gave the greatest range of PIC. In the analysis, Balch looked at 8-day averages because of cloud cover. New observations showed that North and South Atlantic PIC has a lower backscattering cross-section than is used in the current PIC algorithm (for cocco bloom). Ship PIC values vs Aqua values show that Aqua PIC values are 2.6 times too high in the AMT data set on average. This means that the two band estimate should be adjusted.

Vicarious Calibration

Jeremy Werdell

Werdell presented NASA's operational approach for the vicarious calibration of on-orbit ocean color satellites. The approach has tried to be non-satellite specific, but is specific to Gordon and Wang atmospheric correction. The vicarious calibration uses a single set of fractional gains where unity indicates no correction. The correction is an integrated atmospheric correction system that accounts for undetermined post-launch changes and atmospheric correction biases. The calibration assumes that temporal trends are removed. Now, gain is calculated at the top of the atmosphere, which makes calculation less computationally expensive. Normalization corrects for time of day and view angle differences in measurements. From that, the approach calculates the water leaving radiance at the top of the atmosphere. Werdell provided an overview of NIR calculation. The NIR calibration is independent of the VIS calibration. Werdell is using water leaving radiances from MOBY taken at satellite overpass time for calibration. Werdell gave an overview of VIS calculation. Calculations are more complicated than the overview.

A discussion of SeaWiFS gain vs time ensued.

Werdell provided validation statistics. As more samples are added, the standard error of the gain decreases to 0.2 percent and overall variability approaches 0.5%. SeaWiFS vicarious gains and standard deviations for reprocessing were given. Gains for MODIS were also provided with current deep water subset matchups.

Discussion

Paula Bontempi

What data products should be part of the climate data record? We should consider if phytoplankton, chlorophyll-a, is still the Earth system data record. The land community has drafted white papers about what climate data records are. The ocean community should talk about doing the same. A climate data record is a data product that meets the quality needed to measure climate variability and change. We should ask what records could help answer the science questions give in the NASA OBB program. A record of radiances is needed to develop additional products.

Who is the user community that we are trying to reach with climate data records and what do they need? Are they modelers? How many different time series do we need to create? There have been several international efforts to create merged time series data sets, but we may need to narrow the time series down to most the valuable to point to as climate records.

In terms on building on the round robins, we have the report from the data product workshop, but we need to prioritize the most important products to determine where round robins need to focus in the future.

Vicarious calibration should be discussed during mission extension discussions for Terra and Aqua. What is the plan for vicarious calibration for NPOESS data?

What future ocean missions should NASA develop? Having multiple sensors in orbit helps expand coverage in data merging. Planned ocean color sensors: GOCI, GOCI, HES-CS, OCM-II, S-GLI, VIIRS, VIIRS. There may be a more open market for data collaborations. For advanced planning, what do we need to do in the next 30 years? The plan is broken into relevant Earth system science areas. The top mission themes include global separation of in-water constituents, and high temporal and spatial resolution. Some possible observational strategies include: a global hyperspectral imaging radiometer, a geostationary hyperspectral imaging radiometer, a multispectral high spatial resolution imager, portable sensors from suborbital platforms, a variable fluorescence LIDAR, a mixed layer depth and illumination sensor, an ocean particle profiler, and aerosol column distributions.

As part of the US ocean action plan, the White House is interested in putting money into ocean research. Agencies doing ocean research wanted 4 research areas for the next several years, and NASA is a part of 3 of those areas.

What is the plan for reprocessing of VIIRS to create climate data records? No plan is in place now. Discussion of the need for reprocessing to get data reliable enough to serve as a climate data record ensued. Who is going to reprocess the data so that we have climate-quality data? The MODIS science team may be called upon to do that.

MOBY ends in March 2007, but it is essential for the climate data record. What do we do then? We have to recompete the budget to replace MOBY capability. SeaWiFS ends in April 2007. We need plan of some sort for a long term climate data record.

Land Breakout Session (Day One)

Update and priority issues for MODIS land

Chris Justice, University of Maryland

Dr. Justice gave a summary of the current status of the MODIS land products, a description of the outstanding issues related to these products, and an outline of future events relevant to the MODIS land team. He gave the planned schedule for the MODIS Land Collection 5 reprocessing, which is due to complete in September 2008. An ATBD for a new product, Vegetation Moisture Content, is under development and will undergo review before a decision is made on whether to add this product to MODIS land processing.

A senior review for Terra and Aqua is upcoming, and Dr. Justice requested input that would help make the case for the continuation of those sensors. Several other issues that require the attention of the MODIS land science team were then raised by Dr. Justice and audience members. These issues included the consistency of MODIS data products with each other and with other data and models, adaptation of the LAADS/EOSDIS model used for MODIS ocean and atmosphere data to land products, the use of NPP/VIIRS data in the future, and the AVHRR/MODIS/VIIRS long-term data set.

NPP update

Bob Murphy

Murphy stated that he is now less optimistic regarding the state of the NPP and NPOESS programs than he was last year, but still expects the VIIRS instrument to be just shy of the quality of MODIS. The major outstanding issue found in testing of the VIIRS issue is crosstalk, which could add further delay to the production of VIIRS. Other difficulties with the VIIRS instrument include the instrument's line spread function and band-to-band registration. The Santa Barbara facility where the VIIRS instrument is being built will be shut down after the NPP VIIRS is complete, raising the prospect of a loss of expertise if key personnel do not relocate to the new facility.

Proposal for a new 250-meter land/water mask for MODIS

Rob Sohlberg, University of Maryland

The AVHRR heritage land/water mask algorithms have been improved by researchers at Boston University, but inconsistencies and errors still occur in this data, which is only available at 1 kilometer resolution. It was proposed that MODIS 250 meter data be combined with data from the Shuttle Radar Topography Mission (SRTM) to generate an improved product. The SRTM data is at a higher resolution than MODIS, but contains gaps due to clouds and a limited latitude range. Using MODIS data to fill in these gaps would provide a more complete dataset. They are seeking funding to complete this work, which would result in a dataset that could be distributed by the LPDAAC.

Collection 5 status and schedule

Robert Wolfe, Goddard Space Flight Center

Science testing for Collection 5 data has been ongoing since November 2004, including five major tests and 10 minor tests. The data from these tests is examined by the LDOPE quality assessment team and members of the Land Science Team, with support from the MODIS Science Data Support Team. Several Collection 5 milestone dates were given. In September 2006, Collection 5 Terra reprocessing restarted and the 16-day Terra/Aqua combined global test was completed. Currently, time series tests are in progress for a few products. In December 2006, Collection 5 Terra processing for the year 2000 is expected to be complete. In

January 2007 Collection 5 Terra and Aqua combined processing at 7.2X rate should begin. By late May 2007, Terra reprocessing should be finished. By September 2008, Collection 5 reprocessing should be finished.

The following C5 products are ready for release: land surface reflectance, LAI/FPAR, vegetation index, PSN/NPP, BRDF, land surface temperature, and fire. Other products, including sea ice, snow, vegetation continuous fields, land cover change, and burned area are on hold due to reviews, fixes, or requirements for a full year of data. An agenda for the Land Collection 5 workshop to be held in January 2007 was circulated and discussed.

Land Breakout Session (Day Two)

Earth System Data Record (ESDR) for Global Evapotranspiration

Eric Wood, Princeton University

Dr. Wood summarized strategies for obtaining evapotranspiration data on scales ranging from small towers to global. The small-tower level data was obtained from in-situ measurements and compared to the results of a surface energy balance model combined with MODIS data, meteorological ground station data, and radiation parameterizations. The correlations found in these studies are good, which demonstrates that the models used work well.

At medium scales on the order of 10 kilometers, meteorology data are obtained from satellites along with surface and vegetation parameters. An example of results obtained at this scale by combining MODIS data with a network of ground stations in Oklahoma was shown.

At global scales, examples of surface radiation fields calculated from ISCCP meteorology data were shown. It is also possible to obtain this information from MODIS alone, but this approach has the shortcoming of missing surface temperature data under cloudy conditions. However, MODIS-derived evapotranspiration is useful for cross-checking with results from ISCCP data. GMAO meteorological data are unacceptably biased for global evapotranspiration calculations.

MODIS Ice Data Products

Ted Scambos, National Snow and Ice Data Center/ University of Colorado Boulder

Developments in the use of MODIS data to characterize ice and snow covered areas were described. Composites of MODIS reflectance data combined with grain size information derived from MODIS data were used to make mosaics of ice sheets with a high degree of surface detail. MODIS ice albedo and surface temperature data are being validated against ground measurements; better BRDF modeling may improve the performance of the MODIS albedo algorithms. Sub-pixel characterization of snow cover is under development, and will be useful for hydrological applications in mountainous regions. MODIS data were also used to provide more detail for coarser-resolution DEMs and laser altimeter-based change detection.

Retrieval of water and dry matter content from leaf, canopy, and image scales

Susan Ustin, University of California-Davis

The motivation for this work is to provide data that will aid in understanding global carbon and water cycles, surface heat budget partitioning, and drought potential monitoring. The matchup between water absorption bands and MODIS bands was illustrated. Sensitivity analysis using the PROSPECT leaf optical property model showed that MODIS bands 5 and 6 are most responsive to the presence of water within leaves. Leaf area index is related to canopy water content via leaf equivalent water thickness. The structure of the vegetation canopy complicates retrieval of water content, so a canopy model is useful in these measurements.

Data taken during the SMEX North American monsoon soil moisture experiment showed that soil moisture and leaf moisture are closely linked in a dry climate. This relation is weaker in wetter climates. The relation of NDVI to leaf water content also varies with ecosystem. Results from the application of a neural net to data from MODIS and radiative transfer modeling to retrieve canopy water content over the United States were shown. These results show sensitivity to both ecosystem type and seasonal cycles.

A 0.05 degree global climate/ interdisciplinary long-term data set from AVHRR, MODIS, and VIIRS

Eric Vermote, University of Maryland/ Goddard Space Flight Center

Dr. Vermote provided an outline of the Long-Term Data Record (LTDR) project. The goals of this project are to develop a global long-term data set from AVHRR data, using a MODIS-like approach and providing versions of this data to other researchers in order to receive feedback on data quality. A list of proposed products, including vegetation parameters, snow, surface reflectance, and aerosol, was shown. A beta dataset has been produced from AVHRR data taken between 1981 and 2000. This data is going through evaluation similar to that used for MODIS data, including QA evaluation, statistical evaluation of calibration stability, and validation versus in-situ data. Results from other users of this dataset are expected to provide information that will be useful in evaluation of this data and production of future versions. The main LTDR and LTDR QA Web sites were illustrated, and an LTDR workshop to be held in conjunction with the MODIS Collection 5 workshop in January 2007 was announced. Issues generated by the existence of gaps in the AVHRR record and future plans for the project were discussed.

Mid-decadal global land survey

Jeff Masek, Goddard Space Flight Center

The goal of the Mid-Decadal Global Land Survey (MDGLS) project is to obtain a global land cover dataset from data taken by the Landsat satellites from 2005-2006. This project is a follow-up to similar preceding projects, using data from 1975, 1990, and 2000. There are three phases to this project: acquisition and archiving of the data, processing of the data to ortho-rectify it and fill gaps, and analysis of the data set to locate changes in land cover from previous data sets.

The focus on the data gathering for this project is on areas where data is missing, mostly in the Arctic and Antarctic. An attempt is being made to gather data for the peak-NDVI season for each ecosystem. Some international ground stations and temporary stations are being utilized to obtain data.

During the second phase of the project, the best scenes for each area are selected and processed. Landsat-7 data is of better quality than Landsat-5, but contains gaps. The Landsat-7 gaps can be filled easily with Landsat-5 data when no clouds are present, but the gap filling results in a radiometric mismatch if clouds are present. Thus, scenes are selected from Landsat-5, Landsat-7, or composites according to the degree of cloudiness present. Data acquisition and selection is occurring now, and processing will begin soon.

The last phase of this project has not begun yet, but several suggestions were given regarding how to proceed with land cover change analysis based on these data. It was recommended to prioritize areas of high interest, include disturbance data to detect changes that would otherwise be missed, and begin a validation program.

Discussion

Chris Justice, University of Maryland

Justice gave a brief summary of a presentation regarding Landsat data continuity that was to be given by a science team member, Jim Irons, who was not present at this meeting . With Landsat 7 beginning to fail and the next Landsat mission scheduled for launch in 2012-2013, it was proposed that data from international satellites could be used to fill the gap.

Chris Justice then led a discussion regarding response to the upcoming Senior Review. The dominant question of this discussion was the possibility that with the recent launch of the European METOP, a satellite flying an AVHRR instrument in a morning orbit, Terra could be perceived as redundant. A brainstorming session for counter-arguments followed. They included:

- Enhanced vegetation index is not possible with AVHRR

- The spatial resolution of MODIS is higher than that of AVHRR
- It would be valuable to have MODIS Terra data overlapping in time with this newly-launched AVHRR for comparison
- Terra facilitates study of processes where the diurnal cycle or short time scale events are important
- Ocean bands on MODIS can be used for land applications
- Direct broadcast users would need to make adjustments in order to use AVHRR data instead of MODIS Terra
- A longer record from the same instrument is valuable
- Aqua may not outlast Terra, and we want a MODIS instrument up as long as possible
- AVHRR calibration and geolocation issues
- Maintaining Terra through International Polar Year
- General need for current Earth observations

Further discussions related to the other instruments on the Terra platform and multi-instrument synergy.

Discussion Session: Measurement teams

Chris Justice led the first discussion session, which focused on the development of measurement-specific rather than instrument-specific teams for stewardship of NASA Earth science data sets. NASA Headquarters has requested that the community begin working towards forming measurement-focused teams and determining which measurements are most crucial to maintain as long-term, consistent records.

Instrument teams will still be needed for instrument operation and calibration. Measurement teams should include instrument scientists, observational algorithm developers, and modelers.

Discussion followed regarding the categorization of land measurements for the purpose of measurement teams and the role of ATBD reviews. Chris Justice then requested the top two priorities for researchers concerned with each data product. A summary of these priorities follows. (Some groups stated more than two priorities, or just one.)

Product consistency is a repeatedly-mentioned issue that cuts across different data types. Error propagation is another cross-cutting issue.

Fires:

- Continue MODIS active fire and burned area record using VIIRS
- Fire radiative power research
- Validation of burned area detection

Surface reflectance:

- Continue AVHRR and MODIS record using VIIRS
- Fix aerosol over land and refine cloud mask

Cryosphere:

- Snow water equivalent algorithm development
- Snow cover albedo subpixel measurements and validation

Temperature and emissivity:

- Internally consistent global gridded land surface temperature across instruments
- Internally consistent global gridded emissivity across instruments
- Both of these goals include validation efforts

Incident solar radiation and PAR:

- Internally consistent multi-instrument global gridded PAR, with initial MODIS emphasis

Surface albedo and anisotropy:

- Validation of global albedo products
- Diurnal albedo from multiple data sources
- Gap filled products for global modelers

Vegetation Index:

- ? Vegetation index intercomparisons across instruments
- ? Integration of in situ data and use of this data for validation of seasonal cycle

Phenology:

- ? In situ networks for calibration and validation
- ? Research and development on merging optical and microwave data to fill gaps created by clouds in optical products

Gross/ net primary productivity:

- ? Generation of LAI and NPP from VIIRS data
- ? Improved global daily meteorology data sets for better GPP data
- ? Soil respiration, light use efficiency data

Evapotranspiration:

- ? Algorithm intercomparison, including understanding of scaling and resolution

Land cover:

- ? Mid-decadal land cover and disturbance data set development
- ? Internally consistent AVHRR/MODIS/VIIRS land cover and continuous fields
- ? Reconciliation between land cover and continuous fields
- ? Consistency in land cover classification schemes

Two sub-breakout sessions followed, on the following topics:

Breakout Discussion: Product consistency and use of MODIS products by modelers

During the product consistency breakout session, a brief presentation was made by Jeff Morisette of GSFC, describing the generation of smoothed data products for use by modelers with the TIMESAT software. Robert Dickinson led the discussion that followed. The first topic mentioned was that of communications between MODIS team scientists and modelers. This developed into a discussion of how the definitions of parameters often differ between models and data sets.

The question of what sort of data modelers prefer was raised. Modelers prefer consistent and physically-based data sets that they can use easily. Computational and data storage limitations also come in to play, especially since meteorological modeling is computation-intensive. Sub-grid-scale canopy characterization emerged as a topic of particular interest. Then the topic of consistency between MODIS data sets came up again, including the role of the land QA team in this work.

Breakout Discussion: Product specifications for mid-decadal land survey Phases II and III

The mid-decadal land survey product discussion was summarized by Chris Justice once both sub-breakouts were finished. He noted that another meeting would be useful to set priorities for this work, including questions of quality assurance, validation, and lessons learned from previous land surveys. He also mentioned that a summary assessment of NPP land products would be coming out towards the end of 2006 before adjourning the session.

MCST Calibration Workshop (Day Two)

Introduction

Jack Xiong, MCST Lead, NASA/GSFC

Jack Xiong started the MCST workshop with welcome remarks and a workshop outline that includes briefings and presentations from MCST members, MODIS science team representatives, and Cal-Val scientists. The introduction also provided a short description of instrument background.

MODIS Instrument Operation

Bryan Breen, MCST Instrument Opertion Team (IOT)

Both Terra and Aqua MODIS have been performing well on orbit.

Terra MODIS SRCA 10W lamp #3 was verified to be abnormal in February 2006 and taken out of service. Since then, the tests are run in Constant Current Mode (versus Constant Radiance Mode) on remaining 10W lamps #1 and #4. Aqua MODIS SRCA is also running with 10W lamps #1 and #4 in Constant Current Mode. The power load of new CCM is about 90% of CRM. Because of this change from 30W to 20W configuration, the spectral tests for both instruments require to be redesigned. The new macros have been uploaded into RAM and run successfully.

There was a Terra NAD/SVD close incident due to IOT errors on August 22, 2006. The SMIR and LWIR FPA temperatures increased to 101.2K. The SVD and NAD were commended OPEN 2 and half hours later. The cold FPA temperatures returned to 83K nominal in about 24 hours. Data analysis from Terra MODIS on-board calibrators and EV targets indicated that this event had no impact to the detector's characteristics and data quality, except for some data loss. One of the NAD switches stuck during previous NAD operation (December 2003) is now working properly.

The rest of the operational activities (OA), including Blackbody warm-up cycles, electronics calibrations, lunar roll maneuvers, and SD/SDSM operations are doing normally. There has been no new Solid State Recorder (SSR) anomaly or configuration change on Terra and Aqua since last Science Team Meeting in January 2006. The FOT is ready to perform the SSR recycling if another PWA is lost. The recycling plan has been briefed to NASA HQ. No final decision is made yet.

L1B Code and LUT Update

James Kuyper, MCST Level 1B Group

Since last Science Team Meeting, there has been no major change in L1B code or LUT update that had any science impact. The collection 4 and collection 5 are both running and producing L1B data. There were few changes made to L1B code and the PGE02 perl scripts. Most changes were triggered by switch of data distribution from GDAAC to MODAPS. The number of code changes and LUT updates are listed in the presentation package.

The new Level 1 and Atmosphere Archive and Distribution System (LAADS) requires that the data files to be internally compressed before distribution in order to save space and reduce network traffic. This does not include L1A. Production of compressed files started on April 6, 2006. The compressed files (about 43% reduction in file size) can be read using existing programs and HDF utilities without code modification. The files can be decompressed using hrepack utility. The PGE programs will run a lot slower when HDF input files are compressed. So all PGE running under MODAPS decompress their input files, if necessary, before running process code. The slow-down process can be substantially reduced using chunked the SDS. The first L1B products with chunked SDS were produced on October 4, 2006.

The old collection (version) 4 data of L1A and L1B are no longer archived at DAAC. The users will have to order them through MODAPS. Once the data has been ordered, the system will run the Level 1 to recreate the data and deliver it.

RSB On-orbit Performance

Xiaobo Xie, MCST RSB Calibration Group

The Reflective Solar Band (RSB) detector gain trending from Solar Diffuser (SD) and lunar view (Moon), and SD degradation are illustrated for Terra and Aqua MODIS. The recent update of the detector quality status and the signal-to-noise ratio (SNR) are also displayed. The SD/SDSM calibration is running tri-weekly on Aqua. Terra MODIS SD calibration with screen in place is available every orbit since July 2003 and the SDSM operation is still on a bi-weekly basis. All RSB detectors are calibrated except for few inoperable detectors, such as those in Aqua MODIS band 6. The gain trending is tracked smoothly. Both sides of the scan mirror have shown noticeable wavelength dependent degradation. The mirror side difference changes very small on Aqua with less than 1% after four-year on-orbit operation. For Terra MODIS the mirror side differences are much larger, especially in the VIS spectral region. For Terra MODSI band 8, the mirror side difference went as large as 10%.

One of the concerns is about Terra B8 calibration quality due to its response decrease of more than 34% so far and large SD degradation at its wavelength. The detector signal level from the SD is only about 200 counts. The SNR is already below the specification requirement. MCST is looking for other alternatives to improve B8 calibration.

TEB On-orbit Performance

Brian Wenny, MCST TEB Calibration Group

The Thermal Emissive Band (TEB) detector short-term and long-term response trends are stable. The big jump of linear coefficient b1 during Terra's first year operation was due to the electronics change from A-side to B-side. No major issues for TEB since last Science Team Meeting. Totally, there are 24 noisy detectors (2 new since last STM), 1 inoperable detector (B29 D6 due to very large random noises) in Terra MODIS, 1 noisy detector (B27 D3) and 1 inoperable detector (B36 D5) in Aqua MODIS. The Terra MODIS LWIR PC optical leak in B32-36 has been stable since launch and on-orbit corrections are effective and unchanged.

Since last STM, MCST has worked on the update strategy for calibration coefficients A0 and A2. The current method to produce A0 and A2 works well over a broad range of scene temperatures, except for extremely cold scenes (e.g. T ~ 200K). The bias at very cold temperature was identified from MCST investigations by using different methods. It is also noticed from inter-comparison study with coincident AIRS measurements. Sensitivity study from using all combinations of A0 and A2 indicates that fixing A0 at 0 can produce consistent scene temperatures with the current LUT for the typical temperature range, and at the same time reduce the bias at cold temperatures.

Challenging Issues and Future Work

Jack Xiong, MCST Lead, NASA/GSFC

There are a number of issues that MCST is currently working on in order to maintain and improve Terra and Aqua MODIS radiometric calibration and data quality for both TEB and RSB. For RSB calibration the most challenging issue is to accurately track RVS change in the VIS spectral region. For TEB the focus will be on the improvement of A0 and A2 update strategy. MCST is also performing limited cross-sensor calibration to validate Terra and Aqua MODIS calibration consistency. Some results are presented at recent CALCON and SPIE meetings.

As the sensor starts to show aging effect (see Terra MODIS TEB noisy detector history), extensive and constant efforts have to be made (by MCST) in order to continuously maintain instrument calibration and

data quality by combining on-board calibration and other approaches with the input and support from science groups and instrument vendor (SBRS). The re-location (or closing) of Raytheon SBRS may have some impact (TBD) on MODIS operation support.

Reflectance-based Results for Terra and Aqua MODIS

Kurt Thome, MODIS Calibration and Validation, University of Arizona

This vicarious calibration approach relies on the ground-based measurements at the time of sensor overpass. It predicts at-sensor radiance via the radiative transfer code and then compares to the sensor output (L1B products). Such method can be used as a reference between sensors with large and/or small footprint. It does not require coincident looks at the same site at the same time from different sensors. But the size and uniformity of the test site could play important role in this method. Results from Rail Road Valley (RRV) playa show that Terra and Aqua MODIS VIS and NIR calibration is better than 2.5% in terms of precision and accuracy (see plots in the presentation package).

The data points used are from different angles (AOI) and both mirror sides.. There are still some registration effects in the data. Future work is to improve the precision and the surface reflectance measurements.

Analysis of Image Striping due to Polarization Correction Artifacts in MODIS Aqua Ocean Scenes

Gerhard Meister, Ocean Biology Production Group, Futuretech Corp

The inaccuracy in polarization characterization can cause some local striping in ocean color products. Even if nLw accuracy is met within the designed specification of 5%, striping still exists in ocean color images.

MODIS RSB calibration parameters are derived from SD measurements for each detector and from band-averaged lunar measurements. MCST lunar results from SD calibration coefficients show detector 1 is about 0.5% higher than detector 10. The Level 2 validation shows some problems with current polarization correction at 412nm. There are significant differences (different striping patterns) between northern and southern hemisphere for 412nm, but not so at 443nm. MODIS Aqua ocean color products are still affected by residual striping. As for Terra MODIS, we expect this de-striping method will reduce the mirror side differences and unknown polarization effects due to large mirror degradation.

LWIR Band Radiometric Performance

Chris Moeller, Atmosphere Group, University of Wisconsin

The NASA ER-2 aircraft-based assessment is used to validate the LWIR bands calibration accuracy using coincident MODIS overpass data. The LWIR window channel bands 31 and 32 are consistently performing within the spec for Terra and Aqua throughout the mission. However the CO2 bands, especially B35 and B36 are consistently performing out-of-spec. The residual errors for Terra CO2 bands (> 1K) are larger than those of Aqua (~ 1K).

From the calibration algorithm, there are several possible causes to the radiometric error in LWIR bands. (1) On-orbit Calibration Coefficients, which do have some impacts on the low temperatures when different set of coefficients are used but they are small (< 0.2K) compared to pre-launch calibration. (2) Spectral Characterization. A spectral shift estimate based on matching Aqua MODIS and AIRS radiances is significantly (15-20nm) larger than the pre-launch spectral uncertainty for these bands. It is hard to believe that much spectral shift from pre-launch to on-orbit. (3) Optical Cross-talk (Terra only). From the image analysis, it doesn't appear that the Terra MODIS 11 µm optical cross talk correction can be increased significantly to explain the large bias. (4) Out-of-band Filter Leaks. The pre-launch LWIR OOB spectral leak is essentially untested due to poor quality test data (high noise). (5) Scan Mirror Reflectivity. The uncertainty of the RVS is small from the analysis. However, the on-orbit evaluations, e.g. DSM RVS, have significant change and improvement over the pre-launch RVS.

In-Flight Cross Validation of Mid and Thermal Infrared Remotely Sensed Data from MODIS and ASTER Using the Lake Tahoe Automated Validation Site

Simon Hook, *Calibration and Validation, NASA/JPL*

The Lake Tahoe is large (35 km x 16 km) and homogeneous enough to serve as a validation site all year around (5-25 degrees C). There are good infrastructures at the site with easy access. On the shore, we have equipments to measure air temperature, wind speed and direction, relative humidity, short and long-wave radiation, aerosols, and sky imager. Off the shore, we can measure bulk temperature, skin temperature, air temperature, wind speed/direction, relative humidity, and net radiation. This site has been operating since 1999 to valid thermal infrared data automatically. The validated site has been used for multiple sensors, such as MODIS, ASTER, AATSR, Landsat 5, and Landsat ETM+. Results show excellent calibration accuracies for Terra and Aqua MODIS TIR and Aqua MODIS MIR. More work is still need for Terra MODIS MIR.

Validation of Sea-Surface Temperatures from MODIS

Peter Minnett, *Sea Surface Temperature, University of Miami*

MODIS SSTs are derived from measurements in the 10-13 μm atmospheric window bands (SST) and in the 3.5-4.1 μm atmospheric window bands (SST4) at night. The validation is accomplished by comparison with accurate surface-based measurements of SST using ship-based radiometers, e.g. M-AERI, ISAR, CIRIMS and others. Among them, M-AERI is the reference standard for satellite SST retrievals for MODIS, AVHRR, and AATSR. The M-AERI is also being used for AMSR-E & AIRS SST validations.

The differences we see in MODIS and AMSR-E SST comparisons have spatial patterns, indicating geophysical causes. Some of the discrepancies are due to AMSR-E, some to MODIS. The monthly retrieval coefficients have been fairly stable over the past three years. In V5, the monthly coefficients have removed seasonal bias trends, like Terra mirror side trends. We also improved quality filtering to remove most cold clouds and significant dust aerosol concentrations. We developed and implemented the uncertainty Hypercube into Terra and Aqua SST and SST4 products to provide insight into bias and standard deviation trends as a function of time, geo-location, and temperature difference.

In summary, MODIS SSTs have provided climate record quality data with extensive error characterization, and traceability to NIST standards. Current status is a tribute to efforts of MCST in characterizing the instrumental artifacts. Terra SSTs are as good quality as Aqua SSTs. MODIS SSTs can provide the best heritage data for the VIIRS algorithm testing.

MISR Reflectance-based Vicarious Calibration

Stuart Biggar, Calibration and Validation, University of Arizona

MISR radiometric calibration is based mostly on vicarious calibration because of issues of its on-board system. Our reflectance-based method is to collect ground calibration data coincident with imagery data over a field calibration site. The ground reflectance measurement system consists of field spectrometer (350-2500 nm coverage), spectralon reference (calibrated in the lab), ratio measurement to reduce instrument drift, atmospheric extinction, solar radiometer, aerosol and molecular optical depth, gas absorption (water vapor and ozone), and ancillary data such as pressure and temperature. We use Modtran4 to compute at sensor radiance. We reprocessed all our MISR dates with a consistent calibration – special request for “Collection 5” L1B2 terrain projected data to ensure all dates have the same sensor calibration applied. Assuming that MISR is stable over time, we extract the appropriate pixels to determine average radiance as measured by MISR and then compare to MODIS.

Final Plenary Session (Day Three)

MODAPS/LAADS/Goddard DAAC Status, plans, metrics, etc.

Ed Masuoka and Mike Teague, Goddard Space Flight Center

The transition of level 1 processing, archive and distribution from Goddard DAAC to LAADS is now complete. MODAPS has 7x24 production with 10 full time employees. Four people were added to the MODAPS staff to help with distribution and user support. There are two sites, the public site with level 1 and atmosphere products. Land products are at the LP DAAC and NSIDC. A private, password-protected site is also available to the science team for the archive and distribution of land data products. In L5, data products are archived in compressed form. The LAADS atmosphere archive permanently stores all collection 5 geolocation, cloud mask/profiles, browse, and L2+ atmosphere data products. Level-1B products from CONUS and Western Europe are permanently archived. Other data are put in a data pool, which is deleted after a month. Data no longer in the data pool can be generated on demand. Golden month data, including all L3 products, are kept permanently.

Masuoka provided archive and distribution statistics and order response times. There are several methods of distribution in LAADS. LAADS version 4 (available in November 2006) will add land metadata searches, masking, channel subsetting, L0 data distribution, an ECHO interface, tile reprojection, and multiple web/ftp servers. Additional capabilities to be added in 2007 include: granule reprojection, mosaicing and GeoTIFF; sub-sampling; compositing (spatial and temporal); OGC services and clients. The LAAS site can be found at ladsweb.nascom.nasa.gov; the public ftp version is at ladsftp.nascom.nasa.gov; and the science services web site is at modaps.nascom.nasa.gov/services. To access the password-protected section of the LAADS site, contact Mike Teague at psman@saicmodis.com.

OCDPS Status, user support, tools, ordering metrics, etc

Gene Feldman, Goddard Space Flight Center

Feldman discussed the keys to success for the ocean color data processing system. The goal of the ocean color data processing system is to provide the best available ocean color and sea surface temperature data to the broadest user community in the timeliest manner possible. Both internal, mission-specific expertise and access to external expertise from the broader science community have been essential for success. The infrastructure of the ocean color data processing system is continually evolving to meet science needs so that science drives the system rather than the system driving the science. The system consists of a series of connected storage devises, processing systems, and services. In the operational data flow, MODIS data come from NOAA through the bent pipe, so data are available within a few hours of acquisition. Users need online access to source data, so many source data holdings are kept online. Communication with the research community is another key to success. The primary way of working with the community is the ocean color web site: http://oceancolor.gsfc.nasa.gov. The site contains data format documentation, software and tools, publications, processing details, and ongoing validation and calibration information. The site also hosts an ocean color forum for the community. Easy access to data is another key to success. The ocean color data processing system interface allows users to access SeaWiFS, Aqua MODIS, Terra MODIS, and other data in a single page, and to register for data subscriptions. There are currently 249 active subscriptions. Data are also available via ftp. All distribution statistics are available online. To date, about 10 million files have been distributed through the ocean color data processing system. Regional statistics show what regions are being studied. Future developments for the system include community based tools.

NSIDC Status, product ordering metrics, user support, tools, etc.

Ruth Duerr, National Snow and Ice Data Center

NSIDC is part of the University of Colorado and has data relating to snow, sea ice, and the cryosphere. NSIDC maintains strong ties with the National Geophysical Data Center, a NOAA data center. NSIDC is part of the world data center system. Major programs at NSIDC are funded by the NASA DAAC and NOAA and NSF grants. NSIDC has a two-fold mission to make fundamental contributions to understanding the cryosphere and improving data management techniques. NSIDC has the capability to support users based on the ECS data system. Over the next year, the ECS system will be redesigned to simplify it. NSIDC is now getting significant amounts of disk space, so all of MODIS collection 5 will be available online. Metrics show that NSIDC is a popular web site, averaging 16,000 views per week. The top pages visited include data pages. Requests for MODIS data continue to increase: 2006 saw two times the number of requests for MODIS data received in 2005. There were 320 distinct MODIS users in 2006. The products that are most often ordered are snow products and tiled level 3 products. NSIDC distributed more than 419,000 MODIS granules in the last year. NSIDC contains MODIS, AMSR, and GLAS data.

Users can currently access the MODIS data pool through a web interface or direct ftp. The data pool has regridding, reformatting, and subsetting capabilities. NSIDC supports subscriptions for all MODIS data products. One main access route to MODIS data is the EOS data gateway, a comprehensive web interface. A new search and order web interface is now in place for the EOS data gateway. Finally, NSIDC provides a machine to machine gateway interface. The user community doesn't like the HDF EOS format and prefer flat binary files, so NSIDC developed the swath to grid toolbox to reformat MODIS swath data to flat binary gridded files. NSIDC is going through planning and prototyping to figure out how to move from "order data" to "use data" by moving toward on-the-fly formatting. NSIDC is moving this direction with the MODIS mosaic of Antarctica mapserver demo. The data catalogue of in-situ data has been loaded into NSIDC with Google Earth as a search tool.

LPDAAC Status, product ordering metrics, user support, tools, etc

Tom Maiersperger, principal scientist at LPDAAC

In 2007, the LPDAAC will be evolving its system, missions, collections, and access tools and services. In 2006, the public holdings archive contained 1.2 Petabytes of MODIS and ASTER data. LPDAAC has production capabilities for aster and nearline and online storage. Maiersperger provided overall distribution trends for the LPDAAC. The largest period was the end of fiscal year 2005. During fiscal year 2006, the LPDAAC had a large international community of users, a smaller community from .edu and .com domains, and a smaller yet government (.gov) community. There are a large number of repeat users, but the LPDAAC also has a growing number of new users. The LPDAAC gauges user needs through strategic planning, email and phone requests, conferences and workshops, and an online survey. International users are the main drivers of questions coming into DAAC. Requests show a need for an improved MODIS data discovery and delivery system. As a result, the LPDAAC will be developing MRTWeb in the coming year. MRTWeb will leverage GloVis and MRT code to provide tile-based data discovery, mosaicing, spatial and band subsetting, reprojection, and reformatting. A website redesign will streamline the site navigation, improve access to MODIS information, clarify pathways to MODIS data, and provide connections to larger community. The new site includes a universal search, a community page, an rss feed, and breadcrumbs to help people know where they are in the system. The LPDAAC is also going through a systems evolution to improve the flexibility and efficiency of the core systems. The LPDAAC is also striving to increase science activities. To facilitate this, the science advisory panel will be transitioned to the user working group.

NEO Overview and Status

David Herring, Goddard Space Flight Center

The NASA Earth Observations system (NEO) was born out of the Earth Observatory effort. The Earth Observatory is a web-based magazine about the Earth from space. A survey of Earth Observatory users showed that people would be interested in becoming amateur Earth observers if Earth data were more accessible. NEO was developed to provide random access to imagery and data so that users can do what they are interested in doing with Earth science data. Data sets include MODIS ocean, atmospheres, and land data. The target audience for NEO is formal and informal educators.

When a user logs into NEO, the default screen loads a Blue Marble image with interactive functionality. The interface contains a search function and a browse through which users can find data. Each data set includes multiple descriptions at various levels of detail. KML files are provided so that data can be exported into Google Earth. Earth Observatory images and captions may also be available in Google Earth format in the future.

Herring demonstrated the NEO interface. To download data, a user would select "get image." Users can create their own color palette for each data set. The user can also select the data format (jpeg, geotiff, etc), or he or she can download the HDF format data from the DAACs. Five minute subsets are available at 1 kilometer resolution with a link to the MODIS Rapid Response System for the full-resolution images.

NEO will also offer educators a tool to explore data in browser, the ICE tool. Users can select the area and data they want to explore, select the resolution, and launch the ICE tool. In the ICE tool, users can roam, zoom, probe data and color bar, do a transect plot, and select an area and see the average for the parameter in that area. The tool was designed to be browser friendly and easy for teachers to use. NASA is building global network of museums and science centers. NEO will be an important part of IGLOO toolkit distributed to this network during the International Polar Year. Museums and science centers within the network will participate in a workshop in the next couple of weeks that will feature an "online cookbook," guide to Earth Observation.

Current Plans for Long-term Archiving of MODIS Data

Martha Maiden, NASA Headquarters

Maiden discussed current plans for the long-term archiving of MODIS data. The EOSDIS evolution is being implemented in line with the 2015 vision tenets. The primary mandate is research, but NASA will keep an archive for the lifetime of the data. How long do is seamless access to the data needede? Current plans call for seamless access up to four years beyond the end of flight operations. A long term archive will keep the data after that. NASA Earth Missions are moving to a measurements focus. The late REASoN call in ROSES 2006 will be looking at how to move from missions to measurements in terms of earth science data records and climate data records. The USGS is responsible for maintaining the long-term data archive for land. The USGS has established a national archive for satellite data. The archiving partnership with NOAA is moving more slowly. Little progress has been made toward establishing long-term ocean and atmosphere archive. NASA's data responsibility is to make sure transfers to NOAA CLASS can take place when the system is ready. NASA HQ intends to clarify NOAA's intentions for a long-term archive. Headquarters is also looking at alternatives for a long term archive at NASA.

Land Discipline Group meeting summary

Chris Justice, Land Discipline Chairman, University of Maryland

The land discipline group had a series of science presentations and breakout groups. The senior review was discussed at length and the group came up with a strong rationale for keeping Terra and Aqua operating. The Aqua/NPP overlap is a particularly compelling argument. When compared to the data quality of METOP AVHRR, Terra MODIS offers significantly increased science value. Efforts should be made to extend the MODIS data record as long as both instruments are science quality data. The land discipline group recommended that NASA start ingesting and processing the global 1 km METOP AVHRR data into the current LTDR initiative, since METOP will be the only a.m. system after Terra MODIS. A data overlap would be advantageous for the time series. The land team suggested that an EOS special issue on MODIS achievements and the reasons for keeping the sensors operating should be developed based on work undertaken in support of the Senior Review.

An example was presented of recent fire validation utilizing NASA UAV from flights of current California fires. The WRAP, the wildfire partnership, flew over the Esperanza fire in Southern California at the request of the State Governor. At least part of the flight was coincident with a MODIS overpass. These data will be compared to MODIS fire counts for calibration and validation.

Justice reported on critical deficiencies in MODIS land data. The land water mask needs to be improved with a 250 meter mask. A proposal to do undertake that task was presented to and endorsed by the land team. It was proposed that in early 2007, the VIIRS land group will undertake a summary assessment of the utility of VIIRS EDR's for NASA's land science. This will summarize the findings of the land component of the NPP science team.

The Mid-Decadal Global Land Survey (MDGLS) breakout group discussed the acquisition, orthorectification, and science products from the planned global high resolution (Landsat class observations) land assessment. The group recommended that a small LCLUC workshop be held in early 2007 to develop science product requirements. A second breakout session discussed the utility of MODIS for modelers. There is heritage in this activity from the ISLSCP data initiative. To make MODIS data more model friendly, a consistent, common radiation modeling approach is needed. The group discussed how MODIS land data might meet modeling needs and recommended that modeling products be a topic for a community measurement team discussion.

Through previous MODIS land meetings, the emerging land measurement team developed a series of ESDR white papers Justice listed the topics covered in the ESDR white paper available at http://lcluc.umd.edu/products/land_esdr/index.asp. Building on the white papers, the discipline team identified the top 2 priority initiatives or activities needed for each measurement type. For surface reflectance, for example, the top priorities are to develop NPP surface reflectance data continuity and to generate consistent SR products between moderate and high resolution instruments. A common theme across all measurement types was the importance of maintaining long term data records (LTDR's) between moderate resolution sensors. For science land data product continuity, NASA will need a VIIRS land data production capability and an increased emphasis on international cooperation. There is also a need to increase the emphasis on multi-instrument data fusion.

In the land discussions, the question arose as to how the community should organize around the HQ charge to move from missions to measurements. The land discipline group suggested a possible new organizational model centered on the NASA Science Focus Areas and Measurement Teams. The legacy EOS organization was centered on the IWG, of which the MODIS science team was a subset and the associated EOS Science Working Group on Data. One possible approach for a new structure was presented. The new structure would result in a land measurement team that would include representatives from different measurement types and relevant science Focus Areas. Under the new model, cross instrument working groups on instrument calibration and data would support the measurement teams. The team would need to keep a close working relationship with both the instrument calibration and data production. Justice noted that the roles of the measurement teams and ESDR requirements are expected to change as the science evolves. The land discipline group recommended that NASA move ahead on the evolution from missions to measurements, and the next meeting, to be held after the latest EOS selection, should be focused on "getting organized on measurements." The presentation can be found on the MODIS web page.

Oceans Discipline Group meetings summary

Chuck McClain, Goddard Space Flight Center

The ocean team has moved forward in refocusing on measurements with tight connections to the MODIS calibration group. Most of the talks at this meeting were on topics other than MODIS. The SST group is making progress in improving that product. The group is using advanced radiometry at sea to validate products. Improvements have been made to the calcite product, which is important in assessing inorganic carbon in the carbon cycle. Observations of calcite concentrations are also important measures of climate change because of their connection to ocean acidification. The ocean group had a lengthy discussion about data merging. One debate in the group is what to do with CZCS. It is the only sensor that provided data before 1996, but the data aren't high quality and probably couldn't be used as climate data record. The ocean group is trying to find ways to address the quality issues. Significant progress has been made in data assimilation. Ocean data are being assimilated into global models. The ocean group heard a report on a workshop about data requirements for the future. Workshop participants, many of which are on the MODIS

ocean team, wrote a plan on future missions and in-situ data collection strategy for future. The ocean group held a number of pigment analysis round robins, which developed into a good international activity. The analyses were needed because accurate field measurements are necessary for accurate satellite validation. The group discussed ocean color vicarious calibration. The ocean group discussed their potential role in maintaining VIIRS ocean data and decided that the group needs to be prepared for the VIIRS mission. It's unclean what the group's future role will be. The oceans group is working to understand the VIIRS instrument as well as possible. The group is involved in pre-launch testing and analysis so they are prepared to step up and process data down the road if required.

McClain provided an overview of other significant developments. Skin temperature measurements from the ship-based M-AERI sensor are expanding significantly. This has improved statistics on MODIS SST measurement biases, though some systematic biases remain. The group is looking at other methods of validation to resolve the remaining biases, particularly at using microwave data. MODIS SST data are part of the global ocean data assimilation experiment.

A semi-analytic model of water leaving radiances is being used to generate global chlorophyll-a and other products. The model combines SeaWiFS and MODIS Aqua data. It is not ready to be used operationally because of differences between open ocean and coastal waters. The model needs to be more adaptive to account for these differences. Merging data increases the amount of daily coverage.

Data assimilation is making progress. Assimilating data into the model results in substantial improvements to the model, which could provide a large amount of information about the ocean.

Three pigment round robins have been completed and a fourth has been initiated. In the current round robin, 12 labs have been involved. As a result of round robins, labs have been improving their methods, which reduces noise and variability in field data sets. NASA-funded investigators currently submit pigment samples to one laboratory for analysis. Data from quality assured labs is consistently more accurate than data from non-quality assured labs. The Round Robin activity is expected to expand to other topics.

Participation in the Atlantic Meridian Transect (AMT) cruises has improved measurements of calcite, an important component of particulate inorganic carbon. The data are useful in improving the PIC algorithm.

Atmospheres Discipline Group meetings summary

Michael King, Goddard Space Flight Center

Collection 5 production is moving forward: Aqua production is complete, and Terra processing should be done in January. The atmosphere working group focused on data use and validation investigation with 23 presentations. There were also some cross-disciplinary talks and new science results. The group discussed needs and plans for collection 6 and justification for mission extension.

New algorithm theoretical basis documents describing collection 5 algorithms and characterization were released in the last few months. The last peer review was conducted in 1997, prior to launch, to aid the algorithm developers in making adjustments in their approaches to algorithms prior to launch. The new Algorithm Theoretical Basic Documents (ATBDs) are for aerosol properties, cloud mask, cloud top properties, and atmospheric profiles. A new QA plan with QA flags for Collection 5 including flags for the Deep Blue product was recently completed and posted online online at modis-atmos.gsfc.nasa.gov/reference_atbd.php.

The atmosphere team held an open discussion of senior review questions regarding Terra and Aqua for MODIS. The group outlined new science that has come about due to the unique capabilities of MODIS and new applications developed due to the provision of MODIS instrument capabilities and accompanying data products. These applications include improvements in weather forecasts based on polar winds measured with MODIS water vapor, forecasts in air quality for the EPA, strategic maps of aerosols, fires, and clouds for the military, and the growth of direct broadcast users.

The group outlined questions that should be a part of the senior review for Terra and Aqua, including the following. What can an extended MODIS mission contribute to the modeling community? Do MODIS

results indicate that models need to be improved? Do MODIS results offer ways to improve models? Why do we need two MODIS sensors?

What new science could be done that requires 3 or more years of Aqua MODIS beyond the life of the mission? What new science results could be done with 3 more years of Terra MODIS? What new scientific objectives can be pursued if the aqua and terra missions (including MODIS) are extended? How important is it to extend Aqua and Terra in terms of climate data record?

Closing comments and Guidance

Paula Bontempi, NASA Headquarters

The mission extension and senior review process mimics the former space sciences process for extending missions beyond prime life on a two year cycle. Nearly all Earth missions are up for renewal, so there may be difficult decisions about which missions to continue and which to end. In FY06 there were cuts to the budget, so many were put on incremental funding. The next installment of funds should be available soon. Shannell Cardwell is the new contact for contract people. For FY07, we are exercising the 4th year option on the team lead budget, so reductions are possible. A ramp down of MCST was planned in the fourth year.

In future planning for NASA Earth science, NASA is in the process of advanced planning at the mission directorate level for the congressional science plan. The Earth science division is feeding input into that plan. Focus area roadmaps are also being developed. There may be calls for white papers or input as planning moves forward. NASA Earth sciences are still involved in presidential mandates. The NRC NASA/NOAA/USGS decadal survey recommendations will be released in early 2007. The charge letter for the decadal survey asks for a prioritized list of flight missions for the next decade and important directions that should influence planning for mission beyond the next decade.

During the EOS recompete, 322 proposals were received. Panels will be held in January or February 2007 to meet renewal dates in May-July.

Measurement teams are challenged to continue evolving measurement streams so that there will be one science team, competed periodically, that provides scientific guidance to present and future missions and to the utilization of past data sets. Should Terra and Aqua science teams come together for large interdisciplinary meetings once a year? Future recompetes will encompass MODIS and NPP (VIIRS). In the blending of instrument science teams into discipline or measurement teams, we need to decide how to divide and organize the teams. Evolution to measurement teams will support both current and NPP/NPOESS data. It is still not clear who will produce research quality data from NPP/NPOESS, but the division into measurement teams will prepare NASA to do that if necessary.

NASA is looking at the next generation of science measurement strategies, and thinking about other types of missions than NPP. Should the March 2007 NPP science team meeting be followed by a discipline meeting?

The Earth science data records challenge was to use data products to create new scientific understanding of planet Earth and how it is changing. What products are key for climate variability and change research? For future sensors, which agency has the responsibility for climate? At meeting, it seems that climate should be NASA's responsibility, but it is a big financial burden to shoulder. We have to decide what products are needed and where to get funds for data processing, calibration, validation.

We need a plan to review ATBDs for new and alternative EOS algorithms. We should review current algorithms and products to see what needs to be updated and draft ATBDs for new algorithms and data products.

Bontempi outlined a few accomplishments of the MODIS science team. The maturity of the science is phenomenal. The interdisciplinary nature of the science is impressive. In terms of public outreach and publication, the process to get the message out seems to be more difficult than it should be. We need more than a news feature or press release. Should we do a five year NASA science update? The update could be interdisciplinary with a twist of applied science or focus on high latitudes for the International Polar Year. One goal of science is to inspire the next generation of researchers and explorers.

Closing comments, tentative plans for next meeting, etc

V. V. Salomonson, University of Utah

The idea of the MODIS Science Team meeting was to provide a repository of results, so please turn in posters and presentations to provide a record of the meeting. The material is useful for HQ review and the Senior Review proposal.

A large effort is going into improving access to data for the user community. The results and discussions contained in discipline meetings were good, and that will provide good input for the senior review. A data workshop will be held in January 2007. The next meeting may well be different with focus on measurements or an interdisciplinary focus probably in early summer 2007.