MODIS Science Team Meeting
July 13, 2004
Day One Plenary Session

Vince Salomonson – Introduction and Overview

Vince Salomonson, the MODIS Team Leader, started the meeting, drawing attention to the fact that the Terra and Aqua MODIS instruments have been in orbit for two and four years respectively, and have been producing good scientific data since launch. The instruments are meeting specs, which in turn means that the spacecraft systems and instrument performance are leading to well-geolocated products. Calibration and characterization are extremely good, though of course there still remains work to be done.

The data products each discipline produces are varied and of high quality, and the data itself is quite popular. There are 82 Direct Broadcast stations worldwide, with over 900 users receiving the data. They represent 27 science research organizations doing land, ocean and atmospheric processing, and 53 companies that base their application algorithms and value-added products on the data.

In terms of publications, there are a total of 1423 unique publications in the MODIS/MODARCH database from 1990 to the present, though the list is not complete for 2003 and 2004. The Fall AGU Abstracts index lists 434 papers from 1995 to 2003; the ISI Web of Science index lists 557 refereed publications from 1959 to present; and the ISI Proceedings index lists 499 publications from 1990 to present.

As of early 2003, MODIS has supported 89 PhDs, 60 MSs, and 25 MAs, for a total of 174 graduate students. As for workshops, there have been several successes in the Land, Ocean, Atmospheres, and Cal/Val groups.

The new MODIS Science Team has grown from 28 to 90 members. 63 are Science PIs, while the remaining 27 are Refinement/Maintenance PIs. In part because of the new large size of the Science Team, Salomonson stressed the need for us all to work together to meet the goals and objective of the NASA Earth Science Program. As such the Science Team will hopefully be willing and able to be a useful and effective microcosm of the broader science and applications communities regarding improving MODIS products and related services.

Salomonson identified five overarching thrusts he is advocating for the Science Team to pursue now and in the future. These are:

- To improve access to and use of MODIS data products, the MODIS Science Team must support and collaborate with the relevant parts of the Earth Observing System Data and Information Service (EOSDIS) or other entities pursuing the provision and use of MODIS data products to the general science and applications communities or the public at-large,
- Pursue the programmatically necessary goal of providing climate-data-record quality data sets of MODIS products. The characteristics or requirements for these data sets will be those obtained from the science community via procedures approved,

prescribed or represented by NASA Headquarters Office of Earth Science program management,

- Interact with the modeling communities to facilitate and expedite the assimilation of MODIS data products into such Earth system and Earth system component models. These models can include everything from global earth systems processes and trends to regional and local scale models simulations, as well as applications specific to resource management and decision models support needs
- Pursue interdisciplinary efforts including the use of MODIS products; i.e. where appropriate ensure that MODIS land products can be employed effectively by atmospheric efforts, MODIS atmosphere products can be used by land and oceans efforts, etc.
- Educate and train students to appreciate and be able to use remote-sensing (e.g., MODIS) data for doing Earth science and applications.

For the benefit of new team members, Salomonson briefly described the MODIS data system architecture, and identified how the MODIS data suite fits into focus areas for Earth system modeling. He described the Earth Science Enterprise's tier of science questions that MODIS is helping to answer, and how we aim to use MODIS data to answer critical questions about the carbon cycle and ecosystems, climate variability and change, the water and energy cycles, weather forecasting and durability, and atmospheric composition. After briefly listing the status of current MODIS products, Salomonson described the transition schedule from EOS Terra and Aqua satellites to the NPP mission, and gave an overview of the VIIRS instrument, which will continue the work that MODIS has started.

In conclusion, Salomonson noted that the spacecraft and instruments are working well, though there is further work to be done to characterize the sensors' calibration and response. There are a lot of excellent science and application results appearing using MODIS products, though we need to pursue the above general thrusts, which are meant to enhance the data products' usability and accessibility by the science and applications communities. We also need to pursue activities that will facilitate the transition from MODIS to the NPOESS VIIRS project. Overall, MODIS has been a tremendous success, and it holds considerable promise for even greater success in the future.

Diane Wickland - HQ Perspective and Guidance

Diane Wickland, the MODIS Program Scientist from NASA's Office of Earth Science, welcomed the new and old Science Team Members. She noted that the team has grown considerably; there are new algorithm refinement members, algorithm developers, validation/calibration members, and data analysis investigators.

The challenge for everyone is to reap the full science benefits of the MODIS instruments, as well as Terra and the EOS suite of satellites. The team needs to make and keep the existing data products at the best quality possible, develop new data products to enable important new science and applied usages, and utilize MODIS (and Terra and EOS) data products to create and continue a new scientific understanding of the planet and how it is changing so that we can apply this knowledge to decision-making.

She stressed the fact that change is inevitable, is often desirable, and is the very essence of Earth Science. The theme to focus on is MODIS in a changing world. The team itself has experienced significant turnover, with triple the number of PIs than were present in the previous team (and data users now outnumbering algorithm developers). Earth science is changing from mission-oriented to measurement-oriented, and NASA itself is in the process of transforming itself to align with the President's Exploration Vision.

Wickland discussed the recent peer review process that the team went through in choosing the new science team, noting that overall, peer reviewers were impressed with algorithm accomplishments to date, as well as the quality and diversity of proposed science and applied uses. But because the algorithms are so detailed and complex, reviewers had some difficulty understanding the complexities and detailed technical aspects of the algorithm refinement proposals. Algorithm development approaches were more disciplinary than expected, and opportunities to share expertise and avoid redundant efforts were lost.

Key data products had deficiencies that still need to be addressed by algorithm developers and validation investigators (such as cloud mask, atmospheric correction, correction for snow under vegetation, etc.). The team's division into the three major disciplines – Land, Oceans, and Atmospheres – may have hindered interaction across teams, so NASA Headquarters is encouraging the team to tackle these problems. We might want to reconsider our organization so that we can promote more effective communication.

Algorithm developers were rated lower for not acting as representatives/stewards of broader community needs, including demonstrating that they were working with the community and validation scientists for their algorithms and responding to their preferences. Some algorithm refinement proposals didn't provide compelling justification for the importance/utility of the algorithm improvements and/or new data products, so they were also rated lower. Overall, the problem seemed to lie more in *communicating* the algorithms' importance rather than in the importance of the algorithms themselves.

Wickland noted that since the ATBD reviews in the mid 1990s, the EOS Science Teams have been more or less on their own to make decisions and set priorities about the data sets they've been producing. For the most part they've been doing well, but additional review would be useful. EOS data products and Science Team demands on EOS/NASA resources need a periodic review process. They need a plan for review in two or three years of ATBDs for the new and alternative EOS algorithms that have been proposed.

Regular reviews, perhaps every 2-3 years, need to occur for existing EOS data products. Reviews will: assess the quality and importance of data product suites and their components; prioritize EOS data products relative to each other and relative to other needs of the communities they serve; and recommend changes, improvements, and levels of service by data systems and archives. These data product reviews must involve the

broader user community or their representatives, must also take into account NASA resources/program components required to support the products, and hence involve data system and archive management, and NASA HQ Focus Area Leads (program/product managers). She encouraged people to make suggestions on how to accomplish this.

NASA's plan for continuing/evolving measurement streams is that there will be one Science Team, competed periodically, that provides scientific guidance to present and future missions and for the utilization of past data sets. It will also aid in the focus on CDRs, and the creation of one data system that would ensure a seamless time series. Science guidance and priorities would be most representative of the broad user community. Hopefully this would minimize disruptive startup and phase-out stages.

The Ocean Color group has already begun this change, and is fairly advanced. The Land Group is poised to begin. Questions they face include whether they would have one or several measurements (land cover, vegetation indices and biophysical properties, fire and extent, LST, or all together?), and whether they should integrate spatial resolutions to combine moderate (1 km-250m) and high (30 m) resolutions? Can we also assume that surface hydrological and geological measurements will be addressed in other measurement teams? The Atmospheres Group is working on this transition as well.

NASA's transformation is in response to the President's Vision and the Aldridge Commission Report. NASA Headquarters will act first by creating a new Science Mission Directorate formed of the merged Space and Earth Science directorates. Al Diaz will head the directorate, with the AAs being Ghassem Asrar (Science), Orlando Figueroa (programs), and Alison McNally (Management). Everything else is TBD. Wickland herself will be the new NPP Program Scientist, while Paula Bontempi will take over for her as the new MODIS Program Scientist (though Wickland will still be working with the team and Bontempi).

Martha Maiden – ESE Future Data Processing Plans

Martha Maiden, the Program Executive for Data Systems at NASA Headquarters, spoke on the Earth Science Enterprise (ESE) data processing plans for the future.

On the current state of NASA's ESE Data and Info Systems, she briefly described the ESE Data System Architecture, noting that we are moving to a more distributive system. She explained where the disciplinary DAACs are and the types of data they contain. The DAACS focus on intelligent use of NASA's information through sound data management, ensure unencumbered distribution of NASA Earth science data to *all* users, provide complete user services and data expertise services, and exploit advanced technologies to further facilitate the ESE mission. Their focus is on public distribution of products.

The ESE is transferring its attention from missions to measurements, and as such the ESE's DIS will be a resource for Earth science focused on communities, which will enable research and will be flexible, scalable, and suited to the particular community's needs. It will continue along the pathways for acquiring observations to understand

processes and develop Earth system models. The maturity of the ESE sharpens our focus on the environmental view of data: SIPS will be moving to Community-based Measurement Processing Systems (CoMPS); for this we will need an inter-calibrated time series of geophysical records, called CDRs. Processing will be embedded within the science focus areas.

The DIS must continue integrating into Earth System Science. This requires that we facilitate information synthesis by increasing data usability by science research, application, and modeling communities. NASA will remain at the forefront of IT development and will partner with other agencies to ensure strategic use of IT resources, in part helped by the lowering cost of IT infrastructure. We must also work with our Federal partners to transition operational elements of data systems to other agencies while maintaining core data system functions necessary for conducting NASA ESE missions and goals.

On the subject of EOSDIS' elements and plans for evolution, Maiden outlined the Evolution of EOSDIS Elements study, which was chartered by Ghassem Asrar on June 4, 2004 (to be completed some time in FY05). Because the ESE is moving from mission-based data systems to those that focus on Earth science measurements, the ESE's DIS will be a resource for Earth science-focused communities enabling research, and will be flexible, scalable and suited for the particular community's needs. It will also continue on the pathways for acquiring observations to understand processes and develop Earth system models.

The primary goal is evolution to meet future ESE objectives and priorities, which will entail identifying functional elements of the system; considering alternatives allowing us to move towards a more distributed, heterogeneous data and information environment; developing element options and an action plan; and emphasizing science value and cost control. Additional goals include increasing life cycle cost effectiveness, increasing end-to-end data and data system efficiency, and improving support for data use by end users.

The ESE is moving from mission-based data systems to those that focus on Earth science measurements. We want to meet those ESE objectives, and considering our prototype measuring systems, that's where the Science Team is essential, especially considering how hard it is to create a huge architecture for the future.

Maiden's final topic was the Ocean Discipline Processing System and the Precipitation Processing System (OCDPS), which is providing prototyping activity for understanding the elements of measurement-based data systems, variation amongst such systems ("one size does not fit all"), and how such systems will drive evolution of ESE Data and Information System.

The OC Processing System is a system that has multiple instruments from multiple satellites creating a long-term data record. This record can be distributed by having PI-directed peer review. There are FTP capabilities that allow data to be shared with the public, and help the group to get feedback. Public archives also increase data access,

while community-agreed standards and protocols ensure a high quality level. The group can refine formats and standards and keep up with technology.

The Precipitation Processing System has a suite of instruments that feed into it. The system itself can be distributed, evolve, and change, and its priorities are set by ESE Research Science Program Managers in consultation with the funded measurement team and science community. Its requirements are science-driven based on the specific measurement needs and resource constraints. The measurement team has science and system expertise to perform periodic assessments and trade-offs, while the focus on measurement allows science research with seamless data sets across missions. These measurement sets evolve via community collaboration, and exist in a flexible and dynamic framework that is designed to: support a dynamic suite of standard and research products; allow measurement system optimization for functionality and services provided; support distributed functions with science collaborators; and allow negotiated support for common services to the support measurement team.

We want to add people to these teams via REASoNs projects. These can be distributed out to science managers, for example via Ocean Color REASoNs. The management of all these pieces becomes difficult, so from a SEEDS study came the idea to share via Earth Science Data Systems Working Groups (DSWGs).

While we are still working on EOS DIS Evolution, things can still change. Ocean Color support is evolving more toward the public, for example. We can wait for products to mature before going to the DAAC, which avoids people seeing beta prods with warnings. Emphasis is instead on getting stable products, which measurement teams can refine. There are a number of key drivers to this evolution process, which we think will ultimately make it easier to refine and share products with users. Feedback is welcomed, and in the meantime we still have public archives.

NPP is the next project, and we're beginning thinking about how to populate data work for that, as well as thinking about adding SDS to these measurement teams that are just forming.

Shaida Johnston – MODIS Data Processing, Archiving, and Product Distribution Overview

Johnston presented on the overall flow of data at the top level. The Level 0 (zero) data goes to the Goddard Earth Science DAAC (GES DAAC), and from there to MODAPS (or one of the SIPS), which is the largest data processing system. Land, Oceans, and Atmospheres data are sent to various DAACs, the MCST group gets its own data, and the SCFs get Level 2 and validation data. SeaWiFS OCDPS skips the DAAC and uses an ftp site for distribution instead.

Johnston listed the current products, noting that the Level 2 products are produced in 5-minute swaths. There are many more Land than Atmospheres products, and depending on the levels of the products, they can come in multiple temporal and spatial resolutions. The Cryosphere products, which technically are grouped in with the Land products, also

come in multiple spatial resolutions depending on the product level. Oceans products come in four parameters: 36 color, 4 sea surface temperature (SST), 8 ocean primary production, and 38 quality control.

The GES DAAC does all L1 processing and hosts a couple Atmosphere products. The bulk of processing is done in MODAPS: Oceans SST, 4 Atmospheres products, and all Land and Cryosphere products. OCDPS does the L1A and B subsets as well as the Ocean Color products.

Johnston listed the DAACs: Land Processing (LP), National Snow and Ice Data Center (NSIDC), Goddard Earth Science DAAC (GES DAAC), and the Ocean Color Distributed Processing System (OCDPS). They use a combination of tape archives and data pools to store the data. Data pools are disc systems, which are easier to load than tapes, and which hold the freshest data and highest-interest items.

She reported that the Collection 4 Land and Atmospheres reprocessing efforts are almost completed. Ocean Color doesn't follow the same processing scheme. "Collection 4" refers to a processing status, or "event." She explained how collections work, and noted that we will be looking to the new Science Team to decide what to put into Collection 6. Because we're not sure there will be a collection 7, Collection 6 needs to be our best effort.

Once data gets into the DAACs, it needs to be distributed. The EDG has traditionally been the main data-access gateway, and though it was cumbersome to use, it is getting better. We've learned that one-size-fits-all data systems aren't a very good model, though it still provides the most capability. The WHOM system is specific to the Goddard DAAC, and is much more streamlined, including a browse capacity and many other features. There has been some demand for on-the-fly subsetting for the Oceans team; this is still in the works. The LP DAAC works quickly with the data pools, and the NSIDC has its own interface with browse capabilities and other features. The SNOWI interface is for MODIS data only. Finally, the SeaWiFS/Ocean Color team has its own interface.

There has been some discussion about "developing" archives (such as MOVAS), as well as the tools that are available to users (like the MRT, LDOPE, MRT Swath, MODIS Atmospheres tools, etc.). In essence, each DAAC has its own different data access interface tailored to the needs of its particular community.

Ed Masuoka – MODAPS Processing Details (Land and Atmospheres)

Masuoka reported on the MODIS Adaptive Processing System (MODAPS) details for Collections 4 and 5.

The DAACs themselves send 200-300K files per week to MODAPS, while Rapid Response sends 75K of application files per week.

For Aqua Collection 4, Atmospheres data started with July 2002 through January 2004 data, which adds up to about 600 days of data. Some problems were identified with the reprocessing, so MODAPS had to restart the affected portions. Data from 2003 and 2004 has finished, and 2002 data should be completed by mid-August of 2004. Land data will be finished around July 5, 2004, which comprises another roughly 600 days of data. The EDC has been ingesting above their baseline performance, so MODAPS has been able to process at about 3x. MODAPS is doing a combined suite of Aqua and Terra products, and it should be finished around December of this year (as will be science testing for Collection 5).

Aqua SST processing will be done around the 27th of April, 2005. There are some problems with the SST code that was discovered, but it's on hold at the moment, since the issue of where SST is going to be reprocessed hasn't yet been settled. Forward processing will be starting this month.

Collection 5 Terra and Aqua will comprise 8.2 years of Land and SST and 7.6 years of Atmospheres products. MODAPS will be able to reduce processing time by 7 months by beginning from Level 0 data (to speed up overall throughput). This also gives them flexibility in discipline processing. In addition, they are going to make a year of Terra/Aqua combined products from Collection 5, which will be produced within the first few months of the effort. The Collection 5 software delivery dates are being worked out with disciplines, and the schedule is driven solely by those dates. Science tests always take longer than you would think, and they tried to build the Collection 5 schedule based on that.

MODAPS is set up so that it usually uses one main processor to work on weekly through quarterly products at Levels 3 and 1. They also have a CPU farm and disk farms that focus on other products.

Tests have shown that MODAPS can generate L1A, geolocation, L1B, and cloud mask products matched by those done at the GES DAAC (this is verified periodically). MODAPS can maintain the speed for the Atmospheres Collection 5 schedule (running well at 15x). Land and SST products are processing at 8x, and Level 0 data can be sent through MODAPS at rates exceeding 15x. Ingest is at 7x.

The changes to MODAPS will increase reprocessing rate and offer greater flexibility in reprocessing individual disciplines. Software deliveries are on track, and timely evaluation of test results and delivery of patches are vital to keeping Collection 5 on schedule. With a smaller staff supporting software integration, testing, and production, they cannot easily make up schedule slips, which would delay Collection 6 reprocessing.

Chuck McClain/Gene Feldman – Ocean Color Processing Details

Chuck McClain, the Ocean Color Project Scientist, presented on the processing and validation side of Ocean Color.

MODIS Ocean Color processing was reorganized by NASA HQ to coincide with the new MODIS Ocean Science Team selection. It picked up Ocean Color processing of Aqua MODIS data, while SST remains in MODAPS. The emphasis is on the Science Community; the Ocean Color group needs to be able to interact with them and the Science Team to ensure data quality. They've been developing protocols in the Ocean Community for past 10 years, and want to continue that effort.

The Ocean Color processing strategy is to initially focus on MODIS Aqua. It is more stable than Terra, and has the best chance of overlapping with NPP VIIRS. The group will focus on the quality of calibration, especially in water leaving radiances. They'll also reduce the data suite to a more basic level, and let the community decide what additional products the group ought to produce.

They are going to apply the same cal/val approach as SeaWiFS, since a common set of processing codes helps minimize variability between data sets. There are some Aqua calibration issues to address, and they're working with MCST on those. The group's extensive experience with solar and lunar calibrations helps them to communicate with MCST, with whom they're looking at pre-launch data (specifically polarization).

Based on results gained performing calibration using MOBY, in-situ data, and global/regional comparisons between SeaWiFS/MODIS, the group plans on working with MCST to refine calibration. SeaWiFS is quite stable, and comparisons between it and MODIS are favorable. So far they've done a polarization correction, bringing accuracy within +- 10% globally, though there are some artifacts at certain times of year and latitudes. They did a reprocessing after that, which smoothed calibration tables, corrected phase and magnitude polarization tables, corrected BRDF values, and adjusted the OC3 chlorophyll-a algorithm. Remaining issues include stability, in which they see some slight trending; scan modulation (response vs. scan); banding caused by mirror side calibration; and detector-to-detector calibration (which causes striping).

Gene Feldman, the Ocean Color Project Manager, discussed the distribution of data for the Ocean Color team.

NASA HQ's switch in focus from missions to measurements gives a good definition of where the group wants to go. They started out being mission-specific with SeaWiFS, but evolved with advent of SYMBIOS program to try to understand the basic principles behind Ocean Color.

The group develops expertise and addresses broader issues by working the with broadest user-community possible to come up with a collaborative system. Based on that heritage and work, they have gotten a very simple, stable instrument. The goal is to make available the highest-quality ocean color data to the broadest user community possible in the most timely and efficient manner possible.

The group is working on improving based on the lessons they've learned from the SeaWiFS project. They have a highly integrated project structure where all elements of

project are physically co-located, which promotes continuous communication. This includes the broader science community. They've learned that they need a flexible data processing system that constantly upgrades procedures, technologies, and equipment. Science has to drive the system, rather than the system driving the science.

For ocean color, calibration is the most important thing. The group must be comprehensive, but a centralized calibration and validation program closely coupled to the data processing and quality control system is also important, as is having a distinct software development program dedicated to providing user-friendly data processing software to the community. The project's philosophy is designed to support and involve as a large a community as is possible.

Currently the group has a fully automated distributed data system for acquiring, processing, analyzing, archiving, and distributing science data. This is composed of approximately 20-30 distributed multi-processor Linux PCs, with 60 TB of online storage shared by all project components including a web/ftp-based data distribution system. The processing rate for SeaWiFS global data is currently at 3000x, and MODIS Aqua data at 80x.

The SeaDAS enhancement is free software designed for direct broadcast users, which gives full MODIS ocean processing support starting with Level 0 data. In terms of research campaign support, global ocean color and SST data are available for distribution within 3-4 hours of acquisition by the spacecraft. Data access and distribution includes an web/ftp-based browse and order tool that allows the downloading of everything from a single file to the entire multi-mission data set. Doing this within the discipline group adds flexibility and quick response for new products prior to them being designated as CDRs.

Finally, Feldman noted that the MODIS Ocean Color website has moved to the broader Ocean Color website (http://oceancolor.gsfc.nasa.gov/).

MODIS Science Team Meeting
July 15, 2004
Day Three Plenary Session

Jack Xiong, Bill Barnes – Instrument Status and Prospect

Jack Xiong, the MODIS Characterization and Support Team Leader, presented on the MODIS instruments' statuses and prospects. He listed contacts in MCST, and each of their responsibilities. These include maintaining and supporting instrument operations; maintaining and updating L1B code and Look-Up Tables (LUTs); maintaining, designing, and improving algorithms; performing instrument calibration and data analysis, and providing science support. He noted that the MTT meetings and MCST workshops are good avenues of contact.

The team went over calibration and validation issues for the instruments and each of the disciplines at their MCST Workshop. Xiong also provided a number of links to useful sites for ST members; most of them related to the instrument and calibration.

Xiong gave a brief overview of the calibration/characterization schematic, and listed the onboard calibrators. On-orbit calibration activities include lunar observations via the Space View port, and assorted radiometric, spatial, and spectral maneuvers. Instrument performance is monitored in three ways: on-orbit performance (radiometric and spatial/spectral); instrument operations (by following a timeline of configuration changes and spacecraft and instrument events); and L1B/LUTs updates.

On-orbit performance has overall been very good; the sole real issue is with Band 6 on Aqua MODIS. In the reflective solar bands, there are three noisy detectors all in Band 6, and 15 inoperable detectors (13 from pre-launch: 12 in Band 6 and one in Band 5). A smaller issue with Aqua MODIS is a 450m shift in both the along-scan and along-track directions for the SMIR/LWIR FPA (relative to NIR FPA). Otherwise, Aqua MODIS performs better than Terra MODIS.

Terra MODIS has a history of noisy detectors, and Aqua MODIS has a few of its own. Xiong discussed a number of instrument configuration changes partially responsible for (or in response to) these issues, including switching from A-side to B-side electronics and back. This has had some affect on the data, which MCST has worked hard to minimize. Xiong continued by summarizing the L1B and LUTs updates.

The team has and continues to face a number of challenging issues. The team has created valid pre-launch RVS data for the Terra MODIS TEB; solved a Terra MODIS PC optical leak; removed SDSM sun-view signal ripples caused by a design error; properly calibrated Bands 13H and 14H; and characterized an SD vignetting function. They continue to improving uncertainty and striping problems stemming from SWIR crosstalk; and dealing with RSB response changes. Other issues they still face include calibration uncertainties, noisy detectors (leading to uncertainty and striping), and RSB RVS (for Ocean Color).

The instruments have performed well according to their design specifications. Terra MODIS has been operating for more than 4.5 years, and Aqua MODIS for more than two. MCST has made constant efforts to maintain and improve instrument calibration and characterization, including working closely with science group representatives and SBRS instrument vendor representatives. The team has learned lessons from Terra MODIS that they were able to apply to Aqua MODIS development (Aqua MODIS performs better than Terra MODIS in a number of areas.). Overall MODIS experiences have helped NPOESS and NPP VIIRS (and other sensors') design and development.

The next step is to prepare for Collection 5. MCST will work with Science Team representatives from each discipline (Chris Moeller for Atmospheres, Eric Vermote for Land, and Bob Barnes for Oceans) on code changes and LUTs updates. Code changes will include Band 21 b1 mirror-side differences, SWIR crosstalk improvements, and

noise-detector and destriping improvements. LUTs updates will include gathering Deep Space Maneuver (DSM) TEB RVS data; consistently characterizing consistent RSB RVS and SD degradation data, and working out an improved QA timeline.

Salomonson noted in the destriping discussion that the Wisconsin people have come up with a good destriping scheme that they will apply to their products, and which they might be able to provide as a tool to use on L1B data or on products after L1B. While offering the scheme as a tool is a good idea, using it routinely in the L1B data stream would require more discussion. Because this is an important issue that the Science Team needs to work on, he requested that interested parties submit their comments please to Xiong or Salomonson.

David Herring – NEO Gateway: Progress and Goals

David Herring, the Chief Editor of NASA's Earth Observatory website (http://earthobservatory.nasa.gov/) presented on the NASA Earth Observations (NEO) Gateway.

NEO is a collaborative effort sponsored by Salomonson and the MODIS Discipline Groups, in partnership with ESDIS and the Earth Observatory teams, and various others outside NASA.

The NEO mission is to significantly increase demand for NASA Earth Science Enterprise data while simultaneously simplifying access to geo-referenced browse imagery. Goals include:

- Raising awareness of, and providing easier access to, NASA remote sensing data;
- Providing novice and non-traditional users with a one-stop shopping interface for accessing geo-referenced imagery and/or ordering data;
- Helping obtain support for and take advantage of the decentralized community where the expertise and infrastructure resides;
- And simplifying the process and shortening the time span of going from browse to analysis for target audiences.

The question is, who wants NASA images and data? Communication partners and public media want easy access to images and/or data for display, publication, or broadcast. Museums, popular websites, public media, education lesson developers, citizen scientists, and the broader science community all are imagery users, given the chance. NEO wants to facilitate Earth observation as a hobby. The NEO group performed a survey of a number of audience types, including teachers, students, scientists, media professionals, and legislative officials. The results indicated that many of the people in these groups are interested in doing Earth observation as a hobby.

There are a number of obstacles to getting these goals accomplished, both technical and cognitive. Some include accessibility, bandwidth, and a lack of tools, while still others abstract topics, intimidating language, politically charged subjects, and a general lack of perspective.

The system will work very much as a gateway by marrying images to data availability. It will be a centralized repository of geo-referenced browse images, as well as a tool providing a flexible user interface for varied user groups to meet the needs of both novices and advanced users. It will provide functionality to link directly from browse images to source data, as well as a resource that will make browsing for and ordering data much simpler and faster, and will be a site where data-related outreach and education can be centrally coordinated and disseminated.

NEO will work with ECHO for data ordering, and include browse images. It will offer a number of spatial and temporal resolutions, and data will be in 8-bit number arrays. Users will have the option of accepting NEO's palettes, or devising their own. NEO will initially access a number of global data products: eight atmospheres, three oceans, and six land.

NEO will search multiple vectors. The idea is to orient users while managing their expectations, assuming very little initial knowledge. One method is to point and click on a blue-marble type image. Captions will be provided at different levels of technicality, from the very general to the very technical (such as accessing the product's ATBD).

The ability to go from browse to analysis is important. The NEO group has developed a tool called the Image Composite Editor (http://icetool.nasa.gov/). It is java-based, and works in a browser. Among other things, it will build true- and false-color composites, scatter plots or graphs to look for correlations, perform histogram analyses, and animate time-series images.

The project is still in development/testing. Primary issues include questioning format choices, finding a projection server, and getting Terra MODIS Oceans products (since some won't continue being produced). NEO will likely begin ingesting production data in February 2005, and will hopefully be publicly launched with selected MODIS datasets in April of 2005.

Mitch Goldberg – NOAA/NESDIS MODIS Transition to Operations Plan

Mitch Goldberg, Chief of the NESDIS Climate Research and Applications Division, presented on the motivation behind the plan to transition some MODIS operations to NOAA/NESDIS –in part because of problems associated with the AVHRR instrument on the NOAA 16 satellite. This and broader issue of use of MODIS data by NOAA led to a workshop, at which attendees attempted to identify potential operational products from MODIS and define the overlap between MODIS Science Team processing systems, algorithms, products, and the operational requirements of NESDIS users. After the workshop it was agreed that a report containing a "Statement of Needs" (recommendations and budget estimates) would be developed, which will be presented to Greg Withee and NESDIS Office Directors and NASA management.

The NOAA real-time processing system at Goddard managed is by Gene Legg. The currently receive the raw telemetry MODIS data, convert them to Level 0 and process to Level 1B and then Level 2. They provide the Level 0 data to the NASA RapidFire

system (for generating near real time fire images and applications) and to the NASA Oceans Group (for NPP Prototype Applications).

Level 1B data are provided to a number of users, including the ORA and CIMSS for MODIS polar cloud drift winds product (which has had an extremely positive impact at JCSDA (NCEP and GMAO) and ECMWF); and the Air Force (primarily over the Middle East, for tactical support). L1B and L2 Snow data are provided to the NIC (National Ice Center), while L1B and L2 Oceans and SST data are provided to NOAA CoastWatch. L1B data and images are provided to the NOAA Hazards Project in SSD, via SATEPS.

NESDIS is modifying the AIRS processing package to integrate MODIS data to improve cloud clearing. They will provide in near real-time, global subset of products from the existing MODIS science team suite of ocean color and SST products, plus some NOAA unique products from both AQUA and TERRA platforms.

Current issues include communication constraints restricting the distribution of Level 1 and Level 2 data; a lack of NOAA-unique products; a lack of a vibrant and sustained cal/val program to ensure quality; a lack of resources/methods to ensure continued hardware maintenance; and budget issues.

The best people to decide on the type of cal/val program are the scientists themselves. Part of idea for this report was to decide what specific cal/val activities are need. However, the limitation is in funding.

Goldberg noted that this report will be prepared and presented to NESDIS and NASA management sometime around October, and will include end-to-end requirements for MODIS quasi-operational products. These products are important for getting users ready for NPP and NPOESS, and also to obtain important feedback from users so that they can maximize the investment of NPP and NPOESS. In addition, a sustained cal/val program is necessary to support routine production of MODIS products, as MODIS products can also provide a pathfinder for NPP and NPOESS. He finished by noting that NOAA cannot do it alone; they need to continue their relationship with NASA not only for EOS, but also for NPP and NPOESS.

Chuck McClain – Oceans Group Summary and Plans

Chuck McClain, the Ocean Color Project Scientist, presented on the Ocean Color Group's discussions.

A major topic was coordinating data collection activities with the team. SIMBIOS provided a lot of valid data, and the project is ending, so the question is how to get data and investigators to places where they can collect data (perhaps by piggybacking off of programs that other groups are staging?). There are a lot of areas in the world's oceans where we have virtually no data, and our researchers need to get there to collect some. Perhaps the OC group could work through IOCCG to host a website of what cruises are happening when, and help in the solicitation of data.

Data policies for data investigators are in review. The group has decided to maintain those guidelines, but query data submitters to see if they could waive those guidelines and release the data earlier than usual 3-year waiting period. Perhaps more data can get into the open distribution category that way.

Expanding the product suite is also an issue. It makes sense for Science Team members to take leadership roles and work with the community, but progress is important, and a recommendation from each group on an algorithm of choice (goal: one algorithm per product) will be required. One of the considerations is the need to add bands to the L2 processing code to meet these goals, so we would have to revise the processing code.

Data quality, specifically in terms of the SeaWiFS/Aqua MODIS ratios, is an issue. There are some seasonal differences between the two data sets, and there must be some explanation. The OC group is working on correcting the difference by reducing oscillation, etc., while Miami is doing work on improving Terra MODIS data quality. Striping and RVS are still issues for both sensors (Oceans is evaluating the Atmospheres group's destriping methodology).

The OC group has instituted a Calibration Working Group under the leadership of Jan-Peter Muller. The reasons for doing so include losing MOBY and SeaWiFS, which are the backbone of the group's calibration program, and thrusts toward CDRs. The OC group wonders if the loss of those sensors will affect the MODIS Ocean Color data quality once they're gone (after December 2004). The group will have no way of tracking stability afterwards except for what MCST can do with onboard calibrators.

With regards to Salomonson's Team Leader Thrusts, the team had a bit of discussion. For data access, the OCDP strategies for reduced file size, SeaDAS support, and direct browse and distribution are working extremely well. Aqua MODIS distribution now exceeds SeaWiFS. For data assimilation, Ocean Color product assimilation into numerical ecosystem models is a fairly recent development by a few research groups, but has not yet been picked up at operational centers. Different models require different formats and resolutions (the OC group provides regridding/averaging tools rather than special products). In terms of outreach, newsworthy events are captured in ocean imagery; early notification of publications and newsworthy scientific funding are on the website; and articles are published in popular magazines. The team also publishes an annual report (similar to SIMBIOS annual reports). Other considerations include annual formal science team performance reviews, e.g., a teleconference including each PI (this worked very well for the SIMBIOS project, with specific categories of performance defined by procurement).

Chris Justice – Land Group Summary and Plans

Chris Justice, the MODIS Land Group Leader, reported that the group is actively contributing to the emerging ESE Land focus areas. Current emphases for the Land Group addressed in the presentations and discussions are:

- Stewardship of a suite of maturing Land Products
- Outreach to and feedback from the community of data users

- Guiding Land data system development
- Transitioning MODIS capabilities and lessons to the Operational Domain (NOAA and DB groups).
- Defining and Prototyping Land CDRs
- Contributing to the international observation coordination efforts (e.g. GEOSS, GTOS-GOFC/GOLD, CEOS LPV).

Current instrument issues being tracked by the Land Group and MCST include:

- Reflective bands calibration accuracy and stability
- Noise in the Terra longwave bands
- Striping in SWIR (esp. Band7), several methods are being evaluated (eliminating noisy detector, atmosphere de-striping, Xtalk correction; etc.)
- Polarization correction to be used for aerosol inversion over Land at 412nm (characterization has been provided by MCST)

The Land Group held four breakout sessions addressing selected topics. One of the groups met to discuss results from studies comparing the MODIS NDVI and EVI products. The two indices offer different information and have different science issues. The MODIS VI group needs to further educate and guide users on the utility of the two products. The group saw the need to continue broader community evaluation of the two indices and have started by instituting a small working group aimed at building a community consensus. The breakout group recommended that MODAPS continue to provide both indices and noted that both are currently planned as NPP VIIRS EDR's.

Outreach continues to be an important part of the Land Group activities and the group will continue to hold periodic outreach workshops on how to access and use MODIS land data products and report on their current status. Outreach of MODIS imagery has been greatly strengthened by the Land Rapid Response (RR) System The RR system processes over 950 gigabytes of data (Levels 0-2) and 450 granules per day. 350,000 unique visitors have downloaded over 4 million files from RR in the last 12 months. RR imagery has been featured in hundreds of TV, web, and print news stories, while the RR system is the main contributor to MODIS PR, outreach and the Earth Observatory.

During the Land breakout session, one of the groups met to discuss how to increase MODIS data access and improve outreach. The group recognized that there is still uncertainty about where to go for documentation and data (including how to navigate the web sites and use their various tools) which is compounded by an increasing number of sites distributing MODIS data. Naming conventions for products can be confusing, and many of these sites are still missing some very basic access functions (e.g. sub-setting of variables by location and time). The group recommended that efforts to refine and provide tools should be continued and that there is also a need for end-to-end usage tutorials, targeted at different classes of users including education users. Funding for improved tools and education outreach remains a question. There is also a need to enhance the current FAQ pages and User Services.

Modelers are an important part of the MODIS user community and during the Land breakout session one group met to discuss how MODIS products could be improved for modelers. Recommendations included changing projection and format; making measures of uncertainty and QA information easily accessible; making information about the differences and enhancements between various collections more available; providing consistent gap filled data sets for use in climate and ecological models; providing finer-scale data sets (500m and 250m) for regional modelers; and providing global monthly 1km data for global modelers.

A breakout group also met to discuss Land Climate Data Records (CDRs). The background to and definition of CDRs were discussed. The group recognized the need to develop long-term data records of critical variables from multiple sensors of sufficient quality to study global change. Multi-instrument measurements will not be the same but they need to be capable of consistent analysis. It was noted that CDRs will not be the only products generated in the future by NASA, as experimental products will continue to be needed. Questions raised included which long-term land data records are needed to meet the NASA ESE science needs and what are the accuracy and consistency requirements for these data records? These will likely be addressed in the framework of the emerging Science Focus Areas and NASA's contribution to CCSP and GEOSS. The group distinguished between products generated solely from satellite observations and those derived from model output. The group recognized the need to continue to improve the ESE data product requirement definition, and better quantify the impacts of data product accuracy and stability on model output. NASA will need to support the improvement of algorithms and processing to meet those requirements. It was noted that some progress has been made in product requirement definition by the international community, for example for vegetation parameters, land cover/change, fire and albedo.

To be able to generate CDRs, it is essential to preserve the data, instrument and calibration information. Accuracy and stability documentation are essential for individual instruments, so we must decide which ground-based instruments are needed to support the accuracy and stability of the data. Validation needs to be part of the CDR process, and there needs to be an appropriate level of funding commitment. The CDRs will need science stewardship, keeping the CDR generation close to scientists that are using the product. The CDRs need to evolve with an understanding of data and science needs. Products must be generated in the forward mode, and successive improvements should be applied retrospectively. Archive products, which can be used in future assessments or in the recreation of products for comparison, can be made as needed, to save ever-increasing computing needs. If products are being frequently regenerated, we would only need to archive the CDR input data. We must also distinguish between deep archive and active archives, and the cost for maintaining a Long Term Archive needs to be identified. Once measurements are defined, we need to address product formats, tools and access issues etc.

CDRs would benefit from US interagency coordination, since NOAA is in a similar planning stage re. CDRs and the roles and responsibilities for generating CDRs from NPOESS needs further discussion. Some EDRs will likely be useful for global change

science, but multiple reprocessing will need to take place outside of the operational chain. International coordination of CDRs is also highly desirable, since more instruments means more secure long term records, shared validation costs, and feasible global initiatives.

There are a number of areas requiring attention from the Land Group, resulting from the various discussions held at this Science Team meeting. Increased attention is needed to instrument performance/monitoring as the instruments start to age. Continued attention is needed to managing MODIS data volumes and loads and reducing data system costs. Attention is being given to designing and developing a moderate resolution processing capability for the land community which would build on the MODIS and AVHRR experience, providing a foundation for the processing of VIIRS data in support of science team activities. MODIS Land Product Validation (LPV) needs to be completed to Stage 2 for all products and enhanced international cooperation should be explored through the CEOS LPV working group. The Land Group would benefit from a product review in the next 2 years to strengthen the utility of the land data products. The land data system needs further development, as does long-term archiving and community outreach. The land group should continue to solicit user feedback and explore with management ways to support the increased functionality requested by the user community. NOAA and MODIS should increase dialogue/cooperation in the transition of MODIS to an operational domain. Land CDRs need further development, as does transferring MODIS lessons learned to NPP VIIRS particularly with respect to instrument calibration, data systems and validation.

Michael King – Atmospheres Group Summary and Plans

Michael King, the MODIS Atmospheres Group Leader, presented on the results of the Atmospheres Group's breakout meeting. He noted that the group is especially focused on increasing interaction between all of the discipline groups.

Software updates were a large portion of the topics discussed. For calibration, characterization, and L1B data, the destriping detectors are used as a preprocessor of all the Wisconsin algorithms, and they recommend incorporating that practice into L1B data production.

There will be extensive updates to the Cloud Mask algorithm in the thermal infrared (including Polar Regions), and zonal cloud cover during the daytime and night-time will be much closer.

For the Cloud Product, there will be a new global surface reflectance product (a joint Atmospheres/Land initiative) used as an ancillary input into cloud optical properties. Cloud-top pressure will be improved for low clouds where the algorithm switches between CO2 slicing and the infrared window. Multi-layer cloud identification was added, and the uncertainty estimates for Cloud Optical Thickness and effective radius and water path were improved.

Surface albedo is now being calculated by ecosystem-type with spatially complete data. There is a new spatial variability to improve the screening of heavy aerosols and clouds; and a new spectral ratio is being considered to improve biases in aerosol optical thickness retrievals over land.

Precipitable water and atmospheric profiles were substantially improved with regards to total ozone, particularly over Antarctica.

The new Joint Atmospheres Level 2 "best of the atmospheres" product will be available in small, easy to download files (3 MB daytime files, 1 MB nighttime files).

The Gridded L3 product will have new, aggregated L2 parameters and changes in joint histograms.

King pointed out the MODIS Atmospheres website (designed by Paul Hubanks), which is well designed and feature-filled resource useful to both experienced and new data users.

On the subject of data use, assimilation, and interdisciplinary science, King noted that the Polar Winds product is using Terra and Aqua MODIS data, and is showing a strong impact (demonstrated at the ECMWF and GMAO, with lots of interest amongst international agencies). Aerosols are making use of a new algorithm developed for AOT (and single scattering albedo) over bright reflecting surfaces, such as deserts.

The group's modeling activities include a GOCART model of anthropogenic aerosol radiative forcing; and a new clear sky radiance dataset being developed for ingest at SCMWF.

Interdisciplinary activities include simultaneous retrieval of aerosol optical properties and marine constituents; and spatial variability of MODIS and MISR atmospheric products, including studies of 3D error-assessment of clouds.

In the future, the Atmospheres Group will work on a number of issues. ATBDs, last updated in 1997 following the second of two formal peer reviews, will be updated in the next year (including new L3 algorithms that never had ATBDs). Validation plans are less formal, but the documentation of past and future plans in the validation of data products, which were last updated in Feb 2003, will be solicited and integrated in the next 2-3 months.

Because the Atmospheres community is already quite familiar with the HDF file format, the group anticipates no problems and plans no significant changes.

In the effort to integrate MODIS data into the modeling communities, there are a number of projects going on: three independent MODIS-GOCART assimililations; the GMAO working on assimilating MODIS cloud data; and the ECMWF interacting with the MODIS cloud group.

As for CDRs, the group has seen only limited intercomparisons thus far (ISCCP vs. MODIS clouds; HIRS ISCCP-MODIS high clouds in tropics); and there's been no in-depth discussion.

Vince Salomonson – Discussion and Plans for the next 6 months
Salomonson thanked everyone for attending the meeting and contributing to MODIS. He summarized the important points of what transpired during the three-day meeting.

On the subject of accessing and utilizing products, He noted the idea of making it so that state, local, and federal government agency personnel, as well as community college and other users can get the products they want and need easily. We must make simple, intuitive interfaces with good subsetting, and reduced data volumes. OCDPS has displayed many of those attributes: SeaDAS offers tools, a familiar environment, etc. We need to work with the DAACs on Land and Atmospheres products. Evolving toward a distributed/discipline-based processing system should be a move in the right direction. Herring and Ward's work on NEO are good examples of this, but are there others? We must constantly find out what the customer wants and adapt to do so.

We have to continue collaborating and being supportive (insofar as possible) of efforts regarding Direct Broadcast, real-time, and bent-pipe data efforts at NOAA/NESDIS. With regards to QA information, we have to decide how much to provide (just the best or also various levels of usability attached to products?). And for storage at the DAAC archives, we have to prioritize products: "standard," "experimental/developmental," and "validated."

Keeping track of metrics is also quite important. Data, such as the number of products distributed (files, volumes, granules, etc.) and the types of users (private industry (.com), academia (.edu), government (.gov), etc.) are also quite important, though we must also remain aware of privacy concerns. We have to continue keeping track of uncertainties, accuracies, and precision data. These help modelers and others to see in quantitative/summary fashion what is occurring in more detailed QA documentation. It essentially captures our progress over time. We will continue to track publications, key science results, and noteworthy application results.

We need to define what exactly "climate quality" in Climate-Quality Data Sets means. According to the NRC in 2004, a "CDR" is a time-series of measurements of sufficient length, accuracy and stability to determine climate variability and change. We need to learn how to merge in a CDR-sense MODIS data sets with predecessor data sets (e.g., AVHRR, CZCS) and future data sets (e.g., NPOESS VIIRS). "Collections" are hard for some people to deal with. Land and Atmospheres are pretty close, and MODIS Oceans (radiances and chlorophyll, etc.), is hopefully going to make it too. These are important implications for VIIRS. As stability/consistency is being sought, algorithms in developing data sets need to look for stability in the inputs to the algorithms; e.g., GMAO inputs.

One of our goals is to see data assimilated into the big GCM climate and weather modeling groups; e.g., ECMWF, GMAO, NCEP, etc. Data "collections" are challenging for modeling groups to work with, so we need a way to work around that. Modelers tend to want lat/long grids like CMG, but often at much higher resolutions (e.g., 1km). Some groups prefer monthly (e.g., 28 or 29-day February, 30 and 31-day other months, not 32-day months), some prefer sub-weekly, and still others prefer daily data sets, which allows the modelers to fill in the gaps to create their preferred data sets. Often, modelers want remote-sensing folks to "fill in values" or help them aggregate-up. We must also provide the tools for gridding and regridding.

Interdisciplinary efforts are also important, and we have to answer questions on how to further such efforts. Several instances already exist, such as Land product use by the Atmospheres group, and obvious use of cloud-cover screening by the Land and Oceans groups. Student education is a big part of what we do, and we would like to know the number of students we're supporting and have substantively helped through graduation. Finally, we must continue our outreach/workshop efforts. These help us get the "word out" about MODIS. Notable upcoming workshops include the Land/Missoula workshop in August, and the Snow and Ice Users workshop in November.

Hal Maring – Closing remarks

Hal Maring, the NASA Atmospheres Program Manager, said that he was very impressed with the wide application and utilization of MODIS data. It's obvious how carefully the people in this program worry about calibration/validation, because it is so obviously applied to a wide range of applications that are not only global in scope, but in utilization as well. There are multiple ground-receiving stations, more outside the US than inside. He was also particularly impressed with the NEO presentation, and feels that the program is generally headed in the right direction.

During the recompetition, there was a shift in programmatic emphasis. NASA is shifting away from cal/val, and more toward actually using the science data. There is a new emphasis on cross-disciplinary and cross-sensor work. Marking was particularly impressed by the efforts of the Atmospheres group in this area. The team needs to knock down barriers between traditional disciplines, and it was nice to observe Ocean Color members actively participating in the Atmospheres breakout session. Finally, the third emphasis is on data models. MODIS needs to be involved in more of these.

Paula Bontempi – Closing remarks

Paula Bontempi, the new NASA MODIS Program Scientist, noted that as she circulated through the various team meetings, she saw a lot of diverse applications and hard work. She noted the tremendous progress and evidence of hard work over the past decade, and was anticipating the progress over the next three years. Interdisciplinary products are increasingly important, and the team needs to break down the barriers between disciplines. No matter what the HQ reorganization brings, the focus will still be on the Earth science/model as a whole.

She noted that though Headquarters representatives are not accessible at all times, they do read their email, and welcome input and feedback.