MODIS Science Team Meeting
March 22-24, 2005
BWI Marriott, Baltimore, Maryland

Table of Contents

First Plenary Session

Welcome / Meeting Goals / Overview

Vincent V. Salomonson, MODIS Science Team Leader, NASA/Goddard Space Flight Center

Salomonson opened the meeting by thanking everyone for attending. This team is MODIS' biggest yet, with over 90 team members, and the meeting stands at over 260 preregistered attendees. Once it hits full capacity, there will likely be 300 total in attendance. Every team member should feel that they're part of the effort to improve MODIS products, to collaborate with other instrument teams, and to make use of the resources that have been provided.

Both instruments are doing well, and can be considered at least "okay" or better. Statistics indicate that MODIS data are being increasingly used for science and applications purposes, which is very encouraging. Today there will also be an update from Jeff Privette on the NPOESS/NPP project, and how that's progressing.

A lot of posters showing a range of good results have been submitted for this meeting, and are on display. Today the meeting will cover the program thrusts and plans for the future (related to the hopeful approval of the Terra mission extension). Jon Ranson will speak on those topics.

Terra MODIS is doing okay after five years of operation – it is meeting calibration specifications and geolocation goals. The Ocean Color requirements are To Be Determined, and depend on how Aqua MODIS is doing. Overall, there are some tentative signs of aging (noise and vectors), but there is no reason that the spacecraft and MODIS instrument can't go on to the end of the decade.

Aqua MODIS is doing fine after almost three years of operation, including Ocean Color observations coming into line via the Ocean Color Distributed Processing System (OCDPS).

Data processing systems have performed very well over a period of changing conditions; over a petabyte of data at the three DAACs have been delivered, processed, and archived. OCDPS is now also doing its own Ocean Color processing. Collection 4 reprocessing has finished, and Collection 5 is next up. Land processing will start mid-year 2005 and will go through most of 2006 if not 2007 (because of processing speed and the amount of data involved). Atmospheres will go more quickly.

As for publication statistics, there are 1,462 discrete publications in the MODIS database dating from 1990 to the present. There were 186 papers in the 2004 Fall AGU Index, and the Web of Science lists 722 refereed publications (>6,700 citations as of March 21, 2005). The list keeps growing.

As for EOS Direct Readout sites, there are over 100 ingest sites around the world for Terra and Aqua Direct Broadcast downlinks. Using those 100 ingest sites are over 800 known data users. This list is located on the Direct Readout Portal.

On the issue of the satellite transition schedule, there are efforts underway to extend MODIS into the NPP/NPOESS era. There is some question of how EOS-Terra will transition to NPP, and Jeff Privette will now talk about that.

Jeff Privette, VIIRS Deputy Project Scientist: VIIRS is the MODIS successor, and will start flying on NPOESS in the 2009-2010 timeframe. It is one of four instruments scheduled to go up as a precursor in 2006, though there have been some manufacturing issues (such as with the cryoradiator), being over cost, and behind schedule. There has been a management change at SBRS to address this. On that notes, there are three possibilities: try to stay with the current design and fix those issues, go with a new design, or develop a new cooling system. Based on additional testing of the original design, the decision has been to modify and fix it. There's also an Earth Shine problem that's being addressed and that is also seen in MODIS, but it's twice as bad for VIIRS and jeopardizes the calibration requirements. All of this has affected the schedule, and will have an EDU delivery in the fall of 2005 at the earliest. The whole schedule is shifting back. The team hopes for a spring 2008 launch, but can't speak for the other instruments or satellite.

Salomonson continued on the topic of thrusts:

- Support and collaborate with the relevant parts of the Earth Observing System Data and Information Service (EOSDIS) or other entities that provide MODIS data products to the general science and applications communities or the public at-large. The team must improve access to and the use of MODIS data products.
- 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 community(ies) 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 the needs of resource management and decision models support.
- 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.

The NASA Headquarters Perspective

Paula Bontempi, MODIS Program Scientist and Manager, NASA HQ Ocean Biology and Biogeochemistry Programs

Bontempi explained that NASA recently went through a transformation (see presentation for the new organizational chart). There are no more codes; they've all been absorbed into mission blocks. Mission support boxes generally have representatives, and the missions are: Exploration Systems; Space operations; Science; and Aeronautics Research. MODIS is in the Science Mission Directorate in the Earth-Sun System under Mary Cleave (acting director). There are three divisions: Research sciences; applied sciences; and flight programs. MODIS is in Research Sciences, under Jack Kaye. For the most part these representatives are solid. A new NASA Administrator has been nominated, and there may be associated personnel shifting. The new Advisory Committee Structure is still being formed.

On the topic of the budget: with every new fiscal year there are plenty of earmarks. NASA is working first on the President's Exploration Vision. There were some recommended Mission Science Team reductions: originally five percent of the Terra/Aqua Science Data Analysis budget was cut, with 7.5 percent coming out of algorithm refinement and 12.5 percent from the MODIS Team Leader budget. To avoid these deep cuts, they are working on a plan to do incremental funding. More will be heard about this as it gets approved, and it will hopefully avoid cuts at least to science data analysis and algorithm refinement. The Team Lead cut should be cut by about two thirds. In the out years this means that there will be an impact for ROSES (which comes out in January), but this should avoid gaps in funding between 2006/2007. For FY2006, there is a requested vs. enacted budget, and this is supposed to be a one-time cut.

On Mission Extension/Senior Review Process: If there is a mission coming to the end of its prime life, there is an opportunity to extend it at much lower level. This mimics the former Space Science process. These opportunities happen in a two-year cycle, and proposals for this cycle were due March 16 2005. Terra (and its instruments) is currently up for competition, and the proposal will be reviewed by a panel of peers outside NASA, scheduled for April 25-26. Mission Ops and Cal/Val will be reviewed. If the process is successful, it will continue every other year.

The challenge for the Team is to reap the full scientific benefits of MODIS, Terra, Aqua, and EOS. The team must make and keep the existing data products the best they can be; develop new data products to enable important new science and applied uses; and utilize MODIS (and Terra/EOS) data products to create a new science understanding of the planet and how it is changing. The team also needs to develop new applications of this knowledge for decision support. It is high time this was a focus again.

On Continuity: How does MODIS fit into a changing world? Earth System Science and the NASA culture are both changing. The NASA Mission still includes understanding and protecting home planet, but it has to transform and align to President's Exploration Vision. A strategic road-mapping effort is taking place (#9 applies to Earth Science; it includes a mapping of technology out to 2030). Earth Science is still changing from Mission Science teams to Measurement-Oriented Science teams (CDRs). HQ is working on a formal Modeling and Analysis program (under Don Anderson) at NASA, and are developing and linking to GEOSS to do some of the operational observation of land, oceans, and atmospheres – MODIS products could be candidates for this, though it is still in development. At the end of 2004, the US Commission on Ocean Policy (National Academy of Sciences) Report 20 said that the research agencies are not great at transitioning from research to operations. There is a group studying that at HQ, and HQ is also working on identifying candidate products in atmospheres, land, and oceans.

MODIS needs more interdisciplinary algorithm development approaches to share expertise. Hopefully this translates to future missions. Certain algorithm developers and validation investigators should address important deficiencies in key data products; work is going on there, but it needs to be coordinated better. Algorithm developers need to represent the broader community needs by working with them, and algorithm refinement PIs need to provide compelling justification for the importance/utility of the algorithm improvements and/or new data products.

A new EOS Data Review is also needed. This hasn't been done because of what has been happening at HQ, but the Science Team needs to start working on it and do one every 2-3 years. In those, the team has to assess the quality and importance of the data product suites, and prioritize the EOS data products relative to each other and relative to the other needs of the community they serve. It has to recommend changes, improvements, and improve the level of service by data systems and archives. The community must be involved. The team must take into account NASA (or other) resources / program components that are required to support the products, and involve the data system and archive management and NASA HQ Focus Area leads in this process. Suggestions are welcome on how to accomplish this.

They are continuing with and evolving the measurement streams. There will be one science team, competed periodically, that provides science guidance to present and future missions and for the utilization of past data sets. Support and focus will be on CDRs. There will be one data system to ensure a "seamless" time series, and science guidance and priorities must represent the broad user community. The CDR session tomorrow should be very useful.

The Ocean Team already begun the transition from mission to measurements, Land is poised to begin, but it's not clear where Atmospheres is in this process.

For this meeting, HQ needs updates on the "new" team's (PI) progress and integration, especially on algorithm refinement and validation, and Science Data Analysis results. An issue here is future planning in all three disciplines, and MCST has topics that affect everyone. HQ needs to hear about issues critical to those efforts.

Terra Status

Jon Ranson, Goddard Terra Project Scientist, NASA/Goddard Space Flight Center

Jon Ranson, the Terra Project Scientist, gave an update on the status of the Terra Instrument. Some accomplishments of the instruments are: MODIS – global net primary productivity; CERES - global shortwave and long-wave radiation; MOPITT - carbon monoxide; ASTER - 3-D land and natural hazards; MISR - aerosol profile. It is amazing work on connecting the dots between all these products.

Terra's science value is very good. The Terra MISR instrument captured images of a secondary tsunami wave on December 26, 2004, in India. Knowing how to get these images and how they work really helps with modeling.

The satellite has collected five years of science data as of February 24, 2005, and completed over 27,000 orbits. All instruments are acquiring science data. There are unprecedented volumes of validated science data now in the DAACs. Terra was joined by a new EOS Mission – Aura – this past year. There are a few anomalies: MODIS SSR, ASTER SWIR temps, FOT and IOTs. All instruments rose to the occasion in a professional and efficient manner. Despite these issues, there has been relatively little impact on science data from the MODIS SSR issues. Hopefully power recycling will fix the issue, and the Terra team is negotiating with HQ on that. Overall, the anomalies are not serious, and our highly qualified Flight Operations Team (FOT) is working on these. The SSR anomalies have reduced the recording capacity to the minimum needed for current science data collection, but there is a plan devised to recycle power in the SSR boards to recover them. HQ has indicated that they want to wait for a loss of additional data before they approve a recycle. A Deep Space and Lunar Calibration report is in preparation, and a third maneuver is TBD. A Special Issue on data fusion is being considered for inter-platform (e.g., MODIS and MISR), intra-platform (e.g., MISR and Landsat), and intermission (e.g., Terra MODIS and Aqua MODIS) data.

There are a few more Terra issues: a Terra/Aqua follow-on (i.e., NPP); long term archiving; the NASA transformation; and the Earth Sciences Senior Review of all missions that are at the end of their design life. Terra's review will be in March of 2005.

On the Senior Review: NASA's Science Management Directorate (SMD) periodically conducts comparative reviews of Mission Operations and Data Analysis (MO&DA) programs to maximize the scientific return from these programs within finite resources. The acronym "MO&DA" encompasses operating missions, data analysis from current and past missions, and supporting science data processing and archive centers. At present there are more than 18 missions returning science data support for NASA's Earth Science research programs. Most of them are under Senior Review this year: TRMM, TOMS, UARS, SeaWiFS, Terra, ICESat, Jason-1, QuickSCAT, ERBS, SAGE III, POAM, GRACE, ACRIMSAT, and GPS Atmospheric Limb Sounding.

NASA uses recommendations from the Senior Reviews to define an implementation strategy and give programmatic direction to the missions and projects concerned for the next two to four fiscal years. The Terra Extended Mission Proposal [FY06 to FY09] was submitted to the Earth-Sun System Division (ESSD) of the Science Missions Directorate at NASA HQ on March 16, 2005. It concentrated on the HQ focus-area science questions: systematic observations (MODIS, CERES, and ASTER) and the discovery of Earth System processes with a multi-sensor, multi-platform approach.

Aqua Status

Steve Platnick, Goddard Deputy Aqua Project Scientist, NASA/Goddard Space Flight Center

Steve Platnick, the Aqua Project Scientist, presented on the Aqua satellite and instruments status, gave a mission operations update, discussed the instrument data processing status, and gave some science highlights.

The AIRS, AMSU, and HSB instruments cross-track sounding suite is run from JPL. AMSR-E conical scanner (JAXA) is run at the University of Alabama, and CERES is run at NASA LaRC. Their cumulative mission is to enhance the understanding of the global water cycle, improve weather forecasting, and allow for diurnal observations. In addition to the obvious water cycle emphasis, there are some applied uses that will be discussed in a senior science review.

Everything is working well on Aqua except for the HSB instrument, which experienced a scan motor failure in February of 2003. They are doing periodic turn-on tests (the next will be #14), but there is no direct impact on the standard AIRS sounding products. All other instruments are functioning normally. There are only minor spacecraft anomalies, none that affect science data. The instrument has performed a number of orbit maneuvers:

- Periodic drag makeup maneuvers, MODIS lunar calibrations
- A-train coordination
- PARASOL successfully launched into a final orbit about two minutes behind Aqua in early February

There are data downlinks via primary ground stations at Poker Flats (Alaska) and Svalbard (Norway), with a backup antenna at NOAA Gilmore Creek (Alaska). One antenna is certified, and two are awaiting certification. Direct Broadcast X-Band is working well for all instruments. However, orbital debris is a concern. Terra is only getting limited debris screening by DOD Cheyenne Mountain, though eventually it will transition to daily screening. The Terra team is also doing close coordination of Aqua, Aura, and other A-train mission operations.

The primary products for AIRS/AMSU are in their V3 processing, with V4 about to come out. L3 products will be released in 2005. All data are processed and being archived at the GDAAC, and the NOAA/NESDIS "bent pipe" system gets the data from the GDAAC to the NWP centers. Direct Broadcast L1B software are being delivered to the University of Wisconsin CIMSS for inclusion in IMAPP.

AIRS' IR absolute radiometry of 0.2K is stable and meeting specs. The data are being made available to weather forecasting centers all over the world (including NCEP, UK Met Office, ECMWF, GMAO, and the JCSDA, among others), and there is a collection of 23-24 papers being submitted for a JGR special issue. Research products include CO retrievals, Aerosols, and Land Surface Spectral Emissivity, among others. MODIS data are being used for cloud validation, and AMSR-E data for water vapor. There are 12 continuing science team members, and 11 new members.

AMSR-E's standard products fall into five categories: ocean (SST, sfc wind speed, water vapor, cloud water path), rainfall (instantaneous, monthly), snow water equivalent, sea ice products (ice concentration, temperature, snow depth over ice), and surface soil moisture. The LIA data are produced by JAXA, and a new version came out in February of 2005. Data processing is done at SIPS in Huntsville, and the first major reprocessing was completed in October of 2004. The next reprocessing after testing with the new L1A version will begin in June 2005. The data are archived at the NSIDC DAAC. JAXA algorithms and products are archived in Japan. An arrangement to allow the US team to process ADEOS-II AMSR data has just been signed, and products will be archived at NSIDC. Database L1 software packages from RSS are available via Wisconsin/CIMSS, and a public release will be forthcoming.

The global ocean heat storage program and the ERBS/CERES global net fluxes have been found to agree to within 0.3 Wm^{-2} for 1992-2002. A paper on this is in draft form. Further, an investigation of "earthshine" albedo study vs. CERES has been accepted by *Science*. The CERES team is working with the climate modeling community, and it is a major participant in the GEWEX International Radiative Flux Assessment. Further CERES science efforts will be covered in Norm Loeb's talk later in the plenary sessions.

In summary, the spacecraft and instruments are doing well. They are in close coordination with other afternoon constellation platforms, and there are periodic Aqua Science Working Group meetings to encourage inter-instrument science communication.

GSFC-EOSDIS Clearing House (ECHO) Activities

Robin Pfister, NASA ESDIS IMS Lead Engineer, NASA/Goddard Space Flight Center

Robin Pfister presented on ECHO: Foundational Middleware for a Science Cyberinfrastructure (http://eos.nasa.gov/echo).

First and foremost, thanks to the members of the MODIS team who were early adopters of ECHO. Although sometimes working with such new technology was a bit painful, the invaluable feedback received from this community has ensured that the ECHO system evolved and will continue to mature in a direction consistent with community needs.

ECHO is an enabling framework that allows interoperability among diverse and distributed data, service, and client systems. It is a metadata clearinghouse and order broker, and an open system. In the near future it will also be a granule-level service broker. Previously, users of Earth Science data were confined to a single user interface built as a one-size-fits-all solution, using a search and retrieval data access paradigm where searchers were executed at the archives. Many factors contributed to slow or non-performance, and thus scientists spent a significant amount of time performing data access activities when they could have been doing actual science.

ECHO plays a role in a peer-to-peer model in a way that ensures individuals and communities can share data, services, and tools. Scientists will save time by using tools tailored for their data-access needs, and will be cutting out unnecessary steps in the data access process. Tools can be developed by anyone, which will save NASA funds and increase quality through increased competition of services.

Data partners will provide information about their data holdings, and client partners will develop the software (either machine-to-machine or human-to-machine) to access this information. End users who want to search ECHO's metadata must use one of the ECHO clients.

ECHO will enable a rich set of resources to be offered for a variety of purposes. It will be streamlined and can be tailored and show you exactly what you want/need to see. Virtual seamlessness saves time for actual research. Providers can provide and control access to metadata, and match users up to a search interface suited to those data. It provides tracking services and improved availability over the previous architecture.

ECHO is iteratively developed, and is currently on version 5.5.3. 6.0 is being externally tested, 7.0 is ready for an external test, and 8.0 is just getting started. Information on future releases is available on the ECHO website (http://eos.nasa.gov/echo).

The March 10-11, 2005, Client Workshop kicked off 2005 as the "year of the client." It prioritized API areas for development of the Client Libraries and the Reference Client. The Reference Client will provide a view with 'best practices' code that can be copied and pasted into other applications. The workshop also encouraged component sharing among the existing client providers. The ECHO team has repackaged the complete set of toolkit source code, java documentation, and libraries. This repackaging fills in all the remaining "holes" in the toolkit library.

As of March 1, 2005, ECHO lists 1409 public and restricted collections, over 41.6 million granules, and 7.3 million browse images. Operational data partners include:

- ORNL DAAC – Oak Ridge National Laboratory DAAC
- SEDAC – Socioeconomic Data and Applications Center
- LP DAAC – Land Process EOS Core System (ECS) DAAC
- GES DAAC – GSFC Earth Sciences DAAC
- ASE DAAC – Alaska SAR Facility DAAC

Testing partners are:

- LaRC DAAC – Langley Research Center ECS DAAC
- NSIDC DAAC – National Snow and Ice Data Center ECS DAAC

Developmental partners are:

- PO.DAAC – Physical Oceanography DAAC
- SSC SDP – NASA Stennis Space Center Science Data Purchase
- GES DAAC V0 – GSFC Earth Sciences Version 0 DAAC

ECHO Client Partners are:
Operational

- Mercury EOS – ORNL client
- Power User Interface – script for bulk ordering
- SIMECC (Simple MODIS ECHO Client) – MODIS data search and order

In Test

- WIST – EOS Data Gateway using ECHO
- ASF ECHO Client - Alaska SAR Facility client
- WISRD (Web Interface for Searching, Subsetting, Stitching, Resampling, Regridding, and Reformatting Data) – NSIDC Client to search for swath, scene, and gridded data
- MODIS Website – Client via existing MODIS website and ORNL's shopping cart
- Data Validation User Interface – Client for MODIS Land Data Validation Team

Under development

- Annoterra Version2 – Link between EOS news feeds, GCMD, and ECHO granules
- SNOWI-E – NSIDC client
- NEO - NASA Earth Observations client
- Invasive Species Data Service
- OGC/NSDI Client Adaptor - will allow any OGC/NSDI compliant client to plug in. Earth-Sun Gateway (ESG) is an example)

There are plans for other clients (MODIS rapid response, Adaptive Sensor Fleet) as well.

The ECHO Operations Team (ECHO Ops) is the point of contact for direct interaction between ECHO, its Partners, and end users. It is responsible for the operation and maintenance of the ECHO operational and partner test systems. ECHO Ops general support for Partners includes:

- Assisting Partners in understanding the ECHO API and DTDs
- Ingest management and accounting - weekly summaries and metrics on all ingest jobs
- Problem tracking and resolution
- Advertising Data Partner holdings and availability of new datasets
- Promoting and engaging new Client Partners

It will act as a reference client in progress (best practices code reuse), and will improve website content to provide a "front office" for client developer support. It will also improve overview materials; create a sense of this thriving project and community; and reorganize the developer reference materials into a developer center. They will also develop multilevel documentation to promote easy use of the APIs.

ECHO Ops is available at echo@killians.gsfc.nasa.gov and 301-867-2071. The website (http://eos.nasa.gov/echo) includes a holdings summary, details on upcoming functionality, APIs and DTDs, and provides real-time status updates. There are four ECHO mailing lists: echo-all, echo-status, echo-client, and echo-data. ECHO Technical Committee (ETC) Meetings are held on Tuesdays at 3:00pm ET; contact ECHO Ops for dial-in information.

The Atmosphere Archive and Distribution System (AADS)

Bill Ridgway, MODIS Atmosphere Science Discipline Data Team (SDDT) Lead, SSAI

Bill Ridgway presented on the Atmosphere Archive and Distribution System (AADS). The goal is to put a high percentage of L2 and L3 products in a readily-available archive, and to make those data available for those people with large/complicated orders.

The GES-DAAC Production System sends L0 and L1 data to the GES DAAC Data Pool and ECS Archive, and to a shared server that also feeds into the GES DAAC and EDC, NSIDC DAAC archives, and MODAPS L0 archive. From the MODAPS L0 archive, the data go to the MODAPS Production system, which feeds into a shared server, a new LADS L3 archive, and a new AADS L2 and L3 archive.

AADS was originally designed as a science testing utility for Science Team members. It now houses Science Test Data for distribution to the Atmosphere Discipline Science Team, including test Collection 4 and 5 levels 2 and 3 data. It will soon offer an online inventory of all MODIS Atmosphere products: Terra and Aqua levels 2 and 3 data for the complete mission lifetimes. MODAPS will populate AADS with 8+ data years of compressed Collection 5 products and images during the Atmospheres reprocessing campaign planned for April to September of 2005. LADS (the Land product analog) now contains L3 science test data, and will be populated with weekly through yearly L3 Land products starting in September of 2005. Both will offer immediate delivery of native products via an anonymous ftp or web download, with browse images for most products. Both will offer geographic/temporal searches and select-to-order functionality, as well as data subsetting by parameter, geographic cut-out, or sampling to lower resolution.

The goal is to give rapid access to files for anyone that wants to place large/complicated orders so long as they know the filename. Users of the system will be able to browse and select data for download immediately (no staging). Users could also use ftp script robots to facilitate large or complicated orders, or might use global, regional, or granule browse for analysis or to assist in ordering decisions.

There are a number of research scenarios that might apply:

- I have an extensive collection of MODIS L2 granule products that I have compared with surface station data. I would like to repeat my analysis with Collection 5 products.
- I would like to get aerosol optical thickness and cloud mask data for each MODIS daytime overpass of my site – about 5,000 files. I would like the native products to be reduced in size using parameter and geographic subsetting.
- I would like a parameter-subsetted copy of all daily global L3 Atmosphere product files for climate research studies.
- I would like to see global images of cloud top height and aerosol thickness in order to identify specific days and regions for further analysis of cloud-aerosol interactions.

The motivations for a new online archive are rapid access, a desire to offer interactive browse images, the success of DAAC data pools for limited products, the precedent of the Ocean Color Web delivery system, a modest hardware investment, and the availability of new and improved tools for HDF compression (no significant changes were required of the product suite).

The products are immediately available via FTP and a web interface: http://aadsweb.nascom.nasa.gov/ When you know what you want – all MODIS Atmosphere data products will be found in a predictable directory structure – this system is ideal for scripting robots that can acquire lists of L2 granules or gridded L3 products. After a simple web search, orders of native products (without subsetting) can be pulled from a single ftp directory as soon as the order is requested. Gratification is immediate, since there is no delay for data staging. Compression speeds downloads. All L2 and L3 products, including cloud mask, will be internally compressed starting with Collection 5 in order to reduce online storage and speed network delivery. The compressed products are typically three to five times smaller.

Subsetting can be done by geographic and other parameters. This allows for a custom design of delivered products, which reduces bandwidth and researcher storage requirements. Parameter subsetting is particularly valuable for "fat" L3 products. This involves some delay for file preparation, but it runs rapidly in a disk-to-disk environment. The subsetting engine is a prototype for future "custom" products.

AADS is available at: http://aadsweb.nascom.nasa.gov/ and LADS is available at http://ladsweb.nascom.nasa.gov/ Both archives are currently functioning and populated with Collection 4 and 5 science test data. Both are ready for production and public distribution; April for AADS, and September for LADS. AADS is used extensively for distributing science test data, has been tested at production rates of 20 data days per day, and the web server has been tested with 50 simultaneous users. You can expect search results in seconds, with native file orders ready immediately. You can get email notification of when subset orders are completed, and there is support for multiple Collections (Collection 4 L3 data are retained).

Future plans include continued interaction with the science community to refine functionality; add additional parameter imaging to support QA activities; add support for mosaics, reprojections, and format conversions (NEO images, GeoTIFF, etc.), plus new subsetting options; make L1B and geolocation data available on a "processing-on-demand" basis; offer reformatted products without the need for web ordering; and add the potential for data mining at the community's request.

Update on the NASA Earth Observations (NEO) Gateway

David Herring, Program Manager for Education & Outreach, NASA Earth-Sun Exploration Division, NASA/Goddard Space Flight Center

David Herring presented on NEO – NASA Earth Observations Gateway.

NEO is a web-based application and infrastructure to provide formal and informal educators a simple interface for search and retrieving NASA remote sensing imagery and data. Right now it is focusing initially on MODIS data, but the NEO team will continue to add more datasets as the project moves forward. Vince Salomonson commissioned the prototype, and work started on it in the fall of 2003, and is continuing through December of 2005.

The system is designed to rest on the work already done by others. It will make it very easy for customers to access geo-referenced imagery, as well as to order and retrieve data. NEO Browse will work by producing, storing, and making accessible browse images via different servers. The prototype NEO server will interface routinely with each of these servers to retrieve the desired images for storing, indexing, and displaying. Additional browse will also be available from ECHO. For data ordering, NEO will shake hands with the ECHO system, which provides an inventory of NASA's data collections and client APIs for ordering data. Thus, ECHO serves as a portal to the DAACs where MODIS data are archived.

NEO is needed for a number of reasons. According to findings from the November 2004 NASA Earth Explorers Institute (which included science centers, public media, and science advocacy organization personnel), 14 percent of attendees' institutions have in-house software tools for working with HDF data. 23 percent have successfully ordered data via the EDG, while only 14 percent reported that the EDG meets their needs for NASA data. 64

percent prefer to work with data in more familiar image formats, such as GeoTIFF, PNG, or JPEGs. 46 percent said that they would prefer it if NASA would develop another gateway tailored to meet the needs of informal and formal educators. The Earth Explorers Institute will be the 'tire kickers' for NEO. Overall, NEO is driven by needs of formal and informal educators.

NEO will help increase the use of MODIS images and data through education, simple searches, and simple delivery. For education, NEO will teach users about the products, parameters, and data formats. It will provide timely access to imagery in formats that educators can readily incorporate into their workflow, such as formal science lessons, science exhibits and interactive programs, and with amateur Earth observation. It will provide dataset/parameter descriptions tailored to multiple audiences: the lay person, for which general, high-level descriptions are authored by Earth Observatory contributors and/or science team members; and more technical audiences, who will be interested in scientific descriptions and links to ATBDs. NEO will develop "how to" tutorials for looking at data (viewing NEO browse data and doing basic analyses) and basic data manipulation (tools for HDF and other formats).

For searching, NEO will make query parameters easy to understand, and limit options so that complexity is left to advanced users and other interfaces. It will search only a subset of all MODIS datasets/parameters that are selected for popularity and ease of comprehension. NEO will use full-text, semantic searching of datasets and parameters to avoid confusing the audience; there are more technical interfaces out there for those that need them. Semantic searches are the key, not data file name searches.

For delivery, making it simple is very important. This is for those users who want to go the extra step and download the source data. NEO can store pointers to online datasets for direct download (URLs provided by data providers and links to data in DAAC data pools). Users can order source data from the DAACs via ECHO, and all delivery capabilities will be routed and administered through NEO. There will be no shuffling of users off to other sites unless absolutely necessary.

NEO contains browse data and thumbnail images. The browse data are 8-bit grayscale, geo-referenced Plate Carre-projected images. Future implementations might reference Web Mapping services hosted by providers. The definition could be expanded to meet needs of the users. The exceptions will be true-color, surface reflectance, and albedo products, which may be better represented by a greater dynamic range.

NEO will contain a number of global data products covering the Atmosphere, Ocean, and Land datasets:

- Atmosphere products: aerosol optical thickness, fraction of fine aerosol, water vapor, cloud fraction / cloud mask, cloud particle radius, and cloud optical thickness.
- Ocean products: SST (day), chlorophyll concentration, and water-leaving radiances.
- Land products: land cover classification, daily surface reflectance, snow and ice cover, global fire maps, 16-day albedo, land surface temperatures (day and night), NDVI, and LAI.

Credit to participating providers will be provided where appropriate (including links to other sites). NEO will include spatial and temporal metadata, customized content, and references to offsite assets (like ATBDs, websites, etc.).

NEO is currently in its "alpha" release stage, i.e., prototype. The NEO team is working with selected data providers for developing and testing the ingest processes, and the production server is currently going through procurement. It is also working with partners for server collocation, internet connection, and system administration, and exploring Internet2 connectivity, which is designed specifically for educators and scientists.

In the future, the NEO team will establish its production server, and begin to receive ingest packets from participating MODIS data providers. The team will create tutorials, dataset descriptions, other assets, and begin testing with users. It is expected to go live around June of 2005, but the team has not yet made a decision as to who can best host NEO long-term. Future additions to NEO will include an improved semantic search to assist users, more comprehensive coverage of MODIS products, expand to include other missions' data, and could composite datasets from individual PIs.

Geospatial Interoperability & Earth Sun Gateway

Myra Bambacus, NASA Geospatial Interoperability Program Manager, Applied Sciences Program, NASA Science Mission Directorate

Myra Bambacus presented on Geospace Interoperability and the Earth-Sun Gateway.

The current challenges are in transitioning from research to operations; characterizing uncertainty in model forecasts for weather, climate, and natural hazards; acquiring the computing capacity to handle the volume and range of data produced by NASA's Earth observatories; accessing those observations and model outputs throughout the Global Spatial Data Infrastructure, and establishing an Earth Sun Gateway that can provide access to scientists, decision makers, educators, and citizens. There are a number of national and global initiatives (see slides for complete list), in areas including global Earth observations, climate change, weather, natural hazards, sustainability, and the President's E-Government Management Agenda. All of these share a common data-managing element.

There are twelve applications with national priority: Agricultural Efficiency, Air Quality, Aviation, Carbon Management, Coastal Management, Disaster Management, Ecological Forecasting, Energy Management, Homeland Security, Invasive Species, Public Health, and Water Management.

On integrating knowledge, capacity, and systems in to solutions, Bambacus pointed out that data from the Sun-Earth Observatories leads into planetary models. These lead to predictions/forecasts and observations, which in turn lead to the creation of decision-support tools. These tools value to citizens and society by affecting policy decisions, management decisions, and exploration decisions. NASA and its research partners collaborate with the makers of decision-support tools.

There are three main geospatial interoperability standards bodies. The Open Geospatial Consortium (http://www.opengeospatial.org) is a not for profit consortium. ISO TC211-Geographic Information (http://www.isotc211.org) is a technical committee of the ISO with a US delegation (INCITS – L1). The Federal Geographic Data Committee (http://www.fgdc.gov) is a US Federal government directive. The ESG will work with the first to set and develop standards, and harmonize specifications globally with the second. The third is composed of people from different bodies. Those specs and standards are the basis of the prototyping being done now: Synergy V interoperability tasks. MODIS data are being used to start this process.

The Earth Sun Gateway is a portal to information about the Earth-Sun system, including things like:

- Observations of natural phenomena (satellite, in situ, and airborne)
- Predictions from computer models

- Decision support systems from partner agencies
- Image views and visualizations
- Resources available through OGC web services
- Science focus areas

Its intended users are scientists, analysts, decision makers, students, educators, and the public.

The Earth-Sun Gateway concept consists of four services – portrayal, processing, catalog, and authentication – working with four OpenGIS interfaces – WMS, WFS, WCS, and catalog – in an Application Integration Framework. Together, they produce four Earth-Sun components: Digital Libraries (knowledge base), ESMF models, grid resources, and Mission Data Products for the EOS Catalogs. (http://esg.gsfc.nasa.gov)

Geospatial Standards and Interoperability are crosscutting functions need in the current national and international initiatives. They build on existing catalogs and portals, and comments/requests are welcome via http://esg.gsfc.nasa.gov. GIO is built to make accessing data products and model outputs more available via an open systems architecture and OpenGIS interface. Geospatial standards bodies will ensure that your requirements are met, and you can get on a GIO mailing list to keep up with what is happening.

Frank Lindsay, Visiting Senior Scientist for Data and Information Systems, NASA HQ

Frank Lindsay continued after Myra Bambacus, talking about ACCESS: Advancing Collaborative Connections for Earth-Sun System Science.

The premise is to enable earth science and application through near term improvements in NASA's existing Earth science data systems infrastructure and related services. It is also to take advantage of existing solutions developed from members of the science communities that have wider applicability.

ACCESS has two roles: data and information tools and services to support emerging or existing community science processing systems (ComPS), and data and information tools and services to support the seven Science Focus Areas.

To improve ACCESS to data and services, each SFA contributes to three elements: REASoNs (Science), ComPS (Community Science Processing), and Decisions (Applied Sciences).

Bambacus added that this hopefully will settle down to a reasonable number of mechanisms so that users don’t have to keep reinventing the wheel. The metrics should be enriched by people working together, with people focused on output, and capable of measuring customer satisfaction.

MODIS use in Models Presentations

Milt Halem, NASA Goddard Space Flight Center (Emeritus)

Milt Halem introduced the section of plenary focusing on the use of MODIS in modeling. He added that he was pleased to see all the posters on display at the meeting, and gave a brief history of his involvement in the MODIS project.

MODIS Data Assimilation at GMAO

Arlindo da Silva, NASA Global Modeling and Assimilation Office

Arlindo da Silva presented on MODIS Data Assimilation at the GMAO. The group is working on ISCCP and MODIS data for assimilation of cloud observations, wind data, and aerosol data.

The group has been working on developing an aerosol model (see presentation for data slides); but the patterns are off.

There are a number of reasons to assimilate cloud data. It would improve cloud analysis/climatology, improve cloud/precipitation forecasting (which would affect diurnal temperature ranges, visibility, aviation, agriculture, etc.), improve cloud background for interpreting satellite radiances, and improve cloud-radiation parameterizations via constraints by various cloud data types (which would lead to improved understanding of clouds and climate predictions).

There are a number of approaches to cloud data assimilation. Janiskova et al., in 2002, assimilated cloudy radiances via a radiative transfer model that explicitly accounts for clouds with cloud liquid water and cloud ice included as control variables. Pseudo-RH/RH corrections were done by Macpherson et al., in 1996, where cloud observations were used to generate pseudo-RH data consistent with the model's diagnostic parameterizations, or cloud observations were used to correct co-located RH observations to make them consistent with the model's diagnostic parameterization. Cloud fraction parameterization is never modified here. In 1992 Wu and Smith (for GMAO) performed parameter estimation using cloud observations to modify the model's diagnostic cloud parameterization, and the RH analysis is not directly affected by cloud observations. The thing to note here is that for such an assimilation scheme to work, your data have to already be in the ballpark.

The parameter estimation approach recognizes empirical elements of cloud parameterizations that treat unresolved sub-grid-scale moisture variability, uncertain microphysical details, and cloud overlap assumptions. It addresses the resultant biases by slowly varying the associated cloud parameters to drive the model toward cloud observations.

There are lots of things in the cloud fraction parameterization equation, but it is primarily an empirical formula. For the cloud parameter estimation, there is a curve parameterizing that curve and then goes into a variation scheme. (See slides for details of that process.) The results are much closer to actually observed data now, and while there is room for improvement, the results are still good.

MODIS vs. CERES: The results are pretty much the same in Collection 4, and the group is waiting on MODIS Collection 5, which will do a much better job fine-tuning. (See slides for details of the comparison.)

Future plans include extending the algorithm to new statistical-prognostic cloud parameterization in GEOS-5; exploring other MODIS observables (water path, effective radius); using AMSR-E LWP retrievals; merging convective clouds with precipitation assimilations done by Arthur Hou and Sara Zhang; and making assumed-PDF cloud parameterizations.

The MODIS winds data complement other observations in the high latitudes; more so in the SH than in the NH due to the current data sparsity. Based on independent verification statistics, the quality of the information is acceptable. This shows a positive overall contribution to forecast skill with substantial impact in the SH, that extends to the entire hemisphere, and improves in average the forecasting skill results primarily from improving the skill of the worst forecasts. Timeliness remains an important issue; the current delay is 4-6 hours, but some improvement could be made via use of the Direct Broadcast capability.

Aerosol data assimilation at the GMAO emphasizes the estimation of global 3D concentrations, aerosol sources and model parameters, and Observing System Simulation Experiments (OSSE). The Aerosol Transport model data are online within GMAO's Finite-volume Data Assimilation System (fvDAS), and includes aerosol modules from GOCART (including dust and black carbon absorbing aerosols, as well as sulfate, organic carbon, and sea-salt non-absorbing aerosols). Aerosol observing systems include TOMS (aerosol index and 380 nm radiances), MODIS (optical depth retrievals or radiances), and AERONET (optical depth and index of refraction). The assimilation methodology includes a physical-space statistical analysis system (PSAS); antistropic/flow dependent error statistics; bias estimation (indirect information on sources); and joint estimation of source defects. MODIS data are currently assimilated off-line in GOCART.

In summary, cloud observations have a very positive impact on the fvDAS cloud radiative forcing and land surface. MODIS winds complement other observations in the high latitudes, and on-line aerosol data assimilation enables the production of long term analyzed datasets, aerosol forecasting in support of field campaigns, as well as the stimulation of future aerosol instruments.

Ocean Biology Studies – Assimilation of Aqua Ocean Chlorophyll Data in a Global Three-Dimensional Model

Watson Gregg, MODIS Oceans Science Team Member, NASA Goddard Space Flight Center

Watson Gregg presented on the Assimilation of Aqua Ocean Chlorophyll Data in a Global Three-Dimensional Model. The motivations for this are to maximize data use, estimate parameters to improve models, estimate state and flux, and make predictions. (See slides detailing the NASA Ocean Biogeochemical Model.)

The assimilation of satellite ocean chlorophyll Conditional Relaxation Analysis Method has three advantages (fast, very strongly weighted toward data, and less susceptible to model errors) and one disadvantage (it is very susceptible to data errors). To keep the assimilation model bounded requires: 1) smoothing of data (25% monthly mean, 75% daily weight); and 2) increase model weighting relative to data.

Assimilation has to be done every day, because if they take a monthly mean they don't know where and when the fill data is coming from. Therefore do daily to omit monthly biases. Assimilation seems to do well that way.

The objective is to build the NASA Ocean Biogeochemical EOS Assimilation Model (OBEAM). It will assimilate spectral radiance, chlorophyll, and organic and inorganic carbons. There needs to be a data product that is producing realistic fields while being faithful to Aqua data. The motivations are 1) data use maximization; 2) parameter estimation (model improvement); 3) state and flux estimation; and 4) prediction. The emphasis is on #3 in oceans.

(See slides for details of comparisons) SeaWiFS values are still a little higher than Aqua values. Terra values are very close as well. The team uses a monthly RMS log error equation, and then take the average of that to get the annual RMS. SeaWiFS, Aqua, and Terra are all very close together in log errors.

One of the advantages is not just in state estimation, but flux estimation as well (for primary production). This model cuts errors by 2/3 if they assume that the VCGM is correct.

The initial assimilation results are promising, but require further analysis of the new methodologies. The team is awaiting new SeaWiFS data, and will proceed on the incorporation of the MODIS/GMAO products.

Terrestrial Ecosystem Analysis Using MODIS Data

Rama Nemani, Research Scientist, NASA Ames Research Center

Rama Nemani presented on Terrestrial Ecosystem Analysis using MODIS data. MODIS data have been very valuable for terrestrial ecosystems.

NASA HQ has a grand vision (see presentation slides for details) in which everyone has a spot. NASA satellites send about 1.5 TB per day to EOSDIS, which holds 250+ products equaling about 2 petabytes of data. It sends from 0.1 to 10 TB to the Ecocast Architecture, which also receives between ten and 100 MB of data per day from ground observation networks and ancillary data sources. One of the first things the team does when they bring observations together is to grid the climate data, including daily weather data from over 6,000 stations worldwide. There are regional applications for these data (see slides for an example of the Columbia River Basin). The snow model is being improved by moving from an empirical to process-based. Compared to MODIS data, the model performs well. Lots of work went into this. An additional example looks at the European eddy covariance network on the MODIS Land cover grid, and something similar for continental US is in the works as well.

There are also data-driven models, such as one extrapolating fluxtower observations using MODIS. This allows us to test using a machine learning technique, which is an exercise that hasn't been done in the past, but is being done now. These can help in furthering our knowledge.

Another data-driven modeling effort compared MODIS data in mapping wildland fire risk. The algorithms were grained on all the non-arson fires during the 2000-2002 fire seasons, and methods included support vector machines, artificial neural networks, and logistic regression. The modeling matches what MODIS observed in fire mapping. (See slides for charts of biospheric activity and atmospheric CO2, trying to extend the dataset from AVHRR to MODIS, and various studies showcasing the use of MODIS data.)

Another important contribution from MODIS data is that Amazon rainforests green up during the dry season with important implications for global carbon cycling. Improvements to MODIS sensor and data processing are believed to have contributed to the detection of this important biospheric phenomenon.

MODIS use among modelers stresses:

- The importance of QA – goading users to pay attention
- Producing high quality monthly average prods – not all users care about interannual variability
- Interdisciplinary studies - e.g. coastal ecosystems need a lot more effort
- Uncertainty – may be characterized by biome or climate zone. Guidance to users now in how to use the product in modeling is important.

Second Plenary Session (Morning Day Two)

REASON CAN Progress

Nazmi Saleous, Senior System Analyst, SAIC, NASA Goddard Space Flight Center

Nazmi Saleous presented on REASoN CAN: Status of the A 0.05 degree global climate/interdisciplinary long term data set from AVHRR, MODIS, and VIIRS.

For a long-term land data record, they have developed and produced a global long term coarse spatial resolution (0.05 deg) data record from AVHRR, MODIS, and VIIRS for use in global change and climate studies. They use a MODIS-like operational production approach including an operational QA team, and have set up an advisory process. Intermediate versions of the data sets are available to the community through a web interface where users can also give input. They also hold community workshops for outreach and feedback, and are prototyping the development and production of a climate-quality data record.

The proposed LTLDR products for AVHRR, MODIS, and VIIRS are surface reflectance, vegetation indices, surface temperature and emissivity, snow, LAI/FPAR, BRDF/albedo, aerosols, and burned area. Products and formats will be modified based on feedback from the user community workshops.

They are in the earliest stages of the 5-year project with multiple milestones. One milestone is coming up in June 2005 where they will release the first beta AVHRR/MODIS surface reflectance dataset. This is the biggest milestone in this reporting period, and they are looking forward to that. The project is on target, and they are hoping to get this portion completed on time.

There are three data sources: AVHRR (the heritage instrument), MODIS, and hopefully VIIRS data from NPP and NPOESS. Two of these have existing production systems: AVHRR and MODIS. The MODIS data set is the reference data set, since it's reached the validated stage. VIIRS, under NPP/NPOESS, is still under development. AVHRR data will include Pathfinder AVHRR Land (PAL) produced and distributed by the GSFC DAAC, NOAA (GVI), and various others, including GIMMS. The differences in these products are due to different processing approaches, and the most widely-used is the PAL data set. However, it uses a suboptimal radiometric degradation assumption, and includes only partial atmospheric correction. The MODIS Terra and Aqua data will include L1 produced and distributed by the GSFC DAAC, and Land L2 and higher products generated in MODAPS and distributed from the ECS DAACs. Products created in this system are validated to stage 2 and have published accuracies.

They propose to have consistent processing of AVHRR data starting with GAV L1B, paying attention to certain products. For MODIS they will use coarse resolution surface reflection data from 2000 to present, and process those into the same format/resolution as AVHRR data.

The AVHRR data set offers longest record, but lacks onboard calibration. Its limited set of spectral bands reduces the accuracy of atmospheric parameters retrieval and correction (water vapor and aerosols), and the broad spectral bands lead to contamination by the atmosphere. Orbital drift leads to substantial variation in the solar geometry throughout the mission. But regardless of these shortcomings, these data have been used in significant scientific studies. They question how valid these observations are, and whether they justify the scientific conclusions. In order to answer these questions, they want to survey the literature and see what accuracies users are assuming, then compare that to the theoretical accuracy they expect knowing the specific shortcomings.

In order to generate improved AVHRR products, the goal is to make the AVHRR data set temporally consistent with MODIS by using reliable and consistent calibration across the different NOAA platforms, apply MODIS algorithms to AVHRR where possible (e.g., the MODIS aerosol retrieval and atmospheric correction approach), use BRDF correction to address differences in the solar and viewing geometry, and to make coincident the AVHRR/MODIS data to evaluate and improve the AVHRR products and quantify their accuracy.

The project is in its very early stages and is working on first-year activities. They've acquired the needed input data (AVHRR L1B, MODIS coarse resolution surface reflectance) and ancillary data (NCEP surface pressure and water vapor, TOMS ozone), and have evaluated the existing data sets to identify areas where improvement is critical. They've adapted the Vermote/Kaufman AVHRR vicarious calibration approach for AVHRR-3 and used it to calibrate NOAA-07 through NOAA-16. They've evaluated the vicarious calibration approach using coincident MODIS and NOAA-16 observations over invariant targets. They have presented their planned work and calibration to NOAA (Andy Heidinger's group), and provided them with their derived calibration for NOAA-07 through NOAA-16.

They've used coincident MODIS and AVHRR data to develop a split window water vapor retrieval technique for AVHRR, and have established a theoretical error budget for AVHRR and MODIS surface reflectance. They've studied the limitations of the surface temperature derived data from AVHRR, and held a Long Term Data Records session at the Fall AGU conferences to present the project and solicit community feedback. They developed a list of potential evaluators for their beta data set, and have presented their project activities at the ESIPS Federation Meetings, as well as participated in the SEEDS working groups (software reuse, metrics, and standards).

To make AVHRR data set improvements, they're focusing on radiometric VIS/NIR calibration and atmospheric correction. They will use consistent AVHRR calibration across platforms. Their approached to validate N16 calibration with MODIS is to:

- Select a stable calibration site,
- Characterize the reflectance spectral variation using the MODIS narrow bands,
- Use 2 years of data to characterize the site BRDF using the simple linear kernel model used in the MODIS BRDF product.

(See slides for details of comparisons and error budgets)

For production and distribution, they will use a MODAPS-like environment so that they benefit from the MODIS production experiences. Data products will be kept online and accessible by ftp and web, and intermediate data sets will be available for evaluators, rather than waiting until the products achieve provisional/validated status. They will transition the data sets to the DAAC later in the project when the datasets are validated. Quality assessment will build on the MODIS Land QA approach.

For community outreach, they will request user's input through the project website. Workshops/sessions will be held throughout the project to refine requirements and provide feedback on products (the first was held at the AGU meeting last year). They will publish the team's evaluation of existing and intermediate datasets on the web and request input and comments from users, and will participate in scientific conferences and peer-reviewed publications.

In summary, the creation of a long-term Land Surface Data Record with documented and comparable accuracies across instruments is feasible. The long-term trend observed with precursor AVHRR datasets needs to be verified. A beta version of the AVHRR dataset will become available for evaluation in June 2005. The user-community is involved in the definition and approach of the data sets (Pathfinder approach), and they will do incremental releases of the products (Beta → Provisional → Validated) as they are generated (MODIS approach).

Progress/Status of the Ocean Color Data Sets

Chuck McClain, MODIS Ocean Science Team Leader

Chuck McClain presented on the progress/status of the Ocean Color data sets.

The team is making progress on putting together an Ocean Color (OC) time series. Tracking OC changes over time will show us how the ecosystems adjust to atmospheric changes, climate changes, and all those things that affect phytoplankton growth. The team expects changes in inter-annual timescales, productivity, and ecosystem structures. The results probably show those changes now, but documenting them can be difficult.

The NA Carbon Program is one very important project coming up now, and is very important to the team. There is work to do to improve products for this kind of carbon assessment. Another important project is the Southern Ocean Carbon Program. This is important because the Southern Ocean is a kind of a wildcard. The team is going to keep a close eye on that, and spin up research there if possible.

There are a number of data requirements for CDRs:

- Long-term continuous time series
    - Must span interannual and short-term natural variability (e.g., ENSO)
    - Necessarily requires data from multiple missions (e.g., CZCS to NPOESS)
    - Must include most recent data, e.g., NPP/VIIRS
        - Continuous ocean color time series starts in 1996 with ADEOS-I/OCTS
    - Must minimize data gaps to avoid aliasing of natural climate oscillations (e.g., ENSO)
- Highest possible quality (satellite & in situ)
    - Must not include significant sensor artifacts and trends
        - Decadal scale variability and climate trends are small and can be easily confused with sensor drift
        - Ocean color products are particularly sensitive to sensor characterization/calibration errors (e.g., 1% error in calibration produces about a 10% error in water-leaving radiance)
    - Must be validated with ample highly accurate field data
    - Requires reprocessings (e.g., SeaWiFS has been reprocessed 5 times in 7.5 years)
- Consistency between satellite data sets
    - Must be cross-calibrated and processed using similar algorithms, i.e., no abrupt transitions between data sets
    - Requires periodic reprocessings to improve products & maintain consistency

For the long-term continuous time series, seasonal cycles must be gotten past. This is a bit of a challenge, since a continuous data record only started in 1996. Regardless, this can be valuable if the data are gotten to the right quality. The highest possible quality in situ and satellite data are also necessary. It takes a lot of effort to get a statistically significant dataset.

Accuracy requirements were defined back in the late 80s. Bontempi initiated activity to review and refine these, and the community under Bontempi's leadership is reconstituting the derived product data set and deciding what the CDR requirements should be.

OC probably has the strongest accuracy requirements, since a minimum 90% of the OC signal is from the atmosphere. Any error in estimating atmospheric components or sensor characterization/calibration has a big impact on products. It's been a struggle to get the errors low enough to have a fair amount of confidence in the products. OC is sensitive to artifacts at the tenth of a percent level, and that is a very hard requirement to meet. Because of this, they picked satellite data to work with that the team has the most confidence in and access to (MODIS Terra and MERIS not included). The main ambition to achieve consistency through a time series, and then more data can be added as necessary.

There are a number of infrastructure requirements for CDR development. The team is thinking about the things they need to institute to make our goals happen:

- Protocols for laboratory & in situ observations
- Advanced instrumentation development & ongoing instrument performance evaluations
- Calibration and data analyses round robins
- In situ data archive and standardized QC procedures
- Algorithm development (atmospheric & bio-optical)
- On-orbit calibration capabilities
    - On-board methods (e.g., lunar data)
    - Vicarious methods (e.g., MOBY)
- Multi-mission reprocessing capability

The Ocean Color team has been setting protocols since the early 90s, and lots of effort has gone into improving instrumentation and accuracy. Calibration is done by facilities around the world, and the team is cross-calibrating them to maintain consistency. The team started SEABASS (an in situ data archive), and is developing QA procedures as well as algorithms. Data sets are constantly reprocessed: SeaWiFS has been reprocessed five times in 7.5 years. The algorithms continue to improve, but the data also have to be reprocessed just to incorporate the most recent/best calibration. This will always be an issue. On-orbit calibration capabilities have developed and improved; there wasn't much of a plan with CZCS, so the team went into MODIS and SeaWiFS with a robust set of methods. The Ocean Color team also does multi-mission reprocessing.

MOBY was used to adjust prelaunch calibration gains for the visible bands using satellite-buoy comparisons. It was a huge logistical effort to calibrate and refurbish these buoys.

The team has done SeaWiFS & SIMBIOS calibration round robins, with the goals of verifying that all labs are on the same radiometric scale, documenting calibration protocols, encouraging the use of standardized calibration protocols, and identifying where the protocols need to be improved. This is done on a fairly routine basis. The team has developed various field measurement technologies including in-water & above-water radiometers.

The calibration strategy for SeaWiFS is analogous to what is used for MODIS Aqua. The SeaWiFS lunar calibration stability tracking gives corrections on instrument sensitivity, and the MOBY-based vicarious Band 1 gain factors show that comparisons are fairly uniform over time with solar and sensor zenith angle. This is a good thing.

The team verifies the consistency of data records over time by overlaying each year's coverage into a global time series. Very little variation is seen in the bands; this is necessary to see climate change. Radiance changes very slightly globally. These efforts are doing reasonably well, but it takes lots of data to get these scatter plots. There is still some work to do with Aqua MODIS data, but efforts are also doing reasonably well there. When the two time series are compared with an overlap, some offsets are seen because the bands are slightly different, but overall efforts are doing well.

For boreal winter and summer results from a time series looking at productivity from 1997 – 2000, results show what you'd expect going from a time of low-productivity to high-productivity.

A SeaWiFS – CZCS comparison shows an overall decrease between the two periods of about 6%. Seventy percent of the change can be attributed to high latitudes, while productivity tended to increase at low latitudes. This is an example of the kind of work you can do when you have long enough time series. There are things that can be done to improve the CZCS time series though, and the team will do a reprocessing later this year.

For maintaining the Ocean Color CDRs, a number of data set reprocessings will be done:

- Historical Data Sets (REASoN-CAN, Watson Gregg, PI)
    - OCTS: Reprocessing scheduled for Spring 2005
    - CZCS: Reprocessing scheduled for CY 2005
- SeaWiFS: Reprocessing completed in March 2005 (4 km data @ 3700X)
- MODIS/Aqua: Reprocessing completed in March 2005 (1 km data @ 150X)

Atmospheric Data Sets

Paul Menzel, MODIS Atmospheres Science Team Member, University of Wisconsin - Madison

Paul Menzel gave a presentation on achieving climate-quality data sets by using satellite observations of clouds as an example. Clouds are an important factor in climate system energy, since they act like Venetian blinds in the atmosphere. An accurate determination of global cloud cover has been the goal for a long time. There is a need for consistent long-term observation records to enable better characterization of weather and climate variability. However, clouds are tough to measure for a number of reasons, especially since cloud properties can vary by a factor of 1000 in a few hours.

The HIRS CO2 channels have been gathering data/observations since 1979. Their surprising finding is that 1/3 of the globe covered in high clouds; half of these high clouds are thin semi-transparent cirrus not detected by conventional infrared window and visible approaches. The HIRS cloud trends have been adjusted to accommodate (a) anomalous satellite data or gaps, (b) orbit drift, and (c) CO2 increase (constant CO2 concentration was assumed in analysis)..

A satellite-by-satellite analysis covering the period from 1978 to 1992 found that there is a gap in the 8am to 8pm time window, so only from 1985 onwards was used. Orbit drift was corrected using a linear extrapolation to 2 pm equator crossing times in a plot of satellite cloud detection as a function of equator crossing time. Adjusting for CO2 increase involved adjusting the atmospheric transmittance thus causing high cloud detection decrease by 2% in 1978. With these adjustments the trends over 16 years are been plotted (see slides for images). In El Nino years vs. non El Nino years, a shift of cloud cover east west in the equatorial region is seen, but there is no global change in total cloud cover.

Regarding detection of so many high clouds, comparisons were made with ISCCP GLAS data. ISCCP reports 7-15% fewer clouds than HIRS because it misses thin cirrus. HIRS and GLAS report nearly the same high cloud frequencies for one month, while HIRS reports more clouds over land than GLAS (probably because GLAS sees holes in low cumulus below the resolution of HIRS). GLAS finds more tropical clouds over oceans where HIRS reports <40%, and GLAS finds fewer clouds in the Polar Regions and western tropical Pacific. HIRS reports more high clouds in parts of the tropics and southern hemisphere, but areas of differences are scattered and not meteorologically organized.

Wylie et al (2005) report that differences between the UW HIRS analysis and the ISCCP are primarily because:

- ISCCP uses visible reflectance measurements with the infrared window thermal radiance measurements, which limits transmissive cirrus detection to only day light data; and
- The UW HIRS analysis uses only long wave infrared data from 11 to 15 µm, which is more sensitive to transmissive cirrus clouds, but is relatively insensitive to low level marine stratus clouds

Campbell and VonderHaar find that ISCCP may be showing fewer clouds as satellite coverage (and hence more nadir viewing coverage) increases in later years.

Overall, MODIS gives better resolutions, and sees more high- and mid-clouds than HIRS. This is what was hoped for; as more data is better. The ISCCP and HIRS climatology will be continued with MODIS once some of the instrument characteristics are taken care of. Spectral characterization remains a challenge; AIRS is indicating that the MODIS CO2 sensitive bands are likely spectrally shifted by 0.5 to 1.0 cm-1 from the reported values.

Climate data sets are very challenging. They require:

- Spectral consistency (if not possible, at least spectral knowledge)
- Accurate radiative transfer (accommodating seasonal and interannual CO2 changes)
- Orbit constancy (maintain equator crossing times for leos)
- Consistency with the Global Observing System (using NWP data assimilation)
- Reprocessing opportunities (adjusting algorithms with experience)

Overall, given the resources available Menzel felt that these challenges have been met reasonably well.

Climate Quality Data Records – Policy, Programmatic Thrusts, etc.

Lucia Tsaoussi, Deputy Director Research & Analysis Program, Earth-Sun System Division, NASA Headquarters

Lucia Tsaoussi presented on the programmatic considerations of Earth System Data Records (ESDRs)

It is important to give the Earth Science community the opportunities to do this work. The Science Mission Directorate was asked to put together plan to develop a CDR program. A review was held last July to discuss the current framework. Note: this doesn't represent HQ opinions, just discussions they have had.

An ESDR is defined as a unified and coherent set of observations of a parameter of the Earth system, which is optimized to meet specific requirements in addressing Earth science questions and/or provide for science applications. In principle, ESDRs will extent the value of NASA’s existing Data Products. The primary motivation for this plan is the need to develop and generate a unified and coherent data record for a given Earth System parameter by properly merging multi-sensor and multi-platform satellite observations. These data sets are critical to understanding Earth System processes, assessing variability, long-term trends and change in the Earth System and provide input and validation means to modeling efforts.

The framework of the July 22, 2004, review for ESDRs was to develop a plan that would describe ESE actions toward:

- The development of Earth System Data Records (ESDRs), including Climate Data Records (CDRs) within the context of the ESE Research Plan.
- The evolving and systematic generation and distribution of ESDRs and CDRs by leveraging ESE resources and assets.
- The plan development process, which will engage the NASA and external science and technology communities and seek final review from the NAS.

There are a number of ESE Strategy/planning documents: Center Implementation, ESE Strategy, Research, Data/Information Management, Technology, Education, and Applications.

The ESE Research Plan provides the motivation for ESDRs and justification for their development and use. There is clear connection with the Research implementation plan and this plan in

- deriving detailed requirements for answering science questions;
- identifying scientific challenges; and
- providing the means for ESDR evaluation.

Overall, this plan is consistent with the ESE mission articulated in the ESE strategy and describes the ESDR development to achieve the ESE goals.

The Data and Information Management Plan relates to the DIMP in describing the evolution of the ESE data system components to systematically develop and make available to the ESE user communities ESDRs. At least two aspects are key issues: the retrospective ESDR development by re-processing of the current data products, and the continual extension of these data products with newly acquired data.

The Technology Plan addresses developments driven by requirements to facilitate and improve the ESDR management and distribution.

The Applications Plan will describe the requirements for potential NASA ESDR development for requirements driven by decision support tools.

The Science (ESDR) plan will:

- Identify key variables in connection with ESE research science questions:
    - Provide rationale for each ESDR, explain science pay-off and impact in the context of Science Focus Areas
    - Provide priorities for ESDRs in the context of Focus Areas and science questions
    - Identify high priority derived products for each recommended ESDR
- Define requirements for each selected ESDR and describe attributes in context of the proposed science rationale. Examples are:
    - Climate Data Records to establish climate trends (e.g. sea surface temperature)
    - Understanding Earth System processes (e.g. Sea surface height)
    - Mandatory monitoring (e.g. ozone)

    - Establish Earth System baseline (e.g. reference frames)
    - Enhance predictive capability, model input/output (e.g. re-analyses)
- Identify challenges in the development and production of each selected ESDR and describe effort required.

The goal of the near-term plan is to develop and produce systematically the NASA-unique core ESDRs. These selected ESDRs will merge previously acquired data with present and new planned data.

The goal of the long-term plan is to develop observing system requirements. These requirements will be viewed at the higher level as observing system architecture, but should also be addressed as part of the Research Implementation Plan and Technology Plan.

This plan should outline implementation steps to accomplish the near-term goals for ESDRs within the existing ESE resources, particularly describing the systematic production and distribution of past and present NASA data, while bringing-in the planned new observations.

The ESE program components to be leveraged are:

- EOSDIS – should consider ESDR plans in its evolution as appropriate
- NPP SDS – and its evolution to Measurement data systems
- Multiple goal programs, with shared management: REASoN
- New program targeting ESDRs? TBD

Given that ESE management structure is undergoing significant changes such that the present roles of ESE Divisions will be modified, the principles below describe necessary functions:

- Identify all program elements required to accomplish the ESDR goals:
    - Research and development
    - Data production
    - Management and Distribution
- Assign lead organization to program elements as appropriate.
- Identify budget and authorize program elements for implementation
- Define and implement coordination and shared management mechanism among program components

On the premise that NASA core ESDRs are products of NASA-acquired data, other data needed for their development and systematic production must be identified. Based on NASA research requirements, extension ESDRs which include non-NASA data must be considered. Top priority extension ESDRs and CDRs must be identified, as well as providing a rationale for their development (e.g. synthesis and assessments reports). Fostering and establishing partnerships, national and international, for jointly funded efforts and identify co-funding mechanisms for joint ESDRs and CDRs is also critical.

The planning and development process includes road-mapping groups establish top priorities for NASA core ESDRs, holding community workshops by appropriate discipline programs to develop research requirements for these ESDRs, seeking evaluation/comments on the science plan from advisory groups, having the management team develop an implementation plan across ESE program elements.

Current Agency Planning Activities include strategic roadmaps, capabilities roadmaps, and an NRC Decadal Survey. ESDR Planning Requirements include science focus areas roadmaps, developing the EOSDIS Evolution team, and making technology investments.

The interagency context includes GEOSS framework and implementation plans (for CCSP, IOOS, etc.).

Earth Science Research fundamental science questions are:

- How is the Earth changing and what are the consequences of life on Earth?
- How is the global Earth system changing?
- What are the primary forcings of the Earth system?
- How does the Earth system respond to natural and human-induced changes?
- What are the consequences of changes in the Earth system for human civilization?
- How well can we predict future changes in the Earth system?

There is a need for a decadal survey within Earth Science research. NASA wrote a letter of request on October 29, 2003 to the SSB, saying:

> "In light of this progress, and of our recent success in securing continuity of essential EOS measurements through follow-on missions and transitions to operational satellite systems, it is time for the Earth system science community to look afresh into the future and help NASA plot its course ahead. I request that the Space Studies Board take the lead in orchestrating a decadal survey by the community to generate research and observation priorities… The resulting study will be most useful if it conveys the Earth system science community's priorities for questions and measurements."

Other questions asked in the letter of request include:

- What are the significant advances in Earth system science over the past decade?
- What are the principal science questions that remain to be answered?
- What measurements are most critical to answering those questions?
- What types of next generation observing capabilities and orbital vantage points will best enable progress?

A July 7, 2004 letter asks, "What opportunities are afforded by the Exploration Vision and NASA Transformation?" These are all questions that need to be answered. This will be done by a number of panels:

- Earth Science Applications & Societal Objectives
- Terrestrial, Coastal & Marine Ecosystems & Biodiversity
- Weather
- Climate Variability & Change
- Water Resources & the Global Hydrologic Cycle
- Human Health & Security
- Solid Earth Dynamics, Natural Hazards, and Resources

Some disciplines are not visible in the title of a given panel, but will have a roll in several panels.

The first committee meeting was held in November of 2004. Town-hall meetings were held with the AGU/AMS in December of 2004 and January of 2005. An interim report will be due in June 2005, as will be the initial input from several panels. Final inputs will be due November of 2005, and special sections to discuss the draft report will be held AGU/AMS meetings in December 2005 and January 2006. The final report will be published in June of 2006.

GEOSS is the Global Earth Observation System of Systems. Further, it is an international comprehensive, coordinated, and sustained Earth observation system with comprehensive, coordinated, and sustained coverage. Further, the "A-Train" is helping us to move toward the future of integrated earth observation with six satellites: Aura, PARASOL, CALIPSO, CloudSat, Aqua, and OCO.

The data system has evolved such that NASA has an irreplaceable data set created by the Earth Science Enterprise over the last 15 years. Continuing analysis of this data set is consonant with the three Presidential initiatives:

1. Climate Change Research Initiative,
2. Global Earth Observation, and
3. Vision for Space Exploration.

NASA systems will evolve and support integrated, open, and easy access to the data for the purpose of supporting NASA research and shared decision support systems across other federal and state agencies. NASA is moving from selecting missions-oriented systems to measurements availability to support its research programs and focus areas, and it is planning to evolve its EOSDIS over the next several years, and will continue to procure new data systems assets, e.g. REASoNs, to support Earth-Sun research and science applications. Near-term actions for NASA involving the research community are to:

- Review initial REASoNs in FY05
- Review EOSDIS data products
- Solicit for additional REASoNs in FY06 via ROSES

For ESDR implementations/options management, it is proposed that NASA implement an ESDR R&A program and use CAN and/or NRA solicitations specific to prototyping and developing and/or delivering NASA ESDRs. It is possible that the follow-on to the REASoN program can be targeted to ESDRs. Benefits to this approach include:

- Allowing for the widest possible community input in ESDR selection, development, and evaluation. In addition, participation of the research and modeling communities may be promoted.
- Fostering competition and peer review in relevant science and technology development, while allowing for community teaming.
- Enabling research required to answer requirements and/or quality questions surrounding proposed ESDRs.

The directorate is inviting input in the following areas:

- Establishing high priority science products, including ESDRs, and articulate their purpose,
- Identifying scientific challenges for their development and implementation, and
- Participating in any of the planning efforts, collectively and individually.

MISR/MODIS etc. Data Analyses

David Diner, MISR Principle Investigator, NASA Jet Propulsion Laboratory

David Diner presented on MISR/MODIS Data Intercomparisons.

For MISR calibration, a comprehensive review of data sources (vicarious calibrations and validations over desert playas and dark water sites, AirMISR, and MISR lunar images) in 2003-2004 led to the downward revision of the MISR radiances by 3% in the red and 2% in the NIR. MISR puts a lot of care into its calibration. The result is that aerosol optical depths have decreased slightly. New dust models led to a further downward revision of optical depths. Radiometrically, MISR sees a 3-4% bias with MODIS (MISR radiances are higher), though all MISR calibration systems are internally consistent. This difference is seen in MISR and MODIS data covering a wide dynamic range over the Arctic. Near the terminator, it is possible that spectral differences are a factor in some of the larger differences observed, but there are also differences over land compared to over water in the MISR/MODIS ratio. The team is working with MODIS Calibration people to understand these differences.

For Aerosols and Cirrus, there is MISR/MODIS standard product complementarity: MODIS brings broad spectral coverage (which enhances sensitivity to size, particularly coarse mode), where MISR provides multiangle data that is sensitive to shape.

MISR can perform multiangle tests of cloud homogeneity for cloud structure, heights, and detection, and found that cloud morphology, along with cloud microphysics, plays a major role in determining TOA bidirectional reflectance, with implications for the use of 1-D radiative transfer theory for cloud remote sensing.

MISR's Cloud Top Heights algorithm is unique it retrieves a purely geometric height. The significance is that it is completely independent of radiometric calibration, atmospheric temperature profiles, and cloud emissivity. It gets a very good measure of the first optically thick layer. In many instances, MODIS picks up high clouds, while MISR sees first optically thick surface. This is very useful for multi-layer cloud systems.

MISR also has unique angular methods that can help differentiate clouds from snow and ice in Polar Regions. MODIS alone is 86% accurate; the combination of MISR stereo and angular signatures is 92% accurate; and MISR + MODIS is 95-97% accurate. MISR stereo can also be used on aerosol plume heights. This is another area where MODIS/MISR fusion is good – wildfire studies – since MODIS thermal data pinpoints the fires and MISR retrieves smoke injection heights. For vegetation, retrieved surface direction reflectance data are validated against ground data, and are sensitive to vegetation structure. This too shows a very good complement between MODIS/MISR for land surface studies.

Simultaneous broad spectral coverage from MODIS and wide angular coverage from MISR makes a uniquely valuable combination:

- Having independent retrievals of related parameters from each sensor using different methodologies is a key element of a robust observing system.
- Data fusion capitalizes on complementary sensitivities to aerosol, cloud, and surface properties.

MISR/MODIS data fusion is currently being done in research mode. Products using joint retrievals can be considered (Aerosols, Polar clouds, Fires, Land surface). Some of these were described in the Terra extension proposal (Senior Review). A joint data analysis tool development would also be a great benefit to the scientific community.

CERES/MODIS/MISR Data Analyses

Norman Loeb, Research Professor, Hampton University/NASA LaRC

Norman Loeb presented on CERES/MODIS/MISR data analyses.

From the beginning, CERES has been interested in the radiation budget, and has recognized the need for combining measurements from multiple sources such as CERES, MODIS and geostationary instruments. CERES merges data from 11 instruments on seven spacecraft. The merged data have been used to develop new improved shortwave (SW) and longwave (LW) angular distribution models (ADMs) for radiance to flux conversion, detailed radiative transfer model-based calculations of surface, within-atmosphere and top-of-atmosphere (TOA) radiative fluxes, and time and space averages of CERES radiative fluxes.

One example of a merged data product provided by CERES is the Single Scanner Footprint (SSF) product. The SSF merges coincident CERES radiances and fluxes with imager-based cloud and aerosol properties. It uses VIRS (TRMM) or MODIS (Terra or Aqua) data to determine a number of parameters in up to 2 cloud layers over every CERES FOV and includes MOD04 and NOAA-NESDIS aerosol products. Meteorological information from the GEOS-4 data assimilation system is also provided in the SSF product.

Loeb provided three examples of how data fusion from CERES, MODIS, and MISR are being used to tackle science problems. He provided an overview of the development and validation of CERES Terra SW and LW ADMs illustrating how multiangle CERES measurements combined with scene identification from MODIS are used to characterize the anisotropy of Earth scenes. Loeb compared SW TOA fluxes inferred at large viewing zenith angles with those at nadir from the same scene to estimate instantaneous TOA flux uncertainties. Overall, the consistency between oblique and nadir-view SW TOA fluxes is 4% ($\approx$12 W m^{-2}) over both ocean and land/desert. Loeb summarized plans to extend the multiangle TOA flux comparisons by creating a merged CERES, MODIS, and MISR dataset that will utilize nine MISR angles for every CERES footprint instead of two angles. The TOA flux errors will be analyzed as a function of cloud type, degree of anisotropy and inhomogeneity.

Loeb also showed how merged CERES and MODIS data are being used to quantify the global direct radiative effect of aerosols. Over ocean, aerosols radiatively cool the Earth by 5.5 W m^{-2}. However, there is a 2 W m^{-2} uncertainty in this value due to uncertainties in our ability to discriminate clear and cloudy regions, especially in areas where aerosol optical depths are large (e.g., dust regions, biomass burning).

Loeb also showed some preliminary results of estimates of the direct effect of aerosols over land based on CERES SW TOA fluxes and MODIS land albedos. Early comparisons with independent estimates from Aeronet retrievals show good agreement. Loeb pointed out that estimates of the direct effect of aerosols over bright surfaces are highly uncertain due to uncertainties in atmospheric correction, especially in areas affected by heavy dust aerosol.

Loeb also illustrated how combined CERES and MISR data can be useful for examining cloud and aerosol interactions. The SSF product provides cloud and aerosol retrievals in addition to broadband radiative fluxes. He showed examples of correlations between SW TOA flux, cloud fraction and aerosol optical depth anomalies in regions of dust, smoke and marine conditions.

Finally, Loeb pointed out that much more can be done with merged CERES, MODIS and MISR measurements. The instruments are highly complementary providing broadband, spectral and multiangle information from one spacecraft. Such capabilities can be used to improve our ability to infer aerosol and surface properties, cloud-radiation interactions, both globally and regionally (e.g., Polar Regions), and cloud radiative forcing at both coarse and high spatial resolution.

AIRS/MODIS Data Analyses

Mitch Goldberg , Chief, Satellite Meteorology and Climatology Division, Office of Research and Applications, NOAA/NESDIS

Mitch Goldberg presented on integrating MODIS with AIRS to improve AIRS radiance and retrieval products.

The goal of integrating products is to provide better information and understanding, which in turn empowers the public, private sector, and government with informed decision making. A good example of this is with the December 2004 Southeast Asian tsunami - money and lives could have been saved if scientists better understood how they happen. They are working with GEOSS, which recognizes that there is a growing global system of systems which needs coordination to 1) establish standards/protocols for quality, data formats, and data exchange; 2) avoid redundancy; and 3) determine future requirements. This will benefit nine societal areas: Natural & Human Induced Disasters; Water Resources; Terrestrial, Coastal & Marine Ecosystems; Human Health & Well-Being; Energy Resources; Sustainable Agriculture & Desertification; Weather Information, Forecasting, & Warning; Climate Variability & Change; and Biodiversity.

NOAA's objectives and goals are to cooperate and collaborate in building an integrated global earth observation system; expand earth observation science, monitoring technology and applications; perform collaborative data exchange; and create integrated processing systems.

There are three attributes of an Integrated Global Observing System:

- Comprehensive:
    - Consists of physical, chemical, biological systems
    - Encompasses in situ, mobile, airborne and satellite observations
    - Includes broad range of spatial and temporal scales (global to local and years to minutes)
- Sustained:
    - Consists of future, current, and predecessor systems
    - Includes sustained R&D program feeding into evolving long-term operational program, and
- Integrated:
    - Multiple platforms orchestrated to serving one or more missions (need multiple platforms as well as single platforms for multiple missions).

The benefits of this are that efforts will be more efficient, effective, and can ensure sustainability.

Today environmental products are mostly generated from observations that are independent of one another. In the immediate future, NOAA will formulate and integrate environmental products using GOES-R series, NPOESS series, and MetOp satellites along with other structured data sources. But by 2020, products should be formulated and produced in one integrated system.

There are three steps in building an integrated system:

- Integrated Sensors: Initially they need to simplify the complexity of building products between instruments on one platform
- Integrated Calibration: Then they need to evaluate the calibration between multiple satellites at different orbits
- Integrated Satellites: Finally they can utilize these cross-calibrated, collocated data sets to build enhanced products

The AMSU-AIRS processing system is integrated by design. It provides a sounding for every field of view, provides retrievals in overcast conditions, and drives cloud-clearing. These products have about a 50km footprint, and there are about 324,000 footprints per day. The products are:

- Cloud Cleared Radiance
- Temperature

- Moisture
- Ozone
- Land/Sea Surface Temperature
- Surface Spectral Emissivity
- Surface Reflectivity
- Cloud Top Pressure
- Cloud Liquid Water (AMSU product)
- Cloud Fraction (per 15 km footprint).
- Carbon Monoxide
- Carbon Dioxide
- Methane
- Cirrus Cloud Optical Depth and Particle Size

Goldberg gave an AIRS update. NESDIS has implemented the AIRS/AMSU processing system (it is quasi-operational). The processing system is based on retrieval methodologies developed by AIRS science team. The science algorithms were developed by NASA, NOAA, UW, MIT, and UMBC; this was truly a collaborative effort. Science improvements are continuing:

- Adding MODIS to improve the cloud clearing and soundings algorithm;
- Adding trace gas retrieval algorithms to derive CO2, CO, and CH4; and
- Improving surface emissivity/bidirectional reflectance (non-ocean)

AIRS & MODIS products are distributed through three main channels – NOAA/NESDIS, GSFC DAAC, and Direct Broadcast. The team has learned that the AIRS instrument is extremely accurate, and only 5 percent of the globe is clear at 14km fov. AIRS has resulted in positive impacts in NWP, but only the clear channels are assimilated, and larger impacts are still expected. Cloud clearing increases the yield to 50-70%, and retrievals from cloud-cleared radiances are significantly more accurate than AMSU-only. They've also demonstrated 1 K/Km precision.

Challenge for AIRS NWP is to assimilate cloud-cleared radiances to improve the yield of observations in the lower troposphere. The challenges are that the NWP forecast accuracy is highly sensitive to accuracy of input data, and very accurate cloud-cleared radiances need to be provided. The strategy is then to use MODIS data to improve accuracy.

The theory of cloud-clearing is to try to derive clear scenes from a combination of semi-contaminated footprints. MODIS in addition to AMSU will improve cloud clearing. MODIS 1 km resolution data can be used to find clear holes, and clear MODIS channels can be compared with cloud-cleared AIRS data convolved to look like MODIS data, then spatially average the MODIS data to that. Very similar results are seen. MODIS data are currently being used to quality control AIRS cloud-cleared radiances. This results in about 1deg RMS AIRS data alone, but it is possible to get smaller sets when MODIS data are used alone or in combination. Retrieval errors are significantly reduced after MODIS is used to quality control AIRS cloud-cleared radiances.

The team is beginning to build integrated processing systems by focusing on Aqua. The team plans to experiment from sensors from the A-Train, and will be adapting our AIRS/AMSU/MODIS processing system to generate operational products from IASI/AMSU/AVHRR in 2006 and CrIS/STMS/VIIRS in 2008. The same science (e.g., the same transmittance model, etc.) and software will process AIRS, IASI, and CrIS.

ASTER/MODIS Data Analyses

Simon Hook, MODIS Calibration Science Team Member, NASA Jet Propulsion Laboratory

Simon Hook presented on the synergistic use of datasets from multiple instruments for Earth Science research.

ASTER is the zoom lens for the Terra platform. This talk covers hazards, ecology, hydrology, critical factors limiting use of multi-instrument data, and ways to increase multi-instrument studies.

Hazards – Mapping Volcanic Plumes
The objectives of plume mapping are to track changes in SO_2 emission rates, and study the fate of SO_2 in the atmosphere. The team thinks that there are changes in SO_2 emission rates prior to volcano eruptions, and want to track that. This work focuses on mapping passive SO2 emissions from space. The different instruments have different advantages/disadvantages depending on spatial/spectral resolution and revisit time. Only ASTER could detect the small Pu'u O'o plume on 30 Oct 2001. AIRS/MODIS/ASTER detected a plume from the Mt. Etna eruption 28 on Oct 2002. However, the superb spectral resolution of AIRS gave more detail about what is happening with the plume. (See slides for images and charts of these detections.) Comparisons of the Etna plume detected by AIRS and MODIS illustrate the effect of spatial and spectral resolution problem; however, the final amount of SO2 retrieved is similar. The detection algorithm seems to be working well for this data set. Future work will focus on days with Terra and Aqua overpasses (e.g., 27 October 2002), will begin ASTER processing from 30 December 2002, incorporate MISR-based plume geometry, perform a MODTRAN update, and incorporate AIRS-based atmospheric profiles.

Hazards – Validation of MODIS Fire Product
ASTER data are being used to validate the MODIS active fire product. The key benefits and disadvantages of using ASTER are:

- ASTER can be used for detecting active fires that are much smaller than the lower MODIS detection limit.
- ASTER and MODIS fly on the same platform (perfect temporal coincidence).
- But ASTER has limited angular range, tends to saturate (partly addressed with multiple gain settings) and limited availability.

Hydrology – Nutrient Transport In Lakes
ASTER, MODIS and Landsat data are also used for measuring nutrient transport in lakes. For Lake Tahoe in particular, a decline is seen in clarity depth and algal growth rates. MODIS/ASTER/Landsat data can be used to see how nutrients are transported around the lake. Lake Tahoe was used as a validation site because it is very homogeneous in temperature with a mostly regular annual cycle. Observations show spikes that are upwellings of colder water; these can be quite dramatic. Lake-wide, temperature information can be obtained from ASTER and MODIS data. MODIS data show the upwelling despite a resolution difference, which attests to the quality of MODIS data. Combining ASTER and Landsat ETM+ data can show more detail about water/plume movement.

Generic critical factors limiting use of multi-instrument data
Some of the critical factors limiting the use of multi-instrument data are:

- Interoperability /protocols/standards
- Information assurance and security
- Hardware/software
- Infrastructure/bandwidth

- Human and institutional capacity

Specific critical factors are:

- Geospatial data are available but cannot be accessed geospatially – data need to be subsetted down to the pixel-level when the data are ordered.
- Every pixel needs a latitude and longitude – No subset lattices or corner points. Double precision should be used.
- Data are stored in multiple projections – a default, common projection is necessary.
- Data ordering should not require a human in the loop – a SIMPLE subscription service needs to be implemented.
- Software lacks scripting – toolkits with scripting support, e.g. Python and PIL, need to be developed.
- Open access – Users should be allowed to FTP small subsets for free, e.g. the USGS NED approach.

In the end, leadership from the top with input from the bottom is necessary, as is a clearly articulated vision for where they want to go and why. A system that can be used by the individual without requiring a large institutional infrastructure, as well as clear milestones with tangible results (roadmaps, data fusion working group?), is necessary.

Editorial Note:

No minutes were taken at the Land or Oceans breakout sessions. Conclusions from those presentations is presented in the Group Summaries starting on page 61 of this document. Copies of all presentations made during the plenary and breakout sessions are available on the MODIS website (http://modis.gsfc.nasa.gov/) under the Science Team heading, Meetings subhead.

First Atmospheres Breakout Session (Afternoon Day Two)

Recent Developments in Radiance Calibration

Chris Moeller, CIMSS Research Associate, University of Wisconsin - Madison

Moeller discussed the most recent developments in radiance calibration for the Aqua and Terra MODIS instruments.

On the topic of a Deep Space Maneuver (DSM) RVS, Moeller said that it would be used for the thermal bands, with the biggest impact being in the long-wave infrared CO_2 bands (34-36). Cross-track asymmetry would be reduced, as well as mirror-side striping (with the exception of the B-side). The impact on the MWIR bands is small, as expected, as well as for the PVLWIR bands (save for band 29). The biggest effect there is for the atmospheric bands, and is small in the window bands. However, there are a number of lingering issues. The DSM RVS is the right way to go, but there are still things that need attention (e.g Mirror Side Correlated Noise).

Aqua AIRS-MODIS comparisons

For Aqua AIRS to MODIS comparisons, based on global days analyzed (uniform scenes only), the team is seeing a definite scene-dependence to the bias between AIRS and MODIS. The question is why? Is it a MODIS feature, or an AIRS feature? Work is progressing on this at the University of Wisconsin; they've found that if they try doing a spectral shift in the LWIR CO_2 bands, the scene dependence can effectively be eliminated. They're also looking at this in specific for the MOD06 and MOD07 L2 products. These corrections won't be going into Collection 5, however.

5um Leak Correction – Terra Aside 2

The Terra MODIS A-side 2 night time band 26 data reveal artifacts of thermal band features even after the 5 micron thermal leak correction has been applied in L1B. Aqua MODIS shows practically no features. This accounts for up to one percent (of the Ltyp) effect in Terra MODIS B26. As for the other Terra SWIR bands (5-7), the routine nighttime data required for inspection isn't available. This suggests that the daytime imagery has a residual of the 5 micron leak, and bears further review. This is also not going into Collection 5.

TIR (thermal) band Destriping Update

For this, a destriping technique that is being used in Collection 5 was applied. Results are showing artifacts in the granule-based destriping, but the artifacts are eliminated in the global daily-based destriping process. The Atmosphere Group Cloud products (MOD06, MOD07, MOD35) for Collection 5 include destriping of all emissive bands (20-25, 27-36) and band 26. The destriping algorithm is granule-based, and for a small percentage of granules, the impact may be equivocal in bands 31 and 32. Granules with sharp transitions between warm and cool scenes (such as between hot land to cool ocean) may have artifacts in the scene transition zone. The group analyzed a complete day of data (Terra MODIS 2000337, Collection 5) to develop the destriping LUT for bands 31 and 32, with the expectation that sampling a wider range of scenes would remove the artifacts. It did. See presentation for visuals.

Aqua MODIS Band-to-Band registration offset reminder
The team has been aware of the band-to-band registration offset in Aqua MODIS since before launch. The mis-registration causes unexpected results for effective particle radius retrievals when the NIR and SWIR bands are used together. Testing to remove the known band-to-band misregistration shows positive impact on results. This is especially noticeable in high-contrast areas (e.g. cloud edges). Terra MODIS doesn't show the same effect, and agrees with the prelaunch efforts.

Terra MODIS Band 26 Destriping and OOB correction
The team has changed the Terra SWIR leak correction formulation for Collection 5 so that it is now consistent with the formulation used for Aqua MODIS. There is a small influence on Terra B26 destriping coefficients. As a result, observations show slightly lower radiances in Collection 5 than Collection 4, on the order of tenths of a percent.

Earth Shine influence on RSB
Earth-shine is affecting the Solar Diffuser calibrations at varying levels, dependent on earth scene conditions during SD views. The phenomenon is spectrally dependent, showing a scattering effect of about 0.2 percent, and a specular effect of up to 2 percent. For Collection 5, a fitting function will be used within epochs to determine the m1 values for each band, which will reduce any earth shine influence down to < 0.2 percent in L1B. The MCST calibration team has been watching this closely, especially its effects on M1 data. Collection 4 is more susceptible to Earth Shine influence, and so that will be taken care of for Collection 5.

Summary:
The DSM RVS is in place for Terra MODIS. Across-track profiles and mirror-side striping has been improved. There are small influences on the SWIR bands from the 5um leak correction changes for Terra. There are some unresolved behaviors in A-side 2. The Earth-shine influence on the RSB has been well-handled in the Collection 5 epoch using fitting functions. There is probably some residual influence, though hopefully less than 0.2 percent. The interesting findings in AIRS-MODIS L1B comparisons continue under review.

Bulk Scattering Properties for the Remote Sensing of Ice Clouds

Bryan Baum, MODIS Atmosphere Science Team Member, SSEC, University of Wisconsin - Madison

Bulk ice scattering models incorporate the latest computation light scattering research, and in situ data from multiple field campaigns. This team is using it to develop a more comprehensive set of ice scattering models and similar models for a variety of imagers, interferometers, and other sensors. This will facilitate intercomparison of retrieved ice cloud properties from multiple sensors. There are lots of papers being published dealing with this.

On particle size distributions, the data start in 1986 and stretch to Crystal-face in 2002. Size sorting is more pronounced in the mid-latitude cirrus cloud characteristics, while small crystals are apparent at the cloud top, where pristine particles are more often found. Tropical cirrus anvil characteristics form in an environment having much higher vertical velocities, and size sorting is not as well pronounced. Large crystals are often present at the cloud top, and may approach a centimeter in size, though their habits tend to be more complex. In-situ data are looking really different from MODIS measurements.

As for ice particle habit distribution, at this point the team has an ice-particle scattering library, and a wealth of microphysical data for ice clouds. The next issue is to develop an ice particle habit distribution that makes sense (note: each idealized ice particle has a prescribed volume, and hence mass). If a single habit is assumed, the models show that there are differences in ice water content and median mass diameter.

The team tried to come up with percentages to narrow things down a bit, thus trying next to integrate over a spectral response function, and found that habit only seems to make a difference with the larger particle sizes. The delta transmission is included in the asymmetry factor.

A sensitivity study was next. The team has noted that crystal distributions tend to be the narrowest overall, and for all 41 CRYSTAL size distributions, there is an increase in the number of particles with a maximum diameter of greater than 20 microns by a factor of 100 or 1000. It isn't known how many small particles there are.

The team has also been working on the development of band models that they've using to build new LUTs for MODIS. They found four properties and made them internally consistent for a number of narrowband imagers. Several models are also available online (http://www.ssec.wisc.edu/~baum). The team wants to have consistent ice models so that they can come up with a good long-term record.

Algorithm Refinement and Validation of Cloud and Radiation Products Derived from MODIS and CERES Using Ground-Based and Aircraft Data

Jay Mace, MODIS Atmosphere Science Team Member, Department of Meteorology, University of Utah

Jay Mace presented on algorithm refinement and validation of cloud and radiation products derived from MODIS and CERES using ground-based and aircraft data.

They are 1) developing a relational database on the web for cloud property retrieval validation, 2) using the MODIS cloud mask in the CloudSat geometrical profile operational product, and 3) developing an algorithm suite for cirrus property retrievals with the A-Train data as well.

They recently published a paper detailing cloud property retrieval algorithm enhancement activities, including a case study evaluation, overpass matching, and statistical comparisons of cirrus clouds at the ARM SGP site. The overall results are very encouraging in terms of the skill with which MODIS and CERES can retrieve information over this challenging site.

To move beyond what they've done, they're now using the relational database approach for looking at thousands of passes of MODIS on Terra and Aqua over ARM ground sites so that validation of retrieved cloud properties can be conducted generally without regard to specific cloud type. They're also making the validation intercomparison process easier to foster science evaluations. Their approach here is to construct a relational database that brings together MODIS cloud products and ground-based cloud products with web access (http://www.met.utah.edu/cgi-bin/mace/cgalli/mysql/eos_avg_query.pl)

Currently in prototype status: Terra MOD06 IWP, effective radius, and optical depth retrievals of cirrus events from 2001 and 2002 (~300 events). The MOD06 results can be compared to the properties of cirrus retrieved using ground-based sensors such as the ARM MMCR. See the slides for illustrations of a case study.

On the CloudSat Geometrical Profile Product, the goal is to combine the spatial information provided by the MODIS Cloud Mask with the vertical profile information provided by the active sensors. Things to note: Some thin cirrus will be below the detection threshold of CloudSat. Some of these clouds may contribute to the upwelling radiation observed by MODIS. In other cases the MODIS radiance field may suggest a highly variable local cloud field. The approach is to use the MOD35 cloud mask bit tests to identify cloud types allowing them to identify spatial coherence consistent with CloudSat profile observations. The MOD35 cloudmask product will be used in 3x5 pixel arrays surrounding the CloudSat footprint.

Their use of MODIS data and products is very diverse and continuing to expand. They are developing a relational database on the web for cloud property retrieval validation and basic exploration of data sets. They are using the MODIS cloudmask in the CloudSat geometrical profile operational product, and developing an algorithm suite for cirrus property retrievals with A-Train data.

Continuity of cloud Detection with AVHRR, HIRS, MODIS, GLAS, and ISCIP

Andy Heidinger, Physical Scientist, NOAA/NESDIS Office of Research and Applications

Andy Heidinger presented on the continuity of cloud detection using the AVHRR, HIRS, MODIS, GLAS, and ISCIP instruments. The motivation is that NOAA/NESDIS ORA is reprocessing the entire AVHRR data record (1979 to 2005), and AVHRR should exist until 2012. They're improving the Level 1B data, making a new AVHRR SST product, GVI product, and will be working on polar winds climatology. PATMOS-x Cloud Climatology. With the IPO, they are working on continuity of AVHRR/VIIRS cloud climate records. MODSI provides an ideal test-bed for developing algorithms and processing strategies that allow for cross-platform continuity. The goal is to achieve physical consistency with a few selected cloud products that they feel can be consistent between AVHRR, MODIS, and VIIRS.

They're trying to get physical consistency between AVHRR and MODIS cloud properties, including cloud-top temperatures and emissivity (MOD06), and are working toward an objective cloud amount. There are a lot of issues beyond cloud detection in determining the cloud amount.

Outside polar regions, they can achieve consistency in other areas as well: cloud amounts, cloud optical thickness, cloud particle size, and cloud phase. They actively seek guidance from the MODIS Team to help make the AVHRR/MODIS cloud climate records continuous.

Because of ICESAT, there is a GLAS instrument in space, so it should be possible to get a good cloud presence measurement that way. GLAS is performing at its best, and MODIS and GLAS are in good agreement. For high clouds, there is agreement zonally between AVHRR and MODIS covering most zones.

MODIS appears to have colder clouds with lower emissivities, which is an expected consequence of the ability to do CO2 slicing as opposed to the more limited split-window approach used in the AVHRR. However, this does not appear to dramatically affect high-cloud amount comparisons. They will try to make L3 products that are comparable to MODIS.

For long-term trends in cloud amount (total cloud), comparisons show that HIRS and PATMOS-x show little trending compared to ISCCP-D2. Aqua shows a large difference between its daytime value and the daily averaged value; this will be reduced in V5. Some features in PATMOS-x are attributable to AVHRR differences (1.6 vs 3.75 micron channels). They're pretty happy with this record.

A comparison of the yearly variation in the mean July total cloud amount in the Tropics shows that Aqua and PATMOS-x agree in magnitude. ISCCP-D2 daily values suffer from poor night time performance. HIRS shows a slight positive trend, while PATMOS-x shows no trend, and ISCCP-D2 shows a very small negative trend.

They're also doing other cloud products. Aqua MODIS has well-validated cloud optical thickness, while AVHRR does not, but there is work that could be done there to get it in line with MODIS.

ORA is working to improve the quality of the AVHRR data record. They continue to try to achieve physical consistency for selected climate data records between MODIS and AVHRR, which would allow them to use MODIS to connect POES with NPOESS (VIIRS) climate records. The total cloud amount time series from UW/HIRS, ISCCP-D2, and PATMOS-x differ in magnitude and in the long-term trends. They suspect that MODIS V5 data will lie between UW/HIRS and PATMOS-x/ISCCP. MODIS high cloud amounts in the Tropics appear to be in rough agreement with the 24 years of AVHRR data. An analysis of the 2-D histograms of MODIS and AVHRR Cloud Temperature and Emissivities indicate that MODIS is tending to place optically thin clouds at colder temperatures, which is an expected outcome. This does not appear to hurt high cloud comparisons. Finally, they are seeking any involvement from MODIS team members who are interested in the AVHRR/MODIS/VIIRS continuity of cloud climate records. This includes all cloud parameters (optical depths, particle sizes, and cloud types).

Recent Upgrades to the Collection 5 MODIS Near-IR Water Vapor Algorithm and Cirrus Reflectance Algorithm

Bo-Cai Gao, MODIS Atmosphere Science Team Member, Naval Research Laboratory

Bo-Cai Gao presented on upgrades to the Collection 5 MODIS Near-IR Water Vapor and Cirrus Reflectance algorithms. Gao described the two algorithms for new team members, saying that MODIS has three water-vapor absorption channels near 0.94 micron, and two atmospheric window channels near 0.865 and 1.24 micron. The ratio of absorption channels to window channels allows the derivation of water vapor transmittance, and therefore the amount of water vapor in the atmosphere.

Clear true-color images (see slides) show a huge amount of water vapor in MOD05. Validation with MWR data shows good agreement; close to 1:1 in Collection 4. There is other validation work being done by researchers in China; they are measuring water over the Tibetan Plateau using GPS and radiosonde data. The MODIS Collection 4 near-IR water vapor values are about half of the GPS values during the summer season. There are errors related to the LOWTRAN 7 pressure-scaling scheme (incorrect commenting). These errors have been corrected, the code updated, and will be included in the Collection 5 code delivery as well as used in the forward processing stream.

Some other errors with the Collection 4 results include bad lines seen in L2 and L3 water vapor images. Gao worked with Hubanks and Hucek to identify the problem, which is that the QA parameters for the bad and partially missing lines in the L1B data were incorrectly assigned. This has been fixed in the QA routines for the Collection 5 near-IR water vapor algorithm.

There were a number of errors with the Collection 4 Cirrus Reflectance Algorithm that were corrected in Collection 5. Bad lines were seen in the Collection 4 L2 and L3 cirrus reflectance images; these lines were also due to incorrect QA parameter settings for bad or partially missing lines in the L1B data. The L1B reader in the Collection 4 code used a wrong coefficient when converting digital numbers to solar and view zenith angles. Both problems were fixed in the Collection 5 MOD06 CD code.

The user community is very interested in cirrus area fractions, and has raised a lot of questions. In reality, the MODIS near-IR cirrus fraction has inherent problems. The cross-talking problem with the MODIS 1.375 micron channel has never been fully understood, but Chris Moeller at the University of Wisconsin has been able to develop an empirical algorithm to correct for the cross-talking problem. Minor over- or under-corrections still occur over different geographical regions, though.

For the Collection 5 MOD06 CD code, the L2 pixels with cirrus reflectances of less than 0.5% will not be used to produce the L3 1x1 degree data products.

The team would like to encourage modelers to use the L3 cirrus reflectance product instead of cirrus fractions, because the residual cross-talking effect still affects cirrus fraction. Cloud amount does not have a simple and unique answer. Over the same area, Landsat, MODIS, and AIRS will all give very different cloud amounts. Spatial resolution, sensitivity of the channels, and various thresholds all affect the estimates of cloud fractions.

In summary, the global water vapor and cirrus reflectance products have been derived from MODIS channels in the near-IR spectral region. Errors found in the Collection 4 algorithms have been corrected, and the improved Collection 5 codes have been delivered to NASA Goddard. Code integration and testing have been made under the operation computing environment.

Study of Tropical Cirrus Clouds using MODIS data

Ping Yang, MODIS Atmosphere Science Team Member, Department of Atmospheric Sciences, Texas A&M University

Ping Yang presented on a study of tropical cirrus clouds using MODIS data, and started by noting the importance of cirrus detection. Cirrus is one of the most uncertain components in climate research because of its occurrence in high locations, its optically-thin nature, and the nonsphericity of its ice crystals. It may substantially regulate the long-wave radiative energy exchange in the vicinity of the tropopause, and total cirrus cover over the tropics is quite significant (e.g., Dessler and Yang, 2003). Cirrus clouds also significantly affect the water-vapor distribution near the upper troposphere and lower stratosphere, according to some previous studies (e.g., Jensen et al. 1996). The important roles that cirrus clouds have are microphysical and optical properties (optical thickness, ice crystal effective size, etc.).

Visible Cirrus Reflectance (method reported by Gao et al) uses a combination of visible channels and the 1.375 micron "cirrus detection" channel. It detects surface and atmospheric effects (the "virtual surface" is removed from reflectance data in the visible spectrum), and an isolated visible cirrus reflectance is derived for the visible spectrum (which can be used to retrieve tropical cirrus optical thickness data).

Yang described the makeup of the atmosphere, and how cirrus reflectance is derived on the basis of the algorithm reported in Gao et al. (2002). The algorithm uses visible spectrum and 1.375 micron channels to retrieve cirrus cloud reflectances from MODIS and aircraft data.

The ocean is pretty uniform, so reflectances have a uniform slope. This gives the transmittance of the water vapor above cirrus clouds. But over land, because of diverse surface reflection, only the pixels with uniform surface features are used in the derivation of the slope. Note that these pixels are on the left side on the scatter-plot of the 1.38-micron channel versus the 0.66-micron channel. Tropical Cirrus Retrieval is inferred from the visible cirrus reflectance. It follows a look-up table approach; uses the scattering properties of nonspherical ice crystals (averaged over nine size distributions from CEPEX); assumes that cirrus clouds are composed of 41.6 percent aggregates, 24.7 percent bullet rosettes, and 33.7 percent solid columns; and simulates the radiative transfer process using DISORT (Stamnes et al. 1988). The team applied this approach to L1B data, and results were published in a paper last year (Meyer, Yang, and Gao, 2004: IEEE-TGRS, 42, 833-841). MODIS L1B data (0.66 and 1.375 micron reflectance channels used for "virtual surface" removals and solar/satellite geometries) are used for optical thickness retrievals (only considering granules between +/- 30 degrees latitude).

Single-scattering properties are computed from the computational models developed by Yang and Liou (1995, 1996, and 1998) for individual ice crystal habits. For bulk optical properties of ice clouds, a database is input for DISORT calculations (a pre-computed single-scattering database for individual ice crystal habits averaged for various size distributions), and averaging is completed over 3 habits and 24 size bins, including 9 tropical size distributions. It uses 4,864 look-up tables (LUTs), one for each solar/satellite geometry. The visible cirrus reflectance is derived from L1-B 0.66 and 1.375 micron channel data using the 2002 method of Gao, et al. It matches the visible cirrus reflectance values with the corresponding optical thickness values.

An analysis of the topical L3 data – Aqua MODIS L3 daily data (MOD08_D3) – used the modified L1B algorithm for optical thickness retrieval. It considered only high clouds (cloud top pressure < 440 hPa), following the ISCCP definition, and includes the frequency of occurrence, average optical thickness, as well as seasonal and zonal averages. The analysis shows that the team's work is doing well.

HIRS is a high-resolution Infrared Radiation Sounder. The HIRS retrieval uses CO2 slicing method with channels from 13- to 15 microns covering 22 years (1979-2001), and includes only high-cloud frequencies (cloud top pressure <440 hPa). Compared to HIRS data, patterns show that HIRS and MODIS are quite similar. However, HIRS reports higher frequencies than the MODIS instrument does. Possible explanations could be that they have different retrieval methods (HIRS products are based on the IR channels, whereas MODIS cirrus products are based on the visible and near-IR channels), and the lower threshold for reflectance (0.01) on MODIS L2 cirrus reflectance values (which may exclude thin cirrus cloudy pixels during L3 averaging, resulting in an underestimation by MODIS).

There will be a paper covering the comparison between MODIS and HIRS cirrus retrieval:

Meyer, K., P. Yang, and B.-C. Gao, 2005: Tropical cirrus frequency and optical depth fields inferred from the MODIS level-3 data, IEEE Trans Geosci. And Remote Sensing (submitted).

In conclusion, tropical cirrus cloud optical thickness can be inferred from visible (0.66 micron) cirrus reflectance, though the sensitivity-to-habit percentage needs to be explored. Cirrus trends are established using Aqua data, and while Aqua MODIS cirrus coverage patterns compare well to HIRS, the frequency magnitudes differ. MOD06 cloud products agree with surface-based retrievals, according to a case-study based on CRYSTAL-FACE data.

Using MODIS and MISR Observations to Retrieve Cloud Phase and Ice Cloud Habit

Sally McFarlane, Postdoctoral Research Associate, Pacific Northwest National Laboratory

Sally McFarlane presented on efforts to use MODIS and MISR observations to retrieve cloud phase and ice cloud habit. These are fundamentally important to remote sensing and climate situations, and GCM studies show that they are significant in tropical clouds. Further, satellite-based and some ground-based retrievals depend heavily on habit assumptions.

The basic idea is to use MISR's nine cameras and multiple angles to determine phase functions. Retrieval combines multi-angle information from the MISR blue band with the MODIS 2.1 micron band for sensitivity to shape and size. They then retrieve the best-fit r_e, IWP, and crystal habit by minimizing the deviation between modeled and measured reflectance over all cameras. Ice cloud scattering properties (from Yang et al, 2000) assumes a gamma distribution with fixed effective variance and a given r_e. All MISR cameras plus the MODIS camera are all being weighed equally in the metric.

One case study of cirrus at SGP shows that the retrieved ice water path and effective radius depend on which habit you choose. Hollow columns tend to be the best fit to the MISR multi-angular reflectances but there are differences with the MODIS ice water path. A second study of altocumulus at SGP shows that water is clearly the best fit to the multi-angular reflectances. The MODIS cloud property retrieval also retrieved fairly small particle sizes in this cloud, although the IR phase retrieval indicated regions of water and mixed phase. This shows a need for sensitivity studies to determine the depth in clouds to which the retrieval is sensitive.

Current work includes beginning to be able to run operationally rather than in a case-study mode. They've created look-up tables of MISR/MODIS reflectances as a function of habit, water path, effective radius, cloud height, and solar and viewing geometries. For each retrieval, the reflectances are corrected for atmospheric transmittance and surface albedo. They are running retrievals on $(10\text{km})^2$ boxes, where MISR/MODIS reflectances and MODIS cloud properties are averaged over each box. The preliminary results for all MISR overpasses of the SGP site in 2001 show 32 cases with clouds and available MODIS and MISR data. They're beginning comparisons with MOD06 retrievals, and are trying to understand the differences.

An example of a thick cloud retrieval shows that water areas tend to line up pretty well with MODIS Cloud Phase and Final Retrieved Shape. For points identified as water, MISR tends to get a larger optical depth than MODIS does, and it lines up better for ice. The effective radius below 30 lines up well, but above there MODIS doesn't detect the larger radii. This is due to differences between the ice crystal size distributions used in the MODIS retrievals and the current retrievals. A thin cloud retrieval shows that water lines up well, though MODIS' optical depth is lower, and aggregates lower as well.

The group is trying to identify how well they are doing, and determine metrics for deviation from observed reflections. The metric tends to increase when optical depth decreases, and there are variabilities in reflectances.

In the future, the group will work to understand the differences with the MOD06 cloud property retrievals; develop automated statistics to determine where the retrieval is doing well; and look at the effects of vertical structure and habit mixtures. They will also compare retrieved IWP/effective radius to radar retrievals at an ARM site. New radar retrievals that use reflectivity and Doppler velocity can retrieve vertical profiles of R and IWC (Mace et al, 2002). Retrievals are sensitive to crystal habit because particle fall-speed and effective density depend on habit. Constraining the particle habit reduces the uncertainty in radar retrievals. They will look at retrievals over the ocean to extend to lower optical depths, and will include realistic surface albedo from the MOD43 product.

The Effects of Aerosols on California Climate

Mark Jacobson, MODIS Atmosphere Science Team Member, Stanford University

Mark Jacobson presented on the effects of aerosols on the California climate. They are investigating the effects in California and the South Coast Air Basin of all anthropogenic particles and their gas precursors on:

- rainfall
- winds
- pollution content of rainwater
- cloudiness
- near-surface air temperatures
- vertical temperature profiles
- relative humidity
- ultraviolet/total solar/thermal-infrared radiation

They are also investigating how MODIS data can help evaluate those effects.

GATOR-GCMOM is investigating gas processes, aerosol processes, cloud processes (3-D clouds), radiative transfer, meteorological processes, and surface processes (see slide for subpoints). Three-dimensional size resolved clouds form from size-resolved aerosols without parameterization or equilibrium assumption.

The group looked at US EPA emissions data for two months in 1999; difference plots of the black carbon difference with and without AAPPG from February and August show that there is a higher magnitude in August. Results for primary organic matter, sulfate, nitrate (primary and secondary), aerosol and liquid water content, aerosol optical depth, baseline cloud optical depth, cloud optical depth, near-surface cloud fraction, liquid water content, cloud top pressure, surface solar radiation (including night-time averaging), surface thermal IR radiation, and near surface temperature all show similarities (see slides for images and details).

Baseline versus measured February 1999 precipitation difference shows a reduction in the central valley. Similar results were seen for black carbon in fog and precipitation, near surface wind speeds, and water vapor (see slides for images and details). Comparisons of models against MODIS data shows that MODIS is predicting pretty accurately at several locations.

In conclusion, anthropogenic aerosols and gas precursors in California and the South Coast Air Basin were found to:

- decrease near-surface wind speeds
- decrease rainfall in the Central Valley, South Coast, and mountains (e.g., Sierras, San Bernardino)
- increase the pollution content of rainfall
- increase cloud optical depth, fraction, LWC, top height

- decrease near-surface air temperatures
- stabilize the boundary layer
- decrease UV, solar radiation at surface, and
- increase thermal-IR radiation at surface

Global estimates of the horizontal variability of total cloud optical thickness from MODIS L3 data

Lazaros Oreopoulos, Research Assistant Professor, JCET/UMBC

Lazaros Oreopoulos presented on global estimates of horizontal variability of total cloud optical thickness from MODIS L3 data. MODIS estimates of cloud inhomogeneity are based on L3 gridded daily data proving moments and histograms of integrated optical thickness and water path based on about 1km retrievals sampled at about 5km. They analyzed two months of data from both Aqua and Terra, and it turns out that using water path or optical difference doesn't make a difference in outcome (see poster for details). There are separate considerations for each cloud phase, and daily values are averaged for monthly scales. The main shortcoming is the variability of total-column optical thickness instead of cloud layer variability that is needed by LSMs, though the data are still invaluable for validation purposes. A paper on this is has been accepted in the Journal of Climate.

Example maps showed the creation of inhomogeneity parameters for Terra liquid clouds. Stratocumulus regions more homogenized than others, while winter clouds are more inhomogeneous than summer clouds. These images also show that mid-latitude regions of relatively large inhomogeneity in winter become relatively homogeneous in summer for both water and ice clouds.
These are global and hemispheric results (see slides for images and more details). A Land/Ocean and Terra/Aqua contrast shows that Terra liquid clouds are always more inhomogeneous than Aqua clouds. Land clouds are more homogeneous than ocean clouds.

In summary, winter clouds are more heterogeneous than summer clouds. Marine clouds are more heterogeneous than continental liquid clouds. Afternoon clouds are more heterogeneous than morning clouds (except for marine ice clouds). Ice clouds have greater range of inhomogeneity than water clouds, and nearly overcast or overcast scenes are more homogeneous.

The team is planning to analyze the full annual cycle, and do detailed examinations of regions of special interest, and composites of inhomogeneity in different dynamic regimes. They hope to estimate the global radiative bias of the homogeneous approximation.

Issues with L3 Cloud Products

Brent Maddux, CIMSS, University of Wisconsin - Madison

Brent Maddux presented on issues with L3 cloud products. The questions his group has been asking are how do the MODIS L3 products look? Do they represent known physical phenomenon well? They seek to determine what the L3 data are saying in terms of going from information to knowledge. In the future the next steps will be to decrease the limitations, and improve the physical meaning and interpretation.

Overall Terra and Aqua represent lots of things you'd expect. Looking at a one-day scene of cloud-top pressure, there are dust or high-aerosol events affecting clouds in regions. Cloud ice water path for December 2002 Terra MODIS shows possible major ice cloud events, but they aren't visible at all on Aqua. Otherwise, the two agree very well, and the results are the same in the water path as in the ice path.

Possible solutions to differences seen are to conduct secondary data processing; remove questionable data; and create uncertainty products. It would be okay to do this for individual days, but it will have an effect on weekly and monthly averages.

Looking at comparisons of products in the same areas, specifically ice particle size and tropical deep convention evolution, shows complementary findings. However, the main limitation is that the mean phase properties can't be fully characterized.

For Mean Ice Properties, they tried looking at cloud regimes, cloud height or phase, and particle size or path. Histograms are needed for this. There are property comparison limitations in data subsets and multiple data set comparisons. Possible solutions here include a new joint histogram in Collection 5, which means doing property subsets or multidimensional histograms.

In summary, it might be necessary to implement a secondary processing effort between L2 and L3. Adding additional SDSs could also be useful. They could be used to further compare the microphysical properties of clouds and other atmospheric parameters. They could also allow for further intuitive interpretations. These new SDSs would need to be near nadir.

Update on MODIS Polar Winds from Satellite Imagers and Sounders and Thoughts on Transitioning to NPP (around 2008)

Paul Menzel, MODIS Atmospheres Science Team Member, University of Wisconsin - Madison

Update on MODIS Polar Winds from Satellite Imagers and Sounders Paul Menzel gave an update on the MODIS Polar Winds product from satellite images and sounders. This product allows you to track features and estimate winds in the Polar Regions. These winds are filling in an area where data were almost nonexistent; and thus lots of NWP centers are using it, including the European Centre for Medium-Range Weather Forecasts (ECMWF), NASA's Global Modeling and Assimilation Office (GMAO), the Japan Meteorological Agency (JMA), the US Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC), the UK Met Office, the National Centers for Environmental Prediction (NCEP/EMC), Deutscher Wetterdienst (DWD), and the NCAR Antarctic Mesoscale Model (AMPS).

The biggest impact is not on the averages, but on the occasional days where the forecast was very poor - the inclusion of polar winds mitigates the busted forecast significantly. The impact on hurricane track errors is also significant, and represents a real life impact on human lives.

The biggest challenge is to get the data in on time to be of use for operational models and forecasts. Only two thirds of winds are getting to the centers on time to be useful in forecasting.

Thoughts on Transitioning to NPP (around 2008) Menzel continued by presenting on some thoughts about transitioning to NPP around 2008. Major issues are continuing MODIS through NPP/NPOESS and beyond, preparing for VIIRS (participating in VIIRS OAT; Pre-planned product improvement [P3I]), and assuring viable Cal/Val (planning evolution of MAS/VIIRS Airborne Simulator). Because this is a combined military/civilian system, there are a lot more opportunities.

VIIRS is designed to do many things, especially collect SST data and imagery. Water vapor and CO2 sensitive channels are not included in the VIIRS spectral selection. This makes night cloud detection very challenging, and has been the subject of some discussion.

Menzel presented the concept of a VIIRS Airborne Simulator (VAS). The rationale is to collect high-resolution, calibrated data to prepare for and validate the on-orbit performance and calibration of the VIIRS instrument. The VIIRS-like data sets will enable the development and testing of CDR and EDR product algorithms, prior to NPP/NPOES launch. The approach is to capitalize on the NASA MODIS and ASTER Airborne Simulator programs (MAS and MASTER) and the U.W. S-HIS experience, leverage ongoing development programs for accelerated deployment, and apply MAS "lessons-learned" and operational experience for risk reduction. These include

- Spectral stability is critical for atmospheric bands
- Flat-plate blackbody design not capable of <1 degree accuracy
- Cross-track polarization needs to be addressed
- Onboard calibrator for Vis/SWIR bands highly desirable
- Scattered light inside scan cavity needs to be reduced
- Internal IR background radiation has to be better suppressed
- Replace gratings with bandpass filters for LWIR bands
- Eliminate linear-variable filters (LVFs) from design
- Additional SWIR and LWIR water vapor bands are useful

The design features for VAS are:

- Single large dewar for LWIR bands and cold secondary optics to reduce background noise
- Filter-based spectral differentiation in M/LWIR bands
- Added 6.7um (and possible 1.88um) band
- Improved blackbody design, based on S-HIS experience
- Visible/SWIR calibrator
- De-polarization methods to be investigated
- Fully supported by Ames Calibration Lab (NIST-traceable)
- Utilize ground-processing and archive software from MAS, including Level-1B/HDF data production system

The phased development approach is suggested. In phase 1 VIIRS Bands are implemented on the on the NASA MAS System, in phase 2 a dedicated VIIRS Airborne Simulator Instrument is built, and in phase 3 advanced technology is added to the system. The estimated development timeline is roughly 3 years for phases 1 and 2. For the advanced system the timing is TBD.

Second Atmospheres Breakout Session (Morning Day Three)

Study of 3D cloud radiative effects using MODIS data

Tamás Várnai, Research Assistant Professor, Joint Center for Earth System Technology (JCEST), University of Maryland - Baltimore County (UMBC)

Várnai presented on the use of MODIS data in the intercomparison of 3D radiative codes. The goals are to compare 3d radiative transfer models, create benchmark 3d results, create an open source toolkit, and create an educational website for students.

They've already conducted two rounds of intercomparison, and will do a third round this coming October, focusing on lidar multiple scattering and on cloud fields viewed by MISR, MODIS, and ASTER.

The test scenes are in the biomass burning region in Brazil. MODIS contributes brightness temperatures and cloud products, while MISR provides different view angles. ASTER provides fine scale views.

Várnai also discussed the view-angle dependence of MODIS cloud optical thickness and whether 3d effects may affect this view-angle dependence. MODIS views back scattering at one edge of its swath and forward scattering at the other edge.

The data used in this study included virtually all daytime granules over 6 months (August 2005-January 2005); they used about seven percent of all scan lines. They gathered 11um brightness temperatures and cloud products at 1km resolution, and only took high-confidence retrievals indicating liquid cloud phase.

Results for clouds over ocean show that for high sun, cloud optical thickness doesn't change much with view angle. But for low sun, the results are more complex. There is a slight trend even for homogeneous clouds, probably due to the sun-synchronous orbits of the Terra and Aqua satellites. The mean optical thickness of heterogeneous clouds follows a u-shape, with higher values for oblique views at the swath edges than for overhead views in the swath center. The depth of the u-shape increases steadily with solar zenith angle, and is larger over land than over ocean. This is somewhat surprising.

The initial list of possible causes of the u-shaped behavior included daily cycle, latitude dependence, solar elevation, cloud altitude, gaseous absorption, aerosol effects, and surface effects. However, none of these factors could explain the u-shape well, so they were left with two possibilities. Either ice crystals (and their detection) are different for heterogeneous than for homogeneous clouds, or the radiative effects of cloud heterogeneity (the main focus of their study) are the cause.

In summary, MODIS data were used both for setting up test cases in phase three of the I3RC project and for assessing the radiative effects of cloud inhomogeneity. The results suggest that 3D cloud structures influence the viewangle dependence of MODIS cloud optical depths; whereas the influence on cloud droplet size is much smaller.

MODIS Aerosol Algorithms

Lorraine Remer, MODIS Atmosphere Science Team Member, NASA Goddard Space Flight Center

Lorraine Remer presented on the status of the MODIS Aerosol algorithms. There is lots of talk about the need for reprocessing. Everyone is using Collection 4 now, the Collection 5 code was delivered several months ago, and there will be a Collection 6.

For Collection 4, there is a paper appearing in the Journal of Atmospheric Science in April 2005 that explains the algorithms and validation of Terra Collection 4 data. This paper is available online at http://modis-atmos.gsfc.nasa.gov/ under References. Aqua validation in Ichoku et al. (2005) is also available online.

A study of a monthly mean time series of MODIS AOT and Fine Mode Fraction data from 2001-2004 shows that results are very sensitive to changes in instrument characterization. There is also an offset between Aqua and Terra MODIS data. The Terra data are probably more correct, but the team is looking into getting solutions in the next few months.

When compared against AERONET monthly means, ocean AOT values are very close. These are not collocated in time, and the team wonders if this is a true validation of aerosol long term statistics. It could be that both are still affected by thin cirrus.

The team has also been looking at cirrus reflectance vs. optical depth over global oceans. This seems to increase AOT by 0.015+/-0.003 at 0.55um. This slide is a very dramatic example; when they look at the whole globe over oceans they get the previous number.

For Collection 5, the results were showing very high AOT over snowmelt on land (snow contamination), but it has been eliminated. The team is working on cloud clearing in the aerosol product. They were also using 1.38 um over land but not taking negative reflectances; now they are and are getting more retrievals.

For Collection 6, they are going to include Christina Hsu's retrievals over bright surfaces from the Deep Blue product. There will be a new land inversion coming out (a comparison of what they do now to what they will do). The result is no difference in AOT retrieval, and major improvement to fine mode fraction. The results will show better land surface characterization (scattering angle is a better parameter than surface type, BRDF). The end result for the test bed examples is that the offset is reduced significantly.

Will there be a new Aerosol Model for Collection 6? They are testing whether the original estimates for aerosol models are correct. The method now leaves them with 3 fine mode models and 1 dust. But for Collection 6, they will change this in certain ways, yet keep the same results of 3 fine mode models and 1 dust.

Another major change will be in making the Collections 4 and 5 subjective division of the world into the objective clusterings for Collection 6.

Finally, there will be new Ocean aerosol models coming that will address nonsphericity and perhaps additional absorption.

Can MODIS derive anthropogenic aerosol?

Yoram Kaufman, MODIS Atmosphere Science Team Member, NASA Goddard Space Flight Center

Yoram Kaufman presented on using MODIS to derive anthropogenic aerosols. The group is trying to understand these processes globally, and thus they need to know the anthropogenic component of aerosols. They wonder if they can do something directly from MODIS itself to measure that fraction. MODIS measures fine fraction (there are problems with small optical thickness, but the instrument does better with larger particles). They can see that they have a strong signal to separate natural from anthropogenic aerosols.

MODIS distinguishes fine from coarse aerosol particles over the oceans. Dust is visible in both the visible and mid-IR channels, but this doesn't hold true for smoke, which is only visible in the visible channels. They can plot aerosols from different regions around the world, and then measure fine fraction against aerosol optical thickness to see pollution, dust, and maritime aerosols. If they can estimate in clean conditions the marine contribution, they can subtract it from the differences between smoke and dust to determine the fraction that is anthropogenic.

One validation shows good lineup between MODIS fine fraction and Aeronet almucantar fine fraction (see slide 5 of the presentation).

In the anthropogenic optical thickness vs. aerosol optical thickness plot, the results seems good, but they need to be able to prove why it is right. Compared MODIS AOT to models, they see a difference of about 30%. The hypothesis is that satellites and models have larger problems with natural (mainly coarse aerosol) sources than with anthropogenic (mainly fine aerosols) sources. When they add in an estimate of MODIS anthropogenic aerosols, the agreement is very good in averages. When they look at it as a function of latitude vs. AOT, they see a difference from the models. However, anthropogenic detection shows good agreement with MODIS AOT.

MODIS agree better with models regarding the anthropogenic AOT than total AOT. The application of two years of global MODIS data shows that 0.21±0.06 of the aerosol optical thickness has an anthropogenic origin. There is good agreement with the models' average, and anthropogenic AOT increases the confidence in their assessment of direct aerosol forcing of climate at the TOA. Finally, the measured direct forcing in clouds free is -1.3±0.4 W/m2.

Characterization of Aerosols using Airborne Lidar, MODIS, and GOCART Data during the TRACE-P (2001) Mission

Rich Ferrare, MODIS Atmosphere Science Team Member, NASA Langley Research Center

Rich Ferrare presented on the characterization of Aerosols using airborne lidar and MODIS data, and GOCART modeling results during the 2001 TRACE-P mission. The motivation is that key aerosol parameters are required for assessing anthropogenic impacts on radiative forcing. Vertical distribution affects radiative forcing, surface temperature, and climate responses, while aerosol size distribution affects fine mode (biomass burning and pollution) and coarse mode (desert dust, sea salt) particles.

Their methodology was to look at models (global coverage, large uncertainties in vertical distribution), MODIS (estimates of fine and coarse mode over oceans, column average with no profile information), and lidar (high resolution vertical profiles that typically provide little quantitative information on size or composition).

The objective was to use a combination of airborne lidar and MODIS data to provide information regarding the vertical distribution of fine vs. coarse aerosol modes. They wanted to retrieve aerosol extinction and optical thickness profiles from lidar data and identify aerosol types vs. altitude. They also wanted to evaluate the ability of the GOCART model to simulate aerosol extinction profiles and simulate contributions to fine and coarse modes.

As deployed in the TRACE-P and INTEX missions, the NASA Langley UV DIAL Airborne Lidar measures ozone profiles, aerosol and cloud scattering ratio profiles simultaneously in both nadir and zenith directions, and nadir aerosol depolarization profiles (see slide 5 for details). It was deployed on a NASA DC-8 for TRACE-P in 2001, and on INTEX NA in 2004.

To retrieve aerosol extinction profiles, their solution approach was to assume a priori aerosol types and S_p values and use lidar measurements of intensive parameters to determine aerosol types, and/or use external information to constrain the solution (e.g. MODIS AOT). Aerosol types determined from AERONET climatology were used as in the algorithms to be used for CALIPSO retrievals. They used backscatter and extinction "color ratios" to infer aerosol type and the corresponding lidar ratio. This showed good agreement between the techniques for this test case.

For MODIS and lidar aerosol retrievals, they used a retrieval algorithm that determined aerosol size distribution (bimodal lognormal), used 20 combinations of 4 fine, 5 coarse particles from MODIS aerosol models, assumed that the size of each mode was altitude independent, determined the relative weight of each mode as a function of altitude from lidar backscatter color ratio, and constrained the retrievals to fit MODIS measurements of spectral reflectance and column AOT and r_{eff}. They made modifications to the UV wavelength (300 nm) to get more information on fine particle size, and adjusted the backscatter phase function for nonsphericity. For MODIS+GOCART, retrievals show qualitative agreement with in situ measurements and good agreement between techniques for this test case.

They are working to determine how lidar measurements can be used to evaluate aerosol models. Currently, they are developing and evaluating algorithms to retrieve profiles of aerosol extinction and optical thickness from airborne lidar and MODIS data, and infer profiles of aerosol type. They've begun evaluating GOCART results using lidar, MODIS, and in situ data, and initial comparisons show qualitative agreement.

In the future they will refine and implement algorithms for retrieving aerosol profiles from lidar data – with and without MODIS data; evaluate algorithms using data from other TRACE-P, INTEX NA flights; infer aerosol types as a function of altitude using lidar, MODIS, and GOCART; and derive vertical distributions of fine and coarse mode particles for TRACE-P and INTEX NA.

Remote Sensing of Volcanic Emissions using MODIS

I. Matthew Watson, MODIS Atmosphere Science Team Member, Michigan Technological University

I. Matthew Watson presented on using MODIS to remotely sense volcanic emissions. They are interested in this because emissions are indicators of volcanic activity, volcanic eruptions are hazardous to populations, wildlife, the environment, and infrastructure. Volcanoes are long-lived and climatologically active, and are a hazard to aircraft.

This work focuses on bands 28-32 in the infrared range. In the past they pretended that all these species existed in isolation, where most emissions include multiple species at once. MODIS has all of the necessary channels to detect all commonly retrieved volcanogenic species..

Until the advent of MODIS, no one realized that the 7.34μm channel could detect SO_2. This spawned a lot of interesting work, for example a study of the Mt. Hekla volcano eruption on

February 26, 2000 (very close to Terra launch, so there are some caveats with the data). Images clearly show the SO_2 emissions. Volcanogenic SO_2 is typically higher than water vapor in the atmosphere, so they can clearly differentiate the two in TOVS data. MODIS data are very close to SOLVE values, which were gathered by a plane that went directly through the cloud. However, water vapor interference tends to mask the ash signal.

In the forward model, the user specifies 'external' parameters: ground emissivity, ground temperature, atmospheric profile (water vapor, pressure, and temperature as a function of height). They also specify 'plume' parameters: plume (top and base) altitude, effective radius, variance, refractive index, and the number density of particles. The forward model uses MODTRAN to calculate 'external' effects and Mie scattering code to calculate 'plume' effects. This can be used to investigate atmospheric effects on IR retrievals; generate a LUT for multi-species spectra; and generate transmission spectra to be used to correct SO_2 maps for ash/sulfate.

Water vapor in the tropics dramatically effects how well they can detect ash clouds. They need a multi-species algorithm. The volcanic emissions group is working on various parts of the problem. The empirical and theoretical approaches used are:

- Looking at examples of ash- SO_2 separation (e.g. Anatahan 2003)
- Forward modeling of multi-species clouds
- Correction of SO_2 for ash and sulfate
- Multi-sensor comparisons (TOMS, AIRS, TOVS, ASTER)

Several eruptions have been targeted, and this is a work in progress.

The development of the 7.3 □m algorithm has been a significant advance in quantifying volcanic SO_2 (limited species interaction, works at night), and the Hekla-DC8 interaction provided an unprecedented ground-truthing opportunity. Forward modeling can be used to quantitatively determine the effects of different water vapor concentrations on the 'split-window' signal, and water vapor more strongly affects clouds that are optically thinner as relative proportions of signal from the underlying ground (and water vapor) increase. A multi-species algorithm is the holy grail of volcanic emission remote sensing. Only through MODIS' ability to detect and quantify more than one species has the problem been (a) illuminated and (b) potentially solvable.

Participation in IDEA

Kathy Strabala, SSEC and CIMSS Researcher, University of Wisconsin - Madison

Kathy Strabala presented on Infusing Satellite Data into Environmental Applications (http://idea.ssec.wisc.edu).

IDEA is a partnership between EPA, NOAA, and NASA to improve air quality assessment, management, and prediction by infusing NASA satellite measurements in to EPA and NOAA analyses for public benefit. IDEA uses MODIS AOD in near-real-time data fusion with EPA's AIRNow Data (via NOAA bent pipe). This provides daily a pseudo-synoptic view of aerosol loading across North America at a 10x10 kilometer spatial scale, and shows regional transport, natural event, and re-circulation influences. The study focused on late August through September of 2003. It involved NASA LaRC and GSFC, CIMMS/SSEC from the University of Wisconsin-Madison, NOAA/NESDIS/ORA, US EPA OAR/OAQPS, and a select group of Air Quality Forecasters. The objective was to prototype a near-real-time product for the Air Quality Forecasters, and the goal was to improve the accuracy of next-day $PM_{2.5}$ AQI forecast during large aerosol events.

They successfully achieved their goal. The fusion and delivery of multiple input data sets in near-real-time was successful, and the selected group of forecasters routinely used the products to gain an understanding of large-scale aerosol events. However, the satellite data was not timely enough: the data were 3-6 hours behind actual real time, which is not fast enough for forecasters. Implementing MODIS AOD Direct Broadcast will help.

CIMMS participated in order to help with X-band direct broadcast production of MODIS products – this helps with timeliness for forecasts. Their direct broadcast reception is centrally located, they are experienced with running and transitioning operational products, and they are familiar with MODIS (via MODIS Science Team Members and Associates, and IMAPP). There were also aerosol scientists, forecasters, and visualization experts present.

CIMMS was funded to produce IDEA products for the 2004 Fire Season at UW-Madison. They installed the most recent baselined version of the MOD04 and MOD06OD products, transferred IDL and Perl scripts from NASA Langley to UW Dell Linux boxes (for operational and development purposes. Scripts were compiled and tested.). They automated the data gathering process and script execution, and the data sets were processed automatically beginning in April of 2004. Trajectory forecast products were generated by 4:30pm (Eastern time zone), and they monitored site use as well as assisted in forecast discussions and adjusted the site based on feedback from the EPA forecasters.

They used Terra MODIS data because it is the morning overpass and thus gives earlier data.

The IDEA Forecast tool products were:

- Regional summary plots of MODIS AOD and Cloud Optical Thickness
- MODIS AOD 48-hour trajectories forecasts
- Composite PM2.5/MODIS AOD data fusion 3-day animations
- Time series between MODIS AOD and PM2.5 (1 hour and 24 hour) mass concentration
- National Correlation Map between PM2.5 and MODIS AOD
- Daily forecast discussions and blogs

The web utility allows scientists/forecasters to make and comment on forecasts.

IDEA successfully demonstrated the utility of producing and combining multi-source products for improving air quality forecasts. Comments from users include:

> *I try to check the IDEA website daily as it is helpful for PM2.5 forecasting. I particularly use the animated 48-hour trajectory forecast. It would be nice if it were possible for the user to stop the animation at specific times since it runs continuously. Each morning I also read the forecast discussion that comes out the previous evening. It might be nice if the forecast discussion was moved to the morning since it would be timelier for forecasters. It is an excellent product. –* ***John White, EPA***
>
> *I think we should make it a priority to migrate the IDEA graphical products into the AniS applet as soon as possible, to allow a higher level user control and interactivity -- it sounds like they (the users) would appreciate such an improvement. –* ***Jim Szykman, LaRC***

The CIMSS work statement for March – September 2005 is to:

- Continue the current generation of derived air products;
- Incorporate Terra data from Oregon State University's Direct Broadcast station for coverage further west and north;

- Add MODIS AOD/COT images at high resolution for direct visual comparison with MODIS true color images;
- Create training materials for education and out reach, including presenting the VISITview session to state and local forecasters in June; and
- Begin the process of transitioning operational IDEA production to NOAA.

Aerosol Properties over Bright-Reflecting Source Regions: The Deep Blue Algorithm and its Applicability to MODIS

Christina Hsu, MODIS Atmosphere Science Team Member, NASA Goddard Space Flight Center

Christina Hsu presented on her work with the Deep Blue Algorithm and its applicability to MODIS.

The Deep Blue aerosol algorithm originally used SeaWiFS as a proof of concept, and just recently was incorporated for use with MODIS. It utilizes the MODIS Visible and NIR bands (see slides for an example image of the bands superimposed over GOME spectral reflectance taken over the Sahara). On a relatively clear day, surface reflectance increases for wavelengths longer than 500nm; using the Deep Blue algorithm allows you to alleviate aerosol height dependence.

The Deep Blue algorithm doesn't retrieve for cloudy pixels. Details of the retrieval method are published in an IEEE-published paper (see slides for a flowchart of how the algorithm works). Examples of scenes of surface reflectance acquired from SeaWiFS data are very similar to the same scenes/bands acquired from MODIS Aqua data. You can also track movements and evolution of aerosol plumes using Terra AOT; this shows the complementarity with Aqua MODIS data and is very exciting and useful. A lot of good data comes from excellent ground data coverage in the United Arab Emirates; this is very useful for comparing to SeaWiFS and MODIS data. Good results are also observed from the AERONET Sun Photometer site.

In summary, the Deep Blue algorithm performs well for SeaWiFS and MODIS measurements. It also has direct applicability for use with the VIIRS sensors on future NPP and NPOESS sensors. It compares well with surface/aircraft prods, and separates dust well from aerosols due to other anthropogenic sources. They expect to implement the Deep Blue algorithm for MODIS (underway) to produce products over bright-reflecting surfaces. These products will then be integrated into the operational MODIS product stream.

The algorithm continues to be refined, for example, to include a polarization correction due to the MODIS scanning mirror. To correct for a polarization factor, they will use MODIS prelaunch polarization coefficients from MCST and GSFC Oceans group and generate LUTs for Stokes parameters and simulated correction factors. They need 2% error correction at most, but it works really well. The algorithm is currently scheduled to be included in Collection 6.

Suppression of Deep Convection by the Saharan Air Layer (SAL) over the Tropical North Atlantic

Sun Wong, Postdoctoral Research Associate, Earth System Sciences Interdisciplinary Center (ESSIC)

Sun Wong presented on studies using MODIS and other satellite data to track the suppression of deep convection by the Saharan Air Layer (SAL) over the Tropical North Atlantic.

A warm, dry, and dusty air layer is vectored form Africa by Easterlies during the summer. This creates a temperature inversion and stabilizes the boundary layer. Evidence has shown a linkage between SAL and tropical cyclone activity, and it is also associated with the transport/distribution of dust over the Atlantic. This dust can cool the surface and warm the atmosphere.

The three purposes of this study are:

- Using NASA satellite data, including MODIS, to study the thermodynamic structure of the SAL;
- Evaluate simulations of the SAL by NASA's model (fvGFM) using satellite data (ongoing); and
- Understanding the detailed physics used by the model.

The data sources for this study are MODIS AOT, Brightness Temperatures, and NCEP/NCAR Reanalysis T and RH. The first is a tracer for the other two, and the first and second are conductive to frequency. Samples are daily and instantaneous around noon for August-September 2002, and the region is 40°-20°W, 10°-20°N.

They divided the region into a 1x1 degree grid mesh. They grid-averaged the AOT where the standard deviation was less than 20% of the mean, and created a brightness temperature (BT) histogram to ensure validity. For each box, you can associate AOT to BT. The higher the AOT, the lower the probability was to be able to see low BT (deep convection). They chose an NCEP temperature profile to use in calculating anomalies, and this showed an increase with aerosol/dust content. This holds for the Saharan air layer. Dust seems to be a good proxy for tracing the dust layer over the Central Atlantic, but they are not sure it holds true off the coast of Africa.

An analysis of the CAPE and Convection Barrier shows the energy required go get an air parcel across the LFC. (See slide 10 for more information.) This shows a good correlation between MODIS AOT and the convection barrier in the East Atlantic, but it's not as good in the Central Atlantic.

As for trying to find the geographic distribution of the Saharan dust layer, this is ongoing research, and they will do a quantitative comparison later.

In conclusion, the SAL is associated with the suppression of deep convection: the frequency of clouds with BT less than 250K is largely reduced. The SAL suppresses deep convection by lifting the LCL (less moisture), LFC (warmer temperature), and strengthening the temperature barrier (see slides for detailed illustrations).

Near-IR AOD validation and spatial variability studies in the Extended-MODIS-λ Validation Experiment (EVE)

Jens Redemann, Atmosphere Science Team Member, Senior Research Scientist, BAERI, NASA Ames Research Center

Jens Redemann presented on studies looking at the spatial variability of AOD on the US West Coast during the dust transport season.

The EVE study's platform instrumentation includes AATS-14, a 14-channel airborne sunphotometer to track AOD at 0.35 to 2.14 um; CADENZA to track aerosol extinction at 0.675 and 1.55 um; and a 3-λ nephelometer with PSAP to track aerosol extinction at 0.453, 0.519, and 0.675 um. They use these to look at dust transport and clouds, but dust tends to be associated with fronts, so they have to deal with sunglint, clouds, low-level fog, and birds.

They used a forecast model of dust and moderate optical depth in the dust. There were 7 flights, 4 Terra overpasses, and 5 Aqua overpasses totaling 85 L2 retrievals. On an ideal day, there are very few clouds and they get a lot of successful L2 retrievals from the MODIS instruments.

The data show general behaviors, some very good match up in some cases, and some differences as well. Terra wavelengths match up 80% or more with prelaunch estimates, but Aqua is only about 50%. For near-IR validation, Terra and Aqua's slopes are flatter, and Terra has more points within pre-launch AOD estimates. However, more than 75% of Aqua's data points are outside the boundaries (see slide 10 for details). They are trying to figure out why; it could be because of more dust in that overpass, calibration offset, etc.

Plotting spatial variability in AOD shows relative variability in various channels from suborbital sensors, but overall they look very comparable. There are some smaller angstrom exponents, but otherwise the match-ups are very comparable.

In EVE, a total of 36 and 49 coincident AOD validation measurements were collected for Terra and Aqua respectively. These measurements were all taken over dark water, extend to the 1.24, 1.64, and 2.14um MODIS wavelengths, and are for the smallest regular level 2 AOD retrieval scale of 10km. A preliminary analysis indicates that for MODIS-Terra about 80% of the MODIS AOD retrievals are within the estimated uncertainty of ±0.03±0.05*AOD; this is true for both the visible and near-IR retrievals. A preliminary analysis indicates that for MODIS-Aqua about 50% of the MODIS AOD retrievals are within the estimated uncertainty of ±0.03±0.05*AOD; the fraction of near-IR retrievals that fall within this uncertainty range is about 25%. This difference could be due to the fact that there may have been relatively more dust present during the Aqua validation days. Aqua calibration could also be an issue. The spatial variability as derived from the suborbital measurements during a few select flight segments is larger than that derived by MODIS, in particular in the near-IR. The analysis shows that only measurements within the scale of one retrieval box (~10km) can be used for studies of spatial variability of AOD.

Terra/Aqua Direct Broadcast: An Update

Liam Gumley, MODIS Atmosphere Science Team Member, SSEC, University of Wisconsin - Madison

Liam Gumley presented an update on the status of Terra and Aqua MODIS Direct Broadcast.

There will be updates and new features added to IMAPP (International MODIS/AIRS Processing Package). The current MODIS L2 algorithms that it supports are: L1 data; cloud mask; atmospheric profiles (T/q); cloud top properties (IR); aerosol optical depth; sea surface temperature; and near-IR water vapor. These will all be updated to Collection 5 in 2005. New MODIS L2 algorithms that will be ported to IMPAA are: cloud optical properties; land surface reflectance; BRDF; and snow-ice detection. These will all be ported and released in 2005.

The AIRS/AMSU/AMSR-E software currently in IMAPP are: L1B for AIRS/AMSU, and L1B for AMSR-E. L2 retrievals of AIRS/AMSU and AMSR-E precipitation are in development, and will also be released in 2005.

They are also producing real time GeoTIFF products for the Great Lakes: Terra and Aqua MODIS 250m true-color images are produced daily. The GeoTIFF format is in UTM projection (GIS compatible), and NOAA Coastwatch, the National Ice Center, and the Canadian Ice Service can download images in real time and use in daily analyses. The Canadian Ice Service integrates MODIS into their operational data stream for ice monitoring.

A synergistic retrieval algorithm has been developed for Aqua MODIS/AIRS. For AMSER-E, precipitation and soil moisture algorithms have been ported from the official versions. These algorithms will be released in IMAPP in 2005.

There is an upcoming International TOVS Study Conference; it will be held May 25-31 2005 in Beijing, China. The pre-meeting workshop will provide a theoretical and hands-on introduction to MODIS, AIRS, AMSU, and AMSR-E applications. The meeting will discuss EOS Direct Broadcast software/applications, and preparations for NPP/NPOESS. (http://cimss.ssec.wisc.edu/itwg)

The International EOS/NPP DB Meeting will be held October 3-6, 2005 in Benevento, Italy. It will discuss the status of current and future satellite systems (EOS, NPP, NPOESS); processing software and science applications; and receiving system technology. (http://dbmeeting.gsfc.nasa.gov/)

Comparison of an Aerosol Assimilation System of MODIS Radiances with AERONET Retrievals

Clark Weaver, MODIS Atmosphere Science Team Member, NASA Goddard Space Flight Center

Clark Weaver presented on a study comparing an Aerosol Assimilation System of MODIS radiances with AERONET retrievals.

The goal is to construct a simple offline Aerosol Assimilation System that draws to MODIS radiances and validates with AERONET retrievals. Observations would come from MODIS L2 reflectances (cloud screened), seven Ocean channels (.42 – 2.1 um) and five Land channels (.47 – 2.1 um). The Aerosol 3D Transport Model (GOCART) provides spatial and size distribution of aerosols, and the Herman Radiative Transfer Model (Vector Code) converts aerosol concentrations to reflectances.

The motivational question is, why not assimilate retrieved AOD from the MODS Atmospheres group? Differences in assumptions used in GOCART and MODIS Atmospheres retrieval algorithms complicate the assimilation.

The MODIS AOD makes assumptions about optical parameters, size, and shape. Aerosol type is determined by geography. GOCART's AOD makes assumptions about optical parameters, and aerosol type is determined by transport, sources, and sinks.

The GOCART retrievals are high-resolution (.500 x .625 degree), and compared with AERONET using GOCART fields as a first guess they are consistent with GOCART aerosol species.

The Aerosol Transport Model was developed by Mian Chin and Paul Ginoux. It includes assimilated meteorology (winds and relative humidity) and simulates 3D concentrations for dust, sea salt, sulfate, and black and organic carbon. It also tracks humidification growth.

The Forward Model is a set of Set of 48 look-up-tables per MODIS channel generated by the University of Arizona radiative transfer model. It tracks three variants: aerosol species (dust, sea salt, sulphates, and black-carbon organic carbon mixtures), relative humidity, and underlying surface properties (rough ocean wind speeds, and Lambertian land surfaces). Ocean wind speed is from GMAO meteorological assimilation. Land reflectivity uses a dark target approach that is in turn used by MODIS Atmospheres only for *p* (2.13 mm < 0.16), while the MODIS filled Land Surface Albedo product is for "black sky" and was developed by Eric Moody.

They compare the products from this assimilation system with ground-bases measurements of aerosol optical depth (AOD) from the AERONET network. Insertion of MODIS radiances draws the GOCART model closer to the AERONET AOD. However, there are still uncertainties with surface reflectivity over moderately bright surfaces and the amount of absorbing aerosol.

Satellite data and model integration of global distribution of Aerosols to estimate the aerosol radiative effect

Hongbin Yu, Research Professor, Goddard Earth Science and Technology (GEST) Center, UMBC and NASA/GSFC

Hongbin Yu presented on using satellite data and model integration of global distribution of aerosols to estimate the aerosol direct radiative effect.

An IPCC report summarizes that the uncertainly for aerosol direct forcing is a factor of 2-3, based largely on model simulations. In recent years, a great deal of effort has gone into improving measurements and data sets. As a result, it is feasible to shift the estimates from largely model-based to increasingly measurement-based. There is an on-going effort led by Yoram Kaufman, Mian Chin, and Graham Feingold to assess measurement-based aerosol direct forcing for CCSP. Satellite observations can also be used to improve and constrain model simulations through synthesis and integration.

Both satellite retrievals and model simulations of aerosols have uncertainties; and data assimilation or objective analysis should form an optimal estimate of aerosol distributions by combining them with weights inversely proportional to the square of the errors of individual descriptions.

Given the respective strength of current MODIS and MISR aerosol retrievals, the best strategy of data integration is to assimilate MODIS AOT over ocean (great accuracy) and MISR AOT over land (high accuracy and with complete land coverage) with GOCART simulations. Such integrated AOT is designated as MO_MI_GO. Comparisons with AERONET measurements show that integration increases correlation with AERONET measurements of AOT. In general, the integration decreases GOCART AOT in Europe and increases it significantly over the Arabian Peninsula, Northern Indian Ocean, North Pacific, and West coast of the Southern Africa. On global and annual (2001) average, the integrated AOT is larger than GOCART AOT by 13%.

The integrated aerosol optical depth is then used to calculate clear-sky aerosol direct effect on solar radiation. It shows that the integration increases both TOA and surface cooling by about 20% on global and annual average. Compared to AERONET-based direct effect, integration increases correlation and overall brings the direct effect estimates closer to AERONET measurements. However, significant low biases exist especially for high AERONET AOT conditions and some of these could result from mismatching between points and 2.5deg x 2 deg grids. On-going effort of running GOCART at 1.25degx1deg resolution would help quantify such impacts. Over ocean, comparisons also suggest that the integration improves the agreement with CERES measurements [Norman Loeb, NASA/LaRC] and MODIS measurements [Remer and Kaufman, NASA/GSFC].

Atmospheric Correction over Water and Snow/Ice Surfaces

Knut Stamnes, MODIS Atmosphere Science Team Member, Stevens Institute of Technology

Knut Stamnes presented on Atmospheric Correction Issues over water.

Ocean color data can be used to remotely evaluate water quality; the transport of sediments and adhered pollutants; primary production, upon which commercial fish populations depend for food; and harmful algal blooms that pose a threat to public health and the economies of affected areas. However, reliable retrievals require accurate characterization of the atmosphere, which is a challenging problem over turbid coastal waters.

The MODIS Ocean Color group has adopted two basic aerosol models. The first is a small particle "tropospheric" model consisting of 70% water-soluble and 30% dust like particles. The second is a large particle "oceanic" model consisting of sea salt particles. A combination of these two particle models yields a coastal aerosol model with 99.5% small and 0.5% large particles. This in turn yields four aerosol models – two mono-modal and two bi-modal models. But by allowing for four different relative humidities (50%, 70%, 90%, and 99%), one arrives at a total of 16 discrete MODIS aerosol models with have mono-modal and the other half bi-modal. Comparatively, SeaWiFS employs a subset of 12 discrete aerosol models.

The COVE site sits in waters that change between turbid and almost clear, as well as being surrounded by greatly varying aerosol types and loading rates. Because data show that the aerosols are typically bimodal, they are trying to get away from discrete models. By picking models from the right sets, they get a much better coverage.

A case study of two Swedish lakes focusing on simultaneous retrieval of aerosol parameters, chlorophyll concentrations, and remote sensing reflectances shows that the SeaWiFS algorithm performs rather poorly for this particular area and yields lots of negative remote sensing reflectances (water-leaving radiances). By contrast, the simultaneous retrieval CAO-DISTORT algorithm performs much better and yields reasonable error budgets. Because this bio-optical model applies to the ocean rather than lake water, and the aerosol models are generic rather than site-specific, they find these results encouraging. They conjecture that the CAO-DISTORT algorithm could produce better results with a lake-specific bio-optical model, and with local information about aerosol properties.

For the Air-Water Interface, the questions are: Can they construct a reliable sunglint mask that can be used to screen for sunglint? Given a reliable sunglint mask, to what extent is it possible to correct for sunglint in ocean color imagery? Can a better understanding/description of sunglint be used to our advantage?

There are two important issues to consider. What is the correct sunglint BRDF of a real (wavy) ocean surface? And given the correct sunglint BRDF, what is the corresponding TOA radiance?

The first issue relates to our understanding/knowledge of surface roughness due to winds, currents, etc., whereas the second is related to atmospheric radiative transfer. The

Cox/Munk model is used to treat sunglint (see slides for details), and the direct sunglint approach ignores multiple scattering, thus ignoring the contribution from "skyglint" to the TOA radiance. The total "glint" contribution can be obtained by including multiple scattered sky radiation reflected from the surface and ignoring sky radiation *not* reflected from the surface.

For a given sunglint BRDF it is possible to compute accurate TOA radiances for unpolarized light that can be used to construct a reliable sunglint mask, and thereby extend the region of sunglint-corrected imagery by including the effect of multiple scattering on the TOA radiance.

Remaining questions include: Is the Cox/Munk distribution of slopes presently used for surface BRDF adequate? What measurements are needed to improve the situation? Can they use polarization to improve our treatment of scattering effects? Can they use sunglint as a "known" source at the surface to help us retrieve atmospheric properties and thereby improve "atmospheric correction" of ocean color imagery?

Third Plenary Session (Afternoon Day Three)

Oceans Group Summary

Chuck McClain, MODIS Ocean Science Team Leader, NASA Goddard Space Flight Center

Chuck McClain reported on the current status & progress of the Ocean Color Team since the July 2004 Science Team Meeting.

MODIS/Aqua OC Processing:
L0 to L3 processing is fully supported in SeaDAS (Mac support is now available). The major differences between SeaWiFS & Aqua MODIS have been resolved (seasonalities and longer time trends). Reprocessing was recently done after several months of algorithm testing and evaluation, and OBPG is working on reducing striping in L1 & L2 data (mirror-side & detector-to-detector calibration consistency) in collaboration with MCST:

- o Refinements in solar and lunar calibration data analysis.
- o Refinements for atmospheric corrections.

Calibration & Validation:
Jim Mueller & Carol Johnson are leading a calibration/validation working group on error budget & future measurement strategy (e.g. coastal zone). A workshop on this was held at the NIST in November 2004.

Product Suite & Algorithm selections
Algorithm teams were established at a July Ocean Color meeting. A comprehensive chlorophyll algorithm development data set is to be released very soon by the OBPG, and a draft document describing the data set and QC procedure has been completed and is to be submitted for publication. The Ocean Color team held a two-day workshop on this in February 2005. There are issues, however. There are inadequate validation data sets for many products (e.g. inherent optical properties), so they need to solicit additional data from community. There are also limited data sources, e.g. calcite. Product recommendations are to be vetted with the community at an Ocean Color Research Team meeting in April with subsequent generation of new products by the OBPG.

- For chlorophyll, Janet Campbell is to host an algorithm selection/data analysis mini-workshop.
- The K(490) revise algorithm has been recommended, which addresses an algorithm problem in clear waters.
- Mike Behrenfeld is developing a primary productivity website and will recommend a baseline algorithm.
- Barney Balch is to select from two published algorithms on calcite once more validation data from recent cruises is processed.

· The Clark algorithm for POC has been recommended, but algorithms by

- Stramski are being considered and compared with the Clark algorithm. Watson Gregg & Robert Frouin are to provide sensor-specific & multi-sensor based PAR products.
- The IOPs (absorption & scattering products) are still to be determined due to issues of overall data quality that have been raised.
- For SST, the Miami group continues extensive field data collection and refinements in product continue to address both sensor & atmospheric error sources. They are coming up with good strategies for removing aerosol biases from SST.

Atmospheric Correction:
Menghua Wang is working on using 1260 & 1640 nm bands for turbid water corrections (black ocean assumption). The Miami group has demonstrated a methodology for incorporating Saharan dust detection & spectral matching into the atmospheric correction algorithm in standard processing.

MODIS/Terra:
Several team members have expressed a desire for Terra Ocean data processing, and the team members are to provide justification to Bontempi. HQ will consider this pending continued progress on Aqua MODIS, budgets, and other considerations.

Atmospheres Group Summary

Michael King, MODIS Atmosphere Science Team Leader, NASA Goddard Space Flight Center

Michael King gave a summary of the Atmospheres Group's work since the last Science Team Meeting. The difference between this science team and the previous one is unbelievable: there are now 35 atmosphere team members, where before there were only five.

Collection 5 Status
There were a number of modifications and enhancements made in Collection 5 (they are mostly covered in posters). They are ready to commence with processing in early April 2005, and they have already identified enhancements for Collection 6.

Data use and validation investigations showed new uses of MODIS data, and produced 25 presentations for this meeting. MODIS Direct Broadcast is exploding worldwide, and new software is planned for AIRS and MODIS data this year.

All Collection 5 software has been delivered to SDST/MODIS. Science test number four was completed Monday March 21, 2005. There were major enhancements in cloud mask (especially in the night time and Polar Regions). The cloud product has had changes to ice crystal libraries (new), phase determination, atmospheres/land surface reflectance product, atmospheric correction, uncertainties in cloud optical thickness, effective radius, water path, and improved cloud top pressure (especially in low clouds). The aerosol product uses new spatial variability tests to improve the screening of heavy aerosol and clouds, and does better regional characterization of aerosol optical properties. In addition, water vapor over high dry regions, like Tibet, has improved in the near-infrared algorithm.

Collection 6 enhancements have been identified for aerosols, including the new Deep Blue algorithm for bright desert regions.

A very interesting and illuminating study of the Mt. Hekla Eruption was done by Matthew Watson. Christina Hsu's Deep Blue Algorithm tracks movements and evolution of aerosols using a traditionally ocean band to track dust optical properties over deserts. It was tested and published last year in IEEE Transactions on Geoscience and Remote Sensing; it is promising enhancement for the Aerosol product in the future (Collection 6).

Miscellaneous Progress:
Direct Broadcast is exploding internationally. New software at Wisconsin will incorporate MODIS cloud, snow, reflectance, and BRDF products, AMSR-E precipitation, and high resolution AIRS/MODIS analysis in 2005. Kenya has a DB receiving station in Malindi; data are received on the ground and sent by tape to Rome, but the facility was previously unknown by NASA or the Wisconsin/IMAPP group until Michael King's visit in early March.

Applications: the IDEA project (NOAA/NASA/EPA) is using MODIS data and EPA's PM2.5 data to input into air quality monitoring in the US. MODIS polar winds are being used by ECMWF, GMAO, NCEP (June), Japan, and Canada.

There were several data assimilation and modeling investigations described that are showing great progress, such as a new clear-sky radiance dataset being developed for ingest at ECMWF.

Land Group Summary

Chris Justice, MODIS Land Science Team Leader, University of Maryland/College Park

Current Issues and Priorities

- Broadening MODLAND in the framework of the focus area measurement teams and land data processing following the Ocean Color model.
    - Recognizing important land building blocks, e.g. Val LPV, QA LDOPE, Land RR, LADS, ORNL subsets, DAAC data pool, VIIRS Land PEATE, REASONS, e.g. Land LDTR, GLCF, LEDAPS, TRFIC
- Collection 5 Testing
    - Greater emphasis on product testing prior to production
    - Development of LADS (data distribution) of test data – land equivalent of the Atmospheres (AADS)
- Validation
    - Continuing Stage 2 validation
    - Where possible, engaging users in the process of validation
    - LPV WG gathering momentum – transition to IGOS/GEOSS
- New Recompeted Land products
    - SCF Product Demonstration / Proof of Concept underway
- Continued Community Outreach
    - Publication of results
    - They need to keep User Guides and Websites current.
    - Handle NSFAQ and requests as best they can
- Recognize ramping down of MODIS SDST and MCST (support services)
    - Decrease staffing / broadening responsibilities
- Distribution and Archive
    - Continued growth in users and distribution from the DAACs (EDC, NSIDC)
- Hard to keep track of all the new developments in the use of MODIS Land products
- MODIS Land DB
    - Real demand for information, code, advice
    - Need to build a self-help community – lateral tech transfer
    - Prepare for NPP VIIRS
    - Land DB workshop proposed, but there is a question of timing. A broader community DB meeting planned for Italy in October of 2005.
- Continue to integrate Land prods into NASA Applications
- Need to raise the Community Voice
    - Strong advocacy for NASA Earth Science
    - Terra Extension
    - LandSAT Continuity issue
    - International Cooperation, e.g. GOFC/GOLD, IGOL, CEOS LPV

Showcases (see slides for details)

- NSIDC, LP DAAC, Goddard DAAC data volumes, monthly distributions.
- Tracking of snow-cover depletion curves use in famine early-warning in Afghanistan.

- Land bands used for coastal water biophysical parameters retrieval. Correlate that to coastal water suspended solids.
- Improving 500m white sky albedo.
- New Refinements in the V5 Daily MODIS LST PGE code (PGE16). This will be seen in Collection 5.
- NDVI based parameters: the core products are developed, and people are starting to generate higher-order products now.
- MODIS Vegetation Index sees Amazon Rainforest "Green up" in Dry Season and Dry-down in Deforested Areas
- Dry vs. Wet season changes in LAI based on 2000-2004 monthly composites
- Global Net Primary Production (MOD17) Anomalies 2000-2003
- Terra Mean Fire Radiative Power, which is becoming a global product
- Land Rapid Response, which continues to give high visibility to the applications community

Land Measurement Team – Earth System Data Records

Earth system data records (ESDRs) are observations of a parameter of the earth system optimized to meet the requirements to address earth science questions and to provide for applications. The initial ESDRs/CDRs have their priority derived from the importance of end uses, and requirements are derived from end user needs (e.g. science questions, applications, and decision support). These will engage the relevant agencies: NASA, NOAA, USGS, USDA, etc. They will be compatible with other frameworks, e.g. GTOS, GCOS, and will be consistent with records managed by other measurement teams. They will also be linked to historical measurements for continuity.

Land ESDR/CDR White Papers

These will describe a candidate ESDC/CDR. They will be 1-5 pages, and will be submitted during the summer of 2005. They will cover the scientific rationale and importance, expected end uses, and implied requirements, including temporal and spatial resolutions, accuracy, and precision. The approach will cover a number of areas:

- Algorithms, processing/reprocessing, calibration/validation, product dependencies
- Supporting activities, tasks
- Feasibility, reliability, algorithm maturity, heritage
- Relationships to other products

The initial topics will cover reflectances, surface temperature, land cover, snow cover, albedo, vegetation indices, LAI/FPAR, primary productivity, and fire. They will also be liaisons to surface hydrology ESDRs/CDRs.

General Considerations

There are a number of general considerations. Low level and high level products are involved in ESDRs:

- Higher level products depend on products such as reflectance and vegetation index;
- A hierarchical organization is useful; and
- White papers would be structured accordingly in terms of requirements.

Explicit attention will be paid to error, uncertainty, and precision rates as required in product definitions and production. There is the issue of consistency between land subgroups and ESDRs, which are important for the modeling community. They need to not only define the ESDR but make the case as to why it's critical to the program. They need to consider what will be needed to create the retrospective data record, and grouping by modeling objectives is desired.

Next Steps

They need to pay attention to the bigger picture, e.g. Terra extension, LandSAT, and GEOSS. They have to look for ways to do things better, faster, and cheaper, including utilizing the resources they have to the greatest effect. Some mid-course correction may be needed. They have to gather momentum on the Land Measurement Team and CARS – including specifying the needs and rational as soon as possible. Developing a schedule for the new product ATBD reviews is important, as is looking for opportunities to support HQ initiatives, e.g. NACP.

NASA HQ Response

Paula Bontempi, MODIS Program Scientist and Manager, NASA HQ Ocean Biology and Biogeochemistry Programs

Bontempi briefly touched on a few issues mentioned over course of meeting and in summaries. The summaries are very nice; Justice hit a lot of the "big-picture" items they need to think of. There are lots of interesting ideas/uses in the groups, and lots of progress on research and proposals, in addition to algorithms, has been made in a short amount of time.

It is nice to see all the work on Aqua MODIS Ocean Data, and it's encouraging to see that people want to get Terra MODIS Ocean data as well.

The MCST session apparently went really well; the next objective is to sit down with the leads of those sub teams and make sure HQ understands their progress, issues, and see if there are opportunities for integration across disciplines. That's something the team really needs to push.

There are lots of Aerosol measurements – are other disciplines taking advantage of those measurements, and using them in their own work?

Regarding the first day brief talk on the fiscal 2005 budget, HQ is working on it as fast as they can, and will keep the team posted. They want to make it as seamless and painless as possible.

The ATBD review is very important, and you need to come up with suggestion/progress to do that since you are already 1/3 through the funding cycle. It is also important that the program managers from NASA HQ are involved.

It is nice to see the broad uses of data in the past, and see it all over the place by all kinds of people. The impact this team is having on real events is amazing and shows a good bit of progress.

Several people have asked about ROSES, and it is very important to understand what that is. All yearly solicitations will be incorporated into one announcement for the omnibus of space science. When it comes out in January (it will be very long) pay attention to it. The science you are interested in will be in there, but look around at other areas because there might be more than just one opportunity for funding.

Thank you for sticking around; the MODIS team has made really nice progress.

Closing Remarks

Vincent Salomonson, MODIS Science Team Leader, NASA/Goddard Space Flight Center

Salomonson thanked the MODIS Administration Support Team for their efforts, and the Science Team members for their efforts, presentations, and posters. They've seen a very rich set of results. They received lots of help for the Terra extension proposal, and now there is a lot of interesting new stuff to include.

Earth sciences have merged with the space sciences, and there are new opportunities to corroborate our results. They need to get our stuff in refereed journals. The use of our products is growing now that they're firmly established, but they need to keep up the user guides and ATBDs.

The future looks good; Terra and Aqua are working, and the systems are merging into NPP/NPOESS.

At the next meeting they want to emphasize the science and applications with posters and presentations as a way to keep people's attention. It will be in six months to less than a year from now, probably toward end of the calendar year.