NASA GODDARD SPACE FLIGHT CENTER

Improving access to Land and Atmosphere science products from Earth Observing Satellites: helping NACP investigators better utilize MODIS data products.

In response to

NASA's RESEARCH OPPORTUNITIES IN SPACE AND EARTH SCIENCES (ROSES) – 2005, NNH05ZDA001N, Appendix A-26: Advancing Collaborative Connections for Earth-Sun System Science (ACCESS)

A proposal to leverage off of Goddard Space Flight Center's MODIS production facility, Atmospheres Archive and Distribution System (AADS) and the Land Archive and Distribution System (LADS) to serve the remote sensing needs of the North American Carbon Program as a: "Data and Information Systems Support for Science Focus Areas and Applications"

Principal Investigator
Jeff Morisette

Co Investigators:
Robert Wolfe
William Ridgway
Michael Teague
Edward Masuoka

MODIS Adaptive Processing System Team
NASA Goddard Space Flight Center
Greenbelt Maryland, 2077

May 20, 2005

Table of Contents

Summary of Personnel and Work Efforts

Work Commitments in Months per Full Time Work Year

	Year 1	Year 2	Year 3 (optional)
Jeffery Morisette	2 Mon / Year	2 Mon / Year	2 Mon / Year
Robert Wolfe	1 Mon / Year	1 Mon / Year	1 Mon / Year
Bill Ridgeway	1 Mon / Year	1 Mon / Year	1 Mon / Year
Michael Teague	1 Mon / Year	1 Mon / Year	1 Mon / Year

Science/Technical/Management

Abstract

The problem

The North American Carbon Program (NACP) is currently a major component of NASA's carbon cycle and ecosystem research focus. However, serving on, and interacting with, the NACP science steering group, as well as the ad-hoc group on Remote Sensing for NACP and the task force to coordinate NACP's mid-continent intensive campaign has made it clear that NASA's Earth Observing System (EOS) data products are not being used to their full potential within NACP.

The solution

NASA's Goddard Space Flight Center is operationally producing global product from the Moderate Resolution Imaging Spectroradiometer (MODIS). This is done within the MODIS Adaptive Processing System (MODAPS). The related software operates on a cluster of multi-mission processing systems supporting several research teams. Two recent extensions of MODAPS, which were developed for archive and distribution of MODIS products, are the Atmospheres Archive and Distribution System (AADS) and the Land Archive and Distribution System (LADS). AADS and LADS offer new opportunities for custom processing and distribution of MODIS products.

The goal of this proposal is to leverage, extend, and tailor the functionality available through AADS and LADS to serve the remote sensing needs of the North American Carbon Program as a: "Data and Information Systems Support for Science Focus Areas and Applications". The purpose of these enhancements is to streamline access to MODIS atmosphere and land data products, to reduce data volume by providing only those data required by the user, and to improve the utility of data products. The proposed work will provide NACP investigators with a time series of MODIS products and custom preprocessing that will allow for direct ingest into an investigators modeling framework. By reducing the burden associated with ordering and pre-processing of MODIS products, we will enable NACP investigator to focus on the information content in MODIS data and its contribution to understanding carbon budgets.

Anticipated Benefits

This proposal will serve key researchers within the NACP who have an urgent need for enhanced support of MODIS data. The needs of this group will be representative of the larger climate modeling community and other land and atmosphere researchers; and the tools developed for them can be implemented in an operational system to serve this wider community.

1. Project Overview

Our proposal is to develop an advanced data access and distribution component of a measurement science data and information system. It addresses a key area of the solicitation:

> "It is widely recognized from past practices that a single, "one size fits all" science data and information system rarely can satisfy all the broad requirements of the land, oceans, and atmosphere research communities." (ROSES/ACCESS Solicitation)

Our approach is to focus on a very specific research community, the North American Carbon Program (NACP) investigators, and work closely with and for that community to build a system that delivers products that meet their specific data needs. After the first year, we will engage the wider research community in order to focus on the capabilities that have a broad user base. We will make these new interfaces and capabilities available to the broader research community.

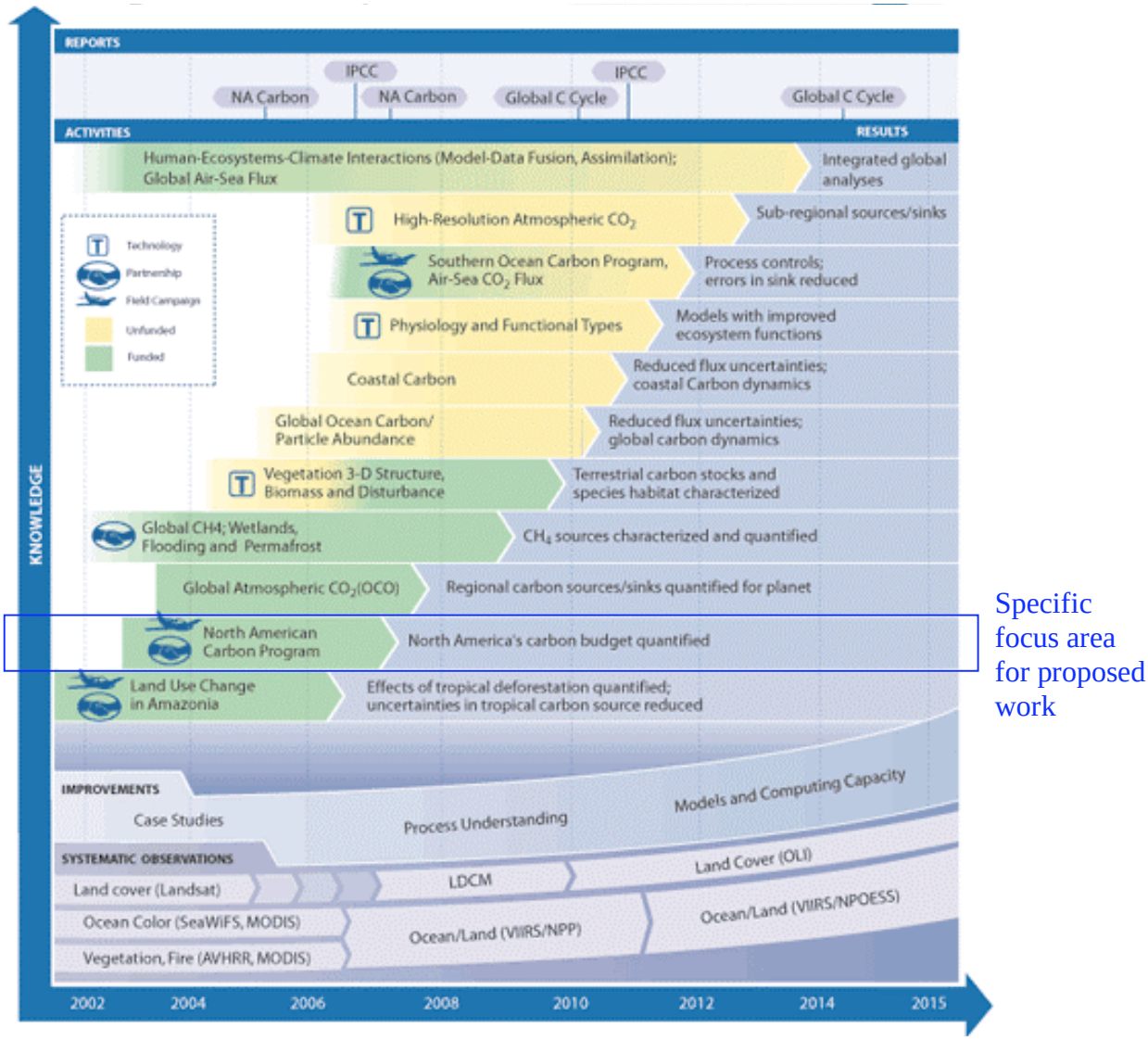
Because of our background in processing and distributing NASA's Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) land and atmosphere products and interactions with NACP we are in a unique position to address another key area of the solicitation:

> "Proposal selected from the ACCESS solicitation are expected to *rapidly bridge specific gaps* in existing information system and services that support NASA Earth-Sun system science investigation and applications… NASA ESSD seeks proposal that *address particular known challenges* in the development of science data…" (ROSES/ACCESS Solicitation, emphasis added)

We will be leveraging our extensive experience in rapid deployment of new data processing capabilities and with our understanding of MODIS algorithms and products. We will also be building upon the capabilities already developed for MODIS data processing and distribution.

In referring to NASA's "Carbon Cycle and Ecosystem" roadmap, one of the components that corresponds to the funding cycle for this ACCESS solicitation is the NACP, see Figure 1. NACP is designed to provide the scientific underpinning to inform future policy decisions involving the carbon cycle, such as managing carbon sources and sinks by efficient and effective options to reduce emission or enhance carbon sinks (Wofsy and Harriss, 2002). Information from earth observing satellites plays a major role in providing spatial and temporal information required to address the carbon accounting sought by the NACP. The programs hopes to capitalize on the information gained from the current generation of satellite data. In particular, MODIS is expected to play a major role in regional and global analysis inherent to NACP. In fact, MODIS is mentioned explicitly 15 times in the NACP committee's report to the Carbon Cycle Science Steering Group (SSG) (Wofsy and Harriss, 2002) and 25 times in the Science Implementation Strategy for the North American Carbon Program (Denning et al., 2004). However, current NASA-funded NACP investigators are experiencing significant challenges in their attempts to utilize MODIS data. Our discussions of this issue with these investigators have led to a strong interest in our approach that they feel with satisfy their needs (see supports letters from Denning and Wofsy). The "one-size-fits-all" tools that have been developed do not address NACP investigators particular needs. The tools provide a fraction of the functionality needed and there remains significant overhead involved with ingesting and processing MODIS data for a particular use. The additional effort required to process the MODIS

products is often prohibitive. The result is that MODIS data are not currently serving to their full potential within the NACP.



Specific focus area for proposed work

Figure 1. NASA's Carbon Cycle and Ecosystem Roadmap.

The PI on this proposal serves on the NACP science steering group, as well as the ad-hoc group on Remote Sensing for NACP (Steve Running, chair) and the task force to coordinate NACP's mid-continent intensive campaign. This experience has made it clear that:

1) some very simple tools (such as subsetting or mosaics) would go along way in getting MODIS data into hands of NACP investigators;
2) several NACP investigators are currently utilizing MODIS data but need assistance with the more involved preprocessing routines (such as filtering by quality assurance bits and gap filling within a time series).

The co-Investigators on this proposal are directly responsible for the production of MODIS products and have extensive experience with the production of MODIS products for the broad research community We also have a long history of delivering MODIS higher level products to the

MODIS science team and validation researchers. This experience gives us a unique capability to respond to the NACP user needs.

Our strategy is to offer a wide range of processing capabilities (described below) to be applied to any of the MODIS land and atmosphere products for a focus group of NACP investigators. This would involve 5-10 investigators in year one. During this first year we will develop the capacity to provide these investigators with very specific products that precisely matches their needs. In year two we will expand the number of users to ~30 while assessing which requests/tools are most common among users. Year three would then develop an operational capacity for the most requested and/or critical tools.

In addition to the NACP concerns, atmospheric researchers have also identified "gaps" in the data distribution process:

1) parameter reprojection onto fixed grids as specified by the user including day-to-day time series on such grids;
2) custom products that combine satellite parameters and simultaneous ancillary meteorological data such as wind fields;
3) a menu of product and image formats that will allow common projections of data acquired from various sources; and finally
4) a mechanism for machine-to-machine ordering that makes most web-based functionality available for scripted procedures.

The research community requires that EOS platforms provide regional time-dependent parameters as well as long-term global data for climate studies. Regional analyses like NACP are connecting atmospheric constituents (mainly greenhouse gases) with surface processes on the land and ocean. MODIS data are key to providing detailed spatial and temporal information about the surface condition and dynamics (Denning et al., 2004) as well as refining physical models of diverse phenomena such as aerosol/cloud interactions, radiative forcing and aerosol/chemical transport (Chin et al., 2004). We are proposing to address a major challenge for researchers, namely, acquiring EOS data at suitable spatial-temporal resolutions and in formats consistent with data integration into model studies.

Our approach meets the solicitation call for a "community-based processing system". Previous tool developers have attempted to meet users need, yet there remain significant gaps. At the risk of this proposal being considered too narrow and only serving a small community, we believe there are two strong points to justify our approach:

1) The relatively small group we are serving are key researchers within the NACP and they have an urgent need for enhanced support of MODIS data.
2) The needs of this group will be representative of the large community that include climate modelers. The tools developed for them can be implemented in an operational system to serve a much wider community.

Our approach provides a low-risk, low-cost, user-directed approach to develop a land measurement-based processing system (akin to the Ocean Color Measurement System (Lavender and Groom, 1999)).

2. Current and Proposed Methods for Utilizing MODIS Products

To help explain the need for the proposed work, it is illustrative to go through an example of what is required for investigators to utilize MODIS data. Consider the case where a research user

needs a statistically clear signal of the year-to-year vegetation variability over North America. The user may want to utilize the 6 years of the standard 1km MODIS/Terra vegetation index (VI) product. The user would like to include the MODIS quality assessment (QA) information in the analysis to filter the data both temporarily and spatially. The end-product is a time series of the vegetation index signal across the US. The user wants the data in the standard map projection and grid to match their modeling system.

The current way of doing this involves setting up a processing environment to:

- hold and process the data,
- order the data and download it through NASA's Earth Observing System Data Gateway (EDG),
- utilize tools, and building others, to generate the products, and finally,
- producing the time series of interest.

Key obstacles the user encounters in getting this data are:

- volume (both size and number of files) that impacts both download speed and local storage resources,
- labor intensive data ordering and retrieval,
- finding, installing and mastering or building the required tools, and
- understanding detailed product QA information.

Just ordering the data is a major undertaking for most researchers. The volume for 6 years of 1 km MODIS/Terra VI data over North America is 1013 GB stored in 7314 individual files. MODIS land data products are stored as 1200 by 1200 km "tiles" in a sinusoidal grid. The tiles covering North America are shown in the upper left of Figure 2. Each data granule represents one time-step (e.g. a 16 day composite for the MODIS VI products). Acquiring the MODIS VI data over North America involves placing an order for the 53 tiles for each 16-day period. Due to the EOS Data Gateway (EDG) limitation on the data volume per order, it would take 138 orders to get the entire time period. Each order will consist of 7.34 GB and take about 1 hour to download (@ 2 MB/sec). If the user orders and downloads continuously for 8-hours a day, it would take about 20 days to get the entire data set. Once all of the data are local, the user must find or build the tools necessary to process the data. The QA data for MODIS products are "bit packed". Even if the user has the tools to unpack the QA bits, it is often not clear to the user how to make use of the QA bits for filtering the data. Tools do exist to reproject the data and perform some operations on the QA bits. However, these tools are standalone and are integrated in the data order system. The user has to spend resources downloading the tools, installing them, and learning to use them. Because most tools are not designed to work end-to-end the user is likely to have to develop software to convert the output of the existing tools so that it matches the input format expected by another program. Further, it is likely that the ultimate application will require additional tools to perform some specialize functions. For example the user might want to eliminate the MODIS VI data with poor quality and do some temporal interpolation to create a reasonable record. The result is very significant overhead for investigators to utilize MODIS products appropriately. Figure 2 provides a diagram for this example.

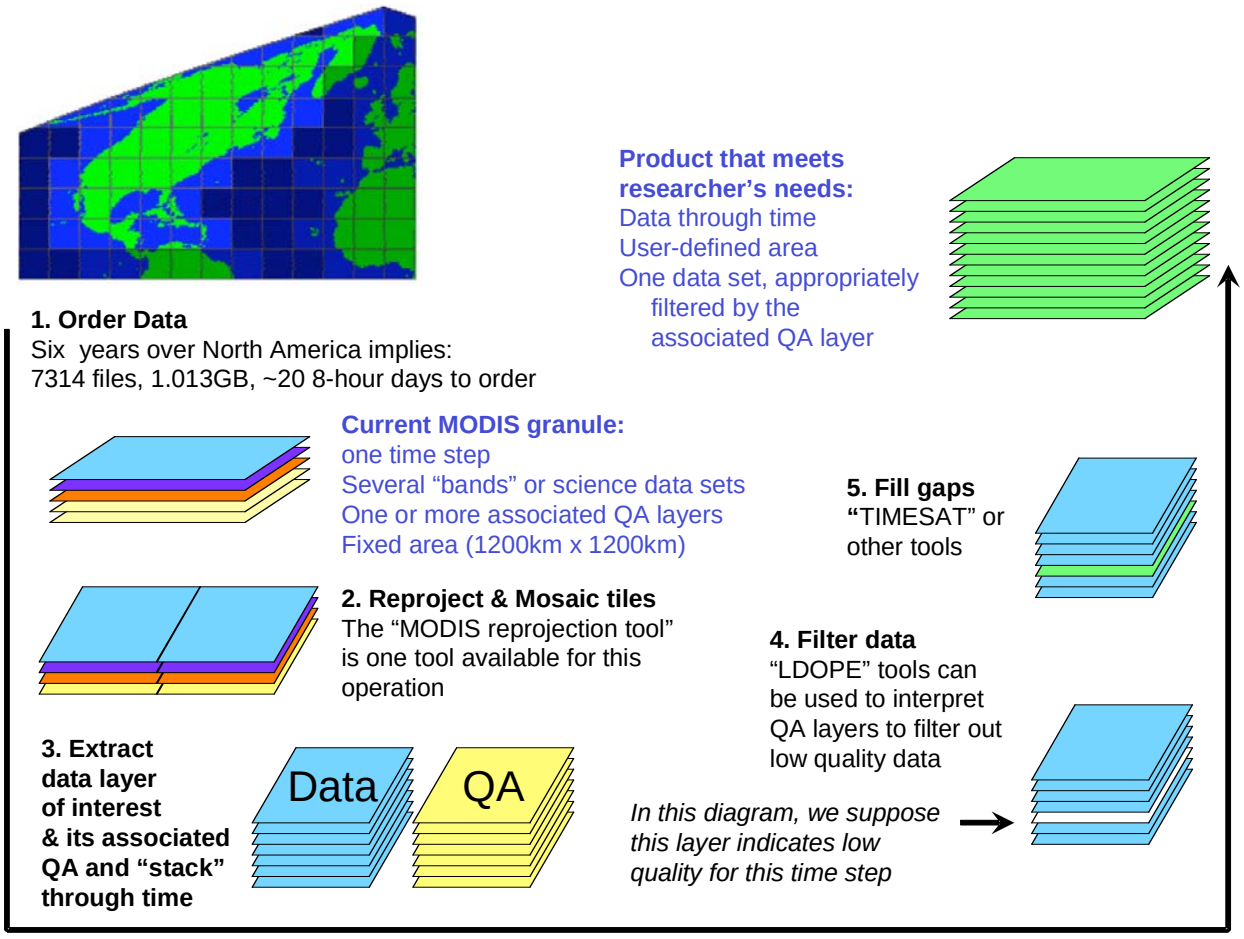


Figure 2. Current steps needed to process MODIS data to obtain a vegetation index time series over North America.

Our proposed way of doing this is much simpler. By having the entire time series of all of the MODIS atmosphere products globally and MODIS multi-day land products over North America available on-line and having a system architecture that allows multiple pre-processing services, our proposed system will conduct the majority of pre-processing step in a way that is transparent to the user and delivers the use not just what they want, but also nothing the do not want. The user first goes to our web site and interacts with it to describe the steps that are needed to produce the needed product. For typical users this step should take less than an hour. The user will be able to use the default values for each step or drill down and tailor the algorithm's user parameters so that it matches the user's requirements. Once this is done, the user submits the request and the system responds by sending an email notification of the request's acceptance and an estimate of the amount of time it will take to generate the products. Based on the user's preference, the system will send email notifications to the user relating the product progress and completion. The system is sized so that about 8-10 users can use the system simultaneously and so a typical job of this type should take about 2 to 3 days to complete. The user can then pick up the results from the system. Only the end product needs to be downloaded, the number of files being 53 times smaller and the volume 25 times smaller.

Figure 3 shows a three-year time series of the MODIS Normalized Difference VI (NDVI) time-series – taken from a 250 pixel in Rocky Mountain National Park. Due to variations in viewing

geometry, sky and cloud properties, and surface conditions, the time series clearly contains some noise. Some of this can be removed by eliminating the values for which the quality assessment layers indicate poor quality. In Figure 3 the dark **x** values represent data for which the QA layer indicated cloud cover. We can remove those data from the time series and use filters or functions to derive an annual curve. This annual curve can then be used to derive phenology metrics that are useful for ecosystem and climate modeling. We propose to provide this gap filling and curve fitting for any of the MODIS land products of interest to the NACP investigators.

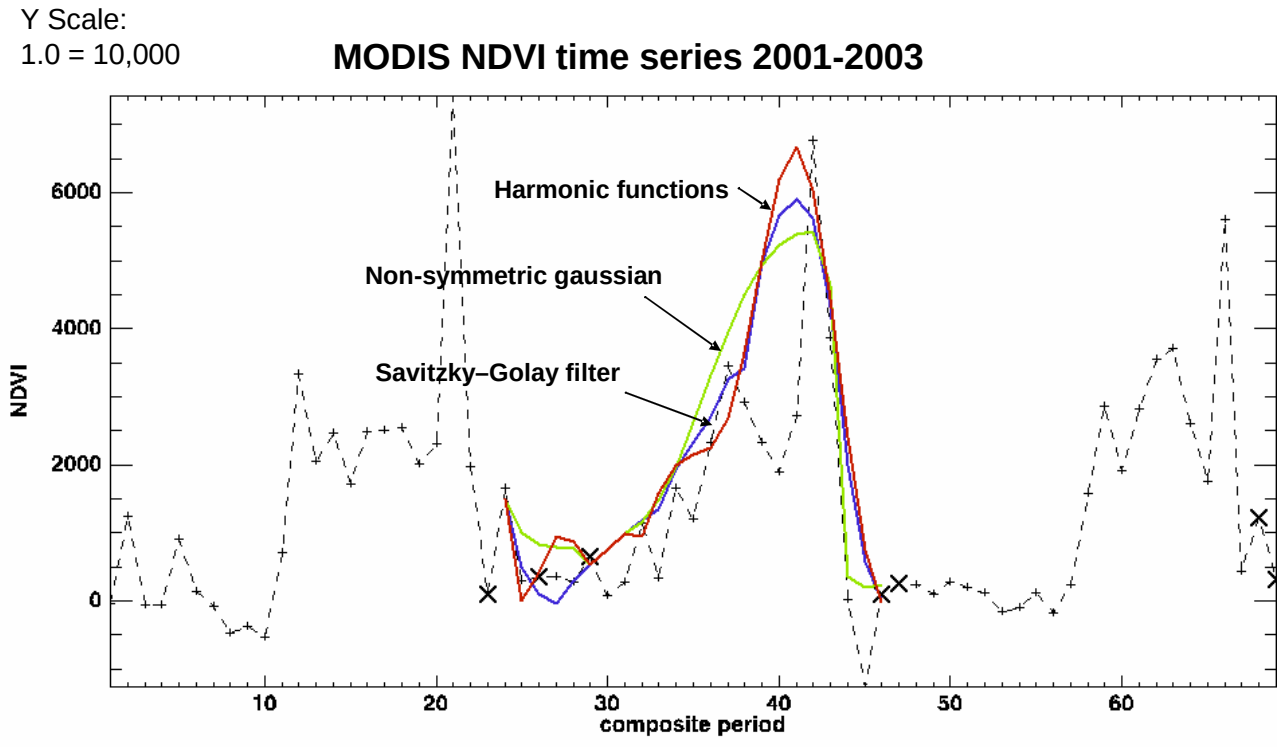


Figure 3. Example functions that can be use to "gap-fill" QA-filtered data. The three methods are Savitzky-Golay, Non-symmetric gaussian, and Harmonic analysis follow Jönson and Eklundh 2004.

3. Our Current MODIS Archive and Distribution Systems

The MODAPS processing system has taken a major step forward by distributing all MODIS Atmosphere products and many multi-day Land products immediately via ftp download. Thus, any researcher with sufficient network connectivity can pull standard MODIS product files in their native HDF-EOS format with their standard grouping of parameters. Additional filtering and subsetting by geographic region, time interval, and by parameter is also currently possible via a web order interface.

The purpose of the Atmospheres Archive and Distribution System (AADS) and the parallel Land Archive and Distribution System (LADS) is to provide the respective science communities with rapid and flexible on-line access to large volumes of MODIS data from the Terra and Aqua spacecraft. The systems have taken advantage of the fact that the cost of disk has reduced sufficiently that it is now cost effective to retain several tens of terabytes of data on-line. To date, the

systems have been used for two purposes in support of the most recent MODIS Collection 5 (C5) reprocessing of Terra and Aqua data. First, in preparation for the reprocessing, a series of comprehensive science tests were performed to enable the algorithm developers to evaluate updates to their codes and to test the effects of these updates on downstream algorithms. These science tests generated between 3 and 20 TB of data products that were ingested into the AADS/LADS to expedite the developers' evaluations. Second, starting in May AADS has been used as the archive and distribution mechanism for the reprocessed C5 atmosphere's products. All Level 2 (L2) through Level 4 (L4) products including aerosol, cloud, water vapor, and L2 and Level 3 (L3) granule and global browse are being archived. By January 2006 the atmospheres C5 reprocessing will be completed and the archive will contain approximately 9 data-years of Aqua and Terra data requiring almost 40TB of disk storage. The archive also contains Collection 4 (C4) L3 data and will contain forward processed C5 data that is approximately 1 day behind real time. The land data volume is more than an order of magnitude larger than atmospheres and only the 8+ day C5 products will be ingested into LADS. The land C5 reprocessing is scheduled to start in late 2005 and will be completed in early 2007. AADS may be accessed at http://aadsweb.nascom.nasa.gov/ and LADS at http://ladsweb.nascom.nasa.gov/.

A key element to the approach used for AADS/LADS is that continued development of the system has occurred in response to the requirements of the atmospheres and land communities. Although the present systems have been restricted to supporting a limited number of users for science test purposes, significant feedback has been obtained from these users and the systems have evolved considerably since the AADS prototype was demonstrated in November 2004. This process is expected to continue and to expand as AADS/LADS moves into the C5 reprocessing phase when the number of users will increase very substantially. Further, the extensions currently proposed in Section 5 for AADS/LADS are directly related to requirements of the NACP and the modeling community at large, which requires more ready access to the MODIS data.

The following is a summary of the present AADS/LADS capabilities:

- A web-based search and order system allows the user to identify and acquire MODIS land and atmospheres data sets based on user-defined criteria. Searches can be performed on Collection number, time interval, spatial criteria using a "rubber band", and day/night coverage. The results of searches are available in seconds even under heavy system load.
- The user can search the L2 and L3 browse images. The granule browse images may be displayed in "thumbnail" or expanded form and side-by-side displays of user-specified parameters can be made.
- Data acquisition uses ftp pull and options include direct access to the distribution archive for experienced users, the use of staging directories, and download using GNU Wget. Following data order, the instructions for the ftp pull are available in seconds even under heavy system load.
- Parameter subsetting (i.e. the selection of specific parameters within a data product) and geographic subsetting (i.e. the elimination of unwanted data outside of a specified geographic region) may be performed. These subsettings may take several minutes to perform and the user is provided with e-mail notification when the products are available.
- The systems maintain comprehensive metrics concerning the products and data volumes ordered and the affiliations of the users.
- Password protection is available and has been used for science test products that are not appropriate for wide distribution.

The systems contain extensive help functions and experience has indicated that users become familiar with the systems in less than 15 minutes.

Future builds will include the ability for users to submit queries through a machine-to-machine interface to enable users to automate the order process and software applications to access the MODIS products.

4. LADS/AADS Architecture

The LADS and AADS product distribution systems are based upon the MODIS Adaptive Processing System (Masuoka et al., 2001) whose architecture is illustrated below in Figure 4. In LADS and AADS, users interact with a web page developed in HTML and Java script (for active components). When a user submits a request for products which meet specific criteria (geographic coverage, time of acquisition, cloud cover, etc.) via the web page, a file containing the search parameters is passed to a Perl script which queries a database containing the metadata for all products in the distribution system and then writes the list of files resulting from the query to the appropriate fields in the web page. Once the information on the web page is updated, the user may order one or more files as they exist in the online archive or request some or all of them be transformed by post-processing on the storage nodes that hold the files. When a user submits an order through the web page, a Perl script reads the information in the order and performs the operations required to fill the order. For files ordered in their original format the script will either return the paths for all requested files in the online archive or within a second or two create links to the requested files in a temporary staging directory for the order and return the staging directory's path to the web page. If files need to be transformed through post-processing, the Perl script will calculate the length of time required transform the files and provide an estimate to the user. Based on the estimate, the user may choose to alter the request or submit it for processing. Once the request is submitted processing, the Perl script will submit the required job to transform the files to the Master Scheduler on the web server and send an email to the user indicating that his request has been submitted for processing. The Master Scheduler updates task queues in the database for the storage servers on which the files to be transformed reside. On each storage server, a Controller process monitors its task queue in the database and runs jobs in the queue on a first-in first-out basis. When all jobs that make up the order have completed, the last step in the task running in the Master Scheduler is to send an email to the user indicating the files have been transformed and are available on a temporary staging directory created for the order.

To maintain security for storage servers within the distribution system, all ftp traffic is tunneled through the server hosting the search and order web site and it handles all user interaction. While it appears that the archive is one large disk system to the end-user, in reality file systems on individual storage nodes are NFS-mounted to the web host with read-only permission and the storage servers are attached to a private network which not accessible to general users.

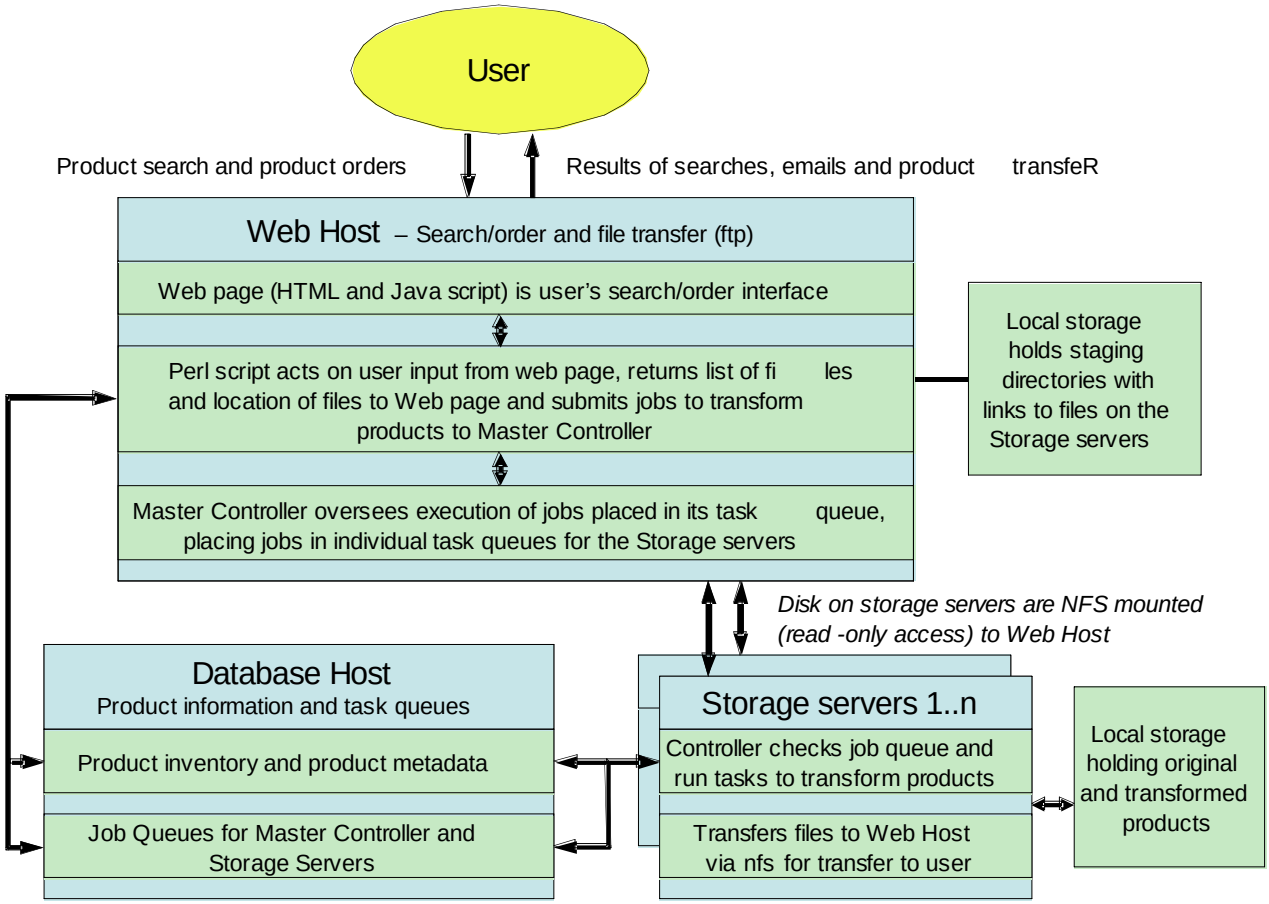


Figure 4. Architecture of the product distribution system.

5. Proposed Tools and Services to Support NACP Investigations

System Overview

The proposed project will build upon capabilities developed in the AADS/LADS system to provide products tailored to the NACP users and then make the capabilities available to the broader research community. The first step in the process is to work with the users to better define their needs. Part of the development effort will involve evaluation of tools that already exist to perform the needed functions (e.g. HDFLook, MODIS Reprojection Tool (MRT), and HDF-EOS to GeoTIFF converter (HEG)).

Task Plan

The following proposed changes to the AADS/LADS are in direct response to requirements identified by our target user community within the NACP and atmospheres discipline. These changes represent the transition of the AADS/LADS from archive and distribution systems to ones that include product analysis capabilities. Consequentially, the Atmospheres and Land Archive, Analysis, and Distribution System (ALAADS) is introduced for this proposal. The time phasing of the changes to AADS/LADS are identified below in the Schedule and Deliverables section.

We plan to combine these capabilities in sequence to allow the final data set to be tailored to the users' needs. For instance, a user may need an aggregated 5 km resolution data set of the surface

reflectance product in a NACP standard grid and in the GeoTIFF format. To generate this product, ALAADS would retrieve the MODIS global grid tiles that cover the area of interest, mosaic the tiles together to form a single regional image, reproject the data to the NACP map projection and then aggregate the product to the user specified resolution and then convert it to the GeoTIFF format. The web-based interface will be designed to minimize the need to be aware of the individual steps needed to generate the end product, but will also allow sophisticated users to drill down and modify individual steps to obtain products that meet their more specific needs.

Requirement collection and refinement

The first phase of the project will be to interact with the NACP community to collect and refine the requirements of the ALAADS so that the system meets their needs. One way we will do this by contacting individual scientists and the key people on their teams that are tasked with dealing with acquiring and using MODIS data. We will also ask to participate at any NACP Science Team meetings and/or other forums so that we can present our understanding of the requirements to groups of scientists and get their feedback on how the requirements can be tailored to fit their needs.

Reprojection

One of the key needs for regional studies such as the NACP is to work with a regional, not a global map projection. There already is an effort within the NACP to settle on a single regional grid so that scientists can more easily compare and share their results. The ALAADS system will have the capability of reprojecting MODIS data from the standard MODIS global grids into one or more regional grids defined by the NACP community, as well as, other grids for which the user specifies the map projection as well as the map projection parameters (e.g. latitude of true scale) and grid parameters (upper-left corner, pixel size, etc.). The re-projection is expected to be to a spatial grid size close or finer than that of the original product. For significantly coarser grid sizes, a second aggregation step will be necessary (see below).

File format conversion

At present data products are distributed in the HDF-EOS only. For ALAADS the user will be offered two options for acquiring products in the GeoTIFF format. First, the user will be able to request a download of the HDF-to-GeoTIFF tool for use at their own facility. The tool site will also include information concerning the use of hdf tools to convert from HDF to Ascii and binary formats. Second, the user will be able to request that the GeoTIFF conversion will be performed by ALAADS. In this event the reformatted products will be available on a delayed basis in the same fashion as subsetted products.

Mosaicing

MODIS land data are currently stored in 10 by 10 degree tiles so that users can easily retrieve data over their region of interest. However, for large regional studies like the NACP, users typically need to spatially combine these tiles into a single large dataset that covers their entire region of interest. This process is commonly referred to as mosaicing. The ALAADS will allow the user to select tiles that cover a continental size region and mosaic them together.

Resample (aggregate) spatial resolution

In some cases users need products that are at a coarser resolution than the MODIS products. For instance, many climate modelers may be interested in products of 0.25 degrees which is coarser than the MODIS 0.05 degree climate modeling grid products. To produce these products in a scientifically useful way, finer resolution data must be aggregated to the coarser resolution. This aggregation step first involves binning the measurements into each coarser resolution gird cell and

then applying some sort of operation (such as averaging or selecting the value with the highest count) to produce a single value for each grid cell. It is important that this last step be able to exclude certain data based on the QA layers (such as cloudy pixels) that would otherwise contaminate the results.

Modification of temporal composites (changing time steps)

Most of the MODIS multi-day products are produced on 8 and 16 day time steps. Some users are interested in other time steps such as weekly, 10-day or monthly. Moving to these different time steps involve either interpolating between the MODIS time steps and/or aggregating multiple time steps. The ADAADS system will implement multiple methods (nearest neighbor, linear, fitted phenological curves, etc.) and allow the user to select the one that is appropriate and that best meets their needs.

QA filtering and gap filling (temporal and spatial)

Many Climate Models can not deal well with data that include pixels were not retrieved because they are cloudy for the entire time step or for which only lower quality data is available (e.g. there were high aerosol levels over the entire surface reflectance product time step). In these cases both temporal and spatial interpolation may be needed to provide a valid value for each pixel. Work at Goddard Space Flight Center (GSFC) is currently implementing the TIMESAT software (Jönson and Eklundh, 2004) to apply gap-filling/smoothing operations to MODIS time series data, including adaptive Savitzky–Golay filtering as well as harmonic and asymmetric Gaussian functions. ALAADS will implement the TIMESAT approach as well as others recommended by the community to allow the users to generate a continuous gap-filled data set.

Ancillary Model Data

Many users need the ancillary data that has been used to generate MODIS products in the same grid as the MODIS data. This would enable easier integration of the ancillary data with the MODIS products (e.g., MODIS Aerosol product with the NCEP TOVS Ozone Daily product). The proposed system will perform the same services that we are proposing for the MODIS products on these ancillary products.

Machine to machine requests (services)

We plan to add a subscription ftp push capability to AADS/LADS that extends the current distribution via user ftp pull only. For certain types of orders, including parameter and geographic subsetting, and format conversions, we will offer users the option of receiving products by ALAADS push. However, certain volume and time restrictions will be applied to pushes to ensure that any disabled receiving systems will not unreasonably consume ALAADS resources.

ALAADS will also support a scripting option, including the capability to submit a series of orders in one step. While all of the capabilities described above would normally be accessed through a sequence of choices on a web interface, advanced users will want to avoid repetitive browser interactions with similar orders having only minor changes. To this end, users will be able to specify (in a text file or equivalent) the criteria for selecting data, the sequence of processes applied to the data, and the information needed to automatically push the data to the users' computer. This “command file” functionality will allow users to easily repeat orders having only minor changes, e.g., the data-day, coverage area, filtering options, etc, as well as to concatenate orders for rapid submission.

6. Deliverables

The primary deliverable is easy access to specific MODIS data products for NACP investigators. The Joint NASA, Dept. of Energy (DOE), and Dept. of Agriculture (USDA) solicitation for "Carbon Cycle Science" funded research in four carbon-related research areas – one of them being NACP. Of the 59 funded investigations, roughly half make an explicit reference to remote sensing or can (or would like to) utilize MODIS products (based on the listing at http://research.hq.nasa.gov/code_y/nra/current/NRA-04-OES-01/winners.html and personal communications or presentations at national-level meeting). Upon funding, we would work directly with the NACP science steering group to select the investigators with whom we will work most directly. We would seek the SSG approval for a questionnaire to send to all investigators funded through the NASA/DOE/USDA "Carbon Cycle Science" program (as well as others the NACP SSG may want to include). The questionnaire would include a brief description of the tools and services we plan to offer and the investigators plans to incorporate MODIS data. We would initially screen to remove those not interested in MODIS data and then arrange them base on the tools and services needed. Depending on the similarity of requests, we anticipate being able to serve from 5 to 20 investigations in year one. We would rely on the SSG to help us determine the focus investigations in year one. We would transition to serving all interested investigators in year two and three.

Our metric for success will be two-fold:

1) Quantify the number of NACP investigations utilizing MODIS data and the number of MODIS data products these investigators are using.
2) The new tools developed through the proposed effort.

These two metrics will help monitor how well our effort is serving the NACP science community as well how much of this work can contribute to future land and atmosphere processing systems.

7. Summary of Personnel and Work Effort

The team members on this proposal bring a wide range of expertise related to data systems and the focus science area. The work proposes to connect MODIS data products with research in the North American Carbon Program. Here we list the team members' experience related to the propose effort and their role in the project.

Jeff Morisette will serve as the principal investigator (PI). He is budgeted to commit a total of 2 month/year of his time on the proposed work (1 month to be cost-shared by GSFC). He will be responsible for the oversight of the project and leading the coordination with NACP investigators. Morisette serves on the NACP science steering group and the ad-hoc groups on Remote Sensing for NACP and NACP's mid-continent intensive campaign. He is a member of the MODIS science team, serving as the coordinator of land product validation activities. He has served as the validation coordinator since 1998. This role has helped him develop the skills required to connect MODIS production capabilities with the science needs of MODIS PIs and other land validation scientists. Similar skill will be required to connect enhanced MODIS processing with the science needs of NACP.

Robert Wolfe will serve as the leader for tools and services related to land products. He is budgeted at 1 month/year. He has over 22 years of experience working in the area of satellite remote sensing. Currently, he plays a key role within the MODIS Land science team by leading the overall land science data processing activities. He also plays a technical role in leading the MODIS geolocation activates, developed key approaches for gridding MODIS land products, and is a

member of the NPP Science Team. Wolfe is currently chair of the EOS Science Working Group on Data and recently led a workshop EOS Data Access and Usability.

William Ridgway will serve as the leader for tools and services related to atmosphere products. He is budgeted at 1 month/year. Ridgway serves as MODAPS Data Processing Coordinator for the MODIS Atmospheres Science Team. He played a major role in the development of the AADS online system for atmospheric product distribution. Ridgway also developed all image products necessary to support the online ordering system. He will develop some tools as well as coordinate all related activities for atmosphere products.

Michael Teague will serve as manager of the two programmers hired for the proposed work and responsible for the overall design of the ALAADS system. He is budgeted at 1 month/year. The two programmers to be hired are budgeted at a total of 16 months/year. Candidate programmers will be drawn from the current AADS/LADS development staff and will have skills in Web programming, databases, Perl scripting and experience working with MODIS and other satellite data. These programmers will work closely with MODAPS developers and operational staff.

Ed Masouka is the head of NASA Goddard Space Flight Center's Terrestrial Information Systems Branch (TISB). His time commitment is 1 month/year, which will be entirely cost-shared by GSFC as this is considered part of his role as branch head (as not time will be charged directly to the project, he is listed as a collaborator). His role will be to ensure that the TISB resources needed for the propose work are readily available and that the proposed work is used to help guide the direction of tools and services produced by TISB. Masouka is responsible for NASA Goddard Space Flight Center's MODIS Adaptive Processing System (MODAPS).

Organization activities include monthly team meeting at GSFC and presentations at related NACP meetings (e.g. science steering group meetings or telecons). However the main organizational aspect of the work will be to maintain close communication between the GSFC team member and the NACP investigators that will be served. This will include e-mail, telecon, and face-to-face meeting as needed. Essentially, we will consider the proposing team to be "on retainer" to the select NACP investigators.

8. Cost Plan

The primary costs include the time of the people as described in the Personnel section. This section describes the budgeted hardware costs. All hardware purchased will include an industry standard 3 year warranty. There will be three hardware buys, each associated with development and deployment of the capabilities (below).

Core

The initial purchase will be of 10 TB of inexpensive RAID storage, four 2 processor (2p) Linux rack mounted computers, two workstations and miscellaneous hardware. The workstations are for the two programmers. One of the 2p computers will be used as a storage server with RAID storage directly attached. Two 2p computers will be a processing node and the remaining computer will function as the web server. Miscellaneous hardware includes a 16-port Gigabit Ethernet switch, a rack and cables.

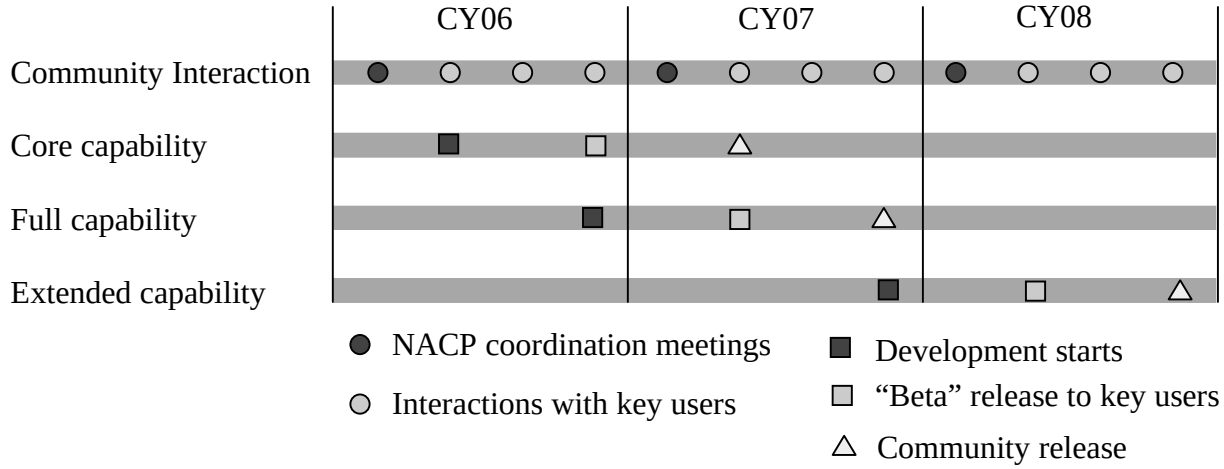
Full

The second purchase will be of 15 TB of inexpensive RAID disk and five 2p computers. One of the 2p computers will be used as a storage server with the additional RAID directly attached. The remaining 2p computers will be used as processing nodes.

Extended
The third purchase will depend on funding for the optional third year of the project. It will consist of 20 TB of inexpensive RAID disk and five 2p computers. One of the 2p computers will be used as a storage server. The remaining 2p computers will be processing nodes.

9. Schedule

The following figure shows the overall schedule for the development of ALAADS. The community interaction with the NACP users will coincide with NACP science steering group meeting and help us focus on the areas that have the largest impact on the research community. The interactions with key users will happen more often and be in the form of monthly telecoms, plus we will meet directly with key users at their facilities or ours.



The ALAADS capabilities will be deployed in three builds: core, full and extended. Each build will take place over about a year from development, through a "beta" release to key NACP users, and then a release to the broader community. The "beta" release will allow us to get feedback from the NACP users and make changes before a larger number of users try out the new capabilities.

The Core capabilities will include: reprojection, mosaicing, core format conversion, spatial resolution aggregation, and initial QA filtering and gap filling for selected products. The format conversion will be limited to three core formats: GeoTIFF, Binary and ASCII (only for very small subsets). The initial QA filtering and gap filling will be limited to one method per product and will be done for four selected products: VI, Albedo, Aerosol Optical Depth and Precipitable Water Vapor.

The Full build will include the following capabilities in addition to the Core capabilities: additional format conversion, modification of the temporal composites and extension of QA filtering and gap filling to all products. The selection of the additional supported formats will be based on input from the research community. Both general and product specific methods will be developed modification of the temporal compositing interval. The specific methods will be user driven. Additional methods for QA filtering and gap filling will be developed so that there is at least one method appropriate for each product.

The Extended build will depend on funding for the optional third year of the project. These extensions to the Full capabilities will to allow the users to define their own methods for modification of the temporal composites, for QA filtering and for gap filtering. In addition, machine-to-machine requests for all of these services will be implemented to allow users to automatically request the specific services.

References

Chin, M., D.A. Chu, R. Levy, L. Remer, Y. Kaufman, B. Holben, T. Eck, P. Ginoux, and Q. Gao, 2004, Aerosol distribution in the Northern Hemisphere during ACE-Asia: Results from global model, satellite observations, and Sun photometer measurements. J. Geophys. Res., 109 (D23), doi: 10.1029/2004GL02014.

Denning, S., R. Oren, and D. McGuire, et al., 2004, "Science Implementation Strategy for the North American Carbon Program", http://www.carboncyclescience.gov/nacp-sis-may04draft.pdf

EOS Science Working Group on Data, "EOS Data Access and Usability Workshop Report", Feb. 26, 2004, http://swgd.gsfc.nasa.gov/reports/acc_use_wkshp_report.pdf.

Masuoka, E., C. Tilmes, N. Devine, G. Ye and M. Tilmes, "Evolution of the MODIS science data processing system", Proceedings of the July 2001 IGARSS Conference, 1454-1457.

Moody, E.G., M.D. King, S. Platnick, C.B. Schaaf, and F. Gao, 2005, Spatially complete global spectral surface albedos: Value-Added datasets derived from Terra MODIS land products. IEEE Trans. Geosci. Remote Sens., 43, 144-158.

Jönson, P., and L. Eklundh, 2004, TIMESAT—a program for analyzing time-series of satellite sensor data Computers & Geosciences 30: 833–845.

Lavender S.J., and S.B. Groom, The SeaWiFS automatic data processing system (SeaAPS). Int. J. Remote Sens. 20: (6) 1051-1056 1999.

Wofsy, S. and R.C. Harriss, 2002. "The North American Carbon Program Plan (NACP): A Report of the Committee of the U.S. Carbon Cycle Science Steering Group", http://www.isse.ucar.edu/nacp/.

Curriculum Vitae

The following pages provide curriculum vitae for all investigators.

Jeffrey T. Morisette

Education

PhD, Forestry/Remote Sensing, North Carolina State University, May 1997
Thesis: *Using Generalized Linear Models to Enhance Satellite-based Land Cover Change Detection*
International Space University, Technical University of Vienna, Summer 1996
MS, Applied Statistics, Oakland University, Rochester Michigan, 1992
BA, Mathematics Siena Heights College, Adrian Michigan, 1990

Current Positions

Physical Scientist: NASA Goddard Space Flight Center, December 2001 – present

- Science team lead for the Invasive Species Forecasting System
- Research in statistical applications in remote sensing as applied to the Earth sciences, with special emphasis on statistical analysis of global land products
- Advises on experimental design to scientists involved in field experiments, guides in development of the appropriate sampling design for field sites, works with researchers to develop a plan for analyzing the data, and consults as required to researchers in the proper application of statistical techniques
- Member of the Moderate Resolution Imaging Spectroradiometer science team. Coordinates validation activities for land products with other team scientists and EOS Data Centers. Manages the infrastructure for the EOS Land Validation Core Sites. Represents EOS land product validation activities within the Committee on Earth Observing Satellites'"Land Product Validation Subgroup"
- Assists the Education and Public Affairs Offices disseminating the Earth resources program's aims, efforts, and accomplishments

Adjunct Asst. Professor: Univ. of Maryland
Earth System Science Interdisciplinary Center, September 2002 - present

- Co-teaches course on field measurement and sampling techniques for remote sensing validation
- Serves on graduate advisory committees for PhD and MS students

Recent Professional Affiliations and Activities

Science Steering Group for the North American Carbon Program (appointed, Jan. 2005)
Member: MODIS Science Team, LBA-Ecology Science team, AGU and IEEE
Chair: Oak Ridge National Lab User Working Group, 2003-present (member since 2001)
Chair: Committee on Earth Observing Satellites, Working Group on Calibration and Validation, Land Surface Parameters subgroup, February 2003-present (Deputy Chair, 12/2000 – 2/2003.
Chair (2001) and Vice Chair (2000): Institute for Electrical and Electronic Engineers, Washington Section of the Geoscience and Remote Sensing Society Chapter

Publications

Book Chapters

Morisette, J.T., J. L. Privette, A. Strahler, P. Mayaux, C. O. Justice, "An approach for the Validation of Global Land Cover Products through the Committee on Earth Observing Satellites", in *Remote Sensing and GIS Accuracy Assessment* Lunetta, R.S., and J.G. Lyon (Editors), 2004, CRC Press, Boca Raton, FL. 304 pp.

Morisette, Jeffrey T.; S. Khorram; H. Cheshire and C. Stallings, 1996, "Creating an Urban-Mask Raster Image with Vector Street Files" p. 172 - 178, in Raster Imagery in Geographic Information Systems, Stan Morain ed., High Mountain Press, Santa Fe, New Mexico, 495 pp.

Refereed Articles

Pedelty JA, Morisette JT, Smith JA, 2004. Comparison of Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and Earth Observing One (EO-1) Advanced Land Imager , *Optical Engineering*, 43 (4): 954-962. (TC = 0)

Morisette, J.T., J. E. Nickeson, P. Davis, Y. Wang, Y. Tian, C. E. Woodcock, N. Shabanov, M. Hansen, D.L. Schaub, A. R. Huete, W. B. Cohen, D. R. Oetter, and R. E. Kennedy, 2003. High spatial resolution satellite observations for validation of MODIS land products: IKONOS observations acquired under the NASA Scientific Data Purchase, *Remote Sensing of Environment, 88* (1-2) 100-110. (TC=0)

Liang, S., H. Fang, M. Chen, C. Walthall, C. Daughtry, J. Morisette, 2002, Atmospheric correction of Landsat ETM+ imagery II: validation and applications, *IEEE Trans. Geos. Remote Sens*, 40(12) 2736-2746. (TC=4)

Morisette, J. T., J.L. Privette, and C.O. Justice, 2002. A framework for the validation of MODIS land products, *Remote Sensing of Environment, 83* (1-2) 77-96. (TC=14)

Liang S.L., H.L. Fang, M.Z. Chen, C.J. Shuey, C. Walthall, C. Daughtry, J. Morisette, C. Schaaf, A. Strahler, 2002, Validating MODIS land surface reflectance and albedo products: methods and preliminary results", *Remote Sensing of Environment, 83* (1-2) 149-162. (TC=12)

Justice, C. O., L. Giglio, S. Korontzi, J. Owens, J.T.Morisette, D. Roy, J. Descloitres, S. Alleaume, F. Petitcolin, Y. Kaufman, 2002. The MODIS Fire Products. *Remote Sensing of Environment., 83* (1-2) 244–262. (TC=16)

Myneni, R.B., Y. Knyazikhin, J.L. Privette, J. Glassy, Y. Tian, Y. Wang, S. Hoffman, X. Song, Y. Zhang, G.R. Smith, A. Lotsch, M. Friedl, J.T. Morisette, P. Votava, R.R. Nemani, and S.W. Running, 2002. Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data, R*emote Sensing of Environment, 83* (1-2) 214-231. (TC=32)

Justice, C.O., J. Townshend, E. Vermote, E. Masuoka, R. Wolfe, N. El Saleous, D. Roy, J. Morisette, 2002. An overview of MODIS Land data processing and product status, *Remote Sensing of Environment*, 83 (1-2) 3-15. (TC=13)

Morisette, Jeffrey T. and S. Khorram, 2000, "Accuracy Assessment Curves for Satellite-Based Change Detection", *Photogrammetric Engineering and Remote Sensing.* vol. 66 (7).876-880. (TC=6)

Justice, C., Belward, A., Morisette, J., Lewis, P., Privette, J., Baret, F., 2000, "Developments in the validation of satellite products for the study of the land surface", *International Journal of Remote Sensing*, v. 21 (17) 3383 – 3390.

Walthall, C., Roujean, J., Morisette, J., 2000, Field and Landscape BRDF optical wavelength measurements: experience, techniques, and the future, for Special Issue on BRDF in *Remote Sensing Reviews*, 18(2-4)503-532.

Morisette, J., S. Khorram, T. Mace, 1999, "Land-cover change detection enhanced with generalized linear models", *International Journal of Remote Sensing*, 20(14)2703-2721.

Morisette, J., Khorram S., "Exact Binomial Confidence Interval for Proportions", Photogrammetric Engineering and Remote Sensing, April 1998, v.64, n. 4, pp. 281-283.

Morisette, J., 1997, "An Example Using SAS to Fit the Model of Coregionalization", Computers and Geoscience, v. 23, n. 3, pp. 317-323.

Refereed Articles (in press)

Morisette, J.T., L. Giglio. I. Csiszar, A. Setzer, W. Schroeder, D. Morton, C O. Justice, in press, Validation of MODIS active fire detection products derived from two algorithms, *Earth Interaction* (special issue for LBA-Ecology).

Morisette, J.T., L.Giglio, I.Csiszar, C.O. Justice, in press, Validation of the MODIS Active fire product over Southern Africa with ASTER data, *International Journal of Remote Sensing*, (special SAFARI 2000 issue).

Schroeder, W, J. Morisette, I. Csiszar, L. Giglio, D. Morton, C. Justice. In press. Characterizing Vegetation Fire Dynamics in Brazil Through Multi-Satellite Data: Common Trends and Practical Issues, *Earth Interaction* (special issue for LBA-Ecology).

Roy, D.P., Frost, P.G.H., Justice, … Morisette, J.T, et al., "The Southern Africa Fire Network (SAFNet) regional burned area product validation protocol", International Journal of Remote Sensing, special SAFARI 2000 issue.

Jeffrey T. Morisette, Frèdéric Baret, Jeffrey L. Privette, Ranga B. Myneni, Jaime Nickeson, et al., Validation of Global moderat resolution LAI Products: a framework proposed within the CEOS Land Product Validation subgroup, submitted to *IEEE TGARS*.

F. Baret, J. Morisette, R. Fernandes, J.L. Champeaux, R. Myneni, J. Chen, S. Plummer, M. Weiss, C. Bacour, G. Derive, Evaluation of the representativeness of networks of sites for the validation and inter-comparison of global land biophysical products. Proposition of the CEOS-BELMANIP, submitted to *IEEE TGARS*.

Molly E. Brown, Jorge E Pinzon, Jeffery T. Morisette, Kamel Didan, Compton J. Tucker, Inter-Sensor Validation of long-term NDVI time series from AVHRR, SPOT-Vegetation, SeaWIFS, MODIS, and LandSAT ETM+, submitted to *IEEE TGARS*.

Refereed Articles (in review)

Frederic Baret, Marie Weiss, Sebastien Garrigue, Denis Allard, Jean Pierre Guinot, Marc Leroy, Hervé Jeanjean, Jeffrey T. Morisette, Hervé Bohbot, Roland Bosseno, Gérard Dedieu, Carlos Di Bella, Marisa Espana, alery Gond, Xing Fa Gu, Dominique Guyon, Camille Lelong, Eric Mougin, Tiit Nilson, Franck Veroustraete, Roxana Vintilla, "VALERI: a network of sites and a methodology for the validation of medium spatial resolution land satellite products", submitted to Remote Sensing of Environment.

Ivan A Csiszar, Jeffrey T Morisette, Louis Giglio, Validation of active fire detection from moderate resolution satellite sensors: the MODIS example, submitted to *IEEE TGARS*.

Archived Data sets

Morisette, J. T., L. Giglio, I. Csiszar, and C. O. Justice. 2003. SAFARI 2000 ASTER AND MODIS FIRE DATA COMPARISON, DRY SEASON 2001. Data set. Available on-line http://www.daac.ornl.gov, from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. Conference Proceeding

Robert E. Wolfe

Education

B.S. Math and Physics, Bridgewater College, Bridgewater VA, 1980.

Current Positions

Chief Scientist: Raytheon TSC @ NASA GSFC, January 1993 – present

- Member of NASA's EOS MODIS science support team
- Leads the integration and testing of MODIS land science algorithms and science data processing
- Developed advanced algorithms to earth-locate (geolocate) MODIS data and grid MODIS land science data
- NPP science team member and chairman of the EOS Science Working Group on Data

Previous Relevant Positions

Chief Scientist: Hughes STX in Lanham MD, August 1984 – Dec. 1992

- Built production systems that performed radiometric geometric rectification of Landsat and SPOT instrument data for commercial and government customers
- Developed satellite geometric models include both on-board navigation data from the spacecraft, instrument characteristics, ground control points and terrain

Recent Professional Affiliations and Activities

- IEEE Geosciences and Remote Sensing Society
- American Geophysical Union

Relevant Publications

Wolfe, R. E., M. Nishihama, A. J. Fleig, J. A. Kuyper, D. P. Roy, J. C. Storey and F. S. Patt, Achieving sub-pixel geolocation accuracy in support of MODIS land science, Remote Sens. of Env., 83 (1-2): 31-49, Nov. 2002.

Justice, C. O., J. R. G. Townshend, E. F. Vermote, E. Masuoka, R. E. Wolfe, N. Saleous, D. P. Roy and J. T. Morisette, An overview of MODIS Land data processing and product status, Remote Sens. of Env., 83 (1-2): 3-15, Nov. 2002.

Wolfe, R. E., D. P. Roy and E. Vermote, MODIS land data storage, gridding, and compositing methodology: Level 2 grid, IEEE Trans. Geosci. Remote Sens., 36 (4): 1324-1338, July 1998.

Masuoka E., A. J. Fleig, R. E. Wolfe and F. Patt, Key characteristics of MODIS data products, IEEE Trans. Geosci. Remote Sens., IEEE Trans. Geosci. Remote Sens., 36 (4): 1313-1323, July 1998.

Recent Honors and Awards

- Goddard Space Flight Center Group Award (2001 and 2003)
- Bridgewater College Young Alumni Award (1996)

William L. Ridgway

Education

Ph.D., Physics, University of Chicago, 1981.
Thesis: *Quantum antiferromagetic spin waves near one dimension.*
B.S., Physics, Massachusetts Institute of Technology, 1974.
B.S., Mathematics, Massachusetts Institute of Technology, 1974.

Current Position

Support Scientist and Project Lead: Science Systems and Appl., Inc., February 2000 – present

- Represents Atmosphere discipline PI's on MODIS data processing team and coordinates data management for Atmosphere science team members and affiliated researchers.
- Project Lead for science support of NASA GSFC Climate and Radiation Branch.

Previous Positions

Support Scientist and Project Lead: Space Applications Corp., 1997 – 2000
Support Scientist: Applied Research Corp., 1984 –1997
Post-Doctoral Research Associate: Purdue University, 1982 – 1984

Sample of Relevant Publications

Chu, D.A., L.A. Remer, Y.J. Kaufman, B. Schmid, J. Redemann, K. Knobelspiesse, J.-D. Chen, J. Livingston, P.B. Russell, X. Xiong and W. Ridgway, Evaluation of aerosol properties over ocean from Moderate Resolution Imaging Spectroradiometer (MODIS) during ACE-Asia, J. Geophys. Res. 110, D07308, 2005.

Harshvardhan, W. Ridgway, V. Ramaswamy, S.M. Freidenreich, and M. Batey, Spectral characteristics of solar near-infrared absorption in cloudy atmospheres, J. Geophys. Res. 103, 28793-99, 1998.

Cahalan, R. F., W. Ridgway, W. J. Wiscombe, Gollmer, S, and Harshvardhan, Independent pixel and Monte Carlo estimates of stratocumulus albedo, J. Atmos. Sci, t51, 3776-3790, 1994.

Betts, A.K., P. Minnis, W. Ridgway, and D.F. Young, Integration of satellite and surface data using a radiative-convective oceanic boundary-layer model, J. Applied Meteor., 31, 340-350, 1992.

Ridgway, W. L., Harshvardhan, and A. Arking, Computation of atmospheric infrared cooling rates by exact and approximate methods, J. Geophys. Res., 96, 8969-8984, 1991.

Davies, R., W. L. Ridgway, and K. E. Kim, Spectral absorption of solar radiation in cloudy atmospheres: a 20 cm-1 model, J. Atmos. Sci., 41, 2126-2137, 1984.

MICHAEL J. TEAGUE

Education

Ph.D., Physics, London University, London England, 1968
M.Sc., Physics, London University, 1965
B.Sc., Engineering, First Class Honors, London University, 1963

Current Position

Assistant VP, Science Applications International Corporation (SAIC), Sept 1998 to Present

- Responsible for operating a data system on a 7x24h basis for Aqua and Terra MODIS science products including forward processing and reprocessing and science testing.
- Responsible for designing, developing, and maintaining the MODIS Adaptive Processing System (MODAPS) used for generating MODIS science products and the Land and Atmospheres Archive and Distribution Systems (LADS and AADS)
- Responsible for developing, testing, and configuration management of 100+ land, oceans, and atmospheres MODIS and NPP land VIIRS science algorithms.

Previous Relevant Positions

Manager, Applied Science Division, Caelum, March 1996 to Sept 1998

- Responsible for 4 contracts in the GSFC Laboratory for Hydrospheric Processes
- Responsible for restructuring the EDOS Level 0 facility and science planning operations under the CSOC contract

US STEP Coordinator, STEP America, Inc., Sept 1991 to March 1996

- Responsible for coordinating the ICSU/SCOSTEP Solar Terrestrial Energy Program (STEP) involving 43 nations and 20 science international space science missions.
- Responsible for identifying and implementing science campaigns.
- Responsible for concept and design of Space Physics Data System

Director, Aerospace Systems Division, EER Systems, Jan 1987 to Sept 1991

- Responsible for the design of the ISTP/GGS data processing system
- Responsible for the design of the ISTP Science Planning and Operations Facility

Relevant Publications

"The Atmospheres and Land Archive and Distribution Systems", IGARSS 2005
"Science Testing for MODIS and NPP Science Algorithms", IGARSS 2005

Recent Honors and Awards

- Group Achievement Award for Aqua MODIS, NASA, 2004
- Group Achievement Award for Terra MODIS, NASA, 2001