SEMI-ANNUAL REPORT

NASA CONTRACT NAS 5-31368

For
MODIS Team Member: Steven W. Running
Assoc. Team Member: Ramakrishna R. Nemani
Software Engineer: Joseph Glassy

31 July 2000

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract:

- Deliver at-launch software for our MODIS products, #15 Leaf Area Index and Fraction Absorbed Photosynthetically Active Radiation, and #17 Daily Photosynthesis - Annual Net Primary Production.

- Develop MODIS applications products for national natural resource management.

- Organization of a validation effort using AMERIFLUX fluxnet sites to correlate and test the MODIS derived Net Primary Production.

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The NTSG lab currently employs:

Dr. Steven Running, Director and Professor,
Dr. Ramakrishna Nemani, Research Assoc. Professor
Dr. Lloyd Queen, Associate Professor
Dr. John Kimball, Postdoctoral Research Associate
Dr. Peter Thornton, Postdoctoral Research Associate
Dr. Jerome Winslow, Postdoctoral Researcher
Mr. Joseph Glassy, Software Engineer
Mr. Petr Votava, Programmer
Mr. Saxon Holbrook, Computer Systems Engineer
Mr. Andrew Weiss, Programmer, Systems Operator
Mr. Mike White, PhD student
Ms. Alisa Keyser, PhD student
Mr Carl Seielstad, PhD student
Mr Jim Plummer, PhD student
Ms. Youngee Cho, Office Manager

All of these members contribute to certain aspects of our MODIS work.

<u>ACTIVITIES OF SWRunning (MODIS Team Member)</u>

WORK ACCOMPLISHED:

<u>MODIS ALGORITHMS</u>:

We have successfully generated products from our MODIS algorithms (MOD15 Leaf Area Index/FPAR, and MOD17 Net Photosynthesis/Net Primary Production). Currently, we are testing these products for their accuracy.

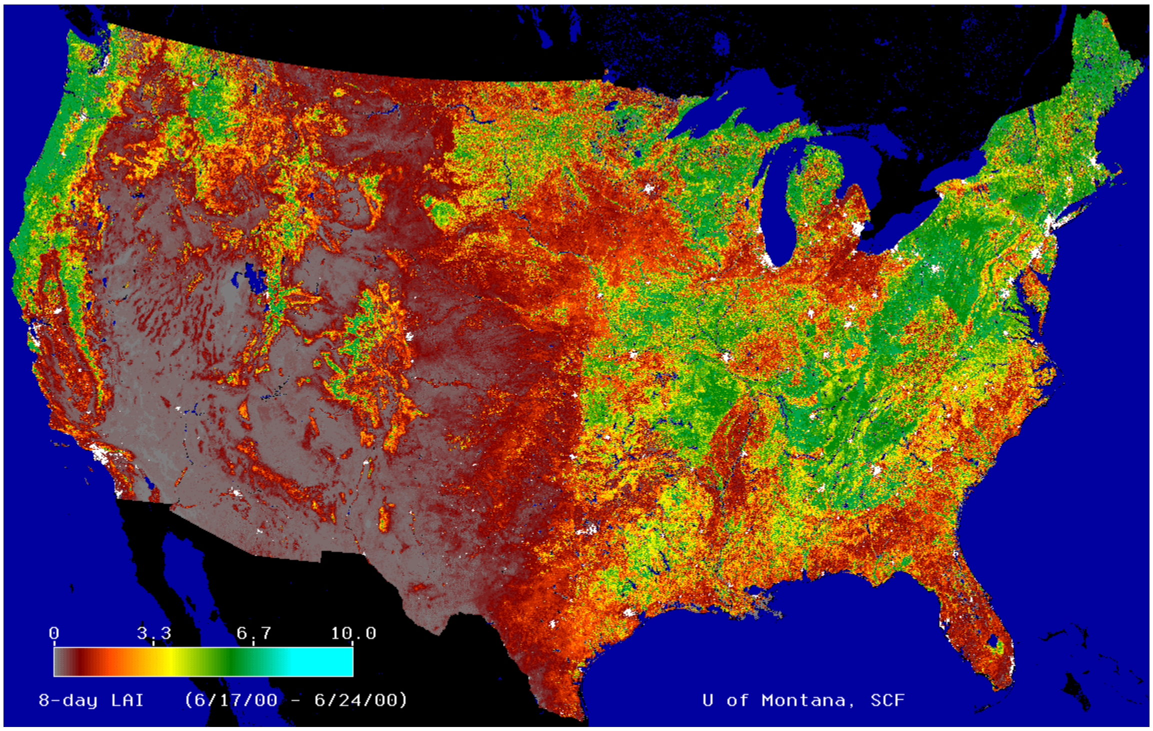


Figure 1

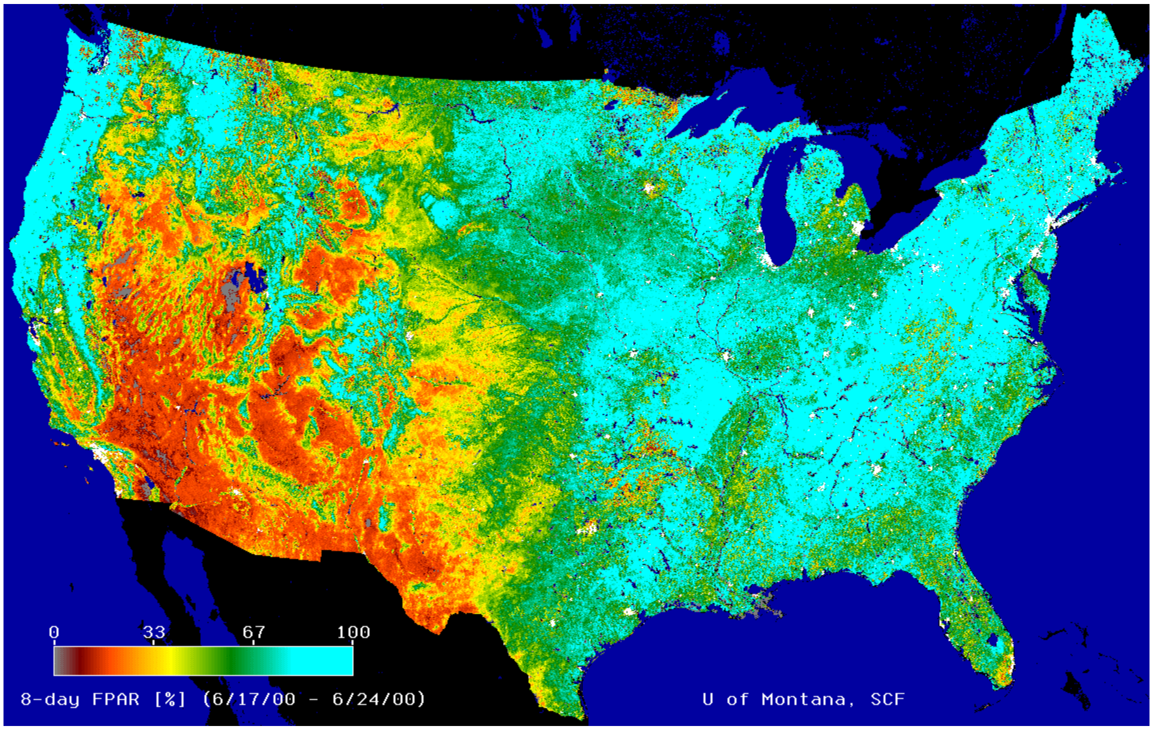


Figure 2

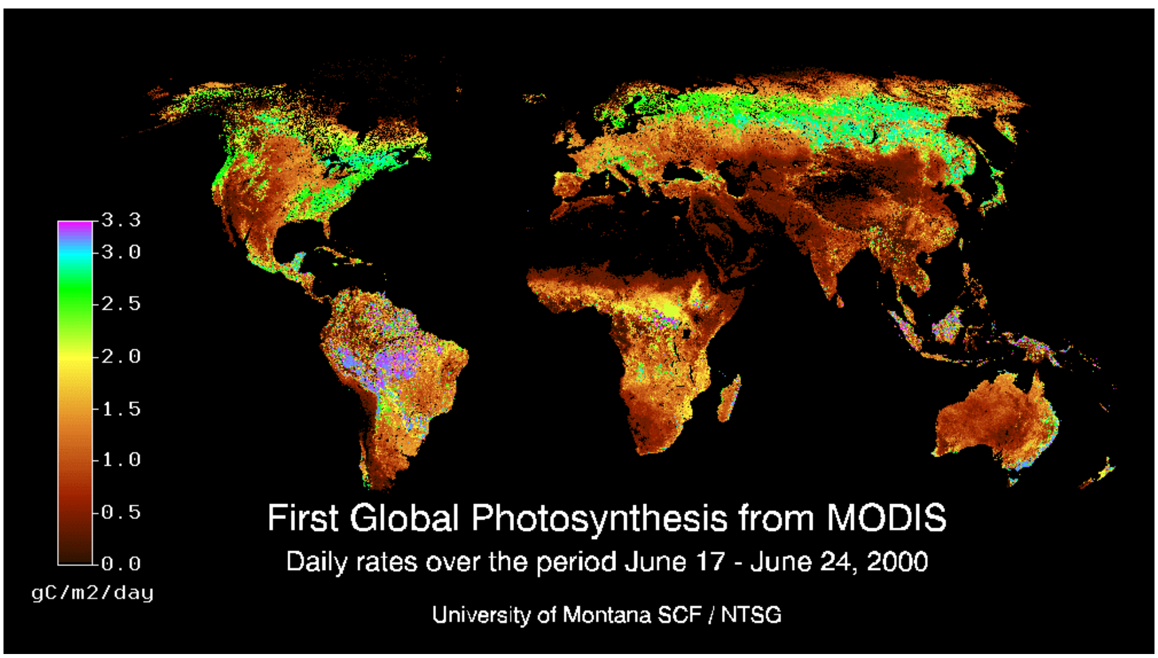


Figure 3

EOS-IWG

I participated in a number of projects to develop both MODLAND, and more generally EOS Land product validation. These projects are in many ways interrelated, and their efficiency is maximized by regular coordination. Following are brief summaries of current activity for:

BIGFOOT = a field ecological measurement program in the US
GTOS-NPP = a global program related to BIGFOOT for GTOS
FLUXNET = a global array of CO2 and H20 flux towers
IGBP-GAIM = a global NPP model intercomparison
VEMAP = a US based ecological model intercomparison

I also served on the NRC committee to review the NASA ESE Research Strategy 2000-2010.

BIGFOOT

I hosted the annual BIGFOOT planning meeting in Polson, MT in March 2000. Four sites will be measured this year, a boreal spruce forest, eastern deciduous forest, grassland, and annual crop.

FLUXNET

The FLUXNET program is maturing rapidly as the cornerstone of EOS Land validation, website at: http://daacl.ESD.ORNL.Gov/FLUXNET/ . There are now 80 sites globally, and substantial international coordination. I attended the annual international FLUXNET meeting in June in Berkeley.

We inaugurated the RealTime flux validation activity with the active participation of ORNL.

Global Climate and Terrestrial Observing Systems (GCOS/GTOS)

The GTOS-NPP project is being initiated to provide coordinated global measurements of landcover, LAI and NPP for EOS validation. I attended a workshop in Ottawa in February as a member of the Terrestrial Observation Panel for Climate (TOPC) to continue GTOS planning.

VEMAP - Vegetation ecosystem modeling and analysis project

VEMAP is a project to intercompare leading biogeography and biogeochemistry models in the US for global change and EOS research programs. VEMAP has a homepage at:

http://www.cgd.ucar.edu:80/vemap/

Highlights of the VEMAP II project were published in Science.

Schimel, D., J. Melillo, S.W. Running, et al. (2000) Contibution of Increasing CO_2 and Climate to Carbon Storage by Ecosystems in the United States. Science 287: pp. 2004-2006.

MODLAND Validation

I hosted Dr. Honda from Japan with his robotic helicopter for test flights over forests grasslands and rangeland in Lubrecht, Montana , June 2000.

NASA EOS and Related MEETINGS ATTENDED (SWR)

TOPC meeting, Ottawa, Feb 2000
FLUXNET meeting, Berkeley, June 2000
BIGFOOT meeting, Polson, MT March 2000
EOS-SEC Jan 2000, and SEC and IWG meeting Tucson, April 2000

Publications:

Schimel, D., J. Melillo, S.W. Running, et al. (2000) Contibution of Increasing CO_2 and Climate to Carbon Storage by Ecosystems in the United States. Science 287: pp. 2004-2006.

Running, S.W., L.P. Queen, M. Thornton. (2000) Applications of the Earth Observing System for Forest Management. Journal of Forestry, Vol. 98, No. 6.

Running, S.W., J.B. Way, K.C. McDonald, J.S. Kimball, S. Frolking, A.R. Keyser. (2000) Radar Remote Sensing Proposed for Monitoring Freeze-thaw Transitions in Boreal Regions. Earth in Space, Vol. 12, No. 5, pp. 1-9.

Kimball, J.S., A.R. Keyser, S.W. Running, S.S Saatchi. (2000) Regional Assessment of Boreal Forest Productivity Using an Ecological Process Model and Remote Sensing Parameter Maps. Tree Physiology, Vol. 20, No. 11, pp.761-775.

Canadell, J.G., H.A. Mooney, D.D. Baldocchi, S.W. Running and et al. (2000) Carbon Metabolism of the Terrestrial Biosphere: A Multitechnique Approach for Improved Understanding. Ecosystems 0:1-16.

Running, S.W., P.E. Thornton, R.R. Nemani, J.M. Glassy. (2000) Global Terrestrial Gross and Net Primary Productivity from the Earth Observing System. In: ***Methods in Ecosystem Science***, O.Sala, R. Jackson, and H.Mooney Eds. Springer-Verlag New York.

Running, S.W. (2000) Why the Earth Observing System Matters to all of Us. The Earth Observer, Vol. 12, No. 1.

White, M.A., M.D. Schwartz, S.W. Running. (2000) Young Students, Satellites Aid Understanding of Climate- Biosphere Link. Eos, Transactions, American Geophysical Union Vol. 81, No. 1, January 4, 2000.

Galina Churkina and Steven W. Running, (2000) Investigating the balance between timber extraction and the productivity of global coniferous forests. Climatic Change (in press).

University of Montana EOS Natural Resource Training Center

A. Overview

The University of Montana, EOS Training Center was initiated February 1, 1999. The EOS Training Center consists of two main components; the EOS Natural Resource Project, which addresses the needs of the scientific and natural resource community and the EOS Education Project, which addresses the needs of the K-16 educational community. The overall objectives of the EOS Training Center are:

OBJECTIVES

We have identified the following near-term objectives for our University of Montana EOS Training Center contract:

EOS Natural Resource Project

- Work with natural resource managers to produce relevant EOS application products particularly in the fields of fire management and vegetation productivity.
- Develop and provide training to remote sensing, GIS, earth system scientists, and natural resource personnel in the acquisition, interpretation, and application of NASA EOS application products.

EOS Education Project

- Expand national outreach efforts on EOS Education Project products and services.
- Expand development of web-based presence.
- Begin integration of Terra data and imagery into existing EOS Education Project programs.

B. Project Partners

The University of Montana, EOS Training Center is actively participating with a number of project partners. These partners include:

1. USDA Forest Service, Region One Fire Sciences Lab, Rocky Mountain Research Station. Contact - Patricia Andrews

The EOS Training Center is coordinating with the Fire Sciences Lab to include current and future EOS data to support wildland fire decision making. We are developing a link between the EOS Training Center World Wide Web site (http://eostc.umt.edu) and the Wildland Fire Assessment System (WFAS) World Wide Web site (http://www.fs.fed.us/land/wfas). The system is in place to post current Satellite Moisture Index (SMI) and meteorological (see Daymet) data to the WFAS web site. This will become operational as soon as the WFAS web site is updated.

2. University of Alaska - Fairbanks. Contact - Dr. David Verbyla

Dr. Verbyla has conducted a number of workshops in Alaska regarding EOS data; Remote Sensing: An Alaskan Natural Resource Perspective, ArcView Processing of Landsat 7 Imagery. Dr Verbyla, and LTER scientist, has also participated in a workshop at the LTER All Scientists Meeting, Snowbird, UT (August 2 - 4, 2000). The workshop was an overview of MODIS and MODIS Land Products.

3. University of Missouri - Columbia. Contact - Dr. David Larsen

Under the direction of Dr. Larsen, an on-line tutorial on change detection based on Landsat imagery is being used by faculty and staff at the University of Missouri to incorporate EOS data into current curriculum and research.

4. University of Idaho

The EOS Education Project is partnering with the University of Idaho and using their expertise in the work they have performed with NASA's GLOBE project.

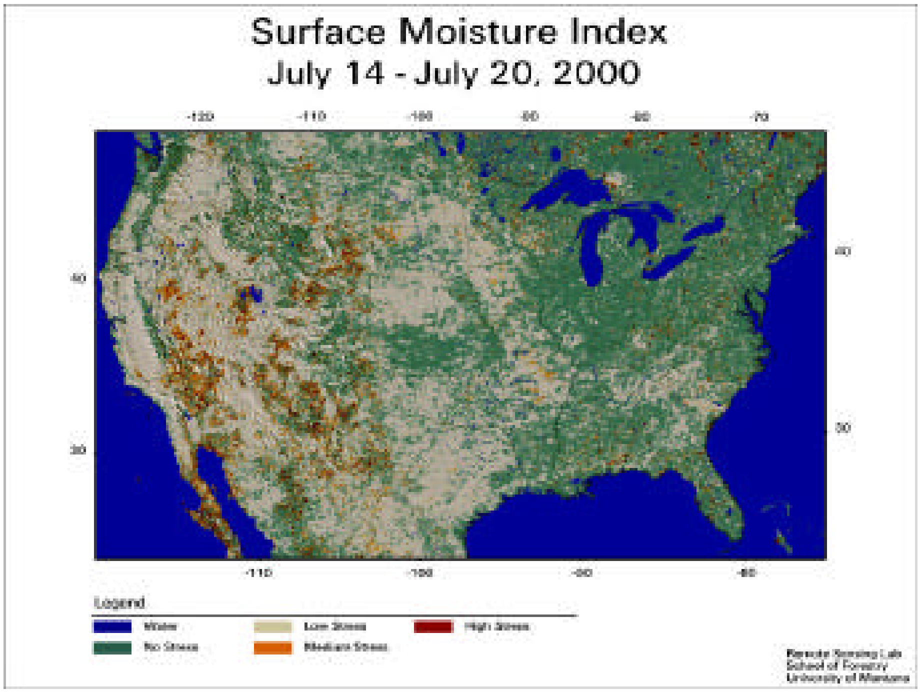
C: NASA'S EOS AND ANCILLARY DATA

The University of Montana EOS Natural Resource Project is focusing on two fields of NASA's EOS Application Products for land natural resource management; fire management and vegetation productivity. In collaboration with the Numerical Terradynamic Simulation Group and the Remote Sensing Lab at the University of Montana, we have been enhancing EOS algorithms within these fields for regional applications.

Fire Management

Remote sensing is becoming more applicable to a number of applications in fire management. The EOS Natural Resource Project, in cooperation with the Remote Sensing Lab and NTSG at the University of Montana operationally tested and produced two UM-EOS application products that will be applied to Terra MODIS data when available.

Surface Moisture Index - The Remote Sensing Lab in coordination with the EOS Training Center continues to process and post the SMI data for the 2000 fire season. The Surface Moisture Index (SMI) estimates vegetation moisture condition over large scales for both fire and drought monitoring. Using both NDVI and surface temperature from the heritage AVHRR instrument, vegetation stress is monitored once a week from composited data. The EOS Natural Resource Project posted the Surface Moisture Index as both a browse image and as a data file in ERDAS Imagine format (.img). An ERDAS Imagine format was selected as a number of popular Remote Sensing/GIS Software packages can read this file format (ERDAS, ARC/Info, ARCView) and it is a reasonable size for ftp download. Departure indexes were established by applying the SMI algorithm to a 10-year historic data base of AVHRR data. With the successful launch of the Terra satellite, we plan on transitioning the SMI algorithm to MODIS data incorporating Land Surface Temperature (MOD 11) and MODIS Vegetation Index (MOD 13) as these data streams become operational.



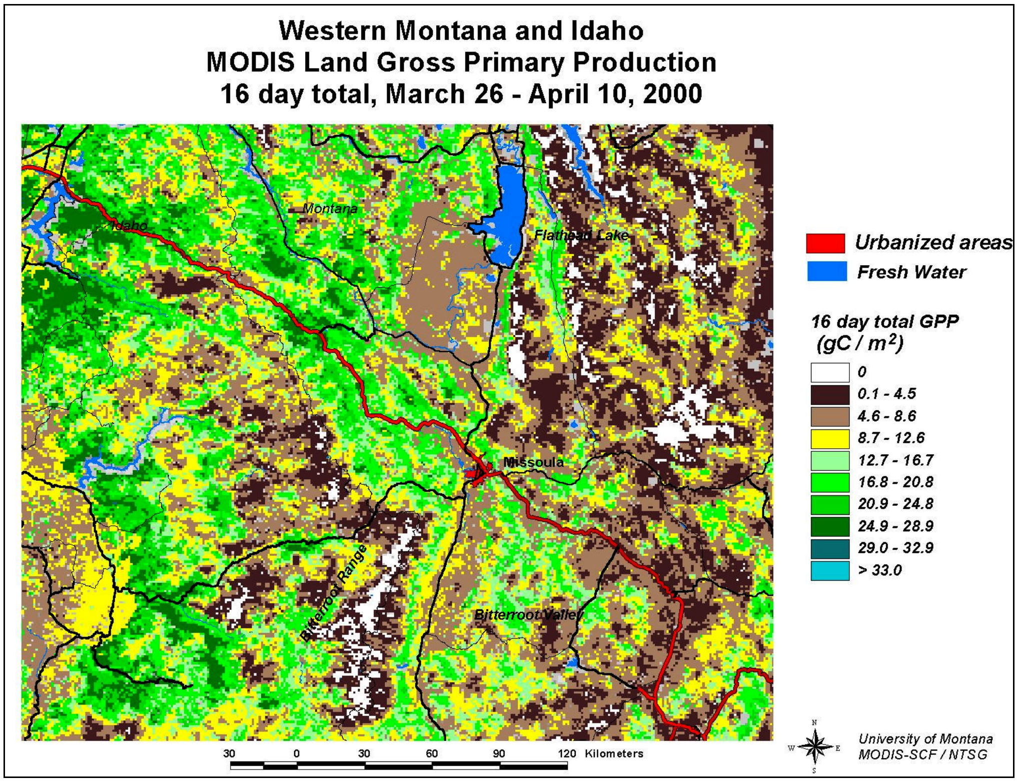
Surface Moisture Index for the Period July 14-July 20, 2000. Derived from NOAA 14 AVHRR.

<u>Fire Detection/Monitoring</u> - Fire detection and monitoring is a MODIS at launch product (MOD 14). The MODIS active fire detection routine relies on a neighborhood analysis in which brightness temperatures of potential fire pixels are compared to mean background brightness temperature of adjacent pixels. Fire pixels are identified using fixed thresholds in the 4μm and 11μm bands. The EOS Natural Resource Project and the Remote Sensing Lab will provide training on the MODIS fire algorithm and regional applications.

<u>Vegetation Productivity</u>

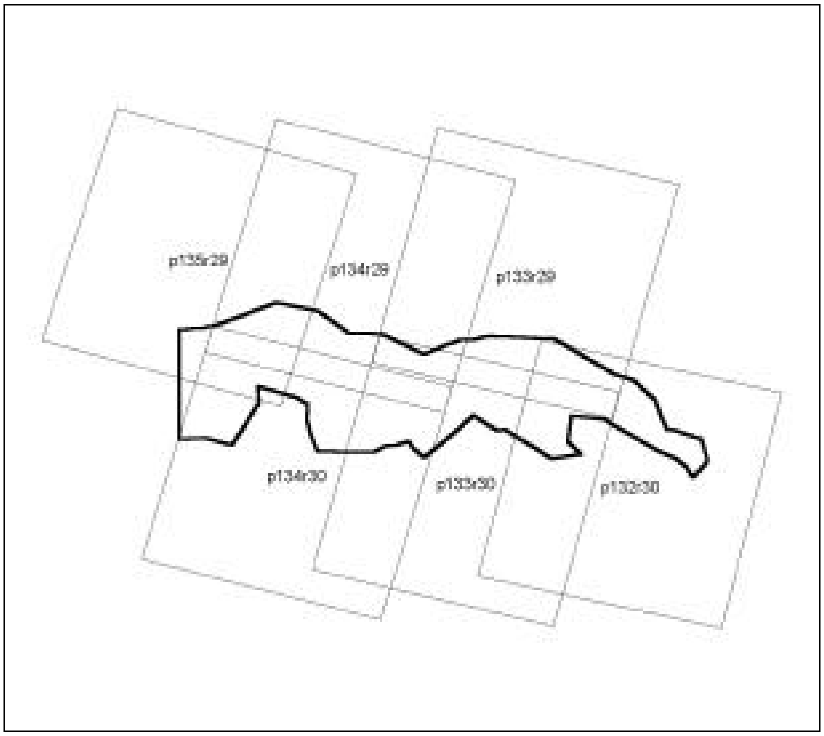
Global estimates of weekly vegetation productivity and annual net primary productivity will be estimated by the MODIS instrument using algorithms developed by Dr. Steven Running and his lab at the University of Montana (Running *et al.*, 2000). The EOS Natural Resource Project has been working with historic Pathfinder data to simulate MODIS products in order to demonstrate estimates of weekly vegetation productivity and annual NPP to natural resource personnel. In addition, range and forest researchers have been investigating resource applications for MODIS vegetation productivity.

With the recent availability of MODIS vegetation productivity data, we have continued discussions with natural resource personnel to develop regional applications for these and similar data sets. We are working closely with the Idaho Panhandle Forest to test some applications of these data with the remote sensing, inventory, and forest health monitoring that they are currently conducting.

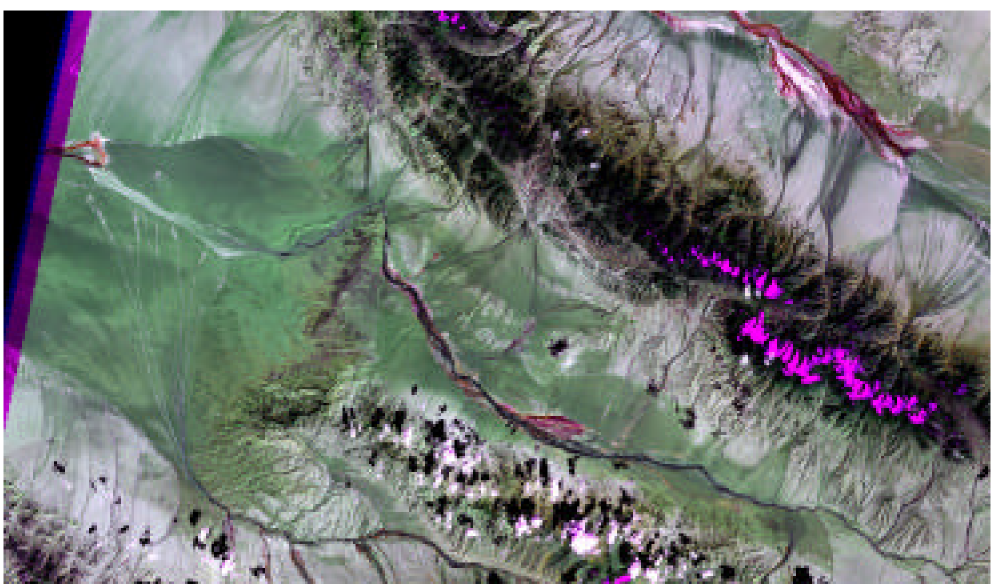


Gross Primary Productivity for western Montana and Idaho as estimated from the MODIS instrument.

<u>International Vegetation Productivity Opportunities</u> - Dr. Donald Bedunah, Professor of Range Management in the School of Forestry, University of Montana has been working with the EOS Natural Resource Project to investigate the possibility of using the MODIS PSN/NPP product in data poor areas of the globe such as Mongolia. Dr. Bedunah and the EOS Natural Resource Project have also been assembling Landsat 7 ETM+ data for areas in Mongolia and central China where he conducts research and advises local herders on range condition.



Landsat 7 ETM+ scene boundaries and park boundary of the Govi Saikhan park in south central mongolia



Landsat 7 Path 136 Row 33 in central China showing the area of interest for range condition study.

Climatology
An ancillary database of gridded climate data is being developed through the EOS Natural Resource Project and the NTSG. The grid will be at a 1km resolution over the conterminous United States. Data will be available on a daily and summary basis for meteorological variables necessary for ecological land-surface processes. Daymet is a model that generates daily surfaces of temperature, precipitation, humidity, and radiation over large regions of complex terrain. The required model inputs include digital elevation data and observations of maximum temperature, minimum temperature, and precipitation from ground-based meteorological stations. The Daymet method is based on the spatial convolution of a truncated Gaussian weighting filter with the set of station locations. Sensitivity to the typical heterogeneous distribution of stations in complex terrain is accomplished with an iterative station density algorithm. Spatially and temporally explicit empirical analyses of the relationships of temperature and precipitation to elevation are performed. A daily precipitation occurrence algorithm is introduced, as a precursor to the prediction of daily precipitation amount. Surfaces of humidity (vapor pressure deficit) are generated as a function of the predicted daily minimum temperature and the predicted daily average daylight temperature. Daily surfaces of incident solar radiation are temperature range.

The Daymet database will be completed by September 2000 with posting of summary data sets to the world wide web to soon follow.

D: WORKSHOPS and TRAINING

The EOS Training Center Natural Resource Project has conducted the following workshops and trainings:

May 4, 2000 - Montana GIS User's Conference, Kalispell, Montana

Remote Sensing Fundamentals and Applications - Lecture Format
Incorporating Remotely Sensed Data into a GIS- An Example Using Vegetation Indices and Departure Products - Laboratory Format

May 17 - 18, 2000 - University of Montana, Missoula, MT

May 17, 2000
Remote Sensing Fundamentals and Applications - Lecture Format
Integrating EOS Digital Images into a GIS - Laboratory Format

May 18, 2000
The EOS Program and Terrestrial Application Products - An Introduction and Overview - Workshop Format

August 4, 2000 - LTER All Scientists Workshop, Snowbird, UT

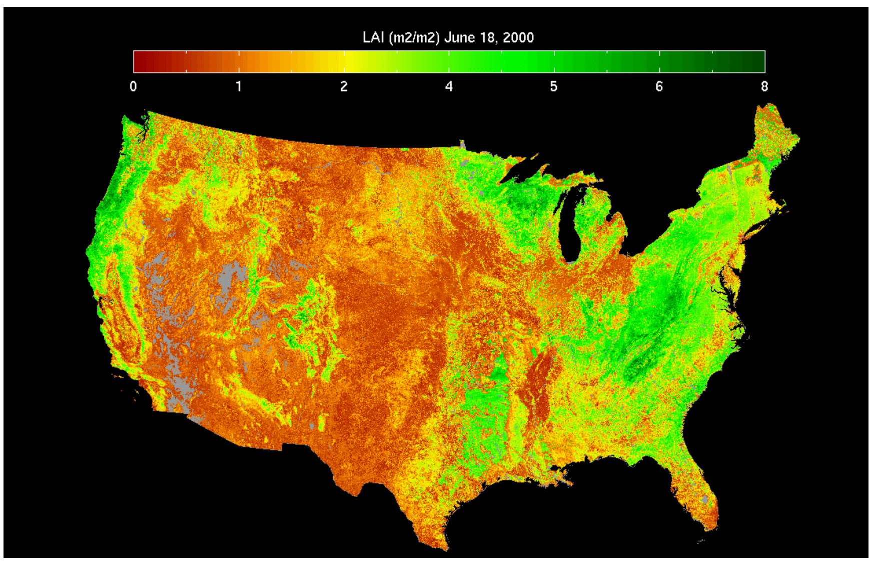
MODIS Land Products - An Introduction and Overview - Workshop Format

ACTIVITIES OF R. Nemani (MODIS Associate Team Member)

1. **MOD15 LAI/FPAR algorithm**:

   We generated biweekly LAI/FPAR fields at 1km for the continental U.S using the MOD15 backup algorithm starting 1989-current. We are currently evaluating MODIS derived LAI/FPAR with AVHRR based LAI/FPAR fields for the CONUS area. Below is an example of Leaf Area Index derived from AVHRR data collected during June 15th-June 20th. Cloud covered areas were filled in from historical LAIs. Since we have several years of AVHRR based LAIs, they will be useful for studying the LAI seasonality from both MODIS and AVHRR.

Figure: Leaf Area Index generated from AVHRR for comparison with MODIS derived LAI.

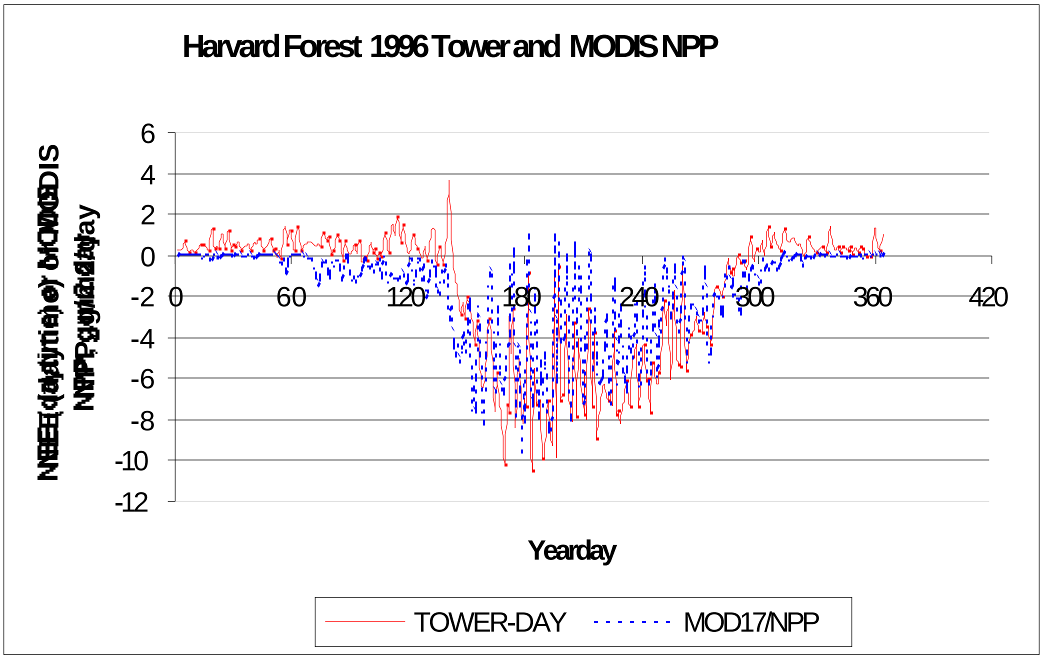


2. **MOD17 PSN/NPP Algorithm:**

   Using monthly LAI/FPAR for 18 years (1983-1999) derived from 8km Pathfinder data (surrogate for MODIS LAI/FPAR) and daily climatic data gridded at 2x2 lat/lon from NCEP reanalysis (surrogate for DAO data), we are testing MOD17 algorithm in the following ways:

   1) One of the key inputs to the MOD17 algorithm is the incident solar radiation obtained from global circulation models (i.e. NCEP or DAO). We tested the accuracy of incident solar radiation from NCEP using the GOES derived 0.5x0.5 radiation for the continental U.S. Significant biases were detected on a grid cell (0.5x0.5) basis with critical implications for the MOD17 product. Work is being continued to quantify the spatial and temporal bias in the incident radiation fields from atmospheric models.

2. **<u>Validation of MODIS GPP/NPP</u>**



A validation effort is underway to test the MOD17 PSN/NPP products based on flux tower data. Since MODIS is not readily available, we are using AVHRR based LAI/FPAR to exercise the system. Currently, there are 21 flux tower sites participating in the validation effort. Each week, the flux towers post their meteorological data. We then use the met data to run BIOME-BGC as well as run the AVHRR based MOD17 algorithm over the flux tower sites.

ON-GOING EFFORTS:

With the help of Dr. Tom Bowden (ORNL), we initiated a cooperative effort with a number of flux tower sites. These sites include: Park Falls, WI, Willow Creek, WI, Tall Grass Prarie, OK, Wheat, OK, Chapparral, CA, Walker Branch, TN, Harvard Forest, MA, Metoleus, OR, Wind River, WA, Blodgett forest, CA. A number of these sites have been posting their meteorolgical data every week. Using these observations, U. of Montana is doing the BGC simulations for each tower site and post the results back to ORNL. Once, MODIS products stabilize, we will produce MODIS NPP for each flux site and post the results. When the tower sites finally, post their actual fluxes- ORNL will post the comparisons on the WWW. Since the provision of actual fluxes will be delayed, we use the BGC estimated fluxes for immediate comparison. Examples of current BGC simulations are shown below.

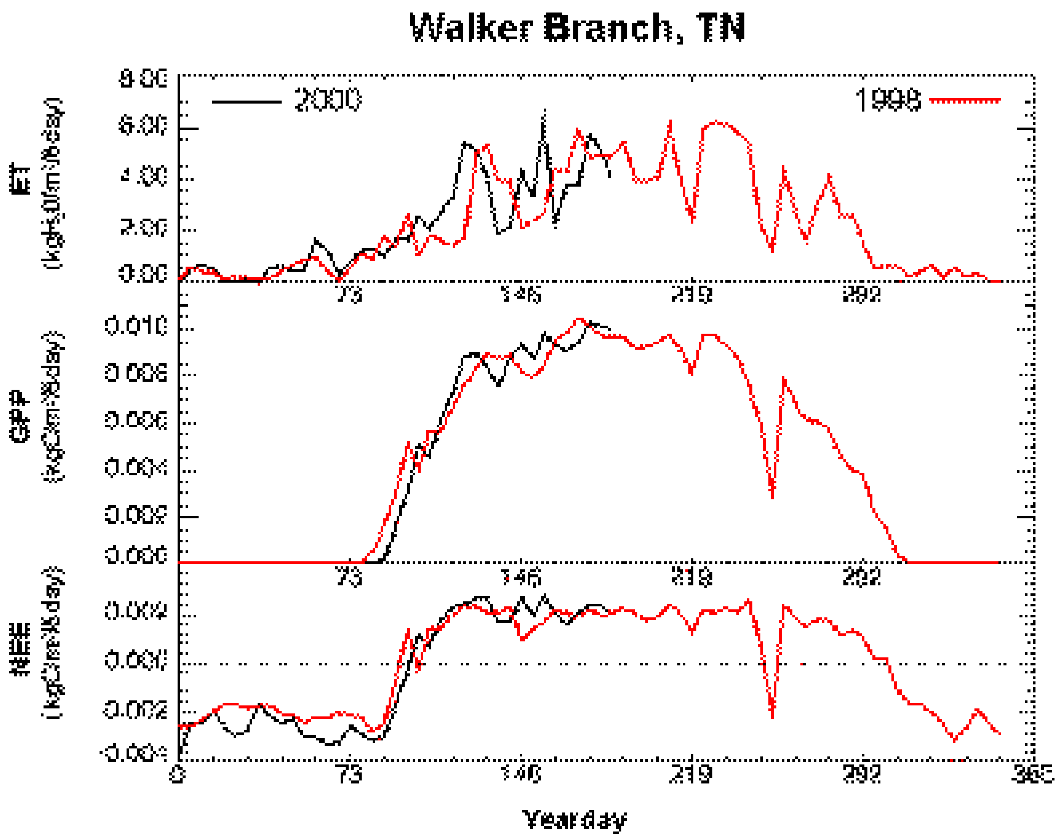


Figure: BGC simulations of ET, GPP and NEE over Harvard forest for 1998 and for the current year generated every week.

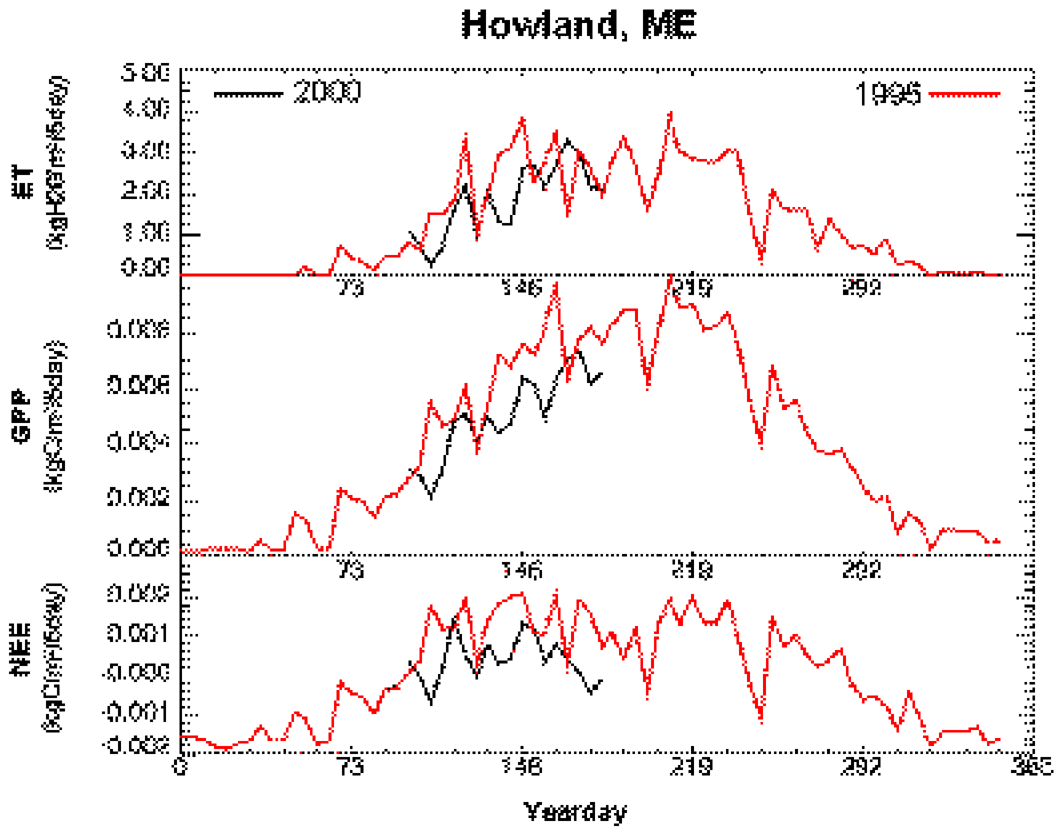


Figure: BGC simulations of ET, GPP and NEE over Howland forest for 1996 and for the current year generated every week.

4. **Developing a biospheric forecast system:**

Early warnings of potential changes in key ecosystem variables such as soil moisture, snow pack, primary production and stream flow could enhance our ability to make better socio-economic decisions relating to natural resources management and food production. The accuracy of such warnings depends on how well the past/present /future conditions of the ecosystem are characterized. Advances in ecosystem modeling, internet based data delivery, operational remote sensing products Climate forecasting skills of many current coupled Ocean-Atmosphere general circulation models (GCM) have steadily improved over the past decade. Given observed anomalies in SSTs from satellite data, GCMs are able to forecast climatic conditions 6-12 months into the future with reasonable accuracy. While such forecasts are useful for climatological purposes, analysis of their impacts on ecosystem response has been at best subjective.

A conceptual framework for developing a Biospheric Forecast System (BFS) with emphasis on natural resource management is provided. The proposed BFS extends the capabilities of our near-realtime modeling system, the Terrestrial Observation and Prediction System (TOPS) into a forecast mode. BFS assimilates NASA's Earth Observing System land products into an ecosystem simulation system, **initialized/restored** with observed weather data and **forced** with short to long-range weather/climate forecasts. The system uses components of RHESSys (Regional Hydro-Ecological Simulation System) as the land surface ecosystem model for the computation of distributed carbon, water and nutrient cycles, which have been used to estimate more basic resource information such as forest productivity, runoff production, snow dynamics and soil moisture stress.

BFS functionality includes automated gathering of input data, setting up model runs and post-processing the model output using data-mining and information extraction tools to provide information rather than data to end-users. Successful implementation of such a system would bring together state-of-the art technologies in information technology, weather/climate forecasting, ecosystem modeling and satellite remote sensing, and would allow better management of floods, droughts, forest fires, irrigation requirements and crop/range/forest production and human health.

Figure 4: Conceptual framework of a biospheric forecast system integrating MODIS products, surface weather data and ecosystem models for real-time estimation of various land surface processes. This configuration also allows for ingesting weather/climate forecasts at various lead-times to compute biospheric responses to projected atmospheric conditions.

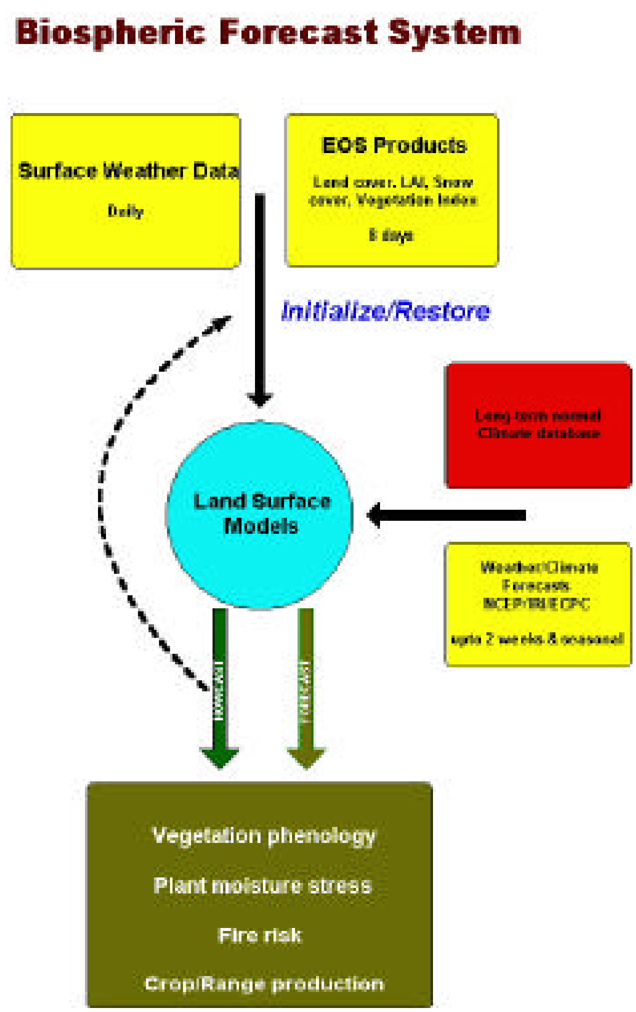
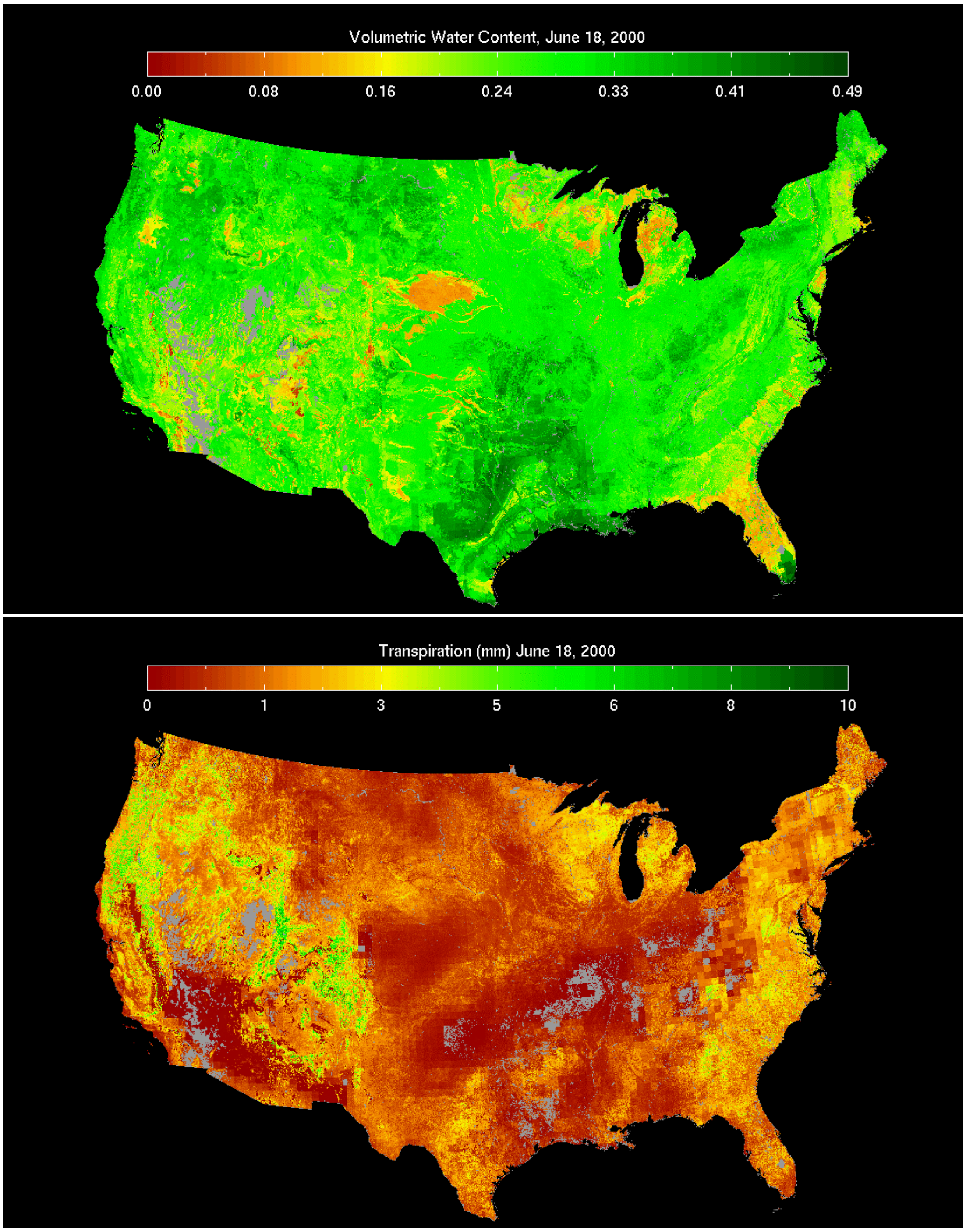


Figure: Example outputs from the BFS, products generated in near-real time using AVHRR based LAI, current surface meteorology and ecosystem models. Again, we will replace AVHRR LAIs with MODIS LAIs very soon.



MEETINGS ATTENDED:

GCIP Investigators meeting, March 2000
NASA/IWG meeting, April 2000
LDEO/IRI meeting, April 2000
AGU Spring meeting, May, 2000
AMS meeting, January, 2000

PRESENTATIONS:

Global to regional modeling of land-atmosphere predictability, GCIP investigators meeting, March 27-28, 2000.

Remote sensing and process modeling in vineyards, NAPA valley wine growers meeting March 29, 2000

Biospheric forecasting: Progress and Prospects, IWG meeting, April 11, 2000

Biospheric forecasting: Application to Napa valley wine growing regions, LDEO/IRI meeting, April 25-27, 2000

Monitoring terrestrial net primary production during NASA/EOS era. AGU Spring meeting, May 19-24, 2000.

PUBLICATIONS:

Keyser, A., J.S. Kimball, R.R.Nemani and S.W. Running. 2000. Simulating the effects of climate change on carbon balance of north American high latitude forests. Global Change Biology (in press).

Nemani, R.R., M.A. White, D.R. Cayan, G.V. Jones, S.W. Running and J.C. Coughlan. 2000. Asymmetric climatic warming in coastal California and its impact on the premium wine industry. Climate Research (in review)

McKay, D.S., R. Nemani and L.E. Band. 2000. Corroborating thermal remote sensing data and distributed hydrologic modeling in a mountainous, forester watershed. Journal of Hydrology (in press)

Nemani, R.R., M.A. White, D.R. Cayan, G.V. Jones, S.W. Running and J.C. Coughlan. 2000. Climate and California vintages. In: Proceedings of " International Conference on Climate forecasts in Agriculture", LDEO/IRI, New York, NY.

Johnson, L., R. Nemani, L. Pierce, M. Bobo and D. Bosch. 2000. Toward the improved use of remote sensing and process modeling in California's premium wine industry. In: Proceedings of IGARS 2000, Vol 1, pp363-365.

Justice, C.J. and MODLAND members. 2000. Preliminary land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS). In: Proceedings of IGAARS 2000, Vol 1

White, M.A., G.P. Asner, R.R. Nemani, J.L. Privette, S.W. Running. 2000. Monitoring fractional cover and leaf area index in arid ecosystems: digital camera, radiation transmittance, and laser altimetry results. Remote Sensing of Environment.(In press)

Nemani, R.R., M.A. White, P. Votava, J. Glassy, J. Roads and S. Running. 2000. Biospheric forecast system for natural resource management. In.4th Symposium on "GIS and Environmental Modeling", Eds: Brad Parks, M. Goodchild and M. Crane. www.colorado.edu/cires/research/banf.

Hasenauer, H., R. Nemani, K. Schadauer and S. Running. 2000. Climate variations and tree growth between 1961 and 1995 in Austria. Proceedings of the European Forest Institute, IUFRO, eds: T. Karjalainen, H. Spiecker and Ol. Laroussinie., 75-86pp.

Running, S.W., P.E. Thornton, R.R. Nemani, J.M. Glassy. (2000) Global Terrestrial Gross and Net Primary Productivity from the Earth Observing System. In: ***Methods in Ecosystem Science***, O.Sala, R. Jackson, and H.Mooney Eds. Springer-Verlag New York.

ACTIVITIES OF J. M.Glassy, Lead MODIS Software Engineer: January, 2000 to July 2000

OBJECTIVES

My objectives during the time period January 2000 to July 2000 are summarized here, with details on each of the indicated activity areas following.

- Oversee and troubleshoot MODAPS production of our biophysical land product suite.
- Perform ad-hoc Quality Assurance/Quality Control activities on the early generation MODIS data products.
- Continue to log trouble-tickets/DDTs for our land algorithms, to fold into code patches for future patch deliveries as appropriate.
- Refine our SCF procedures and architecture using early MODIS product experience.
- Augment the MODAPS production team efforts by implementing selected SCF production scenarios required to supply NASA collaborators with early PR materials, to.

WORK ACCOMPLISHED

This has been a period of intense activity for our SCF, starting with the launch of the Terra platform in December, 18, 1999 leading into a long series of Land data product startup activities. The primary focus within the University Montana SCF Computing Group during this period has been to oversee the initial production of the Terra instrument derived daily and 8-day biophysical land products in the MODIS Adaptive Processing System (MODAPS) located at GSFC. This oversight role has included predominantly ad-hoc Quality Control and Quality Assurance procedures, effecting code patches, and helping the NASA production team identify work-arounds to problems encountered as the land products have gone operational. In the production arena we have undertaken a series of efforts to characterize our early generation MODIS data products, and better understand the instrument limitations.

Key accomplishment milestones for this period were highlighted by the SCF production of first ever USA Continent FPAR, LAI, and PSN (GPP) images, as well as the production and publication of the first ever PSN images derived from MODIS instrument data. Presentation images of these variables are included in the appropriate algorithm section below.

ALGORITHM DEVELOPMENT

FPAR, LAI Daily and 8-day Composite (PGE33,34)

The main science logic in the daily and 8-day FPAR, LAI has been stable for quite some time, with the changes effected during this period mostly applying to minor engineering issues pertaining to QA handling and ECS metadata interpretation. The single largest change within the FPAR, LAI codeset involved a MODLAND wide decision to relax the interpretations of cloud tagged pixels. In the original interpretation, for pixels marked by the L2/L2G/L3 surface reflectance processes as cloud contaminated, our biophysical model algorithms marked these with fill values, as unprocessable, and assigned the MODLAND wide QA value of “Not produced, due to cloud”. After initial experience with MODIS surface reflectances produced using the new very sensitive cloud mask, the MODLAND team felt it was more desirable to produce pixels in spite of possible cloud contamination. A new policy was adopted wherein the backup algorithm was used to produce pixel estimates of FPAR and LAI in these instances, along with explicit assignment of a new cloud state bit for these cases. The Quality Control assignments used currently for FPAR, LAI are shown in the table below.

New Quality Assurance Variables used for FPAR, LAI

Variable (8-bit unsigned)	*Bitfield*	Bits	Values *(Binary, Decimal)*	Bitfield Description
FparLai_QC	MODLAND_QC	0,1	00 = 0 01 = 1 10 = 2 11 = 3	Best possible Acceptable, not the best Not produced, cloudy(*) Not produced, regardless
	ALGOR_PATH	2,3	00 = 0 01 = 1	R-T method used Backup method used
	CLOUDSTATE	4,4	00 = 0 01 = 1	No significant clouds present Significant clouds were present
	SCF_QC	5,7	000 = 0 001 = 1 010 = 2 011 = 3 100 = 4	Very best possible Good,acceptable Passable;minor problems Poor,problematic Worst,unable to process.
FparExtra_QC	VIS_PASSTHRU	0,1	000 = 1 001 = 1 010 = 2 011 = 3 100 = 4	Very best possible Good,acceptable Passable;minor problems Poor,problematic Worst,unable to process.
	SNOW_ICE	2	00 = 0 01 = 1	No snow,ice detected Substatial snow,ice detected
	AEROSOL	3	00 = 0 01 = 1	Low or no aerosols detected Average or high aerosols
	CIRRUS	4	00 = 0 01 = 1	No cirrus clouds detected Cirrus clouds detected
	ADJACENT_CL	5	00 = 0 01 = 1	No adjacent clouds detected Adjacent pixel has clouds

	CLOUDSHADOW	6	00 = 0 01 = 1	No cloud shadow detected Cloud shadows detected
	SCF_CUSTOM	7	00 = 0 01 = 1	SCF or user mask off SCF or user mask on

The daily FPAR, LAI algorithm (PGE33) is currently at version v2.4.3, and is built using the SDPTK v5.2, HDFEOS 3.2, HDF 4.1r2, and MUM v.2.5.1 libraries. This algorithm is now at 17,659 LOC (70,510 LOC total includes the MUM API).

The first publication image of the FPAR variable was produced for the period March 24, 2000 to April 8, 2000 inclusive. This longer than normal compositing period was required to account for typical spring period cloudiness. Examples of the first look FPAR and LAI variables were projected into the Lambert's Azimuthal Equal Area projection and masked to the USA continent; these are shown earlier in this report as Figures 1 and 2 for FPAR and LAI, respectively.

PSN, NPP (PGE36,37,38) Algorithm

The PSN, NPP biophysical algorithm (ESDT: MOD17A1,A2,A3) is unique among the other MODIS Land algorithms in the degree to which it is a model oriented rather than instrument radiometry oriented process. It requires daily availability of the new DAO DAS subset of global surface climatology variables, as well as the FPAR, LAI 8-day composite tiles from the most recent period relative to the day, the MOD12Q1 landcover definition, and its static ancillary data. The single most critical factor that sets the PSN, NPP algorithm apart from the others its temporal sensitivity, driven by the way that cumulative (additive) state variables for GPP, GPP minus maintenance respiration, maximum leaf mass and annual sum of maintanence respiration are carried forward throughout the year. From a production standpoint, delivering a temporally reliable stream of FPAR, LAI data to the daily PSN, NPP algorithm has become one of the most challenging, quality limiting aspects of the MODAPS. In the larger MODIS Land processing stream, persistent production gap problems arising in the EDOS portion of the ground system have propagated tile and time drop-outs of the MODAGAGG to the daily FPAR, LAI processing. These in turn are reflected in drop-outs of 8-day MOD15A2 to the daily PSN algorithm. While corrections to EDOS problems are reportedly on their way, to run our PSN, NPP algorithm reliably, our SCF has had to locally stage up the required inputs, to implement limited processing here. Recently we were able to generate two back to back 8-day period sequences of PSN, NPP daily runs, culminating in the generation of (2) 8-day period PSN data product sets, each approximately 288 tiles globally. A global 1 Km resolution example of the gross photosynthesis variable for the year day period 169-176, projected in the Robinson map projection, is shown earlier in this report as Figure 3.

The daily PSN, NPP algorithm (PGE36) is currently at version v2.1.13, built using the SDPTK v5.2, HDFEOS 3.2, HDF 4.1r2, and MUM v.2.5.1 libraries. The PSN, NPP algorithm is now at 18037 LOC (71,309 LOC total includes the MUM API).

QA AND OPERATIONAL ACTIVITIES

Quality Assurance activities for this period focused mainly on retrieving and visually inspecting frequent samples of golden tile products of FPAR, LAI 8-day composite product. The PSN, NPP algorithm went into production only sporadically during this period due to various issues in clarifying the production-rules at runtime. We did update our QA tool environment during this time, as summarized here:

- Our ENVI/IDL visualization software was upgraded to v3.2/5.2.1. We are still awaiting solid support for the HDFEOS 3.x and HDF data models from the major COTS vendors (RSI, ESRI, etc).
- Our HDFLook visualization and QA software was upgraded to v.8.2
- A number of small, console tools were refined, including the ***eosmt*** tool for quick analysis of FPAR and LAI products.
- Until a more rigorous public reprojection tool becomes available, we have developed a tile-wise reprojection utility (reprojtool, v1.4), for reprojecting MODIS ISINUS tiles into the Lambert Azimuthal Equal Area, Robinson's, or Goodes interrupted homolosine rectangular map projections. Tiles thus projected are then mosaiced at in our SCF using several IDL scripts.

The most significant Quality Assurance activity involved the hiring of an additional summer FTE staff (David Gray), to increase the staff hours we can dedicate to QA and test from this point onward.

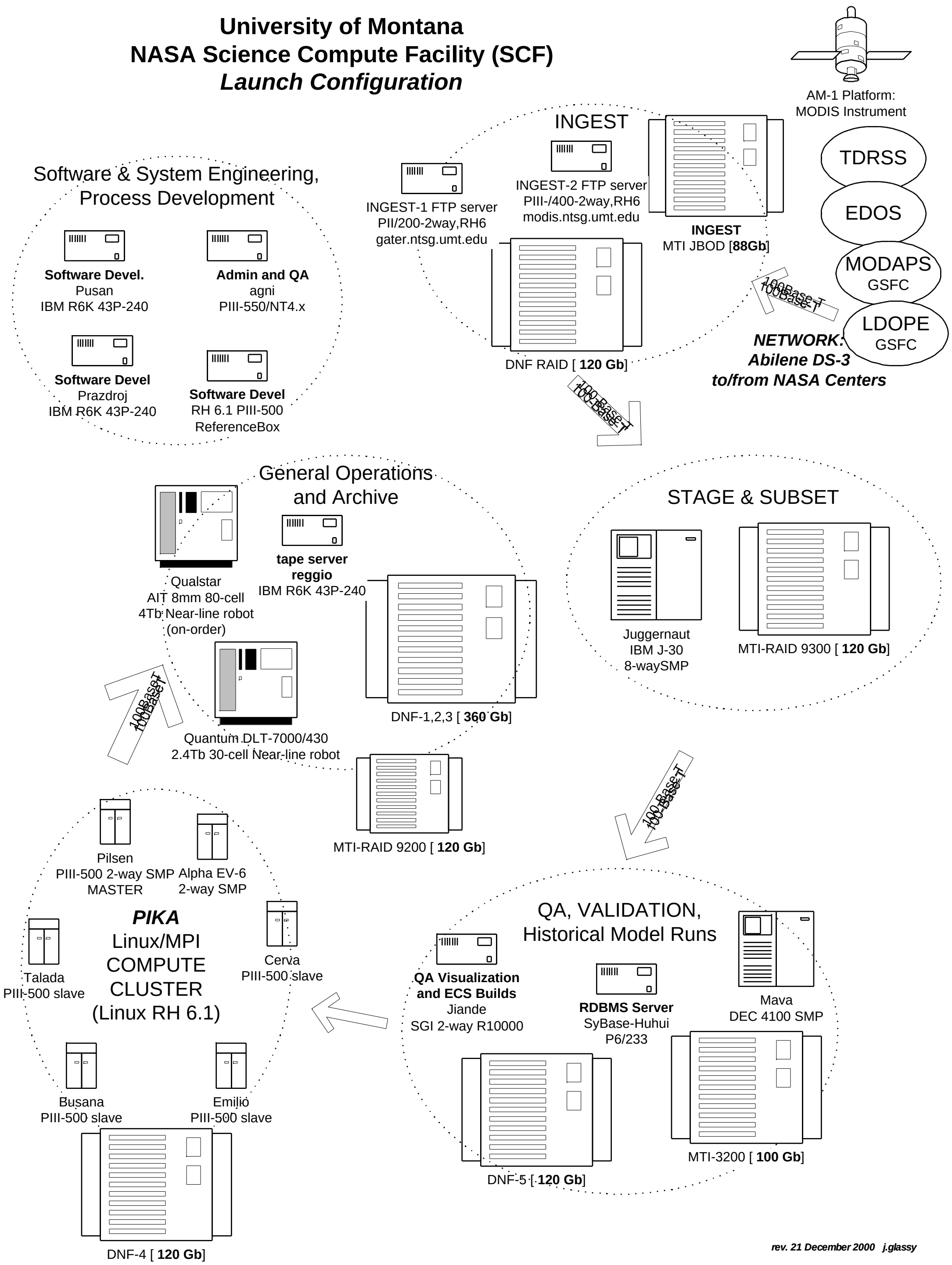
SCF DEVELOPMENT

Incremental additions to the Montana SCF were made during this period to increase our ability to perform high volume QA, test, and limited production in support of our global validation program. Hardware additions are summarized here:

- A total of (7) additional Dynamic Network Factory Enterprise 182Gb RAID5 storage units were added to the MODIS Compute Ring
- Our network performance profiles were refined and stabilized at ca 300Kb/sec transfer rates to/from the GSFC, using our Abilene DS-3 connection routed through the NW-Net GigaPOP.
- We purchased and installed a AIT-2 8mm 2.4Tb 80-cell tape library, for inclusion in our back-end archival processes.
- We deployed an additional (2) compute servers; Microway Alphaserver 21264/EV-6 SMP 750mhz workstations, running Linux Redhat 6.1.x operating system. These systems increased our previous Linux cluster of (5) nodes to (7) total.

Our current configuration is depicted in the diagram below:

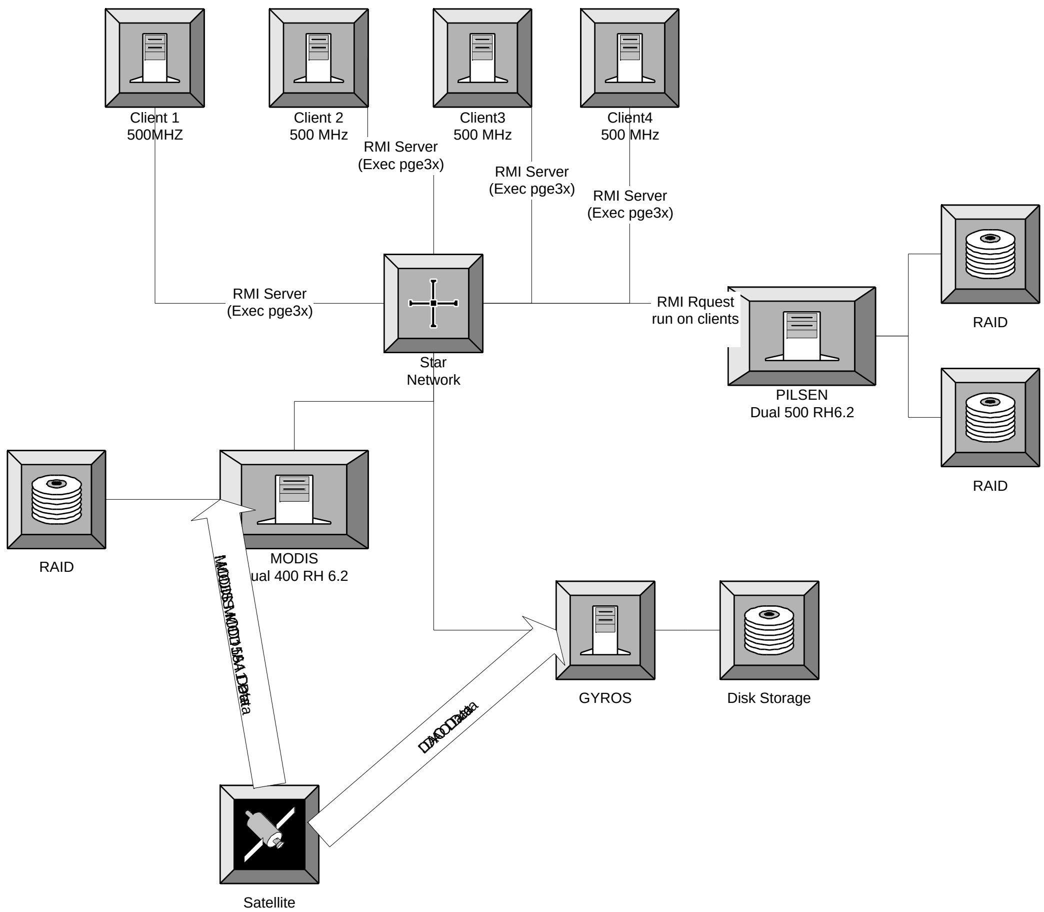
University of Montana
NASA Science Compute Facility (SCF)
Launch Configuration



Linux Cluster Development and Implementation

In last several months we have geared up to do several processing campaigns that involved our Linux cluster. The development of the cluster and automation software has spanned several versions. We are moving from collection of Perl and shell scripts towards an integrated Java environment that would give us more control in the distributed environment. We have used Java client/server model to implement the distribution of tasks among the hosts in the cluster. One of the advantages of this approach is that we are remove the limitation of running the distributed environment only on Linux hosts – the Java portability should allow us to operate in truly heterogeneous environment. A diagram of our distributed cluster environment is shown below:

UM SCF Cluster and Processing Development



We have currently implemented distributed cluster servers to run both the FPAR, LAI 8-day (PGE34) and PSN daily (PGE36). On the client side we have a first version of PGE34 client and scheduler that implements a simple load balancing scheme. This system has been used in runs that produced our latest FPAR/LAI composites. Using 5 hosts we were able to process daily global FPAR/LAI composite in about 25 minutes. A similar system was used to produce our global 8-day PSN composite, which is quite bit more complicated. In the latter case, we needed to perform around 5,000 tile executions using the PGE. On current Linux cluster this required ca 4 hours to complete. In the next versionl, we plan on implementing a better graphical user interface for our system and to unify the Java/RMI environment. The initial step of each processing campaign starts with a PCF (runtime input command set) generation step, which are currently written in Perl and with a graphical front end written in PerlTk.

COLLABORATIONS: SCIENCE AND DATA SYSTEMS

During this period the following collaborations were pursued for MODIS related activities:

- Continued to collaborate with MODIS Oceanographer Dr. Mark Abbott of Oregon State University on the MODIS Direct Broadcast program progress, involving his satellite dish installation at Corvallis, performing a limited series of network throughput tests using the Abilene DS-3 between Corvallis and Missoula.
- Continued to closely collaborate with the Boston University staff (Yura K, Yu Zhang, Yujie Wang, Ranga Myneni in the refinements to QA procedures and interpretation of mod15a1 and mod15a2.
- We initiated a series of MODLAND telecons to revisit a number of global land cover classification issues as they pertain to consistency across land products. These have resulted in a refinement of the MOD12Q1 strategy and development of a prototype 6-biome end-member classification by Dr. Mark Friedl of Boston University for our evaluation and use.
- We initiated an interim scheme to locally archive our daily intermediate data products (MOD15A1 and MOD17A1), in support of our on-going Quality Assurance program, via periodic downloads from the MODAPS production environment.

TRAINING

- J. Glassy, P. Votava, and R. Nemani all attended the RSI IDL Intermediate IDL 1 week training course, July 18-22, 2000 in Missoula, Montana with IDL Consultant Dr. David Fanning.

MEETINGS ATTENDED

MODIS Science Team Meeting, June 7-9, 2000, College Park, MD
LAND QA Visiting Scientist Meeting, July , 2000