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

15 July, 1999

OBJECTIVES:

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

- Organization of a global biospheric monitoring network with collaborating U.S. and international science agencies for EOS Land validation.

- 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 fire management.

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. Soizik Laguette, 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.

ACTIVITIES OF SWRunning (MODIS Team Member)

WORK ACCOMPLISHED:

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
PIK-NPP = a global NPP model intercomparison
VEMAP = a US based ecological model intercomparison

BIGFOOT -- Characterizing Land Cover, LAI and NPP at the Landscape Scale for EOS/MODIS Validation:

The BigFoot project has now started as a part of the EOS Validation program. Four sites have been selected for initial field activity, all FLUXNET sites. The BIGFOOT measurement protocol is the guide for the international GTOS-NPP project. So BIGFOOT scaling principles will be propogated globally.

The project website is at:
http://www.fsl.orst.edu/larse/bigfoot/slide1.html

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. This network is ready for EOS launch now.

To accelerate the use of FLUXNET for EOS validation we have just recently started a Real-Time Flux Validation project with Ameriflux. The invitation letter is printed below, giving science rationale and methodology planned.

29 June 1999

Invitation to Ameriflux members for a Real-time validation program

Dear Ameriflux members;

One of the ongoing justifications for a flux tower network has been the oppurtunity to use the measurements for validation of both satellite data and SVAT model simulations. Some model validation efforts have now been published for certain sites, however there has not been a coordinated, network wide program. Part of the impediment has been the assumption that a tower team would be obligated to publicly post their flux data before having sufficient time to make corrections. I think we can develop a coordinated validation program and avoid this impediment.

Specifically I would like to invite each tower team to join in a real-time multi-dimensional validation program. The key component will be that each tower team transmit their micrometeorology measurements every week, (but NOT their flux measurements) to a central data center. My research group will then ingest that week's data and make two calculations,

(1) first the weekly Net Primary Production as computed by the standard global NASA EOS algorithm, see http://www.forestry.umt.edu/ntsg/eos/
(2) and second, the daily NPP, NEE and ET as computed by our BIOME-BGC ecosystem biogeochemistry model, see http://www.forestry.umt.edu/ntsg/research/projects/

for examples from the BOREAS project. Incidently, we will also invite any other modeling teams that want to do these computations weekly to participate.

These calculations will be posted back to the host data center, on an ongoing graph for each participating tower site within 24hr. Note that we will post these calculations without seeing your flux data, so this is a blind validation of the computations on our part (and professional suicide according to some of my friends). We suggest the FLUXNET data center at the Oak Ridge Lab as host for this activity. We plan to automate all of the delivery and transmission of datasets. As these are only point (not spatial) datasets, they are very small.

Specific data request

Air temperature
Soil temperature at 10cm
Absolute humidity
Incident PAR or shortwave radiation
Precipitation
Windspeed

These measures should be from your top of canopy location at 0.5hr reporting intervals.

To initialize our BIOME-BGC model, we must know something about the vegetation at your site. We need to know the biome type, and the following parameters. Note that we are equally interested in all biome types, not only forests.

Site and Stand Parameters

Leaf area index, leaf longevity, specific leaf area
Soil water holding capacity in top 1m

Leaf, stem, litter and soil carbon content
Leaf, litter and soil N content

Much of this data is already established on the Ameriflux website, and we can retrieve it there. We also plan to use any previous flux data that each site has released to the Ameriflux web site to tune our model before starting the "blind" validation.

We hope to initiate this program on January 1 (avoid Y2K!), presuming successful EOS launch in Sept-Oct 1999. We request each tower site to specifically respond with their intentions to participate, or not participate in this activity. Any tower that wishes to participate, but is limited by hardware, such as remote access to their datalogger, should include the equipment requirement they need to participate.

Please respond by 15 July 1999. I think this will be great fun, and an immense scientific challenge. If you have any questions or suggestions about this plan as currently stated, feel free to comment.

Thank you,
Steve Running
Univ. Montana

THE GAIM-NPP model intercomparison study

We co-authored 3 papers for a special issue of Global Change Biology that came out in April 1999. See the publication list.

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. Reports from the ILTER office are that international field sites are slow in joining the program. Until real EOS data is available as an inticement, I expect this reluctance to continue.

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/

VEMAP Phase II is currently building the datasets and initialization files for transient simulations of climate and vegetation response for the continental United States. These new simulations will be executed within the next 6 month period.

COLD REGIONS BIOSPHERIC MONITORING

As part of our interests in improving biospheric monitoring, we have developed with JPL the concept of a high repeat cycle SAR for high latitude monitoring. The

following paper (intro reprinted here) in EOS this spring summarizes our current thinking.

RADAR REMOTE SENSING PROPOSED FOR MONITORING FREEZE/THAW TRANSITIONS IN BOREAL REGIONS

EOS Transactions Vol 80. No. 19 pp213, 220-221.

S.W. Running, J. S. Kimball and A. R. Keyser

Numerical Terradynamic Simulation Group, University of Montana, Missoula, MT 59812

J.B. Way, and K. C. McDonald,

Mail Stop 300-233, Jet Propulsion Lab, California Institute of Technology, Pasadena, CA 91109

S. Frolking

Complex Systems Research Group, University of New Hampshire, Durham, NH 03824

R. Zimmerman

Bayreuth Institute for Terrestrial Ecosystem Research, University of Bayreuth, Bayreuth, GERMANY

(Email contact: swr@ntsg.umt.edu)

Recent atmospheric General Circulation Model (GCM) projections summarized in the 1995 IPCC report indicate an average global warming of the lower troposphere from 1 - 3.5°C during the next century, depending on the greenhouse gas emissions scenario used. Further, the IPCC 1995 report states that "all model simulations show...a maximum warming in high northern latitudes in winter." Evidence that high latitude warming has begun is accumulating. Our analysis of local weather records across Alaska suggests that the growing season has been extended by over 14 days in the last 50 years by increasing spring temperatures (***Figure 1***).

High latitude warming may have amplified implications on global change rates because the impacts will not necessarily be linear. The state transition of the land surface from a frozen to a thawed condition is abrupt near 0deg, and initiates a number of terrestrial processes that are nearly dormant during frozen conditions. This state transition represents the closest analog to a biospheric and hydrologic on/off switch existing in nature, affecting surface meteorological conditions, ecological trace gas dynamics and hydrologic activity profoundly. This rather abrupt state transition occurs each year over roughly 50 million km^2 of the Earth's terrestrial surface at latitudes above 40 degrees. If the timing and/or areal extent of this state transition were to change significantly, measurable changes in climate, hydrology and biogeochemistry would result.

Our recent research is finding that satellite based radar remote sensing techniques are particularly well-suited to quantifying this freeze/thaw transition over broad landscapes, due to specific molecular features of how electromagnetic radiation at radar wavelengths interacts with polar water molecules in solid and liquid states. We applied Ku-band (2.1 cm) 25 km resolution NASA Scatterometer (NSCAT) data to examine the feasibility of spaceborne radars for operational mapping of circumpolar freeze/thaw cycles for the northern high latitudes (McDonald et al. 1998). We used NSCAT mosaics to derive landscape scale freeze/thaw maps of Alaska during spring 1997, and compared with interpolated surface temperature records (**Figure 2**). The NSCAT temporal response shows a 3 to 5dB (decibel) shift in measured backscatter, well correlated with landscape springtime thaw processes. The NSCAT-based maps clearly show the progression of the landscape from an initial frozen to a thawed state.

The large range of seasonal and interannual variability of the boreal frozen surface, and its broad ranging impact on regional and even global climate, hydrology and biogeochemistry would suggest that regular, accurate monitoring be a priority in global change research. However, the density of reporting surface weather and hydrologic stations in sparsely populated high latitudes is very low, on the order of 1 per million km^2, especially in Canada and Siberia. Current optical satellite data suffer from cloud contamination and seasonal illumination problems, while passive microwave data have a very coarse (100-625km^2) spatial resolution. At present no adequate monitoring system is in place to document high latitude climate change. An additional benefit is that radar sensors do not rely on solar illumination or cloud free conditions for effective monitoring.

This paper summarizes recent progress in quantifying the land surface freeze/thaw transition regionally by satellite, the broad consequences of the freeze/thaw transition in boreal biogeochemistry, and the potential for future global monitoring of this significant boreal phenomenon.

NASA EOS and Related MEETINGS ATTENDED (SWR)

EOS-SEC
NASA EOS IWG Vail, CO June 1999
MODIS Meeting May 1999
VEMAP meeting, April 1999

Publications:

Churkina, G., Running, S.W., Schloss, A.L. (1999) Comparing global models of terrestrial net primary productivity (NPP): the importance of water availability. Global Change Biology. 5:46-55.

Running, S.W., Collatz, G.J., Washburne, J., Sorooshian, S. (1999) Land Ecosystems and Hydrology. EOS Science Plan. 5:197-260.

Running, S.W. (1999) A Blueprint for Improved Global Change Monitoring of the Terrestrial Biosphere. Proceedings of International Workshop on Land-Surface Water Budget. Tsukuba, Japan. 271-297.

Thornton, P.E., and Running, S.W. (1999) An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. Agriculture and Forest Meteorology. 93:211-228.

Waring, R.H., Running, S.W. (1999) Remote Sensing Requirements to Drive Ecosystem Models at the Landscape and Regional Scale. Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes. 2:23-37.

S.W. Running[1], D. D. Baldocchi[2], W. B. Cohen[3], S.T. Gower[4], D. P. Turner[3], P. S. Bakwin[5], K. A. Hibbard[6] A GLOBAL TERRESTRIAL MONITORING NETWORK INTEGRATING TOWER FLUXES WITH ECOSYSTEM MODELING AND EOS SATELLITE DATA. REMOTE SENSING OF ENVIRONMENT (in press)

White, J.D., Running, S.W., Thornton, P. (1999) Impact of growing season length variability on carbon assimilation and evapotranspiration over 88 years in the eastern deciduous forest. Int.J. Biometeorol. 42:139-145.

Cienciala, E., Running, S.W., Lindroth, A., Grelle, A., Ryan, M.G. (1998) Analysis of carbon and water fluxes from the NOPEX boreal forest: comparison of measurements with FOREST-BGC simulations. Journal of Hydrology. 212-213:62-78

Galina Churkina, Steven W. Running, Annette L. Schloss and the participants of ”Potsdam ‘95”; (1999) Comparing global models of terrestrial net primary productivity (NPP): The importance of water availability. Global Change Biology. 5:46-55.

Wolfgang Cramer, David W. Kicklighter, Alberte Bondeau, Berrien Moore III, Galina Churkina, Bernard Nemry, Anne Ruimy, Annette L. Schloss and the participants of “Potsdam ‘95”, (1999). Comparing global models of terrestrial net primary productivity (NPP): Global Change Biology. 5:1-15

Galina Churkina and Steven W. Running, (1999) Investigating the balance between timber extraction and the productivity of global coniferous forests. Climatic Change (in press).

Steven W. Running Peter Thornton Ramakrishna Nemani Joseph M. Glassy (1999) GLOBAL TERRESTRIAL GROSS and NET PRIMARY PRODUCTIVITY from the EARTH OBSERVING SYSTEM METHODS IN ECOSYSTEM SCIENCE O.SALA, R.JACKSON, H. MOONEY Eds.
Springer-Verlag (in press)

University of Montana International 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 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:

EOS Natural Resource Project

- To produce enhanced EOS land application products for natural resource management.
- To train natural resource land managers to download, display and interpret EOS data to enhance the utility of EOS in land management.

EOS Education Project

- To identify, develop and disseminate EOS-related curricula for K-16 education.
- To provide professional development of K-16 pre-service and in-service teachers.

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 World Wide Web site (http://www.fs.fed.us/land/wfas).

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

Under the direction of Dr. Verbyla, curriculum is being developed for EOS data products that will be taught this fall and winter in Fairbanks and Anchorage, Alaska. The participants will include natural resource personnel working in Alaska.

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

Under the direction of Dr. Larsen, curriculum is being developed for EOS data products that will be taught this fall and winter at the University of Missouri, Columbia. Dr. Larsen is particularly interested in teaching University personnel to incorporate EOS data in their curriculum and research.

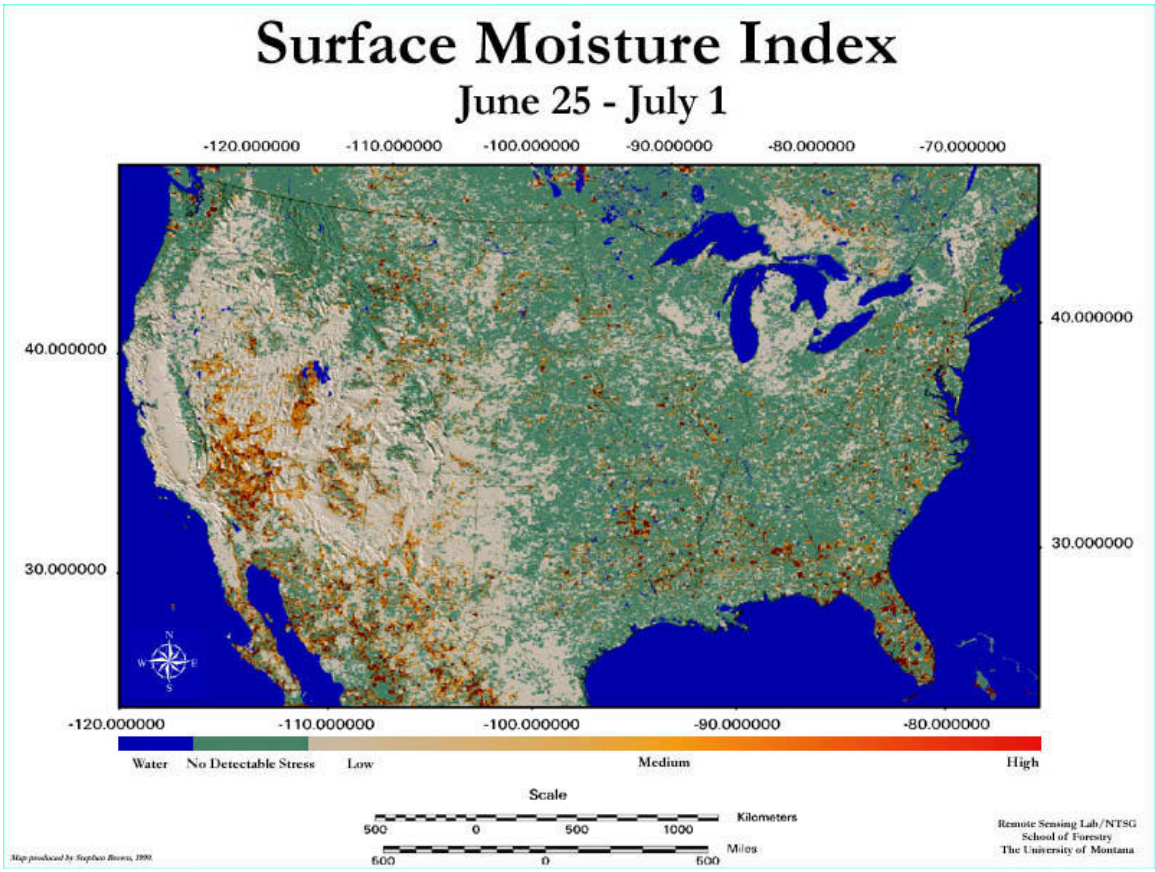
4. University of Idaho

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. EOS Data Processing and Sample EOS/MODIS Products

1. Surface Moisture Index

We have been actively producing and posting to our web site a Surface Moisture Index product (http://eostc.umt.edu). Postings to our web site occur once per week. The Surface Moisture Index is derived from weekly composited Pathfinder data (to be replaced by MODIS data when available). The two main inputs for the Surface Moisture model are NDVI and radiometric surface temperature.

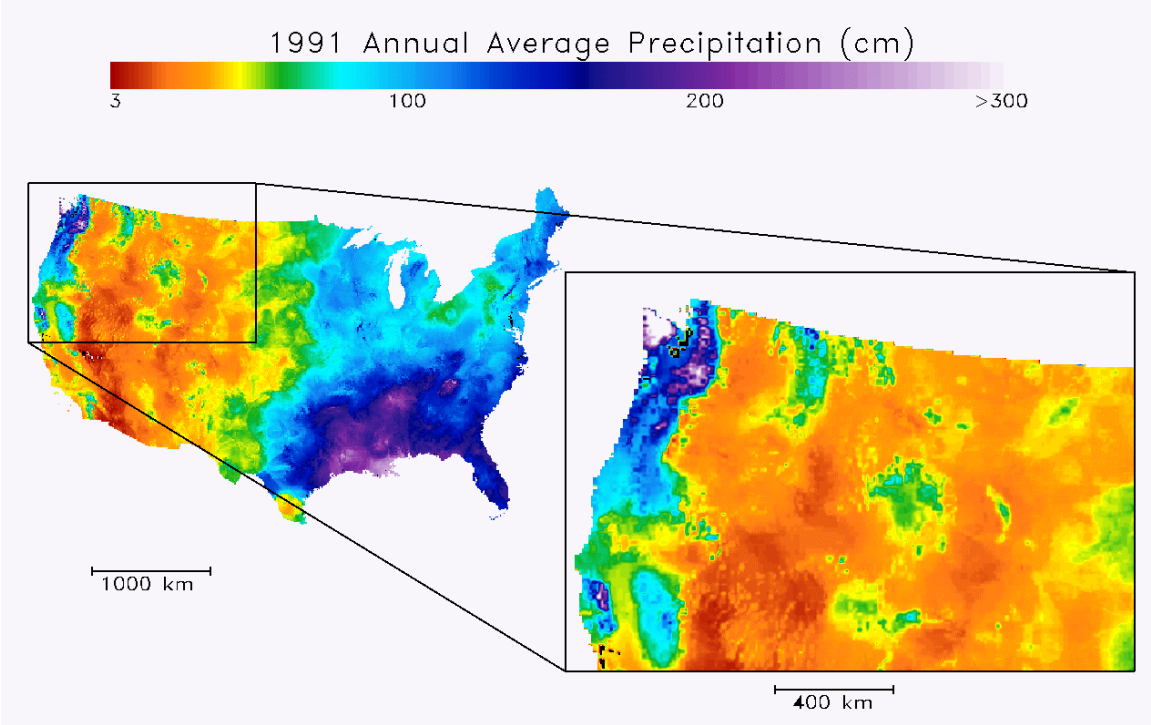


The Surface Moisture Index has applications for both fire and land managers. Fire managers need to track seasonal fire potential for resource allocation, severity budgeting, and fire preparedness. The condition of fuel is described primarily by moisture content, which changes due to season and weather. In addition, land managers can effectively

monitor landscape moisture stress levels in the soil/vegetation surface. This data is also posted for the 1998 season with plans to provide a full historic data base.

2. Climatology

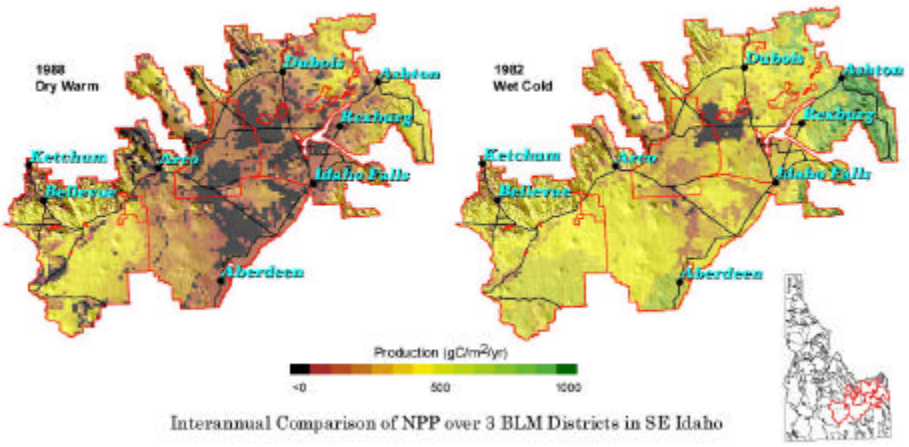
As an ancillary data base to EOS data products, we are actively processing 18 years of historic weather station data to produce daily meteorological continuous surfaces for the period 1980 - 1997, over the conterminous United States. Reliable surface meteorological data are a basic requirement for hydrological and ecological research at any spatial scale. Likewise, accurate meteorological and climatological information is an important component of natural resource management decision making.
For regional and landscape level assessments of daily meteorological data, a station network of routine observations is a uniquely valuable source of information. Networks such as those operated in the USA by the National Weather Service (NWS Cooperative Observer Network) and by the Natural Resources Conservation Service (SNOTEL Network, USDA Soil Conservation Service) are of particular value for their wide geographic distribution, duration of record, frequency of observations, and standardized measurement techniques. For accurate simulations of hydrologic and ecological land-surface processes, the minimum required daily meteorological variables are; precipitation, surface air temperature, surface air humidity, and incident shortwave radiation. Daymet is a model that has been developed to interpolate heterogeneously distributed station data in complex terrain to a continuous surface and provides estimates of the minimum required variables mentioned above.



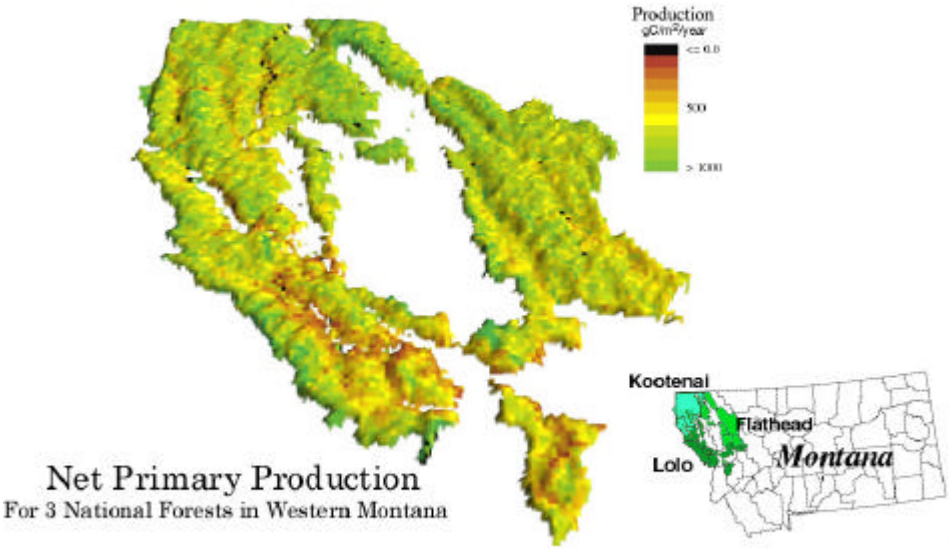
3. Forest and Range Productivity

We have been producing surrogate data for MODIS PSN/NPP using Pathfinder data with MOD15 and MOD17 simplified algorithms and meteorologic data from modeled input. We are sharing these mock data sets with land managers in order to introduce them to anticipated MODIS data streams. Forest land managers require estimates of primary production to monitor forests for long-term sustainability. Rangeland vegetation can be highly variable from week to week. Monitoring range

condition is significant to the management of a productive system for wildlife and domestic animals. We are also investigating proper unit conversions from MODIS PSN/NPP outputs to units more relevant to land managers.



Interannual Comparison of NPP over 3 BLM Districts in SE Idaho



Net Primary Production
For 3 National Forests in Western Montana

D. Web Development

We have an on-line web site (http://eostc.umt.edu) with branches to the EOS Education Project and the EOS Natural Resource Project. Access to the University of Montana EOS Training Centers data streams will be provided via this web site as well as on-line training and overviews of data products and NASA's EOS program. The web site is data base driven and will continue to grow as EOS data streams become available and processed. We are currently posting satellite derived Surface Moisture Index once a week and targeting fire and land managers for training and application.

E. User Group Meetings

We have been actively recruiting participation from key personnel in the natural resources as we develop, process, and post EOS data. Land managers are also providing us with the information necessary to develop meaningful curriculum for short courses. Thus far, we have had conferences with personnel from the Bitterroot National Forest, the USDA Forest Service Rocky Mountain Research Station, the USDA Forest Service Remote Sensing Applications Center (RSAC), the Montana Natural Resource Information System (NRIS), and the Northwest Empire Growth and Yield. We have also met with our project partners, Dr. David Verbyla and Dr. David Larsen on site at the University of Montana, Missoula.

F. Curriculum Development

1. EOS Natural Resource Project

We are actively developing curriculum for two to three day short courses for natural resource managers. We have identified a modular concept as the best approach for these workshops. Day 1 of the course will consist of basic remote sensing theory, day 2 will build on that theory in relation to the specific EOS application product as well as train natural resource managers on how to download, display, and interpret specific EOS data. Finally, day 3 will be an application day that applies EOS data to a land managers needs.

2. EOS Education Project

The EOS Education Project has developed on-line courses for educators that teaches them the basics of microcomputers. They will also offer an on-line course that will result in a GIS certificate. In addition, new protocols and curriculums are being developed to enhance EOS education in already existing programs such as NASA's Global Learning and Observations to Benefit the Environment (GLOBE) program and the Montana Geographic Alliance.

G. MODIS Data Stream Preparation

The EOS Training Center benefits from its relationship to the Numerical Terradynamic Simulation Group (NTSG) within the School of Forestry by having an archive of Pathfinder and Landsat data (current and historic EOS data). We are currently developing methods and internet capabilities to download EOS data (specifically MODIS) in an HDF-EOS format. We are also currently developing methods to automate the downloading and post processing of EOS data products so that natural resource managers have timely access to these data sets.

H. Metrics

We are actively assessing and complimenting the metrics developed and used by NASA specific to Regional Earth Science Applications Centers (RESACs). We will follow the outline below as identified by NASA:

The Government Performance Results Act (GPRA) requires that all Government funded projects report their accomplishments and the resulting impact these accomplishments have on the socio-economic well-being of society and the Nation.

Description:
Summary of the project written for an outside audience i.e., reader who is not intimately familiar with the technology, science, applications and techniques.
Project Work Location:
Geographic location where the work is actually being performed.
Inputs:
All the inputs that are needed to complete and carry out the project. This includes human and physical capital and materials required for the research and applications process. It describes the cost of doing business and includes: budget, number of researchers/teams, participating users, data required, and use of other assets e.g., ancillary data.
Outputs:
Immediate observable products of the research and applications activity. Describes the efficiency resulting from the use of the resources. Includes data sets and applications developed, models developed, number of presentations made, papers published, number of graduate students supported (if applicable), and other direct results of the project.

Outcome:
Longer term results to which the program contributes. Includes understanding gained, applications demonstrated, resulting programmatic decisions enabled as a result of these applications. Examples included outcome such as "the rate of growth of the northern forest was accurately measured for the first time".
Impact:
This section discusses the total consequences of the program, including intended benefits and unintended positive results. Includes description of utility and socio-economic benefit to the end users/customers. This section shall answer questions such as: Why were the results of the projects useful? How were they useful? How were the end results (i.e., applications and data products developed) used in decision-making? What kind of significant economic or policy consequence resulted from the project? Most important of all-it answers the question: **"So what?"** Includes assessments such as new knowledge shared, cost saved, new applications or functions that were done that were not possible before. How did or would the results impact the public good or expanded commercialization of value-added Earth Science data.

ACTIVITIES OF R. Nemani (MODIS Team Member)

WORK ACCOMPLISHED:

1. MOD17 PSN/NPP Algorithm:

Using monthly LAI/FPAR for 12 years (1983-1994) derived from 8km Pathfinder data (surrogate for MODIS LAI/FPAR) and daily climatic data gridded at 1x1 lat/lon (surrogate for DAO data), we are testing MOD17 algorithm in the following ways:

1) Ability to handle missing composite periods: When continuous cloud cover or other instrument problems preclude the production of LAI/FPAR, what is the best way to handle the lack of LAI/FPAR input into the GPP/NPP algorithm? We are exploring various options in this regard: 1) no estimation of GPP/NPP for that particular composite period and subsequent exclusion from the annual estimates. 2) Using LAI/FPAR from the previous composite period, but flagging the GPP/NPP as less than perfect in the Q/A.

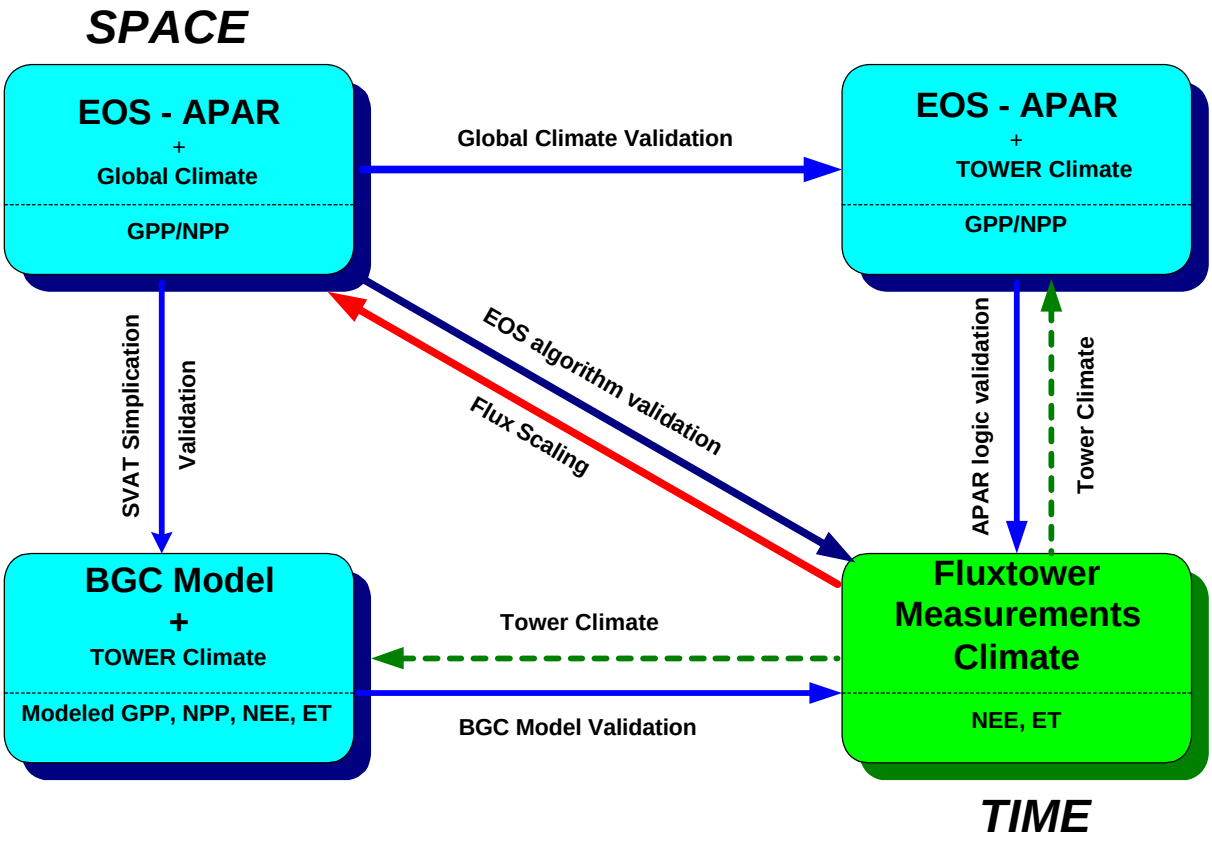
2) Magnitudes and seasonality of GPP/NPP for various biomes: Monthly GPP/NPP computed from the historical data will be compared to the estimates reported from various NPP models for Pottsdam global NPP modeling effort. This effort concentrates on the spatial distribution and seasonality of NPP, to identify geographic areas or seasons that are clearly not reproduced.

3) Inter-annual variability in terrestrial carbon exchange: 12 years of historical data provides a valuable dataset to exercise the MOD17 algorithm for its ability to capture inter-annual variations in GPP/NPP.

4) Comparing the MOD17 GPP/NPP with carbon fluxes estimated using BIOME-BGC: MOD17 algorithm is a simplified version of BIOME-BGC, an ecosystem model that simulates complete daily carbon, water and nitrogen cycles. By comparing the outputs of MOD17 with full-up BIOME-BGC estimates, we verify the loss of accuracy in the estimates and how these losses are distributed seasonally and geographically.

2. **Validation of MODIS GPP/NPP**

Working details of a flux tower based validation of MODIS GPP/NPP (Figure 1) are being finalized. The strength of this validation plan is its ability to provide validation of several key components of MODIS GPP/NPP algorithm. For example, flux tower based climatic data is useful for checking the climate drivers for MOD17 derived from DAO. Observed climatic conditions are also used to drive an ecosystem model which computes various carbon fluxes useful for interpreting the net ecosystem exchange observations from the eddy correlation measures. Protocols for automated data exchange are being developed to share observed tower climate data and MODIS products between MODLAND members and FLUXTOWER scientists. As a part of this validation effort, several AMERIFLUX sites have agreed to participate in this effort. The proposed validation scheme provides a continuous and near-realtime validation of MODIS GPP/NPP products. The tower sites, in turn, receive MODIS derived GPP/NPP, leaf area index, FPAR and land cover data around their sites.



2. Asymmetric warming over West Coast of the U.S.

Recent climate warming trends are reported to be asymmetric with night minimum temperatures rising faster than daytime maximum temperatures. Increases in greenhouse gases, cloud cover, rainfall etc. have been proposed as possible mechanisms for the observed asymmetry. Here we explored the possibility of increased sea surface temperatures resulting in higher atmospheric water vapor to be a possible cause for the observed asymmetry in climate warming.

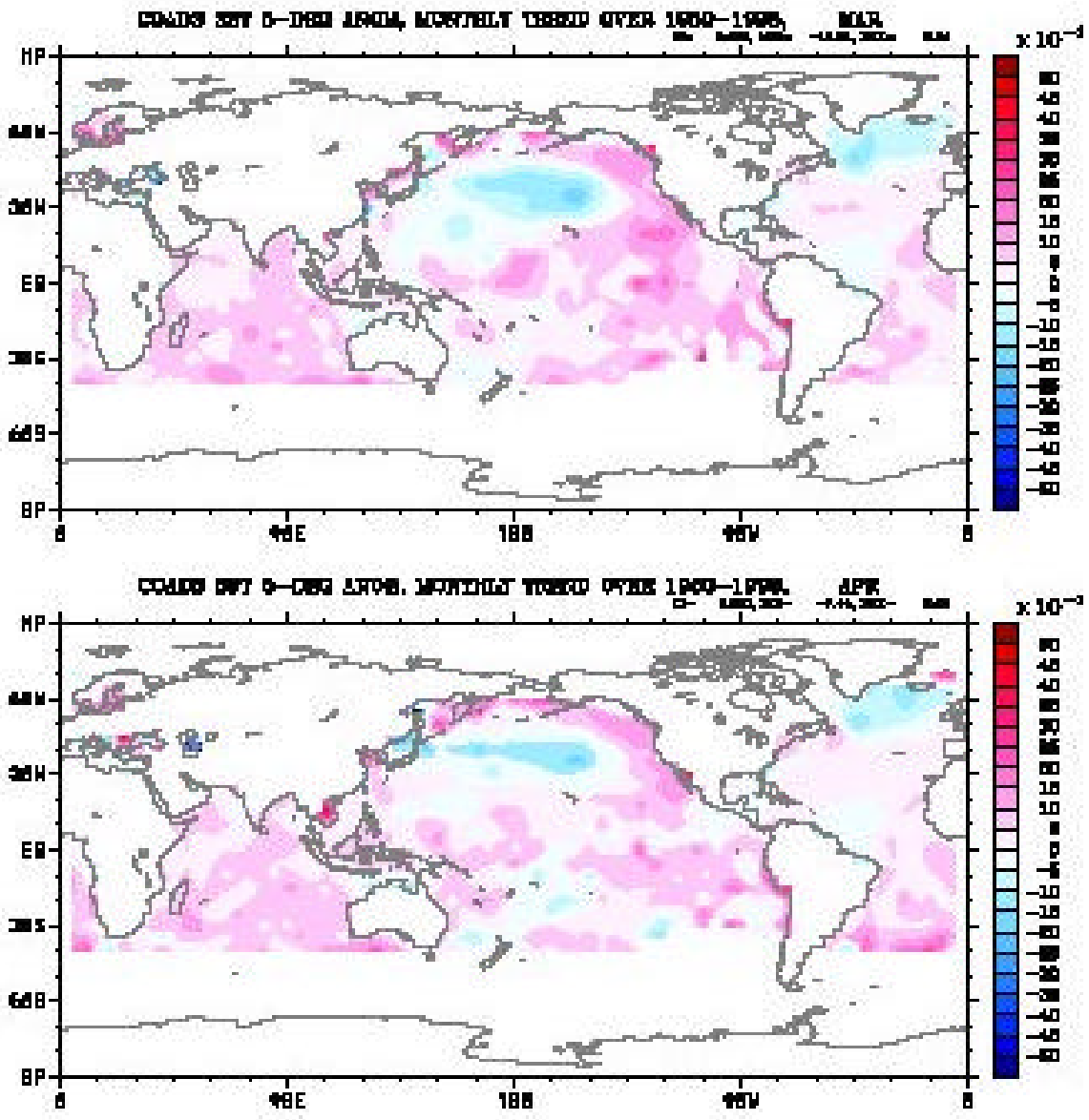


Figure 2: March and April trends in global sea surface temperatures between 1948-1998. Strong warming trends are seen in both months over North Pacific Ocean influencing much of North America. Increasing SSTs enhance surface evaporation, consequently more humidity is advected over land. This increase in humidity over land is, at least, partly responsible for the asymmetric warming (Tmin rising more than Tmax) reported over much of North America.

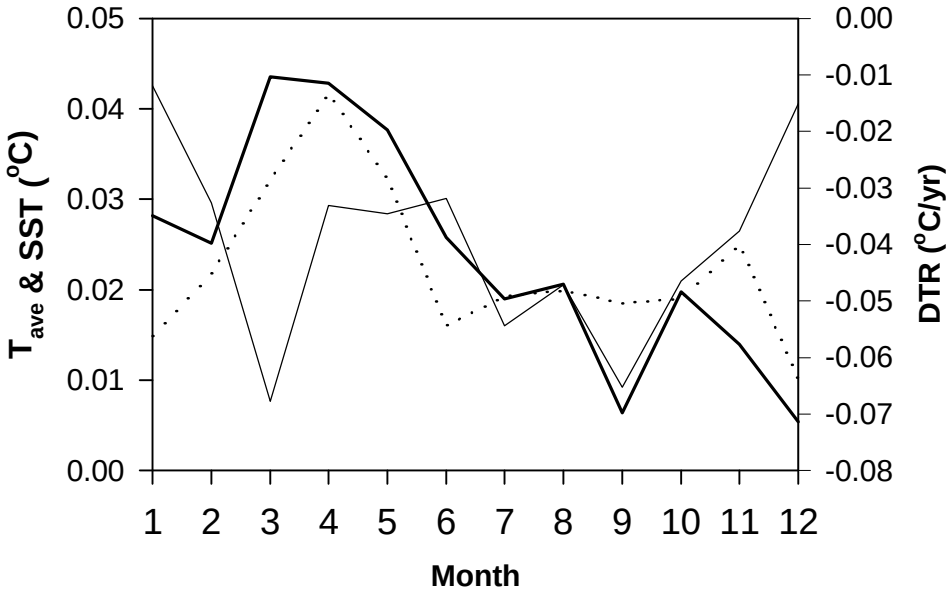


Figure 3. Monthly trends in Tave (thick line), DTR (thin line) and SST (dashed line) over the west coast of U.S. Climatic data available for several stations between San Diego and Seattle were averaged for this analysis. The large DTR decline in March was accompanied by the highest monthly increases in nighttime cloud cover (18%/47 yr, $p=0.010$), T_{dew} (2.73ºC/47 yr, $p<0.001$), and T_{min} (3.62ºC/47 yr, $p<0.001$) along with a small but insignificant increase in precipitation.

MEETINGS ATTENDED:

MODIS Science meeting, Greenbelt, MD, May
Workshop on 'Long-lead climate forecasts for California', La Jolla, CA, May
International conference on global carbon cycle, Tsukuba, Japan, April
Workshop on 'Data fusion and data mining', Moffett Field, CA, July

CONFERENCE PRESENTATIONS:

'Land surface products from the NASA/EOS', La Jolla, CA
'Monitoring terrestrial net primary production during NASA/EOS era', Tsukuba, Japan
'Data fusion in EOS/MODIS algorithms', Moffett Field, CA.

PUBLICATIONS:

Nemani, R.R., S.W. Running, P.E. Thornton and J.G. Glassy. 1999. Monitoring terrestrial net primary production during NASA/EOS era. In: Proceedings of the International Conference on global environmental monitoring, Tsukuba, Japan.

Wessman, C., R. **Nemani** et al. 1999. Remote sensing perspectives and insights for study of complex landscapes. In: Integrating hydrology, ecosystem dynamics, and biogeochemistry in complex landscapes, Dahlem workshop report., eds: J.D. Tenhunen and P. Kabat., John&Wiley, NY.

Chase, T.N., R.A. Pielke, Sr., T.G.F. Kittel, R.R. **Nemani** and S.W. Running. 1999. Simulated impacts of historical land cover changes on global climate in Northern winter. Climate Dynamics (in press).

Hasenauer, H., R. **Nemani**, K. Schadauer and S.W. Running. 1999. Forest growth response to changing climate between 1961-1990 in Austria. Forest Ecology and Management (in press)

Keyser, A., J.S. Kimball, R.R.**Nemani** and S.W. Running. 1999. 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. 1999. Asymmetric climatic warming in coastal California and its impact on the premium wine industry. Climate Research (in review)

Nemani, R.R., M.A. White, D.R. Cayan, G.V. Jones, S.W. Running and J.C. Coughlan. 1999. Have recent climatic changes helped the California wine industry? California Agriculture (in review).

ACTIVITIES OF J. M.Glassy, MODIS Software Engineer: July 1999

OBJECTIVES

My objectives during the time period January 1999 to July 1999 are summarized next. Details on each of these activity areas follow below.

Algorithm Development

- Implemented an updated PGE-33 (daily FPAR,LAI) algorithm, version 2.1.5 due deliver to SDST late July 1999. Currently the version 2.1.6 is baselined at MODAPS.
- Implemented an updated PGE-34 (8-day composite) algorithm, version x.y.z, due for SDST delivery mid-July 1999.
- Implemented an updated PGE-36 (daily PSN,NPP) intermediate algorithm, to use a revised "n-day-committed" intermedaite data layer, and to interface to a new subset DAO file, and to integrate to the newest SDPTK v.5.2.5.
- Implemented updated PGE-37 and PGE-37 algorithm codes.
- Maintain the latest versions of the NASA software tools required for algorithm implementation: (SDPTK, HDFEOS and HDF software libraries)
- Updated the MUM API library (now at version 2.3.5) on all supported compute platforms.
- Oversee the development of the MODIS Climate Modeling Grid (CMG) variants of the above land algorithms, implemented as monthly aggregated products.

Pre-Launch QA and Certification Activities

- Participate with the MODADPS and LDOPE staff in a number of on-going algorithm readiness tests, including the N-day test, the X-day test and the Y-day test.
- Deployed new versions of COTS tools (IDL and ENVI) with LDOPE supplied QA software scripts.
- Deployed new version (v.1.1) of the Land Data Operational Processing Environment (LDOPE) command line QA tool suite.

SCF Development

- Manage the overall development of the Univ. Montana NASA Science Compute Facility, to assure effective deployment in the at-launch era.
- Major SCF activities included an entire re-location of our SCF to another room at the University of Montana Science Complex.
- Refined organization of FTP ingest activity to include system redundancy.
- Established operational viability of our MTI 2.4Tb DLT tape robot for full 30 cell robotic operation.
- Performed orders for (5) 120Gb Dynamic Raid Factor (DNF) RAID 3/5 units of new disk storage and a prototype Linux cluster were made.

Collaborations: Science and Data Systems

- Collaborate with Boston University staff on establishing quality assurance practices and procedures for the MOD15A1 FPAR, LAI product.
- Coordinate with with Dr. Mark Abbot's MODIS Oceanography group (Oregon State University) in an evolving program to implement a western USA X-band direct broadcast feed from OSU to U.Montana, to allow us a near-real-time feed of key MODIS products for SCF use.
- Officially enlisted as a NASA SDPTK beta test site/advisory group, in anticipation of the migration to the new HDF v.5.0 data standard for HDFEOS and SDPTK.
- Attended NASA MODIS (Science Team and MODLAND/SDST) meetings.

WORK ACCOMPLISHED

From January 1999 to July 1999 we have divided our efforts between QA operations preparations, implementing a variety of minor ECS algorithm refinements, and initiating new collaborations for MODIS related activities.

ALGORITHM DEVELOPMENT

Several minor changes were applied to all Montana SCF PGE's across the board. These included:

- use of a standardized UM_VERSION version-date-time stamp placed as a global file attribute in all product files
- updated ancillary files (MOD15A1_ANC_v21.hdf, MOD15A2_ANC_v21.hdf, and MOD17A1_ANC_v21.hdf) which now contain all archive product field specifications. This data-driven approach allows minor modifications in the output product gridfields to be made with only a change in the ancillary file and not a re-compilation of the software itself.
- standardized use of an optional within-tile subset scheme whereby the .PCF file for a given algorithm contains a runtime user parameter specifying the corner points (in raster coordinates) of a rectangular region to restrict processing to. For example for PGE-33, the .PCF parameter would be: "FPAR_PCF_MBR|0,0,100,100" to restrict processing to just a 100x100 pixel subset of the tile. In the future we will expand the syntax to recognize the region described in terms of {latitude,longitude} coordinates.

Updated code deliveries from our SCF to SDST for PGE-33, PGE-34, and PGE-36 are planned for the mid to late July 1999 timeframe. Assuming launch occurs no earlier than September 13, 1999, we anticipate there will be enough time to integrate these PGEs into MODAPS prior to start-up time, approximately launch + two months.

PGE 33 and PGE 34 : (MOD15) FPAR, LAI daily intermediate and 8-day algorithms

Changes to the PGE-33 and PGE-34 code sets this period included integration with the

new NASA libraries (SDPTK v.5.2.5 and HDF-EOS v.2.5.1), the most recent MUM API library (v.2.3.5) as well as some minor refinements involving QA metadata field processing. Full IS grid (integerized sinusoidal land projection) tile processing for PGE-33 is now (479 sec/tile, 38.45 hours/1 CPU) and for PGE-34 is (59 sec/tile; ca 12.04 hours/1 CPU for a global coverage of 289 tiles) as certified on our AIX4.2.x build platform. Performance should be slightly better on the SGI production platform.

PGE 36 : (MOD17) PSN, NPP daily algorithm

Changes to PGE-36 primarily involved the addition of a new 2D data plane to the daily intermediate state file (e.g. MOD17A1.A1996214.h12v04.1998195101215.hdf). This new data plane (Yd_N_Committed) tracks for each pixel/tile combination the number of year-days successfully completed by the algorithm, providing a actual-date adjusted annual NPP estimate at the end of the year. This change increased the size of the daily intermediate file insignificantly-- from ca 11Mb/tile to 14Mb/tile. In response to an SDST request, we have also added a new PGE processing state table (held in the ancillary file MOD15_PROCSTATE.hdf) that consists of a 2D matrix of tile/year-day combinations. As each tile-yearday combination is successfully completed, the 0 in the slot is adjusted to 1. This facility should provide us with a second level check in the event that the daily intermediate files which accumulate values over the course of the year become corrupt, and we need to re-start the model at the "last known good date". Performance for the PGE-36, broken down by temporal model events is:

- First-in-year event: ca 45 sec/tile/CPU
- Eight-day composite event: ca 61 sec/tile/CPU
- Annual NPP event: ca 61 sec/tile/CPU

Another major change for PGE-36 made during this period involves the new layout for the ancillary daily climatology from the NASA GSFC Data Assimilation Office (DAO). The five surface climatology fields we need for PGE-36 are now packaged in a single HDFEOS file (rather than two before) and contain only these fields instead of the 25 to 30 fields present in the earlier scheme. This dramatically reduces the transfer data volume required to run PGE 36,37, and 38 and should also result in slightly increased performances for these PGEs.

PGE-37 and PGE-38 : PSN, NPP 8-day and annual NPP algorithm

The only changes made this period involved those discussed above involving the new year-day tracking facility. The current version of the PGE 36/37/38 algorithm is now under final integration and test at our SCF prior to delivery to SDST. Integration problems resulting from the migration to the new single file DAO DAS subset involved the way HDF dimension scale objects (masquerading as SDS fields) were interleaved with the actual 2D grid fields. A patch for this layout was implemented and tested as of July 13, 1999.

CMG Algorithm (PGE 39,63,64) Development

The CMG algorithm development is being led by software engineer Petr Votava. Three CMG algorithms are currently under development:

- Monthly FPAR, LAI : PGE 63
- Monthly PSN : PGE 39
- Annual NPP : PGE 64

The design of the CMG algorithm is completely done using object-oriented techniques. The mapping from the input pixels to the output CMG pixel is done on the fly using a special set buffer and a two-level aggregation process. Care has been taken to allow for any possible order of input data – i.e. if not all the inputs are present at once, a special intermediate file is created which enables us to keep track of the progress of the algorithm. This is especially important given the fact that pixels from several input tiles can map into single CMG output pixel.

There is a design document that accompanies the implementation. Currently we are working on much more detailed document, an API guide and a template document. Great attention has been paid to generality and abstraction of important classes so that this design can be easily used as a template for other teams working on the CMG products. The classes have been also implemented in a way that ensures that there is a lot of potential for reuse in other products, so that not only the design, but also the implementation can be used as a template.

Currently we are at work on a proposal that will add another PGE to the suite that will make the composition of our inputs (i.e. monthly, yearly) more efficient and simple. Estimated performance of the prototype CMG algorithm for a 0.25 degree global resolution coverage, all data layers, is 4.5 hours/CPU.

QA ACTIVITIES

The primary QA activities during this time period involved refining QA operational procedures involved in querying the LDOPE QA database and working with the MODAPS (MEBDOS) system to practice retrieving data granules for our algorithms. Several successful tests of these activities were conducted, but in general retrieving data from MODAPS was difficult due to the extremely short time periods our product data was available between formal test episodes (e.g. WILT, N-day, X-day, Y-day, MOSS-2 etc). We expect to participate more fully in these tests throughout the summer in anticipation of launch readiness. A summary of QA activity progress follows:

- MODAPS accounts were established for Point of Contact Joe Glassy and Petr Votava.
- LDOPE QA database accounts were established and tested for Joe Glassy and Petr Votava.
- MEBS and LDOPE QA database test sessions were conducted in which the ECS metadata fields SCIENCEQUALITYFLAG and SCIENCEQUALITYFLAG

EXPLANATION granules were adjusted to reflect quality examinations.

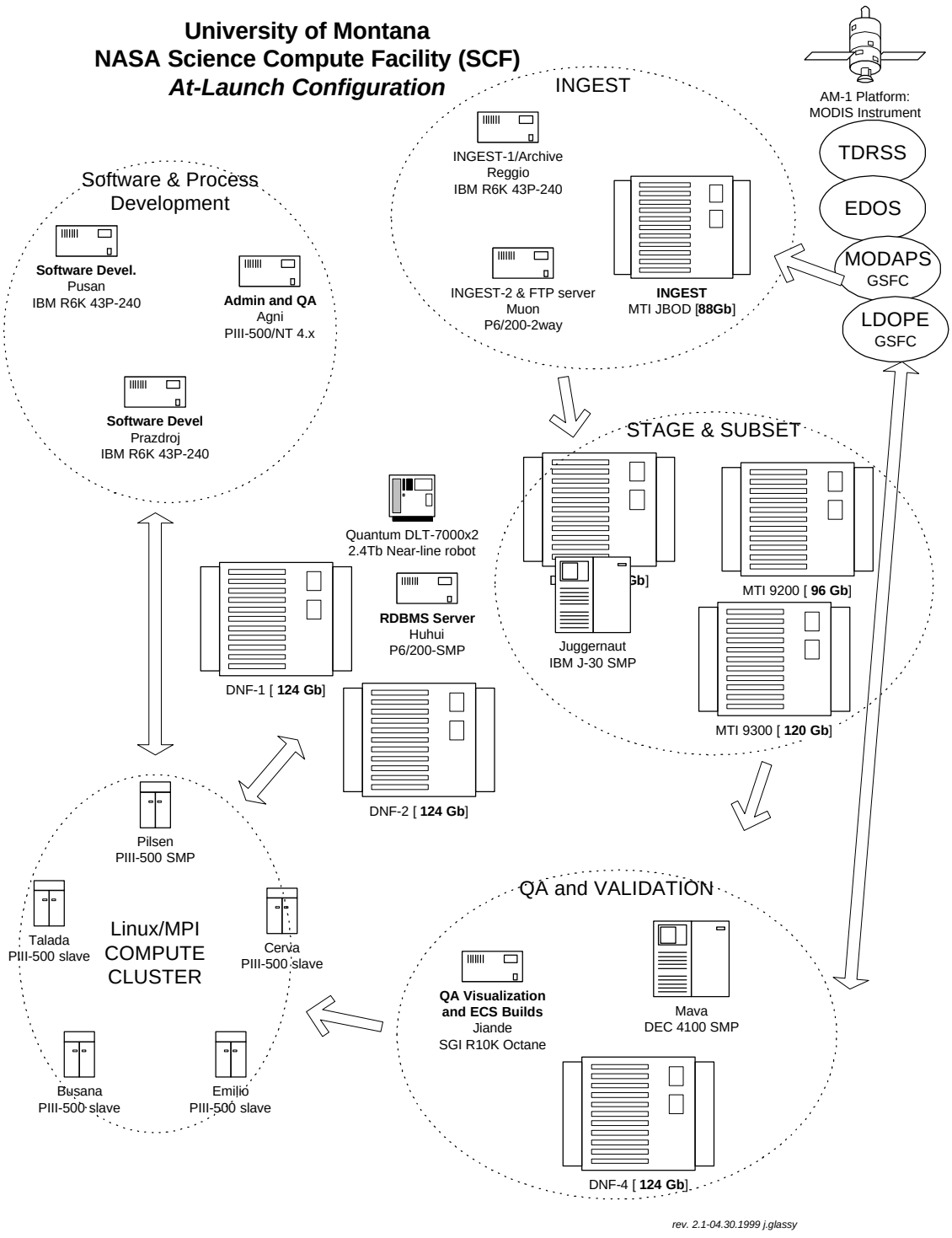
- Runtime QA assignment procedures for MOD15 were reviewed and improvements made as problems surfaced. This refinement process is likely to be on-going for some time with all algorithms.
- New versions of QA COTS software (RSI's IDL and ENVI) were purchased and installed on the AIX and SGI platforms. Additional licenses for these available for our SCF for the Linux and NT platforms.
- We built and minimally tested the new version (v.1.1) of LDOPE command line tool suite, as well as the LDOPE ENVI QA scripts.
- We successfully tested the automated "FTP-push" DAO ingest operational capability with Mark Carle at GSFC DAAC and others at DAO.
- We have successfully setup a dedicated database server (a dual 200mhz SMP workstation running RedHat Linux 6.0), running the SyBASE SQL Server 11.x relational database management (RDBMS) software. A set of prototype database scheme for tracking QA and algorithm performance logs, DAO ingests, and internal SCF model runs will be implemented and tested throughout this next period.

SCF DEVELOPMENT

SCF development continued apace during this period, despite reduced operational budgets. The primary facility issue for our SCF involves a wholesale move of our entire MODIS Compute Ring equipment to a new room in the Science Complex. We are now preparing for this move which should occur in August, 1999 timeframe. Another key facility issue involves our network services migration from the current dedicated T-1 NASA interface to a proposed Abilene DS-3 service level, slated for autumn 1999. We are taking steps to assure continuous network service via the T-1 prior to any switch to Abilene's DS-3. A new CISCO Catalyst C5K module has been installed to facilitate this migration, opening up additional 100-Base-T ports.

Data Storage and Archive

Augmenting our current disk store of approximately 500Gb, we have recently taken delivery of an additional (5) 100Gb RAID 3/5 DNF rack units, bringing our on-line disk media to ca 1 Tb. Two operational FTP ingest channels have now been designated, one for standing orders of MODAPS product data, and one for the automated FTP push of DAO custom DAS data to our SCF. To facilitate a load balanced flow through our segmented server architecture, we are deploying a 2.4Tb MTI Digital Linear Tape (DLT) 30-cell robot. Recently we have tested the viability of the RLM robotics software required to exploit this high capacity tape service, via a command line


University of Montana
NASA Science Compute Facility (SCF)
At-Launch Configuration
INGEST
AM-1 Platform:
MODIS Instrument
TDRSS
EDOS
MODAPS
GSFC
LDOPE
GSFC
INGEST-1/Archive
Reggio
IBM R6K 43P-240
INGEST-2 & FTP server
Muon
P6/200-2way
INGEST
MTI JBOD [88Gb]
Software & Process
Development
Software Devel.
Pusan
IBM R6K 43P-240
Admin and QA
Agni
PIII-500/NT 4.x
Software Devel
Prazdroj
IBM R6K 43P-240
STAGE & SUBSET
Quantum DLT-7000x2
2.4Tb Near-line robot
RDBMS Server
Huhui
P6/200-SMP
Juggernaut
IBM J-30 SMP
MTI 9200 [96 Gb]
MTI 9300 [120 Gb]
DNF-1 [124 Gb]
DNF-2 [124 Gb]
Pilsen
PIII-500 SMP
Linux/MPI
COMPUTE
CLUSTER
Talada
PIII-500 slave
Cerva
PIII-500 slave
Busana
PIII-500 slave
Emilio
PIII-500 slave
QA and VALIDATION
QA Visualization
and ECS Builds
Jiande
SGI R10K Octane
Mava
DEC 4100 SMP
DNF-4 [124 Gb]
rev. 2.1-04.30.1999 j.glassy

or GUI interface. The RLM system allows us to perform full indexed retrieves on 30 bar-coded DLT tapes (each 35Gb capacity) from the split level jukebox. Our plan is to integrate the real-time tape indexing into our larger SyBASE RDBMS database schema.

Compute Server Summary

Our current SCF compute server set includes an IBM RS/6000 J-30 (SMP 8-way 166mhz CPUs), and a DEC Alpha Model 4100 2-way SMP workstation. Support workstations now include (3) IBM RS/6000 Model 43P-240's (an archive server, and two software development workstations), an SGI/Irix Octane SMP QA workstation, as well as an Intel based QA workstation. For security reasons, we are planning on segmenting our external FTP ingest activities off to a high performance Linux workstation, will communicate to the archive server on a internal network link. For additional compute resources, we are currently beginning to investigate the performance and scaling of a limited size Linux cluster, starting with a prototype 4-way cluster of single CPU P-III 500mhz slaves. This prototype cluster is currently at the design phase, with early operational tests estimated to begin in the late September timeframe.

COLLABORATIONS: SCIENCE AND DATA SYSTEMS

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

- Assisted Boston University staff (Yu Zhang, Yujie Wang, Ranga Myneni) in establishing QA procedures for the daily FPAR, LAI product (MOD15A1). The next QA coordination trip is planned to BU for August 1999.
- Established contact with MODIS Oceanographer Dr. Mark Abbott of Oregon State University to participate in the evolving plan to setup a western USA MODIS X-band direct broadcast receiving facility at OSU for network feeds of key regional MODIS products to U.Montana.
- Worked with MODIS GSFC staff Jeff Morrisette, Robert Wolfe and others on setting the methodology for core validation site product subsetting for MODLAND products.
- Enlisted as a member of the Raytheon/ESDIS SDPTK and HDF-EOS beta test team, in anticipation of the adoption of the new HDF v.5.0 standard in coming versions of the SDPTK and HDFEOS libraries.
- Worked in cooperation with NTSG International EOS training center staff (Andy Weiss et al) in formation of a new compute facility and data system for this mission.

MEETINGS ATTENDED

MODIS Science Team Meeting, May 1999
MODLAND/SDST Meeting, March 1999

ACTIVITIES OF J by Lloyd P. Queen, Remote Sensing of Biomass Burning

Brief Description of Progress

Research on the two fire products (fire location and surface moisture index) has progressed in four main areas. First, we have completed runs for the period April-October for the years 1995 through 1996; completing an 8-year period of record.

This historic archive is the database needed to calibrate model performance to actual ranges in historic condition for the satellite moisture index. Second, all model outputs have been posted to an internal web site and documented using Federal Geographic Data Committee (FGDC) metadata standards. The web site is being accessed by a limited number of users from the National Forest System (NFS); and is being used as part of the EOS Training Center activity.

Third, we have compiled GIS databases for the State of Alaska and the eleven western US states. These GIS's contain geographic records of actual fire occurrence, and will provide the empirical basis for measuring the performance of our model.

Fourth, progress in improving model performance, completion of Phase I model runs, and access to the GIS databases have allowed examination of viewing geometry and image compositing effects on model performance. Significant variation in samples of NDVI/Ts values appear to be driven by viewing angle and timing/duration of AVHRR compositing. As presented in our ASPRS paper, we have recently adapted the U-Maryland Landcover (1KM) database to segment SDI images by biome type in order to test model sensitivity to landcover class, convolution filter size, water/edge effects, data compositing, as well as image geometry. As a direct result of that research we have adopted a new process model that utilizes a trapezoid method to determine surface moisture status rather than the former warm-edge extraction technique. A significant improvement in model performance in areas of mountainous terrain has been achieved through implementation of an air-temperature adjustment to the extraction of surface temperatures used in calculating SMI values. The historic wet and dry seasons of 1994 and 1993, respectively, have been re-compiled using the new trapezoid method, and validation of those data using the historic GIS databases of fire occurrence are underway.

Exploratory discussions with the Institute of Chemical Kinetics and Combustion, Siberian Division of the Academy of Science of Russia and the V. N. Sukachev Institute of Forestry were also initiated during the period. A one-day research workshop was held at UM in June, 1999 to discuss possible joint activities in application of our remote sensing products for fire and forest productivity assessments. Possible scientist exchange programs are being discussed at the current time; and may be in-place by the second quarter of 2000.

Publications and Presentations

"Developing a Computationally Efficient Fire Potential Index from Satellite-derived Estimates of Surface Moisture Status." Edited manuscript published in the Proceedings

of the 1999 American Society for Photogrammetry and Remote Sensing Annual Meeting Proceedings. Portland, OR. (Also presented as an invited paper at the meetings).

"Fire Potential and Fire Location Mapping Using the Advanced Very High Resolution Radiometer." C. Seilestad, J. Plummer, and L. Queen. Presented to the Interior West Fire Council Meetings. Big Sky, MT.

"Remote Sensing of Biomass Burning." J. Plummer, L. Queen, W. Hao, D. Ward, and S. Running. Presented at the MT/ID GIS User's Group Meeting. Idaho Falls, ID.

"Implementation of EOS Sensor Data Streams to Forest Fire Detection, Monitoring, and Characterization." L. Queen and J. Plummer. Presented to visitors from the USDA Forest Service Vegetation Management and Protection Research Group; the Institute of Chemical Kinetics and Combustion, Siberian Division of the Academy of Science of Russia; and the V. N. Sukachev Institute of Forestry.

Participants Including: Undergraduate Students, Graduate Students,Postdoctoral Positions, Faculty or Research Assistants or Technicians

James Plummer-Riddering, Ph.D. student. UM School of Forestry. This research is the core of his doctoral dissertation. He has developed the surface moisture index, applied it to current and historic growing seasons, and is now developing a comprehensive empirical and theoretical validation strategy for the index. Also the recipient of a MSGC Fellowship for the second consecutive year. The new Fellowship will allow Riddering to work with Dr. Yoram Kaufman at the GSFC for 11 weeks during the fall/winter of 1999/'00.

Carl Seielstad, Ph.D. student. UM School of Forestry. The current SMI model emphasizes the role of live fuels and portrays spatial and temporal patterns of live vegetation moisture status. Carl's doctoral thesis will add a complementary element to fire fuels/fire potential assessments by considering dead fuels as well as meteorological data. Co-investigator on a new NASA research project exploring the use of LIDAR data for forest fuel type characterization.

Steven Brown, M.S. student. UM School of Forestry. A new graduate student developing change detection and monitoring strategies for historical sequences of SMI image maps. Also generating image and graphics files for EOS Training Center distribution.

Eva Karau, M.S. student. UM School of Forestry. A new graduate student implementing data translation and documentation protocols for SMI data.

Collaborations Including: NASA Centers, NASA Headquarters, Businessand Industry, Other Federal Agencies, State Agencies, Other Agencies
Rocky Mountain Research Station/Intermountain Fire Sciences Laboratory (IFSL). USDA Forest Service, Missoula, MT. A one-year Research Joint Venture Agreement

(RJVA) has been signed with the IFSL to use our EOS research to scale estimates of biomass burning in time and space.

University of Alaska Fairbanks and the Alaska Fire Service. The State of Alaska provides three unique opportunities for validation of our SDI model. First, the high latitude provides several satellite overpass opportunities per da; second the Alaska Fire Service has compiled GIS-based databases of actual fire occurrence; and third the scale of biomass burning in Alaska is such that satellite-derived data have suitable resolution to assess fire occurrence and distribution. I have entered in to a working relationship with UA and the AFS to share data and validation techniques for Alaska for the 1998 growing season (arranged on a trip to Fairbanks in August, 1998 using RJVA monies from the IFSL).

Goddard Space Flight Center. As part of our RJVA with the Forest Service, I am collaborating on a project entitled "Biomass Burning and Emissions of Trace gases and Aerosols: Validation of EOS Biomass Burning Products." Investigators include IFSL scientists as well as Y. Kaufman and B. Holben from GSFC. We are developing an AVHRR implementation of two satellite-driven models for fire detection and burn scar characterization. This is a three-year project that started in 1998.

Montana Space Grant Consortium. The MSGC funded three proposals aimed at enhancing graduate and undergraduate remote sensing research. The first new program is a PhD Fellowship award that will enable a doctoral student to visit and work collaboratively with scientists at the GSFC. The second is a new PhD scholarship program that will enable us to recruit high-quality PhD candidates to UM. Third is a new Undergraduate Research Opportunities program which will be run jointly between Forestry and the UM Honors College. This third program is designed to provide realistic research experience for upperclass students intending to pursue a career or further studies in aerospace-related sciences.