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 January 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.

ACTIVITIES OF SWRunning (MODIS Team Member)

WORK ACCOMPLISHED:

My efforts in organizing a validation program for MODIS NPP have been summerized and published in a journal article appeared in remote sensing of environment.

A GLOBAL TERRESTRIAL MONITORING NETWORK INTEGRATING TOWER FLUXES, FLASK SAMPLING, ECOSYSTEM MODELING AND EOS SATELLITE DATA

S.W. Running[1], D. D. Baldocchi[2], D.P.Turner[3], S.T. Gower[4], P. S. Bakwin[5], K. A. Hibbard[6]

Remote Sensing of Environment, 1999, 70: 108-127.

ABSTRACT

Accurate monitoring of global scale changes in the terrestrial biosphere has become acutely important as the scope of human impacts on biological systems and atmospheric chemistry grows. For example, the Kyoto Protocol of 1997 signals some of the dramatic socioeconomic and political decisions that may lie ahead concerning CO_2 emissions and global carbon cycle impacts. These decisions will rely heavily on accurate measures of global biospheric changes (Schimel 1998, IGBP TCWG 1998). An array of national and international programs have inaugurated global satellite observations, critical field measurements of carbon and water fluxes, and global model development for the purposes of beginning to monitor the biosphere. The detection of interannual variability of ecosystem fluxes and of longer term trends will permit early indication of fundamental biospheric changes which might otherwise go undetected until major biome conversion begins. This paper describes a blueprint for more comprehensive coordination of the various flux measurement and modeling activities into a global terrestrial monitoring program that will have direct relevance to the political decision making of global change.

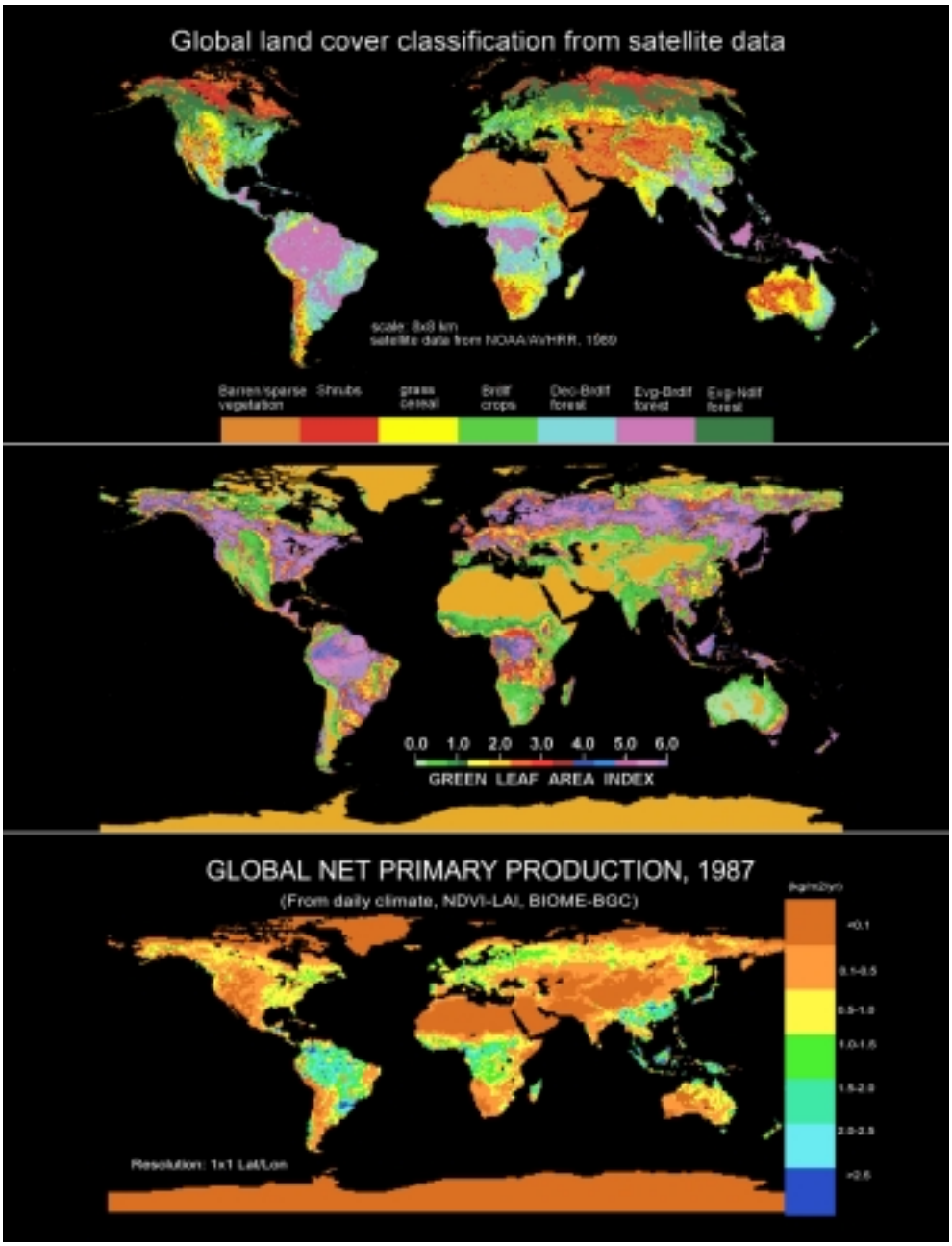

Figure 1: An example of global land cover, leaf area index and net primary production, terrestrial variables that will be produced from the Earth Observing System every 8 days at 1km resolution. These data will be invaluable for scaling of ecological research and land management, but first need global field validation.

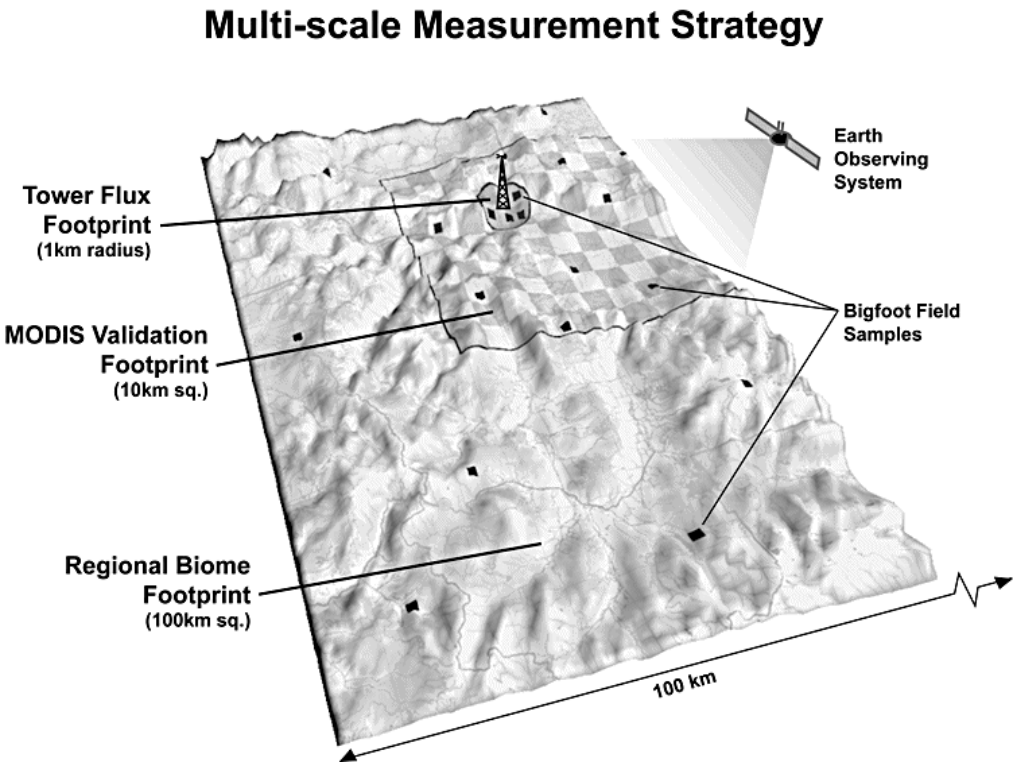

Figure 2: Illustration of the three spatial scales that must be considered for ecological scaling and validation. Measures of vegetation parameters (see Table 2) in the atmospheric footprint of the FLUXNET towers are required for SVAT models to simulate the NEE measured by the towers. Second, a larger area of minimum 3x3 km must be sampled to provide ground truth of MODIS LAI and NPP vegetation products. Third, the representativeness of the FLUXNET tower and MODIS sampling site to the larger biome/climate complex must be evaluated by cross biome sampling. Aircraft flux transects and atmospheric flask measurements can provide independent validation of regional flux calculations. Only after all of these scales of measurement are co-validated can comprehensive synthesis of ground data, ecosystem models and satellite data be 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

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.

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 enticement, 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.

NASA EOS and Related MEETINGS ATTENDED (SWR)

Ecological Society of America, Spokane, 8/1999
Data Mining for Earth Sciences, Huntsville, 10/1999

Ameriflux meeting, Denver, 10/1999
EOS-SEC, 11/1999
VEMAP meeting, 11/1999

Publications:

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, 70: 108-127.

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.

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:

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 natural resource managers 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 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: 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 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.

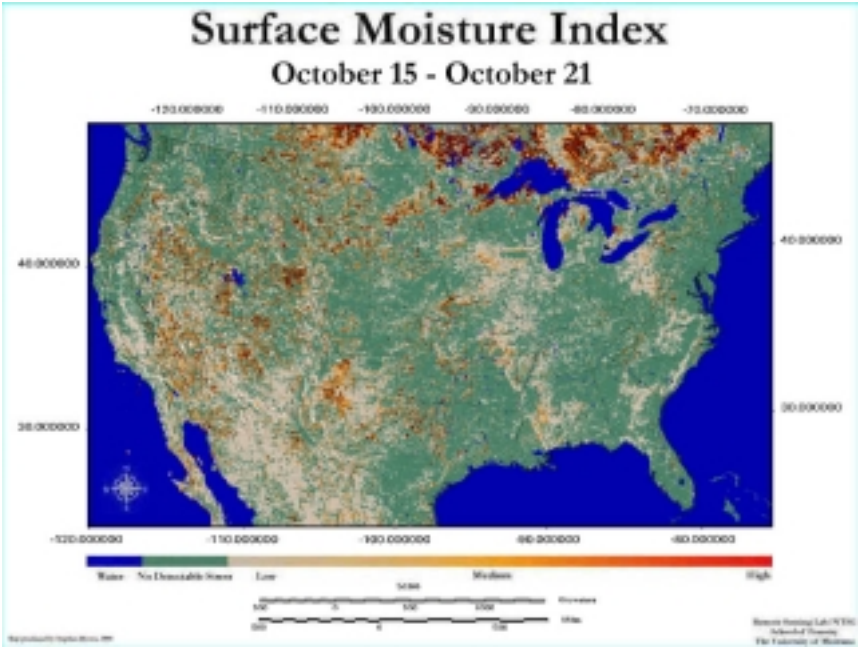

Figure3: Surface Moisture Index for the Period Oct 15-21, 1999. Derived from NOAA 14 AVHRR.

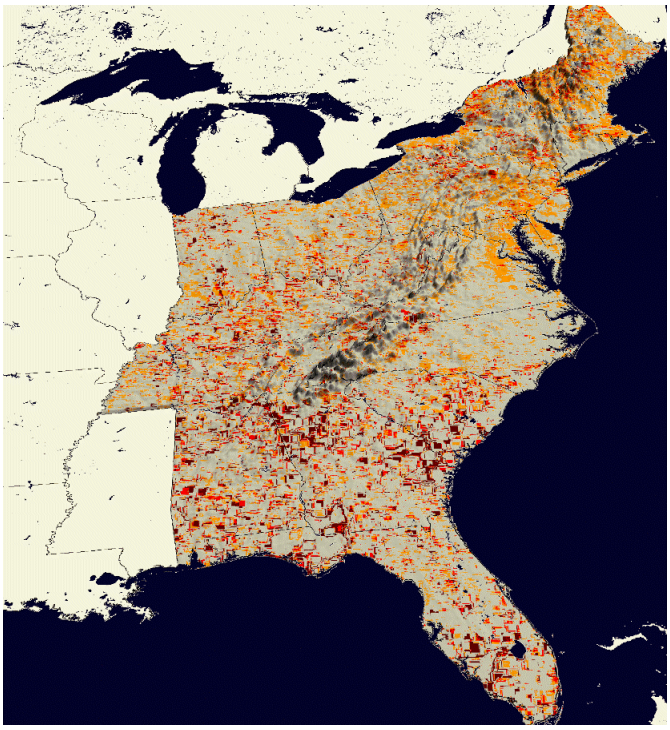

Figure 4: Surface Moisture Index (departure from 10 year average) highlighting summer 1999 drought in eastern U.S. Derived from AVHRR data for period July 13-19, 1999.

Fire Detection/Monitoring - Fire detection and monitoring is a MODIS at launch product (MOD 14). The Remote Sensing Lab at the University of Montana has tested the MOD 14 algorithm for the state of Alaska and has demonstrated that regional applications of the global logic do not perform as well as resource personnel would require for management needs. The sensitivity to NASA's fire detection algorithm in Alaskan boreal forests was tested. It was demonstrated that modifications may be necessary to optimize model performance. 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. We tested the sensitivity of the MODIS fire detection product at various 4μm and 11μm thresholds during the most active portion of the Alaskan fire season. This approach provided a means of assessing the costs and benefits of different MODIS algorithm thresholds and demonstrated that the algorithm can be optimized differently for different purposes. This test was performed using AVHRR daily images for the 1997 fire season and compared to a GIS database of actual fire occurrence. Remote areas such as Alaska would benefit from operational fire detection and monitoring logic that would allow coarse monitoring thereby alleviating the need for repeated fly-overs. Working with the Alaska Fire Service and other interested parties, the EOS Natural Resource Project and the Remote Sensing Lab will provide training on the MODIS fire algorithm and regional applications.

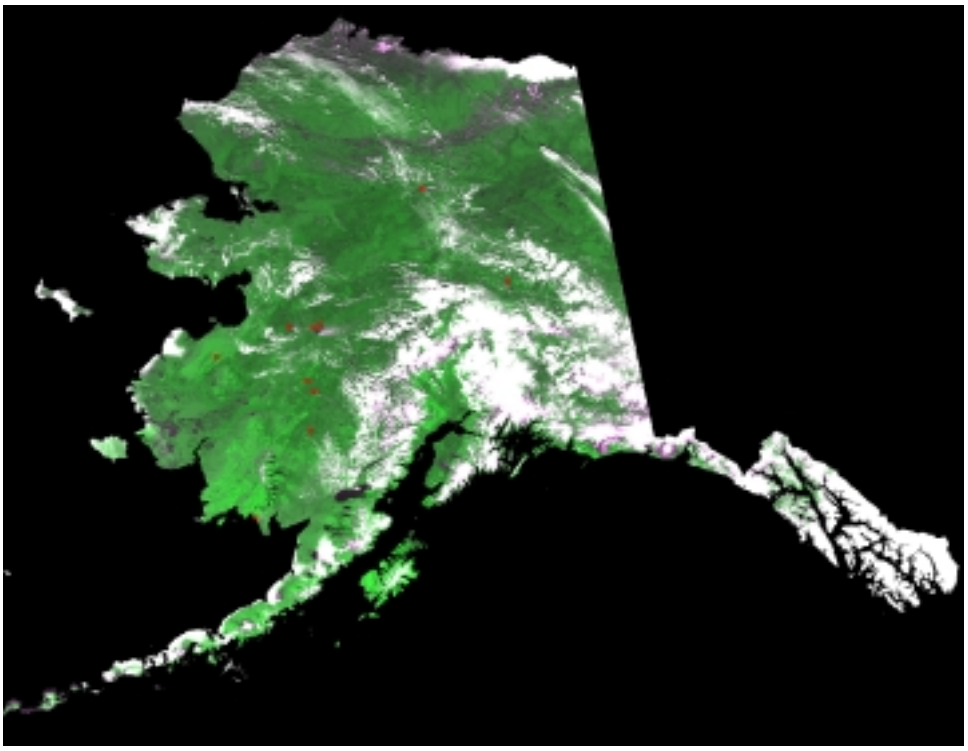

Figure 5: AVHRR image of the state of Alaska. Level 1B daily images were acquired from the University of Alaska-Fairbanks Geophysical Institute. The 1:1M Digital Chart of the World hydrography layer was used to georegister the daily images. Additional calibrations were modeled and applied to obtain brightness values. A point vector file of fire locations is shown courtesy of the Alaska Fire Service.

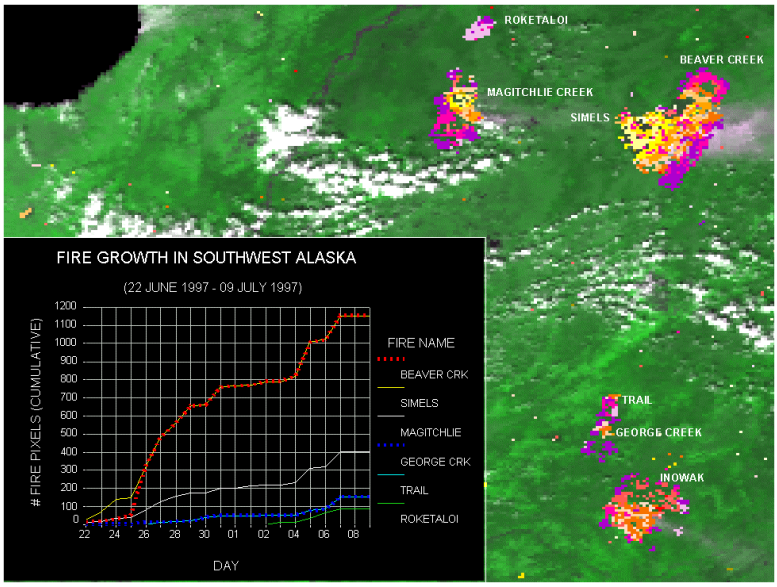

Figure 6: Fire detection and monitoring in SW Alaska. Yellow pixels show recent detection while darker purple pixels show earlier detection. "Fire" pixels derived from modified MOD17 algorithm using 1997 AVHRR daily images.

Vegetation Productivity

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 (Churkina, submitted; White, submitted). 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.

MODIS Simulated NPP - Forest, Range and Cropland Productivity

The MODIS algorithms for global estimates of net primary productivity have been developed at the NTSG at the University of Montana. The EOS Natural Resource Project spent this first year developing realistic examples of future MODIS vegetation productivity products. These are aiding us in developing regional applications with input from natural resource managers. As a first step, we adapted the MODIS backup algorithm for LAI/FPAR (MOD15) and MODIS net primary productivity (NPP) (MOD17) algorithms for use with NOAA AVHRR derived NDVI. For examples of the productivity products, we then applied the MOD15 and MOD17 simulators to a region of the Salmon River Basin. MODIS NPP simulations were produced for the years 1990-1994 from composite AVHRR NDVI data and meteorological inputs previously derived. Our conversations with range managers from the BLM and US Forest Service suggested that MOD17 derived NPP could be used as an objective indicator of when a grassland is growing well enough in the Spring to sustain grazing. In

addition, discussions with forest managers revealed that the NPP might be useful for updating forest inventories.

With additional processing, we produced an NPP departure index to seasonal trends in vegetation growth. The departure index is intended as an aid for determining range readiness, stocking rates and assessing reforestation efforts. This product will be shown to resource managers for evaluation in the very near future.

We modified the MOD15 and MOD17 simulators to produce an estimate of the 1999 Montana Wheat Yield. Members of the Montana Wheat Commission were favorably impressed with the accuracy of the estimates along with the possibility of timely, global coverage. They suggested that, if applied to key wheat producing areas (Kansas, China, Ukraine), this MODIS product could be used to monitor the global wheat supply (with obvious implications to futures speculators) and maybe even aid in the formulation of national trade policy.

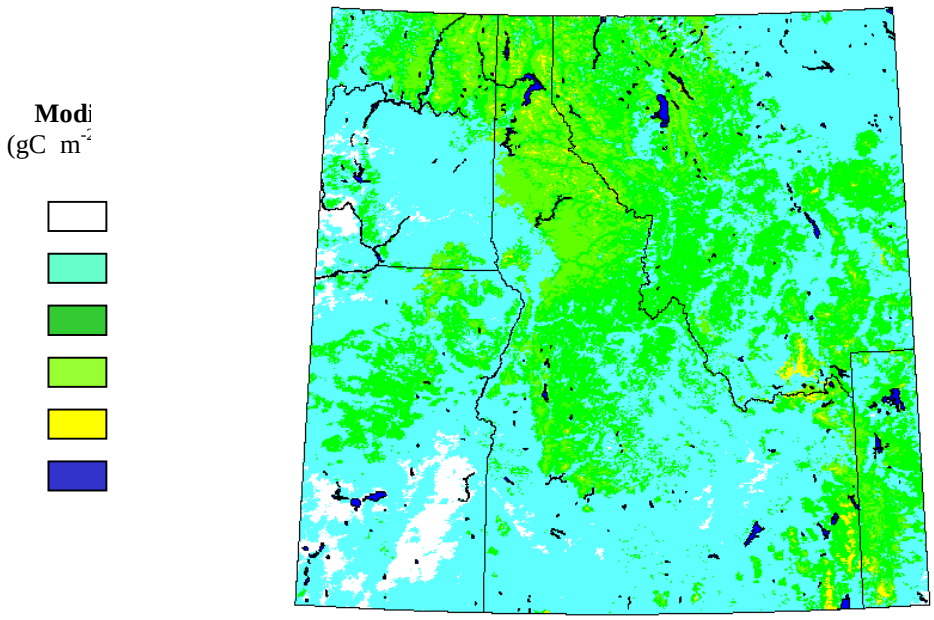

Figure 7: Simulated MODIS NPP for the Salmon River Region during June and July of 1990 (calculated from NOAA AVHRR satellite period 9: days 172 -185).

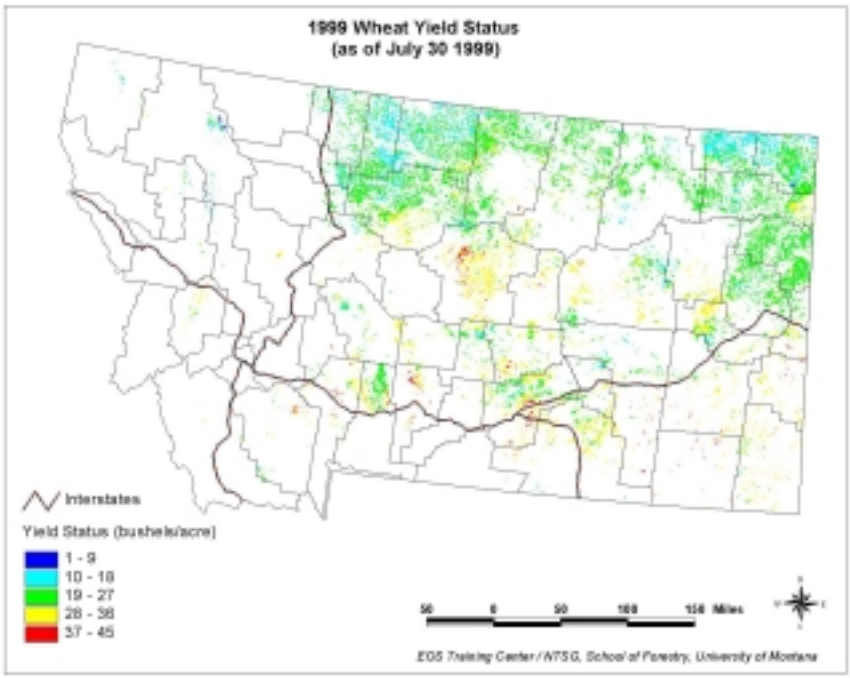

Figure 8: The 1999 Montana Wheat Yield as of July 30 derived from applying the MODIS MOD15 and MOD17 simulators to NOAA AVHRR derived NDVI.

International Vegetation Productivity Opportunities - Dr. Donald Bedunah, Range Specialist 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. His report is found in Appendix A.

Remote Sensing of Satellite NPP - Additional work was performed by Dr. Richard Waring, Dr. Nicholas Coops and Steven Brown in remote sensing of forest productivity using the model Physiological Principles Predicting Growth from Satellites (3-PGS) (http://www.fsl.orst.edu/bevr). This work included extrapolating weather data across a 54,000 km square area to deriving solar radiation, VPD, and frost events; inputs used to drive the 3-PGS model (Coops *et al*. 1999a, Coops *et al*. 199b). In addition, a routine was developed to relocate survey plots to the described slope and aspect as measured in the field and compared to a DEM (Coops *et al*. 1999a). Continued research on established plots confirmed the general reliability of the 3-PGS model in predicting site potential and soil water availability and also demonstrated good comparability with the Biome-BGC model (Coops and Waring, 1999; Coops *et al*. 1999). The 3-PGS model was tested over a additional areas including southwest Oregon (Coops and Waring, 1999; Coops and Waring, 1999), and NASA sites where climatic and water availability data were available (Coops, Waring, and Landsberg, 1999).

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.

This first year, the EOS Natural Resource Project has purchased and assembled the necessary hardware to run and store the Daymet algorithm, assembled the appropriate digital elevation data, and processed and quality assured meteorological data from ground-based stations. Ground based station data was provided by the Cooperative Summary of the Day National Climate Data Center (NOAA) and the Natural Resources Conservation Service (USDA).

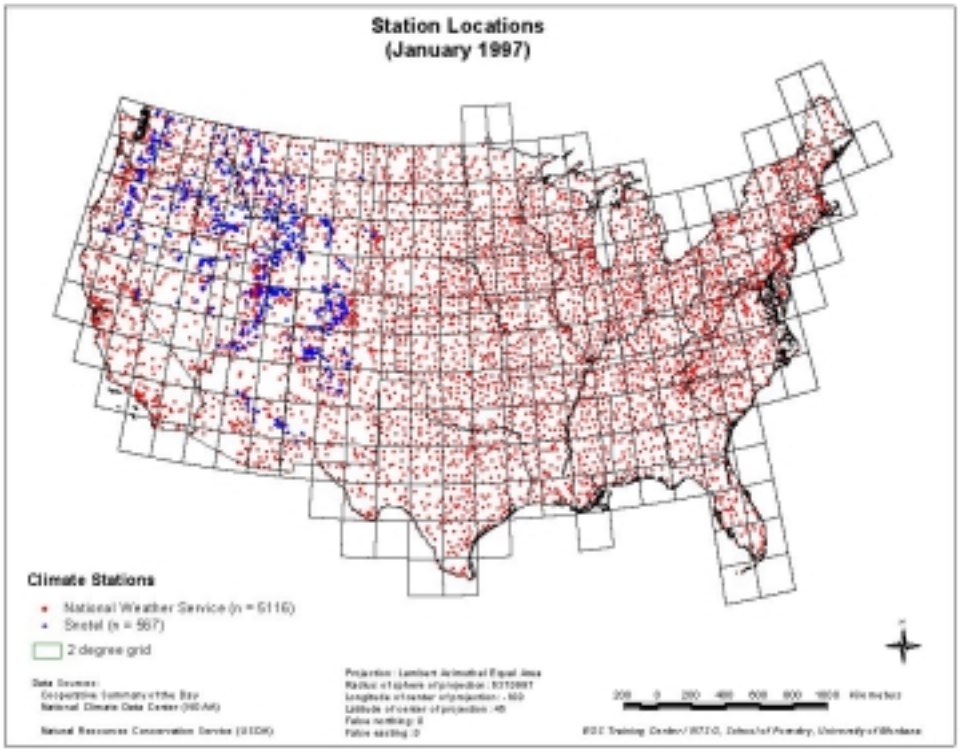

Figure 9: Ground-based weather stations over the conterminous United States for January 1997. Temperature and precipitation measurementsused for input into Daymet runs.

The Daymet algorithm has been enhanced by recent research activities that improve on the radiation and humidity estimates (Thornton and Running 1999). These improvements were tested over complex terrain through a research cooperative with the country of Austria and are currently being applied to the U.S. Daymet program (Thornton *et al*. (submitted), White *et al*. (submitted)).

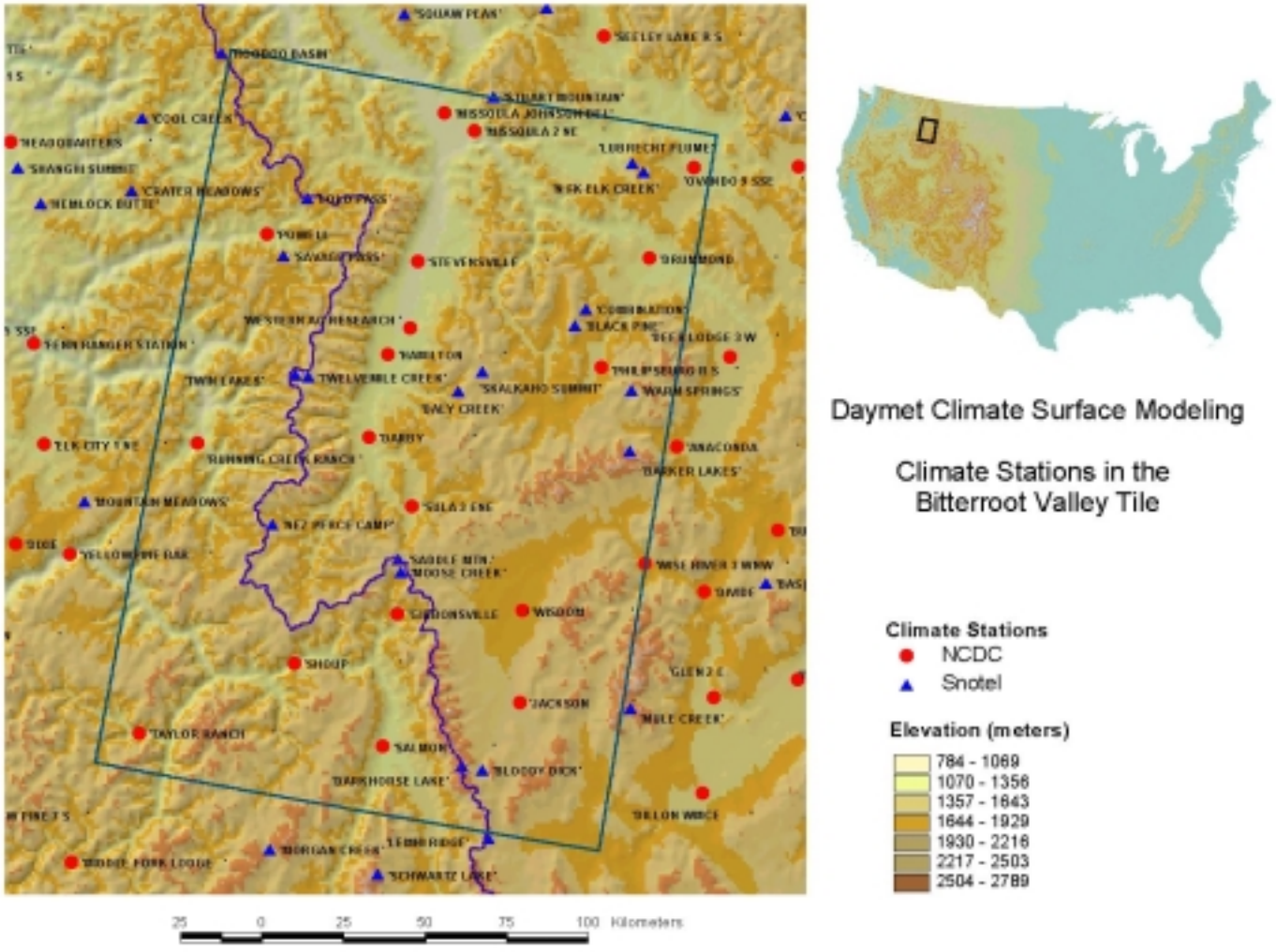

Figure 10: **Bitterroot Valley 2x2 degree tile location with stations located.**

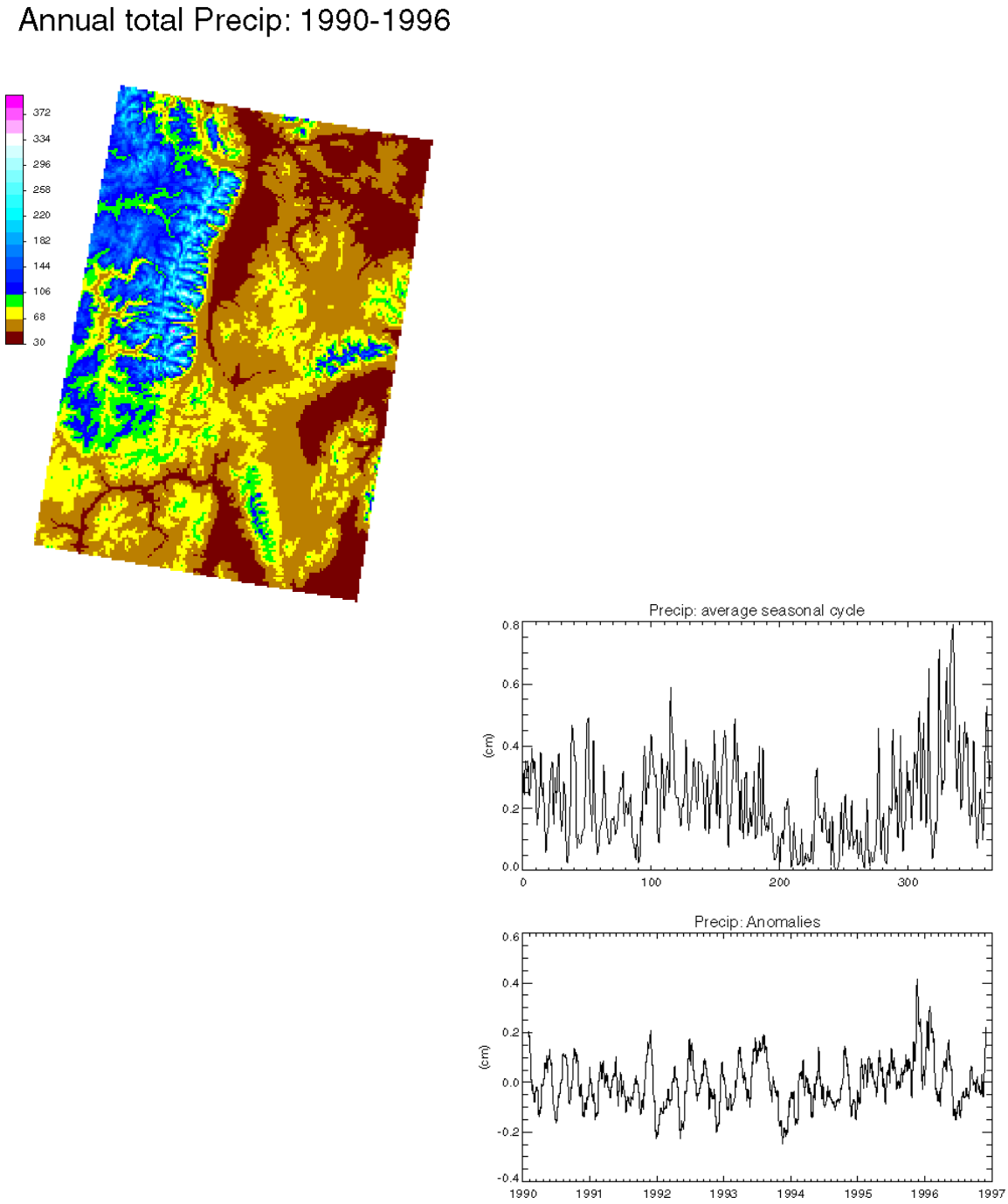

Figure 11: Annual total precipitation (cm) over a 7 year period for the Bitterroot Valley 2x2 degree tile. The top graph shows the average seasonal precipitation cycle for each year day. The bottom graph shows departures from average for the 7 year simulated period.

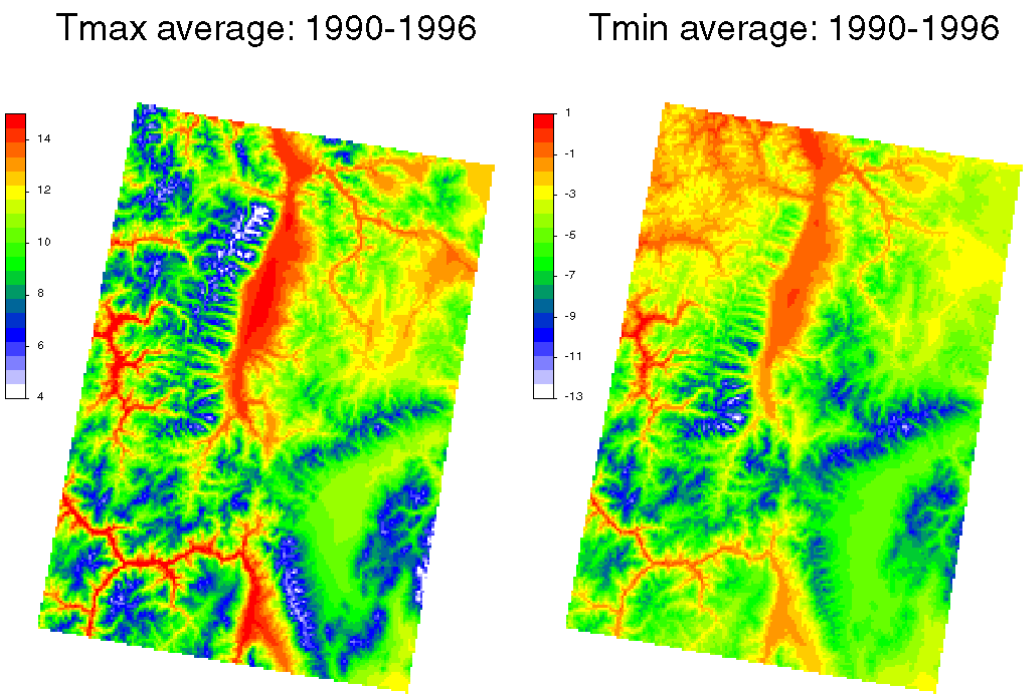

Figure 12: Seven year maximum and minimum temperatures for the Bitterroot Valley 2x2 degree tile as output from the Daymet simulator.

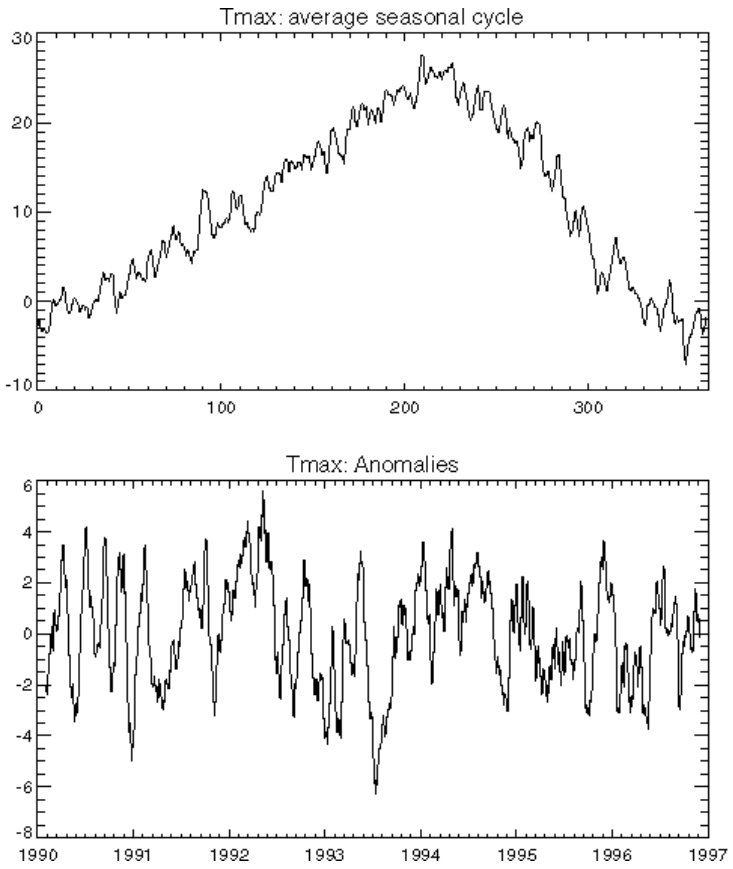

Figure 13: Maximum temperature anomolies for the seven year simulated period from the Bitterroot Valley tile. The top graph shows the maximum temperature average seasonal cycle while the bottom graph shows departures from average for the seven year simulated period.

Ancillary Geographic Information System (GIS) Data Layers

We have derived, gathered, and organized a number of vector and raster files and digital elevation models (DEMs) for overlay operations and distribution. These files were downloaded from a number of WWW sites and standardized to a common projection system that will match UM-EOS Application Products as they are operationally produced. The common projection system for conterminous U.S. files have the following parameters:

Projection: Lambert Azimuthal Equal Area
Radius of sphere of projection: 6370997
Longitude of center of projection: -100 00 00
Latitude of center of projection: 45 0 00
False northing: 0
False easting: 0

Regional files have a more appropriate projection to maintain area accuracy.

The following files have been organized:

US (coarse scale) Files

American Indian/Alaskan Native Area Boundaries, US Cities and Towns, Counties, Federal Lands, Hydrologic Unit (HUC) Boundaries, Hydrography, Lakes, Census Data, Major Roads, State Boundaries, Geographic Area Coordination Centers (GACC), Land Cover Type derived from AVHRR

Regional (fine scale) Files
NW States - Roads, Hydrography, Cities, Counties, Federal Lands, State Lands, Land Cover Type derived from Landsat

Digital Elevation Models
1:2M - United States Coverage
1:24k - Local (state) coverage(s)

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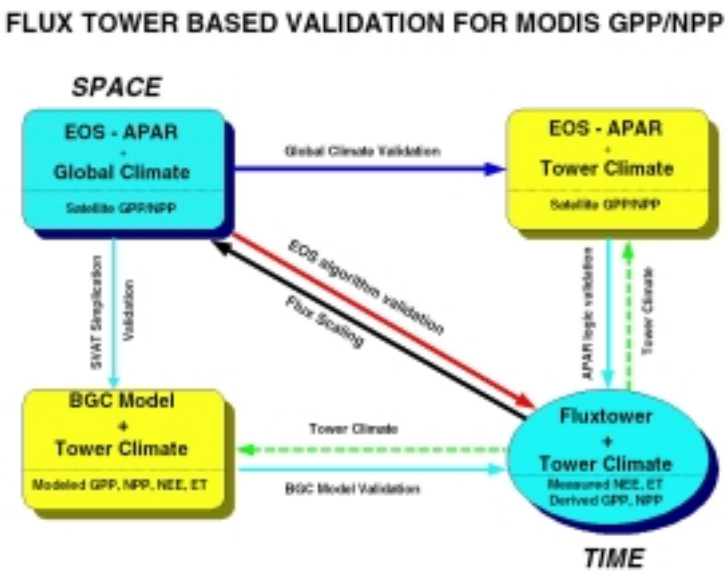
ACTIVITIES OF R. Nemani (MODIS Associate Team Member)

Objectives:

My objective is to design an implementation program for realizing the validation of MODIS PSN/NPP product as outlined above in SWR et al. (Remote Sensing of Environment, 70: 108-127). The goal is to use the flux measurements as well as micrometeorological observations collected by various fluxnet sites to test the driving variables of MODIS/NPP as well as the outputs (PSN/NPP).

Overview

Working details of a flux tower based validation of MODIS GPP/NPP (Figure 14, below) 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.



WORK ACCOMPLISHED

We initiated the validation work using Harvard Forest as a test case. Harvard Forest flux tower has been continuously operating for over 5 years, therefore provides an ideal test case scenario. We obtained daily CO2 fluxes as well as micrometeorological observations for this site collected during 1996. We also obtained AVHRR based NDVI data from EDC and converted them to LAI/FPAR values using the back-up algorithm proposed for MOD15 (LAI/FPAR). While the AVHRR data is not corrected for atmosphere etc. it would provide valuable experience in streamlining the validation program procedures. The driving variables for MOD17 (solar radiation, air temperatures and humidity) are provided by the NASA/DAO. These variables exert a strong control on seasonality as well as total net primary production. First, we wanted to test these input variables. Since the DAO data is not available as of now, we used NCEP re-analysis data (NCEP uses procedures that are very similar to DAO). We obtained re-analysis data for 1996, and compared the shortwave radiation with satellite derived incident solar radiation as estimated by Rachel Pinker at U. of Maryland. The advantage with satellite derived radiation estimates is that the spatial resolution (0.5x0.5 lat/lon) is coarse and comparable to NCEP (2.5x2.5 lat/lon). Instead of comparing the NCEP data with Flux tower measured radiation, we chose to compare with GOES derived estimates.

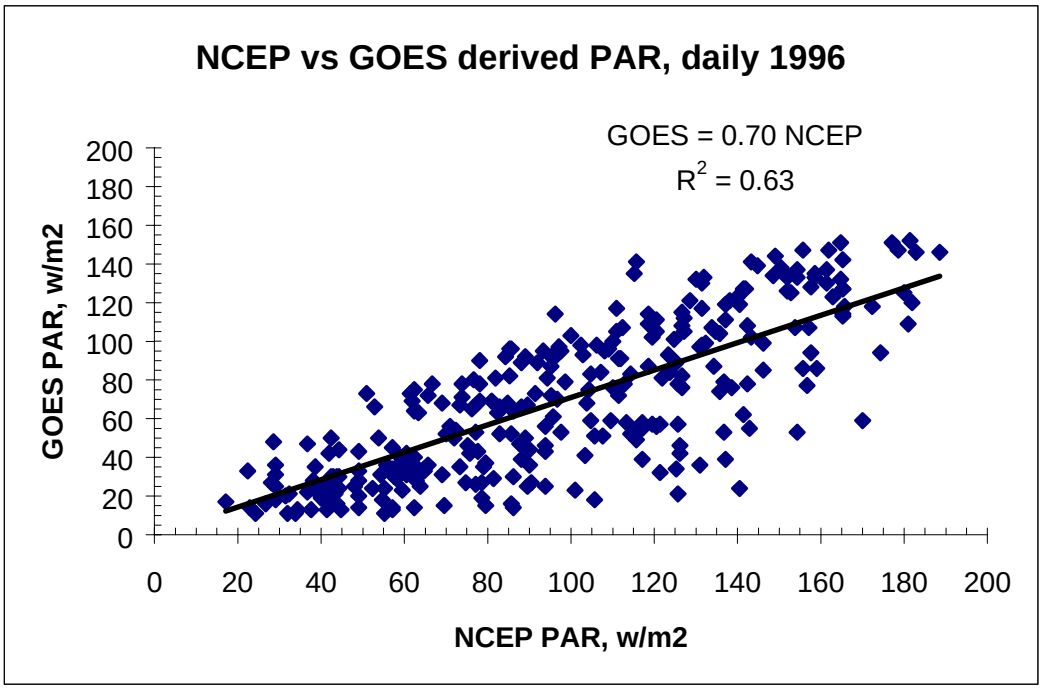


Figure 15: GOES derived photosynthetically active radiation (main input into the MODIS/NPP algorithm), when compared to NCEP (surrogate for DAO) estimates. Similar comparisons were performed for Tmax and Tmin with R2 values determined to be above 0.80.

Since MODIS/NPP is not directly comparable to the flux tower estimates of Net Ecosystem Production (NEE includes the night respiration also). We used the BIOME-BGC, an ecosystem model designed to simulate carbon, water and nutrient flux

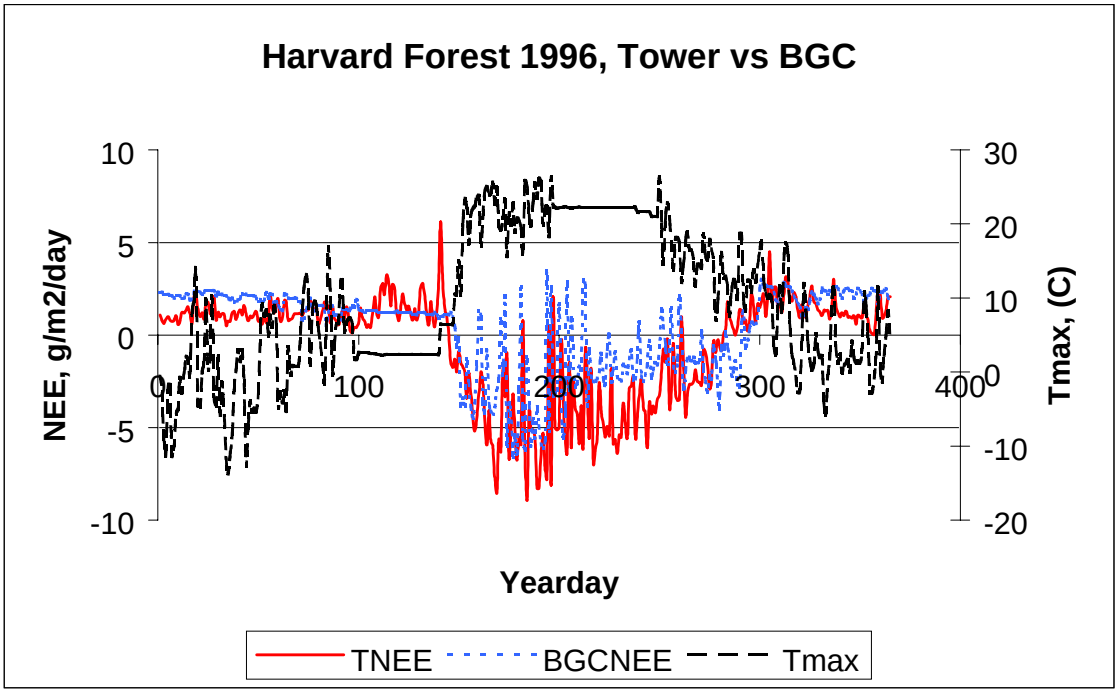


Figure 16: Observed and BGC predicted Net Ecosystem Exchange at the Haravard Forest. Missing temperature data (filled) during the mid-summer caused the BGC to predict significantly different NEE estimates. The model was able to reproduce the seasonality as well as the magnitudes of NEE properly, given accurate driving variables. Therefore, BGC estimates can used to derived NPP that is directly comparable to MODIS derived NPP.

processes. The model was initialized with observations of leaf area, biomass, soil carbon and soil nutrition. The model was then run with daily micrometeorological data (solar radiation, Tmax, Tmin, VPD) observed at the flux tower site. BGC estimates daily gross primary production, auto and heterotrophic respiration. From these estimates, we can compute Net Primary production that is directly comparable to the MODIS derived NPP.

Using AVHRR derived FPAR/LAI and climate data observed at the tower site, we ran the MODIS/NPP algorithm on a daily basis. Then we compared the tower observations during daytime (where uptake dominates release and the values are closer to net primary production) with MODIS/NPP algorithm output.

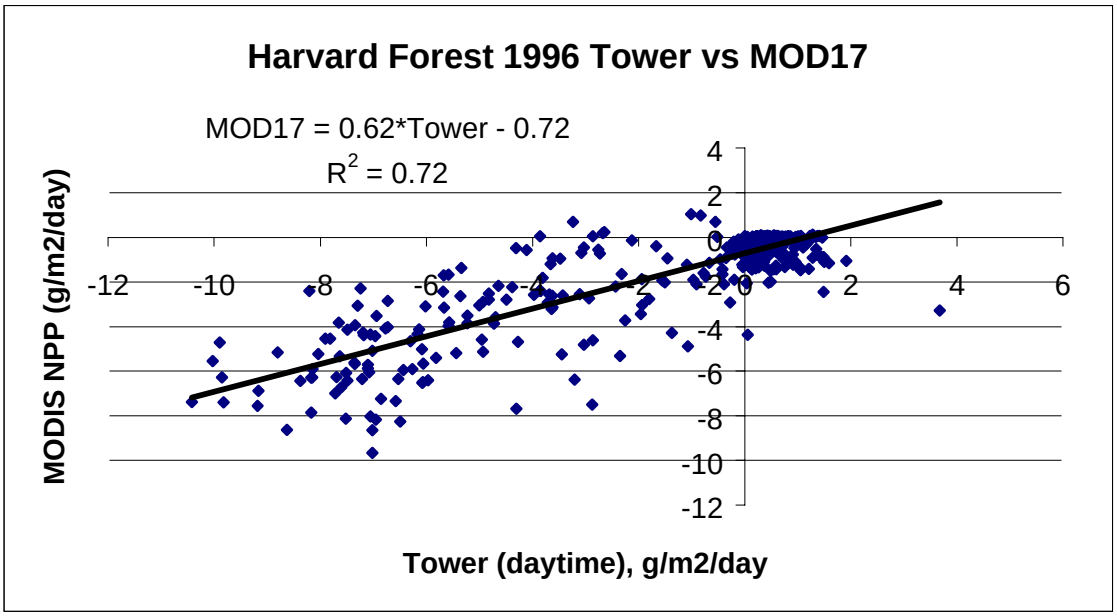


Figure 17: Relation between MODIS/NPP algorithm estimates vs tower measurements during daytime.

In order to test if observations taken at a tower site (point) are representative of a larger footprint, we used the AVHRR data to quantify the spatial heterogeneity. First, we took a 3x3km around the tower site and progressively increased the grid size to 35x35km.

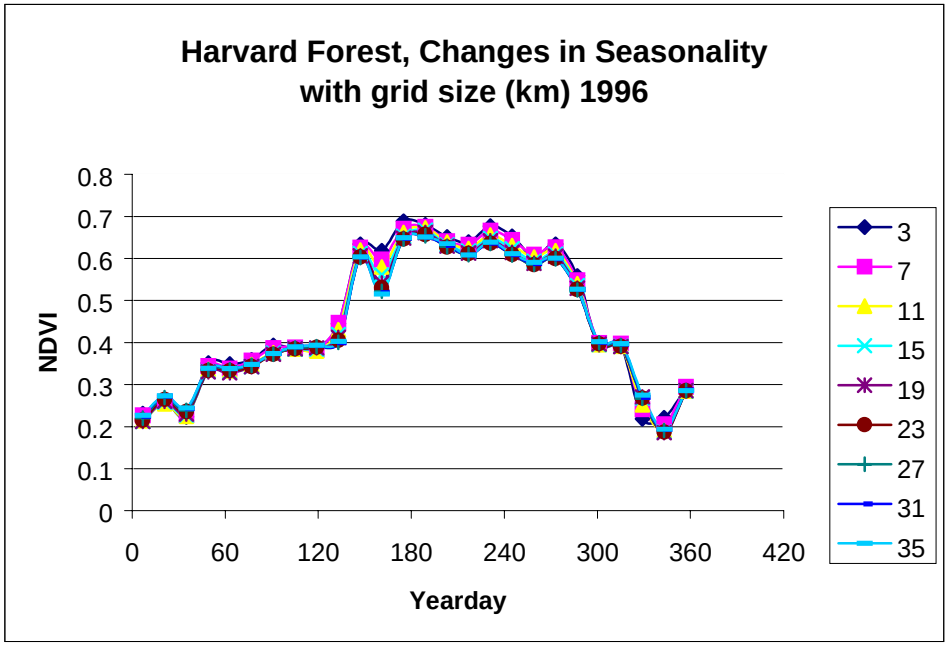


Figure 18: Testing the spatial heterogeneity around the flux tower site in Harvard forest. Even at 35x35km, the NDVI values did not differ from 3x3km around the tower site by more than 5% indicating that flux observations from Harvard tower can represent large areas.

Finally, we tested the spatial heterogeneity around the Harvard tower using the land cover data (EDC). The land cover data showed that at 1km scale, there is little heterogeneity. Much of the area is covered by mixed forest, the rest by deciduous broadleaf forest, both cover types would be very similar in terms of their carbon and water fluxes.

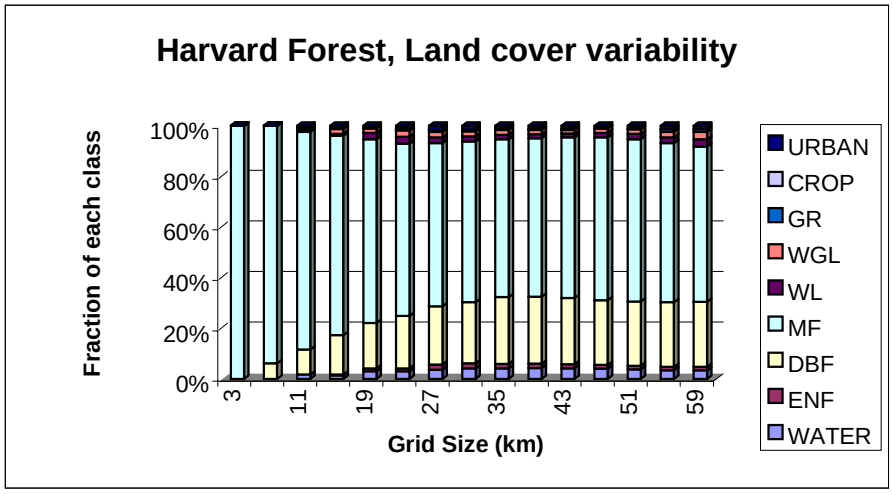


Figure 19: Spatial distribution of land cover types at different grid sizes around the Harvard flux tower site.

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 agreed to participate in this validation effort. Initially, these sites would provide micrometeorolgical observations to ORNL, then U. of Montana will do the BGC simulations for each tower site and post the results back to ORNL. Once, MODIS starts operating, 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.

MEETINGS ATTENDED:

Ecological Society of America, Spokane, 8/1999

CONFERENCE PRESENTATIONS:

Asymmetric warming over coastal California and its impact on the premium wine industry, ESA, Spokane, 8/99

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.

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,122: 209-219.

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).

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).

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)

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

OBJECTIVES

My objectives during the time period July 1999 to January 2000 are summarized here, with details on each of the indicated activity areas following.

Algorithm Development

- We have implemented a series of minor updates to the daily FPAR, LAI algorithm (PGE33, which is now at launch version 2.4.1), as well as incorporate major changes in the Quality Assurance (QA) interpretation logic as agreed upon team wide by a MODLAND review of QA logic. This particularly affects the MODLAND pixel-wise QA bits which categorize a pixel as {Good,Ok,Not Produced due to cloud, and Not Produced due to other reasons).
- We are currently in the progress of updating the 8-day composite FPAR, LAI algorithm (PGE34) and the daily and 8-day PSN,NPP algorithm (PGE36, PGE37) to syncronize with the PGE33 QA changes as proposed by the LDOPE and SDST.
- We have built and used the latest versions (now at v.5.2.5) of the NASA software tools required for algorithm implementation: (SDPTK, HDFEOS and HDF software libraries), with preparations being made to transition to the new SDPTK 5.2.6 due shortly from the contractor.
- We have updated the MUM API library (now at version 2.4.9) on all supported

compute platforms, with a new emphasis on better Linux (Redhat v.6.x distribution) support) on both the Pentium III and Alpha EV-6 chip architectures.

Launch QA and Certification Activities

- We monitored the on-going J-DAY readiness tests with the MODADPS and LDOPE staff.
- We deployed new version (v.1.2) of the Land Data Operational Processing Environment (LDOPE) command line QA and ENVI/IDL tool suite.

SCF Development

- Now that launch has successfully occurred and the MODIS instrument has been enabled, we continue to refine the Univ. Montana NASA Science Compute Facility, to assure effective deployment in the at-launch era.
- Major SCF activities included assignment and deployment of new DNF RAID 3/5 units within our compute facility at the University of Montana Science Complex.
- Added a second dedicated FTP server (host: modis.ntsg.umt.ed) to further parallelize our external data interfaces to the MODAPS, LDOPE, and EDG suppliers.
- Broadened our off-line high volume data store strategic plan to incorporate a state of the art AIT-2 80-cell tape robot (4+ Terabyte capacity), and placed an order for this robot.

- Refined the deployment of our prototype Linux (RHv6.x) parallel cluster based on (5) Pentium P-III/500 slaves, led by a dual SMP P-III 550/master.
- Performed orders for (8) 120Gb Dynamic Raid Factor (DNF) RAID 3/5 units of new disk storage.

Collaborations: Science and Data Systems

- Continued our collaboration with Boston University staff on establishing quality assurance practices and procedures for the MOD15A1 FPAR, LAI product.
- In the MODIS Direct Broadcast (DB) area, we've been officially named as the terrestrial data interface in cooperation with Dr. Mark Abbot's MODIS Oceanography group (Oregon State University). Under NASA sponsorship, Mark's group will now deploy an X-band dish at OSU, and shunt low level MODIS data to our group to produce a subset of regional terrestrial algorithms.
- Continue with work with Doug Ilg of the NASA SDPTK team as a beta test site/advisory group, covering the new NT limited-function toolkitin 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 July 1999 to January 2000 we have divided our efforts between QA operations preparations, implementing a variety of minor ECS algorithm refinements. We were also fortunate to be able to attend the launch of the Terra satellite platform hosting the MODIS instrument on December 18, 1999 at Vandenberg Air Force Base.

ALGORITHM DEVELOPMENT

The major change dominating our attention for all University of Montana SCF algorithms involved a reformulation of the QA interpretation logic, as addressed by several MODLAND wide telecons. In short, the intent of this new focus is to assure that algorithms produce as much signal as possible, even in the face of suspected input data problems. Previously many of our algorithms inserted a fill value in place of an estimated biophysical measure, when known input conditions were sub-optimal (e.g. contained excessive cloud, high aerosols, etc). The problem this earlier strategy caused is that when the upstream cloud mask (MOD03 and MOD35) were very sensitive (as we currently suspect they are), relatively large regions in many products were set to fill values. This was felt to provide insufficient insights into the underlying model logic. The new proposal emphasizes the desire to provide estimates of model outputs whenever possible, and reflect any problem conditions through more rigourous quality assurance information layers carried with the product data.

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 the QA logic revisions as discussed above, and 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.2.4.9) as well as some minor refinements involving QA metadata field processing (the ECS QAPERCENTCLOUDCOVER metadata field was added to accommodate the new QA strategy discussed above).

Figure 20: Below we include several representative test outputs from PGE33, showing various image artifact that will now be carried through to the products:

PGE 36 : (MOD17) PSN, NPP daily algorithm

The only changes of note to PGE36,37,38 involve syncronization with the new QA logic scheme used in PGE33/34.

QA AND OPERATIONAL ACTIVITIES

The primary QA activities during this time period involved continuing to prepare for the actual MODIS operational phase.

- 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.
- New versions of QA COTS software (RSI's IDL and ENVI) were purchased and installed on the AIX and SGI platforms. Additional licenses are deployed on the Linux Redhat v6.x and NT 4.x hosts.

- We built and minimally tested a new version (v.1.2) of LDOPE command line tool suite, as well as the LDOPE ENVI QA scripts.
- We successfully re-tested the automated "FTP-push" DAO ingest operational capability with George Serofino, Stephen Berrick, and Mark Carle at GSFC DAAC and others at DAO, hosted via our ingest server. The latest test involved the new DAO PGE custom subset for our SCF (DFLAXMNT.hdf).
- We have successfully setup a dedicated database server (a dual 200mhz SMP workstation running RedHat Linux 6.0, modis.ntsg.umt.edu), 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

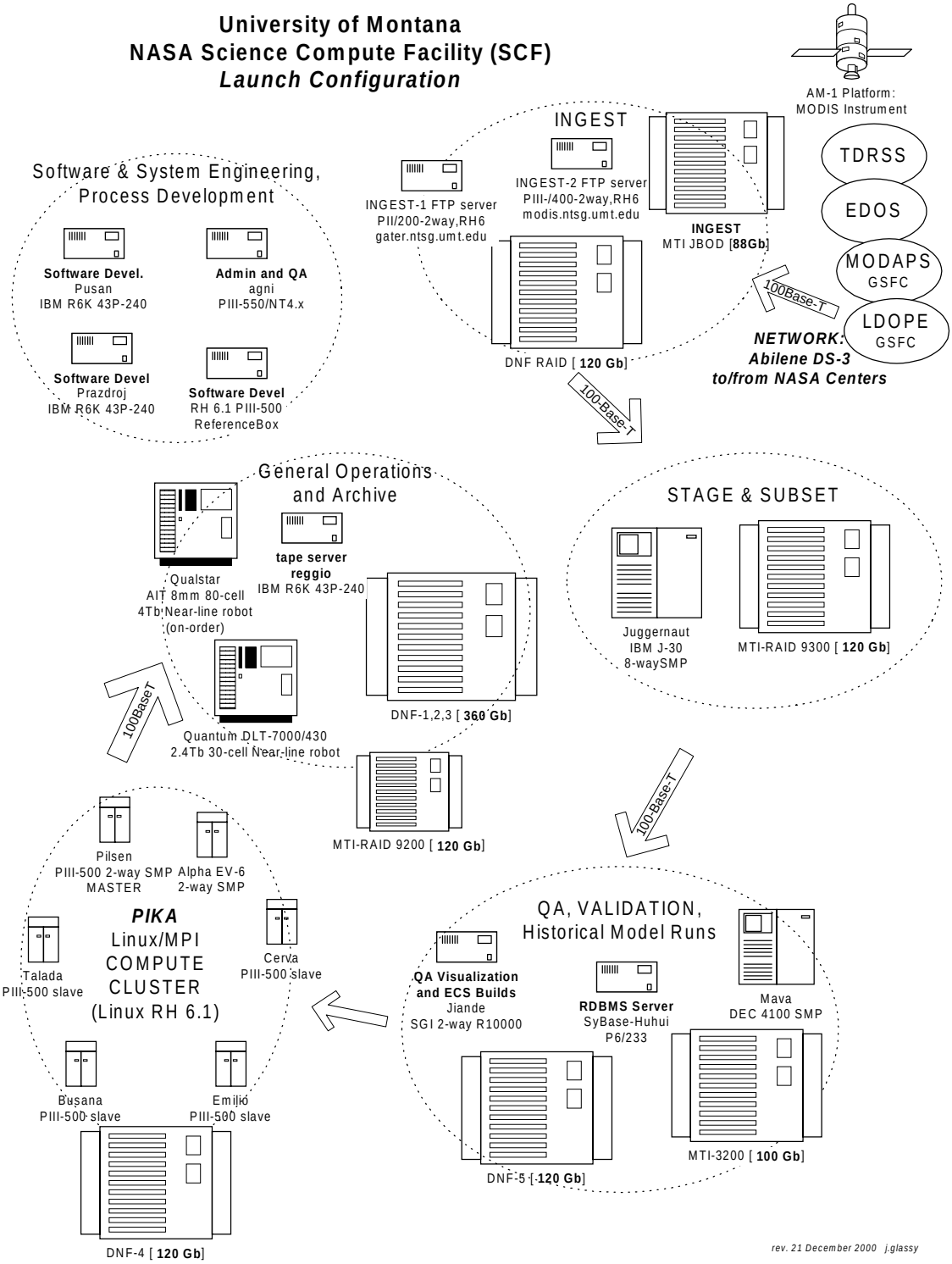
next period.
- For added security, we have deployed the industry accepted "secure shell" (ssh, version 2.0.13 on all servers that interface to the external world.

SCF DEVELOPMENT

During this period, we have completed several accomplishments of note:
- we have completed the move into our new SCF Compute room at the University of Montana Science Complex, 4th floor, re-deploying all floor equipment in this room.
- A new CISCO C5K 100Base-T module has been purchased and installed to serve the room with a minimum 100BaseT service level.
- Our new Abilene DS-3 (45Mbit/sec circuit via the Seattle NW Net GigaPOP) network service has been connected to campus, and is now being tested for our facility in anticipation of lighting up by late January 2000.

Data Storage and Archive

We currently have approximately 600 Gb of fixed disk store, comprised of several 72" racks of Dynamic Network Factory RAID 3/5 120Gb units and MTI RAID 3/5 100Gb units. At this time we have an additional (8) DNF 120Gb units on order, awaiting deployment on our servers. To augment our Quantum 430/2 DLT 7000 30-cell (2 Tb) tape robot we have one Qualstar AIT-2 80-cell (4 Tb) tape robot on order. An updated diagram depicting our current SCF configuration appears below (Figure 21)



Compute Server Summary

Our current SCF compute server set includes an IBM RS/6000 J-30 (8-166mhz 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 (2-R10000 195mhz SMP architecture) QA, as well as an Pentium architecture QA workstation.

For security and performance reasons, we have segmented our external FTP ingest activities using two FTP servers (one IBM R6K 43P/240 reggio.ntsg.umt.edu and one Pentium III-400 SMP Linux server). These will communicate to the archive server over the internal 100BaseT network link.

For additional compute resources, we have implemented a prototype Pentium PIII/500 architecture 5-node cluster (4 slaves, 1 master) running the MPICH 1.12 parallel tasking arbitration software. We currently plan on adding two more computation nodes to this cluster to accommodate a variety of QA operations, as well as several new validation and historical retrospective modeling campaigns within year 2000. These servers are slated to be Microway Alpha 667mhz EV-6 SMP servers running Redhat v.6.1 Linux, and will host all our standard MODIS software (SDPTK, HDFEOS, HDF, and all PGEs).

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). We had a successful trip in August 1999 to BU, and plan periodic coordination meetings throughout 2000.
- We are now a NASA designated data interface to the MODIS Direct Broadcast effort, via MODIS Oceanographer Dr. Mark Abbott of Oregon State University.
- We have been 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.
- We continue to work with Andy Weiss in various coordination activities involving the MODIS project and the University of Montana NTSG International EOS project.

MEETINGS ATTENDED

MODIS Science Team Meeting, November, 1999
Boston University in August, 1999.
Terra launch, Vandenberg Air Force Base, December 18, 1999