SEMI-ANNUAL REPORT

NASA CONTRACT NAS5-31368

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

January 15, 1998

PRE-LAUNCH TASKS PROPOSED IN OUR CONTRACT OF DECEMBER 1991:

We propose, during the pre-EOS phase to: (1) develop, with other MODIS Team Members, a means of discriminating different major biome types with NDVI and other AVHRR-based data; (2) develop a simple ecosystem process model for each of these biomes, BIOME-BGC; (3) relate the seasonal trend of weekly composite NDVI to vegetation phenology and temperature limits to develop a satellite defined growing season for vegetation; and (4) define physiologically based energy to mass conversion factors for carbon and water for each biome.

Our final core at-launch product will be simplified, completely satellite driven biome specific models for net primary production. We will build these biome specific satellite driven algorithms using a family of simple ecosystem process models as calibration models, collectively called BIOME-BGC, and establish coordination with an existing network of ecological study sites in order to test and validate these products. Field data sets will then be available for both BIOME-BGC development and testing, use for algorithm developments of other MODIS Team Members, and ultimately be our first test point for MODIS land vegetation products upon launch. We will use field sites from the National Science Foundation Long-Term Ecological Research network, and develop Glacier National Park as a major site for intensive validation.

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract based on the long term objectives stated above.

- Organization of an EOS ground monitoring network with collaborating U.S. and international science agencies.
- Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.
- Develop improved algorithms for estimating LAI and FPAR for different biome types from AVHRR data.

- Test of a generalized ecosystem process model, BIOME-BGC, for the simulation of the carbon, water and nitrogen cycles for different biomes.
- Implementation of the Global Ecological Simulation System (GESSys) to estimate continental net primary production (NPP) for the globe.
- Deliver formal software engineering of our MODIS products, #14 Leaf Area Index and Fraction Absorbed Photosynthetically Active Radiation, and Daily Photosynthesis - Annual Net Primary Production, #16 and 17.

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. Kathy Hibbard, Postdoctoral Research Associate
Dr. Soizik Laguette, Postdoctoral Research Associate
Dr. Peter Thornton, Postdoctoral Research Associate
Mr. Joseph Glassy, Software Engineer
Mr. Petr Votava, Programmer
Mr. Saxon Holbrook, Computer Systems engineer
Ms. Galina Churkina, Ph.D. student
Mr. Mike White, Ph.D. student
Mr. Geoff Poole, Ph.D. student
Ms. Alisa Keyser, Ph.D. student
Mr. Carl Seilstad, Ph.D. student
Mr. Jim Plummer, Ph.D. student
Ms. Youngee Cho, Office Manager

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

ACTIVITIES OF Seven W. Running - Team Member, January 1998

WORK ACCOMPLISHED

EOS-IWG

As Chair of the EOS Land Science panel, Running completed Chapter 7, Land Ecosystems and Hydrology for the EOS Science Plan. The Science Plan is now scheduled for publication in March 1998. The text can be found at:

http://eospso.gsfc.nasa.gov/sci_plan/chapters.html

In a related activity, Running served on the External Biennial Review team for Mission to Planet Earth that met in June-July. The report from that effort was delivered to NASA Headquarters in August.

MODLER

The MODLER project was funded by the EOS Validation competition to explore sampling and instrument methodologies for measuring 3 MODIS core products, landcover, LAI and NPP over multi-hundred kilometer areas. This MODLER project brings together 14 Long-Term Ecological Research (LTER) Network sites and NASA's MODIS Land (MODLAND) Science Team for the purpose of locally validating Earth Observation System-era global data sets. Using several standardized methods that incorporate extensive ground data sets, ecosystem models, and remotely-sensed imagery, each LTER site is developing local maps of landcover class, leaf area index, and aboveground net primary productivity for a 100 km2 area at a grain size of 25 m. A nested, hierarchical ground-based sampling scheme will help establish error bounds on the variable estimates. A number of different strategies are being used to spatially aggregate the fine-grain site maps to a coarse grain (1 km) so that they can be compared to coincident portions of global maps of the same three biosphere variables developed by the MODLAND Science Team. The web site is at:

http://atlantic.evsc.virginia.edu/~jhp7e/modlers/

Global Climate and Terrestrial Observing Systems (GCOS/GTOS)

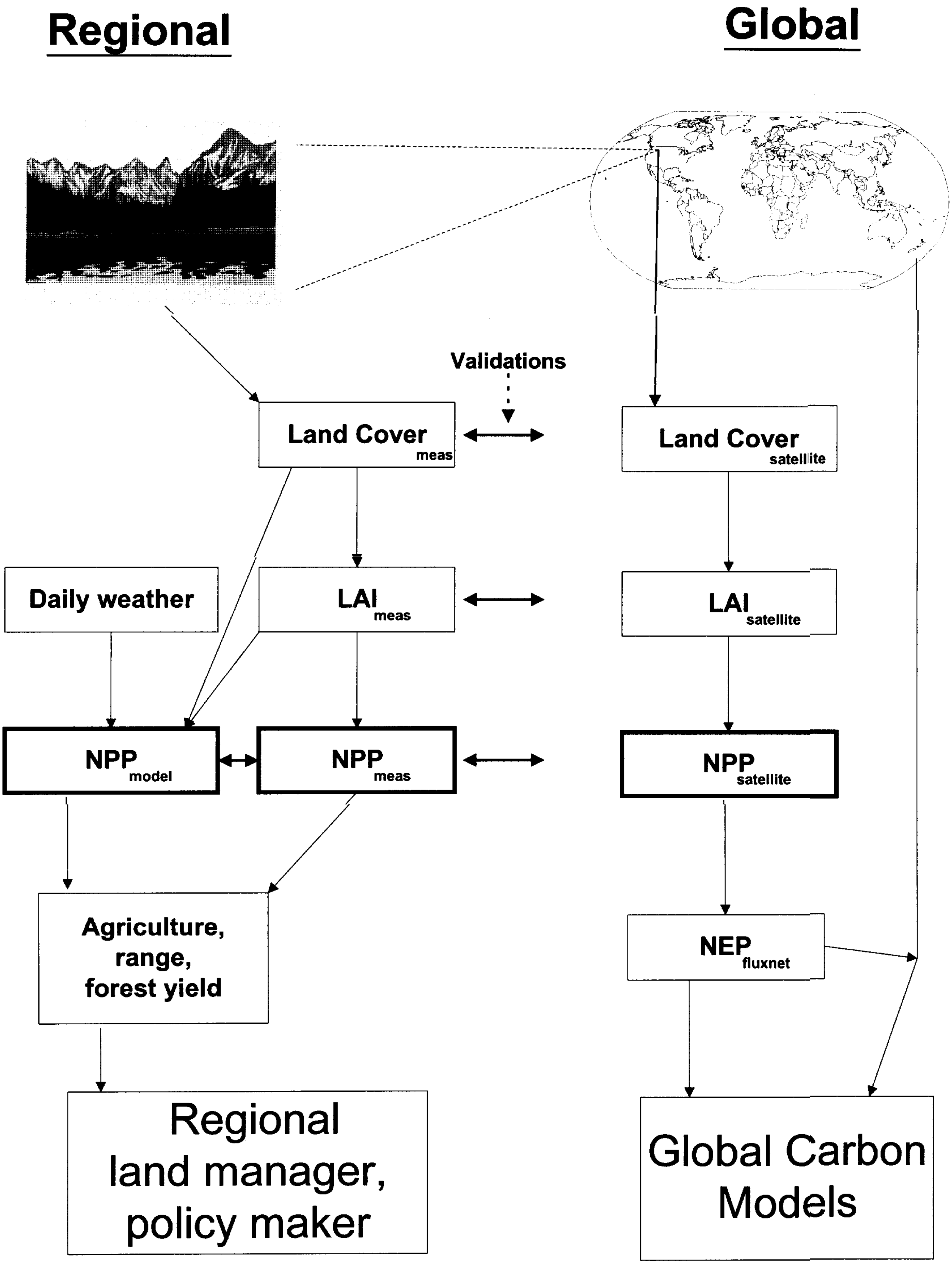
Running attended an IGOS (Integrated Global Observing System) meeting in June 1997 to plan a strategy for synergism amongst the Global Climate and Terrestrial Observing Systems. The meeting, in Guernica, Spain ended with an agreement to use the MODLER protocol (see above) to organize a global network of sites taking compatible measurements of landcover, LAI and NPP over multi-kilometer scales. This network, now called GTOS-NPP will provide MODLAND with a very full sampling globally of these variables for validation. The project plan is diagramed below:

[GTOS-NPP flowchart]

IGBP Biospheric Aspects of the Hydrologic Cycle (BAHC)

Running is working with Drs. Dennis Baldocchi and Ricardo Valentini concerned with organizing a global network of CO2 and H20 flux towers for continuous validation of MODLAND vegetation flux products. This network called FLUXNET, is based on the La Thuile, Italy workshop, and was published in Global Change Biology, in June 1996. We propose that FLUXNET will host the EOS Simple Tower configuration suggested in the MODLAND validation plan. A proposal to organize the network and archive office at the Oak Ridge DAAC was submitted to the EOS Validation program. The proposed network will be a combination of Ameriflux for North America (http://www.esd.ornl.gov/programs/NIGEC/), EUROFLUX for Europe, OZFLUX for Australia/New Zealand, and other regions as they develop. Running will be hosting the international FLUXNET workshop in June 1998 in Montana. Running sees FLUXNET

GTOS - NPP


Regional
Global
Validations
Land Cover meas
Land Cover satellite
Daily weather
LAI meas
LAI satellite
NPP model
NPP meas
NPP satellite
NEP fluxnet
Agriculture, range, forest yield
Regional land manager, policy maker
Global Carbon Models

and GTOS-NPP as the backbone of global-scale terrestrial vegetation validation for EOS.

PIK NPP Workshop

The IGBP-GAIM project is running a global NPP model inter-comparison. This activity is the most organized effort in the world to determine best NPP analysis for validating the MODLAND NPP product. The following two papers have been submitted for summarizing and analyzing PIK-NPP results:

Churkina, G., SWRunning, A.Schloss and PIK-95 1997. Comparing global models of terrestrial NPP: The importance of water availability to primary productivity in global terrestrial models. Global Change Biology (in review)

Churkina, G., and SWRunning. 1998. Contrasting climatic controls on the estimated productivity of different biomes. Ecosystems (In press)

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/

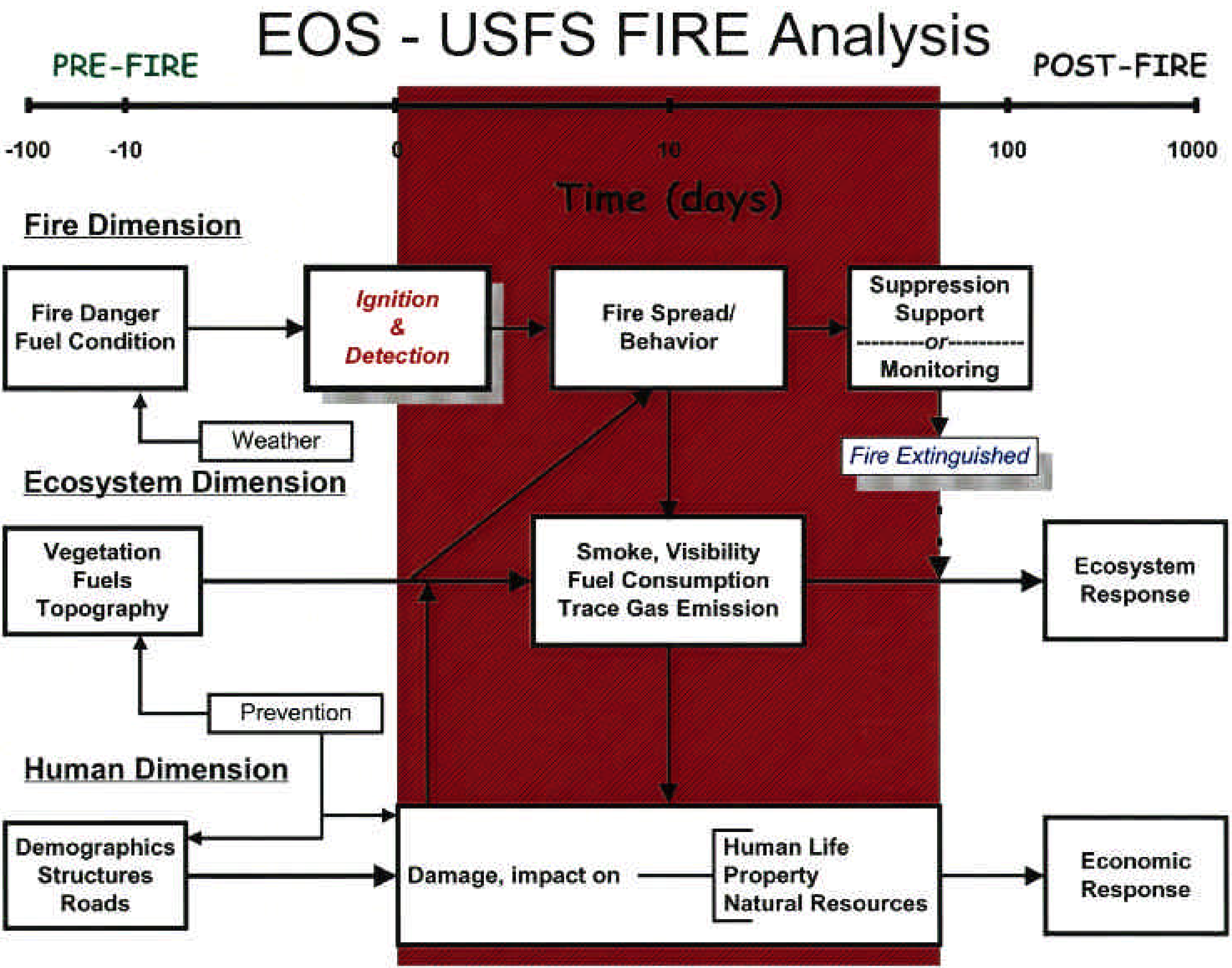
The BIOME-BGC model that is part of our MODIS algorithm development for the EOS NPP product is one of the three biogeochemistry models being tested. Currently VEMAP is building transitory climate and CO2 datasets for the next generation of simulations. The next models will be prototypes of what now are called DGVMs Dynamic Global Vegetation Models incorporating interacting biogeography and biogeochemistry models. We are teaming with Ron Nielson and his MAPPS biogeography model. Test simulations will occur in Spring 1998.

EOS – US Forest Service Fire Management project

Running has worked with the US Forest Service Intermountain Fire Research Lab for the last year to design a plan to incorporate EOS data into a next generation Wildfire Management Plan. These ideas were presented at the EOS-IWG meeting in San Diego in February. The current project outline is given below:

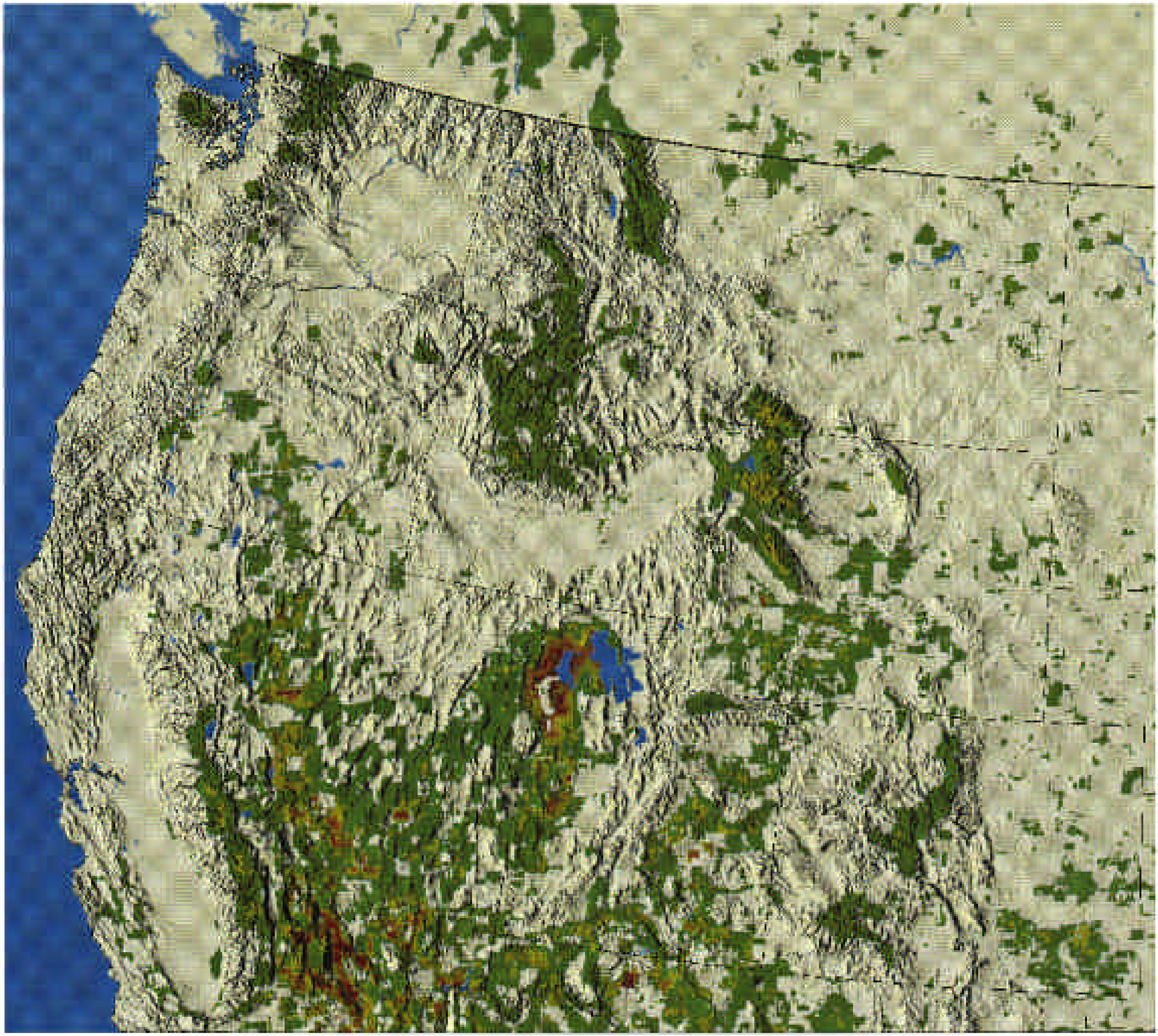
[Fire flowchart]

The Fire Lab is currently preparing a detailed implementation plan for this project.


EOS - USFS FIRE Analysis
PRE-FIRE
POST-FIRE
-100
-10
0
10
100
1000
Time (days)
Fire Dimension
Fire Danger
Fuel Condition
Ignition
&
Detection
Fire Spread/
Behavior
Suppression
Support
----------or----------
Monitoring
Weather
Fire Extinguished
Ecosystem Dimension
Vegetation
Fuels
Topography
Smoke, Visibility
Fuel Consumption
Trace Gas Emission
Ecosystem
Response
Prevention
Human Dimension
Demographics
Structures
Roads
Damage, impact on
Human Life
Property
Natural Resources
Economic
Response

FIRE POTENTIAL INDEX

Derived from June 6 - 12 1997 AVHRR NDVI and Surface Temperature Data



Numerical Terradynamic Simulation Group

Potential

Low Medium High

Remote Sensing Program

School of Forestry
University of Montana

GLOBE

The University of Montana has been selected as a GLOBE regional Training Center. We will host a GLOBE training workshop in May 1998. Additionally, we have written protocol for a new GLOBE variable to be measured by all participating GLOBE schools worldwide.

GLOBE PHENOLOGY PROPOSAL

Michael White and Steven Running

University of Montana

BACKGROUND

1. Phenology is the study of recurring biological cycles and their connection to climate. Many events we see every year in nature are at least partially controlled by climate. For example, annual bird migrations, insect outbreaks, and salmon spawning are phenological cycles. While these events occur at around the same time each year, their precise timing tends to vary from year to year. This is called interannual variability. In this research, you will be working with the network of Globe schools to try and better understand the influence of climate on phenological interannual variability all over the world.

2. In the examples mentioned above, because the subjects are mobile animals, monitoring is difficult and requires lots of time. On the other hand, because plants don't move around, they are easier to monitor. That's why for this project, we are interested in vegetation phenology. Have you ever noticed that leaves on trees in your neighborhood begin to appear at different times during spring? This happens because of year-to-year changes in weather. There are two main reasons for this variability. First, in temperate areas with cold winters, warm springs will usually cause leaves to appear sooner than they would in cold springs. This means that the growing season will be longer in warm years and that plants will have a greater opportunity to conduct photosynthesis. Second, in tropical areas where it is always warm, many plants begin growth when there is enough moisture. In these areas, the timing of growth should be controlled by precipitation patterns, not temperature. By monitoring phenology and climate, we can test these hypotheses. For example, if over many years we see a trend toward warmer temperatures and earlier dates of spring growth, this will be a strong indication that growing seasons are lengthening in response to warmer climates.

3. The Globe project is especially important for this research. We need to understand how vegetation responds to interannual climatic variability. Yet while some scientists have studied phenology for some areas or some species, there has never been a consistent, world-wide effort to monitor vegetation phenology in the field. By participating in the project, you will not only see for yourself how vegetation

responds to climate, you will also be providing important information that we need to better understand how global climate influences our vegetation.

4. In forests, bushes, and shrubs, the growing season can be defined by the appearance of leaves in the spring and the dropping of leaves in the fall. Buds are small, hard, protective structures containing miniature leaves formed in the previous growing season. In the spring, the buds open and new leaves begin to expand. This is called budburst and is easy to detect. In the fall, leaves develop yellow, red, or orange color and eventually fall off their branches. Fall patterns, such as coloring and leaf drop, are more gradual processes than budburst. Because there is no one specific event like budburst to identify, it is difficult to establish an accurate date for the end of the growing season. In evergreen canopies, where there are always some leaves on the tree, detection of the end of the growing season is even harder. Additionally, in temperate climates, fall cycles are strongly controlled by the amount of daylight. Since this will always be the same for a given day, fall cycles are usually more regular than the temperature controlled dates of budburst. For these reasons, we will only monitor dates of budburst.

5. Now you must decide if you live in an appropriate area for the Globe phenology project. First of all, you must live in an area with trees. Both deciduous and evergreen trees have buds, so either type may be used. Areas with shrub and bush vegetation do have phenology, but the annual patterns are so variable that accurate monitoring would take too much time. If you live in a tropical area with a normally warm and wet climate, your vegetation may not have strong annual vegetation cycles. If so, you should not participate. But if you have a dry season and most of the vegetation loses its leaves at some time, you should definitely participate. You most likely live in the part of the world for which we have the worst understanding of vegetation phenology.

SITE SELECTION

1. For your site selection, you have two options. First, since you will already have a site set up and dominant species identified, phenology monitoring could be done in the same area as one of the Biology/Land Cover quantitative sites. Since you will need to make frequent visits to the site, select the site closest to your school. Second, and probably more convenient, you could use your school grounds. Before you decide to do so, you must find out if the grounds are watered, fertilized, or otherwise different from the Biology/Land Cover site. If so, do not use the grounds. Since watering or fertilization will alter the plants' phenological cycles, the data would not be representative of natural vegetation - climate connections.

2. At the site, identify the dominant species. This will be the species with the largest individuals and most extensive coverage. Select two of the largest overstory trees for permanent phenology monitoring. Plants from the layer of vegetation under the large trees, called the understory, will have a different phenological cycle than the overstory. Since we're trying to establish the connection between climate and the dominant vegetation types, we won't study understory plants. The trees should be

easily accessible and you should be able to see individual leaves. Try not to select trees where the lowest branches are several meters above the ground. If you can't find trees with low branches, don't worry. Just bring a pair of binoculars when you visit the site. For each tree, select two south-facing branches for permanent monitoring (north-facing branches if you live in the souther hemisphere). Since the dates of budburst can vary within a single tree's canopy, you need to monitor the same branches each year. Mark these branches with flagging tape or some other identification.

3. When selecting your trees, choose native species. Non-native species, called exotics, have phenological cycles that are not tied to the local climate. Fruit trees are a classic example. You may have heard on the local news that a late spring frost ruined a fruit crop in your area. This is because exotics are not evolved to survive in the local climate. If you are unsure which plants are natives, ask your teacher, a local greenhouse, or a university professor.

BUDBURST DETECTION

1. Since budburst is highly variable from year to year, you will need to start monitoring well before average date of budburst. Ask your biology teacher if they have any record of this for your area. If not, try contacting local horticultural societies or university biology professors. The date does not need to be exact. You are just trying to establish when, on average, leaves begin to appear.

2. In the spring, approximately two weeks before the average date, the entire class should make a field trip to the site so that the students all know which trees and branches to monitor. After that, you will begin to make daily trips to the phenology monitoring site. Look at the buds at the end of the branch. Again, as for the selection of trees and branches, you should look at buds at the same branch position each year. Have any of the buds burst open? Can you see signs of tiny green leaves inside the bud? If you answer yes to both these questions, enter the date of budburst on the internet data entry form. Since you are trying to detect the first signs of budburst, don't worry if some of the buds haven't opened yet. Keep monitoring until you see budburst on all four of your branches.

3. It is important that someone visits the site each day until budburst.
   For two to three weeks, this will mean a lot of visits to the site. So that not everyone has to visit the site every day, try to make up a schedule so that students can take turns visiting the site with their parents or other adults. If budburst occurs on a day before which no one had visited the site, make sure to include this information in the comments section of the data entry form.

WEATHER MODELING

1. Once you have detected budburst, you now need to establish the associated climatic conditions. You will use the meteorology records from your school to calculate the amount of warming associated with budburst and the level of moisture availability.

2. Growing degree summation (GDS) is a common measure of warming. For this method, you will need to get the weather records from your school's air temperature station. For each day, calculate the daily average temperature (Tavg) as maximum + minimum temperature divided by two. Beginning on January first in the northern hemisphere and July first in the southern hemisphere, you will calculate GDS.

3. On January or July first, check to see if the mean temperature is greater than 1 deg C. If it is, record this temperature. If not, ignore it. Go to the next day. Again, check to see if the mean temperature is greater than 1 deg C. If it is, add it to the previous summation total. If not, again ignore it.

4. For example, look at the following series of temperatures and the summation that would go with them:

Mean Temperature	-3	-2	2	3	-1	5	6
GDS	0	0	2	5	5	10	16

5. For each branch, calculate GDS up to the day at which you record budburst.

6. Moisture availability is often measured by comparing the input of water to the surface with the amount of water that could leave the surface. In other words, inputs are compared with outputs. If inputs exceed potential outputs, the environment is moist. On the other hand, if potential outputs are much larger than inputs, drought conditions exist. The precipitation measured at your school is the input. Outputs are evaporation and transpiration. Transpiration is the process of water loss from plants while they absorb CO_2 for photosynthesis. The sum of evaporation and transpiration is called evapotranspiration, or ET. ET can be accurately estimated using fairly complicated equations. Here, you will use a very simple method to calculate the potential amount of water that could leave the surface under the observed meteorological conditions. This is called potential evapotranspiration, or PET.

7. To estimate PET, we will rely on the concept that for a given temperature, air can only hold a certain amount of water. Warmer air can hold more water. This means that under warm conditions, PET is higher than in cold conditions. In reality, PET also depends on the amount of solar radiation, but we can still obtain useful data using only temperature.

8. Once you have detected budburst, you will get PET from table 1. For the day of budburst, find Tavg in Table 1. Then look in the column to the right. This is PET in mm per day. Record this value. Since plants respond to long-term moisture trends, record PET for the 29 days prior to budburst for a total of 30 values. Add up all the PET values. Next, add up all the precipitation values for the same 30 days. Subtract the PET total from the precipitation total. We will call this the water difference (WD). If WD is positive, this shows that there was more precipitation than the area

could use. This indicates wet conditions. Negative WD values suggest dry conditions. Make the same calculation for all four branches.

9. Record the GDS and the WD values on the internet data entry form.

GOALS

From year to year, even though the dates of budburst will vary, the local meteorological conditions should be fairly constant. By monitoring budburst, GDS, and WD over time, we will be able to establish three different goals. First, using the network of Globe phenology data, we will map annual dates of budburst across the continents. Second, we will establish the weather patterns that control phenology in your area and across the world. Over time, you will be able to find out if your growing season responds to GDS or WD. Using all the Globe data, we will be able to map areas of the world where the growing season is controlled by temperature and where it is controlled by moisture. Third, we will develop a better understanding of how global vegetation responds to interannual climate variability.

Table 1

Tavg	PET	Tavg	PET
0	0.8	26	4.0
1	0.9	27	4.3
2	0.9	28	4.5
3	1.0	29	4.7
4	1.1	30	5.0
5	1.1	31	5.3
6	1.2	32	5.6
7	1.3	33	5.9
8	1.4	34	6.2
9	1.5	35	6.5
10	1.6	36	6.9
11	1.7	37	7.2
12	1.8	38	7.6
13	1.9	39	8.0
14	2.0	40	8.4
15	2.1	41	8.9
16	2.3	42	9.3
17	2.4	43	9.8
18	2.5	44	10.3
19	2.7	45	10.8
20	2.9	46	11.3
21	3.0	47	11.9
22	3.2	48	12.4
23	3.4	49	13.0
24	3.6	50	13.7
25	3.8		

DATA TO BE ENTERED BY STUDENTS IN ADDITION TO STANDARD LOCATION

1) LOCATION OF PHENOLOGY STUDY SITE
   A) Biology/Land Cover Site
   B) School Grounds
   C) Other (DESCRIBE)

2) SPECIES
   A) Latin Name
   B) Common Name
   C) Description

3) PHENOLOGY DATA

	Tree One		Tree Two	
	Branch 1	Branch 2	Branch 1	Branch 2
Budburst	month, day	month, day	month, day	month, day
GDS	deg C	deg C	deg C	deg C
WD	mm	mm	mm	mm

4) COMMENTS. The most important information is whether or not the site was visited regularly before budburst. If not, the students should enter the number of missing days before the recorded budburst dates.

NASA EOS and Related MEETINGS ATTENDED (SWR)

EOS-SEC Meetings, September, November 1997
MODIS Science Team Meeting October 1997
EOS IWG Meeting November, 1997
NRC Climate Research Committee October 1997
EOS Land Validation workshop December 1997

PUBLICATIONS

Running, S.W. , RR Nemani and J. Glassy. 1998. GLOBAL NET PHOTOSYNTHESIS AND TERRESTRIAL NET PRIMARY PRODUCTIVITY from the EARTH OBSERVING SYSTEM To appear in Methods in Ecosystem Science, edited by Sala, Jackson, Mooney and Howarth, Springer-Verlag New York, Inc.

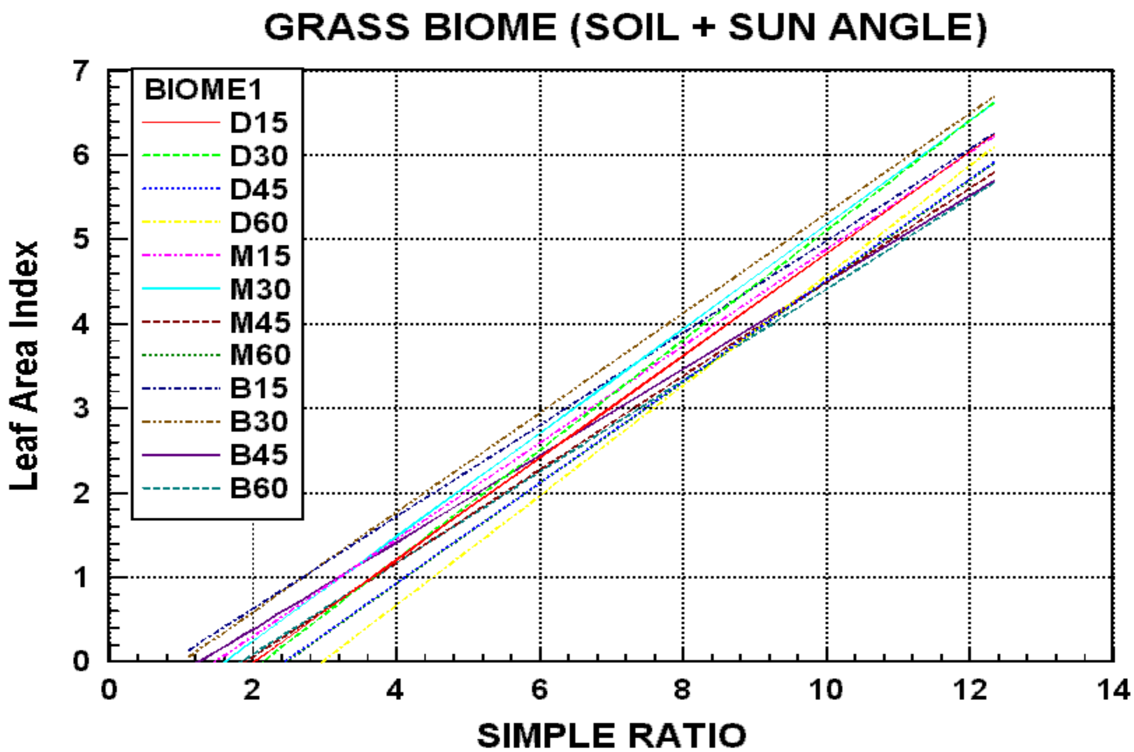
Waring, R.H. and S.W.Running 1998. Forest Ecosystems: Analysis at Multiple Scales. Academic Press. (in press).

White, J.D., S.W.Running, PE Thornton, REKeane, KCRyan, DBFagre, and CHKey (1998) Assessing regional simulations of carbon and water budgets for climate change research at Glacier Nat Park. USA. Ecological Applications (in press).

MODLAND ACTIVITIES of R. NEMANI

WORK ACCOMPLISHED

MODIS Algorithms

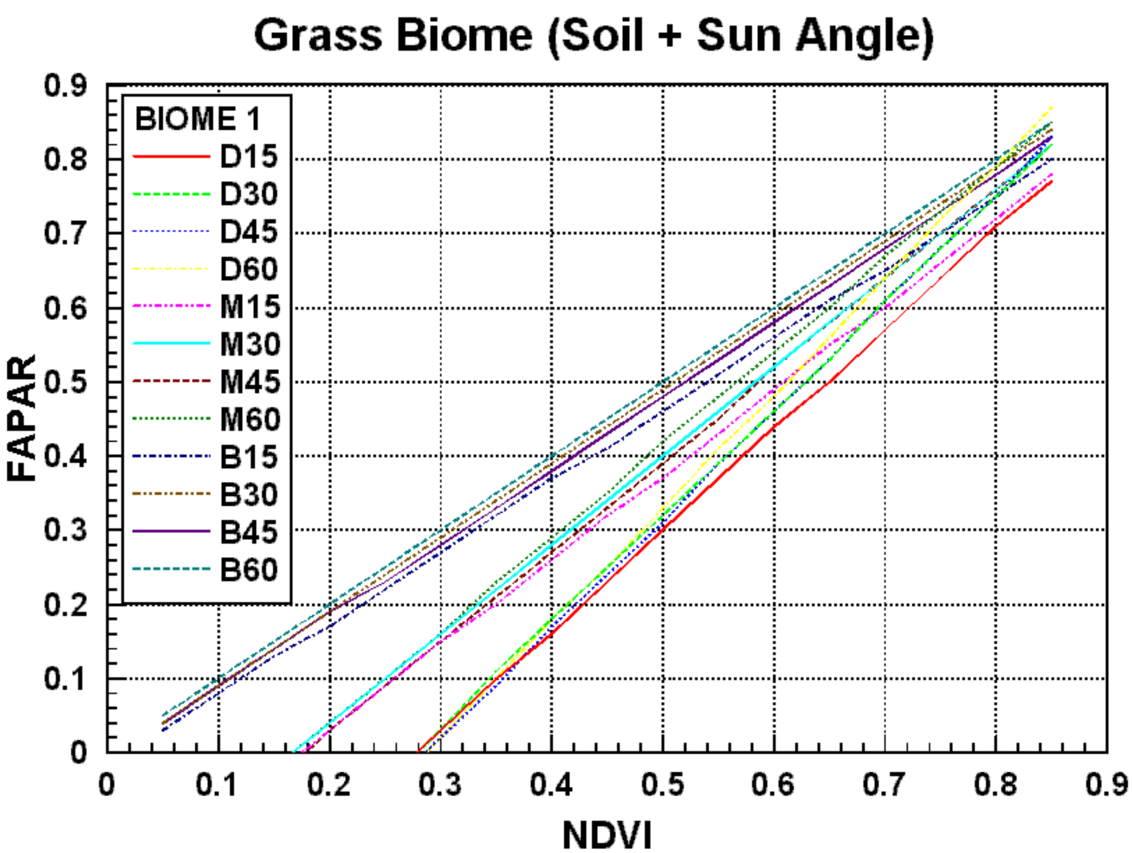


Net Primary Production

The Production Efficiency based model is simplified and streamlined to use currently available datasets from DAO. A number of decisions had to be made on the use of several variables produced by the DAO, the most important one being the use of variables produced at 10m instead of 2m height. This decision has significant influence on NPP estimates over low canopies such as grasses and crops. The DAO does not have much confidence on their estimates at 2m height.

Leaf Area Index/fAPAR

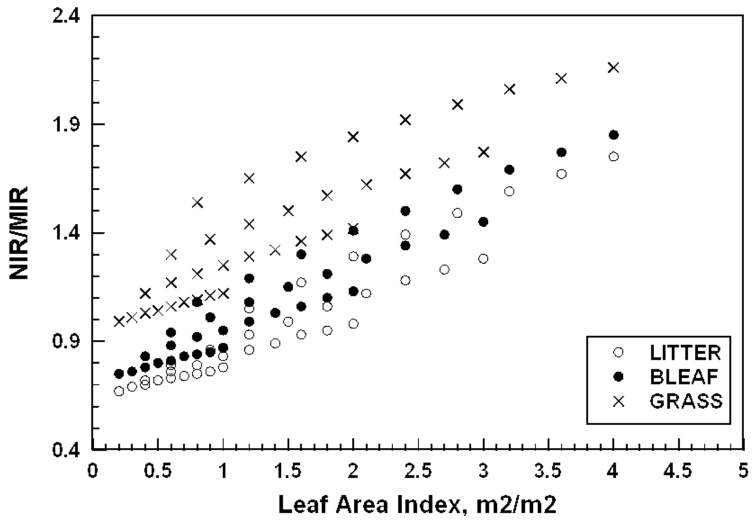
Following our earlier work (in IEEE Trans. Geoscience and Remote Sensing) on the back-up algorithm, we further refined the empirical relationships to account for variations in soil background, view angle, sun angle. Aproximately 400 relationships each have been developed for LAI and FPAR for the six biomes. The sun and view angle dependent relationships help in better estimation of LAI and FPAR. Our earlier NDVI based relations have been modified to use SIMPLE RATIO for estimating LAI. The SR based relations are found to be linear over much of the observed range (0-6) of LAI for different biomes. The following examples show variations in the relationships between NDVI and fAPAR and SR and LAI for grass biome for various combinations of soil (Dark, Medium, Bright), and sun angles (15-60).



Role of Mid-IR in vegetation studies

Several studies over the past 15 years have shown the utility of MIR wavelength band for quantifying vegetation type and density. Negligible impact of the atmosphere on MIR, and high contrast between soil and vegetation allow MIR measurements to be extremely useful for land cover classification, and for deforestation studies. Since MODIS carries a MIR band, we would like to use this information to strengthen our LAI/FPAR algorithm.

Using 3-D radiative transfer model, we simulated the response of several canopies with varying backgrounds in terms of MIR response. Results were quite promising as relationships between NIR/MIR have significantly changed depending on the background type, as shown below.



Climate change and Vegetation response

Response of Austrian forests to changes in climate

The purpose of this study is to explore if changes in climate could have caused the increased increment rates reported for European forests, specifically in Austria. Using 30 years of climate records from 20 weather stations in Austria, we investigated the magnitudes of temperature changes and the change in length of the growing season between 1961-1990. Special attention was paid to the period between 1981-90 over which forestry observations were available. In order to understand the significance of changes in climate on forest growth, we used the ecosystem model, FOREST-BGC, to predict annual net primary production. The results indicate: (1) no change in precipitation over the period; (2) an average temperature increase of 0.7 C between 1981-90 vs. 0.2 between 1961- 1980; (3) length of growing season increased by 21 days between 1981-1990; (4) net primary production increased by 11% between 1981-90 and only 0.6% between 1961-1980. The trends in NPP are consistent with observed diameter increment rates determined from 614 increment cores of Norway Spruce distributed all over Austria.

Validation of MODIS products

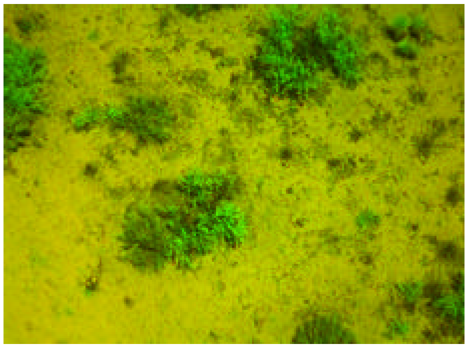
Jornada PROVE

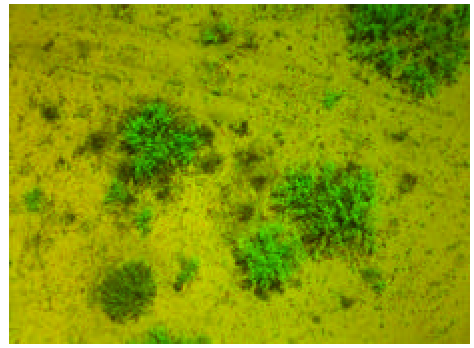
Field validation of MODIS satellite data is a crucial component of algorithm development and product quality testing. Leaf area index (LAI), a central MODIS product, is a major input for ecosystem models and landcover monitoring. In canopies with a high proportion of bare ground, such as shrublands, satellite estimates of LAI are often confounded by soil reflectances. Thus, field measurements of shrub LAI are critical components of the MODIS LAI product. The high proportion of woody material versus green matter renders most optical field LAI instruments, such as the LICOR LAI 2000 or the Decagon Ceptometer, of limited utility. Reflectance measurements more sensitive to green matter should be more useful.

On May 23 and 24 1997, as part of the NASA PROVE campaign, we acquired red ® and near infra-red (NIR) reflectances with a Dycam Digital Camera along three experimental transects at the Jornada Long Term Ecological Research site. We found that traditional methods for LAI estimates, such as the normalized difference vegetation index (NDVI) vs. LAI correlation, are not possible with the Dycam Digital Camera. The wide bandwidth of the instrument leads to frequent saturation even at fairly low vegetation levels. We propose an alternative method based on fractional cover and destructive LAI sampling. The methodology, currently under development, is as follows. First, using threshold reflectance values, fractional cover will be calculated by dividing pixels into vegetated or non-vegetated fractions. Since this method is binary, not continuous, band saturation should be less of a problem. Second, destructive LAI estimates for the dominant landcover species will be obtained from the PROVE dataset. The percent dominance for each species will then be used to calcualte the ecosystem-level destructive LAI (DLAI). Multiplying fractional cover by DLAI will produce ecosystem LAI. Finally, we will compare the digital LAI with the Ceptometer and LAI 2000 measured LAI. This method has the potential for accurately and quickly measuring shrub LAI in situations where optical and satellite measurements are less than optimal.

We are separately defining a set of field sites measured by USForest Service scientists in the northern Rocky Mtns to provide comprehensive validation of our MODIS LAI product.

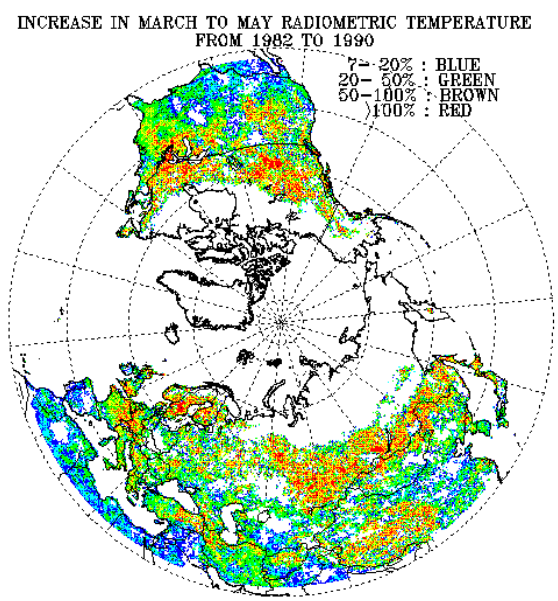
WORK IN PROGRESS

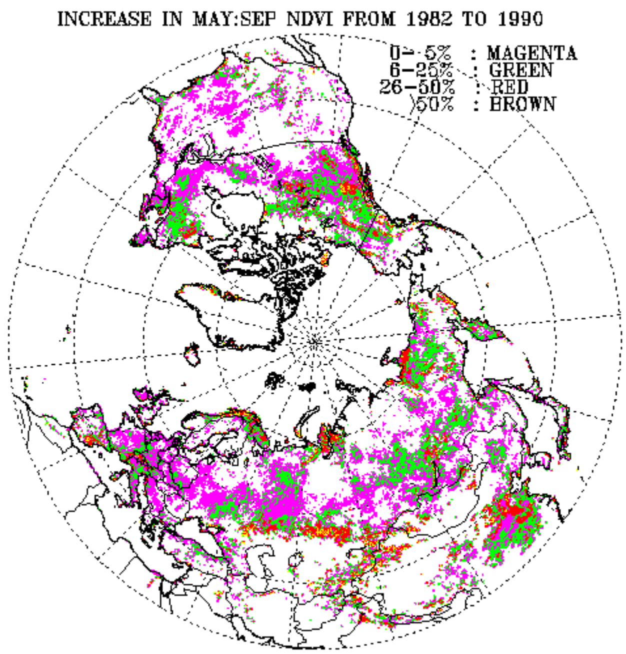


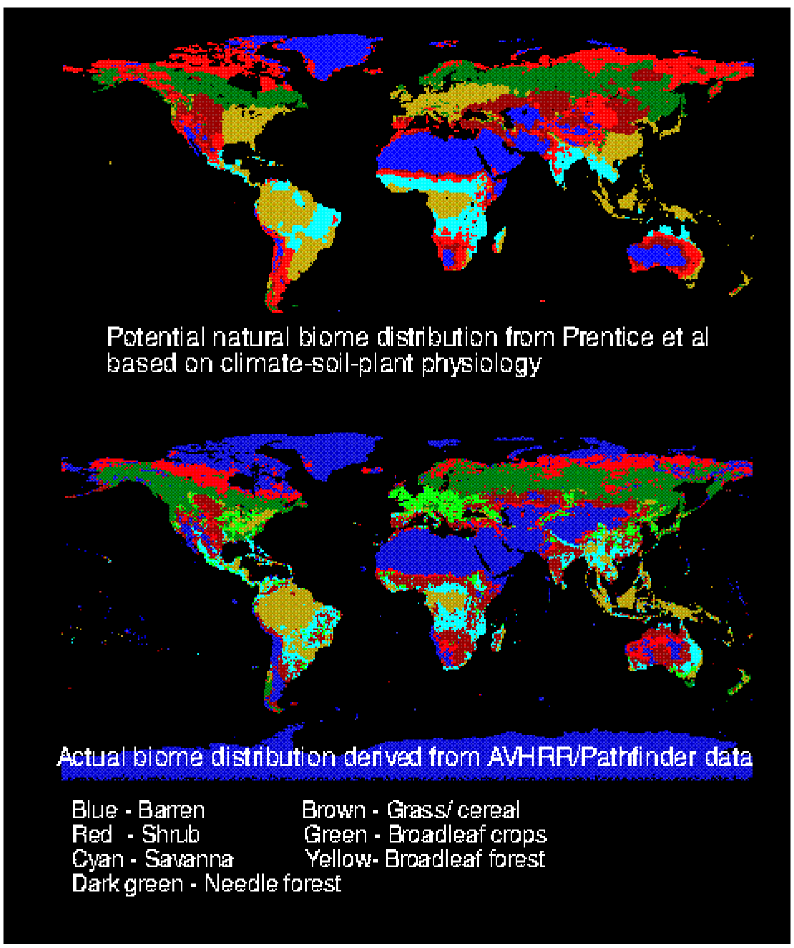


Inter-annual variations in Ts/NDVI and changes in landcover

This study follows our earlier work on the inter-annual variations in NDVI over the northern hemisphere. Though both measures were collected simultaneously, they carry complementary information about the surface processes. An increase in Ts should help in better growth conditions for plants in the high latitudes, as temperature is the main limiting factor for growth. Therefore, a study involving both Ts and NDVI would help in better understanding of the processes that lead to higher plant growth. Our earlier work on land cover changes concentrated solely on defining change based on density of vegetation. Having completed our 8km satellite based land cover classification, wewanted to study changes in fluxes in terms of their timing and magnitude. The 14 year pathfinder dataset would be used to study changes in absorbed radiation and surface temperature between potential and actual vegetation.




INCREASE IN MAY:SEP NDVI FROM 1982 TO 1990
0–5% : MAGENTA
6–25% : GREEN
26–50% : RED
>50% : BROWN


Potential natural biome distribution from Prentice et al
based on climate-soil-plant physiology
Actual biome distribution derived from AVHRR/Pathfinder data
Blue - Barren
Red - Shrub
Cyan - Savanna
Dark green - Needle forest
Brown - Grass/ cereal
Green - Broadleaf crops
Yellow- Broadleaf forest

PUBLICATIONS

Kimball, J., S.W. Running, and R. **Nemani**. (1997). An improved method for estimating surface humidity from daily minimum temperature. *Agricultural and Forest Meteorology* 85:87-98.

Myneni, R.B., **Nemani, R.R**., and Running, S.W. (1997). Algorithm for the estimation of global land cover, LAI, and FPAR based on radiative transfer models. *IEEE Trans. Geoscience and Remote Sensing*. 35:1380-1393.

White, J.D., S.W. Running, **R.Nemani**, R.E. Keane, and K.C. Ryan. (1998). Measurement and mapping of LAI in Rocky Mountain Montana Ecosystems. *Canadian Journal of Forest Research* (in press).

Hasenauer, H., R. **Nemani**, K. Schadauer and S. Running. 1998. Forest growth response to change climate between 196-1990 in Austria. Forest Ecology and Management (submitted).

ACTIVITIES OF J. M.Glassy, MODIS Software Engineer: January, 1998

OBJECTIVES

My objectives during the time period from July 1997 to January 1998 were to:

1) Re-engineer the daily input scheme for the FPAR, LAI MOD15 V2 codes to use the new 1KM aggregated surface 7 band reflectance data product.
2) Re-engineer the MOD15 and MOD17 code implementation for compliance with the new SDPTKv.5.2.1 and HDFEOS v.2.1 API software interfaces, particularly the latest ECS metadata changes, as well as minor HDFEOS patches.
3) Revise our MOD15 and MOD17 product specification documents to reflect the latest (minor) changes, and resubmit for baseline.
4) Participate in the evolving implementation of the new Boston University FPAR, LAI (MODIS/MISR) integrated algorithm.
5) In anticipation of AM-1 launch on July 9, continue building up the University of Montana Science Compute Facility (SCF) at the School of Forestry NTSG laboratory MODIS Compute Ring Facility (MCR).
6) Plan approach for the at-launch L3/L4 Land Product validation, and QA, particularly evaluating approaches and software tools for QA.

WORK ACCOMPLISHED

MOD15: FPAR/LAI Product

Preparation of the V2 codes for MOD15 should be a straightforward evolutionary step, since the algorithm science has not substantively changed from V1 and V2. Delivery of the final V2 codes for MOD15 is still pending, but we predict these will be delivered in late January. Numerous "minor" complications in transitioning the software have presented themselves, due to the following requirements:

1) To advance our teamwide efficiency in data product stream, we have switched our main surface reflectance input product from the original L2G variant produced by the pre-processor "laifp3" to the new consolidated, 7 band 1KM aggregated surface reflectance product, MOD_PRAGG.hdf. This new data input form includes all geolocation fields, instrument geometry, as well as band level spatially aggregated surface reflectances and band QA. There are numerous benefits to adopting this new input, but final samples of it did not arrive to our lab until mid-December.

2) The new input file (as well as the latest samples of DAO global surface climatology) is in the HDFEOS v.2.1 format, itself an evolving data model based on the NCSA HDF v.4.1r1 data model and library, another evolving format. The service functions comprising the GRID interface, while similar to the older SD interface of the HDF data model have just enough differences to warrant significant re-work of our algorithm code task setup and I/O portions.

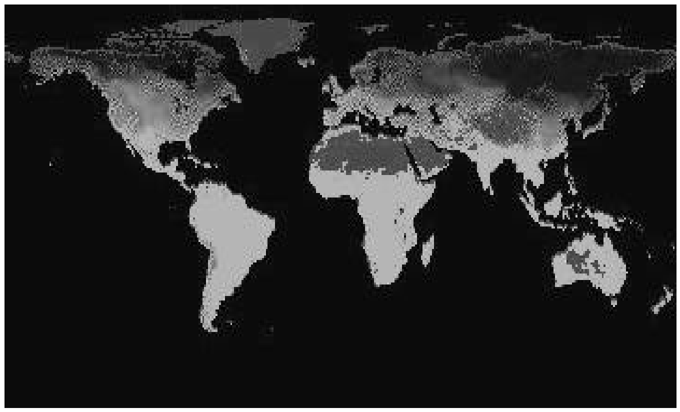
3) Lastly, the ECS metadata handling task within all our L3/L4 algorithms continues to require minor software changes. There is now a growing collection of partially overlapping software elements dedicated to servicing the ECS metadata, and properly reconciling these software components and handling strategies, as well as dealing with last minute "undocumented behavior" has consumed extra time.

4) The evolution of the SCF facility itself has required continued attention, in this period particularly surrounding our recent move to a new room in the UM Science Complex, where new network, cooling, and all other infrastructure had to be retrofitted from scratch. The section below on the SCF details these issues.

Other development activities conducted during this period included finalizing a number of structural (format) details of the new 1KM aggregated surface reflectance MOD_PRAGG intermediate product, and monitoring development of the new Boston University implementation of the MODIS/MISR form of integrated MOD15 FPAR,LAI algorithm. Note that the present V2 codes are not being delayed for availability of an operational MODIS/MISR form of the algorithm. When complete and tested, this new method potentially represents a significant advance over the current scheme.

<u>MOD17: PSN/NPP Product</u>

The MOD17 algorithm efforts during this period have been dominated by the preparation of a static global surface climatology, as well as for software to handle the DAO daily climatology product. The DAO product has continued to undergo minor format changes, and now has been promised only after a 72-hour real-time lag during production periods. The static daily global climatology we will deliver at launch is a coarse resolution data gridded from daily data from 1987. This one degree by one degree dataset consists of 14943 "land" pixels of 64800, for the following fields: daily near-surface minimum and maximum temperature, precipitation, relative humidity, incident shortware solar radiation, and surface pressure. The static climatology will be our "fallback" data source in the event the DAO daily data is not available for a given day. The figure above is an example of a 1 deg. by 1 deg. Tmax field, from day 69.



Evolution of the MODIS-University of Montana (MUM) API software library

The multi-platform MUM API library is now at version 1.07.6, with most changes dedicated to those required to add capabilities to work with the HDFEOS v.2.1 data model within our algorithms. This version will be baselined as part of the V2 delivery when it is made. Support for standard HDF 4.1r1 data objects is complete via the MAHI interface, with the MEH (MUM-HDFEOS interface) dedicated to the HDFEOS data model services., with incremental performance improvements have been made across the board. The MUM API now consists of 34310 lines of code (LOC), including comments, across 283 functions in version 1.07.6. This API library has been successfully ported to the following UNIX compute environments: IBM AIX 4.1, SGI IRIX v.6.4, DEC Unix v.3.2. On the Intel architecture, a subset of the MUM API library has been ported to Linux v. 2.0.x, and Microsoft NT version 4.0. The MUM API's full NASA PGS compatibility mode is only supported for workstation environments the SDPTK v.5.2.1 is ported to. The more general SCF mode is supported across all port platforms.

A new full time assistant programmer, Petr Votava, will be hired in late January, which should augment the productivity of our local programming team considerably. Petr has just completed an MS in Computer Science at the U.Montana, and has broad experience in the area of C, JAVA, multi-threaded,

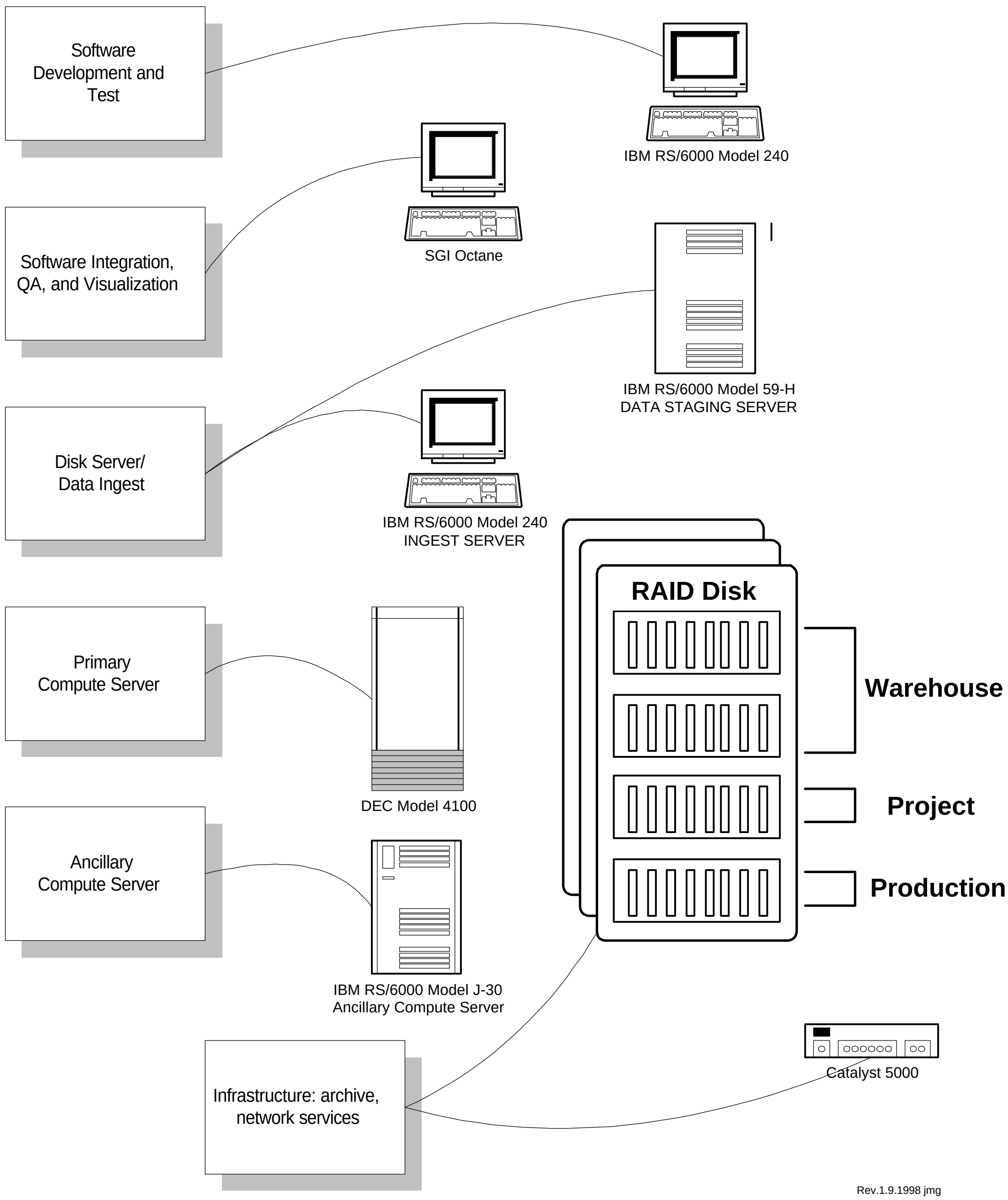
and Web programming, as well as skills in visualization and data analysis.

MODIS Compute Ring (MCR) at the University of Montana SCF

During this period, development of the MODIS Compute Ring focused on data storage. We have ordered additional RAID and bulk disk storage during this period to bring us up from 210GB to 700GB of on-line disk, comprised of a 128GB MTI Model 3200 (production RAID) volumes, (4) upgraded MTI Model 9200 RAID racks, and 2 new racks of bulk storage. In addition to the disk ordered and installed, we have also just taken delivery of a new MTI two rack, 2.2TB DLT tape robot, comprised of (30) DLT 7000 series (highest density) cartridges, connected via an automated elevator robot. Software driving the DLT will be MTI's RLM package, as well as Legato. To manage the ingest and other data storage activities, an IBM RS/6000 Model 43P/240 disk service has been added to our MODIS Compute Ring, sharing these duties with an IBM RS/6000 Model 59-H.

The Montana SCF MCR functional roles are illustrated in the following diagram, as mapped to major facility components:

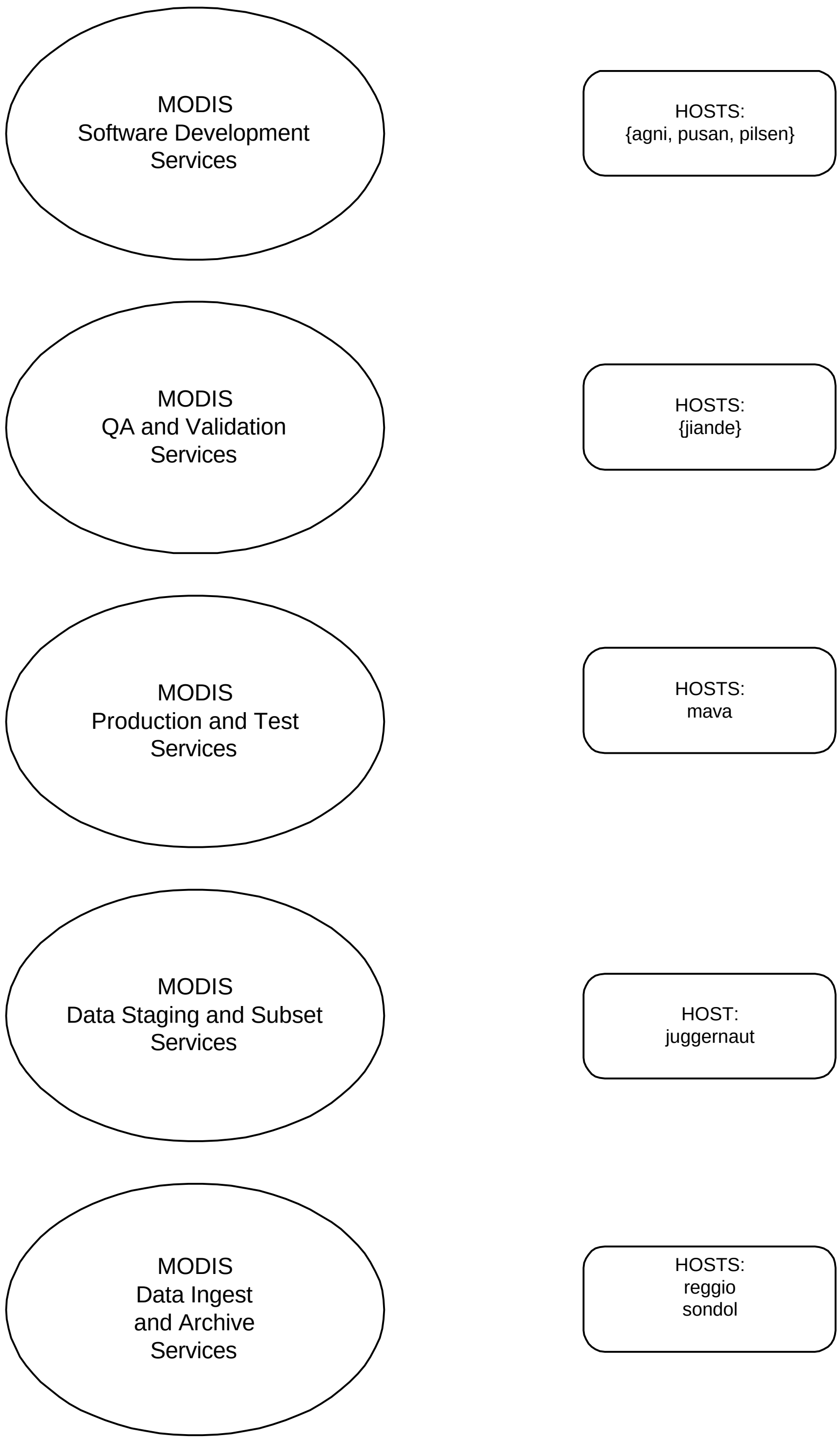
Montana SCF
MODIS Compute Ring Facility: Functional Roles for Major Components



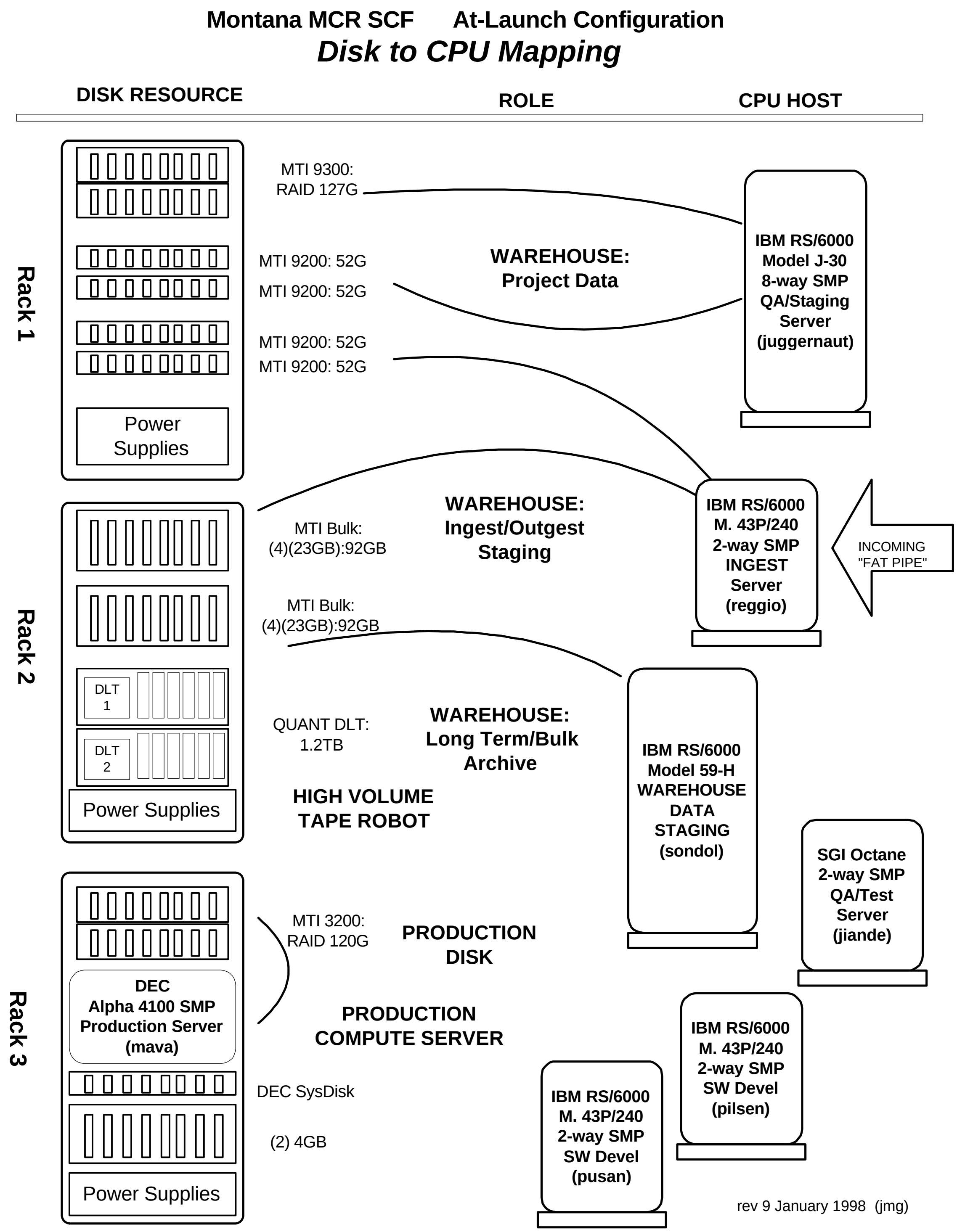
Montana SCF Hardware Components

The components of the SCF are organized into several service groups, illustrated by the following diagram:

University of Montana
NASA SCF
Hardware Service Groups



The following diagram illustrates the MODIS Compute Ring's current configuration of CPU to data-store mapping:



MEETINGS ATTENDED

- MODLAND/SDST Workshop, July, 1997
- V2 algorithm workgroup session at with Brad Castalia, January 1998

ON GOING ACTIVITIES

Algorithm Development

During the next period, after delivery of V2 codes, we will concentrate on these algorithm and QA issues:

1) Testing robustness of V2 code science,using a sample of 8KM and 1KM AVHRR data sources.
2) Completion of documetation revisions for the UM Algorithm Implementation Plans for the MOD15 and MOD17 products.
3) Completion of design and initiation of implementation for a limited set of local QA tools for rapid subsetting of HDFEOS datasets, statistical analysis and visualization of targeted globally distributed spatial samples.
4) Evolution of a local at-launch SCF Operations Plan, to include handling of specific planned (and unplanned) scenarios for various at-launch production, QA, and data transfer and storage activities.

<u>MODIS UM SCF Compute Ring Infrastructure</u>

In the next period, we are planning on acquiring more RAID on-line disk. If our budget allows, we also plan on adding a fourth CPU to our alpha compute server, the DEC Model 4100. On the data cataloging side, we still anticipate developing an integrated data and metadata ingest facility to interface to the GSFC LDOPE, using a variety of Web based technologies including JAVA, Java Beans, dbAWARE, and related software technologies. Our new programmer, Petr Votava, will hopefully take the lead on this development.