SEMI-ANNUAL REPORT
NASA CONTRACT NAS5-31368
FOR MODIS TEAM MEMBER STEVEN W. RUNNING
ASSOC. TEAM MEMBER RAMAKRISHNA R. NEMANI
SOFTWARE ENGINEER JOSEPH GLASSY
15 JULY 1995

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 based on the logic of the current FOREST-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 ET and PSN based on this modified dNDVI logic. These algorithms will be in MODISDIS before launch. 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 datasets 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) and n for the globe.
- Finish 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.

WORK ACCOMPLISHED:

Our MODIS Team now consists of SWRunning, Team Member, R. Nemani, Associate Team member, and Joe M. Glassy, Software Engineer. The following will be reports on individual activities during this reporting period.

ACTIVITIES OF SWRunning - Team Member, January - July 1995,

EOS-IWG

SWRunning was elected Chair of the EOS Land Panel in September 1994. This position requires attendance at all IWG meetings and all EOS Science Executive Committee meetings. SWR attended EOS-SEC meetings in January 7 and February 28 in Chicago, May 9-10 in Paris with the ESA executive committee, and the IWG meeting in Santa Fe, June 27-30.

On May 4, I gave testimony to a Senate subcommittee hearing, the following is key portions of my testimony:

WRITTEN CONGRESSIONAL TESTIMONY

by

DR. STEVEN W. RUNNING

DIRECTOR, NUMERICAL TERRADYNAMICS SIMULATION GROUP

SCHOOL OF FORESTRY

UNIVERSITY OF MONTANA

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE

SENATE COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORATION

HEARING ON THE HIGH PERFORMANCE COMPUTING

AND COMMUNICATIONS PROGRAM

4 MAY, 1995

A tremendous synergism is evolving amongst the technologies of satellite remote sensing, computing and telecommunications for Earth sciences and natural resource management. When the first Earth Resources Technology Satellites were launched in 1972, the optical accuracy of the satellites was poor and uncalibrated, and the computer power to process the stream of digital imagery transmitted to Earth was primitive compared to todays capabilities. As the suite of Earth Observing System satellites are launched beginning in 1998, part of the NASA Mission to Planet Earth, an unprecedented array of satellite based information will become available. EOS will produce satellite data covering the globe at variable space and time detail with a consistency not now possible. Of equal importance will be the high precision of new EOS data resulting from sophisticated in-flight calibration of the sensors. The inhanced precision of EOS satellites will allow accurately measured land products, ! prototypes of which I will show to
day.

Fortunately, as satellite technology is evolving, computer technology is doing likewise, so the personal laptop computer I carry today is probably 1000 times more powerful than the university mainframe computer we used as graduate students at Oregon State University in 1972. The 1000GB/day processing planned by the EOS Data Information System would have been absolutely impossible 10 years ago.

The final step in exploiting the vast information that will be collected by EOS is the distribution of that processed data to users. Distribution of these data to the global-scale research community will be fairly straightforward, as those scientists work at major universities or government research centers which will be linked by state-of-the-art network connections. I will show two examples of these global terrestrial science products that will be available from the EOS computer network. First will be a map of vegetation productivity useful for estimating forest, range and crop productivity worldwide. The second image will be a map of global landcover change from human activities. Both of these satellite based products are important in representing the land surface in global climate models.

However, the utility of EOS and other advanced remote sensing products by the larger scientific and resource management community will hinge on their ability to access a regional subset of these global data in a timely fashion. In my demonstration today, I want to concentrate on the remote sensing based products that should prove particularly valuable for future natural resource management IF managers and land owners can receive the data quickly and easily. I will show samples of research products that have been developed over the last five years in the western United States, and discuss how these need to be delivered for optimal utility.

The single biggest factor in making these advanced remote sensing products truly useful to managers and land owners is near-real time delivery at low cost, and this is where the "information superhighway" is the critical final component. The best current example of near-real time satellite data use is the nightly weather forecasts we all watch on television, distributed by the National Weather Service, derived in part using the NOAA Geostationary Operational Environmental Satellites (GOES) data. I invision a new era of land management that can have weekly satellite data distributed to users in much the same way over the "information superhighway".

Some of these products are generated by incorporating topography, soils, daily weather information, and landcover maps integrated with advanced computer simulation models of biophysical and ecological processes. The final products give much more realistic and quantitative mapping of land surface activity than satellite data alone can provide. Here are some examples:

(1) Drought monitoring: This image shows the change in a Drought Index that was calculated from Spring to the Summer of 1990. Both visible light and temperature data from the NOAA AVHRR meteorological satellite are used for this index. This Drought Index could be computed and distributed weekly, but is currently

only a research product developed at the University of Montana. Decisions on grazing concentration or irrigation timing are possible uses.

(2) Burning Index: This is a fire danger index map of Oklahoma that incorporates topography, ground fuels, daily weather data and satellite data into a mid-afternoon measure of the risk of wildfire ignition. This is a propotype for the next generation National Fire Danger Rating System of the US Forest Service, developed at the Intermountain Fire Sciences Lab in Missoula, and could be distributed daily. Mobilization of fire crews depends on these forecasts.

(3) Snow Cover: Accurate monitoring of spring snowmelt is essential in the Western United States for predicting flood events, summer irrigation supplies, and dam operations for hydroelectric power. This image from the NWS National Operational Hydrologic Remote Sensing Center in Minneapolis used NOAA AVHRR data to map the snow cover change from February 19 to May 1, 1990. These snowcover maps could be distributed bi-weekly via computer network.

(4) Water quality: This image, from the University of Montana, shows water quality of Flathead Lake, in western Montana, on July 16, 1984 as measured by chlorophyll concentration. Satellite based water quality monitoring of freshwater and oceans will be done weekly with the new EOS sensors.

(5) Wildlife habitat: This image shows the vegetation cover of the Seeley-Swan, a mountain valley in western Montana, and the mountain goat habitat of that area. Topographic and habitat preference factors are merged with satellite data into this analysis of wildlife habitat, done at the University of Montana as part of the U.S. Dept. of Interior, Fish and Wildlife Service GAP analysis program.

(6) Forest/Range/Crop productivity: The seasonal production rate of crop, range and forest land can be followed by integrating NOAA AVHRR satellite Greenness Index data with daily surface weather data. This image is an example, sponsored by the State and done at the University of Montana, of a system to calculate the productivity of forested land using satellite data. Decisions on range cattle allotments or forest harvesting are examples of land management that could benefit from these data. These Production Indices could be computed and distributed weekly nationwide.

Of course there are many other interesting projects using satellite imagery in innovative ways elsewhere in the world, such as mapping malaria outbreak potential or grasshopper population dynamics in Africa. These examples highlight activities I am involved with in the western United States only. All of the above products have been developed and tested by various research groups and agencies in the last five years. All of them could be used by landowners and managers if they could get access to the datasets quickly with low cost computers and network connections. In each case the primary remaining hurdle is to provide the networking that can allow this information transfer, particularly to rural agency offices and landowners.

The Earth Observing System program is concentrating on a

Data Information System to transmit processed satellite data to users. The EOS Data Information System is a cooperative activity of NASA, the Dept. of Commerce (NOAA), the National Science Foundation, the Dept. of Defense, the Dept. of Interior (USGS), and the Dept. of Energy. However, the computer network facilities to reach beyond the science community to land managers in rural parts of the United States, require more than EOS program responsibility alone. Advances in land management in the western United States will rely on high speed telecommunications to use the types of new information shown today. I encourage the continued devlopment of the "information superhighway".

EOS-NSF/LTER

A joint proposal to NASA and the National Science Foundation was completed and submitted November, 15 1994. It is now under review.

National Center for Ecological Analysis and Synthesis

SWR was selected for the Scientific Advisory Board of the newly NSF funded NCEAS. This center can play a significant role in organizing terrestrial research data for EOS science as research priorities are established in the coming year.

Global Terrestrial Observing System (GTOS)

SWRunning participated in a meeting of the joint Global Climate and Global Terrestrial Observing System (GCOS-GTOS) Terrestrial Observing System January 9-11 in Asheville, North Carolina.

IGBP Biospheric Aspects of the Hydrologic Cycle (BAHC)

SWR attended a workshop in La Thuile, Italy, March concerned with organizing a global network of CO2 and H20 flux towers for continuous validation of MODLAND vegetation products.

ISPRA Visit

SWR visited the ISPRA center in Italy, March 12-14 and presented a paper "Biospheric modeling from local to global scales using remote sensing."

PIK NPP Workshop

SWR attended the 2nd workshop on global NPP model intercomparisons at the Potsdam Institute for Climate change in Potsdam, Germany. This activity is the most organized effort in the world to determine best NPP analysis for validating the MODLAND NPP product.

Stanford Seminar Series

SWR presented a seminar "How much physiological ecology can we jam in to global models, and does it matter?" 19 April

GAP Analysis Project

The GAP analysis project is a US National Biological Service funded project to map wildlife habitat in each state using high resolution satellite imagery. I have contacted the national

GAP office about sharing their database with the MODLAND team to use as a validation source for our Landcover algorithm. Details of this agreement are being developed.

MEETINGS ATTENDED (SWR)

European Geophysical Society Meeting, Hamburg, Germany. April 2-7

IGBP-BAHC 1st Science Meeting, and Science Steering Committee meeting, Hamburg Germany, April 8-9

MODIS Science Team Meeting, May 1995

EOS-IWG Meeting, Santa Fe June 1995

Ecological Society of America annual Meeting, August 1995, Snowbird, Utah

PUBLICATIONS (SWR)

Running, S.W., T.R. Loveland, L.L. Pierce, & E.R. Hunt, Jr. 1995. A remote sensing based vegetation classification logic for global land cover analysis. Remote Sensing of Environment 51:39-48.

Nielson, R. P. and S.W.Running. 1995. Global dynamic vegetation modeling: coupling biogeochemistry and biogeography models. Global Biogeochemical Cycles (in press)

Kremer, R. G., E. R. Hunt, Jr., S. W. Running, and J. C. Coughlan. 1995. Simulating vegetational and hydrologic responses to natural climatic variation and GCM-predicted climatic change in a semi-arid ecosystem in Washington, U.S.A. Journal of Arid Environments (in press).

ACTIVITIES OF R. Nemani, Assoc Team Member, January - July 1995

OBJECTIVES

My objectives were to 1) refine the implementation details on the LAI and FPAR products, 2) continue development and testing of our land cover classification logic.

Work Accomplished

LAI/FPAR Products

Significant improvements in the implementation details of the LAI/FPAR product have been made over the last six months. Using Myneni's 3-D RT model, we have identified key canopy structural variables controlling canopy reflectance. Table 1 shows the key variables and their association to different biomes. The six biomes from this analysis, shown in Figure 1, are very similar to the ones from our earlier classification logic.

The RT model has been modified for each biome to reflect the influence of the key structural variables in that biome. The biome-specific RT models will be used to produce LAI/FPAR relations from MODIS reflectances.

We started a sensitivity analysis of LAI/FPAR products to various input variables. The signal to noise ratios (figures 2 and

3) are important to determine the accuracy of retrieved LAI/FPAR products from MODIS reflectances.

Land cover classification

To be compatible with our FPAR/LAI algorithm, we have been working on producing an in-house land cover product with six biomes. Preliminary results from Pathfinder data show encouraging results (figure 1).

Meetings Attended

American Meteorological. Society, Global change studies, Dallas, TX, Jan 15-20, 1995.

MODIS Science Team meeting, May 4-6.

MODLAND meeting, Boston, July 24-27, 1995.

Publications

Nemani, R.R., S.W. Running, R. Pielke. 1995. Global vegetation cover changes from coarse resolution satellite data. Journal of Geophysical Research-Atmosphere (in press).

Nemani, R.R., S.W. Running. 1995. Global vegetation cover changes and their impact on climate. Climatic Change (in press).

Nemani, R.R., S.W. Running. 1995. Land cover characterization using multi-temporal red, nir and thermal-ir data from NOAA/AVHRR. Ecological Applications (in press).

Nemani, R.R., S.W. Running. 1995. Implementation of a hierarchical vegetation classification in biospheric models. Journal of Vegetation Science (in press).

Chase, T.N., R. Pielke, T. Kittel and R. Nemani. 1995. The sensitivity of a general circulation model to global changes in leaf area index. Journal of Geophysical Research-Atmosphere (in press).

Nemani, R.R. E.R. Hunt, S.Running, L. Pierce, S.Piper and C. Keeling. 1995. Influence of global land cover changes on biospheric processes. Proc. of the 6th symposium on global change studies, AMS, Boston. pg 224-226.

Presentations

Influence of global land cover changes on biospheric processes at the 6th symposium on global change studies, Dallas, TX, Jan 15-20.

Global land cover classification from remote sensing data. Joint Research Center, Ispra, Italy, March 13, 1995.

Land surface products from EOS/MODIS, National Remote Sensing Agency, Hyderabad, India, May 29, 1995.

Estimation of LAI/FPAR from MODIS reflectances, EOS/MODLAND meeting, Boston, July 24-27, 1995.

On-going Activities

LAI and FPAR Products

The 3-D RT code is being re-written to optimize the computer resources as the LUT generation requires a large number of simulations. This is being done with Dr. Ranga Myeneni from NASA Goddard Space Flight Center. We will generate LUTs for all six biomes and then start a full scale sensitivity analysis of LAI/FPAR products to various combinations of input parameters. The sensitivity analysis will also determine the size of our LUTs for various biomes.

Land cover classification

The generality of our logic is being tested with AVHRR Pathfinder data collected over several years. In addition to reflectance and surface temperature data, we plan to explore the use of long-term climate and soils data to improve the classification accuracies.

ACTIVITIES OF J. M.Glassy, MODIS Software Engineer: January - July, 1995

OBJECTIVES

My principal objectives during this time period were to 1) produce and deliver prototype algorithm software codes for the MOD15 FPAR,LAI algorithm, 2) refine our PSN, NPP algorithm implemention logic, working toward a Beta-3 delivery of the PSN, NPP codes as soon as they are in stable condition. Other objectives are to continue to evolve our local University of Montana MODIS SCF Compute Facility Plan, with provisions for taking advantage of new UM network technology (e.g. FDDI based Catalyst 5000C switched hubs with future ATM expansion), and implementating the new SCF MODIS Compute Ring hardware.

WORK ACCOMPLISHED

MODIS UM SCF Compute Ring Infrastructure

An important centerpiece of the UM SCF MODIS Compute Ring infrastructure was acquired and deployed in this period: a high performance IBM RS/6000 Model 59H server. This server conceptually sits at the center of the compute ring, and will probably be augmented at a later point with a IBM Model J30 SMP or equivalent. Current IBM workstations on the compute ring include the 59H with 256MB memory and 20G of disk, a Model 41T with 256MB of memory and 11G of disk, and a Model 370 with 96MB of memory and

14G of disk. To accomodate the integrity of the increased disk loads, we now have on order an Exabyte EXE-440 40 cartridge, twin head 8 mm tape jukebox with Legato software.

During this time period, the NASA ECS SDP Toolkit v. 4.0 build was performed on the SCF hardware, and a test build of the SDST MODIS API (M-API) for Level 2 support was also conducted. Offline I/O efficiency testing of the native NCSA HDF access functions was also begun.

FPAR/LAI Product

A revised MOD15 FPAR, LAI ATBD was delivered to both the MODARCH document archive facility and the SPSO facility during this period, and the accompanying FPAR, LAI Algorithm Implementation Plan (AIP) was updated to reflect ATBD changes. Data flow diagrams were refined for this product (see attached), and a pre Beta-3 delivery of working FPAR, LAI algorithm software was made to the modis-xl.gsfc.nasa.gov host, SDST configuration manager. This prototype code delivery consisted of version 0.96 MODIS-Univ.Montana (MUM) application programming interface codes (4451 lines of ANSI C code), and the prototype FPAR, LAI client algorithm codes (2605 lines of ANSI C code), with Makefiles and approximately 237 MB of test data, including a 64MB six biome prototype lookup table.

PSN/NPP Product

The revised MOD17 PSN,NPP ATBD document was delivered to both MODARCH document archive facility and the SPSO facility during this period. Working with Rama Nemani and new lab member Galina Churkina, we further refined our PSN,NPP implementation logic to use NMC derived daily surface climatology data to be supplied by the NASA GSFC Data Assimilation Office (DAO). We also revised our epsilon (light efficiency index) calculation approach to compute epsilons in real time driven from a biome properties lookup table (BPLUT) rather than draw these from a pre-computed epsilon lookup table.

MEETINGS ATTENDED

MODIS Science Team Meeting, May 4-6, 1995,

MODLAND Goddard workshop in April, 1995,

MODLAND Boston workshop on July 24-27, 1995.

PRESENTATIONS

Presentations detailing our current algorithm implementation approach and status were made at both the April, 1995 MODLAND Goddard workshop as well as the July, 1995 MODLAND

Boston workshop.

ON GOING ACTIVITIES

MODIS UM SCF Compute Ring Infrastructure

Activities involving University of Montana SCF network connections with the EROS Data Center Land DAAC in South Dakota are expected to increase in importance over the next period. The availability and timing of the DCE network layer between our SCF and the EROS DAAC remain outstanding issues to resolve, as are firmer estimates of realtime Q/A traffic between these sites. Locally, the University of Montana is now in the process of increasing our network technology to eventually implement the MODIS SCF Compute Ring as a high performance FDDI based subnet, with an evolving plan to use 10MB switched hubs, to 100MB switched hubs, to eventually using ATM. The next planned additions to the compute ring are several dedicated 41T class compute workstations for asyncronous parallel processing of FPAR, LAI lookup tables by biome and end-to-end algorithm testing.

LAI and FPAR Products

Activities over the next period will involve implementing the next full generation of LAI, FPAR algorithm logic which requires a two-stage LUT probe. Our original approach used a single LUT probe per output pixel, whereas the new refined approach will run an initial probe to locate a LUT region matching the original (8) compound keys, followed by a second stage probe to perform a goal seek for minimum root mean squared error (RMSE) among the set of plant LAI's modeled by the Myneni radiative transfer (R-T) model. We will also be producing full six biome lookup tables, and testing them using a variety of sensitivity analyses. During this time we will evolve our reflectance test data source from the global NASA Pathfinder AVHRR to simulated MODIS instrument reflectances as they become available over larger regions.

PSN and NPP Products

Prototype Beta-3 PSN and NPP products are slated to be delivered by 30 September, 1995, so efforts will be made to finalize the implementation of these codes by that timeframe. We will use synthetic daily surface climatology data to perform trial end-to-end tests of these codes during this period, eventually evolving from use of FPAR, LAI products generated using 8 KM resolution NASA Pathfinder dataset to simulated MODIS instrument data sets.

Table 1: Land cover classification based on radiative transfer theory. Important canopy structural variables are identified in each biome that control canopy reflectance. We believe biome classification based on this approach would be useful and compatible, for extracting surface biophysical parameters such as LAI and FPAR.

Figure 2. global land cover classes derived from AVHRR pathfinder data using temporal observations of red, nir and thermal-ir observations.

Figure 3: Sensitivity of LAI estimates to soil background. Importance of soil properties at low vegetation densities is clearly evident for grass canopies. d/dL is the signal due to LAI, and d/dws is noise due to soils.

Figure 4: Sensitivity of FPAR to soil background. FPAR is not as sensitive as LAI to background soil properties over grass canopies. d/dL is the signal due to LAI, and d/dws is noise due to soils.