SEMI-ANNUAL REPORT
NASA CONTRACT NAS5-31368
FOR MODIS TEAM MEMBER STEVEN W. RUNNING
ASSOC. TEAM MEMBERS E.RAYMOND HUNT, RAMAKRISHNA R. NEMANI
15 JULY 1994

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 ‰NDVI 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.
- Development 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).
- Use GESSys to estimate continental net primary production (NPP) and Ó for the globe.
- Begin 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, E.R.Hunt Jr. and R. Nemani, Associate Team members, and Joe M. Glassy, Software Engineer. The following will be reports on individual activities during this reporting period.

ACTIVITIES OF SWRunning - Team Member

Algorithm Theoretical Basis Documents (ATBDs)

We produced ATBDs for our leaf area index (LAI) and fraction absorbed photosynthetically active radiation (FPAR) products, and our photosynthesis(PSN)-net primary production (NPP) products. Revised documents were submitted in February, and we participated in the oral review in May 9-11.

1. Organization of an EOS ground monitoring network with collaborating U.S. and international science agencies.

EOS-LTER

There has been little progress in writing the EOS-LTER proposal, however a steering committee was established by the LTER Executive Committee to accelerate this project. A meeting is now scheduled for 18 August to finalize a proposal draft. I have great concern that ground validation activity is not adequate to meet EOS science objectives at this time.

Global Terrestrial Observing System (GTOS)

SWRunning participated in a meeting of the joint Global Climate and Global Terrestrial Observing System (GCOS-GTOS) Terrestrial Observing Panel in Arlington, Virginia on June 28-30. A conceptual structure was planned for a terrestrial observing system that will be very important to validating EOS MODLAND products. A full report of this meeting is being prepared by John Townshend, Univ of Maryland.

IGBP Biospheric Aspects of the Hydrologic Cycle (BAHC)

The Science Steering Committee of BAHC met in Tucson, Arizona with the ISLSCP Science Panel for coordination of global science initiatives. SWR is a member of both of these committees. The IGBP-BAHC SSC also met in Wallingford, UK July 14-16. a workshop for designing a network of coordinated trace gas flux towers globally is scheduled that has high importance for EOS MODLAND product validation.

BOREAS project

We plan for BOREAS to provide us with a wealth of field data for MODLAND algorithm testing and validation. Field measurements of LAI, FPAR and NPP are all part of the BOREAS experiment. SWR hosted a modeling program as part of BOREAS science on February 7-9, 1994 in Missoula, Montana. An outcome of that workshop was an initial BOREAS modeling test that will be reported on during a meeting during IFC-2 on July 23-24 in Prince Albert, Saskatchewan.

2. A Journal article summarizing the products planned by MODLAND during the EOS era.

The MODLAND manuscript is in press with the International

Journal of Remote Sensing.

3. Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.

SWR introduced a new logic for global vegetation cover classification, first published in Ambio, in February 1994 as part of a special issue from the IGBP-SAC meeting in Ensenada, Mexico. A related manuscript was submitted for the ISLSCP Special Issue of Remote Sensing of Environment. I presented these ideas at the IGBP-DIS Workshop on a "Strategy for a Fast-track 1-km Global Land-cover classification" in Las Vegas in February 23-24. IGBP-DIS and MODLAND are now planning to use a refinement of this classification for global initial vegetation classification for biospheric modeling activities.

R. Nemani is developing an automated global implementation scheme for this vegetation classification, see his report below.

PRESENTATIONS (SWR)

Running, SW. "Representing vegetation in global biogeochemical models" Global Change Lecture Series, University of Arizona, January 19.

Running, SW. "Biospheric modeling in the EOS era" EOS IWG Meeting, San Antonio, Texas. January 11-13

Running, SW. "Measured human impacts on the global hydrologic budget" US Global Change Research Program Workshop on Earth Systems Modeling, Washington, DC. May 1-4.

Running, SW. "Multiple scale regional hydrologic modeling" Goddard Space Flight Center, May 5.

MEETINGS ATTENDED (SWR)

EOS-IWG Meeting, San Antonio, January
IGBP-DIS Land Cover Meeting, Las Vegas, February
IGBP-BAHC Meeting, Tucson, March
ISLSCP Meeting, Tucson, March
USGCRP Meeting, Wash, DC May
EOS-MODIS Meeting, MAy
OIES Meeting, Wash, DC June
WCRP GCOS-GTOS Meeting, Wash, DC June
IGBP-BAHC Meeting, Wallingford, UK July

PUBLICATIONS (SWR)

Running, S.W., C. Justice, V. Salomonson, D. Hall, J. Barker, Y. Kaufmann, A. Strahler, A. Huete, J.-P. Muller, V. Vanderbilt, Z. M. Wan, P. Teillet, and D. Carnegie. 1994. Terrestrial remote sensing science and algorithms planned for EOS/MODIS. International Journal of Remote Sensing (in press).

Running, S.W., Loveland, T.R., and L.L. Pierce. 1994. A remote sensing based vegetation classification logic for use in global biochemical models. Ambio 23:77-81.

Running, S.W., T.R. Loveland, L.L. Pierce, & E.R. Hunt, Jr. 1994. A remote sensing based vegetation classification logic for global land cover analysis. Remote Sensing of Environment (in press).

ACTIVITIES OF E.R.Hunt, Assoc Team Member

Objectives (ERH)

My principal objectives were 1) Revisions of the Algorithm Technical Basis Document, 2) continued development and testing of a generalized ecosystem process model, BIOME-BGC, and 3) examine the utility of synthetic aperature radar data as a means of remotely sensing ecosystem model parameters.

Work Accomplished

Algorithm Technical Basis Document (ATBD)

The primary task accomplished over the last six months was the final revisions to Algorithm Technical Basis Document of MODIS products daily Net Photosynthesis (PSN, MODIS product # 17) and annual Net Primary Productivity (NPP, MODIS product # 16). We proposed two alternative algorithms depending on the availability of ancillary climatic data to EOSDIS.

The first algorithm is to use daily climatic data representing a large region and our model, BIOME-BGC, to estimate the conversion efficiency of photosynthetically active radiation (PAR, MJ/m2) to dry matter (Ó, g/MJ). The MODIS Vegetation Index (MVI) would be used to estimate the fraction of PAR that is intercepted by vegetation, and with ancillary PAR data, average daily PSN over each compositing period would be estimated for each land cover type in the region by the product (Ó ˘ MVI ˘ PAR). NPP would be estimated as the sum of PSN for all compositing periods times the number of days per compositing period. We have tested this algorithm using data for the United States and found it to be superior to using a constant Ó for each land cover type. We have obtained global daily climate data gridded at 1¯ latitude by 1¯ longitude for 1987 from Steve Piper (Scripps Oceanographic Institute) and longer-term data from selected stations around the world from NOAA to define these climatic regions for this algorithm.

If the climatic data are not available, we proposed a second algorithm based on MODIS daytime and nighttime surface temperature data products. Daytime and nighttime surface temperatures may be used to estimate average daily temperature, whereas nighttime surface temperature alone may be used to estimate the daytime average relative humidity. Moreover, the slope of daytime surface temperature and MVI is related to available soil moisture. These variables would be used as a series of modifiers on a maximum Ó for each landcover type. The AM equator crossing time of MODIS may present some problems, so more work is required developing this second algorithm. However, other MODIS data products would be used to replace the daily climatic data, making the data flow considerably less complicated.

We have received some of the ATBD reviews and are considering the questions raised.

Development and Testing of BIOME-BGC

BIOME-BGC (for BioGeochemical Cycles) was modified into a global model of Net Ecosystem Exchange (NEE) of CO2 incorporating the 7 land cover types defined by Running et al. (1994). The outputs of this model were used in two different studies, one global using a resolution of 1¯ latitude by 1¯ longitude grid cells of the land surface with C. David Keeling and Steven Piper, and the other at 10 km resolution for the VEMAP model comparison. We are attempting to validate the output of global version by comparing model outputs with the monthly atmospheric CO2 concetrations measured at Mauna Loa and other stations around the world. A manuscript is currently be prepared on this work.

Our current task in developing BIOME-BGC is to have different users run the model to find problems with the code. Two manuscripts documenting BIOME-BGC and presenting validation data are being edited for submission to peer-reviewed journals based on work done for the First ISLSCP Field Experiment (FIFE) and for nitrogen-limited forest stands in Newfoundland and New Brunswick, Canada. Figure 1 presents some comparisons between data and simulations for the FIFE experiment; these comparisons are important by showing BIOME-BGC is indeed a general ecosystem model. We are currently modifying BIOME-BGC's soil water routine and input files for a comparison of models for the BOReal Ecosystem Atmosphere Study (BOREAS).

Synergism of Optical with Synthetic Aperature Radar (SAR) Data

E. Raymond Hunt along with colleagues at the University of Calgary and the Canadian Forest Service are studying the synergism of optical and SAR data for remotely sensing PSN and NPP. Whereas there will not be an EOS SAR as originally planned, other SAR missions or satellites may provide estimates of woody biomass, which could be stored in EOSDIS. One paper was published from this work, and one is in review.

Oak Ridge National Laboratory Distributed Active Archive Center

E. Raymond Hunt attended the Oak Ridge National Laboratory Data Active Archive Center (ORNL DAAC) User's Working Group meeting in March, 1994. The charge to the ORNL DAAC is to handle the biogeochemical data for EOSDIS, which will be important for validating MODIS land data products, such as PSN and NPP. ORNL DAAC will be archiving the FIFE, BOREAS, Oregon Transect Terrrestrial Ecosystem Research (OTTER), and other NASA experimental data sets.

Anticipated Future Actions (ERH)

ERH has agreed to test the data information system software for the ORNL DAAC. This would give our group early and important experience with V0 of EOSDIS.

ERH will compare remotely sensed NPP with measured NPP for 300 deciduous and coniferous forest stands in New Brunswick, Canada. JERS-1 SAR data will be collected next year for

incorporation to determine if our remotely-sensed estimates of NPP are improved with the inclusion of woody biomass.

Presentations

Hunt, E.R., Jr., 1994. Generalization of a conifer ecosystem model to other ecosystems, BIOME-BGC: Application to local and global carbon budgets. Invited seminar to the Appalachian Environmental Laboratory, Frostburg, MD.

MEETINGS ATTENDED Jan - July 1994

Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) User Working Group Meeting March 21-22, 1994

Oak Ridge National Laboratory Conference on Global Change, March 28-31, 1994

PUBLICATIONS

Ryan, M.G., E.R. Hunt Jr., R.E. McMurtrie, G.I. ègren, J.D. Aber, A.D. Friend, E.B. Rastetter, W. J. Parton, R.J. Raison, and S. Linder. 1994. Comparing models of ecosystem function for coniferous forests. I. Model description and validation. In SCOPE Volume "Effects of Climate Change on Production and Decomposition in Coniferous Forests and Grasslands", edited by J.M. Melillo, G.I. ègren, and A. Breymeyer. (in press).

Ryan, M.G., R.E. McMurtrie, G.I. ègren, E.R. Hunt Jr., J.D. Aber, A.D. Friend, E.B. Rastetter, and W.J.Parton. 1994. Comparing models of ecosystem function for coniferous forests. II. Predictions of response to changes in atmospheric [CO2] and climate. In SCOPE Volume "Effects of Climate Change on Production and Decomposition in Coniferous Forests and Grasslands", edited by J.M. Melillo, G.I. ègren, and A. Breymeyer. (in press)

Hunt, E. Raymond, Jr. 1994. Relationship between woody biomass and PAR conversion efficiency for estimating net primary production from NDVI. International Journal of Remote Sensing 15:1725-1730.

Franklin, S. E., M. B. Lavigne, B. A. Wilson, E. R. Hunt, Jr. 1994. Empirical relations between balsam fir (Abies balsamea) forest stand conditions and ERS-1 SAR data in western Newfoundland. Canadian Journal of Remote Sensing 20:124-130.

Kremer, R. G., E. R. Hunt, Jr., S. W. Running, and J. C. Coughlan. 1994. 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).

Franklin, S. E., M. B. Lavigne, E. R. Hunt, B. A. Wilson, D. R. Peddle, G. J. McDermid, and P. T. Giles. In review.

Topographic dependence of synthetic aperature radar imagary. IEEE Transactions on Geoscience and Remote Sensing.

Zheng, D., S.W. Running & E.R. Hunt, Jr. In review. Prediction of available soil water capacity based on topographic analysis for regional applications. Landscape Ecology.

Waring, R.H., J.B. Way, E.R. Hunt, Jr., L. Morrisey, R. Oren, J. Ranson, & J.Weishampel. In review. Remote sensing with radar in ecosystem studies. Bioscience

ACTIVITIES OF R. Nemani, Assoc Team Member

OBJECTIVES

My objectives were to 1) finalize ATBDs for LAI and FPAR products, 2) continue development and testing of an automated implementation of our land cover classification logic, 3) global NPP simulations and 4) estimation of global land cover change and its impacts on climate and carbon cycles.

Work Accomplished

Algorithm Theoretical Basis Document (ATBD)

Over the last six months, ATBDs for MODIS products # 14 (Leaf Area Index) and # 15 (FPAR) were finalized and submitted for review. We proposed to use the 3-D radiative transfer model of Myneni to generate a look-up-table (LUT) of LAI and FPAR for various combinations of LAI, background, land cover type and sun-sensor geometry. Modis Vegetation Index (MVI) values will be used in conjunction with our LUT to obtain LAI and FPAR values for each pixel.

Land cover classification

A simple remote sensing based land cover classification scheme was developed for regional to global applications. The classification scheme requires multi-temporal observations of surface temperature, Red and NIR. The logic for separating various land cover classes based on thresholds is given in Fig 2. Preliminary results from tests over conterminous U.S are quite promising (Fig 3).

Global NPP simulations

We used a Global Ecosystem Simulation System (GESSys, Fig 4) to estimate the spatial and temporal patterns of global net primary production. Key features of the system are, a process based ecosystem model, BIOME-BGC, use of remotely sensed data for parameterizing leaf area index of vegetation and gridded daily climate data. Figure 5 shows spatial patterns of our simulated global NPP during 1987.

Global land cover change

Recent GCM simulations indicate that changes in global land cover could be as important as the increase in atmospheric greenhouse gases. We developed a methodology to detect changes in land cover from pre-agricultural times as a function of biome type and leaf area index. Leaf area index of potential and actual

vegetation were computed using biogeographic principles and satellite data respectively. Figure 6 shows dramatic changes in land cover as a result of deforestation and agriculture expansion. We will be using these two LAI maps for global biospheric change detection analysis in the coming months.

Meetings Attended

Test and evaluation of the USGS 1-km AVHRR-Land cover characteristics data for the conterminous U.S: Results and recommendations. EROS Data Center, April 18-20, 1994.

MODIS Science Team meeting, May 4-6. NASA Goddard

IGBP-DIS/GCTE/GAIM Global NPP model intercomparision meeting, July 5-8, Potsdam, Germany.

Publications

Ford, R., S. Running and R. Nemani. 1994. Large scale terrestrial ecosystem modeling. IEEE Computational Science and Engineering (in press).

Presentations

Land cover classification using Red, NIR and TIR AVHRR Data', EROS Data Center, Sioux Falls, SD.

Spatial and temporal patterns of global net primary production during 1987', IGBP-DIS/GAIM/GCTE meeting at Potsdam, Germany.

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.

Land cover classification

The generality of our logic is being tested with AVHRR data collected over various climate and vegetation conditions around the globe. This work is being pursued in collaboration with Dr. Strahler (U. of Boston), Dr. Eric Lambin (JRC, Ispra) and Tom Loveland (EROS Data Center).

Global NPP Estimation

As a result of the Potsdam meeting on model inter-comparison, a standard database for vegetation, soil and climate are being developed so that results from various models could be compared against each other as well as with measured NPP observations. We will be participating in this global NPP analysis.

Global land cover change

We will start analyzing the impacts of changes in land cover on water and carbon cycles using GESSys in manuscripts being written this fall.

ACTIVITIES OF J.M.GLASSY, Software Engineer

Summmary of Work Accomplished

Progress has been made in a number of MODIS software development areas from January 1994 to July 1994. These accomplishments include:

1) Assignment of Univ. Montana SCF Director of MODIS Software Development
2) Software related ATBD Activities
3) NASA MODIS Project contacts and signup onto official electronic mailing lists
4) PGS Toolkit 2 v. 1.01 build on IBM RS/6000 AIX platform.

Accomplishments in each of the above areas are described in more detail below.

1) A director of software engineering (Joseph Glassy) has been hired as of June 1, 1994 to act as a University of Montana SCF software development liason to NASA with responsibility to oversee the development of the University of Montana Science Computing Facility (SCF) NASA MODIS software algorithm deliverables. Joe will be involved with many phases of the software development effort, including design and coding, algorithm analysis, testing, documentation, as well as integration of UM SCF legacy codes as necessary into intermediate and final EOSDIS MODIS deliverables.

2) Software development ATBD Activities for MODIS Data Products.

   a) Initial compute load estimates for the following Univ. Montana SCF algorithms have been prepared and submitted to the SDST: (Data Product MODIS #15 (FPAR,LAI), and MODIS #17 (Veg,NPP). Note that MODIS # 16 (ET and surface resistance) product has now been classified as a post-launch product, and so no specific ATBD on this has been prepared at this time.

   b) Local compute hardware/software planning and implementation is progressing as per the original UM MODIS SCF plan. In addition to our current AIX workstation cluster, an order is now pending for a fully equipped IBM RS/6000 41W PowerPC based workstation to serve the specific needs of MODIS algorithm software development, testing, and documentation. Office automation applications and some software development tasks will be performed on a fully equipped Pentium P-90 based microcomputer we're now awaiting delivery of.

   c) Work is progressing on the development of the prototype algorithm software for both MODIS product deliverables. The MODIS #15 FPAR,LAI product will be implemented via a pre-computed lookup table strategy, and we are currently working on the design of a mock-up LUT for this product.

The at-launch NPP data product algorithm relies on our BIOME-BGC model (legacy code), so we are currently focusing on the design and implementation issues involved in migrating these codes into the EOSDIS/MODIS processing stream.

3) A number of NASA MODIS project contacts have been established, and initiation into EOSDIS/MODIS information and document disperal facilities has begun. Specifically, the UM software engineering director has :

   a) obtained from Janine Harrison and Barbara Conboy updated MODIS personnel lists, and Mail and Phone lists in both hard copy and digital formats. Joe should now be on all relevant agency and contractor lists to directly receive email pertinent to software development activities.

   b) connected to and evaluated the operation of both the EOSDIS WWW Mosaic v. 2.x and MODIS MODARCH (EFS) software facilities for MODIS and EOSDIS information dispersal and retrieval. The MODARCH EFS software has been evaluated on both the PC and IBM AIX RS/6000 platforms; the newer EFS release will be evaluated as soon as it is received.

   c) ordered, received, and evaluated the Adobe Acrobat reader software for Microsoft Windows 3.1. We plan to implement the Adobe Acrobot reader on the IBM AIX RS/6000 platform as soon as it is made available to us.

4) PGS Toolkit 2 V. 1.01 test build on the Univ Montana SCF IBM AIX RS/6000 platform.

   A full test build of the Production Generation System toolkit 2 version 1.01 has been successfully performed on the Univ. of Montana SCF RS/6000 platform. The build went very cleanly under the AIX 3.2 xlc (ANSI C) and xlf (Fortran 77) compiler suite, and no significant platform-specific errors or warnings were encountered with this test build. Standard PGS 2 v.1.01 toolkit binary libraries were built, and tests on the individual PGS calls relevant to our algorithm development have begun. New versions of the PGS libraries will be built locally as new revision levels are made available to us by NASA.

Figure Captions

Figure 1. Comparison of simulated and measured A) daily evapotranspiration, B) soil moisture content, and C) daily net ecosystem exchange of carbon for the First ISLSCP Field Experiment (FIFE). The measured evapotranspiration and net ecosystem exchange data were obtained by Sashi Verma at Station 16 using eddy flux correlation instrumentation and soil moisture was measured using a neutron probe to a depth of 1.4 m.

Figure 2. Flowchart of our global land cover classification logic showing the inputs and various thresholds applied to differentiate among the major land cover classes. (gs refers to growing season).

Figure 3. Land cover map of the conterminous U.S generated from our simple and completely remote sensing based logic using USGS/EROS 1991 AVHRR 1 km data. A comparative test of our results with those of Loveland et al (1991) derived using extensive ancillary information showed good agreement.

Figure 4. A schematic diagram showing simulation models, various inputs and data sources used to compute and map daily carbon and water fluxes at global scales.

Figure 5. Global annual net primary production during 1987, computed at 1x1 degree resolution using observed daily climate and satellite data.

Figure 6. Changes in global land cover shown as differences in leaf area index from pre-agricultural times. Based on 1987 AVHRR data