Section I. General Information

Leaf Area Index for Fire Chronosequences of the Black Hills and Southern Siberia: A Comparative Study

ESE 13 Terrestrial Ecology

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Amount requested: $492,000 for a 3-year project

Membership Page

The following institutions, industries, and agencies will be involved with the proposed research:

South Dakota School of Mines and Technology/Institute of Atmospheric Sciences
Augustana College
EROS Data Center
South Dakota State University
United States Forest Service/Black Hills National Forest

Leaf Area Index for Fire Chronosequences of the Black Hills and Southern Siberia: A Comparative Study

Lee Vierling
Institute of Atmospheric Sciences
South Dakota School of Mines and Technology

Education

UNIVERSITY OF COLORADO — Boulder, CO
Ph.D., Environmental, Population, and Organismic Biology — 1999
Dissertation Title: Light heterogeneity and gas exchange dynamics above and within a monodominant Congolese rain forest canopy; Carol A. Wessman, Advisor

THE COLORADO COLLEGE — Colorado Springs, CO
B.A., Distinction in Geology, magna cum laude — 1992

Research Experience

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY — Rapid City, SD
Assistant Professor, Institute of Atmospheric Sciences — 1999-present
- main research and teaching interests: biosphere-atmosphere interactions, biogeochemical cycling, impacts of land use and landcover change on environmental change, remote sensing of ecological phenomena

UNIVERSITY OF COLORADO — Boulder, CO
Graduate Student/Research Assistant — 1994-1999

NASA/GODDARD SPACE FLIGHT CENTER — North Slope, AK; Greenbelt, MD
Participant, Graduate Student Summer Program in Earth System Sciences — 1995
- conducted field (AK) and laboratory (MD) research aimed at developing a new approach to assess tundra phenology and biogeochemical cycles using remote sensing

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH — Boulder, CO
Research Assistant — 1993-1995
- conducted atmospheric and ecological research to measure biogenic trace gas fluxes
- duties included all aspects of experimental research, from developing scientific instrumentation to gathering field and laboratory data to analyzing and publishing study results

Selected Fellowships and Grants

- NSF CAREER Program, NRA 99-110, *"An Integrated Research/Educational Plan to Develop and Deploy a Pointable, Hyperspectral Remote Sensing Instrument on a Tethered Balloon"* (PI: L. Vierling; $500,000) — 2000-2005
- NASA Earth Science Enterprise Education Program, NRA-99-OES-02 *"Earth Systems Connections: An Integrated K-4 Science, Mathematics,and Technology Curriculum"* (PI's: L. Vierling, SDSM&T, G. Glasson, Virginia Tech, and J. Frykholm, U. of Colorado; $471,100) — 2000-2002
- STAR Graduate Fellowship, U.S. Environmental Protection Agency ($75,000) — 1996-1999
- Biosphere-Atmosphere Research Training Fellowship, U. of Colorado ($20,000) — 1995-1996
- Full Undergraduate Scholarship, Boettcher Foundation, Denver, CO ($80,000) — 1988-1992

Selected Honors and Awards

- PIF Faculty Award for Outstanding Scholarly and Professional Service Activity, SD School of Mines and Technology — 2000
- J. Juan Reid Academic, Athletic, and Service Award, Colorado College — 1992
- Rhodes Scholarship Finalist (Oxford University), State of Colorado — 1991

Professional Society Memberships
- American Geophysical Union
- Ecological Society of America
- *Phi Beta Kappa*
- *Sigma Xi*, The Scientific Research Society

Professional Service
•Reviewer, *Remote Sensing of Environment, IEEE Transactions on Geoscience and Remote Sensing,* and *Journal of Environmental Management*
•Review panel member, National Science Foundation
•SDSM&T education coordinator for the Upper Midwest Aerospace Consortium (1999-2000)
•Mentor, National Center for Atmospheric Research SOARS minority research program (1997)

Selected Publications

Vierling, L.A., Guenther, A.B., and Harley, P.C. Effects of changing sky diffuse fraction on the net foliar carbon assimilation and isoprene emission of a monodominant Congolese rain forest canopy. In preparation for submission to *Journal of Geophysical Research-Atmospheres.*

Vierling, L.A. and Wessman, C.A. 2000. Photosynthetically active radiation dynamics within a monodominant Congolese rain forest canopy. *Agricultural and Forest Meteorology,*103(3): 265-278.

Guenther, A., B. Baugh, G. Brasseur, J. Greenberg, P. Harley, L. Klinger, D. Serca, and L. Vierling, 1999. Isoprene emission estimates and uncertainties for the Central African EXPRESSO study domain. *Journal of Geophysical Research-Atmospheres*, 104(D23): 30,625-30,639.

Guenther, A., Archer, S., Greenberg, J., Harley, P., Helmig, D., Klinger, L., Vierling, L., Wildermuth, M., Zimmerman, P., and Zitzer, S., 1999. Biogenic hydrocarbon emissions and land-cover/climate change in a subtropical savanna. *Physics and Chemistry of the Earth*, 24(6): 659-667.

Helmig, D., Klinger, L.F., Guenther, A.B., Vierling, L.A., Zimmerman, P.R., and Geron, C. 1999. Biogenic volatile compound emissions. 2. Flux potentials from three sites in the U.S. *Chemosphere* 38: 2189-2204.

Isebrands, J.G., A.B. Guenther, P. Harley, D. Helmig, L. Klinger, L. Vierling, P. Zimmerman, and C. Geron, 1999: Volatile organic compound emission rates from mixed deciduous and coniferous forests in Northern Wisconsin, USA. *Atmospheric Environment*, 33, 2527-2536.

Vierling, L.A. 1998. Palynological evidence for late- and postglacial environmental change in central Colorado. *Quaternary Research*, 49: 222-232.

Eck, T.F., Deering, D.W., and Vierling, L.A. 1997. Estimation of total albedo from spectral hemispheric reflectance for arctic tundra. *International Journal of Remote Sensing*, 18(17): 3535-3549.

Vierling, L.A., Deering, D.W., and Eck, T.F. 1997. Differences in arctic tundra vegetation type and phenology as seen using bidirectional radiometry in the early growing season. *Remote Sensing of Environment*, 60(1): 71-82.

Guenther, A., Greenberg, J., Harley, P., Helmig, D., Klinger, L., Vierling, L., Zimmerman, P., and Geron, C. 1996. Leaf, branch, stand and landscape scale measurements of volatile organic compound fluxes from US woodlands. *Tree Physiology*, 16: 17-24.

Vierling, L.A., D.W. Deering, and T.F. Eck. 1996. Nadir and bidirectional surface measurements of arctic tundra: site differentiation and vegetation phenology early in the growing season. International Geoscience and Remote Sensing Symposium (IGARSS), Lincoln, NE. *Proceedings of IGARSS '96*, 4: 1897-1900.

William J. Capehart, SDSM&T-IAS

Dr. Capehart attended the University of North Carolina at Asheville, between 1985 and 1989 where he received his B.S. degree in Atmospheric Sciences - Climatology Track in May 1989. While there, he investigated water budget aspects of the 1984-88 southeastern US drought. While at UNC-Asheville, Dr. Capehart was also a research assistant at the National Climatic Data Center, where he worked on the remote sensing of snow melt on the Arctic ice cap and compiling a database of snowfall and snow cover for the United States.

In 1989, he came to Penn State University where he developed a soil hydrology model for now being used to provide initial soil moisture conditions for the Penn State/NCAR Mesoscale Model (MM). He received his M.S. degree in Meteorology from Penn State in May 1992. While at Penn State, he participated in the EOS-supported Susquehanna River Basin Experiment and investigated the potential for incorporating remote estimates of regional-scale soil moisture and other remotely-derived parameters into hydrological models. He received his Ph.D. in Meteorology from Penn State in May 1996, following which, he appointed a post-doctoral scholar at Penn State in 1996 where he worked with the Penn State/NCAR MMM coupled with the Biosphere Atmosphere Transfer Scheme (BATS).

In 1997, he joined the South Dakota School of Mines and Technology's Institute for Atmospheric Sciences as an assistant professor in the meteorological analysis group where he as participated in a number of projects including regional coupled atmospheric-hydrologic modeling, carbon sequestration research, remote sensing and modeling of land surface processes, and wetlands research. His teaching interests include Remote Sensing, Climatology, Boundary Layer Processes and Synoptic Meteorology. Dr. Capehart is also active in South Dakota interdisciplinary research efforts in scientific computing, atmospheric, hydrology and ecological issues through the state’s NASA and NSF EPSCoR programs.

Dr. Capehart is a member of the American Meteorological Society, American Geophysical Union, IEEE Geoscience & Remote Sensing Society, European Geophysical Union, and the Society of Wetland Scientists. He is published in the Journal of Hydrology, Bulletin of the American Meteorological Society, Remote Sensing of the Environment, Water Resources Research and Journal of Hydrometeorology.

Selected References

Crawford, T.M., D.J. Stensrud, T.N. Carlson and W.J. Capehart, 2000: Using a soil hydrology model to obtain regionally averaged soil moisture values. *Journal of Hydrometeorology*, **1**, 353-363.

Capehart, W.J., and T.N. Carlson, 1997: Decoupling of surface and near-surface soil water content: a remote sensing perspective. *Water Resources Research*, **33**, 1383-1395.

Carlson, T.N., W.J. Capehart, and R.R. Gillies, 1995: A new look at the simplified method for remote sensing of daily evaporation. *Remote Sensing of Environment*, **54**, 161-167.

Capehart, W.J., and T.N. Carlson, 1994: Estimating near-surface moisture availability using a meteorologically driven soil- water profile model. *Journal of Hydrology*, **160**, 1-20.

Smith, C.B., M.N. Lakhtakia, W.J. Capehart, and T.N. Carlson, 1994: Initialization of soil-water content in regional scale atmospheric prediction models. *Bulletin of the American Meteorological Society*, **75**, 585-593.

Steven Matzner

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Positions held:

Assistant Professor	Augustana College, Sioux Falls, SD	1999-present
Postdoctoral Researcher	Boyce Thompson Inst. for Plant Res. Cornell University Campus	1997-1999

Education:

Ph. D. Ecology — University of California, Davis, CA — 1999

Dissertation: Population and/or size class differences in gas exchange, xylem water potential, water-use-efficiency and vulnerability to xylem cavitation in blue and interior live oak.

M.S. Ecology — University of California, Davis, CA — 1994

Masters thesis: The effect of soil water stress on nitrogen and phosphorus uptake capacity in sagebrush (*Artemisia tridentata* Nutt.).

B.A. Biology — Augustana College, Sioux Falls, SD — 1990

Undergraduate research: Dietary reconstruction based on stable isotopes (^{13}C, ^{15}N, ^{34}S) of Chilean cultural groups and of the Guanche, a pre-hispanic Canary Islands people.

Current Research:

Environmental Effects on Xylem Cavitation: Received a USDA Seed Grant (CSREES #00-35106-9403).

* Testing hypotheses regarding how environmental effects may alter plant xylem pit pore diameter and affect xylem cavitation resistance.

Postdoctoral Research: (Hydraulic integration of stomatal regulation) Postdoctoral Advisor: Jonathan P. Comstock

* Tested hypotheses regarding the dependence of liquid phase hydraulic conductance on temperature and the regulation of stomatal conductance through leaf water potential using a whole-plant gas exchange system and a root pressurization chamber .
* Familiar with operation of LiCor CO_2 and H_2O infrared gas analyzers

Selected Publications:

Matzner SL, Rice KJ, Richards JH**.** 2001. Factors affecting the relationship between carbon isotope discrimination and transpiration efficiency in blue oak (*Quercus douglasii)*. *Australian Journal of Plant Physiology*, 28, 1-8.

Matzner SL, Rice KJ, Richards JH**.** 2001. Intra-specific variation in xylem cavitation in interior live oak *Quercus wislizenii*. **Accepted**: *Journal of Experimental Biology* (April).

Matzner SL, Richards JH**.** 1996. The effect of soil water stress on nutrient uptake capacity in sagebrush (*Artemisia tridentata* Nutt.). *Journal of Experimental Botany* 47:1045-56.

Tieszen LL**, Matzner SL,** Bouseman S**.** 1992. Dietary Reconstruction Based on Stable Isotopes (^{13}C, ^{15}N, ^{34}S) of the Guanche, Pre-Hispanic Tenerife, Canary Islands. PP 41-57. In: *Proceedings of 1 World Congress on Mummy Studies* . Museo Arqueologico Y Etnografico De Tenerife. Tenerife, Canary Islands.

Daniel L. Swets

Education:

Calvin College, B.S. Computer Science, 1982-1986.
Michigan State University, M.S. Computer Science, 1987-1991.
Michigan State University, Ph.D. Computer Science, 1992-1996.

Current Professional Experience:

· Assistant Professor, Augustana College, Sioux Falls, SD, 1995-present
· NASA Space Grant Fellow, 1996-present.
· Owner, Swets Software Systems, Sioux Falls, South Dakota, 1982-present.

Selected Past Professional Experience:

· Ameritech Fellow, Michigan State University, East Lansing, Michigan, 1994-1995.
· Lead Graduate Assistant, Michigan State University, East Lansing, Michigan, 1993.
· Software Engineer, Smiths Industries, Grand Rapids, Michigan, 1987-1992.

Selected Publications:

Daniel L. Swets and Juyang Weng, "Hierarchical Discriminant Analysis for Image Retrieval," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 21, No. 5, pp. 385-401, 1999.

Daniel L. Swets, Shaun E. Marko, James Rowland, Bradley C. Reed, "Statistical Methods for NDVI Smoothing," in *Proceedings, American Society for Photogrammetry and Remote Sensing*, 1999.

Juyang Weng and Daniel L. Swets, "Face Recognition," in *Biometrics*, Anil Jain, Ruud Bolle, Sharath Pankanti, editors, Kluwer Academic Press, 1998.

Daniel L. Swets, Yogesh Pathak, and John J. Weng, "An Image Database System with Support for Traditional Alphanumeric Queries and Content-Based Queries By Example," in *Multimedia Tools and Applications*, Vol. 7, Number 3, Kluwer Academic Publishers, November, 1998.

Daniel L. Swets and John J. Weng, "Discriminant Analysis and Eigenspace Partition Tree for Face and Object Recognition from Views," in *Proceedings, International Conference on Automatic Face and Gesture Recognition*, 1996.

Daniel L. Swets and John J. Weng, "Using Discriminant Eigenfeatures for Image Retrieval," *IEEE Trans. Pattern Anal. Machine Intell.*, Vol. 18, No. 8, pp. 831-836, August, 1996.

Daniel L. Swets, *The Self-Organizing Hierarchical Optimal Subspace and Learning Inference Framework for Object Recognition and Image Retrieval*, Ph.D. Thesis, Michigan State University, East Lansing, Michigan, 1996.

Daniel L. Swets and John J. Weng, "View-based recognition using SHOSLIF," in *Proceedings, International Conference on Neural Networks and Signal Processing*, (Nanjing, China), December 1995. Most Excellent Paper award.

Daniel L. Swets and John J. Weng, "Image-based recognition using learning for generalizing parameters," in *Proceedings, Asian Conference on Computer Vision*, (Singapore), December 1995.

Selected Grants:

- "Assessment of Land Cover Classification, Phenology and Biomass Production in Great Plains Grasslands," funded by the U. S. Geological Survey, Central Region, $56,954 ($45,845 from USGS, cooperative agreement 1434-CR-96-AG-00777), 1997-1998.

Patrick R. Zimmerman, SDSM&T/IAS

Dr. Zimmerman holds a BS in Environmental Science (Zoology) and an MS in Environmental Science (Chemical Engineering) from Washington State University. He received his Ph.D. in Rangeland Ecosystem Science at Colorado State University.

Dr. Zimmerman has served as the Director of the Institute of Atmospheric Sciences (IAS) at the South Dakota School of Mines and Technology since June 1997. He has also served as Chair of the department of Atmospheric Sciences since June of 1999. Prior to this position, he served as Senior Scientist and head of the Trace Gas Biogeochemistry Section at the National Center for Atmospheric Research. Dr. Zimmerman was recruited to NCAR by Dr. Paul Crutzen (Nobel Laureate) in 1979 as a Staff Scientist II in the Air Quality Division. At that time he originated the Biosphere/Atmosphere Interaction Project. He was promoted to Scientist III in 1985 and named Section Head in 1989. In 1991 he was promoted to Senior Scientist. Zimmerman's NCAR research focused on measurements of biogenic hydrocarbon emissions, including tropical biomass burning; measurements of ambient hydrocarbons in the remote troposphere; tethered-balloon hydrocarbon profiles; laboratory and field measurements of methane fluxes; the development of methods to study the physiological basis of biogenic hydrocarbons; and the development of tracer and micrometeorological flux measurement techniques. At NCAR, Dr. Zimmerman assembled an interdisciplinary team including expertise in ecology, plant physiology, remote sensing, micrometeorology and analytical chemistry. The group developed technology, experimental approaches and models that allowed measurements and predictions of ecosystem trace gas emissions over scales ranging from leaves to landscapes. Their publications have shown that these emissions affect regional and global atmospheric chemistry.

From 1973 to the present, Dr. Zimmerman has been a principal investigator on over two dozen grants and contracts from federal agencies (EPA, DoE, NASA, NOAA), industry (Gas Research Institute, American Petroleum Institute) and nonprofit organizations (National Geographic Society, Frost Foundation). He has served as a consultant in several research areas. He is the author or co-author of more than 80 refereed publications and holds three patents. Dr. Zimmerman has been on several graduate student committees, and has supervised many graduate and undergraduate research assistants. Recently, Dr. Zimmerman delivered the keynote address on at the Gordon Research Conference on Biogenic Hydrocarbons in Ventura, California, in April, 2000.

Selected References

Zimmerman, P.R., J.P. Greenberg, S.O. Wandiga, and P.J. Crutzen, 1982: Termites: A potentially large source of atmospheric methane, carbon dioxide and molecular hydrogen. *Science*, **218**, 563-565.

Zimmerman, P.R., J.P. Greenberg, and C.E. Westberg, 1988: Measurement of atmospheric hydrocarbons and biogenic emission fluxes in the Amazon boundary layer. *J. Geophys. Res.*, **93**, No. D2, 1407-1416.

Guenther, A., P. Zimmerman, and M. Wildermuth, 1994: Natural volatile organic compound emission rate estimates for U.S. woodland landscapes, *Atmos. Environ.*, **28**, 1197-1210.

Harley, P., A. Guenther, and P. Zimmerman, 1996: Effects of light, temperature and canopy position on net photosynthesis and isoprene emission from leaves of sweetgum (*Liquidambar styraciflua L.). Tree Physiology*, **16**, 25-32.

Abstract

Leaf area index (LAI, the leaf area per unit area of soil surface) is a fundamental biophysical parameter through which vegetation canopy physiological functioning can be related to remotely sensed observations. Canopy LAI can be highly correlated with the fraction of absorbed photosynthetically active radiation (FPAR) and, ultimately, net primary productivity and biosphere-atmosphere exchange of heat, momentum, and many important trace gases. However, quantifying LAI presents numerous challenges. Existing methods for quantifying LAI include direct measures via destructive harvesting techniques (accurate but prohibitively labor-intensive) and indirect derivations via ground-, aircraft-, and satellite-based remote sensing observations (rapid and appropriate for a wide range of measurement scales, but with varying and difficult-to-define accuracy due to complex interactions between canopy geometry, sensor resolution, and sun-sensor geometry). Although a large body of work has been done to establish baseline relationships between LAI and remote sensing measurements from various platforms, there is still a great need for comprehensive and novel field data to validate and improve remotely sensed LAI derivations.

Here, we propose to work in collaboration with Donald Deering and his research team at the Goddard Space Flight Center to collect and analyze comprehensive data sets at two coniferous forest canopies. These data will be used to evaluate and improve the accuracy of remotely derived LAI estimates. Two specific questions to be addressed in our research are *1) What is the spatial scale at which the LAI of a coniferous forest can be most accurately derived using above-canopy remote sensing?*, and *2) To what extent can bidirectional measurements be used to improve LAI (and FPAR) estimates using remote sensing?* We will collect field data at the boreal forest of southern Siberia and the ponderosa pine-dominated forest of the South Dakota Black Hills. Field sites will occur along forest fire and thinning chronosequences in order to capture a wide range of conifer LAI values. This project will build upon and assist in the analysis of two years of ground LAI measures already completed by Deering and colleagues near Krasnoyarsk, Russia and provide comparison measurements in the Black Hills region to determine the broad scale applicability of satellite-based LAI derivations for conifer forests. Field measurements will include destructive sampling to establish allometric LAI relationships, and non-destructive optical sampling using established techniques. In addition to these within-canopy measurements, satellite remote sensing data at several scales will be analyzed using kriging methods to evaluate how well LAI can be scaled. Remote sensing imagery to be analyzed using kriging methods will include multispectral IKONOS, Landsat 7, and MODIS data. In addition, recently developed spectral indices that incorporate the bidirectional character of canopy reflectance will be applied to Multi-Angle Imaging Spectroradiometer (MISR) data in order to assess how such data may provide improved LAI estimates. At the Black Hills sites, additional spectral measurements will be made with the South Dakota School of Mines and Technology Short Wave Aerostat-Mounted Imager (SWAMI), a pointable hyperspectral instrument with an adjustable ground instantaneous field of view between approximately 1-500m. We expect that the novel observations acquired using the SWAMI will provide useful data for independently testing the results obtained using the various satellite remote sensing systems.

Introduction

Because leaves serve as the primary interface of mass and radiation exchange between plants and the atmosphere, leaf area index (LAI; a dimensionless measure of the green leaf area per unit area of soil surface) is a fundamental biophysical parameter used in a wide range of ecological, biogeochemical, and meteorological studies. Because green leaves absorb strongly in the visible portion of the spectrum, LAI is inherently related to the fraction of photosynthetically active radiation absorbed by a canopy (FPAR), and therefore can be estimated using optical remote sensing techniques (e.g. Baret and Guyot, 1991). As a result, much work has been conducted over the past two decades to derive net primary productivity and biogeochemical cycling rates by relating remotely sensed data to LAI and FPAR across a broad range of spatial and temporal scales (e.g. Field et al., 1995; Schimel, 1995).

The recent successful launches of several earth-viewing satellite sensors such as the Landsat 7 Enhanced Thematic Mapper + (ETM+), the various *Terra*-based sensors, and the commercial IKONOS sensor provide a wealth of new data with differing spectral, spatial, and view angle characteristics. By coupling these various sensor characteristics with state-of-the art numerical models that describe the physical nature of vegetation-photon interactions, data from these new sensors are expected to deliver much improved derivations of LAI and FPAR across the globe (Tian et al., 2000; Zhang et al., 2000). Field campaigns have been initiated to validate many remote sensing-derived “products” such as LAI and FPAR at a variety of sites, however measurements at additional field sites will enable better assessments to be made.

We propose to conduct a series of field measurements and data analyses at field sites in the Black Hills of South Dakota to investigate the accuracy and various potential improvements of LAI and FPAR derivations from satellite sensors. This work will be done in parallel with a current NASA-funded effort taking place (now in its third year) near the Krasnoyarsk, Russia EOS Validation Core Site in the boreal forest of Southern Siberia led by Dr. Donald Deering of Goddard Space Flight Center. While the work done during this NASA-EPSCoR effort will primarily focus upon the development and collection of validation-related measurements in South Dakota, this effort will be partly patterned after the Russian field experiment so as to enable comparisons between the two sites. As such, a small part of the work proposed here will include collection and analysis of field data from the Russian field sites so that it may be integrated with the South Dakota results.

Specifically, the work done in South Dakota and Siberia will provide baseline LAI measurements from field surveys to which a number of remote sensing measures can be compared. The field sites will occur along forest fire and thinning chronosequences; however, the principal aim of this project will not be to analyze these sites with respect to post-fire growback *per se*, but instead will utilize these sites to represent the range of LAI that occurs in coniferous forests. Because the canopy of a coniferous forest is not continuous, canopy geometry can influence the proportion of shaded and sunlit trees/background that is viewed by any given sensor (Woodcock et al., 1997). Therefore, the spatial resolution of the satellite measurement may directly influence the quality of the LAI/FPAR retrieval using current algorithms (Tian et al. 2000). Work at these two sites will allow us to investigate these two primary scientific objectives:

(1) What is the spatial scale at which the LAI of a coniferous forest can be most accurately derived using above-canopy remote sensing?

(2) To what extent can bidirectional measurements be used to improve LAI (and FPAR) estimates using remote sensing?

Field measurements at the two sites will largely follow existing protocols at EOS validation core sites such as those in the BigFoot program (Campbell et al. 1999). A significant new aspect of the South Dakota study will be the addition of balloon-based remote sensing measurements that will be used to examine scaling and bidirectional effects. This pointable hyperspectral balloon-based remote sensing instrument, the Short Wave Aerostat Mounted Imager (SWAMI) is currently under development at the South Dakota School of Mines and Technology (SDSM&T) and will be field tested during the summer of 2001. Incorporation of SWAMI into this project will first occur during the summer of 2002. Use of this instrument will represent a novel ground-truthing technique that will enable the sampled image to be examined at scales ranging from 1-500m in diameter.

Research Plan

Four ponderosa pine forest sites will be selected in the Black Hills that correspond with different points along an LAI continuum. These sites will be selected such that each endpoint of the LAI spectrum will be represented with intermediate LAI sites included. Coniferous forests in the Black Hills are routinely thinned but have experienced different fire histories. The sites chosen in the Black Hills will include various fire/thinning intensity and age since burn/treatment. The same methodology will be used in the Black Hills and Siberia to facilitate comparisons between the Black Hills and the 2 years of data already gathered in Siberia. In Siberia, test sites of 3km x 3km were selected in June 1999 to represent the desired chronosequence (1 year, 2-3 years, 8-15 years, and +20 years since last fire). These selections were based on discussions with local forest rangers and site surveys. Final site selection was based on homogeneity of species, accessibility, and logistical constraints. All study sites underwent the same fire intensity and will have begun regrowth at approximately the same time after the fire (1 to 2 years ideally). For each age class, at least one replicate site was selected. An open field area near each study site was identified for reference measurements of radiation. Landsat 7 ETM+ images will be investigated to ensure homogeneity exists within each test site.

Segment I - Ground LAI Measurements

A. Indirect Sampling of LAI

Sampling Design

The sampling design for LAI will be a nested cluster. Similar to the methodology used in Siberia, 10 plots will be selected in an area of 3 km x 3 km in such a way that the maximum variation of LAI is captured. The selection of the plots will be based on field reconnaissance and remote sensing data. In 8 of the 10 plots LAI-2000 measurements will be taken at 6 locations along with hemispherical photographs (Fig. 1). In addition, data from a Tracing Radiation and Architecture of Canopies instrument (TRAC; Chen and Cihlar, 1995) will be collected along two transects of 25 m length each. With a walking pace of 1m per 3 s and an instrument sampling frequency of 32Hz, the TRAC measurement interval will be about 10mm.

plot level (25m x 25m) site level (3km x 3km)

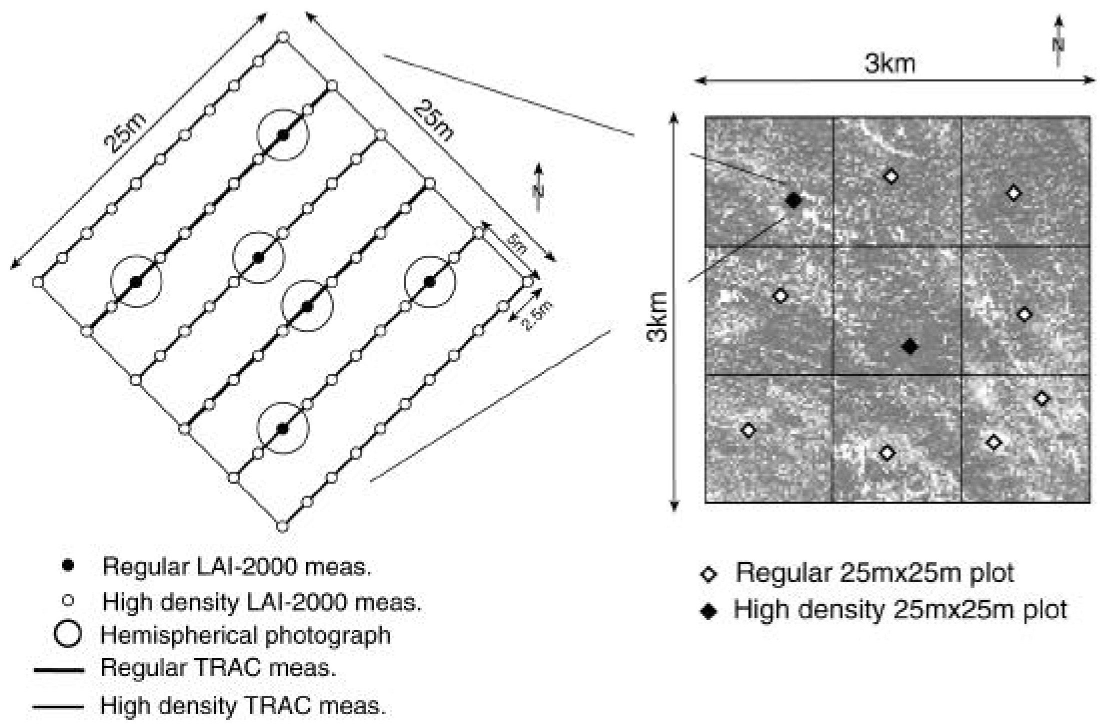

Fig. 1: *Sampling design for LAI-2000 and TRAC measurements and hemispherical photographs.*

In 2 plots per site, LAI will be sampled at a very high density with LAI-2000 and TRAC instruments (Fig. 1). LAI-2000 measurements will be taken every 2.5m along six transects that are 25m long and 5m apart. TRAC measurements will be taken along the same transects with a sampling frequency of 32Hz. Aggregating these multiple plots will capture micro- and large-scale variations in LAI at each site. Each site will be replicated once.

The transects will be oriented in SE-NW or SW-NE direction in order to reduce the influence of shadow from the operator on the TRAC and LAI-2000 instruments during data acquisition. LAI-2000 measurements will be taken consecutively from both canopy and understory levels at approximately the same measurement positions. Reference and field measurements with the LAI-2000 instruments will be taken quasi-simultaneously. Synchronization of the measurements will be guaranteed by internal instrument clocks.

LAI-2000 measurements and hemispherical photographs will be taken during dusk or under overcast skies, i.e. under predominantly diffuse irradiance conditions. TRAC data will be acquired under bright and clear sky conditions. Each of the 25m x 25m plots will be geographically referenced as precisely as possible using differential GPS.

Determination of LAI

LAI will be determined following a technique recommended by Chen et al. (1997):

$$LAI = (1 - \alpha) L_e \gamma_E / \Omega_E$$

where LAI is the leaf area index, L_e is the effective leaf area index, γ_E is needle-to-shoot area ratio, Ω_E is a factor describing foliage clumping for scales larger than the shoot, and α is the woody-to-total area ratio.

L_e will be measured with the LAI-2000 PCA instrument and Ω_E will be provided by the TRAC instrument. α and γ_E, however, will be obtained through the destructive sampling techniques, which are described in Section IB.

Derivation of FPAR

The fraction of photosynthetically active radiation (FPAR) absorbed by the canopy will be quantified with the TRAC measurements (Chen, 1996b). TRAC provides the mean value of the transmitted light through the canopy, which is directly related to FPAR (Chen, 1996b):

$$F_g(\theta) = (1-\rho_1(\theta) - (1-\rho_2(\theta))\exp[-G_t(\theta)L_{eg} / \cos\theta]$$

where $F_g(\theta)$ is the FPAR due to green leaves (green FPAR), $\rho_1(\theta)$, $\rho_2(\theta)$, and $G_t(\theta)$ are species specific constants, L_{eg} is the effective green LAI, and θ is the view angle.

B. Destructive Sampling of LAI

LAI will be derived from direct sampling methods for verification of LAI data sets obtained from indirect measurements. We will sample 3-6 trees immediately adjacent to one of the 25m x 25m plots for each study site (3km x 3km area). The plot selected for destructive sampling within each study site will be chosen based on the results of the indirect LAI measurements. This will ensure that destructive sampling occurs in an area that is most characteristic of the site as a whole. We will sample 2-4 trees of the dominant ponderosa pine, and if necessary will sample 1-2 individuals of other locally important species; the number sampled will be dependent upon the diversity in tree sizes found across the site. Allometric equations will be developed and applied to achieve site-level LAI.

Procedures will follow those described by Gower et al. (1997). For each tree that is destructively sampled, the crown will be divided equally into thirds with all live and dead branches at each position weighed separately. One live branch per canopy position will be chosen for detailed analyses that will be conducted immediately after felling of the tree. Shoots will be divided into age classes (current, 1-2 years, 3-4 years and >5 years) and counted. Roughly 30-50 foliage shoots per age class and canopy position will be weighed to determine fresh mass. From each subsample, 5-10 shoots will be measured for specific leaf area (leaf area/mass) and percent moisture (water content) of the leaf and woody tissues. Specific leaf area will be calculated following the volume displacement method (Chen et al. 1997). The needle surface area for each age class and canopy position will be determined by taking the product of foliage mass and specific leaf area. For each age class and canopy position, photographs of shoots against a white background will be taken at a variety of view angles for a permanent record of shoot architecture and area. The ratio of woody (nongreen) to total area (green and nongreen areas), α, will be obtained (Chen 1996a, 1996b). The needle to projected shoot area ratio, γ_E, will also be determined (Chen 1996b). Within each plot, stem density will be measured, and all trees will be sampled for diameter at breast height.

C. Analysis and Evaluation

The goals for this portion of the study will include:

- Production of LAI maps for each 3km x 3km test site by spatial interpolation (kriging) of ground LAI measurements
- Comparison between LAI measurements from direct and indirect (optical) sampling methods
- Characterization of the relationship between ground-measured LAI and post-fire forest age (for Siberian forest only)

Scientific questions that will guide the analysis will include:

- How well do LAI-2000 PCA and direct LAI measurements correspond?
- How well do LAI-2000 PCA and LAI data derived from hemispherical photographs correspond?
- What is the mean LAI for each plot and each test site?
- What is the variability of LAI on the plot level (25m x 25m) for each test site?
- What is the variability of LAI on the site level (3km x 3km) (derived from the five plots per site and replicates)?

Optical Measurement of LAI: LAI-2000 and TRAC measurements will be resampled to a raster of 1-m resolution using kriging methods. Contour maps of each individual plot will be made to investigate the spatial distribution of LAI on the plot level (25m x 25m). Statistical measures and variograms will be used for representing the spatial pattern of LAI. Hemispherical photographs will be digitally stored on photo CDs and analyzed with the LAICALC software (Rich et al., 1995). The LAI values derived from the photographs will be overlaid to the resampled data from LAI-2000 and TRAC measurements for verification and comparison reasons. Mean and standard deviation of LAI on the plot level will be used as ground reference information in Segment II for LANDSAT ETM+ and IKONOS data.

The average LAI for all of the plots within the 3km x 3km site area will be used along with kriging techniques to generate the spatial distribution of LAI on the site level. Mean and standard deviation of LAI for the site will be used as ground reference information for remote sensing data in Segment II.

Direct Measurement of LAI: Allometric equations derived from destructive sampling will be used to extrapolate LAI from the tree to the plot and site level. Plot level and site level estimates of LAI will be compared to the resampled optical measurements of LAI. Direct measurements of LAI will also be used as ground reference data for remote sensing data.

<u>Segment II – Single look angle remote sensing</u>

Goals

- Establish the relationship between NDVI and LAI for the Black Hills
- Investigate the ‘up- scaling' of LAI products to compare ground to satellite data using image processing techniques as well as field measurements with the SWAMI

Scientific Questions

- How well do ground LAI and remotely sensed LAI data correspond?
- Do LAI data derived from IKONOS and aggregated to the spatial resolution of ETM+ correspond to the LAI data derived from ETM+?

- How much information is lost by aggregating satellite data from a spatial resolution of 4m (IKONOS) to 30m (ETM+) pixel size?
- Do LAI data derived from ETM+ and aggregated to the spatial resolution of MODIS correspond to the LAI data derived from MODIS?
- How much information is lost by aggregating satellite data from a spatial resolution of 30m (ETM+) to 1 km (MODIS) pixel size?

Satellite data

IKONOS data will be requested via the NASA Data Buy program to address scaling issues of LAI only in the Black Hills region whereas images from ETM+ and MODIS can be used at both the Black Hills and Siberia sites.

Atmospheric correction: The 6S atmospheric code (Vermote et al., 1997) will be used along with a physically-based radiometric correction model (Sandmeier and Itten, 1997) to correct atmospheric influences. Aerosol optical thickness data will be derived from a Cimel sunphotometer installed at a forest research site of the Sukachev Institute for the Siberian data and from a Microtops II sunphotometer at the South Dakota field sites; these values will be used as the main input parameters to 6S. Other atmospheric conditions will be selected from standard atmospheric profiles provided in 6S. In addition, results from the IKONOS-ETM+ cross-calibration effort proposed by Helder et al. in another proposed South Dakota NASA-EPSCoR research effort will be applied to IKONOS data in order to ensure that it is of the highest possible quality.

Overlaying ground and satellite data: Both ground LAI and all three spatial scales of satellite-derived data will be included in a GIS. The 3km x 3km site size corresponds with nine MODIS pixels, 10,000 ETM+ pixels, and 562,500 IKONOS pixels for cross-comparison. Some pixels along the periphery of the sites may need to be discarded depending upon GPS location inaccuracy.

Field Data

Understory Spectral Reflectance Measurements: Multiple spectroradiometric measurements of each dominant understory species (shrubs, herbaceous species (including grasses), will be acquired with an Analytical Spectral Devices (ASD) FieldSpec FR (400-2500nm spectral range). This instrument will be borrowed from Dr. Ed Duke of the SDSM&T Engineering and Mining Experiment Station. A Spectralon white reference panel will be used to quantify irradiance conditions. Illumination geometry will be noted in order to account for surface bidirectional reflection distribution function (BRDF) effects. Spectroradiometric data will be most valuable for specifying the NDVI characteristics of the canopy understory, which often cannot be obtained from remote sensing data.

Above-canopy Spectral Reflectance Measurements: Scientists and engineers at the SDSM&T are currently developing the Short Wave Aerostat-Mounted Imager (SWAMI) using funds granted by the NSF. The first test flights of this instrument are scheduled for June, 2001; the first data-collection flights for the purposes of this NASA-EPSCoR proposal will occur in the summer of 2002. The SWAMI remote sensing package is designed to mount to the tether line of a large, robust aerostat (free lift capacity ~75kg at 2 km elevation). Two primary remote sensing instruments operate in tandem to collect data. The first instrument is a lightweight visible-near infrared dual spectroradiometer capable of rapidly (<1 s) gathering contiguous, narrow-band (4 nm bandwidth) spectral data between 350 and 1050 nm (Fieldspec Dual UV/VNIR, ASD, Boulder, CO). The "dual" nature of the instrument allows for parallel acquisition of two separate radiometric signals. As a result, it is possible to simultaneously quantify both upwelling ground radiance using a downward-pointing sensor, as well as measuring total downwelling solar irradiance using an upward-pointing sensor. This feature is essential for quantifying reflectance in the absence of a white reference target and thus facilitates its use on a remote platform such as the tethered balloon. The package will be attached to the tether line well below the balloon to eliminate interference with downwelling radiation. The spectral range of this instrument is sufficient to characterize all common SVIs that utilize red and near-infrared canopy reflectance or radiance, such as the NDVI. The spectrum measured by this instrument represents an integrated signal of the whole area subtended by the solid viewing angle (adjustable between 10° and 25°). This area, therefore, represents the pixel size of the measurement. Using an 18° foreoptic, for example, a circular pixel with an area similar to that of a Landsat 7 ETM+ pixel can be observed with an instrument altitude of 100m. This same viewing geometry would allow the measurement of an area one quarter the size of a MODIS pixel at a flight altitude of approximately 1700 meters, a height well within range of the tethered balloon flight capability.

The second remote sensing instrument is a small, high resolution color video camera (Supercircuits, Inc., Leander, TX). This camera transmits imagery to the ground which may be viewed and recorded in real time. This camera will be fitted with foreoptics that will limit the field of view to be the same size and geometry as that measured by the spectroradiometer. Thus, the video imagery collected with this camera will serve to define spatial ground cover characteristics within the area of spectral measurement.

The instruments will be mounted side-by-side and will be fully pointable using remote control from the ground. Therefore, the instrument will acquire spectra with very well-defined pixel size and location for co-registration and validation to satellite imagery. The SWAMI flight altitude (i.e. pixel size) can be accurately controlled using a winch on the ground, and for this study SWAMI data will be acquired near-nadir above three plots in each Black Hills study site with pixel size ranging from 1m to approximately 30m in diameter. If flight conditions are favorable, we will continue to gather data to a pixel size of approximately 250m in diameter at as many sites as possible.

Analysis

For each test site the atmospherically and geometrically corrected satellite data will be used to derive NDVI. Then, for each field site, the relationship between NDVI and LAI will be established using LAI data acquired within the framework of Segment I. Uncertainties in the relationship between NDVI and LAI will be characterized with error bars derived from the standard deviations of the data for the test site areas.

The relationships between NDVI and LAI will be established for each forest site and for all three satellite systems. Using this relationship, LAI data from ground measurements will be compared with satellite derived LAI for various cases: ETM+ and MODIS data, IKONOS and ETM+, and primary and replicate sites.

Based on the relationship between NDVI and ground LAI, LAI will be derived from the satellite data for the total overlapping area of MODIS, ETM+, and IKONOS scenes for each site and for all three satellite systems. Images showing the differences between MODIS and ETM+ LAI will be produced and analyzed. For this purpose, MODIS data will be resampled to the pixel size of ETM+, ETM+ will be resampled to the pixel size of IKONOS, and LAI will be compared for corresponding areas in each satellite scene. For each MODIS pixel of 1km x 1km the average and standard deviation of LAI of the corresponding ETM+ pixels will be calculated.

Similarly, for each ETM+ pixel of 30m, the average and standard deviation of the corresponding IKONOS pixels will be calculated. Ground LAI data will be correlated with SWAMI NDVI measurements to analyze and identify key spatial scales where LAI-NDVI correlation inflections may occur.

Segment III-Multiple Look Angle Remote Sensing

Goals of this portion of the work include:

- Investigating the potential of BRDF data for improving LAI derivation with remote sensing data
- Establishing the relationship between spectral BRDF effects and LAI for Siberian and South Dakota conifer forests

This portion of the experiment will focus on the extent that bidirectional measurements can be used to improve LAI (and FPAR) estimates using remote sensing.

Satellite and Field Data

Images from the MISR and Polarization and directionality of the Earth's reflectance (POLDER) instruments will be acquired to correspond with as many of the field data acquisitions as possible. In addition, field data will be acquired above 3 plots per Black Hills study site using SWAMI. For these data acquisitions, SWAMI will be flown at a nadir height of approximately 50 meters. A second tether will be attached to the balloon and pulled to describe an arc in the solar principal plane. SWAMI will be pointed to image the same point on the ground at each of nine view zenith angles along the solar principal plane: ±70°, ±60°, ±45°, ±25°, and nadir. Unlike bidirectional measurements made by aircraft, the GIFOV will not change because the tether line will be kept the same length for all measurements. The measurement will approximate that obtained using a field goniometer (Sandmeier, 2000) in one azimuth direction, with a radius that is 25 times that of the Sandmeier Field Goniometer at NASA-Stennis. The longer radius will enable meaningful data to be acquired over the forest canopy sites.

Methods

Atmospheric correction: If POLDER and/or MISR data are not atmospherically corrected (level 2 products), we will perform the same radiometric correction followed for the single-view angle data (described in Segment II).

Anisotropy Indices: In order to analyze the spectral variability of BRDF effects and its relationship to LAI, two indices will be used: the anisotropy index (ANIX) and the normalized difference anisotropy index (NDAX). ANIX is defined as the ratio of maximum (R_{max}) and minimum (R_{min}) bidirectional reflectance factors per spectral band in the solar principal (or defined azimuthal) plane (Sandmeier et al., 1998; Sandmeier and Deering, 1999a):

$$\mathrm{ANIX}(\lambda, \theta_i) = \frac{R_{max}(\lambda)}{R_{min}(\lambda)} \quad [\text{dimensionless}]$$

NDAX is a surrogate for the spectral variability of BRDF effects. It is derived similarly to the normalized difference vegetation index (NDVI) from a red (maximum BRDF effects) and a near-infrared (minimum BRDF effects) band but uses ANIX rather than nadir reflectance data (Sandmeier and Deering, 1999b):

$$\text{NDAX}(\theta_i) = \frac{\text{ANIX}_{red}(\theta_i) - \text{ANIX}_{nir}(\theta_i)}{\text{ANIX}_{red}(\theta_i) + \text{ANIX}_{nir}(\theta_i)}$$

To compare ANIX and NDAX data acquired in various azimuth planes and under different solar zenith angles, a suitable BRDF model will be incorporated such as the Rahman-Pinty-Verstrate model (Rahman et al., 1993) or the 4-scale model (Chen and Leblanc, 1997). The model will be fitted to ANIX and NDAX derived from POLDER and MISR satellite data using standard simplex procedures. Then, the model will be used to produce ANIX and NDAX data that are consistent in terms of azimuth plane and solar zenith angle conditions.

Analysis

The relationship between the spectral BRDF characteristics and LAI at the field sites will be investigated in three different ways: (1) bidirectional reflectance characteristics in the principal plane, (2) spectral ANIX, and (3) NDAX. POLDER, MISR, and SWAMI data acquired close to the principal plane will be used. Results from the single view angle and multiple view angle remote sensing methodologies will be evaluated in regard to the sensitivity and linearity of NDVI, ANIX, and NDAX with respect to LAI. Recommendations for LAI derivation from satellite data will be made after comparing results between the Siberia and South Dakota field sites.

Expected Results and Anticipated Impact

The results obtained through this work will provide novel field validation data with which satellite derivations of LAI and FPAR can be assessed. SWAMI will enable measurements to be acquired and scaled in ways not previously possible. Ground truth approaches generally fall into two methodological categories. In the first type of approach, spectral data is gathered on the ground using portable spectrometers positioned above specific surface plots. A main drawback to this approach is that the ground area seen by the instrument is limited, and often is too small to investigate spectral changes associated with varying densities of forested ecosystems. In the second type of approach, biophysical characteristics are measured at a large number of locations without concurrent ground-based spectroradiometric measurements, but close in time to sensor overflight. The measurement locations are later co-registered with the overflight image, and relationships between the image data and ground parameters are derived. However, inherent to this approach are errors that stem from the fact that the exact amount of overlap between pixel and sample plot locations is difficult, and often impossible, to ascertain. SWAMI will enable exact geolocation and vegetation cover characterization of sampled pixels, and therefore serve as a tool to directly scale measurements from the level of IKONOS to ETM+ and beyond. In addition, new bidirectional measurements are enabled by SWAMI when deployed in an analogous manner to that of a smaller field goniometer, therefore providing insights on forest structure and reflectance anisotropy.

Relevance to NASA Research Priorities

This project closely relates to several ongoing NASA research activities and priorities within the Earth Science Enterprise. Relevant NASA-ESE program elements include Land-Cover and Land-Use Change (ESE-3) and Terrestrial Ecology (ESE-12). Within these program elements, this research supports work being done in several programs, specifically GSFC2.36: Vegetation and Soil Science and KSC2.1: Ecology. This project arose from conversations between Drs. Lee Vierling (SDSMT) and Don Deering (GSFC). For two years Deering has directed the effort to quantify and scale Leaf Area Index (LAI) using ground and satellite remote sensing techniques near Krasnoyarsk, Russia to produce LAI validation for EOS. Deering anticipates that at least one more year of field work and data analysis are required for the Russian site and has invited Vierling and colleagues to participate. Since this ongoing NASA field study focuses on an ecosystem that has several parallels with the ponderosa pine forest of the Black Hills makes the South Dakota study site a natural extension and comparison site. An Ameriflux tower site was recently established in the Black Hills Experimental Forest (see description below), and the SDSM&T Institute of Atmospheric Sciences is considering the purchase of an automated Cimel sunphotometer so that this site can become an Aerosol Robotic Network (AERONET) site. We also plan to make this site suitable for inclusion in the EOS validation core site network.

Existing Research

This project complements the following research projects currently being conducted by the PI's:

"*An Integrated Research/Educational Plan to Develop and Deploy a Pointable, Hyperspectral Remote Sensing Instrument on a Tethered Balloon";* L. Vierling, PI (5 years beginning 2000). This NSF-funded project is the foundation for the development and testing of the SWAMI (Short Wave Aerostat-Mounted Imager) to be used for this NASA-EPSCoR project.

"*Establishing an Ameriflux Site in the Black Hills of South Dakota";* P. Zimmerman and T. Meyers (Oak Ridge National Laboratory), PI's. (7 years beginning 2000). This project will provide long-term flux measurements of CO_2, water vapor, heat, momentum, and radiation, as well as a wide range of meteorological variables, at an intensively managed ponderosa pine stand in the Black Hills Experimental Forest. Future measurement plans include aerosols and fluxes of non-methane hydrocarbons, and installation of a Cimel Sunphotometer and Vitel data transmitter for inclusion in AERONET.

"*Earth Systems Connections: An integrated K-4 Science, Mathematics, and Technology Curriculum";* L. Vierling, J. Frykholm (U. Colorado), G. Glasson (Va. Tech), PI's. (3 years beginning 2000). This NASA-sponsored curriculum development project will pilot new earth systems science curricula at 7 elementary schools across the country. Two of the pilot schools are located in South Dakota, one on a Native American reservation. This project will be linked with the plan presented here by conducting one "open house" at a Black Hills field site each year. Elementary teachers and students will learn by asking questions and by observing field data collections in and above the forest. This activity will be jointly coordinated through the South Dakota Space Grant Consortium.

"*Scaling Issues in the Direct Use of Satellite Data in Mesoscale Model Land-Surface Parameterizations";* W. Capehart, PI. (NSF-ATM, 2 years beginning 2000). Vegetation parameters such as fractional vegetation cover and leaf area index are critical to the accurate characterization of the land-surface energy budget. We are investigating the impact of utilizing various resolution satellite data to drive regional-scale atmospheric models. Research to improve LAI estimates from remote data at various scales will strengthen this project as well as other related IAS research relating to integrating remotely derived data into numerical weather prediction schemes.

"*Seasonality Investigations Using AVHRR Data"* (NASA EPSCoR) Augustana College and USGS EROS Data Center researchers (including D. Swets) have been studying algorithms to utilize AVHRR NDVI data for improved land cover analysis. The first phase has centered around the development of a smoothing technique that captures the underlying behavior of the vegetation index while eliminating contaminating effects (i.e. clouds, atmospheric perturbations, and variable illumination and viewing geometry). NASA EPSCoR preparation grants have provided funding to pursue algorithm development for seasonal metrics, such as reliable, automatic start- and end-of-season finders, with a goal of improved land cover classification utilizing these metrics.

This project also closely links to ongoing projects at EROS and at the NASA Goddard Space Flight Center, Earth Sciences Directorate, Biospheric Studies. NASA's stated goals include the analysis of time series satellite data "to study the seasonal dynamics of global vegetation, inter-annual variations in production of semi-arid grasslands, tropical forest alteration, and to provide improved surface characterization for input into global models."

NASA Interactions

During the NASA-EPSCoR preparation grant, researchers associated with this project have fostered collaborations with Compton "Jim" Tucker and Donald Deering at the GSFC Biospheric Sciences Branch. GSFC and SD researchers have identified two specific areas where the SD EPSCoR program can directly assist and extend ongoing GSFC research efforts: 1) assisting with data processing and analysis tasks that still remain from the last two years of Siberia data collections, and 2) coordination of research efforts among Dan Swets, Jim Tucker, and scientists at the EROS Data Center to work on AVHRR NDVI seasonality smoothing and metrics computations of analysis.

Personnel

The Lead Investigator of this project is L. Vierling. He will oversee and coordinate the research program and will lead the field data collection efforts of the project. Co-Investigators (and their major project responsibilities) at SDSM&T include W. Capehart (scaling and algorithm development) and P. Zimmerman (data synthesis, and field technology development), and D. Swets (image processing and algorithm development) and S. Matzner (field data collection and interpretation) at Augustana College. In addition, two full-time graduate students and three part-time undergraduates will be an integral part of this work. The two graduate students will be enrolled in the interdisciplinary AEWR (Atmospheric, Environmental, and Water Resources) Ph.D. program joint between SDSM&T and South Dakota State University. AEWR Ph.D. candidates interact with students and faculty at each of these two institutions through shared classes, seminars, and committee meetings. This multi-institutional degree program fosters an open exchange of ideas between the schools to strengthen the research infrastructure of the state. In addition, one undergraduate research assistant at SDSMT and two undergraduate research assistants at Augustana College will participate. This project represents the first time that faculty members from these schools will work together on a research project, therefore marking a significant step in collaborative SD research capabilities. Since Augustana College is an undergraduate institution, this collaboration will expose Augustana students to SD graduate research programs, therefore increasing awareness of graduate opportunities in the state.

Management and Evaluation

Research Program Management

The multifaceted nature of this project will require frequent communication between program participants to ensure its success. As the lead investigator, L. Vierling will coordinate the large scale workings of the project with consultation from P. Zimmerman, the Director of IAS.

Because most of the field data collections will take place during the summer months, the SD research team will meet once in March to discuss field and laboratory data collections and analyses to be done during the summer, and once in October after the intensive data collections are completed to discuss the data analysis goals during the winter months. At least one of the annual meetings will take place at the EROS Data Center in Sioux Falls, SD, and EROS researchers will be invited to include them in the research at hand. On a day-to-day basis, Vierling will coordinate efforts at SDSMT, while D. Swets will serve to coordinate at Augustana. We fully intend to include graduate and undergraduate students working on this project in each statewide meeting. Students and senior project members will present seminars on research-in-progress as necessary.

In addition to the biannual SD science meetings, close coordination with D. Deering and his GSFC research team will be necessary. We therefore plan to hold one annual meeting at GSFC where L. Vierling and one other member of the SD research team will discuss the coordination of Siberia data analyses and the SD site intercomparisons. An important topic of this annual GSFC meeting will be the transfer of datasets and publication of results. We intend to provide all raw data to the GSFC team for archive after each field season, and will make processed data available for public access through NASA within one year of analysis.

Program Evaluation

We propose the following classes of metrics to be used for tracking and evaluating progress of this program:

Scientific metrics will include:
- the number of papers that are published in peer-reviewed scientific journals;
- the number of undergraduate and Master's level theses as well as Ph.D. dissertations written in conjunction with this project;
- the number of presentations at scientific meetings relating to this research; and
- the inclusion of NASA scientists as co-authors on journal articles.

Administrative metrics will include:
- timely budget spending;
- maintenance of communications with NASA collaborators;
- maintenance of collaborative interactions with participating schools; and
- strengthening NASA collaborations over the long term

Programmatic metrics will include:
- achievement of scientific goals;
- the number of K-12 students and laypersons exposed to remote sensing science via this project; and
- adherence to the project timeline shown in Figure 2.

Tracking of Program Progress

The ability of this research program to enable long term scientific research self-sufficiency within the state depends greatly upon the strengths of the collaborative relationships we will be able to make within the state as well as at NASA field centers. This proposed work will provide our research team with a solid framework on which to build these collaborations. We have already made significant progress during the NASA-EPSCoR preparation grant period to link our

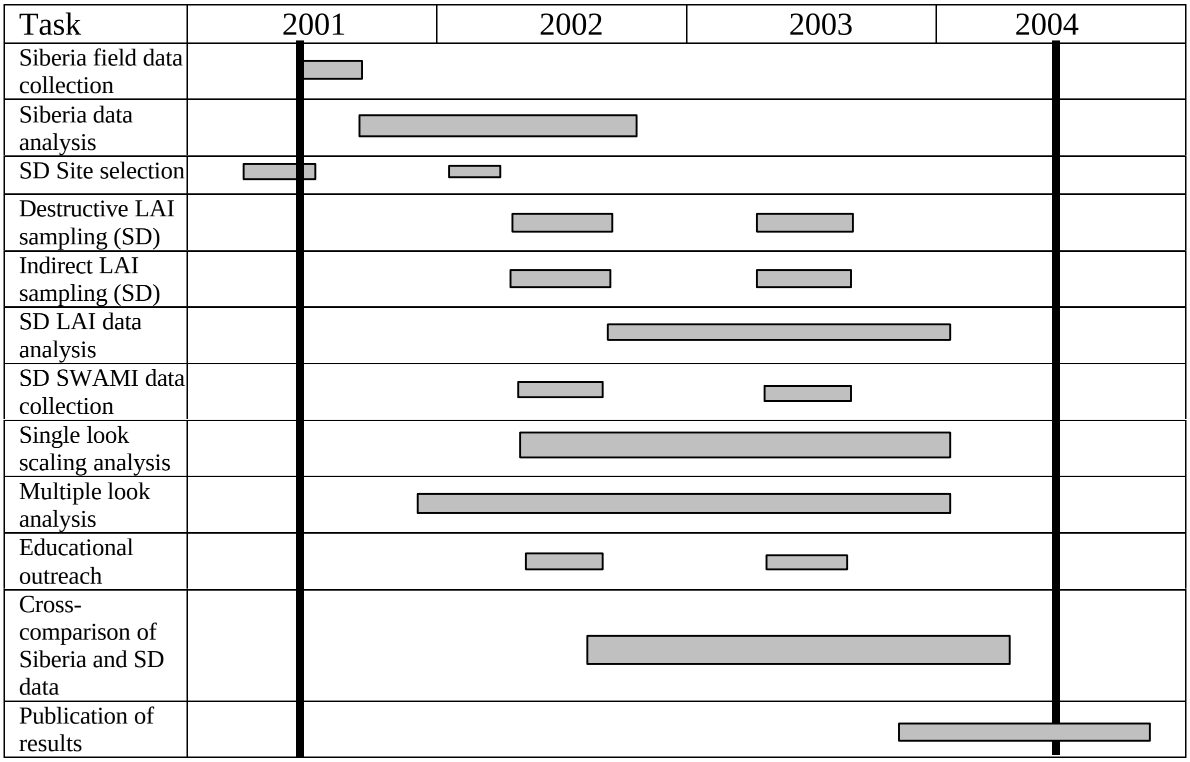

Figure 2. Timeline of significant research efforts and milestones within this project

research with that of scientists at the Goddard Space Flight Center Biospheric Sciences Branch, and expect this collaborative work to strengthen as we enter this new phase of NASA-EPSCoR research. Through this program we feel that we will be able to develop the necessary technical skills to be able to provide valuable resources for future NASA goals. In addition, this work is likely to result in a site that will be suitable as a future EOS validation core site, thereby serving as a future resource for not only SD and NASA researchers, but for potential collaborators from a variety of research institutions worldwide.

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