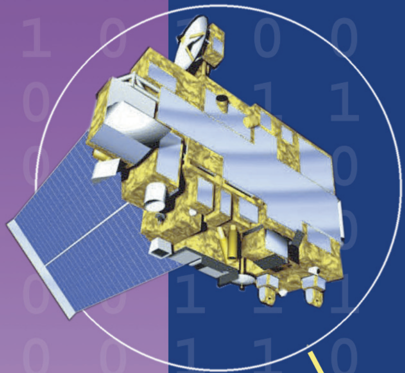
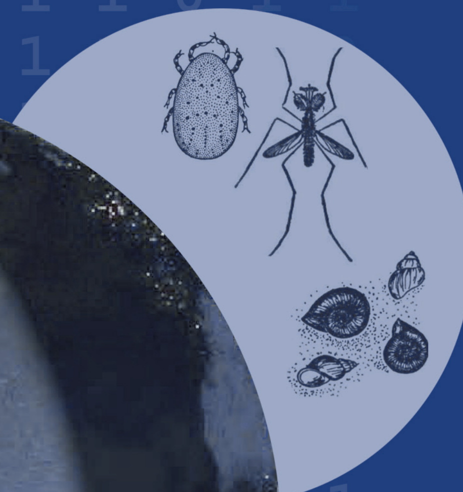
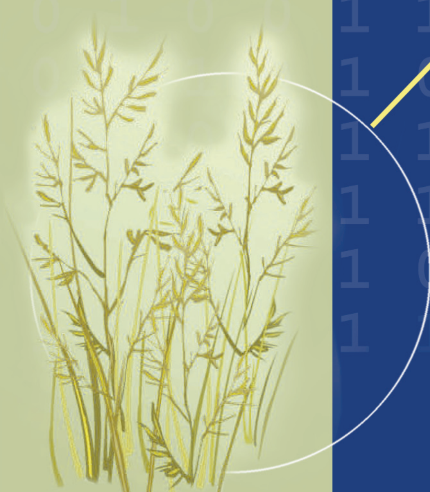


NASA ECOLOGICAL MODELING WORKSHOP

MARCH 29 TO APRIL 1, 2005
ASILOMAR CONFERENCE CENTER
PACIFIC GROVE, CALIFORNIA





The Center for Health Applications of Aerospace Related Technologies

NASA Ames Research Center

NASA Applied Sciences Program

NASA ECOLOGICAL MODELING WORKSHOP

MARCH 29 to APRIL 1, 2005
ASILOMAR CONFERENCE CENTER
PACIFIC GROVE, CALIFORNIA

Organizers:

Earth Science Division,
NASA Ames Research Center

Sponsors:

The Center for Health Applications of
Aerospace Related Technologies

NASA Ames Research Center

NASA Applied Sciences Program

In memory of
Louisa R. Beck

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SCIENTIFIC PROGRAM

Tuesday, March 29

RECEPTION

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18:00-19:00 Dinner, Dining Hall

Wednesday, March 30 (Merrill Hall)

WELCOME

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Cindy Schmidt, NASA Ames Research Center

08:30-09:00 *Introduction to the NASA Applied Sciences Ecological Forecasting Program*
Woody Turner, NASA HQ

09:00-09:30 *Introduction to the NASA Applied Sciences Invasive Species Program*
Ed Sheffner, NASA HQ

SESSION 1:
Models and Modeling Approaches for Ecological Management
Moderator: Woody Turner, NASA HQ

09:30-10:00 *Challenges in Modeling Spatio-temporal Variation in Biogeophysical Fields: Examples from Ecological Remote Sensing*
Geoffrey M. Henebry, University of Nebraska, Lincoln

10:00-10:30 *The Terrestrial Observation and Prediction System: Integration of Model, Climate, and Remote Sensing Data for Ecosystem Monitoring and Forecasting*
Ramakrishna Nemani, NASA Ames Research Center

10:30-11:00 Break

11:00-11:30 *Biophysical and Land-use Controls of Biodiversity: Regional to Continental Scales*
Andrew Hansen, Montana State University

11:30-12:00 Session 1 Panel Discussion

12:00-13:00 Lunch, Dining Hall

SESSION 2:
Habitat Suitability and Niche Modeling for Invasive Species
Moderator: Ed Sheffner, NASA HQ

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David Spencer, USDA

13:30-14:00 *Ecological Niche Modeling and Environmental Forecasting Using Remotely Sensed Data and a Genetic Algorithm*
Ed Wiley, University of Kansas

14:00-14:30 *Advances in Ecological Niche Modeling*
David Stockwell, San Diego Super Computer Center

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15:00-15:15 Break

SESSION 3:
Remote Sensing, Ecosystem Observation and Environmental Change

15:15-15:45 *Climate Change Impacts on the Biosphere: What Should We Look For?*
Steve Running, University of Montana

15:45-16:15 *Space Based Ornithology: On the Wings of Migration and Biophysics*
Jim Smith, NASA Goddard Space Flight Center

16:15-16:45 *New Directions in Spatial Modeling of Terrestrial Biodiversity for Conservation Assessment and Planning*
Simon Ferrier, New South Wales Department of Environment and Conservation, Australia

16:45-17:15 Session 3 Panel Discussion

17:15-18:15 Poster Session, Merrill Hall

18:15-19:00 Dinner, Dining Hall

19:30-21:00 Issues in Ecological Modeling: an optional, informal discussion open to all workshop participants.
Led by Ed Sheffner and Woody Turner, NASA HQ.
Location: Dolphin Room

Thursday, March 31 (Merrill Hall)

07:30-08:10 Breakfast, Dining Hall

08:15-08:35 *Welcome to Day 2 and Recap*
Ed Sheffner and Woody Turner, NASA HQ

08:35-09:00 *Introduction to the NASA Applied Sciences Public Health Program*
John Haynes, NASA Headquarters

SESSION 4:

Modeling, Remote Sensing, and Other Techniques for Extending Geoscience to Public Health

09:00-09:30 *Landscape Ecology of Microbial Pathogens: A Neo-Pavlovskian Approach to Landscape Epidemiology*
Durland Fish, Yale University

09:30-10:00 *Invasion and Dispersal of Vector-borne Diseases: Landscape Determinants and Ecological Forecasting*
Uriel Kitron, University of Illinois

10:00-10:30 Break

10:30-11:00 *Environmental Public Health Tracking: Health and Environment Linked for Information Exchange-Atlanta (HELIX-Atlanta): A Cooperative Program Between CDC and NASA for Development of an Environmental Public Health Tracking Network in the Atlanta Metropolitan Area.*
Dale Quattrochi, NASA Marshall Space Flight Center, and Amanda Sue Niskar, CDC

11:00-11:30 *Satellite Detection of Ebola River Hemorrhagic Fever Epidemic Trigger*
Compton J. Tucker and Jorge E. Pinzon, NASA Goddard Space Flight Center

11:30-12:00 Session 4 Panel Discussion

12:00-13:00 Lunch, Dining Hall

13:00-14:00 Special Session: *Extending the use of satellite data sets or derived products in ecological models, followed by audience feedback on obstacles encountered and lessons learned.*
Moderator: Bradley Reed, SAIC, USGS National Center for Earth Resources Observation and Science

SESSION 5:

The Multiscale Issue: from Local Observations to Regional Conclusions and Back Again
Moderator: John Haynes, NASA HQ

14:00-14:30 *A Regional Project for Modeling Dengue in Latin America and the Caribbean*
Joan Aron, SCS/CRN/CHIEX

Thursday, March 31 (cont'd.)

14:30-15:00 *The Time is Right to Deliver Operational Ecological Forecasts for Use in Decision Support Systems*
Dick Barber, Duke University

15:00–15:15 Break

15:15-15:45 *The Invasive Species Forecasting System*
John L. Schnase, NASA Goddard Space Flight Center

15:45–16:15 Session 5 Panel Discussion

SESSION 6:

Extending the Use of Predictive Models for Decision Support
Moderator: Ed Sheffner, NASA HQ

16:15-16:40 *Satellite Data Analysis and Ecosystem Modeling for U.S. Carbon Management*
Chris Potter, NASA Ames Research Center

16:40-17:05 *SERVIR: an Environmental Monitoring and Decision Support System for Mesoamerica*
Danny Hardin, University of Alabama in Huntsville

17:05-17:30 *Predicting Mosquito-Borne Virus Activity in California for Decision Support*
Chris Barker, University of California, Davis

17:30-18:00 Session 6 Panel Discussion

18:00-19:00 Dinner, Dining Hall

19:00-20:00 Issues in Ecological Modeling: an optional informal discussion open to all workshop participants.
Led by Ed Sheffner, Woody Turner and John Haynes, NASA HQ.
Location: Dolphin Room

20:00-22:00 Bonfire at Barbecue Area/Bonfire Pit

Friday, April 1 (The Chapel Room)

07:30-8:30 Breakfast, Dining Hall

08:30-08:45 *Welcome to Day Three and Recap*
Ed Sheffner, Woody Turner and John Haynes, NASA HQ

08:45-09:15 *Testing alternative methodologies for modeling species' ecological niches and predicting geographic distributions*
Catherine Graham, Department of Ecology and Evolution, SUNY at Stony Brook, State University of New York

09:15-10:30 Summary Session A: *Common themes: Are there common approaches and models that appear to work across the applications areas and yet require further development? How should further investments in ecological modeling be directed? What are the current needs in terms of data sources, infrastructure, and models?*
Moderators: Ed Sheffner, Woody Turner and John Haynes, NASA HQ

10:30-11:15 Summary Session B: *Next steps and how to proceed with them. Potential new collaborations and sharing of models, data sources and resources. Plans for publication of workshop proceedings.*
Moderators: Ed Sheffner, Woody Turner and John Haynes, NASA HQ

11:15-11:30 Closing Remarks

11:30-12:00 Break for hotel check-out, followed by lunch, Dining Hall

Note:

Wireless Access:
The Dolphin Room will be available from 07:00 until 19:00 each day for informal meetings and wireless internet access. Wireless internet access will also be available in the Asilomar Lobby at all times.

Poster Session:
Currently a poster session is scheduled for 17:15 - 18:15 on Wednesday, March 30. Authors will put up their posters Wednesday morning and should plan to be available at their posters during the poster session. Poster authors will need to mount posters on provided boards which have a tackable surface. Each poster must be no wider than 4 ft. (120 cm), but can be taller than 4 ft.; 36" x 48" is the recommended size.

PROGRAM ABSTRACTS

ORAL PRESENTATIONS

A Regional Project for Modeling Dengue in Latin America and the Caribbean

Joan Aron (SCS/CRN/CHIEX)

Diagnostics and Prediction of Climate Variability and Human Health Impacts in the Tropical Americas is a collaborative research network supported by the Inter-American Institute for Global Change Research. The main focus is on vector-borne diseases, especially dengue and malaria. The principal investigators represent different disciplines and come from Brazil, Colombia, Jamaica, Mexico, Venezuela, and the United States. They formed the Climate and Health Information Exchange (http://chiex.net). Associated epidemiological modeling investigations have been developed in collaboration with the Nonlinear Dynamics Systems Section of the U.S. Naval Research Laboratory.

This presentation addresses three aspects of modeling dengue in Latin America and the Caribbean.

- First, analyses of local relationships between climate variables and dengue incidence reveal how climate affects the transmission cycle. An examination on a monthly time scale provides insight into seasonal patterns and the effects of the El Nino-Southern Oscillation climatic anomaly.

- Second, a regional picture of the dynamic behavior of dengue in the Americas considers the dynamics of both the mosquito vectors and the dengue viruses. A key regional factor is the geographic expansion of the *Aedes aegypti* mosquito vector population since 1970. But even if the vector population were unchanging, the dynamics of transmission of a single dengue virus can theoretically generate oscillations in incidence in two human populations coupled by migration. In addition, interactions among four dengue virus serotypes can theoretically generate chaotic behavior in which the four serotypes become desynchronized, that is peak in incidence at different times.

- Third, the effective use of modeling in making decisions depends on the structure of knowledge-action systems. The National Research Council has identified six characteristics of effective knowledge-action systems. The CHIEX Colombian partner is applying those recommendations to improve the use of seasonal to interannual climate forecasting in Colombia for disease control. The Colombian effort is initially focusing on malaria, but will try to expand to dengue and leishmaniasis.

The Time is Right to Deliver Operational Ecological Forecasts for Use in Decision Support Systems

Dick Barber (Duke University)

In 1971 a multi-disciplinary research project, Coastal Upwelling Ecosystems Analysis (CUEA), was organized around the premise that predicting the response of upwelling ecosystems to natural and human perturbations is possible given knowledge of a few forcing functions. The CUEA goal was to understand the coastal upwelling ecosystem well enough to predict its response far enough in advance to be useful to resource managers. This laudable goal proved unattainable given the technology of the 1970s and an incomplete understanding of the ENSO phenomenon, which has since proved to be the major source of interannual variability in coastal upwelling ecosystems. Recent advances in satellite and in situ observing systems, together with high performance computing power, now make it possible to run the complex, high-resolution ecological forecast models that are required to realize this goal. Furthermore, these technical advances and model improvements can now be combined with a much improved understanding of the ENSO phenomenon and with skillful ENSO forecasts of at least nine months' lead time. Our research project is focusing on three applications that exploit this progress in ecological forecasting: 1) managing the Peruvian anchovy fishery, the world's largest single-species fishery, which is supported by the world's most variable ocean ecosystem; 2) protecting threatened large oceanic animals, especially mammals, birds and sea turtles; and 3) providing public health responders with long lead-time forecasts of outbreaks of vector-borne tropical diseases, such as malaria. We believe the time is right for operational ecological forecasting to provide decision makers with the information they need to ensure sustainability of fish stocks, conserve threatened large ocean animals, and protect against climate-related tropical disease outbreaks. We also believe these three applications are only a few of many that are now possible given the technology that NASA has made possible.

Predicting Mosquito-Borne Virus Activity in California for Decision Support

Christopher M. Barker (Center for Vectorborne Diseases and Department of Entomology, UC Davis), William K. Reisen (Center for Vectorborne Diseases, UC Davis), Bruce F. Eldridge (Center for Vectorborne Diseases and Department of Entomology, UC Davis)

California mosquito control agencies need reliable prediction of the probability of mosquito-borne virus transmission prior to detection by conventional surveillance methods to allow adequate preparation during years of heightened risk or resource conservation during periods of lower risk. In this study, we used regression analysis in five representative California vector control agencies over a 21-year period (1983-2003) to examine the effects of mosquito abundance during the spring amplification and summer transmission seasons on the annual probability of detecting seroconversions in sentinel chickens for western equine encephalomyelitis or St. Louis encephalitis viruses during the same year. Other potential predictors considered for inclusion in the logistic model were vector control agency effort as measured by budget/area and number of flocks, and meteorological factors such as precipitation, temperature, and El Nino-Southern Oscillation indices. Plans for integration of risk predictions into the California mosquito-borne virus surveillance program's decision support system will be discussed.

New Directions in Spatial Modeling of Terrestrial Biodiversity for Conservation Assessment and Planning

Simon Ferrier (New South Wales National Parks and Wildlife Service)

Planning for conservation of terrestrial biodiversity requires information on the spatial distribution of species and communities across large regions. Direct biological sampling of such regions is typically sparse, with survey or collection sites separated by extensive areas of unsurveyed land. To overcome this problem planning often employs remotely derived environmental surrogates for biodiversity such as land-cover or vegetation maps, and abiotic environmental classifications.

The surrogacy value of remotely derived data can be enhanced by linking this information more explicitly to available biological survey or collection data through statistical modeling and extrapolation. The most popular approach to such integration has been to model distributions of individual species as a function of remotely derived environmental variables (e.g., climate, terrain, soils, land-cover). However, this is just one of a wide range of possible strategies for modelling relationships between biological and environmental data.

In highly diverse, yet sparsely sampled, regions (e.g., many tropical forest regions) it may make sense to supplement or replace species-by-species modeling with various community-level modeling strategies, which model spatial pattern in biodiversity by considering all species simultaneously. Generalized dissimilarity modeling (GDM) is one such strategy that has been designed to accommodate very large numbers of species with few records per species. GDM models dissimilarity in community composition between biological survey or collection sites as a non-linear function of inter-site differences in remotely derived environmental variables and/or raw spectral bands from various forms of remote sensing.

GDM and related community-level modeling techniques offer a rapid and cost-effective means of mapping spatial pattern in biodiversity across large highly diverse regions, thereby supporting a variety of applications ranging from biological survey design through to reserve selection and land-use planning.

Landscape Ecology of Microbial Pathogens: A Neo-Pavlovskian Approach to Landscape Epidemiology

Durland Fish (Professor, Dept. of Epidemiology and Public Health, Yale School of Medicine; Director, Yale Institute for Biospheric Studies, Center for EcoEpidemiology)

The notion that microbial pathogens causing disease in humans have characteristic environmental determinants which regulate their geographic distribution and prevalence was elegantly expressed more than 50 years ago by Russian academician Evgeny Pavlovski in his published concept of landscape epidemiology. Largely ignored by Western medical epidemiology, which relies almost entirely upon human population studies, Pavlovski's ideas reflect an understanding of basic ecological principles that is generally absent from the mainstream medical science of infectious disease epidemiology. Recognition that recent epidemics of emerging infections are dominated by pathogens of vector or zoonotic origin has forced a re-evaluation of the Western anthropocentric approach to surveillance and control of infectious agents. However, progress in facilitating a more envirocentric approach is limited by a void of ecologically trained epidemiologists responsible for addressing current infectious disease threats. Recent interest in the role of infectious diseases in ecosystem processes has recruited some help from ecologists, but few ecologists have adequate training in medical epidemiology. Technological developments in the fields of remote sensing, geographic information systems, spatial statistics, and molecular biology provide powerful new tools for re-examining Pavlovski's concept of landscape epidemiology. Integration of landscape epidemiology with landscape ecology has great potential for fostering an interdisciplinary approach between the environmental and medical sciences to advance the field of infectious disease epidemiology. Examples of attempts at integration are illustrated with Lyme disease and West Nile virus.

Testing alternative methodologies for modeling species' ecological niches and predicting geographic distributions

Catherine Graham (Department of Ecology and Evolution, SUNY at Stony Brook, State University of New York)

Species distributional modeling is increasingly used to produce information on the pattern of biodiversity and as such is an important tool for applied and theoretical research initiatives. Researchers interested in presence-only models are faced with this wide array of methods and very little guidance as to what method may perform well for a given region or species. We use 14 methods to create species distribution models for 226 species across six distinct geographic regions. We evaluated models with independent presence/absence test data. There was significant variation in model performance; however some models tended to perform consistently well. Within the suite of relatively common methods, methods that characterize the background tend to outperform those that only use presence data (here, BIOCLIM, DOMAIN and LIVES). The regression-based methods (i.e., GLMS, GAMS) were largely indistinguishable in terms of predictive performance. Several models, that were either recently developed (general dissimilarity models) or applied distribution modeling (boosted trees, maximum entropy, mars community models), outperformed more traditional methods. A common thread in these models is that all of them have some mechanism for stabilizing them, that leads to a more robust and reliable identification of trends than the simpler methods. Also, community models (gdm and mars.comm) use information from a suite of species to inform variable selection and modeling, and relevant predictors are included because of their strong community signal, whereas that signal might be insufficient to trigger inclusion of these predictors when fitting a single species model. This research is the most comprehensive model comparison to date and represents the input from over 30 data providers, modelers and other scientists.

Biophysical and Land-use Controls of Biodiversity: Regional to Continental Scales

Andrew Hansen (Ecology Department, Montana State University)

Ecological theory suggests that the potential for biodiversity varies across the continent as determined by biophysical factors. Ecosystem energy, for example, sets an upper limit on species richness. Intensive human land use is now widespread over North America and likely reduces biodiversity below the biophysical potential. The nature of biophysical controls and the impacts of land use on biodiversity are not currently well understood. New satellite data offer promise of major breakthroughs in addressing these topics. This paper will present pilot studies on biodiversity potential across the Pacific and Inland Northwest US, how land use may alter biodiversity from this potential, and to identify places high in bird diversity.

Introduction to the NASA Applied Sciences Public Health Program

John Haynes (NASA Headquarters)

The Public Health Program Element of the NASA Applied Sciences Program extends products derived from science information, models, technology, and other capabilities into partners' decision support tools for public health, medical, and environmental health issues. The focus of the program with the public health practice community is the decision support systems known as Epidemiologic Surveillance Systems in the areas of:

- infectious disease
- environmental health
- bioterrorism

NASA collaborates with the professional public health community that is responsible for surveillance to understand and respond to factors in the environment that adversely impact the health of the American public. These factors include disease vectors, air and water contaminants, ambient temperature extremes, ultra-violet radiation, and a myriad of other factors associated with public health problems. NASA's Public Health Program Element uses Earth-observing instruments, advanced communication technology, high speed computing capabilities, data products, and predictive models of Earth-Sun System phenomena associated with the occurrence of disease to assist partners in enhancing their surveillance systems. International health is included in the scope of the Program as it represents a national concern through its potential impact on American public health, economics, and national security. To this end, the program has strong connections with the Group on Earth Observations (GEO), the Inter-agency Working Group on Earth Observations (IWGEO), the World Health Organization (WHO), and The Observing-System Research and Predictability Experiment (THORPEX) program under the auspices of the World Meteorological Organization (WMO). The program also collaborates with the U.S. State Department.

The decision support structure of the public health community is based partially upon health information provided by epidemiologic surveillance. According to the Centers for Disease Control and Prevention (CDC), epidemiologic surveillance may be described as "the ongoing and systematic collection, analysis, and interpretation of health data in the process of describing and monitoring a health event." A useful surveillance system enables the continual collection of data for monitoring disease trends and outbreaks for a public health response. While these data may be used for scientific investigations, research is not the primary purpose of a surveillance system. Surveillance systems are designed primarily to support decision makers.

Challenges in Modeling Spatio-Temporal Variation in Biogeophysical Fields: Examples from Ecological Remote Sensing

Geoffrey M. Henebry (Center for Advanced Land Management Information Technologies [CALMIT], School of Natural Resources, University of Nebraska-Lincoln)

A principal challenge to integrating sensing datastreams into models of ecological pattern and process lies in the duality of objects and fields. This is not new ground, but what was once a raging debate has cooled to simmer as technological advances have made many of the earlier debating points moot. Nagging ontological and epistemological issues remain and, with the enormous increase in data volume, new challenges have arisen. Some key questions include: (1) What are the appropriate units of analysis for time series of images that portray variations in electromagnetic radiation within the context of spatial and temporal coordinates? (2) What constitutes an appropriate baseline for the ecological phenomenon of interest and how can we derive such a baseline? (3) How can we conduct change analysis? (4) How do uncertainties propagate and affect model reliability for decision support? I will illustrate some approaches to these questions using land surface phenologies and landscape trajectories.

Invasion and Dispersal of Vector-Borne Diseases: Landscape Determinants and Ecological Forecasting

Uriel Kitron (University of Illinois)

Several recent programs testify to the importance of an ecological approach to studies of invasive species and infectious diseases. In particular, NSF's National Ecological Observatory Network (NEON) initiative and the NSF/NIH Ecology of Infectious Disease program are geared to address local, regional and continental scale scientific questions, and to have the interdisciplinary participation necessary to achieve credible ecological forecasting and prediction. Three examples from collaborative studies are presented:

a. For a regional study Lyme disease in the US, a statistical spatial model capable of predicting habitat suitability for *Ixodes scapularis* ticks using a spatial database of land cover, soil, climate and a range of host variables was developed.

b. For a local study of schistosomiasis in Kenya, field and satellite data were integrated to study transmission dynamics and connectivity of aquatic snail habitats. Dynamic patterns of infection clusters and of snail dispersal can be used to identify selective control measures focused in space and time.

c. For Chagas disease in the dry Chaco of Argentina, fine resolution satellite imagery was an effective way to map remote areas, including the detection of an unknown (heavily infested) household and vegetation corridors/obstacles. Molecular/morphometric data were integrated with entomological/parasitological data and with satellite data to explain temporal and spatial dispersion pattern of triatomine bugs and the reinfestation process of domestic and peridomestic structures.

Overall, while new tools can play a significant role in ecological forecasting, successful predictions remain entrenched in solid understanding of the underlying biological processes and their interactions with environmental and climatic factors.

The Terrestrial Observation and Prediction System: Integration of Model, Climate, and Remote Sensing Data for Ecosystem Monitoring and Forecasting

Ramakrishna Nemani (NASA Ames Research Center), Petr Votava (California State University, Monterey Bay), Forrest Melton (CSUMB), Andy Michaelis (CSUMB), Keith Golden (NASA Ames Research Center), Hirofumi Hashimoto (CSUMB), Matt Jolly (NTSG, University of Montana), Michael White (Utah State University, Logan), Steve Running (NTSG, University of Montana), and Joseph Coughlan (NASA Ames Research Center)

The latest generation of NASA Earth Observing System satellites has brought a new dimension to continuous monitoring of the living part of the Earth System, the Biosphere. EOS data can now provide weekly global measures of vegetation productivity and ocean chlorophyll, and many related biophysical factors such as land cover changes or snowmelt rates. However, information with the highest economic value would be forecasting impending conditions of the biosphere that would allow advanced decision-making to mitigate dangers, or exploit positive trends.

We have developed a software system called the Terrestrial Observation and Prediction System (TOPS) to facilitate rapid analysis of ecosystem states/functions by integrating EOS data with ecosystem models, surface weather observations and weather/climate forecasts. Land products from MODIS (Moderate Resolution Imaging Spectroradiometer) including land cover, albedo, snow, surface temperature, leaf area index are ingested into TOPS for parameterization of models and for verifying model outputs such as snow cover and vegetation phenology. TOPS is programmed to gather data from observing networks such as USDA soil moisture, AMERIFLUX, SNOWTEL to further enhance model predictions.

Key technologies facilitating TOPS implementation include the ability to understand and process heterogeneous-distributed data sets, automated planning and execution of ecosystem models, causation analysis for understanding model outputs. Current TOPS implementations at local (vineyard) to global scales (global net primary production) can be found at http://ecocast.arc.nasa.gov.

Satellite Data Analysis and Ecosystem Modeling for U.S. Carbon Management

Chris Potter (NASA Ames Research Center, Moffett Field, CA), Matthew Fladeland (NASA Ames Research Center, Moffett Field, CA), Seth Hiatt (San Francisco State University and Education Associates, Moffett Field, CA), and Steven Klooster, Vanessa Genovese, and Peggy Gross (California State University Monterey Bay, NASA/ARC, Seaside, CA)

Ecosystem modeling and satellite remote sensing are being used in combination to assess activities such as land use change and climate variation on carbon pools and fluxes across the United States. The main objectives of this research and application are to: 1) predict major forest and agricultural sinks of atmospheric carbon dioxide using NASA satellite data and ecosystem modeling, 2) support U. S. Government interagency programs for voluntary greenhouse gas emissions reductions, and 3) develop an internet-based decision support tools for users nationwide. A new combination of ecosystem carbon modeling and high-resolution land cover mapping of the country by the MODIS satellite sensor was used to estimate potential carbon sequestration rates in croplands and rangelands resulting from potential future afforestation activities. Afforestation of marginal agricultural lands represents a promising option for carbon sequestration in terrestrial ecosystems. Using a satellite-driven model called NASA-CASA for predictions of regrowth forest production, a conservative national projection of 0.3 Pg C is reported as potential carbon stored each year on relatively low-production crop or rangeland areas. Afforestation at this level of intensity has the capacity to offset at least one-fifth of annual fossil fuel emission of carbon in the United States. These projected afforestation carbon gains also match or exceed recent estimates of the annual sink for atmospheric CO_2 in currently forested area of the country. We are further comparing the NASA-CASA satellite-derived estimates of afforestation gains to the DOE/USDA regional projections to assess the role of replanted forest trees, soils, and dead wood pools in sequestration potentials.

Environmental Public Health Tracking: Health and Environment Linked for Information Exchange-Atlanta (HELIX-Atlanta): A Cooperative Program Between CDC and NASA for Development of an Environmental Public Health Tracking Network in the Atlanta Metropolitan Area

Dale Quattrochi (NASA Marshall Space Flight Center), Amanda Sue Niskar (Centers for Disease Control and Prevention)

The Centers for Disease Control and Prevention (CDC) is coordinating HELIX-Atlanta to provide information regarding the five-county Metropolitan Atlanta Area (Clayton, Cobb, DeKalb, Fulton, and Gwinett) via a network of integrated environmental monitoring and public health data systems so that all sectors can take action to prevent and control environmentally related health effects. The HELIX-Atlanta Network is a tool to access interoperable information systems with optional information technology linkage functionality driven by scientific rationale. HELIX-Atlanta is a collaborative effort with local, state, federal, and academic partners, including the NASA Marshall Space Flight Center. The HELIX-Atlanta Partners identified the following HELIX-Atlanta initial focus areas: childhood lead poisoning, short-latency cancers, developmental disabilities, birth defects, vital records, respiratory health, age of housing, remote sensing data, and environmental monitoring. HELIX-Atlanta Partners identified and evaluated information systems containing information on the above focus areas. The information system evaluations resulted in recommendations for what resources would be needed to interoperate selected information systems in compliance with the CDC Public Health Information Network (PHIN). This presentation will discuss the collaborative process of building a network that links health and environment data for information exchange, including NASA remote sensing data, for use in HELIX-Atlanta.

Climate Change Impacts on the Biosphere: What Should We Look For?

Steve W. Running (University of Montana)

The global warming trend has now been documented for a sufficient time that we can look for impacts on ecosystem processes. What trends in ecosystem processes are now observable? What do we expect for the future?

The Invasive Species Forecasting System

John L. Schnase, Jeffrey T. Morisette (NASA Goddard Space Flight Center), and Thomas J. Stohgren (USGS National Institute of Invasive Species Science)

The spread of invasive species is one of the most daunting environmental, economic, and human-health problems facing the United States and the World today. It is one of several grand challenge environmental problems being addressed by NASA's Science Mission Directorate through a national application partnership with the US Geological Survey. NASA and USGS are working together to develop a National Invasive Species Forecasting System (ISFS) for the management and control of invasive species on Department of Interior and adjacent lands. The system provides a framework for using USGS's early detection and monitoring protocols and predictive models to process MODIS, ETM+, ASTER and commercial remote sensing data, and create on-demand, regional-scale assessments of invasive species patterns and vulnerable habitats.

Recent work on the ISFS project has shown the importance of remotely-sensed time-series data in geostatistical models for mapping the distribution of Tamarisk, Cheatgrass, and other invasive plant species. Our studies have used field surveys of species richness, one 30-m spatial resolution Landsat 7 Enhanced Thematic Mapper plus (ETM+) image, and a four year time-series of 250m spatial resolution Moderate Resolution Imaging Spectrometer (MODIS) imagery over three sites. Summary values from the MODIS time series were added as explanatory variables in the ISFS framework. In a model to predict species richness, results show the MODIS summary values are at least as statistically significant as ETM+-derived predictors. This indicates the importance of including temporal information for large area mapping of invasive species, even at the more coarse 250m spatial resolution.

The ISFS project significantly broadens the use of NASA data in managing the Nation's invasive species threat. In this talk, we will describe the NASA/USGS invasive species partnership, provide an overview of Invasive Species Forecasting System, describe our early results using MODIS time-series data, and show how this work is contributing to the invasive species effort.

SERVIR: an Environmental Monitoring and Decision Support System for Mesoamerica

Tom Sever, Dan Irwin (NASA/Marshall Space Flight Center), Sara Graves, Danny Hardin (presenting) (University of Alabama in Huntsville)

In 2002/2003 NASA, the World Bank and USAID joined with CCAD to develop an advanced decision support system for Mesoamerica (named SERVIR) as part of the Mesoamerican Environmental Information System. Mesoamerica - composed of the seven Central American countries and the five southernmost states of Mexico - make up only 0.5% of the world's land surface. But the region is home to seven to eight percent of the planet's biodiversity (14 biosphere reserves, 31 Ramsar sites, 8 world heritage sites, 589 protected areas) and 45 million people including more than 50 different ethnic groups. Today the region's biological and cultural diversity is severely threatened by extensive deforestation, illegal logging, water pollution, and uncontrolled slash and burn agriculture. Additionally, Mesoamerica's distinct geology and geography result in disproportionate vulnerability to natural disasters such as earthquakes, hurricanes, drought, and volcanic eruptions. NASA Marshall Space Flight Center, the University of Alabama in Huntsville and the SERVIR partners are developing state-of-the-art decision support tools for environmental monitoring as well as disaster prevention and mitigation in Mesoamerica. These partners are contributing expertise in space-based observation with information management technologies and intimate knowledge of local ecosystems to create a system that will be used by scientists, educators, and policy makers to monitor and forecast ecological changes, respond to natural disasters and better understand both natural and human induced effects. In its first year of development and operation the SERVIR project has already yielded valuable information on Central American fires, weather conditions and the first ever real-time data on red tides. This presentation reports progress thus far in the development of SERVIR and plans for the future.

Introduction to the NASA Applied Sciences Invasive Species Program

Ed Sheffner (NASA Headquarters)

Invasive species is one of 12 areas of national importance and program elements in the Applied Sciences Program of the Earth-Sun System Division. The goal of the invasive species program element is to assist operational agencies meet their mandates to manage invasive species. The goal is met through partnerships between NASA and operational agencies, partnerships that take advantage of NASA's Earth observations, modeling and systems engineering capabilities to enhance the decision support tools used by the operational agency to predict the spread of invasive species and maximize the use of available resources in response to the invasive species threat. The Invasive Species Forecasting System (ISFS), a partnership between NASA and USGS, is an example of NASA's approach to invasive species. The ISFS combines NASA Earth observations and statistical models to enhance USGS capabilities to map, monitor and predict the spread of significant invasive plant species.

Space Based Ornithology -- On the Wings of Migration and Biophysics

Jim Smith (NASA Goddard Space Flight Center)

The study of bird migration on a global scale is one of the compelling and challenging problems of modern biology with major implications for human health and conservation biology. Migration and conservation efforts cross national boundaries and are subject to numerous international agreements and treaties. Space based technology offers new opportunities to shed understanding on the distribution and migration of organisms on the planet and their sensitivity to human disturbances and environmental changes.

Migration is an incredibly diverse and complex behavior. A broad outline of space based research must address three fundamental questions: (1) where could birds be, i.e. what is their fundamental niche constrained by their biophysical limits? (2) where do we actually find birds, i.e. what is their realizable niche as modified by local or regional abiotic and biotic factors, and (3) how do they get there (and how do we know?), that is, what are their migration patterns and associated mechanisms?

Our working hypothesis is that individual organism biophysical models of energy and water balance, driven by satellite measurements of spatio-temporal gradients in climate and habitat, will help us to explain the variability in avian species richness and distribution. Dynamic state variable modeling provides one tool for studying bird migration across multiple scales and can be linked to mechanistic models describing the time and energy budget states of migrating birds. Such models yield an understanding of how a migratory flyway and its component habitats function as a whole and link stop-over ecology with biological conservation and management

Further these models provide an ecological forecasting tool for science and application users to address what are the possible consequences of loss of wetlands, flooding, drought or other natural disasters such as hurricanes on avian biodiversity and bird migration.

Application of Structural Models to Invasive Species Management

David Spencer (USDA - ARS, Exotic & Invasive Weeds Research Unit), David Thornby (Department of Vegetable Crops, UC Davis), Jim Hanan (Centre for Plant Architecture Informatics, University of Queensland)

Structural models are computer simulations of the development and growth of individual plants in 3-dimensional space. The approach utilizes rules of development expressed as L-systems. Using experimental data on shoot emergence, growth, and survivorship we developed a structural model of the invasive riparian species, *Arundo donax*. The model is driven by accumulated degree-days and it produces a realistic number of plant components from a single rhizome segment over the course of the first year of growth. Biomass production is simulated through the use of equations relating shoot height to weight and rhizome and root weight to shoot weight. Both the visual simulations and numerical data produced by the model indicate that the majority of shoot emergence in central California occurs prior to July but that most biomass accumulation of Arundo clumps occurs between July and October. The model extrapolates to several years of growth beyond the first. In addition, the model has been used to study biomass allocation patterns, interactions between an Arundo canopy and light, and the potential impact of an herbivorous insect. The model allows us to demonstrate the yearly pattern of growth in an effective, understandable, and succinct way. It will improve biological control efforts by identifying combinations of Arundo architecture and damage caused by insects and pathogens that interact effectively to limit Arundo populations.

Advances in Ecological Niche Modeling

David R.B. Stockwell (San Diego Supercompter Center, University of California, San Diego)

Ecological niche modeling (ENMs) algorithms are increasing being used to map and explain species distributions in wide range of ecological research including invasive species, bird migration, human health, and climate change. Most methods create a kind of 'environmental envelope' around observations using limited annual climate variables. Recent algorithmic developments using image processing methods and large environmental datasets (> 1000 variables) indicate a significant ($p<0.01$) 14% increase in accuracy over the GARP algorithm using models with two or fewer independent variables. These results indicate accuracy and explanatory ability can be improved by additional environmental data particularly monthly vs. annual climate averages. This 'data mining' approach is a new paradigm for ENM, and is leading to new applications such as mapping landslide risk worldwide, and new infrastructure for handling large data sets. Software and datasets are available from the web site http://biodi.sdsc.edu/ww_home.html.

Satellite Detection of Ebola River Hemorrhagic Fever Epidemic Trigger Events

Compton J. Tucker and Jorge E. Pinzon (NASA Goddard Space Flight Center)

Ebola hemorrhagic fever, named after the Ebola River in Central Africa, first appeared in June 1976, during an outbreak in Nzara and Maridi, Sudan. In September 1976, a separate outbreak was recognized in Yambuku, Democratic Republic of the Congo (DRC). One fatal case was identified in Tandala, DRC, in June 1977, followed by another outbreak in Nzara, Sudan, in July 1979. Ebola hemorrhagic fever outbreaks results in a very high mortality of patients who contract the disease: from 50 to 80% of infected people perish from this highly virulent disease. Death is gruesome, with those afflicted bleeding to death from massive hemorrhaging of organs and capillaries.

The disease was not identified again until the end of 1994, when three outbreaks occurred almost simultaneously in Africa. In October, an outbreak was identified in a chimpanzee community studied by primatologists in Taï, Cote d'Ivoire, with one human infection. The following month, multiple cases were reported in northeast Gabon in the gold panning camps of Mekouka, Andock, and Minkebe. Later that same month, the putative index case of the 1995 Kikwit, DRC, outbreak was exposed through an unknown mechanism while working in a charcoal pit. In Gabon, two additional outbreaks were reported in February and July, 1996, respectively, in Mayibout II, a village 40 km south of the original outbreak in the gold panning camps, and a logging camp between Ovan and Koumameyong, near Booue.

The largest Ebola hemorrhagic fever epidemic occurred in Gulu District, Uganda from August 2000 to January 2001. In December 2001, Ebola reappeared in the Ogooue-Ivindo Province, Gabon with extension into Mbomo District, The Republic of the Congo lasting until July 2002. Since 2002 there have been several outbreaks of Ebola hemorrhagic fever in Gabon and adjacent areas of Congo.

Of interest is the seasonal context and occasional temporal clustering of Ebola hemorrhagic fever outbreaks. Near simultaneous appearances of Ebola epidemics in Nzara, Sudan and Yambuku, DRC in 1976 occurred within two months of each other in two geographic locations separated by hundreds of kilometers involving two separate viral strains (Sudan and Zaire EBO strains). The outbreaks of Taï, Cote d'Ivoire; Mekouka, Gabon; and Kikwit, DRC in late 1994 also occurred within months of each other in three different geographic regions involving two different viral strains (Cote d'Ivoire and Zaire EBO strains). Fifteen years passed between the 1976-9 and 1994-6 temporal clusters of Ebola cases without identification of additional cases.

Despite extensive field investigations to define the natural history of the Ebola hemorrhagic fever virus, the origin and mechanism of disease transmission, from reservoir to humans, remains a mystery. We have used satellite data to (1) investigate the vegetation type(s) associated with Ebola outbreaks and (2) to identify variations in the wet and dry seasons that are directly associated with Ebola outbreaks.

Normalized difference vegetation index (NDVI) time series data is used in this study as proxy for rainfall. These data are derived from measurements made by the Advanced Very High Resolution Radiometer (AVHRR) instruments carried on the NOAA series of meteorological satellites. The NDVI is computed from the red (550-700 nm) and near infrared (730-1100 nm) channels of the AVHRR as NDVI = (ir-red)/(ir+red).

A number of studies have shown that monthly NDVI time series shows the vegetation response to seasonal dynamics of rainfall and evapotranspiration in a wide range of environmental conditions. The NDVI is a surrogate for photosynthetic capacity since it is highly correlated to the absorbed fraction of photo-synthetically active radiation (FPAR) and thus gross photosynthesis. We use the NDVI to infer FPAR that is directly influenced by rainfall, even in tropical forests.

We used singular value decomposition analysis to identify the time series behavior of the NDVI data from the documented outbreak sites of Ebola hemorrhagic fever. Landsat data confirmed that all Ebola hemorrhagic fever outbreaks occurred in either tropical moist forest or gallery tropical forest in a matrix of savanna. This enabled us to restrict our analysis to only areas of tropical moist forest or gallery tropical forest in Africa.

Employing singular value decomposition analysis we identify areas in Africa with exactly the same time series behavior as the documented outbreak areas. Our study has identified the "Hot Zone" of Ebola hemorrhagic fever in Africa. This is the area where our analysis indicates Ebola hemorrhagic fever is endemic, thus directing more study to specifically these areas.

Ecological Modeling at NASA and a Brief Introduction to NASA's Ecological Forecasting Program

Woody Turner (NASA Headquarters)

Modeling in the NASA Earth Science Program has largely focused on the physical modeling of climate. While ecology has a long history at NASA and has been associated with a large number of modeling efforts, ecological modeling has lagged its physical counterparts-at least at the programmatic level. An increasing focus on scenario generation and simulations within the new NASA Earth-Sun System Division will result in a greater emphasis on models to synthesize analyses resulting from the large suite of satellite observations. What path should ecological modeling follow at NASA? Of particular relevance to researchers and natural resource managers is linking information at the landscape and coarser scales to data at the scale of the organism. In fact, such linkage is required for the advancement of the three NASA Applied Science Programs participating in this workshop: Ecological Forecasting, Invasive Species, and Public Health. An approach to this linkage involves two components: (1) defining the niche of the organism from the surrounding environment in and also from the organism out and (2) connecting NASA observations and physical models to trophic models capturing the flow of energy among organisms. In this way, we should be able to capture the organism in space and time. The ultimate challenge for NASA ecological modeling activities lies in extending this linkage across a greater range of spatial scale to connect landscape observations to changes seen in genomes and proteomes of target organisms and understanding, in turn, how these changes affect the environment (e.g., through the cycling of elements).

The NASA Ecological Forecasting Program seeks to apply NASA's research results for decision support in three broad areas: regional environmental management, protected area management, and marine fisheries forecasting. Understanding the drivers of biodiversity-the structural side of ecosystems-provides the research focus underlying the Ecological Forecasting Applied Sciences Program.

Ecological Niche Modeling and Environmental Forecasting Using Remotely Sensed Data and a Genetic Algorithm

E. O. Wiley (Biodiversity Research Center and Department of Ecology and Evolutionary Biology, University of Kansas)

Authenticated biodiversity information resides as specimen records in repositories spread throughout the world. These data are peculiar from an ecological standpoint because they are idiosyncratically collected and they are not associated with comparable ecological data, yet they represent the single most comprehensive record of biodiversity on earth. In this presentation I discuss tools that have been developed that produce statistically robust models of species ecological niche requirements and as such, have considerable predictive power for a variety of studies of biodiversity. These include analyses of native marine, freshwater and terrestrial biotas, predictions of invasive species (potential and realized), and responses to climate change. I discuss results from one particular example in depth; ecological forecasting of the Pacific lionfish (*Pterois volitans*), a species that has invaded Atlantic coastal regions of North America and poses a threat to Caribbean reef communities. I show that station-based environmental data limit predictive capability while remotely sensed data yield accurate predictions in areas where station-based data fail. Brief examples are also shown for predicting West Nile virus cases and Argentine ant invasions.

Monitoring Sustainability in Tropical Forests: How Changes in the Spatial Pattern of Reflectance Can Indicate Forest Stands for Biodiversity Surveys

Naikoa Aguilar-Amuchastegui and Geoffrey M. Henebry (Center for Advanced Land Management Information Technologies [CALMIT], School of Natural Resources, University of Nebraska-Lincoln)

Sustainable management of tropical forests has been identified as one of the main objectives for global conservation and management of carbon stocks. Toward this goal, managers need tools to determine whether current management practices are sustainable. Several international initiatives have undertaken the development of criteria and indicators to help managers move towards sustainability. Despite these efforts, the question of how to apply and assess these indicators remains to be answered from an operational, field-based perspective. Field surveys are expensive and time-consuming when management areas are large and in the face of logistical constraints. Thus, there is a need for an approach to prioritization. We seek to determine whether satellite imagery can be used, in conjunction with standard forest inventory data, to identify priority areas for field surveys of indicators of ecological sustainability of tropical forests.

Linking Remotely Sensed Data to Personal Health Records: Ecological Modeling for Individual-Based Prevention of Lyme Disease

John Brownstein (Division of Emergency Medicine, Children's Hospital Boston, Department of Pediatrics, Harvard Medical School)

Ecological models of vector-borne diseases based on remotely-sensed data provide local estimates of human transmission risk. New strategies are needed to translate these detailed measures of spatial risk to disease prevention efforts. Because disease maps may provide individualized risk estimates, we suggest a framework to promote prevention efforts through a personally controlled health record. We use landscape model for residential risk of Lyme disease risk as an example of this approach. The Lyme disease model characterizes peridomestic risk for Lyme disease based on environmental conditions suitable for tick vector populations. Spectral indices were derived from Landsat Thematic Mapper data and provide relative measures of vegetation structure and moisture (wetness), as well as vegetation abundance (greenness). The model was initially developed using entomological data on 337 residential properties in two communities of suburban Westchester County, NY, yielding categories of property-level risk. Validation was subsequently performed by sending surveys to 1300 randomly selected properties in the county. High risk properties were identified with an accuracy of 76%. Extrapolating this model provides risk estimates for peridomestically acquired Lyme disease for all individuals across a region. Through use of a personally controlled health record, this information can then be disseminated to high risk individuals as a health message that provides strong motivation for the use personal protection measures. Targeting individualized health promotion messages based on remote-sensed risk indicators can potentially provide an effective means for improving public health prevention efforts.

Modeling Decadal Variability of Primary Production of the Pacific Ocean

Fei Chai (University of Maine, School of Marine Science), Yi Chao (Jet Propulsion Laboratory, California Institute of Technology), Francisco Chavez (Monterey Bay Aquarium Research Institute), and Richard T. Barber (Duke University, NSOE Marine Laboratory, Beaufort, NC)

The Pacific Ocean exhibits strong variations at decadal time scale, and the changing Pacific climate has direct impact on marine ecosystems. The response of primary production in the Pacific Ocean to decadal climate variability is investigated using a three-dimensional physical-biogeochemical model forced with observed atmospheric surface wind stress and heat flux. The ocean circulation model resolves decadal variations over the past 40 years, such as mixed layer depth and upwelling velocity. The analysis focuses on two important regions, the equatorial upwelling system and the central North Pacific. The modeled primary production and phytoplankton biomass decrease by 10% over the past 40 years mainly due to reduction of upward nutrient flux. In the central North Pacific, the modeled surface nitrate concentration increases after 1976-77 climate shift, which caused by deepening of mixed layer depth and increase of the Ekman pumping velocity. Higher nitrate concentration after 1976-77 enhances primary production in the central North Pacific, which also contributes to higher phytoplankton biomass and therefore elevates chlorophyll level in the central North Pacific.

Decision Support for Western Weed Management

R. Carruthers (USDA-ARS), D. Spencer (USDA-ARS), D. Bubenheim (NASA-Ames), C. Potter (NASA-Ames), M. Kramer (UC Santa Cruz), L. Johnson (Cal State Univ Monterey Bay)

Scientists at USDA-ARS and NASA-Ames will adapt, test, verify, validate and benchmark NASA remote sensing, mapping, and spatial modeling capabilities for critical invasive species management programs. The effort was designed through an interactive scoping process with field users, invasive species regional managers and national coordinating bodies such as the National Invasive Species Council and the Secretary of Agriculture's Office. The study will include spatially explicit invasive species and biological control agent modeling that will involve the use of the Columbia supercomputer at NASA-Ames. In addition, hydrologic modeling will examine the impact of invasive species impact on stream flow and watershed yields. Remote sensing, GIS technology, field assessments and physiological measurements will support the modeling effort. A specialized web-based information delivery system will provide end users with critical information in an accessible, interactive format. The results will be used by field practitioners to assess invasive weed distributions over wide areas, to plan control measures on a watershed or larger basis, and to assess the effectiveness of controls that have been implemented over large areas.

Statewide GIS-Based Landscape Modeling Methodologies for Predicting West Nile Virus Exposure Risk in Mississippi

William H. Cooke (Geosciences Department, GeoResources Institute [GRI], Mississippi State)

West Nile Virus (WNV) represents an emerging infectious disease in the United States and has the potential to impact the entire country. The disease has already had severe impacts on birds and other wildlife as it has moved westward from its point of introduction in New York. Because WNV is apparently carried by migrating birds, there are growing concerns over its impact on wildlife populations and the ripple effects on recreational activities like camping, fishing, and hunting.

Development of a system for predicting, monitoring, and responding to outbreaks of mosquito and tick vectored diseases is a critical need for community well-being including; public health and water management, disaster management, and agricultural competitiveness. Creation of a geospatially-based dynamic monitoring and prediction system that is sensitive to changing environmental, social, and political variables is the ultimate goal. This GIS modeling project compared Map Algebra (Tomlin) with Logistic Regression for mosquito habitat prediction. Mosquito habitat is treated as a surrogate for risk. Weighting processes and final models with validation are presented. Risk estimates for recreation facilities is also presented.

Ecologic Niche Modeling and Differentiation of Populations of Triatoma brasiliensis Neiva, 1911, the most important Chagas' disease vector in northeastern Brazil (Hemiptera, Reduviidae, Triatominae)

J. Costa (Colecao Entomologica, Dept. Entomologia, Instituto Oswaldo Cruz, FIOCRUZ), A.T. Peterson (Natural History Museum and Biodiversity Research Center, University of Kansas, Lawrence, Kansas), and C.B. Beard (Division of Vector-Borne Infectious Diseases, Fort Collins, Colorado, Centers for Disease Control and Prevention)

Ecologic niche modeling has allowed numerous advances in understanding the geographic ecology of species, including distributional predictions, distributional change and invasion, and assessment of ecologic differences. We used this tool to characterize ecologic differentiation of *Triatoma brasiliensis* populations, the most important Chagas' disease vector in northeastern Brazil. The species' ecologic niche was modeled based on data from the Fundacao Nacional de Saude of Brazil (1997-1999) with the Genetic Algorithm for Rule-Set Prediction (GARP). This method involves a machine-learning approach to detecting associations between occurrence points and ecologic characteristics of regions. Four independent "ecologic niche models" were developed and used to test for ecologic differences among *T. brasiliensis* populations. These models confirmed four ecologically distinct and differentiated populations, and allowed characterization of dimensions of niche differentiation. Patterns of ecologic similarity matched patterns of molecular differentiation, suggesting that *T. brasiliensis* is a complex of distinct populations at various points in the process of speciation. Currently, the potential risk of the complex to invade new areas is being evaluated.

Land Surface Phenology and Climatic Variation in the IGBP High-Latitude Transects

Kirsten M. de Beurs and Geoffrey M. Henebry (Center for Advanced Land Management Information Technologies (CALMIT), School of Natural Resources, University of Nebraska-Lincoln)

The International Geosphere-Biosphere Program (IGBP) has delineated five areas that form a northern high-latitude network for the analyses of vegetation and carbon dynamics. We examined the magnitude and significance of changes in the land surface phenologies of ecoregions within these transects using the NASA Pathfinder AVHRR (PAL) dataset. We applied the seasonal Mann-Kendall (SMK) trend test, a robust and nonparametric approach, to determine the significance of trends in NDVI over the five transects. SMK provides a marked improvement over simple but unreliable trend analysis based on linear regression, even though it does not model the trend.

In addition, we modeled the land surface phenology using quadratic or nonlinear spherical models to relate the NDVI data to accumulated growing degree-days (base 0-deg C). Nonlinear spherical models parsimoniously describe the green-up dynamics in taiga and tundra ecoregions. Models for each ecoregion within each transect were fit separately for two time periods (1985-88 and 1995-99) and their parameter coefficient estimates were compared. In ten of 24 ecoregions that comprise 72% of the land area in the transects, the date of the peak NDVI value advanced significantly between the first and the second study periods (range 2-18 days). The progression was more pronounced in North America than in Siberia (weighted average of advance: -9.3 versus -6.3 days).

Understanding of variation and change in land surface phenology is a critical component of global change science. A diversity of datasets, techniques, and study areas has led to a range of conclusions about boreal phenology. We discuss statistical pitfalls in standard analyses and offer a framework to conduct statistically reliable change assessments of land surface phenologies.

The Role of Spectral Imagery for Monitoring & Modeling Transgenic Crop-Pest Interactions

John A. Glaser (U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH)

Crops bioengineered to contain toxins derived from *Bacillus thuringensis* (Bt) are under regulatory scrutiny by USEPA under the FIFRA legislation. The agency has declared these crops to be “in the public good” based on the reduced use of pesticides required for management of these crops. Hence they are environmental assets that are valued for crop protection having significant human health and ecological protection features. From a sustainability perspective, it is important to protect these crops so that society can enjoy long useful lifetimes for these new forms of biotechnology.

The major threat to extended lifetimes is the development of resistance toward the crop in pest populations for which the crop protects. Detection and monitoring of resistance development becomes crucial to avoid any premature crop loss due to pest resistance. Research efforts leading to the development of new detection technology and standardization of more established detection technology are important to the ability to sample for resistance at the field level.

The US crop acreage for Bt corn is about 25+ million acres. Any realistic attempt to sample such a large area for pest resistance is difficult and probably beyond the cost that can be economically endured for resistance management. A new approach to this problem that uses spectral imagery is outlined. Simulation models for pest resistance prediction have been used to portray possible lifetime for these crops and to develop management options to lengthen their useful lifetimes. Verification and validation of the predictive strengths of the models are important to the understanding the utility of these models to assist bioengineered crop management. Spatially explicit models can be enhanced with the incorporation of digital imagery features of the agroecosystem landscape. It is anticipated that these different research elements will be assembled into decision support systems and tools that will enhance the management of transgenic crops. The research program designed to achieve these objectives is built from internal EPA research alliances and external NASA & USDA supported research.

Vulnerability of National Parks to Urbanization: A Regional Analysis in the Eastern United States

S. J. Goetz, C. A. Jantz (The Woods Hole Research Center)

The contemporary pattern of urban development in industrialized countries is increasingly taking the form of low density, decentralized residential and commercial development commonly known as "urban sprawl." The urbanization process poses several threats to the functional integrity of the national parks and protected area network, including fragmentation of the surrounding natural and cultural landscape, geographic habitat isolation, degradation of water quality, and aesthetic impacts on the park visitor's experience. Recently, several geographic data sets have become available that can be used for broad scale vulnerability assessments of National Parks and protected areas. A national data set of modeled impervious surface cover at one-kilometer resolution was used in conjunction with a 500 meter resolution forest cover and U.S. population data to perform a GIS-based assessment identifying parks threatened by urbanization in the eastern United States. The results of this pilot project can be used to further develop methodologies for broad scale vulnerability assessments.

Biospheric Monitoring and Ecosystem Modeling for Decision Support

Keith Golden (NASA Ames Research Center), Ramakrishna Nemani (NASA Ames Research Center), Forrest Melton (California State University, Monterey Bay), Petr Votava (CSUMB), Andy Michaelis (CSUMB), Michael White (Utah State University, Logan), Clark Glymour (Carnegie Mellon University), Steve Running (University of Montana, Missoula), and Joseph Coughlan (NASA Ames Research Center)

With NASA Earth Observing System satellites currently producing over two terabytes of data per day, there is a need for automated systems capable of utilizing EOS data to extract knowledge and information for decision support. Our research has combined biospheric models with remotely sensed data and new computer science techniques to develop a biospheric monitoring and forecasting system. The Terrestrial Observation and Prediction System (TOPS) is an operational system and has capabilities for rapid access, analysis, and utilization of multiple large, heterogeneous data sets. Using TOPS, we are implementing models from multiple domains to develop applications including vineyard irrigation management, mapping of wildland fire risk, tracking vegetation phenology and net primary production anomalies, and mapping vector abundance and disease transmission risk. TOPS is currently being used to produce nowcasts and forecasts of biospheric conditions from local to global scales; products and images are distributed via the web and available for use by scientists, educators, and decision makers.

Climate Change and Intertidal Biogeography: Coupling Remote Sensing Data to Thermal Physiology Across a Cascade of Scales

Brian Helmuth, Sarah Gilman, David S. Wethey, Venkat Lakshmi and T. Jerry Hilbish (University of South Carolina, Departments of Biological Science and Geological Sciences, Columbia, SC)

Intertidal organisms are often assumed to live close to their thermal limits, and thus have emerged as potential early indicators of the effects of climate change on natural ecosystems. Yet, patterns in body temperature during low tide are often counterintuitive because of the interactive effects of climate, tidal regime, and organism characteristics on heat flux. Using biomimetic instruments designed to match the thermal characteristics of rocky intertidal mussels and barnacles, we have recorded *in situ* temperatures at a series of 20 sites along the Pacific coast of the United States. We then created a thermal energy budget that uses ground-based, buoy, and NASA remote sensing data, to predict intertidal animal temperatures to within a few degrees C. Results indicate that while water and air temperature serve as important environmental drivers of animal body temperature, neither is sufficient as a proxy for animal temperature. For example, whereas maximum air temperatures are, on average, 7-8 deg C different from maximum body temperature, our model predictions generally have an error of only 2.5 deg C. Estimates generated from satellite data are approximately the same level of accuracy as those produced using ground-based data. Analyses of elasticity (the proportional change in body temperature relative to change in environmental input) show that at upper intertidal levels responses to body temperature are less than 1 for both air and water temperature. That is, a 1 deg C increase in air temperature generally causes less than a 1 deg C increase in maximum body temperature. Importantly, however, elasticity changes with tidal height and between sites along the west coast. Our results thus suggest that responses to climate change in rocky intertidal ecosystems will be highly site-specific, and that the relative importance of air and water temperature as drivers of intertidal body temperature varies between sites. Our model provides a mechanism for predicting the site-specific impacts of climate, and climate change, on species range boundaries of several ecologically key species at sites worldwide. We have surveyed the current northern and southern geographic limits of mussel species in Japan, and have begun to map species distribution in relation to predictions based on remotely sensed data.

Landscape Trajectory Analysis: Spatio-temporal Dynamics from Image Time Series

Geoffrey M. Henebry (Center for Advanced Land Management Information Technologies [CALMIT], School of Natural Resources, University of Nebraska-Lincoln) and Douglas G. Goodin (Department of Geography, Kansas State University)

Landscape dynamics can be revealed through analysis of image time series. The temporal development of spatial patterns holds significant information about ecosystem processes. Yet, the tools for the characterization of spatio-temporal structure are few. We describe some of the challenges facing spatio-temporal analysis and demonstrate a method for identifying and measuring pattern in image time series using a standard data product, the USGS maximum AVHRR NDVI biweekly composites for 1990-2000. We selected six distinct and diverse ecoregions as delineated and recently revised by Omernik and colleagues. The analysis extracts expectations of landscape spatial pattern during the growing season. The resulting landscape trajectories can serve as building blocks for the development of operational environmental monitoring and ecological forecasting systems.

Delineating and Resolving Ecoregions Statistically: Sorting Out Contexts for Wildlife Habitat

Geoffrey M. Henebry (Center for Advanced Land Management Information Technologies [CALMIT]), William W. Hargrove (Environmental Sciences Division, Oak Ridge National Laboratory), Forrest M. Hoffman (Environmental Sciences Division, Oak Ridge National Laboratory), Brian C. Putz (CALMIT) and James W. Merchant (CALMIT)

Ecoregions are partitions of geographic space that use to some kind of model of environmental patterns and process to delineate these partitions. That model may be motivated theoretically or empirically. As with any type of map, the form of the ecoregions will necessarily reflect the intentions of the mapmaker. The suitability of a particular ecoregionalization to answer a specific question will thus rely on the degree of correspondence between the question of interest and the data and model used to produce the ecoregionalization. Here we explore how input data and thematic resolution interact to produce alternative ecoregionalizations of Nebraska. Specifically, we are interested in assessing the suitability of including current land cover information into an ecoregionalization to support wildlife-habitat relationship modeling and forecasting of range distributions.

Pixel Nested Sampling Design: A New Approach for Forecasting Landscape-Scale: Ecology, Model, and Map

Mohammed A. Kalkhan (Natural Resource Ecology Laboratory, Colorado State University)

The integration of spatial information (remote sensing and GIS) with field data is an important, cost-effective tool for assessment of landscape environments and resource management. Current research sampling protocols for collection of field data lack the direct linkage between satellite imagery and ground location. Thus, there is a need to link field data or correlate sampling designs site with respect to satellite resolution. This can be accomplishing by using a new pixel nested plot (PNP) sampling design. The plot design is based on different nested-levels of pixel resolutions such as 15m x 15m with 5m2 and 1m2 sub-pixel resolutions, or 20m x 20m with 6.67m2 and 2m2 sub-pixel resolutions, or 30m x 30m with 10m2 and 3m2 sub-pixel resolutions. This paper provides an example of ongoing research at Rocky Mountain National Park (RMNP), Colorado and Grand Teton National Park (GRTE), Wyoming. We established about 120 plots of 15m x 15m cover an area about 48,500 ha of the east central region of RMNP. For our study site at RMNP, we collected field data on plants and soil characteristics, forest characteristics and parameters such as growth, health, fire and fuel loading (variability and characteristics), and thematic mapping accuracy protocols. Then, the data was integrated with spatial information and spatial statistics to spatially model and map landscape characteristics. At GRTE study area, we will use 20m x 20m of PNP size to collect data similar to RMNP study site and compare it with existent data collected within GRTE. The uniqueness of these new sampling designs is that they provide an opportunity to address multiple resource management tasks, including forecasting landscape environments, by better linking to correlate satellite pixel resolution with ground field size locations.

Forecasting Wetlands Along the Texas Coast: Integration of Spatial Information and Geospatial Statistics

Mohammed A. Kalkhan (Natural Resource Ecology Laboratory, Colorado State University) and Ricardo D. Lopez (U.S. EPA's Office of Research and Development [ORD], Office of Research and Development)

We present a primly results ongoing study that utilizes a landscape approach to assessing ecological/hydrologic functions and related human values of depressional wetlands along coastal Texas, considered to be vulnerable to human disturbance. Our research approach integrates remotely sensed data, GIS data, field data, and a priori knowledge of depressional wetlands to estimate their extent; connectivity to other waterbodies and ecosystems; and their ecological/hydrologic functions. This approach focuses on locating and quantifying the cumulative area of depressional wetlands, invasive species, and geospatial model the ecological/hydrologic functions and services of wetlands. This research will increase the cooperative exchange of knowledge between governmental agencies [e.g., U.S. Environmental Protection Agency (USEPA), NASA- Invasive Species Program, USGS- National Institute of Invasive Species, and the National Park Service (NPS- Inventory and Monitoring Program {I & M}) - USGS- NPS Vegetation Mapping Program], and educational/ research institutes [e.g., Natural Resource Ecology Laboratory (NREL) at Colorado State University, and others. The study uses remote sensing data types, such as Landsat ETM+ and other high spectral/spatial resolution sensors to assess wetlands at a landscape scale. Further, this study will be used as the foundation of long-term monitoring of wetlands, specifically focusing on depressional wetlands throughout the USA. These techniques are particularly applicable to the detection and monitoring of invasive species in wetlands, carbon-nitrogen cycling in the biosphere, forest characteristics, forest health, and forest fuel variability parameters, and they provide an ideal ecosystem type for hypothesis-testing regarding the influence of human activities on these four main topics. This approach is a unique departure from other traditional statistical models of the environment, in that it provides a unique tool that links field data, remote sensing, and geospatial-statistical analyses in a way that could be used in a client-oriented model (e.g., a decision support system and a self-guided web-link system with a windows-based graphic user interface). The tool that will result would facilitate the production of predictive spatial maps, would be accessible by a variety of end-users, and could be used from any location connected to the Internet. Current empirical statistical models may be limited with respect to: (1) providing a clear spatial description of the environmental characteristics of interest; (2) flexibility of use with new and emerging remote sensing data types; and (3) accessibility for individuals who do not possess specialized geostatistical backgrounds/education. Thus, the research team will focus on providing an educational opportunity to new scientists and graduate students who can provide knowledge and perspective on the development of these tools.

Malaria Modeling and Surveillance for the Greater Mekong Subregion

Richard Kiang (NASA Goddard Space Flight Center) and Farida Adimi, Valerii Soika, Joseph Nigro (Science Systems and Applications, Inc.)

At 4,200 km, the Mekong River is the tenth longest river in the world. It directly and indirectly influences the lives of hundreds of millions of inhabitants in its basin. The riparian countries - Thailand, Myanmar, Cambodia, Laos, Vietnam, and a small part of China - form the Greater Mekong Subregion (GMS). This geographical region has the misfortune of being the world's epicenter of falciparum malaria, which is the most severe form of malaria caused by Plasmodium falciparum. Depending on the country, approximately 50 to 90% of all malaria cases are due to this species.

In the *Malaria Modeling and Surveillance Project*, we have been developing techniques to enhance public health's decision capability for malaria risk assessments and controls. The main objectives are: 1) identifying the potential breeding sites for major vector species; 2) implementing a dynamic transmission model to identify the key factors that sustain or intensify malaria transmission; and 3) implementing a risk algorithm to predict the occurrence of malaria and its transmission intensity. The potential benefits are: 1) increased warning time for public health organizations to respond to malaria outbreaks; 2) optimized utilization of pesticide and chemoprophylaxis; 3) reduced likelihood of pesticide and drug resistance; and 4) reduced damage to environment.

Environmental parameters important to malaria transmission include temperature, relative humidity, precipitation, and vegetation conditions. These parameters are extracted from NASA Earth science data sets. Hindcastings based on these environmental parameters have shown good agreement to epidemiological records.

Access to Synthetic Aperture Radar (SAR) Data from the Alaska Satellite Facility

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The Alaska Satellite Facility (ASF) downlinks, archives, processes and distributes Synthetic Aperture Radar (SAR) data to NASA-approved researchers and U.S. government agencies. The EOS Data Gateway (EDG) provides the ability to examine the ASF catalog for data and perform searches by satellite, time, and/or geographic region. Once a researcher becomes an approved NASA investigator through a simple proposal process, data in the ASF catalog can be ordered as a Level 0 or Level 1 product at no cost to the researcher. The extensive archive contains SAR data acquired by the ERS-1, ERS-2, JERS-1, and RADARSAT-1 SAR sensors. As SAR sensors image day or night, regardless of cloud cover, many regions of interest have extensive historical data available. Arctic researchers can find SAR data for Alaska; the Arctic Ocean; the North Pacific Ocean; and the Bering, Beaufort and Chukchi Seas from September 1991 to the present. Antarctica researchers looking for SAR data of the continent and surrounding seas can find data from December 1994 to the present in the archive. Data from elsewhere in the world, including the interferometric collection over Greenland, may be found in the archive as well. Mosaics of the Amazon Basin and Boreal North America are available on CD and DVD; the source data for the mosaics is available from the archive. The ASF User Services Office (USO) is available to assist with the proposal process, data searches, and to answer questions about using SAR data. In addition, USO can guide researchers to the technical experts within ASF who can assist in utilizing the data in modeling applications.

Modeling Schistosomiasis Risk Zones in East Africa Using Remote Sensing and GIS

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Introduction: Environmental characterizations based on RS/GIS methods, as compared to classical laboratory and field studies, allows a given disease agent-intermediate host-final host biocoenose to 'define itself' as to environmental preferences and limits of tolerance based on records of its known distribution and abundance. Results can then be extrapolated, within a GIS, to develop spatial models of disease risk in areas where a paucity of data exists.

Materials and Methods: Point data on parasite prevalence and snail hosts were geolocated in a GIS of the Horn of Africa. The GIS was constructed using: 1) feature data (point, polygon, line) on agroclimatic parameters, hydrology, and population-political-infrastructure data, and 2) raster data on topography, land use, and satellite sensor data on vegetation index (NDVI) and land surface temperature (LST). GIS disease risk models were developed using water budget analysis, reported minimum-optimum-maximum thermal limits, NDVI/LST ranges and human host populations for the *Schistosoma mansoni-Biomphalaria pfeiffei* and *S. haematobium-Bulinus* parasite-snail host systems. Schistosomiasis records consisted of a comprehensive survey of potential snail hosts in southern Kenya, and prevalence data from WHO.

Results: If *B. pfeifferi* or *Bulinus* spp. was present it was assumed *S. mansoni* or *S. haematobium* transmission was possible, respectively. NDVI, a surrogate moisture regime, and LST, a surrogate of thermal regime, were then used to prepare annual, wet season and dry season composite maps; map queries based on ranges of NDVI and LST within 5-km circular buffers centered on 212 snail survey sites were used to depict areas where criteria of both NDVI and LST threshold values were met. GIS map query analysis resulted in a representation of the potential distribution zones of the intestinal and urinary forms of schistosomiasis. The relative risk for disease propagation and transmission within this distribution zone was defined using a long-term normal climate surface grid to develop a 'growing degree day-water budget' (GDD-WB) model that defined a suitability gradient in the environment. GDD were accumulated if Rain/PET >0.5 for a given month, with one potential generation of *S. mansoni* or *S. haematobium* when 267 GDD and 293 GDD was reached in a year, respectively. More accurate modified generations/year models risk maps were developed by multiplying GDD x Rain/PET to better account for moisture availability. *B. pfeifferi* reproduction is reportedly sterilized by >27-deg C for >2 weeks, a criteria used to create a 'mask' overlay of unsuitable areas, as was elevation (>2200m) due to insufficient annual accumulated GDD (>14.2oC). For *Bulinus*, 28.5-deg C was considered the upper thermal limit.

Conclusions: Use of NDVI/LST sensor data from earth observing satellites as surrogate climate data enables maps to be constructed of the potential distribution zones of schistosomiasis. Within this distribution zone, relative risk classes can be defined using GDD-water budget analysis, with the unique thermal-hydrological preferences and limits of tolerance of individual parasite-vector systems, to define the 'permissiveness' of an areas for supporting the environmental niche of disease agents in the landscape using GIS/RS tools. Maps created can be used to guide appropriate control program interventions.

Using the Normalized Differential Wetness Index to Map Leaf Area Index and Evapotranspiration along the Middle Rio Grande Riverine Corridor

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This work creates temporally and spatially explicit data layers of leaf area index (LAI) and evapotranspiration (ET) in forested habitats along the middle Rio Grande using the normalized differential wetness index (NDWI). NDWI normalizes near infra-red (NIR) with mid infra-red (MIR) reflectance. This index replaces the commonly used normalized differential vegetation index (NDVI), which normalizes near NIR with red reflectance. NDVI is ineffective when LAI measurements exceed 2 because chlorophyll absorbs red light within the first leaf layer while NIR and MIR penetrate through eight leaf layers. Landsat 7 and SPOT measurements of NDWI represent the water per unit area of vegetation in forested habitats. Because of this relationship, plot scale measurements of LAI and ET correlate well with NDWI in cottonwood, saltcedar, and willow canopies. Plot scale LAI measurements were measured both in the summer and winter with the LAI-2000 Plant Canopy Analyzer (LI-COR Inc., Lincoln, Nebraska). The winter LAI measurements represent stem area. Saltcedar and willow canopies contain a greater amount of stem area per unit area of leaves than cottonwood canopies. In saltcedar and willow canopies the actual leaf area equals the summer LAI minus 2/3 of the stem area (i.e., winter LAI). Cottonwood sites, however, relate best to NDWI when the stem area is not subtracted. Plot scale ET is measured at 3-D eddy covariance towers in cottonwood and saltcedar sites. ET relates well to NDWI when corrected for day length and temperature extremes.

Assessing the Influence of Land Cover and Environmental Temperature on the Incidence of West Nile Virus in Southern Ontario, Canada.

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West Nile virus (WNv) was first identified in North America in and around New York City during the summer of 1999. The first avian cases in Canada were found in the summer of 2001, with human cases being identified in the summer of 2002. Land cover derived from Landsat7 imagery using a progressive generalization classification was used in conjunction with known incidence of human WNv cases in the Greater Toronto Area. The purpose of this research was to test if there was any relationship between specific land cover classes and WNv infections. This relationship was tested using a quadrant analysis using ArcView GIS and a Poisson regression using SAS. The results of this analysis found a strong relationship between the land cover class “wetland” and the rate of human infection from WNv in the Greater Toronto Area. The amount of “wetland” pixels in a quadrant was subsequently used to predict high-risk areas.

Environmental temperature has been suspected to play a role in the intensity of WNv outbreaks in Southern Ontario. Laboratory based experiments have shown that the extrinsic incubation period (EIP) of WNv in mosquitoes is largely regulated by temperature, with conversion rates ranging from 4 - 28+ days with higher temperatures providing a shorter EIP. If environmental temperature thresholds in a region are not met, the virus will be unable to replicate efficiently in mosquito populations, and the risk to humans will be dramatically reduced. In order to measure environmental temperatures we have developed a method of calculating WNv degree-days. WNv degree-days are based upon daily data from weather stations and are adjusted based upon the observations of the EIP in laboratory studies. We have found that this measure has a higher correlation with the incidence of WNv infections than degree-days or other existing measurements of environmental temperature.

Urban Sprawl Impacts on Net Primary Production in the US

Cristina Milesi (NRC Associate, NASA Ames Research Center) and Christopher Potter (NASA Ames Research Center)

In the process of urbanization, portions of land previously covered by cropland, pastures or forests are replaced by impervious surfaces for roads, buildings, and infrastructure, subtracting it, most often in a permanent way, from the processes of photosynthesis and respiration. In the American urban landscape, this loss is typically counterbalanced to some extent by the intensive management of the remaining vegetation (lawns, trees, etc.), which is pruned, irrigated, and fertilized. Although this results in urban areas maintaining a significant net primary productivity, often higher than that of the pre-urban vegetation, these ecosystems are generally excluded from the analysis of the contribution of terrestrial ecosystems to the carbon cycle. Here we analyze a decade of urban land development in the conterminous US inferred from the nighttime city lights data from DMSP/OLS and present an assessment of the contribution of urban areas to the continental net primary productivity using MODIS data and the NASA-CASA model.

Modeling and Mapping Evapotranspiration on Western U.S. Rivers by the Enhanced Vegetation Index from MODIS and Data from Eddy Covariance and Bowen Ratio Flux Towers

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We combined remote sensing and ground station measurements to estimate evapotranspiration (ET) by riparian vegetation, including the invasive species, saltcedar (*Tamarix ramosissima*), over large stretches of western U.S. rivers. ET measured from nine eddy covariance or Bowen ratio flux towers set in the five major plant types on the Middle Rio Grande, Upper San Pedro River, and Lower Colorado River was strongly correlated with Enhanced Vegetation Index (EVI) values from the Moderate Resolution Imaging Spectrometer (MODIS) sensor system on the NASA Terra satellite, and with maximum daily air temperatures (Ta) measured over the canopy at each tower site. Sixteen-day composite values of EVI and Ta were combined to predict ET across species and tower sites (r2 = 0.74). The relationship was then used to estimate ET for 2000 - 2004 over large river reaches on each river system, using MODIS EVI values and Ta from meteorological stations. Measured and estimated ET values for large river stretches tended to be moderate when compared to historical, and often indirect, estimates and ranged from 851 - 874 mm yr-1 across river systems. ET of individual plant stands ranged more widely. Cottonwood (*Populus* spp.) and willow (*Salix* spp.) stands generally had the highest annual ET rates (1100-1300 mm yr-1), while mesquite (*Prosopis glandulosa*) (400-1100 mm yr-1) and saltcedar (*Tamarix ramosissima*) (300-1300 mm yr-1) were intermediate, and giant sacaton (*Sporobulus wrightii*) (500-800 mm yr-1) and arrowweed (*Pluchea sericea*) (300-700 mm yr-1) were lowest in ET. ET rates estimated flux towers and by remote sensing in this study were much lower than values estimated for riparian water budgets using crop coefficient methods for the Middle Rio Grande and Lower Colorado River. Contrary to expectations, ET of saltcedar was low to moderate.

Development of Diagnostic and Predictive Bio-Physical Models Dolphin Fish and King Mackerel.

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The ultimate goal is to provide diagnostic and predictive bio-physical models to fisheries resource managers and policy makers. The functional relationships that exist between two economically important pelagic fish (king mackerel, *Scombermorus cavalla* and dolphin fish, *Coryphaena hippurus*) and their coastal and oceanic ecosystems are being determined and characterized. Of particular interest is the linkage of the information across different spatial scales (local, regional, and continental), as well as, smaller, in-situ spatial scales.

Oceanographic data products derived from the satellite data (sea surface temperature and ocean color) are being used to identify and define quantitative relationships between the distribution of fish and their ecosystems. Evaluation of the development and coherence in time and space of fish and their ecosystems. Evaluation of the development and coherence in time and space of such physical and chemical discontinuities as ocean frontal boundaries (temperature, chlorophyll, turbidity, etc.) related to coastal plumes, as well as, Gulf Stream circulation features (e.g., meanders and eddies) is a critical aspect of this research. Part of this study is the development of image processing and visualization tools to evaluate and merge data that exist in different spatial and temporal resolutions, as well as, different spectral bands.

The partial results of the first year of this three year study to determine which environmental parameters can be used to forecast the effects of climate variability on dolphin fish (*Coryphaena hippurus*) and king mackerel (*Scombermorus cavalla*) in the oceanic waters off South Carolina and coastal waters off Tampa, FL, respectively will be shown. Emphasis will be given to the challenges of using satellite data for deriving ecological models.

Assessing Tamarisk in Nevada Using Satellite Imagery: A NASA DEVELOP Internship Project

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Tamarisk (*Tamarix* sp.) is a prevalent invasive species that infests the riparian zones in the western United States. Mature salt cedar plants are resistant to high stress environments and drought conditions mainly due to their extensive root systems. This has altered hydrology patterns, decreased recreational water use, and changed regional plant diversity in some areas. Many federal and state agencies have implemented programs for monitoring and controlling the spread of salt cedar, however, a scientifically based invasive species data collection protocol that combines field data with remote sensing and GIS methods is conspicuously absent from many land management plans; many less accessible areas are ignored during standard mapping studies. The DEVELOP student research group at NASA Ames Research Center has designed and implemented an invasive species sampling protocol that integrates field data collected in the state of Nevada, environmental variables including elevation, groundwater and percent coverage of Tamarisk, water areas, a GIS, and Landsat TM imagery. The results of this project were a map summarizing an estimate of Tamarisk presence throughout the study area, as well as a “predictive” map deducing which regions might be more susceptible to Tamarisk group.

WhyWhere: “Where is it and Why?” Prediction and Explanation of Global Location Data.

David R.B. Stockwell (San Diego Supercompter Center, University of California, San Diego)

The aim of the Biodiversity Insight Systems project is provide systems for global prediction and explanation of biodiversity data.

With WhyWhere, a user can enter the latitude and longitude of a set of locations (say species locations) anywhere on the earth’s surface or marine environment and obtain: 1) a fine-scale predictive map, 2) a set of geographic raster data sets suitable for inout into a GIS, and 3) potential explanations for the distribution of the points. These functions will be of interest to a wide range of such physical and chemical discontinuities as ocean frontal boundaries (temperature, chlorophyll, turbidity, etc.) related to coastal plumes, as well as, Gulf Stream circulation features (e.g., meanders and eddies) is a critical aspect of this research. Part of this study is the development of image processing and visualization tools to evaluate and merge data that exist in different spatial and temporal resolutions, as well as, different spectral bands.

The partial results of the first year of this three year study to determine which environmental parameters can be used to forecast the effects of climate variability on dolphin fish (*Coryphaena hippurus*) and king mackerel (*Scombermorus cavalla*) in the oceanic waters off South Carolina and coastal waters off Tampa, FL, respectively will be shown. Emphasis will be given to the challenges of using satellite data for deriving ecological models.

Environmental Change and Human Health in the Tropics: Deforestation and Malaria in Brazilian Amazonia

John Sydenstricker-Neto (Department of Development Sociology, Cornell University), Max J. Pfeffer (Department of Development Sociology, Cornell University), and Stephen D. DeGloria (Department of Crop and Soil Sciences, Cornell University, presenting author)

Tropical deforestation has disturbed ecosystem functioning and impoverished rural livelihoods. Economic development such as investment in roads, hydroelectric dams, mining complexes, and settlement projects has produced environmental stress and exposed specific social groups to health consequences of natural systems disruptions. Knowledge of human health-environment relationships within Brazilian Amazonia is limited. There is a need to better understand the extent, patterns, and determinants of land cover-change and its impacts on human health. This poster presents initial findings on the relationships between malaria and deforestation in Machadinho D'Oeste, Brazil. Drawing from field research including household socioeconomic survey, qualitative interviews, and land-use maps derived from satellite imagery the study shows that environmental changes have direct and severe impacts on human health. Improved knowledge and redesign of approaches and policies are necessary to minimize environmental degradation and improve the effectiveness of health care providers in dealing with regional environmental health problems like malaria.

The ORNL DAAC: A Source for Biogeochemical and Ecological Data

Larry D. Voorhees, Robert B. Cook, B. Timothy Rhyne (Oak Ridge National Laboratory)

The Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) archives and distributes terrestrial biogeochemical dynamics data collected as part of the NASA's Earth Observing System (EOS) Program. The DAAC's 700+ data sets center around three core activities: (1) field campaigns, (2) validation of remote sensing products, and (3) terrestrial ecosystem modeling. Field campaigns combine ground-, aircraft-, and satellite-based measurements of biogeochemical features in specific ecosystems over a few years. Field campaign, focus on a particular issue or set of issues and are crucial to providing an integrated understanding of biogeochemical dynamics that can be extended across spatial and temporal scales. The ORNL DAAC supports the validation of remotely sensed measurements by compiling data, such as net primary productivity (NPP) and leaf area index (LAI), from global test sites for comparison with remote sensing products. Realistic models that simulate ecosystem properties and processes are needed to improve our understanding of the structure and function of these ecosystems. Biogeochemical dynamics data, such as those available from the ORNL DAAC, can be used to parameterize and validate terrestrial ecosystem models at local, regional, and global scales. Although our efforts focus on NASA-funded data products, we also hold selected biogeochemical dynamics data collected by non-NASA researchers worldwide. Data at the ORNL DAAC are available to the global change research community, policy makers, educators, and the general public at no charge.

Architecture for Automated Regional Biospheric Monitoring and Forecasting: Case Study - California

Petr Votava (California State University, Monterey Bay), Andy Michaelis (CSUMB), Ramakrishna Nemani (NASA Ames Research Center), and Forrest Melton (CSUMB)

While global modeling and data analysis efforts such as MODIS are important for understanding Earth's ecosystems, these efforts tend to generic and often not applicable at local scales. There are numerous reasons for that, from data availability to computational complexity and lack of general models that perform equally well all over the world. However, if we break up the world into a set of smaller regions, we can achieve the desired quality by obtaining additional data from sources not available anywhere else, yet at the same time significantly decreasing the data volume requirements. We can also exploit the "fine-tuning" of models with respect to the specific region, and thus improve the quality even further.

We present a prototype system that was developed to automate biospheric monitoring and forecasting in California. In this system, we bring together satellite data (34 MODIS products from both Terra and Aqua), climate data (station networks and gridded data), soils, terrain, population as well as number of models to provide a comprehensive look at the state of the ecosystem in California. In order to provide timely responses to extreme events, we are also integrating real-time satellite data from the MODIS Direct Broadcast system. The responsiveness, failover and scalability are provided through database replication and parallel processing techniques. Because the architecture is fairly flexible, we aim to deploy separate systems (both hardware and software) for other regions of interest. This should eventually enable us to provide better analysis at continental or even global level.

Forecasting species dispersal: Methods using remote sensing and landscape simulation models

Fred Watson, Wendi Newman, Simon Cornish, Thor Anderson, Ryan Lockwood, Jon Detka, Rick Wallen, Susan Alexander, PJ White, Bob Garrott (California State University, Monterey Bay)

We are developing data, models, and algorithms in support of prediction of wildlife responses to landscape-scale ecosystem changes. This poster illustrates an improved algorithm for describing animal space use and movement based on historic wildlife data, and remote sensing and modeling of their habitat. The example shown is for bison in Yellowstone National Park - whose use of space outside the Park is controversial, and whose future is predicted to depend on human management of the landscape.

The Terrestrial Observation and Prediction System Soil Water Forecasts: Controlling Mechanisms and Error Propagation.

Michael A. White (Utah State University) and Ramakrishna R. Nemani (NASA Ames Research Center)

Forecasts of the states and fluxes of terrestrial ecosystems are an increasingly important tool for a large fire, famine, irrigation, energy, recreation, and agriculture community. A detailed understanding of the relative importance of vegetation phenology and meteorology, two of the main forcings of ecosystem forecasts, and the likely impact of errors in phenological and/or meteorological forecasts are required prior to management implementation. Using the terrestrial observation and prediction system (TOPS) and 1982-1997 leaf area index (LAI) and meteorology for the conterminous United States, we tested the relative importance of interannual variability in meteorology and LAI for soil water simulations. In nearly all cases, meteorological variability influenced simulations far more than did LAI; effects of ignoring realistic variability in either variable were most pronounced in arid, low LAI regions. We then identified the critical meteorological forecast errors in temperature and precipitation that were required to generate statistically significant differences in one-week soil water forecasts. Temperature critical errors approached 10C in winter but were only about 2-3C in summer. Precipitation critical errors were much more constant throughout the year and were usually less than 1 cm (error in weekly total precipitation).

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