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MEMORANDUM

TO:	Participants of the USA-National Phenology Network (NPN) Workshop, August 24-26, 2005, Westward Look Resort, Tucson, AZ Members of the USA-NPN Implementation Team
FROM:	Julio Betancourt, USGS & University of Arizona, and Mark Schwartz, UW-Milwaukee
DATE:	July 5, 2006
SUBJECT:	UPDATE ON PROGRESS- NATIONAL PHENOLOGY NETWORK

Ten months have passed since we met in Tucson to begin planning and organizing a National Phenology Network, and we wanted to update you on the steady and exciting progress made since the August 2005 workshop. As a result of positive feedback from the USGS (details below) and their interest in offering a financial commitment to the NPN, we are hoping to have a national coordinating office funded and an executive director hired and located by Fall 2006. Our goal is to start making systematic phenological observations at the national level by growing season 2007. We invite all of you to jump back in to volunteer your time, ideas and energy to the National Phenology Network, which is increasingly described as an "*idea whose time has come*."

Below is a blow-by-blow description of the progress made, including important links (in blue) or email attachments (in red).

- The summary of the August 2005 Workshop was published in the 12/05 issue of EOS http://www.uwm.edu/Dept/Geography/npn/meetings/2005/betancourt_etal_2005.pdf
- Brad Reed organized session on *Land Surface Phenology: Characterization, Modeling, and Analysis of Change* at the December 5-9, 2005, AGU Fall Meeting in San Francisco, CA,
- Eric Post and David Inouye have recruited authors and manuscripts for a Special Feature on phenology for the journal *Ecology*. Manuscripts are due July 6, 2006.
- An Implementation Team of 27 members was formed to canvas key disciplines, federal agencies, and environmental networks. The list of Team members is available at: http://www.uwm.edu/Dept/Geography/npn/pdf/npn_it.pdf. We recently added another member, Gary Frazier from U.S. Fish and Wildlife Service.
- The Implementation Team met at Westward Look Resort, Tucson, on March 22-24 to begin drafting an Implementation Report. Most of the writing happened before the meeting,

resulting in a 60-page, single-spaced draft ms. The report will be prepared for formal publication by November 1, 2006, pending key developments outlined below.

- At the March meeting, the Implementation Team produced an abbreviated version of the report for use in recruiting financial support for the network. We encourage you to download and read this document http://www.uwm.edu/Dept/Geography/npn/meetings/2006/towards_a_usa-npn.pdf
- The Implementation Team discussed the need for a full-time Executive Director and national coordinating office for USA-NPN, and directed USGS Team members (Julio Betancourt, Brad Reed, Mike Dettinger, Jack Waide, Bruce Jones, and DeWayne Cecil) to approach USGS officials for financial support. The Team drafted a mock job announcement for the Executive Director position (Attachment_1_Mock_Job_Announcement).
- On June 12, 2006, Julio, Mike, and Brad traveled to USGS National Headquarters in Reston, VA to give a presentation on USA-NPN and and to request that USGS consider supporting a national coordinating office. The presentation can be downloaded directly from http://www.uwm.edu/Dept/Geography/npn/graphics/index.html
- USGS officials, including the Associate Directors for each of the disciplines in the bureau (water, biology, geology, geography, and informatics) responded to the presentation favorably (Attachment_2_USGS_MEMO). The Chief Scientists for each of the disciplines were asked to offer recommendations to be presented at the USGS Budget Planning Committee meeting on July 6, 2006. The Chief Scientists met on June 23, and have agreed to recommend support.
- Julio gave the presentation again at the USGS Global Change Sciences Workshop in Denver on June 26. On the following day, both the Acting Director of USGS, Pat Leahy, and DOI Deputy Assistant Secretary for Water and Science, Tim Petty, discussed the NPN in their keynote talks at this workshop. This is a positive sign.
- On July 3, 2006, the Deans of the Colleges of Agriculture and Science, University of Arizona, wrote a letter to USGS officials, offering free space and other resources, pending a business and staffing plan for the national coordinating office (Attachment_3_University_Arizona_letter).
- In May 2006, Mark Schwartz received internal funds from the University of Wisconsin-Milwaukee. This grant provides release time and other support that will allow Mark to:1) plan/manage/attend semi-annual NPN Implementation Team meetings; 2) do quality control (QC) processing/documentation on the existing national lilac phenology database, as well as develop and QC a similar national honeysuckle phenology database from existing data; 3) collect and organize the information necessary to develop a national phenology metadatabase, linked to the NPN web page; 4) maintain specialized energy balance (since 2002) and phenology (since 2000) data collection at the UW-Milwaukee Field Station, which will be critical for future research projects; and 5) develop collaborative research proposals to pursue other prospective funding opportunities related to initial NPN infrastructure development.
- On May 30, 2006, the National Phenology Network was written up in USA Today. In response to this media report on NPN, Mark received about 50 registrations for new public observers. http://www.usatoday.com/weather/climate/2006-05-29-spring-blooms_x.htm
- On July 3, 2006 Mark Schwartz, Susan Mazer, Stephen Baenziger (High Plains Initiative, Univ. Nebraska), Julio Betancourt, David Inouye, Brad Reed, Mike Dettinger, Carol Brewer (University of Montana), Bev Law (Ameriflux and Oregon State), and Bob Waide (LTER)

submitted a $500K, 5-yr proposal to NSF for a Research Coordination Network in the Biological Sciences focused on NPN (Attachment_4_NSF_RCN_Proposal).

- Through Arnold Van Vliet and Nauurkalendar, the Netherlands will contribute a Ph.D. student, Sara Mulder, to help with NPN organization and implementation. Sara is funded by the Fulbright Scholar Program and other scholarships; she will use the experience to develop a Ph.D. thesis focused on the ecological and socio-economic relevance of phenological monitoring and research. We are particularly interested in the exchange of phenological methodologies, data and techniques between the Netherlands and the U.S.A. and in learning from the Dutch and other European networks how to successfully engage 'citizen science.' Sara will spend September 2006 through February 2007 in the U.S., bouncing between Tucson, Milwaukee, Lincoln, Santa Barbara, and Washington, D.C. We are hoping to bring Arnold to the U.S. for the Washington, D.C. leg of Sara's visit. The intent would be to for Arnold, Sara, and the NPN Executive Director to visit federal programs involved in global monitoring programs, including Global Earth Observation System of Systems (GEOSS), Global Climate Observing Systems (GCOS), and Global Terrestrial Observing Systems (GTOS), and make a pitch for support to enable phenological monitoring at the international level.

If all works out well with USGS, we hope to have a full-time Executive Director and a national coordinating office by year's end. Some tasks that need to be completed include:

- A formal data management plan (John Gross has offered to take the lead and small workshop may happen in late summer/early fall)
- A formal education and outreach plan (Carol Brewer and Susan Mazer have offered to take the lead)
- A fully-vetted and justified list of target species and protocols for the U.S. (Julio Betancourt has started on this, but will need help to complete it)
- Organized efforts to develop state or regional phenology networks (Arizona is talking about starting one, but we'll need other states and regions to initiate other local and regional efforts)
- Mark Schwartz is looking to expand the lilac and honeysuckle networks, and is looking for volunteer observers, particularly at long-term weather stations, biological stations, or agricultural stations

Please let us know if you are interested in helping with these or any other assignments. There are still a lot of pieces that need to be in place, but we are truly excited that NPN will soon become a reality.

Mock Job Announcement

Executive Director – National Phenology Network

The U.S. Geological Survey is recruiting for an Executive Director for the USA-National Phenology Network (NPN). The USA-NPN will produce tangible scientific and societal benefits by providing phenological information at local to continental scales that can be used to (1) understand the role of the timing of life cycle events in the biosphere and (2) guide a wide range of practical decisions made routinely by individual citizens, industry, government, and the Nation as a whole. Through the leadership of the Executive Director, the USA-NPN will respond to the needs of the USGS disciplines and other agencies within the Department of the Interior and the US Government, while serving as a nucleus for research and applications in the broader scientific and user communities. As Executive Director, the incumbent will develop, coordinate and advocate phenological research within USGS. Critical duties include securing funding for network implementation, extending phenological observations across existing environmental networks through negotiation and interagency agreements, directing data management, and coordinating integration of spatial, analytical and climate data to achieve the wall-to-wall objectives of this continental network. The job is being advertised at the GS-14/15 grade levels (salary range $91,407 - $139,774) in three federal job series (Biologist, Ecologist, Physical Scientist). Requirements include a PhD. in the Natural or Earth Sciences; professional experience in management and/or scientific leadership of regional to national monitoring and research projects; demonstrable experience in multi-agency coordination and public outreach; proven record of grantsmanship and peer-reviewed publications; desired technical knowledge and experience in spatial analysis, including remote sensing, data management and network development, and forecasting models based on ecological/environmental observations; and experience in managing research personnel. The Executive Director will be a USGS employee. USGS will seek to place the Executive Director at a university with adjunct faculty status to facilitate access to academic and technical capabilities required for the position. Interested applicants are welcome to contact the Chief Scientist for *TBD DISCIPLINE* for further information (contact information shown at end of text). Applications will be accepted through the closing date of TBD 2006. The job announcements may be viewed on USAJOBS (www.usajobs.opm.gov) or the USGS OARS system (www.usgs.gov/ohr/oars/). Applications must be submitted on line through OARS.

20 June 2006

MEMORANDUM

To: Members of Implementation Team, USA-NPN

From: Julio Betancourt, Mike Dettinger, Bruce Jones, Brad Reed, Jack Waide

Subject: Briefing of USGS officials in Reston on USA NPN and on the prospect of USGS funding a national coordination office and a national coordinator position to support development of NPN

On June 12-13, we met in Reston, VA with high-level officials in the US Geological Survey (USGS). Our intent was to follow the recommendations of the NPN Implementation Team from the March 22-24 meeting, inform USGS officials about progress in establishing a USA-NPN, and encourage the bureau to establish and fund a national coordination office and a national coordinator position. We are pleased to report a uniformly positive response and a genuine enthusiasm for the network on the part of USGS.

We briefed members of the USGS Executive Leadership Team (ELT) on NPN, and met individually with other key agency officials. The ELT includes the Associate Directors (ADs) for the component Disciplines in the bureau (Water Resources, Biological Resources, Geography, Geology, and Geospatial Information Office) and other senior agency leaders. The ELT Special Session was hosted by Bob Hirsch, AD for Water Resources and chair of the USGS Bureau Planning Council (BPC), the senior leadership group in USGS charged by the Director with leadership for science in the bureau. Julio Betancourt presented the background, status, and the way forward for the NPN. The USGS NPN presentation can be accessed directly on the NPN web page (http://www.uwm.edu/Dept/Geography/npn/graphics/index.html). Attendees expressed strong interest in the concept underpinning NPN and asked pertinent questions about plans for initiating NPN.

At the conclusion of the ELT session, Bob Hirsch asked that the Chief Scientists of the five USGS Disciplines meet to develop a recommendation to bring to the BPC at its July 6 meeting, as to what the USGS should do to respond to this briefing and the funding/support request we made to them. Bruce Jones (formerly with EPA, now with USGS and on the USA-NPN Implementation Team) is the Chief Scientist for Geography, and will be able to address questions from the other Chief Scientists directly. Jack Waide has arranged a meeting of the Chief Scientists on Friday, June 23. We are pleased with the prompt response and prospect for a USGS decision in such a short time-frame. Needless to say, USGS is moving quickly and, we hope, decisively in our favor.

Each of the individual briefings was also positive, both in respect to the value of a NPN for the US, and in terms of the possible role for the USGS in terms of providing a base level of support for a national office/coordinator for NPN. Each of the ADs was very engaged in the discussions, and expressed a willingness to consider making funding available within their discipline to support the NPN. This is a positive development for the USGS and NPN, as it expresses the interdisciplinary support that is required for NPN to be successful.

While the response was decidedly positive, there were still some remaining issues of concern, including:

- *Is USGS the appropriate federal agency to support/host the NPN coordinating office and coordinator on behalf of other organizations on the Implementation Team?*
- *Should a central coordinating office be located in a federal agency headquarters such as Reston or at a major university?*
- *How might a national coordinator be selected?*
- *What interest do the National Science Foundation (NSF) and other funding sources have in NPN, and might they consider funding grants to support specific parts of NPN?*
- *What are the next steps for securing USGS support?*

These are all important issues for the Implementation Team to address, but none of them are show-stoppers. In summary, we all felt quite positive about the NPN briefing in Reston. Barring unforeseen consequences, the odds are in our favor for USGS to assume a leadership role and fund/host a national coordinating office and national coordinator position for USA-NPN. We will keep you fully informed as these discussions continue, and would he happy to answer any questions you may have about the briefing and subsequent developments.

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July 3, 2006

Dr. Pat Leahy
Acting Director, U.S. Geological Survey
12201 Sunrise Valley Dr.
Mail Stop 100
Reston, VA 20192-0002

Dear Dr. Leahy:

On June 29, Julio Betancourt gave a nice update at the Institute for the Study of Planet Earth (ISPE), University of Arizona, on the recent progress made in planning and organizing a USA-National Phenology Network. In attendance were 15 faculty members representing several academic units. ISPE formally hosted both the August 24-26, 2005 Workshop and the March 22-24, 2006 meeting of the USA-NPN Implementation Team, which included several participants from the University faculty. Thus, we were very pleased hear the great news from Julio that USGS is considering support for a national coordinating office and Executive Director for USA-NPN. We feel that this will definitely accelerate the implementation process, as well as ensure the long-term stability of this critical, ecological network. Monitoring phenology is critical to understanding and predicting fundamental natural processes and their interactions, and as Julio documented in his presentation, wall-to-wall phenological observations have myriad scientific and practical applications.

The University of Arizona is very enthusiastic about the concept of a USA-National Phenology Network, and is keenly interested in participating in development of NPN and, to the extent possible, contributing to its successful implementation. We understand that recent discussions have focused on where the USA-NPN director should be located and have identified potential advantages of having the director affiliated with a major research university. The University of Arizona would be pleased to fulfill this emerging USA-NPN need.

The University of Arizona offers numerous strategic advantages for helping to initiate and maintain USA-NPN program:

- The University includes all of the major academic entities that have a stake in the data the network would produce: agriculture, biophysical sciences, natural resources sciences, social sciences, public health, and medicine.
- The University is nationally recognized for the strength of its interdisciplinary research environment.
- University faculty have been actively involved in planning for a USA-NPN and interest in this network is pervasive across campus. Among the numerous academic units that could contribute to NPN and phenological research are Ecology and Evolutionary Biology; School of Natural Resources; Atmospheric Sciences; Soil, Water and

Environmental Science; Hydrology and Water Resources; Geosciences, Geography and Regional Development; Laboratory of Tree-Ring Research; Public Health; Medicine; Water Resources Research Center; Udall Center for Studies in Public Policy; Office of Arid Lands; Institute for the Study of Planet Earth (ISPE); Sustainability of Arid Hydrology and Riparian Areas (SAHRA) and Cooperative Extension.

- The University already has a strong on-campus relationship with USGS, and several other major federal agency entities, including the National Weather Service, the Forest Service, and the National Park Service.
- The University boasts one of the most innovative Cooperative Extension programs in the country, one that not only offers services to the agricultural sector, but also provides climate, geospatial and water resource extension services.
- The University is a recognized leader in remote sensing and associated geospatial analyses, and includes several formal programs including the Terrestrial Biophysics and Remote Sensing Lab, the Arizona Remote Sensing Center, and the Advanced Resource Technology Group. The Committee on Remote Sensing and Spatial Analysis, formed in 1975, coordinates remote sensing activities across campus.
- The University has significant cross-campus strengths in development of Decision Support Systems.

These seven advantages would collectively provide a strategic base for USA-NPN and are all part of the University of Arizona's Focused Excellence initiative, which places Earth Sciences and Environmental Programs among its highest priorities.

The University is implementing numerous statewide observational technologies and networks directly focused on phenology and related environmental processes. Examples of NPN-relevant endeavors at UA include implementing a statewide citizen's monitoring network for drought; participating in the development of the National Integrated Drought Information System (NIDIS); leading the NOAA-funded Climate Assessment for the Southwest Project, which covers AZ, NM and the US-Mexico border; and implementing coordinated strategies for rapidly addressing invasive species challenges.

Arizona offers a strategic location for launching USA-NPN. Arizona is one of the most biodiverse states in the nation and includes numerous sky islands that provide classic research venues for relating climate and biology. These research venues have led to a rich legacy of bioclimatological research that includes the work of C. H. Merriam, J. W. Powell, W. G. McGinnies, A. E. Douglass, and F. Shreve, among others. Arizona offers a strategic location for launching NPN by virtue of the expanding network of observational instrumentation across many parts of the state. Cooperation among the state's three universities allows sharing of data among researchers.

In conclusion, the University of Arizona would like to contribute to the development of NPN by providing a strong academic home for the USA-NPN Directorship. UA is prepared to provide space for the director, and, as the business plan for USA-NPN develops, would welcome the opportunity to discuss how it can work with USGS and others to ensure effective implementation.

We look forward to exploring this opportunity. To ensure rapid coordination across the UA campus, please copy communication to Dave Breshears, Professor in the School of Natural Resources, who is a member of the USA-NPN Implementation Team (daveb@email.arizona.edu; 520 621-7259). In case Dr. Breshears is not reachable, please contact ISPE Sr. Program Coordinator Teresa Woolfenden at the Institute for the Study of Planet Earth (teresac@email.arizona.edu; 520-622-906).

Sincerely yours,

Eugene G. Sander
Dean, College of Agriculture
and Life Sciences
Vice President, Outreach

Joaquin Ruiz
Dean, College of Science

cc: Bob Hirsch, Associate Director, Water Resources Division
Sue Haseltine, Associate Director, Biological Resources Division
Barbara Ryan, Associate Director, National Mapping Division/Geography
Linda Gundersen, Associate Director, Geologic Division
Karen Siderelis, Associate Director for Geospatial Information and Chief Information Officer
Matthew Larsen, Chief Scientist, Water Resources Division
Bob Szaro, Chief Scientist, Biological Resources Division
K. Bruce Jones, Chief Scientist, National Mapping Division/Geography
Peter Lyttle, Chief Scientist, Geologic Division
Anne Frondorf, Chief Scientist, Geographic Information Office

Project Summary
RCN: USA National Phenology Network

Core Participants (Steering Committee)
Lead PI: Mark D. Schwartz, University of Wisconsin-Milwaukee
Steering Committee Members: P. Stephen Baenziger, University of Nebraska; Julio Betancourt, U.S. Geological Survey/University of Arizona; Carol Brewer, University of Montana; Mike Dettinger, U.S. Geological Survey/Scripps Institution of Oceanography; David Inouye, University of Maryland; Beverly Law, Oregon State University and AmeriFlux Network; Susan Mazer, University of California-Santa Barbara; Eric Post, Penn State University; Bradley Reed, U.S. Geological Survey; and Robert Waide, University of New Mexico and LTER Network Office

Intellectual Merit

The USA National Phenology Network (USA-NPN) is an emerging and exciting partnership among academic communities, federal agencies, and volunteers. The NPN was initiated by an NSF-funded planning workshop held in August 2005 and a follow-up meeting of the resulting Implementation Team (IT) in March 2006. The IT consists of 27 scientists spanning multiple disciplines, institutions and related environmental networks. The USA-NPN consists of four components or tiers, representing different levels of spatial coverage and quality/quantity of phenological and related environmental information: 1) Locally intensive sites focused on process studies; 2) Spatially extensive scientific networks focused on large-scale phenomena; 3) Volunteer and Education Networks; and 4) remote sensing products that can be ground-truthed and assimilated to extend surface phenological observations to the continental-scale.

A Research Coordination Network (RCN) will allow USA-NPN to achieve eight primary research and educational objectives: 1) promote progress and leadership in phenological science; 2) inform and guide NPN design and implementation with sound science; 3) develop and field test protocols for data collection and management by students, citizen-scientists, and scientists; 4) synthesize, prioritize, and integrate research projects that take advantage of NPN data at all levels; 5) identify and address key gaps in theory and data that limit phenological research; 6) inspire new multi-disciplinary experimental designs and models to increase utility and relevance of phenological research; 7) develop new Web resources to increase awareness and access to phenological data; and 8) guide development of new software that integrates multiple data types and is compatible across relevant computer platforms.

The USA-NPN RCN will create four general products: 1) a meta-database of existing phenological data in the USA; 2) a broadly-vetted and tested set of data-collection and -management protocols; 3) lists of target species representative of the Nation's ecoregions and customized for each of four network tiers; and 4) enhancement of the existing prototype NPN Web page with new software and tools that will facilitate communication among and access to data by the entire research community. Focused workshops will address issues such as the integration of past phenological data collected with differing protocols, and annual retreats will review ongoing progress and promote exchange with international phenological research groups.

Broader Impacts

At hand is a unique opportunity to increase collaboration between federal agencies and the academic community, to facilitate and recruit public participation in the study and understanding of Nature, and to serve public needs in Agriculture, Commerce, Education, Health, Recreation, and Natural Resources. The USA-NPN RCN will actively support student/early researcher exchange/training programs among participating organizations, as well as participation by students, citizens, and scientists from under-represented communities in all network activities. The USA-NPN is committed to substantial participation from members of the public as citizen-scientist phenological observers. The RCN will enhance this opportunity by developing additional features for the USA-NPN Web page that will promote science education and foster better understanding of complex environmental issues.

Project Description
RCN: USA National Phenology Network

I. Background

Phenology is the study of periodic plant and animal life cycle events, and how these are influenced by environmental changes, especially seasonal variations in temperature and precipitation driven by weather and climate. Examples include the timing of leafing and flowering, agricultural crop stages, insect emergence, and bird, fish, and mammal migration. All of these events are sensitive integrators of both weather and climate, are relatively simple to record and understand, and are vital to the public interest.

Phenology, defining the seasonal cycles on Earth, is a far-reaching component of environmental science but is poorly understood. Critical questions include how environmental factors affect the phenology of different species and species interactions, and how those factors vary in importance on different spatial and temporal scales. Moreover, *we need to know how phenology affects the abundance and diversity of organisms, their inter-specific interactions, their ecological functions, and their effects on fluxes in water, energy, and chemical elements at various scales*. With sufficient observations and understanding, phenology can be used as a predictor for other processes and variables of importance at local to global scales, and could drive a variety of ecological forecast models with both scientific and practical applications. The predictive potential of phenological data requires a new data resource—***a national network of integrated phenological observations and the tools to access/analyze them at multiple scales.***

A USA-National Phenology Network is essential to detect and to evaluate ongoing environmental changes, and can now capitalize on integration with other physical and atmospheric observation networks and remote sensing products, emerging technologies and data management capabilities, formal and informal educational opportunities, and a new readiness of the public to participate in investigations of natural systems on a national scale.

II. Genesis of a National Phenology Network for the USA

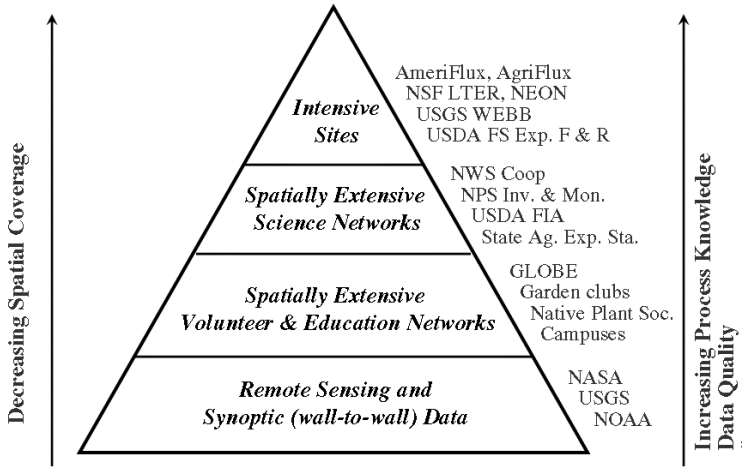
The idea for a USA-National Phenology Network (NPN) has many instigators. In 1956, Joseph M. Caprio (Montana State University) initiated lilac phenological research in the USA. He developed a network of volunteer observers (~1000, growing to 2500 by 1972) reporting from 12 Western states (Caprio 1966). Caprio's program stimulated development of a similar program in the Eastern USA in 1961, initially under the direction of W.L. Colville (University of Nebraska; ~300 observers in 1970). The Eastern network lost funding in 1986, but was continued at ~40-50 stations by Mark D. Schwartz (University of Wisconsin-Milwaukee). The Western States Phenological Network was terminated upon Caprio's retirement in 1993, but was reactivated at a handful of sites by Dan Cayan (Scripps Institution of Oceanography/USGS) and Mike Dettinger (USGS/Scripps) to complement their studies on changes in timing of snowmelt discharge (Cayan et al. 2001). Cloned lilacs (and models developed from them) now serve as "anchor points" binding together commonalities among phenological observations from native species in diverse ecoregions, climate data, and remote sensing observations across a continent-wide network (Schwartz 1998; Schwartz et al. 2006). In the absence of other continental phenological monitoring, legacy lilac data provide the most logical tie to the mid-twentieth century before the major inflection in temperature and growing season trends.

More recently, Schwartz foresaw the need for a national network that would revitalize and broaden the lilac network, while extending phenological observations to other native and

non-native species, drawing in part on co-location with a subset of National Weather Service Cooperative Observer stations and cooperation with other existing networks. In summer 2004, Julio Betancourt of the U.S. Geological Survey independently arrived at the same conclusion after co-chairing an AIBS Grand Challenge Workshop that explored NEON's role in studying ecological responses to climate (AIBS 2004). When it appeared that NEON might be designed around intensively-sampled regional nodes, Betancourt teamed up with Schwartz to begin organizing a spatially-distributed network that would achieve wall-to-wall continental coverage for phenological observations and operate independently but ultimately in collaboration with NEON.

In August 2005, Betancourt, Schwartz and a steering committee of diverse scientists convened a workshop in Tucson, AZ, to initiate an implementation plan for a USA-National Phenology Network (NPN). The workshop was funded by NSF and four other federal agencies (USGS, National Park Service, EPA, and USDA-Forest Service), and included 40 scientists from across the country and the globe (presentations and notes from breakout sessions at http://www.uwm.edu/Dept/Geography/npn/meetings/wkshop_2005_8.html; workshop summary in Betancourt et al. 2005).

The 2005 workshop reinforced the need for the broader scientific community to organize a nationwide network of phenological observations with simple and effective means to input, report, and utilize these observations, including the resources to provide the right information at the right time for a wide range of decisions made routinely by individual citizens and by the Nation as a whole. Separate breakout groups converged on a framework of four expandable components or tiers, each representing a different level of spatial coverage and quality/quantity of phenological and environmental information: 1) *locally intensive sites* focused on process studies (e.g., LTER, AmeriFlux, AgriFlux); 2) *spatially extensive science networks* focused on large-scale phenomena (e.g., National Weather Service Coop stations, National Park Service Inventory & Monitoring sites); 3) v*olunteer and education networks* (e.g., garden clubs, bird and butterfly monitoring networks, college campuses); and 4) *Remote sensing data* that can be ground-truthed and assimilated to extend surface phenological observations to the continental-scale. Workshop participants emphasized that observations be entered into a database management system and be made available to the public in mapped form and near real time (see prototype web page at http://www.npn.uwm.edu).



At the 2005 Workshop, an Implementation Team was recruited with representation across disciplines, institutions, and existing environmental networks that already incorporate or could adopt phenological monitoring, with the goal of launching the first monitoring activities in 2007. The NPN team met in Tucson on March 22-23, 2006 to draft an implementation report and continue to organize the network. The NPN Team has been tasked with aspects of network development such as securing stable support from federal agencies for a national coordinating

office; renewal and expansion of the lilac network; and adoption of phenological monitoring across existing environmental networks (LTER, AmeriFlux, National Park Service Inventory & Monitoring, and the National Weather Services COOP Network). The NPN Team was also charged with developing mechanisms and funding for coordinating research across the network, which led to the current proposal for a focused NPN Research Coordination Network in Biological Sciences. The NPN Team will serve as an additional support group for the goals and activities of the USA-NPN RCN.

USA-National Phenology Network Implementation Team

*Baenziger, P. Stephen, *Univ. of Nebraska*	*Law, Bev, *Ameriflux/Oregon State University*
*Betancourt, Julio, *USGS Desert Laboratory*	LeDuc, Sharon, *NOAA*
Breshears, David, *University of Arizona*	*Mazer, Susan, *UC Santa Barbara*
*Brewer, Carol, *University of Montana*	Morisette, Jeffrey, *NASA*
Cayan, Dan, *Scripps Inst. of Oceanography*	Pielke, Roger, *Colorado State University*
Cecil, DeWayne, *USGS (currently at NASA)*	*Post, Eric, *Penn State University*
Crawford, Ken, *NOAA*	*Reed, Bradley, *USGS, Flagstaff*
Crow, Tom, *U.S.D.A., Forest Service*	*Schwartz, Mark D., *Univ. of Wis.-Milwaukee*
*Dettinger, Mike, *USGS/Scripps Institution of Oceanography*	Sheffner, Ed, *NASA*
	Turner, Woody, *NASA*
Easterling, William, *Penn State University*	Van Vliet, Arnold, *Wageningen University*
Gross, John, *National Park Service*	Waide, Jack, *U.S. Geological Survey*
*Inouye, David, *University of Maryland*	*Waide, Robert, *LTER/Univ. of New Mexico*
Jones, Bruce, *U.S. Geological Survey*	Wolfe, David, *Cornell University*
	USA-NPN RCN Steering Committee members

III. Theme and Goals of the USA-NPN Research Coordination Network (RCN)

The USA National Phenology Network (USA-NPN) Research Coordination Network (RCN) will initiate active collaboration in order to move phenological research forward. It will create new research opportunities through multidisciplinary exchange and the ability to examine innovative questions at multiple scales, drawing on new continental-scale phenological data that will be collected and distributed by the USA-NPN.

The USA-NPN RCN will build on the progress and incipient organization resulting from the two previous planning workshops by initiating carefully coordinated collaborations among an interdisciplinary group of scientists to achieve eight objectives: 1) promote progress and leadership in phenological science; 2) inform and guide USA-NPN design and implementation with sound science; 3) develop and field test protocols for data collection and management by students, citizen-scientists, and scientists; 4) synthesize, prioritize, and integrate research projects that take advantage of NPN data at all levels; 5) identify and address key gaps in theory and data that limit phenological research; 6) inspire new multi-disciplinary experimental designs and models to increase the utility and relevance of phenological research; 7) develop new Web resources to increase awareness and access to phenological data; and 8) guide development of new software that integrates multiple data types (climatic, remote-sensing, and on-ground observations) and is compatible across relevant computer platforms.

IV. Scientific Value of Multiple-Scale Phenological Research

Phenology has significance for many aspects of science and resource management, including ecology, climatology, hydrology, agriculture, forestry, human health, and education. It can be studied on scales ranging from global to continental to regional to local, and even down to

the scale of individual anthers on a flower. Phenology can use tools as sophisticated as satellites for remote sensing, or as simple as observations by citizen-scientists. Below we summarize the scientific value and need of multiple-scale phenological observations in the context of biology, agriculture, remote sensing, climate and hydrology, and biogeochemistry.

A. Biological Significance of Phenology

As a discipline, phenology is one of the branches of ecology that investigates processes occurring at the interface of evolutionary and ecological time scales. Evolutionary adaptation of populations to environmental conditions depends in large part on the synchronization of their timing of development to seasonal variations in climate. Hence, the phenology of a species—and the cues that initiate phenological events—has a strong influence on its distribution and abundance, both of which are amenable to modeling and validation. For example, PHENOFIT is a process-based model for predicting tree species distributions that offers an alternative to statistically and niche-based biogeographic models (Chuine & Beaubien 2001; Morin & Chuine 2005). PHENOFIT is parameterized with actual phenological observations of focal species. The further development and application of this model and others like it hinges on the quality and quantity of phenological data available for multiple species and ecoregions.

The interface between evolution and ecology in the study of phenology is particularly evident in the study the effects of climate change, during which ecological dynamics may outpace evolutionary responses. Such tensions between the proximal environmental drivers of the timing of annual events and the reproductive strategies of sessile organisms such as plants will undoubtedly have consequences for community structure, population dynamics, and evolution in a changing climate.

The timing of the onset of flowering is a common subject for study, with obvious importance for plant reproduction and for all species dependent upon flowers, fruits and seeds. Thus it is not surprising that flowering phenology has been the object of study in many ecosystems, including alpine (Molau et al. 2005), montane (Inouye et al. 2002), desert (Kemp 1983, Bowers & Dimmitt 1994), aquatic (Philbrick & Retana 1998), tropical (Vanschaik et al. 1993, Reich 1995), and prairie (Tepedino & Stanton 1980) ecosystems. Because of its importance to biological processes, vegetative activity in forests has also been well-studied, focusing on leaf out, leaf fall and leaf turning (e.g., White et al. 1999, Jenkins et al. 2002).

The timing of migration and reproduction of birds and mammals and the intersection with changes in plant phenology is extremely important, and can be influenced by climate disruption (e.g., Mason 1995, Loxton et al. 1998, Cotton 2003). Such decoupling may occur more subtly and slowly than other manifestations of climate change, and could go unnoticed without proper monitoring. For example, birds must synchronize nesting with available food resources (Visser et al. 1998), and amphibians must reproduce when conditions are appropriate. Amphibian reproduction also offers opportunities for citizen-scientists to contribute observations of the timing of reproduction (e.g., Frogwatch USA, a joint project of the National Wildlife Federation and USGS). Mammalian reproduction is also often synchronized with plant phenology, and may be under strong selection to continue to overlap with appropriate resource availability (Réale et al. 2003). Phenology of emergence of aquatic insects has also been studied (Paasivirta et al. 1988), and is likely to change in response to climate change.

Annual phenological events (e.g., the timing of spring green-up and the onset and duration of flowering) are often correlated with regional primary productivity, which in turn predicts the magnitude of foliage, wood, pollen and seed production. Consequently, phenological "landmarks" may be used to anticipate phenomena that affect human health and

welfare, such as rodent population spikes, pollen allergies, wildfire risk, and mammalian- and bird-borne diseases.

Given the ecological significance of phenology, it's not surprising that it also has evolutionary implications. This could include the responses to competition for pollinators (Kochmer & Handel 1986, Rathcke 1988), selection for avoidance of environmental factors such as frost (Cannell et al. 1985) or drought, or avoidance of predators and parasites (Waldbauer & LaBerge 1985, Lyons 1999). Relationships between herbivores and plants are also fertile grounds for evolutionary responses mediated by phenological change (Crawley & Akhteruzzaman 1988, English-Loeb & Karban 1992, How et al. 1993). Bradshaw & Holzapfel (2006) indicate that diverse animal populations have already changed genetically in response to the rapid climate changes of the last few decades. These genetic changes are in response to altered seasonal events, and not to the direct effects of increased summer temperatures as some might have expected.

The recent growth in interest in phenology has been sparked by ongoing biological changes that may be associated with global climate change (e.g., Menzel 1999, Schwartz et al. 2006). Studies indicating effects of climate change have detected changes in the timing of budburst (Murray et al. 1989), changes in bird nesting and migration dates (MacInnes et al. 1990, Sparks et al. 2005), and alterations of mammalian hibernation behavior (Inouye et al. 2000). These changes have generated public attention and offer opportunities for increased involvement of citizen- scientists in providing phenological observations. Long-term records maintained by non-scientists have already received attention from both scientists and the public (e.g., Sparks & Carey 1995).

Phenological responses by plants and animals are also amenable to modeling, which may help with predictions of the consequences of climate change. For example, studies have been conducted of the effects of temperature on bud burst (Hannerz 1999), selection on flowering time (O'Neil 1999), effects of flowering time on harvest dates (Piper et al. 1996), and a mid-domain effect on flowering diversity (Morales et al. 2005).

Finally, it bears emphasis that the main roadblock to understanding the fundamental role of phenology in population and community dynamics is that phenological events and population abundance are seldom monitored in tandem, and certainly not at regional to continental scales. This highlights the value in fully implementing the NPN across existing ecological networks such as LTER and NPS Inventory & Monitoring, as well as planned ones such as NEON.

B. Agricultural Management

The economic relevance of having better models for agricultural production is that commodity trading is based upon predicted supply. The "futures" market relies heavily upon global supply predictions and having better predictive capability will affect literally billions of dollars of agricultural trade. Using phenological data to optimize planting dates can facilitate agricultural management. Planting date is one of the most important decisions that crop producers make (Anapalli et al. 2005; Ishibashi et al. 2003), and it is the starting point for many simulation models. Most growers plant on or after a historically determined date, based on climate. Yearly variation in weather is such, however, that these climatically determined dates provide only estimates of the "optimal" planting date. If producers knew in a specific year they could plant earlier or later, in the case of winter cereals, they might be able to escape some of the effects of late season heat or drought or pest epidemics.

What is needed is a clearer and predictive understanding of diverse seasonal weather fluctuations and climate information that can be used to help producers make better daily

decisions. Using a reliable biological indicator, we can enhance agricultural decision models and use the NPN for timely decisions on a daily, weekly, monthly, or annual basis. Hence, the NPN will have significant short-term and long-term benefits for agriculture.

Due to its importance, there is a wealth of phenological information that has been collected in agriculture and forestry to understand plant growth, development, and yield. For example, heading date (when 50% of the spikes have emerged from the boot of a wheat plant) data for Kharkof winter wheat, a long-term cultivar in USDA-coordinated regional nurseries, has been used to identify a progressively earlier start for the spring growing season over the past 70 years (Hu et al. 2006). There is a similar wealth of phenological data for most crops. It is possible that many economically important agricultural crops can provide useful phenological information for the NPN on a regional basis, especially perennial ones.

C. Remote Sensing

Remote sensing data have been used to identify the greening of northern latitudes (Myneni et al. 1997), characterize urban heat islands (Zhang et al. 2002), and analyze medium-term trends in seasonality across North America (Reed 2006). High-resolution satellite sensors, principally the Landsat series, have been utilized for phenological studies almost since the data have been available, especially in the 1970s and 1980s (e.g. Wiegand et al. 1979; MacDonald & Hall 1980). Early efforts were directed toward utilizing multi-date Landsat imagery for land classification or toward establishing a relationship between temporal/spectral variability and crop calendars (Crist & Malila 1981, Meltzer et al. 1982). They were based largely on observations of the temporal profile of the greenness component of the crop canopy, rather than of individual plant species (Badhwar 1980).

The same principle is still applied today with large-area satellite phenology, but taken further. Most researchers are tracking the integrated greenness component of 250-m to 1000-m resolution pixels, rather than of single plants or dominant plant types. Research efforts using relatively high resolution sensors, such as Landsat, for measuring phenology over large areas are limited for two reasons: (1) the revisit period (16 days) is too long for identifying critical phenological dates and (2) the fine spatial resolution of the sensors requires prohibitively large computing resources for characterizing phenology at the national scale.

The satellite sensor that has primarily been used for phenology studies is the National Oceanic and Atmospheric Administration's (NOAA) advanced very high resolution radiometer (AVHRR). This sensor has a near daily repeat cycle of the Earth and a 1-km spatial resolution. Both the temporal density of the data and the moderate spatial resolution make this sensor well suited for studying large area phenology. AVHRR-NDVI data are readily available in a consistently processed database from 1982-present at an 8-km resampling grid covering the globe (Tucker et al. 2004) and at 1-km resolution from 1989 covering the conterminous United States (Eidenshink 1992). More recent moderate resolution satellite sensors including SPOT Vegetation (1-km data, launched in 1998) and Envisat MERIS (300-m data, launched in 2002) have the proper instrumentation for greenness studies. The moderate resolution imaging spectroradiometer (MODIS) launched in December, 1999 is used frequently for phenology studies. Improved geometry, radiometry, and overall data quality of MODIS, combined with its free-of-charge data policy, provide high quality data for time-series analysis.

The key phenological variables that are often estimated from satellite remote sensing are the start, end and length of the growing season length (GSL). When deriving phenological characteristics from remote sensors, the object is not species-, population-, or even community-specific phenology, but rather the characteristics of individual pixels. Depending on pixel size,

such observations may reflect the phenology of a mosaic of several vegetation types. This kind of resolution may allow only general observations such as the start or the end of the growing season based on threshold values or inflection points in time series greenness curves, rather than more specific measures such as first-leaf or bud-burst (Reed et al. 2003).

Remote sensing-based phenology, coupled with NPN ground-based observations, will provide a mechanism to progress from plant-specific to regional- and continental-scale uses of phenology. A wealth of remote-sensing research fields will be opened with the availability of the NPN data sets, including: 1) comparative studies of alternative phenology characterization techniques; 2) techniques to validate remote sensing phenology parameters; 3) characterization of relationships of key phenology parameters to climatic variables; 4) characterization of relationships of remote sensing-based phenology parameters to indicator species and natural vegetation; and 5) scaling studies. Phenological data collected by the various tiers of the NPN will be a critical source for validating land surface phenology estimates from satellite sensors and, conversely, estimates from remote sensing can fill gaps between ground observations to produce a continuous surface of phenology estimates at the continental scale.

D. Climate and Hydrology

The NPN will provide a framework for systematically monitoring phenological trends and relating them to local and regional climate variability and trends (e.g., Stohlgren et al. 1998, Cayan et al. 2001, Hodgkins et al. 2003, Stewart et al. 2005). Because growing conditions vary substantially over the complex landscape across the United States, the NPN will provide a direct, from-the-ecosystem metric of how climate fluctuations or changes relate to phenological responses in vegetation.

If maximum and minimum daily temperatures were to become 2ºC warmer or colder year-round, for example, phenological responses would vary geographically depending on the importance of radiative vs. advective freezes in defining a region's growing season. Estimated growing season lengths would be expected to increase (decrease) by at least one to two weeks in most areas, but by as much as 2 months along the West Coast. Accordingly, the western and northeastern U.S. have warmed significantly in the last two to three decades. As a result, snowmelt and stream flow have begun to occur earlier in the year (e.g., Stewart et al. 2005, Hodgkins et al. 2003), as have first-bloom dates for lilacs across the West and Northeast U.S. (Schwartz & Reiter 2000, Cayan et al. 2001).

In the western U.S., wildfire activity increased suddenly and dramatically in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. The greatest increases occurred in mid-elevation forests of the Northern Rockies, where land-use histories have relatively little effect on fire risks. This increased fire activity is strongly associated with increased spring and summer temperatures and an earlier spring snowmelt; it may be predictable from both phenological and hydrological indicators (Westerling et al. in press). In fact, wildfire activity becomes most severe when lilacs bloom before May 20, suggesting that a suite of phenological indicators can help predict severe fire seasons.

The vegetation changes to be measured by the NPN are important climatic factors themselves, influencing local climate and climate changes by their influences on transpiration, albedo, and roughness (Pielke et al. 2002). Thus the NPN will provide a framework for monitoring an important climatic metric (vegetation), as identified in NRC (2005). Combined with the more traditional climate metrics, such as temperature and precipitation, NPN will contribute to a more comprehensive monitoring of climate variability and change.

The role of vegetation as an important influence on weather and climate variability, as documented by NPN, will provide additional information that can be assimilated into weather and climate simulation, prediction and analysis models. For example, the different phases of the seasonality of vegetation serve as important controls on the relative contributions of transpiration fluxes to surface moisture and heat budgets, as well to large-scale albedo. A NPN would therefore provide a hands-on, participatory collective for large-scale input and validation of models and, especially, for deciphering remote sensing estimates of vegetation state. Finally, the NPN can enhance the regular National Drought Monitor by providing important measurements of vegetative conditions.

To inform climate science most effectively, NPN will need sites in proximity to locations in which other variables are monitored, including weather, radiation, biogeochemical fluxes, hydrology (especially soil moisture), and plant and animal demography. Sites need to include both urban and non-urban settings, but with a backbone of rural sites to monitor and discriminate "pristine" signals. The fundamentally wall-to-wall (north-to-south, coast-to-coast) geographic coverage planned for the NPN is crucial to match and capture the large-scales of important climate variations. A dense coverage of at least some kinds of measurements is desirable to discern smaller scales of climate variations and to avoid aliasing all small-scale processes into the large climate scales. Important topography-mediated climatic features need to be factored into siting decisions as well. Finally, to provide optimal input to climate sciences, the NPN should develop a strategy for including non-climatic controls (observations of phenological stations that are less climatically controlled than the main network) to provide some basis for discriminating climatic effects from those caused by nonclimatic biological, population-density, pollution-mediated, pathogen-driven, pest activated, land-use-driven or other processes.

A key goal for NPN is the strategic co-location of phenological measurements with weather stations, taking advantage of ongoing modernization of weather networks in the U.S., which may free volunteer observers to undertake phenological observations. NPN will work with NOAA, the National Weather Service, and state climatologists to recruit observers; NPN will also encourage NPN citizen-scientists to make co-located climatic observations. For the most complete stations in existing weather networks, USA-NPN organizers will work to facilitate, design, and arrange for phenological observations to be made alongside intense climatic and environmental data collection efforts of existing environmental networks. These sites would allow the network to benefit directly from those programs, and in turn would benefit those efforts by providing a phenological base for interpreting climatic and other environmental observations.

E. Terrestrial Biogeochemistry

In any given year, plant phenological activities determine when terrestrial ecosystem carbon uptake changes rapidly in spring and autumn, how fast this transition can occur, and how long the ecosystem functions as a sink. Many studies have established the importance of the link between phenology and terrestrial carbon cycles. For example, eddy covariance observations of net ecosystem exchanges of carbon dioxide revealed that the growing season length is a good predictor of annual net carbon uptake across a variety of terrestrial ecosystems (Baldocchi et al. 2001). Keeling et al. (1996) found a seasonal trend in atmospheric CO_2 concentration measured at Mauna Loa since 1950s that is attributed to terrestrial vegetation in the higher latitudes. In addition, they found that there had been a systematic change in the magnitudes of seasonal cycles of atmospheric CO_2 that was most logically explained by a lengthening in the growing season associated with the warming trend. Therefore, largely through phenology, climate influences terrestrial carbon cycles at multiple temporal and spatial scales.

Law et al. (2002) showed seasonal coupling of gross photosynthesis and water vapor exchange estimated from eddy covariance measurements, and there was a consistency within biomes. It implies that the coupling of CO_2 and water is strong at the ecosystem scale, and if phenological changes alter carbon uptake, then water vapor exchange with the atmosphere will also be affected. Thus, coupled biogeochemical cycles are strongly influenced by phenology. The relationship between phenology and terrestrial carbon cycles can be examined broadly from the following processes: (1) photosynthetic assimilation of CO_2, and (2) terrestrial release of CO_2 through respiratory fluxes.

While the life-cycle events of plants determine the relative proportions of plants' time spent in active growth vs. dormancy in a year, the relationship between phenology and photosynthetic assimilation of CO_2 is more complicated. For example, an earlier start of bud break may increase the risk of frost damage and reduces plants' potential of carbon assimilation later in the growing season. Another important issue relates to soil moisture depletion. Before the growing season starts, the loss of soil water is through physical evaporation from soil surface - a relatively slow process because moisture has to first diffuse from inner soil to the surface in order to escape from the soil. Once the growing season starts, a direct conduit for water transport from soil to air is established (soil - root - xylem - leaf - air), allowing a shift in water loss primarily from surface evaporation to transpiration. If the precipitation regime remains the same, a longer growing season may reduce soil water through the season and increase plant water stress and thus adversely affect photosynthetic assimilation of CO_2. The rate of plant response to favorable environmental changes and the length of time that conditions are favorable for growth relative to plant phenology play a critical role in determining annual carbon uptake by plants. Many process models compute timing of leaf-on and leaf-off from meteorological data, and phenological events in process models could be improved with observations (e.g., data assimilation).

Many forest sites have observed abnormal soil effluxes or ecosystem respiration rates during spring and fall, periods of rapid phenological changes (e.g., Davidson et al. 2006). Although the exact causes of these unusual respiratory fluxes are still not clear, they are almost certainly related to plant community phenology. Photosynthetic effects of changing phenology also affect changes in the root-rhizosphere (autotrophic) respiration because photosynthesis drives root respiration once new photosynthates are available to root activity during the growing season (Bowling et al. 2002; Hogberg et al. 2001; stored carbohydrates are used earlier and later). Phenology can also affect heterotrophic respiration. Phenological events determine the timing of substrate transport (through fine root dynamics and litter fall) to the soil and therefore affect microbial activity. Another pathway for phenology to affect soil respiration is through its control on the within-canopy radiation environment. Canopy structure affects how much solar radiation is absorbed by soil. In the spring before leaf emergence, much solar radiation reaches the forest floor. After leaves are out, however, more of the total solar radiation is absorbed by leaves. As a consequence, soil temperature regimes change after leaf emergence relative to air temperature, particularly in deciduous forests, agricultural crops, and grasslands. Similar changes in the within-canopy radiation environment and soil temperature regimes occur in the fall. Temperature is a controlling factor for root activity, which influences photosynthesis and soil respiration. Therefore, canopy structural changes associated with advancing of phenological events will have consequences on soil respiration.

Despite the importance of phenology in biogeochemical and ecohydrological studies, rigorous and systematic monitoring of surface phenology remains to be adopted across U.S. flux

networks like AmeriFlux, USDA AgriFlux, or USGS-Water Energy and Biogeochemical Budget (WEBB).

V. NPN Leveraging of Existing Ecological Networks: LTER and AmeriFlux as Examples

NPN intends to leverage existing ecological networks. There are several participating networks but for the purposes of this proposal we will feature two—LTER and AmeriFlux—that will play a formative role in the design and implementation of NPN beginning in the 2007 growing season. Similar relationships are being established with other relevant networks, including the National Weather Service Cooperator Observer Network; National Park Service Inventory & Monitoring; USDA Agriflux; Forest Service Experimental Forests & Range; and Organization of Biological Field Station (OBFD) sites.

A. Coordination with LTER Network

The partnership between the NPN, a distributed network of professional and citizen-scientists collecting phenology data using fixed protocols, and the Long Term Ecological Research Network, a continental network of intensive research programs focused on ecosystem, community and population processes, would be benefit both partners. Many LTER sites conduct phenological research on key organisms as part of their core monitoring programs. Research on ecological processes conducted at LTER sites would provide insight into the fundamental causes and influences of phenological variations in 20 major ecoregions spread across the United States. Because the LTER Network focuses on processes that act over long temporal and broad spatial scales, the data collected at LTER sites are specifically relevant to phenological patterns and dynamics. Moreover, the developing emphasis on cross-site synthesis within the LTER Network makes the timing of the proposed partnership extremely propitious.

Participation in the NPN would provide impetus for the comparison of existing LTER phenological records and the synthesis of patterns across sites. The adoption of standard NPN protocols by LTER sites provides a mechanism to calibrate phenological changes across the LTER Network and to determine the cause of similarities and anomalies in continental patterns. In addition, an enhanced emphasis on and an improved understanding of local and regional phenology will provide information that will contribute to the understanding of ecosystem processes across the LTER Network.

In addition to the emphasis on long-term ecological processes, LTER sites conduct specific observations and conduct experiments on characteristic climate change patterns and responses at each site. They provide over 6,000 accessible, well-documented databases on every ecosystem component from sites that range from deserts to rainforests, and from coastal wetlands to mountaintops. The extensive archive of remotely-sensed data from LTER sites, including MODIS, Space Station photography, and high-resolution Global Fiducial Library data (http://www.lternet.edu/technology/ltergis/index.html), is accessible from the LTER web site. The Schoolyard LTER Program (http://schoolyard.lternet.edu/) links a network of K-12 education programs with LTER research sites. The resources available within the LTER Network will complement and enhance activities of the NPN.

B. Coordination with AmeriFlux

AmeriFlux is a network of micrometeorological tower sites that measure, on a long-term and continuous basis, the exchanges of carbon dioxide, water vapor and energy between terrestrial ecosystems and the atmosphere using the eddy covariance technique. The sites also measure meteorological variables above the canopy and soil temperature and moisture. Currently there are about 120 sites in the network, mostly in the U.S., covering a broad spectrum of ecosystem

types ranging from forests to savannas to grasslands to agricultural crops (http://public.ornl.gov/ameriflux/). In addition to ecosystem-level flux observations, most AmeriFlux sites also take a suite of measurements on leaf biochemistry, plant physiology, and soil respiration. The uniqueness of the AmeriFlux scientific mission, the nature of its datasets, the well-developed infrastructure, and the representativeness of ecosystem types mean that partnership with AmeriFlux can contribute significantly to achieving the objectives of the National Phenology Network (NPN).

Traditional phenological studies focus on structural aspects of plant phenology such as bud break, flowering, fruiting, and leaf coloring, features of plant activities that can be visually examined. However, our ability to predict a phenological event will eventually depend on how well the underlying biological mechanism is understood. Data collected from AmeriFlux sites can be used to investigate the functional aspects of phenology. Several indices that define the functional phenology of plant communities have been developed based on AmeriFlux datasets (Gu et al. 2003). These indices include spring photosynthesis development velocity, fall photosynthesis recession velocity, growing season initiation day, growing season termination day, center day of the growing season, length of the growing season, effective length of the growing season, effective daily maximum canopy photosynthetic rate, and seasonal carbon dioxide assimilation potential index. All of these can be expressed in terms of gross and net carbon uptake and respiration of CO_2. Establishing relationships between these functional phenological indices and traditional phenological events would be important for NPN.

Targeting individual species makes sense because phenological responses to environmental changes are species-specific (e.g., Bradley et al. 1999, Spano et al. 1999, Peñuelas & Filella 2001). For a variety of reasons, however, it is also desirable to monitor overall phenological characteristics of plant communities at a scale that is intermediate between population-level studies and remote sensing. Seasonal variations in fluxes collected from AmeriFlux sites provide such community-level observations.

To understand precisely how environmental variables affect plant life-cycle events, plant–environment interactions over the whole time domain must be considered. Most observations at AmeriFlux sites are automated and measurements are taken at half hourly time steps. Therefore data from AmeriFlux represent an excellent source of information for describing the transient changes in plant states between individual phenological events.

In order to make maximal contributions to understanding and predicting ecosystem dynamics and their feedbacks on climate change, NPN must channel its datasets and transfer the phenological knowledge gained by the network to the modeling community efficiently. At present, terrestrial ecosystem models are known for their inadequacy in predicting plant and community phenology; this inadequacy is often demonstrated by their inability to predict carbon, water, and energy fluxes during spring and fall. Thus NPN will add value to evolving ecosystem models by improving the predictive ability of terrestrial ecosystem models in plant and community phenology. AmeriFlux can facilitate the role of NPN in the development of better ecosystem models because data from AmeriFlux sites can be used to test new phenological representations in ecosystem models.

VI. Organizational Objectives of the USA-NPN RCN

In order to achieve the stated goals regarding enhancement of phenological research, as well as improved tools, web resources, and communication to facilitate these enhancements, the USA-NPN RCN will conduct the following activities:

A. Workshops

Each year a 6-day workshop will be conducted at an appropriate location with a specific research or organizational goal [candidate sites include UW-Milwaukee, U. Arizona, U. Nebraska, UC-Santa Barbara (NCEAS), U. Maryland, and Penn State]. These meetings will consist of 2 invited experts (including up to one international expert) appropriate to the topic, selected members of the steering committee, and 2-3 invited graduate students/early career scientists. High-priority topics, activities, and goals include: 1) develop approaches to make past phenological data collected with different protocols compatible, especially data collected for use in agricultural applications; 2) develop a broadly-vetted set of protocols and lists of target species representative of the Nation's ecoregions and customized for research applications in each of the four network tiers; 3) identify non-traditional phenological data sets for use as baselines; 4) implement NPN within partner agencies and networks (e.g., Ameriflux, LTERs, USDA-WEBB, AgriFlux, and other intensive sites that offer similar opportunities to link phenological monitoring and flux measurements/studies); 5) further design and development of informational infrastructure on the USA-NPN web page; 6) develop a strategy to promote the use of phenological data in applied research; and 7) develop a strategy to enhance the coupling of phenological research objectives with observational/educational goals for primary and secondary school students as well as members of the general public.

B. Annual Retreats

Each year members of the steering committee, along with selected members of the USA-NPN Implementation Team, and 3-4 invited graduate students/early career scientists will meet in Milwaukee for a 4-day retreat to share research and to assess progress of the RCN.

C. Graduate Student Exchanges

Members of the steering committee will identify graduate students at their own or cooperating institutions that would benefit from the opportunity to make short (up to 2 week) "cross-training" visits to another phenological research center. Applications for these trips will be made to the steering committee, and 1-2 exchanges will be supported each year.

D. Database and Web Tool Development

The USA-NPN web page will be enhanced to promote development of continental-scale phenological data collection and dissemination infrastructure by adding: 1) a data archive and metadata search tool; 2) a web interface to allow observers/users an effective means to enter, locate, and retrieve data; and 3) a visualization tool that will allow data in the archive to be graphically displayed in a variety of formats. In order to facilitate these developments, web development services will be contracted in years 3 and 4 of the RCN.

E. Citizen-Science, Outreach, and Education

"Phenology is your neighborhood nature's clock, watch it and use it."

Phenology has a long and interesting tradition of involving citizens in making observations, as a past-time and hobby, and has engaged famous historical figures such as Aldo Leopold, Henry David Thoreau and Alexander MacKay. Citizen-science is the essence of successful phenology networks in Europe and Canada, and likewise the USA-NPN aims to develop a state-of-the-art education program that engages the public in the science of phenology. From school children to participants in elderhostel programs, citizens can be trained to record and report phenological observations and thus become the "eyes of the science." Why is engaging the public critical to the success of the NPN? Scientists engaged in phenological research will need data collected across immense spatial and temporal scales. Engaging school

children and the lay public alike will allow scientists to gather seasonal information on a wide range of organisms spanning widely distributed habitats across the USA and beyond.

During the annual USA-NPN-RCN retreats, teams of scientists and educators will work together to develop the vision and implementation strategy for the NPN. The education effort will be led by Carol Brewer and Susan Mazer. Only one workshop during the five-year NPN program will focus on education, but education planning and implementation activities will be integrated into each of the annual retreats. Education planning for the NPN will focus on five areas: 1) identifying and engaging key partners who have implemented/capitalized on successful citizen-science programs for the public (e.g., Teaching Issues in and Experiments in Ecology (TIEE), Cornell Laboratory of Ornithology, GLOBE program); 2) taking stock of the state of curricula related to phenology at the undergraduate and graduate level, and identifying opportunities for short courses and new majors; 3) reviewing the National Science Standards to learn where phenological topics are part of the K-12 curriculum; 4) communicating with other environmental research networks that (will) utilize web portals and cyber infrastructure to acquire environmental data and make the data available in the public domain for researchers; and 5) launch several phenology pilot programs to develop exemplar materials for engaging and training students and the public in phenological research.

A critical product of the RCN education program will be a set of field manuals, classroom guides, and instructions that can be used to instruct informal science educators, schoolteachers, citizen-scientists, and undergraduate and graduate students in the collection, management, sharing, and interpretation of phenological data for taxa and habitats. Protocols established by the RCN steering committee and at annual RCN retreats will be field-tested to ensure their scientific and educational value and to guarantee the clarity and ease with which phenological data may be uploaded to (and downloaded from) the NPN website.

Pilot programs to create and test these material will be led and implemented by Mazer and Brewer, in collaboration with University of California at Santa Barbara's *Center for Biodiversity & Ecological Restoration,* University of California's Sedgwick Ranch Reserve, University of California's Coal Oil Point Reserve, and K-12 schools participating in the University of Montana GK-12 Program (phenology is one theme of this program). The goals of these activities are to: (a) create written instruction manuals that will serve as a template for NPN data-collection sites elsewhere in the U.S.; (b) initiate phenological observations and data collection on multiple plant and animal species appropriate for the central California Coast and northern Rockies/western Great Plains; (c) establish field-tested protocols for uploading, downloading, managing and analyzing data that will be available nationally; (d) create a model for NPN sites or "nodes" for which the methods can be applied to any site at any place in the U.S. where focal plants and animals have been identified for study; and (e) provide a model for the integration of NPN data-collection into the undergraduate curriculum. At the same time we will identify similar organizations (e.g., museums, nature centers, ecological GK-12 programs, etc.) across the country for beta testing the materials that are developed.

The activities and products of the education program of the NPN will be disseminated via the program website, in presentations at annual meetings of scientific and education professional societies, and in articles for appropriate journals (e.g., *Frontiers in Ecology and Environment*, *Conservation Biology*, *American Biology Teacher*). The manuals and guides also will be available for use and downloading from the NPN website.

VII. Management Plan

A. Initial Organization

The University of Wisconsin-Milwaukee has provided seed funding to support a teaching reduction in Fall 2006, and a 50% Project Assistant and travel funds in the Fall 2006 and Spring 2007 semesters for the PI. These funds will allow the PI to plan an initial meeting of the RCN steering committee in Fall 2006, and (through the work of the Project Assistant) to develop and post a preliminary version of the USA phenology meta database to the USA-NPN web page. In June 2007 the PI will devote one month to plan deployment of the RCN. Subsequently, the Project Assistant will assist the PI in facilitating communication and collaboration among RCN participants, planning and conducting workshops, retreats, and student exchanges, as well as subsequent refinement/expansion of the meta database. In 2006-2007, we will be joined by Sara Mulder, a Ph.D. student from Wageningen University in the Netherlands who will be supported by a Fulbright fellowship. Sara will visit the USGS-University of Arizona Desert Laboratory (Betancourt), the University of Wisconsin-Milwaukee (Schwartz), and the High Plains Phenology Initiative at the University of Nebraska-Lincoln (Baenziger) to enhance the exchange of protocols for recording phenological data between the Dutch phenological monitoring Network 'De Natuurkalender' (Director Arnold Van Vliet, is on USA-NPN Implementation Team), the European Phenology Network, and USA-NPN.

B. USA-NPN RCN Steering Committee

The USA-NPN Implementation Team has been formed as an outcome of the earlier developmental workshops (see list above) and includes representatives from government agencies, academia, and research institutes with topical expertise in phenology, ecology, agriculture, education/outreach, climatology, hydrology, and remote sensing. The composition of the RCN steering committee (a subset of the Implementation Team) has been carefully selected to assure that multiple science perspectives inform the development of the RCN, which will, in turn, assure the network's relevance to various scientific constituencies, government agencies, and the public. Defining the bylaws of the steering committee will be one of their first items of business.

C. Workshops

The topics of the workshops will shift from operational to topical concerns as the Network matures. Workshops will focus on fundamental issues such as:

1) *Protocols for observations of native plants*. This is a critical component of the Network and will vary from region to region within the country. A workshop (led by Betancourt) with representatives from different parts of the country will determine which native plant species to target for observation, what phenophases to record, and protocols for observing the events. Selection of species and protocols will be determined by research priorities and other criteria (dominance, widespread distribution, etc.).
2) *Citizen-Science, Outreach, and Education*. A workshop led by Brewer and Mazer will advance the RCN citizen-science, outreach, and educational objectives (listed above in section VI.E.). Representatives from other phenology-related citizen-science networks (specifically Monarch butterfly and hummingbird observations) will also be invited to this workshop to discuss coordination of efforts and possibilities of harmonizing observations, data formats, and data flow. The initial focus of NPN will be on plant phenology, but look to integrate insect and other animal phenology as soon as feasible.
3) *Cooperation with intensive research sites*. A key element of NPN is the set of phenological observations to be made by trained scientists at instrumented sites (e.g.,

Ameriflux, Agriflux and LTER sites). These observations, coupled with high quality data on weather, climate, and biogeochemistry are critical to understanding driving forces of phenology and the subsequent changes in boundary layer conditions. Agreements need to be made to assure that the Network contributes to the mission of the other networks and that information flow reflects consensus. This workshop (led by Law and Waide) will also serve as a forum for experimental approaches to phenology.

4) *Promotion of phenology data in basic and applied research: Empirical needs for ecological and other kinds of forecast models*. This workshop (led by Dettinger) will focus on making the USA-NPN data sets known to various research communities. Strategies will be developed for publicizing the data and their potential use in climate, ecological, and hydrological models, as well as for other applications.
5) *Interface between surface observations and remotely-sensed data:* This workshop (led by Reed) will emphasize calibration of remote sensing data at intensive sites, development of hyperspectral libraries for species targeted by NPN, and use of remote sensing in scaling surface observations.

Additional workshops (funded as possible from non-RCN sources) will be defined by the Steering Committee and include themes such as identification of non-traditional phenology datasets, approaches for making past phenological data (different protocols) compatible and a part of the Network, and developing the informational infrastructure of the USA-NPN.

D. RCN Management and Assessment

The PI and steering committee will govern the USA-NPN RCN. In preparation for the annual retreat, the PI will prepare a report that will be shared with the entire group during the meeting, outlining the accomplishments during the past year, and preliminary plans for the next year. The PI and steering committee will meet during the retreat to discuss the plan. Feedback from all participants will also be solicited.

E. Overall Task Timetable

(see Budget Justification)

VIII. Coordination Plan with Other Relevant Networks

The USA-NPN Implementation Team includes representatives from the LTER and Ameriflux networks. Members of the NEON Design Team participated in the August 2005 planning meeting, and communication has been maintained with NSF's NEON program director. At least one workshop will be devoted to finalizing strategies for coordinating phenological observations and protocols with intensive research (NEON, Ameriflux, LTER, and other network) sites.

IX. Information and Material Sharing Plan

The data and other research products developed by the USA-NPN RCN will be shared through the USA-NPN web page (http://www.npn.uwm.edu), which will also be substantially enhanced (using contracted web development services) during the life of the RCN.

X. Plan for Increasing Diversity

The USA-NPN RCN will actively support student/early researcher exchange/training programs among participating organizations, as well as participation by students and scientists from under-represented communities in all network activities.

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Education

Ph.D. 1985	Geography, University of Kansas (G.A. Marotz, advisor)
M.S. 1982	Geography, Michigan State University (J. R. Harman, advisor)
B.S. 1980	Lyman Briggs College (Earth Science) Michigan State University (with honor)

Employment

2002-present	*Professor and Chair* (Chairship ended in Spr.2004), Geography, UW-Mil.
1996-2002	*Associate Professor and Chair*, Geography, UW-Milwaukee
1992-1996	*Assistant Professor*, Geography, UW-Milwaukee
1987-1992	*Lecturer*, Geography *Assistant Research Scientist* (1989-1992), Romberg Tiburon Center for Environ. Studies San Francisco State University
1985-1987	*Assistant Professor*, Geography, San Francisco State University

Honors and Awards

2005:	Association of American Geographers R. F. Abler Distinguished Service Honors
2000:	UWM Foundation and Graduate School Excellence in Research Award, $1500
1993:	Graduate School Research Incentive Program award, Fall semester
1992:	Sigma Xi, The Scientific Research Society, full membership

Research Grants

2001a:	Development of an Integrated Energy Flux/Phenology Monitoring Site at the UW-Milwaukee Field Station, NIGEC Midwestern Regional Center/Indiana University ($5,200) awarded for July 2001 - June 2002.
2001b:	Collaborative Research: Connecting Spring Phenology with Lower Atmospheric Energy-Mass Exchange, Phase Two, National Science Foundation, Climate Dynamics and Geography and Regional Science divisions (UWM Budget $159,999) awarded for March 2001 - September 2004. (with David Fitzjarrald, University at Albany)
1998:	Connecting Spring Phenology with Lower Atmospheric Energy-Mass Exchange, National Science Foundation, Climate Dynamics division ($188,122) awarded for October 1998 - September 2001 (Add. $3700 supplement awarded March 1999)

1995: Connecting Satellite and Surface Measures of Spring's Onset, National Science Foundation, Climate Dynamics division ($126,735) awarded for August 1995 - July 1999

1994: Development of a Phenological Model to Predict Peach Maturity from Meteorological Variables (with G. Carbone and G. Reighard), Southeast Regional Climate Center ($80,000, UWM Budget $33,669) awarded for June 1994 - May 1996

Five Most Relevant Publications

Referred Journal Articles

Schwartz, M. D. 1998: Green-wave phenology. *Nature* **394** (6696): 839-840.

Schwartz, M. D. 1994: Monitoring Global Change with Phenology: The Case of the Spring Green Wave. *International Journal of Biometeorology* **38**: 18-22.

Schwartz, M. D., Ahas, R., & A. Aasa, 2006: Onset of Spring Starting Earlier Across the Northern Hemisphere. *Global Change Biology* **12**(2): 343-351.

Schwartz, M. D., & B. E. Reiter, 2000: Changes in North American Spring. *International Journal of Climatology* **20**(8): 929-932.

Other Articles

Betancourt, J. L., Schwartz, M. D., Breshears, D. D., Cayan, D. R., Dettinger, M. D., Inouye, D. W., Post, E., & B. C. Reed, 2005: Implementing a U.S. National Phenology Network. *EOS* **86**(51, 20 December): 539-541.

Five Additional Publications

Book--Schwartz, M. D. (editor), 2003: *Phenology: An Integrative Environmental Science.* Kluwer, Netherlands, 592 pp.

Referred Journal Articles

Schwartz, M. D. 1996: Examining the Spring Discontinuity in Daily Temperature Ranges. *Journal of Climate* **9**(4): 803-808.

Schwartz, M. D., & T. R. Karl, 1990: Spring Phenology: Nature's Experiment to Detect the Effect of "Green-up" on Surface Maximum Temperatures. *Monthly Weather Review* **118**: 883-890.

Schwartz, M. D., Reed, B. R., & M. A. White, 2002: Assessing Satellite-Derived Start-of-Season Measures in the Conterminous USA. *International Journal of Climatology* **22**(14): 1793-1805.

Zhao, T., & M. D. Schwartz, 2003: Examining the Onset of Spring in Wisconsin. *Climate Research* **24**(1): 59-70.

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B. Appointments:

2004 – 2008. Councilor, Association for Tropical Biology and Conservation
January 2004 – December 2005. Program Director, Ecological Biology Program, Division of Environmental Biology, National Science Foundation, Washington, D.C.
July 1999 - Present. Full Professor, Department of Ecology, Evolution and Marine Biology, UCSB
1999 - 2001: Executive Vice-President, Society for the Study of Evolution
2000 - 2001: American Institute of Biological Sciences, Council member for BioOne Consortium of Societies providing on-line access to academic journals.
July 1993 - 1999. Associate Professor; Department of Biological Sciences, UCSB.
July 1988 - June 1993. Asst. Professor; Department of Biological Sciences, UCSB.
January 1987 - June 1988. Smithsonian Post-Doctoral Fellow; National Museum of Natural History, Smithsonian Institution, Washington, D.C.

C. Publications (five most relevant)

Mazer, S. J. & G. L. Lebuhn. 1999. The genetic basis of life history traits in plants: heritability within and genetic differentiation among populations. Pp. 85 ñ 171, In P. Mutakainin and T. Vuorisalo (eds), Life History Evolution in Plants, Kluwer Academic, The Netherlands.

Ashman, T. L., T. M. Knight, J. Steets, P. Amarasekare, M. Burd, D. R. Campbell, M. R. Dudash, M. O. Johnston, S. J. Mazer, R. J. Mitchell, M. T. Morgan, and W. G. Wilson. 2004. Pollen-limitation of plant reproduction: ecological causes and consequences. Ecology 85: 2408-2421.

Paz, H., S. J. Mazer, and M. Martinez-Ramos. 2005. Comparative ecology of seed mass in *Psychotria* (Rubiaceae): within- and between-species effects of seed mass on early performance. Functional Ecology 19: 707 – 718

Knight, T. M., J. A. Steets, J. C. Vamosi, S. J. Mazer, M. Burd, D. R. Campbell, M. R. Dudash, M. O. Johnston, R. J. Mitchell, T. L. Ashman. 2005. Pollen Limitation of Plant Reproduction: Pattern and Process. Annual Reviews of Ecology, Evolution and Systematics, 36:467 - 497.

Vamosi, J. C., T. M. Knight, J. A. Steets, S. J. Mazer, M. Burd, and T-L Ashman. 2006. Pollination decays in biodiversity hotspots. Proceedings of the National Academy of Sciences, 103: 956 – 961.

Publications (five additional)

Mazer, S. J. & V. A. Delesalle. 1998. Contrasting variation within and covariation between gender-related traits in autogamous versus outcrossing species: alternative evolutionary predictions. Evolutionary Ecology 12: 403 - 425.

Mazer, S. J. & D. A. Meade. 2000. Geographic variation in flower size in wild radish: the potential role of pollinators in population differentiation. Pp. 157 – 186, In T. A.Mousseau and B. Sinervo, Adaptive Genetic Variation in the Wild, Oxford University Press.

Mazer, S. J. and J. D. Damuth. 2001. The evolutionary significance of variation: among populations, pp. 16 - 28, In Charles Fox, Daphne Fairbairn, and Derek Roff, Evolutionary Ecology: Perspectives and Synthesis, Oxford University Press.

Mazer, S. J., D. E. Lowry, & T. Hansen. 2003. Effects of nutrient availability on primary sexual traits and their response to selection in Spergularia marina (Caryophyllaceae). Journal of Evolutionary Biology 16: 767 – 778.

Hufford, K. and S. J. Mazer. 2003. Plant ecotypes: Genetic differentiation in the age of ecological restoration. Trends in Ecology & Evolution. 18: 147-155.

D. Synergistic activities

2006. Presented basic genetic concepts to an urban restoration ecology workshop (What is local?), sponsored by the Greenbelt Native Plant Nursery, Staten Island, NY.

2005. Participated in an international pollination biology workshop, sponsored by the University of Lausanne, Switzerland, to introduce graduate students to current research topics and methodological approaches to pollination ecology.

2001. NSF-supported workshop: evaluation of an Evolutionary Synthesis Center

2000. NSF's Committee of Visitors Panel. Systematics & Population Biology Programs.

1999. NSF Advisory Panel for the Integrated Research Challenge Program.

1998-2001. Associate Editor, Editorial Review Board, Journal of Evolutionary Biology

For the last 10 years, I have supervised an undergraduate research program in my lab. I supervise 8 - 10 students per year who work in the lab ~10 hours/week during the academic year, either for upper division course credit or as paid technicians. *Michael Bell, Kelly Ann Dawson, and Jennifer Knies have been undergraduate co-authors.* Since 1991, I have also supervised 2-3 students per year through NSF's REU program, providing training in laboratory, greenhouse and field techniques for the study of mating system evolution in *Clarkia* spp. and in *Spergularia marina*. During 2002 – 2004, I was the co-organizer of two collaborative working groups funded by the National Center for Ecological Analysis and Synthesis: *Beyond hand-pollinations: Linking pollen limitation to plant population biology* (2002 - 2004) and *Life-history variation and community structure in neotropical rainforest communities*: *Ecological and phylogenetic influences* (2002 – 2003). These projects have resulted in four publications to date (Ashman et al. 2004, *Ecology*; Knight et al. 2005, *AREES*, Vamosi et al., in press, *PNAS*; Wright et al., in press, *Annals of Botany*). Two more are near submission.

E. Collaborators : David Ackerly (Stanford University), Tia-Lynn Ashman (University of Pittsburgh), Martin Burd (Monash Univ.), Diane Campbell (UC Irvine), Veronique Delesalle (Gettysburg College), Lisa Dorn (U. Wisconsin, Osh-Kosh), Kathleen Donohue (Harvard), Michelle Dudash (U. Maryland), Bernard Godelle (Univ. de Montpellier, France), Tiffany Knight (Washington University), Kristina Hufford (post-doc, UC Irvine), Mark Johnston (Dalhousie U.), Miguel Martinez-Ramos (UNAM, Morelia, MX), Nathalie Machon (Conservatoire Botanique National du Bassin Parisien, Museum Nat. d'Hist. Nat., Paris, FR), Randall Mitchell (U. Akron) Horacio Paz (UNAM, Morelia, MX), Nigel Pitman (Los Amigos Biological Station, Manu, Peru), Sam Scheiner (NSF), Miles Silman (Wake Forest University), Janette Steets (U. Pittsburgh), Jana Vamosi (U. Calgary), Cam Webb (Yale University), Lorne Wolfe (Georgia Southern University), Ian Wright (Macquarie University). **No Co-editors to Report.**

ii. **Graduate and Postdoctoral Advisors**: Maureen Stanton (Ph.D. advisor, UC Davis); Scott Wing (post-doctoral, National Museum of Natural History, Wash., DC)

iii. **Thesis and Post-doctoral advising: Post-doctoral (7 post-docs):** Dr. Lorne Wolfe, (Georgia Southern University); Dr. Paul Neal (U. Connecticut); Dr. Mark Camara (Oregon State University); Dr. Clementine Gimaret-Carpentier (Ecole Normale Superiere in Lyon, France); Dr. Horacio Paz (UNAM, Morelia, MX); Dr. Kristina Hufford (UC Irvine); Dr. Leah Dudley (UCSB).

Graduate Advising: Committee Chair for 9 students: Aldicir Scariot, Ph.D.; Daniel Meade, Ph. D. (Private Environmental Consultant); Gretchen LeBuhn, Ph.D. (San Francisco State University); Steven Travers, Ph.D. (Kansas State University); Charles T. Schick, Ph. D. 1999; David E. Lowry, Ph.D (expected June 2006); Virginia Hayes, M.S.; Elizabeth Mason, M.S. (exp. June 2006); Previous committee member for 8 PhD students.

P. Stephen Baenziger

University of Nebraska, Department of Agronomy and Horticulture, Lincoln, Nebraska 68583-0915
e-mail: pbaenziger1@unl.edu

I. Personal Data

Born 25 April 1951 (Toronto, Ontario, Canada)

II. Professional Preparation

B.A. *magna cum laude*, 1972, Harvard University (Biochemical Sciences)
M.S. 1975, Purdue University (Plant Breeding and Genetics)
Ph.D. 1975, Purdue University (Plant Breeding and Genetics)

III. Professional Appointments:

1993-present Eugene W. Price Professor, Dep. Of Agronomy & Horticulture, University of Nebraska
1993-1996 Interim-Head, Department of Agronomy, University of Nebraska, 1993-1996
1991-1993 Professor, University of Nebraska
1986-1991 Associate Professor, University of Nebraska,
1983-1986 Research Manager, Monsanto Agricultural Products Company, St. Louis, MO
1976-1983 Research Geneticist, USDA-ARS, Beltsville, MD

IV. 5 Publications most closely related to the proposed project.

Streck, N. A., A. Weiss, and P. S. Baenziger. 2003. A generalized vernalization response function for winter wheat. Agron. J. 95:155-159.

Streck, N. Augusto, A. Weiss, Q. Xue, and P. Stephen Baenziger. 2003. Improving predictions of developmental stages in winter wheat: a modified Wang and Engel model. Agricultural and Forest Meteorology 115:130-150.

Streck, N. A., A. Weiss, Q. Xue, P. S. Baenziger. 2003. Incorporating a Chronology Response into the Prediction of Leaf Appearance Rate in Winter Wheat. Annals of Botany 92(2):181-190.

Xue, Q., Albert Weiss, and P. Stephen Baenziger. 2004. Predicting leaf appearance in field-grown winter wheat: evaluating linear and non-linear models. Ecological modeling 175: 261-270.

Hu, Qi, A. Weiss, S. Feng, and P. S. Baenziger. 2006. Earlier winter wheat heading dates and warmer spring in the U.S. Great Plains. Agric. and Forest Meteorology 135: 284-290.

5 other significant publications

Xue, Q., M. Soundararajan, A. Weiss, T. J. Arkebauer, and P. S. Baenziger. 2002. Genotypic variation of gas exchange parameters and carbon isotope discrimination in winter wheat. J. Plant Physiol. 159:891-898.

Campbell, B. T., P. S. Baenziger, K. S. Gill, K. M. Eskridge, H. Budak, M. Erayman, I. Dweikat, and Y. Yen. 2003. Identification of QTLs and Environmental Interactions Associated with Agronomic Traits on Chromosome 3A of Wheat. Crop Science 43:1493-1505.

Xue Q, A. Weiss, and P.S. Baenziger. 2004. Predicting phenological development in winter wheat. Climate Res. 25:243-252.

Xue, Q. , Albert Weiss, Timothy J. Arkebauer and P. Stephen Baenziger. 2004. Influence of soil water status and atmospheric vapor pressure deficit on leaf gas exchange in field-grown winter wheat. Env. Exp. Bot. 51: 93-181.

Dhungana, P., K. M. Eskridge, and A. Weiss, and P.S. Baenziger. 2005. Designing crop technology for a future climate: An example using response surface methodology and the CERES-Wheat model. Agricultural Systems 87:63-79.

V. Synergistic Activities

1. Chair, University of Nebraska cluster group "*The High Plains Observatory for Integrated Phenology: Predicting The Behavior and Life Cycles of Introduced and Native Plants, Insects, and Plant Diseases on the Landscape"*

2. President-elect, President, and Past-President of Crop Science Society of America, 2001-2004.
3. Chair-elect, Chair, and Past Chair, Section O (Agriculture, Food, and Renewable Resources), American Association for the Advancement of Science, 2001-2003
4. Member, National Wheat Improvement Committee (1998-2001)
5. Member-at-Large, Section O, American Association for the Advancement of Science, 1995-1999.
6. Councilmember-at-Large, American Institute of Biological Sciences (1993-1996)
7. CROPS99 Symposium Co-Chair (1997), Coalition for Research on Plant Systems
8. Editor-in-Chief (1992-1997), Crop Science Society of America; Editor (1990-1991), Crop Science; Associate Editor (1987-1989), Crop Science

VI. Collaborators & Other Affiliations

i. Collaborators

Dr. Jim Anderson, University of Minnesota
Dr. Guihua Bai, USDA-ARS
Dr. Brett Carver, Oklahoma State University
Dr. Ming-shun Chen, USDA-ARS
Dr. Jorge Dubcovsky, University of California-Davis
Dr. Allan Fritz, Kansas State University
Dr. Kulvinder Gill, Washington State University
Dr. Robert Graybosch, USDA-ARS
Dr. Scott Haley, Colorado State University
Dr. Yue Jin, USDA-ARS
Dr. Shahryar Kianian, North Dakota State University
Dr. Eitan Millet, Tel Aviv University, Israel
Dr. Jackie Rudd, Texas A&M University
Dr. Oscar Riera-Lizarazu, Oregon State University
Dr. Mark Sorrells, Cornell University
Dr. Yang Yen, South Dakota State University

ii. Graduate and Postdoctoral Advisors- none still in academia

iii. Thesis Advisor and Postgraduate Sponsor (4 current and 11 finished M.S. students; 3 current and 22 finished Ph.D. students, 1 current and 7 former postdoctoral scientists). Complete list can be found at http://agronomy.unl.edu/grain/

Representative Honors and Awards

Distinguished Agriculture Alumnus Award, 2002, Purdue University
Crop Science Research Award, Crop Science Society of America, 2000
Distinguished Service Award, Nebraska Crop Improvement Association, 2000
Agronomic Achievement Award-Crops, American Society of Agronomy, 1997
Elected Member, Nebraska Hall of Agricultural Achievement, 1997
Honorary Professor, Ningxia Academy of Agricultural and Forestry Sciences, 1992
Fellow, American Association for the Advancement of Science, 1991
Fellow, American Society of Agronomy, 1990
Fellow, Crop Science Society of America, 1990
Member, IANR Interdisciplinary Team Research Award, 1989
Crop Science Society of America Young Crop Scientist Award, 1987
Monsanto Management Incentive Awards in 1985 and 1986

BIOGRAPHICAL SKETCH

JULIO L. BETANCOURT

EDUCATION

Ph.D. Geosciences, University of Arizona, 1989
M.S. Geosciences, University of Arizona, 1983
B.A. Anthropology/Geography College, University of Texas, 1975

PROFESSIONAL AND ACADEMIC EXPERIENCE

Senior Scientist and Research Hydrologist, USGS 1989-present
Adjunct Professor, Depts. of Geosciences, Geography, & Laboratory of Tree-Ring Research, University of Arizona, current

TEN SELECTED PUBLICATIONS: http://wwwpaztcn.wr.usgs.gov/julio_cv.html

Van de Water, P.K., Leavitt, S.L., Betancourt, J.L., Fischer, T. and Pedicino, L. 2006. Evaluation of $\delta^{13}C$ of *Atriplex* leaf cellose as a proxy for $\delta^{13}C$ of atmospheric CO_2 on time scales of decades to millennia. *Plant Cell & Environment* (In press).

Holmgren, C., Norris, J., Betancourt, J. L. 2006. Inferences about winter temperatures and summer rains from the late Quaternary record of C_4 perennial grasses and C_3 desert shrubs in the northern Chihuahuan Desert. *Journal of Quaternary Science* (In press).

McCabe, G., Betancourt, J.L., Hidalgo, H.G. 2006. Associations of decadal to multidecadal sea-surface temperature variability with Upper Colorado River flow. *Journal of the American Water Resources Association* (In press).

Gray, S.T., Betancourt, J.L., Jackson, S.T., Eddy, R. 2006. Role of multidecadal climate variability in a range extension of pinyon pine. *Ecology* 87, 1124-1130.

Norris, J., Jackson, S.T., and Betancourt, J. L., 2005. A classification tree analysis of the distribution of ponderosa pine in the western U.S.A. *Journal of Biogeography* 33, pp. 342-360.

Betancourt, J.L., Schwartz, M.D., Breshears, D.D., Cayan, D.R., Dettinger, M.D., Inouye, D.W., Post, E., and Reed, B.C. 2005. Implementing a U.S.A.-National Phenology Network. *Eos Transactions American Geophysical Union*, Vol. 86, p. 539.

Gray, S. T., Fastie, C., Jackson, S. T., and Betancourt, J. L. 2004. Tree-ring based reconstruction of precipitation in the Bighorn Basin, Wyoming since A.D. 1260. *Journal of Climate* 17, 3855-3856.

McCabe, G. J., Palecki, M. A., and Betancourt, J. L. 2004. Pacific and Atlantic Ocean influences on multidecadal drought frequency in the United States. *Proceedings of the National Academy of Sciences* 101, p. 4136-4141.

Lyford, M.E., Jackson, S.T., Betancourt, J.L. and Gray, S. 2003, Influence of landscape structure and climate variability in a late Holocene natural invasion. *Ecological Monographs* **73**, 567–583.

Smith, F. A. and Betancourt, J.L. 2003. The effect of Holocene temperature fluctuations on the evolution and ecology of *Neotoma* (woodrats) in Idaho and northwestern Utah. *Quaternary Research* **59**, 160-171

SYNERGIST ACTIVITIES

Innovations in teaching and contributions to the science of learning: As a USGS scientist, I do not teach formal courses. However, I annually support and mentor an average of 1 postdoc, 3 graduate and 3 undergraduate students. I regularly participate as a mentor and source of funding for undergraduates in the NASA Space Grant Internship Program and the Undergraduate Biology

Research Program (UBRP) at the Univ. of Arizona. In 1996-2000, I led an NSF-InterAmerican Institute program to develop late Quaternary vegetation histories of arid South America drawing on my own experience in arid North America. The main objective of the program was to provide field and laboratory training for professionals and students from Argentina, Bolivia, Chile and Peru. I've continued this tradition in my subsequent work in Chile. Two of my Chilean Ph.D. students currently occupy professorships in prominent Chilean universities.

Communication of research results to the general public: In my capacity as a federal scientist, I strive to assume leadership in response to emerging regional and national, environmental issues of environmental concern. For example, in 1997-1999, I coordinated a series of field visits by USGS interdisciplinary team to various National Park Service and USDA Forest Service Districts across the western U.S. to consider the effects on increasing wildfires on western watersheds. In 2003-2004, I gave over 30 presentations across the country on the climatic and historical context of the 1999-2004 drought, including keynote talks at several drought summits and workshops organized in western and Great Plains states. Beginning in 2004, I initiated a demonstration and outreach project to promote eradication of an invasive species (buffelgrass) in the Sonoran Desert. I also grant frequent interviews for national, regional and local print, radio, and television media.

Refinement of research results: I have coordinated key national and international workshops, such as the annual Pacific Climate (PACLIM) Workshops in 1989-1991 (http://meteora.ucsd.edu/paclim/); "Advances in Central Andes Paleoclimatology" in 2001 (http://wwwpaztcn.wr.usgs.gov/pcaw/); "Improving the Application of Science in Western Drought Management & Planning" for the Western Governor's Association in March 2004; "Role of NEON in Addressing Ecological Implications of Climate Change" for AIBS in August 2004 (http://www.neoninc.org/documents/neon-climate-report.pdf), and the workshop to begin organizing the USA-National Phenology Network in August 2005.I serve on the Editorial Board of *Diversity and Distribution* and was a Founding Member of the International Biogeography Society. I currently serve on the NAS-NRC-Water Science Board Committee on Science needs for Colorado River Water Management, and just completed a stint on the subcommittee that evaluated and collated the U.S. Government review of the IPCC Fourth Assessment Report.

Broadening the participation of groups underrepresented in science: I came up through USGS as a graduate student under the DOI Minority Participation in the Earth Sciences Program, and have myself mentored several MPES students. I also make it a point to give lectures at local high schools with predominantly Hispanic student bodies.

NAMES OF POTENTIAL CONFLICT

1. Adviser/Advisee (Ph.D. advisors): Paul Martin, Vic Baker, C. Vance Haynes, Ray Turner, Jim Brown

2. Co-Authors & Collaborators (past 48 months): Craig Allen, Scott Anderson, Jim Cane, Ken Cole, Jeff Dean, Chris Fastie, Steve Gray, Lisa Graumich, Henri-Grissino-Mayer, Michael Hofreiter, Kim Hunter, Steve Jackson, Claudio Latorre, Steve Leavitt, Mark Lyford, Raina Maier, Jim Mead, Bruce Milne, Vera Markgraf, Greg McDonald, Stuart Pearson, Elise Pendall, Cristina Peñalba, Hendrik Poinar, Jay Quade, Jason Rech, Brett Riddle, Bill Romme, Matt Salzer, Felisa Smith, Mark Schwartz, Geof Spaulding, Scott Steppan, Tom Swetnam, Valerie Terwilliger, Pete Van de Water, Tom Van Devender, Peter White, Mathias Vuille

3. Graduate Students: Angela Barclay, Steve Gray, Camille Holmgren, Kim Hunter, Claudio Latorre, Mark Lyford, Jodi Norris, Lisa Pedicino, Elise Pendall, Christa Placzek, Jason Rech, Amanda Reynolds, Pete Van de Water, Tamara Wilson; **Postdocs:** Sean Connin, Qinfeng Guo, Steve Gray

CAROL A. BREWER, PH.D.
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406-243-6013; brewerc@mso.umt.edu; www.bioed.org

Professional Preparation

BA	Biology	California State University – Fullerton	1981
BS	Science Education	University of Wyoming	1985
MS	Zoology and Physiology	University of Wyoming	1986
Post Graduate Research		Norwegian Institute for Water Research	1986-87
Ph.D.	Botany	University of Wyoming	1993

Appointments

Professor, Division of Biological Sciences, and Adjunct Associate Professor, Department of Curriculum and Instruction and Department of Society and Conservation (June 2006 - present), University of Montana

Associate Professor, Division of Biological Sciences, and Adjunct Associate Professor, Department of Curriculum and Instruction (1999 – present) and Department of Society and Conservation (October 2003 - present), University of Montana

Visiting Scientist (on sabbatical), Institute of Ecosystem Sciences, Millbrook NY (Feb - Jun 2002)

Senior Fulbright Research Scholar and Visiting Professor, Centro Regional Universitario Bariloche, Universidad Nacional del Comahue, Argentina (Jan - Jun 1998)

Coordinator, Master of Science Teaching Program, University of Montana (1995 – 1999)

Assistant Professor, Division of Biological Sciences, and Adjunct Assistant Professor, Department of Curriculum and Instruction, University of Montana (1994 – 1999)

Visiting Assistant Professor, Division of Biological Sciences and Department of Curriculum and Instruction, University of Montana (1993 - 1994)

Selected Recent Publications

Brewer, C.A. 2006 (in press). Translating data into meaning: education in Conservation Biology. *Conservation Biology* 20:000-000.

Brewer, C.A., A. Berkowitz, P. Conrad, J. Patz, J. Porter, and M. Waterman. 2006 (in press). Educating about the ecology of infectious diseases. In, Ostfeld, R.S., F. Keesing, and V.T. Eviner, eds. Infectious disease ecology: effects of ecosystems on disease and of disease on ecosystems. Princeton University Press, Princeton, NJ.

Berkowitz, A., M. Ford, and **C.A. Brewer**. 2005. A framework for integrating ecological literacy, civics literacy and environmental citizenship in environmental education. In, Johnson, E.A. and M.J. Mappin (eds.), *Environmental Education or Advocacy: Perspectives of Ecology and Education in Environmental Education*. Cambridge University Press. New York. Pp 227-266.

Brewer, C.A. and D. Maki. 2005. Building the Renaissance team: fostering cross-disciplinary collaborations. In, Steen, L.A. (ed.) Math & Bio 2010: Linking Undergraduate Disciplines. The Mathematical Association of America (Washington, DC). pp 45 – 50.

Cooperman, M. S. and **C.A. Brewer**. 2005. Relationship between plant distribution patterns and the process of river island formation. *Journal of Freshwater Ecology* **20**:487-501.

Brewer, C.A. 2004. Near real - time assessment of student learning and understanding in biology courses. *BioScience* 54:1034-1039.

Blank, L. and **C. Brewer**, et al. 2003. Ecology education when no child is left behind. *Frontiers in Ecology and the Environment* 1:383-390.

Brewer, C.A. and L.J. Gross. 2003. Training ecologists to think with uncertainty in mind. *Ecology.* **84**:1412-1414.

Inouye, D. and **C.A. Brewer**. 2003. Who are we training in conservation biology graduate programs? A case study of the Program in Sustainable Development and Conservation Biology at the University of Maryland. *Conservation Biology* **17**:1204-1208.

Brewer, C. A. 2002. Outreach and partnership programs for conservation education where endangered species conservation and research occur. *Conservation Biology* 16:1-3.

Synergistic Activities

1. *Scientific Society Leadership and Service*: Vice President, Ecological Society of America and Governing Board, 8/00 – 8/06. Chair, Standing Committee on Education and Human Resources. Frequent leader of education/diversity workshops (e.g., Strategies for Changing the Face of Ecology in America; "Integrating Hot New Research Findings into Undergraduate Ecology Courses" (*Chronicle of Higher Education* 8/9/02); "Uncertainty in Estimation, Forecasting, and Decision Making: Teaching Students to Think with Uncertainty in Mind" (with L. Gross); Integrating Scientific Research and Education (with M. Krasney and D. Ebert-May). Co-Organized NSF-funded Institute that evolved from an ESA science initiative on Ecological Forecasting (Summers 2004, 2006) with Dr. Jim Clark (Duke University). Oversaw Committees that developed *Status of Ecology in the Undergraduate Curriculum* survey, *Women and Minorities in Ecology* Report, and *Profiles of Ecologists* Survey.
2. *National Research Council Service* - Standing Committee on Science Education COSE K-12 (8/00 - 5/03); member of ad hoc committee for the "Science Learning Study" (2002 – 2003), Co-leader and presenter at "Integrating Education in BioComplexity Research" by the *National Research Council – National Science Foundation – National Academy of Science*s, Washington DC (4/02).
3. *Editorial Board Service* - *Conservation Biology*, *Associate Editor (conservation education),* January 2001 – present. Write for and edit column on education and training for conservation biologists. *Editorial Board*, *Frontiers in Ecology and the Environment*.
4. *Service to the Field of Ecology* - Led the development of the education and diversity plan as Chair of the Education Committee for *National Ecological Observatory Network)* 2003 – 2006.
5. *Education and Public Outreach in Science, Conservation Biology, and Ecological Education* – Directed UG curriculum and research program funded by the Howard Hughes Medical Institute, led faculty and graduate student professional development activities, and led program assessment activities (1998-2004). Curricular, mentoring, professional development and student research activities are featured at www.bioed.org. Led or mentored partnership programs to introduce local teachers and their students to the schoolyard as an ecological laboratory – see www.bioed.org/ECOS; named "Earth Day Hero" in western Montana for outreach to K-12 Schools.

Collaborators, Co-Authors and Co-Editors (Previous four years, students co-authors listed below):
P. Alaback (UM), C. Baru (UCSD), A. Berkowitz (IES), L. Blank (UM), B. Braatz (Duke), E. Caton (UM), F. S. Chapin, III (UA), J. Clark (Duke), P. Conrad (UCDavis), M. Cooperman (OrSU), D. Ebert-May (MiSU), V. Eviner (IES), D. Estrin (UCLA), M. Ford (IES), J. Franklin (UWa), J. Gobert (Salish Kootenai College), J. Goldman (AIBS), L. Gross (UTenn), B. Hayden (UVa), C. Heine (Physician), P. Hurley (Salish Kootenai College), D. Inouye (UMd), J. Johnson (UM), F. Keesing (Bard), M. Krasney (Cornell), L. Krishtalka (UKa), P. Kukuk (UM), D. Maki (UIn), M. Mappin (Kananaskas Field Station), J. MacMahon (UtS), W. Michener (UNM), L. Mills (UM), D. Oberbillig (UM), R.Ostfeld (IES), J. Patz (UWisc), M. Plautz (UM), J. Porter (UGa), A. Premoli (CRUB), J. Twiggs (UM), D. Udovic (UOr), L.W.A. van Hove (Wageningen), M. Waterman (MOSt), A. Whiteley (UM), C. Zabinski (MtSU)

Graduate and Postdoctoral Advisors:
Thesis advisor: Michael Parker, Ph.D., University of Wyoming
Post Graduate advisor: Bjørn Rørslett, Ph.D., Norwegian Institute of Water Research
Dissertation advisor: William K. Smith, Ph.D., Wake Forest University

Advisor to (underline signifies current students)**:** *Post Doctoral NSF-PFSMETE Scholars* - E. Caton (UM), K. Bright-Emlen (UM); *Ph.D. Students* – A. Perkins, C. Nuñez, M. Schreuder, R. Loehman (co-advisor), C. Rosier (co-advisor), B. McBride (co-advisor); *M.S. and MST* Students* – M. Cooperman, J. Chodish, M. Erickson, K. Notin, M. Hourdequin, C. Langmaid*, J. Marangelo, S. Pankratz, K. Olson* (co-advisor), C. Snetsinger*, B. Swanson, C. Wall, K. Warner*, A. Wyrick

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U.S. Geological Survey 858.822.1507
Scripps Institution of Oceanography, Dept 0224
9500 Gilman Drive
UC San Diego
La Jolla, CA 92093-0224

Professional Preparation

U.C. San Diego (Revelle College), Physics, B.A., 1977
Massachusetts Institute of Technology, Civil Engineering, M.S., 1979
University of California, Los Angeles, Atmospheric Sciences, M.S., 1991
University of California, Los Angeles, Atmospheric Sciences, Ph.D., 1997 (Advisor, Michael Ghil)

Appointments

Research Hydrologist, USGS, Bureau of Regional Research, & Research Associate, Scripps Institution of Oceanography, Climate Research Division, La Jolla, CA, 2002-present
Research Hydrologist, USGS, & Research Associate, Climate Research Division, Scripps Institution of Oceanography, La Jolla, CA, 1997-2002
Research Hydrologist, USGS at NOAA/Climate Diagnostics Center, Boulder, CO, 1996-1997
Research Hydrologist, USGS, California District, San Diego, CA, 1990-1997
Hydrologist, U.S. Geological Survey, Carson City, NV, 1981-89
Engineer-scientist, Camp Dresser & McKee, Inc., Walnut Creek, CA, 1979-1981

Selected other Professional Activities

Vice President's National Performance Review Award for physical-sciences leadership in Mojave Desert Ecosystems science and data management planning efforts, 1996.
Climate Representative, USGS National Ground-water Levels Network Committee, 1995-97
Associate Editor, Water Resources Research, 1998-2000.
Program chair and fundraiser, 1998-2004, Pacific Climate (PACLIM) Workshops, 1998 (El Nino 1998), 1999 (Climate and Society), 2000 (Planning for the 2000s), 2001 (Climates of the Last 1000 Years), 2002 (Climate and Oceanic Biology), 2003 (Integrated Mountain Climate Research), and 2004 (Coastal Climates); Program committee and fundraiser, MTNCLIM Mountain Climate Workshops, 2005, 2006.
USGS representative on US Climate-Change Science Program (CCSP) Observations Working Group, 2002-present.
Founding member, CIRMOUNT Western Mountain Climate Sciences Consortium, 2002-present.
Member, CALFED San Francisco Bay-Delta Restoration Program Water-Management Science Board, 2004-2005.
Member, Science Steering Group for US CCSP Water Cycle Working Group, 2004-present.
Executive committee, National Phenological Network Implementation Team, 2005-present
Department of Interior Superior Service Award for exceptional contributions to hydroclimatology in the USGS, 2005.

Significant and Related (*) Journal Publications

* Dettinger, M.D., and Cayan, D.R., 1995, Large-scale atmospheric forcing of recent trends toward early snowmelt in California: Journal of Climate 8(3), 606-623.

Dettinger, M.D., Cayan, D.R., Diaz, H.F., and Meko, D., 1998, North-south precipitation patterns in western North America on interannual-to-decadal time scales: Journal of Climate, 11, 3095-3111.

Dettinger, M.D., and Diaz, H.F., 2000, Global characteristics of streamflow seasonality and variability: Journal of Hydrometeorology, 1, 289-310.

* Cayan, D.R., Kammerdiener, S., Dettinger, M.D., Caprio, J.M., and Peterson, D.H., 2001, Changes in the onset of spring in the western United States: Bulletin, American Meteorological Society, 82, 399-415.

Dettinger, M.D., Battisti, D.S., Garreaud, R.D., McCabe, G.J., and Bitz, C.M., 2001, Interhemispheric effects of interannual and decadal ENSO-like climate variations on the Americas, in Markgraf, V. (ed.), Interhemispheric climate linkages: Academic Press, 1-16.

* Lundquist, J.D., Cayan, D.R., and Dettinger, M.D., 2004, Spring onset in the Sierra Nevada—When is snowmelt independent of elevation?: J. Hydrometeorology, 5, 325-340.

Simpson, J.J., Dettinger, M.D., Gerhke, F., McIntyre, T.J., and Hufford, G.I., 2004, Hydrologic scales, cloud variability, remote sensing and models—Implications for forecasting snowmelt and streamflow: Weather and Forecasting, 19, 251-276.

Dettinger, M.D., 2005, From climate-change spaghetti to climate-change distributions for 21st Century California: San Francisco Estuary and Watershed Science, 3(1), http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4 .

* Hidalgo, H.G., Cayan, D.R., and Dettinger, M.D., 2005, Sources of variability of evapotranspiration in California: Journal of Hydrometeorology, 6, 3-19.

* Stewart, I., Cayan, D., and Dettinger, M., 2005, Changes towards earlier streamflow timing across western North America: Journal of Climate, 18, 1136-1155.

Recent Collaborators

David Peterson, Gregory McCabe, Anne Jeton, Randall Hanson and Julio Betancourt, USGS; Daniel Cayan, Hugo Hidalgo, Noah Knowles, Jessica Lundquist, Jim Simpson, Iris Stewart, Tony Westerling, SIO; Michael Ghil and Ferenc Varadi, UCLA; Henry Diaz, NOAA CDC; Marty Ralph and Paul Neiman, NOAA ETL; Malcolm Hughes and David Meko, U. Arizona Treering Lab; David Stahle, U. Arkansas Treering Lab; Kelly Redmond, Western Regional Climate Center; Lynn Ingram and Francis Malamud-Roam, UCB; Norman Miller, LBL; Tom Pagano and Phil Pasteris, NRCS; Michael Mann, U. Virgina; Robert Wilby, University of Derby, UK; Myles Allen, Rutherford Appleton Lab, UK; and Jose Marengo, INPE, Brazil.

DAVID W. INOUYE

University of Maryland, Department of Biology, College Park, MD 20742 e-mail: Inouye@umd.edu

I. Personal Data

Born 7 January 1950 (Philadelphia, Pennsylvania, USA)

II. Professional Preparation

Undergraduate: Swarthmore College, Zoology major, Bachelor of Arts, with Distinction, 1971
Graduate: University of North Carolina, Zoology. Doctor of Philosophy, 1976
Postgraduate: NATO Postdoctoral Fellow, Botanisches Institut der Universititaet Wien, 1978

III. Professional Appointments

2003 - Professor, University of Maryland, Department of Biology
2001 - Certified Senior Ecologist, Ecological Society of America
1990 - Director, graduate program in Sustainable Development and Conservation Biology
1981-03 Associate Professor, University of Maryland, Department of Zoology (now Biology)
1976-81 Assistant Professor, University of Maryland, Department of Zoology (now Biology)

IV. 5 publications most closely related to the proposed project

Inouye, D. W., and F.-E. Wielgolaski. 2003. Phenology of high-altitude climates. Pages 195-214 in: Phenology: An Integrative Environmental Science (M. D. Schwartz, ed.) Kluwer Academic Publishers.

Wielgolaski, F.-E., and D. W. Inouye. 2003. Phenology of high-latitude climates. Pages 175-194 in: Phenology: An Integrative Environmental Science (M. D. Schwartz, ed.) Kluwer Academic Publishers.

Betancourt, J. L., M. D. Schwartz, D. D. Breshears, D. R. Cayan, M. D. Dettinger, D. W. Inouye, E. Post, and B. C. Reed. 2005. Implementing a USA-National Phenology Network (USA-NPN). EOS 86(51): 539-542.

Inouye, D. W., F. Saavedra, and W. Lee-Yang. 2003. Environmental influences on the phenology and abundance of flowering by *Androsace septentrionalis* L. (Primulaceae). American Journal of Botany 90(6):905-910.

Inouye, D. W., M. Morales, and G. Dodge. 2003. Variation in timing and abundance of flowering by *Delphinium barbeyi* Huth (Ranunculaceae): the roles of snowpack, frost, and La Niña, in the context of climate change. Oecologia 130: 543-550.

5 other significant publications

Inouye, D. W., W. A. Barr, K. B. Armitage, and B. D. Inouye. 2000. Climate change is affecting altitudinal migrants and hibernating species. Proceedings of the National Academy of Science 97(4): 1630-1633.

Inouye, D. W. 1988. Natural variation in plant and animal populations, and its implications for studies of recovering ecosystems. Pages 39-50 in Cairns, J., editor. Rehabilitating Damaged Ecosystems. CRC Press. Second edition 1995.

Maloof, J. E., and D. W. Inouye. 2000. Are nectar robbers cheaters or mutualists? Ecology 81(10):2651-2661.

Inouye, D. W. 2000. The ecological and evolutionary significance of frost in the context of climate change. Ecology Letters 3(5):457-463.

Morales, M., D. W. Inouye, M. L. Leigh and G. Lowe. 2003. Considering interactions: Incorporating biotic interactions into viability assessment. Pages 267-287 in: Population Viability in Plants (C. A. Brigham and M. W. Schwartz, eds.); Ecological Studies, Volume 165. Springer-Verlag, Berlin.

V. Synergistic Activities

1. I started and moderate the listserv lists ECOLOG-L, ESANEWS, and OCNET-L.
2. I served for 10 years as a member of the Board of Trustees of the Rocky Mountain Biological Laboratory, served on many committees for RMBL.
3. I started and edit the Technological Tools and Ecological Classics columns for the Bulletin of the Ecological Society of America, and am Secretary of the ESA Board of Governors.
4. I am Co-Chair of the Conservation and Restoration committee of the North American Pollinator Protection Campaign.
5. I co-developed and now direct a highly-rated graduate program in Sustainable Development and Conservation Biology at the University of Maryland.
6. I have consulted on development of other graduate programs in conservation biology.
7. I am a member of the Board of Governors of the Ecological Society of America, and Secretary of the Board.
8. I recently organized and led a workshop for the National Park Service and other land managers in the Washington, D.C. area on Pollinators in Public Places.

VI. Collaborators & Other Affiliations

i. Collaborators.

Dr. Ken Armitage, University of Kansas
Dr. Carol Boggs, Stanford University
Gary Dodge, University of Maryland
Dr. Brian Inouye, Florida State University
Dr. Peter Kevan, University of Guelph
Dr. Michael Loik, UC, Santa Cruz
Dr. Susan Lambrecht, San Jose State Univ.
Dr. Manuel Morales, Willams College
Dr. James Thomson, University of Toronto
Billy Barr, Rocky Mtn. Biological Lab
Dr. James Dietz, University of Maryland
Dr. John Harte, UC Berkeley
Dr. Carol Kearns, University of Colorado
Brendon Larson, UC, Santa Barbara
Garrett Lowe, University of Maryland
Dr. Joan Maloof, Salisbury State University
Dr. Francisca Saavedra
Dr. Nicklas Waser, UC Riverside

ii. Graduate and Postdoctoral Advisors - none still in academia

iii. Thesis Advisor and Postgraduate Sponsor (2 postdocs, 9 M.S., 7 Ph.D. students finished, 5 current Ph.D. students; advised approximately 160 non-thesis M.S. students in Sustainable Development and Conservation Biology, with about 36 current students).

Dr. Manuel Morales (Williams College, was RTG post-doc 1999-2001)
Dr. Paul Callo (Mary Baldwin College, Ph.D. 2002: The genetic distribution model of offspring defense and the influence of predator identity on prey response)
Dr. Francisca Saavedra (Ph.D. 2000: Potential impact of climate change on the phenology and reproduction of *Delphinium nuttallianum* (Ranunculaceae))
Dr. Joan Maloof (Salisbury State University, Ph.D. 1999: The ecological effects of nectar robbers, with an emphasis on the reproductive biology of *Corydalis caseana*)
Dr. Carol Kearns (University of Colorado, Ph.D. 1990: The role of fly pollination in montane habitats)
Dr. Garrett Lowe (Ph.D. 2005 Wax myrtle (*Myrica cerifera*) and Myrtle Warblers (*Dendroica coronata coronata*): Reciprocal specialization in a fruit-frugivore interaction)
Dr. Gary Dodge (Ph.D. 2005: Population-level and regional non-target effects of inflorescence feeding by two biocontrol agents, *Larinus planus* and *Rhinocyllus conicus*, on native North American thistle species)
Dr. Tashi Wangchuk (Ph.D. 2005): Reproductive isolation in Langurs in Bhutan

BIOGRAPHICAL SKETCH: BEVERLY E. LAW

Professional Preparation
B.S. Forest Resources & Conservation (1980) University of Florida
Ph.D. Forest Science (1993) Oregon State University

Employment
200 – Science Chair, AmeriFlux network of research sites in the Americas
2006 Professor, Forest Science Department, Oregon State University
2001-2005 Associate Professor, Forest Science Department, Oregon State University
1998-2001 Assistant Professor, Forest Science Department, Oregon State University
1999-present Adjunct, College of Oceanic & Atmospheric Sciences, OSU

Advisory Panels
2006 – Global Terrestrial Observing System panel on Terrestrial Carbon Observations
2005 – US Carbon Cycle Science Program Science Steering Group
2005 – North American Carbon Program Steering Committee
2005 – NSF NEON Design Consortium

Honors and Awards:
2004 World Meteorological Organization Norbert Gerbier-MUMM International Award publication of the year (conferred in Genève Switzerland, 2004)
2004 Aldo Leopold Leadership Fellow

Ten Relevant Publications (out of 80)

1 **Law, B.E.**, D. Turner, M. Lefsky, J. Campbell, M. Guzy, O. Sun, S. Van Tuyl, W. Cohen. 2006. Carbon fluxes across regions: Observational constraints at multiple scales. In J. Wu, B. Jones, H. Li, O. Loucks, eds. Scaling and Uncertainty Analysis in Ecology: Methods and Applications. Columbia University Press, New York, USA.

2 **Law, B.E.** 2006. Carbon dynamics in response to climate and disturbance: recent progress from multiscale measurements and modeling in AmeriFlux. In S. Yamamoto, ed. Plant Responses to Air Pollution and Global Change. Springer, Tokyo, Japan.

3 **Law, B.E.**, D. Turner, J. Campbell, O.J. Sun, S. Van Tuyl, W.D. Ritts, W.B. Cohen. 2004. Disturbance and climate effects on carbon stocks and fluxes across western Oregon USA. *Global Change Biology* 10:1429-1444.

4 **Law, B.E.**, E. Falge, D.D. Baldocchi, P. Bakwin, P. Berbigier, K. Davis, A.J. Dolman, M. Falk, J.D. Fuentes, A. Goldstein, A. Granier, A. Grelle, D. Hollinger, I.A. Janssens, P. Jarvis, N.O. Jensen, G. Katul, Y. Mahli, G. Matteucci, R. Monson, W. Munger, W. Oechel, R. Olson, K. Pilegaard, K.T. Paw U, H. Thorgeirsson, R. Valentini, S. Verma, T. Vesala, K. Wilson, S. Wofsy. 2002. Carbon dioxide and water vapor exchange of terrestrial vegetation in response to environment. *Agricultural and Forest Meteorology* 113:97-120.

5 Van Tuyl, S., **B.E. Law**, D. Turner, A. Gitelman. 2005. Variability in net primary production and carbon storage in biomass across Oregon forests – An assessment integrating data from forest inventories, intensive sites, and remote sensing. *Forest Ecology and Management* 209:273-291.

6 Thornton, P., **B.E. Law**, H. Gholz, K.L. Clark, E. Falge, D.H. Ellsworth, A.H. Goldstein, R.K. Monson, D. Hollinger, M. Falk, J. Chen, J.P. Sparks. 2002. Modeling and measuring the effects of disturbance history and climate on carbon and water budgets in evergreen needleleaf forests. *Agricultural and Forest Meteorology* 113:185-222.

7 Campbell, J.L., O. Sun, **B.E. Law**. 2004. Disturbance and net ecosystem production across three climatically-distinct forest landscapes. *Global Biogeochemical Cycles* 18:GB4017, doi:10.1029/2004GB002236, 11pp.
8 Sun, O.J., J. Campbell, **B.E. Law**, V. Wolf. 2004. Dynamics of carbon storage in soils and detritus across chronosequences of different forest types in the Pacific Northwest, USA. *Global Change Biology* 10:1470-1481.
9 Reichstein, M., A. Rey, A. Freibauer, J. Tenhunen, R. Valentini, J. Banza, P. Casals, Y. Cheng, J. Grunzweig, J. Irvine, R. Joffre, **B.E. Law**, D. Loustau, F. Miglietta, W. Oechel, J-M. Ourcival, J. Pereira, A. Peressotti, F. Ponti, Y. Qi, S. Rambal, M. Rayment, J. Romanya, F. Rossi, V. Tedeschi, G. Tirone, M. Xu, D. Yakir. 2003. Modeling temporal and large-scale spatial variability of soil respiration from soil water availability, temperature, and vegetation productivity indices. *Global Biogeochemical Cycles* 17(4):1104, doi:10.1029/2003GB002035, pp. 15-1 to 15-15.
10 Coops, N.C., R.H. Waring, **B.E. Law**. 2005. Assessing the Past and Future Distribution and Productivity of Ponderosa Pine in the Pacific Northwest using a Process Model, 3-PG. *Ecological Modelling* 183:107-124.

Synergistic Activities

- Science Chair, AmeriFlux network of ~115 research sites
- PI on cluster of three AmeriFlux sites on disturbance gradient (young and mature ponderosa pine) and climatic gradient (mature Douglas-fir and pine) that include eddy covariance measurements of CO_2 and water vapor exchange, observations of carbon storage in vegetation and soils, and automated measurements of soil respiration and sapflux scaled to site (transpiration). Collaborating with soil carbon turnover studies (LLNL 13C, 14C) at our AmeriFlux sites
- PI on a regional study with CO_2 concentration measurement sites along a west-east climatic gradient from the coastal margin (Yaquina Head), to Mary's Peak in the Coast Range, to Mary's River Douglas-fir, the Metolius ponderosa pine site on the east side of the Cascade Mountains and the Burns site in sagebrush.

Collaborators and co-editors within the last 48 months:

Aber, J. (Univ. New Hampshire); Asner, G. (Carnegy Institute, CA); Baldocchi, D. (Univ. California Œ Berkeley); Bowling, D. (Univ. Utah); Brooks, R. (US Environmental Protection Agency); Cohen, W. (USFS PNW Forest Sciences Laboratory, Corvallis); Coops, N. (CSIRO, Australia); Davidson, E. (The Ecosystems Center, Woods Hole Marine Biological Lab.); Ehleringer, J. (Univ. Utah); Falge, E. (Max Plank Institute, Jena, Germany); Harmon, M. (Oregon State Univ.); Hibbard, K. (Univ. New Hampshire); Lefsky, M. (Coloradeo State Univ.); Mahrt, L. (Oregon State Univ.); Meinzer, R. (USDA Forest Serv. Pacific Northwest Lab.); Thornton, P. (NCAR); Treuhaft, R. (NASA Jet Propulsion Lab.); Turner, D. (Oregon State Univ.); Unsworth, M. (Oregon State Univ.); Williams, M. (Univ. Edinburgh, UK); Wofsy, S. (Harvard Univ.).

Graduate advisor:

R.H. Waring (Oregon State Univ.)

Thesis advisor and postgraduate sponsor (last 5 years):

Major advisor: Nole, A., PhD; Alberti, G., PhD; Stiefel, T., MS; Campbell, JL, PhD; Van Tuyl, S., MS; Johnson, T, MS., Donato, D., M.S.
Co-advisor: Ainsworth, A., MS; Tete M., MS; Kennedy, R., PhD; Walsh, C., PhD; Guild, L., PhD; Swearingren, K., MS; Foster, T., MS; Woodruff, D., MS.
Postgraduate sponsor: Goeckede, M.; Thomas, C.; Campbell, J.; Irvine, J.; Sun, O.; Anthoni, P.; Schwarz, P.; Kurpius, M.; Styles, J.; Loescher, H., Hibbard, K.; Falk, U.

Biographical Sketch

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Education

University of Minnesota	Biology	B.S. 1989
University of Alaska, Fairbanks	Biology	Ph.D. 1995
University of Oslo, Norway (postdoctoral)	Climate Change	1996 - 2000

Appointments

2005-	Associate Professor of Biology, The Pennsylvania State University
2000-2005	Assistant Professor of Biology, The Pennsylvania State University
1998-2000	NSF post-doctoral fellow, University of Oslo, Department of Biology
1996-1998	Norwegian Science Council post-doctoral fellow, University of Oslo, Department of Biology

Five Related Publications

Post, E. 2005. Large-scale spatial gradients in herbivore population dynamics. *Ecology* 86:2320-2328.

Forchhammer, M.C., Post, E., Berg, T.B.G., Høye, T.T., & Schmidt, N.M. 2005. Large-scale climatic fingerprint in local short-term plant and herbivore behaviour. *Ecology*, 86:2644-2651.

Post, E., Bøving, P.S., Pedersen, C., & MacArthur, M.A. 2003. Synchrony between caribou calving and plant phenology in depredated and non-depredated populations. *Can. J. Zool.*, 81:1709-1714.

Schmitz, O.J., Post, E., Burns, C.E., & Johnston, K. M. 2003. Ecosystem responses to global climate change: moving beyond color-mapping. *Bioscience*, 53:1199-1205.

Post, E.S. & Klein, D.R. 1996. Relationships between graminoid growth form and levels of grazing by caribou (*Rangifer tarandus*) in Alaska. *Oecologia,* 107:364 - 372.

Five Other Publications

Post, E. & Forchhammer, M.C. 2004. Spatial synchrony of local populations has increased in association with the recent Northern Hemisphere climate trend. *PNAS*, 101:9286-9290.

Post, E. 2003. Large-scale climate synchronizes the timing of flowering by multiple species. *Ecology* 84:277-281.

Post, E. & Forchhammer, M.C. 2002. Synchronization of animal population dynamics by large-scale climate. *Nature* 420:168-171.

Post, E., Peterson, R.O., Stenseth, N.C., & McLaren, B.E. 1999. Ecosystem consequences of wolf behavioural response to climate. *Nature*, 401:905-907.

Post, E. & Stenseth, N.C. 1999. Climatic variability, plant phenology, and northern ungulates. *Ecology,* 80:1322-1339.

Synergistic Activities

Innovations in teaching and contributions to the science of learning:

I have mentored or currently mentor 7 undergraduate students in my research at Penn State, including supervision of 2 undergraduate honors theses and 2 undergraduate projects in remote field sites in Greenland and Alaska. I have applied aspects of my research on the development of population models that incorporate global climatic variation in advanced study courses at: Penn State, the University of Oslo, Norway; the Agricultural University of Norway, Ås; and Abisko Scientific Research Station, Sweden ("Integrated Regional Impact Studies in the European North: Basic Issues, Methodologies, and Regional Climate Modeling"). I have also communicated novel research approaches to the study of climate change through invited speaking engagements at a conference on "Dynamics in time and space: basic and applied issues" held at The Norwegian Academy of Science and Letters, Oslo, Norway (1999); and at the ARTERI workshop "Europe's cold regions: scenarios for animal responses to global change", held in Abisko, Sweden (1998).

Communication of research results to the general public:
I regularly present my research in public forums, including public lectures at Penn State, talks at resorts, and talks at kindergartens and primary schools. My research on the ecology of climate change has been publicized in numerous media outlets, including The Daily Globe and Mail, The Guardian, The Smithsonian Institution's National Zoo publication ZooGoer, Science, US News & World Report, Discovery Channel Online, EurekAlert!, ABC News Online, BBC Wildlife Magazine, Swedish National Public Radio, and DLF Cologne Radio (Germany).

Refinement of research results:
I have recently participated in NSF-sponsored workshops on the National Ecological Observatory Network (NEON), Flagship Observatories, and National Phenology Network. I am currently consulting with the Greenland Nature Institute (GNI), including participation in their workshops and sharing of preliminary data with them. I have testified in public hearings on wolf control in Alaska, served as a consultant to the Greenland Homerule Government on the environmental impacts of introducing muskoxen to remote regions in West Greenland, contributed to the development of studies concerned with the potential negative effects on wild reindeer of the construction of high power electrical lines in Norway, and advised representatives of the Greenland Environmental Ministry on monitoring programs of wild reindeer in West Greenland, and worked to educate non-scientists in arctic and sub-arctic ecology as an interpretive guide for Greenland Tourism and the Kantishna Roadhouse (Denali, Alaska).

Broadening the participation of groups underrepresented in science:
I have recruited 5 female undergraduate students and 3 female graduate students (2 minority) into my research group, lectured to minority high school students about education and careers in the life sciences, have assisted and directed the development and execution of thesis research by a female native Greenlandic graduate student at the University of Copenhagen, and have involved native Greenlandic subsistence hunters in research on muskox habitat suitability in West Greenland.
Collaborators: Eric Barron (Penn State University), Ottar Bjørnstad (Penn State University), Oswald J. Schmitz (Yale University).
Advisors: Doctoral: David R. Klein (University of Alaska); **Post-doctoral:** Nils Chr. Stenseth (University of Oslo, Norway).
Graduate Students: Angela Anders (Ph.D.) 2003 – present; Amy Dechen (M.S.) 2000-2003; Alicia Ellis (M.S.) 2000-2002; Danielle Garneau (Ph.D.) 2000-2005; Christian Pedersen (Ph.D.) 2001- present.

BRADLEY C. REED

U.S. Geological Survey, Flagstaff Science Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001
e-mail: reed@usgs.gov

I. Personal Data

Born 21 November 1957 (Aurora, Missouri, USA)

II. Professional Preparation

Undergraduate:	Southwest Missouri State University, B.S., Geography, 1981
Graduate:	University of Kansas, M.A., Geography, 1986
	University of Kansas, Ph.D., Geography, minor Plant Ecology, 1990

III. Professional Appointments

2005 – Research Geographer, US Geological Survey, Flagstaff, AZ
2002 - Principal Scientist, SAIC, EROS Data Center, Sioux Falls, SD
1995 - Principal Scientist, Raytheon, EROS Data Center, Sioux Falls, SD
1992 - Senior Scientist, Hughes STX Corporation, EROS Data Center, Sioux Falls, SD
1990 - Assistant Professor, Department of Geosciences, New Mexico State University

IV. 5 publications most closely related to the proposed project

Reed, B.C., 2006, Trend Analysis of Time-Series Phenology of North America Derived from Satellite Data, GIScience & Remote Sensing, Vol. 43, No. 1, 24-38.

Betancourt, J. L., M. D. Schwartz, D. D. Breshears, D. R. Cayan, M. D. Dettinger, D. W. Inouye, E. Post, and B. C. Reed. 2005. Implementing a USA-National Phenology Network (USA-NPN). EOS 86(51): 539-542.

Reed, B.C., M. White, and J.F. Brown, 2003. Remote Sensing Phenology. Chapter 5 in Phenology: An Integrative Environmental Science, Kluwer Publishing, pp. 365-382.

Schwartz, M.D., B.C. Reed, and M.A. White, 2002. Assessing Satellite-derived Start-of-Season (SOS) Measures in the Conterminous USA, *International Journal of Climatology*, Vol. 22, No. 14, pp. 1793-1805.

Reed, B.C., J.F. Brown, D. VanderZee, T.L. Loveland, J.W. Merchant, D.O. Ohlen, 1994. "Measuring phenological variability from satellite imagery," Journal of Vegetation Science 5: 703-714.

5 other significant publications

Gallo, K., B. Reed, T. Owen, and J. Adegoke, 2005. Characteristics of Seasonal Vegetation Cover in the Conterminous USA, Photogrammetric Engineering and Remote Sensing, Vol. 71, No. 8., pp. 959-966.

Wylie, B.K., Gilmanov, T.G., Johnson, D.A., Saliendra, N.Z., Akshalov, K., Tieszen, L.L., Reed, B.C., Laca, E., 2004. Remote sensing and geographic information system in rangelands of northern Kazakhstan: Quantification and mapping of seasonal CO2 fluxes. Environmental Management, DOI: 10.1007/s00267-003-9156-8, March.

Zhang, X, M.A. Friedl, C. B.Schaaf, A.H. Strahler, J.C. F. Hodges, F. Gao, B.C. Reed, and A. Huete, 2002. Monitoring vegetation phenology using MODIS Remote Sensing of Environment, Vol. 84, No.3, pp. 471-475

Reed, B.C., J.F. Brown, and T.R. Loveland, 2002. Geographic data for environmental modeling and assessment. In Environmental modeling using geographic information systems and remote sensing (Chapter 4). Taylor and Francis, London, pp. 52-69.

Hansen, M.C. and B. Reed, 2000. A comparison of the IGBP DISCover and University of Maryland 1 km global land cover products. International Journal of Remote Sensing, Vol. 21, No. 6/7, April 2000, pp. 1365-1374.

V. Synergistic Activities

1) Member of Executive Committee of the USA National Phenology Network (2005-present).
2) American Geophysical Union (2005) – Organized and chaired 3 scientific sessions on land surface phenology
3) USGS LPDAAC's representative to the MODIS Science Team (1997 – 2005).
4) Member of International Steering Committee on Global Mapping (1997-1999).
5) Served as Chairman of Land Sub-group of Global Observation International Network (1996-1999)

VI. Collaborators & Other Affiliations

i. Collaborators.

Jesslyn Brown, EROS Data Center……Bruce Wylie, EROS Data Center
John Dwyer, EROS Data Center……Jeff Eidenshink, USGS
Thomas Loveland, USGS……Larry Tieszen, USGS
Geoffrey Henebry, South Dakota State University……Kevin Gallo, NOAA
Matt Hansen, South Dakota State University ……Dan Swets, Augustana College
Mark Schwartz, University of Wisconsin-Milwaukee……Mark Friedl, Boston University
Michael White, Utah State Univerity

ii. Graduate and Postdoctoral Advisors

James Merchant – University of Nebraska-Lincoln

T.H. Lee Williams – University of Oklahoma

iii. Thesis Advisor and Postgraduate Sponsor

South Dakota State University

M.A. Thesis Advisor, Shannon Hofstadter, South Dakota State University, Brooking, SD, 2002, "*An Evaluation of AVHRR, MODIS, and SPOT 4 VEGETATION NDVI Products"*
M.A. Thesis Advisor, Michael Budde, South Dakota State University, Brooking, SD, 1999, "*A Comparison of Satellite Derived Vegetation Metrics and Climate Variables in the Central United States"*
M.A. Thesis Advisor, Paul Olsen, South Dakota State University, Brooking, SD, 1998, "*Visualizing A Complex Global Land Cover Database on a Hardcopy Map"*
M.A. Thesis Advisor, Kristi L. Sayler, South Dakota State University, Brooking, SD, 1998, "*An Assessment of Change Vector Analysis Using Landsat Data Over Sioux Falls, South Dakota"*

ROBERT B. WAIDE

POSITIONS: Executive Director, Long-Term Ecological Research Network Office
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EDUCATION:
Doctor of Philosophy in Zoology, University of Wisconsin – Madison (1978)
Master of Science in Zoology, University of Wisconsin – Madison (1973)
Bachelor of Science in Biology, University of Illinois – Urbana (1969)

Dissertation: Interactions between tropical resident and north temperate migrant birds in southern Campeche, Mexico. (Edward A. Beals, major advisor)

SYNERGISTIC ACTIVITIES:

- Program co-chair LTER All Scientists Meeting 2000, 2003, 2006
- Member, development committees for NEON, CLEANER, National Phenological Network
- Member, Science Task Force for the LTER Planning Project

RELEVANT PUBLICATIONS:

González, J.E., J.C. Luvall, D. Rickman, D. Comarazamy, A.J. Picón, E.H. Harmsen, H. Parsiani, N. Ramírez, R.E. Vásquez, R. Williams, R.B. Waide, and C.A. Tepley. 2005. Urban heat islands developing in coastal tropical cities. EOS 86:397-412.

White, E. P., P. B. Adler, W. K. Lauenroth, R. A. Gill, D. Greenberg, D. M. Kaufman, A. Rassweiler, J. A. Rusak, M. D..Smith, J. R. Steinbeck, R. B. Waide, and J. Yao. 2006. A comparison of the species-time relationship across ecosystems and taxonomic groups. Oikos 112:185-195.

Waide, R. B. M.R. Willig, C. F. Steiner, G. Mittelbach, L. Gough, S. I. Dodson, G.P. Juday, and R. Parmenter. 1999. The relationship between primary productivity and species richness. Annual Review of Ecology and Systematics 30:257-300.

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Current Activities-Mark D. Schwartz

The research goals of this RCN proposal complement Mark D. Schwartz's research and programmatic activities in his capacity as a climatologist and Professor of Geography at the University of Wisconsin-Milwaukee.

Schwartz's primary research area is vegetation phenology. His work has helped advance study of the annual springtime plant leafing and bloom from a little known topic, of interest primarily to botanists, to an important tool for assessing the impacts of global climate change. His publications have appeared in journals such as *Nature*, *Journal of Climate*, and *Global Change Biology*, and he is editor of *Phenology: An Integrative Environmental Science*, a recently published book that is a synopsis of the current state and future prospects for phenological research.

With over fifty papers given and thirty articles and book chapters published in the field since 1986, Schwartz has contributed to defining phenological studies at a continental-scale, demonstrating the environmental impact of the exchange of energy between land and the atmosphere during plants' yearly awakening. His large-scale visualization of phenology has outlined the development of global environmental monitoring systems that combine phenological measurements at the Earth's surface with satellite observations. Such integrative monitoring, when further combined with global-scale phenological models and examinations of historical phenological records, will allow analysis of many important questions including (but not limited to) changes in the start of the growing season.

So the vision of the USA National Phenology Network (collection of continent-wide plant phenological data for indicator and appropriate native plant species, integrated with satellite-derived measures of phenology) is in harmony with Schwartz's current research program and future agenda. Specifically, current projects by Schwartz and his students are concentrating on bridging local to regional scales by using spatially concentrated phenological measurement of tree species in the vicinity of the WLEF (Park Falls, WI) Ameriflux tower to improve understanding of the relationships among variable phenology, environmental drivers, plant physiology, and remote sensing measurements.

Current Activities-Susan Mazer

The research goals of this Research Coordination Network proposal complement the research activities being conducted in the Mazer lab in several ways.

First, Mazer's empirical research focuses on the evolutionary ecology of wild plant species. This work includes studies of the process and outcome of natural selection on life history and reproductive traits, including flowering time, gender allocation, seed size, and fecundity. Mazer has examined genetic vs. environmental effects on these traits and estimated the fitness consequences of phenotypic variation in flowering time in wild radish (*Raphanus raphanistrum* and *R. sativus*). She is currently investigating the joint evolution of flowering time, floral development, and mating system in several pairs of closely related outcrossing and selfing taxa in the wildflower genus *Clarkia*.

Second, a major component of Mazer's research includes the broad-scale analysis of the joint distribution of plant traits and habitat preferences among hundreds of plant species. The methods used in these comparative analyses represent a hybrid between phylogenetic approaches and the methods of community ecology. The kinds of data that will comprise the National Phenology Network will be well-suited to these kinds of analyses. Questions that may be addressed, for example, include: Which phylogenetic groups exhibit the strongest phenological responses to climate change? Which life histories or mating systems are most sensitive to climate change? Do species most commonly respond to anticipated changes in the onset of spring by simply shifting their phenological schedules (but not altering the length of their flowering season) or by extending the length of their flowering period? Do taxa with different pollination syndromes (e.g., wind- vs. insect-mediated pollen dispersal) differ with respect to the effects of phenological changes on seed production?

Third, the graduate student assistant to be partially funded on this project, Brian Haggerty, conducted his Master's thesis research at the University of Virginia on the phenological consequences of climate change in the wild flowering species, *Campanula americana*. He will enter the Mazer lab as a PhD student in September 2006, at which time he will continue to prepare his Master's work for publication and to develop ideas for his dissertation research. He is interested in the long-term goals of the National Phenological Network and in continuing to develop his skills in the use of integrated data sets (e.g., data from climatological, remote-sensing, and the observation of wild species) to tackle problems of ecological and human importance.

Finally, Mazer is keen to engage community groups and students in informal education activities that will re-connect them with an understanding of the natural evolutionary processes and ecological cycles occurring in their local environment. She has developed both new and long-standing partnerships with UCSB's Center for Biodiversity and Ecological Restoration (CBER), the Sedgwick Natural Reserve, Coal Oil Point Natural Reserve, the Santa Barbara Botanic Garden, and the Carpinteria Family School to fulfill this aim. The scientific activities of the NPN are highly adaptable to a wide range of technical and conceptual sophistication, and Mazer looks forward to engaging the public in our efforts.

Current Activities-P. Stephen Baenziger

The research goals of this Research Coordination Network proposal complement the research activities being conducted in the Baenziger lab in several ways.

First, Baenziger's empirical research focuses on the understanding of how best to develop new cultivars of small grains (winter wheat, barley, and triticale). This work is long term in nature as it takes 12 years from the time a cross is made to the release of a new cultivar. With the possible exception of winter temperatures that determine if the winter annual crop survives the winter, there is nothing more important than understanding how the phenology of the plant relates to seasonal weather changes. These seasonal weather changes in large part determine the genotype by environmental interaction, which determines cultivar adaptation and also the level of risk in growing the cultivar. For this reason, phenological measurements are routinely taken on his diverse breeding nurseries and similar nurseries throughout the Great Plains and the United States. In addition, seasonal variation coupled with long-term trends in climate are critical in determining which parents should be used in the breeding efforts (creating new genetic variation), as well as which selection strategies are best (selecting new variants).

Secondly, in managed ecosystems, it is very important to understand how the "system" works as a whole. It is not enough to understand only the small grain component in the evolving and increasingly complex farming systems (e.g. crop rotations). As such, the NPN is viewed as a critical link to tie agricultural crop/plant phenology to a much broader group of plants that will provide a richer understanding of seasonal variation. This richer understanding is expected to lead to better real-time decisions and predictions of the onset of disease or insect pests, and possibly economically important traits, such as, protein content which affects bread making quality.

Finally, due to the size and scope of his research, he and his colleagues at the University of Nebraska are keenly interested in developing automated measuring systems (sensor networks) that will allow better measurements of phenology, especially at remote sites and for validating observer data.

Current Activities-Julio L. Betancourt

The research goals of this RCN proposal complement Julio Betancourt's research and programmatic activities in his capacity as Senior Scientist, U.S. Geological Survey, and Adjunct Professor, University of Arizona:

Betancourt is based at University of Arizona/U.S. Geological Survey Desert Laboratory on Tumamoc Hill, a 370-ha reserve on Tucson's westside with a 103-yr legacy in ecological research in deserts and a seminal role in the development of American ecology (http://wwwpaztcn.wr.usgs.gov/internal/). The permanent vegetation plots on Tumamoc Hill, protected from grazing since 1907, are among the longest-studied parcels anywhere in the world. They represent the only systematic effort to monitor and analyze the long-term population dynamics of perennial plants in the Sonoran Desert. Long-term mapping and monitoring of individual plants on these permanent plots have made it possible to determine life spans of long-lived perennials; to evaluate and model the influence of local weather and climate on phenology, seed germination, seedling survivorship, and plant mortality; to understand the population biology of desert annuals; and to map colonization and spread by more than 50 non-native species. We view the USA-NPN-RCN initiative as an excellent opportunity to intensify and further institutionalize phenological observations on our ecological reserve, and plan to use the Desert Laboratory as a springboard for establishing a regional phenology network for the southwestern deserts. At present, we are collaborating on a proposal with remote sensing scientists at the University of Arizona to develop hyperspectral libraries for desert species, and a decision support tools that require phenological observations and models to manage invasive species in the Sonoran Desert. Betancourt's research generally emphasizes the influence of climate variability on biological systems. He is currently working on statistical analyses of instrumental weather records to understand patterns, sources and impacts of decadal-to-multidecadal variability, and on tree-ring reconstruction of precipitation and drought variability in the American West.

Betancourt and his USGS colleagues on the Implementation Team (Mike Dettinger, Brad Reed, Bruce Jones, Jack Waide and DeWayne Cecil) are working within the bureau to secure stable, base support for a national coordinating office and executive director of USA-NPN. On June 12, 2006, they gave a presentation to the Executive Leadership Team of USGS (Director, Associate Directors and Chief Scientists of each discipline- water, biology, geography, geology, and informatics). The reaction was very positive, and the Chief Scientists met on June 23, 2006 to develop recommendations that will be presented to the USGS Budget Planning Committee on July 6, 2006. Barring any budget mishaps, the chances are good that USGS will fund the national coordinating office and hire, most likely through an IPA appointment, an Executive Director for USA-NPN. The Executive Director would make sure that USA-NPN responds to the needs of USGS disciplines & other agencies within DOI and the US Government; serve as one nucleus for research & applications in the broader scientific and user communities; develop, coordinate and advocate phenological research within USGS; work with the Implementation Team to help secure funding for network implementation and extend phenological observations across existing environmental networks through negotiation and interagency agreements; and direct data management. One option for the national coordinating office is for it to be located at a major university with required strengths in ecology, remote sensing, physical geography, hydrology and climate studies. Betancourt is an adjunct professor at the University of Arizona, and is currently discussing the initiative with the University of Arizona.

Current Activities-Carol A. Brewer

My research interests are in physiological plant ecology and ecological education. My work in physiological ecology focuses on comparative morphology, physiology, and conservation ecology of plants, most recently in Andean Patagonia. My research program in physiological ecology has two main foci: 1) functional plant morphology – particularly at the leaf level, and 2) conservation biology of temperate forests in southern South America. My lab's work on the functional morphology of leaves (more than 150 species of montane/subalpine plants from North, Central, and South America) has identified of variety of leaf-level adaptations related to the extent and duration of leaf surface wetness (e.g., location of stomatal pores, trichome density and arrangement). This work has provides a foundation for interpreting the role of surface water on the function of stomata, the uptake of CO_2, air pollution deposition, pathogen infection, and seasonal biomass production. Naturally, I am interested in the role of phenology in plant growth.

My scholarship in ecology and conservation education includes training teachers to use their schoolyards for leading ecological investigations, facilitating teacher-researcher partnerships with ecologists, integrating research into introductory biology courses, evaluating nature films for accurate scientific content, and promoting ecological literacy in the United States and Latin America (www.bioed.org). My research program in science education stems from the belief that acquisition of knowledge alone will not be sufficient for improving scientific literacy unless such knowledge is disseminated and applied effectively. To improve science literacy, we need improved methods for training future scientists, teachers and the lay public. Moreover, understanding the nature of the connections between teaching and learning requires further exploration and consideration.

Recent and on-going projects in my laboratory include facilitating collaborations between scientists and teachers, training teachers to use their schoolyards for leading ecological investigations with their students, exploring new methods for teaching science to undergraduates, and using new assessment strategies to clearly connect teaching and learning. With funding from the Howard Hughes Medical Institute to the University of Montana (http://ibscore.dbs.umt.edu/), we are changing our biology curriculum to make research experiences central to the training of all undergraduates in the Division of Biological Sciences at UM. As part of USA-NPN, I am dedicated to incorporating both students and private citizens in phenological monitoring and research, and to integrating Phenology and the data products and tools of the USA-NPN into biology curricula across college campuses in the U.S.

I currently serve on the governing board of the Ecological Society of America (Vice President for Education and Human Resources). I also served on the Committee on Science Education K-12 and the Committee on Integrating Education with BioComplexity Research projects of the National Research Council of the National Academies. I am on the Board of Directors of the Montana Natural History and Nature Center, and I serve on the advisory council for the office of Environmental Education of the U.S. Environmental Protection Agency. I am a co-PI on the National Ecological Observatory Network (NEON) grant, co-chair of the Education Committee, and a member of the Senior Management Team and National Network Design Committee.

Current Activities-Michael D. Dettinger

My current research encompasses studies of global, Western North American, and Sierra Nevadan hydroclimatology of precipitation, snowpacks, ground water and streamflow using historical and paleo-records and models of atmospheric composition, atmospheric circulations, ocean temperatures, streamflow, ground water, and water quality. My research evaluates near-term to interannual climate predictions, and climate-change projections, of western climates, large-scale Pacific-basin climate modes, and resulting hydrologic variations. As part of an informal multi-agency team, I develop and test new hydrometeorological monitoring methods in the high country of Yosemite National Park and the Santa Margarita Ecological Reserve in Southern California. In recent years, with my close colleague at Scripps, I have worked to reestablish—at barest levels—remnants of Joe Caprio's Western States Phenological Network of lilac and honeysuckle observations. Some key hydroclimatic questions that arise in my research include: What is the role of plant phenology in the hydrology of the West? How does plant phenology coordinate with major hydroclimatic episodes including snowmelt and winter storms? Will plants and streamflow respond to future warming at the same rates? What will be the ecological, socioeconomic, and water resources consequences if they don't? How will we even know whether their respective changes are synchronized? The USA-NPN offers the primary basis for regionalizing our nascent answers to these questions.

I also am a founding member of the Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT), a collaborative, interdisciplinary consortium dedicated to understanding climates and ecosystems of western North American mountains (http://www.fs.fed.us/psw/cirmount/). CIRMOUNT's goal is to bring together researchers from diverse disciplines and institutions to measure and understand climate-driven changes in western North American mountain setting. CIRMOUNT objectives that dovetail with those of USA-NPN-RCN include promotion of installation and analysis of coordinated high-elevation climate, hydrologic, and ecosystem monitoring; catalyzing integrated research on mountain climates and their effects on ecosystems; communication of science among diverse disciplines to provide sound science for effective land-use planning and management; and promotion of development of long-term, policy-relevant mountain climate and ecosystem databases. I have (and will continue to) worked to incorporate and advance USA-NPN activities in western mountains under the auspices of CIRMOUNT's regular workshops and products, including providing for prominent summaries of the USA-NPN mission in our first MTNCLIM workshop last year and in our upcoming report, "Mapping New Terrain--Climate Change and America's West".

Finally I am an active member of the Science Steering Group of the Water Cycle Working Group of the U.S. Climate Change Science Program. The steering group provides scientific frameworks and recommendations to the interagency working group, regarding scientific issues and opportunities that span multiple agencies or that fall between the activities of the Federal agencies involved in all aspects of the global to local water cycle. As part of that steering group, I will work to advance USA-NPN activities across the country and to raise phenological issues and methods with all Federal agencies involved with the water sciences.

Current Activities-David W. Inouye

The research goals of this Research Coordination Network proposal complement the research activities being conducted in my labs at the University of Maryland and Rocky Mountain Biological Laboratory in several ways.

The major focus of my research at present is work funded by an LTREB grant to continue long-term (since 1973) studies of variation in the phenology and abundance of flowering by montane wildflowers. This study is documenting the effects of local, regional, and global environmental change on flowering, and to a lesser extent, on pollinators, plant demography, and seed predators. My co-PI (Barr) is continuing long-term daily environmental measurements (e.g., snowpack) for analysis with phenological data, and recording first sightings each year of a variety of birds, mammals, and insects. This work fits in well with the goals of the RCN.

My research project will contribute observations to the proposed meta-database of existing phenological data (meta-data for my research should be completed in fall 2006 after survey-grade GPS mapping of the plots). The meta-data will also provide a tested protocol for detailed community-level studies of phenology. Concomitant with the goal of an educational component to the RCN, I plan to use a subset of my phenology data for a data publication for Teaching Issues and Experiments in Ecology (http://tiee.ecoed.net/). The phenological observations I have made also provide the subject for articles I write for the local newspapers each year, and for annual interviews on a local radio program (Nature Notes).

The fine-scale data that I am recording could be extended to even finer scales (e.g., looking at the phenology of individual flowers, or their parts such as anthers and stigmas), or in collaboration with others, to broader scales (e.g., using them to ground-truth satellite measurements of phenology). The RCN would facilitate advertising of these opportunities, and the search for potential collaborators.

Current Activities-Beverly Law

Relationship between proposal and current research activities in Law Lab, TERRA-PNW:

- Dr. Law is the Science Chair of the AmeriFlux research network of ~115 sites in the Americas. Responsible for the research direction of AmeriFlux with contributions from the AmeriFlux Steering Committee; development of standards and protocols for instrumentation, data acquisition and analysis; data submission to the archive; guidelines for the data management system. Responsible for network-wide synthesis of results in reports to agencies and in publications. The RCN proposal includes collaboration with the AmeriFlux network PIs, and Law will need to work with the PIs to determine feasibility and encourage collaboration.
- Law is the PI of a cluster of three AmeriFlux sites on disturbance gradient (young and mature ponderosa pine) and climatic gradient (mature Douglas-fir and pine) that include eddy covariance measurements of CO_2 and water vapor exchange, observations of carbon storage in vegetation and soils, and automated measurements of soil respiration and sapflux scaled to site (transpiration). Collaborating with soil carbon turnover studies (LLNL 13C, 14C) at our AmeriFlux sites. Law's sites may be suitable for NPN observations.
- PI on a regional study with CO_2 concentration measurement sites along a west-east climatic gradient from the coastal margin (Yaquina Head), to Mary's Peak in the Coast Range, to Mary's River Douglas-fir, the Metolius ponderosa pine site on the east side of the Cascade Mountains and the Burns site in sagebrush. The synthesis of results from this research group may benefit from long-term phenological records in determining the influence of climate on carbon uptake across the climatically diverse region.

Current Activities-Eric Post

I am interested in population and community dynamics in northern ecosystems, where climatic and ecological responses to global change are expected to be most pronounced. My research involves many approaches aimed at divulging and understanding ecological consequences of climate change. The techniques I use include observational fieldwork, large-scale field experimentation, and quantitative analytical modeling of long-term data.

Current research projects I and my students are conducting include:

- experimental manipulation of near-surface temperatures in arctic meadows to investigate spatial dynamics of plant phenological response to climate change;
- analytical modeling of the role of large-scale climatic warming in the spatial dynamics of plant phenology and timing of bird migration;
- observational monitoring of relationships between timing of reproduction by caribou and plant phenology in arctic Greenland;
- analysis of spatial synchrony in the population dynamics of caribou and muskoxen in Greenland;
- experimental assessment of the role of caribou and muskoxen in mediating vegetation response to climate change in Greenland;
- spatio-temporal niche separation among multiple predators in a single-prey system in sub-arctic Alaska; and
- analytical modeling combined with observational fieldwork to assess influences of large-scale climatic fluctuation on population dynamics of neotropical-nearctic migratory birds.

I am planning to conduct an International Tundra Experiment (ITEX) compliant field experiment to test hypotheses relating spatial synchrony in plant phenology to climatic warming. This experiment represents a novel application of the ITEX protocol, and will provide valuable information on plant phenological response to artificial warming in low-Arctic shrub steppe communities. By encouraging participation of native Greenlandic students from the University of Greenland in this research, this initiative will expand the infrastructure for education and research in Greenland.

My interest in the RCN would be to explore issues of spatial scale and dynamics of synchrony in relation to climatic variability and warming by coordinating analyses of data from multiple studies. Our experimental and observational data from Greenland could, for example, contribute a low-arctic example. Norwegian data are already in hand, and beyond representing many plant species (listed in Post & Stenseth, 1999, Ecology 80:1322-1339), also include data on many species of birds, and things like ice-out and planting dates from Norwegian farms.

Current Activities-Bradley C. Reed

The research goals of this RCN proposal complement Bradley C. Reed's research and programmatic activities in his capacity as a research geographer for the U.S. Geological Survey (USGS), based in Flagstaff, AZ.

As a remote sensing specialist, Reed's work is focused on assessment of continental-scale vegetation conditions (including seasonal land cover characteristics and their relationships to carbon fluxes) from moderate-scale satellite-based sensors (AVHRR and MODIS), with particular attention to development of phenological metrics. His co-authored article "Variability of land cover phenology in the United States" (published in 1994) was among early studies that set the development and assessment of satellite-based phenological metrics as a central research goal. Reed's most recent journal article "Trend Analysis of Time-Series Phenology of North America Derived from Satellite Data" (published in 2006) demonstrates his sustained interest and continued contributions to this area of study.

The NPN RCN will support phenological research by facilitating data collection from the plant level to satellite observations. To assist in the implementation of the remote sensing component of USA-NPN, Reed will play a key role in the formation and leadership of a remote sensing advisory panel consisting of 4-5 people to advise on initial implementation, review progress, recommend changes, and promote the remote sensing component of NPN at conferences and meetings. The panel will consist of a mix of representatives from government agencies and academia that have a strong interest in remote sensing.

The advisory panel will assist in securing and using two levels of satellite data sets appropriate for use by the NPN: 1) intensive data site collections; and 2) wall-to-wall coverage of the conterminous U.S. and Alaska. A strategy that can be followed for data collection at intensive sites is that used by the EOS Land Validation Core Sites (http://landval.gsfc.nasa.gov/). In this strategy, MODIS (and other) satellite data are packaged as 200 x 200km subsets centered on 26 sites worldwide. The core sites leverage off of existing science networks (such as Aeronet, Fluxnet, and LTER); which provide high-quality *in situ* data collection that can be expected to continue. The remote sensing of phenology component of NPN would be well served if the field component of NPN included some of the EOS land validation cores sites. Likewise, NASA could consider using the core site infrastructure to support additional NPN sites within the U.S. (Details on the EOS core sites can be found at http://landval.gsfc.nasa.gov/coresite_gen.php)

One of the strengths of the remote sensing component of NPN is its capability of providing "wall-to-wall" coverage of the U.S., i.e., filling the gaps between the surface observations. For this level of observation two needed efforts include: 1) contacting researchers who have published remote sensing phenology results and seek permission to link to their phenology data sets; and 2) supporting a collection of wall-to-wall MODIS 250m Vegetation Indices (VI) data using MODIS direct broadcast system (DBS). USGS Center for Earth Resources Observation and Science (EROS) is currently producing this data set for the conterminous U.S. Discussions between USGS EROS and UAF regarding the possibility of UAF utilizing EROS software for similar production over Alaska should be encouraged.

Current Activities-Robert B. Waide

The proposed USA National Phenology Network (USA-NPN) has multiple intersections with my personal research program as well as my broader responsibilities as the Executive Director of the Long Term Ecological Research (LTER) Network Office. The proposal contains a vision of a network of networks which has long been a goal of the LTER program. The integration of multiple networks into a broader infrastructure provides an important connection between the intensive process-based work conducted at LTER sites and the broader spatial scales contemplated in the USA-NPN. Participation in the USA-NPN will provide links between measurements conducted at LTER sites and national-scale field protocols to be developed under the current proposal. Moreover, the existence of a national network collecting phenological data will facilitate one of the key objectives of the LTER Network, to synthesize data across broad spatial and long temporal scales to achieve an improved understanding of LTER ecosystems.

My personal research addresses the dynamics of tropical forest ecosystems subject to a variety of press and pulse disturbances, the most imposing of which are frequent tropical storms and hurricanes. Along with my colleagues at the Luquillo LTER program in Puerto Rico, I follow temporal changes in many ecosystem components that are affected by natural disturbances. Most of these measurements are conducted on the Luquillo Forest Dynamics Plot (LFDP); a 16 ha plot in which all stems > 1 cm dbh have been followed since 1989. Seasonal and annual population measures of plants, birds, frogs, lizards, snails, shrimp, and insects are conducted throughout this plot and related to intensive studies of ecosystem drivers and processes. For example, a long-term study of the phenology of leaf and litter production by J. Zimmerman has been ongoing since 1992. These data are being used to (1) determine the seasonality of flowering and fruiting in tabonuco forest and test hypotheses concerning the causation of seasonality (or lack thereof), (2) test the effect of annual variation in rainfall and other climatic variables on seed and fruit production of individual species, and (3) compare the relative dispersability of species on the Luquillo Forest Dynamics Plot by applying information on the spatial distribution of canopy trees to the data on seed and fruit fall. The results from these measurements are used to better understand the dynamics of bird populations, for which I have conducted measurements since 1989. The dynamics of populations and phenology in the LFDP are related to broad-scale climate patterns (e.g., ENSO) that also affect continental partners in the USA-NPN. Participation in the USA-NPN will provide an important context to analyze and understand patterns that occur in our tropical forest sites in Puerto Rico.

Phenological studies are common throughout the LTER Network, but these studies have never developed a common framework and focus. Participation in the USA-NPN will provide the LTER Network with an impetus to synthesize information across sites, to develop common measurement protocols, and to initiate a new research area focusing on phenology. As Executive Director of the LTER Network Office, I am in an excellent position to serve as a liaison between LTER and USA-NPN. In particular, an ongoing effort to develop a new science plan for LTER provides an immediate opportunity to build strong links between these two organizations.