PHENOLOGY RESEARCH AND OBSERVATIONS OF SOUTHWEST ECOSYSTEMS SYMPOSIUM (PROSE)

U.S.A. National Phenology Network (NPN) &
Southwest U.S. Region, American Society of Photogrammetry & Remote Sensing (ASPRS)

October 2nd, 2009
Coyote Room, Park Student Union, University of Arizona, Tucson, AZ

KEYNOTE

MILLER-RUSHING, ABE: HENRY DAVID THOREAU'S CONTRIBUTION TO CLIMATE CHANGE SCIENCE: HOW CLIMATE CHANGE IS RESTRUCTURING ECOLOGICAL COMMUNITIES

ABSTRACTS OF PRESENTED PAPERS (LISTED ALPHABETICALLY BY FIRST AUTHOR)

PHENOLOGY OF MUTUALISM: TEMPORAL DYNAMICS OF A SONORAN DESERT ANT/CACTUS INTERACTION AND THE SPECTER OF GLOBAL CLIMATE CHANGE

BRONSTEIN, JUDITH[1], Joshua Ness, Michele Lanan, Ginny Fitzpatrick, and William F. Morris

[1] Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ, judieb@email.arizona.edu

The fishhook barrel cactus Ferocactus wislizeni possesses extrafloral nectaries that are visited by four common species of ants at the Desert Laboratory in Tucson, AZ. The ants, in return for the nectar reward, defend the cacti from herbivores. Here we summarize results from a multi-year study that is documenting predictable seasonal turnovers in the dominant ant species defending this cactus population. Ant species differ in their response to temperature, both at a diurnal and seasonal scale, and also differ in the efficacy with which they reduce herbivory. Using current projections for anthropogenic climate change in the desert Southwest, we offer predictions for how the quality of mutualistic defense, and hence fitness and population growth, will change in the future for barrel cacti. As the majority of Sonoran Desert cacti have similar mutualisms with ants, these results shed light on a potentially broad and underappreciated effect of global change.

PROSPECTS FOR PHENOLOGICAL MONITORING IN AN ARID SOUTHWESTERN U.S. RANGELAND USING FIELD OBSERVATIONS WITH HYPERSPATIAL AND MODERATE RESOLUTION IMAGERY

BROWNING, DAWN[1], Andrea Laliberte, Albert Rango, and Jeffrey Herrick

[1] Jornada Experimental Range, USDA-ARS, Las Cruces, NM, dbrownin@nmsu.edu

Relating field observations of phenological events to remotely sensed depictions of land surface phenology remains a challenge to the vertical integration of data from disparate sources. This research conducted at the Jornada Basin LTER site in southern New Mexico capitalizes on legacy datasets and hyperspatial imagery. Large amounts of exposed bare soil and modest cover from shrubs and grasses in arid and semi-arid ecosystems challenge the integration of field observations and remotely sensed data to monitor land surface phenology. Drawing on established field protocols for reproductive phenology, hyperspatial imagery (4 cm), and object-based image analysis, we explore the utility of two approaches to

scale detailed observations (i.e., field and 4 cm imagery) to the extent of long-term field plots and moderate resolution Landsat Thematic Mapper (TM) imagery. Color-infrared imagery was collected June 2007 across 15 LTER study sites that transect five distinct vegetation communities along a continuum of grass to shrub dominance. We examined two methods for scaling spectral vegetation indices (SVI) at 4 cm resolution: pixel averaging and object-based integration. Pixel averaging yields the mean SVI value for all pixels within the plot or TM pixel. Alternatively, the object-based method is based on a weighted average of SVI values that correspond to discrete image objects (e.g., individual shrubs or grass patches). Object-based image analysis of 4 cm imagery provides detailed depictions of ground cover and allows us to extract species-specific contributions to upscaled SVI values. The ability to discern species- or functional-group contributions to remotely sensed signals of vegetation greenness greatly enhances design of field phenology sampling protocols. Furthermore, imagery from unmanned aerial vehicles (UAV) is a cost-effective and increasingly available resource. Generation of UAV mosaics has been accomplished so that larger study areas can be addressed, providing a robust basis for scaling relationships for phenology-based research applications.

PLANT PHENOLOGY MONITORING TODAY THE USA-NPN WAY

CRIMMINS, THERESA[1] and Alyssa Rosemartin

[1] USA National Phenology Network, Tucson, AZ, theresam@u.arizona.edu

The USA National Phenology Network (USA-NPN) encourages people of all ages and backgrounds to observe and record plant and animal phenology as tools to discover and explore the nature and pace of our dynamic world. The USA-NPN promotes the use of standard monitoring approaches and provides step-by-step instructions for recording observations, downloadable and online data entry sheets, and a list of recommended species to monitor, several of which are appropriate for the southwestern US. This presentation will walk potential observers through the steps of monitoring plant phenology following the USA-NPN approach, focusing on plant species of the southwestern US. Animal phenology monitoring will be available through the USA-NPN starting spring 2010.

MONITORING VEGETATION DYNAMICS IN TURKMENISTAN USING REMOTE SENSING

KAPLAN, SHAI[1] and Lea Orlovsky

[1] School of Geographical Sciences, Arizona State University, Phoenix, AZ, skaplan3@asu.edu

The Natural Resource Ecology Laboratory at Colorado State University (CSU) is partnering with local schools and teachers to develop a regional phenology monitoring network to collect data on seasonal vegetation changes and to provide teacher professional development on ecologically-relevant science. Documenting and understanding local to regional changes in phenological events is a current hot topic in ecology and global change studies. Phenological observations are an ideal hands-on and inquiry-based science topic for K-12 schools to implement. Phenology relates well to several science-based standards that teachers in Colorado currently emphasize in their curricula. Measurements and observations that teachers & student implement are simple, quick to conduct, cheap, and can be done on local school grounds. Data collection & observational methods are adapted from the National Phenology Network and Project BudBurst. Teachers are supported by CSU through regular trainings, follow-on meetings, on-site visits by scientists, and materials development. Training on how to conduct phenological observations on bud-burst, green-up, green-down and leaf-drop are provided along with supporting activities on GPS, sketch mapping, compass use, data recording, and species identification. Three training workshops have been conducted since Fall, 2008 with over 20 teacher participants. Initial feedback from teachers confirms that phenology is an activity that provides students the opportunity to participate in relevant systems science. Future efforts include building regional interest in participation and yearly data analysis on timing of phenological events.

CONTEMPORARY CLIMATE CHANGE IN THE SONORAN DESERT FAVORS COLD-ADAPTED SPECIES

KIMBALL, SARAH[1], Amy L. Angert, Travis E. Huxman, and D. Lawrence Venable

[1] University of Arizona, Tucson, AZ, kimballs@email.arizona.edu

mpacts of long-term climate shifts on the dynamics of intact communities within species ranges are not well understood. We show that warming and drying of the Southwestern United States over the last 25 years has corresponded to a shift in the species composition of Sonoran Desert winter annuals, paradoxically favoring species that germinate and grow best in cold temperatures. Winter rains have been arriving later in the season, during December rather than October, leading to the unexpected result that plants are germinating under colder temperatures, shifting community composition to favor slow growing, water-use efficient, cold-adapted species. Our results demonstrate how detailed ecophysiological knowledge of individual species, combined with long-term demographic data, can reveal complex and sometimes unexpected shifts in community composition in response to climate change. Further, these results highlight the potentially overwhelming impact of changes in phenology on the response of biota to a changing climate.

LAND USE AND VEGETATION COVER CHANGE ALONG THE US-MEXICO BORDER, THE CASE OF AMBOS NOGALES

MYINT, SOE[1]

[1] Arizona State University, Tempe, AZ, soe.myint@asu.edu

Land use and vegetation cover changes are ubiquitous throughout the U.S.-Mexico borderlands and portend significant impacts on ecosystem functions and forms. This study attempted to detect the general trends of land-use and vegetation cover changes such as urban growth, loss of agriculture and grasslands, deforestation, and land degradation that have occurred in Ambos Nogales over the past 20 years. The selected land-use and land-cover classes include urban; agriculture/grassland; riparian vegetation; forest; shrubs; exposed soil; and water. A series of Landsat TM images acquired on different dates between 1985 and 2004 (i.e., 20 October 1985, 1 July 1991, 2 February 1995, 3 September 2000, and 20 July 2004) were used in the study. A supervised classification was first performed on the 2004 image using different band combinations: (a) all the original bands (b) bands 5,4,3 and (c) bands 4,3,2. The band combination 5,4,3 achieved the highest overall accuracy (91.5%). This research employed a spatial autocorrelation approach called Getis index (*Gi*) integrated with the original bands to improve the overall classification accuracy. The *Gi* approach with different window sizes (i.e., 3x3, 5x5, 7x7, 9x9, and 11x11) was examined using bands 5, 4, and 3. The significant difference appeared during 1995-2000 where only 6.9% of agriculture and grassland in Nogales, Arizona was converted into urban areas in comparison to 54.6% in Nogales, Sonora. In addition, during 1985-2000 both cities converted similar amounts of forest (2.14% in Arizona and 2.84% in Sonora) and shrubs areas (3.15% in Arizona and 4.01% in Sonora) into urban land. The majority of land (84% in Nogales, Arizona and 95% in Nogales, Sonora) was observed under the top four land degradation categories (i.e., highly stable, stable, low, and moderate). Hence, it can be concluded that Nogales, Sonora has experienced more land degradation than that of Nogales, Arizona.

COMBINING GROUND AND REMOTE SENSING METHODS TO SCALE RIPARIAN AND AGRICULTURAL WATER USE OVER THE LOWER COLORADO RIVER

NAGLER, PAMELA[1], Kiyomi Morino, Scott Murray, Edward Glenn, and John Osterberg

[1] USGS Sonoran Desert Research Station, Tucson, AZ, pnagler@usgs.gov

Accurate wide-area estimates of agricultural and riparian evapotranspiration (ET) are needed to apportion water for human and ecosystem needs on arid zone rivers. We used the Enhanced Vegetation Index (EVI) from the MODIS sensor on the Terra satellite to scale ET over agricultural and riparian areas along the

Lower Colorado River in the southwestern U.S. Ground measurements of ET by alfalfa, saltcedar, cottonwood and arrowweed were expressed as fraction of reference crop ETo (ET-F) calculated from meteorological data, then regressed against EVI scaled between bare soil (0) and full vegetation cover (1.0) (EVI*). Saltcedar, the dominant riparian species on the river, exhibited moderate to severe midday depression of transpiration and stomatal conductance at five of six sites where they were measured by sap flow sensors at Cibola National Wildlife Refuge, indicating it was growing under stress. This violates some of the assumptions by which ET is scaled

ECOSYSTEM SERVICES ANALYSIS OF CLIMATE CHANGE AND URBAN GROWTH; THE SANTA CRUZ WATERSHED ECOSYSTEM PORTFOLIO MODEL (SCWEPM)

NORMAN, LAURA[1], Nita Tallent-Halsell, Bill Labiosa, Katie Hirschboeck, Matt Weber, Amy McCoy, James Callegary, Floyd Gray, Charles van Riper, Hans Huth, Francisco Lara-Valencia, and Joe Marlow

[1] U.S. Geological Survey, Tucson, AZ, lnorman@usgs.gov

The goal of the Santa Cruz Watershed Ecosystem Portfolio Model (SCWEPM) is to develop a decision support tool that addresses sustainable use of natural resources, inequitable access to environmental goods, and distributions of environmental burden along the U.S.-Mexico border. Industrial and biological pollutants and industrial facilities along the border stress the environment in lands where natural and anthropogenic systems provide goods such as nutritious food, clean air and water, open spaces for recreation and cultural appreciation, health care, education, and transportation for hundreds of thousands of people. The processes or conditions through which natural ecosystems provide goods and sustain or benefit people are referred to as "ecosystems services." Some of these services have value that can be quantified and documented for cost-benefit or tradeoff analysis that will be integrated into the model. Integrating the principles of the biophysical and social sciences via decision support tools facilitates public decision making about ecosystems services and addresses issues of environmental justice, such as the equitable distribution of environmental benefits and burdens. Our portfolio approach combines the respective strengths of the biological, physical and social sciences. Biologists and ecologists provide measurements of the quality and distribution of ecosystem services and associated environmental goods; climatologists and hydrologists address the impact of climate change on the watershed (i.e., climate destablization, temperature increases, precipitation and runoff variability and extremes); and social scientists provide an understanding of how people are affected by changes in the climate and urban development. Our research will bridge the biophysical and socioeconomic processes that provide local ecosystem services by developing an ecosystem portfolio for the Upper Santa Cruz Watershed, along the Arizona-Sonora International border. Ultimately, the SCWEPM will generate forecasts of responses to ecosystem drivers and stressors, including land use change, scenarios of climatic shifts, contaminant loadings, spread of invasive species, economic trends, and environmental hazards that may impact social welfare, human health, and water. The SCWEPM will help promote understanding of how the phenology of plants, landscapes, and habitats respond to changes in climate, and how these responses affect ecosystem services we have come to depend upon.

SPECTRAL SEPARABILITY OF SPECIES AND PHENOPHASES IN A COASTAL MEDITERRANEAN GRASSLAND

ROTH, KEELY[1], Ryan Perroy, and Dar A. Roberts

[1] University of California, Santa Barbara, CA, klroth@geog.ucsb.edu

Imaging spectroscopy has been used to map species in a wide range of ecosystems with a high level of success, but few studies have explicitly accounted for the effect of phenophase on mapping accuracy. Thus, the potential of imaging spectroscopy for mapping plant phenophases has been largely unexplored. Spectral Mixture Analysis techniques, like Multiple Endmember Spectral Mixture Analysis (MESMA) enable researchers to map sub-pixel fractions of vegetation cover and plant species using spectral reflectance endmembers. Because the shape of a species' reflectance spectra changes with

phenophase, selecting and using endmembers which come from the correct phenophase may be crucial for accurate mapping. Concurrently, if the location/area of a species is known, MESMA should select endmembers which identify the dominant phenophase of the species at the time the image was acquired. While photosynthetic and non-photosynthetic vegetation states are readily distinguished, it is also possible to separate flowering/non-flowering states for some species. This study seeks to quantify the spectral separability of several plant species and functional types during different phenophases at a coastal Mediterranean site. Using field-collected spectra in a phenological spectral reference library, we apply the Bhattacharyya distance to measure the spectral separability between species at different times during the season and between phenophases within the same species/assemblages. The results demonstrate the potential for merging field-collected phenological data with imaging spectroscopy to produce more accurate vegetation maps and help define the criteria necessary for mapping particular phenophases within a species.

MODELING PERENNIAL AND ANNUAL VEGETATION IN THE MOJAVE DESERT USING MODIS-EVI DATA

WALLACE, CYNTHIA[1], Kathryn A. Thomas, and Robert H. Webb

[1] U.S. Geological Survey, Tucson, AZ, cwallace@usgs.gov

This study developed estimates of total perennial vegetation cover and a relative index of annual plant growth throughout the Mojave Desert, USA. To model the perennial cover, MODIS-EVI data were coupled with 447 measurements of total perennial cover and the elevation of each plot, using stepwise linear-regression techniques. To validate the models, we created 10 realizations of the final perennial cover models, each of which was trained using a random 80% subset of the field data and tested using the remaining 20%. The testing and training R^2 for these 10 realizations ranged from 0.62-0.83 and 0.79-0.85, respectively. The final models were used to create maps of perennial vegetation cover at 250-m resolution for the Mojave Desert. In contrast, the annual growth model was developed from MODIS-EVI data alone, with field measurements used to evaluate rather than to calibrate the model. We used landscape phenologies revealed in MODIS data together with expert knowledge of annual plant seasonality to develop a suite of metrics to describe annual growth on a yearly basis. Each of these metrics was applied to temporally-composited MODIS-EVI images to develop a relative model of annual growth. Each model was evaluated by testing how well it predicted field estimates of annual cover collected during 2003 and 2005 at the Mojave National Preserve. The best performing metric was the spring difference metric, which compared the average of three spring MODIS-EVI composites of a given year to that of 2002, a year of record drought. The spring difference metric showed correlations with annual plant cover of R^2 = 0.61 for 2005 and R^2 = 0.47 for 2003.

ABSTRACTS OF PRESENTED POSTERS (LISTED ALPHABETICALLY BY FIRST AUTHOR)

A NEW APPROACH TO GENERATING RESEARCH-QUALITY DATA THROUGH CITIZEN SCIENCE: THE USA NATIONAL PHENOLOGY MONITORING SYSTEM

DENNY, ELLEN G.[1], Abraham Miller-Rushing, Brian P. Haggerty and the NPN Development Team

[1] USA National Phenology Network, Tucson, AZ, ellen.denny@yale.edu

Traditional phenological observation protocols identify specific dates at which individual phenological events are observed. The scientific usefulness of long-term phenological observations could be improved with a more carefully structured protocol. At the USA-NPN we have developed a new method that directs observers to record each day that they observe an individual plant, and to assess and report the state of specific life stages (or phenophases) as occurring or not occurring on that plant for each observation date. Evaluation is phrased in terms of simple, easy-to-understand, questions (e.g. “Do you see open flowers?”), which makes it very appropriate for a citizen science audience. From this method, a rich dataset of phonological metrics can be extracted, including the duration of a phenophase (e.g. open

flowers), the beginning and end points of a phenophase (e.g. traditional phenological events such as first flower and last flower), multiple distinct occurrences of phenophases within a single growing season (e.g multiple flowering events, common in drought-prone regions), as well as quantification of sampling frequency and observational uncertainties. These features greatly enhance the utility of the resulting data for statistical analyses addressing questions such as how phenological events vary in time and space, and in response to global change. This new protocol is an important step forward, and its widespread adoption will increase the scientific value of data collected by citizen scientists.

MONITORING SPECIES FLOWERING OBSERVATIONS AND REMOTELY SENSED VEGETATION DYNAMICS IN THE SANTA CATALINA MOUNTAINS

LANDAU, KATHERYN[1], Willem van Leeuwen, Theresa Crimmins, Michael Crimmins, and David Bertelsen

[1] Office of Arid Lands Studies, University of Arizona, Tucson, AZ, klandau@email.arizona.edu

Climate change and variability impacts the phenology, diversity and distribution of plant species and the productivity of plant assemblages. Elevation and climate gradients are well suited to explore and assess how seasonal flowering diversity is related to vegetation greenness and productivity. This study analyzes the relationship between 20 years of flowering plant species observations and time series of satellite based vegetation greenness observations based on the normalized difference vegetation index (NDVI) measured with the AVHRR sensors. Specifically, we examine how well NDVI data can be used to assess seasonal and interannual patterns in species flowering. The study area consists of five segments of approximately 1 mile (1.61 km) in length across a 4,158 ft (1,200 m) elevation gradient in a semi-arid ecoregion, in the Santa Catalina Mountains near Tucson, Arizona, USA. All flowering plant species along these sections were recorded at approximately weekly intervals. Flowering data were compared to multi-temporal AVHRR NDVI data by deriving alpha diversity of species in flower and AVHRR based land surface phenological variables, such as the timing of the start, peak of the growing season, and annual productivity. Preliminary results show that vegetation productivity generally increased with elevation, while alpha diversity is lowest in mile 5 and variable through miles 1 through 3. Alpha diversity and phenological metrics also show long term trends and variability for the observed time period between 1985 and 2009, suggesting climate impacts on flowering and vegetation productivity.

USING THE PANOPT INTERFACE FOR LINKING MEASURES OF SEASONAL GREENNESS ACROSS SPATIAL SCALES IN A MEDITERRANEAN-CLIMATE ECOSYSTEM

ROTH, KEELY L., Eliza S. Bradley, Michael P. Toomey, Dar A. Roberts, and Chris Still:

[1] University of California, Santa Barbara, CA, klroth@geog.ucsb.edu

Land Surface Phenology (LSP) measurements from satellites are typically made at medium to coarse resolutions (i.e., AVHRR- or MODIS-scale). In order to bridge the scales at which greenness is measured and provide validation for LSP metrics, several studies have used digital repeat photography. However, current online interfaces for viewing and using photo archives when completing this type of analysis are not data-driven nor integrate satellite imagery. Here we present the PanOpt system (http://zulu.geog.ucsb.edu/panopt) for linking measures of seasonal greenness at two scales, ground-based webcam and MODIS satellite, via image visualization and data-mining/analysis tools. The PanOpt system enables users to simultaneously view time-series charts for two regions of interest (ROIs) (e.g., one from the camera and one from the satellite) and currently includes three camera sites in a Mediterranean ecosystem (a coastal site, an island site, and an inland site) near Santa Barbara, CA. Using this system and a statistical software package, we assess correlations between ROI-based repeat photo greenness metrics and MODIS pixel vegetation indices. Differences among sites, species and plant functional types are examined. The results demonstrate the suitability of the PanOpt system for tracking vegetation phenology at multiple scales. Furthermore, because standard measures of LSP are often difficult to apply to Mediterranean and semi-arid ecosystems, this analysis provides insight into the relationship between

greenness at the landscape scale and intra-ecosystem patterns in phenology. The PanOpt system is also useful for other environmental monitoring applications, such as creating cloud climatologies from camera and GOES imagery.

IMPLEMENTING A REGIONAL PHENOLOGY OBSERVATIONAL NETWORK: A PARTNERSHIP BETWEEN COLORADO STATE UNIVERSITY & NORTHERN COLORADO SCHOOLS

SPENCER, SHANNON[1], Tom Noel, Kimberly Melville-Smith, and Andrew Warnock:

[1] Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO, shannon.spencer@colostate.edu

The Natural Resource Ecology Laboratory at Colorado State University (CSU) is partnering with local schools and teachers to develop a regional phenology monitoring network to collect data on seasonal vegetation changes and to provide teacher professional development on ecologically-relevant science. Documenting and understanding local to regional changes in phenological events is a current hot topic in ecology and global change studies. Phenological observations are an ideal hands-on and inquiry-based science topic for K-12 schools to implement. Phenology relates well to several science-based standards that teachers in Colorado currently emphasize in their curricula. Measurements and observations that teachers & student implement are simple, quick to conduct, cheap, and can be done on local school grounds. Data collection & observational methods are adapted from the National Phenology Network and Project BudBurst. Teachers are supported by CSU through regular trainings, follow-on meetings, on-site visits by scientists, and materials development. Training on how to conduct phenological observations on bud-burst, green-up, green-down and leaf-drop are provided along with supporting activities on GPS, sketch mapping, compass use, data recording, and species identification. Three training workshops have been conducted since Fall, 2008 with over 20 teacher participants. Initial feedback from teachers confirms that phenology is an activity that provides students the opportunity to participate in relevant systems science. Future efforts include building regional interest in participation and yearly data analysis on timing of phenological events.

TAKING THE PULSE OF OUR PLANET: THE USA NATIONAL PHENOLOGY NETWORK (2ND YEAR PROGRESS)

WELTZIN, JAKE F.[1] and the USA-NPN National Coordinating Office Development Team

[1] USA National Phenology Network, Tucson, AZ, jweltzin@usgs.gov

Patterns of phenology for plants and animals control ecosystem processes, determine land surface properties, control biosphere-atmosphere interactions, and affect food production, health, conservation, and recreation. The USA National Phenology Network (USA-NPN; HYPERLINK "http://www.usanpn.org" www.usanpn.org) is an emerging and exciting partnership between federal agencies, the academic community, and the general public to establish a national science and monitoring initiative focused on phenology as a tool to understand how plants, animals and landscapes respond to climate variation, and as a tool to facilitate human adaptation to ongoing and potential future climate change. In its second year of operation, USA-NPN produced many new phenology products and venues for phenology research and citizen involvement that will facilitate local, regional or national assessments of phenology. A new web-page contains an advanced on-line user interface to facilitate entry of contemporary data into the National Phenology Database. The new plant phenology monitoring program provides standardized methods and monitoring protocols for 215 local, regional, and nationally distributed plant species. Monitoring methods have been modified to facilitate collection of sampling intensity and absence data for both plants and animals. Coordinated development of regional networks will facilitate focused communication and interaction around regional phenology issues. Future directions include the implementation of a national wildlife phenology monitoring program for the 2010 season; increased integration with national and international formal and informal science networks;

enhanced consistency and availability of remote sensing of phenology terminology, methods, products and services; tools for discovery, description, ingestion, curation and distribution of historic phenology datasets; and, improvement of tools for data entry, download and visualization.