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Oregon State University
Long-Term Ecological Research at the H.J. Andrews Experimental Forest (LTER6)

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Participants' Detail

Partner Organizations:

The Nature Conservancy: Collaborative Research

USFS Pacific Northwest Research Station: Financial Support; In-kind Support; Facilities; Collaborative Research; Personnel Exchanges
The Forest Service is a key partner in LTER research at the Andrews Forest. They not only contribute financial support, but also personnel, and senior scientists. The Andrews LTER would not be able to function without this partner!

USDA Forest Service: In-kind Support; Facilities; Collaborative Research
The management side of the Forest Service through the Willamette National Forest is actively engaged in research in and around the Andrews. Maintenance of roads and buildings is aided by their staff. Long-term experiments are installed and protected with their help and landscape-level studies and application of research results are only possible with their collaboration.

Oregon Department of Forestry: Collaborative Research

United States Geological Survey: Collaborative Research
USGS Western Ecological Research Center.

USDA Agricultural Research Service: Collaborative Research

University of Washington: Collaborative Research

Other collaborators:
Gray Family Foundation
Hatfield Marine Science Center
Lewis and Clark College
McKenzie Watershed Council
Mercury Deposition Network
National Atmospheric Deposition Program
National Phenology Network
Oregon Forest Resources Institute
Oregon Watershed Enhancement Board
Portland State University
South Dakota State University
The Ecosystem Center, Marine Biological Laboratory
University of Portsmouth, England
University of Washington
US EPA, Corvallis Laboratory
USDA Agricultural Research Service
USDA Risk Management Agency
USGS Biological Resources Division, Corvallis, OR
Watershed Sciences
Western Oregon University
Woods Hole

Activities and findings:

General Overview
The Andrews LTER program seeks to understand the long-term dynamics of forest and river ecosystems of the Pacific Northwest. We are now completing the fourth year of the sixth funding cycle for this program (hereafter referred to as "LTER6"). For the past five funding cycles, and continuing in the present funding cycle, the Central Question guiding Andrews LTER research has been: *How do land use, natural disturbances, and climate change affect three key sets of ecosystem processes: carbon and nutrient dynamics, biodiversity, and hydrology?* In LTER6 we are approaching this Central Question from the perspective of our mountainous landscape: focusing on how this complex landscape affects the interactions

of drivers and responders. We intend to use this understanding—in addition to the deep knowledge we have gained about our system through past research—to forecast how variability and change in climate and land use may impact future ecosystem states, processes, and services. This will be done through the use of models that we will modify, parameterize, calibrate and finally implement to examine outcomes from a set of scenarios involving alternate trajectories of climate and land use in future decades. In addition to our biophysical research, we are expanding the scope of inquiry by more explicitly considering humans as a part of the ecosystem, following the model of the LTER Network's ISSE to use ecosystem services as a way to connect the biophysical states and processes of ecosystems to human welfare and behaviors that in turn feed back on ecosystem states and processes.

In previous funding cycles of the Andrews LTER, the principal spatial scale of inference for LTER studies was the Andrews Forest and adjacent upper Blue River watershed, an area of ~16,000 ha. In some of our work in LTER6, we are expanding this spatial scale to encompass the entire drainage of the McKenzie River, which includes a continuum of public and private land ownerships and a diversity of interactions between humans and the biophysical landscape. The principal temporal extent of ongoing LTER studies spans the past 500 years and projects several centuries into the future.

In LTER6, core research activities and syntheses have shifted from a disciplinary focus (e.g., climate, hydrology, disturbance), to a set of interdisciplinary studies with linked and overlapping objectives. These are: (1) retrospective analyses, (2) understanding climate dynamics and forecasting future climate in complex terrain, (3) phenology and trophic interactions, (4) water, air, nutrient and carbon cycle processes in Watershed 1, (5) the "digital forest" (detailed characterization of the physical and vegetative landscape), and (6) forecasting potential impacts of scenarios of change in land use and climate on biophysical processes and ecosystem services.

In LTER6 we also aim to expand our educational, international, social science, and humanities activities. These are not funded in the core Andrew LTER6 budget, but each has received support through supplements, so they are included in this report. We consider these efforts as significantly enhancing the core long-term ecological research conducted at the Andrews.

General Site Activities

Site leadership. Our leadership structure calls for an Executive Committee (EC) that meets monthly and includes 5 signatory PIs, the Forest Director, the IM manager, a social scientist, and a rotating member. Additionally, we have an emeritus faculty member and a grant manager that add much to our leadership team. Our leadership plan calls for a turnover in the lead-PI at the midterm. Upon her retirement, former lead-PI (Bond) successfully negotiated to have her endowed chair position replacement also serve as the next lead-PI for the Andrews LTER program. During the Spring of 2012, Oregon State University (OSU) conducted a search for the new Ruth H. Spaniol Chair of Natural Resources and Andrews lead-PI position. The OSU College of Forestry hired Dr. Michael P. Nelson from Michigan State University to serve in this capacity. This search and hire was an example of a collaborative effort involving both Oregon State University and our partners in the USDA Forest Service.

Nurturing and expanding our program. In this fourth year of the sixth funding cycle for the Andrews LTER program, our site has continued to cultivate an expanded and inclusive community, both in terms of numbers of researchers as well as the disciplines they represent. Recognizing that our goals greatly exceed the resources available to us through the LTER6 grant, we are putting a great deal of energy into writing and submitting research proposals to expand the scope of work, often in collaboration with "non-LTER" colleagues at OSU and elsewhere. As in the past, such efforts continue to pay off.

Linked directly to the successes in the LTEReflections program (discussed more specifically in sections on supplement funding and intersite activities, below), we have been closely aligned with OSU faculty and administrators in the creation of an Environmental Humanities Master's program at OSU. Andrews LTER leaders are serving on the executive committee for that program.

In our on going effort to make our science relevant and accessible, we devoted significant effort over the past year to strengthen our connections with policy and decision-makers at the state and federal levels. We

hosted scientists and managers (mainly USFS up to the Deputy Supervisor) exploring a new forestry initiative, dubbed "ecological forestry," which is gaining traction and promises to have important policy implications. Staffers from Oregon Senator Jeff Merkley's office attended our public HJA Days event in June. The updated Spotted Owl demography analysis done at the Andrews has made its way into the revised Critical Habitat for Spotted Owl. Spies and Harmon also hosted a stakeholder workshop in Portland on carbon tradeoffs. This meeting included representatives from Federal agencies, state agencies, industry and NGOs. The work was associated with their NASA carbon tradeoffs project, which has a regional scope but one of the focal areas is centered on the Andrews. A number of Andrews scientists also participate in an ongoing fashion with CCAMP, which includes managers from the BLM, USFS. Johnson is involved in several management research linkages throughout the broader region, including a social network analysis of researchers and managers interaction around the issue of fish and fire, and an evaluation of effectiveness of current forest practices and forest harvest across ownerships on water quality and stream communities (Partners in this include USGS, ODF, ODFW, BLM, OSU, ODEQ, USFS, Weyerhaeuser Company, Plum Creek Timber, NGOs, and relevant counties).

Strengthening relationships with partners. Over the past year we paid close attention to maintaining good communication and collaboration among the principle partners involved in our program: Oregon State University, the Willamette National Forest, and the PNW Forest Research Laboratory. This was challenging during 2012 given the retirement of PI Bond and the introduction of a new, outside PI Nelson, as well as by the fact that the College of Forestry underwent a search for a new Dean of the college during the summer of 2012. The inclusion of both OSU and PNW researchers on the search committee for the new lead-PI helped strengthen our partnerships.

Progress on Andrews books. We have two main book projects under way:
Judy Li and Peg Herring have written and illustrated a children's book about exploring forests, the working title is *Ellie's Log*. The book is scheduled for release in the Spring of 2013. Some funding was contributed for illustrations by the foundation of Charles Andrews (nephew of H.J. Andrews), and some from a recent NSF supplemental grant.

A draft of the Andrews book for the LTER Series with Oxford Press. is posted online:
http://andrewsforest.oregonstate.edu/webmast/hjabook/hjabook.cfm?next=main
Given staff and leadership changes work on this project was stalled a bit this past year, but Andrews leadership still believes this to be an important synthesis project that we need to share.

Infrastructure and Facilities. In 2008, the Andrews LTER was funded by NSF's Field Stations and Marine Laboratories (FSML) program to improve our site's infrastructure for research and education. In late 2008 we purchased a new 4-person SnoCat vehicle that has already been used extensively for graduate student research projects, ongoing climate and hydrological data collection and management, field courses, citizen science and RET training. With another component of this funding we built a network of towers and 5.8 gigahertz that provide wireless data communications between the Headquarters and remote areas spanning our site. Tower access points using 900 megahertz radios and modems provide coverage to >80% of the Andrews Forest and stream data from climate and meteorological stations, as well as new climate and ecosystem research installations employing acoustic profilers, infrared cameras and phenocams. Supplemental funding through the LTER program allow us to extend a link to watershed 1, where a dense sensor network has been established with LTER and other NSF funding. In 2009 we were thrilled to receive another FSML grant to construct a new "Green" residence on our site to house visiting scientists and writers and to include in our data collection and research program (highlighting exchange of matter and energy in the built environment alongside our ecological research). Construction of the building envelope will be completed in early November 2012. Interior finishing and furnishing will continue through the first half of 2013. Installation of the environmental monitoring systems will begin in November and development of a web portal and educational materials will follow. We anticipate a June 2013 open house and public launch of the web-based monitoring and education portal.

Much effort was devoted to maintaining and upgrading the computer facilities and field research technology at the Andrews, supported in part by Technology Resource Funds (TRF) from Oregon State University. These facilities are relied upon by more than 100 students and dozens of researchers each

year. We have 16 workstations, full printing and plotting capabilities, as well as a laser range finder, field computers and a high-precision GPS. TRF funds also were awarded recently for the development of portable wireless communication systems to allow researchers and instructors to access our wireless infrastructure from most anywhere within the forest. For short-term education needs, a lightweight battery operated radio system with laptop computer and digital video camera allows instructors to connect to headquarters or the Internet from the forest, making it possible to broadcast field lectures or engage in field to lab video-conferencing. For longer-term research installations, two units – one solar powered and another with fuel using a methanol fuel cell – allow researchers to power and communicate with sensors at remote locations. These units have played a key role in recent atmospheric science research conducted by Dr. Chris Thomas.

Inter-site activities

A number of inter-site activities already established continued over the past year. A number of new inter-site activities were also conducted. In May the Andrews hosted the annual Science Council meeting for the LTER network. We also had strong participation and leadership in the All Scientists Meeting (ASM) in Estes Park. A healthy number of the working groups were organized by Andrews researchers, our lead PI presented one of the plenary talks, and our site won the award for the best site flash-presentation at the meeting. Andrews Forest researchers were also featured prominently in the April 2012 issue of the journal *BioScience*, which included a special section on the LTER network in recognition of 30 years of LTER science. All of the pieces focused on inter-site activities. Andrews researchers were co-authors on 3 of the 6 papers in that special section, and Jones was the lead author on a piece that integrated stream flow data from a number of LTER sites.

Research Activities

Retrospective analyses: Long term trends

In the fourth year of this project, a number of activities were conducted as part of retrospective analysis of data.

Sampling of pollinator networks. Ten plots in each of fifteen meadows in five meadow complexes were sampled six times per summer for 15-minute intervals to detect plant-pollinator interactions, in summers of 2011 and 2012.

Spatio-temporal analysis of patterns of tree invasion in Bunchgrass meadow. Use of nearest-neighbor and Ripley's K analysis to detect clustering and repulsion among tree seedlings over time.

Climate Trend Analysis. Analysis of trends in climate (temperature and precipitation) and streamflow from 35 sites in the US and Canada based on records archived in climDB/HydroDB.

Manuscript (ms.) Preparation. Ongoing work to write up publications from Highland (2011) PhD thesis. Two publications are in preparation: (1) responses of nocturnal moth communities to vegetation and disturbance, and (2) extinction debt – lagged responses of moth communities to meadow contraction. Both ms.s should be submitted by the end of 2012. Revisions of ms. authored by Kendra Hatcher and Julia Jones for resubmission to Atmosphere-Ocean. Using data from 28 streamflow gages in the major subbasins of the Columbia River basin (including the Andrews Forest), the ms. examines evidence for ecological and engineering resilience of streamflow to climate change over the period 1950 to 2010. This manuscript will be resubmitted by Nov 1, 2012. Ongoing work on ms. authored by Kate Lajtha and Julia Jones examining the long-term trends (1978-2010) in precipitation acidity, SO4-S, Ca, and NO3-N at thirty sites in the US and Canada (including the Andrews Forest). Manuscript will be submitted before the end of 2012. Ongoing work on ms. with multiple authors, led by Jun Yu in OSU's School of Computer Science, applying multi-label species distribution modeling to datasets, including bird and moth datasets from the Andrews Forest. Manuscript will be submitted before the end of 2012.

Understanding climate dynamics and forecasting future climate in complex terrain

Long-term climate monitoring continued at six benchmark meteorological stations and more than two-dozen supplemental temperature (air, soil, water) stations distributed across the Andrews Forest. With phenology temperature monitoring stations, we now have more than two hundred supplemental climate

stations within the Andrews Forest. This spatially distributed monitoring is contributing to efforts to understand how cold air drainage and competing air flows contribute to microclimate variability in complex terrain and to develop high-resolution spatial models of microclimate.

In year four, we made significant investments to enhance the climate program. Supplemental funding allowed us to add net radiometers and sonic anemometers to a high- and a low-elevation met station. These instruments improve our ability to track weak air flows and to better track dynamics of cold air drainage and pooling in relation to net radiation balance at ridge top and valley floor sites. Through internal allocations we increased redundancy of air temperature sensors at our 10 long-term forest understory climate stations (reference stands). Similar to the situation at our benchmark climate stations, these redundant sensors facilitate the identification of measurement errors due to sensor drift and malfunction, reducing costs associated with manual QA/QC and eliminating gaps in the climate record. In conjunction with the modeling component, we added 25 air temperature monitoring stations in the Blue River watershed north of the Andrews Forest. We are in the process of adding six precipitation stations and six snow depth stations in this watershed. The Blue River watershed provides a larger area and more diverse management history than the Andrews itself, making it the ideal study area for modeling of ecosystem dynamics under different climate, disturbance and land use scenarios. The supplemental climate stations will be used to field check spatially explicit climate model assumptions based on extrapolations from the Andrews Forest.

The LTER climate program also supported research by Dr. Chris Thomas into watershed-scale air circulation dynamics using infrared cameras and acoustic profilers. Acoustic profilers were installed near the mouth of Lookout Creek and along a major tributary ca. halfway up the drainage. Continuous monitoring of airflows using this technology helps elucidate the complicated interactions between cold air drainage and competing airflows, furthering our understanding of how cold air drainage influences microclimate variation within Lookout watershed under different regional circulation patterns. Infrared cameras were tested as means of studying cold air drainage patterns across the watershed, as inferred from temperature gradients in vegetation canopies spanning a cross section of the drainage.

We made significant strides in automation of QA/QC of climate data. Streams such as temperature are now largely screened as they are downloaded through telemetry. We are working on automating more complicated streams such as snow depth and precipitation.

Spatio-Temporal dimension of climate

The past year's research activities have focused on monitoring and understanding the spatio-temporal relationships of the climate of the HJA, and expanding ideas generated from these activities to the regional and continental scale. HJA's unique temperature monitoring database has allowed us to make significant first steps in understanding the complexity of the spatial and temporal patterns of climate in mountainous regions. The result was a manuscript published in the *International Journal of Climatology* in 2010. We would also like to increase our confidence in determining historical trends and variations at HJA. Doing so involves examining changes in equipment that have occurred over the years and assessing their potential impacts on the historical temperature record. To that end, we are conducting a radiation shield comparison experiment, in which all radiation shields used in a significant way in the climate monitoring program are being operated side-by-side. The results of this experiment will allow us to adjust the historical temperature record for changes in shield type, if necessary.

Expansion of the HJA network is also occurring, creating exciting possibilities for increasing our understanding of the spatio-temporal relationships of temperature at HJA and beyond. In 2002, a monitoring vision with this goal in mind enabled the establishment of two so-called "cold air transects" of 10 sensors each, to supplement the longer-term temperature record. These cold air transects, which span Lookout Creek and adjacent hill slopes at two crossings, one at low elevation and one at high elevation, have been in place for nearly ten years. These transects were specifically designed to provide temperature response data over a wide range of topographic positions, from river-level, where cold air pooling is common, to ridge-top, above most cold air pools. As these data accumulate, we are nearing the point where we will be able to markedly increase the spatial richness of our knowledge. In addition, a large expansion of the temperature monitoring network (~160 stations) is occurring as part of the HJA phenology

and bird nesting studies. Once these new sites have been in operation for a few years, we will again be able to substantially increase the resolution and detail of our understanding of the spatio-temporal relationships of the climate of the HJA.

The rationale for focusing on this research is that while general circulation models are widely used to simulate future climate changes at global and regional scales, how these changes might manifest themselves locally is not well understood. Current methods for downscaling from regional to local scales produce a high degree of regional coherence, i.e. local climate change is closely coupled to regional change. While most climatologists would agree that this depiction is oversimplified, the scale, pattern, and magnitude of the variability in coupling between regional and local climate have never been quantified. This work is important because biodiversity and ecological impacts are partly determined by spatial and temporal variability in microclimate. The impacts of regional mean global warming on ecosystems may be amplified or diminished depending on the degree of coupling between regional and local climates.

Phenology and trophic interactions in complex terrain
This research is directly answering the following questions from the LTER 6 proposal: a) What local abiotic drivers determine the phenology, e.g., bud break, instar development, activity of songbirds, of the biota in our model system? b) How is the synchrony of phenology of these biota affected by environmental conditions varying across space and time, within and between years?

Insects. With changing climates, hydroclimatic impacts are expected in both aquatic and terrestrial ecosystems. Because insects are short lived and ectotherms, they should be quickly responsive to local temperature changes. However, the extent to which insects are responding to current climate is not well understood, especially for forest species. Here we have an opportunity to test responsiveness of both aquatic and terrestrial insect species to temperature gradients and hydrologic variation in order to better understand climate change impacts.

The phenology of insects is influenced by multiple climatic factors. For example, for flying insects, the timing of precipitation in addition to temperature would likely very important. For aquatic insects, because of the thermal inertia of water, we expect that the temperature they experience is more predictable than for terrestrial insects and therefore aquatic emergence would be responsive to degree-days than terrestrial insect activity. But we also know that during springtime, both flow and stream temperatures are changing and either or both could be important cues for phenologic activity. It is challenging but important to evaluate these factors independently as well as to better understand the interactions between flow and temperature on emergence.

In the Year 4 of the Phenology project, weekly sampling of flying insects occurred from April through June at the 16 core sites established in Year 1. These core sites extend across elevation, topographic and vegetation gradients. Flying insect activity was assessed using malaise traps deployed at 16 core sites each year. These sites are located across elevational and topographic gradients, from 450m to 1100m, and with a variety of forest stand ages and slope aspects. Activity of insects from malaise traps is the total number collected in each trap. Specific taxa are being identified to genus and tally of their abundances calculated separately.

Emerging aquatic insects were collected for the 4th springtime season using emergence traps at the same six, 1st to 2nd order streams studies in previous years. These span 450m to 1000m in elevation, and differ by water source (spring vs. run-off) and forest age. Adult aquatic insects were identified to lowest level possible, from subfamily to species. We monitored overall activity levels and emergence rates over time as well as the activity/emergence of selected key taxa.

Birds. We completed the fourth year of sampling birds at 180 individual point count stations across a 1200 m gradient. These data enable us to test the hypotheses that species distributions are primarily associated with climate, land-use or other biotic factors (e.g., prey availability, competition, heterospecific attraction).

We continue to conduct automated recordings of bird song at 14 stations distributed across the HJA. We have now amassed 8 TB of data representing hundreds of thousands of individual bird songs.

We have developed statistical models (ensemble classifier chains) to predict bird distributions that allow testing the hypothesis that inter-specific factors increase the prediction success of species distribution models.

Vegetation. In the fourth year of the project, weekly sampling of plants occurred from April through early July at sixteen core sites established in year one across elevation, topographic and vegetation gradients. Five marked individuals of each of 17 representative plant species are observed at each site. Air and stream temperature have been measured at these sites continuously since May of 2009, and for many of the core sites records extend back to the 1980s.
We continued to invest in remote cameras for monitoring of vegetation phenology. We expanded the network of timelapse camera sites to 18 sites on the Andrews forest and 20 sites in the adjacent Blue River watershed. In addition, we installed four new webcams on towers associated with our wireless communications infrastructure. The camera network now allows us to monitor canopy phenology at daily time steps across the entire year and spanning a large range of microclimate conditions. The cameras also provide an intermediate resolution data source to link ground observations with satellite observations. Graduate student Kevin Briggs is working to adapt the STARFM blending algorithm for MODIS and LANDSAT images to track canopy phenology at large scales. Briggs will use ground and camera observations to ground truth remote sensing data. His project will use phenology as an indicator of forest successional development following logging. REU student Sarah Ward explored the application of cameras to monitor spring phenology of individual species and of a MatLab script, PhenoCam Image Processor, developed to monitor canopy 'green-up' in deciduous forests.

Water, air, nutrient and carbon cycle processes in small watersheds
This multi-investigator, integrated project is designed to contribute to Goal I of LTER6, specifically focusing on the influence of complex terrain on carbon and water cycle processes at spatial scales ranging from the small plot level (5 to 10 square meters) to the small watershed scale, using Watershed 1 (WS1) as our testing ground. We aim to quantify components of fluxes, to characterize their spatial heterogeneity, to explain causes of spatial heterogeneity, and ultimately to examine potential impacts of spatial heterogeneity in these biophysical processes on the sensitivity of processes to variability in environmental drivers at the watershed scale. In year 4 we accomplished the following activities:

Evaluate the effects of environmental, biotic, and historical drivers on aboveground net primary productivity (ANPP) at the small-plot and whole-basin scales. PhD student Fox Peterson completed these analyses and they will be included in her dissertation, which will be defended at the end of 2012.

Characterize spatial variability and seasonality of Dissolved Organic Carbon (DOC) and its relationship to spatial variability in litterfall and primary productivity. These investigations are ongoing. Preliminary results have been analyzed by PhD student Fox Peterson; they will be included in her dissertation.

Initiate overall synthesis of biomass and carbon dynamics for WS1. Mark Harmon is leading this effort, which will include data inputs from many other investigators and will eventually include both terrestrial and aquatic components. A range of estimates is being made using plausible calculations pathways so as to represent the model uncertainty in these estimates.
MS student Scott Allen completed this analysis, which included both field measurements and modeling, and included it in his thesis, which was defended in spring, 2012.

Initiation of the first measurements of net ecosystem exchange and evapotranspiration using the eddy covariance (EC) method at WS1. Synergistic efforts between the activities funded by the LTER 6 grant and the Career award of Dr. Thomas (AGS 0955444) enabled this addition to the WS1 research. This is a very exciting and ambitious attempt to apply EC techniques in extremely complex terrain. The simultaneous EC measurements above the canopy and in the subcanopy above the stream commenced on 17-July-2012 and will be continued until the onset of winter precipitation. Measurements of the air circulation within the WS1 airshed were made using an additional network of 12 sonic anemometers to measure spatially distributed wind speed and direction and turbulent mixing strength across the entire domain. The latter is needed to describe how the airflow connects carbon sinks and sources vertically and

horizontally within the WS1 airshed, and its communication with the larger Lookout Creek watershed. The airflow at the boundaries of the WS1 airshed was observed using two ground-based acoustic remote sensing systems.

Improvement of infrastructure. To complement biometric estimates of carbon and water cycle components, two additional measurements complexes were installed on the existing tower located at the mouth of WS1 in July 2012. The first complex consists of two eddy covariance (EC) systems to measure the atmospheric carbon dioxide flux and evapotranspiration using high-frequency (20 Hz) observations of scalar concentrations and winds above the main canopy at 37 m and 4 m agl (above ground level). The second complex measures the vertical concentration profiles of carbon dioxide ($^{12}CO_2$), its stable isotope ($^{13}CO_2$), and water vapor every 8 seconds. Significant improvements comprise the installation of new chemically inert tubing in combination with a continuous tube heating to minimize sampling artifacts caused by contaminations and condensation of water vapor inside the tubing. The latter is particularly important at WS1 since low nighttime temperatures often lead to dewfall and condensation inside the tubing, which may cause a fractionation of the carbon dioxide. A total of 11 sampling inlets cover the entire vertical profile from 38 m above the main canopy to 1m above the surface ground, an inlet placed 0.02 m above the creek and the litter layer to determine carbon dioxide concentrations in direct vicinity of the water-air and soil-air interface, and one long-term calibration gas standard.
Adding the new measurements complexes was made possible by combining existing instruments from both Bond and Thomas labs, while some additional supplies were purchased using LTER6 funds. In addition, all meteorological instrumentation installed at the WS1 base tower was cleaned, verified, and recalibrated.

Vegetation/Permanent Study Plots
The main activity has been to measure the growth, recruitment, and mortality of trees on a series of long-term permanent plots within the PNW region. The majority of effort has been within the Andrews Forest itself, although with help from collaborators remeasurements of plots in Washington State have also been undertaken. Within the Andrews Forest, this year we have completed remeasurement of the plots within watershed 1 and 3 and within several old-growth stands some of which are on the Olympic Peninsula in Washington. The former data is being used in an assessment of carbon dynamics within Watershed 1.

There were also measurements of live and dead wood within several of the old-growth stands that had some of the first dead wood inventories in the region. This information is being used to examine how live and dead carbon modulate each other in old-growth stands.

Another ongoing activity is to improve the software used to estimate biomass, carbon stores, NPP, and other aspects of trees as part of the proposed Veg-DB intersite project. Our ultimate goal is to contribute to an online system that makes estimates automatically and produce user-friendly reports of the results.

Forecasting potential impacts of change in land use and climate on biophysical processes and ecosystem services
The primary activity in the past year has been finalizing plans for future scenario testing. A two-day workshop was held with all the participants in which the status of the models to be used was reviewed and plans for scenario testing were finalized. Decisions were made about the temporal and spatial extent of the analysis, the types of model output that will be produced, and the types of input data that will be required and how it will be provided. In addition the participants outlined three complementary studies that would result in manuscripts that address the questions posed in the LTER6 proposal. These include examinations of 1) the effects of complex topography, 2) the trade-offs between greenhouse gas mitigation versus climate adaptation, and 3) a multi-scale view of possible climate response forested ecosystems in the Pacific Northwest region. The latter would involve sites other than the H. J. Andrews Experimental Forest, but would put results from that site in a regional context. One of the challenges and opportunities of using multiple models to examine these topics will be to create an integrated view. Each model places emphasis on somewhat different sets of processes at a range of difference spatial and temporal scales. This means that no model can look at everything at every scale. An alternative is to use a range of models and coherently integrate them. As there are no standard methods to achieve this integration, a key contribution of this work will be to examine how this may be effectively achieved.

Other Activities

Visiting Scholars. This project continues at a pace of one to two visiting scholars per year.

- Kurt Fausch, Professor, Fisheries and Wildlife Biology, Colorado State University. Fall 2011. Fausch is working on an NSF Opus grant project writing a book on fish and rivers.
- Todd Gilens (freelance installation artist) and Maria D'Agostino (arborist). Nov 2011. Both were from San Francisco writing about Todd's urban art project in which five busses had images of endangered species and their San Francisco Bay habitat wrapped entirely around the busses – and they hurtled through the city attracting attention to URLs for conservation organizations on the back. Maria wrote about tree climbing as work and aesthetic experience.

Visiting writers. We continue to have writers visit the Andrews Forest in two residency programs: Blue River Fellows (two per year) are invited, very accomplished writers, and Andrews Forest Residents (four per year) are earlier career writers chosen from applications. This work is supported by funding from US Forest Service Pacific Northwest Research Station and conducted in cooperation with the Spring Creek Project. Collecting and archiving the steady stream of works from past residents is a continuing effort, as reflected in the Forest Log of the Andrews Forest webpage, where we archive and make available the collected works of visiting writers. (http://andrewsforest.oregonstate.edu/lter/research/related/writers.cfm?topnav=167) Also, the better-known writers give public lectures in Corvallis and some are interviewed on local radio programs.

Visiting Artists. We initiated a Visiting Artists program by hosting Debby Kaspari, who worked at Harvard Forest for 8 months. In summer 2012 she did a series of pastels in Andrews Forest and we see the potential for inter-site artistic comparison. The second artists in residence, Leah Wilson, will reside in the Forest in October 2012.

Other Andrews Forest-based activities

The Eye of the Storm: Re-imagining Ethics for a Changing Planet – This was a gathering at Andrews Forest Sept 29-Oct 2, 2011. Organized by the Spring Creek Project for Ideas, Nature, and the Written Word the group produced "The Blue River Declaration: An Environmental Ethic". Among the ancient, moss-draped Douglas-fir at the Andrews Forest twenty-three people gathered to take seriously the task of penning an environmental ethic appropriate for our time. The assembled philosophers, scientists, writers, poets, students, and professors of various bents did this work, reported it to a gathering of ca. 100 in Corvallis, and published the work and carried into their teaching at many institutions. The Spring Creek Project continues to host gatherings of 20-30 environmental philosophers and creative writers on alternating years for autumn weekend retreats to ponder their crafts and how their work can be made more effective in supporting the wellbeing of the natural world.

Ecological Reflections Network. A major focus over the past two years has been advancing the engagement of arts and humanities in work at LTER sites and other sites that have deeper arts or humanities roots than science roots characteristic of LTER. We have made great progress and attracted a good deal of interest, highlighted by an art exhibit at NSF in Spring 2012 and multiple activities at the ESA and All-Scientists Meetings. The Andrews Forest group and humanities partners in the Spring Creek Project for Ideas, Nature, and the Written Word have been central players in these developments.

- We hosted an LNO-sponsored workshop in May 2011 at Andrews with 12 LTER and 2 non-LTER sites to share efforts, outcomes, and ambitions.
- That workshop led to establishment of the www.ecologicalreflections.com WordPress webpage to share profiles of programs at nearly 20 sites/programs and provide links to site webpages. The purpose is to provide information that others may use to advance their own site programs.
- We helped organize an art show of works from NTL, BNZ, and HFR for four months at NSF offices in DC, which was very well received.
- Those works plus panels with text and photos from the Andrews Forest program were displayed at ESA in Portland OR in Aug 2012, where over 400 people visited the showing.
- Also at ESA Portland we spearheaded an Organized Oral Session of ten talks and a how-to-do-it workshop concerning engaging arts/humanities with LTER and related programs.

- Art and writing works (including Andrews Forest) were displayed at the LTER All-Scientists Meeting in Estes Park CO and a four-hour workshop was conducted with 29 participants representing 13 sites.
- Andrews Forest works were also displayed at the Organization of Biological Field Stations meeting in Florida in September.

International
Chile [Jones (PI) and Swanson]. Volcano ecology supported by LTER supplemental from International Programs NSF for study of effects of eruptions of Chaiten (2008) and Caulle-Puyehue (2011) volcanoes on the forests of southern Chile. Travel occurred in January 2011 and 2012 for field work and collaboration with faculty and students at Universidad Austral de Chile, Valdivia.

Information Management
Improvements to the Andrews Ecological Metadata Language (EML) files were made through enhancement of web scripting programs (ASP.NET, C#, XSLT), which directly produce EML from our relational metadata database. This work prepares the Andrews for validating and harvesting data into the LNO PASTA architecture.

Redesign of the Andrews long-term permanent study plot (PSP) vegetation data to 1) more efficiently manage this vegetation data, 2) standardize attribute names and descriptions, and 3) improve overall data quality.

Streamlining the handling and processing of Andrews streaming data, as the new Andrews wireless communication towers and high-bandwidth radios have recently been activated. The established system is intended to handle most data loggers and other sensor networks at the Andrews.

Regular series of core data sets were updated and additional data entities were added to accommodate new research activities.

Manuscripts in the Andrews publication library are being scanned and abstracts are being added to the database to provide better access to publications. Publication search capabilities from the Andrews webpage have been enhanced to allow specific keyword searching of authors, titles, and abstracts.

Restructuring of the Andrews long-term stream chemistry dataset to make data comparable to other sites and accommodate addition to the StreamChemDB.

Development of methods for ensuring the inclusion of spatial data into the Network Information System (NIS) for discovery and download through the PASTA system.

Completion of the conversion of historical aerial photos into geo-registered electronic format.

Schoolyard LTER
Through two-day workshops at the Andrews LTER site and intensive research experiences, the Andrews Schoolyard LTER program connected twenty-three Oregon middle and high school teachers with Andrews LTER research. Seventeen of these teachers teach in Title One Schools. The goal of our Schoolyard LTER program is "to increase teachers' understanding of environmental science research by involving them in projects directly related to LTER research, and to expand their capacity to involve their students in similar field-based science inquiry." In May of 2012, ten middle and high school teachers worked closely with Andrews LTER scientists to collect data for the LTER6 long-term phenology research project as part of a Teachers as Researchers (TAR) workshop. Teachers and Andrews LTER scientists to collect data from beetle traps for the LTER6 long-term phenology research project. The workshop used the beetle investigation to take the teachers through all aspects of the scientific process, from forming a research question, collecting field data, to analyzing data and making conclusions. The three 2012 Andrews LTER Research Experience for Teachers (RET) fellows helped identify the beetles collected during the May workshop as part of their RET experience.

Eight middle and high school teachers participated in longer-term intensive research experiences during the summer of 2012 through the RET program and the NASA-funded Researcher-Teacher Partnerships (RTP) project to involve teachers in climate change research. Three RETs worked with Andrews LTER scientists investigating different methods of insect collection as part of the LTER6 phenology research project. Another RET worked with Andrews LTER scientist, Chris Thomas on a project investigating airflow in mountainous terrain and potential links to climate change. In addition to the RETs, four teachers worked with Andrews LTER researchers Mark Harmon and Anne Nolin for an intensive two-week research experience on forest carbon sequestration and climate change effects on snow, respectively.

In August of 2012, ten teachers funded through the NASA RTP project participated in a two-day teacher workshop at the Andrews LTER site, where they learned about climate change research at the Andrews LTER and collaborated on developing climate change units to implement with their students.

Findings:

Retrospective analyses

Plants and Pollinators. Montane meadows comprise less than 5% of the landscape of the western Cascades of Oregon, but they provide habitat for diverse species of plants and pollinators. Little is known about plant-pollinator network structure at these sites. This study quantified plant-pollinator interactions over the summer of 2011, based on six observations of 10 permanent subplots in 15 meadows, stratified by size and isolation. The study examined (1) relationships between richness and abundance of flowers, pollinators, and interactions; (2) distribution of abundance and richness of flowers, pollinators, and interactions with regards to surrounding meadow habitat; (3) change in flower and pollinator abundance over the season; (4) factors associated with the presence of various guilds of pollinators; and (5) the structure of plant-pollinator networks. *Major findings of this study are that (1) richness of pollinators increased 2x faster than richness of flowers with increased abundance; (2) density of flowers and interactions was positively correlated with meadow size and diversity of pollinators and interactions were both correlated with surrounding habitat at two spatial scales; (3) peak flower abundance coincided with or preceded peaks in pollinator populations; (4) abundance of three guilds of bees exhibited different patterns of association to surrounding habitat and meadow soil moisture corresponding to various dispersal potential and phenology of guild species; and (5) the number of network pairings for plants and pollinators increased with increasing species richness of potential interaction partners and all networks were found to be significantly nested.* Results of this study indicate that plant-pollinator networks are complex assemblages of species, in which spatial and temporal patterns of habitat affect species composition and network structure. In particular, flower and pollinator abundance and richness are depressed in small and isolated meadows. Significant nestedness emerged as a pattern of network level organization across the study meadows.

Tree Invasions. Tree invasions of grasslands are occurring globally, with profound consequences for ecosystem structure and function. We explore the spatio-temporal dynamics of tree invasion of a montane meadow in the Cascade Mountains of Oregon, where meadow loss is a conservation concern. We examine the early stages of invasion, where extrinsic and intrinsic processes can be clearly delineated. In a 0.21-ha plot, we mapped and aged 929 trees **C**0.3-m tall, yielding a detailed record of the spatio-temporal dynamics of invasion. For the primary species, *Abies grandis* and *Pinus contorta*, we correlated age structures (unimodal in both species) with climate (precipitation, temperature, and snowpack) and cone production, but found weak or nonsignificant relationships. Evidence of biotic interactions within and between species was obtained by examining the spatial associations of trees to a distance of 5 m and how these changed over time. We used multiple methods including uni- and bivariate forms of the Ripley's K and pair-correlation function (pcf) (corrected for inhomogeneity), the J-function, an evolving nearest-neighbor metric, and a test for directional bias in establishment. *Pinus* and *Abies* contributed in contrasting ways to the pace and spatial structure of invasion. *Shade-intolerant* Pinus *tended to establish in the open, initiating clusters. In contrast, shade-tolerant* Abies *established in association with* Pinus *or in conspecific clusters. Preferential establishment of* Abies *to the north of older* Pinus *suggests that facilitation occurs by shading. The factors responsible for initial establishment remain unresolved, but positive interactions are pivotal in accelerating invasions, once initiated. Similar processes are likely to occur in other grasslands undergoing rapid conversion to woodland or forest***.** In combination, analyses of spatial and temporal patterns of

establishment provide insight into the processes that structure invasions.

Ecosystem Processes and Human Influences Regulate Streamflow Response to Climate Change at Long-Term Ecological Research Sites. Analyses of long-term records at 35 headwater basins in the US and Canada indicate that climate change effects on streamflow are not as clear as might be expected from trends in climate, perhaps because of ecosystem processes and human influences. Evapotranspiration was higher than predicted by temperature in water-surplus ecosystems and lower than predicted in water-deficit ecosystems. Streamflow was correlated with climate variability (ENSO, PDO, NAO), especially in seasons when vegetation influences are limited. Air temperature increased significantly at 17 of 19 sites with 20- to 60-year records, but streamflow trends were directly related to climate trends at only seven sites, due to changes in ice and snow. Past and present human and natural disturbance, vegetation succession, and human water use can mimic, exacerbate, counteract, or mask the effects of climate change on streamflow, even in "reference" basins. Long-term ecological research sites are ideal places to disentangle these processes.

Understanding climate dynamics and forecasting future climate in complex terrain

Recent investments in the climate monitoring infrastructure will begin producing tangible results over the next year. We anticipate significant advances in climate modeling at the watershed scale, and subsequent advances in understanding potential ecosystem responses to climate change and forest management (see modeling section).

Analysis of the first two years of data from our experiment comparing measurement error from different temperature sensor - radiation shield combinations yielded valuable insight into analysis of temperature trends in historic records. As expected, non-aspirated shields did not fully protect sensors from radiation effects under some conditions. Wind speed and incoming and outgoing radiation were significant factors explaining deviations from the standard. Although 90% of measurements were essentially identical among sensor-shield combinations, deviations as great as 8 degrees Celsius were observed under conditions of high solar radiation, deep snowpack and low wind speed. This has implications for analysis of long-term trends, not just at the Andrews Forest, but at most sites that have long-term periods of record, accompanied by significant technological advances. When analyzing such records, it appears unlikely that mean or median values will be substantively influenced by sensor-shield type. However, trends in daily and even monthly maximum values must be interpreted with care.

The radiation shield experiment is in its second year of operation. At the PRIMET meteorological station, shields compared include Gill shields - cylindrical with slats, short and long varieties; "HJA" shields - cutaway PVC pipes, short and long varieties; and a cotton region shelter - large, louvered wooden box painted white and mounted about 4 feet above ground level. An RM Young aspirated shield was used as the control. Initial results show that the choice of radiation shield has a significant effect on temperature bias, especially during the day, when solar radiation is at its peak. Surprisingly, the cotton region shelter, used for over 100 years as a thermometer shelter for the US Cooperative Observer Program, consistently had the lowest biases for daily maximum temperature. This appears to be the result of the shelter's large size, good ventilation, and high heat capacity. The cotton region shelter was used for many years at PRIMET, but was taken out of service in 2004. The HJA shield had the highest bias, due to its minimal coverage of the temperature probe and design that exposes the probe to lateral radiation. The HJA shield was used extensively in the past, suggesting that the potential for biased readings exists in the historical record.

Phenology and trophic interactions

Birds. This is an on going project. While we anticipate more major findings by December 2012, we found that Multi-instance Multi-lable (MIML) classifiers function very effectively at automatically identifying bird species in our recordings. This work has been published in the *Journal of the Acoustical Society of America*. We also found that using heterospecifics (information about the broader bird community) can be effective for predicting species distributions. The magnitude, of these improvements, however, is not large, and is dependent on a variety of factors including spatial location and year.

Vegetation: Results from the first few years of this project illustrate that microclimate and plant response to site conditions are more complicated than simple elevation-based climate envelope models would suggest. The elevation range of more than 1000 m across Lookout Creek watershed creates a general gradient in air temperature, snowpack and growing season from low to high elevation. However, other factors such as cold air drainage, vegetation cover and slope aspect combine to produce microclimate complexity, under which sites at the same elevation can have widely differing spring phenologies, and at some higher elevation sites budbreak and leaf development can occur much earlier than at sites that are substantially lower in elevation (e.g., *Linnaea borealis, Fig. 1*). For a given species, budbreak can occur more than one month earlier at some sites than at others within the same watershed. We have also seen that inter-annual variability in regional climate can translate into variation in timing of spring phenophases at a given site as great as 40 days. Moreover, this climate variability among years can affect the relationship among sites in terms of timing of key phenophases, particularly for species that are strongly influenced by snowpack dynamics.

At a subset of our current monitoring sites, comparable records for focal species in the early 1970s allow a glimpse into how well our current sampling window captures climate variability over a longer interval (e.g., *Acer circinatum. Fig 2*). While our records suggest that for some species there were years in the early 1970s when budbreak occurred later than in any year during the current monitoring period, the high degree of variability from one year to the next highlights the importance of long-term, continuous monitoring of phenology to understand trends related to climate variability and change.

Initial analysis of camera and satellite images has been promising. Manual scoring of plants and groups of plants within camera images allows for consistent monitoring key spring phenophases. However, there are significant limitations with camera images related to image quality and resolution. Only coniferous trees within the foreground of images could be judged with enough precision for reliable estimates of budbreak, needle development and cone production. For deciduous species, useful information could be gathered at much greater distance from the camera. The excess greenness index developed for analysis of phenocam images in eastern deciduous forests also works well for the deciduous component of vegetation in images from our sites. A new index will have to be developed for this image analysis approach to be applied successfully to coniferous canopy phenology.

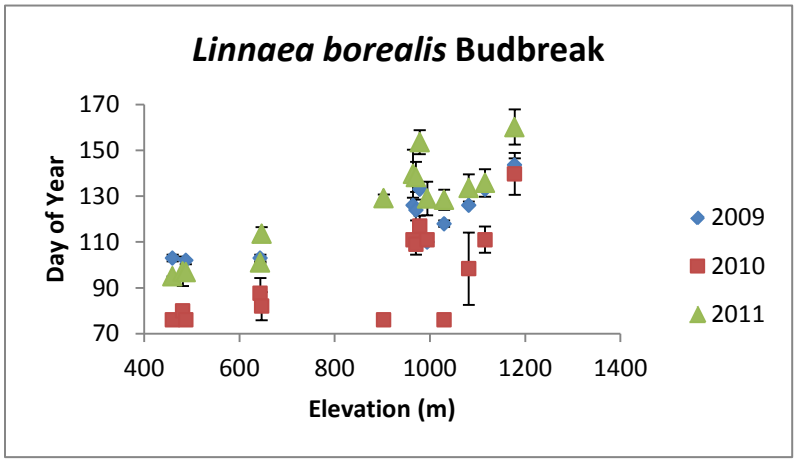

Figure 1. Timing of budbreak in *Linnaea borealis* (twinflower) shows wide variation among sites within a year that is only partially explained by elevation. Among years timing fluctuates widely, and is strongly influenced by snowpack dynamics in the winter and early spring.

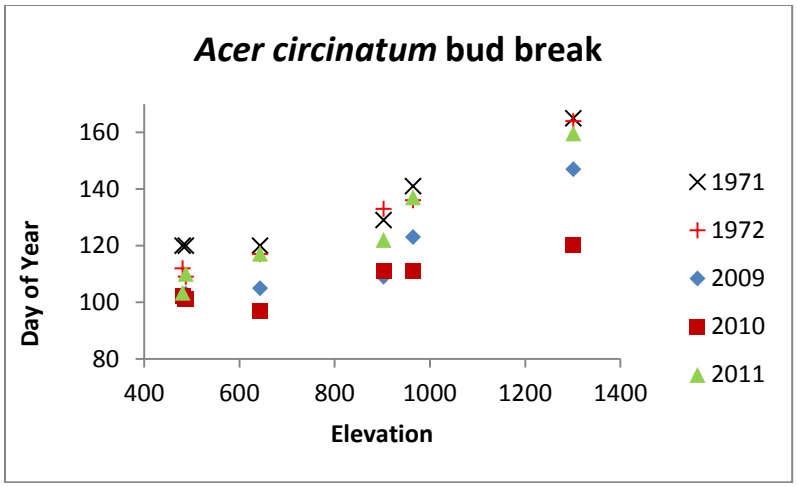

Figure 2. Observations of *Acer circinatum* (vine maple) budbreak in the early 1970s and in recent years illustrates the wide variation in timing among years and the need for long-term continuous observations in order to detect trends related to climate change.

Insects: We hypothesized that insect emergence from aquatic environments is responsive to site specific accumulation of water temperature degree days but terrestrial insect activity is not correlated with site specific accumulation of degree days of air temperature. We also expect to find that aquatic insect emergence rates or biomass are most related to climatic drivers of instream temperature and hydrology at interannual and seasonal scales as opposed to weekly or daily scale.

For samples from Year 1-3 (2009-2011), flying insect activity levels (number of individuals captured per day) were assessed for three time periods—early May, late May, and mid June. Taxa richness and numbers of individuals captured were lower in early May than later in the spring, during late May or mid June. An in-depth examination of samples collected in mid-June showed no apparent relationship between insect activity levels and site elevation or adjacent forest age. Comparison of activity with air temperature differences among sites suggests that air temperature is not a good predictor of activity.

Trends in aquatic insect emergence have been evaluated for springtime in Years 1 through 3. Field season for Year 4 has just been completed. Over the first three years, we are finding a much stronger and more predictable relationship between site elevation, stream temperature and adult insect emergence rate than for temperature and flying terrestrial insects (Figs.3 and 4). For aquatic insects, lower elevation sites tend to have warmer temperatures and earlier peaks of emergence. In addition, within sites during sampling period there is an increase in emergence rate and taxa richness. Most samples from core sites had similar taxa richness and diversity, even at the very cold spring-fed stream. There taxa were slower to emerge but community composition was surprisingly similar.

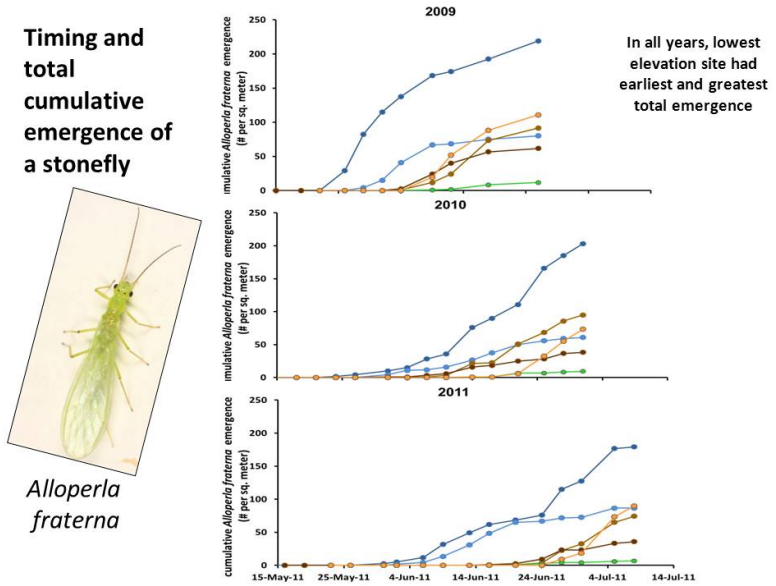

Figure 3. Emergence from the streams is generally predictable for some taxa as a function of stream temperatures, which coincides with elevation.

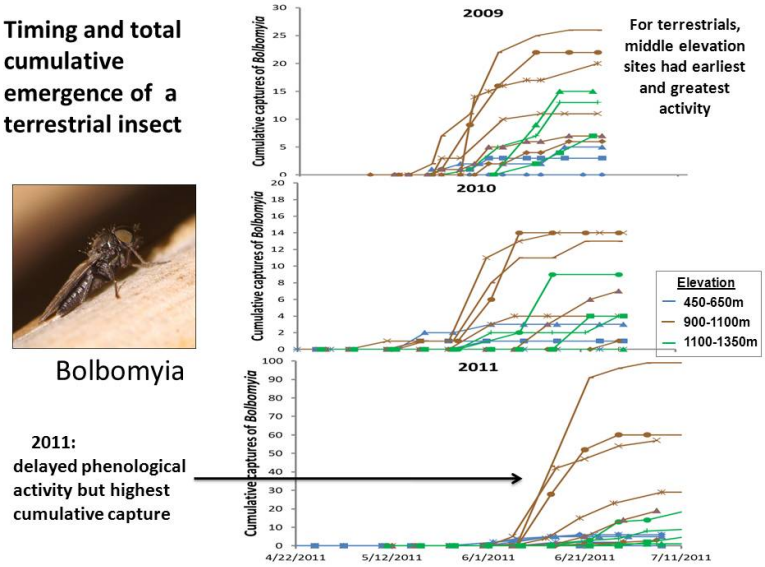

Figure 4. Activity for terrestrial insects is less predictable and does not coincide with elevational gradients or air temperatures.

Water, air, nutrient and carbon cycle processes in small watersheds *Effects of environmental, biotic, and historical drivers on aboveground net primary productivity (ANPP) at the small-plot and whole-basin scales*. In earlier reports, we shared analyses revealing very large spatial variability in ANPP in WS1 (see also upper left chart in Figure 5), despite the fact that the entire basin was uniformly clear-cut harvested and then replanted with a single species (Douglas-fir) in the late 1960s. Subsequently, we investigated fundamental questions about how to address the relationships between ANPP and ecosystem structure (topography, forest composition, and disturbance history. Potential topographic drivers included slope, soil depth, and aspect. Biotic drivers included percentage of hardwoods and species richness. Historical drivers included regeneration attempts and disturbance history. On WS 1, long term data exists to characterize these drivers for 133 long-term re-measurement plots, and there is a high degree of spatial variability in all of them (Fig. 5).

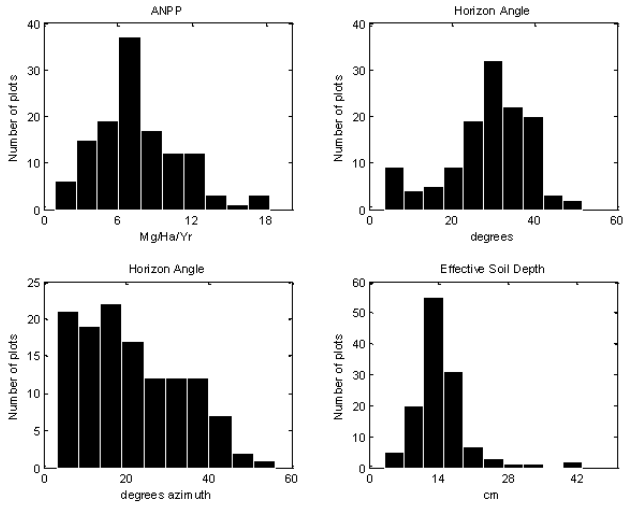

Figure 5. Non-normal distributions of ecosystem drivers and ANPP response on WS1

Spatial variability and seasonality of Dissolved Organic Carbon (DOC) and its relationship to spatial variability in litterfall and primary productivity. Depending on how the watershed is parsed (for example, spatially by soil type or temporally by species composition at establishment), different environmental drivers affect ANPP. In turn, this functional link between site and function affects the belowground storage and release of carbon. We used a non-linear fitting to quantify the relationship between current ANPP and DOC. There is a strong (log-transformed, $r^2 = 0.64$) positive, exponential correlation (Figure 6). As ANPP increases, DOC increases exponentially. This suggests that there is a positive feedback loop between a productive stand and carbon leechate.

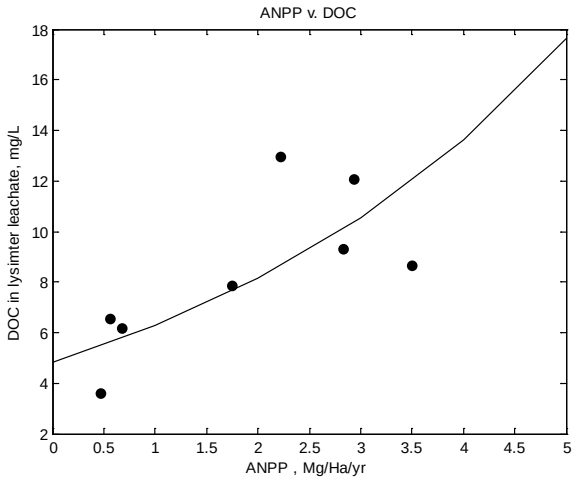

Figure 6. ANPP v. DOC collected in lysimeter leechate 2010-2012

One mechanism by which ANPP contributes to the soil is through litterfall. Interestingly, a relationship between DOC and litterfall is only found on the north-facing slope of WS1 (Figure 7). On the south-facing slope, litterfall is not a strong predictor of DOC. This evidences how the selection of the topographic drivers used in the analysis may change the correlation between ANPP and the belowground release of carbon.

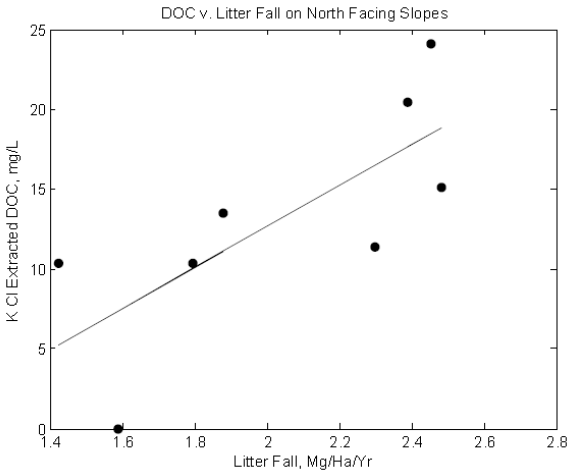

Figure 7. DOC from KCl extractions v. litter fall on the north-facing slope of WS1

Synthesis of biomass and carbon dynamics for WS1.

A range of estimates is being made using plausible calculations pathways so as to represent the model uncertainty in these estimates. Regardless of method, biomass increased linearly from 1984 to 2007 (Figure 8). The range of total biomass estimates is approximately ±12% of the average estimate. A similar series of estimates is being made for NPP expressed as organic matter that indicates that NPP increased between 1984 and 2010 and has remained relatively constant between 2001 and 2007 (Fig. 9). The range of total NPP estimates is approximately ±10% of the average estimate. However, the uncertainty related to NPP is likely much higher due to poorly constrained estimates of fine root turnover.

We are currently adding in estimates of understory biomass and NPP, which is likely to no change biomass estimates greatly, but will likely increase NPP by 20-30% if past work is any guide. To estimate changes in carbon balance estimates of dead and soil stores and their associated fluxes will also be made. In addition to providing empirical evidence for how the carbon balance of this watershed is evolving, the uncertainty framework being used will be helpful in targeting major areas for improvement.

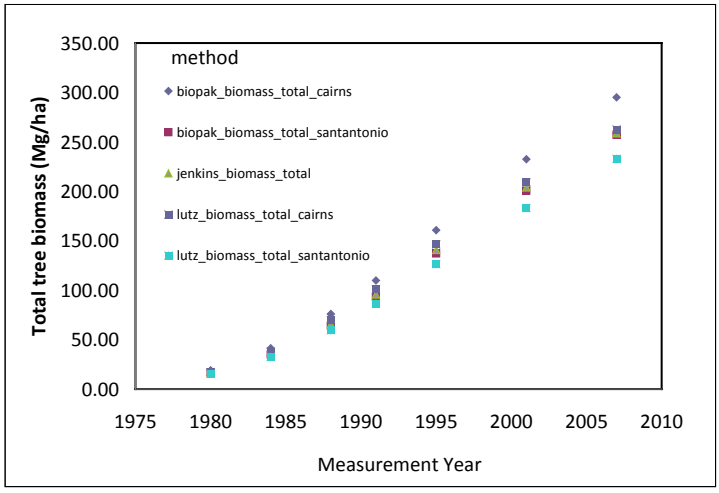

Figure 8. Estimates of total tree biomass (above- and belowground) from WS1. Five different equation pathways were used to estimate above- and belowground biomass.

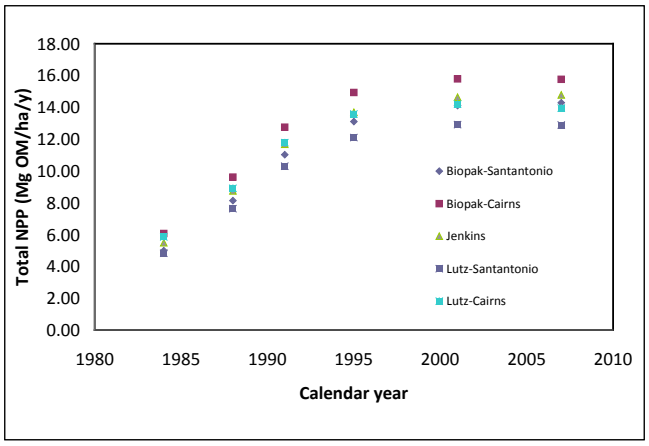

Figure 9. Estimates of total tree-related NPP (above- and belowground) from WS1. Five different equation pathways were used to estimate above- and belowground NPP expressed as organic matter.

Spatial and temporal variability of evaporative losses and throughfall of precipitation during rain events.
The proportion of total precipitation that is intercepted by the canopy and lost to evaporation varies dramatically both seasonally and spatially (Figure 10). Interception losses are relatively small in the fall and winter, ranging between 4 and 7 percent, but in the summer months more than one third of all rainfall is intercepted by the canopy and lost before it hits the ground. On an annual basis, less than 10% of precipitation is lost to evaporation because there most of the rainfall occurs between October and April. However, the biological impacts may be greatest in the summer due to the important role that summer drought plays in both biogeochemical cycling as well as vegetation processes. Not surprisingly, canopy leaf area plays a strong role in the spatial variability of interception losses, with the interesting consequence that the parts of the watershed that have experienced the greatest productivity and currently have the highest biomass are also receiving the lowest moisture inputs during the summer.

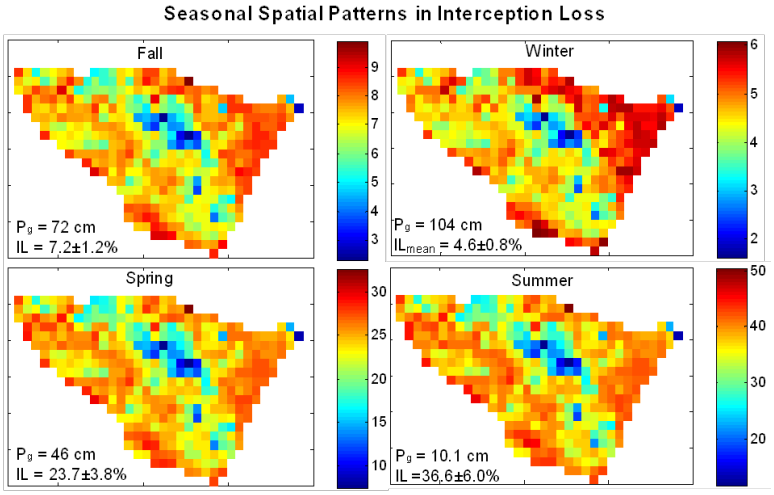

Figure 10. Total interception loss for fall, winter, spring, and summer from the 2006-2008 water years. Gross precipitation (P_g) depth and IL (%) are the averages of the two year period with mean ± standard deviation.

Net ecosystem exchange and evapotranspiration using the eddy covariance (EC) method.
First results of the vertical turbulent carbon dioxide exchange, evapotranspiration, and sensible heat exchange indicate a strong dependency of the fluxes on the topography (Figure 11). Upon sufficient levels of diffuse short-wave radiation at approximately 6:30 local time, the above-canopy ecosystem fluxes indicate the onset of photosynthesis and transpiration with a net transport uptake of CO_2 and a release of water vapor. The above-canopy sensible heat flux, however, lags behind FCO_2 and ET by approximately 2 to 3 hours and exceeds 50 W m-2 only around 10:00 local time when most of the South-facing slope of this deeply incised watershed is sunlit. The early onset of evapotranspiration driven by diffuse shortwave radiation leads to a reversal of the above-canopy sensible heat flux indicated by a net transport toward the

canopy to supply its energy demand, which can also be observed during the late afternoon hours. The negative sensible heat flux in the late afternoon hours leads to a stabilization of the air in the canopy layer inhibiting the vertical exchange of air, which leads to a vertical decoupling as indicated by the positive carbon dioxide fluxes starting around 16:00 local time. This phenomenon is called 'oasis effect' and leads to a net cooling of the foliage, which may lead to an extended period of production of cold-air drainage beyond the period of net radiative loss at nighttime. The forest canopy thus appears to play an active role in regulation its airflow and thermal microclimate, which in the late afternoon hours and at night is dominated by cold-air drainage leading to down-valley flows. Sub-canopy fluxes indicate the close proximity to the stream with negative heat fluxes, i.e, net transport of heat toward the stream, and evapotranspiration when sufficient sunlight is available.

A complete evaluation of the atmospheric carbon dioxide and water vapor mass balance will use the additional vertical profile measurements as well as detailed observations of the airflow of the water- and airsheds to account for the change on storage terms and advection in this complex terrain.

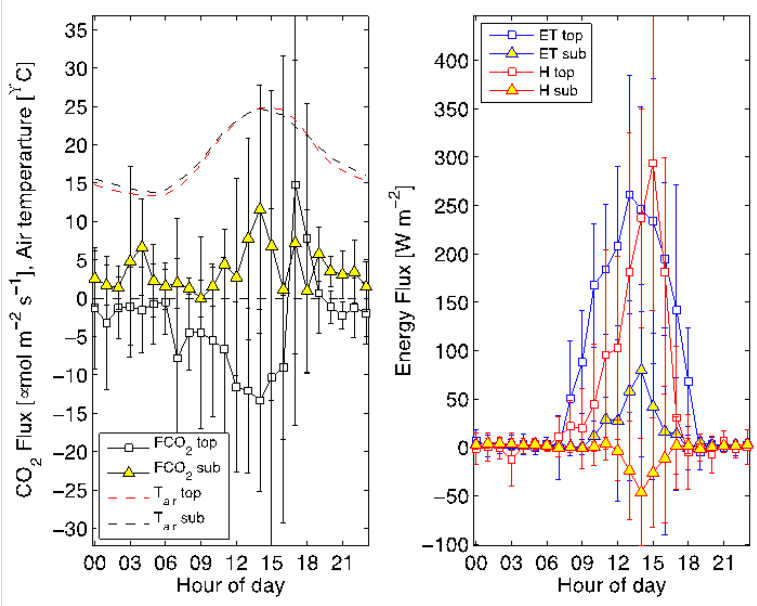

Figure 11: Mean diurnal course of ensemble-averaged carbon dioxide (FCO_2), water vapor (ET), and sensible heat (H) exchange between the forest and the atmosphere at WS1 measured using the eddy covariance technique over the period July 18 to July 27, 2012. The above-canopy (top) measurements were made at 37 m agl above the mean canopy height of approximately 30 m, wile the below-canopy (sub) data were observed at 4 m agl.

Forecasting potential impacts of change in land use and climate on biophysical processes and ecosystem services

An examination of the impacts of the Northwest Forest Plan (NWFP) on carbon stores in the forest sector (i.e., ecosystem and harvested carbon) using the LANDCARB 3.0 simulation model (developed in part with LTER6 funds) indicates that as implemented, the Northwest Forest plan has resulted in a major increase in carbon stores in the forest sector of western Oregon and Washington region in the next 100 years (Krankina et al in press). This was also true for several three other scenarios that included several conservation oriented strategies. In contrast, the Industry Scenario which envisioned a return to historic high levels of timber harvest led to a decrease in forest sector carbon stores. In comparison with the Industry Scenario, the low levels of timber harvest under the NWFP between 1993 and 2010 were estimated to increase total C stores by 86.0 TgC (5.1 TgC yr^{-1} or 2.16 MgC ha^{-1} yr^{-1}) in OR; in WA the respective values were 45.2 TgC (2.66 TgC yr^{-1} or 1.33 $MgCha^{-1}$ yr^{-1}). The projected annual rate of C accumulation, reached a maximum between 2005 and 2020 approaching 4 TgC yr^{-1} in OR and 2.3 TgC yr^{-1} in WA, then gradually declined towards the end of projection period in 2100.

Vegetation/Permanent Study Plots

The results related to Watershed 1 are described elsewhere in this report, however, the calculations and related files used for that analysis are being used as part of the Veg-DB intersite project. A total of four

old-growth stands have been examined for live versus dead wood carbon dynamics. One stand has had very large changes in live and dead wood carbon stores related to wind- and insect-related disturbances, but the total wood carbon store has changed very little (<2%) over a 35-year period. Another stand has had a steady increase in live wood carbon and a steady decrease in dead wood carbon with an overall increase of 5% over a 35-year period. Thus live and dead wood are modulating each other to a large degree, but the temporal of these two pools is highly variable from stand to stand.

Outreach Activities:

see activities section

Journal Publications:

Abdelnour, Alex;Stieglitz, Marc;Pan, Feifei;McKane, Robert B.;, "Catchment hydrological responses to forest harvest amount and spatial pattern", *Water Resources Research*, vol. 47, (2011), p. ., " " Published

Adair, E. Carol;Parton, William J.;Del Grosso, Steven J.;Silver, Whendee L.;Harmon, Mark E.;Hall, Sonia A.;Burke, Ingrid C.;Hart, Stephen C.;, "Simple three-pool model accurately describes patterns of long-term litter decomposition in diverse climates", *Global Change Biology*, vol. 14, (2008), p. 2636-2660., " " Published

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Other Specific Products:

Map
H.J. Andrews Experimental Forest [Map]. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. distributed through USFS stations, at the experimental forest, other public venues

Internet Dissemination:

http://andrewsforest.oregonstate.edu/

This is the main HJ Andrews Experimental Forest website which is used to disseminate data and information about projects and research at the Andrews Forest.

Contributions:

Contributions within Discipline:

Principal disciplinary fields: hydrology, climate science and ecology

- The work makes significant contributions to climate science by using unique, long-term records of climate variables to show magnitude and timing of trends in (1) air temperature, precipitation, and snowpack in forested landscape, and (2) magnitude of correlations of air temperatures and precipitation with sea surface temperatures. The picture that emerges from this work is of a climate system strongly controlled by ocean temperatures.

- This work makes significant contributions to hydrology by using unique, long-term records of precipitation and streamflow chemistry in small, paired watersheds to show (1) the pristine character of precipitation inputs (2) surprising declining trends in precipitation inputs, especially cations and P, (3) lack of trends in streamflow chemistry over time from unmanaged forests, and (4) short-term responses of streamflow chemistry

to forest harvest and related disturbances. The significance of this work is that it provides a unique insight into the resilience of old-growth forests to native and anthropogenic disturbances: prior publications on watershed biogeochemistry are either from watersheds significantly affected by anthropogenic inputs, or from watersheds with low anthropogenic inputs but lacking long-term records.

Contributions Beyond Science and Engineering:

The insight and expertise developed through the Carbon modeling project has contributed to public presentation, media reports, and Congressional testimony on the subject of forest carbon dynamics.