Pacific Northwest Climate Science Conference
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Abstracts

Opening plenary

Climate impacts on wildlife populations

Chad Wilsey and Josh Lawler, University of Washington, School of Environmental and Forest Sciences; Nathan Schumaker, US Environmental Protection Agency

Climate change is already affecting many wildlife populations. Managing these populations requires an understanding of the nature, magnitude, and distribution of current and future climate impacts on wildlife species and their habitats. Typically, this is done using bioclimatic niche models that relate species' current distributions to historical climate. The models are then used to project the distribution of suitable climates into the future based on output from global climate models. Although useful for characterizing the direction and magnitude of change, the bioclimatic modeling approach ignores species' associations with habitat, dispersal ability and population-level responses, among other processes. Here, we explore the impacts of future climate change on several wildlife species in the Pacific Northwest using a spatially explicit individual- or population-level simulation model, HexSim. We run the model with downscaled climate projections as well as simulated future vegetation produced using a dynamic vegetation model. This framework allows us to visualize annual, climate-driven changes in regional populations as well as the ability of the species to track changing habitats and climates over time. We apply this approach to meso-carnivore species (Canada lynx and wolverine) in alpine regions, small mammals (Townsend's grounds squirrel and pygmy rabbit) of the Columbia Plateau, and an amphibian (Columbia spotted frog). Outputs include maps of simulated future change in species distributions and abundance across the Pacific Northwest.

From climate scenarios to impacts: Key considerations for managers

Guillaume S. Mauger, Amy K. Snover, Meade Krosby, Lara Whitely Binder Climate Impacts Group, College of the Environment, UW

There is widespread disagreement on the appropriate application of climate change projections to resource management (e.g., Snover et al. 2013). Indeed, planners frequently disagree on whether to use climate projections at all, citing concerns about the "compounding uncertainties" inherent in using climate models to predict and respond to the impacts of climate change (Beier & Brost, 2009; Anderson & Ferree, 2010). In addition, climate models are typically available at much coarser scales (e.g., 100 km resolution) than are required for management, leading many to believe that climate models must be downscaled to fine scales to guide local to regional scale management decisions. Yet despite these reservations, it is also well accepted that climate models represent our best means of estimating future climate, and therefore may offer powerful tools for climate change adaptation.

The goal of the presentation is to provide a frame for evaluating the utility of climate impacts datasets for impacts assessment. Specifically, we highlight the considerations in selecting global climate models, deciding whether or not to downscale, deciding which downscaling approach to implement, proper application of "downstream" models, and approaches for estimating uncertainty in each. The presentation draws on recent work at CIG and PNW Climate Impacts Research Consortium (e.g., Abatzoglou, 2013; Rupp et al., 2013; Snover et al., 2013, WHCWG, 2013).

Closing the gap between climate science and climate economics

Kristen Sheeran, Ecotrust

Economic analysis occupies a central role in national debates over climate and energy policy. As the scientific consensus on climate change becomes clear and unambiguous, the case for inaction on climate change is increasingly argued on grounds that is will be too costly to initiate more than token initiatives. While many scientists advocate stringent emissions targets aimed at stabilizing atmospheric greenhouse gas concentrations during this century, economic models of climate change recommend a more cautious approach, involving only modest early actions to limit emissions with gradually increasing limits over time. This presentation explains the assumptions in climate economic models that contribute to the disconnect between climate science and economics and highlights the large and growing literature in economics that demonstrates rigorous economic support for immediate, large-scale policy responses to the climate crisis.

Communicating with Global Warming's Six Americas: Strategies for Building Public Understanding and Issue Engagement

Connie Roser-Renouf, Center for Climate Change Communication, George Mason University

Despite the overwhelming agreement among scientists that climate change is real, dangerous, and caused by human activities, it remains a politically polarized issue among Americans, viewed from multiple perspectives. To build public understanding and issue engagement, climate change communicators must recognize and respond to these varied points-of-view; messages are unlikely to be effective if the population is treated as a homogeneous mass, ignoring the diversity of opinion.

Public opinion research has identified six climate change audiences within the U.S. – Global Warming's Six Americas – that fall along a continuum of belief and concern, ranging from the Alarmed, who are convinced of the reality, dangers and anthropogenic causes of climate change, to the Dismissive, who are convinced climate change is not occurring and are likely to believe it a hoax. Between these two extremes lie four groups comprising 70 percent of the population, and characterized by varying levels of uncertainty about the reality and dangers of climate change: The Concerned, Cautious, Disengaged and Doubtful.

Differences among the Six Americas in issue engagement, beliefs, and willingness to process climate information will be described in this talk, and strategies to reach and influence them will be discussed in light of their informational needs.

Successful Adaptation to Climate Change in the Coastal Context: Insights from Scientists and Practitioners

Amy Snover, University of Washington Climate Impacts Group; Susanne Moser, Susanne Moser Research & Consulting and Stanford University; Hannah Gosnell, Oregon State University; Adina Abeles, Center for Ocean Solutions; Steve Adams, Institute for Sustainable Communities; Lara Whitely Binder, University of Washington Climate Impacts Group

Adaptation to climate change is a common concern on policy and management agendas of many federal, state, local and tribal governments; planning for a climate-altered future is becoming more widespread and some adaptive actions are being taken. This has led many decision-makers, program managers, funders, and other stakeholders to ask what adaptation success would look like and how one would evaluate adaptation effectiveness over time. In addition, the academic community is increasingly asking similar questions and publishing on this topic in peer-reviewed journals and books. To try to define successful adaptation in a scientifically robust yet practically useful way, we hosted a multi-disciplinary workshop with scientists and three workshops with coastal managers and stakeholders in California, Oregon, and Washington. Results from these workshops, interviews with stakeholders, and a review of the peer-reviewed literature on adaptation success indicate the necessity of considering both adaptation process and outcomes and the challenges of defining "successful outcomes" given their context-dependent, temporal, and inevitable normative dimensions.

Concurrent session 1

Advancing climate-smart landscape conservation in the North Pacific LCC Region

Patricia Tillmann, National Wildlife Federation; Dan Siemann, National Wildlife Federation; Lara Whitely Binder, University of Washington Climate Impacts Group

Spanning multiple jurisdictions and diverse ecosystems from Alaska to California, the North Pacific Landscape Conservation Cooperative (NPLCC) is uniquely positioned to meet the region's need for landscape-scale climate change adaptation and interdisciplinary cross-boundary collaboration. To inform the NPLCC's near- and long-term development of applied science and traditional ecological knowledge priorities, we engaged 195 natural resource and conservation professionals working in the region to identify, assess, and synthesize challenges, needs, and opportunities associated with addressing climate change in their work. Qualitative content analysis of their survey responses, focus group input, and workshop documents identified four core needs and a range of conservation delivery opportunities that respond to the challenges of addressing climate change in participants' daily work and long range planning. Core needs are dominated by decision-support, collaboration, capacity-building, and communication needs, but also include the need for new or different science, data, and information. Conservation delivery opportunities emphasize cross-ecosystem activities.

Assessment results increase understanding of practitioner needs in a climate change era in at least four ways. The assessment is the first of its kind to focus specifically on the NPLCC region and its cross-boundary roles within its international and multi-jurisdictional geography. Within that context, the assessment began at the local level and proceeded to the regional level, synthesizing practitioners' place-based challenges and needs into a regional understanding of conservation delivery and applied science opportunities. The assessment also employed a cross-ecosystem approach, and results emphasize practitioner challenges, needs, and opportunities across marine, coastal, freshwater, and terrestrial ecosystems. Finally, the assessment includes specific requests made by tribal members and representatives to respond to climate change impacts on the Indigenous Way of Life. In addition to being used by the NPLCC to help develop their 2013-2016 Strategy for Science and Traditional Ecological Knowledge, assessment results can also be of use to regional Climate Science Centers, universities, or others interested in addressing applied science and conservation needs in the region.

Regional Agricultural Pathways and Scenarios (RAPS) and Climate Impact Assessment for the Pacific Northwest Agricultural Systems

John Antle, **Jianhong Mu,** Hongliang Zhang, Susan Capalbo: Oregon State University; Sanford Eigenbrode, University of Idaho; Chad Kruger and Claudio Stöckle, Washington State University; J.D. Wolfhorst, University of Idaho

Representative Agricultural Pathways and Scenarios (RAPS) are projections of plausible future biophysical and socio-economic conditions used to carry out climate impact assessments for agriculture. The development of RAPS was motivated by the fact that the various global and regional models used for agricultural climate change impact assessment have been implemented with individualized scenarios using various data and model structures, often without transparent documentation or public availability (Antle et al. 2013). These practices have hampered attempts at model inter-comparison, improvement, and synthesis of model results across studies (Nelson et al. 2013; Antle et al. 2013. This paper aims to (1) present RAPS developed for the principal wheat-producing region of the Pacific Northwest, and to (2) combine these RAPS with downscaled climate data, crop model simulations and economic model simulations to assess climate change impacts on winter wheat production and farm income. This research was carried out as part of a project funded by the USDA known as the Regional Approaches to Climate Change in the Pacific Northwest (REACCH).

The REACCH study region encompasses the major winter wheat production area in Pacific Northwest and preliminary research shows that farmers producing winter wheat could benefit from future climate change (Antle, Mu and Abatzoglou 2013). However, the future world is uncertain in many dimensions, including commodity and input prices, production technology, and policies, as well as increased probability of disturbances (pests and diseases) associated with a changing climate. Many of these factors cannot be modeled, so they are represented in the regional RAPS. The regional RAPS are linked to global agricultural and shared social-economic pathways, and used along with climate change projections to simulate future outcomes for the wheat-based farms in the REACCH region.

To develop RAPS for the REACCH region, project scientists and other experts with knowledge of the region's agricultural systems are working together through a step-wise process designed to record and document the information used to create RAPS. The REACCH team developed 3 RAPS represent the future agricultural pathways and scenarios, labeled Business-as-Usual, Dysfunctional World and Aggressive Climate Policy. In each RAP, we define key variables, provide narratives and capture different time scales. When completed, these RAPS will be used by the modeling team to simulate climate change impacts and how technological innovations will help farmers adapt to changing environmental and economic conditions.

Weed Management from Present to Future: Assessing Wheat Producer and Crop Advisor Decision-making Strategies

Joanna K. Parkman (1,2), Leigh A. Bernacchi (2), Monica A. Reyna (3), J.D. Wulfhorst (2,3), Stephanie L. Kane (3)
1 Sewanee: The University of the South;
2 Regional Approaches to Climate Change in Pacific Northwest Agriculture (REACCH-PNA), Department of Agricultural Economics & Rural Sociology, University of Idaho
3 Social Science Research Unit, University of Idaho

Inland Pacific Northwest wheat producers and Certified Crop Advisors (CCAs) are a source of biogeographical and local knowledge of organisms affecting their fields, informing range shifts of species due to climate change. Through surveying the methods of and decision-making processes for weed management, we develop a critical communication strategy for adapting to future climatic conditions.

This research contributes to understanding the relationships among producers and growers with respect to weed management in the face of climate change. We investigate wheat producers' perceptions of climate change; adoption of new technologies and management practices; and CCA perceptions of weed control and decision-making processes. We primarily assess processes for prescribing treatments and determining agricultural inputs, namely herbicides, on wheat-based systems.

Preliminary results describe opportunities for adaptation to climate change. For communication strategies, most respondents found both company (83%) and independent crop advisors (74%) to be trustworthy sources with respect to production management, but when queried about climate change information, all sources dropped in trustworthiness, including company (44%) and independent CCAs (40%). For efficacy of weed control, we began with the capacity to confidently identify weed species studied in the region: producers could identify downy brome (95%); Italian ryegrass (79%); mayweed chamomile (62%). Additionally, producers defined the degree to which they could control species, with downy brome as most "treated and controlled" (55%) but also most "treated, but not controlled" (29%). The implications of this study inform the development of effective, place-based, and sustainable weed management strategies and aid in illuminating opportunities and barriers to climate change adaptation and mitigation. We offer recommendations for weed management and development of climate communication strategies that can address site-specific audiences.

Comparing a real 200-year flooding event to projected precipitation extremes

Stephen Sobie, **Trevor Murdock**, Alex Cannon: Pacific Climate Impacts Consortium

In recent years, certain stretches of highway in British Columbia have experienced extreme precipitation events resulting in substantial damage to infrastructure. As part of the planning process to refurbish or replace components of these highways, information about the magnitude and frequency of future extreme events are needed to inform the infrastructure design. To address this need, we have produced projections of climate extremes at high spatial resolution by statistically downscaling regional climate model output from the North American Regional Climate Change Assessment Program (NARCCAP). The increased resolution provided by downscaling improves the representation of topographic features, particularly valley temperature and precipitation effects. A range of extreme values, from simple daily maxima and minima to complex multi-day and threshold-based climate indices have been computed and analyzed from the downscaled output. Selected results from this process and how the projections of precipitation extremes are being used in the context of highway infrastrucure planning in British Columbia will be discussed.

Progress on the NorWeST regional stream temperature climate scenarios for the Northwest U.S.

Dan Isaak, U.S. Forest Service, Rocky Mountain Research Station (RMRS); Seth Wenger, Trout Unlimited; Erin Peterson, CSIRO Division of Mathematics, Informatics, and Statistics; Jay Ver Hoef, NOAA National Marine Mammal Laboratory; Dave Nagel and Charlie Luce, RMRS; Steve Hostetler U.S. Geological Survey, Water Resources Center; Jason Dunham, U.S. Geological Survey, Forest and Rangeland Ecosystem Research Center; Jeff Kershner, U.S. Geological Survey, Northern Rocky Mountain Science Center; Brett Roper, U.S. Forest Service, Fish and Aquatic Ecology Unit; Dona Horan, Gwynne Chandler, Sharon Parkes, Sherry Wollrab, RMRS.

Anthropogenic climate change is warming rivers and streams across the Northwest U.S. and threatens many of the region's valuable aquatic resources. Effective threat response will require prioritization of limited conservation resources and coordinated interagency efforts guided by accurate information about climate, and climate change, at scales relevant to the distributions of species across landscapes. Here, we describe progress on the NorWeST (i.e., NorthWest Stream Temperature) project to develop a comprehensive interagency stream temperature database and high-resolution climate scenarios for all streams across Washington, Oregon, Idaho, Montana, and Wyoming (~350,000 stream kilometers). The NorWeST database consists of stream temperature data contributed by >60 state, federal, tribal, and private resource agencies and may be the largest of its kind in the world (>45,000,000 hourly temperature recordings). These data are being used with spatial statistical stream network models to develop accurate ($R2 = 90\%$; RMSE < 1 ˚C) scenarios at 1 kilometer resolution. The NorWeST stream temperature model is forced with air temperature data from RegCM runs for the NCEP historical reanalysis and the GENMOM model representing the A2 warming scenario at years 2050 and 2090 (http://regclim.coas.oregonstate.edu/). At present, stream climate scenarios based on more than 16,000 summers of monitoring data have been developed for 180,000 stream kilometers across Idaho and western Montana. The temperature data and stream climate scenarios from this project are made available as ArcMap geospatial products for download through the NorWeST website as individual river basins are completed (http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml). A series of related projects are being developed that use NorWeST stream climate scenarios, including: 1) biological vulnerability assessments, 2) definition of species' thermal niches, 3) improvement of bioclimatic models, 4) development of decision support tools, and 5) refinement of temperature and biological monitoring programs. Additional project details are contained in this Great Northern Landscape Conservation Cooperative newsletter (http://greatnorthernlcc.org/features/streamtemp-database).

In hot water: developmental plasticity in response to a warming climate in a high elevation amphibian assemblage

Lindsey L. Thurman and Tiffany S. Garcia, Department of Fisheries & Wildlife, Oregon State University

The rapid loss of habitable climate space in montane ecosystems has resulted in a disproportionate number of extinctions in high elevation-restricted amphibian species. However, species capable of plastically altering life history traits, such as larval development rate, may exhibit optimal strategies for resisting a warming climate. We examined the larvae of three high elevation Anuran species from the US Pacific Northwest, the Cascades frog (Rana cascadae), Western toad (Anaxyrus boreas), and Pacific chorus frog (Pseudacris regilla), for their ability to increase larval development rates in response to warming. Each species was exposed to two temperature regimes: the control treatment simulated historical, summer temperatures for the decade of 2001 to 2011; the warmed treatment mirrored the seasonal trend, but simulated a 4°C average increase in temperature. We quantified multiple larval growth characteristics to compare the variability in development as a function of these temperature regimes. We found significant acceleration in larval development rates under the warmed temperature regime ($F=21.68$, $P<0.01$), with differential reductions in body size at metamorphosis for all three species ($F=85.64$, $P<0.01$). For R. cascadae, the consequences of plasticity in development rates for emerging adults may be detrimental to populations that are already of serious conservation concern.

Understanding the effects of climate on mountain pine beetle outbreaks in whitebark pine

Polly C. Buotte, Environmental Science Program and Department of Geography, University of Idaho; Jeffrey A. Hicke, Department of Geography, University of Idaho; Haiganoush K. Preisler, Pacific Southwest Research Station, USDA Forest Service

Whitebark pine has been identified by the US Fish and Wildlife Service as warranting protection as a threatened or endangered species. A major contributor to this finding is the recent outbreaks of mountain pine beetle that have attacked large areas of whitebark pine forests across the western United States. Climate is a critical driver of these outbreaks through effects on beetle life stage development, winter survival, and susceptibility of host trees. Here, we evaluated the effects of climate variables on beetle outbreaks using regional data sets and statistical analysis. We used the presence of mountain pine beetle attacks recorded by Forest Service Aerial Detection Surveys in a logistic regression with multiple climate variables representing the effect of temperature on beetle development (fall, spring, and summer temperature) and winter survival (winter minimum temperature) and drought stress on trees (vapor pressure deficit, precipitation, and climatic water deficit). To allow for spatial variation in model parameters, we developed different models for three subregions of whitebark pine in the US (Cascades, Greater Yellowstone Ecosystem (GYE), and Northern Rockies). For all subregions, models predicted yearly total area with attacks well (R2 of observed versus predicted (n=12 years) was 0.84-0.99 and RMSE was 10-18% of the average area with attacks). However, we found variation in the relative importance of temperatures and drought stress among subregions, with drought stress most important in the Northern Rockies and temperatures and drought having approximately equal contribution to predictions in the Cascades and GYE. These findings increase our understanding of how climate influences beetle outbreaks in whitebark pine forests, and will lead to better predictions of the effects of climate change on this widespread forest disturbance.

Winter dormancy requirements for Pacific Northwest tree species: Will it be cold enough in future years?

Constance Harrington, USFS Pacific Northwest Research Station; Peter Gould, Washington Department of Natural Resources

Many Pacific Northwest tree species have a chilling requirement, that is, they require cold but not freezing temperatures during the fall and winter to break bud normally in the spring. This requirement has been studied for some species, particularly in relation to cold storage of nursery-grown seedlings prior to out-planting. However, most such studies only include a relatively narrow range of chilling hours and relatively few species. We have started examining the range of responses to winter temperatures for tree species including: Abies amabilis (Pacific silver fir), Abies grandis (grand fir), Abies procera (noble fir), Arbutus menziesii (Pacific madrone), Larix laricina (western larch), Thuja plicata (western redcedar), Tsuga heterophylla (western hemlock), Pinus contorta (lodgepole pine), Pinus monticola (western white pine), Pinus ponderosa (ponderosa pine), and Pseudotsuga menziesii (Douglas-fir). This has been done with seedlings located in, and moved among, greenhouses, growth chambers and outdoor environments. As we have seen for multiple genotypes of Pseudotsuga menziesii in past analyses, these analyses with other species have demonstrated that high levels of chilling mean that low amounts of forcing temperatures are needed to result in rapid bud burst of normal shoots. Very low levels of chilling, however, mean the plants require very high amounts of forcing temperatures, and even with long photoperiods, not all plants will burst bud normally. Abnormal bud burst can take the form of no terminal budburst but budburst of some lateral buds in the terminal bud cluster, irregular needle formation on new shoots, or new shoots arising from lower branches to become the new terminal shoot. The species with the lowest chilling requirements are Arbutus menziesii and Thuja plicata. The species with the lowest forcing requirement at high levels of chilling is Larix laricina. It has been widely reported that climate warming has resulted in earlier dates of budburst for many horticultural plants; however, the substantial warming predicted in the future will reduce chilling and may result in later dates of vegetative budburst, abnormal shoot development, and abnormal flowering or seed development. Future work with multiple genotypes for each species will allow modeling of plant responses on a landscape level. This will allow determination of which species and locations are of greatest concern. Conversely, modeling will also allow us to suggest which species will be most robust in future environments with warmer winters.

Evaluating uncertainty from different sources for population viability analysis under climate change scenarios – what does management need to know? A case study of threatened Chinook salmon

Lisa G. Crozier and Richard W. Zabel, NOAA-Fisheries

Incorporating climate change projections into recovery planning and ESA Section 7 consultations has become a management imperative. But uncertainty in our biological conclusions stems from many different sources – stochasticity in population dynamics in general, biological sensitivity to climate, and projections in driving factors such as stream flow and temperature. Climate projections themselves contain uncertainty from hydrological modeling, downscaling techniques, GCM process error, and emissions futures. For migratory species, additional uncertainty stems from differential impacts at multiple life stages (e.g., freshwater versus ocean stages). We characterized these various sources of uncertainty in a case study of population viability of Snake River Chinook salmon. We explored over 100 climate scenarios for each of 9 populations with individual sensitivity to climate drivers. We identified the most important areas of uncertainty for targeting restoration or management decisions. For all populations, the uncertainty in future ocean projections outweighed all other sources. The next crucial factor was the biological assessment of the relative population sensitivity to temperature versus stream flow. Uncertainty in climate projections from downscaling methods, GCM or emissions behavior was much less important for management decisions for most populations; however, a subset of populations might either increase or decline depending on future patterns in precipitation. This ranking of uncertainty is useful because it facilitates focused research on studies that will most affect management decisions, and thus have the greatest conservation impact.

Concurrent session 2

Klamath River streamflow reconstructed from tree rings: Extracting meaningful information from imperfect data

Connie A. Woodhouse, School of Geography and Development, University of Arizona; S. Brewster Malevich, Department of Geosciences, University of Arizona; David M. Meko, Laboratory of Tree-Ring Research, University of Arizona; Subhrendu Gangopadhyay, U.S. Bureau of Reclamation, Denver, CO

Reconstructions of past streamflow from tree rings have proven to be useful tools for water resource management in a number of basins in the western U.S. Extended records of hydrologic variability allow recent droughts to be assessed in a long-term context. They document a broader range of drought characteristics that have occurred under natural climate variability than contained in the gage record. Basin development, infrastructures such as dams and reservoirs, and historical use of water present challenges to the reconstruction of past streamflow which require calibration with natural streamflow. Virtually no basins of significance have escaped the impact of human activities, but the upper Klamath River basin, the focus of this study, poses particular challenges. The hydrology of the basin, which was once a region of marshes, wetlands, and extensive shallow lakes fed by snowmelt, seasonal precipitation and groundwater, is complex. In addition, development of water and other resources have had significant impacts on the basin. As a consequence, accurate records of hydrologic variability necessary for reconstructing past flows are lacking. The Bureau of Reclamation has generated estimates of natural flows for the Klamath River near Keno OR, but the difficulties presented by both natural conditions and the history of human water use resulted in many uncertainties and a lack of confidence in these estimates. Since no records exist that accurately reflect natural flows, our Klamath River reconstruction model contains uncertainties due to imperfect gage records, along with the uncertainties inherent in the reconstruction models. While magnitudes of flow are rather variable among the gaged, estimated natural, and reconstructed flow records, agreement among these records in terms of sequences of flow is strong. Because of this, the most robust aspect of the Klamath River reconstruction is the information on the sequences of high and low flows, runs of dry years, and distribution of droughts over past centuries. This information has potential value to the many stakeholders who have recently signed an agreement addressing the restoration of the Klamath basin. The agreement includes the development of drought plans and assessment of climate change impacts, both of which could be informed by an extended record of Klamath River flow. A goal of this project is to find ways to make the most reliable information contained in the streamflow reconstruction available and useful to these stakeholders.

The secrets of the trees: A history of water availability in the Pacific Northwest to enhance management of risk associated with uncertain future precipitation patterns

David Noone, University of Colorado; Lowell Stott, University of Southern California; Lisa Sloan, University of California Santa Cruz; Axel Timmerman, University of Hawaii; Nikolaus Buenning,University of Southern California; Lisa Kanner,University of Southern California; Sally Langford, University of Colorado; Mark Snyder, University of California Santa Cruz

The choices made on how limited water resources are managed are often based on knowledge of present-day estimates of water available from rainfall and seasonal melt of alpine snow pack. Historically, and for pragmatic reasons, the budgeting of water to various uses was based on limited knowledge of regional hydroclimate. Although records of regional hydroclimate have improved in recent decades with modern monitoring, there is a need for information on likelihood of prolonged drought, flood, and less severe hydrological variations, that affect the Pacific Northwest (PNW). Long hydrological records both characterize the history of regional hydrologic balance and also enable evaluation of forecast models that can be used in planning infrastructure investments and managing hydrological risk. In an integrated study of drought, information obtained from core samples drilled from old trees in the PNW have been used to show changes in precipitation and evaporation patterns over a century. The information recovered comes from measurement of the 18O/16O isotope ratio in the cellulose of the annual growth rings in trees. Trees from the PNW are particularly valuable sources of information about past water balance because the isotope ratios of cellulose correspond closely to the isotope ratios of precipitation. The isotope ratio information reveals changes in the altitude of the clouds from which precipitation forms and which in turn is related to the transport of moisture to the PNW from the Pacific Ocean. It is found that the isotope ratio in precipitation in the PNW is dominated by variations in the percentage of moisture that has a subtropical origin versus high latitudes in the Pacific Ocean. The frequency and occurrence of storm systems that control this fraction are associated with shifts in latitude of the storm track from year-to-year. The type of changes to the circulation that are suggested by the tree records are not unlike those that accompany El Nino events and that are expected with global warming. This historical insight to the water balance of the PNW offers opportunities to test climate model projections of future water resources in the region. The combination of high quality historical information from trees, and other natural recorders of past climate, and the sophisticated analytical tools like climate models, allow tailored decision support solutions to be constructed to better manage risk associated with future change to water availability, forest system health and society growth.

Vulnerability of Oregon Hydrologic Landscapes and Streamflow to Climate Change

Scott G. Leibowitz, Randy L. Comeleo, and Parker J. Wigington, Jr., (ret.), U.S. EPA, National Health and Environmental Effects Research Laboratory, Corvallis, OR; Christopher P. Weaver, U.S. EPA, National Center for Environmental Assessment, Washington, DC; **Eric A. Sproles**, ORISE post-doc, c/o U.S. EPA, National Health and Environmental Effects Research Laboratory, Corvallis, OR; Philip E. Morefield, U.S. EPA, National Center for Environmental Assessment, Washington, DC

Hydrologic classification systems can provide a basis for broadscale assessments of the hydrologic functions of landscapes and watersheds and their responses to stressors. Such assessments could be particularly useful in determining hydrologic vulnerability from climate change. Wigington et al. (2012) have developed a hydrologic landscape (HL) map for the State of Oregon. The HL classification is composed of five indices that represent factors controlling the hydrologic characteristics of watersheds: annual climate, climate seasonality (the season of maximum available water), aquifer permeability, terrain, and soil permeability. The climate and seasonality indices were based on 30 year normals from 1971-2000. Here we describe changes in HL class distribution and consequent vulnerability to streamflow when the maps are reclassified using predicted normals for 2041-2070. These were based on changes in monthly temperature and precipitation using the European Centre HAMburg (ECHAM) and Parallel Climate Model (PCM) global climate change models (which represent high and low sensitivity to CO2, respectively) and three different CO2 emission scenarios (A2, A1b, and B1, representing high, medium, and low CO2 levels, respectively). We examined a number of factors statewide, including changes in the HL indices (climate and seasonality) as well as the continuous variables that these indices are based on (Feddema Moisture Index and available water). Initial results indicate that 4-18% of the state's 5660 assessment units changed climate class; in all cases, the change was to the next drier class. Areas that changed climate class are distributed throughout most of the state. For seasonality, initial results indicate that 3-9% of the assessment units experience a change in class. However, 20-68% of units with maximum available water in the spring switched to winter seasonality. In addition, 100% of the units with summer seasonality switched to spring seasonality for all realizations except for PCM-B1, where only 43% of the units switched. These preliminary results indicate a significant loss of area that is dominated by spring or summer snowmelt to winter rain, suggesting that irrigated areas in eastern Oregon are particularly vulnerable to the effects of climate change. We illustrate the utility of the HL classification for identifying hydrologic vulnerability using several case study basins located throughout the state.

Hydrologic sensitivity to changes in climate and land use in the Santiam River Basin, Oregon.

Cristina Mateus, Desiree D. Tullos and Christopher G. Surfleet

Water supply and demand are likely to vary across river basins and across water users in the future as climate and land use change. Some areas will be more sensitive to change than others. The influence of climate and land use change on the future availability of water resources across basins with different hydrogeological characteristics was examined in the Santiam River Basin (SRB), Oregon. In this study, we explored a) how sub-basin characteristics contribute to hydrologic sensitivity and response to climate and land use change, and b) how elevation, intensity of water demands, and intensity of groundwater interactions relate to vulnerability of water scarcity. Hydrologic responses varied with sub-basins. Within-basin differences in seasonal and annual runoff depth illustrate how responses to changes in climate and land use can vary with hydrogeology. The groundwater connectivity in the North Santiam River appears to contribute to the basin's low sensitivity to changes in climate and land use. Larger increases in winter and annual runoff, as well as larger decreases in summer runoff, indicates that lack of groundwater connectivity in the South Santiam River may contribute to greater sensitivity to land use and climate change. Furthermore, annual runoff variability is projected to increase in the future, with the degree of increase varying by basin geology and elevation indicating increased variability for the South Santiam Basin compared to the North Santiam Basin. Land use change has less effect than climate change on streamflow variability and monthly runoff, though land use change appears to dominate hydrologic response at the annual scale. Results of the vulnerability analysis highlight how, across the entire Santiam River, water demand exerts the strongest influence on the basins' vulnerability to water scarcity, regardless of sub-basin hydrogeology. Higher vulnerability areas are located in the lower reaches of the basin where water demands are high. Areas located in the upstream reaches of the basin are subject to lower water demands and vulnerability is governed by intensity of groundwater interactions. The results contribute to evaluation of vulnerability to climate and land use changes in the Santiam River basin, and more broadly to increased capacity for planning the storage and allocation of water resources across basins in variable hydrogeologic settings.

Positive Trends in Summer Evapotranspiration in Eastern WA State

Nicholas A. Bond and Karin Bumbaco, University of Washington, Office of the Washington State Climatologist

The summertime demands for water in agricultural regions depend in part on the rate of evapotranspiration (ET). Daily records of potential ET are available from the mid-1980s through the present for five stations in eastern Washington state (George, Harrah, LeGrow, Lind and Odessa) through the Pacific Northwest Cooperative Agricultural Weather Network (AgriMet) maintained by the Bureau of Reclamation. These records reveal a secular increase in the seasonal mean (June-August) potential ET over the period 1987-2012. The overall changes are equivalent to an extra 3-4" of water required in the recent versus early years of this record. While year-to-year fluctuations in potential ET are positively correlated with temperature, the positive trend over the period of record can be attributed largely to an increase in solar irradiance (from an average of roughly 270 to 300 W/m2). Daily data for potential ET and other atmospheric variables are used to determine the regional atmospheric circulation patterns associated with periods of large water demands. Among other factors, anomalous ridging aloft centered to the west of the study area generally precedes the days with the greatest potential ET. The relationships that have been found will ultimately be used in empirical downscaling of potential ET from global climate model projections.

Rain-on-Snow (ROS) Occurrence Across Elevations in the Washington Cascades: Monte Carlo Simulation of Large Storms Under Recent and Projected Climatic Conditions

Matthew J. Brunengo, Geology Department, Portland State University

Many hydrogeomorphic processes are activated by extraordinary water inputs that cascade through the system, amplifying discharge and erosion rates and thus affecting downhill/downstream environments. Rain-on-snow is an important mechanism in some landscapes, as rainfall can be augmented by rapid melt when warm, moist air moves into latitudes and elevations having vulnerable snowpacks. ROS happens most often in maritime temperate regions experiencing considerable winter precipitation, particularly in middle elevations where torrential rain and seasonal snow are most likely to coincide. Northwestern North America is a broad target for Pacific storms: ROS here commonly produces high runoff, with occasionally disastrous flooding and landsliding; wet, heavy snow contributes to avalanches, transportation obstacles, and excessive roof loads.

In frequency analysis, probabilistic modeling can compensate for sporadic events and scattered stations by combining random selection of storm properties with physical rules governing hydrologic behavior. A simple Monte Carlo program simulates large storms over 1000 "years", computing realizations of weather, snow and infiltration for each event, governed by observations (1940–2005) in the Washington Cascades. Model outcomes based on these conditions showed that precipitation measurements often overestimate stormwater reaching the ground; but melt enhances input in some events, most notably at ~500–1100 m. Water available for runoff exceeds precipitation (WAR>P) in ~20% of storms at 800 m, declining to ~2% in lower and higher terrain. The model was subsequently applied to scenarios incorporating a range of predicted warming (1–5°C) and snowpack reduction (variable with elevation). These results suggest that ROS will play a larger role in the projected future, as the proportion of WAR>P events increases at all elevations, with enhancements in these storms averaging ~20–35% (~2–5 cm) above precipitation (to >7 cm for 100-yr events). Elevations of greatest ROS effect would rise from ~700–900 m (late-20th century) to ~800–1100 m, where ~30–60% will be WAR>P events under the warmest scenarios.

Prior model results corroborated notions that ROS creates its peak hydrologic importance in middle elevations of the Washington Cascades, involving about half the study region's landscape. These alternate-scenario runs suggest that warming and snowpack shrinkage will shift the maximal ROS zone uphill, while also boosting the incidence of hydrologically significant ROS (and associated water volumes) across most elevations in the maritime Northwest (and elsewhere?). Such changes would probably alter the locations and rates of runoff and erosion, with concomitant effects on ecosystems, infrastructure, and public safety.

Superensemble regional-scale climate modeling

David Rupp (1), Myles Allen (2), Richard Jones (3), Sihan Li (1), Helen Mallett (1), Robert Mera (1,4), Philip Mote (1), and Dean Vickers (1)
1: Oregon Climate Change Research Institute
2: Oxford University
3: UK Met Office Hadley Centre
4: Now at Union of Concerned Scientists

For over a decade, a citizen science experiment called climateprediction.net organized by Oxford University in collaboration with the UK Met Office Hadley Centre has used computer time contributed by tens of thousands of volunteers around the world to create superensembles (many thousands) of global climate simulations. A regional-scale experiment, a partnership between Oregon State University, Oxford University, and the Met Office Hadley Centre, brings these computing resources to bear on regional climate modeling for the Western US and other regions. Launched in November 2010 as 'weather-athome', the experiment uses a spatial resolution of 25 km which permits important topographical features -- mountain ranges, valleys, and inland waters -- to be resolved and to influence simulated climate, which consequently reproduces many important features of the observed climate. Within the large ensemble, perturbations can be made of initial conditions and land and sea surface boundary conditions and of the model formulation to explore how well these models are able to simulate the detailed climate of the region and to quantify uncertainty originating from each of these three sources. Over 200,000 simulations have been completed, providing a combination of high spatio-temporal resolution and statistical richness which results in unprecedented levels of detail on the temporal and spatial variability of the climate of the Western US. This presentation will outline the experiment, show results comparing simulated and observed climate over the western US for 1960-2009, illustrate the power of the large ensemble size in quantifying uncertainty, and show simulated changes for 2030-2049.

Analysis of the present and future winter Pacific-North American teleconnection in the ECHAM5 global and RegCM3 regional climate models

Andrea M. Allan, Oregon State University; Steven W. Hostetler and Jay R. Alder, U.S. Geological Survey

We use the NCEP/NCAR Reanalysis (NCEP) and the MPI/ECHAM5 general circulation model (GCM) to drive the RegCM3 regional climate model to assess the ability of the models to reproduce the spatiotemporal aspects of the Pacific-North American teleconnection (PNA) pattern. Composite anomalies of the NCEP-driven RegCM3 simulations for 1982–2000 indicate that the regional model is capable of accurately simulating the key features (500-hPa heights, surface temperature, and precipitation) of the positive and negative phases of the PNA with little loss of information in the downscaling process. The basic structure of the PNA is captured in both the ECHAM5 global and ECHAM5-driven RegCM3 simulations The 1950–2000 ECHAM5 simulation displays similar temporal and spatial variability in the PNA index as that of NCEP; however, the magnitude of the positive and negative phases are weaker than those of the Reanalysis. The RegCM3 simulations clearly differentiate the climatology and associated anomalies of snow water equivalent and soil moisture of the positive and negative PNA phases. In the RegCM3 simulations of the future (2050–2100), changes in the location and extent of the Aleutian Low and the continental high over North America alter the dominant flow patterns associated with positive and negative PNA modes. As a result, the future projections display a shift in the patterns of the relationship between the PNA and surface climate variables, which suggest the potential for changes in the PNA-related surface hydrology of the Pacific Northwest.

Interdisicplinary Data Management and Analysis - Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCHPNA)

Erich Seamon, REACCHPNA, University of Idaho; Paul Gessler, Dept. of Forest Ecology & Biogeosciences, College of Natural Resources, University of Idaho; Steve Fricke, REACCHPNA, University of Idaho; Von Walden, Washington State University

The Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCHPNA) is a five-year USDA/NIFA-funded coordinated agriculture project – to examine the sustainability of cereal production systems in the Pacific Northwest, in relationship to ongoing climate change. As part of this effort, an extensive data management system has been developed to enable researchers, students, and the public, to upload, manage, and analyze various data. This presentation will outline the strategy for development of the system, its components, with a demonstration of REACCH analytical tools at the end.

The REACCH data management team has built out three core systems to encompass our cyberinfrastructure and data management needs: 1) Our reacchpna.org portal. Accessible at https://www.reacchpna.org – the REACCHPNA portal is the entry point for all public and secure information, with secure access by REACCHPNA members for data analysis, uploading, and informational review. 2) The REACCH Data Repository. The REACCH data repository is a replicated, redundant database server environment that allows for file and database informational storage and access. The REACCH Data Repository is the heart of our efforts, and is where all core data resides. 3) REACCH Libraries. REACCH Libraries are functional groupings of data for REACCH members and the public to access REACCH data – based on their access level. These libraries are accessible thru our https://www.reacchpna.org portal.

The REACCH data management system is structured on a three - tier server environment (data, applications, web), a geospatial database/web server environment for web mapping services (ArcGIS Server), use of ESRI's Geoportal Server for data discovery and metadata management, use of THREDDS data cataloging and the IPython notebook server technology for data analysis, an LDAP secure login server for unified user logins across systems, replication/mirroring of data @ Idaho National Laboratories (INL), and authentication methods for allowing REACCH members outside of the University of Idaho to securely access data, based on user roles.

Leveraging provincial and private weather monitoring networks to enhance the provincial climate record

E. (Ted) J. Weick, Air and Climate, Water and Air Monitoring and Reporting, British Columbia Ministry of Environment; Faron Anslow and James Hiebert, Pacific Climate Impacts Consortium; Sarah O'Keefe and Thomas White, Climate Action Secretariat, British Columbia Ministry of Environment

British Columbia shares its high-relief topography and diverse climatology with the northwestern United States. Over the past four years, the provincial government has enhanced its understanding of the climate of BC in partnership with other network operators and academic groups. It has done so by consolidating information from public and private weather observing networks to enhance the official record maintained by Environment Canada. Using the network of networks approach to compile and analyze data is new to British Columbia and Canada, but undertaking said approach is leading to real opportunities to incorporate science into planning.

In this paper we will outline the data-contributing networks involved and how we addressed the challenge of combining information with differing operational standards and requirements. We discuss efforts to enhance public access to the data, including a map-based web application for downloading point observations and gridded climatologies. We discuss opportunities to use the consolidated data to improve climatological products. Finally, we conclude with a discussion of new opportunities to extend the scope and product offerings of the program.

POSTER SESSION

P1 Climate Change Adaptation in U.S. Federal Land Management Agencies: Progress and Next Steps

Jessica E. Halofsky, University of Washington, School of Environmental and Forest Sciences; David L. Peterson, USDA Forest Service, Pacific Wildland Fire Sciences Lab; Kailey Marcinkowski, University of Washington, School of Environmental and Forest Sciences

Federal land management agencies in the U.S. are beginning the process of incorporating climate change into their management planning and operations. Stemming partly from executive- and departmental-level orders, there has been a flurry of climate change-related activity in federal agencies over the last few years, resulting in myriad assessments, strategies, guiding documents, and new agency positions and organizations focused on climate change. We documented past and ongoing climate change adaptation activities in federal land management agencies to allow comparison of approaches among agencies and assess overall agency progress in the adaptation process. We found that while many agencies have developed strategic plans and guidelines for developing and implementing adaptive actions, adaptive actions have yet to be broadly implemented at the field-unit level. We discuss barriers to implementation and potential next steps in overcoming barriers and making progress in agency efforts to adapt to climate change.

P2 Climate Change Adaptation in the National Parks and Forests of the North Cascades Region, Washington

Crystal L. Raymond, Seattle City Light (Crystal.Raymond@seattle.gov); David L. Peterson, USDA, Forest Service, Pacific Northwest Research Station, Pacific Wildland Fire Sciences Laboratory; Regina M. Rochefort, U.S. Department of the Interior, National Park Service

The U.S. Forest Service (USFS) and National Park Service (NPS) have prioritized climate change adaptation through agency-wide strategies that direct administrative units to incorporate adaptation into planning. In response, the USFS PNW Research Station and North Cascades National Park initiated the North Cascadia Adaptation Partnership (NCAP) in 2010. The goals of the NCAP were to build an inclusive partnership, increase climate change awareness among staff, assess vulnerability, and develop science-based adaptation strategies to reduce these vulnerabilities. The NCAP expanded previous science-management partnerships on federal lands to a larger, more ecologically and geographically complex region and to a broader range of stakeholders. The NCAP focused on two national forests and two national parks in the north central region of Washington (USA), a total land area of 2.4 million ha, making it the largest science-management partnership of its kind. The adaptation planning process involved four two-day workshops that facilitated a dialogue among regional scientists and managers on climate change vulnerability and adaptation. The workshops focused on one of four resource sectors: hydrology and access; vegetation and ecological disturbance; wildlife and wildlife habitat; and fish and aquatic habitat. For each resource sector, scientists and resource managers worked collaboratively to identify climate change impacts and potential strategies and "on-the-ground" tactics for adapting resource management to reduce adverse effects of climate change. Examples of adaptation strategies and tactics will be presented for each resource sector. The NCAP process has proven to be a successful approach for linking regional climate change projections with local management needs, increasing communication among scientists and resource managers, and planning for adaptation, but the next step, moving from planning to implementing "on-the-ground" adaptation actions, continues to be a challenge. Lessons learned from the NCAP process can assist other land management agencies that are engaged in adaptation planning.

P3 Climate Change Adaptation and Access Management in North Cascades National Park Complex

Regina M. Rochefort, North Cascades National Park Complex; Ronda Strauch, University of Washington; David L. Peterson, U.S. Forest Service; Erkan Istanbulloglu, University of Washington; Chris Lauver, National Park Service

Land managers from North Cascades National Park, Mount Baker-Snoqualmie National Forest, and Washington Department of Transportation met with climate scientists from University of Washington and the US Forest Service to discuss the integration of climate change into management of access to and within North Cascades National Park Complex, Washington. This workshop was an extension that of the North Cascadia Adaptation Partnership principles to a specific place-based management application. Projected climates were applied to two watersheds and alternative access management adaptations were esxlored. Workshop participants evaluated data on projected climate change, including basin type, 100-year stream flows, and snowmelt date upon the current baseline of as anadromous fish and landform type, to identify exposures and sensitivities related to existing transportation facilities. The goals of the workshop were to: 1) elevate the dialog on climate change and incorporate it into management of park access, 2) discuss integration of climate change into risk assessment, and 3) to determine how to enhance land management planning with available climate change data and NCAP vulnerability assessment.

P4 Free online decision support for Pacific Northwest forest managers

David Diaz, Matt Perry, Mike Mertens, Will Moore, Jocelyn Tutak, Ryan Hodges, Edwin Knuth, and Brent Davies. Ecotrust (all authors).

Climate impact assessment and adaptation strategies require projected changes in climate at scales relevant for impacts modeling and decision making. A total of 20 climate models from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) that have been evaluated for model credibility were statistically downscaled to ~6-km horizontal resolution for the Columbia basin and western United States using the Multivariate Adaptive Constructed Analogs (MACA) method. Resultant fields of daily precipitation, maximum and minimum temperature, specific humidity, surface downward short-wave radiation and wind speed from 1950-2100 for two Representative Concentration Pathways (RCP45 and RCP85) provide the requisite data for running most ecological and hydrological models as part of the Integrated Scenarios for the Northwest project supported by the PNW Climate Science Center. A couple examples on the utility of such projections to inform potential changes in agricultural suitability and wildfire potential elucidate the applicability of the database for proactive management. Finally, an interface for accessing customized datasets will be presented.

P5 An Experimental Approach to Science Delivery: The Big Wood Basin Alternative Futures Project Knowledge to Action Network.

John Stevenson, Oregon Climate Change Research Institute, Oregon State University; Allison Marshall, Water Resource Engineering, Oregon State University; Denise Lach, School of Public Policy, Oregon State University; John Bolte, Biological and Ecological Engineering, Oregon State University; Matt Bragg, Masters of Public Policy, Oregon State University

The Big Wood Basin Alternative Futures Project is an ongoing collaboration among PNW Climate Impacts Research Consortium (CIRC) researchers and local stakeholders to explore future scenarios of water supply under climate and local drivers of change in the Big Wood River Basin in Central Idaho. During the past 24 months, this project has developed as a 'knowledge-to-action network' (KTAN) whereby researchers and stakeholders collaborate to co-produce information that is credible, salient, and legitimate so that it is useable to local decision makers (Cash and Buizer, 2005). This approach is in contrast to what Cash et al. (2006) refer to as the traditional or 'loading dock' approach where science is developed independent of local knowledge and made available to decision makers at the end of the research process (Cash et al. 2006).

The KTAN approach is an experimental one, however, and requires significant investments of time, resources and staff to manage the boundaries between researchers and local stakeholder participants at each stage of project. Given these demands, and the relatively nascent understanding of KTANs, the

CIRC has administered an evaluation protocol to track the project's success in order to improve understanding of KTANs efficacy in developing usable science for local communities. This poster reviews the major steps of this project since it began in July 2011 and shares initial findings from the evaluation protocol and preliminary lessons learned.

P6 An Experimental Approach to Science Delivery: A Collaborative Modeling Approach in the Big Wood River Basin, Idaho

Allison Marshall, Kellie Vache, and John Bolte, Oregon State University; Jennifer Koch, UNC Charlotte; John Stevenson, Oregon Climate Change Research Institute; Denise Lach, Oregon State University; Matt Bragg, Oregon State University

The Pacific Northwest Climate Impacts Research Consortium (CIRC) has proposed a method of conducting place-based climate research in a manner that produces not simply information, but useable knowledge for end users. This approach entails developing a knowledge-to-action-network (KTAN) that merges the expertise of traditional researchers with local stakeholders. The KTAN then collaboratively designs the research objectives, scope, data sources, and methodology used to address the pertinent questions for the project.

To test the methodology, CIRC has developed a case study in the Big Wood River Basin in central Idaho. Based on the priorities identified by the KTAN, the project objectives include assessing future water supply and demand in the basin under a range of both internal and exogenous drivers of change. A modeling platform called Envision is being used to visualize and assess potential changes over time under these drivers. Envision is a spatially-explicit, agent-based, coupled human and natural systems platform that was designed to compare alternative scenarios across a landscape. The main components of Envision include the landscape; autonomous processes, which simulate natural processes that affect the landscape; actors, who make decisions that affect the landscape; and policies, which guide the actor decisions. The interactions and feedbacks between these components over time provide information that allows the users to assess how various policies or processes may result in landscape change.

In this project, under the guidance of the KTAN, Envision is being customized to represent the hydrology of the basin, land use/land cover, and policies that govern land and water use. A plug-in model to Envision called Flow will be used to simulate the basin hydrology. Flow is a semi-distributed, conceptual hydrological model that uses gridded precipitation and temperature inputs and is calibrated to stream discharge measurements. In terms of the human system, the KTAN has identified a range of scenarios exploring combinations of land and water management techniques with different economic bases of the region. These scenarios will be run under low, medium, and high impact climate models as well as high and low population growth rates within Envision. Simulation outcomes will be compared across the scenarios in order to identify a preferred scenario. By exploring a large decision space, this project aims to provide resource users and managers with a range of possible future trajectories for water resources in their basin under various assumptions of climate, population growth, and human drivers of change.

P7 Helping Communities Proactively Adapt to Climate Change Impacts

Jenna Kay, Kearns & West / MIT Science Impact Collaborative
Carri Hulet, Consensus Building Institute / MIT Science Impact Collaborative

Climate change represents a threat to our built environment and infrastructure. Proactively adapting is greatly complicated by the fact there is significant uncertainty around how and when the impacts will be felt. While there is overwhelming evidence that the climate is changing and the oceans are rising, how exactly this will manifest in any particular place or threaten any specific piece of infrastructure is less clear. Adaptation is further complicated by the fact that different stakeholders have a great deal to gain or lose depending on the adaptation options chosen. Yet adaptation decisions need to be made, particularly when we are considering large-scale infrastructure that we expect to serve us far into the future.

Infrastructure planners, decision-makers and other stakeholders around the world are starting to grapple with how to account for climate change threats. They are experimenting with various tools to resolve or reconcile with uncertainty, and to manage conflicts that emerge and make decisions.

We have developed tools to help decision-makers and communities proactively think about these issues in a simulated environment. These tools put players into a situation in which they must, for example, consider how climate change threatens a proposed road project and what they should do in response.

During our conference session, we will discuss how we are working with communities to teach them about: climate risks, possible ways to plan in the face of uncertainty, the concept of scenarios or multiple possible futures, and approaches to reach consensus when there are competing interests.

P8 Preparing for Climate Variability: The City of Portland and Multnomah County's Climate Change Preparation Strategy

Michele Crim, Ingrid Fish, Alice Brawley-Chesworth, **Kaitlin Lovell** - (City of Portland); and Tim Lynch, Kari Lyons-Eubanks and Matthew Davis - (Multnomah County)

The Portland/Multnomah County 2009 Climate Action Plan called for a vulnerability assessment and the development of a Climate Change Preparation Strategy. The City and County anticipate adopting the final Strategy in late 2013. The development of the Strategy relied on available international, national, regional and local data to conduct a vulnerability assessment of three systems: Human, Infrastructure and Natural Resources. Following an asset management approach, the Strategy assessed the likelihood and consequences of risk on these three systems. Where data was highly variable or nonexistent, the team employed the precautionary principle.

Portland and Multnomah County have identified 5 primary climate risks as the top priority for adaptation actions:
Risk 1: Increased temperatures and frequency of heat events.
Risk 2: Increased incidence of drier summers and drought.
Risk 3: Increased wildfire frequency and intensity.
Risk 4: Increased incidence of floods and frequency of heavy precipitation events.
Risk 5: Increased incidence of landslides.

The Plan proposes over a dozen 2030 Objectives and over 100 three year actions to maintain and increase the resilience of these three systems to the impacts of climate change due to the priority risks. The Objectives and Actions meet the following principles 1) use the best available science and stay abreast of new developments; 2) promote flexible approaches that leave a range of future options available; 3) leverage existing efforts, policies and programs; 4) maximize the co-benefits, improve equity outcomes and meet the needs of vulnerable populations; 5) institutionalize climate change preparation into existing operational and decision-making processes; 6) engage the community and coordinate climate preparation efforts with other local and regional partners. The City and County will formalize action plans for implementation including current programs and efforts, and provide updates and revisions every three years.

P9 Generating local sea level rise projections to support community adaptation

Ian Miller, WA Sea Grant
Sascha Petersen, Adaptation International
Byron Rot, Jamestown S'Klallam Tribe
Hansi Hals, Jamestwon S'Klallam Tribe
Jamie Parks, Adaptation International

As part of a comprehensive assessment of community vulnerability to climate change by the Jamestown S'Klallam Tribe in Washington State a set of locally specific sea level vulnerability maps were developed. The maps combined global projections of mean sea level rise with local estimates of vertical land movement to create a set of sea level rise scenarios. An additional "storm impact" layer was added to the maps using estimates of the 50-year return frequency storm-surge magnitude.

The Jamestown S'Klallam Tribe identified three priority geographic areas and for each area the team mapped a low-, medium-, and high- severity sea level rise scenarios based on the local sea level rise curve. The team then presented these maps along with the local sea level rise curve to the community during a climate vulnerability workshop, This allowed the community to assess the scenarios both in terms of the levels of confidence associated with the scenarios as well as the time frame of potential impacts. Of the various potential climate impacts and associated areas of vulnerability assessed, we found that these maps generated the most detailed discussion regarding adaptation at the community level.

While successful, this collaborative scenario-building exercise relies on a set of assumptions, including: 1) vertical land movement estimated from logging GPS networks is linear and non-varying; 2) climate change will have little effect on patterns of storminess over the project time frame; 3) over the project relevant time scales (multiple decades) regional sea level rise is approximately equivalent to global average sea level rise; and 4) shoreline morphology is static (i.e. climate change impacts will not significant alter shoreline morphology). Some of these assumptions are almost certainly invalid and therefore compromise our ability to plan for sea level rise at the local level, even with relatively robust estimates of global sea level rise with quantifiable confidence levels. These gaps include: 1) reliable information on storm surge return frequencies; 2) reliable information on vertical land movement; and 3) reliable models regarding the morphologic response of shorelines due to the coastal impacts of climate change. These gaps also present scientific research opportunities as the climate community continues to work to support community efforts to increase climate resilience.

P10 EPA Region 10 Climate Change and TMDL Pilot

Steve Klein, EPA ORD; Laurie Mann, EPA Region 10; Bruce Duncan, EPA Region 10; Jon Butcher, Tetra Tech; Hope Herron, Tetra Tech; Oliver Grah, Nooksack Indian Tribe; Tim Beechie, NOAA Fisheries; Steve Hood, Washington Department of Ecology; Teizeen Mohamedali, Washington Department of Ecology; Dwight Atkinson, EPA OW.

This presentation is an update on the conceptual framework for the EPA Region 10 Climate Change and TMDL Pilot that was presented at the 2011 2nd Annual Pacific Northwest Climate Science Conference in Seattle, WA. Since that time, we have completed two Workshops, the Project Research Plan and most of Risk Assessment (Quantitative and Qualitative Analyses). This Project is a Climate Change Adaptation Pilot Demonstration.

The U.S. Environmental Protection Agency (EPA) Region 10 and EPA's Office of Research and Development (ORD) and Office of Water (OW) have launched a Pilot Research Project to consider how projected climate change impacts could be incorporated into a Clean Water Act (CWA) 303(d) Temperature TMDL and influence restoration actions in the WRIA 1 ESA Salmonid Recovery Plan. The Pilot Research Project uses a temperature TMDL being developed for the South Fork Nooksack River (SFNR), in Washington, as the Pilot TMDL for climate change analysis. An overarching goal of the pilot research project is to ensure that relevant findings and methodologies related to climate change are incorporated into the SFNR Temperature TMDL. Key Stakeholders and Research Collaborators on this project are the Nooksack Indian Tribe, Lummi Nation, Washington's Department of Ecology, WRIA 1 Salmon Recovery Team, UW's Climate Impacts Group (CIG), Tetra Tech (Contractor to EPA), U.S. Forest Service, NOAA Fisheries and USGS.

P11 Lessons learned from adaptation planning in five Oregon county health departments

Andrea Hamberg, Oregon Health Authority

Oregon Health Authority has spent the past two years leading a cohort of 5 local health jurisdictions to understand and prepare for the health impacts of climate change. Partners at the Resource Innovation Group (TRIG) and Oregon Climate Change Research Institute (OCCRI) provided local climate predictions, and the health departments of Benton, Crook, Jackson, and Multnomah counties, and North Central Health District, used local data to identify possible health outcomes and vulnerabilities. Then, with partners from Emergency Management, Public Health Preparedness, Communicable Diseases, local hospitals, and others, the counties developed strategies to help them monitor possible increases in climate-related deaths and diseases, prepare appropriate local responses, and develop plans to communicate with their communities about the risks.

The presenter will give an overview of the two-year project with five local health jurisdictions to pilot a tool for developing an adaptation plan, highlighting processes and resources used, and partnerships developed. She will highlight the different approaches used across jurisdictions of varying size, and discuss lessons learned throughout the project about adaptation planning at the local level.

P12 Using Social Science Methods to Better Prepare Outreach and Engagement Professionals to Assist Communities with Climate Change Adaptation Planning

Miriah Russo Kelly, Joseph Cone, Kirsten Winters, Patrick Corcoran, Oregon Sea Grant.

Helping coastal communities prepare for climate change is vital, as they face potentially significant effects of climate variability and change during this century. A pilot project with Oregon and Maine Sea Grant programs initially demonstrated the valuable role that Sea Grant and Cooperative Extension programs play in providing trustworthy scientific information and decision support services in coastal communities. Washington, Minnesota, Maryland, North Carolina, South Carolina, and Florida Sea Grant programs participated in a follow-up project led by Oregon Sea Grant. The main internal objective was to help outreach and engagement professionals use social science methods in their adaptation planning, but fewer than half had taken social science courses at the college or graduate level in the past 10 years. With each of the states separately and with all together, we discussed and, when desired, gave training on tools derived from risk communication methodology (Morgan et al, 2002): mental model interviews, focus groups, and surveys. In addition, the project offered training in (1) planning how to conduct the local project, what to focus on, and how to evaluate it; (2) forming a representative and activist stakeholder advisory committee; (3) understanding and using models of decision making; (4) organizing and conducting qualitative research with key audiences to gather baseline knowledge and perceptions of climate issues; and (5) developing an "expert" model of local climate issues to help frame the critical decisions that key, identified audiences might want to make. Sea Grant partners in the states used many of these tools, applying them slightly differently in a range of different situations. We report on our evaluation of the states' implementation of the methods. A number of lessons were learned which are applicable to others conducting community outreach and engagement around climate adaptation planning.

P13 PRIMA: The Platform for Regional Integrated Modeling and Analysis

Ian Kraucunas, PNNL, on behalf of the PRIMA Team

The Platform for Regional Integrated Modeling and Analysis (PRIMA) is a unique modeling framework developed at Pacific Northwest National Laboratory (PNNL) to simulate the complex interactions among natural and human systems at scales relevant to regional decision making. The PRIMA framework brings together models of regional climate, hydrology, agriculture, socioeconomics, buildings, electricity, and other sectors using a flexible software architecture. The framework is portable and can be customized to inform a variety of complex questions and decisions including, but not limited to, the planning, implementation, and evaluation of mitigation and adaptation strategies. PRIMA also includes extensive stakeholder interactions and analysis to inform model development, applications, and the characterization of uncertainties. Ongoing numerical experiments are yielding new insights into regional interactions, with initial foci on the climate-energy-water-land nexus in the upper Midwest and, through a separate DOE-funded project, the vulnerability of energy infrastructure in the Southeast. Ultimately, the vision for PRIMA is to provide a unique regional modeling and analysis tool that can systematically address questions such as:
* How are regional mitigation and adaptation opportunities shaped, enhanced, or constrained by intrinsic regional characteristics?
* How do projected changes in mean climate versus climate extremes affect the development of adaptation and mitigation strategies?
* How might interactions between management decisions and natural processes contribute to rapid or nonlinear changes in the environment?
* How will adaptation and mitigation strategies interact in the next few decades in terms of achieving their respective goals?

This presentation will provide an overview of PRIMA including its component models, the integrating framework, and results to date from its application and demonstration in two U.S. regions.

P14 Animal Agriculture and Climate Change: An Online Course to Educate Extension Educators

Elizabeth Whitefield and Joe Harrison (1); Rick Stowell and Crystal Powers (2); Mark Risse, Pam Knox, and Gary Hawkins (3); Larry Jacobson and David Schmidt (4); David Schmidt and Saqib Mukhtar; Curt Gooch and Jenny Pronto (6)

(1) Department of Animal Sciences, Washington State University
(2) Department of Biological Systems Engineering, University of Nebraska-Lincoln
(3) Department of Biological and Agricultural Engineering, University of Georgia
(4) Department of Bioproducts and Biosystems Engineering, University of Minnesota;
(5) Department of Biological & Agricultural Engineering, Texas A&M University, Department of Biological & Agricultural Engineering
(6), Department of Biological and Environmental Engineering, Cornell University

This 12 hour online course is a product of a national effort to build capacity amongst Extension with the goal of informing and influencing livestock and poultry producers and consumers of animal products. The lessons are web-based, using the Moodle platform and include individual livestock species and region-relevant information covering: 1) climate impacts to animal agriculture; 2) risk management and adaptation; 3) climate science; 4) contributions and solutions to GHG emissions; 5) science communication during controversy. Each lesson includes one or more narrated video presentations, knowledge assessments, and essential reading material pertinent to each topic. Students are also encouraged to participate with other students and instructors through live forums. After completing the online course, students are eligible for 10 Certified Crop Advisor (CCA) Continuing Education Credits (CEUs) as well as 8 American Registry of Professional Animal Scientists CEUs. Students will also receive a certificate of completion validating knowledge and competency in the area of animal agriculture and climate change. The course is intended primarily for Extension educators, technical service providers, and other animal agriculture consultants that could use the lessons in preparation for communicating the issues of basic climate science and climate change with clientele. The course examines the impact climate change is having on farmers and ranchers, presents tools to help adapt to risk and uncertainty, and summarizes strategies for communicating these topics.

P15 Characterizing Pineapple Express Storms in British Columbia's Lower Mainland Using Meteorological, Streamflow and Stable Isotope Data

Christina M. Spry and Karen E. Kohfeld, School of Resource and Environmental Management, Simon Fraser University; Diana M. Allen, Department of Earth Sciences, Simon Fraser University; David Dunkley, Policy and Planning Department, Metro Vancouver, Ken Lertzman, School of Resource and Environmental Management, Simon Fraser University

Pineapple Express (PE) storms are subtropical winter storm systems that are known to trigger precipitation-induced natural hazards, have a negative impact on water supply and quality, and lead to costly remediation and risks to public health and safety. However, they have not previously been well characterized in the Lower Mainland of British Columbia in terms of their a) meteorological, b) streamflow and c) stable oxygen isotope characteristics. This study compares the characteristics of PE and non-PE storms using storm precipitation samples and station data from the Vancouver International Airport and Capilano watershed, and examines historical trends in PE storm magnitude and frequency. Results indicate that high magnitude PE storms have significantly heavier oxygen isotope composition, higher precipitation, and higher streamflow rates than non-PE storms. From 1948-2007, Vancouver experienced 0-7 PE storm days/year, and PE storms contributed an average of 11% and 17% to annual precipitation and stream discharge totals, respectively. Annual PE storm maxima (i.e., total precipitation for the largest PE storm day in a given year) are positively correlated with both storm frequency ($p < 0.05$) and annual average temperature ($p < 0.05$), which suggests that future, warmer climate conditions could result in strong PE seasons that produce numerous high magnitude PE storm events. While no significant relationships exist between PE storms and phases of either the Pacific Decadal Oscillation or the El Niño Southern Oscillation, water years (October-September) with strong PE contributions to annual precipitation are significantly correlated with negative phases of the Madden-Julian Oscillation (MJO; $p < 0.05$). Understanding the localized characteristics of specific storm types provides valuable information that informs municipal climate change adaption and water resource management planning.

P16 Modeling snowcover sensitivity to global warming across a climatic gradient in the Oregon Cascades

Matthew G. Cooper, Water Resources Graduate Program, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University; Anne W. Nolin, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University.

One of the most identifiable effects of climate change in the Pacific Northwest during the last century has been the decline of mountain snowpack. Previous research on this topic has focused on spatial scales appropriate for regional trend identification but generally does not provide the level of detail required for watershed scale management adaptation planning. Furthermore, previous studies have focused on the wet, western Cascades snowpack. To date, no study has examined changes in snowpack across the east-west divide of the Cascades. The goal of this research is to model the effect of warming temperatures on the eastern Cascades Metolius River Basin snowpack on a spatial and temporal scale appropriate for watershed-level management. Following the methods of Sproles et al. 2013, we will use the process-based snow evolution modeling system SnowModel (Liston and Elder 2006) to model the spatial distribution of snow water equivalent (SWE) in the Metolius River Basin and nested sub-basins. The modeling period covers 1991-2009, during which time the region experienced high, low, and average SWE. For each sub-basin, we quantify the date and magnitude of peak SWE, the date of snow disappearance, the ratio of SWE to winter precipitation (SWE:P), and the snow-covered area (SCA) at peak SWE for each year. We validate our model results using available SWE measurements and snow extent from Landsat remote sensing imagery. SnowModel is then run using perturbed meteorological input data (+1°C, +2°C, +3°C, +4°C and ±10% precipitation) to evaluate the potential effects of a warmer, wetter/drier winter climate on snowpack accumulation and melt. The results will be analyzed by elevation and land cover to determine spatial patterns of SWE sensitivity to warming temperatures. The results for the eastern Cascades will be compared to the results from Sproles et al. 2013 for the western Cascades McKenzie River Basin to identify when and where the sensitivity of SWE differs across the east-west divide of the Cascades.

P17 The role of glacial melt and areal recession on historical dry season streamflow in the Hood River Basin, Oregon

Chris Frans, Theodore Bohn, Erkan Istanbulluoglu, and Dennis Lettenmaier, Department of Civil and Environmental Engineering, University of Washington; Garry Clarke, Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia

The Hood River Basin in Northwest Oregon is located in a temperate climate, and is home to highly productive agricultural lands which are vital to the local and regional economies. Melt water originating from snow and glacier ice high on Mount Hood is critical for sustaining streamflow and agricultural water supply during the driest times of the year, especially during drought years. Moreover, water diversions for irrigation districts are located at high elevations along the Middle fork of the Hood River, increasing the importance of, and dependence on snow and glacier ice melt. Over the course of the previous century the areal extent of Mount Hood's glaciers have decreased up to 60%. Leveraging a recently developed coupled glacier dynamics model (University of British Columbia, UBC-Glacier Model) and a distributed watershed scale hydrology model (Distributed Hydrology Soil Vegetation Model, DHSVM), the relative influence of, and trends in glacier melt are analyzed during the historical period 1915-2010. Using historical estimates of glacier extent and dynamic modeling of glacier mass evolution, we describe the influence of spatial changes in glacier extent on melt contribution and dry season streamflow variability. Additionally, the influence of debris cover in the ablation zones of Eliot and Coe glaciers on the partitioning of energy for melt is examined. This study sets the stage for future inference of water resource availability in the Hood River basin as climate driven glacier recession continues.

P18 Stream temperature monitoring program in Portland, Oregon for detecting long term, city wide trends in water temperature

Jason Law and Chris Prescott, City of Portland Oregon

Climate change is expected to have a large effect on cities in the future. Land use changes and climate change can create synergies that together exacerbate the impacts of changes in temperature. Additionally, the City has adopted a Climate Action Plan which includes strategies to reduce the City's contribution to climate change and to mitigate the effect of climate change within Portland.

The City of Portland sits at the confluence of the Willamette and Columbia rivers. These rivers are major migration corridors and rearing habitat for endangered salmon that spawn throughout the Columbia River basin. Stream temperature is critical to the survival, metabolism and behavior of these endangered species. Ensuring that at least 50% of stream miles in the city meet 'urban water temperature goals' is a key action identified in the City's Climate Action Plan.

The City's Bureau of Environmental Services has a comprehensive watershed monitoring program based on a 4 rotating panel GRTS survey design. Continuous temperature monitoring is conducted at 20 perennial stream sites each year. So far, three years of data have been collected from 60 sites. These data along with analysis tools developed by the NorWeST temperature project and spatial network statistical models can be used to assess how stream temperatures are changing in the Portland region over time. This information can inform policy makers whether actions taken to mitigate the effect of climate change are effective and how these temperature changes may affect endangered salmon and other aquatic organisms.

P19 Assessing Shifts in Hydrologic Ecosystem Services Resulting from Climate and Land Use Changes Using the SWAT Model

Mike Psaris, Heejun Chang, and Wes Hoyer, Geography Dept. Portland State Unieristy

As human activities strain Earth's supply of natural resources, there is an increasing need to define and quantify the services nature provides to humans, also known as ecosystem services. Detailed assessment of ecosystem services requires an understanding of the biophysical processes taking place on a landscape, and researchers use models to help them conduct their assessments. These models, which function at a variety of spatial and temporal scales, were initially developed with different goals in mind, and excel at modeling different groups of services at different scales. The Soil and Water Assessment Tool (SWAT) is a watershed model that was originally developed to help researchers and water managers conduct water quality studies. Recently, researchers have begun adapting the model to hydrologic service assessment due to its process-based architecture and semi-distributed output. In this study we use two different urbanizing watersheds in Oregon to assess ecosystem service shifts under climate and land use changes using SWAT. The Yamhill subbasin is dominated by forest (40 %) and agriculture (34%) and has minimal urban development (7%), while the Tualatin is an urbanizing, highly managed watershed with mixed land uses and some of the highest population growth rates in the state. Forests still account for 33% of the basin, and agriculture 25%, however 22% of the basin is developed. Current models have monthly NSE values ranging from 0.54 to 0.91 for flow, 0.4 to 0.81 for sediment, -0.29 to 0.58 for TN, and -15.55 to 0.61 for TP. We anticipate flows to decrease in the summer months and increase during winter months under climate change. Additional riparian vegetation may reduce sediment and nutrient loadings, while increased agricultural activities that do not implement farming BMP's may reduce water quality in the future. This study illustrates the usefulness of SWAT for assessing potential shifts and tradeoffs of hydrologic ecosystem services under environmental change and alternative management scenarios.

P20 Spatial distribution of long-term hydrologic trends: Implications for regional streamflow sensitivity to climate warming in the Pacific Northwest, USA

Mohammad Safeeq, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR; Gordon E. Grant, USDA Forest Service, PNW Research Station, Corvallis, OR; Sarah L. Lewis, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR; Christina. L. Tague, Bren School of Environmental Science and Management, University of California, Santa Barbara, CA; Marc Kramer, Soil and Water Science Department University of Florida, Gainesville, FL; Brian Staab, USDA Forest Service, PNW Region, Portland, OR

Predicting the consequences of climate change on streamflow remains a major challenge in climate science, in large part because of the varying hierarchy of landscape level controls on the magnitude and timing of streamflow sensitivity. Previous work has identified elevation, a proxy for snowpack dynamics, as the primary control on streamflow sensitivity to warming. But along with changes in the timing of snowpack accumulation and melt, summer streamflows are also sensitive to intrinsic, geologically mediated differences in the efficiency of landscapes in transforming recharge (either as rain or snow) into discharge; we term this latter factor drainage efficiency. Here we present a framework for analyzing and predicting the streamflow sensitivity to climate change at the regional scale by combining the snowpack dynamics and drainage efficiency. This conjunctive analysis shows coherent spatial patterns in terms of streamflow decline in the western US during the period 1950-2010. For example, summer streamflows in watersheds that drain slowly from deep groundwater and receive precipitation as snow are most sensitive to climate warming. In contrast, during the spring watersheds that drain rapidly and receive precipitation as snow are most sensitive. We use this framework to map the summer streamflow sensitivity to climate change in a spatially explicit fashion across Oregon and Washington. Results of this analysis point to a robust, practical, and scalable approach that can help assess risk at the landscape scale, and provide a framework to assist land and water managers to adapt to an uncertain and potentially challenging future.

P21 An Intercomparison Study of Climate Change Scenarios for the Canadian Columbia River Basin

Alan F. Hamlet, Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame; Markus Schnorbus and Arelia Werner, Pacific Climate Impacts Consortium, University of Victoria; Matt Stumbaugh and **Ingrid M. Tohver**, Climate Impacts Group, University of Washington

The headwaters of the Columbia River basin in British Columbia provide valuable resources for both Canada and the U.S. so there is considerable interest from both sides of the border on how this portion of the basin will respond to climate change. Projections from coupled hydrologic and climate models offer insights about the basin's responses to climate change. This study compares the results from two large-scale hydrologic modeling studies conducted over the upper reaches of the Columbia River basin. The Climate Impacts Group (CIG) from the University of Washington and the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria independently implemented the Variable Infiltration Capacity hydrologic model at 1/16th degree resolution to determine the sensitivity of the Canadian portion of the Columbia River. The two studies offer points of comparison for 18 key hydroclimatic variables for four climate change scenarios for the 2040s shared by both studies, including the following: cool-season (October – March) precipitation (P), cool-season P extremes, warm-season (April - September) P, warm-season P extremes, cool-season Temperature (T), cool-season T extremes, warm-season T, warm-season T extremes, April 1 snow water equivalent (SWE), SWE to P ratio, annual streamflow, cool-season streamflow, warm-season streamflow, July-September streamflow, August streamflow, center of timing of flow, high flow extremes, and low flow extremes. We found qualitative consensus on the majority of the metrics in terms of the direction of change. However, substantial discrepancies in the quantitative, or numerical values, and percent changes of hydrologic variables were frequently encountered in the simulations. The projection of changes in cool-season streamflow, and hydrologic extremes (high and low flows) were among the most quantitatively divergent metrics analyzed. The inclusion of glaciers was also an important point of comparison between the two models. The absolute value of August streamflows were very different for the two model formulations (due to the inclusion of glacier effects in the PCIC simulations), but the sensitivity to climate change of August flows was not strongly divergent between the two models. The differences that exist between these results have varying implications for water managers. For those whose decisions are influenced primarily by the direction of change and qualitative impacts, the strong consensus among the modeling approaches should provide sound decision support. However, for decisions sensitive to the numerical values, these results indicate a need to employ multiple modeling approaches to better quantify the uncertainty in future decisions.

P22 A quick approach to evaluating climate change projections for trends in future streamflow

Julie Vano and Dennis Lettenmaier, Department of Civil and Environmental Engineering, University of Washington

In the Pacific Northwest, there have been numerous efforts to translate global climate model (GCM) output to more local scales for water management evaluations. One of the most common approaches is downscaling and bias correcting climate model projections, and then running them through a hydrologic model to obtain future streamflow projections. This requires considerable computing and data management and each time new climate model runs are released (e.g., the fourth Assessment Report (AR4) GCM results were available around 2007 and AR5 models are becoming available now) the entire process has to be repeated. We describe a simplified method that uses basin-scale hydrologic sensitivities to changes in precipitation (defined as precipitation elasticities, the fractional change in runoff divided by the fractional change in precipitation) and changes in temperature (defined as temperature sensitivities, the percent change in runoff per degree change in temperature). We use seasonal sensitivities to determine basin-specific transfer

functions, essentially two 4x12 matrixes, to estimate future changes in long-term mean seasonal responses. These capture the basin-specific hydrologic characteristics and can provide first-order estimates of the likely range in long-term (e.g., 30-year) annual seasonal streamflow changes without performing detailed model simulations. Our results show that the sensitivity-based estimation approach compares well with the more common, computationally intensive full-simulation approach in five major tributaries (order 10^4 – 10^5 km^2) in the Columbia River basin. These methods can be easily applied to newly released climate information to assess underlying drivers of change and to bound, at least approximately, the range of future streamflow uncertainties for water resource planners.

P23 Which climate scenarios should we simulate? A sensitivity analysis of MC2 DGVM simulation results using 3 sparsely sampled CMIP5 projections.

John B. Kim, USFS Pacific Northwest Research Station
Bear (G. Stephen) Pitts, Oregon State University

CMIP5 provides 147 climate projections in the RCP experiment family alone. Some framework is needed to guide selection of projections for use in regional climate impact modeling. An initial sensitivity analysis of MC2 DGVM results using shifted historical climate values ("Poor-man's Sensitivity Analysis") indicated a decrease in live vegetation carbon in response to future increases temperature, and the reverse effect for increases in precipitation. We used MC2 on 3 CMIP5 projections to confirm this initial analysis, and to characterize variations among various regions of the western U.S.

We ran MC2 on three CMIP5 climate projections, downscaled to 1/24 degree resolution for the Western U.S: GFDL-ESM2M/RCP4.5, MIROC5/RCP8.5, and HadGEM2-ES/RCP8.5. These 3 projections represent low warming, reference, and high warming scenarios, respectively. The climate data were sampled every 6th cell to accelerate simulation and analysis. Western U.S. was divided into 2 deg lat x 4 deg lon tiles. We used multiple regression to calculate effect of temperature increase (dT) and precipitation increase (dP) on changes to the simulated live vegetation carbon (dCVEG).

Regression results did not confirm the results of the Poor Man's Sensitivity Analysis. On average, both dT and dP lead to increases in live vegetation carbon (CVEG). Across the west, dT was a more reliable driver of increases in CVEG. Precipitation increase (dP), on average, had a greater impact yet with more uncertainty. Greatest regression errors are observed in the Pacific Northwest and in the Rockies. Separate multiple regression in the Rockies shows dP is a much stronger driver of CVEG in that region.

The results suggest that when selecting CMIP5 projections for regional vegetation simulations, one should choose projections representing diverse precipitation scenarios to minimize uncertainty. Projections should also span the full temperature range, but fewer projections are needed to address variations due to increases in temperature. For the Pacific Northwest, projections need to capture variations in both temperature and precipitation increases.

P24 Wildfire effects on forest biomass in the Pacific coast states

Bianca N.I. Eskelson, Oregon State University; Vicente J. Monleon, USDA Forest Service PNW Research Station

The frequency of large wildfires and the duration of the fire season have increased in the western United States. Because wildfires are an important component of the terrestrial carbon cycle, understanding their effect on forest biomass pools is crucial in anticipating future changes in those pools, determining the ability of forests to continue sequestering carbon, and evaluating the carbon impact of wildfire mitigation options. However, the effect of wildfire on forest carbon is still poorly understood, in part because studies are typically limited to individual fires and fairly small sample sizes, and because very few studies present empirical data on all forest carbon pools and rely heavily on assumptions of the impact of fire in some biomass components. Forest Inventory and Analysis (FIA) data provide a unique source of empirical data that can be used to analyze wildfire effects on all aboveground forest biomass components at a regional scale across a large number of fires. Thus, we estimated wildfire effects on live tree, snag, and coarse (CWD) and fine woody detritus (FWD) biomass components using FIA's spatially balanced probability sample of all lands in Washington, Oregon, and California. FIA plots that burned five years prior to plot measurement were included in the study and these plots were spatially matched with unburned plots resulting in 441 pairs of burned and unburned plots. Differences in biomass (Mg/ha) of live and dead trees, CWD, and FWD were analyzed with mixed effects models with a random block effect and wildfire disturbance, ownership group, elevation, and climate variables as fixed effects. Median live tree biomass on unburned plots was 6.41 (95% CI: 4.66-8.82) times as large as live tree biomass on burned plots, while median snag biomass on burned plots was 6.97 (5.31-9.14) times as large as that on unburned plots. Median CWD and FWD on unburned plots were 2.11 (1.64-2.71) and 2.60 (2.11-3.2) times as large as on burned plots, respectively. Wildfire shifts biomass from live pools into dead pools and consumes most of the FWD. While burn severity has an impact on the amount of decrease and increase in standing live and dead tree biomass, respectively, there is little difference in CWD and FWD biomass consumption across burn severity classes. Our results provide insights on the effects of wildfire on all woody forest biomass components at a regional scale, and will help improve biomass projections under changing fire regimes due to climate change.

P25 Charred Forests Increase Snowmelt: Effects of Burned Woody Debris and Incoming Solar Radiation on Snow Ablation

Kelly E. Gleason, Anne W. Nolin, and Travis R. Roth, College of Earth, Atmosphere, and Ocean Sciences, Oregon State University

In the Western U.S., wildfires have increased and snowpacks have declined in concert with higher temperatures. We document impacts from post-fire forest conditions on snow accumulation, snow albedo, and snow ablation in the Oregon High Cascades. We measured snow water equivalent, solar radiation, snow albedo, and snowpack surface debris at a pair of burned and unburned forest plots. Snow accumulation was greater in the burned forest; however the snowpack disappeared over three week earlier and had twice the ablation rates than in the unburned forest. Approximately 60% more solar radiation reached the snow surface, while measured snow albedo was 50% lower in the burned forest during ablation driving a substantial increase in net shortwave radiation. Significant amounts of pyrogenic carbon particles and larger burned woody debris shed from standing charred trees, accumulated on the snowpack and darkened its surface. Spatial analysis shows that across the Western US 80% of forest fires occurred in the seasonal snow zone, and those fires are over four times larger than elsewhere.

P26 Toward a Regional Droughty Soils Map: Using Legacy Forest Service Soil Resource Inventory Data to Augment NRCS SSURGO Data

Chris Ringo and Jay Noller, Department of Crop and Soil Science, Oregon State University; Karen Bennett, USDA Forest Service Pacific Northwest Region

Understanding and quantifying the potential impacts of climate change on our Northwest forests requires reliable datasets representing variety of environmental variables. Of primary importance in evaluating the response of forests to potential changes in drought stress is the availability of good soils data, particularly soil texture, soil depth, and organic content for estimating soil water holding capacity. Unfortunately NRCS soil surveys (SSURGO) do not exist for the majority of National Forests in the Pacific Northwest, and so researchers have had to fall back on the NRCS General Soils Map (STATSGO) data for these areas. These data were compiled at a considerably smaller scale than SSURGO data (1:250,000 versus 1:24,000), and generally do not have the detail needed by most users.

During the 1970s and 1980s however, all Pacific Northwest National Forests conducted Soil Resource Inventories (SRI) at a mapping scale of 1:63,360 (1 inch to the mile) to provide some basic soil, bedrock, and landtype information for use in resource management. Most Forests did not subsequently convert these datasets to digital form, however. We will present our efforts to bring these legacy spatial and tabular data into the digital world, focusing particularly on the development of soil moisture metrics such as Available Water Storage (AWS) for integration with SSURGO data where available, and the use of these data in a regional droughty soils analysis. Development of these legacy data will prove useful in filling the gaps in regional soils information, and provide researchers and resource managers with valuable information for assessing the potential impacts of climate change on forested ecosystems in our region. The information can also be used for climate change adaptation by prioritizing forest vegetation thinning treatments to drought prone areas and thereby increasing overall forest resiliency to climate change.

P27 A continental scale approach to understanding climate sensitivity in Douglas-fir

Christina Marie Restaino, Fire and Mountain Ecology Laboratory, College of the Environment, University of Washington; and David L. Peterson, Pacific Wildland Fire Sciences Laboratory, Pacific Northwest Research Station, United States Forest Service

Tree life-history processes like establishment, growth, and mortality are partially controlled by climate. Even relatively small shifts in climate can influence these processes and may result in shifts of species distributions. Climate change models that address ecosystem impacts simulate these distribution shifts at coarse spatial scales. However, this information lacks utility for resource managers who operate at finer resolutions. Tree growth rates serve as an alternative method of predicting climate effects on trees. Coniferous trees, for example Douglas-fir, can record changes in growth that relate to climate. These Douglas-firs have radial growth rings that express the spatial and temporal variability in tree growth and climate sensitivity. Past growth fluxes can provide early indications of climate change effects on trees. We are investigating the climate-growth interaction of Douglas-fir across its entire range in the United States to better understand how water and energy influence growth from stand to regional to continental scales.

P28 Incorporating grazing into an eco-hydrologic model: Simulating coupled human and natural systems in grasslands

Julian J. Reyes and Ming-Liang Liu, Department of Civil and Environmental Engineering, Washington State University; Christina L. Tague, Bren School of Environmental Science and Management, University of California Santa Barbara; Janet S. Choate, Bren School of Environmental Science and Management, University of California Santa Barbara; R. Dave Evans, School of Biological Sciences, Washington State University; Kristen A. Johnson, Department of Animal Sciences, Washington State University; and Jennifer C. Adam, Department of Civil and Environmental Engineering, Washington State University

Grasslands, managed and unmanaged, provide us an opportunity to investigate the coupled feedbacks between human activities and natural ecosystems. These areas comprise at least 35% of the Earth's land surface and provide support for livestock operation and agricultural production. Capturing the interactions among water, carbon, and nitrogen cycling within the context of regional scale patterns of climate and management is important to understand feedbacks between human and natural systems, as well as provide relevant information to stakeholders and policymakers. The overarching objective of this research is to understand the full (intended and unintended) consequences of changes in management and climate over time by incorporating grassland dynamics into an eco-hydrologic model. For this paper, we include a grazing component through representation of the physiological mechanisms for grass regrowth after defoliation.

The Regional Hydro-ecologic Simulation System (RHESSys) is a process-based, watershed scale model that couples water, nitrogen, and carbon. Within the watershed, climate, soil, vegetation, and management effects are represented in a nested landscape hierarchy to take into account heterogeneity, as well as lateral movement of water and nutrients. We incorporated a daily time-series of carbon loss or uptake from the rangeland, a weighting scheme for grazers to preferentially eat more palatable grasses, and parameter set for grasses. For the latter, this set of parameters captured the reallocation of carbon and nutrients after grass defoliation. We conducted simulations at the Curlew Valley site in northern Utah, a former International Geosphere-Biosphere Programme Desert Biome site. We found that grasses were most sensitive to model parameters affecting the daily-to-yearly ratio of net primary productivity allocation of carbon, non-structural carbohydrate pool, rate of root turnover, and leaf on/off days. We also tested the competition of two different grass types, crested wheatgrass and cheatgrass, with different physiological parameters such as C:N ratio and surface leaf area within a single patch. Preliminary results indicated gradual declines of the more edible vegetation (crested wheatgrass) and takeover by the invasive species of the Intermountain West (cheatgrass).

P29 The importance of soils in vegetation modeling

Wendy Peterman, Oregon State University/Conservation Biology Institute; and Dominique Bachelet, Conservation Biology Institute

Over the last decade, scientists have documented unprecedented levels of forest dieback in response to prolonged droughts, floods and/or changes in snowpack. As the main determinant of belowground water availability, soils play an integral role in ecological responses to changes in precipitation and temperature. Increasing the realism of belowground processes and the sensitivity of vegetation models to soil conditions will improve their representation of real-world conditions, thus improving their predictive power. For the North Pacific LCC, we are developing new improved soils datasets and evaluating overall soil vulnerability to climate change. The new soil data will be used to test the sensitivity of statistical models, process models and dynamic global vegetation models (DGVMs) and deepen our understanding of forest mortality in response to changing conditions. We have created a vulnerability index for the Southwest US but there, drought conditions have caused carbon starvation and embolism while beetle outbreaks have overwhelmed the trees stress resistance. In the Pacific Northwest, factors other than drought are affecting forest resilience.

P30 Climate change and agricultural intensification impacts on Steelhead (Oncorhynchus mykiss) populations in the Umatilla River as evaluated with a species-specific ecosystem model Ecosystem Diagnosis & Treatment

Laura E. McMullen and Jonathan R. Walker, ICF International; Sandra J. DeBano, David E. Wooster, and Don Horneck, Oregon State University; and Willis E. McConnaha, ICF International

Climate change is expected to increase summer air temperatures and change precipitation and river flow patterns in the Umatilla River Subbasin of Eastern Oregon. In addition, the region may experience agricultural intensification in the near future if programs aimed at increasing the availability of water for irrigation are successful. These changes will modify the environment and can be expected to negatively impact salmonid fish populations in the basin, which in the past have been regionally extirpated due to lack of suitable habitat. Here, we present results of a spatially-explicit species-specific ecosystem model, Ecosystem Diagnosis & Treatment (EDT), in predicting effects of future climate and agricultural change on steelhead (Oncorhynchus mykiss) in the Umatilla Subbasin. EDT assesses fish population performance as a function of habitat conditions. EDT allows multiple climate and environmental stressors (water temperature, flow regime, etc.) to be evaluated simultaneously in their impact on fish habitat, which can be measured as habitat quality and quantity for species and their life stages. We used the model to assess the potential change in fish performance under low, moderate, and high climate change scenarios for 2040 and 2080; partial and "doomsday" agricultural intensification scenarios; and four combinations of climate and agricultural change scenarios. Climate scenarios were evaluated per their predicted effects on water temperature and availability of summer habitat. Agricultural scenarios were evaluated per their hypothesized reduction in riparian areas and impact on water temperatures. As expected, results indicate that the "worst case" scenario for steelhead is a high climate scenario with "doomsday" agricultural intensification in 2080, followed by the other combination scenarios. Climate change scenarios reduced the quality of fish habitat due to the modeled increase in water temperature during summer. Quantity of suitable habitat was most affected by the "doomsday" scenario and combinations of it with climate scenarios. Separately and in combination, climate change and agriculture intensification are predicted to reduce steelhead performance significantly to levels that jeopardize the future viability of the population.

P31 Can fish adapt to warmer climates?

Shawn Narum, Columbia River Inter-Tribal Fish Commission

Anthropogenic climate change is well documented and expected to affect biodiversity richness and distribution according to species' capacities for adaptation or relocation. Since many freshwater fishes have limited relocation potential, it is critical to evaluate the potential for species and populations to adapt to warming environments. Here we discuss physiological and genetic mechanisms for thermal adaptation in salmon and trout in the Pacific Northwest using redband trout (Oncorhynchus mykiss) as a case study. This species is widely distributed in the interior Columbia River drainage and is typically found in cool montane streams, but it also occupies desert streams where water temperatures can greatly exceed thermal preferences (>30° C). Studies indicate that redband trout have evolved over generations to desert stream environments through an adaptive heat shock response that conserves energy and an increased heart rate to deliver more oxygen to tissues. These genetic and physiological indicators are being developed as biomarkers for broad-scale evaluation of redband trout in the Pacific Northwest in order to predict which populations are most likely to adapt over time or be extirpated under scenarios of climate change.

P32 Location matters: geographical variation in predicted effects of climate change on site occupancy of American pikas (Ochotona princeps)

Donelle L. Schwalm and Clinton W. Epps, Department of Fisheries and Wildlife, Oregon State University; Thomas J. Rodhouse, National Park Service, Upper Columbia Basin Network

While climate is a fundamental influence on the distribution of plants and animals, the relationship is not necessarily consistent across species' ranges. Modeling the potential impacts of future climate change on species distributions at broad spatial scales may fail to accurately predict species' response at fine scales, hampering the development of effective conservation strategies. The American pika (Ochotona princeps) is generally expected to experience dramatic declines in distribution as a result of global climate change, based on macroecological assessment of its bioclimatic envelope. However, the species occurs outside of this envelope in many locations due to behavioral adaptations and the presence of local environmental features that ameliorate harsh climatic conditions. To gain a better understanding of how pika populations are likely to respond to climate change at local scales, we modeled predicted changes in pika site occupancy in five U.S. national parks. Pika occurrence was modeled using a Bayesian framework for one current (1970-2010) and three future (2011-2040, 2041-2070 and 2071-2100) time steps. We modeled current pika occurrence using estimated site occupancy and turnover rates derived from 2-3 years of intensive surveys in each study site. Individual models were developed for each park using 19 environmental variables which represented heat stress, cold stress, growing season duration, and measures of habitat connectivity based on genetically-derived dispersal distances. We derived gridded 800 m resolution climate variables using an ensemble climate model and two RCP emissions scenarios (4.5 and 8.5). Importantly, we found that the importance of predictor variables varied between parks and, further, that the magnitude and direction of the estimated effect sizes of these variables differed widely, resulting in highly variable future occupancy scenarios across parks. Interestingly, we found that habitat connectivity was more important than climate for predicting occupancy in some parks. Our results indicate that the realized effects of climate change on pika distribution over the course of this century is likely to be highly idiosyncratic from place to place, underscoring the importance of accounting for local-scale factors in predictive analyses used to develop effective conservation strategies for this and many other climate-sensitive species.

P33 Climate Change Vulnerability Assessment and Adaptation Options for Transportation Infrastructure

Margi Bradway and **Geoff Crook**, Oregon Department of Transportation

Climate change is projected to impact the Pacific Northwest through this century. Oregon's transportation infrastructure is increasingly vulnerable to these impacts. To better understand and respond to the effects of climate change and extreme weather, the Oregon Department of Transportation (ODOT) is conducting a Climate Change Vulnerability Assessment and Adaptation Pilot (Pilot) on the north coast of Oregon.

ODOT manages more than 19,000 lane miles of state highways, 2,700 bridges and thousands of culverts. This infrastructure is vulnerable to climate change impacts such as sea level rise and storm surge, landslides, rock falls, flooding and coastal erosion. Powerful storms over the last decade have washed out roads and isolated coastal communities. These storms have cost tens of millions of dollars for repairs and have strained maintenance resources. To proactively plan for the future, ODOT is using a Federal Highway Administration grant to assess its systems and build adaptive capacity.

ODOT's Pilot will assess and map vulnerable highway infrastructure using a condition rating scale. The agency will rely on regional and global climate and weather data to analyze current and potential future conditions. A workshop with maintenance and technical staff will be held to collect information about specific risks to the highway network and to inventory and prioritize hazard areas. A Study Corridor will also be selected for more detailed analysis. An engineering and technical review will be conducted for hazard locations within the Corridor. Adaptation options will be developed for hazard locations that address future potential impacts and will help improve system resiliency. These options will be included in a final Adaptation Implementation Plan for the selected Study Corridor. ODOT is also collaborating with other agencies and coastal communities who are developing resilience plans for a range of natural hazards on the north coast.

The Pilot will be guided by ODOT's Adaptation Work Group in cooperation with the Oregon Climate Change Research Institute and other state agencies. Lessons learned from the Pilot will be used to inform future work on ODOT's broader Statewide Vulnerability Assessment.

P34 The Economic Value of Water in the Tualatin River Watershed: Potential Effects of Land Use Change and Climate Change on Water Provisioning

Samantha Hamlin, Wes Hoyer, and Heejun Chang, Department of Geography, Portland State University; David Ervin, Departments of Economics and Environmental Sciences and Management, Portland State University

The economic value of water in a region is determined by numerous factors, including regulatory requirements, land use planning, and water-related infrastructure. In addition, climate change is projected to increase the spatial and temporal variability in water quantity and quality in many regions. When coupled with increasing population, a potent driver of land use change in urbanizing areas, the economics of water provisioning in some areas may be greatly altered. This study explores the potential impacts on the economic value and provisioning of water from both climate change and land use change, using the Tualatin River Watershed, a rapidly urbanizing watershed in the Portland metropolitan area, as a study site. The possible effects that different climate change and land use change scenarios might have on freshwater provisioning and waste water treatment were modeled using Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST). The economic impact of regulating water-related ecosystem services was analyzed using the avoided cost method using wastewater treatment data for the basin. These costs include nutrient and sediment removal costs, in addition to the costs of riparian restoration, which has been undertaken to meet regulatory requirements for decreased thermal loading and possible nutrient loading. This analysis illustrates the economic impact that climate change, coupled with land use change, can be expected to have on critical water-related ecosystem services. Additionally, our analysis shows how potential negative economic impacts could be mitigated through the retention of nutrient loads by riparian restoration.

P35 A socio-ecological approach to landscape legacy and change in the Rogue River Basin, Oregon

Jodi L. Schoenen, Fellow, NSF IGERT Program on Ecosystem Services in Urbanizing Regions, Institute for Sustainable Solutions, Portland State University

The Rogue River Basin in Oregon serves as a microcosm for the complex issues around ecosystem services being experienced throughout the West. Pressures from urbanizing areas, changing climate, and shifting economies and cultures are major issues within the Rogue River Basin and all along the western United States. Despite the threatened status of the Rogue River Basin and its importance for biodiversity and hydrology, there has been no research that specifically examines how coupled biophysical and social forces within the basin have affected the flow of ecosystem services across time and ownership boundaries. This research focuses on telling the stories of the Rogue River basin through a biophysical and socio-ecological lens in order to illuminate the drivers of change on ecological systems in the region. This poster summarizes and presents proposed research that will be conducted beginning in Fall 2013.

P36 Incorporating Stakeholder Engagement In Regional Earth System Modeling

Elizabeth Allen and Chad Kruger, Washington State University; Kruger, Chad, Washington State University; Jennie Stephens, Clark University;
Fok-Yan Leung and **Georgine Yorgey**, Washington State University

Engaging directly with regional stakeholders who may use model results to inform decision-making has the potential to improve model accuracy and the relevance of results. This work describes the outcomes of initial engagement efforts for BioEarth, a 5-year regional earth systems modeling project. BioEarth aims to improve understanding of climatic and anthropogenic impacts on water availability, nitrogen and carbon cycling in the Pacific Northwest by integrating and modifying multiple existing models at different scales. Through a stakeholder advising process, individuals from government agencies, farm and forestry advocacy organizations, conservation organizations, industry, and other scientific disciplines were asked to define their information needs and specify possible future economic, environmental and policy scenarios to be addressed by the BioEarth model. Identified needs are being incorporated into mid-range project planning efforts. Concurrent study of stakeholders' perceptions of the advisory process provides insights about how to develop a model that is useful to communities outside of academia.

P37 Coastal Ecosystem Response to Climate Change: Assessing sea-level rise and storm impacts to Pacific Coast salt marshes

Kevin Buffington, Oregon State University; John Takekawa, USGS; Bruce Dugger, Oregon State University; Karen Thorne, USGS; Glen Macdonald, UCLA; Glenn Guntenspergen, USGS; Rich Ambrose, UCLA; Neil Ganju and Patrick Barnard, USGS

Projections of sea-level rise (SLR) and increasing storminess place coastal habitats on the forefront of climate change. The Coastal Ecosystem Response to Climate Change (CERCC) research group has established study sites in 16 estuaries along the Pacific coast to examine local geomorphic processes and develop elevation response models to SLR for decision makers. We established baseline conditions by surveying each salt marsh parcel for elevation (with RTK GPS) and vegetation, and monitor water levels with remote sensors. Digital elevation models were built from the survey data and serve as the initial condition in site-specific elevation response models. In salt marshes, rates of elevation gain (accretion) or loss (subsidence) are heterogeneous across estuaries and are critical to determining their vulnerability to SLR. Historic accretion rates from soil cores and data such as percent organic matter and bulk density are used to parameterize the response model. We have also installed permanent sediment elevation tables (SETs) which track accretion rates over time. We use these site-specific measurements of sedimentation and organic matter production and decomposition along with accurate elevation data to build our salt marsh response models. Our high-resolution models generate projections for SLR at scales relevant to local and regional land managers tasked with allocating climate change mitigation resources and developing conservation plans for wildlife.

With study sites spanning a latitudinal and tidal range gradient, we will be able to investigate how changes in temperature, precipitation, tidal amplitude, and storminess may affect salt marshes by using a natural laboratory approach. Through comparisons of baseline conditions and model results across estuaries, we will also be able to identify which areas are most vulnerable to SLR due to site-specific characteristics. Ongoing monitoring of water levels and accretion rates will capture the local effects of storms and changes in geomorphology to further refine model predictions.

P38 Analysis of Carbon Cycling at Different Agricultural Sites in the Pacific Northwest

Jinshu Chi, Sarah Waldo, Patrick O'Keeffe, Shelley Pressley, and Brian Lamb, Laboratory for Atmospheric Research, Washington State University

Croplands have the potential to mitigate climate change by functioning as a carbon sink. Associated with the Regional Approaches to Climate Change (REACCH) program, this study aims to understand the carbon cycling at croplands and the relationship between local meteorology, management practices, site characteristics, and ongoing climate change. Multiple eddy covariance (EC) flux towers have been deployed to continuously measure CO2 fluxes within the inland Pacific Northwest. The cropping systems under observation represent a range of characteristics, with three sites located in the high-rainfall, continuous-cropping area, including no-till and conventional tillage systems, a fourth site situated in low-rainfall, crop-fallow area, and a fifth site located in an irrigated continuous-cropping area. The variability of the meteorology and management practices can influence the carbon budget within the agricultural ecosystem. This paper addresses this topic by analyzing the carbon balance at these sites. First, Net Ecosystem Exchange (NEE), Gross Primary Productivity (GPP) and total respiration were obtained from the EC measurement. Then, carbon storage in each characterized cropping system was estimated by comparing NEE with the carbon content in the harvested biomass samples. Finally, statistical analysis for the uncertainties of EC measurements and biomass sampling will be presented to better determine each component involved in carbon cycling.

P39 Regional Approaches to Climate Change for Inland Pacific Northwest Cereal Production Systems

Sanford D. Eigenbrode1, John T. Abatzoglou2, John Antle11, Erin Brooks16, Kristy Borrelli1, Ian C. Burke5, Susan Capalbo11, Penelope Diebel11, Paul Gessler3, David R. Huggins9, Stephen Machado10, Jodi Johnson-Maynard1, Stephanie Kane12, Chad Kruger6, Brian K. Lamb8, Stephen Machado10, David Meyer14, Philip Mote13, Kate Painter12, William Pan5, Steven Petrie10, Timothy C. Paulitz9, Jeff Reimer11, Claudio Stöckle7, Jonathan Velez15, Von Walden2, Chelsea Walsh1, J.D. Wulfhorst12, Kattlyn J. Wolf4

1. Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID, 2. Department of Geography, University of Idaho, Moscow, ID, 3. Dept. of Forest Ecology & Biogeosciences, University of Idaho, Moscow, ID, 4. Agricultural & Extension Education, University of Idaho, Moscow, ID, 5. Crop and Soil Sciences, Washington State University, Pullman, WA, 6. Center for Sustaining Agriculture & Natural Resources, Washington State University, Wenatchee, WA, 7. Biological Systems Engineering, Washington State University, Pullman, WA, United States, 8. Civil and Environmental Engineering, Washington State University, Pullman, WA, 9. USDA-ARS, Pullman, WA, 10. Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, OR, 11. Agricultural & Resource Economics, Oregon State University, Corvallis, OR, 12. Agricultural Economics and Rural Sociology, University of Idaho, Moscow, ID, 13. Oregon Climate Change Institute, Oregon State University, Corvallis, OR, 14. Boise State University, Boise ID, 15. Agricultural Education, Oregon State University, Corvallis, OR, 16. Biological and Agricultural Engineering, University of Idaho, Moscow, ID

The long-term environmental and economic sustainability of agriculture in the Inland Pacific Northwest (northern Idaho, north central Oregon, and eastern Washington) depends upon improving agricultural management, technology, and policy to enable adaptation to climate change and to help realize agriculture's potential to contribute to climate change mitigation. To address this challenge, three land-grant institutions (Oregon State University, the University of Idaho and Washington State University) (OSU, UI, WSU) and USDA Agricultural Research Service (ARS) units are partners in a collaborative project - Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCH-PNA). The overarching goal of REACCH is to enhance the sustainability of Inland Pacific Northwest (IPNW) cereal production systems under ongoing and projected climate change while contributing to climate change mitigation. Supporting goals include: - Develop and implement sustainable agricultural practices for cereal production within existing and projected agroecological zones throughout the region as climate changes, - Contribute to climate change mitigation through improved fertilizer, fuel, and pesticide use efficiency, increased sequestration of soil carbon, and reduced greenhouse gas (GHG) emissions consistent with the 2030 targets set by the USDA National Institute for Food and Agriculture (NIFA), - Work closely with stakeholders and policymakers to promote science-based agricultural approaches to climate change adaptation and mitigation, - Increase the number of scientists, educators, and extension professionals with the skills and knowledge to address climate change and its interactions with agriculture. In this poster, we provide an overview of the specific goals of this project and activities that are underway since its inception in spring of 2011. Information on the USDA, NIFA, AFRI, CAP entitled "Regional Approaches to Climate Change for Pacific Northwest Agriculture" can be found at: http://reacchpna.org.

P40 The Cereal Leaf Beetle and its Parasitoid under Projected Climates in the Pacific Northwest

Sanford D. Eigenbrode and Nathaniel Foote, Plant Soil and Entomological Sciences, University of Idaho; John Abatzoglou, Department of Geography, University of Idaho

Climate change can influence the range and severity of pests directly as these insects respond to climatic factors, and indirectly because of the effects on competitors and natural enemies. This study uses downscaled climate models to examine the historical and projected suitability of PNW climates for the invasive pest, the Cereal leaf beetle (CLB), Oulema melanopus. Climate models indicate the environment is suitable for CLB and that in the future, the environment will be at least as suitable or more suitable well into the 21st century. CLB populations are evidently held in check in the PNW by biological control from the parasitoid, Tetrastichus julis. We use a model of phenological overlap to examine the potential changes in the effectiveness of this biological control to mid 21st century. Results indicate overlap shifts will occur but do not appear likely to disrupt biological control.

P41 Climatic Controls of Earthworm Activity/Aestivation in Agroclimatic Zones of the Inland Pacific Northwest

Heath Hewett, Savannah Sheehy, Chelsea Walsh, and Jodi Johnson-Maynard, University of Idaho

Earthworm activity promotes nutrient cycling and yield potential in agroecosystems, but is highly constrained by soil moisture and temperature. As climate conditions change across space and time they will influence the overall impact of earthworms on soil quality and yield. The overall goal of this research is to determine soil moisture and temperature values at which earthworms begin to aestivate in different agroclimatic zones of the Inland Pacific Northwest wheat production region. Earthworms were collected from a total of 20 sites across four agroclimatic zones in the spring and summer of 2013. Earthworm density and biomass, volumetric soil moisture, temperature and the presence of aestivating earthworms were recorded. Between the spring and summer sampling periods, average soil moisture in the top 30 cm of soil decreased in all zones, while average soil temperature within the same depth went up in all but one. On average soil moisture decreased by 11% and temperature increased by 3.6 degrees C. Aestivating earthworms were found in only one zone in spring. In the summer sampling, earthworms were aestivating in 50-55% of sites sampled in the annual cropping, transition and crop/fallow zones and 100% of the sites in the driest zone characterized by a combination of fallow and irrigated agriculture. Earthworm density ranged from 8 to 190 individuals/m2 (mean 69.8) in the spring to 0 to 45.8 individuals/m2 (mean 7.2) in the summer, suggesting a high degree of mortality. Soil moisture and temperature values with depth will be compared to earthworm data and discussed.

P42 Climatic and Biophysical Constraints on Earthworm Density Across Agroclimatic Zones

Chelsea Walsh, University of Idaho; Valerie Espinoza, University of Georgia; Ian Leslie and Jodi Johnson-Maynard, University of Idaho

High earthworm densities have been associated with increased crop production, nutrient cycling and water infiltration. Both physical and chemical soil properties determine earthworm activity, distribution and density. Variations in earthworm activity and density have been observed between agroclimatic zones, however, large variations have also been observed within zones. This research seeks to determine what role soil texture and pH play in determining earthworm distribution and density both between and within agroclimatic zones in the Inland Pacific Northwest wheat production region. Earthworms were collected from 18 sites across the region in the springs of 2012 and 2013. Soil moisture and temperature were recorded at the time of collection and soil samples were collected in 10 cm increments from 0-50cm and analyzed for texture and pH, two factors known to influence earthworm density. Sites were classified into 4 agroclimatic zones, annual cropping systems, transition systems, crop-fallow rotation systems, and irrigated systems, based on observed dominant land management practices. Over the 2 years of sampling earthworm densities ranged from 0 to 1497 individuals m-2. Earthworms were present at all sites within the annual cropping and transitional zone but only at 19% of sites in the crop-fallow zone and only 1 irrigated field. Within the annual cropping and transition zone densities ranged from 1.9 to 290 individuals m-2 over both years. Preliminary data indicate that soil textural classes are predominately silt loam and loam. Soil moisture, temperature, pH, as well as seasonal and annual precipitation, will be compared to earthworm biomass and density data and discussed. Together, these data will be useful in predicting changes the response earthworm density and activity to climate change

P43 The Impacts of Wind Speed Trends and Long-term Variability in Relation to Hydroelectric Reservoir Inflows on Wind Power in the Pacific Northwest

Benjamin Cross, Karen Kohfeld, Harry Joe Bailey, and Andrew Cooper, School of Resource and Environmental Management Simon Fraser University; and Magdalena Rucker, BC Hydro

The use of wind power is growing rapidly in the Pacific Northwest (PNW) due to environmental concerns, decreasing costs of implementation, strong wind speeds, and a desire to diversify electricity sources to minimize the impacts of streamflow variability on electricity prices and system flexibility. In hydroelectric dominated systems, like the PNW, the benefits of wind power can be maximized by accounting for the relationship between long term variability in wind speeds and reservoir inflows. Clean energy policies in British Columbia make the benefits of increased wind power generation during low streamflow periods particularly large, by preventing the overbuilding of marginal hydroelectric projects. The goal of this work was to quantify long-term relationships between wind speed and streamflow behavior in British Columbia. Wind speed data from the North American Regional Reanalysis (NARR) and cumulative usable inflows (CUI) from BC Hydro were used to analyze 10m wind speed and density (WD) trends, WD-CUI correlations, and WD anomalies during low and high inflow periods in the PNW (40°N to 65°N, 110°W to 135°W) from 1979-2010. Statistically significant positive wind speed and density trends were found for most of the PNW, with the largest increases along the Pacific Coast. CUI-WD correlations were weakly positive for most regions, with the highest values along the US coast ($r \sim 0.55$), generally weaker correlations to the north, and negative correlations ($r \sim -0.25$) along BC's North Coast. When considering seasonal relationships, the Spring freshet was coincident with lower WD anomalies west of the Rocky Mountains and higher WDs to the east. A similar but opposite pattern was observed for low inflow winter months. When considering interannual variability, lowest inflow years experienced positive WD anomalies (up to 40% increases) for the North Coast. In highest inflow years, positive WD anomalies were widespread in the US and for smaller patches of central BC. By accounting for regional and temporal differences in the relationship between wind (WD) and streamflow (CUI) behaviour during wind farm site selection, the benefits of energy diversification can be maximized.

P44 Quantifying uncertainty in regional climate model projections over British Columbia watersheds

Charles L. Curry and Andrew J. Weaver, University of Victoria; Daniel Caya and Michel Giguere, Ouranos Consortium; and Edward Wiebe, University of Victoria

Uncertainty in model projections of future climate change presents a key challenge for adaptation policy. In particular, the uncertainty inherent in models' unforced internal variability is irreducible, and differs in kind from uncertainties in future emissions or in model representations of climate processes. For projection horizons shorter than a few decades,
model internal variability can dominate these other uncertainties in specific sub-continental regions.

In this study, the role of model internal variability is studied using an ensemble of 10 climate model simulations over Western Canada with a single regional climate model (RCM), the Canadian Regional Climate Model, CRCMv.4.3. Eight ensemble members are driven at the large (i.e. continental) scale by a different global climate model simulation over the period 1950-2100, while the remaining two members are driven by global reanalyses up to 2005 only.

Of particular interest is the spread amongst model projections of surface temperature and hydrological variables at sub-regions within the RCM domain corresponding to specific watersheds. We focus on three British Columbia watersheds, the Peace, Nechako and Upper Columbia basins and two comparison periods, 1979-2000 and 2039-2060. While the ensemble members agree reasonably well with respect to present-day climatology over these watersheds, projected changes of climate variables vary widely across the ensemble, especially with respect to fall and winter temperature and precipitation. Snowpack, especially, is particularly variable from one realization to the next, leading to considerable uncertainty in projected spring runoff. These results suggest that relying on only one or even a few realizations of climate model response over watershed-scale regions is often not sufficient to capture the uncertainty associated with climate variability.

P45 Assessing Climate Change in the Columbia River Basin: A Comparison of NARCCAP and CMIP5

Darrin J. Sharp, David E. Rupp, Philip W. Mote, Oregon Climate Change Research Institute, Oregon State University

The inability of Atmosphere-Ocean General Circulation Models (AOGCMs) to run at the resolution required for local impacts planning has long been recognized. To address this mismatch of scales, a number of downscaling efforts have been executed in order to produce higher resolution climate data. One such effort is the North American Climate Change Research Project (NARCCAP). NARCCAP uses dynamical downscaling of CMIP3 AOGCMs to provide climate projections at 50km resolution. This project analyzed NARCCAP output for the Columbia River Basin. Results include maps showing changes in temperature and precipitation from the historical (1970-1999) to the future (2040-2069) period. In addition, NARCCAP results are compared to CMIP5 results (at both native and downscaled resolutions) for the same domain, illustrating the evolution of state-of-the-art AOGCM climate modeling.

P46 Hydro-climatic projections for the Western U.S.: online interface, results, and applications

Guillaume S. Mauger, Eric P. Salathé Jr., Jeremy S. Littell, Se-Yeun Lee, and Matt R. Stumbaugh, Climate Impacts Group, College of the Environment, University of Washington

We describe a new internally-consistent set of downscaled projections across the full Western U.S. The dataset includes information about projection uncertainty, results from both statistical and dynamical downscaling, and hydrologic results obtained from the Variable Infiltration Capacity (VIC, Gao et al., 2010; Liang et al., 1994) macroscale hydrologic model. The dataset includes a particular emphasis on changes in hydrologic extremes, including summaries of changes in flooding, low flows, and soil moisture extremes (a proxy for summer water stress). Since evaluation and processing of the data is frequently a barrier to implementation, we have developed a simple online interface of summary products intended to facilitate browsing and easy digestion into standard spreadsheet software such as excel. Climate and hydrologic projections are summarized over both ecologically and hydrologically-relevant domains, and products are organized into climatological average and simple time series summaries for each domain, all browsable online. Additional products include example maps of changes for the entire domain and selected sub-domains, intended to both illustrate the content of the dataset and highlight the potential for further analyses. In this presentation we describe the new online interface, some key results, and several recent applications of the dataset.

P47 Correlations between inter-annual climate variability and nitrogen wet deposition in the United States

Tsengel Nergui1, Brian K. Lamb1, Raymond D. Evans2, Jennifer C. Adam1 and Serena H. Chung1
1Laboratory for Atmospheric Research and 2School of Biological Sciences, Washington State University, Pullman, WA

Human activities, primarily agricultural practices and fossil fuel combustion, have caused a significant increase in nitrogen (N) emissions and atmospheric deposition rates. Chronic N deposition to the ecosystems has reached to a level that causes human health and welfare issues through degradations in air quality, water quality and alternations in structures and functions of many ecosystems across the United States.

In addition to emissions rates, climate variability can play a major role in N deposition rates because N deposition is strongly influenced by precipitation. The El Niño/Southern Oscillation (ENSO), Arctic Oscillation (AO), North Atlantic Oscillation (NAO), Pacific-North American Pattern (PNA) and Western Pattern (WP) are the indices that characterize climate over the North America at annual to inter annual timescales. The study goal is to determine connection between these climate indices and N wet deposition in the United States using wavelet analysis. The last 30 years of observational data on seasonal precipitation, and ammonium and nitrate wet depositions from 151 sites of the National Atmospheric Deposition Program (NADP/NTN) are examined against variability of the climate indices.

The analysis revealed that the highest variances of nitrate and ammonium wet depositions are observed at 0.5-3 year band (time scale) during 1979 to 2012. Although correlation between ENSO and N wet deposition at 2-6 year band varies from site to site, ENSO was found to be most correlated with precipitation and total N wet deposition among all examined climate indices. The higher correlations are found in the coastal region of the Gulf of Mexico, southern Arizona, near the Great Lakes, and northeast of Appalachian Mountains, with r2 value ranges from 0.3 to 0.56. Connection of total N wet deposition with other climate indices (AO, PNA, NAO and WP) at the 0.5-2 year band are weaker across the U.S., with the second strong connection found with the PNA index. Higher correlations are again seen in the Northeast (maximum r2 value of 0.2).

P48 Early results from an effort to downscale a global dissolved inorganic nitrogen model to achieve a regional assessment of nitrogen dynamics in the Columbia River Basin

Cody C. Miller and John A. Harrison, Washington State University Vancouver

Excessive nitrogen (N) export to coastal systems has increased dramatically since the early 20th century. The increase in N has been linked to significant environmental impacts such as eutrophication, fish kills, and harmful algal blooms and is caused in part by the increasing use and quantity of synthetic fertilizer on farmland. Due to inefficiencies in crop uptake of N some of the N in the form of dissolved inorganic nitrogen (DIN) can make it into the waterways and contribute to environmental degradation of these waterways. Significant portions of both the Willamette River Valley in Oregon and the Palouse region of eastern Washington are agricultural land, approximately 20% and 57% respectively. Because of this it is important to understand what effects changes in DIN application will have on water quality and DIN export to the coast. DIN export data, retrieved from the U.S. Geological Survey National Water Information System, was analyzed for 23 major subbasins in the Columbia River Basin (CRB) and estimates DIN export (per area yield) ranging from 5.0 to 883.1 kg N km-2 yr-1. Here we present early results from our effort to downscale the Global Nutrient Export from WaterSheds (Global NEWS) DIN model for application within the Columbia River Basin (CRB). This first attempt at downscaling Global NEWS is missing some key higher-resolution N inputs for the model as well as accurate dam retention and runoff factors which could account for the low correlation between model output and observed data (R2 = 0.30).Our regional model predicts DIN yields ranging from 9.7 to 898.3 kg N km-2 yr-1. Both the model output and observed data predict the highest per area DIN yields occurring in the Willamette river subbasin. Total DIN export to the coast was modeled as 0.05 Tg N yr-1 compared to 0.07 Tg N yr-1 calculated from the measured data. Based on current model inputs biological N2 fixation is the dominant source of DIN in 15 of the 23 subbasins, including the CRB as a whole. N fertilizer is the dominant source of anthropogenic DIN export among the rest of the subbasins. With improvements to the model inputs we expect to see a higher correlation between the measured data and the model output.

P49 Projecting Future Hydrologic Extremes

Eric P Salathé Jr, School of STEM, University of Washington Bothell

Significant work has been done in projecting future hydrologic extremes in the Pacific Northwest using statistical downscaling methods and hydrologic models. However, intense short-term precipitation events depend on processes poorly resolved both by the global models and the observing network, and it is not clear whether statistical methods can adequately represent changes in these processes in a future climate. In contrast, regional climate models (RCMs) can explicitly represent the mesoscale processes that control the timing, intensity, and extent of extreme events and can produce local climate responses quite different from those indicated by global models combined with statistical downscaling. RCMs, however, introduce additional sources of bias and uncertainty into projected climate information, which must be addressed using methods similar to statistical downscaling.

This presentation will discuss recent research using a regional climate model to illustrate how RCMs can inform our understanding of extreme events and provide projections of future flood risks. Heavy precipitation in the western United States depends on well-known weather patterns associated with atmospheric river events and topographic enhancement along the major mountain ranges. The ability of regional climate models to represent these processes and their connection to global climate change is essential to projecting future changes in heavy precipitation and hydrologic extremes. To illustrate these connections, the effect of climate change on these processes will be discussed using both observed data and RCM simulations. In particular, results will be presented from a study applying WRF simulations to projecting future flood risk in the Columbia Rive Basin. These results will be contrasted to the projections from statistical methods to illustrate how changes in mesoscale processes can have important regional implications.

P50 The impacts of GCM downscaling on hydrologic projections for the Pacific Northwest

Javier Homero Flores Cervantes, University of Washington; John Abatzoglou and Katherine Hegewisch, University of Idaho; Philip Mote, Oregon State University; and Dennis Lettenmaier, University of Washington

Climate projections from global climate models (GCMs) have been combined with hydrologic models to estimate changes in the future water resources of the Pacific Northwest in several recent studies. Translating coarse scale information from GCMs to the finer scale resolution of hydrologic models is a required step that can be done through a variety of downscaling methods. We report on an evaluation of three statistical, one dynamical and one hybrid-bias-corrected-dynamical downscaling method, and their implications for hydrologic predictions using the Variable Infiltration Capacity (VIC) hydrology model aimed at better understanding the uncertainty in future hydrologic projections associated with alternate downscaling methods. Four of the methods downscale solar radiation and specific humidity from climate model output in addition to the typical downscaled variables in these types of studies (e.g., precipitation, maximum and minimum temperature, and wind speed). This is a departure from previous hydrologic modeling work where solar radiation and specific humidity have been estimated from index methods that use downscaled temperature (and daily temperature range) and precipitation as inputs. An outstanding question we address is whether this alternate approach influences hydrologic projections. In addition, these same four methods directly translate daily information from the GCMs, in contrast to the more commonly translated monthly aggregated data. Our results indicate that in general, the statistical downscaling methods yield similar hydrologic results, and better reproduce (by construct) historical observations than does dynamic downscaling. However when the dynamic downscaled output is bias-corrected (through the hybrid approach), the historical results are comparable to those produced by the statistical methods.

P51 30 Arc-Second Historical and Forecast Monthly Climate Data: a Case Study for Oregon

Thomas Mosier and David F. Hill, School of Civil and Construction Engineering, Oregon State University; Kendra V. Sharp, School of Mechanical, Industrial, and Manufacturing Engineering, Oregon State University

High spatial resolution climate data are necessary to study many of the systems affecting people and resources in the Pacific Northwest and beyond. This study presents datasets, gridded to 30 arc-seconds, of historical and forecast monthly precipitation and mean temperature, produced using a Delta downscaling method. For the historical period, from 1901 through the present, inputs of time-series data from Willmott and Matsuura and climatology data from WorldClim are used. For Oregon, the historical Delta grids are of similar quality to analogous datasets by PRISM, when evaluated through comparing the Delta grids to Global Historical Climatology Network station data for the region (e.g. the aggregated mean absolute errors for the Delta downscaled and PRISM data are 0.61 and 0.75 degrees Celsius, respectively). 30 arc-second datasets of forecast climate conditions are constructed through an analogous Delta downscaling method, but using global climate model (GCM) time-series data from the National Center for Atmospheric Research's (NCAR) CCSM3 model and corresponding GCM climatologies distributed by WorldClim. GCM Delta downscaled data are produced for the A1B, A2, and B1 emissions scenarios developed by the Intergovernmental Panel on Climate Change, thus allowing a range of possible future conditions to be compared. The resulting 30 arc-second spatial resolution monthly precipitation and mean temperature datasets are then used to evaluate relative seasonal and long-term trends between emissions scenarios. Analysis focuses on Oregon; however, three strengths of the Delta downscaled datasets discussed herein are that they are made freely available by the authors, have a spatial resolution of 30 arc-seconds, and coverage for all global land surfaces.

P52 Changing Waveforms of Winter Precipation in Western Washington and Oregon

Gregory D. Bothun, University of Oregon, Dept. of Physics; Adrien Wilkie, University of Oregon, Dept. of Physics and USEPA, Chapel Hill, NC; Stephanie C. Ostrander, University of Oregon, Dept. of Physics

Total winter season precipitation in Western Oregon and Western Washington is relevant to many PNW economic and social domains including a) watershed/habitat management b) forest management, c) hydroelectric power yield, d) the length of the ski season, etc. Reliable future predictability of total winter time precipitation is therefore helpful to various planning exercises. Using the available Historical Climate Network (HCN) we have analyzed approximately 30 sites in both Inland Western Washington and Oregon (mostly Willamette Valley) that have good data going back to approximately 1900. We define a baseline of 1900-2000 to assess "normal" behavior and then measure individual year data deviations in units of standard deviations. We define the winter precipitation season to be 4 months long beginning in November and ending in February. Using a weighted z-score analysis, coupled with adaptive kernel smoothing, we are able to generate statistical waveforms of this total precipitation to detect and analyze change with time. To date, this analysis has produce two statistically significant results: a) on timescales of 10-15 years there are significant changes in the overall precipitation amounts in terms of excess or deficit rainfall amounts relative to the 20th century baseline average – that is, multi-decadal variability is large for this parameter; b) since around 2000 we are currently experiencing the longest period of deficit rainfall over the history of this data set. In general, Inland Western Washington shows higher volatility than Inland Western Oregon. This analysis has also reaffirmed the presence of two significant droughts in the late 1920s and 1930s but those drought waveforms are significantly different than the current one. A functional fit to the whole data set indicates that, as of a few years ago, the precipitation waveform should have shifted away from this current deficit. To the extent that the real precipitation has remained in deficit (the major exception is the La Nina spike in the winter of 2006/7) defines the nature of climate change currently happening in this region. Based purely on this emerging deficit waveform, there is no indication that Western Oregon/Western Washington will return to seasons with excess precipitation.

P53 Providing climate change projections and impacts through databasin.org

D. Bachelet, Data Basin team, Conservation Biology Institute; P. Mote, D. Rupp, Oregon State University; J. Abatzoglou, University of Idaho; D. Lettenmaier, U. Washington

Multiple Landscape Conservation Cooperatives (LCCs) have identified the need to develop or leverage existing regional information management and decision-support systems as a critical component to achieve sustainable landscape conservation. The Conservation Biology Institute (CBI) collaborated with several LCCs and the Integrated Data Management Network team on pilot projects to develop Conservation Planning Atlases (CPAs). CBI has started to design, develop and launch CPAs for the South Atlantic LCC (http://salcc.databasin.org/), Gulf Coast Plains and Ozarks LCC (http://gcpolcc.databasin.org/), and the Southeast Region (http://seregion.databasin.org/) while working on similar CPAs for the North Atlantic LCC and Gulf Coast Prairie LCC. A new project will soon create a contiguous cluster in the northwest (California, Great Basin, Great Northern, North Pacific), and Alaska region (Western Alaska LCC, Northwest Boreal LCC, Arctic LCC, and Aleutians and Bering Sea LCC). CPAs make it easy to find, visualize, and process basic geospatial data in support of conservation planning and science delivery. Access to the downscaled CMIP5 climate projections as well as future climate impacts from VIC (hydrological results), 3PG (species range contraction/expansion), and MC2 (fire risk, vegetation type shifts) will bring added value to these sites and allow for wide use and recognition of their valuable contribution to the design of climate change management strategies. We will demonstrate the user-friendly interface, well-documented datasets, basic geo-processing tools, and collaborative networking that databasin.org can provide to each of the LCCs in close collaboration with the NW Climate Science Center climate change scientists who are providing the climate and impacts data and their documentation.

P54 A new waterhshed-scale research landscape: Berners Bay, Juneau

Brian Buma and Sanjay Pyare, University of Alaska Southeast; Anne Beaudreau, University of Alaska Fairbanks; Dave Tallmon, Eran Hood, and Brian Vander Naald, University of Alaska Southeast

A new research area has been established in Berners Bay, Alaska, as part of the NSF EPSCoR program. This new research area, a rich landscape of Northwest temperate rainforest on the Alaskan coast just north of Juneau, spans a landscape from ice fields to saltwater and encompasses a diverse range of abiotic conditions, biotic inhabitants, and human pressures. Many interesting ecological and geological processes are evident. The area is subject to glacial recession and rebound, which alters the fluvial, biogeochemical, and thermal properties of the hydrologic system, upon which a range of natural systems and ecosystem services rely. In addition to a wide range of natural systems (from saltwater to forests to tundra), this area is also home to several industries such as mining, fishing, and logging and a new US Forest Service Experimental Forest, the Heen Latinee.

The research goals of the Berners Bay test case are to (1) understand how climate-glacier dynamics influence spatiotemporal variability in other ecosystem complexes within the watershed, (2) understand how this variability affects key ecosystem services such as salmon and the communities that rely on those services, and (3) understand the capacity of local businesses, governments, and others to adapt to changes in the ecosystem. Several governmental agencies and non-governmental groups have provided information, datasets, and other resources, and new faculty have been hired. Research is centered at the University of Alaska Southeast, in Juneau. Research into near-shore systems, glacial dynamics, forest dynamics and biogeochemistry are already underway.

The Berners Bay ecosystem presents an excellent opportunity to investigate a range of climate change impacts and human pressures on a relatively pristine ecosystem. The poster will present the research area, the people currently conducting research in the Berners Bay system, and serve as a catalyst for further research ideas, collaborations, and interdisciplinary/interagency projects.

P55 A comparison of approaches to producing downscaled future vapor pressure when it is not provided by the General Circulation Model

Raymond J. Drapek, USDA Forest Service, Pacific Northwest Research Station

The lack of vapor pressure data is a problem that frequently arises when downscaling climate datasets for vegetation modeling from general circulation models (GCMs). A frequently used workaround is to use minimum temperature as a proxy for the dew point. This is known to cause problems, particularly in dry locations where nightly minimum temperatures frequently are above the dew point. We explored three alternative approaches to approximating vapor pressure when it is not explicitly provided by the climate model. These include: 1) using minimum temperature as a proxy for dew point, 2) assuming that relative humidity for the baseline period is maintained into the future, 3) use known relationships between temperature anomalies and vapor pressure anomalies to estimate vapor pressure from temperature changes. To explore these approaches we used GCM models and scenarios (IPCC Fourth Assessment) for which some measure of surface water vapor was available in the monthly future climates. We compared vapor pressure from our three proxy methods to the vapor pressure produced by the GCM. We found that the second and third approaches were significant improvements over the first, and that the second approach was marginally better than the third since errors did not grow as much for late 21st century estimates of vapor pressure.

P56 The Use of Innovative Emissions Accounting Frameworks to Provide Multiple Perspectives on Oregon's Contribution to Global Greenhouse Gas Emissions

Colin McConnaha and David Allaway, Oregon Department of Environmental Quality; **Bill Drumheller**, Oregon Department of Energy; Brian Gregor, Oregon Department of Transportation

The manner in which Oregon residents, businesses, governments, and other entities contribute to greenhouse gas emissions span nearly all activities that Oregonians engage in. These emissions occur both in-state and out-of-state, and as a consequence of both production and consumption. No single emissions accounting method adequately captures all of the emissions. As a result, no single approach to inventorying greenhouse gas emissions at the state level is necessarily the "right" method for all contexts. This multi-agency project, and the resulting technical report, is the first attempt by a state government to provide a greenhouse gas inventory using multiple emission accounting methodologies, each of which utilize innovative methodologies or models and that collectively represent a novel approach to the presentation of a state's greenhouse gas emissions.

Three separate inventories were developed for this project with a primary focus on the year 2010, but also with varying historical data included depending on the inventory approach.

1. In-boundary emissions: Emissions that occur within Oregon's borders and emissions associated with the use of electricity within Oregon. For the year 2010 this inventory combines for the first time the "top down" modeling and estimation data which has historically comprised the Oregon greenhouse gas inventory with "bottom up" data reported to the state from emitting facilities and energy providers as part of the state's greenhouse gas reporting program.

2. Consumption-based emissions: Global emissions associated with satisfying Oregon's consumption of goods and services, including energy. This inventory includes life-cycle emissions associated with the food, vehicles, appliances, furnishings, electronics, other goods, services, fuels and electricity that comprise final demand.

3. Expanded transportation sector emissions: An expanded evaluation of the emissions associated with the transportation sector using life-cycle emissions from fuel use by ground and commercial vehicle travel, freight movement of in-bound goods by all other modes of transportation (heavy trucks, railroads, ships, airplanes, and pipelines), and air passenger travel.

Emissions in the in-boundary inventory declined approximately eight percent between 2005 and 2010, while the consumption-based inventory shows no change between these years, even as population grew. The expanded transportation inventory shows a recent decline in emissions from passenger vehicles, while emissions from the freight and air travel market segments have increased. Regardless of the inventory approach utilized, the inventories show that the legislatively adopted greenhouse gas emission reduction goal for Oregon of arresting emissions growth by 2010 has been met.

P57 Researcher Teacher Partnerships: Improving climate literacy and the teaching of science in middle and high school classrooms

Kari O'Connell, Oregon Natural Resources Education Program, Forestry & Natural Resources Extension, Oregon State University; Patricia D. Morrell, School of Education, University of Portland; Peder Nelson, Department of Forest Ecosystems and Society, Oregon State University; Ryan Collay, Science and Math Investigative Learning Experiences, Oregon State University

A great need exists for transferring accurate, timely, and research-based information about climate change to the public. However, the relative isolation of the scientific community from the public results in a slow trickle-down of scientific knowledge, methods and technologies. As a way to bridge this gap and to improve the teaching of climate science to Oregon middle and high school students, we designed a professional development project that brings together OSU science educators and climate change researchers to engage Oregon teachers in three-week summer research institutes. The institutes include two weeks for conducting research with scientists studying climate change in forests of the Pacific Northwest and one week of training to introduce teachers to key climate change topics and support application of their research experiences to their classrooms. 14 Oregon middle and high school teachers, working with over 1400 students per year have so far participated in the NASA-funded Researcher-Teacher Partnerships (RTP) professional development project. Through participation in the RTP project, the teachers increased their own climate literacy, strengthened their understanding about the nature of current scientific practices and research, and were better able to convey these important concepts to their students. In addition, OSU scientists reported that working with the teachers resulted in improving their ability to communicate with people outside their field. We will present examples of how teachers used their climate change research experiences to design and implement inquiry-based teaching units about climate change in their classrooms and ideas for expanding on this model for improvement of teaching about climate change science.

P58 Demonstration of Kepler workflows for efficient management of eco-hydrologic model simulations over the Pacific Northwest region

Tristan Mullis, Mingliang Liu, Anantharaman Kalyanaraman, Joseph K. Vaughan, and Jennifer C. Adam, Washington State University

Kepler is a workflow design tool that enables scientists to develop and implement complex scientific workflows that are automated, reusable and portable across a wide range of computational environments including those including multiple high performance computing platforms. In this project, we are investigating the development of Kepler workflows for the BioEarth project. BioEarth seeks to improve our understanding of the interactions among carbon, nitrogen, and water at the regional scale (PNW). BioEarth is exploring these issues in the context of global change, to inform decision makers' strategies regarding natural and agricultural resource management. The BioEarth project presents a highly challenging and compelling case study for Kepler demonstration, owing to the diverse range of model codes and execution environments involved. As a pilot demonstration of Kepler, we are currently designing fully-automated workflows for running the GIS-based RHESSys hydrological modeling framework, for the purposes of both calibration and actual modeling of BioEarth scenarios. Our goal in developing these workflows is not limited to providing an easier way to run models such as RHESSys, but also to create the building blocks required to perform larger and more complex modeling tasks. Hence, in this demonstration case, by using Kepler the tasks of preprocessing, executing RHESSys, and output data post-processing can all be expressed as a single workflow made of smaller individual workflows.

Kepler is a multi-institutional collaborative project led out of UC-Davis, UC-Santa Barbara and UC-San Diego. The Kepler graphical user interface (GUI) provides the user with a diverse and growing library of predefined workflow functions, called actors. Workflows created by the user are stored and are reusable and modifiable into new workflows. The GUI represents workflows as icons with explicit, visible input and output flows for files or other data streams, parameters, trigger signals and error flags. Workflows therefore make explicit and visible those kinds of interface 'hooks' that are required to run a specific model (RHESSys in our demonstration) but are quite invisible to the user in the case of a shell script, a common and default means of running such models. Additionally, Kepler supports a feature known as Provenance, which refers to the maintenance of a database storing metadata describing workflow executions. Provenance offers a means to log, report and track progress of required model executions and to determine file identities and dependencies throughout a complex project.

Concurrent session 3

Toward integrated scenarios of climate, hydrology, and vegetation for the Northwest

Philip Mote (1), John Abatzoglou (2), Dominique Bachelet (3), Javier Homero Flores Cervantes (4), Katherine Hegewisch (2), Dennis Lettenmaier (4), and David Rupp (1)

1: Oregon Climate Change Research Institute, Oregon State University
2: Department of Geography, University of Idaho
3: Conservation Biology
4: Department of Civil and Environmental Engineering, University of Washington

As scientists strive to understand and predict effects of climate change on various aspects of the region, including not least the ecosystem services that nature provides, a foundational piece of knowledge they require is how the climate, the water cycle, and the vegetation will change in the future. This project integrates, for the first time, state-of-the-science predictive modeling of these different attributes of the future environment in the Northwest, and will provide coherence and guidance for many scientific studies seeking to work out the details of how climate change will affect river flows, various plant and animal species, and other aspects of the Northwest environment. The climate scenarios are developed from the Coupled Model Intercomparison Project (CMIP5) by evaluating the performance of CMIP5 models in the region and by using a fairly new statistical downscaling approach, Multivariate Adaptive Constructed Analogs (MACA). Hydrologic data are developed using most of the CMIP5-MACA scenarios and two hydrologic models, a recent version of the workhorse Variable Infiltration Capacity model and a new model, the Unified Land Model. The suitability of future habitat for native tree species is projected using the 3PG hybrid modeling approach using climate niche species models and mechanistic model algorithms. Vegetation shifts and fire regime changes are simulated using a new version of the MAPSS-Century model, MC2.Throughout, the emphasis is on using best available methods to quantify uncertainty and describe how well each change is understood. Digital data produced by the project are becoming available through the Northwest Knowledge Network.

H-14 Integrated scenarios in the Pacific Northwest: hydrology

Javier Homero Flores Cervantes, University of Washington; John Abatzoglou and Katherine Hegewisch, University of Idaho; Philip Mote, Oregon State University; and Dennis Lettenmaier, University of Washington

Climate and hydrologic projections indicate changes in the water resources of the Pacific Northwest in the coming decades, with implications for water management and potential shifts in ecosystems. Generally climate, hydrology and vegetation studies are carried out independently, resulting in an array of estimates that sometimes are incongruent. This presentation is part of a collaborative and coordinated effort to produce integrated future scenarios of climate, hydrology and vegetation for the region; this presentation focuses on the hydrology scenarios. For this work we use a subset of 'the best' ten of the IPCC 5th Assessment Report (AR5) scenarios from global climate models (GCMs) as archived by the Coupled Model Intercomparison Project 5 (CMIP5), and two global greenhouse gas emissions scenarios, with a focus on the implications of these scenarios for the hydrology of the Pacific Northwest. New methods to downscale the coarse resolution GCM data (1-2 degrees latitude by longitude) to the finer hydrologic modeling resolution (1/16 deg) were evaluated as well. Future hydrologic scenarios were produced using the Variable Infiltration Capacity (VIC) and Unified Land Model (ULM) hydrologic models, forced with downscaled GCM data, at a 3-hourly, 1/16 degree spatial resolution. Among the variables produced were: evapotranspiration, soil moisture, snow water equivalent, base flow and runoff, sensible and latent heat, and net radiation. We present preliminary results of our modeling effort, including changes in climatology for specific locations in the domain and spatial maps of average values of each variable in the region at the 1/16 degree spatial resolution during different future periods. In general, as mean temperatures rise, there is an increase in evapotranspiration losses at the expense of water available for runoff, and both base flow (especially in summer) and soil moisture decrease by the 2040-2070 future scenarios, relative to the 1970-1999 historical period.

Simulating vegetation change, carbon cycling and fire over the western US using CMIP5 climate projections

Dominique Bachelet, Ken Ferschweiler, and Tim Sheehan, Conservation Biology Institute; Dave Turner, Oregon State University

The dynamic vegetation model MC simulates vegetation distribution, biogeochemical cycling and wildfire in a highly interactive manner. It has been widely used at multiple scales (30arc sec to .5 deg) to simulate potential vegetation shifts, C fluxes and dynamic wildfires in National Parks, individual states, across the nation and the continent as well as globally for a handful of climate change scenarios. In this new project, the model is using a suite of climate futures from the Coupled Model Intercomparison Project (CMIP5) downscaled using a fairly new statistical downscaling approach, Multivariate Adaptive Constructed Analogs, over the western US. The model is run on the NASA Earth Exchange (NEX) platform at 4km resolution since it requires the large-scale computing power to produce results for > 30 climate futures in a reasonable time frame. Early results show large shifts in vegetation towards warmer types (e.g. temperate to subtropical forest types, warm subtropical grasslands replacing cool temperate grasslands) and an expansion of forest types enhanced by a moderate CO_2 effect on water use efficiency and production when water availability declines. While all climate models project warmer conditions, they differ in their projections of the seasonality and magnitude of rainfall. The model is sensitive to the water available for plant production and soil organic matter decomposition, fuel-build up and wildfire occurrence. Complex interactions of climate and disturbance drive the large changes the model is simulating with much geographic patchiness due to soil types as well as temporal variability due to changes in rainfall seasonality.

BioEarth: A Regional Biosphere-Relevant Earth System Model to Inform Agricultural and Natural Resource Management Decisions

J.C. Adam (a), J.C. Stephens (b), S.H. Chung (a), M.P. Brady (c), R.D. Evans (d), C.E. Kruger (e), B.K. Lamb (a), M.L. Liu (a), C.O. Stöckle (f), J.K. Vaughan (a), K. Rajagopalan (a), J.A. Harrison (g), C.L. Tague (h), A. Kalyanaraman (i), Y. Chen (j), A. Guenther (k), F.Y. Leung (a), L.R. Leung (l), A.B. Perleberg (m), J. Yoder (c), E. Allen (n), S. Anderson (d), B. Chandrasekharan (c), K. Malek (f), T. Mullis (i), C. Miller (g), T. Nergui (a), J. Poinsatte (d), J. Reyes (a), J. Zhu (h), J.S. Choate (h), X. Jiang (k), R. Nelson (f), J.H. Yoon (l), G.G. Yorgey (o), K.J. Chinnayakanahalli (p), A.F. Hamlet (q), B. Nijssen (r)

(a) Civil and Environmental Engineering, Washington State University; (b) Environmental Science & Policy, IDCE, Clark University; (c) School of Economics, Washington State University, (d) School of Biological Sciences, Washington State University; (e) Center for Sustaining Agriculture and Natural Resources, Washington State University, Wenatchee; (f) Biological Systems Engineering, Washington State University; (g) School of the Environment, Washington State University, Vancouver; (h) Bren School of Environmental Science and Management, University of California, Santa Barbara; (i) School of Electrical Engineering and Computer Science, Washington State University; (j) Agricultural and Resource Economics, Oregon State University; (j) Atmospheric Chemistry Division, National Center for Atmospheric Research; (k) Atmospheric Sciences and Global Change Division, Pacific Northwest National Laboratory; (l) Chelan County Extension, Washington State University, Wenatchee; (n) School of the Environment, Washington State; (o) Center for Sustaining Agriculture and Natural Resources, Washington State University West, Seattle; (p) State of Washington Water Research Center, Washington State; (q) Civil and Environmental Engineering and Earth Sciences, University of Notre Dame; (r) Civil and Environmental Engineering, University of Washington

As managers of agricultural and natural resources are confronted with uncertainties in global change impacts, the complexities associated with the interconnected cycling of nitrogen, carbon, and water present daunting management challenges. Existing models provide detailed information on specific sub-systems (land, air, water, economics, etc). An increasing awareness of the unintended consequences of management decisions resulting from interconnectedness of these sub-systems, however, necessitates coupled regional earth system models (EaSMs). Decision makers' needs and priorities can be integrated into the model design and development processes to enhance decision-making relevance and "usability" of EaSMs. BioEarth is a current research initiative with a focus on the U.S. Pacific Northwest region that explores the coupling of multiple stand-alone EaSMs to generate usable information for resource decision-making. Direct engagement between model developers and non-academic stakeholders involved in resource and environmental management decisions throughout the model development process is a critical component of this effort. BioEarth utilizes a "bottom-up" approach, upscaling a catchment-scale model to basin and regional scales, as opposed to the "top-down" approach of downscaling global models utilized by most other EaSM efforts. This paper describes the BioEarth initiative and highlights opportunities and challenges associated with coupling multiple stand-alone models to generate usable information for agricultural and natural resource decision-making.

Assessment of uncertainties on the impact of climate change on water resources management using an integrated Earth System Model: application over the Columbia River Basin.

Nathalie Voisin, Maoyi Huang, Teklu Tesfa, Hongyi Li, and Ruby L-Y Leung, Pacific Northwest National Laboratory

Multiple integrated climate change impact assessments have been performed over the Pacific Northwest hydrology, water resources management and crops models. Usually downscaled climate change meteorological forcing force a hydrology model which in turns forces a crop model and/or a water resources management model. Most of the time, the chain is integrated but without feedback between all of the components. For example the impact of climate change on crop is assessed assuming no change in irrigation water availability. On the other end the effect on water resources management is usually assessed assuming no change in irrigation demand and using existing operations rules for optimization. Both crop and water resources management models assume negligible effect of their redistribution of water resources in space and time over evapotranspiration fluxes and consequently feedback into the atmosphere. A large scale water resources management model was recently developed and coupled to a new dynamic routing model (MOSART-WM). WM differs from decision support systems that require the perfect knowledge of future flow and dynamically optimize reservoir operations. Instead, reservoirs releases are configured based on long term mean monthly inflows into the reservoirs, water demand associated to the reservoir, reservoir usage and physical characteristics Those "generic operations" are calibrated using unregulated flow and irrigation demand of a recent retrospective period. We estimate the uncertainty in climate change assessment on the water resources management over the Columbia River Basin, USA by comparing regulated flow and irrigation supply when using the MOSART-WM forced with constant historical demand and CLM simulated hydrology under future climate with generic operating rules configured with either i) past flow or ii) future flow characteristics.

Extreme events in dynamically downscaled climate change scenarios for North America

L. R. Leung, Y. Liu, Y. Gao, M. Huang, and Y. Qian, Pacific Northwest National Laboratory

Driven by large scale as well as regional scale forcing, the signals and impacts of climate change can vary across a wide range of spatial and temporal scales. To provide insights on regional climate change, particularly related to processes such as extreme events that are more local to regional in scales, we used a regional climate model based on the Weather Research and Forecasting (WRF) model coupled with the Community Land Model (CLM) through a flux coupler to develop regional climate change scenarios for North America. WRF-CLM was applied at 20 km grid resolution with large-scale boundary conditions provided by the Community Climate System Model version 4 (CCSM4) as part of the Coupled Model Intercomparison Project (CMIP5) multi-model ensemble of global climate projections. Simulations were performed for the historical climate from 1975 – 2004, and for the future (2005 – 2100) for two Representative Concentration Pathway emission scenarios, namely RCP4.5 and RCP8.5. The downscaled climate is being evaluated using observations and compared with the global simulations, with a focus on extreme events such as heat waves and droughts. The regional climate change scenarios are being used as part of the Platform for Regional Integrated Modeling and Analysis (PRIMA) to advance understanding of the nexus among climate, energy, and the environment.

Impact of projected changes in wave climate on extreme total water levels in the US Pacific Northwest

Katherine A. Serafin and Peter Ruggiero, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University; and Li H. Erikson, Pacific Coastal and Marine Geology Program, United States Geological Survey, Santa Cruz

The Pacific Northwest (PNW) has one of the most energetic coastlines in the world, with storm induced wave heights exceeding 10 m approximately once per year. Extreme wave heights have been documented to increase over the past thirty years; however, projections of future wave climates dynamically downscaled from Global Climate Model (GCM) outputs indicate a possible reduction in wave height by the end of the 21st century. Projections also indicate a slight increase in wave period and a possible counter-clockwise rotation in incident wave direction, complicating the resultant impacts on future coastal hazards. Because of the large role that each of these variables describing the wave climate plays in erosion and flooding along the coast, the projected changes are investigated by examining extreme total water levels (TWLs) at the coastline.

TWLs are computed by combining sea level elevations extracted from tide gauges with wave runup estimates, calculated as a function of foreshore beach slope and incident wave height, period and direction, shoaled to the 20 m contour. A newly developed time-dependent, full simulation model is applied to produce multiple, synthetic time series of the TWL, accounting for seasonality and trends in wave heights and water levels. Synthetic time series are generated based on (1) the present day wave climate, and (2) projections of the future wave climate using two climate change scenarios: RCP4.5 and RCP8.5, a lower level and a higher level emissions scenario, respectively. The impact of changes in wave climate on TWLs is compared to present day TWLs to estimate the possible range of future flooding and erosion events. Understanding the variability and trends in extreme TWL events will aid in coastal planning and hazard preparedness efforts.

Incorporating stakeholders' perspectives into ecosystem services assessment under climate change and land conversion scenarios in the Lower Willamette Valley

Heejun Chang, Wes Hoyer, and Mike Psaris, Department of Geography, Portland State University; Samantha Hamlin, School of the Environment, Portland State University; Dave Ervin, Department of Economics, Portland State University; and Bobby Cochran, Willamette Partnership

While there is a growing interest in addressing potential shifts in future ecosystem services under a combination of climate change and land conversion scenarios, few has incorporated the viewpoints of different stakeholders into ecosystem services assessment. Here we present a method of integrated assessment of climate change and land development for quantifying possible changes in the provision of ecosystem services with explicit stakeholder engagement. A rapidly growing urbanizing area in the Lower Willamette Valley serves as our case study. Our stakeholders, comprised of local land owners, regional planners, and environmental conservationist, have provided valuable inputs not only in the development of possible land conversion and alternative conservation scenarios but also different weighting schemes for assessing potential tradeoffs among multiple ecosystem services under different set of scenarios. Feasible future land development and conservation scenarios were constructed by expert panel, and weighting schemes for the relative importance of individual ecosystem service and location were ranked by stakeholder preference. While there is a general consensus on the value of water provisioning services among different stakeholders, other site-specific ecosystem services such as agricultural production and biodiversity maintenance differ significantly by different stakeholders. By engaging stakeholders at multiple stages of project implementation, we demonstrate the co-benefits of dialogues between scientists and policy makers in identifying mutually agreeable areas of conservation to maximize the provision of multiple ecosystem services. Such a participatory decision-making process can be transferable to any areas for prioritizing possible conservation areas under increasing climate uncertainty.

Assessment of water-related ecosystem services in the Tualatin and Yamhill basins under climate and land cover change: A scenario-based approach

Wes Hoyer, Heejun Chang, Mike Psaris
Department of Geography, Portland State University

Water-related ecosystem services (WES) are vital to human populations in need of a clean and adequate water supply. The ability to assess WES is an important task facing researchers as the quality and quantity of these services are sensitive to variable climatic and landscape conditions. Projecting the response of WES to climate and land use/land cover change has utility in supporting future policy decisions to help insure they are not degraded under future pressures. We estimated potential changes in WES in the Tualatin and Yamhill basins of northwest Oregon that are anticipating increased pressures from climate change and population growth. A spatially-explicit ecosystem service specific model, Integrated Valuation of Environmental Services and Tradeoffs (InVEST), was used to assess 30 year annual average water yield and quality (total phosphorus, total nitrogen, and total suspended sediments). Historic climate (1981-2010) and current land cover data were first used to create baseline outputs for InVEST. They were calibrated to aggregated average daily runoff data, and empirically estimated water quality constituent loadings using the USGS's maximum likelihood regression LOADEST software. Future climate and land cover data were then employed to produce eighteen scenarios for a thirty year annual average centered on the year 2050. Water yield results agree well with the well-respected hydrological model Soil and Water Assessment Tool (SWAT). Nutrients and sediments results show less agreement with SWAT indicating greater uncertainty. The scenario analysis shows annual water yield remains similar or is slightly reduced compared to current conditions, and is more sensitive to climate change than to land cover change. InVEST's nutrients and sediment models are more sensitive to land cover change. The spatial configuration at the sub-basin scale of ecosystem services remain relatively unchanged however as agriculture land converts to urban, the load contribution of some basins decline. Findings suggest InVEST's current potential is as a policy decision support tool for long-term and landscape scale planning. Its utility lies in analyzing service tradeoffs among differing land management visions and has limited efficacy for targeting specific locations for field/local scale management. As InVEST tools continue development, we suggest enhancing their sensitivity to climate as well as adapting to a mid-scale time-step.

Evaluation of a Soil and Water Assessment Tool stream temperature model for assessing the impact of climate and land use change on stream habitat conditions in the Lower Willamette Valley

Tammy Winfield and John Lambrinos, Department of Horticulture, Oregon State University; Mike Psaris and Heejun Chang, Department of Geography, Portland State University

The regulation of water temperature is an important ecosystem service, but climate and land use change could alter the spatial and temporal patterns of water temperature. A number of existing models can predict stream temperature. However, many of these are either difficult to apply at regional and long term scales or lack the mechanistic detail to produce robust results. In this study we evaluated the potential of a recently developed stream temperature model within the Soil and Water Assessment Tool (SWAT) to evaluate the impact of climate and land use change on stream temperature within the Tualatin and Yamhill basins of the Willamette Valley. We first evaluated how well the temperature model reflected observed patterns in stream temperature at multiple locations and then preliminarily evaluated the sensitivity of the model to climate and land use parameters. We parameterized SWAT models for both the Tualatin and Yamhill basins as a whole and for three separate sub-basins within the Tualatin. We calibrated models based on observed daily and monthly stream flow, and then used the flow calibrated models to compare simulated and observed stream temperature. The globally parameterized Yamhill and Tualatin models accurately predicted mean monthly stream temperature over the observed periods with R2 ranging from 0.89 to 0.92 and % bias ranging from -8.72 to -15.72. Models specifically parameterized at the sub-basin level produced similar results with calibration statistics within the ranges observed for the globally parameterized models. The models accurately predicted the observed seasonal patterns in mean stream temperature as well as yearly variation in observed maximum stream temperatures. The models also produced expected spatial patterns with stream temperature generally increasing downstream and in more urbanized sub-basins. We conducted a preliminary sensitivity analysis by independently running our models using different climate and land use data sets. Initial results suggest that the SWAT temperature model is highly sensitive to changes in climate parameters, but relatively insensitive to land cover parameters in our study area. These results could reflect the fact that the SWAT temperature model only implicitly accounts for the influence of land cover on stream temperature. Overall, our findings indicate that the SWAT temperature model can be a valuable tool for evaluating the influence of climate change on stream temperature patterns at basin and sub-basin scales, but more analysis is needed to evaluate the degree to which the influence of land cover changes are accurately accounted for by the model.

Concurrent session 4

Interagency and Community Collaboration to increase resiliency in a Changing Climate

Mary Gwyneth Myer, Southern Oregon Forest Restoration Collaborative; Ken Wearstler, Rogue River-Siskiyou Forest Service

The Southern Oregon Forest Restoration Collaborative has engaged a variety of partners and stakeholders to create a Climate Adaptation and Implementation Plan for the Rogue Basin. Information and data gathering incorporated non-profits, environmental organizations and timber industry, cities and planning offices, watershed councils and agencies. The adaptation plan describes the Rogue Basin's climate variability and change over time; makes connections between climate and forest, water, and economics; addresses climate-related natural hazards such as wildfire, drought, flooding, and invasive species; and incorporates actionable, localized solutions. While the science is noteworthy, we choose to focus here on our efforts to incorporate science into community engagement, planning, policy, and resource management programs and decisions.

The Collaborative has partnered with the Rogue River-Siskiyou Forest Service (RRFS) in the development of this climate adaptation plan, with the shared goal of bringing climate resilience to our public land forests. The RRFS is stretched thin with budget cuts and heavy workloads. At the same time, needs are increasing with the stress of climate change impacts, as exemplified by increased wildfires. Working with the Collaborative and other partners increases community involvement, and helps the Forest Service address challenges. In turn, the Forest Service helps to increase the organizational capacity of partners, such as the Collaborative, by assisting with funding, research, data collection, and monitoring, and helping the community find other sources of funding. This collaborative effort also engages the community and helps increase trust. The ultimate goal is that the science and recommendations put together by the Collaborative, RRFS, and partners will lead to an all lands approach to forest management to increase resilience for climate change, and build RRFS capacity and community support for adaptation focused forest restoration implementation.

Challenges and successes will be shared, which include stakeholder engagement and building community capacity. As climate change will affect our resources, regardless of measures taken, the main goal of this project is to build capacity to engage and adapt to the changing environment and create a shared vision across federal, local, and private organizations to manage our lands to increase resiliency.

Can cities achieve what Kyoto failed to do? A case study of Seattle's climate policy

Lucy A. Gelderloos

The inadequate progress of international climate policy negotiations, combined with increasing urbanization across the globe, have begun to draw attention to the role that cities might play in addressing climate change at the local level. This presentation will share the results of research just completed on such efforts in the city of Seattle. Seattle is a pioneer in this area, acknowledging the threat of climate change in 1992, making its city-owned electric utility carbon-neutral in 2005, and reducing emissions to 7% below 1990 levels in 2008. This case study of Seattle's climate policy was conducted within a broader examination of questions about scales of governance. It found that a multi-scale approach to climate policy with cities as key players is an effective way to combat global climate change.

Cities, driven by concerns about the threats they face from climate change and by the potential for economic and other benefits from implementing climate policies, face unique advantages and disadvantages in the policy process. On the one hand, they are able to take a very fine-grained approach to climate policy, addressing emissions, adaptation, and other concerns at the level of neighborhoods or even individual buildings. They are able to interact with citizens and build trust in a way that is not practical at the state or federal level. On the other hand, cities often lack jurisdiction in key areas, placing limits on policy as well as financing. This study joins a growing body of research investigating the processes by which cities can play an important role in building a comprehensive and robust global climate policy through a coordinated, multi-scale approach to climate governance.

Translating Climate Futures Into Forest Management Guidance: the experience from British Columbia

Harry Nelson, Forest Resources Management, University of British Columbia; Casey Macaulay, Association of BC Professional Foresters

One of the many challenges in addressing climate change is not only just understanding how it may impact forest ecosystems but also translating what could happen into useful guidance for policy-makers and resource managers taking into account the multiple sources of uncertainty. Many vulnerability assessments paint a broad picture of potential climate scenarios and ecosystem responses; some assessments may then offer a broad array of possible options or promote particular principles to be used in selecting a particular option. Yet given the wide range of options and impacts, often couched with caveats around uncertainty, managers and decision-makers still struggle to understand how that information can be used to provide guidance that can lead to management actions. Indeed the lack of guidance and information has been highlighted as the most important barrier facing forest professionals around climate change in BC (http://www.abcfp.ca/publications_forms/publications/documents/ABCFP_Climate_Change_Survey_2013.pdf).

We examine this barrier through the use of a case study involving the Kamloops Future Forest Project (K2) project, which involved a multi-disciplinary research team consisting of researchers, professional foresters, resource managers, and practitioners. to directly address this challenge of how to generate and use information to provide guidance. The K2 project involved developing a suite of models around tree regeneration, stand development, and forest growth incorporating climate change and management assumptions calibrated to a region within the Kamloops TSA in the British Columbia Interior. These models allowed the team to simulate future climate scenarios and project possible outcomes through which policy makers and resource managers could explore the effectiveness of different management actions in meeting management goals. Through this exercise the team was able to develop management guidance at different scales, corresponding to the different management scales in forestry (strategic and operational).

We discuss the role such models can play in assisting managers and decision-makers while realistically recognizing the uncertainty associated with climate change. We also discuss ongoing efforts to identify additional barriers around the use of generating new information and how information is then utilized as part of the broader effort required to assist forestry professionals in turning adaption principles into actions.

Identifying actionable adaptation pathways for aquatic ecosystem management within the Pacific Northwest Region of the USFS

Shannon Hagerman and **Amy Snover**, University of Washington, Climate Impacts Group

The need to adapt natural resource management to the expected impacts of climate change is well recognized by agencies and organizations across the Pacific Northwest. This recognition has led institutions including the United States Forest Service (USFS) and others to develop polices that require adaptation at regional and sub-regional scales. Yet much of the guidance from within these same institutions and within the adaptation literature more broadly, tends to be limited to principle-based, general recommendations (i.e. increase resilience, foster habitat connectivity, engage stakeholders).

This proposed presentation describes the process and the outcome of a recent collaboration between the USFS and the Climate Impacts Group to translate adaptation principles into a set of actionable guidance to inform decisions relating to aquatic ecosystem management in the PNW. We discuss our approach, key challenges, and underappreciated dimensions of developing adaptation guidance. We also address the broader challenge of implementing adaptation initiatives in ecologically and institutionally distinct resource management contexts.

Predicting optimal forest management strategies to maximize snowpack duration across the Pacific Northwest

Susan E. Dickerson-Lange and Jessica D. Lundquist, University of Washington; Rolf Gersonde, Seattle Public Utilities; Timothy E. Link, University of Idaho; James A. Lutz, University of Washington; Steve Malloch, American Rivers; Anne W. Nolin, Oregon State University; Amy K. Snover, Climate Impacts Group, University of Washington

Both climate and forest characteristics influence the seasonal timing of snowmelt in the mountain watersheds of the Pacific Northwest. Snowmelt is projected to occur earlier in the year due to climate change, which will reduce summer water availability, increase stream temperature, and stress the terrestrial ecosystem. The presence, canopy cover, and species composition of forest are known to influence the timing of snowmelt, but the effect switches direction in different locations. We find that snow lasts two weeks longer on average at our study plots in forest gaps versus dense 2nd growth forest in the maritime climate of the western slope of the Cascades. Previous studies in continental climates have found opposite results with similar magnitudes of difference in snow disappearance timing. Forest management strategies such as thinning, gap-cutting, and forest fuels management have the potential to mitigate climate change effects on snow retention, and consequently streamflow and soil moisture. However, the optimal forest management actions to delay snow disappearance will vary spatially, and under changing climate conditions. Depending on local climate and topographic position, managers in some areas would need to prevent catastrophic fires to retain forest cover while those in other areas would want to strategically open gaps in the canopy.

We combine regional plot-scale observations with an empirical framework derived from an analysis of previous investigations to predict where different forest management strategies could be used to retain snowpack. A synthesis of global plot-scale studies indicates that temperature is a first-order control on whether the presence of forest cover results in a net delay or acceleration of snow disappearance. We leverage this understanding and use 800-m gridded temperature data to build a map of where snow lasts longer under the forest versus in the open in both current and future climate conditions. We will test these predictions against field observations in WA, OR, and ID, and have launched the beta version of a citizen science campaign to gather additional spatially distributed observations from hikers, skiers, and snowmobilers. Refinement of these predictions will include consideration of aspect, which has been previously shown to be as important as the presence of forest on snowpack duration, and detailed watershed scale modeling of two climatically contrasting test basins. Participation in future webinars and meetings, scheduled for January and October 2014, is encouraged for land and water managers, and any interested groups.

Spatial and temporal partitioning of wildland-urban interface fire regimes under future climate, development and management scenarios

Bart R. Johnson, Max Nielsen-Pincus, Cody Evers, Robert Ribe, Christopher Bone, and David W. Hulse, University of Oregon; Alan A. Ager, USDA Forest Service; and John P. Bolte, Oregon State University

Planners, policy makers, land managers and the public need tools for exploring alternative approaches to reducing development impacts in the wildland-urban interface (WUI) under projected climate change. In many areas of the U.S. these include increased wildfire risks to people and homes, as well as biodiversity losses. Tools that allow people to simultaneously consider important tradeoffs in the light of uncertainty are particularly useful. We simulated the interactions and feedbacks among landowner decisions, land use, vegetation and wildfire under 12 alternative scenarios that bracketed key uncertainties in climate change intensity, exurban development and vegetation management. We performed simulations for 50 years (2007-2056) in an 80,000 ha study area outside the Eugene-Springfield metropolitan area in Oregon, USA using Envision, a spatially explicit agent-based model of land use decisions coupled to climate-sensitive models of vegetation succession and wildfire. Five landowner types were classified, located and parameterized for their decision propensities based on a survey of ~1,000 local landowners. The 12 scenarios crossed two climate scenarios (MIROC A2 and Hadley A2) with two land use scenarios (compact and dispersed development) and three approaches to fire hazard management (conventional fire hazard thinning, a mixed thinning/oak-grassland restoration approach, and no fuels management). Using large output data sets that track every landscape change over time, we partitioned wildfire risk in space by examining risk probabilities in different WUI and management zones, and decomposed risk over time as a function of climate change, population growth, and the amount and type of management in place at any given time. Both management approaches substantially reduced the number of homes threatened by wildfire compared to no management in all scenario comparisons. Under MIROC A2, the area burned doubled compared to the recent past but increases were driven almost entirely by increased ignitions from population growth. Large expenditures for conventional thinning did little to reduce wildfire risk compared to grassland restoration, and resulted in continued losses to these imperiled ecosystems. Under Hadley A2, episodic spates of wildfire drove as much as 50-fold increases in area burned. The higher rates of fire spread in grasslands compared to conventional thinnings allowed fire to reach untreated areas that had a high potential for stand-replacing crown fire, resulting in greater risk to homes. Our results identify when, where and under what circumstances wildfire may occur and homes may be threatened. They reveal the complexity of attempting to manage climate impacts while maintaining multiple ecosystem services.

Green infrastructure solutions: a Salish Sea case study evaluating the role of wetlands in protecting communities from increasing storm impacts

Roger Fuller, Western Washington University, and Eric Grossman, U.S. Geological Survey

Communities are protected from floods and storms by both engineered infrastructure like levees, and natural habitat infrastructure like wetlands. We understand the performance and cost effectiveness of grey infrastructure well. However, recent natural disasters have illustrated both its insufficiency in protecting communities and the high repair costs. We know that green infrastructure, or habitat, also protects communities from river floods and coastal storms but we know little about its performance and cost. This knowledge gap leads to greater investment in grey at the expense of green. In Puget Sound we evaluated the changes in ecosystem and community vulnerability that may result from climate change, including changes in high and low flows, sea levels, storm dynamics, sediment recruitment and salinity intrusion, as well as the vulnerability of built infrastructure. Both green and grey infrastructure are vulnerable to climate change and at the same time provide protection from many climate change impacts. We developed a model to quantify the risk reduction provided by tidal wetlands. Storm waves can erode dikes and flood nearby communities. Vegetated tidal wetlands reduce storm wave energy and height by physical interference. And, by trapping sediment, they can self-maintain, a feature that grey infrastructure lacks. Certain habitat characteristics determine the degree to which community risk and economic costs can be reduced. Key habitats for protecting communities can be identified with a wave attenuation model, along with opportunities to reduce risk through restoration. Where tidal wetlands are receding with sea level rise, the model allows users to evaluate the potential change in community risk that may result from this loss of protective infrastructure. With this information, communities can develop better response plans that reduce the costs of disaster prevention and recovery.

The Climate Impact - Decision Support Tool (CIMPACT-DST): A Platform for Integrating Climate Science Information into Everyday Decision Making

Andrea Martin and Spencer Reeder, Cascadia Consulting Group

CIMPACT-DST (Climate Impact – Decision Support Tool) is a first-of-its-kind integrated platform for climate adaptation planning. Currently in use by staff at the City of Seattle and in Hue, Vietnam, the tool helps local governments, planning agencies, and organizations incorporate key data and information regarding current and future climate change impacts into their planning and operations. The tool works by compiling and synthesizing multiple sources of locally-relevant information—including scientific reports, policies, and spatial information (e.g., GIS, maps)—and filtering it based on simple user inputs. This way, the user sees only information that is germane to the task at hand. Once customized for a jurisdiction or locale, the tool supplies the latest climate change information and best-practice adaptation strategies along with local policies and guidelines to provide consistent, sector-relevant climate impact summaries and adaptation strategy recommendations. Within 10-15 minutes, a user can obtain climate impact exposure and guidance information for their project or asset at varying temporal scales, including summary outputs for each of the primary climate impacts: temperature change, precipitation/streamflow changes, and sea level rise. Consistent use of this tool across departments, sectors, and projects within an organization can raise awareness of key climate change issues, build capacity to identify and assess climate risk, and lead to improvements in system-wide resilience to current and future climate impacts.

Strategic prioritization of restoration projects in an urban stream under climate change

Chip McConnaha, ICF International, and **Kaitlin Lovell**, City of Portland Bureau of Environmental Services

The City of Portland has a strategic watershed approach to habitat restoration investments in its urban streams that achieves ecological and infrastructural benefits. A fish-habitat model based on Ecosystem Diagnosis & Treatment (EDT) was constructed to identify restoration potential, prioritize restoration areas and define environmental targets for restoration based on the needs of ESA listed salmonids. Analysis of Johnson Creek, the largest stream within the Portland metropolitan area, indicated two major priorities for restoration: upper watershed sites linking mainstem reaches to Kelley Creek, and lower watershed sites linking Tideman Johnson Park and Crystal Springs. Limiting factors identified for restoration included high water temperature, water quality and lack of woody structural elements. Crystal Springs is a 2.7 mile spring fed tributary to Johnson Creek in urbanized southeast Portland. Intrinsic habitat potential of the stream is relatively high for salmonids but is limited by numerous culverts that restrict fish passage and aesthetic ponds that increase water temperature.

In 2008, the City of Portland committed $2 million to upgrade 8 culverts in Crystal Springs to provide for fish passage, remove ponds and improve stormwater management. The potential value of these and other restoration investments in Johnson Creek appears to be high. However, their biological value could be compromised by climate change. To address this issue, restoration priorities and projects were re-evaluated using the EDT model and a set of assumptions regarding potential increases in water temperature and changes in precipitation that could result from climate change in the Portland area. These presumed future conditions altered the underlying environment and the EDT model then predicted a population and life history response for salmonids. The EDT analysis demonstrated that climate change could significantly reduce salmonid habitat potential in Crystal Springs and Johnson Creek. However, restoration projects, particularly those in Crystal Springs, moderated the impact of climate change; improved habitat fared better than degraded habitat under the climate change assumptions. Important synergisms between projects were revealed that contributed to the benefits under climate change. Because Crystal Springs has the potential to be a steady source of cooler water in the lower watershed with appreciable habitat potential in its own right, its restoration had very high potential under climate change scenarios. These results highlight both the urgency and the continued benefit of salmon restoration projects in urban streams even with expected changes due to climate change.

Closing plenary

The Naional Climate Assessment

Kathy Jacobs, Office of Science and Technology Policy, Executive Office of the President

The US National Climate Assessment is an opportunity for people in every region to document and evaluate the changes occurring within their communities, and to be a part of a scientific process of analyzing impacts and vulnerabilities to climate change. Development of the Third National Assessment Report is nearing completion, with a high-profile release anticipated next spring. More important than the report itself, however, is the process that is being built to support ongoing, rigorous approaches to sustaining the assessment process itself. Building capacity to conduct vulnerability assessments, use scenarios and indicators of change, and document changes over time will help people understand and project potential impacts in the future. This is critical to enhancing resilience and to effective adaptation strategies. A new report providing advice to the federal government on how to sustain such assessment activities and ensure that they are useful for decision-making is near completion.

The Northwest Climate Assessment Report 2013

Meghan Dalton and **Philip Mote**, Oregon Climate Change Research Institute, Oregon State University; Amy Snover, Climate Impacts Group, University of Washington

In an effort that was interleaved with the development of the Northwest chapter of the Third National Climate Assessment, a large team of authors has prepared the Northwest Climate Assessment Report. The approach used a novel risk framework to identify key risks of climate change facing the Northwest. Beginning with a workshop in December 2011, scientists and stakeholders from many backgrounds and many types of organizations from all over the Northwest engaged in an exercise to begin the process of ranking climate risks according to likelihood of occurrence and magnitude of consequences. The intial list of risks considered had been identified in the Oregon Climate Change Adaptation Framework, and the process considered both the likelihoods and consequences of changes. The Report covers risks related to snowmelt-driven hydrology, shoreline change, forest disturbance, agriculture, human health, tribal communities, and economics.

Northwest Tribal Approaches to Climate Change

Kathy Lynn, University of Oregon

Climate change will have complex and profound effects on tribal resources, cultures, and economies. Indigenous peoples have lived in the region for thousands of years, developing cultural and social customs that revolve around traditional foods and materials and a spiritual tradition that is inseparable from the environment. Projected changes in temperature, precipitation, sea level, hydrology, and ocean chemistry threaten not only the lands, resources, and economies of tribes, but also tribal homelands, ceremonial sites, burial sites, tribal traditions, and cultural practices that have relied on native plant and animal species since time immemorial. The cultural, social, and economic integrity of tribal communities, as well as the physical and spiritual health of tribal members, are intertwined with the places, foods, medicines, and resources they adapted to over the centuries. Ecologically and culturally, tribes in the Northwest are embedded in the landscape. As such, climate change could lead to extirpation of some species, migration of species away from traditional gathering areas, and altered timing of resource availability relative to traditional practices, all of which could have disastrous impacts for tribes.

This presentation, which draws from the recent chapter on Northwest Tribes in the forthcoming Northwest Climate Assessment, will synthesize what is currently understood about key climate change vulnerabilities for tribes in the Northwest and potential consequences to a range of tribal cultural and natural resources, traditional foods, and economies. Many tribes in the Northwest are working with others to address climate change by contributing their knowledge about the environment, their staff and equipment on the ground and in the water, their resource management experience, and their authority as natural resource trustees. The wide-range of unique and progressive tribal climate change initiatives including climate assessments, adaptation and mitigation plans, research, monitoring, outreach, and education. In conclusion, the presentation will also discuss challenges of climate change for many tribes, including the need for strengthened government-to-government relationships, increased tribal capacity building and training, tribal participation in climate research and access to climate data, and development and deployment of resources for early detection and monitoring of fundamental ecosystem changes.