PACIFIC NORTHWEST CLIMATE IMPACTS RESEARCH CONSORTIUM (CIRC)
PROGRESS REPORT – YEAR 1

1.AWARD TITLE: CIRC 2.0: Transforming Data into Usable Knowledge for Adapting to Climate Related Hazards in the Pacific Northwest (NA15OAR4310145)

2.PERFORMANCE PERIOD: SEPTEMBER 2015–MAY 2016

3.TEAM MEMBERS:

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- Stephen Lee, University of Idaho
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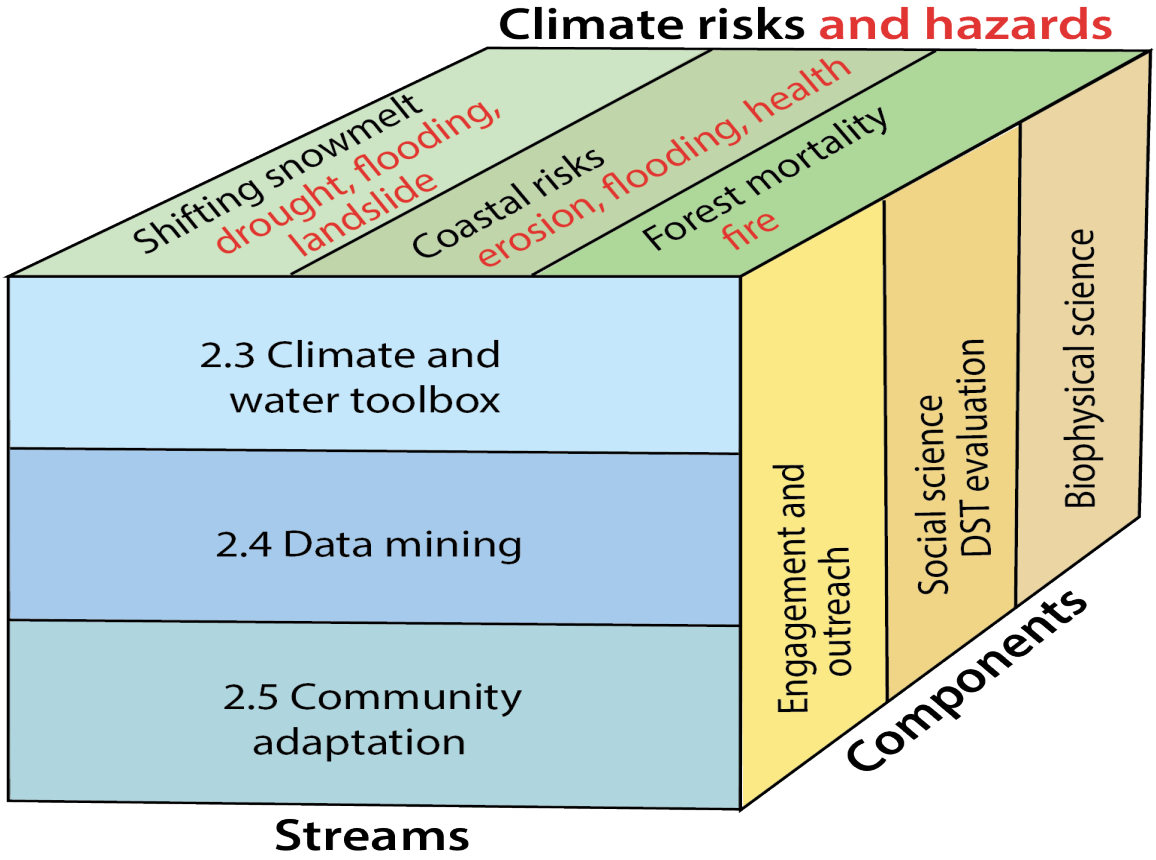
CIRC (stakeholder) Advisory Council (current members as of June 2016)
- Tom Byler, Oregon Water Resources Department
- Angus Duncan, Bonneville Environmental Foundation, and Oregon Global Warming Commission
- Marc Daudon, Cascadia Consulting
- Paul Fleming, Seattle Public Utilities
- Rich Ferrero, US Geological Survey
- David Hoekema, Idaho Department of Water Resources
- Wayne Lei, Portland General Electric
- Paul Lumley, Columbia River Intertribal Fish Commission
- John Mankowski, North Pacific Landscape Conservation Cooperative
- Sarah Rees, Washington Department of Ecology
- Mark Strom, NOAA Northwest Fisheries Science Center
- Beatrice Van Horne, US Forest Service Pacific Northwest Research Station and USDA Regional Climate Hub
- Richard Whitman, Oregon Governor's Office

4. NEW AREAS OF FOCUS AND PARTNERSHIPS:

NEW STREAM FOCI: CIRC 2.0 was launched in September 2015 focusing on three new "streams" and some integrating components (see CIRC 2.0 cube below). All streams include elements of biophysical and social science, evaluation, decision support tools,

and outreach and engagement. New streams are: climate toolbox, data-mining, and community adaptation/health. Integrating components include co-production of useable knowledge, decision support tool development and evaluation, PNW Drought Early Warning Systems (DEWS), tribal and water law, and PNW regional climate enterprise and partnerships.



CIRC 2.0—NEW GUIDING RESEARCH FOCI: We focus on three risk areas identified as part of the regional assessment report (Dalton, et al., 2013), namely (1) impacts of warming on snowpack accumulation and resulting effects on hydrology and related systems (drought, flood, landslides); (2) consequences of changes in the coastal environment (erosion, flooding, health); and (3) cumulative effects of climate change on forest ecosystems and mortality (fire/drought). Each risk area connects with one or more of the three streams.

- **TOOLBOX:** The toolbox stream is a new focus seeking to understand the nexus of climate, water, and water users by improving and applying seasonal forecasts, data, and tools initially for drought and agriculture. The toolbox stream spent year 1 integrating water and climate-weather databases and model output from CIRC

1.0, including adding 'real time' (up to the moment) observational data updates and output for users; developing the Climate Engine (in the Google Earth Engine cloud), including customizable and select preloaded information (including climate-weather, geophysical, demographic, imagery data); and developing a variety of visualization tools at different timescales (past-historical, present-seasonal, and future-climate change). The toolbox stream co-developed tools with the Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCH PNA) project, including an Ag-Climate Atlas and several hydropower related tools for the Columbia River Basin. The toolbox stream had select interactions with agricultural and drought interested stakeholders via workshops and webinars. Examples include: NIDIS-DEWS pre-scoping meeting, Boise, ID, May 2015; Pacific Northwest Inland Drought Outlook, Boise, ID, May 2015; PNW DEWS Kickoff Meeting, Portland, OR, February 2016; Agriculture in a Changing Climate Workshop, Kennewick, WA, March 2016; interest from Washington state extension service in co-developing a climate-entomology tool for the NW; and USDA Northwest Climate Hub interest in collaborating on climate toolbox development. The toolbox stream was invited to the White House Water Summit in March 2016 and presented on the Climate Engine website.

- **DATA MINING:** The data-mining stream is also a new focus seeking to inventory, apply, and synthesize big datasets of climatic, hydrologic, ecologic, and socioeconomic variables around the topic of drought. The data-mining stream was built on the Integrated Scenarios and REACCH projects to create a prototype data-mining portal (http://dmine.io), largely for the team's use at this point. Included in the portal is a "What is data-mining?" tutorial, a DMINE climate "dashboard," list of data-mining and machine learning resources, literature review of data-mining research publications, inventory of climate/environmental/ demographic/impacts data repositories, and research team and project descriptions. The data-mining stream has developed an initial strategy for data-mining and machine learning, and built out two machine-learning test models based on landside analysis, and a drought-based economic crop loss data map displayed using an animated demonstration. Stakeholders will be asked to review and beta-test these prototypes for interoperability and usability. The data-mining stream engaged stakeholders in a webinar on March 3, 2016, drawing carefully selected participants from the February 2016 DEWS/National Integrated Drought Information System (NIDIS) meeting, from the CIRC Advisory Council (e.g., Regional Climate Hub director), and collaborators from CIRC 1.0 and beyond. The webinar discussion was the first chance for stakeholders to suggest data-mining priorities and metrics around the theme of drought, and they responded enthusiastically with suggestions to quantify the full hydrologic cycle, especially the demand side; links between soil moisture and crop loss; or finding patterns in stream temperature data for fish conservation. The DMINE.io website also has been organized similar to NOAA's Climate Resilience Toolkit (CRT) around

several climate impacts categories, including ecosystem vulnerability—fire regimes, carbon balance, invasive species, biodiversity, water resources, human health, and agricultural food resilience—food production, food distribution, food safety, food economics, and security.

- **COMMUNITY ADAPTATION STREAM (PHASE ONE):** Although the community adaptation stream builds on work from CIRC 1.0 in Tillamook County, Oregon, CIRC 2.0 is focusing on an entirely new community, set of stakeholders, and co-produced priorities in Grays Harbor County, Washington. Similar to Tillamook, the Grays Harbor place-based co-production process seeks to understand climate change vulnerability to outer coastal zone erosion and flooding but has added an inner bay component based on stakeholder interest. In addition, we have added a public health component to the coastal adaptation initiative. Each of these is discussed briefly below.

- **COASTAL:** During summer 2015, the team began making contacts and stimulating interest in a new knowledge to action network process, presenting Tillamook coastal futures work at a conference in Aberdeen, WA put on by the nonprofit Surfrider Foundation. During Fall 2015, the coastal stream began networking and engaging stakeholders in Grays Harbor County remotely. In November 2015, the coastal stream was invited to attend Changing Shorelines, a local Marine Resource Council meeting and discussion panel on coastal hazards in Aberdeen, again to present on Tillamook coastal futures work. This event marked the soft rollout of the Grays Harbor project. The coastal stream convened the first CIRC-organized stakeholder kick-off meeting in Aberdeen in February 2015. The goal of this meeting was to introduce the project, characterize priority hazards in Grays Harbor County with potential stakeholders, and start exploring with stakeholders alternative visions for Grays Harbor County futures under various climate change scenarios. Ongoing ENSO impacts provided motivation for discussion. Key vulnerabilities/hazards raised by stakeholders included: outer coastal flooding and erosion from ENSO winter storms, bay flooding and water quality, property and flood protection, bay habitat conservation, and Chehalis River basin issues (land management in upper basin watershed). Meeting follow-up in winter and spring 2016 included organizing results and drafting new climate and policy scenarios. A spring webinar was held with county planners to discuss urban development as a lead up to a second stakeholder meeting. At the June 2016 stakeholder meeting, results from the first meeting were reviewed with stakeholders, draft policy scenarios of baseline, protect, realign, restore were further co-developed, and technical working groups were formed to guide scenario and model implementation on coastal development and planning: coastal ecosystems and habitats, coastal hazards and climate change scenarios, and model results visualization/communication. Stakeholder perception that ENSO-driven winter storms during 2015/2016 could be causing greater coastal erosion and

potential bay flooding analogous to future climate change conditions acted as kind of "triggering event" stimulating interest and likely drawing greater participation than otherwise. To stimulate further stakeholder interest in the Grays Harbor project, the coastal stream created a "citizen science" project providing stakeholders an opportunity to record their observations (possible ENSO-related) of local bay flooding in an online mapping tool. The coastal stream also has monitored a Shoreline Master Program Planning (SMPP) process on-going in Grays Harbor County given potential for feedback to policy scenarios.

- **HEALTH:** Additionally, CIRC 2.0 has added a health focus working with Grays Harbor County to test, for the first time in a northwestern coastal setting, the efficacy of the Centers for Disease Control (CDC) BRACE (Building Resilience to Against Climate Effects) framework, a public health vulnerability assessment framework and tools. CIRC has subcontracted the Grays Harbor County Health Department to help with testing, and is linking efforts with the county Emergency Management Department. The CIRC health team has investigated climate change related temperature and precipitation drivers for Grays Harbor that may create health risks (e.g., heat-related illnesses or health-related storm impacts on land). However, the Health Department seems more interested in economic drivers of health problems related to climate, such as fishing industry deaths from increased storms. Eventually, the County Health Department may become interested in water quality and vector borne disease issues if data can be collected and the value of that information can be demonstrated within the BRACE context.

- **CO-PRODUCTION:** The co-production integrating activity builds on and continues knowledge to action network research from CIRC 1.0 but has a new focus on evaluation. Co-production evaluation goals include better understanding of information value and decisions, engaging and developing networks to evaluate decision success and failure, and exploring decision support tool transfer across contexts and settings. During 2015/2016, the co-production stream evaluated CIRC 1.0 lessons learned on knowledge to action network development. Findings were presented at a Desert Research Institute Co−Produced Climate Science Workshop, in Reno, NV, February 2016. The team is also developing co-production protocols for all of the streams; and a spring 2016 OSU Reading Seminar on Climate Co-production has made materials available for training CIRC 2.0 researchers (see further details in answer to #3).

- **DECISION SUPPORT TOOL EVALUATION:** The decision support tool evaluation activity is another new focus associated with co-production and will integrate with the Streams, particularly toolbox and data-mining. The decision support tool activity seeks to understand decision support tool use and efficacy for adaptation, how to incorporate tools and NW big data-mining activities, and a new goal of evaluating decision support tool use, including tools that CIRC

develops compared with other climate-water decision support tools. Evaluation criteria include: (1) usability, (2) suitability, and (3) utility. The decision support tool activity has created a year 2 work plan and framework for evaluating tools that other streams are developing with the goal of enhancing delivery and use of tools as proto-type climate services (see further details in answer to #3).

- **DROUGHT EARLY WARNING SYSTEM (DEWS):** Although CIRC 1.0 included a drought focus working with stakeholders to develop a PNW Drought Monitor, CIRC 2.0 is working with NIDIS to develop a new Drought Early Warning System (DEWS) for the northwest, integrating with the toolbox and data-mining streams. CIRC has been tasked with co-leading DEWS development in the PNW in collaboration with NIDIS/Drought.gov based on established connections. A February 2016 DEWS Kick-off Meeting in Portland, OR, co-led by CIRC and NIDIS, launched a DEWS strategic planning process for the PNW. The kick-off meeting included 95 specifically targeted and invited stakeholders from across four states. Topics developed and prioritized included vulnerability assessments, vulnerable populations, and state drought planning. The meeting started a process of developing a two-year strategic plan with likely focus on drought indicators in the short term, and Oregon and Washington drought planning and response needs specifically over the long term. CIRC participated in a NIDIS-sponsored all-chair and "Engaging Preparedness Communities" meeting in Lincoln, Nebraska, April 28-29, 2016. CIRC will work to connect NIDIS working groups with PNW DEWS development. CIRC intends to link drought information and tools with the data-mining, toolbox, and coastal/health streams. The NW Climate Toolbox, Climate Engine, and the DMINE.io portals have the potential to provide a customizable means to explore drought indicator development as stakeholders become more familiar with potential applications.

- **TRIBAL/WATER LAW:** CIRC 2.0 has added a new tribal focus and is combining it with previously developed water law work to develop new understanding of tribal water rights under a changing climate. The tribal activity has created an online Tribal Climate Change Guide (primarily for tribes), including categories of funding, adaptation plans, climate programs, climate tools, scientists, publications, climate education, disaster resources, climate jobs, and events. As an open source portal, tribes in the region are adding content as well as using it as an information source.

- **EXTENSION:** CIRC's Regional Extension Climate Specialist is continuing to support all of the new streams and partnerships, especially for the coastal stream in Grays Harbor County in cooperation with Oregon Sea Grant; and continues as a member of the West Coast Governor's Alliance Climate Action Team. The Regional Extension Climate Specialist also continues to serve agricultural extension initiatives in Oregon and Washington via presentations and support of

the AgClimate.net collaboration with the Center for Sustaining Agriculture and Natural Resources at Washington State University.

- **THE REGIONAL CLIMATE ENTERPRISE** builds on new relationships with the USDA Northwest Regional Climate Hub, emerging focus for the NW Climate Science Center research mission (e.g., ecological drought), and other evolving regional climate partnerships (e.g., with various tribes and tribal organizations) to support the streams.

5. STATES IN THE NORTHWEST USING CLIMATE SERVICES

Similar to CIRC 1.0, each stream and integrating activity in CIRC 2.0 is working across the Pacific Northwest region (Idaho, Oregon, Washington, and western Montana) to engage and provide technical assistance to stakeholders, jointly co-produce knowledge, develop decision support tools, and evaluate tool use. Given one of CIRC's goals is to develop and test prototype climate services, in just nine months, building on CIRC 1.0, CIRC 2.0 has deployed several "toolkits" on websites that users can customize and apply in myriad ways depending on their needs (Climate Engine, Climate Toolbox, DMINE.io, PNW Drought Monitor, Grays Harbor flood and erosion recording, and Integrated Scenarios Portal). CIRC also deployed drought knowhow as a service throughout 2015/2016 in lead up to NW DEWS launch in February 2016. These efforts are described in greater detail under #4: New Foci and #12: Project Narratives, but below are a few specific applications of these tools/processes in practice:

- Greg Jones from Southern Oregon University has used the NW Climate Toolbox growing-degree-day maps for viti-cultural applications, and has helped guide development of these Toolbox products in practice.
- Weather Forecast Offices in Washington and Oregon use the PNW Drought Monitor
- PNW Drought Monitor also used for weekly US drought monitor inputs.
- Ron Abramovich, from that Natural Resources Conservation Service (NRCS) in Boise, Idaho, has used the Climate Engine in bi-monthly briefings to constituents.
- Oregon State University is co-leading with NIDIS the development of a Drought Early Warning System (DEWS) pilot for the PNW region—building on Oregon State agency drought planning and water resilience efforts. The DEWS effort also builds on work with the Washington State Departments of Ecology on drought and groundwater and Washington Department of Agriculture on crop losses and drought. Coping with Drought/DEWS activities in 2015:
    - Higher resolution PNW Drought Monitor from University of Washington provided situational awareness and is one of many tools that NW water managers use in the evaluation of drought conditions in the region, including accessing NW information that has been blended into the National Drought Monitor.

- DEWS launch facilitated connections between state-level decision makers in similar roles. Developed new network of the drought coordinators in Oregon, Washington, and Idaho. Network includes state climatologists NIDIS, NDMC and CIRC.
- DEWS work is being coordinated with Oregon's Water Supply Availability Committee and Drought Readiness Council. Translates technical science into policy.
- CIRC PI Nijssen presented current conditions from PNW Drought Monitor to monthly meetings of water managers in Washington and Oregon.
- Nijssen also evaluating when 2015 snow conditions may become norm under climate change (in progress).
- Water managers used the ability CIRC provided to evaluate individual water balance components of snow versus soil moisture, which played a role in changing official drought status assessments.
- CIRC supported state drought planning and drought declarations in Oregon and Washington including delivering targeted drought briefings and input to state drought calls, allowing a chance to operationalize the Yakima River Basin Integrated Water Resource Management Plan, and putting NW drought in historical context during 2015/2016 as a "dress rehearsal" for future climate change conditions.
- *The Climate CIRCulator* newsletter provided ongoing narratives of drought conditions, including improving communication via social media, and CIRC conducted numerous media interviews as a means to support state drought decision-making. CIRC editorials on drought were published online in OSU's *Terra* magazine and *Climate Central*'s blog *WXShift*.
- *Documenting the Drought*: In cooperation with Oregon Sea Grant, CIRC's Regional Extension Climate Specialist Stevenson produced a video for a general audience, *Documenting the Drought*, a look at how Oregon businesses had been affected by the drought. A *CIRCulator* post on video was picked up by *WXShift.*
- CIRC is participating in a state of Oregon Interagency Working Group updating the Oregon Integrated Water Resources Strategy, including drought, led by the Oregon Water Resources Department.
- CIRC conducted interviews with stakeholders in Oregon and Idaho to improve on the ground drought assessments and communications with stakeholders about drought related issues such as water year, and growing and fire seasons.

- The CIRC 2.0 coastal stream, under the Grays Harbor Coastal Futures (Washington), has created new climate change models for coastal erosion and a Flood and Erosion Observation Recording Website, supporting citizen science in mapping and visualizing bay flooding in Grays Harbor and the region.

- The University of Oregon has created an online Tribal Climate Change Guide, including funding sources, adaptation plans, climate programs, climate tools, scientists, publications, climate education, disaster resources, climate jobs, and events. Tribes throughout the region are using the existing content and adding new content as appropriate.
- The Integrated Scenarios of the Future Northwest Environment project was a coordinated effort during CIRC 1.0 using the latest climate, hydrologic, and vegetation models to produce a consistent series of projections and potential scenarios associated with climate change in the Northwestern US during the 21st century. In an example of regional and cross-center leveraging of research and funding, over the last year the NW Climate Science Center has developed an Integrated Scenarios Portal to increase the accessibility and usability of the Integrated Scenarios datasets developed by CIRC1.0 to a broader range of stakeholders. CIRC 2.0 is playing a limited role in promoting, testing, and evaluating this tool as a decision support option for stakeholders. An example application of the tool demonstrates correlation of snow water equivalent (SWE) under different Representative Concentration Pathway scenarios to project snowpack reductions leading to reduced wolverine habitat during the 21st century.

6. OVERALL PROGRAM-LEVEL IMPACT OF CIRC:

A: EVALUATION MODEL: In the first nine months, CIRC 2.0 has supported an extensive evaluation of CIRC 1.0 co-production processes. CIRC 2.0 developed a logic model and formulated five principal questions to explore: 1) What difference did this project make? And for whom?; 2) What kind(s) of capacities were built? And for whom?; 3) What did CIRC learn about co-production of knowledge or one of its constituent components? Is co-production a continuous or binary phenomenon?; 4) What changes in behavior, policy, and/or practice can we observe?; 5) What role might CIRC play in the future of these networks, projects, results? Ten stakeholders were identified via a "snowball" method to discover the most relevant interviewees on a "one-leads-to-another" basis. Eventually, seventeen semi-structured interviews of CIRC researchers, staff, and select stakeholders were conducted drawing from the Big Wood, Willamette Water 2100 (a CIRC subsidized project), and the Tillamook Coastal Futures projects. Interview results were coded based on themes of capacity, process, usability, and impact/ future role. (Results from interviews were compiled and conclusions have been summarized in narratives under question 6B.)
The CIRC 2.0 decision support tool evaluation activity also created a work plan and framework for evaluating decision support tools developed for and/or used by PNW stakeholders. This integrative stream will evaluate tools using a variety of research criteria, including: 1) How can DSTs effectively facilitate the use of data and information, knowledge development, and building of adaptive capacity across scales and sectors and sustained over time (i.e., practical to support climate scientists, information intermediaries, and operational climate services), and commensurate with evolving

climate adaptation challenges?; 2) Can CIRC provide more powerful and effective decision support tools by linking big data, Web 3.0 capabilities, advanced software infrastructure, and social science research (e.g., for participatory planning, situational assessment and early warning, integrated environmental forecasting, and crowdsourcing)?; 3) How should decision support tools and their use be evaluated?

The initial work-plan will implement process-oriented principles for effective decision support that emphasize decision maker needs within a conceptual framework of iterative risk management. Climate change decision support refers to organized efforts to produce, disseminate, and facilitate the use of data and information in order to improve the quality and efficacy of climate-related decisions. Because decision support tools are often conceived, implemented, and evaluated within the RISA program as unique experiments, CIRC 2.0 will take a comprehensive and integrative approach to decision support tool evaluation from three perspectives: decision makers and users, technology sustainability, and research evaluation. Each category uses its own framework for evaluation, involving different objectives, criteria, metrics, and evaluation methodologies. Decision support tools created and/or used in CIRC 2.0 will be evaluated using the framework(s) appropriate to their stage of development and implementation. The framework for developing and evaluating decision support tools from the perspective of decision makers and users will have three components: usability, suitability, and utility.

B SUMMARY OF RESULTS: Key results from CIRC 1.0 co-production evaluation: 1) Co-production processes build capacities necessary for communities to continue co-producing knowledge and incorporate climate change in discussions after the end of CIRC's participation; 2) involving non-traditional participants along with experts was critical to success of co-production processes; 3) significant work and preparation is required before any co-production takes place; 4) co-production provides researchers a different kind of experience than typical academic projects, combining traditional skill building with exposure to policy-making and stakeholder involvement; and 5) co-production helps overcome communication barriers among scientists and with other audiences.

In the co-production process, CIRC has gained credibility as an organization that can help inform climate change adaptation and management dialogues, turn qualitative discussions into measurable quantitative models and policy scenarios, and branded itself as a source of trusted scientific knowledge and science translation. CIRC is seen as having expertise at convening diverse stakeholder groups, enabling communication among those who may not have interacted before on climate or resource management challenges. For example, during the Big Wood project in Idaho, lower basin farmers and irrigators met for the first time with upper basin resort operators to discuss common climate change vulnerabilities. CIRC also has been effective at building knowledge to action networks by cultivating trust in co-production methods and dialogs.

Preparation is essential before co-production processes begin. Reviewing existing data with stakeholders and connecting existing knowledge to current issues is a first step before any new research is undertaken. Starting with understanding local context, learning about regional players, examining community issues, and first contacting then recruiting and finally engaging pivotal stakeholders as 'champions' and conveners are critical to a successful start of a knowledge to action networks. Determining focus and scale of study, even if it limits the number of stakeholders involved, is essential to achieving realistic timelines. Graduate students can provide a low-pressure entre to communities, facilitating early stakeholder engagement, especially if they already know the local people or topics important to the community.

Co-production workshops are better than virtual interactions, and "ice-breaker" activities are an essential component of effective meetings. Opening sessions should help participants understand the meanings of different key terms, create a starting point for discussion, and develop shared terminology and language. Start co-production workshops by informing potential participants about CIRC's capabilities, including running prototype, simplified, or representative models of current and future conditions, and performing preliminary vulnerability assessments. It is necessary to constrain the amount of information presented, keeping participants' understanding and attention in mind (e.g., less graphs and statistics, more stories, simple visual information). Additionally, build trust by acknowledging concerns of stakeholders and making available prompt and in-depth responses to questions on models, scenarios, and tools showing it's "not just another academic exercise." Framing questions and terms in manners conducive to opening a two-way dialog with stakeholders and avoiding conflicts is an iterative process, ensuring that stakeholders feel respected and listened to.

Designing decision tools to answer questions in the context of the stakeholders' concerns is a more effective approach than just handing them pre-created tools. During co-production processes, customized or tailored research and paying attention to each case and each stakeholder individually has helped co-develop plans for the future. However, expectations also must be managed given that stakeholders may at times want information that is impossible for science to deliver at this time (e.g., accurate ground-water models). Generally, participants and communities think in terms of long-term planning regarding climate change so plausible projections and scenarios are essential.

In a few instances, after a CIRC community project ended, the community continued co-producing knowledge themselves, incorporating climate change in their planning discussions toward creating policy changes—especially if CIRC remains available for consultation. Their new capability to access and request climate change information on their own from sources they consider reliable (e.g., online data and tools, CIRC researchers) and do "in-house assessments" shows that new capacity has been built. State and local agencies and NGOs involved in the same planning effort also have started

communicating across sectors, and have formed new collaborative partnerships at various levels of management.

Generally, CIRC co-production work influenced policy discussions and interactive behavior among stakeholders in Big Wood, Tillamook, and WW2100 to varying degrees via communication, convening, mediating, and translating roles, although there is little or no evidence of major policy changes at this point. In Big Wood, Idaho, CIRC co-produced alternative water and landscape management scenarios highlighting the need for greater upper (resort) and lower basin (agriculture) coordination as climate change increases water scarcities, but no comprehensive basin planning has started to date. Tillamook, Oregon, spurred several coastal land-use planning processes, particularly to manage coastal erosion and flooding and to preserve beach accessibility. However, to date no planning recommendations have been implemented, let alone changes to land use laws or regulations. Willamette Water 2100 convened stakeholders in Oregon to explore various scenarios produced from a suite of interactive and integrated climate, water, vegetation, land-use, socio-economic, and legal policy models, creating a greater awareness of alternative future outcomes depending on decisions made in the present. However, no local or regional planning has been obviously affected as of this report submission.

7. LOCAL/REGIONAL ADAPTATION:

The Grays Harbor County work is only in the early stages of relationship and trust building with stakeholders, but a new group of diverse stakeholders has become engaged and seems appreciative of the potential for a CIRC facilitated co-production process that offers adaptive solutions to emerging local climate change impacts. Results of this effort can potentially be incorporated into such activities as Shoreline Master Program Planning efforts. Additionally, the 2015/2016 ENSO event has sparked interest for inclusion of climate change and extreme events in coastal hazard planning. Stakeholders also seem appreciative of CIRC's co-production process combining scientific expertise (e.g., data, models, tools) with local environmental and planning knowledge, and that development of climate scenarios and policy narratives are directed toward real decision needs. Consequently, CIRCs presence and project outcomes already are viewed as potentially more useful than the standard applied research project. Stakeholders also have begun to test use of information in practice from the Climate Engine, Climate Toolbox, and data-mining portals.

8: PROUD ACCOMPLISHMENTS

In just nine months, our coastal stream team has met with stakeholders three times in a community (Aberdeen, WA) that is three hours from Seattle and five hours from Corvallis. The team is well on the way to assembling datasets, applying our models, and framing policy options in close partnership with key stakeholders. They have responded

to stakeholder wishes by adding a new modeling capability that was not in our original plan. This stream is moving effectively by building on (and learning from) previous experiences working together in Tillamook County, Oregon, and the Big Wood Basin, Idaho.

9. RESEARCH FINDINGS

a. The Toolbox Stream created a tool to estimate PDFs showing at what point historical snow water equivalent (SWE) 10th percentile from 1980 to 2009 will become the 50th percentile for different locations in the PNW across a range of model runs and RCPs showing future snowpack declines.
b. From coastal: even with one meter swing in sea level rise (SLR), local land-use policies and regulations still have greater impact on decisions than SLR water fluctuations
c. From coastal: In order to better understand how several individual processes combine to cause coastal hazards, we investigated the relative contribution each component (waves, tides, and non-tidal residuals) has on extreme total water levels (TWL) on sandy beaches. The TWL is defined as the superposition of wave run-up (R2%) and the still water level (SWL). The SWL is a combination of all water level processes recorded at a tide gauge, and includes tides and non-tidal residuals (storm surge, monthly sea level anomalies and seasonal signals), while wave run-up is a function of wave height, length and beach slope, and parameterized using empirical formulations.
   Regional variability exists in both the magnitude and composition of TWL extremes along the U.S. West Coast. The magnitude of extreme TWLs decreases from north to south, largely driven by tidal ranges and differences in patterns of storminess. Slight regional differences in the relative contribution to extreme TWLs also exist, where Oregon and Washington have a more intense wave climate than California, the wave-run up (R2%) contributes 10% more to the annual and 100 year TWL events in California. During the annual event 10% of the SWL is comprised of the non-tidal run up (NTR), while during the 100-yr event, 20% of the SWL is comprised of the NTR. This alteration of the composition is driven by large elevation storm surges during the 100-yr event.

   Understanding the present-day contributions to extreme return level events will ultimately help provide context to how future changes to climate may affect coastal flooding and erosion events.

d. Key results from CIRC 1.0 co-production evaluation:

i. Co-production processes build capacities necessary for communities to continue co-producing knowledge and incorporate climate change in discussions after the end of CIRC's participation;
ii. Involving non-traditional participants along with experts was critical to success of co-production processes;
iii. Significant work and preparation is required before any co-production takes place;
iv. Co-production provides researchers a different kind of experience than typical academic projects, combining traditional skill building with exposure to policy-making and stakeholder involvement; and
v. Co-production helps overcome communication barriers among scientists and with other audiences.

10: COMMUNICATION AND OUTREACH:

- **February 2016, DEWS Kickoff Meeting:** Dello and Stevenson presented at the DEWS Kickoff Meeting in Portland, OR.

- **March 2016, White House Water Summit:** CIRC's toolbox stream, represented by CIRC Postdoc Hegewisch, presented at the White House Water Summit. Hegewisch's presentation included a demonstration of the Climate Engine website.

- **September 2015–May 2016, *The Climate CIRCulator*:** CIRC continues to maintain a monthly newsletter that reaches roughly 1,700 subscribers. The *CIRCulator* reviews climate science relevant to Northwest stakeholders and routinely promotes CIRC research. From September 2015–May 2016, the CIRCulator included 9 stories on CIRC projects and researchers (roughly one story a month), 6 stories covering research by one or more CIRC researchers, and several climate updates. The *CIRCulator* and researcher Dello are now regular contributors to the nonprofit news source *Climate Central*'s blog *WXShift*, the result of managing editor Brian Kahn's interest in newsletter.

- **April 2016, *The National Academies Press*:** PI Mote was one of several authors contributing to "Attribution of Extreme Weather Events in the Context of Climate Change," report on extreme weather and climate written by the National Academies of Sciences, Engineering, and Medicine. Project included media interviews. (See Appendix for publication listing.)

- **May 2016, *Documenting the Drought*:** In cooperation with Oregon Sea Grant, CIRC's Regional Extension Climate Specialist Stevenson produced a video for a general audience, *Documenting the Drought*, documenting how drought had affected Oregon businesses.

- **May 2016, *Terra Magazine*:** CIRC's Communications Specialist Gilles wrote a feature story highlighting CIRC's research for Oregon State University's research Magazine *Terra*. Story was well received. CIRC has been asked to continue contributing to the magazine.

11: KEY PUBLICATIONS:.

- Cohn, Nicholas, and **Peter Ruggiero**. "The influence of seasonal to interannual nearshore profile variability on extreme water levels: Modeling wave runup on dissipative beaches." Coastal Engineering (2016). doi:10.1016/j.coastaleng. 2016.01.006.
    - CIRC PI: Ruggiero.
        - Description: *Paper examines wave runup (a key factor in extreme water levels from storms) in complex beach morphology settings. Employing numerical experiments, the study breaks down new methods to factor morphology into wave calculations with direct implications for modeling efforts examining hazards faced by coastal communities.*

- Inouye, Allison, **Denise Lach, John Stevenson, John Bolte**, and Jennifer Koch. "Participatory Modeling to Assess Climate Impacts on Water Resources in the Big Wood Basin, Idaho." Chapter 14 in "Gray, Paolisso, Jordan, and Gray, Including Stakeholders in Environmental Modeling: Theory, Methods, and Applications." Springer Publishing. In Press.
    - Project: Big Wood Basin. CIRC PIs: Lach, Stevenson, Bolte
        - Description: *Synthesizes lessons learned from the Big Wood Basin project. Covers the coproduction of knowledge and what it means for climate adaptation.*

- **Rupp, David E.**, Sihan Li, **Philip W. Mote**, Karen M. Shell, Neil Massey, Sarah N. Sparrow, David C. H. Wallom, and Myles R. Allen. "Seasonal spatial patterns of projected anthropogenic warming in complex terrain: a modeling study of the western US." Climate Dynamics (2016): 1-23. doi:10.1007/s00382-016-3200-x
    - Project: Integrated Scenarios. PIs: Rupp. Mote.
        - Description: *Paper examines temperature heterogeneity in complex landscapes, including the mountainous Northwest. Concludes detection of heterogeneity in complex landscapes requires a combination of high spatial resolution and multiple model runs.*

- **Sheehan, T., D. Bachelet**, and K. Ferschweiler. "Projected major fire and vegetation changes in the Pacific Northwest of the conterminous United States

under selected CMIP5 climate futures." Ecological Modeling 317 (2015):16-29: doi:10.1016/j.ecolmodel.2015.08.023.

- Projects: Integrated Scenarios, Willamette Water 2100. CIRC PIs: Bachelet, Sheehan.
  - Description: *Paper examines how disturbances are the primary agents of change in forests. The researchers' simulations—from the Integrated Scenarios project—reveal that with the warmer, drier summers expected under future climate change, fires across the U.S. will become more frequent.*

- Vano, J. A., B. Nijssen, and D. P. Lettenmaier. "Seasonal hydrologic responses to climate change in the Pacific Northwest." Water Resources Research 51 no.4 (2015): 1959–1976. doi:10.1002/2014WR01590.
  - Projects: Integrated Scenarios, Willamette Water 2100. PIs: Nijssen, Lettenmaier. Postdoc: Vano.
    - Description: *Outlines series of perturbation experiments called the sensitivity approach, an efficient method used in hydrologic modeling and for selecting climate scenarios. The sensitivity approach was developed by CIRC Postdoc Vano and employed in Willamette Water 2100.*

12: IMPLEMENTATION OF WORK:

CIRCs co-production approach across different streams has the explicit goal of building stakeholder capacity for adaptation planning and policy development, as well as collaborating to create new strategies and decision support tools to help stakeholders manage hazard risks. Broader conversations on hazard planning will occur in each stream, as well as updating management and adaptation plans for different sectors, and thinking about long-term planning for specific communities. For example, although still early in the process, the Grays Harbor County work under the coastal stream has the strong potential to develop and effectively incorporate scenarios and policy narratives into local land use planning activities and policies as they are co-produced over the coming year. The DEWS development process, in collaboration with NIDIS, provides the best example of an emerging region-wide strategic planning process to develop an alert system-incorporating drought early warning into four state drought policies and planning.

In the first nine months, CIRC also is completing prototypes of various online tools, including the Climate Toolbox, Climate Engine, and DMINE.io websites, and coastal tools (also described under #4: New Foci). CIRC is actively seeking feedback from stakeholders, and testing potential applications of information from these tools.

Building on CIRC 1.0, CIRC 2.0 is stakeholder-testing two decision support tools that can be applied throughout the region: The Climate Engine and the NW Climate Toolbox. The Climate Engine is an on-demand cloud computing and visualization of climate and remote sensing data tool. The Climate Engine is evolving and combining climate and hydrology data and model output from the CIRC 1.0-based Multivariate Adapted Constructed Analogs (MACA) project (at the University of Idaho), and the NW Drought Monitor (at University of Washington). The Climate Engine uses a Google Earth cloud platform to analyze and facilitate interactions with climate and land-surface environmental monitoring datasets in real-time to improve decision making related to drought, water sustainability, agricultural productivity, wildfire, and ecological health. Examples of frequently requested 'preloaded' daily data, polygons, forecasts, and projections include: temperature and precipitation ranges, soil moisture/storage, snow water equivalent (SWE)/snowpack, and snow cover. Data can be visualized, mapped, spatially analyzed, compared, or downloaded in customizable formats (e.g., for user defined geographies). Synthesized data and time-series also have been preloaded, such as vegetation/fire/drought indices, growing degree days, crop maturity, irrigation demand, heat-frost risk, and set-up for testing integration of data with seasonal forecasts. Similarly, the NW Climate Toolbox provides users an opportunity to map data, view time-series, map and compare current and future climate, and use a few prototype decision support tools. An added benefit is both tools provide means for users to develop their own decision support tools using underlying data.

The data-mining stream also has developed a prototype data-mining portal (http://dmine.io) for the region. Included in the portal is a "What is data-mining?" tutorial, a DMINE climate "dashboard," list of data-mining and machine learning resources, literature review of data-mining research publications, inventory of climate/environmental/demographic/impacts data repositories, and data-mining research team and project description.

The coastal stream has created new climate change models for coastal erosion and a citizen science visualization tool for mapping bay flooding observations in Grays Harbor County. This work has succeeded in attracting stakeholders to join a process to co-produce coastal hazard scenarios and policy narratives similar to those developed in Tillamook County. The new public health component in Grays Harbor County has begun testing the CDC BRACE framework and tools for the first time in a northwest coastal setting.

13: COPING WITH DROUGHT:

DROUGHT EARLY WARNING SYSTEM (DEWS): CIRC 1.0 included a drought focus working with stakeholders and developed a PNW Drought Monitor. CIRC 2.0 is working with NIDIS to develop a new DEWS for the northwest. DEWS also will integrate with other CIRC 2.0 streams.

The PNW DEWS is a federal, tribal, state, and local interagency effort to enhance drought early warning capacity and resilience within the region. This is accomplished through local stakeholder-driven activities encompassing data collection and monitoring; research; planning for climate extreme events; and communication, education and outreach. Activities will focus on areas throughout the states encompassing the Columbia River Basin (Idaho, Montana, Oregon, and Washington). DEWS OBJECTIVES: 1) Provide a forum for a diverse group of federal, tribal, state, and local stakeholders who represent all economic sectors, including water and land resource management, to strategize and develop appropriate, relevant, useful, and readily available drought, climate, weather, and water-related information. 2) Develop an understanding of existing observation and monitoring networks, data, tools, research, and other planning and mitigation resources available for a drought early warning system. 3) Identify economic sector-specific and geographic needs for future.

A series of preparatory meetings led up to a NW DEWS launch in February 2016:

- NIDIS-DEWS pre-scoping, Boise, ID, May 2015
- Pacific Northwest Inland Drought Outlook, Boise, ID, May 2015
- Western States Water Council, San Diego, CA, May 2015
- Western States Drought Coordinators and Emergency Managers Meeting, Seattle, WA, July 2015
- Pacific Northwest Coastal Drought Outlook, Vancouver, WA, September 2015
- Wildfire and Drought: Impacts on Wildfire Planning, Behavior and Effects, Boise, ID, October 2015

A February 2016 DEWS Kick-off Meeting in Portland, OR, co-led by CIRC and NIDIS, launched a DEWs strategic planning process. The kick-off meeting included 95 specifically targeted and invited stakeholders from across four states. Topics developed and prioritized included vulnerability assessments, vulnerable populations, and state drought planning. The meeting started a process of developing a two-year strategic plan with likely focus on drought indicators in the short-term, and Oregon and Washington drought planning and response needs specifically.

Outcomes from the meeting:

1. Increased knowledge and awareness of present decision-support tools and processes, including the National Integrated Drought Information System;
2. Identification of current knowledge and information gaps;
3. Development of recommendations for improved early warning, which would include better coordination of integrating, displaying, and disseminating climate, weather, and water data and information;
4. Development of recommendations for future actions, collaborative research, and decision support tools;

5. Identification of baseline evaluation metrics for drought and its associated impacts.

CIRC participated in a NIDIS all-chair and "Engaging Preparedness Communities" meeting in Lincoln, Nebraska, April 28-29, 2016. CIRC will work to connect NIDIS working groups with PNW DEWS development.

For PNW DEWS, a 20-person (mostly Federal) steering committee will be developing a strategic plan for the next two years. Planned DEWS meetings over 2016: OR/WA/ID drought triggers meeting with Colorado to learn from their earlier DEWS implementation (Sept. 2016); PNW Water Year Outlook meetings (Sept. 2016) in Boise, ID, Olympia, WA, or Portland, OR; Eastern OR/western ID focused meeting; drought and public health TBD (in coordination with the Oregon Health Authority and Oregon Water Resources Department). CIRC also has goals to link drought with the data-mining, toolbox, and community adaptation streams supported by Coping with Drought. The Toolbox and Climate Engine have potential to provide a customizable means to explore drought indicator development as the tools are finalized and stakeholders become more familiar with its potential applications.

14: PROJECT DATABASE: (See Attached Excel Document "2016 CIRC Project Database".)

APPENDIX

FULL LIST OF PUBLICATIONS SEPTEMBER 2015–MAY 2016:

Bachelet, Dominique, Ken Ferschweiler, Timothy J. Sheehan, Benjamin M. Sleeter, and Zhiliang Zhu. "Projected carbon stocks in the conterminous USA with land use and variable fire regimes." Global Change Biology 21, no. 12 (2015): 4548-4560. doi: 10.1111/gcb.13048. (Integrated Scenarios)

Bachelet, D., K. Ferschweiler, T. Sheehan, and J. Strittholt. "Climate change effects on southern California deserts." Journal of Arid Environments 127 (2016): 17-29. doi: 10.1016/j.jaridenv.2015.10.003. (Integrated Scenarios)

Bachelet, Dominique, Brendan M. Rogers, and David R. Conklin, "Challenges and Limitations of Using a DGVM for Local to Regional Applications." Global Vegetation Dynamics: Concepts and Applications in the MC1 Model (2015): 31-40. doi: 10.1002/9781119011705.ch3. (Project: Integrated Scenarios)

Cohn, Nicholas, and Peter Ruggiero. "The influence of seasonal to interannual nearshore profile variability on extreme water levels: Modeling wave runup on dissipative beaches." Coastal Engineering (2016). doi:10.1016/j.coastaleng.2016.01.006.

Committee on Extreme Weather Events and Climate Change Attribution, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, National Academies of Sciences, Engineering, and Medicine. "Attribution of Extreme Weather Events in the Context of Climate Change." Washington, DC: The National Academies Press, 2016. doi:10.17226/21852. (PI Mote co-author)

Inouye, Allison, Denise Lach, John Stevenson, John Bolte, and Jennifer Koch. "Participatory Modeling to Assess Climate Impacts on Water Resources in the Big Wood Basin, Idaho." Chapter 14 in Gray, Paolisso, Jordan, and Gray, "Including Stakeholders in Environmental Modeling: Theory, Methods, and Applications." Springer Publishing. In press. (Project: Big Wood)

Lach, Denise. "An Experiment in Post-Normal Science: Building a Knowledge-to-Action-Network in Idaho." Chapter 6 in Weber, Lach, and Steel "Wicked Problems, Science, and Problem Solving: New Strategies for Moving Forward." OSU Press. Forthcoming. (Project: Big Wood Basin)

Li, S., P. W. Mote, D. Vickers, R. Mera, D. E. Rupp, A. Salahuddin, M. R. Allen, and R. G. Jones. "Evaluation of a regional climate modeling effort for the western US using a superensemble from climateprediction.net." Journal of Climate (2015). doi:10.1175/JCLI-D-14-00808.1. (Project: Integrated Scenarios)

Maldonado, Julie, T. M. Bull Bennett, Karletta Chief, Patricia Cochran, Karen Cozzetto, Bob Gough, Margaret Hiza Redsteer, Kathy Lynn, Nancy Maynard, and Garrit Voggesser. "Engagement with indigenous peoples and honoring traditional knowledge systems." Climatic Change 135, no. 1 (2016): 111-126. doi:10.1007/s10584-015-1535-7.

Parker, Lauren E., and John T. Abatzoglou. "Projected changes in cold hardiness zones and suitable overwinter ranges of perennial crops over the United States." Environmental Research Letters 11, no. 3 (2016). doi: 10.1088/1748-9326/11/3/034001

Ruggiero, Peter, George M. Kaminsky, Guy Gelfenbaum, and Nicholas Cohn. "Morphodynamics of prograding beaches: A synthesis of seasonal-to century-scale observations of the Columbia River littoral cell." Marine Geology 376 (2016): 51-68. doi: 10.1016/j.margeo.2016.03.012.

Rupp, David E., Sihan Li, Philip W. Mote, Karen M. Shell, Neil Massey, Sarah N. Sparrow, David C. H. Wallom, and Myles R. Allen. "Seasonal spatial patterns of projected anthropogenic warming in complex terrain: a modeling study of the western US." Climate Dynamics (2016): 1-23. doi:10.1007/s00382-016-3200-x

Sheehan, T., D. Bachelet, and K. Ferschweiler. "Projected major fire and vegetation changes in the Pacific Northwest of the conterminous United States under selected CMIP5 climate futures." Ecological Modeling 317 (2015):16-29: doi:10.1016/j.ecolmodel.2015.08.023.

Vano, J. A., B. Nijssen, and D. P. Lettenmaier. "Seasonal hydrologic responses to climate change in the Pacific Northwest." Water Resources Research 51 no.4 (2015): 1959–1976. doi:10.1002/2014WR01590.

Wolters, Erika Allen, Brent S. Steel, Denise Lach, and Daniel Kloepfer. "What is the best available science? A comparison of marine scientists, managers, and interest groups in the United States." Ocean & Coastal Management 122 (2016): 95-102. doi:10.1016/j.ocecoaman.2016.01.011.