INTEGRATING CIRC'S EFFORTS TO AID CLIMATE ADAPTATION IN THE PACIFIC NORTHWEST UNITED STATES

The Pacific Northwest Climate Impacts Research Consortium (CIRC)
CIRC 2.0 YEAR 5 PROGRESS REPORT

Performance Period: June 1st, 2019–May 31st, 2020

Award Title: CIRC 2.0: Transforming Data into Usable Knowledge for Adapting to Climate-related Hazards in the Pacific Northwest (NA15OAR4310145)

Oregon State University

About CIRC

The Pacific Northwest Climate Impacts Research Consortium (CIRC) is a team of climate and social science researchers based in the Pacific Northwest United States. CIRC helps Pacific Northwest communities become more resilient to extreme climate and weather impacts. CIRC is publicly funded through the National Oceanic and Atmospheric Administration's Regional Integrated Sciences and Assessments (RISA) program. Part of NOAA's Climate Program Office, the RISA program supports research teams that help expand and build our nation's capacity to prepare for and adapt to climate variability and change. CIRC team members can be found at Oregon State University, the University of Idaho, the University of Washington and the University of Oregon.

Our NOAA RISA Team Members

CIRC Lead:

Denise Lach, CIRC Lead, April 2019–present; CIRC Co-Lead, September 2010—April 2019 (Oregon State University)

Staff:

Nathan Gilles, Science Communicator (Oregon State University)

Ann Mooney, Project Manager and Stakeholder Engagement Specialist (Oregon State University)

Researchers:

John Abatzoglou (University of Idaho)

Adell Amos (University of Oregon)

Meghan Dalton (Oregon State University)

David Rupp (Oregon State University)

Holly Hartmann (Carpe Diem West)

Katherine Hegewisch (University of Idaho)

Philip Mote, CIRC Co-Lead, September 2010–April 2019 (Oregon State University)

Bart Nijssen (University of Washington)

Peter Ruggiero (Oregon State University)

Student Researchers:

Jessica Andrepont (Oregon State University)

Oriana Chegwidden (University of Washington)

Linnia Hawkins (Oregon State University)

Laura E. Queen (University of Oregon)

Erich Seamon (University of Idaho)

Iva Sokolovska (Oregon State University)

Stakeholder Advisory Council:

Brenda Batemen (Oregon Department of Water Resources)

Marc Daudon (Cascadia Consulting)

Angus Duncan (Bonneville Environmental Foundation and Oregon Global Warming Commission)

Laura Gephart (Columbia River Inter-Tribal Fish Commission)

Lynn Helberecht (Washington Department of Fish and Wildlife)

David Hoekema (Idaho Water Resources)

Wayne Lei (Portland General Electric)

John Mankowski (North Pacific Landscape Conservation Cooperative)

Katherine Rowden (National Weather Service/NOAA)

Changes from Last Year

New Team Members:

Linnia Hawkins (Oregon State University)

Laura E. Queen (University of Oregon)

Team Members Who Left CIRC

Kathie Dello (Oregon State University) (CIRC Researcher)

Kathy Lynn (University of Oregon) (CIRC Researcher)

Danielle Moruzzi (Oregon State University) (Student Researcher)

Paul Gessler (University of Idaho) (CIRC Researcher)

Members of the Stakeholder Advisory Council Who Left:

Thomas Byler (Oregon Water Resources Department)

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About This Report—Integrating and Leveraging CIRC's Efforts

This report covers the accomplishments and findings of the CIRC NOAA RISA team for the period June 1st, 2019–May 31st, 2020, year five of CIRC's second phase of funding, or what our team refers to as *CIRC 2.0*. Our NOAA RISA team's goal throughout CIRC 2.0 has been to "transform data into usable knowledge" in order to help CIRC's Pacific Northwest stakeholders adapt to climate variability and change and related hazards.

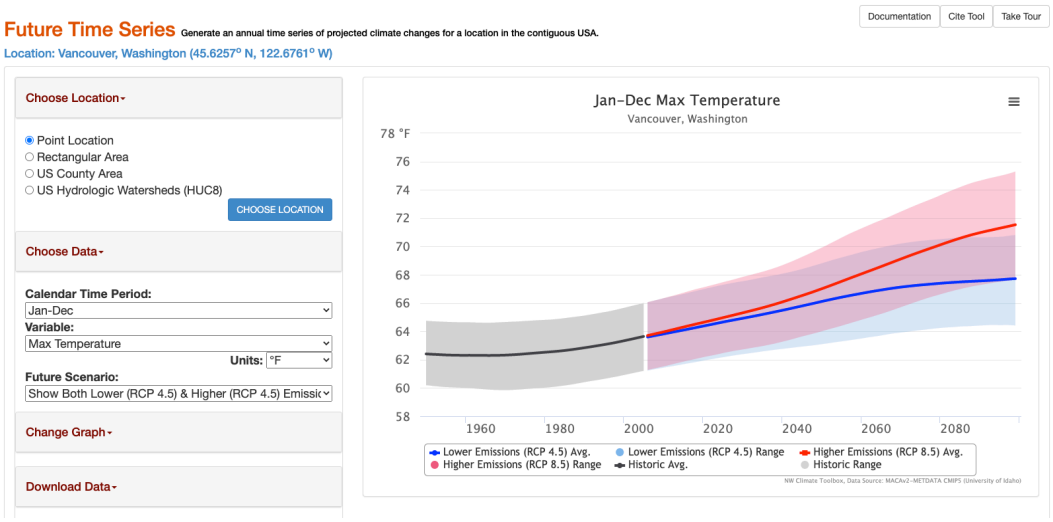
To address the climate impacts faced by our Pacific Northwest stakeholders, CIRC has undertaken several different efforts. Starting in year four of CIRC 2.0, we successfully started integrating these efforts. In year five, this integration reached a still higher level. Below is a list of CIRC's efforts and how our team has integrated them internally to leverage our effectiveness.

- **Climate Toolbox/Climate Tools**— The Climate Toolbox (formerly the *Northwest Climate Toolbox*) is a suite of freely available online tools designed to help Pacific Northwest farmers, water managers, foresters and other resource managers deal with water scarcity and other climate impacts as our region's climate changes. The Toolbox is now the centerpiece of our Climate Tools effort. CIRC's Climate Tools effort was designed to provide tools (sometimes called *decisions support tools*) intended to help our Pacific Northwest stakeholders incorporate climate and weather information into their adaptation and resource management strategies. The majority of these tools now reside inside the Climate Toolbox. (See ***Proudest Accomplishment***.) In addition, in year five we finished the *Climate Resilience Workbook Series*, which was designed to work in conjunction with the Climate Toolbox and as part of our Community Adaptation efforts.
- **Community Adaptation**— As part of our Community Adaptation efforts, CIRC team members meet regularly with our Pacific Northwest partners and stakeholders, engaging and collaborating with them to craft tailor-made climate adaptation strategies that help them visualize the many changes they face in the future, and, most importantly, to outline what they can do to prepare. Starting in year four of CIRC 2.0, through the ***Spokane Climate Project*** (formerly the Spokane Community Adaptation Project) we incorporated our Community Adaptation effort with our Climate Tools effort, creating *The Climate Toolbox Workbook*. In year five, we built upon this work, expanding our efforts to include vulnerability and resilience planning. The result was the ***Climate Resilience Workbook Series***, a set of three workbooks that teach communities to use the Climate Toolbox as part of the climate adaptation process. (See ***CIRC's Significant Outputs***, ***CIRC's Outreach***, and ***New and Continuing Partnerships***.)
- **Research**— CIRC team members regularly publish the results of our research in peer-reviewed scientific journals. In year five, our team integrated our research efforts with the Climate Toolbox and our Community Adaptation efforts. Multiple research studies were spun off as usable tools and as actionable information intended to aid community adaptation. (See ***Proudest Accomplishment***, ***CIRC's Significant Outputs***, and ***Advancing Science***.)
- **Communication**— In year five of CIRC 2.0, CIRC's communication efforts were fully integrated with all of the above efforts. CIRC's newsletter, *The Climate CIRCulator*, was used to promote and highlight the Climate Toolbox and the efforts of the Spokane Climate Project, and was used as a platform to review in plain English the research our team produced in peer-reviewed journals. In addition, CIRC's Science Communicator worked with our other teams to edit and fact-check the research conducted by our Spokane stakeholders as part of the Spokane Climate Project. (See ***CIRC's Significant Outputs, CIRC's Outreach***, and ***Advancing Science***.)
- **Data Mining**— Throughout CIRC 2.0, CIRC developed and applied data mining techniques to a variety of datasets to better understand and predict drought impacts in the Pacific Northwest. During year five, CIRC's data mining team, with the aid of our other teams, applied our data-mining analysis to the Spokane Climate Project. (See ***CIRC's Significant Outputs***.)

Proudest Accomplishment—The Climate Toolbox, Its Users and Usages

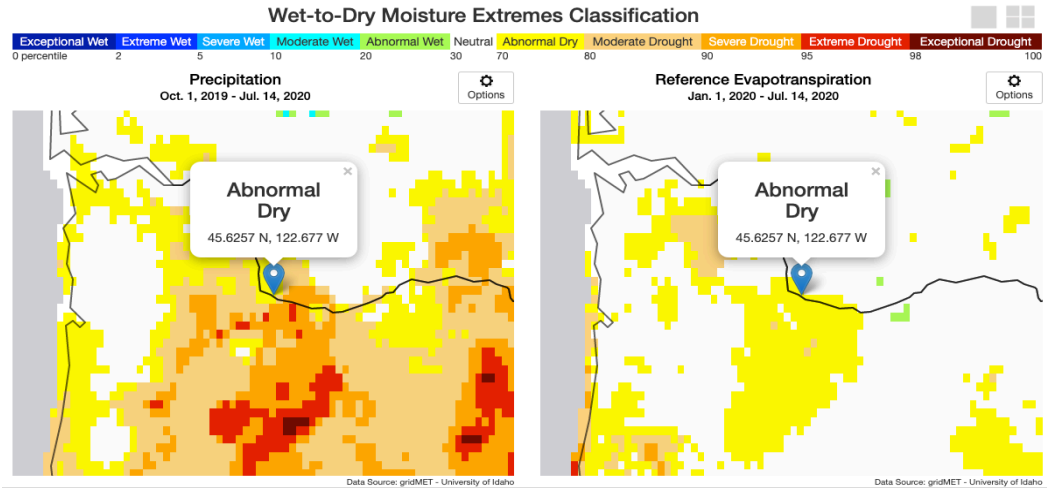
By far our proudest accomplishment in year five of CIRC 2.0 has been the continually expanding number of users of and uses for The Climate Toolbox, our suite of free online climate tools and related datasets. (In fact, this year we changed the name of our Toolbox from *The Northwest Climate Toolbox* to just *The Climate Toolbox* in part to reflect how our user base has expanded beyond the Pacific Northwest stakeholders we originally designed it for.) We are so very proud of this work because it shows our NOAA RISA team's ability to connect and engage with the Toolbox's many users as well as our resourcefulness in addressing their needs. It also highlights our ability to work together as a team. (See ***About This Report—Integrating and Leveraging CIRC's Efforts***.)

The continued positive impact of the Climate Toolbox has everything to do with the effort and teamwork we have put into this project. Our NOAA RISA team has continued to maintain, expand and refine the tools and features found in the Climate Toolbox. (See ***CIRC's Significant Outputs***.) Our team spends several hours every week answering queries from Toolbox users. Feedback from our users has allowed us to create new tools and features in the Toolbox as well as refine old tools, an effort we will be expanding next year. (See ***Evaluating Our RISA Team's Efforts*** and ***Next Steps***.) This user-based approach has led to the Climate Toolbox's now over 9,800 users, 137 of whom are daily users and 327 of whom use the Toolbox on a weekly basis. In fact, we gained 9,707 new users this year alone. (see ***Table–2 CIRC By the Numbers***.) The uses of the Toolbox are as varied as our users. Natural resource managers use the Toolbox. Journalists use the Toolbox. The Toolbox is also being used by research organizations that do work similar to our own. (See ***Appendix A—Climate Toolbox, Users and Usages***.) The Toolbox has been an essential component of our work with the National Integrated Drought Information System (NIDIS). (See ***NIDIS Coping with Drought***.) The Toolbox has been key to the success of the Spokane Climate Project (formerly the Spokane Community Adaptation Project), which is helping the community of Spokane, Washington create a climate vulnerability and resilience assessment. (See ***CIRC's Societal Impact—Narrative Examples***.) And we have even integrated the Toolbox into our efforts to advance the scientific community's understanding of our changing climate. (See ***Advancing Science***.) To any Toolbox users reading this, we thank you sincerely. You have made all this possible.



The Climate Toolbox's Future Time Series Tool displays annual maximum daily temperature to the end of this century for two emissions scenarios. Use this and other Toolbox tools to perform your own analysis: https://climatetoolbox.org.

The Climate Toolbox's Historical Water Watcher Tool displays moisture extremes using two variables: total precipitation and reference evapotranspiration. Use the Historical Water Watcher Tool to make your own variable comparisons. https://climatetoolbox.org/tool/Historical-Water-Watcher.



New and Continuing Partnerships

During year five of CIRC 2.0, our NOAA RISA team worked hard to create new partnerships while also nurturing our continuing partnerships. Below is a list of both.

New Partnerships:

- **Quinault Indian Nation on behalf of Quinault Indian Nation, the Hoh Tribe, and the Quileute Tribe**—CIRC researchers performed a flooding analysis for the community of La Push, Washington. The work was undertaken and partially funded on behalf of the Quinault Indian Nation, the Hoh Tribe, and the Quileute Tribe. The Quileute Tribe is working with a consultant who is applying the model developed in a CIRC-associated paper (**Serafin et al., 2019**) to develop new flood maps for the region. (See ***Advancing Science, CIRC's Significant Outputs, and CIRC's Societal Impact***.)
- **Union of Concerned Scientists**—CIRC researcher John Abatzoglou worked with the Union of Concerned Scientists on an analysis of heat index projections of the United States and examined how rising temperatures were likely to impact the nation's population. (See ***Advancing Science***.) This partnership is expected to continue into next year as the Union of Concerned Scientists expands its analysis to include economic impacts to the US economy due to work days lost to extreme heat.

Continuing Partnerships:

- **American Geophysical Union (AGU)**—CIRC researchers continue to play an active role in the key professional organization the American Geophysical Union (AGU). CIRC researcher and former Co-Lead Philip Mote currently acts as AGU's President of Global Environmental Change, a member of the AGU Council, AGU Vice Chair of the Council Leadership Team, and a member of the Board for AGU.
- **Every Individual and Every Organization Involved in the Spokane Climate Project**—As a volunteer-based coproduction effort, the Spokane Climate Project (formerly the Spokane Community Adaptation Project) relied on the time and funds of multiple individual participants and their associated organizations. Here are some of the key partner organizations CIRC has worked with since the start of the project:
    - Avista
    - Eastern Washington University
    - E2 Environmental
    - Gonzaga University
    - GSI Water Solutions, Inc.
    - Lands Council
    - Measure Meant
    - Northwest Renewables
    - Spokane Riverkeeper
    - Washington Department of Ecology
    - 350 Spokane
    - City of Spokane, Washington
- **National Integrated Drought Information System (NIDIS)**—CIRC has continued to work with our sister NOAA program, the National Integrated Drought Information System (NIDIS). This work includes developing tools for the Climate Toolbox as well as co-developing, co-hosting, and co-promoting the Pacific Northwest Drought Early Warning System Drought and Climate Outlook Webinars, a bimonthly, publicly available webinar series that provides timely information on current and developing drought conditions and climatic conditions relevant to the Pacific Northwest United States.
- **Oregon Climate Change Research Institute (OCCRI), Oregon State University (OSU), and the College of Earth, Ocean, and Atmospheric Sciences (CEOAS)**—CIRC continues to have productive relationships with it host organizations, the Oregon Climate Change Research Institute (OCCRI), Oregon State University (OSU), and the College of Earth, Ocean, and Atmospheric Sciences (CEOAS).
- **Pacific Northwest Climate Conference**—CIRC team members have continued to attend and present their research at the annual Pacific Northwest Climate Conference.

CIRC's Significant Outputs

Our NOAA RISA team is very proud of everything we were able to accomplish in year five of CIRC 2.0. ***Table 1*** details what we consider to be our most significant outputs. Because we couldn't fit everything we did on two pages, additional outputs can be found in ***Appendix F—Additional Outputs***.

Table 1—CIRC's Significant Outputs

Stakeholders	State/Region	CIRC Product/Products	Activity Using CIRC Product
Community of Spokane, Washington	Washington/ Pacific Northwest generally	The Spokane Climate Project (formerly the Spokane Community Adaptation Project) The Climate Toolbox Drought data-mining analysis CIRC's peer-reviewed research findings *Climate Resilience Workbook Series*: The Northwest Climate Toolbox Workbook. https://pnwcirc.org/sites/pnwcirc.org/files/nwct.pdf. The Vulnerability Assessment Workbook. https://pnwcirc.org/sites/pnwcirc.org/files/vulnerability_assessment_workbook.pdf. The Resilience Actions Workbook. https://pnwcirc.org/sites/pnwcirc.org/files/resilience_actions_workbook.pdf.	**Climate Adaptation and Resilience in Spokane**—During years four and five of CIRC 2.0, through the Spokane Climate Project (formerly the Spokane Community Adaptation Project), CIRC aided community members in Spokane, Washington to write a series of climate data stories concerning how projected future climate changes are expected to impact their community's businesses and well-being in the decades ahead. A *climate data story*, a term coined by CIRC, is a narrative outlining climate facts and impacts specific to local communities. The SCAP climate data stories were written by community members using CIRC's *Northwest Climate Toolbox Workbook* as a guide. During years four and five of CIRC 2.0, CIRC team members provided organizational support (Ann Mooney, CIRC Outreach Specialist), scientific support (CIRC researchers John Abatzoglou and Meghan Dalton), technical support with the Climate Toolbox (CIRC Researcher Katherine Hegewsich), and editorial, fact-checking, and writing support (CIRC Science Communicator Nathan Gilles) to the effort. In addition, CIRC Graduate Researcher Erich Seamon created an additional analysis for this project employing data mining and machine learning techniques he developed while at CIRC. Beyond using the Climate Toolbox, Spokane community members employed several peer-reviewed studies from the CIRC team as part of their climate analysis. The results of the climate data stories will be part of a larger climate vulnerability and adaptation resilience plan the community is currently developing using CIRCs *Climate Resilience Workbook Series*. The results of CIRC's effort with Spokane can be viewed at the Spokane Climate Project website (https://www.spokaneclimateproject.org/). The climate data stories and related resilience analysis is expected to become a key part of an ongoing climate vulnerability and resilience plan for Spokane.

United States population generally/Pacific Northwest Stakeholders generally Specific Stakeholders (For highlights from specific users, see ***Proudest Accomplishment*** and ***Appendix A—Climate Toolbox Users and Usages***.)	United States/ United States Pacific Northwest	Climate Toolbox and related datasets and analyses, including peer-reviewed research	**Climate Toolbox Development Continues**—During year five of CIRC 2.0, CIRC developed the following new features and tools in the Climate Toolbox ● **New Features:** ○ **Heat Index**—adds US county-level visualization of heat index data to the Climate Mapper Tool. ○ **Vapor Pressure Deficit (VPD)**—adds VPD data visualizations to the Climate Mapper Tool. ○ **Fire Potential Modeling**—adds to the Climate Mapper Tool fire potential data from a 2015 study showing monthly and seasonal risks for very large fires across the US. Feature was developed at the request of multiple users. ○ **Regional and County Specific Data**— allows users to use multiple Toolbox point-based tools to show information for specific regions, including at the county and watershed scales and a rectangular bounding box. ● **New Tools:** ○ **Find Your Variable**—allows users to determine which variable best suits their interest and to see which tools contain that variable. ○ **Future Vegetation**—provides maps and graphs of future vegetation projections. ○ **Historical Seasonal Progression**—provides graphs of historical weather and forecasts for selected locations; includes past averages and ranges, current seasonal progression, and subseasonal and seasonal forecasts for climate, agriculture, and fire variables. ○ **Seasonal Forecast Maps**—provides seasonal climate forecasts for the western United States. ○ **Seasonal Forecast Graphs**—provides graphs of seasonal climate forecasts for specific locations. ○ **Historical Scatter Plot** —allows users to compare two historical climate variables for specific locations. In addition to the development of new tools and datasets for the Climate Toolbox, the CIRC Toolbox team also worked on three publications associated with the Toolbox that garnered significant media attention, further highlighting our team's efforts and the importance of responding to climate impacts with evidence-based approaches: ● Williams, A. Park, John T. Abatzoglou, Alexander Gershunov, Janin Guzman Morales, Daniel A. Bishop, Jennifer K. Balch, and Dennis P. Lettenmaier. "Observed impacts of anthropogenic climate change on wildfire in California." *Earth's Future* (2019). https://doi.org/10.1029/2019EF001210. ● Dahl, Kristina, Rachel Licker, John T. Abatzoglou, and Juan Declet-Barreto. "Increased frequency of and populations exposure to extreme heat index days in the United States during the 21st century." *Environmental Research Communications*. (2019). https://doi.org/10.1088/2515-7620/ab27cf. ● Marshall, Adrienne M., John T. Abatzoglou, Timothy E. Link, and Christopher J. Tennant. "Projected changes in interannual variability of peak snowpack amount and timing in the Western United States." *Geophysical Research Letters*(2019). 46, 8882-8892

The Quinault Indian Nation, the Hoh Tribe, and the Quileute Tribe/ Communities near estuaries	Washington	CIRC peer-reviewed research: Serafin, Katherine A., Peter Ruggiero, Kai Parker, and David F. Hill. "What's streamflow got to do with it? A probabilistic simulation of the competing oceanographic and fluvial processes driving extreme along-river water levels." Natural Hazards and Earth System Sciences 19 (2019). https://ir.library.oregonstate.edu/concern/articles/5m60qz50n. CIRC White Paper: Ruggiero, Peter, Katherine A. Serafin, Kai Parker, and David Hill. "Assessing the Impacts of Coastal Flooding on Treaty of Olympia Infrastructure. A report to the Quinault Indian Nation, Hoh Tribe, and Quileute Tribe." Corvallis, Oregon: Oregon Climate Change Research Institute, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 2019. https://pnwcirc.org/sites/pnwcirc.org/files/qtaii_report_final.pdf.	**Flooding in a Pacific Northwest Estuary**—Building on previous CIRC-funded research, former CIRC researcher Katherine Serafin and current CIRC researcher Peter Ruggiero developed and applied a flooding analysis for the coastal community of La Push, Washington. The work was undertaken and partially funded on behalf of the Quinault Indian Nation, the Hoh Tribe, and the Quileute Tribe. The Tribes plan to use the analysis in their long-term risk management planning. The Quileute Tribe has already begun this work by hiring the engineering firm Tetra Tech, which is using CIRC's flooding model and data to calibrate and build its own even more robust model for designing bank stabilization and habitat restoration projects undertaken at the Tribe's request. (See ***CIRC's Societal Impact***.)

Advancing Science

While our researchers published over 30 studies during year five, three of them stand out. These three studies are especially relevant to climate resiliency, risk mitigation, and resource management in the Pacific Northwest. All three studies not only advance the state of the science, they also each have a direct application either as part of an existing adaptation project (see ***Climate and Coastline Flooding*** and ***Extreme Heat, Climate Change, and Human Health***) or because the datasets that resulted from the peer-reviewed publication were turned into online tools (see ***Wildfires, Vapor Pressure Deficit, and Climate Change*** and ***Extreme Heat, Climate Change, and Human Health***). All three studies have also been translated into blog posts on CIRC's blog, *The Climate CIRCulator*. We feel these two aspects, providing a direct application and a plain English summary of our research, is essential for fulfilling our obligations not only to NOAA, CPO, and RISA, but also to the American people who fund our work with their tax dollars and who ultimately should benefit and understand how that money has been spent.

Climate and Coastline Flooding

Publication: Serafin, Katherine A., Peter Ruggiero, Kai Parker, and David F. Hill. "What's streamflow got to do with it? A probabilistic simulation of the competing oceanographic and fluvial processes driving extreme along-river water levels." *Natural Hazards and Earth System Sciences* 19 (2019). https://ir.library.oregonstate.edu/concern/articles/5m60qz50n.

CIRC Project: Builds on the Grays Harbor Coastal Futures project

Rationale for Research: The flooding that occurs in estuaries is both dangerous for the communities that live near them and considerably difficult to model. This CIRC-associated research was partially funded by a grant administered by the Quinault Indian Nation on behalf of Quinault Indian Nation, the Hoh Tribe, and the Quileute Tribe. The tribes have seen periodic flooding in their local estuaries and are using the results of this study in their risk management planning.

Key Findings: Rare, extreme flooding events can result from a combination of more common, less extreme events.

Summary: Building on previous CIRC-associated research, this study, developed in conjunction with the Oregon Climate Change Research Institute (OCCRI) by former CIRC researcher Katherine Serafin and current CIRC researcher and former Interim Director of OCCRI Peter Ruggiero, further developed and applied a hybrid model that combines a statistical-based modeling approach and a physics-based modeling approach. The novel hybrid approach was taken to overcome a shortcoming in previous research related to the reoccurrence of rare but dangerous flooding events. Much previous research on 100-year flooding events (rare, extreme events so-named because they have just a 1% chance of occurring within any given year) rested on the assumption that multiple 100-year events—for instance, 100-year storms and 100-year river heights—tended to occur together. However, this paper demonstrated that 100-year flooding events in estuaries can occur when more common, less extreme events occur simultaneously, compounding their effects and cumulatively creating an extreme flooding event. Estuarine dynamics were examined for the estuary where the Quillayute River meets the Pacific Ocean. The research findings from this study have direct applications to risk management planning overseen by local tribal governments. Presently, the Quileute Tribe is working with a consultant who is applying the novel hybrid model created for this paper to develop new flood maps for the region. Beyond this regional work, the methods developed for this paper could be replicated elsewhere, further aiding risk management planning.

***CIRCulator* Review:**

- "Flooding in Estuaries"

Direct Application:

- **Risk Management Planning**—(See ***CIRC's Societal Impact*** for more details.)
- **Associated White Paper**—Ruggiero, Peter, Katherine A. Serafin, Kai Parker, and David Hill. "Assessing the Impacts of Coastal Flooding on Treaty of Olympia Infrastructure. A report to the Quinault Indian Nation, Hoh Tribe, and Quileute Tribe." Corvallis, Oregon: Oregon Climate Change Research Institute, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 2019. https://pnwcirc.org/sites/pnwcirc.org/files/qtaii_report_final.pdf.

Wildfires, Vapor Pressure Deficit, and Climate Change

Publication: Williams, A. Park, John T. Abatzoglou, Alexander Gershunov, Janin Guzman-Morales, Daniel A. Bishop, Jennifer K. Balch, and Dennis P. Lettenmaier. "Observed impacts of anthropogenic climate change on wildfire in California." *Earth's Future* (2019). https://doi.org/10.1029/2019EF001210.

CIRC Project: The Climate Toolbox and Related Curated Datasets

Rationale for Research: Understanding the relationship between climate change and wildfire activity in the American West continues to be an important research subject with direct applications for saving lives and protecting public and private property. This study acts as both an attribution study—providing a clear link between climate change and wildfire activity in California—as well as demonstrating the efficacy of a rarely used diagnostic method—employing the variable vapor pressure deficit (VPD) for determining current and projected future wildfire activity in the American West generally.

Key Findings:

- Human-caused climate warming is very likely responsible for the large increase in California's wildfires.
- The relationship between the dryness of the air as measured using vapor pressure deficit (VPD) and fire activity is exponential, meaning each historical increase in VPD led to larger burn areas.
- VPD numbers in California are likely to double under projected warming by 2060, which is expected to lead to an increase in wildfire activity.

Summary: The rise and destructiveness of California's wildfire activity in recent years has been staggering.

To determine the role climate change might have played in the recent destruction, a group of researchers, including CIRC researcher John Abatzoglou, examined the relationship between temperature increases, burned area, and a little-known climate variable called *vapor pressure deficit* (VPD). VPD is a means for determining how dry air is as represented by how large a difference there is between the moisture content of the air and how much moisture the air can hold when saturated. The higher the deficit, the drier the air. VPD is closely connected to temperature and, as Abatzoglou and colleagues discovered, it can tell you about fire potential. By examining seasonal changes in VPD found in California over the historical period 1972–2018 and comparing that to area burned over the same period, the researchers demonstrated that the relationship between VPD and wildfire activity was exponential, meaning each incremental increase in VPD led to larger and larger burn areas. This finding is important because it represents not only a way to diagnose wildfire activity in the past, but also a way to examine projected wildfire activity in the future. VPD numbers in California are likely to double under projected warming by 2060, according to the study. In other words, California is in for some very destructive fire seasons in the decades ahead. The analysis established by Abatzoglou and colleagues has direct applications beyond California and is especially relevant to the Pacific Northwest, which, along with its neighbor to the south, has seen an increase in the size and severity of wildfire activity in recent years.

***Climate CIRCulator* Articles:**

- "California Wildfires and Climate Change"
- "This Summer—A Welcome Reprieve"

Direct Applications:

- **Vapor Pressure Deficit Toolbox Feature—**To put the above analysis and data specific to California to work for our Pacific Northwest stakeholders, our RISA team created a Vapor Pressure Deficit (VPD) feature for the monitoring and forecasting attributes in the Climate Toolbox's Climate Mapper Tool. We then demonstrated how the VPD feature could be employed in a real-time assessment of wildfire risk by highlighting the new Toolbox feature in the "Northwest Climate Currents" section of our newsletter, *The Climate CIRCulator*, as well as in an installment of the Pacific Northwest DEWS Drought & Climate Outlook Webinar Series.

Extreme Heat, Climate Change, and Human Health

Publication: Dahl, Kristina, Rachel Licker, John T. Abatzoglou, and Juan Declet-Barreto. "Increased frequency of and population exposure to extreme heat index days in the United States during the 21st century." *Environmental Research Communications*. (2019). https://doi.org/10.1088/2515-7620/ab27cf.

CIRC Project: The Climate Toolbox and Related Curated Datasets and Methods

Rationale for Research: Most studies that examine future temperature projections and their projected impacts to human health have tended to employ temperature alone without considering the combined effects of temperature and humidity on the human body. This publication bucks that trend, providing United States regional projections using the *heat index*, a metric that is used by NOAA's National Weather Service when it issues Heat Advisory warnings to the general public. Projections are provided for both the lower emissions scenario (RCP 4.5) and the high emission scenario (RCP 8.5).

Findings:

- By the middle of this century (2036–2065) under both RCP 4.5 and RCP 8.5, the annual numbers of days with heat indices exceeding 100 °Fahrenheit and 105 °F are projected to double and triple, respectively, compared to the historical baseline 1971–2000.
- By the end of the century (2070–2099), the contiguous US is projected to see a quadrupling in the number of days annually during which the heat index reaches or exceeds 100 °F under RCP 8.5, and a doubling of the days annually during which the heat index reaches or exceeds 100 °F under RCP 4.5.

Summary: When it's especially hot and especially humid, the human body has trouble cooling itself by sweating. This "feels-like temperature" is represented in the *heat index* metric, which combines heat and humidity. This study—undertaken in partnership with the Union of Concerned Scientists and including CIRC researcher John Abatzoglou—calculates how many days each year the United States is projected to experience under future climate change that will be too hot and humid for the human body to cool itself by sweating alone. The study provides heat index projections by US regions (Northwest, Northeast, Midwest, etc.) that are further broken down at the US county level in two online tools: one created for the Union of Concerned Scientists, the other created by CIRC as an added feature to the Climate Toolbox's Climate Mapper Tool.

***CIRCulator* Article:**

- "Extremely Warm Days to Continue Under Climate Change"

Direct Applications:

- **SCAP Climate Data Stories**—Using the Climate Toolbox heat index feature, CIRC provided an additional heat index analysis to the climate data stories created by Spokane community members as part of the Spokane Climate Project. (See ***CIRC's Significant Outputs***.)
- **Toolbox Heat Index Feature**—CIRC used the datasets created for this study to create a heat index feature for the Climate Toolbox' Climate Mapper tool.
- **Union of Concerned Scientists Tool**—The Union of Concerned Scientists created a heat index tool that displays projected heat index values at the level of US counties.
- **"Killer Heat in the United States, Climate Choices and the Future of Dangerously Hot Days"**—A plain English summary of projected heat index impacts on the United States population published by the Union of Concerned Scientists for journalists and the general public.

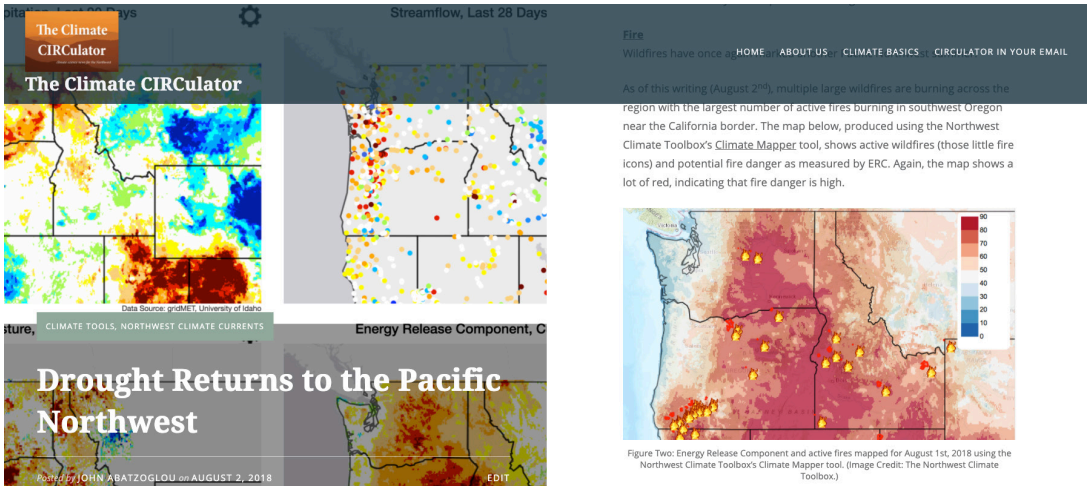
CIRC's Outreach

CIRC's outreach encapsulates all of our efforts, including Community Adaptation, Climate Tools, our research, and our communication efforts. Here are some of the highlights.

Community Adaptation—CIRC currently has two Community Adaptation efforts underway in Washington and Oregon. Our Washington project, the Spokane Climate Project (formerly the Spokane Community Adaptation Project), is similar to other CIRC Community Adaptation efforts and uses *coproduction*, a collaborative process between experts and stakeholders to set and meet project goals. Coproduction participants work together to define research objectives, making decisions about data and methodological design, interpreting results, and, ultimately, applying an effort's findings to the problems and challenges initially identified at the start of each effort. Coproduction efforts typically involve multiple interactions among scientists, local experts, and stakeholders. The Spokane Climate Project was no exception to this general rule. But we feel this effort with the community of Spokane has paid off and is ultimately our greatest outreach accomplishment during CIRC 2.0. Our Community Adaptation effort in Oregon, the Oregon Water Resources Department Integrated Place-Based Water Planning effort (OWRD effort), looks a little different. For the OWRD effort, our CIRC team trained OWRD project participants in the use of the Climate Toolbox and ***The Climate Resilience Workbook Series***, the latter of which was coproduced through the Spokane Climate Project. The OWRD effort is being led and facilitated by the Oregon Water Resources Department and does not involve coproduction. Here are the highlights from these two very different projects:

- **Spokane Climate Project**—CIRC advised community members in Spokane, Washington by providing editorial, scientific, organizational and technical support to community members as they used CIRC's Climate Toolbox and *Climate Resilience Workbook Series* to create a climate vulnerability assessment and related resilience strategies for the Spokane region. (See ***CIRC's Societal Impact***.)
- **Oregon Water Resources Department Integrated Place-Based Water Planning**—CIRC hosted two training webinars for participating water managers in the state of Oregon. CIRC led participants through orientation and use of the Climate Toolbox and *The Northwest Climate Toolbox Workbook*. This helped participants analyze climate data questions related to their watersheds. The OWRD effort has a proscribed progression based on the state agency's planning process. The Toolbox and related workbook serve as components of this broader analysis.

The Climate CIRCulator's Northwest Climate Currents series uses the Climate Toolbox to help readers better understand the climate of the Pacific Northwest. Learn more here: https://climatecirculatororg.wordpress.com/category/northwest-climate-currents/.



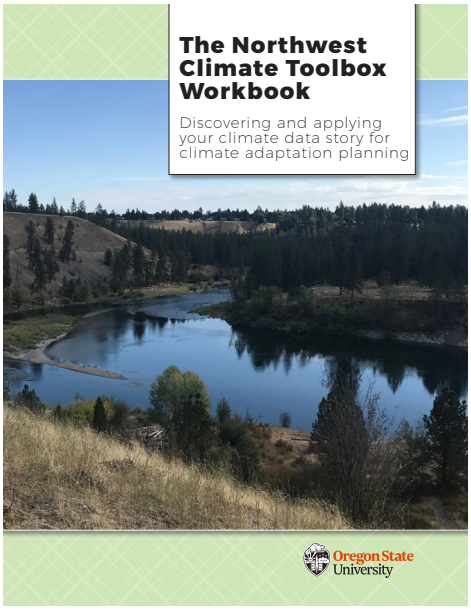
Communication Products—Each year, CIRC creates multiple communication products. Here is a list of the highlights from year five:

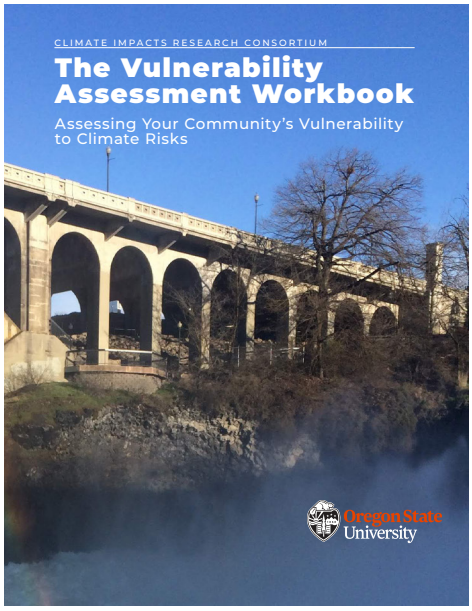
- ***Vulnerability Assessment Workbook***—Book two in the three-volume *Climate Resilience Workbook Series*, *The Vulnerability Assessment Workbook* picks up where *The Northwest Climate Toolbox Workbook*, developed in year four of CIRC 2.0, ends. *The Vulnerability Assessment Workbook* was created to help users assess and catalog their community's vulnerabilities to climate change.
    - Mooney, Ann, Nathan Gilles, and Denise Lach, "The Vulnerability Assessment Workbook: Assessing your Community's Vulnerability to Climate Risks." Corvallis, Oregon: The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 2020. https://pnwcirc.org/sites/pnwcirc.org/files/vulnerability_assessment_workbook.pdf.
- ***Resilience Actions Workbook***—Book three in the *Climate Resilience Workbook* series, *The Resilience Actions Workbook* provides users with tools to help them understand the human landscape of their communities and to plan resilience actions that integrate the best available scientific research and tools with their local experiences and judgements.
    - Mooney, Ann, and Denise Lach. "The Resilience Actions Workbook: Building and Communicating Resilience Actions Using your Climate Data Story and Vulnerability Assessment." Corvallis, Oregon: The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 2020. https://pnwcirc.org/sites/pnwcirc.org/files/resilience_actions_workbook.pdf.
- **Spokane Climate Project Climate Data Stories**—During year four and five, CIRC helped community members in Spokane, Washington write a series of climate data stories concerning how projected future climate changes are expected to impact their community's businesses and well-being in the decades ahead. The results of that effort can be viewed at the Spokane Climate Project website. (See ***Appendix B*** for more details.)

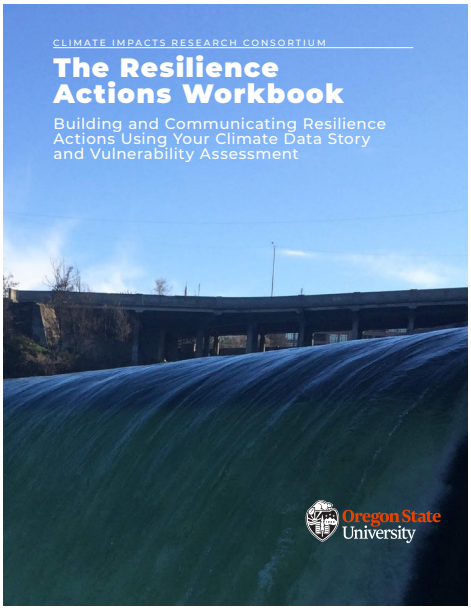
- ***The Climate CIRCulator* and *Northwest Climate Currents***—In existence since CIRC 1.0, CIRC's periodic newsletter, *The Climate CIRCulator*, continues to maintain a readership of around 1,500–1,600 subscribers. In year three of CIRC 2.0, CIRC added a new section to our newsletter, ***Northwest Climate Currents***. *Northwest Climate Currents* uses CIRC's Climate Toolbox to provide periodic climate updates to our readers. It frequently receives 300+ page views per issue.
- **CIRC's website**—CIRC continues to maintain and update our website (https://pnwcirc.org/) listing our research findings and accomplishments.

Media Engagement—CIRC researchers gave over 40 media interviews during year five of CIRC 2.0. Our research and interviews appeared in several national publications (including, *The New York Times*, *The Washington Post*, *Forbes*, *Scientific American*, *Arstechnica*, *American Progress* and *Grist)* as well as several key Pacific Northwest publications (including *The Oregonian*, *The Astorian* and *The Idaho Statesman*). (See ***Appendix C—Media Engagement***).

Conferences, Presentations, Posters, Webinars, and Videos—To better communicate our science and to participate in the betterment of science and scientific professionalism generally, CIRC team members attend multiple conferences, give multiple talks, and present multiple posters each year. During year five of CIRC 2.0, our team members attended and presented at two key conferences (the fall meeting of the American Geophysical Union and the Northwest Climate Conference). We also gave over 30 in-person presentations and online webinars. (For a full list, see ***Appendix E—Outreach***.)







The Climate Resilience Workbook Series helps users to access and apply global climate information at a local scale to develop relevant resilience actions. Learn more: https://pnwcirc.org/climate-resilience-workbook-series

What We're Doing & Next Steps

(Projected Work Plan for Performance Period June 1st, 2020–May 31st, 2021, year six of CIRC 2.0)

CIRC's overall goal for our final year of CIRC 2.0 (year six) has two main components: maintaining and expanding the Climate Toolbox and advancing Community Adaptation. However, while we refer to these as two components, like all of CIRC's efforts in recent years, our work during year six will intersect and interact with all of our ongoing efforts.

Maintaining and Expanding the Climate Toolbox—In year six of CIRC 2.0, our NOAA RISA team led by researchers John Abatzoglou, Katherine Hegewisch, and Bart Nijssen will continue to maintain the Climate Toolbox and its related datasets. Our team has in development a series of ambitious new tools. We plan on releasing these new tools to the public next year.

- **Maintaining the Climate Toolbox and its Datasets**—The multiple tools inside the Climate Toolbox are built on real-time datasets (gridMET, CFS, NMME) and JavaScript libraries (HighCharts, Leaflet). These datasets are ever-changing and require constant maintenance and updating. In addition, we estimate that our Toolbox team spends on average five hours per week responding to inquiries from Toolbox users. We believe in providing the best available science and tools to our users. Which is why in year six of CIRC 2.0, our team is committed to continuing to maintain the Toolbox and respond to user inquiries as they arise. In addition, the Toolbox team will work with CIRC's Science Communicator to engage in the following activities to increase the quality of our users' experiences:
    - **User Guides and User Outreach**—In response to requests from our stakeholders, our RISA team plans to develop a series of user guides and outreach materials intended to both promote the Toolbox and to inform current and potential users as to how our tools can be used. This work builds off two efforts developed during CIRC 2.0: the use of the Toolbox in the ***Northwest Climate Currents*** section of ***The Climate CIRCulator*** and the creation ***The Climate Resilience Workbook Series***. Here are the details:
        - **Two-Pagers**—in simple, two-page, compact summaries we will provide targeted introductions to the various Toolbox tools and related datasets and how to use them. Similar to material produced by University Extension, our 2-pagers will be posted on the Toolbox website and available for download.
        - **Introductory Training Videos**—Because we recognize that people learn in different ways, our team also plans to develop a series of short training videos that will provide the same information contained in our two-pagers. Our introductory training videos will be available to view on our Toolbox website as well as on CIRC's YouTube page.
- **Expanding the Climate Toolbox**—In year six, our team plans to release several new and innovative Toolbox tools, features and user guides. This work includes:
    - **Coastal Flooding**—In year six of CIRC 2.0, our team plans to develop a tool within the Toolbox that will generate projections of coastal flooding for much of the Pacific Northwest coast under multiple climate scenarios. The tool will employ a new Total Water Levels (TWL) analysis developed by CIRC researcher Peter Ruggiero and colleagues called the *Time varying Emulator for Short and Long-term Analysis of coastal flooding and erosion hazards*, or TESLA. TWL projections combine multiple factors—including projected sea level rise scenarios, changing patterns in storminess, projected changes in El Niño and La Niña events, the shape of local coastlines, and calculations of the tides—to determine by how much a given coastal community is likely to be inundated by a coastal flood. The proposed Coastal Flooding Tool will enable users to spatially explore chronic coastal hazard risks along the outer coasts of Oregon and Washington and pull TWL products for their own analyses.
    - **Drought Recovery Tool**—During year two and three of CIRC 2.0, our team, with support from the National Integrated Drought Information System (NIDIS), created a diagnostic method that estimates whether individual Pacific Northwest counties (extending to the western United States) are likely to recover from drought. This percentile drought indicator allows state drought coordinators to explore questions related to likelihood that current drought conditions—for instance, drought conditions in February—will either persist or recover by June or later for a given county. The tool will be developed in conjunction with state drought coordinators via state water supply availability committee meetings and other regular communications.
    - **Probabilistic Forecasting**—CIRC has developed a prototype weather forecasting system for using downscaled weather-climate forecasts using the data output from the CFSv2 (48 ensemble members, through day 28) and NMME ensembles. The NMME multi-model ensemble uses eight models to create forecasts that reach seven months into the future. Our prototype forecasting system includes inputting this short-term forecast data through a hydrologic model (run at the University of Washington, by CIRC Researcher Bart Nijssen and team). The Toolbox team is currently investigating how to create intuitive ways for visualizing these advanced probabilistic forecasts and how to make them more applicable to local and regional planning efforts. This work includes: creating probabilistic maps, visual representations of likelihoods of above/below normal conditions, and disseminating this information via webinars, conferences, and blog posts. CIRC will work closely with decision-makers across the region to understand their needs for understanding and acting on such information.

Advancing Community Adaptation Capacity—In year six of CIRC 2.0, our team has several efforts planned that will help advance community adaptation capacity in the Pacific Northwest. These efforts are intimately tied to the Toolbox and include the following:

- **Handing Off the Spokane Climate Project**—During year six, our RISA Team plans to wrap up the Spokane Climate Project. During years four and five of CIRC 2.0, Spokane Climate Project participants in Spokane began their own process of outreach. This effort has included giving talks at the Northwest Climate Conference, giving talks to local stakeholders and public officials, as well as the creation of a website highlighting the results of the project. In year six, we expect the community will continue to use the work they co-produced with us to help make their community more resilient to climate variability and change.

- **Community-Centered Additions to the Toolbox**—In addition to finishing up our work with the community of Spokane, CIRC plans on implementing the following community-centered efforts connected to the Toolbox:
    - **Deeper Dive Videos**—In addition to our introductory video series, CIRC plans to develop a how-to video series that will provide a deeper examination of the Toolbox and its data sets. These deeper dive videos are intended to provide in-depth instructions for using the Toolbox and how to relate Toolbox data to local contexts. This effort will build off and work in conjunction with *The Northwest Climate Toolbox Workbook*.
    - **Help Desk via the User Community**—In year six, CIRC plans on extending the usability of the Toolbox by creating a virtual help desk that will draw on the community of existing Toolbox users. The idea here is to crowdsource some of the queries to the Toolbox to its broader community of users. Using a phone-a-friend model, this will provide less-experienced users with access to the larger brain trust of current, more-savvy users and will allow the CIRC team to spend more time maintaining the Toolbox and developing new features and tools.
    - **Train-the-Trainer**—To further extend the reach and usability of the Toolbox in year six, CIRC will pilot a train-the-trainer curriculum with our current stakeholders in Spokane, Washington. The idea is to systematically teach Spokane Climate Project participants how to train others to use the Toolbox, something the project's participants are already interested in doing in neighboring communities. This work will then enable us to create a template for a future train-the-trainer curriculum.
    - **Talking with Educators**—CIRC also plans to gather materials from educators currently using the Toolbox in order to determine how the Toolbox and similar products might be used by educators who are teaching the science of climate and weather.

Online Interactive *Tribal Climate Adaptation Guidebook*

During year three of CIRC 2.0, the Oregon Climate Change Research Institute (OCCRI), the nonprofit Adaptation International (AI), and CIRC among multiple other contributors worked together to produce ***The Tribal Climate Adaptation Guidebook*** to support the unique challenges that climate change poses to tribal nations in the Pacific Northwest and across the United States. In response to feedback from the guidebook's users and the project's Tribal Advisory Group, during year six of CIRC 2.0, the CIRC team, in partnership with OCCRI and AI, will transform the existing *Tribal Climate Adaptation Guidebook*, currently available as an interactive PDF, into an interactive website.

As was done during the first iteration of the guidebook, CIRC, OCCRI, and AI will use a co-production method, working closely with the Tribal Advisory Group (or representatives they identify) to create a usable website with culturally relevant guidelines for adapting to climate change. The Tribal Advisory Group will review and critique the website to ensure that the *Guidebook* in its new online form continues to address the needs, concerns, and decisions faced by tribal communities in the Pacific Northwest and beyond. The project's Tribal Advisory Group includes representatives from the following:

- The Jamestown S'Klallam Tribe
- The Yurok Tribe
- The Quinault Indian Nation
- The Central Council of Tlingit and Haida Tribes
- The Quinault Indian Nation
- The Confederated Tribes of the Umatilla Indian Reservation
- The Confederated Tribes of Siletz Indians

Evaluating Our RISA Team's Efforts

The CIRC 2.0 evaluation process consists of multiple approaches to evaluate CIRC's efforts in community adaptation, decision support tools, and science communication through both formative (during activities) and summative evaluations.

Community Adaptation—Community adaptation projects were evaluated using a mixed methods research design, including surveys of stakeholder participants during activities and open-ended interviews at the end of year five of CIRC 2.0. Both are described briefly below, with a full report to follow in a separate document.

- **Survey**—At the end of each stakeholder meeting or webinar, stakeholders were asked to fill out a short questionnaire (***Appendix G—Evaluation Table 2)***. Participants were asked the same six questions. Responses were collected and entered into a secure database, and later analyzed separately for each CIRC 2.0 community adaptation project (see example from CIRC 1.0 analysis in ***Appendix G: Figure 1***). The survey results were used to debrief stakeholder meetings/webinars, identify challenges, and develop best practices.
- **Open-ended interviews**—From November 2019 to March 2020, interviews were conducted with CIRC 2.0 community stakeholders, the CIRC advisory board, and CIRC 2.0 staff who worked on community adaptation projects. The open-ended questions (***Appendix G: Table 3***) were based on the CIRC logic model (***Appendix G: Figure 2***). The open-ended interviews were recorded with consent of the participants and later transcribed (omitting identifying information). The evaluation team conducted 40 open-ended interviews. The data will be analyzed using Theme Coding, in which key themes are assigned (through review of each response) using a coding system. The coding system relies on a pre-established set of codes that were extracted from the CIRC logic model.

Decision Support Tools—Development of CIRC's decision support tools, namely The Climate Toolbox, was informed by an iterative assessment and evaluation process. This process consisted of a series of training webinars for support developers and trainings, workshops with stakeholders (to gain the perspective of users of the tools), and open-ended interviews with CIRC 2.0 staff who work on creating and maintaining CIRC's decision support tools (see ***Appendix G: Table 4*** for interview items). In addition, CIRC commissioned two comprehensive usability reviews of the Toolbox's tools:

- CIRC Researcher Holly Hartmann reviewed the tools inside the Climate Toolbox, providing feedback to Katherine Hegewisch and John Abatzoglou. The work resulted in the following document:
    - Hartmann, Holly C. "Documentation of Water Climate Toolkit Usability Review" Corvallis, Oregon: The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, 2019. https://pnwcirc.org/sites/pnwcirc.org/files/toolboxhartmann.pdf.
- CIRC then hired Oregon State University graduate student researcher Linnia Hawkins to turn Hartmann's work into a structured work plan developed with Hegewisch that would ensure consistency in language and functionality of the Toolbox's tools by:
    - Identifying potential problems
    - Suggesting solutions
    - Fixing and tracking solutions
    - Revisiting solutions to determine their efficacy

Science Communication—The evaluation team gauged CIRC 2.0's science communication efforts by surveying the users of *The Climate CIRCulator*, a periodic newsletter covering climate science and the Pacific Northwest and a content analysis of CIRC media mentions (news articles, videos, blog posts, mentions by other websites).

- ***The Climate CIRCulator* User Questionnaire**—The *CIRCulator* survey was conducted online using the software Qualtrics (see ***Appendix G: Table 5*** for questionnaire items). Readers of the *CIRCulator* were informed and invited to take part in the survey via a pop-up tab on the website. Example preliminary results are presented here (***Appendix G: Figure 3*** and ***Figure 4***), while collection of data is ongoing.

CIRC By the Numbers—In addition to the above analysis, our CIRC team acquired the following metrics in ***Table 2—CIRC By the Numbers*** for the current performance period.

Table 2—CIRC By the Numbers, Performance Period: June 1st, 2019–May 31st, 2020

Climate Toolbox

Users and Sessions:

Users	Sessions
Total Users: 9,804	**Total Sessions: 19,703**
New Users: 9,707	Average Session Duration: 3:49 min
Active Daily Users: 137	Engaged Sessions (3–30 mins): 3,202
7-Day Active Users: 327	Very Engaged Sessions (+30 mins): 670
Monthly (28 Day) Active Users: 1,328	Page Views: 53,276
(See ***Proudest Accomplishment*** for information about individual users)	Bounce Rate: 50.72%

Users by Top Set Locations:

City	State
Corvallis, Oregon: 606	**Oregon:** 1,666
Not Set (Users did not set a specific location): 555	**Washington:** 1,493
Seattle, Washington: 358	**California**: 885
Portland, Oregon: 339	**Idaho:** 492
Moscow, Idaho: 270	**Colorado:** 336
Olympia, Washington: 215	**Virginia:** 260
New York, New York: 186	**New York:** 257

Pacific Northwest Drought Early Warning System Drought and Climate Outlook Webinars

With the National Integrated Drought Information System (NIDIS)

Month	YouTube Views	Registered	New Registrants	Attended
June	107	163	2	101
Aug.	87	158	40	108
Oct.	73	138	20	82
Dec.	0	178	42	105
Feb.	114	165	17	117
Apr.	158	348	111	257
Total:	539	1150	232	770

The Climate CIRCulator

Email Subscribers: 1,641	**Blog subscribers:** 17	**Total Subscribers:** 1,658	**Unique Page Views:** 5,627	**Unique Visitors:** 3,422

Social Media and Media Engagements

Twitter: **Followers:** 1,686	**Facebook:** **Likes:** 255 **Follows:** 296	**Total Media Engagement:** 41 (includes direct interviews and use of CIRC data and products)

Presentations, Conferences, Workshops, and Publications

Major Conferences Attended: 2	**Presentations:**24	**Poster Presentations:** 5	**Webinars:** 12	**Peer-Review:** 37	**Other Publications (white papers, workbooks, etc.)**: 12

Engaged Stakeholders (Spokane Community Adaptation Project)

Core Participants: 25	**Total Participants:** 85	**Key Partner Organizations:** 11

CIRC's Societal Impact—Narrative Examples

During year five of CIRC 2.0, CIRC continued to have a positive social impact in the Pacific Northwest United States. Below are some of the highlights.

Flood Management and Ecological Restoration in Washington

Building on previous CIRC-funded research, former CIRC researcher Katherine Serafin and current CIRC researcher Peter Ruggiero led the development of a flooding analysis of the Quillayute River and its estuary for the nearby Quileute Tribe community of La Push, Washington. The work—which has also led to a peer-reviewed publication (**Serafin et al., 2019**) (See ***Advancing Science***)—was undertaken and partially funded on behalf of the Quinault Indian Nation, the Hoh Tribe and the Quileute Tribe. The Quileute Tribe is currently using the CIRC researchers' river flow modeling component and data for multiple projects and grant proposals designed to aid fish-friendly habitat restoration and infrastructure resilience efforts along the Quillayute River and its estuary. Specifically, CIRC research, in conjunction with a 2016 climate change vulnerability assessment performed by our partner organization the Oregon Climate Change Research Institute (OCCRI), is being used as support for a $2 million grant proposal to the Washington Coast Restoration and Resiliency Initiative (WCRRI). Using previously awarded WCCRI grant funds, the Quileute Tribe hired the engineering firm Tetra Tech, which has used CIRC researchers' flooding model and data to calibrate and build its own even more robust model for designing bank stabilization and habitat restoration projects along the Quillayute River. Using CIRC's model and data and WCCRI funding, Tetra Tech has designed wood structures and channel modifications intended to reconnect sections of the local floodplain, restore salmon habitat, and protect regionally vital economic infrastructure from flooding. In addition to this, CIRC's and OCCRI's research for the Tribe has been used as support for a successful $169,000 grant proposal to the National Fish and Wildlife Foundation (NFWF), and is being cited in support of requests for the additional funding from WCRRI as well as another NFWF grant for $1.5 million. The additional grant money if received will pay for the construction and implementation of the wood structures and channel modifications designed by Tetra Tech. This is what Frank Geyer, Director of the Quileute Natural Resources department, had to say about how CIRC research has aided the Quileute Tribe's efforts:

"The Quileute Indian Reservation consists of a mere two square miles where the Quillayute River meets the Pacific Ocean on the Olympic Peninsula in Washington State. With much of the reservation consisting of wetlands and unstable steep slopes, the vast majority of the Tribe's infrastructure is on a bench at sea level where the river meets the ocean. The reservation village of La Push includes government offices, the Tribal Court, tribal school, senior center, tribal member housing, wastewater treatment plant, and the Tribe's main economic enterprises, as well as the only U.S. Coast Guard station serving 200 miles of this rugged coastline between Neah Bay and Westport, Washington. Flooding, avulsion, sea level rise, and tsunami are constant threats to this tribe's members, lands, infrastructure, and natural resource base. The 2016 climate change vulnerability assessment and the 2019 assessment of infrastructure vulnerability produced for the Treaty of Olympia Tribes by the researchers from the Climate Impacts Research Consortium and the Oregon Climate Change Research Institute have been invaluable to the Quileute Tribe's ability to develop plans and design projects to protect the reservation, restore our fisheries and natural resources, and provide resilience in the face of climate change."

—Frank Geyer, Director, Quileute Natural Resources

Transferring the Spokane Community Adaptation Project (SCAP) to the Community of Spokane

From the summer of 2017 to the end of this reporting period, our NOAA RISA team worked with Spokane, Washington community members as part of the Spokane Climate Project (formerly the *Spokane Community Adaptation Project*), an effort designed to help the community of Spokane assess and respond to climate impacts. During year four and five of CIRC 2.0, our CIRC team members provided the community with organizational support (Ann Mooney, CIRC Outreach Specialist; Denise Lach, CIRC Lead), scientific support (John Abatzoglou, CIRC Researcher), technical support with the Climate Toolbox (Katherine Hegewsich, CIRC Researcher), an additional data-mining analysis (Erich Seamon, Student Researcher), and editorial, fact-checking and writing support (Nathan Gilles, Science Communicator). The result was a coproduced collection of *climate data stories*, data-driven narratives written by Spokane community members that identified and described climate impacts Spokane has faced and is continuing to face as the region's climate changes. The community was particularly concerned about how climate impacts have affected and could continue affecting Spokane's key businesses. The community looked at multiple business sectors, including farming, the local winter recreation industry, and the local whitewater rafting industry. This work included an examination of how climate impacts to these business sectors could have trickle-down effects on the economic health of the local hospitality industry, including hotels, restaurants, and retail outlets, as well as their related labor markets. Community members also examined how climate impacts are likely to affect human health, including how projected rising temperatures and smoke from a projected rise in wildfires could impact the health of the local community. The Spokane group concluded that climate change was likely to have a profound impact on both their local economy and the health of their community.

The Spokane Climate Project's climate data stories were created using the Climate Toolbox and *The Northwest Climate Toolbox Workbook*. (See ***Significant Outputs*** and ***Appendix B*** for more details.) The community's climate data stories are expected to become part of a larger climate vulnerability and assessment plan for the community of Spokane. The plan will be put into practice by the City of Spokane by the City's Sustainability Policy Analyst, who is a project participant. CIRC also helped train project participants in the use of CIRC's ***Climate Resilience Workbook series***, a set of workbooks designed to help users access and apply global climate information at a local scale to develop relevant resilience actions. The workbook series and the training our team provided has taught Spokane community members how to:

- Use CIRC and others' climate tools to query climate data sets and apply their findings to events impacting their local community;
- Use methods to combine those quantitative results with judgement and reasoning to develop a robust vulnerability assessment that reflects the collective knowledge and conclusions of the community;

- Use this body of knowledge to develop inclusive action plans relevant to their community and its economy;
- Build a cadre of knowledgeable climate data users who are connected with climate experts region-wide.

In addition, CIRC was also able to provide a small amount of monetary support to key Spokane Climate Project participants. This funding was used to develop a project website, as well as organize and conduct community presentations on the Toolbox and the community-produced climate data stories. These funds also supported our Spokane stakeholders as they expanded their effort to neighboring Coeur d'Alene, Idaho, which was done at the request of the Kootenai Environmental Alliance. Spokane Climate Project participants are currently guiding a similar group in Coeur d'Alene as they pursue their own climate assessment and adaptation effort. We could tell you more about this work, but it would be better if we let our stakeholders speak for themselves. In the summer of 2019, the City of Spokane wrote a letter to United States Representative Kathy Castor Chair, House Select Committee on the Climate Crisis in support of CIRC and the RISA program. Here is an excerpt:

"The Climate Impacts Research Consortium, the Pacific Northwest RISA, created The Climate Toolbox, an online tool for researching local climate data. It includes downscaled multi-model climate data that is relevant at a local level. This tool is at risk of losing its funding which means it is at risk of not being maintained and updated. Please continue to fund these NOAA RISA programs and similar programs so that regional climate scientists can continue to provide this data to communities working on climate action & resiliency measures. Without this climate data, our planning is less effective."

—Spokane City Council

NIDIS Coping with Drought

During year five of CIRC 2.0, CIRC research contributed to the goals of the National Integrated Drought Information System (NIDIS). NIDIS's work advances drought early warning systems for the Pacific Northwest through progress on the activities in the NIDIS-CIRC Coping with Drought statement of work. The statement of work reflects CIRC activities and priorities that overlap with NIDIS's mission and strategic plan for the Pacific Northwest Drought Early Warning System (PNW DEWS). Specifically, CIRC advances drought early warning through:

- Improving capabilities in monitoring and forecasting drought and climate conditions;
- Improving capabilities for identification of vulnerability and risks;
- Improving capabilities for drought planning and preparedness;
- And improving awareness and communication about drought.

CIRC and NIDIS collaboratively revised the statement of work (July 29, 2019). Specific deliverables from the revised Coping with Drought Statement of Work are noted in parentheses.

Improving Capabilities in Monitoring and Forecasting Drought and Climate Conditions

CIRC improves capabilities in monitoring and forecasting of drought and climate conditions through ongoing development of the Climate Toolbox. During the reporting period, CIRC researchers continued to develop the surface water component of the Toolbox by incorporating features and tools to extract, visualize and interpret observed and forecasted hydroclimate information (2.1.1). The following lists a sample of new developments during the reporting period:

- Sub-seasonal (28-day) and seasonal (7-month) climate and hydro-forecasts were added to Toolbox's Climate Mapper. (CIRC Graduate Student, Oriana Chegwidden, presented this on the April 2020 PNW DEWS Webinar (2.2.2).) Includes forecasts for EDDI, SWE, Total Soil Moisture, etc.
- A new Historical Seasonal Progression Tool was added to the Toolbox. The tool displays past averages and ranges, current seasonal progression, and subseasonal and seasonal forecasts for climate, agriculture, and fire variables all on the same plot.
- New phenology and irrigation demand features were added to the Toolbox's Future Crop Suitability Tool for certain crops under future climate scenarios.
- The Future Streamflows Tool can now download the daily data from Integrated Scenarios right from the tool.
- New variables (vapor pressure deficit, heat index, and fire variables) were added to the Toolbox's Climate Mapper and other point extraction tools.
- The team implemented Toolbox-wide evaluation and improvements to achieve consistency across all tools and identify gaps (2.4.1).
- The team added the new Find Your Variable tool for users to choose a variable of interest to see which tools contain that variable.
- The capability to view spatial aggregations of data (by county, watershed, rectangle) is starting to be incorporated into Toolbox point-extraction tools.

In addition, CIRC continued to develop the US Water Watcher Tool (2.1.4); for example, CIRC added the ability to view datasets over their period of record to the tool and added an additional 8 datasets: NRCS(2),GRACE(3),LERI,ESI,MCDI.

Improving Capabilities for Identification of Vulnerability and Risks

As part of CIRC's Community Adaptation activities, CIRC engaged with the community of Spokane, Washington as part of the Spokane Community Adaptation Project (SCAP). The Spokane Climate Project built capacity within the community to identify climate vulnerabilities and risks and develop a climate vulnerability assessment and adaptation plan. The climate vulnerability assessment and adaptation plan was written by community members who employed the Climate Toolbox. CIRC provided organizational, technical, scientific and editorial support to the community members. (See ***CIRC's Significant Outputs*** and ***CIRC's Societal Impact—Narratives Examples***.)

Continuing to engage this targeted set of stakeholders (2.3.1), CIRC created *The Climate Vulnerability Assessment Workbook* (2.2.5) and *The Resilience Actions Workbook*, second and third user guides that connect CIRC's first Toolbox user guide (*The Northwest Climate Toolbox Workbook)* to climate change vulnerability assessment and adaptation planning.

Improving Capabilities for Drought Planning and Preparedness

During the reporting period, CIRC re-engaged the state drought coordinators in Oregon, Washington, and Idaho (2.3.1) to co-develop a tool to use the results from the total moisture percentile drought indicator project (3.1.1). This new indicator, based on total moisture percentile, a variable in the hydrological monitoring system on the Toolbox, allows state drought coordinators to explore questions related to how likely it is that current drought conditions in, say, February will either persist or recover by June or later for a given county. The three state drought coordinators and CIRC researchers successfully pursued additional funding from NIDIS to expand on the indicator (3.1.1) to build a more robust tool within the Toolbox's framework that includes additional geographies (county and watershed levels), domains (expanded to western US), and capabilities. The stakeholders expect to use this new tool to aid state drought declarations and others decisions related to drought preparedness and planning. The tool will be developed in part with state drought coordinators via state water supply availability committee meetings and other regular communications.

Through CIRC's Data Mining activities, CIRC developed and applied data mining techniques to a variety of datasets to understand the nature of predicting drought impacts in the Pacific Northwest (4.1.1). CIRC has developed several dashboard tools (see Agricultural Data Mining Systems website) that allow advanced users to explore relationships between crop loss insurance claims and climate conditions and explore predictive models for crop loss based on recent climate conditions. CIRC Graduate Student Erich Seamon presented CIRC's data mining work to NIDIS staff (4.2.1) and other stakeholders (4.1.2) in an hour-long webinar in March 2020. In addition, Seamon, at the request of Spokane stakeholders, provided an additional analysis to the *Precipitation* chapter of the Spokane climate vulnerability assessment and adaptation plan. Seamon's additional analysis examined the relationship between recent regional droughts and drought loss insurance claims for wheat filed during those droughts.

Improving Awareness and Communication about Drought

CIRC supports communication and outreach for the Pacific Northwest Drought Early Warning System by writing an on-going series called *Northwest Climate Currents* as part of CIRC's newsletter, *The Climate CIRCulator* (1.1.1–2); engaging in drought rapid response activities in partnership with NIDIS (1.2.1); co-hosting the PNW DEWS bi-monthly Drought and Climate Outlook webinar series (1.3.1–2); and presenting the Climate Toolbox through a variety of venues (2.2.3). *Currents* articles provide a recap of recent climate conditions, making use of Toolbox tools. These climate recaps serve to provide a broader context behind current drought and climate conditions in the region and are frequently picked up and repackaged by regional media outlets. (See ***Proudest Accomplishment***.)

- In August 2019, CIRC wrote a *Currents* article about the relatively calm summer wildfire season in the Pacific Northwest (https://climatecirculatororg.wordpress.com/2019/08/27/this-summer-a-welcome-reprieve/) (1.1.1).
- In January 2020, CIRC wrote a *Currents* article about the late winter snowpack recovery in the Pacific Northwest (https://climatecirculatororg.wordpress.com/2020/01/30/snowpack-comeback/) (1.1.2).

CIRC engages in drought rapid response activities. This work includes providing content and/or review of materials for the drought.gov Snow Drought Page updates, as well as regularly posting drought-related communications on social media (2.2.4). CIRC has invited speakers and hosted six PNW DEWS Drought and Climate Outlook webinars during the reporting period (1.3.1–2). During these webinars, CIRC researchers and others have presented and promoted the Climate Toolbox (2.2.1) and CIRC's data mining research. CIRC researchers have presented the Toolbox at multiple conferences and training sessions. Conferences include the Northwest Climate Conference, American Geophysical Union fall meeting, and the American Association for the Advancement of Science Pacific Division annual meeting. Training sessions include ones performed for the Washington Department of Fish and Wildlife, the Oregon Water Resources Department, and several for regional farmers held by the Northwest Climate Hub. (2.2.3). (See ***Appendix E*** for a list of presentations and other outreach activities.) In addition, the Toolbox and its datasets have been used by multiple news outlets, including *The New York Times*, *CBS News*, and *The Oregonian*.

Appendix A—Climate Toolbox Users and Usages (June 1st, 2019–May 31st, 2020)

- **CBSNews.com, CBSN, CBS This Morning**—Jeff Berardelli, CBS News Meteorologist and Climate Specialist, uses the Climate Toolbox and related data for his reports for CBSNews.com, CBSN, and CBS This Morning.
- **City of Spokane, Washington**—CIRC has been working closely with the City of Spokane's Sustainability Policy Analyst, who was a participant in the Spokane Community Adaptation Project (SCAP). SCAP used the Climate Toolbox extensively to create its climate data stories.
- **Evenstad Center for Wine Education, Linfield College**—Director of the Evenstad Center for Wine Education and Evenstad Chair in Wine Studies at Linfield College continues to use maps from the Climate Toolbox in his group's newsletter for wine makers. In addition, this Toolbox super user has given us tips on the design of our growing degree days tool in the Climate Toolbox.
- **Fisheries and Oceans Canada, Government of Canada**—is performing a comparison of projected air temperatures to determine water temperature estimates for the lower Columbia River.
- **Idaho Department of Fish and Game**—is using the Climate Toolbox in a vegetation study. CIRC responded to requests from the Idaho Department of Fish and Game to develop software on the Climate Toolbox to provide area-averages over counties and HUCs.
- **Montana Climate Office**—is using the Climate Toolbox to answer questions from their stakeholders related to climate and drought. The agency is also developing its own set of tools and is using the Climate Toolbox as a template for its efforts.
- ***New York Times***—In a March 3rd, 2020 story, *The New York Times* used Climate Toolbox data in its reporting:
    - March 3, 2020. "California Had Its Driest February on Record. Here's How Bad It Was." *The New York Times*. https://www.nytimes.com/interactive/2020/03/03/climate/dry-california.html.
- **North Central Climate Adaptation Science Center**—Uses Climate Toolbox and MACA data for climate analyses.
- **Northwest Climate Adaptation Science Center (NW CASC) at the University of Washington**—The NW CASC Research Coordinator has been using vegetation data from the Climate Toolbox to provide climate information to the US Fish and Wildlife Service for the Species Status Assessment for the white-tailed ptarmigan in Washington state.
- **National Weather Service Spokane**—Uses the Toolbox for reporting climate summaries for their forecast area.
- **NW News Network Regional Public Journalism**—In an April 20th, 2020 story, the NW News Network Regional Public Journalism used a Toolbox graphic and data in its reporting:
    - **Apr. 20, 2020**—"Fire Camp Germ Spread Is Dicey In Normal Times. COVID-19 Could Rip Through Crews This Season." *NW News Network Regional Public Journalism*. https://www.nwnewsnetwork.org/post/fire-camp-germ-spread-dicey-normal-ti....
- **Pacific Northwest Climate Conference**—CIRC researchers have continued to attend and present their research findings at the annual Pacific Northwest Climate Conference. The Toolbox was featured in several presentations at the conference, including several by researchers not affiliated with CIRC.
- **Portland Water Bureau**—A partner with CIRC since CIRC 1.0, the Portland Water Bureau is using the Climate Toolbox in its resource management planning.
- **Oregon Climate Change Research Institute (OCCRI)**—OCCRI researcher Meghan Dalton is currently using the Climate Toolbox to examine projected vegetation change for coastal Washington.
- ***Idaho Statesman, Oregonian,* and *Astorian*** —In a September 20, 2019 story, *The Idaho Statesman* repackaged a *Climate CIRCulator Northwest Climate Currents* post using the Toolbox as part of the newspaper's reporting. On October 4th, the *Oregonian*, Oregon's leading paper of record, also repacked the same reporting from the *CIRCulator*. The story was then rerun in the associated paper the *Astorian*.
    - **Sept. 20, 2019**—"Idaho just had its most mild wildfire season in years." *Idaho Statesman*. https://magicvalley.com/news/local/idaho-just-had-its-most-mild-wildfire-season-in-years/article_3ccffa19-98a4-53e6-bf04-9111efc39c1f.html.
    - **Oct. 4. 2019**—"Summer 2019: the Oregon wildfire season that wasn't." *The Oregonian*. https://www.oregonlive.com/environment/2019/10/summer-2019-the-oregon-wi....
    - **Oct. 4, 2019**—"Oregon Mostly Spared From Wildfires this Year." *The Astorian*. https://www.dailyastorian.com/oregon-mostly-spared-from-wildfires-this-s....
- **Spokane Community Adaptation Project**—Members of the SCAP group in Spokane, Washington utilized the Climate Toolbox as a data resource for creating their climate data stories and in building their climate vulnerability assessments. They also utilized maps/graphs from the Toolbox in their public presentations in and around Spokane, including at the Recreational Equipment Incorporated (REI) store in Spokane.
- **Umatilla Tribe in Pendleton**—CIRC has worked with the Tribe over much of CIRC 2.0, fielding questions related to the Climate Toolbox. CIRC has also provided custom downscaled (MACA) data for use in a hydrologic model.
- **Union of Concerned Scientists**—CIRC researcher John Abatzoglou worked with the Union of Concerned Scientists for an analysis of heat index projections of the United States and how this was likely to impact the nation's population. (See ***Advancing Science***.)
- **United States Geological Survey (USGS)**—USGS is currently using Climate Toolbox data to run its National Integrated Water Availability Assessments—Concept Map for the US. (https://labs.waterdata.usgs.gov/estimated-availability/#/.)
- **Washington Department of Ecology's Water Resources Program**—Washington Department of Ecology's Water Resources Program continues to use CIRC's Climate Toolbox and associated datasets to help monitor drought conditions in the state of Washington and to inform decisions related to drought declarations.

Appendix B—Complete list of Publications (June 1st, 2019–May 31st, 2020)

Peer-reviewed Publications (Note: Current and Past CIRC team members' names have been bolded):

- **Abatzoglou, John T.,** Solomon Z. Dobrowski, and Sean A. Parks. "Multivariate climate departures have outpaced univariate changes across global lands." *Scientific Reports* 10, no. 1 (2020): 1-9. https://doi.org/10.1038/s41598-020-60270-5.
- Anderson, Dylan L., A. Rueda, Laura Cagigal, J. A. A. Antolinez, F. J. Mendez, and **Peter Ruggiero**. "Time-varying Emulator for Short and Long-Term Analysis of Coastal Flood Hazard Potential." *Journal of Geophysical Research: Oceans* (2019). https://doi.org/10.1029/2019JC015312.
- Antolinez, J.A.A., Anderson, D., Mendez, F., **Ruggiero, P.**, Kaminsky, G., 2019. Understanding long term coastal change and variability using a simple and efficient multi-process model, *Proceedings of Coastal Sediments* 2019, St. Pete Beach, Florida.
- Bennett, Andrew, Joseph Hamman, and **Bart Nijssen**. "MetSim: A Python package for estimation and disaggregation of meteorological data." *Journal of Open Source Software* 5, no. 47 (2020): 2042. https://doi.org/10.21105/joss.02042.
- Biel, Rueben G., S. D. Hacker, and **Peter Ruggiero**. "Elucidating coastal foredune ecomorphodynamics in the US Pacific Northwest via Bayesian networks." *Journal of Geophysical Research: Earth Surface* 124, no. 7 (2019): 1919-1938. https://doi.org/10.1029/2018JF004758.
- Bonnema, Matthew, Faisal Hossain, **Bart Nijssen**, and Gordon Holtgrieve. "Hydropower's hidden transformation of rivers in the Mekong." *Environmental Research Letters* 15, no. 4 (2020): 044017. https://doi.org/10.1088/1748-9326/ab763d.
- **Chegwidden**, **Oriana, David E. Rupp**, and **Bart Nijssen.** "Upstream processes to determine flood response to climate change." *Environmental Research Letters*. (**In Press**.)
- Cheng, Yifan, Nathalie Voisin, John Yearsley, and **Bart Nijssen**. "Thermal extremes in regulated river systems under climate change: an application to the southeastern US rivers." *Environmental Research Letters* (2020). (Accepted Manuscript.)
- Craig, Michael T., Paulina Jaramillo, Bri-Mathias Hodge, **Bart Nijssen**, and Carlo Brancucci. "Compounding climate change impacts during high stress periods for a high wind and solar power system in Texas." *Environmental Research Letters* 15, no. 2 (2020): 024002. https://doi.org/10.1088/1748-9326/ab6615.
- **Significant Publication (reviewed above in *Advancing Science*):** Dahl, Kristina, Rachel Licker, **John T. Abatzoglou**, and Juan Declet-Barreto. "Increased frequency of and populations exposure to extreme heat index days in the United States during the 21st century." *Environmental Research Communications* (2019). https://doi.org/10.1088/2515-7620/ab27cf.
- Daly, Kensey, Shahryar K. Ahmad, Matthew Bonnema, Claire Beveridge, Faisal Hossain, **Bart Nijssen**, and Gordon Holtgrieve. "Recent warming of Tonle Sap Lake, Cambodia: Implications for one of the world's most productive inland fisheries." *Lakes & Reservoirs: Research & Management* (2020). https://doi.org/10.1111/lre.12317.
- Doyle, Thomas B., Andrew D. Short, **Peter Ruggiero**, and Colin D. Woodroffe. "Interdecadal Foredune Changes along the Southeast Australian Coastline: 1942–2014." *Journal of Marine Science and Engineering* 7, no. 6 (2019): 177. https://doi.org/10.3390/jmse7060177.
- Droppers, B., W. Franssen, M. van Vliet, **B. Nijssen**, and F. Ludwig, 2020: Simulating human impacts on global water resources using VIC-5. *Geoscientific Model Development*. (In Press.)
- Ficklin, Darren L., **John T. Abatzoglou**, and Kimberly A. Novick. "A new perspective on terrestrial hydrologic intensity that incorporates atmospheric water demand." *Geophysical Research Letters* 46, no. 14 (2019): 8114-8124. https://doi.org/10.1029/2019GL084015.
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- Kalashnikov, Dmitri A., Paul C. Loikith, Arielle J. Catalano, Duane E. Waliser, Huikyo Lee, and **John T. Abatzoglou.** "A 30-year climatology of meteorological conditions associated with lightning days in the interior western United States." *Journal of Climate* 2020 (2020). https://doi.org/10.1175/JCLI-D-19-0564.1.
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- Li, Sihan, **David E. Rupp**, **Linnia Hawkins**, **Philip W. Mote**, Doug McNeall, Sarah N. Sparrow, David CH Wallom, Richard A. Betts, and Justin J. Wettstein. "Reducing climate model biases by exploring parameter space with large ensembles of climate model simulations and statistical emulation." *Geoscientific Model Development* 12, no. 7 (2019).
- Mao, Yixin, Wade T. Crow, and **Bart Nijssen**. "A unified data-driven method to derive hydrologic dynamics from global SMAP surface soil moisture and GPM precipitation data." *Water Resources Research* 56, no. 2 (2020): e2019WR024949. https://doi.org/10.1029/2019WR024949.
- Mao, Yixin, Wade T. Crow, and **Bart Nijssen**. "Dual state/rainfall correction via soil moisture assimilation for improved streamflow simulation: Evaluation of a large-scale implementation with SMAP satellite data." *Hydrology and Earth System Sciences Discussions* (2019): 1-34. https://doi.org/10.5194/hess-2019-41.
- Marshall, Adrienne M., **John T. Abatzoglou**, Timothy E. Link, and Christopher J. Tennant. "Projected changes in interannual variability of peak snowpack amount and timing in the Western United States." *Geophysical Research Letters* (2019). https://doi.org/10.1029/2019GL083770.
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- **Significant Publication (reviewed above in *Advancing Science*): Serafin, Katherine A.**, **Peter Ruggiero**, **Kai Parker**, and David F. Hill. "What's streamflow got to do with it? A probabilistic simulation of the competing oceanographic and fluvial processes driving extreme along-river water levels." *Natural Hazards and Earth System Sciences* 19 (2019). https://ir.library.oregonstate.edu/concern/articles/5m60qz50n.
- **Significant Publication (reviewed above in *Advancing Science*):** Williams, A. Park, **John T. Abatzoglou**, Alexander Gershunov, Janin Guzman-Morales, Daniel A. Bishop, Jennifer K. Balch, and Dennis P. Lettenmaier. "Observed impacts of anthropogenic climate change on wildfire in California." *Earth's Future* (2019). https://doi.org/10.1029/2019EF001210.
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    - With Special Thanks: Katherine Hegewisch, Crystal Barnes, Nancy Steinberg, Abby Metzger, Linnia Hawkins, and our RISA network review team: Tina Buxbaum from Alaska Center for Climate Assessment and Policy, and Amanda Farris from Carolinas Integrated Sciences and Assessment. https://pnwcirc.org/sites/pnwcirc.org/files/vulnerability_assessment_workbook.pdf.

- **Mooney, Ann** and **Denise Lach**. "The Resilience Actions Workbook: Building and Communicating Resilience Actions Using your Climate Data Story and Vulnerability Assessment." Corvallis, Oregon: *The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2020.
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- **Spokane Community Adaptation Project (SCAP) Climate Data Stories as part of *The Spokane Climate Vulnerability and Resilience Assessment* (Working Title)**

    - **Temperature (Chapter 1)**
      MacMullan, Rebecca, Kara Odegard, Jim Simon, and David Camp. "Temperature Impact Study for Spokane, Washington." In *The Spokane Climate Vulnerability and Resilience Assessment*, edited by **Nathan Gilles**, **Katherine Hegewisch**, **John Abatzoglou**, **Ann Mooney**, and **Meghan Dalton.** Corvallis, Oregon: *The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2020. https://pnwcirc.org/sites/pnwcirc.org/files/chapter_1-temp_scap.pdf.
    - **Precipitation (Chapter 2)**
      Breems, Joel, and Kevin Booth. "Precipitation Study for Spokane, Washington." In *The Spokane Climate Vulnerability and Resilience Assessment*, edited by **Nathan Gilles**, **Katherine Hegewisch**, **John Abatzoglou**, **Erich Seamon**, **Ann Mooney**, and **Meghan Dalton**. Corvallis, Oregon: *The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2020. https://pnwcirc.org/sites/pnwcirc.org/files/chapter_2-precip_scap_.pdf.
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      Porcello, John, Kara Odegard, Karl Rains, Jule Schultz, and Brad Morin. "Streamflow Impact Study for Spokane, Washington." In *The Spokane Climate Vulnerability and Resilience Assessment*, edited by **Nathan Gilles**, **Katherine Hegewisch**, **John Abatzoglou**, **Ann Mooney**, and **Meghan Dalton**. Corvallis, Oregon: *The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2020. https://pnwcirc.org/sites/pnwcirc.org/files/4-streamflow_scap.pdf.
    - **Fire (Chapter 5)**
      Petersen, Mike, Levi Keesecker, Wei Li, Terry Lawhead, Katherine Rowden, and Joel Breems, Jerusha Hampson, and **Katherine Hegewisch**. "Fire and Smoke Impact Study for Spokane, Washington" In *The Spokane Climate Vulnerability and Resilience Assessment*, edited by **Katherine Hegewisch**, **Nathan Gilles**, **John Abatzoglou**, **Ann Mooney**, and **Meghan Dalton**. Corvallis, Oregon: *The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2020. https://pnwcirc.org/sites/pnwcirc.org/files/5-fire_scap.pdf.

Appendix C—Media Engagement (June 1st, 2019–May 31st, 2020)

- **Apr. 28, 2020**—"Study: American Southwest faces a 'megadrought,' the region's worst in centuries." *Las Vegas Sun*. https://lasvegassun.com/news/2020/apr/28/study-american-southwest-faces-...
- **Apr. 20, 2020**—"Fire Camp Germ Spread Is Dicey In Normal Times. COVID-19 Could Rip Through Crews This Season." *NW News Network Regional Public Journalism*. https://www.nwnewsnetwork.org/post/fire-camp-germ-spread-dicey-normal-ti.... (Features Climate Toolbox data.)
- **Apr. 10, 2020**—"Evening Report – Fri., Apr 10, 2020 – Australian Vs US Wildfires." KRFP Radio Free Moscow 90.3. http://radiofreemoscow.org/2020/04/20200410/.
- **Mar. 8, 2020**—"Flash Drought Understanding Advances, OSU Prof Paper Published." *The Corvallis Advocate*. https://www.corvallisadvocate.com/2020/flash-drought-understanding-advan....
- **Mar. 8, 2020**—"Brown seeks executive order to cut the state's climate impacts." *The Bend Bulletin*. https://www.bendbulletin.com/localstate/brown-seeks-executive-order-to-c....
- **Mar. 4, 2020**—"Yes, Climate Change Did Influence Australia's Unprecedented Bushfires." *Scientific American*. https://www.scientificamerican.com/article/yes-climate-change-did-influe....
- **March 3, 2020**—"California Had Its Driest February on Record. Here's How Bad It Was." *New York Times*. https://www.nytimes.com/interactive/2020/03/03/climate/dry-california.html. (Features Climate Toolbox data.)
- **Feb. 27, 2020**—"Clear Skies Mean California's Snowpack Is Now Below Half of Normal." *KQED*. https://www.kqed.org/science/1957569/clear-skies-mean-californias-snowpa....
- **Feb. 27, 2020**—"Low Snowpack In California Mountains May Mean More Wildfires This Summer." *National Public Radio*. https://www.npr.org/2020/02/27/810095428/low-snowpack-in-california-moun...
- **Feb.5, 2020**—"Photos of 'king tides' globally show risks of climate change." *KGW8*, *ABC News*, *Associated Press*. https://www.kgw.com/article/weather/king-tides-oregon-climate-change/283....
- **Jan. 27, 2020**—"Want to see what the Apocalypse in Idaho will look like? Look at Australia." *Idaho Statesman*. https://www.idahostatesman.com/opinion/editorials/article239619133.html.
- **Jan. 14, 2020**—"The Inconvenient Facts On Australian Bushfires." *Forbes*. https://www.forbes.com/sites/rogerpielke/2020/01/14/the-inconvenient-fac....
- **Jan. 10, 2019**—"Oregon coast braces for massive king tides this weekend; researchers warn this is the future." *The Oregonian*. https://www.oregonlive.com/environment/2020/01/as-huge-tides-bear-down-o....
- **Jan. 10, 2020**—"As huge tides bear down on Oregon coast, researchers warn this is the future." *The Daily News*. https://tdn.com/news/state-and-regional/as-huge-tides-bear-down-on-orego....
- **Jan. 10, 2020**—"Future Crop Suitability Tool." *USDA Climate Hubs*. https://www.climatehubs.usda.gov/hubs/northwest/tools/future-crop-suitab....
- **Dec. 23, 2019**—"Coastal towns confront rising sea levels." *Daily Astorian*. https://www.dailyastorian.com/news/coastal-towns-confront-rising-sea-lev....
- **Nov. 12, 2019**—"Here's why Australia is having a cataclysmic wildfire season." *Grist*. https://grist.org/article/heres-why-australia-is-having-a-cataclysmic-wi....
- **Oct. 31, 2019**—"NW snowpack at center of ongoing debate." *Capital Press*. https://www.capitalpress.com/ag_sectors/water/nw-snowpack-at-center-of-o...
- **Oct. 29, 2019**—"Wildfires are more common than ever." *Coveteur*. https://coveteur.com/2019/10/29/why-wildfires-are-new-normal/.
- **Oct. 28, 2019**—"Fires across California have been stoked by distinctly dangerous Santa Ana and Diablo winds. Here's where they come from." *Business Insider*. https://www.businessinsider.sg/santa-ana-winds-why-they-spark-fires-2018-12.
- **Oct. 28, 2019**—"As We Watch California Burn Yet "Again It's Time to Say Yes to 'Save Our San Diego Countryside." *Ocean Beach Rag*. https://obrag.org/2019/10/as-we-watch-california-burn-yet-again-its-time....
- **Oct. 28, 2019**—"What's driving the historic California high-wind events, and worsening the wildfires." *Washington Post*. https://www.washingtonpost.com/weather/2019/10/28/whats-driving-historic....
- **Oct. 25, 2019**—"The New Normal: How Humans Are Going To Have To Adjust To A World On Fire." *Kaiser Health News*. https://khn.org/morning-breakout/the-new-normal-how-humans-are-going-to-....
- **Oct. 24, 2019**—"A Forecast for a Warming World: Learn to Live with Fire." *New York Times*. https://www.nytimes.com/2019/10/24/climate/california-wildfires-climate-....
- **Oct. 18, 2019**—"Editorial: Columbia Forum's 30th year is loaded with fascinating speakers." *Chinook Observer*. https://www.chinookobserver.com/opinion/editorials/editorial-columbia-fo...
- **Oct. 10, 2019**—"Beacon of progress at Beacon Hill Work begins on big development near Hillyard after years of delays." *Journal of Business*. https://www.spokanejournal.com/local-news/beacon-of-progress-at-beacon-h....
- **Oct. 4, 2019**—"Climate Change is Ruining Skiing. Aspen is Fighting Back." *Bitterroot*. https://bitterrootmag.com/2019/10/04/climate-change-is-ruining-skiing-as....

- **Oct. 4. 2019**—"Summer 2019: the Oregon wildfire season that wasn't." *The Oregonian*. https://www.oregonlive.com/environment/2019/10/summer-2019-the-oregon-wi....(Repackaged Climate CIRCulator Northwest Climate Currents Post.)
- **Oct. 4, 2019**—"Oregon Mostly Spared From Wildfires this Year." *The Astorian*. https://www.dailyastorian.com/oregon-mostly-spared-from-wildfires-this-s....(Repackaged Climate CIRCulator Northwest Climate Currents Post.)
- **Sept. 20, 2019**—"Idaho just had its most mild wildfire season in years." *Idaho Statesman*. https://magicvalley.com/news/local/idaho-just-had-its-most-mild-wildfire.... (Repackaged Climate CIRCulator Northwest Climate Currents Post.)
- **Sept. 11, 2019**—"Drastic snowfall decreases in Western United States." *The University of Idaho Argonaut*. https://www.uiargonaut.com/2019/09/11/drastic-snowfall-decreases-in-west....
- **Sept. 4, 2019**—"A World on Fire." *BioBrief*. https://biobrief.org/a-world-on-fire/.
- **Aug. 28, 2019**—"The Amazon, Siberia, Indonesia: A World of Fire." *New York Times*. https://www.nytimes.com/2019/08/28/climate/fire-amazon-africa-siberia-wo....
- **Aug. 21, 2019**— "The coming snow droughts." *Mountain West News*. https://mountainwestnews.org/the-coming-snow-droughts-88a67ee45a25.
- **Aug. 14, 2019**—"Washington Post analysis reveals two Oregon counties are among the fastest-warming in the country." *The Oregonian*. https://www.oregonlive.com/environment/2019/08/washington-post-analysis-....
- **Aug. 8, 2019**—"BACK-TO-BACK LOW SNOW YEARS WILL BECOME MORE COMMON, STUDY PROJECTS." *AGU Advancing Earth and Space Science*. https://news.agu.org/press-release/back-to-back-low-snow-years-will-beco....
- **Aug. 8, 2019**—"Climate change will mean more multiyear snow droughts in the West." *The Conversation*. https://theconversation.com/climate-change-will-mean-more-multiyear-snow....
- **Jul. 25, 2019**—"After the Fire: Vulnerable Communities Respond and Rebuild." *American Progress*. https://www.americanprogress.org/issues/green/reports/2019/07/25/472738/....
- **Jul. 22, 2019**—"It will feel much hotter in WA over the next century. We aren't prepared." *Crosscut*. https://crosscut.com/2019/07/it-will-feel-much-hotter-wa-over-next-centu...
- **Jul. 18, 2019**—"Warming climate likely leading to larger California fires." *Arstechnica*. https://arstechnica.com/science/2019/07/warming-climate-likely-leading-t...
- **Jul. 15, 2019**—"Study bolsters case that climate change is driving many California wildfires." *Science Daily*. https://www.sciencedaily.com/releases/2019/07/190715103311.htm.

Appendix D—Funds Leveraged by CIRC

Partners/Leveraged Funds:

- **Climate Toolbox Leveraged Funds**—While primarily a CIRC effort, CIRC has nonetheless leveraged funding and support from multiple partners and sources to make the Toolbox and its multiple resources possible. Here is a list of some of our key funders/partners:
  - **Great Basin Landscape Conservation Cooperative**—provided funding for the Future Tribal Climate Tool.
  - **Northwest Knowledge Network**—provided web-hosting for the Toolbox.
  - **National Integrated Drought Information Service (NIDIS)**— provided partial funding for the development of the Historical Climate Scatter, Historical Climate Normals, Historical Climate Tracker, US Water Watcher, Real-Time Climate Dashboard, Seasonal Forecast, Seasonal Forecast Maps, Future Crop Suitability Tool, Climate Mapper Tool, and Historical Seasonal Progression Tool.
  - **Northwest Climate Adaptation Science Center**—provided funding for the Future Tribal Climate Tool.
  - **Regional Approaches to Climate Change Project (USDA NIFA)**—provided partial funding for the Future Cold Hardiness Zones, Future Climate Dashboard, Future Climate Boxplots, Future Time Series, Historical Climate Scatter, Historical Climate Normals, Historical Climate Tracker, Real-Time Climate Dashboard, Seasonal Forecast, Seasonal Forecast Maps, and Climate Mapper tools.
  - **USGS Northwest Climate Science Center (NW CSC)**—provided partial funding for the Future Streamflow Projections, Future Climate Dashboard, Future Climate Boxplots, Future Time Series, and Climate Mapper tools.
  - **USDA Northwest Climate Hub**—provided partial funding for the Future Crop Suitability, Future Climate Dashboard, Future Climate Boxplots, Future Time Series, and Climate Mapper tools.
- **Coastal Hazards Research**—CIRC's flooding hazard analysis for the Quileute Tribe community of La Push, Washington, as well as elsewhere in the PNW, relied on multiple leveraged funds. These included the following funding sources and grants:
  - **National Oceanic and Atmospheric Administration**—The grant "Optimizing the ecosystem services of US Pacific Northwest coastal beaches and dunes through adaptation planning" (EESLR 2019) provides support for quantifying various ecosystem services of beaches and dunes in the Pacific Northwest.
  - **Oregon Sea Grant**—The "Envisioning a Resilient Oregon Coast: Co-developing alternative futures for adaptation planning and decision-making") provides support for considering various adaptation options for climate change induced coastal hazards.
  - **DOD SERDP, via sub-award from National Oceanic and Atmospheric Administration, NESDI**—The grant "Advancing the Analysis of Pacific Basin Coastal Flood Sensitivity under a Changing Climate" provides support in the development of coastal surrogate models used for compound flood analysis.
  - **National Oceanic and Atmospheric Administration**—The grant "Pacific Northwest Regional Coastal Ocean Observing System (RCOOS) of NANOOS" supported nearshore bathymetric data that was used in Serafin et al. 2019 analysis.
- **College of Earth, Ocean, and Atmospheric Sciences design team**—performed design and editing of *Climate Resilience Workbook series* for free.
- **Spokane Community Adaptation Project (SCAP)/Community of Spokane, Washington**—As a volunteer-based coproduction effort, the Spokane Community Adaptation Project (SCAP) relied on the time and funds of multiple individual participants and their associated organizations. Here some of the key organizations we worked with:
  - Avista
  - Eastern Washington University
  - E2 Environmental
  - Gonzaga University
  - GSI Water Solutions, Inc.
  - Lands Council
  - Measure Meant
  - Northwest Renewables
  - Spokane Riverkeeper
  - Washington Department of Ecology
  - 350 Spokane
  - City of Spokane

Appendix E—Outreach (Conferences, Presentations, Posters, Webinars, and Videos)

Conferences Attended:

- Northwest Climate Conference 2019
- American Geophysical Union Fall Meeting 2019

Presentations and Training Sessions Given:

- **June 19, 2019**—Keynote Presentation (American Association for the Advancement of Science meeting, Pacific Division, Ashland, Oregon) (Philip Mote)
- **June 27, 2019**—Talk all-staff meeting. (Oregon's Department of Land Conservation and Development) (Philip Mote)
- **Aug. 20, 2019**—Climate Adaptation Framework Workshop Hosted by The Oregon Climate Change Research Institute (OCCRI.) (Peter Ruggiero, acted as host and moderator for experts discussing the likelihoods and consequences of various climate change risks in the context of Oregon state agency hazard mitigation planning)
- **Sept. 23, 2019**—"Climate tools for specialty crop growers in the Northwest." (John Abatzoglou and Lauren Parker) (webinar for USDA Climate Hub)
- **Oct. 9, 2019**—"State of the Pacific Northwest Climate 2019" (John Abatzoglou) (plenary talk Northwest Climate Conference, Portland, Oregon)
- **Oct. 9, 2019**—"Beyond the CIRCus—Communities Level Up." (Ann K. Mooney) (special session Northwest Climate Conference, Portland, Oregon)
- **Oct. 9, 2019**—"Climate Adaptation in Spokane, Washington." (Kara Odegard and Brian Henning) (SCAP participants from Spokane, Washington) (special session Northwest Climate Conference, Portland, Oregon)
- **Oct 10, 2019**—"The Northwest Climate Toolbox." (Katherine Hegewisch) (Stakeholder Meeting of the Northwest Climate Adaptation Science Center, Portland, Oregon)
- **Oct. 10, 2019**—"Visualizing climate change." (Katherine Hegewisch) (special session Northwest Climate Conference)
- **Oct. 23, 2019**—Presented using Climate Toolbox data and other CIRC-funded work (Metro [Portland] Policy Advisory Council)
- **Oct. 29, 2019**—"Ten Myths About Climate Change." (Philip Mote) (Community event in Astoria, Oregon)
- **Nov. 1, 2019**—"The US Water Watcher". (Katherine Hegewisch) (Drought Decision Support Platform Workshop, Moscow, Idaho)
- **Nov. 5, 2019**—"Updates on Monitoring and Forecast Tools in the Northwest Climate Toolbox." (Katherine Hegewisch)(invited talk) Oregon/Washington Water Year 2019 Recap and 2020 Outlook Meeting, Portland, Oregon.)
- **Nov. 13, 2019**—"Tools for accessing future climate change information: The Tribal Climate Tool." (Katherine Hegewisch) (Healthy Forests, Healthy Watersheds Workshop, Tucson, Arizona)
- **Dec 3, 2019**—"Developing the Northwest Climate Toolbox." (Katherine Hegewisch) (B.C. Agricultural Climate Adaptation Research workshop. Kelowna, BC, Canada.)
- **Dec. 2019**—"Seasonal Forecasts in the Climate Toolbox." (Oriana Chegwidden) (American Geophysical Union fall meeting; NOAA Office of Atmospheric Research booth)
- **Dec. 2019**—"The sensitivity of hydrologic extreme events to climate change: How changes in precipitation and temperature alter flood-generation processes." (American Geophysical Union fall meeting)
- **Feb. 6–7, 2020**— Seasonal Climate Forecasts for Yakima Water Basin." (Katherine Hegewisch) (Talk for Tech4Trade Annual Meeting. Wenatchee, Washington.)
- **Mar. 3, 2020**—"Climate 102" (Philip Mote) (Joint briefing for Oregon House and Senate committees)
- **Apr. 2020—**"Climate change impacts on hydropolitical risk in transboundary rivers." (Oriana Chegwidden) (eScience Seminar, University of Washington)
- **Apr. 22, 2020**—Presented on the Climate Toolbox. (Philip Mote) (Board of Directors of American Geophysical Union)
- **May 7 & 8, 2020**—The Vulnerability Assessment Workbook: Assessing Your Community's Vulnerability to Climate Risks (Ann Mooney) for the Spokane Community Adaptation Project
- **May 28 2020**—The Resilience Actions Workbook: Building and Communicating Resilience Actions Using Your Climate Data Story and Vulnerability Assessment (Ann Mooney) for the Spokane Community Adaptation Project

Posters etc.:

- **Sept. 2019**—Poster and lightning talk on Climate Toolbox and Spokane Community Adaptation Project. (National RISA meeting) (Philip Mote)
- **Oct. 9, 2019**—"Sensitivities of extreme hydrologic events to climate change in the Columbia River Basin." (Oriana Chegwidden) (special session Northwest Climate Conference)
- **Oct. 9, 2019**—"The Tribal Climate Tool" (Katherine Hegewisch, Meade Krosby, and Climate Impacts Group) (Northwest Climate Conference, Portland, Oregon).

- **Dec. 2019**—"Subseasonal to seasonal (S2S) forecasts supporting water resource management." (American Geophysical Union fall meeting)
- **Feb. 6, 2020**—"Hegewisch, K.C., Abatzoglou, J.T., Downscaled Seasonal Climate Forecasts from NMME." (Katherine Hegewisch) (Tech4Trade Annual Meeting. Wenatchee, Washington.).

Videos:

- **Nov. 2019**—"Climate Change Impacts on Agriculture and Utility of AgBiz Logic to Support Farm-Level Adaptive Management." (Katherine Hegewisch) (Northwest Climate Hub).

Webinar Presentations:

- **Sept. 9, 2019**—"Toolboxing–Connecting Your Question to a Climate Question." (Katherine Hegewisch and Ann Mooney) (Oregon Water Resources Department.)
- **Sept. 23, 2019**—"Climate tools for specialty crop growers in the Northwest" (John Abatzoglou and Lauren Parker) (Northwest Climate Hub webinar)
- **Aug. 14, 2019**—"The Northwest Climate Toolbox." (Katherine Hegewisch) (Climate Adaptation Science Center meeting of directors).
- **Aug. 8, 2019**—"Toolboxing–Learn to use the Northwest Climate Toolbox." (Katherine Hegewisch and Ann Mooney) (Washington Department of Fish and Wildlife).
- **July 12, 2019**—"Toolboxing–Learn to use the Northwest Climate Toolbox." (Katherine Hegewisch and Ann Mooney) (Oregon Water Resources Department).
- **July 9, 2019**—"Tips for using the Northwest Climate Toolbox to tell your climate story." (Katherine Hegewisch) (Interagency Climate Adaptation Network July Meeting, Olympia, Washington).

Pacific Northwest Drought Early Warning System Drought & Climate Outlook Webinar Series

- **June 25, 2019**—"Climate Recap and Current Conditions." (John Abatzoglou) (Meghan Dalton "Welcome & Agenda Overview) https://www.youtube.com/watch?v=SAnuNOGLKIA.
- **Aug. 26, 2019**—"US Water Watcher Tool." (Katherine Hegewisch) https://www.youtube.com/watch?v=BuJEL8g9xxc.
- **Oct. 28, 2019**—"How Models Affect Hydrologic Climate Impacts Studies in the Pacific Northwest." (Oriana Chegwidden) https://www.youtube.com/watch?v=F49ZjGhjuRo&list=PLmhxKH4OH8KLvTYCvq9AiUCECR0U0K5Lt&index=18.
- **Feb. 24, 2020**—"Climate Recap and Current Conditions." (John Abatzoglou) (Meghan Dalton "Welcome & Agenda Overview) https://www.youtube.com/watch?v=YxUy_-997MQ.
- **April 15, 2020**—CIRC: Transforming data into usable knowledge (Ann Mooney) NAEP & APU 2020 webinar series
- **Apr. 28, 2020**—"A Climate Crystal Ball? Using Forecasts in the Climate Toolbox." (Oriana Chegwidden) (Meghan Dalton "Welcome & Agenda Overview) https://www.youtube.com/watch?v=LWiPYghxcPU.

Appendix F—Additional Outputs

Stakeholders State/Region CIRC product/products Activity Using CIRC Product

United States population generally/US Government	United States/ United States Pacific Northwest	CIRC peer-reviewed research: Queen, Laura E., Philip W. Mote, David E. Rupp, Oriana Chegwidden, and Bart Nijssen. "Ubiquitous increases in flood magnitude in the Columbia River Basin under climate change." *Hydrology and Earth System Sciences Discussions* (2019): 1-31. https://doi.org/10.5194/hess-2019-474. (In Press.)	**Columbia River Treaty Analysis Continues**— The Columbia River Treaty between the United States and Canada is currently being renegotiated. The treaty defines rights and responsibilities between the two nations concerning hydropower and flood control. Because climate change is projected to affect the Pacific Northwest's hydrology, influencing both hydropower and flood control and many other current uses of the river, any effective renegotiation of the treaty should include climate change projections. To this end, in the summer and fall of 2019, CIRC funded student researcher Laura Queen to examine projected future flooding throughout the Columbia River Basin. The result of this research is an article currently in review at the journal *Hydrology and Earth System Sciences*. Queen's work builds off a data set developed by CIRC during year four of CIRC 2.0. Queen's study is the fourth study CIRC researchers have participated in related to the Columbia River Treaty.
Water Resource Managers in the Pacific Northwest and the Western United States Generally/Pacific Northwest Stakeholders Generally	Pacific Northwest-wide/ Western United States	CIRC peer-reviewed research Jaeger, William K., Adell Amos, David R. Conklin, Christian Langpap, Kathleen Moore, and Andrew J. Plantinga. "Scope and limitations of drought management within complex human–natural systems." *Nature Sustainability* 2, no. 8 (2019): 710-717. https://doi.org/10.1038/s41893-019-0326-y.	**Water Law and Drought Analysis**—In year five, CIRC researcher and University of Oregon law professor Adell Amos provided a legal analysis for a study that imagined a very bad drought year impacting fish in Oregon's Willamette River Basin. The work is a continuation of Willamette Water 2100 project, a National Science Foundation-funded effort the CIRC team participated in during CIRC 1.0. Amos's analysis examines the rule curves that dictate when water should be stored and when water should be released from local reservoirs. Amos concluded that the rule curves give water resource managers at the reservoirs far more legal as well as operational flexibility than previously thought, allowing those a great deal of discretion to release water as needed to meet environmental requirements necessary to protect local endangered salmonids. Amos's analysis could be directly applied to aid endangered salmonids during future drought years in the Willamette River Basin. It also applications outside of Oregon and could be applied during low water years elsewhere in the American West where Western water law is in effect.

Appendix G—CIRC's Evaluation Methods

Table 3—Post-Meeting Stakeholder Questionnaire

1. Were the right people at the meeting? Yes/No, who else should be at the meeting
2. This approach increased their understanding of county, coast, and/or local hazards? Strongly agree/Somewhat agree/Disagree/Neutral/Don't know yet
3. They understood how the information presented was produced? Strongly agree/Somewhat agree/Disagree/Neutral/Don't know yet
4. Were confident this project would produce useful knowledge: For themselves? For their organization/community? Highly/Somewhat/Not confident/Don't know yet
5. How they heard about the meeting.
6. Were likely to share this information with: Colleagues/People they know socially/Family/No one

Figure 1. Example survey results: CIRC 1.0 community adaptation project in Big Wood, ID: Respondents who responded the right people were at the meetings

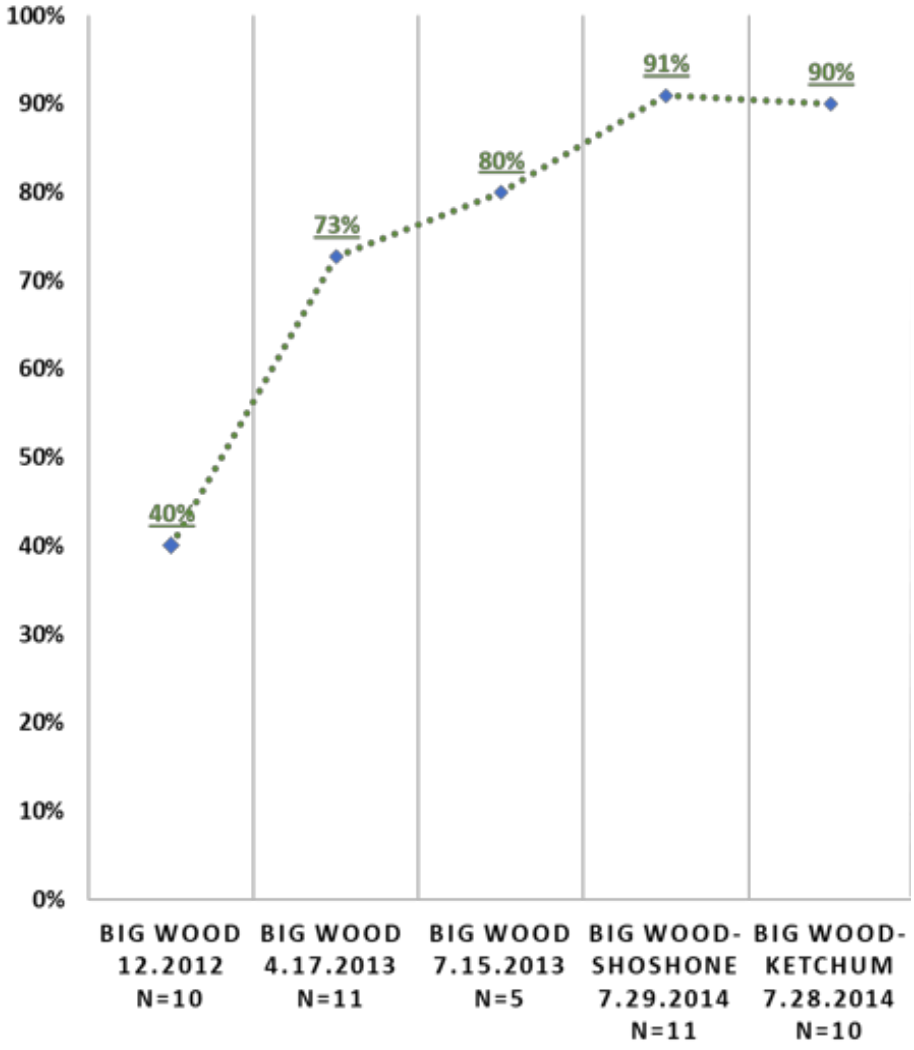


Table 4—Open-ended interview questions

Stakeholders in community adaptation projects	1. What were your goals/expectations for participation in the project? How well were the goals met? 2. What worked in the process of the project? What were some obstacles? 3. What needs to be done for you/your org/your community to integrate the knowledge from this project into your decision-making? 4. What has happened since CIRC left? Ex. community actions, policies, usability, new projects. How can CIRC help the community move forward? 5. How have we contributed to greater local awareness, knowledge, and preparedness to respond to weather and climate?
CIRC Advisory board	1. How has CIRC advanced the understanding of what it means to adapt to changing climate (implications/ needs/ dimensions/ elements/ practices)? 2. Where did we "miss the mark"? ex. missed opportunities 3. How has CIRC helped create better adapted/more resilient/more prepared PNW communities? 4. What is CIRC's role in the future of the PNW? How do we move forward? 5. Other comments
CIRC staff involved in community adaptation projects	1. What capacities (knowledge/practices/skills) were built for your team with this project? (For your lab? For your graduate students? For CIRC?) 2. How have we contributed to greater local awareness, knowledge, and preparedness to respond to weather and climate? 3. What did we learn about the coproduction-of-knowledge process? Ex. what worked, obstacles 4.What role might CIRC play in the future of these networks, projects, results? 5. Other comments

Table 5—Climate Tools production open-ended interview questions

1. What capacities (knowledge/practices/skills) were built for your team with this project? (For your lab? For your graduate students? For CIRC?)
2. What are the next 3-5 things that can be done to stabilize/maintain the toolbox?
3. What did we learn about the coproduction-of-knowledge process? Ex. what worked, obstacles
4. How have we contributed to greater local awareness, knowledge, and preparedness to respond to weather and climate?
5. Other comments

CIRC Logic and Reflection Model, January 2015.

Inputs → Activities ↔ Learning → Goals and Objectives → Institutional Transformation

People	Activities Designed to Enable Coproduction of Knowledge		What have we learned?	Short & Intermediate Term Objectives (from proposal)	Long Term Goals
Leads: Mote and Lach PIs: Abatzaglou (UI), Amos (UO), Bethel (OSU), Bolte (OSU), Hulse (UO), Lettenmaier (UW), Nijssen (UW), Turner (OSU), Ruggerio (OSU) Advisory Council Staff: Foster, Gilles, Stevenson (Dello, Dalton, Sharp) Partners: USFS, PNW CSC, UDSA Climate Hub	*Collaborators* Who is involved (key individuals, communities, boundary organizations, networks), how are they involved in each stage (problem/goals/ common language formulation, engagement-workshops/meetings, data collection and analysis, data interpretation, dissemination) *Data/Information* What kind/type of data are produced (primary/new, secondary, modelled), who produces data) *Decision Tools* How data used to make decisions; specific tools, generic tools *Dissemination and communication* How results are communicated, who receives communication and who seeks out communication	Integrated Scenarios of the Future PNW Climate Willamette Water 2100 Big Wood Basin Tillamook Futures & North Coast Climate Adaptation National Climate Assessment? Law of the River PNW Regional Climate Assessment PUMA (Piloting Utility Modeling Applications) Eugene/Benton County Coping with Drought Hydrologic Sensitivity Analysis Climate Extension Specialist USFS Adaptation Partnership CIRCulator	1. What difference did this project make? For whom? 2. What kind(s) of capacity were built? For whom? 3. What did we learn about coproduction of knowledge or one of its constituent components? Is coproduction a continuous or binary phenomena? 4. What changes in behavior, policy, and/or practice can we observe? 5. What role might CIRC play in future of these networks, projects, results?	1. Locally specific awareness, knowledge, and learning prototypes extensible to other sites 2. Partner-specific future climate scenarios 3. Decision support, tools and information dissemination through Extension and Sea Grant programs 4. Curriculum for training the trainers 5. Interactive website with tools, models, data, 6. Alternative Scenario Generator Toolkit 7. Mobile decision theater 8. Stories/Narratives	1. Increased understanding of collaborative knowledge production 2. Increased capacity for utilizing climate scenarios in local decisions 3. Understanding of what it means to adapt to changing climate (implications/ needs/ dimensions/ elements/ practices—shift the context) 4. Integration of adaptation/resilience/ preparedness into policies and management practices 5. Adapted/resilient/prepared PNW communities.

Figure 2. CIRC Logic and Reflection Model, January 2015

Table 6—CIRCulator user questionnaire

Q1: How do you use *CIRCulator* info? Please select all that apply.

- ☐ Inform work decisions
- ☐ Inform personal decisions
- ☐ Follow up with CIRC for more details on some topics
- ☐ Read the original study for more info
- ☐ Other, please describe _____

Q2: How did you hear about the *CIRCulator*?

- ☐ Word of mouth
- ☐ CIRC website (pnwcirc.org)
- ☐ News story
- ☐ Facebook
- ☐ Twitter
- ☐ Related blog
- ☐ Search engine topic search
- ☐ Newsletter or email listserv other than the *CIRCulator*, please specify_____
- ☐ Other, please describe_____

Q3: What part of the *CIRCulator* are you most interested in?

- ☐ *Northwest Climate Currents*
- ☐ Research reviews
- ☐ CIRC project updates

Q4: Which of these best describes your occupation?

- ☐ Resource manager
- ☐ ournalist
- ☐ Teacher
- ☐ Researcher / Academic
- ☐ Other, please specify _____

Figure 3. Uses for the CIRCulator

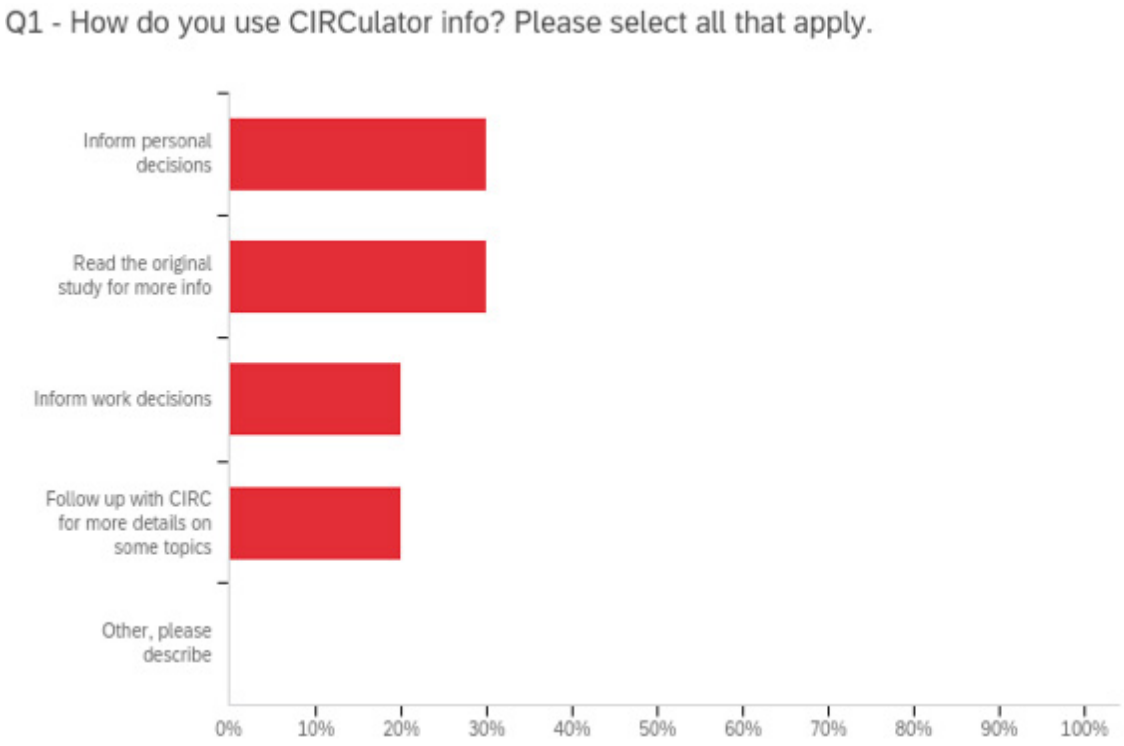
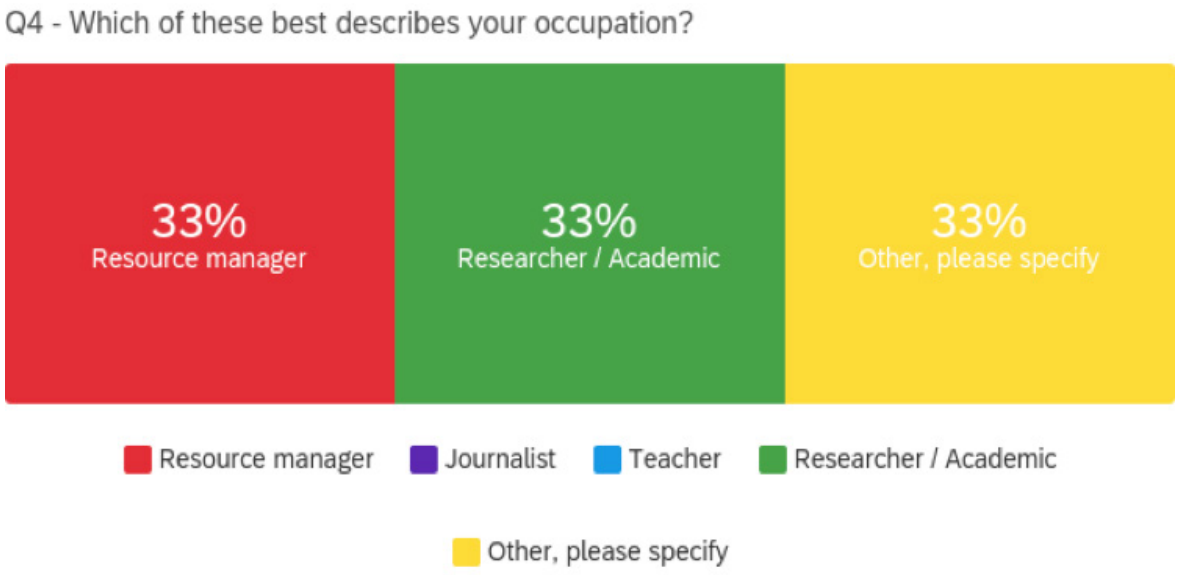


Figure 4: Occupations of CIRCulator readers



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CIRC
Climate Impacts Research Consortium
A NOAA RISA TEAM

RISA
Regional Integrated Sciences and Assessments

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

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