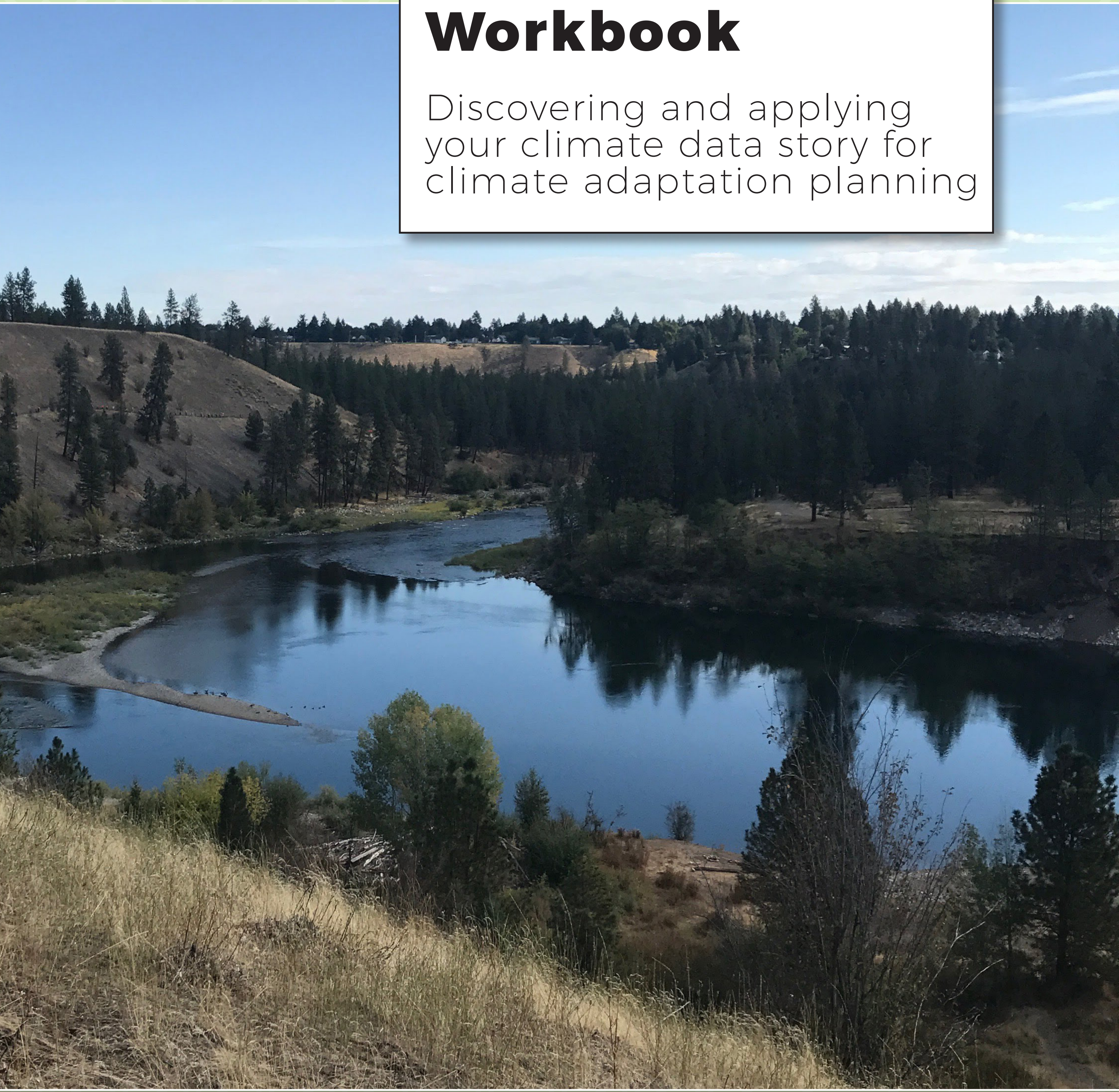
The Northwest Climate Toolbox Workbook

Discovering and applying your climate data story for climate adaptation planning



Oregon State University

About RISA, CIRC, and the Northwest Climate Toolbox: The mission of the National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Sciences and Assessments (RISA) program is to put climate science to work for stakeholders. The Pacific Northwest Climate Impacts Research Consortium (CIRC) is the NOAA RISA team for Washington, Oregon, Idaho, and western Montana. CIRC directly aids climate adaptation efforts by Northwest communities, policymakers, and resource managers. CIRC acts in a supporting role, providing applied climate and social science meant to complement the needs, concerns, and expertise of the stakeholders we work with. To reach as broad an audience as possible, CIRC researchers created the Northwest Climate Toolbox, a suite of free, online tools designed to put climate data and information within the reach of people and organizations not necessarily trained in the science of climate variability and change.

Telling Your Climate Data Story: The goal of this workbook is to provide step-by-step instructions for using the Northwest Climate Toolbox. The Toolbox and this workbook are meant to aid and empower you to discover and craft what we are calling a *climate data story,* a narrative outlining the climate impacts and trends relevant to your community. Ultimately, the CIRC team hopes to see your climate data story used to inform climate adaptation strategies in your community.

About this Workbook: This workbook is intended both as a user's guide to the Northwest Climate Toolbox as well as a guide to using the Toolbox to craft your climate data story.

Workbook Organization: To structure and organize your interaction with the Toolbox, this workbook has been organized into two modules with accompanying worksheets to practice what you have learned:

- ***Module 1—Navigating & Querying the Toolbox***
  Provides a guide for navigating and asking questions of the Toolbox.
  - ***Worksheet 1—Querying the Toolbox***
    Outlines and provides examples of how the Toolbox can be used to answer specific questions.
- ***Module 2—Telling Your Climate Data Story***
  Provides recommendations to consider as you use the information and data you have gathered to create a compelling climate data story.
  - ***Worksheet 2—Worksheeting Your Climate Data Story***
    Provides a structure and you can use to organize the components of your climate data story.
- **Appendices**
  - Additional resources, including an example climate data story, other online climate tools, and a list of peer-reviewed publications, can be found in the appendices of this document.

CIRC Resources:
- Northwest Climate Toolbox: climatetoolbox.org
- CIRC website: pnwcirc.org
- *The Climate CIRCulator*: https://climatecirculatororg.wordpress.com
- Get the *CIRCulator* in your email: http://bit.ly/2SqJrRL
- Twitter: @PNWclimate
- Facebook: @PNWclimate

Tip: This workbook is not a novel meant to be read cover to cover. Instead, feel free to visit the modules, worksheets, and appendices as you see fit.

Give CIRC Feedback: CIRC is committed to responding to the needs of our stakeholders. This workbook is meant to be a living document. The CIRC team is open to feedback on how to improve and expand this workbook. If there is something you feel this workbook needs, just let us know. We'll do our best to help.

Email us: pnw.circ@oregonstate.edu

A Shout-Out to the Community of Spokane: This workbook was originally created for the community of Spokane, Washington as part of the Spokane Community Adaptation Project (SCAP). CIRC would like to thank the SCAP participants who made this workbook possible. https://pnwcirc.org/spokane-community-adaptation-project.

Photo: CIRC team members and Spokane community members. May 21st, 2018 meeting of the Spokane Community Adaptation Project. (Photo Credit: Ann Mooney, all rights reserved.)

Special Thanks: Special Thanks to Denise Lach, the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University, especially Crystal Barnes for design, Abby Metzger for seeing this through, and Dean Roberta Marinelli for her leadership.

Recommended Citation: Mooney, Ann, Nathan Gilles, Katherine Hegewisch, John Abatzoglou, and Meghan Dalton. "The Northwest Climate Toolbox Workbook: Discovering and applying your climate data story for climate adaptation planning," Corvallis, Oregon: *The Pacific Northwest Climate Impacts Research Consortium (CIRC), College of Earth, Ocean, and Atmospheric Sciences, Oregon State University,* 2019.

Tip: Learning to work inside the Toolbox can be complicated and even frustrating at the beginning. Keep with it! As you have questions, please reach out to the CIRC team. pnw.circ@oregonstate.edu

Cover Photo: Spokane River, September 2017. (Photo Credit: Britt Parker, all rights reserved.)

Contents

Module 1—Navigating & Querying the Toolbox

About Module 1: Every tool in the Toolbox is a little different. However, many have common features, themes, and designs. Consider this module a reference that you can draw on as you work with the Toolbox to investigate your climate questions.

This module provides tips for negotiating the Northwest Climate Toolbox's organization and common features (***Navigating the Toolbox***), asking questions of the Toolbox (***Querying the Toolbox***), interpreting your results (***Assessing Toolbox Outputs***), and saving and citing your results (***Downloading & Citing Your Results***).

What's Next?: After you get comfortable with using the Northwest Climate Toolbox, you'll combine your expertise and on-the-ground knowledge of your areas of interest with the data the Toolbox provides.

Module 1 at a Glance

Navigating the Toolbox

Querying the Toolbox

- Identify Your Climate Question
- Pick Your Tool by Climate Impact Category
- Consider Time & Space
- Pick a Variable in Your Chosen Tool
- Calendar Time Periods—Considering Time Again

Assessing Toolbox Outputs

- Downloading & Citing Your Results
- Downloading Data
- Screenshots
- Citing Figures and Data

Worksheet 1—Toolboxing Practice

- Possible Solutions to Practice Questions 1 & 2

Navigating the Toolbox

Key Terms:
***Climate impacts*—**effects on human communities and natural systems that result from changes in the climate. Climate impacts can result from human-caused climate change or from natural climate variability. Climate impacts covered by the Toolbox include drought, wildfire, and growing conditions.

***Climate conditions*—**a broad climate factor, such as air temperature or precipitation. Climate conditions can affect climate impacts, but can be considered on their own.

***Climate data story*—**a narrative outlining climate facts and impacts specific to your community.

Tools & Climate Impacts

Tools in the Toolbox are organized according to four broad climate impact-related categories:

- **Agriculture**—climatetoolbox.org/agriculture
- **Climate**—climatetoolbox.org/climate
- **Water**—climatetoolbox.org/water
- **Wildfire**—climatetoolbox.org/wildfire

Common Navigation Features

Common navigation features are displayed as buttons found at the top right of a tool's page. These include:

- **Documentation**—provides information on:
  - **Source**—documentation concerning the tool's data sources
  - **Variables**—an explanation of the variables used
  - **Calculation**—an explanation of the calculations made by the tool
  - **Tool**—a rough description of the tool, its potential use, and its collaborators and funders
- **Example**—provides you with an example of how the tool could be used.
- **Take a Tour**—guides you through a tool's functions and capabilities.
- **Cite Tool**—describes Creative Commons licensing used and guidance on how to cite a figure developed using the tool.

Tips: If you're interested in a broad climate impact, consider dividing your inquiry into pieces. For instance, climate impacts to human health can include poor air quality due to smoke (*Wildfire*) and impacts from rising temperatures, including heatstroke (*Climate*).

Climate categories often share the same tools and variables.

If you're looking for water issues, some Toolbox variables use hydrology as an umbrella term.

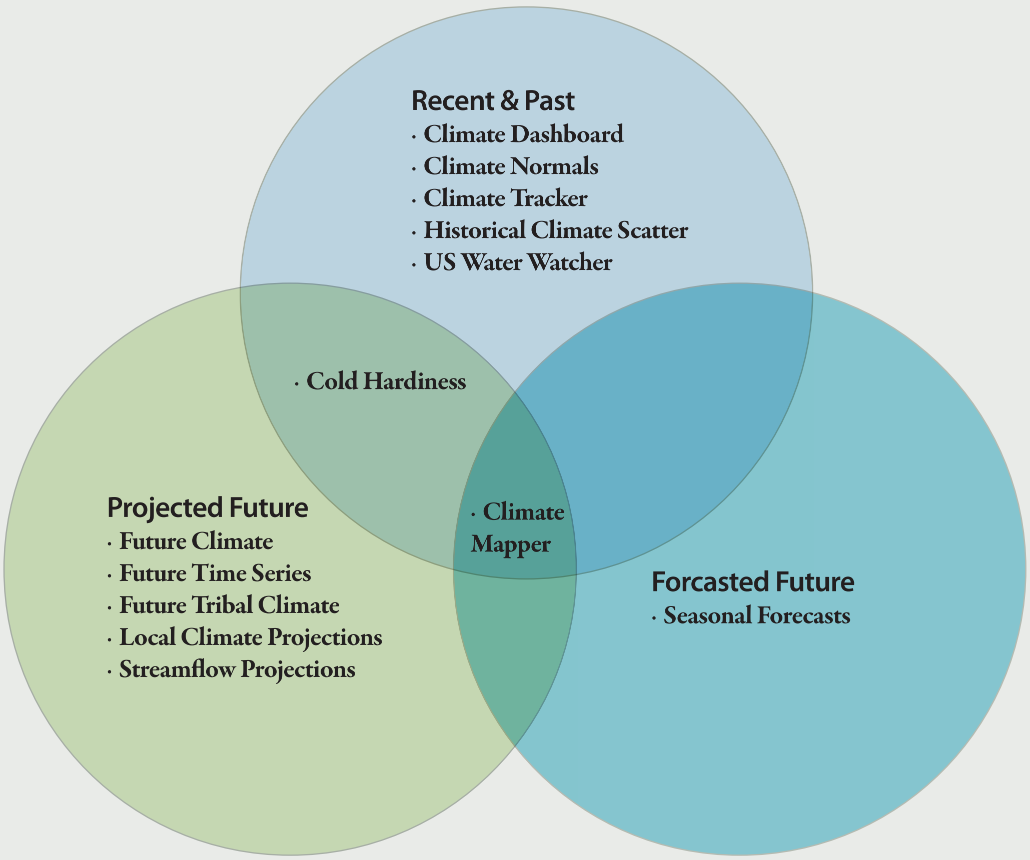
Querying the Toolbox

Querying the Toolbox is a process of whittling and pruning. Start broad and then refine your climate-related question. Let the information from the Toolbox guide you to a more focused question.

Identify Your Climate Question

Frame your climate question by considering a climate condition or impact that currently affects your community or that you are concerned will affect your community in the future.

Figure 1—Tools Sorted By Time



Pick Your Tool by Climate Impact Category

Once you have a climate question in mind, choose a tool from the climate category that best fits your impact.

- **Agriculture**—climatetoolbox.org/agriculture
- **Climate**—climatetoolbox.org/climate
- **Water**—climatetoolbox.org/water
- **Wildfire**—climatetoolbox.org/wildfire

Consider Time When Picking a Tool (see *Figure 1*):

The Toolbox uses three basic categories to represent time:

- **Recent & Past Conditions**—examines current climate conditions and how they stack up to conditions experienced in recent decades.
- **Forecasted Future Conditions**—provides short-term (on the order of months) climate and weather forecasts.
- **Projected Future Conditions (Emission Scenarios)**—provides long-term (on the order of decades) climate projections.

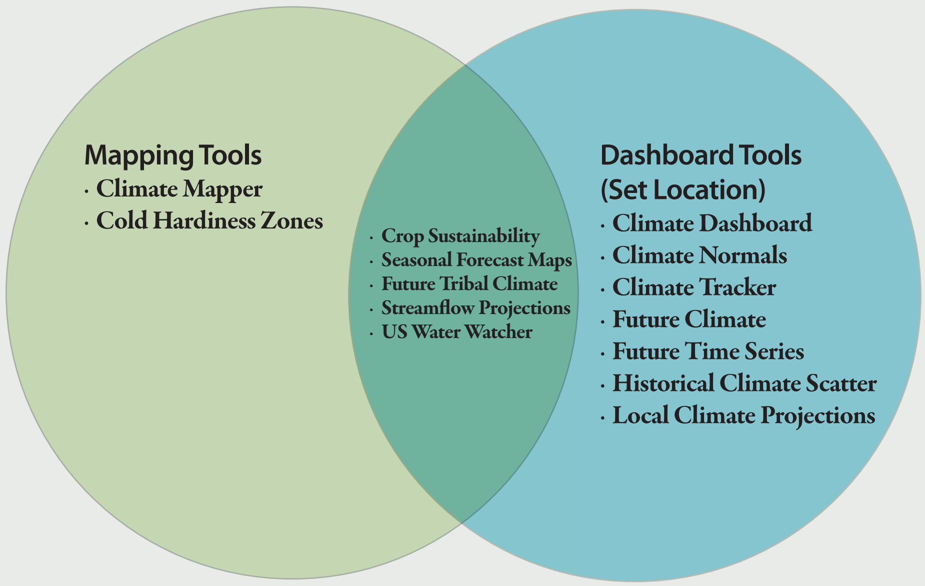
Tips: It's okay for your initial question to be simple. You will have plenty of time to refine your question as you become more comfortable with the Toolbox.

Consider Time & Space

Now it's time to pick a tool. Consider the timeframe and location/geographic area you are interested in by asking two questions:

- Am I interested in past, present, or projected future conditions?
- Do I need a tool that includes a mapping feature so that I may consider a large geographic area, or will a specific location work?

Figure 2—Tools Sorted By Mapping and Dashboard (*Set Location*) Functions



Consider Location/Geographic Area When Picking a Tool (see *Figure 2*):

Considered spatially, Toolbox tools have two main designs:

- **Mapping Tools**—tools that display climate data on maps of the United States
- **Dashboard Tools (Set Location)**—tools that create graphs and other visualizations for specific locations using climate data

Pick a Variable in Your Chosen Tool

Variables differ from tool to tool, ranging from simple metrics to more complex ones. Variables can be viewed in their simple, raw form or expressed as percentiles or anomalies. Choose from the list of variables most relevant to your climate condition or impact question.

Calendar Time Periods—Considering Time Again

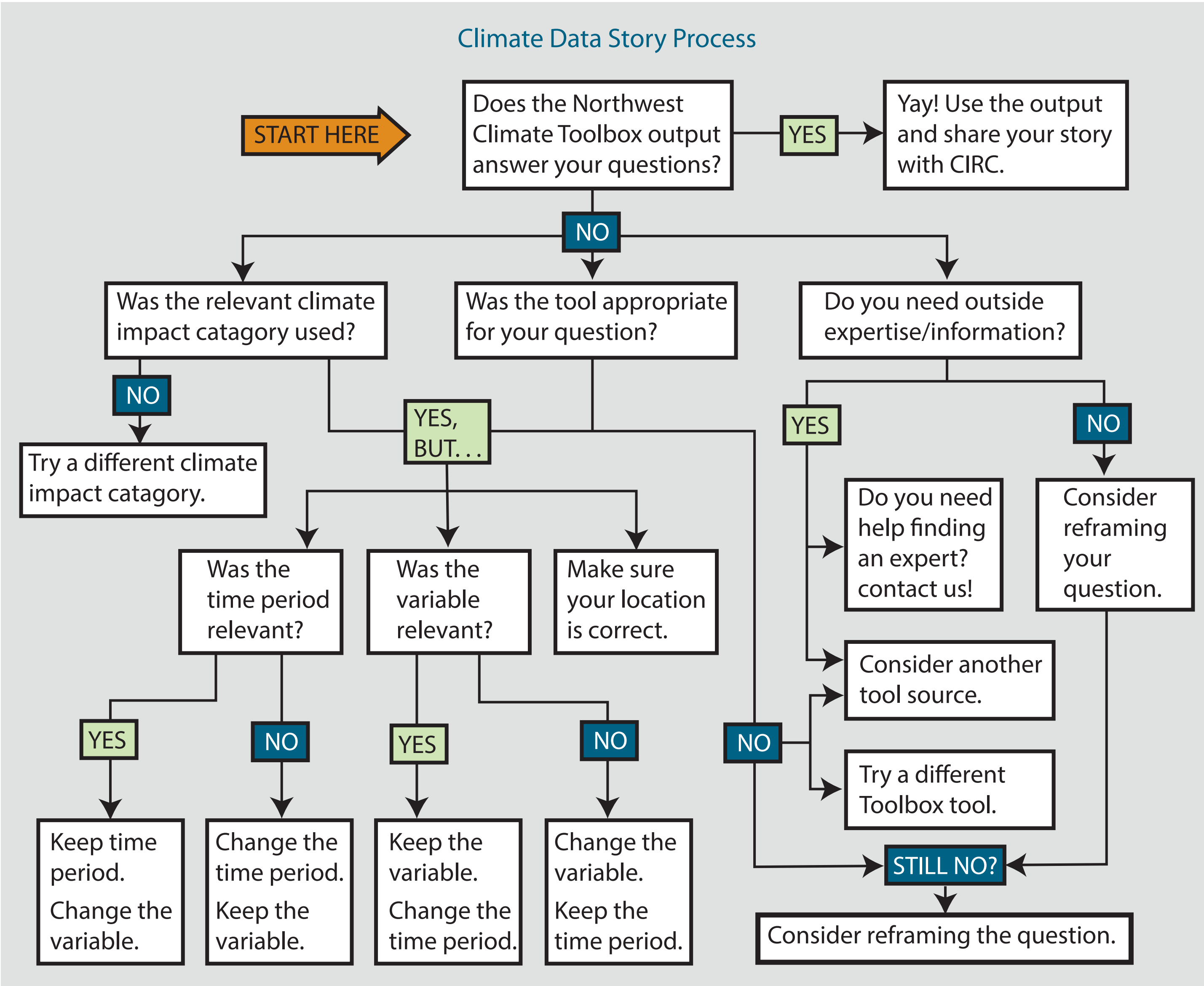
Climate conditions and impacts can differ significantly during different times of the year. Along with allowing you to examine variables across past, present, and projected future climate conditions, the Toolbox also allows users to examine variables across specific Calendar Time Periods, including:

- Yesterday (literally yesterday)
- Last 7 Days
- Last 15 Days
- Last 60 Days
- Last 90 Days
- Next 7 Days
- Next 15 Days
- Next 30 Days
- Since the 1st of each calendar month (Since Oct. 1st, Since Jan. 1st, etc.)
- Winter (Dec/Jan/Feb)
- Spring (Mar/Apr/May)
- Summer (Jun/Jul/Aug)
- Fall (Sept/Oct/Nov)
- Annual (conditions across all months of the year)

Tip: Compare multiple time periods when asking your climate question. For example, it might have rained more than normal over the past 7 days, but less than normal over the past 90 days.

Assessing Toolbox Outputs

The following section will help you assess whether the Toolbox has answered your climate question or if you need to take additional steps to get your answer.



Tip: Querying the Toolbox takes practice. Keep playing with it and be patient. If you continue to struggle, contact CIRC and we will help. pnw.circ@oregonstate.edu

Downloading & Citing Your Results

Here is a short to-do list that you may want to consider when downloading and citing your work.

Downloading Data

Some Toolbox tools allow you to download the data used in your visualizations. This varies from tool to tool.

- **Download Data**—To download data in the Climate Mapper, click on the *Download Data* button on the left.
- **Save Dashboard**—Dashboard tools like the Climate Projection Dashboard and Real-Time Climate Dashboard have *Save Dashboard* buttons that allow you to save their dashboards as simple image files.
- **"Hamburger" (Three Stacked Lines)**—Other apps use an icon made of three stacked lines (sometimes called a "hamburger") that functions as a download button. Click the icon to see your download options.

Screenshots

Perhaps the easiest way to save your work is by taking a screenshot. Instructions on how to take a screenshot using different operating systems can be found alongside many of the Toolbox's mapping tools.

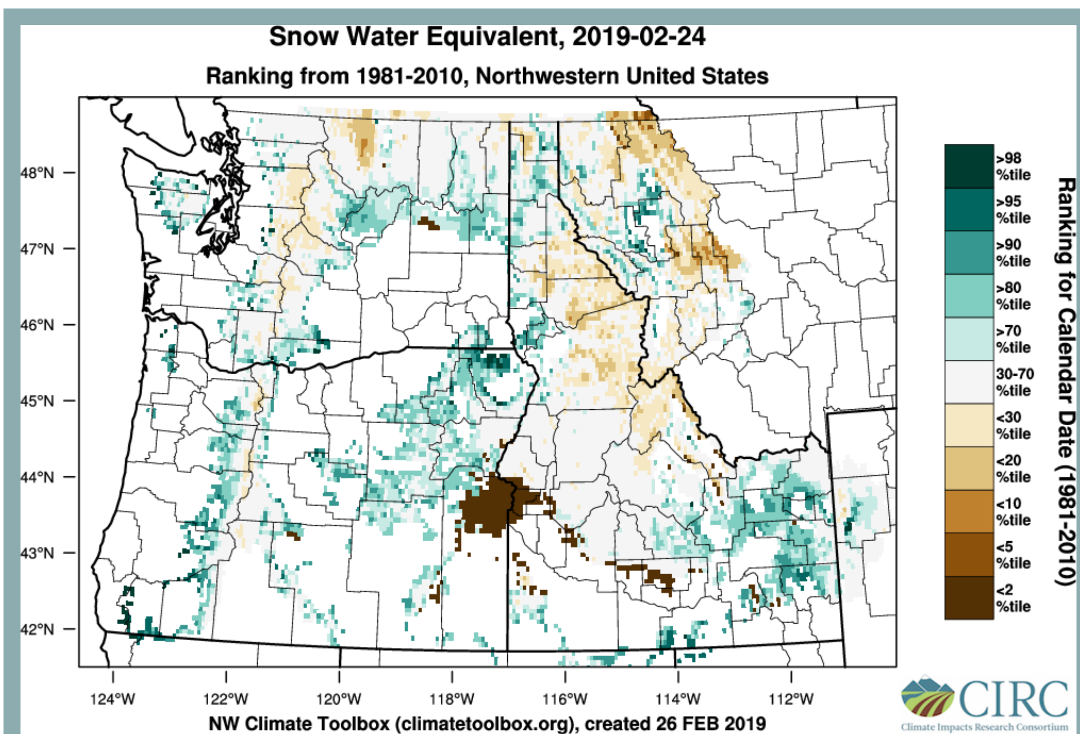
- **Mac**—Press Shift-Command-4 (shift-⌘-4). Pointer changes to a crosshair. Move the crosshair to where you want to start the screenshot. Click and hold your mouse/trackpad cursor. Drag crosshair, creating a rectangle that encompasses desired area. Release mouse or trackpad when ready. Image file will download to your computer.
- **Windows**—Microsoft includes a built-in utility for Windows called the Snipping Tool. In the *Snipping Tool*, click the *New* button. This freezes the screen and lets you frame your screenshot by clicking the mouse on the screen and dragging it to form a rectangle view of the screen. Once the screenshot is taken, the image is automatically pasted into a new Paint window. It is also copied to the clipboard. This allows you to paste image file into another program.

Citing Figures & Data

Click on the *Cite Tool* button to cite a figure. A suggested citation will populate at the bottom of the window. If you want to cite the data a figure uses, click *Documentation*. Next, click *Source* to find a suggested citation for the data used in your visualization. Below is an example map pulled from the Climate Mapper tool listing a citation.

Caption: February 24th, 2019 snow water equivalent (SWE) percentiles for the Northwest United States. SWE percentiles were calculated by comparing Feb 24th, 2019 SWE conditions to SWE conditions for every Feb 24th from 1981 to 2010.

Citation: Hegewisch, Katherine C., John T. Abatzoglou, Bart Nijssen, Liz Clark, Hordur Bragi, Oriana Chedwiggen, Nathan Gilles, and Holly Hartmann. "Climate Mapper web tool, The Northwest Climate Toolbox." *The Pacific Northwest Climate Impacts Research Consortium, a NOAA RISA Team*. Imaged created on February 26th, 2019.



https://climatetoolbox.org/tool/Climate-Mapper.

Worksheet 1—Toolboxing Practice

About Worksheet 1: This worksheet will help you apply the knowledge you've learned from ***Module 1—Navigating & Querying the Toolbox.*** Using the framework from the module handout, practice the steps using the following exercises:

<table>
<tr><td colspan="2">Example Question: Was the Summer of 2018 weird?</td></tr>
<tr><td>1. Identify your climate question:

During June to August 2018, was maximum temperature in Spokane, Washington different from the expected normal temperatures?</td><td>4. Pick a variable in your chosen tool:

Maximum Temperature</td></tr>
<tr><td>2. Pick a climate impact category:

Climate</td><td>5. Consider location/geographic area:

Spokane, Washington</td></tr>
<tr><td>3. Pick a tool:

Historical Climate Tracker
(https://climatetoolbox.org/tool/historical-climate-tracker)</td><td>6. Time frames/time periods
(decades, calendar time, etc.) /emissions scenarios:

June–August
1979–2018</td></tr>
<tr><td>What outputs did the Toolbox provide?

A bar chart representing average temperatures. The bar chart can be downloaded as an image file. The data displayed in the bar chart can also be downloaded and used to make custom charts.</td><td>Can you use the outputs from the Toolbox to answer your question? How would you get this output?

Yes. My steps to get the output would be:
• Select Spokane, Washington as a location
• Select Data: Maximum Temperature
• Select Data: Jun–Aug</td></tr>
<tr><td colspan="2">What are your conclusions and possible next steps?

Conclusions:
Maximum temperature averaged over June–August in Spokane, Washington was 83°F. This was 1.1°F above the historical baseline (1979–2018 average), that is, "above normal." However, I wouldn't say 2018 was "weird" in terms of Spokane maximum temperature averaged over June–August because there were many other past years in which June–August maximum temperature was higher than in 2018. For example, in 2015, June–August maximum temperature was 87.3°F which was 5.4°F above the historical baseline. THAT IS WEIRD.

Possible next steps include:
• downloading the .csv file
• ranking downloaded data to figure out where 2018 sits in comparison with all years in the record
• exploring this same question with summer precipitation
• using the Historical Climate Scatter tool to explore temperature and precipitation simultaneously</td></tr>
</table>

Practice Question 1: Can I grow Gala apples in Spokane, Washington in 50 years? (*See possible solutions at the end of this Module*).	
1. Identify your climate question:	**4. Pick a variable in your chosen tool:**
2. Pick a climate impact category:	**5. Consider location/geographic Area:**
3. Pick a tool:	**6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:**
What outputs did the Toolbox provide?	**Can you use the outputs from the Toolbox to answer your question?**
What are your conclusions and possible next steps?	

Practice Question 2: Under what time periods (early, mid, and/or late 21st century) and future scenarios (greenhouse gas emissions) will people still be able to go skiing at Schweitzer Mountain Resort on New Years? Note: you need at least 4 inches of snow water equivalent to go skiing. (*See possible solutions at the end of this Module).*	
1. Identify your climate question:	**4. Pick a variable in your chosen tool:**
2. Pick a climate impact category:	**5. Consider location/geographic Area:**
3. Pick a tool:	**6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:**
What outputs did the Toolbox provide?	**Can you use the outputs from the Toolbox to answer your question?**
What are conclusions and possible next steps?	

Now it's your turn to think of some questions that are relevant to you and your interests. Once you have your question, practice walking through the steps.

Your Question:	
1. Identify your climate question:	**4. Pick a variable in your chosen tool:**
2. Pick a climate impact category:	**5. Consider location/geographic area:**
3. Pick a tool:	**6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:**
What outputs did the Toolbox provide?	**Can you use the outputs from the Toolbox to answer your question?**
What are conclusions and possible next steps?	

Your Question:	
1. Identify your climate question:	**4. Pick a variable in your chosen tool:**
2. Pick a climate impact category:	**5. Consider location/geographic area:**
3. Pick a tool:	**6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:**
What outputs did the Toolbox provide?	**Can you use the outputs from the Toolbox to answer your question?**
What are your conclusions and possible next steps?	

Possible Solutions to Practice Questions 1 & 2

Solutions to Practice Question 1: *Can I grow Gala apples in Spokane, Washington in 50 years?*	
1. Identify your climate question: *Will the crop suitability zone for Gala apples still cover Spokane, Washington by mid-century?*	**4. Pick a variable in your chosen tool:** *Crop: Apple (Gala)* *This corresponds to a Cold Hardiness Zone Range of 4a to 10b.*
2. Pick a climate impact category: *Agriculture*	**5. Consider location/geographic area:** *Spokane, Washington (Latitude: 47.644 North, Longitude: -117.422 East)* *While the location feature is not available on this tool, I can zoom in and hand select a location over Spokane.*
3. Pick a tool: *Future Cold Hardiness Zones/Crop Suitability (https://climatetoolbox.org/tool/future-cold-hardiness-zones)*	**6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:** *1971–2000 (Current Day)* *2040–2069, Lower Emissions (RCP 4.5)* *2040–2069, Higher Emissions (RCP 8.5)*
What outputs did the Toolbox provide? *Map layers showing the projected crop suitability zones for Gala Apples in historical and future time periods over the Continental US.* *Using the hand tool to click on a location near Spokane, a pop-up box gives the cold hardiness zone (CHZ) and the average annual minimum temperature on which CHZs are based.*	**Can you use the outputs from the Toolbox to answer your question? How would you get this output?** *Yes.* *Steps to get the output:* • Choose the Maps of Crop Suitability Zones tool • *Select 1971–2000 (Current Day)* • *Select Crop: Apples (Gala)* • *Zoom in on the map and click on Spokane, WA (Latitude: 47.644 North, Longitude: -117.422 East) and record the value in the popup.* • *Keeping the popup open, select 2040–2069, Lower Emissions (RCP 4.5) and record updated value in the popup.* • *Keeping the popup open, select 2040–2069, Higher Emissions (RCP 8.5) and record updated value in the popup."*

What are your conclusions and possible next steps?

Conclusions:
The current day crop suitability zone for Gala apples covers almost the entire continental US and continues to cover almost the entire continental US in future conditions. This is probably because the cold hardiness zone (CHZ) range for Gala apples is so large. However, Spokane remains suitable (within the cold hardiness zone range) for growing Gala apples even though CHZ changes as the average annual minimum temperature increases in future periods.

In the historical baseline (1971–2000), the CHZ is 7a with the average annual minimum temperature of -0.4°F. However, by the 2050s (2040–2069) under the Lower Emissions Scenario (RCP 4.5), the CHZ becomes 7b with an average annual minimum temperature of 8.4°F. By the 2050s (2040–2069) under the Higher Emissions Scenario, the CHZ becomes 8a with an average annual minimum temperature of 10.8°F.

In conclusion, one could still grow Gala apples in Spokane in 2050 because the projected future CHZ under both the Lower and Higher Emissions Scenarios are still within the CHZ range for Gala apples.

Possible next steps?
Since CHZ is one variable to determine the ability to grow a crop, possible next steps might include:

- *Exploring additional variables (e.g., chilling hours, water availability, heat accumulation, heat extremes) that may influence the ability to grow apples of adequate quality.*
- *Using the following tools to explore additional relevant variables:*
    - *Future Climate Mapper (https://climatetoolbox.org/tool/climate-mapper)*
    - *Future Crop Suitability (https://climatetoolbox.org/tool/future-crop-suitability)*
    - *Future Climate Boxplots (https://climatetoolbox.org/tool/future-climate-boxplots)*
    - *Future Streamflow Projections (https://climatetoolbox.org/tool/future-streamflow-projections)*
    - *AgBizLogic (https://www.agbizlogic.com/), a non-Toolbox tool to explore potential economic outcomes of potential changes in crop yield/quality based on climate projections*

Solutions to Practice Question 2: *Under what time periods (early, mid, and/or late 21st century) and future scenarios (greenhouse gas emissions) will people still be able to go skiing at Schweitzer Mountain Resort on New Years?*

<table>
<tr><td>1. Identify your climate question:

When (decades) and under what emissions scenarios will snow water equivalent (SWE) on January 1st at Schweitzer Mountain Resort be at least 4 inches?</td><td>4. Pick a variable in your chosen tool:

Snow water equivalent (SWE) on January 1st.</td></tr>
<tr><td>2. Pick a climate impact category:

Snow is an aspect of the climate impact category 'Water'. Hydrology is another name for this.</td><td>5. Consider location/geographic area:

We are looking at a specific location, that of Schweitzer Mountain Resort (in Northern Idaho).</td></tr>
<tr><td>3. Pick a tool:

Since there is only one tool that has the snow water equivalent (SWE) metric, we need to use the Climate Mapper (https://climatetoolbox.org/tool/climate-mapper). Though this is primarily a mapping tool, the Climate Mapper provides values at locations on the map by using the 'Get Grid Cell Values' options on the left. There, we can enter 'Schweitzer Mountain Resort' in the box under 'Geolocate.'</td><td>6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:

<u>Time Frame:</u>
Historical Simulation (1971–2000)
Projected Future Conditions
<u>Time Periods:</u>
Early 21st century (2010–2039)
Mid 21st century (2040–2069)
Late 21st century (2070–2099)
<u>Scenarios:</u>
Higher Emissions Scenario (RCP 8.5)
Lower Emissions Scenario (RCP 4.5)</td></tr>
<tr><td>What outputs did the Toolbox provide?

The Climate Mapper provides maps of SWE, but also point values of SWE in a popup window at specific locations on the map. We can use the values in the popup window to answer our question.</td><td>Can you use the outputs from the Toolbox to answer your question? How would you get this output?

Yes.
Steps to get the output:
Under Main Menu:
• Focus: select Hydrology from "Projected future conditions"
• Variable: select Snow water equivalent (SWE)
• Calendar Time Period: select January 1st
• Future Scenario: select each of the 6 choices: Lower/Higher emissions and all 3 time periods (2010-2039, 2040-2069, 2070-2099) and record the values in the popup for each.
Click "Grid Cell Values" Menu
• Under Geolocate, enter 'Schweitzer Mountain Resort.'
• A popup opens on the map with the value displayed.</td></tr>
</table>

What are your conclusions and possible next steps?

Conclusion:

- *To arrive at a conclusion it would be necessary to compile a table of outputs from the tool's popup windows:*
  - *Historical Values: historical simulation, 1971–2000: SWE on Jan 1st = 7.4 inches*
  - *Lower Emissions (RCP 4.5), 2010–2039 mean: SWE on Jan 1st = 6.4 inches*
  - *Lower Emissions (RCP 4.5), 2040–2069 mean: SWE on Jan 1st = 5.5 inches*
  - *Lower Emissions (RCP 4.5), 2070–2099 mean: SWE on Jan 1st = 4.6 inches*
  - *Higher Emissions (RCP 8.5), 2010–2039 mean: SWE on Jan 1st = 6.3 inches*
  - *Higher Emissions (RCP 8.5), 2040–2069 mean: SWE on Jan 1st = 4.4 inches*
  - *Higher Emissions (RCP 8.5), 2070–2099 mean: SWE on Jan 1st = 2.6 inches*

Comparing all the SWE Jan 1st values to 4 inches, we see that currently (historical simulation) and for all the lower emissions scenarios, we can expect to ski on Jan 1st, i.e SWE > 4 inches. However, under the high emissions scenario (which is the track our current emissions are one), we won't be able to ski on Jan 1st by the end of the century (2070–2099).

Next Steps:

- *Go through flowchart to see if question was answered or if there are other steps to take.*
- *Data Source: Make sure to write down next to the table where the data came from (gridMET)*
- *Citation: Make sure to write down a citation for where I got the data from:*
  - *Abatzoglou, John T. "Development of gridded surface meteorological data for ecological applications and modelling." International Journal of Climatology 33, no. 1 (2013): 121-131. https://doi.org/10.1002/joc.3413.*
  - *Hegewisch, Katherine C. and John T. Abatzoglou, "Climate Tracker" web tool. Northwest Climate Toolbox (https://climatetoolbox.org/) accessed on Feb 6, 2019.*

Tip: This is how our CIRC team filled in the solutions to the practice questions. You might do it differently.

Module 2—Telling Your Climate Data Story

About Module 2: This module compiles a set of recommendations to consider as you use the information you have gathered in ***Module 1—Navigating & Querying the Toolbox*** to organize and compose your climate data story. In this module you will learn how to clearly outline your climate data story (***Parts of Your Climate Data Story***) and how to and how to handle tricky concepts and specialized terms (***Tricky Concepts & Specialized Terms***). Think of this module as your outline to help you organize your Toolbox outputs into a narrative that will help make your climate data story relevant, clear, and compelling for you audience.

Key Term:
Climate data story—a narrative outlining climate facts and impacts specific to your community.

Module 2 at a Glance

Parts of Your Climate Data Story

- Introduce a Clear & Concise Topic
- Make Your Story About Local Issues
- Know Your Audience
- Structuring Your Climate Data Story
- Results
- Describing & Citing What You Did

Tricky Concept & Specialized Terms

- Tricky Concept 1—Projections, Not Predictions
- Tricky Concept 2—Percentiles & Anomalies
- Tricky Concept 3—Interpreting Differences in Terms (Percentiles vs. Anomalies & Different Representations of Anomalies)

Worksheet 2—Worksheeting Your Climate Data Story

- Step 1. Query the Toolbox
- Step 2. Climate Data Story Outline

Case Study—Spokane Community Adaptation Project

Parts of Your Climate Data Story

Introduce a Clear & Concise Topic: Begin your climate data story by introducing a clear topic.

- **State Your Take-Away Message:** In one to two sentences, state your topic and why it is important.
- **Summarize your Topic:** Start your climate data story with a brief summary of what your audience can expect, including the key elements you will cover in your climate data story.
- **Describe What Your Audience Can Do With the Information You Present:** Include:
    - Decisions that can be informed by your climate data story
    - Further study and analysis that might be needed

Tip: Frequently a larger climate category, such as temperature, will lead to a specific impact, such as heat stroke or increased water demand. Climate categories in turn are represented by specific variables in the Toolbox, such as ***Mean*** and ***Maximum Temperature***.

Tip: We recommend you start with general concepts and themes. You can flesh-out your topic with further details and specific examples as your climate data story progresses. Appendix 1, 2, and 3 of this document were created to provide further details and guidance as you develop your climate data story.

- *Appendix 1—Climate Impacts & Toolbox Variables:* Lists climate variables found in the Toolbox and how they can be used to assess specific climate impacts. The table found in Appendix 1 allows you to search by climate impact in order to find a related Toolbox variable, or vice versa.
- ***Appendix 2—Additional Resources Organized by Climate Data Story Themes:*** Lists additional online tools and publications you may need to consult when developing your climate data story. This appendix, originally developed as part of CIRC's Spokane Community Adaptation Project, provides a lists possible climate themes (*Temperature, Precipitation Snowpack, River Flow and Stream Temperature, Fire and Ecological Change*) and associated subject matter experts and publications that might be helpful in constructing your climate data story.
- ***Appendix 3—Northwest-Relevant Climate Assessments:*** Lists national, regional, state, and tribal climate assessments relevant to the Northwest United States.

Make Your Story About Local Issues:

- **Apply Local Knowledge & Expertise:** The most essential piece to telling your climate data story is you, your local knowledge and expertise, and how your knowledge integrates with the impersonal data provided by the Toolbox. Add your knowledge to make your story locally relevant.
- **Use Observed Historical Climate:** Use observed historical climate data to make comparisons with current and projected future climate. Make this personal, include anecdotes about past climate (local stories, newspaper clippings, your own memories). This will add context to observed past and current conditions as well as project future conditions.
- **Add Your Sense of Place:** Be sure to make the local landscape a key feature of your climate data story. This will help contextualize your climate data for your community.

Know Your Audience: Tailor your communication to your audience. Different audiences come with different concerns and different levels of knowledge about climate science. Ask yourself,

- Who will be using your information?
- What decisions and policies could result from your climate data story?
- What is the expertise of your audience? Be inclusive.

Structuring Your Climate Data Story: Think of your topic or theme as composed of three broad elements:

1. **Facts**—all the scientific data and information you have gathered.
2. **Impacts**—what the information you have gathered means for your community.
3. **Narrative**—a storyline that structures your facts and impacts into a timeframe that is meaningful for your audience. Be sure to have a beginning, middle, and end to your narrative. Show change when it exists.

Results: Describe your results simply and succinctly. If possible, save comments, caveats, and details about the process you took to arrive at your results until after you have stated those results.

Describing & Citing What You Did: Describe which tools you used to develop your climate data story and how you queried the Toolbox. Be transparent as you describe which tools you used to develop your climate data story and how you used the Toolbox. If it was necessary to derive, or calculate information, include that information as well as a short description of that process. Be transparent about your methods and assumptions and share what you did and did not do and what you do and do not know. As you describe what you did, be mindful of:

- **Historical Baselines:** The Toolbox uses several different data sets that cover different historical periods. These historical baselines tend to differ from variable to variable. Be sure to describe what historical baseline you used when telling your climate story.
- **Calendar Time Comparisons:** When considering a variable displayed as a unit of *Calendar Time—Last 90 days, Winter (Dec/Jan/Feb)*, etc.—be sure to describe the specific dates your Calendar Time covers. For instance, when describing the variable *Maximum Temperature Percentile* for the calendar period *Last 90 Days*, you are comparing your last 90 calendar days to the same 90-day calendar period for each year from 1979 to 2015 (1979–2015 is the historical baseline used for this variable). Let your audience know this.
- **Variables:** The Toolbox uses multiple variables to help you tell your climate story. Be sure to explain what the variables are when you present your story. To learn more about variables, click the *Documentation* tab then the *Variables* tab in your tool.
- **Data Sources:** Note your data sources. Whenever possible describe the assumptions and limitations of the data sets you used. (See ***Downloading & Citing Your Results*** in ***Module 1—Navigating & Querying the Toolbox***.
- **References & Citations:** List all sources you used to form your conclusions, including:
    - Toolbox tools
    - Data sets
    - All other sources outside the toolbox including, but not limited to other online tools and data sources, publications, interviews, etc.
- **Charts & Figures:** To provide captions for all figures and tables.(See ***Module 1—Navigating & Querying the Toolbox***). You can use any style depending on your institution's standards. Just be sure to provide enough information for others to replicate your work and conclusions.
- **Using a Standard Citation Format:** CIRC uses the Chicago Manual of Style for its communications. Feel free to follow whatever style manual you like.

Tricky Concept & Specialized Terms

Climate science and social science use many specialized terms and tricky concepts. Below are some of the big ones and how to handle them.

Handle specialized terms in one of two ways:

- Substituting Terms: Consider whether you need to use a specialized term or if a common term could be used to replace it.
- Defining Terms: If you do use a jargon term, remember to define the term for your audience. This should include defining the variables related to the information you are presenting. In the Toolbox, you can find definitions of variables in the Variables tab found under the Documentation tab. You can also find definitions in ***Appendix 1—Climate Impacts & Toolbox Variables***.

Tip: Try not to be boring. You can lose your audience when you start presenting methods and facts. As you describe your methods and facts, be sure to restate your topic and why it matters to your community.

Tricky Concept 1—Projections, Not Predictions: The future climate projections, or future scenarios, the Toolbox uses present probable future effects of climate change. These projections are based on the best available science, but they are not predictions depicting a set-in-stone future. It's key when talking about future climate projections that you use the word projection.

Projected Future Scenarios/Emission Scenarios (the Representative Concentration Pathways)

Representative Concentration Pathways (RCPs) are used as proxies for the warming associated with CO_2 and other greenhouse gasses. RCPs are the standard used to represent future emissions of greenhouse gases, also called emission scenarios.

While a broad range of scenarios exist, the Toolbox uses just two RCPs:

Higher Emissions Scenario (RCP 8.5)—considers the current trajectory of increased greenhouse gas emissions and population growth through the end of the century with nominal policies to reduce emissions. This "business as usual scenario" assumes warming will continue at its current high rate.

Lower Emissions Scenario (RCP 4.5)—considers a curtailment in greenhouse gas emissions through greenhouse gas mitigation efforts. Assumes warming will continue but will slow from its current rate.

Projected Future Scenarios employing the RCPs can be viewed for the early (2010–2039), middle (2040–2069), and late decades (2070–2099) of this century.

Tricky Concept 2—Percentiles & Anomalies: Because they tell slightly different stories, it's helpful to explain to your audience the difference between percentiles and anomalies. (See ***Table 1***.)

Table 1—Toolbox Representations of Percentiles & Anomalies.

Percentiles	Anomalies
Percentiles—the percentage of values from the distribution of historical values that are equal to or lower than the metric's current value. **Note:** Percentiles use median to represent normal. **What It Does:** Helps you see where current conditions are ranked in an ordered list of all past observed conditions. Helpful in showing how extreme or normal a variable's current value is compared to past records. **How the Toolbox Represents Percentiles:** The Toolbox represents percentiles as follows: • record lowest (0 percentile) • bottom decile (bottom 10 percentile) • bottom tercile (bottom 33 percentile) • median (50 percentile) • middle tercile (middle 33 percentile) • top tercile (top 33 percentile) • top decile (top 10 percentile) • record highest (100 percentile)	***Anomalies***—a representation of how above or below normal current conditions are compared to past conditions. **Note:** Anomalies use mean to represent normal. **What It Does:** Helps you see how current conditions differ from past averages. **How the Toolbox Represents Anomalies:** The Toolbox represents anomalies as the difference from a climatological average expressed over a 30-year base-period—for instance, 1981–2010 or 1971–2000. Conditions above the historical mean are displayed in positive numbers, while conditions below the historical mean are displayed in negative numbers. The Toolbox uses three forms of anomalies that each have slightly different meanings: change from normal (mean) percent of normal (mean) percent change from normal (mean)

Tricky Concept 3—Interpreting Differences in Terms (Percentiles vs. Anomalies & Different Representations of Anomalies): It is easy to confuse the terms *from normal* and *of normal*. The ***Table 2*** below breaks down these differences. ***Table 3*** provides an example of different ways to present data look for a single variable.

Table 2—Different Representations of Data

Representation of Data	'Normal'	Lowest observed	Highest observed	Interpretation (i.e. scale from good to bad)	What it helps you do
Percentile	50 percentile = median	0 percentile	100 percentile	If the number is between 0 and 50, it is below normal (median). If the number is between 50 and 100, it is above normal (median). If the number is 50, it is normal (median).	Can help you understand extremes better. Interpret your results by using the following equation: 1-in-100/p occurrence, where p is your percentile value. For instance, if the current value is at the 1 percentile, this corresponds to the 1-in-100 year occurrence of this value, whereas, if your value is at the 2 percentile, this corresponds to the 1-in-50 year occurrence of this value..
Change from normal (anomaly)	0 = mean	–biggest observed	+biggest observed	If the number is below 0, it is below normal (mean). If the number is above 0, it is above normal (mean). If the number is 0, it is normal (mean)	Helps you understand where normal is and what is above or below normal.
% of normal (anomaly)	100 % = mean	0 %	+biggest observed %	If the number is between 0 and 100, it is below normal. If the number is above 100, it is above normal. If the number is 100, it is normal (mean).	Helps you understand where normal is and what is above or below normal.
% change from normal (anomaly)	0 % =mean	–biggest observed %	+biggest observed %	If the number is below 0, it is below normal (mean). If the number is above 0, it is above normal (mean). If the number is 0, it is normal (mean).	Helps you understand where normal is and what is above or below normal.

Example Table 3—Different Representations of Precipitation Data

Representation	Precipitation Example	Toolbox Example (Tool: Climate Mapper)	Interpretation
change from normal (mean)	−1.5 inches from normal	Focus: Recent & Past Conditions, Climate Variable: Precipitation Anomaly (inches) Link: https://bit.ly/2HUBRtO —OR— Focus: Projected Future Conditions, Climate Variable: Precipitation Future Scenario: Future Changes Link: https://bit.ly/2GcLLFB	Precipitation is projected to decrease in the future —OR— Precipitation is 1.5 inches below what is normal for this time period (1971–2000).
% of normal (mean)	67.6 percent of 1971–2000 mean	Focus: Current & Past Conditions, Climate Variable: Precipitation Link: https://bit.ly/2GpUgfI	Precipitation is 67.6 percent ofwhat is normal for this time period (1971–2000).
% change from normal (mean)	−6 % change	Focus: Future Projections, Climate Variable: Precipitation, Percent Change Link: https://bit.ly/2MZePkJ	Precipitation is below what is normal for this time period (1971–2000). Specifically, it is below normal by 6 percent of normal.
percentile	below normal (bottom 33 percentile)	Focus: Recent & Past Conditions, Climate Variable: Precipitation, Link: https://bit.ly/2UJ4ax5	Precipitation is in the bottom third (33 percentile) of observations for this time period (1971–2000).

Tip: Each tool represents data slightly differently depending on the timeframe and variables considered. For instance, the tools occasionally represent data associated with future projections in different ways than data associated with current conditions.

Case Study—Spokane Community Adaptation Project

About this Case Study: Participants in the CIRC Spokane Community Adaptation Project (SCAP) were the first to use The Northwest Climate Toolbox Workbook to write climate data stories.

SCAP was created to help the community of Spokane respond to climate impacts related to local water resources. As with all CIRC Community Adaptation projects, CIRC's goal with SCAP is to empower local community members to ask and answer complicated questions about how climate variability and change is likely to impact them. The other key goal of SCAP is to build the Spokane community's in-house capacity to make climate adaptation a part of everyday operations for local decision makers. This workbook and Toolbox training it offers is intended to do just that.

Starting in September 2018, CIRC researchers began meeting with Spokane community members to learn how to use the beta version of this workbook as part of a climate vulnerability assessment. The community chose their top climate concerns and impacts for the Spokane region, then sorted into teams organized around those concerns and impacts—Temperature Impacts Team, Snowpack Impacts Team, Fire Impacts Team, Streamflow Team. The impacts teams then created a series of climate data stories that help them better understand the chosen climate concerns.

Starting with Temperature: The Temperature Impacts Team was the first team to produce a climate data story (***Appendix 4—Example Climate Data Story***). The Temperature Impacts Team met together to choose key temperature impacts to explore. The team then divided their workload. One team member used ***Module 2—Telling Your Climate Data Story*** to provide the skeleton for their report. Another team member explored the Toolbox and ***Module 1—Navigating & Querying the Toolbox*** to examine temperature data and make figures that helped examine conditions. Another team member provided continuity throughout the process, looked for gaps, and brought in additional expertise to fill out the team's climate data story.

Putting It All Together Using the Temperature Impacts Team's framework as a starting point, the rest of the SCAP participants chose to add on to this initial work, integrating snowpack, streamflow, and fire information into the temperature impact story. As of this writing (March 2019), SCAP participants are working together to prepare a presentation to the annual Spokane River Forum. See their final products at https://pnwcirc.org/spokane-community-adaptation-project.

Tip: Just get started. Drafting a climate data story can be challenging. Don't worry about the state of your first draft (professional writers call this their "puke draft"). Just get it started. You can edit and refine your work as you proceed.

Share with CIRC: We love to hear from our stakeholders. Share your climate data story with us and we'll make sure the Pacific Northwest's larger climate adaptation community hears about it through our newsletter, *The Climate CIRCulator.*

- https://climatecirculatororg.wordpress.com/
- pnw.circ@oregonstate.edu

Worksheet 2—Worksheeting Your Climate Data Story

About Worksheet 2: This worksheet provides a structure and helpful tips you can use to organize the recommended components of your Climate Data Story.

Step 1. Query the Toolbox

Question:	
1. Identify Your Climate Question:	**4. Pick a Variable in Your Chosen Tool:**
2. Pick a Climate Impact Category:	**5. Consider Location/Geographic Area:**
3. Pick a Tool:	**6. Time frames/time periods (decades, calendar time, etc.)/emissions scenarios:**
What outputs did the Toolbox provide?	**Can you use the outputs from the Toolbox to answer your question? How would you get this output?**
What are your next steps?	

Step 2. Climate Data Story Outline

Introduce Topic (facts and impacts):
Definitions:
Calculations and Tools:
Data:
Results:
Analysis (facts and impacts):
Summary:
Charts and figures:
References:

Tip: CIRC recommends you begin by writing down a draft outline that roughly describes what you're planning to investigate. If you're working in a team, this is helpful to get all members on the same page, seeing the same big picture.

Appendix 1—Climate Impacts & Toolbox Variables

About Appendix 1: This appendix lists climate variables found in the Toolbox and how they can be used to assess specific climate impacts.

About the Table: The below table connects variables you've worked with already with terminology describing variables used by the Toolbox. Since the Toolbox combines data and information from many different disciplines, CIRC developed the following table to define the terms as they are analyzed in the Toolbox.

Direct & Derivable Variables: The CIRC team identified two types of Variables: Variables that can be directly translated into Toolbox outputs (*Direct*) and Variables that can be derived using Toolbox outputs combined with further analyses and information found outside of the Toolbox (*Derivable*).

- **Direct**—variables that translate directly into a Toolbox Variable output.
- **Derivable**—variables that can be derived from a Toolbox Variable output and will require additional information.

Tip: Some variable definitions will require users to add local information.

Climate Impact	Toolbox Variable(s)	Definition	*Variable*
Agriculture	—Direct— *Chill Hours*	A unit of chill accumulation defined as the number of hours between 32°Fahrenheit and 45°F accumulated between October 1st and April 30th.	*Chilling Hours*
	—Direct— *Growing Degree Days*	Accumulated growing degree days is a proxy for the heat accumulation needed to assess the thermal suitability of various crops in order to achieve maturity. Four growing degree thresholds are used to span the requirements for a variety of crops: 32°F, 37.4°F, 41°F, and 50°F.	*Growing Degree Days*
	—Direct— *Growing Season Length*	Number of days between the last spring freeze and the first fall freeze.	*Length of Growing Season*
	—Direct— *Potential Vapotranspiration*	Mean evapotranspiration during specified months.	*Mean Evapotranspiration*
	—Direct— *Soil Moisture*	Mean soil moisture during the months of June, July, and August.	*Summer Soil Moisture*
Drought & Flooding	—Derivable—	Length of rain-free days. The duration and magnitude of drought.	*Precipitation Timing*
	—Derivable—	Mean/min/max streamflow during the months of ___ to ___.	*River Flow Rate*
	—Derivable—	Rare storm defined as a 1 in ___ year precipitation event or precipitation amount exceeding ____ inches.	*Storm Frequency/Severity*

Fish & Wildlife	—Derivable—	Mean/min/max streamflow during the months of ___ to ___.	*River Flow Rate*
	—Derivable—	Mean stream temperature during the months of ___ to ___.	*Water Temperature (Streams/ Lakes)*
Climate Impact	**Toolbox Variable(s)**	**Definition**	**Variable**
Human & Animal Health	—Derivable—	Max daily temperature over a specified time period.	*Heat Extremes/Waves*
	—Direct— *Mean Temperature*	Average daily temperature during the months of June, July, and August.	*Summer Temperature*
	—Direct— *Mean Temperature*	Average daily temperature during the months of October to March.	*Cool Season Temperature*
Water	—Direct— *Precipitation*	The amount of precipitation received over the months of June, July, and August.	*Summer Precipitation*
	—Direct— *Precipitation*	Mean precipitation during the months of December, January, and February.	*Winter Precipitation*
	—Direct— *Snow Water Equivalent*	The amount snowpack defined by *snow water equivalent*—the water contained in the snowpack.	*Snowpack*
Wildfire	—Derivable—	The number of fires in a fire season.	*Fire Frequency*
	—Direct— *100 Hour Fuel Moisture*	The number of days each year in which the 100-hour fuel moisture is less than the __th percentile. *100-hour fuel moisture*—the amount of moisture in dead vegetation which is 1-3 inch in diameter and is available to burn in a fire.	*Fire Intensity*
	—Derivable—	The number of consecutive days where Energy Release Component is greater than ___. *Energy Release Component*—A calculation how hot a fire could burn (the energy release part) given recent climate and weather conditions specifically the moisture content of the various fuels (vegetation) present, both live and dead.	*Fire Season Length*

Appendix 2—Additional Resources Organized by Climate Data Story Themes

About Appendix 2: This appendix and the following table provides you with resources (some of them not associated with CIRC) that you may wish to use to further dissect the climate questions you're exploring with the Toolbox.

Resources are organized by broad themes and have been broken into three categories:

1. **Data and Resources**—other tools and data sets.
2. **Subject Matter Experts**—regional experts in your chosen topic.
3. **Studies**—peer-reviewed literature providing a broader context for local climate impacts.

Temperature

Suggested Data and Resources:
Multivariable Adaptive Constructed Analogs (MACA)
https://climate.northwestknowledge.net/MACA/

Subject Matter Experts:
John Abatzoglou, University of Idaho, jabatzoglou@uidaho.edu
Nick Bond, Washington State Climatologist, nicholas.bond@noaa.gov
Karin Bumbaco, kbumbaco@uw.edu
David Rupp, Oregon State University, drupp@ceoas.oregonstate.edu

Sample Studies:
Abatzoglou, John T., David E. Rupp, and Philip W. Mote. "Seasonal Climate Variability and Change in the Pacific Northwest of the United States." *Journal of Climate* 27, no. 5 (2014): 2125-2142. https://doi.org/10.1175/ JCLI-D-13-00218.1.

Rupp, David E., John T. Abatzoglou, and Philip W. Mote. "Projections of 21st century climate of the Columbia River Basin." *Climate Dynamics* 49, no. 5-6 (2017): 1783-1799. https://doi.org/10.1002/jgrd.50843.

Rupp, David E., Sihan Li, Philip W. Mote, Karen M. Shell, Neil Massey, Sarah N. Sparrow, David CH Wallom, and Myles R. Allen. "Seasonal spatial patterns of projected anthropogenic warming in complex terrain: a modeling study of the western US." *Climate Dynamics* 48, no. 7-8 (2017): 2191-2213. https://doi.org/10.1007/s00382-016-3200-x.

Rupp, David E., John T. Abatzoglou, Katherine C. Hegewisch, and Philip W. Mote. "Evaluation of CMIP5 20th Century Climate Simulations for the Pacific Northwest USA." *Journal of Geophysical Research: Atmospheres* 118, no. 19 (2013). https://doi.org/10.1002/jgrd.50843.

Precipitation

Suggested Data and Resources:
Multivariable Adaptive Constructed Analogs (MACA)
https://climate.northwestknowledge.net/MACA/

Subject Matter Experts:
John Abatzoglou, University of Idaho, jabatzoglou@uidaho.edu
Nick Bond, Washington State Climatologist, nicholas.bond@noaa.gov
Karin Bumbaco, University of Washington, kbumbaco@uw.edu
David Rupp, Oregon State University, drupp@ceoas.oregonstate.edu

Sample Studies:
Klos, P. Zion, Timothy E. Link, and John T. Abatzoglou.
"Extent of the rain-snow transition zone in the western US under historic and projected climate." *Geophysical Research Letters* 41, no. 13 (2014): 4560-4568. https://doi.org/10.1002/2014GL060500.

Rupp, David E., John T. Abatzoglou, and Philip W. Mote. "Projections of 21st century climate of the Columbia River Basin." *Climate Dynamics* 49, no. 5-6 (2017): 1783-1799.
https://doi.org/10.1002/jgrd.50843.

Publications on Precipitation Extremes

Parker, Lauren E., and John T. Abatzoglou. "Spatial coherence of extreme precipitation events in the Northwestern United States." *International Journal of Climatology* 36, no. 6 (2016): 2451-2460.
https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/joc.4504.

Snowpack

Suggested Data and Resources:
Historical—
Snow Telemetry Network (SNOTEL): https://www.wcc.nrcs.usda.gov/gis/snow.html
Snow Drought Page: https://www.drought.gov/drought/data-maps-tools/snow-drought

CIRC Projections—
Northwest Climate Toolbox: https://climatetoolbox.org
Integrated Scenarios: https://climate.northwestknowledge.net/IntegratedScenarios/

Subject Matter Experts:
Philip Mote, Oregon State University, philip.mote@oregonstate.edu
Bart Nijssen, University of Washington, nijssen@uw.edu

Sample Studies:
Gergel, Diana R., Bart Nijssen, John T. Abatzoglou, Dennis P. Lettenmaier, and Matt R. Stumbaugh. "Effects of Climate Change on Snowpack and Fire Potential in the Western USA."
Climatic Change 141, no. 2 (2017): 287-299. https://doi.org/10.1007/s10584-017-1899-y.

Mote, Philip W., Sihan Li, Dennis P. Lettenmaier, Mu Xiao, and Ruth Engel.
"Dramatic declines in snowpack in the western US." *Nature Partner Journals: Climate and Atmospheric Science volume 1, 2.* (2018). https://doi.org/10.1038/s41612-018-0012-1.

Mote, Philip W., David E. Rupp, Sihan Li, Darrin J. Sharp, Friederike Otto, Peter F. Uhe, Mu Xiao, Dennis P. Lettenmaier, Heidi Cullen, and Myles R. Allen. "Perspectives on the Causes of Exceptionally Low 2015 Snowpack in the Western United States." *Geophysical Research Letters* 43, no. 20 (2016). https://doi.org/10.1002/2016GL069965.

River Flow & Stream Temperature

Suggested Data and Resources:
Climate Toolbox: https://climatetoolbox.org/tool/Future-Streamflow-Projections
Hydrologic Response of the Columbia River Basin to Climate Change: http://www.hydro.washington.edu/CRCC/
NorWest stream temperature tool: https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html

Subject Matter Experts:
Hydrology—Bart Nijssen, University of Washington, nijssen@uw.edu and
Orianna Chegwidden, University of Washington, orianac@uw.edu

Fish—Daniel Isaak, US Forest Service, disaak@fs.fed.us

Sample Studies:
Vano, Julie A., Bart Nijssen, and Dennis P. Lettenmaier. "Seasonal hydrologic responses to climate change in the Pacific Northwest." *Water Resources Research* 51, no. 4 (2015): 1959-1976. https://doi.org/10.1002/2014WR015909.

Li, Dongyue, Melissa L. Wrzesien, Michael Durand, Jennifer Adam, and Dennis P. Lettenmaier. "How Much Runoff Originates as Snow in the Western United States, and How Will That Change in the Future?." *Geophysical Research Letters* (2017). https://doi.org/10.1002/2017GL073551.

Isaak, Daniel J., Michael K. Young, David E. Nagel, Dona L. Horan, and Matthew C. Groce. "The cold-water climate shield: delineating refugia for preserving salmonid fishes through the 21st century." *Global Change Biology* 21, no. 7 (2015): 2540-2553. https://www.fs.fed.us/rm/pubs_journals/2015/rmrs_2015_isaak_d001.pdf.

Fire & Ecological Change

Suggested Data and Resources:
National Interagency Fire Center: https://www.nifc.gov/

Northwest Climate Toolbox: https://climatetoolbox.org

Subject Matter Experts:
John T. Abatzoglou, University of Idaho, jabatzoglou@uidaho.edu

Sample Studies:
Abatzoglou, John T., and A. Park Williams. "Impact of Anthropogenic Climate Change on Wildfire across Western US Forests." *Proceedings of the National Academy of Sciences* 113, no. 42 (2016): 11770-11775. https://doi.org/10.1073/pnas.1607171113.

Barbero, Renaud, John T. Abatzoglou, Narasimhan Larkin, Crystal A. Kolden, and B. J. Stocks. "Climate Change Presents Increased Potential for Very Large Fires in the Contiguous United States." *International Journal of Wildland Fire* 24, no. 7 (2015): 892-899. https://doi.org/10.1071/WF15083.

Littell, Jeremy S., Donald McKenzie, Ho Yi Wan, and Samuel A. Cushman. "Climate Change and Future Wildfire in the Western United States: An Ecological Approach to Nonstationarity." *Earth's Future* 6, no. 8 (2018): 1097-1111. https://doi.org/10.1029/2018EF000878.

Gergel, Diana R., Bart Nijssen, John T. Abatzoglou, Dennis P. Lettenmaier, and Matt R. Stumbaugh. "Effects of Climate Change on Snowpack and Fire Potential in the Western USA." *Climatic Change* 141, no. 2 (2017): 287-299. https://doi.org/10.1007/s10584-017-1899-y.

Sheehan, Timothy J., Dominique Bachelet, and Ken Ferschweiler. "Projected Major Fire and Vegetation Changes in the Pacific Northwest of the Conterminous United States under Selected CMIP5 Climate Futures." *Ecological Modeling* 317 (2015): 16-29. https://doi.org/10.1016/j.ecolmodel.2015.08.023.

Appendix 3—Northwest-Relevant Climate Assessments

About Appendix 3—This appendix lists national, regional, state, and tribal climate assessments relevant to the Northwest United States.

National Climate Assessments

Fourth National Climate Assessment (2018)
Reidmiller, David, Christopher W. Avery, David R. Easterling, Kenneth E. Kunkel, Kristin L.M. Lewis, T.K. Maycock, and Brooke C. Stewart, eds. "USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II." Washington, D.C.: *U.S. Global Change Research Program*, 2018. https://nca2018.globalchange.gov.

Third National Climate Assessment (2014)
Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, eds. "Climate Change Impacts in the United States: The Third National Climate Assessment." Washington, D.C.: *U.S. Global Change Research Program*, 2014. https://nca2014.globalchange.gov.

Northwest Regional

Fourth National Climate Assessment,
Chapter 24: Northwest (2018)
May, Christine, Charles Luce, Joe Casola, Michael Chang, Jennifer Cuhaciyan, Meghan Dalton, Scott Lowe, Gary Morishima, Philip Mote, Alexander (Sascha), Gabrielle Roesch-McNally, and Emily York. "Northwest." In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, edited by Reidmiller, David, Christopher W. Avery, David R. Easterling, Kenneth E. Kunkel, Kristin L.M. Lewis, T.K. Maycock, and Brooke C. Stewart, 1036–1100. Washington, D.C.: *U.S. Global Change Research Program*, 2018. https://nca2018.globalchange.gov/chapter/24/.

Third National Climate Assessment,
Chapter 21: Northwest (2014)
Mote, Philip W., Amy K. Snover, Susan Capalbo, Sanford D. Eigenbrode, Patty Glick, Jeremy Littell, Richard Raymondi, and Spencer Reeder. "Chapter 21: Northwest." *In Climate Change Impacts in the United States: The Third National Climate Assessment*, edited by Jerry M. Melillo, Terese (TC) Richmond, and Gary W. Yohe, 487-513. Washington, D.C.: *US Global Change Research Program*, 2014. https://nca2014.globalchange.gov/report/regions/northwest.

Extended version of Third National Climate Assessment,
Chapter 21: Northwest (2013)
Dalton, Meghan M., Philip W. Mote, Amy K. Snover, eds. "Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities."Washington, D.C.: *Island Press*, 2013. Print ISBN: 9781610914284. E-Book ISBN: 9781610915120. https://pnwcirc.org/sites/pnwcirc.org/files/climatechangeinthenorthwest.pdf.

Northwest States

Washington
Washington Climate Change Impacts Assessment (2009)
Littell S., Jeremy S., Marketa McGuire Elsner,Lara C. Whitely Binder, and Amy K. Snover. "The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate-Executive Summary." Seattle, Washington: Climate Impacts Group, University of Washington, 2009. http://www.cses.washington.edu/db/pdf/wacciaexecsummary638.pdf.

Idaho
Academic Paper Covering Climate in Idaho(2015)
Klos, P. Zion, John T. Abatzoglou, Alycia Bean, Jarod Blades, Melissa A. Clark, Megan Dodd, Troy E. Hall et al. "Indicators of climate change in Idaho: an assessment framework for coupling biophysical change and social perception." *Weather, Climate, and Society* 7, no. 3 (2015): 238-254. https://journals.ametsoc.org/doi/full/10.1175/WCAS-D-13-00070.1.

Oregon
Fourth Oregon Climate Assessment Report (2019)
Mote, Philip W., John Abatzoglou, Kathie D. Dello, Katherine Hegewisch, and David E. Rupp, "2019: Fourth Oregon Climate Assessment Report, Oregon Climate Change Research Institute." Corvallis, Oregon: *College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2019. http://www.occri.net/media/1095/ocar4full.pdf.

Third Oregon Climate Assessment Report (2017)
Dalton, Meghan M., Kathie D. Dello, Linnia Hawkins, Philip W. Mote, and David E. Rupp. "The Third Oregon Climate Assessment Report, Oregon Climate Change Research Institute." Corvallis, Oregon: *College of Earth, Ocean, and Atmospheric Sciences, Oregon State University*, 2017. https://pnwcirc.org/sites/pnwcirc.org/files/ocar3_finalweb.pdf.

Oregon Climate Assessment Report (2010)
Dello, Kathie D., and Philip W. Mote, eds. "Oregon Climate Change Assessment Report, December 2010. Corvallis, Oregon: Oregon Climate Change Research Institute, *College of Oceanic and Atmospheric Sciences, Oregon State University*, 2010. https://pnwcirc.org/sites/pnwcirc.org/files/ocar2010.pdf.

Montana
Montana Climate Assessment (2017)
Whitlock Cathy, Wyatt Cross, Bruce Maxwell, Nick Silverman, Alisa A. Wade. "2017 Montana Climate Assessment." Bozeman and Missoula, Montana: *Montana State University, University of Montana, and Montana Institute on Ecosystems*, 2017. http://montanaclimate.org/sites/default/files/thumbnails/image/2017-Montana-Climate-Assessment-lr.pdf.

Tribes

Fourth National Climate Assessment,
Chapter 15: Tribes and Indigenous Peoples (2018)
Jantarasami, Lesley C., Rachael Novak, Roberto Delgado, Elizabeth Marino,Shannon McNeeley,Chris Narducci, Julie Raymond-Yakoubian, Loretta Singletary, and Kyle Powys Whyte, "2018: Tribes and Indigenous Peoples." In I*mpacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, edited by Reidmiller, David, Christopher W. Avery, David R. Easterling, Kenneth E. Kunkel, Kristin L.M. Lewis, T.K. Maycock, and Brooke C. Stewart, 572–603. Washington, D.C.: *U.S. Global Change Research Program*, 2018. https://nca2018.globalchange.gov/chapter/15/.

Third National Climate Assessment,
Indigenous Peoples (2014)
Bennett, T.M. Bull, Nancy G. Maynard, Patricia Cochran, Robert Gough, Kathy Lynn, Julie Maldonado, Garrit Voggesser, Susan Wotkyns, and Karen Cozzetto, "Ch. 12: "Indigenous Peoples, Lands, and Resources. Climate Change Impacts in the United States:" In *The Third National Climate Assessment*, edited by Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, 297- 317. Washington, DC: *U.S. Global Change Research Program*, 2014. https://nca2014.globalchange.gov/report/sectors/indigenous-peoples.

Tip: CIRC regularly covers current climate science relevant to the Pacific Northwest through our newsletter, *The Climate CIRCulator*.

- *The Climate CIRCulator*: https://climatecirculatororg.wordpress.com
- Get the *CIRCulator* in your email: http://bit.ly/2SqJrRL

Appendix 4—Example Climate Data Story

Excerpt from the *Boise Climate Adaptation Assessment Report* prepared by CIRC's John Abatzoglou

Metric III: Irrigation demand

Defined: Evapotranspiration is the water lost through evaporation and transpiration from vegetation. To keep both crops and urban landscapes "well watered" during periods where precipitation does not meet the water demands of vegetation, additional water is required through irrigation.

How it is calculated: Reference evapotranspiration (ETo) is the potential amount of water used by a reference grass surface for given ambient meteorological conditions. ETo is calculated using the Penman-Monteith equation, which is the standard for estimating crop water use in Idaho when meteorological observations are complete (Allen et al., 1998). Actual evapotranspiration can differ from ETo as a function of both vegetation type and if vegetation undergoes water stress. For the purposes of this exercise, ETo will be used as it approximates the amount of water a reference grass surface will use when it is well watered. The total ETo from April through October is used to approximate the irrigation demand. Although precipitation does occur during this time period, it is typically insufficient to meet ETo demands.

Data: Monthly temperature, wind speed, solar radiation and humidity data were obtained from 20 downscaled climate models (Table 3.1) for a ~2.5 mile by 2.5 mile grid point centered over Boise, Idaho (43.61°N, 116.2°W). These data were downscaled using the Multivariate Adaptive Constructed Analogs (MACA, Abatzoglou and Brown, 2012) statistical downscaling method that applies observational relationships between fine-scale and coarse resolution meteorology to the coarse resolution output of global climate models. The gridded observational dataset of Abatzoglou (2013) from 1979-2016 was used as the training data. These data are not intended to provide fine-scale information on climate at the scales of individual buildings, parks, or neighborhoods -- all of which have their own microclimate, but rather a broader scale representation of climate experienced throughout the Boise metropolitan area. An additional factor is further included to account for the fact that under elevated carbon dioxide concentrations, crops before more water efficient by closing their stomata and limiting transpiration rates. There are numerous ways to approximate this effect, and science is still evolving on precisely how climate change and additional carbon dioxide will alter water use by crops. For the purposes of this analysis, an empirical transformation of Kruijt et al. (2008) is applied for a grass surface that effectively reduces ETo with rising levels of carbon dioxide. A scalar factor is applied to each year by considering the projected changes in atmospheric carbon dioxide levels under low and high emission scenarios from a reference 1980 baseline. This has the effect of approximately reducing the calculated ETo for low and high emissions scenarios by 1.5% and 1.8%, respectively, for the early 21st century (2020-2049), and 2.25% and 3.65% for the mid 21st century (2050-2079).

Analysis: The total ETo during irrigation season (April-October) was calculated for the historical modeled data (1950-2005) and future climate scenarios for the early (2020-2049) and mid-21st century (2050-2079).

Results: The annual April-October ETo over the contemporary climate was 41.4 inches, which is comparable (about 3% higher) with that of the Boise AgriMet station. Despite the enhanced water use efficiency of crops with enhanced carbon dioxide concentrations, estimated ETo is projected to increase by approximately 2 inches (5%) by the early-21st century, and an average of 2.6 inches (+6.4%) and 4 inches (+9.7%) by the mid-21st century. These increases are based on substantial warming of summer temperatures, increased vapor pressure deficit (difference between atmospheric moisture and potential water holding capacity of the air), and slight increases in solar radiation (a function of more clear days). For the mid-21st century under high-emissions, a couple models project increase in ETo of 6 or more inches (14.5%), whereas a couple project more subtle increases of around 2 inches.

Summary: Human-caused climate change will increase evaporative demand and hence irrigation demand during the warm season across Boise. An increase of approximately 2 inches of irrigation is projected by the early 21st century and up to 4 inches of irrigation by the mid-21st century under high emissions scenario.

Figure 3.1: Modeled average reference evapotranspiration (ETo) from April-October under historical (left), early 21st century (middle) and mid-21st century (right) from 20 downscaled climate models for low emissions (RCP 4.5) and high emissions (RCP 8.5) scenarios. The black box shows the average of the 20 models.

Table 3.1: Average reference evapotranspiration (inches) from April-October for different models (rows) and time period/scenarios (columns).

	1950-2005	2020-2049 RCP45	2020-2049 RCP85	2050-2079 RCP45	2050-2079 RCP45
inmcm4	41.6	42.7	43.0	43.1	44.8
CSIRO-Mk3-6-0	41.6	44.0	43.9	44.7	46.3
CanESM2	41.5	43.6	43.8	44.3	45.0
CNRM-CM5	41.5	42.8	43.6	44.0	45.2
MIROC5	41.5	44.0	43.6	44.2	43.7
GFDL-ESM2M	41.5	42.2	44.2	43.7	45.3
GFDL-ESM2G	41.6	42.9	42.7	43.3	44.9
MRI-CGCM3	41.5	42.2	42.3	42.3	43.0
HadGEM2-ES365	41.5	44.9	44.8	45.3	48.1
HadGEM2-CC365	41.6	44.0	44.4	44.7	47.2
bcc-csm1-1	41.5	44.3	44.8	44.6	46.4
MIROC-ESM	41.5	43.9	44.3	45.2	46.2
MIROC-ESM-CHEM	41.5	44.0	43.9	45.2	46.5
BNU-ESM	41.5	43.0	42.9	43.9	45.0
bcc-csm1-1-m	41.5	43.0	43.0	44.1	45.6
CCSM4	41.5	43.2	43.4	43.5	44.8
IPSL-CM5A-LR	41.5	43.5	44.3	44.5	46.2
IPSL-CM5A-MR	41.5	43.5	44.1	44.3	46.4
IPSL-CM5B-LR	41.6	43.3	42.9	43.6	44.4
NorESM1-M	41.5	44.2	44.5	44.8	46.0
MEAN	**41.5**	**43.5**	**43.7**	**44.2**	**45.6**

References:

Abatzoglou, John T., and Timothy J. Brown. "A comparison of statistical downscaling methods suited for wildfire applications." *International Journal of Climatology* 32, no. 5 (2012): 772-780. https://doi.org/10.1002/joc.2312.

Abatzoglou, John T. "Development of gridded surface meteorological data for ecological applications and modelling." *International Journal of Climatology* 33, no. 1 (2013): 121-131. https://doi.org/10.1002/joc.3413.

Allen, Richard G., Luis S. Pereira, Dirk Raes, and Martin Smith. "Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56." Fao, Rome 300, no. 9 (1998): D05109.

Kruijt, Bart, Jan-Philip M. Witte, Cor MJ Jacobs, and Timo Kroon. "Effects of rising atmospheric CO2 on evapotranspiration and soil moisture: A practical approach for the Netherlands." *Journal of Hydrology* 349, no. 3-4 (2008): 257-267. https://doi.org/10.1016/j.jhydrol.2007.10.052.

Scratch Paper

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