Climate and Impacts in the Pacific Northwest

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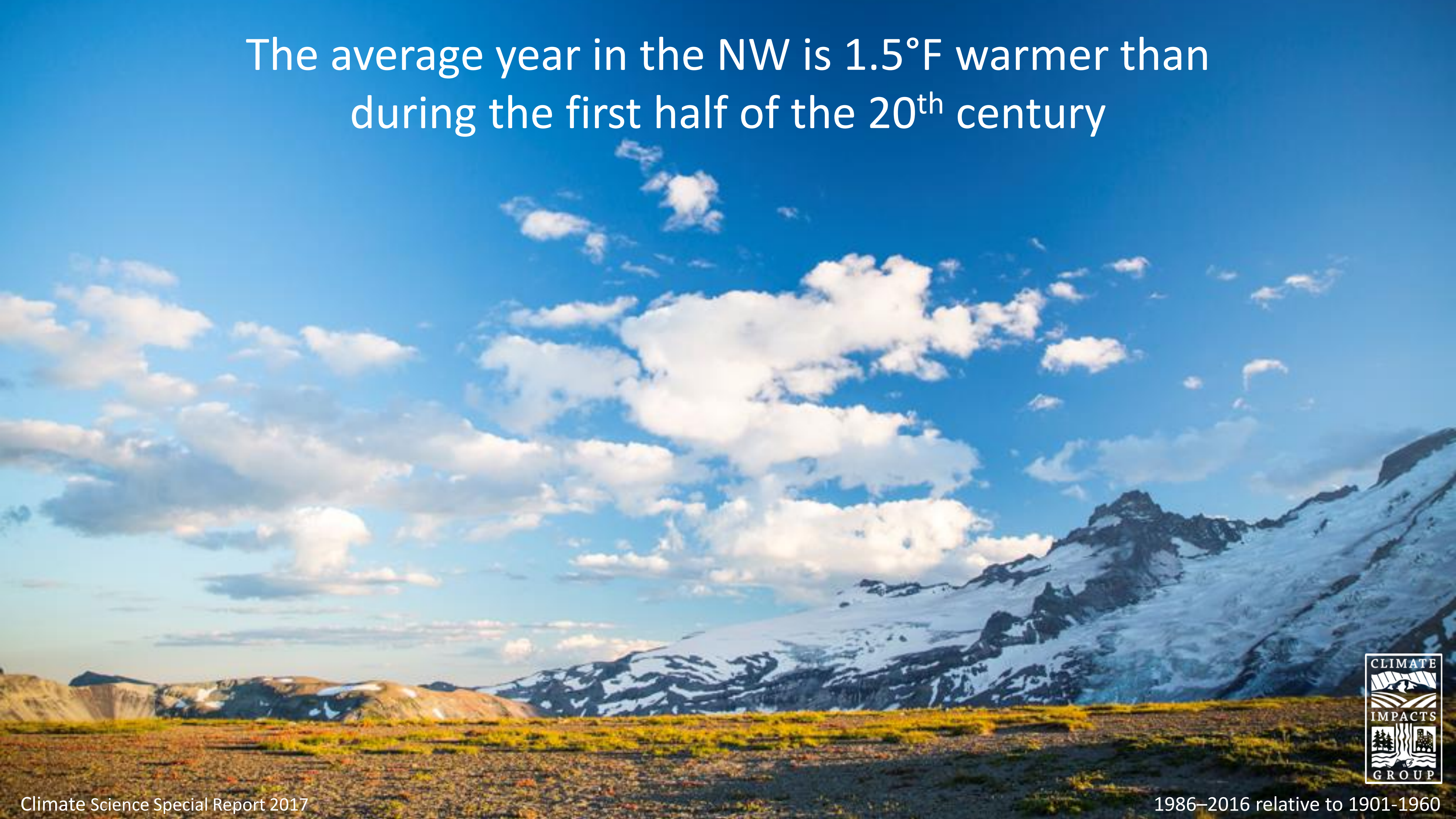
Observed Changes




Images: University of Washington

The average year in the NW is 1.5°F warmer than during the first half of the 20th century



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Climate Science Special Report 2017

1986–2016 relative to 1901-1960

The coldest day of the year is 4.78°F warmer

NCA, 2018

1986–2016 relative to 1901-1960

The frost-free season is 16 days longer

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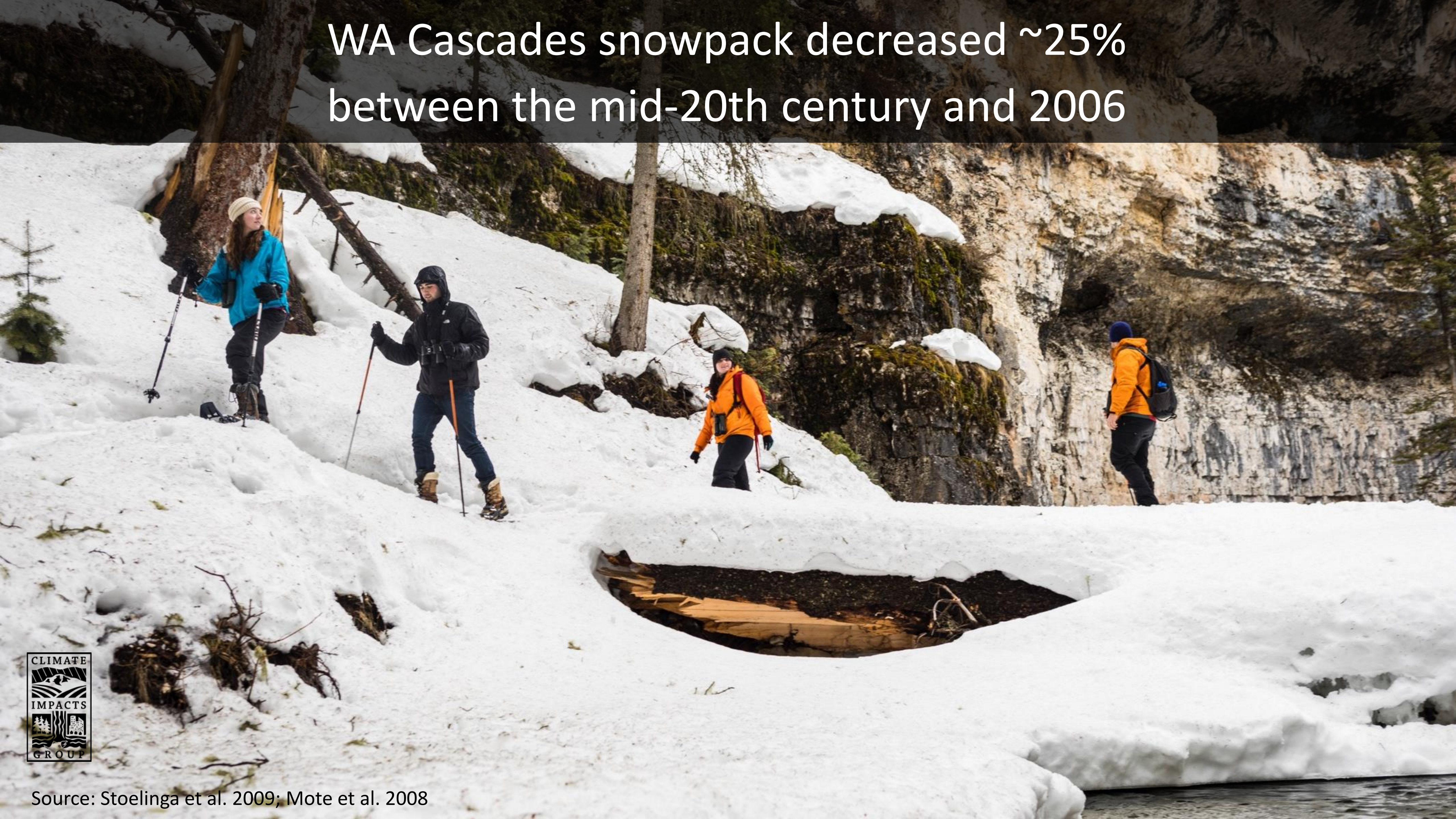
NCA 2014

1991-2012 relative to 1901-1960

WA Cascades snowpack decreased ~25% between the mid-20th century and 2006



Source: Stoelinga et al. 2009; Mote et al. 2008

Peak streamflow from snowmelt is occurring up to 20 days earlier in the Northwest (1948-2002)

Source: Snover et al. 2013

Sea level has risen by about 4 in. since the 1930s

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Source: Friday Harbor tide gauge, NOAA

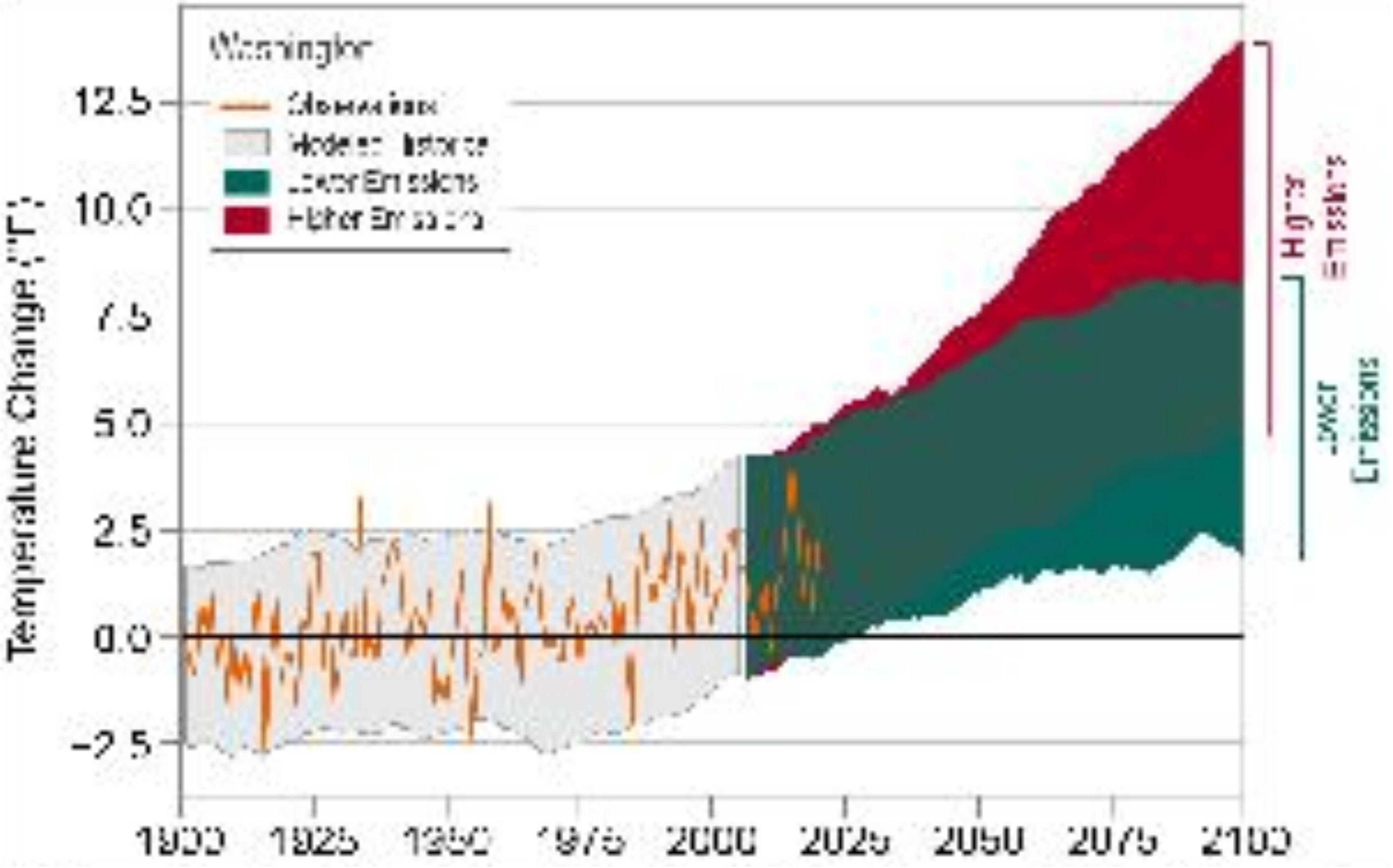
The number of large fires and area burned in the Northwest increased from 1973 to 2012

Source: Westerling 2016

Projected Changes

Images: University of Washington

Accelerated Warming



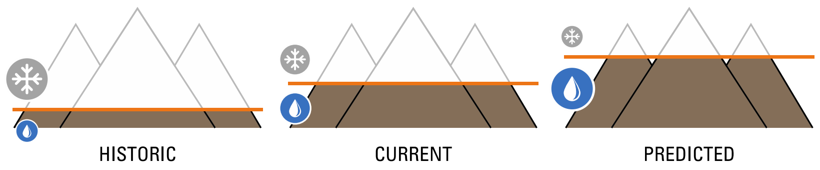
https://statesummaries.ncics.org/

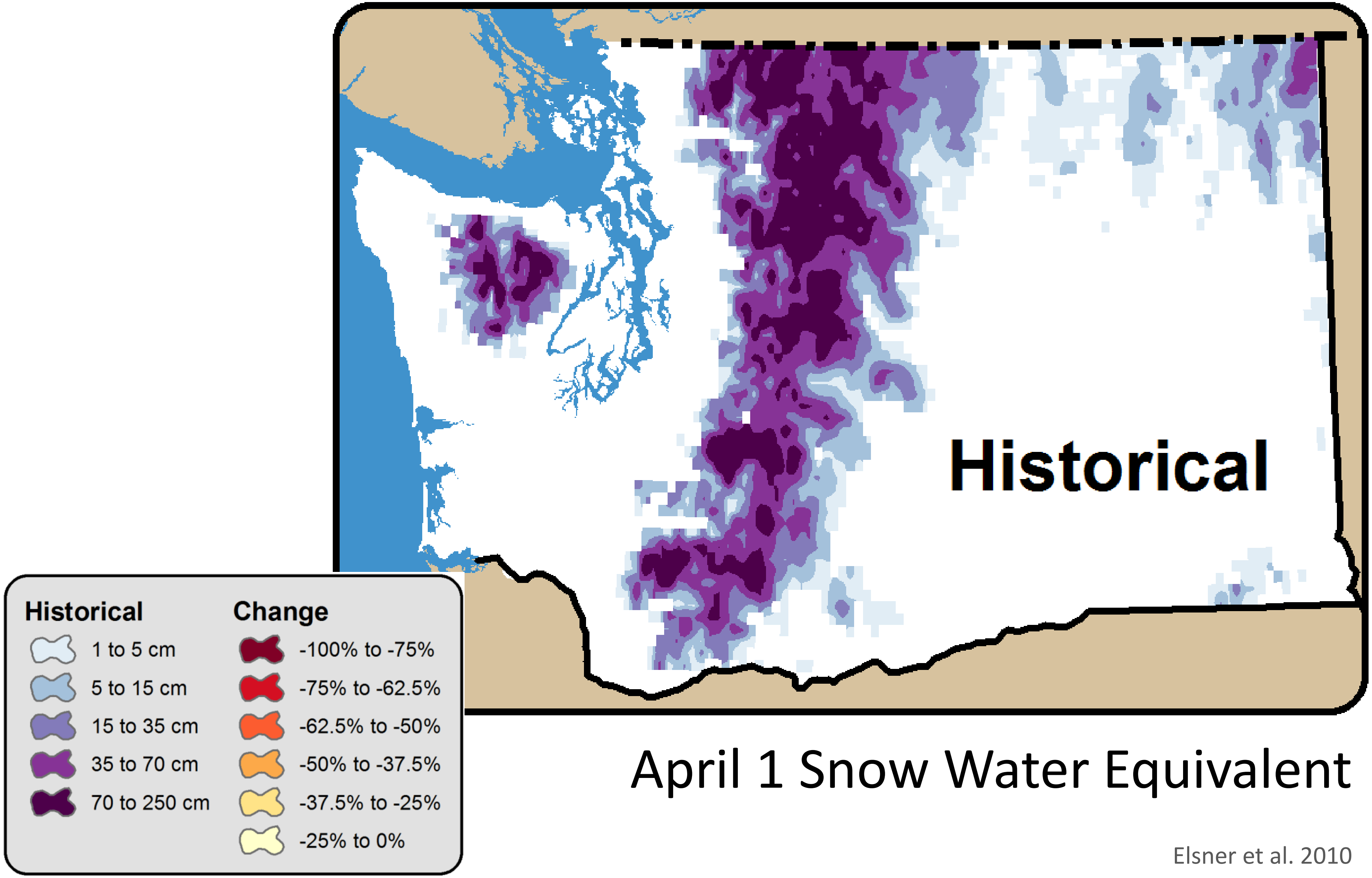
Declining Snowpack

Our primary mechanism for storing water – snow – is sensitive to warming.

Projected change for 2080s:
-55% (range: -83 to -17%)

(Hamlet et al. 2013: moderate A1B scenario, rel. to 1980s)





April 1 Snow Water Equivalent

Elsner et al. 2010

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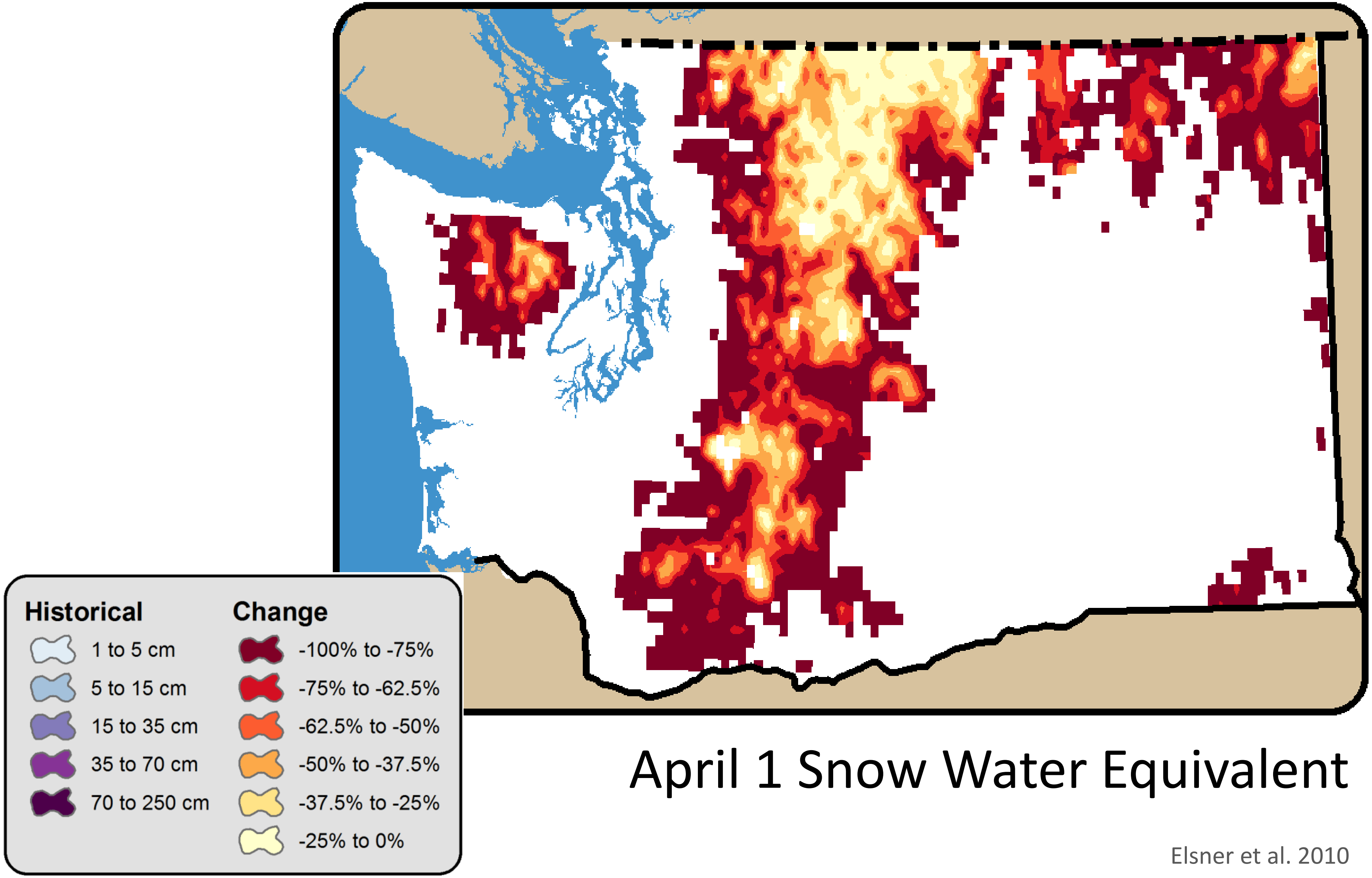
2040s



April 1 Snow Water Equivalent

Elsner et al. 2010

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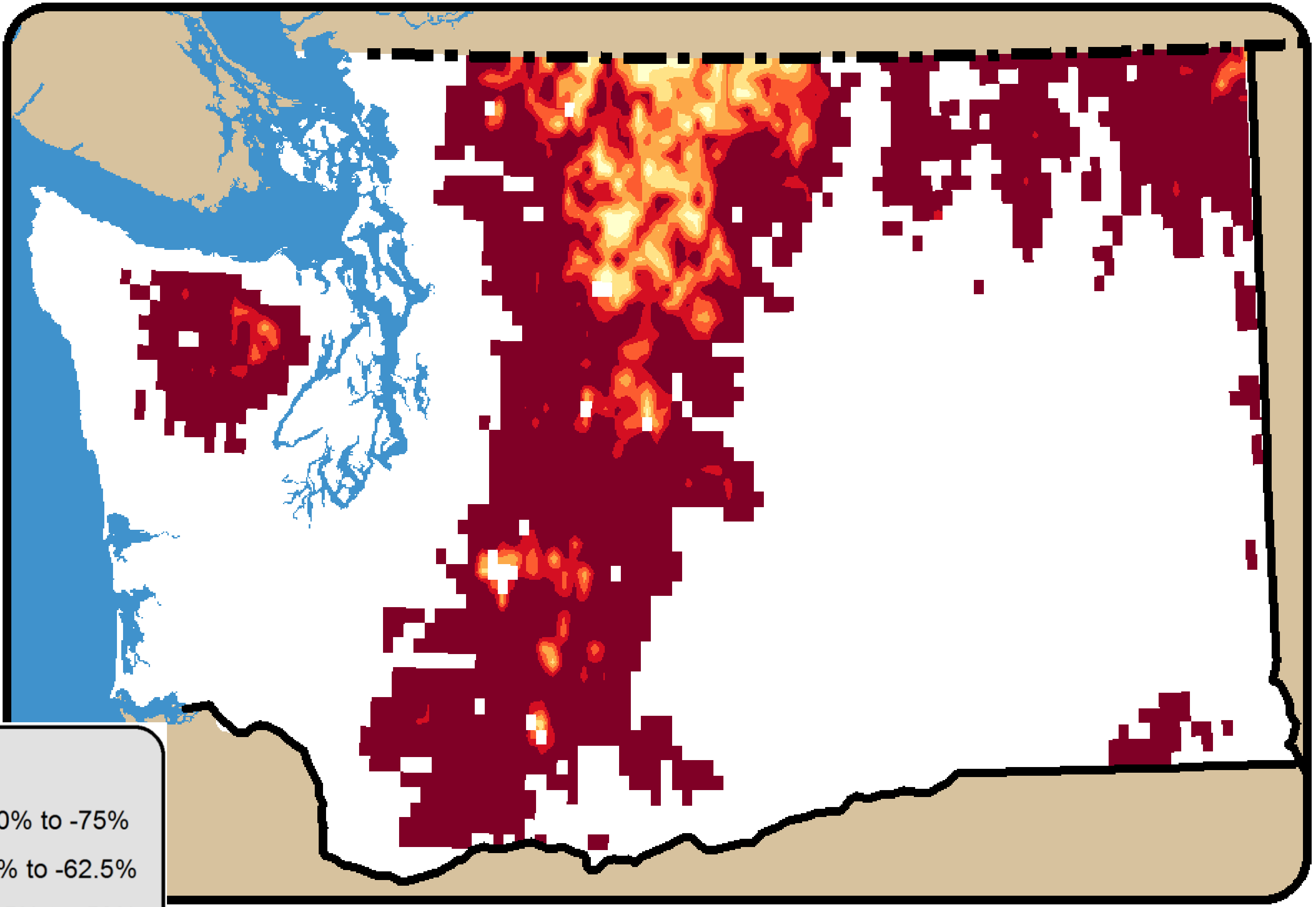
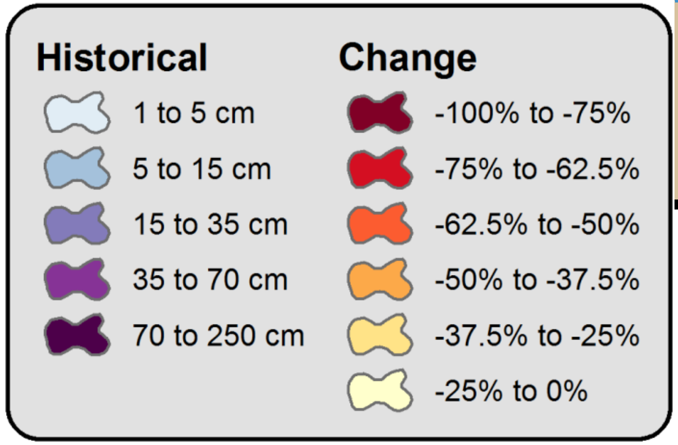
2080s

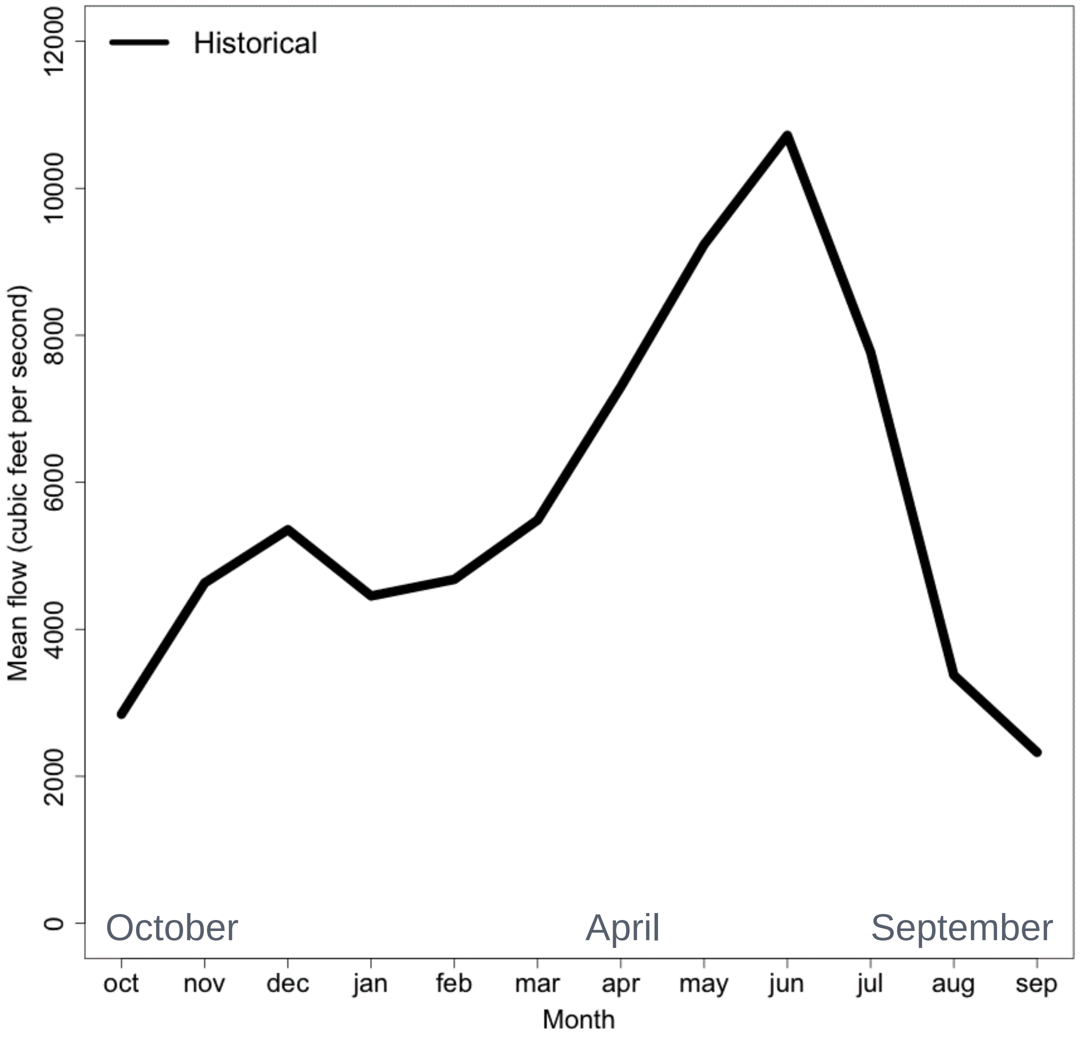




April 1 Snow Water Equivalent

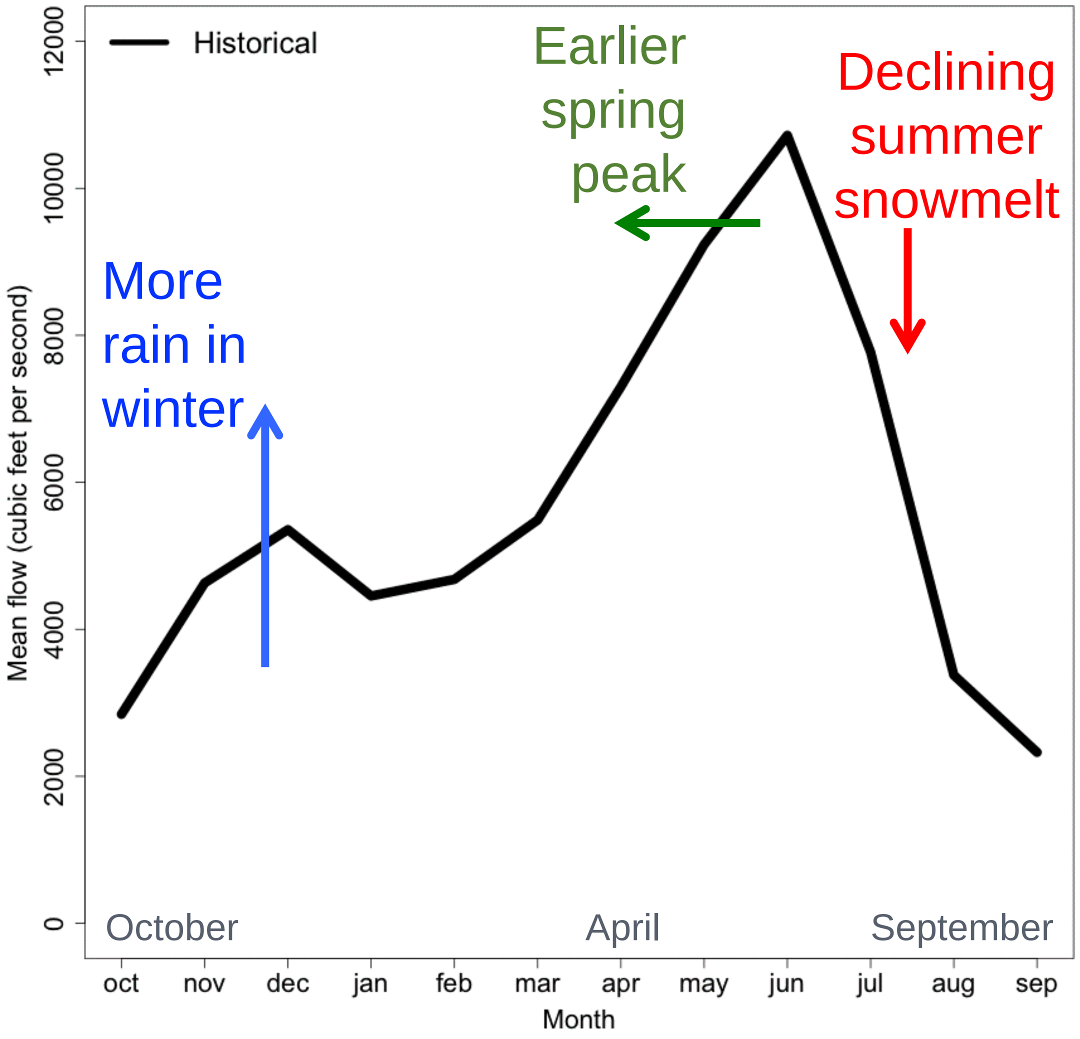
Elsner et al. 2010

Shifting Streamflows – Yakima Basin



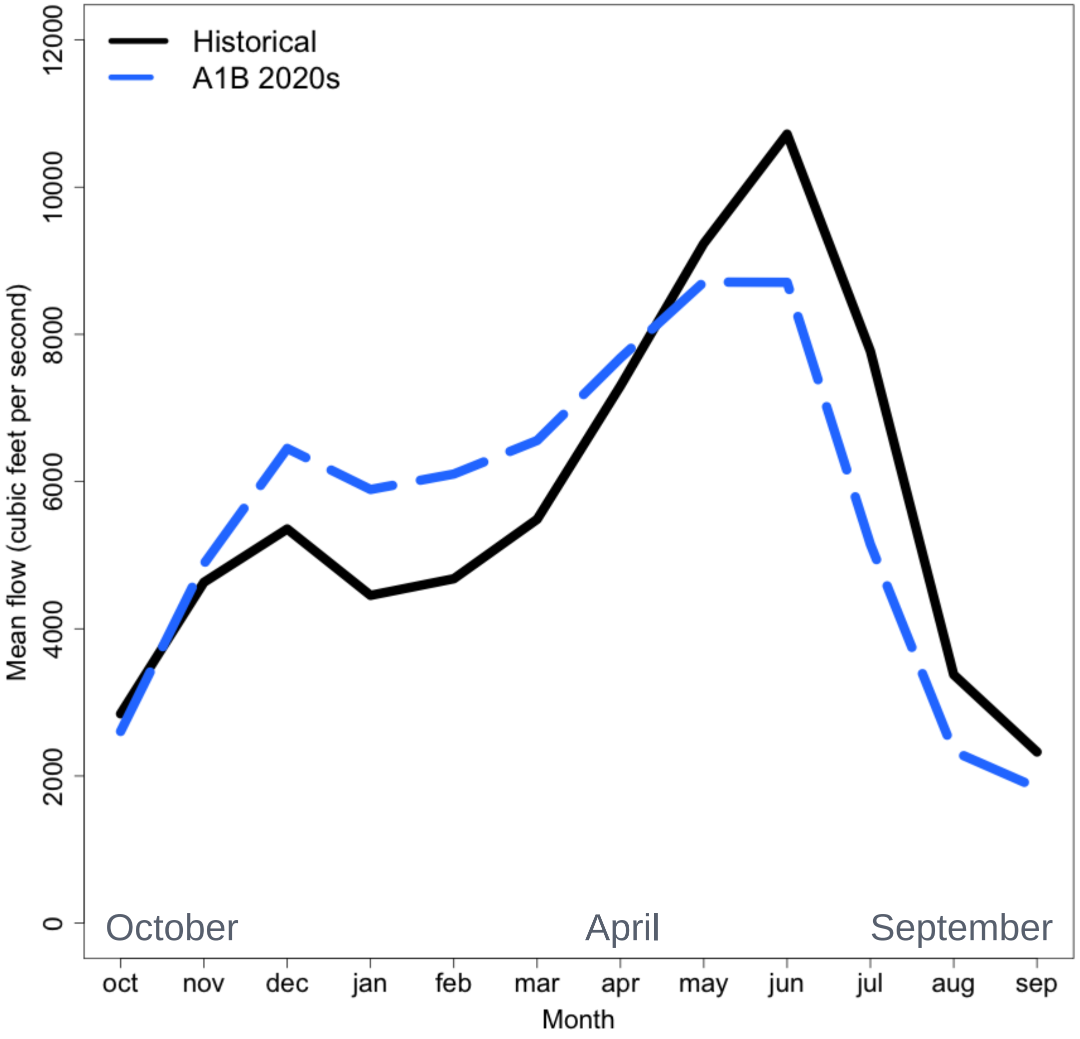
Source: Elsner et al. 2010

Shifting Streamflows – Yakima Basin



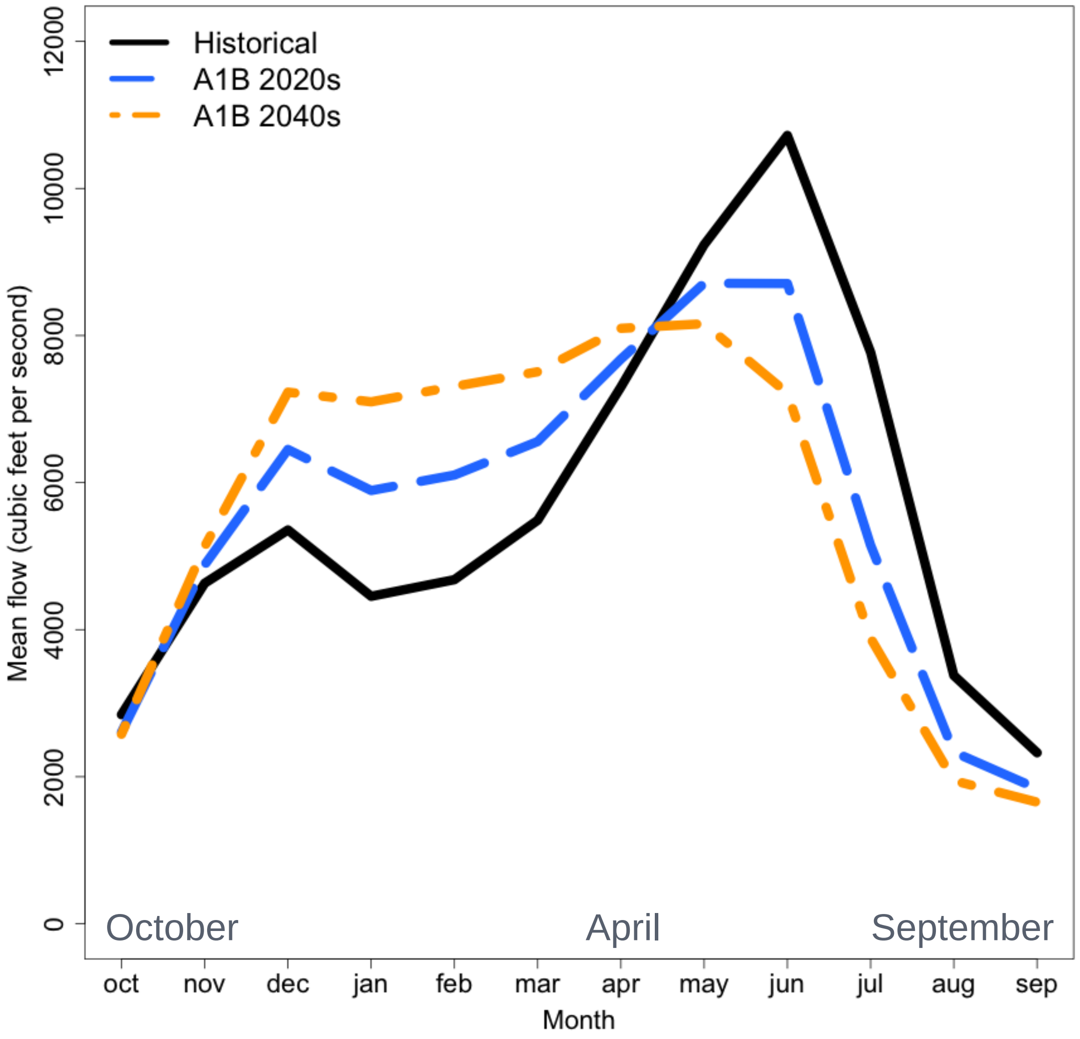
Source: Elsner et al. 2010

Shifting Streamflows – Yakima Basin



Source: Elsner et al. 2010

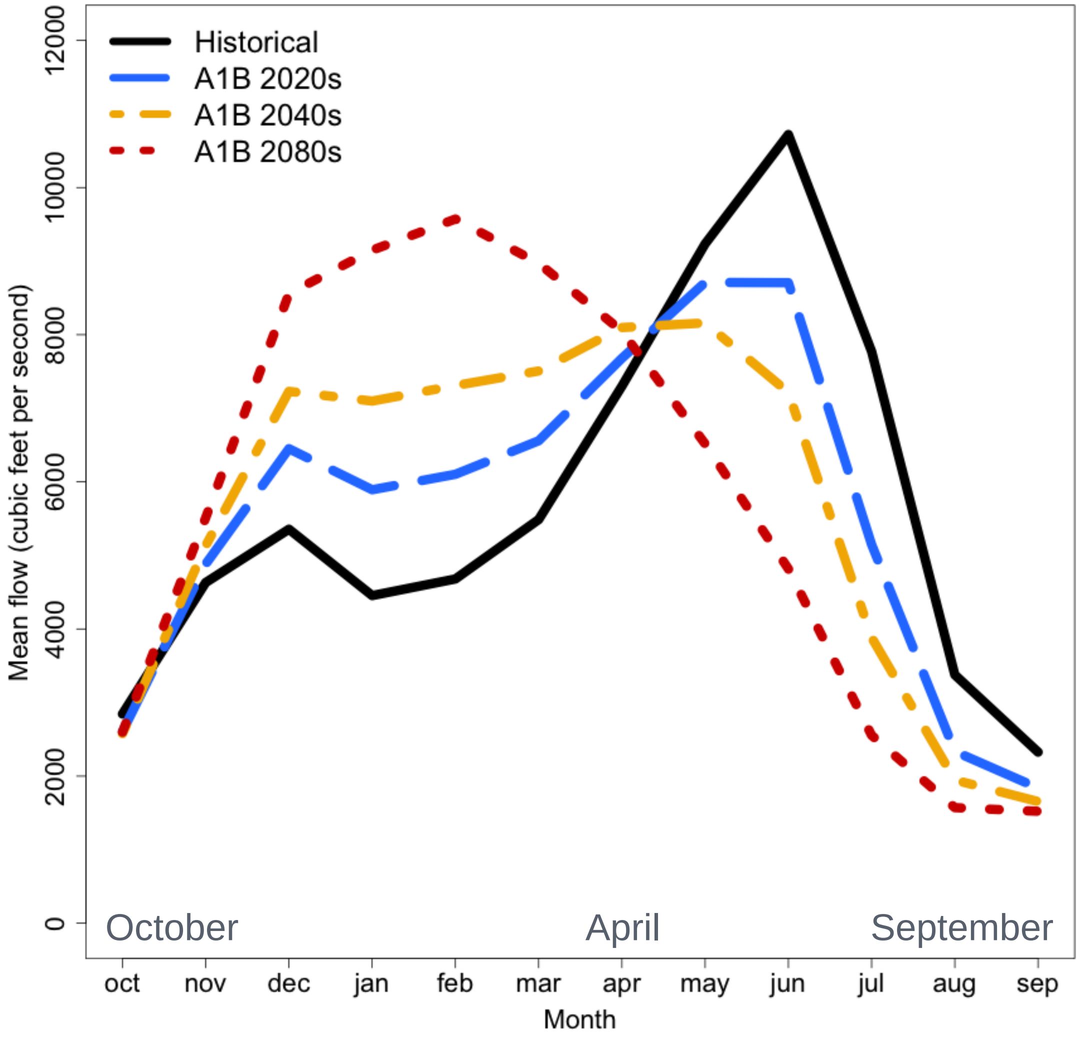
Shifting Streamflows – Yakima Basin



Source: Elsner et al. 2010

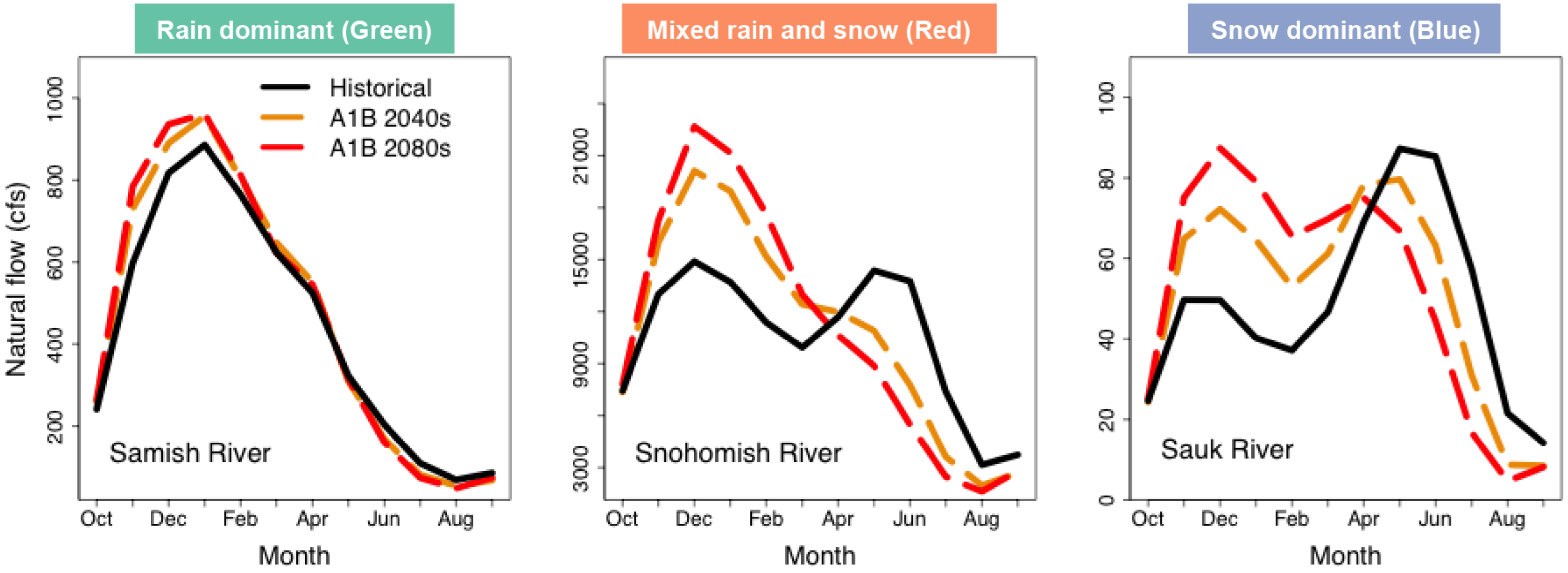
CLIMATE IMPACTS GROUP

Shifting Streamflows – Yakima Basin



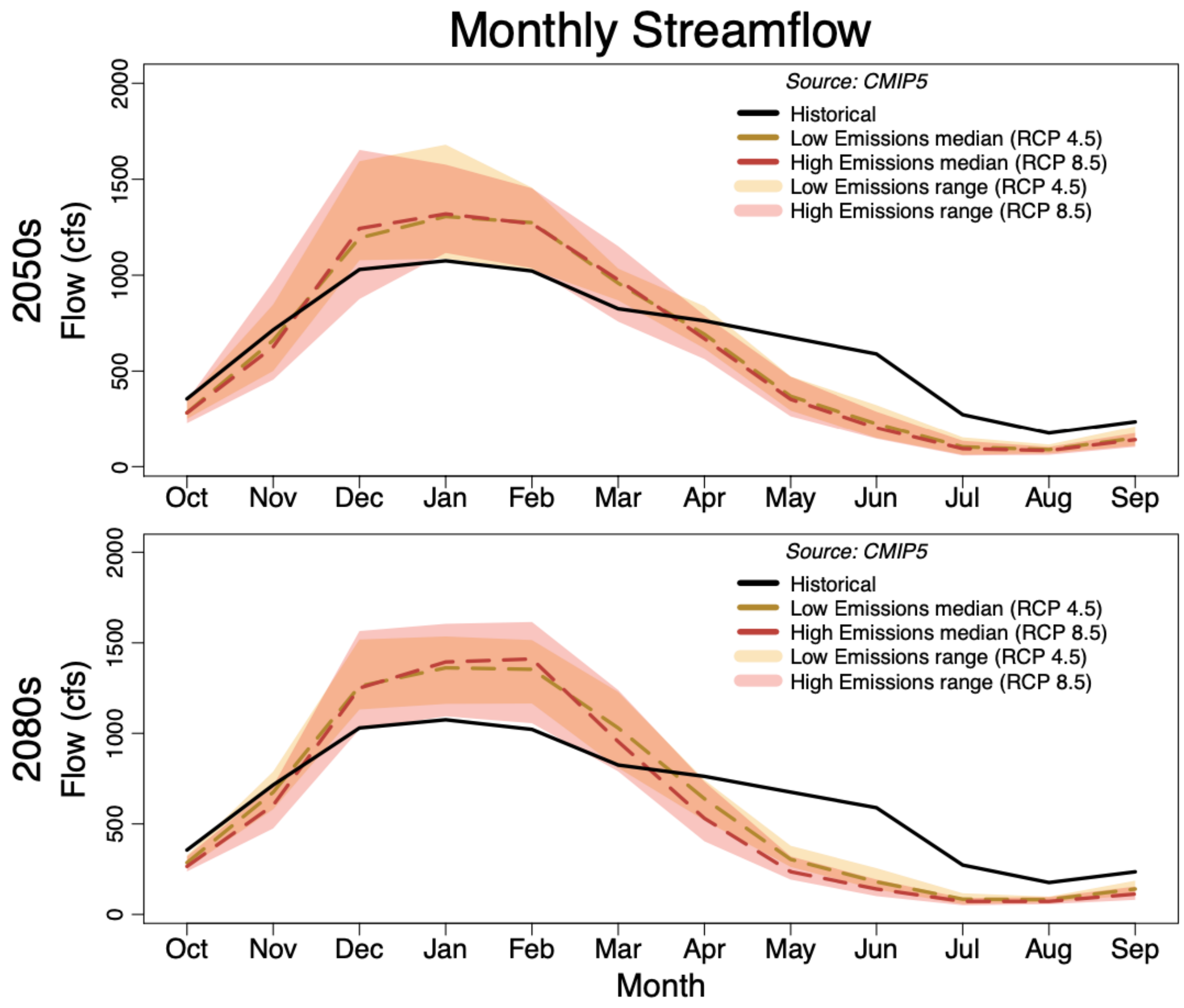
Source: Elsner et al. 2010

Hydrology is most affected in basins that historically accumulated snow



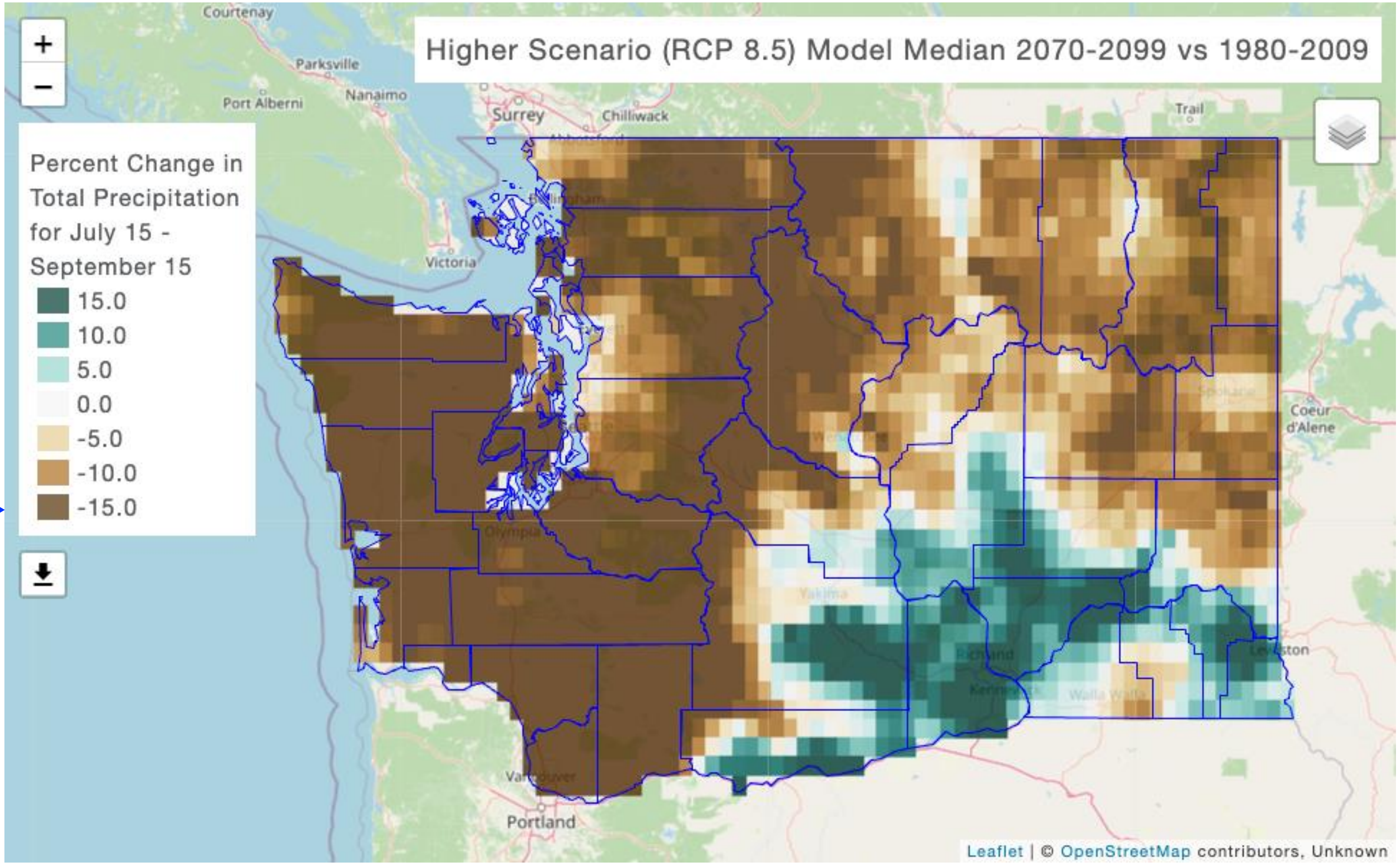
Source: Hamlet et al. 2013, https://cig.uw.edu/projects/climate-change-in-puget-sound-state-of-knowledge/

Projected Changes for the Cedar River

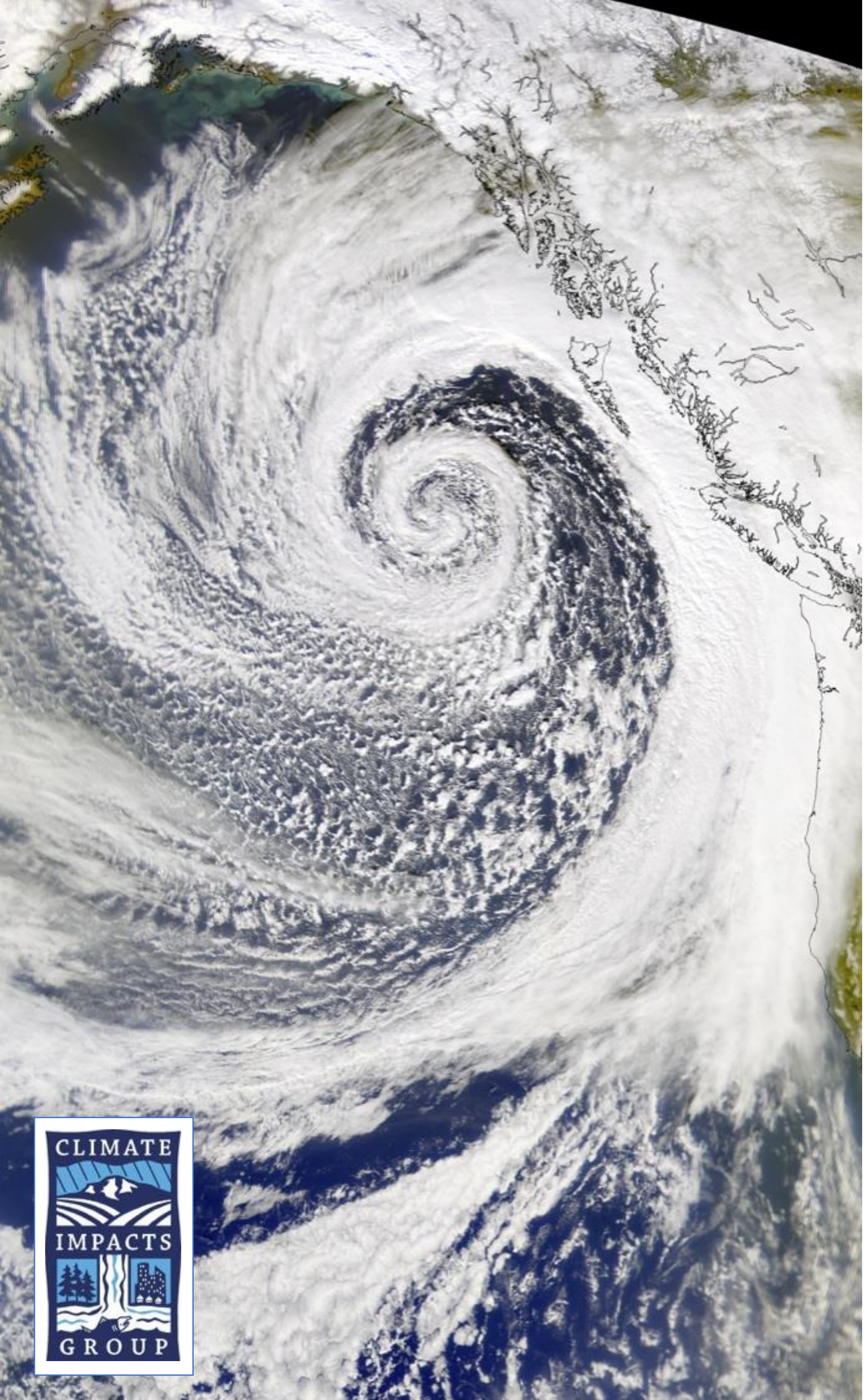


Source: https://cig.uw.edu/projects/climate-change-in-puget-sound-state-of-knowledge/

Small declines in summer precipitation



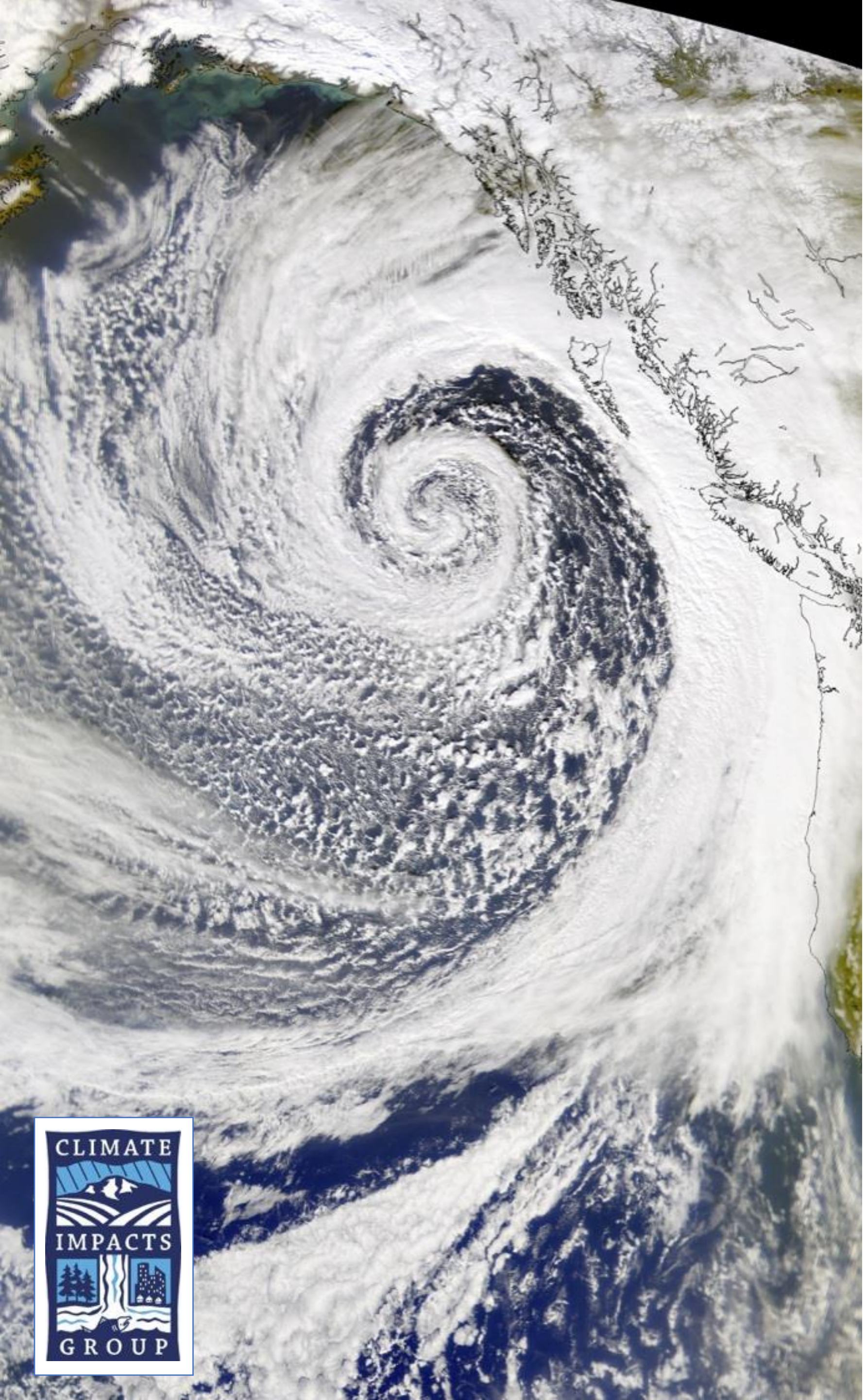
https://data.cig.uw.edu/climatemapping/



More Intense Heavy Rains

Heaviest rain events (top 1% daily) are projected to become **+22% more intense** (*range:* +5 to +34%) by the 2080s.

Warner, Mass, Salathé, J Hydromet, 2015



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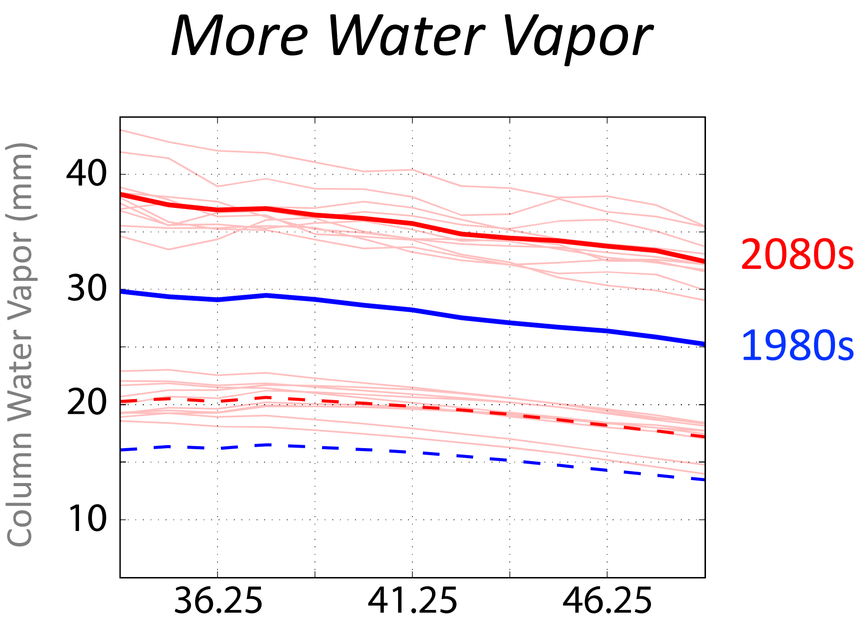
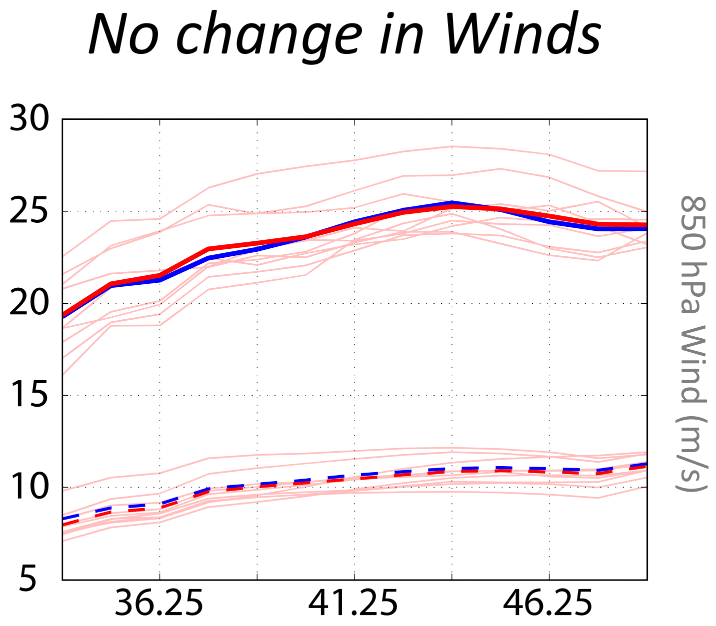
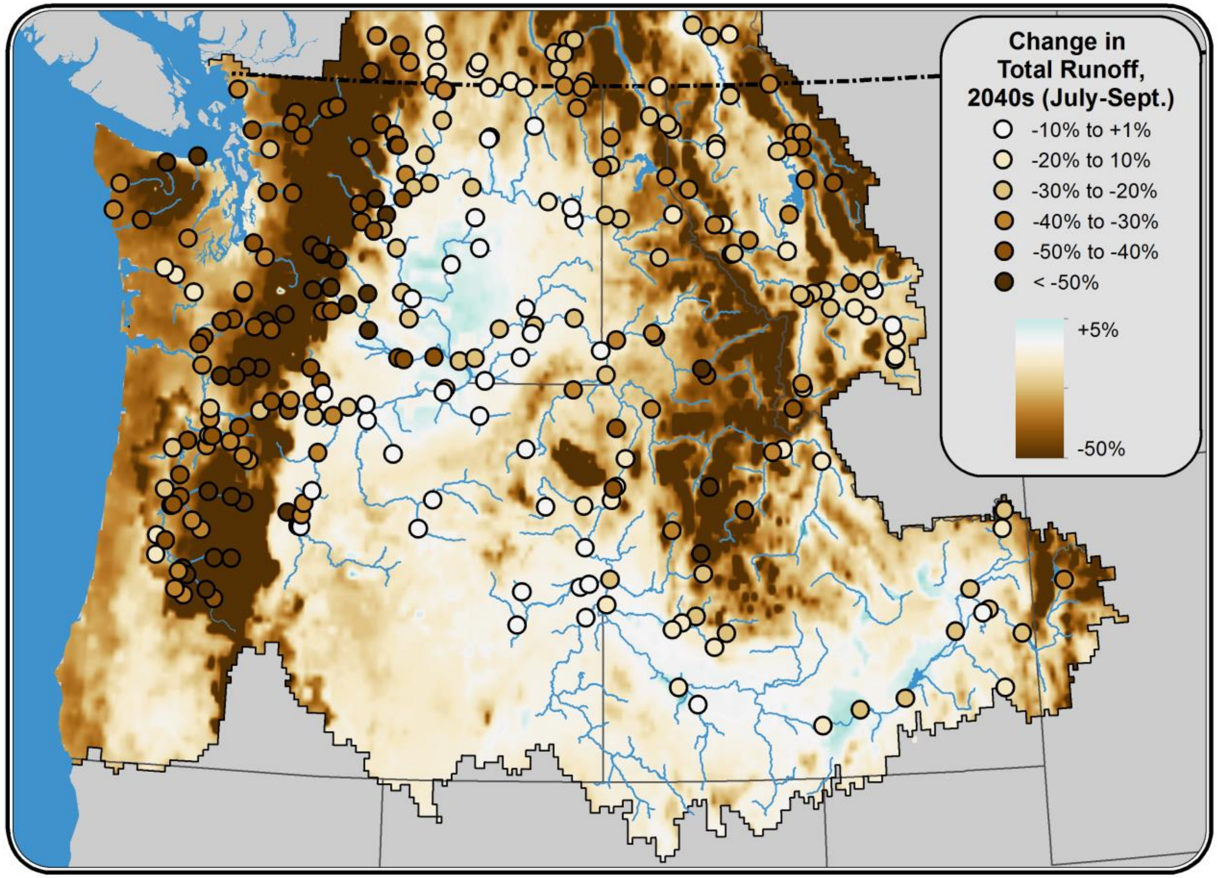


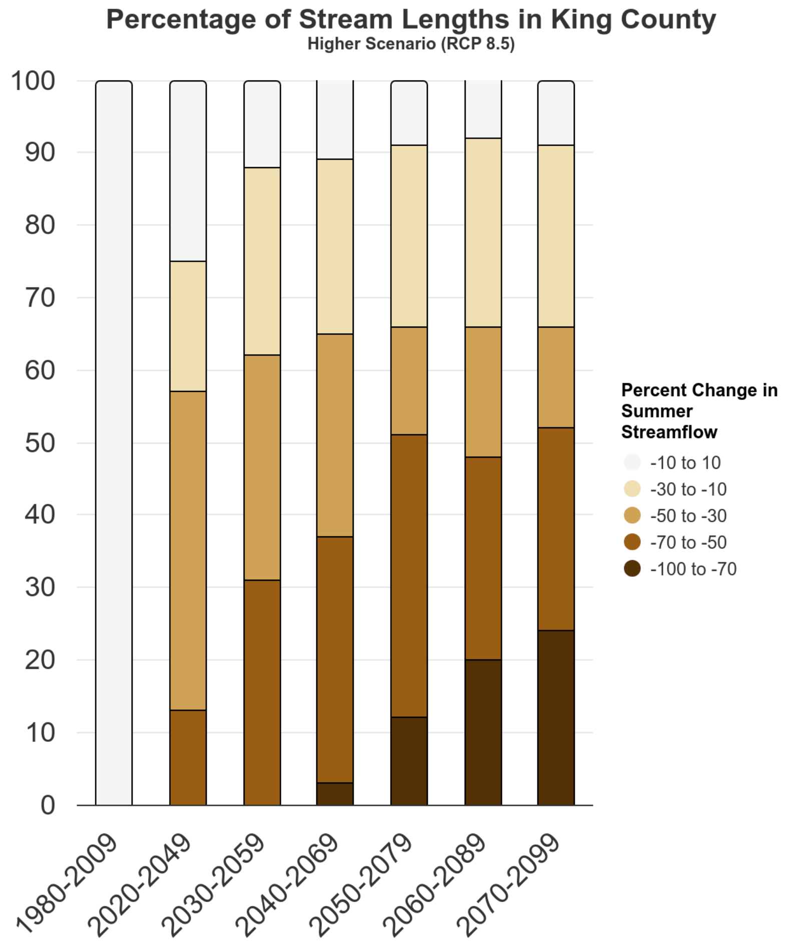


Warner, Mass, Salathé, J Hydromet, 2015

Impacts

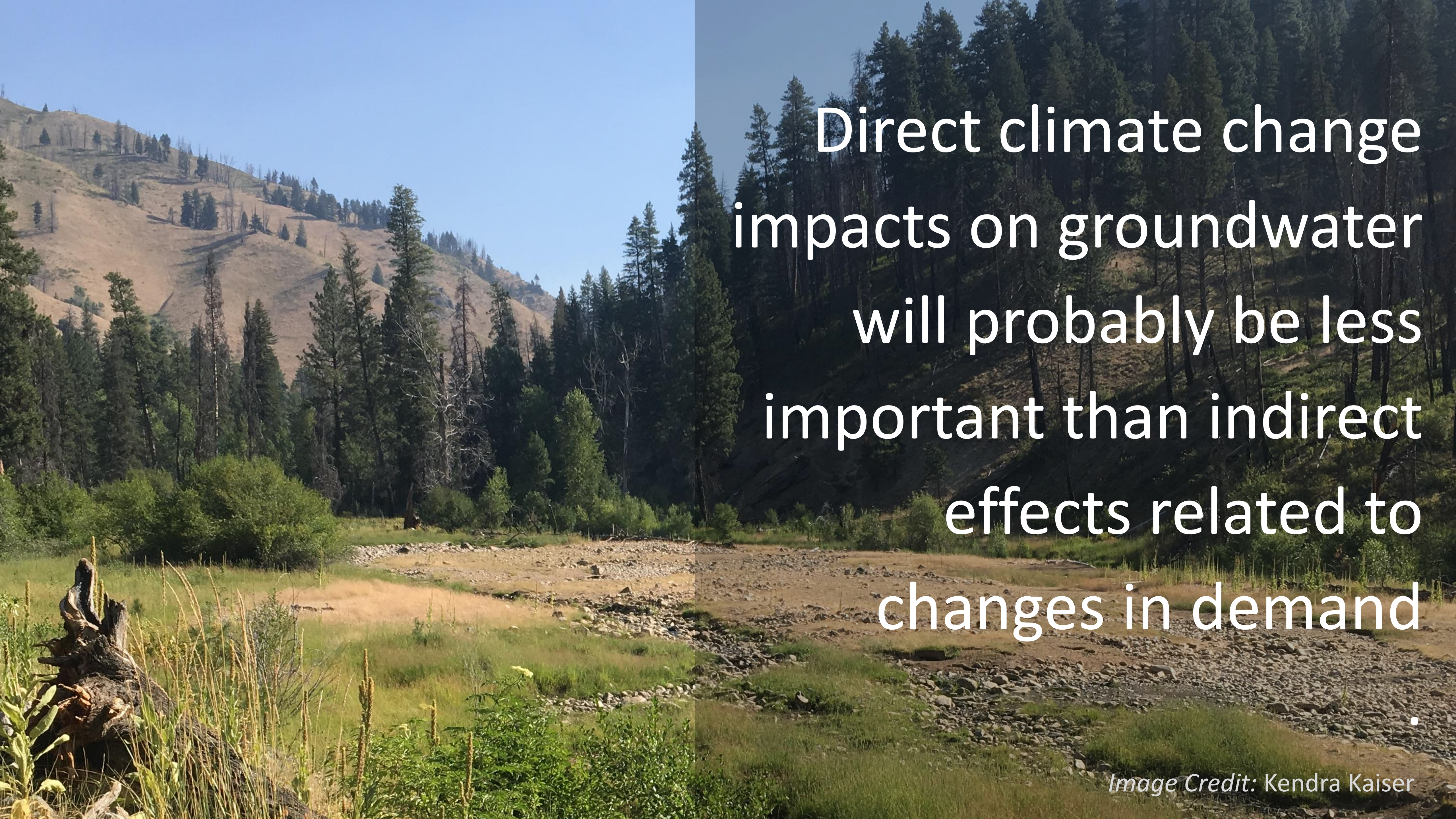
Declining Summer Water Availability





Source: Dalton et al. 2013. https://islandpress.org/books/climate-change-northwest

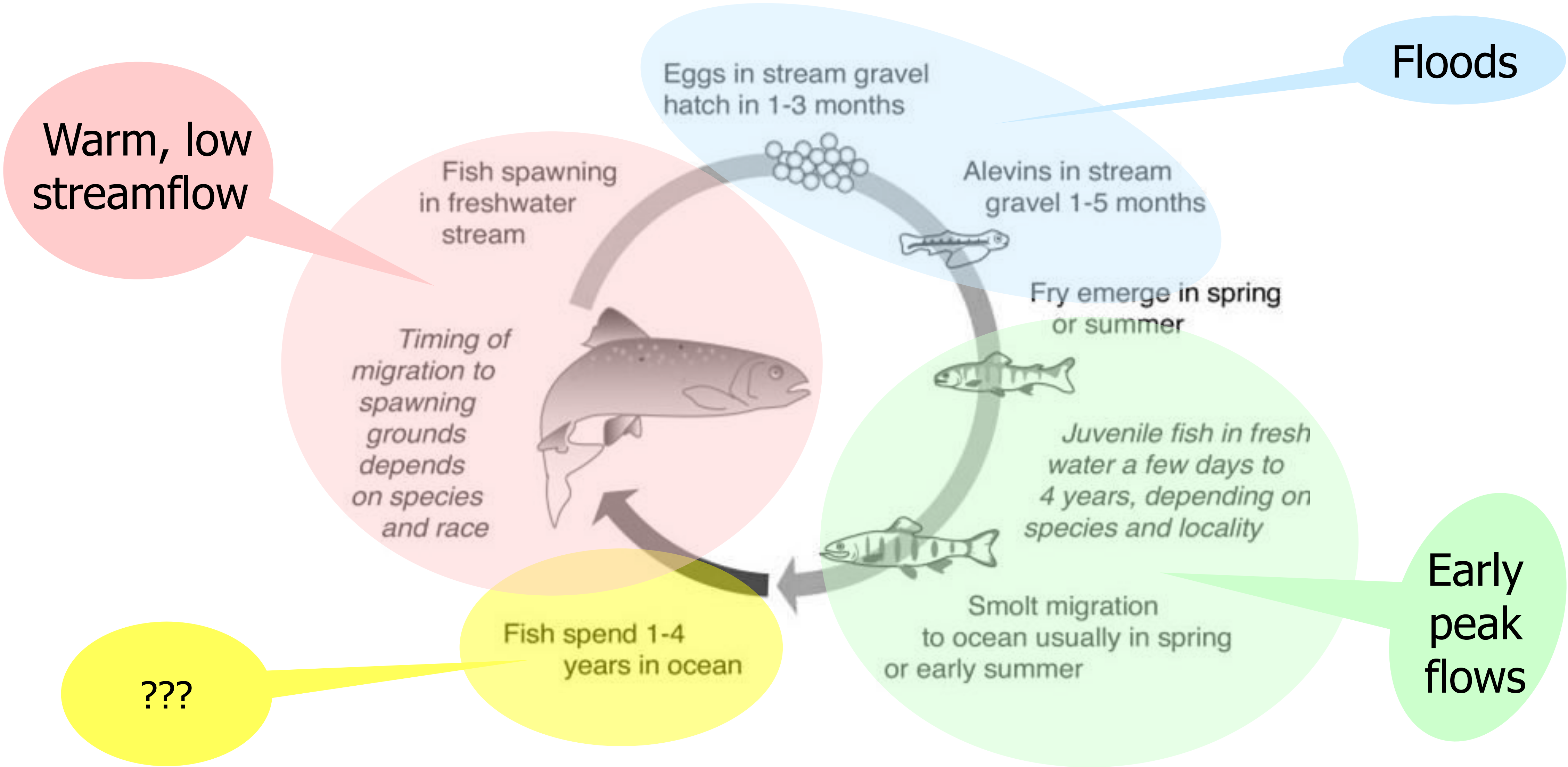
Source: https://data.cig.uw.edu/climatemapping/



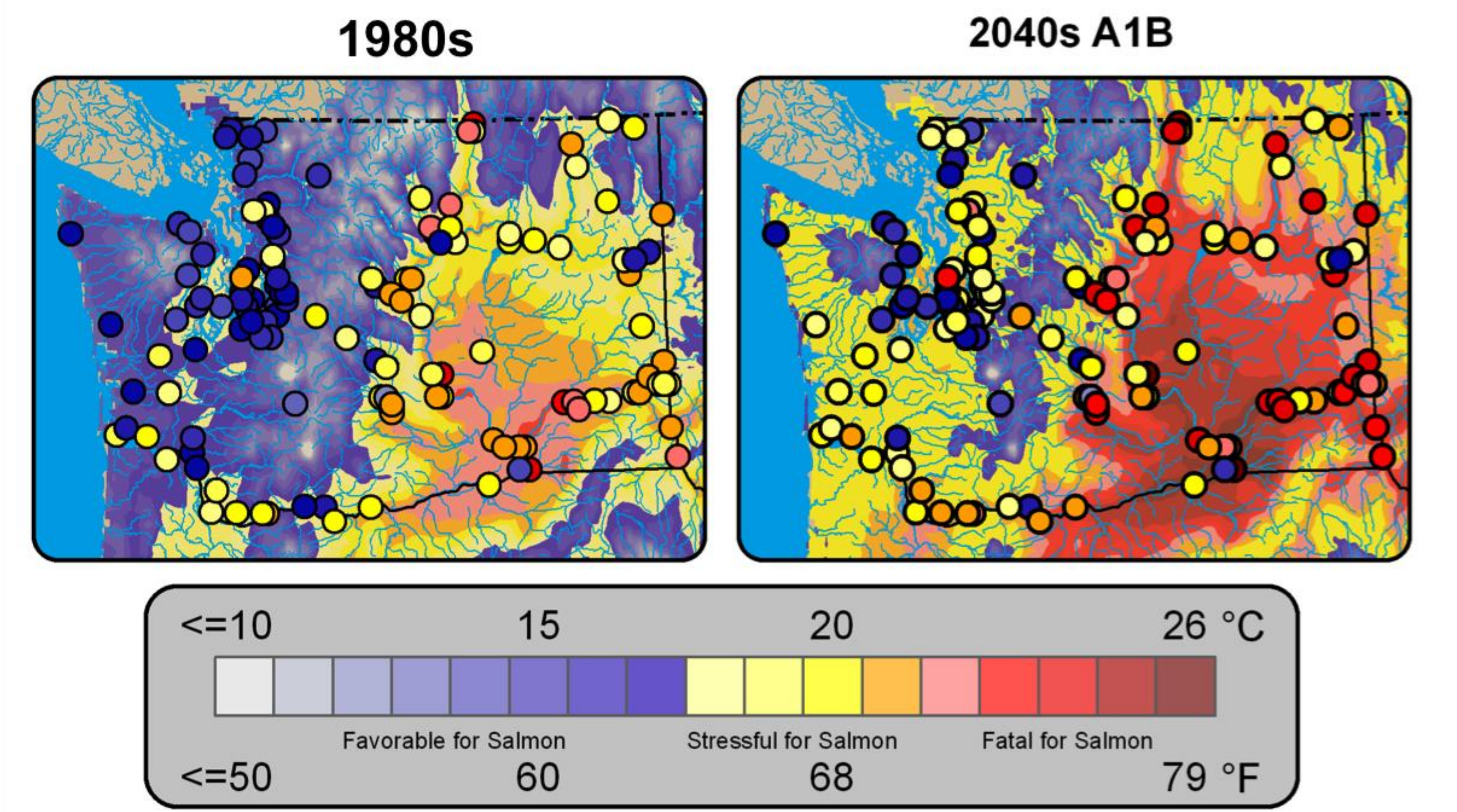
Direct climate change impacts on groundwater will probably be less important than indirect effects related to changes in demand.

Image Credit: Kendra Kaiser

Salmon Impacted Across Full Life-Cycle

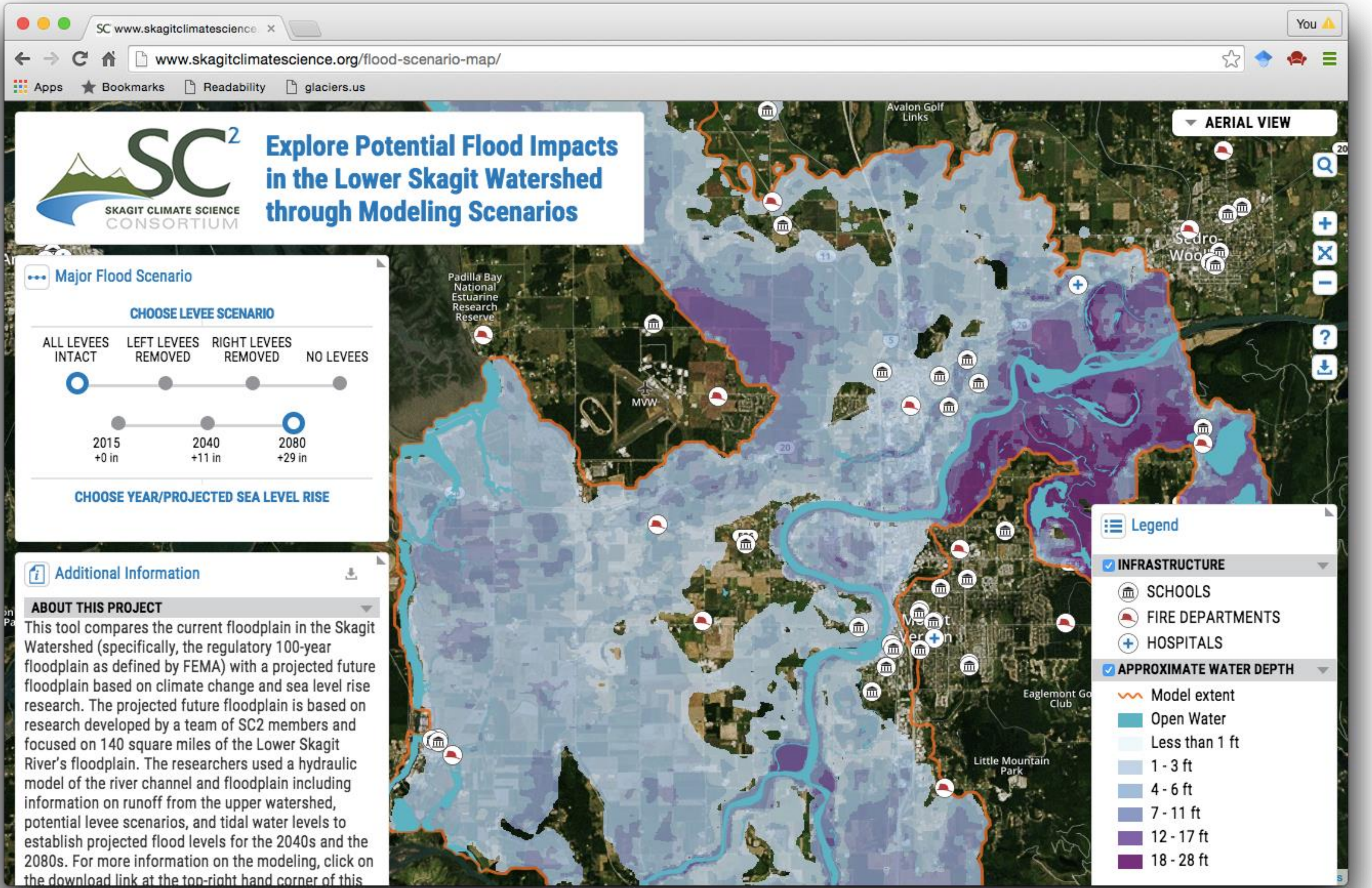


Warming + Declining Flows = Warmer Water



Mantua et al., Climatic Change, 2010

Current v Future Flooding in the Skagit Valley

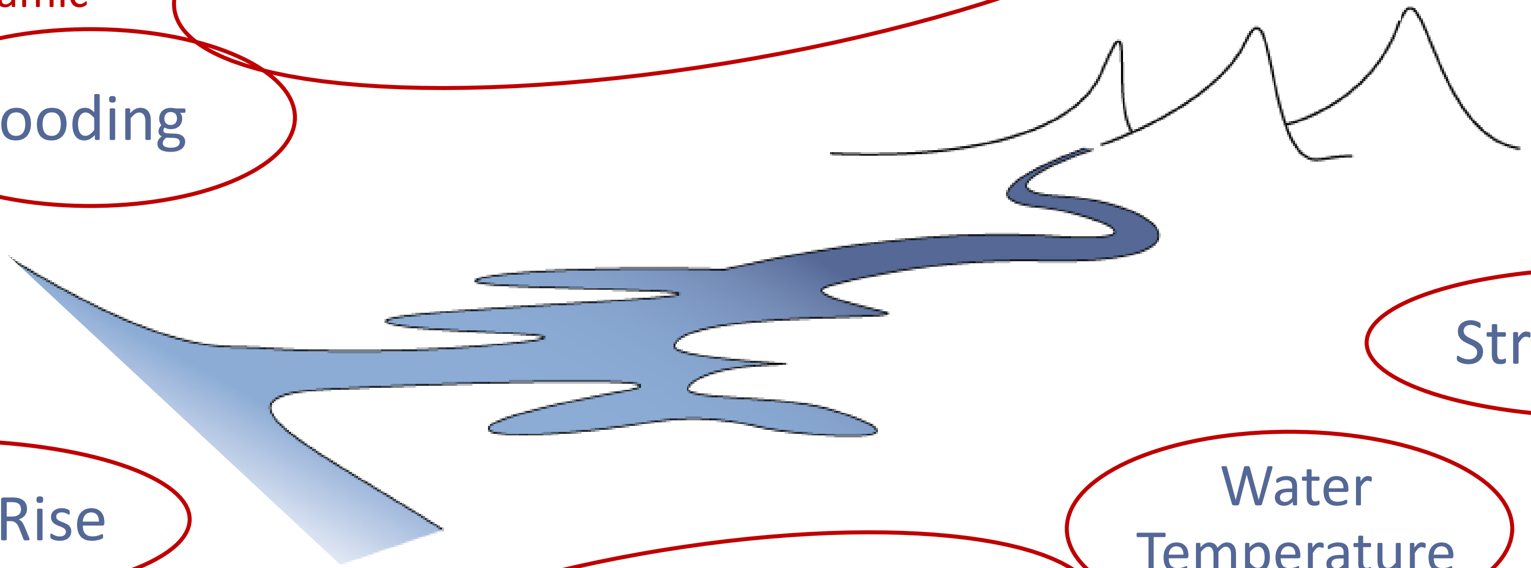


http://www.skagitclimatescience.org/flood-scenario-map/

Assessing & Interpreting Impacts

Source: Pamplin Media Group, Portland Tribune

Many datasets, all different:



Dynamically-downscaled
climate projections:
PNNL, UW, UCLA

Precipitation
Evapotranspiration

Glaciers

Snowpack

Hydraulic/Hydrodynamic
Modeling:
FloodFactor
SSM
PS-CoSMoS

Flooding

Wildfire

Streamflow

Hydrologic model projections
RMJOC-II (coarse, comprehensive)
DHSVM, VELMA (fine, localized)

Water
Temperature

NoRWeST: August average
Siegel et al. (2023): Daily

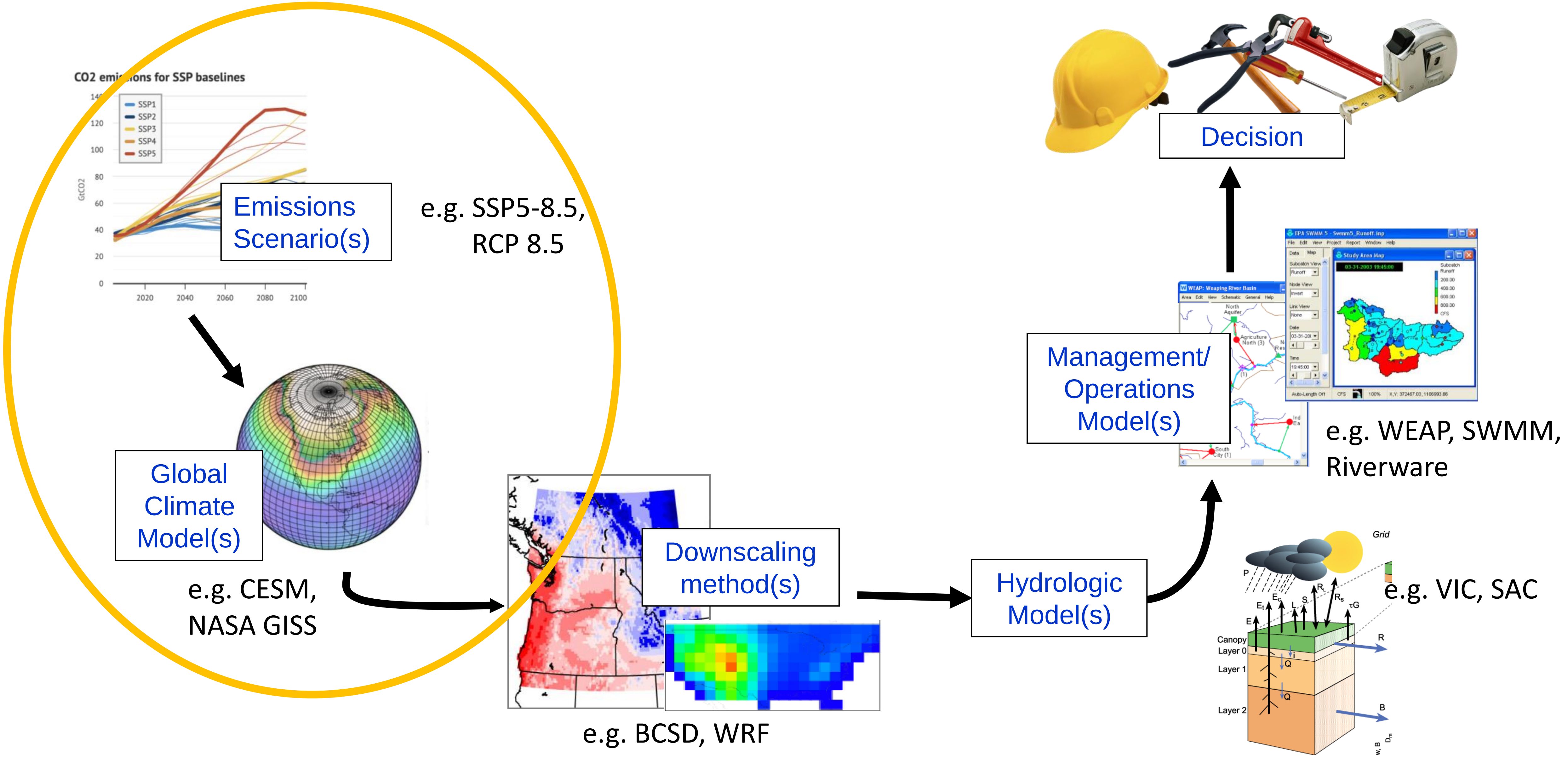
Sea Level Rise

Miller et al. 2018
NOAA 2022

Sediment
Groundwater

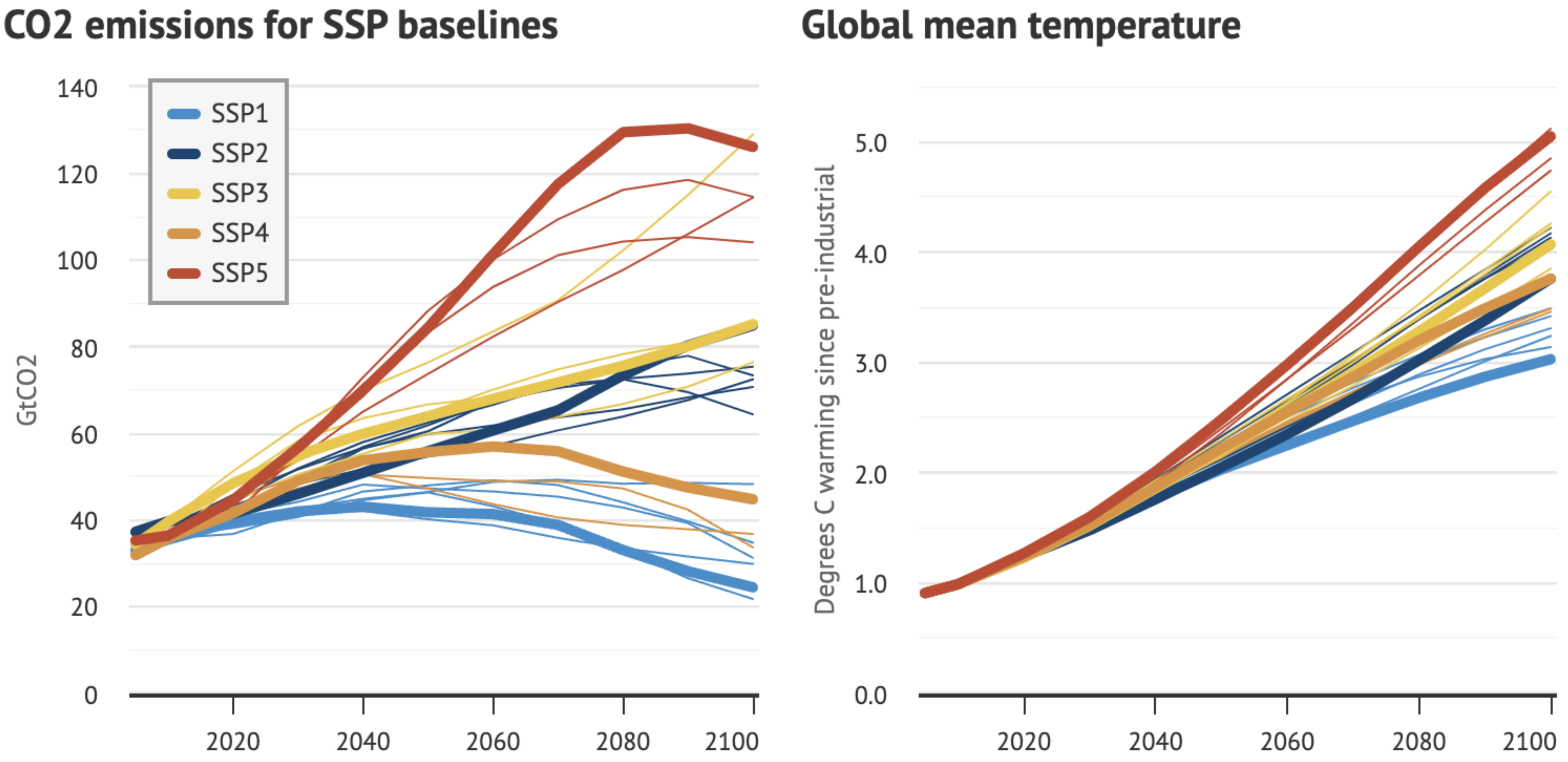
Very little information

Classic Top-Down Modeling Approach



Greenhouse gas "scenarios" = "what if" scenarios

they are used to drive global climate model simulations



Source: https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/

Aside: Crosswalking old vs new scenarios

(approximate: there are no exact matches)

	CMIP6 (2020)	CMIP5 (2014)	CMIP3 (2007)
Low	SSP1-2.6	RCP 2.6	
Mid-Low	SSP2-4.5	RCP 4.5	B1
Mid-High	SSP3-7.0	RCP 6.0	A1B
High	SSP5-8.5	RCP 8.5	A1FI

RCP = Representative Concentration Pathway
SSP = Shared Socioeconomic Pathway

Global Climate Models (GCMs)

- GCMS break the world into large grid sizes (~100 to 250 km) and model complex interactions within each grid cell.

- GCMs are mostly “coupled”, meaning that separate models for the land surface, ocean, sea ice, and atmosphere all interact.

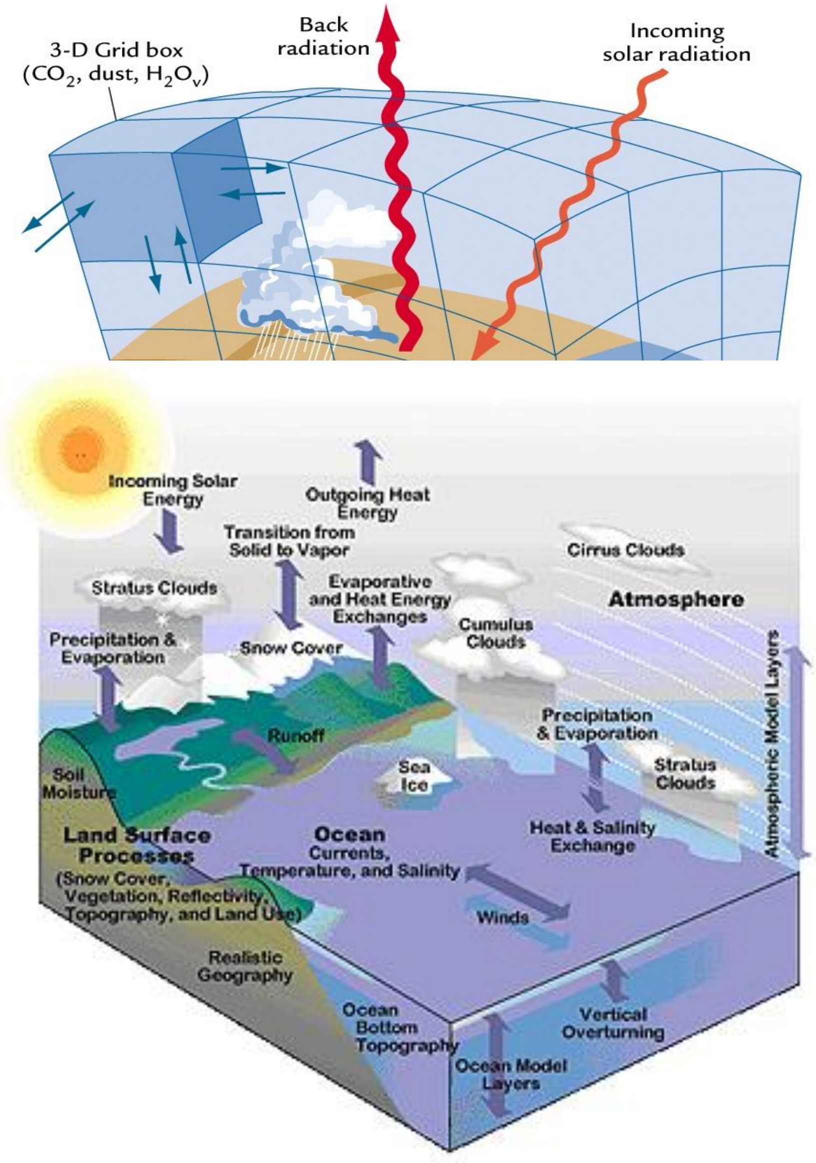


Image Source: NOAA

GCMs have improved over time

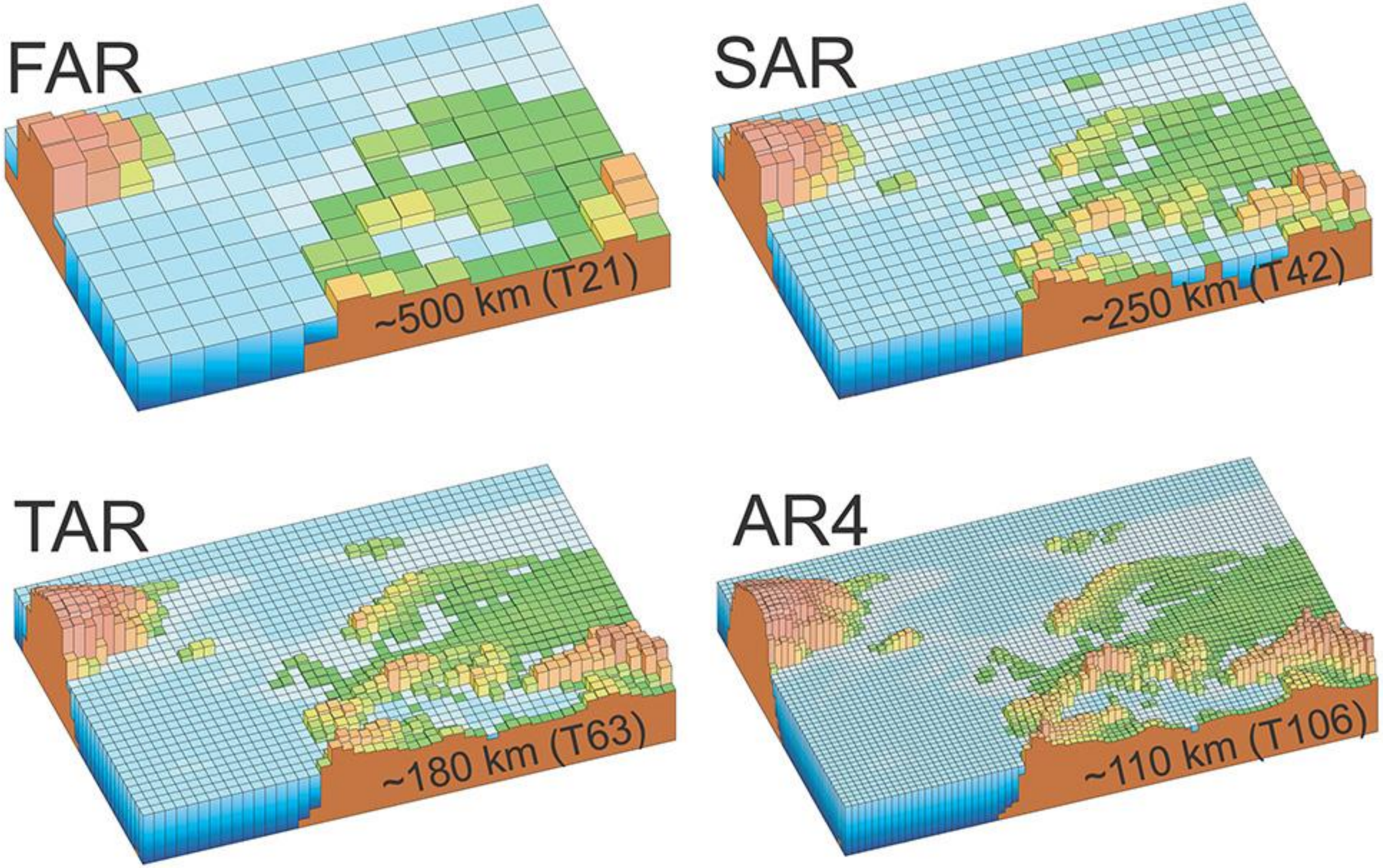


Image Source: https://www.carbonbrief.org/qa-how-do-climate-models-work

GCMs have improved over time

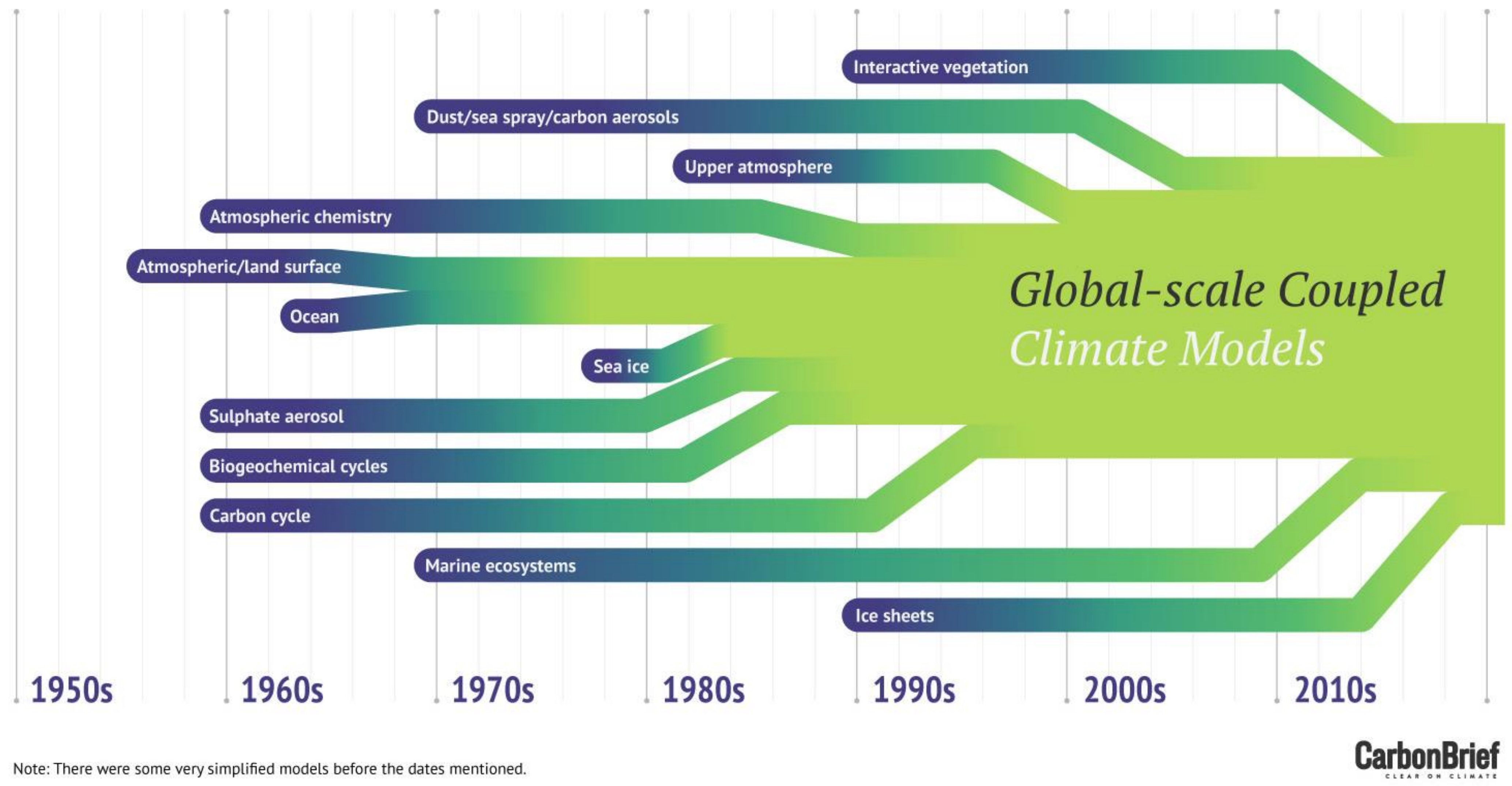
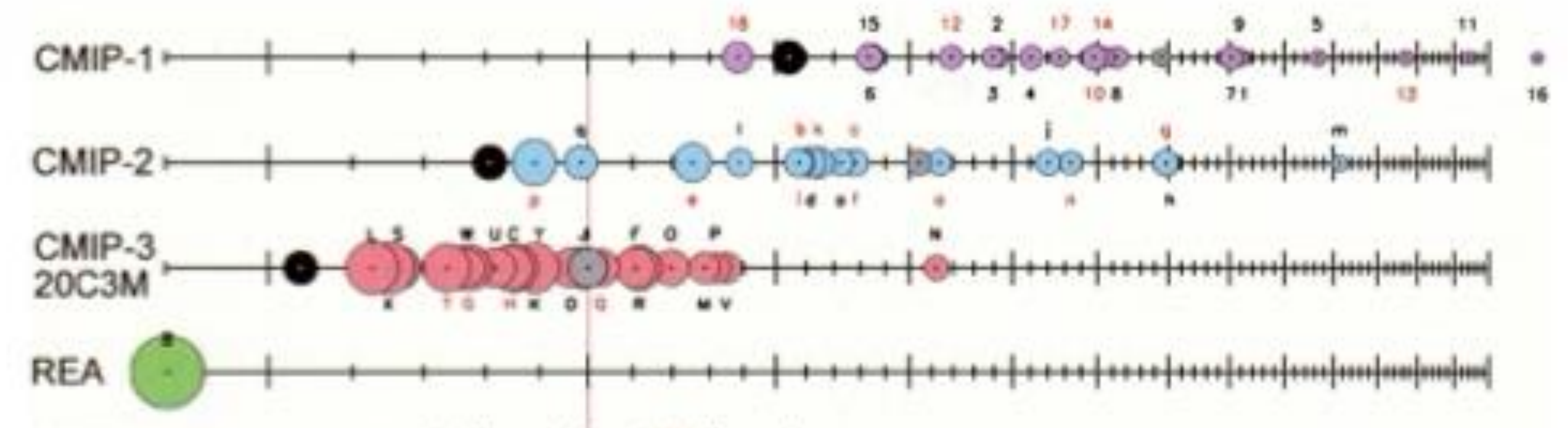


Image Source: https://www.carbonbrief.org/qa-how-do-climate-models-work

GCMs have improved over time

Older

Newer



Better ← → Worse

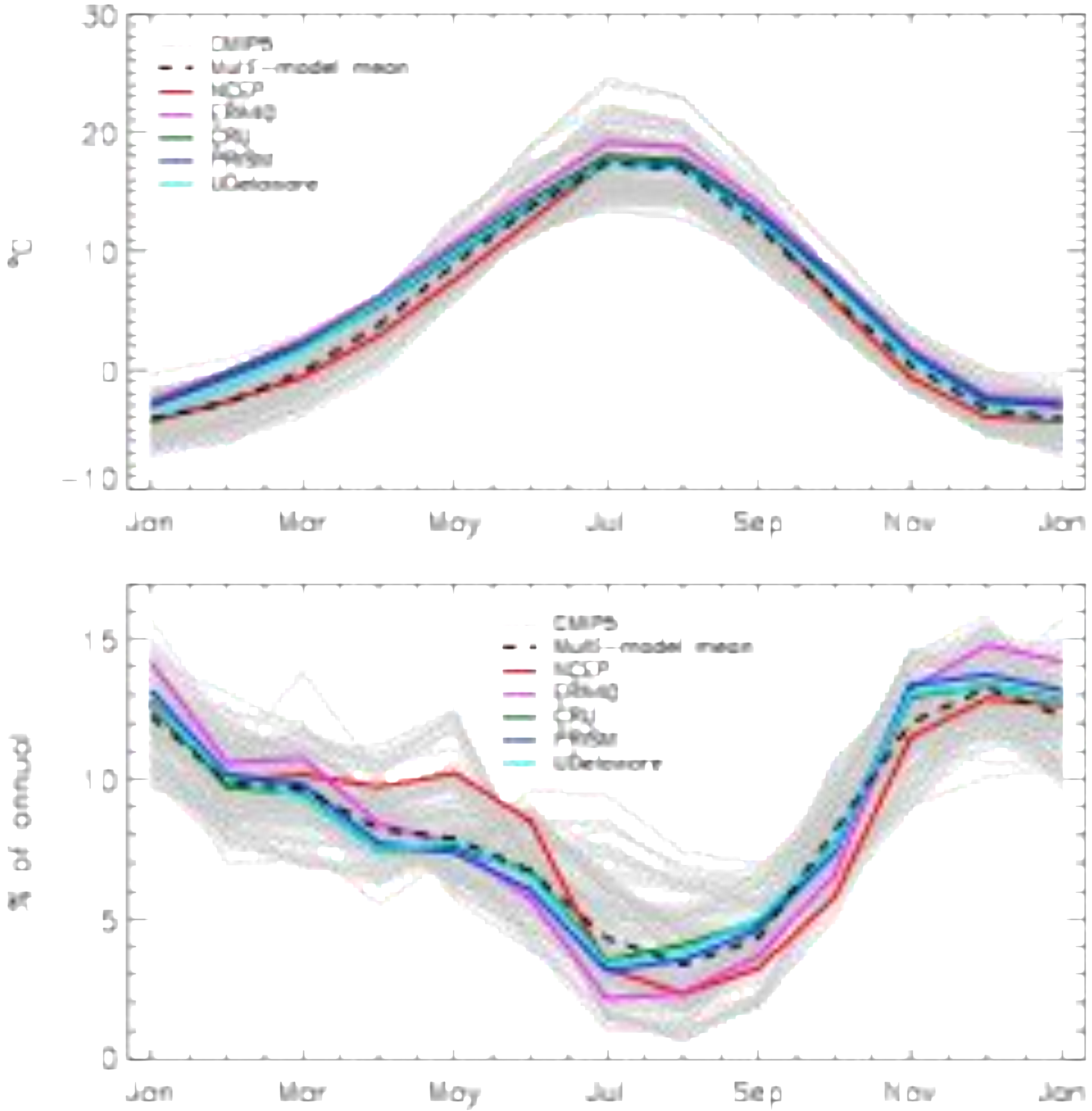
Source: Reichler & Kim 2008; https://doi.org/10.1175/BAMS-89-3-303

GCM "ensembles"

- "Ensemble" could mean:
  - Average of many different GCMs
  - Average of multiple runs from the same GCM (different initial conditions)

- Ensemble average (dashed line) is generally better than any individual GCM (grey lines)

- The range among models is an *approximation* of the uncertainty



Source: Rupp et al. 2013; https://doi.org/10.1002/jgrd.50843

What don’t we know about future climate?

1. How much we will emit in the future.

   Greenhouse gas scenarios = “what if” storylines

2. The timing and magnitude of natural climate variations

   Natural variability will enhance & obscure climate change for decades at a time

3. Limitations in our modeling of key processes

   GCMs are our best estimates of future climate, but they are imperfect

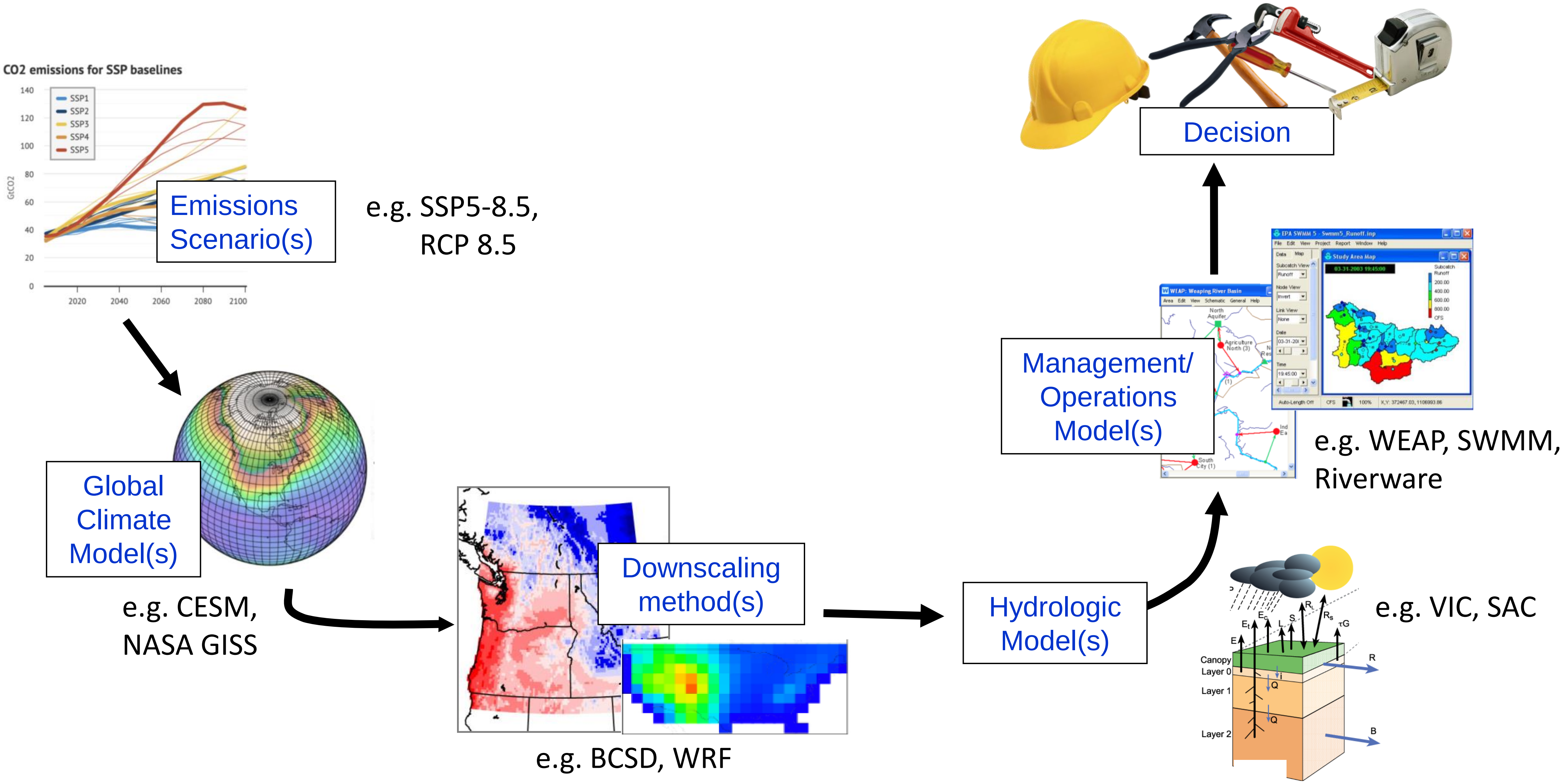
What does this mean for assessing impacts?

1. Greenhouse gas scenarios drive ***projections***, not predictions

2. There will always be a range of projections

3. Projections will evolve over time as the science improves

Classic Top-Down Modeling Approach



Key Takeaways

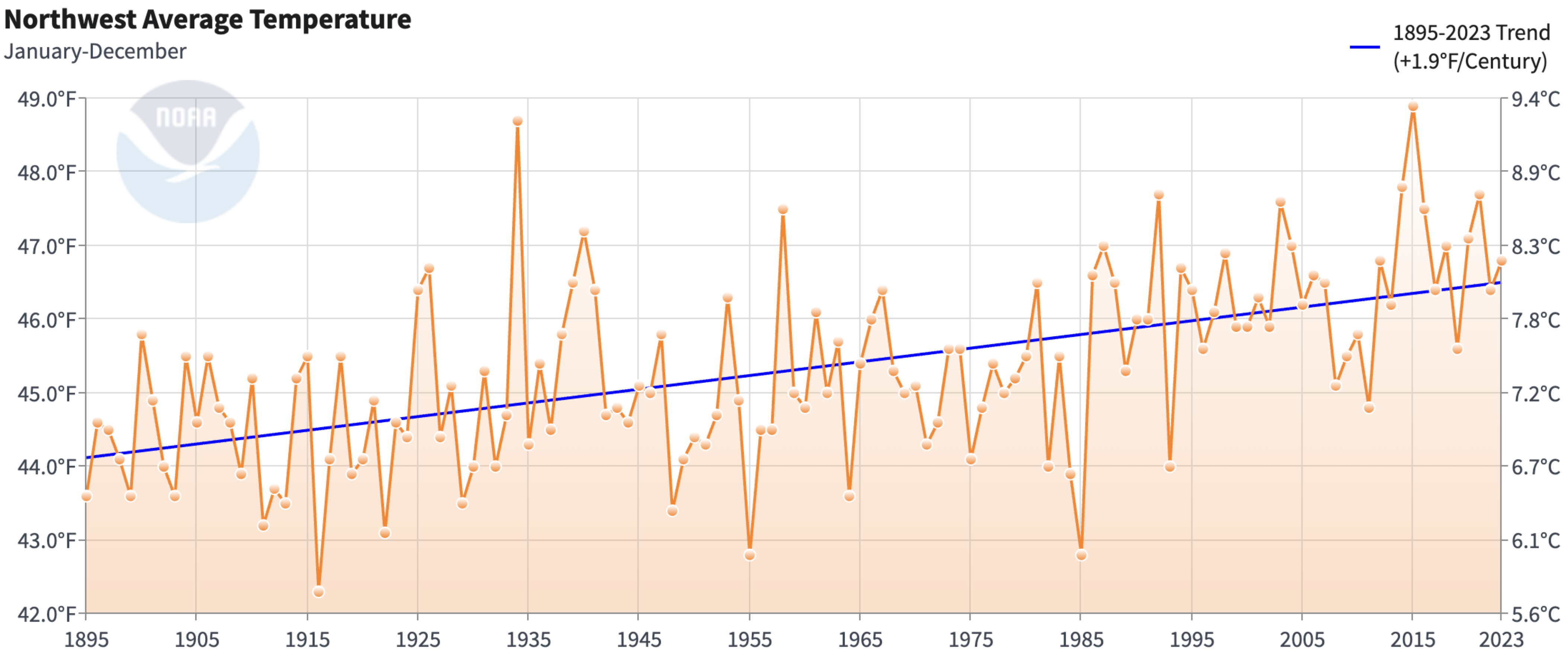
- The climate has already changed:
  Higher Temperatures, Lower Snowpack, Higher Sea Level
- *Future:* accelerated warming, drier summers, heavier rain events
- *Impacts:* Less water in summer, warmer water in summer, larger floods in winter. All life stages of salmon are affected.
- Greenhouse gas scenarios drive projections, not predictions
- There will always be a range of projections
- Projections will evolve over time as the science improves

https://twitter.com/LigaDos32

https://cig.uw.edu
gmauger@uw.edu
206.685.0317
Image Credit: Kendra Kaiser, Boise State University

extra slides

Pacific Northwest average annual temperature has increased more than 2°F since 1895.



https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/

2015: A preview of the future

Warmest year on record for the NW
~5ºF warmer than pre-industrial

7th driest January to June in the Northwest

Lowest snowpack on record for WA
30% of normal (1970-1999 average)

Data: NCA 2018
Figure: Climate Impacts Group

2015:

FISHERIES

Low summer streamflow & warm waters resulted in fishery closures

>250,000 Columbia River sockeye salmon died

RECREATION

Low snowpack led to reductions in winter & summer recreation

42% shorter ski season at Stevens Pass

WILDFIRE

The most severe wildfire season in Washington's recorded history

>1,000,000 acres burned

>$253 million fire supression

AGRICULTURE

Warm temperatures & reduced water availability stressed WA agriculture

17 major crops with reduced yields

$633-733 million economic losses

CLIMATE IMPACTS GROUP

Data: NCA 2018
Figure: Climate Impacts Group

AK: ACCAP
Alaska Center for Climate Assessment and Policy
A NOAA RISA TEAM

BC: PACIFIC CLIMATE IMPACTS CONSORTIUM

WA: CLIMATE IMPACTS GROUP

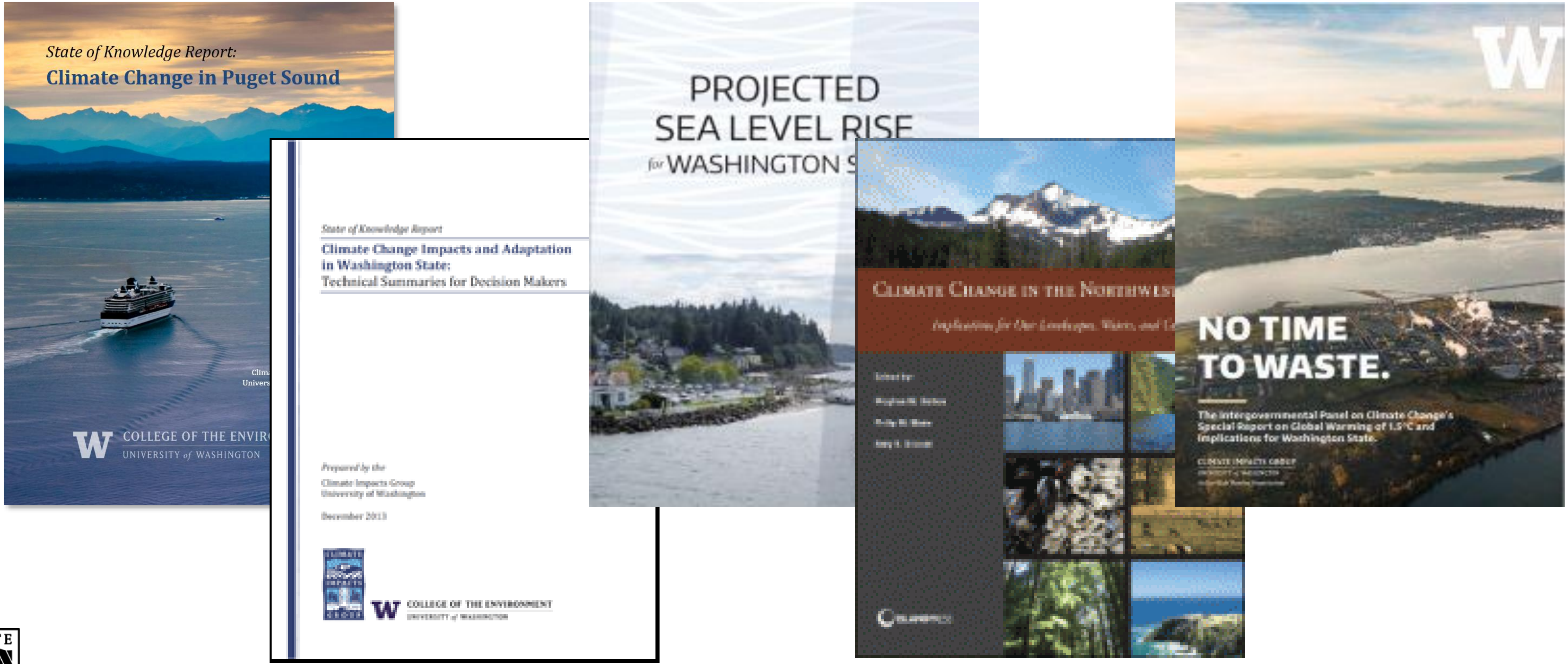
OR: CIRC
Climate Impacts Research Consortium
A NOAA RISA TEAM

NORTHWEST Climate Adaptation Science Center — USGS

NOAA Climate Adaptation Partnerships
Formerly RISA — NOAA

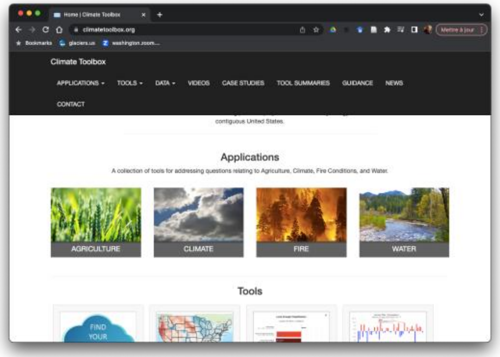
USDA CLIMATE HUBS — USDA

Fact Sheets and Synthesis Reports



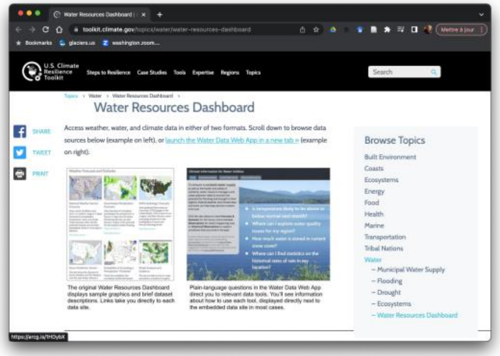
https://cig.uw.edu/resources/special-reports/

Resources for assessing impacts:



Climate Toolbox

https://climatetoolbox.org/



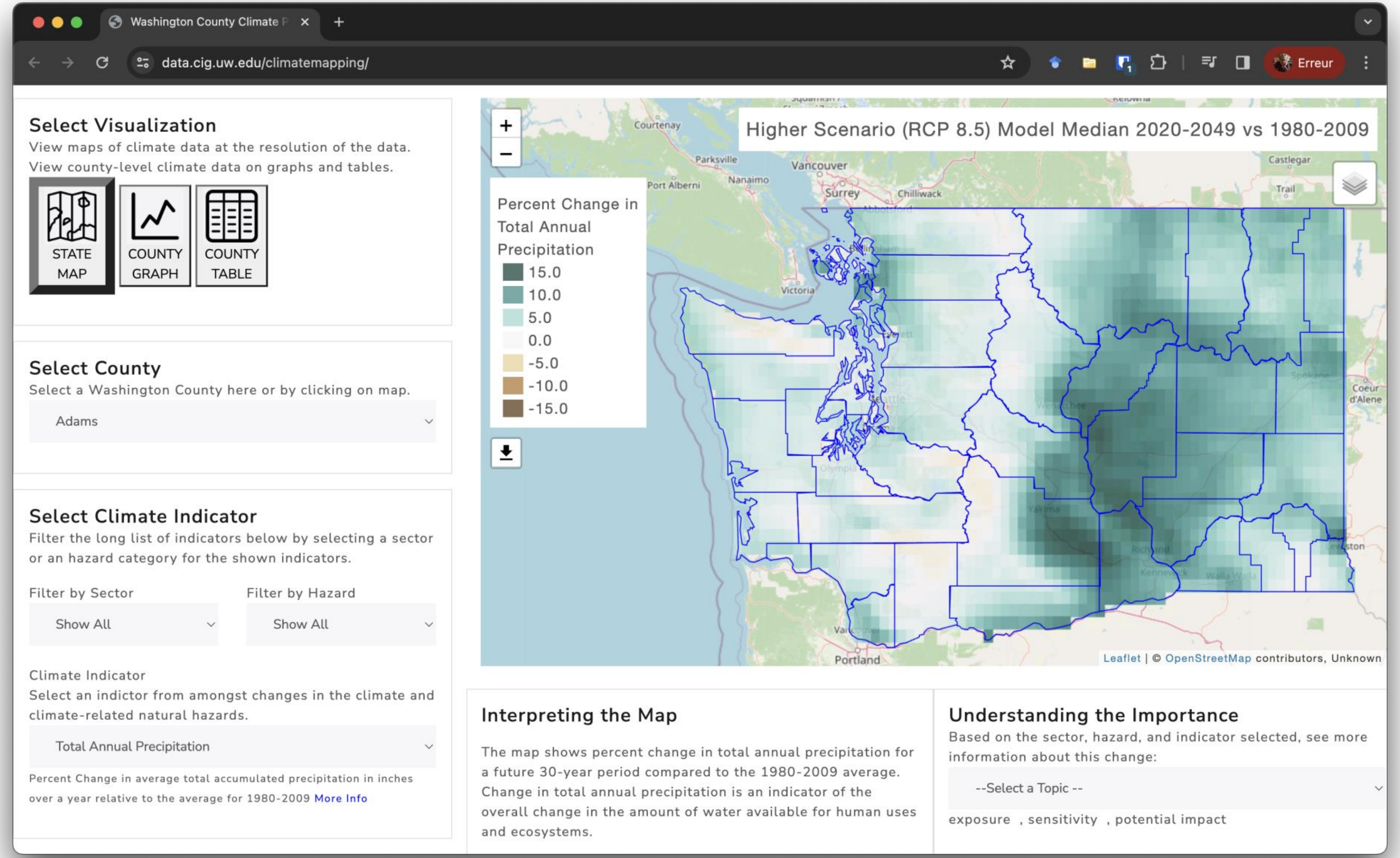
Water Resources Dashboard

https://toolkit.climate.gov/topics/water/water-resources-dashboard

Climate Impacts Group

https://cig.uw.edu/resources/analysis-tools/

Climate Mapping for a Resilient Washington



https://cig.uw.edu/resources/analysis-tools/climate-mapping-for-a-resilient-washington/

New Data Guide: *"Quantifying Sensitivity + Exposure"*

THIS 18-PAGE COMPANION DOCUMENT IS WRITTEN FOR STAKEHOLDERS AND MANAGERS INTERESTED IN QUANTIFYING SENSITIVITY AND EXPOSURE TO CLIMATE CHANGE.

This guide will help answer the questions...

1. *How do I quantify sensitivity?*
2. *How do I quantify exposure?*
3. *How do I manage uncertainty?*
4. *Where can I find the latest data?*
5. *What do I need to consider when seeking new data?*

1. How do I quantify sensitivity?

The first step in any climate assessment should be to consider the anticipated consequences – whether physical, economic, ecological, cultural, etc. – of climate change. Another way of looking at this is to ask: ***"How much would the climate have to change to matter?"*** or ***"How do impacts scale with the anticipated changes?"***

This may be easy to intuit in some cases (e.g., water overtopping a levee) and more difficult to quantify in others (e.g., consequences for businesses when transportation is disrupted). In either case, the *sensitivity* to climate change is key to understanding the timing and severity of climate change impacts.

An approachable way to quantify sensitivity is to determine *when* the impacts will become a problem. Once you know this, you can then assess *how often* the impact will cause problems, and by *how much*. We suggest approaching this in one of two ways:

Approach #1: Observations

Historically, we have experienced climate impacts resulting from natural variations in climate – warm winters, dry years, big storms, etc. – that vary on time scales from days to several decades. When past events can be related to projected trends due to climate change, the consequences of those events can paint a picture of the potential impacts of climate change.

Approach #2: Modeling

The alternative to the observational approach is to use models to estimate the consequences of projected changes in climate. In a recent study, for example, the City of Portland used an existing stormwater model, testing varying precipitation intensities to see how consequences scale with changes in precipitation.

What if you aren't sure at which point an impact becomes a problem for your community? There are lots of reasons it might be hard to identify a time frame when impacts become important. Knowing exactly when an impact becomes a problem could help prioritize resilience-building efforts, but it isn't the most important part of this step. Instead,

2. How do I quantify Exposure?

The three different approaches that are briefly discussed in the accompanying *Introduction to Adaptation* guidance document include (1) using global climate model data, (2) "downscaling" global climate model data, and (3) using impacts model data. You will need to consider the strengths and weaknesses of each approach to decide which path to pursue. Use the flowchart (Figure 1) as a reference for deciding among the different approaches for quantifying exposure.

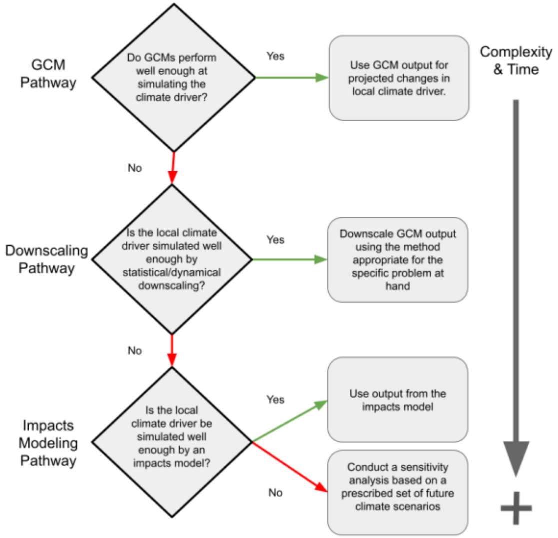


Figure 1. Flowchart for selecting which data are needed to quantify exposure to climate impacts.

4. Where can I find the latest data?

Raw global climate model output can be downloaded from the World Climate Research Programme's (WCRP) website. The WCRP website provides access to several different generations of climate model data, however this data is not always straightforward to access, nor is it in a format that is user-friendly.

A more approachable way of accessing available global climate data is this Tableau visualization, which provides an overview of changes in temperature and precipitation for the Pacific Northwest in three generations of global climate model project.

For additional resources on available climate model data visualizations, raw downscaled climate models data, coarse-scale hydrologic projection output, and fine-scale DHSVM output see tables 1-4.

5. What do I need to consider when seeking new data on sensitivity and exposure?

The first things to consider are the costs and benefits of conducting new modeling or obtaining new observations. Finding or creating new datasets is expensive and time-consuming, and it may not be worth the effort for the information it provides. In many instances, you will be able to leverage existing data for quantifying sensitivity and exposure.

Should existing data be insufficient for your needs, the following considerations may be important when seeking new data.

1. ***Do I need new observations or modeling?***

   Obtaining new observations can often be more time-consuming and expensive than modeling, especially when considering that multiple years of observations may be needed to draw accurate conclusions.

   It is important to consider, however, that model simulations require observations for validation. If you are unable to find observations in your region that will allow you to validate model simulations, then obtaining new observational data should be a priority. Modeling may be needed in addition to observational data if the changes you are interested in cannot be measured directly, or if the changes in the future go beyond the range of what has been seen in the past.

2. ***If I need modeling, what sort of impact model should I use?***

   Answering this question depends on the impact you are concerned about, and will require conversations about project constraints (e.g., time, funds, etc.) with those providing technical guidance. Additionally, many previous impacts modeling efforts have their

https://cig.uw.edu/projects/supporting-climate-resilient-floodplain-management-in-whatcom-and-snohomish-counties/