Northwest **Power** and **Conservation** Council

November 6, 2018

MEMORANDUM

TO: **Council members**

FROM: **Daniel Hua**

SUBJECT: Streamflow and Temperature Projections of the Latest Climate-Change Datasets for the Columbia River Basin

BACKGROUND:

Presenter: Eric Pytlak, Manager of Weather and Streamflow Forecast Group and Climate Change Technical Lead at Bonneville Power Administration

Summary: The overarching objective of the Bonneville Power Administration (BPA), US Army Corps of Engineers (USACE) and the Bureau of Reclamation (USBR), which comprise the River Management Joint Operating Committee (RMJOC), is to continuously evaluate and anticipate vulnerabilities, risk, and resiliency of the Federal Columbia River Power System (FCRPS). Assessments include potential future changes to hydropower generation and reliability, flood risk management, water supply, recreation, cultural resources, fisheries, navigation, and functioning of the ecological system. The purposes served by the Columbia River Reservoir system can be challenged by changes in future conditions, including changes to the regional hydro-climatology. The priority of these agencies is to identify and anticipate the impacts of these changes in regional hydro-climatology to infrastructure and system objectives, irrespective of what is driving the changes.[1]

[1] Excerpted from “Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition (RMJOC-II), Part I: Hydroclimate Projections and Analyses”

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This objective motivated the RMJOC to work with the research community to update and improve the first climate study completed in 2009 – 2011. Over the past four years, technical experts from the RMJOC agencies collaborated closely with research teams at the University of Washington and Oregon State University to develop and produce the RMJOC-II regional climate change dataset derived from the latest climate models in the 5th Coupled Modeling Intercomparison Project (CMIP-5) published in 2013. The RMJOC-II climate change dataset was completed in October 2017 and is publicly available.

Erik will present “Streamflow and Temperature Projections of the Latest Climate-Change Datasets for the Columbia River Basin,” specifically, the temperature, precipitation, snowpack and streamflow changes that are projected to occur as the regional climate changes through the rest of the 21st century.

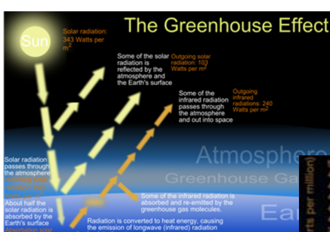
More Info: The first RMJOC report, “Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition (RMJOC-II), Part I: Hydroclimate Projections and Analyses” is available at https://www.bpa.gov/p/Generation/Hydro/hydro/cc/RMJOC-II-Report-Part-I.pdf

RMJOC-II Climate Change Research Project Update and Findings

Erik Pytlak
Manager, Weather and Streamflow Forecasting
Climate Change Technical Lead
Bonneville Power Administration

November, 2018

Greenhouse Gases and Climate Change



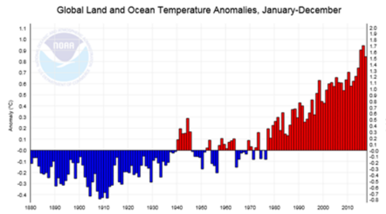
Source: NASA Climate Page

- We actually want a Greenhouse Effect – just not too much
- Carbon dioxide is a pretty efficient greenhouse gas, and is increasing rapidly in the atmosphere
  - Methane is many times more efficient in re-emitting heat energy, and is also included in climate change models

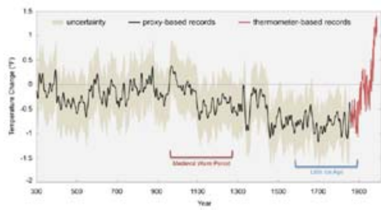
B O N N E V I L L E P O W E R A D M I N I S T R A T I O N

Observed Temperature Trends

- Rapid warming since the 1970s, especially in the subarctic northern Hemisphere
- Global temperatures have risen 1.7°F since the 1970s
- 2016 was the warmest year ever recorded (going back to the 1880s), and possibly the warmest *in over 2000 years.*
- The last time atmospheric CO_2 levels were this high:
  - 3 million years ago
  - 5-7°F higher
  - Sea levels 60-80 feet higher



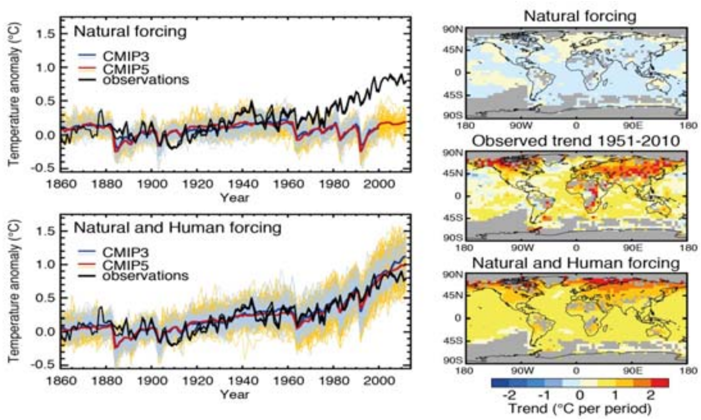
Source: NOAA, 2018



Source: National Climate Assessment, 2017

B O N N E V I L L E P O W E R A D M I N I S T R A T I O N

Human vs. Natural Causes



- Observed warming is only explained by models that include carbon dioxide increases
- In the past 60 years, absent greenhouse gas increases, we should have had no change, or slight global cooling
- Climate models may still be underestimating the degree of warming already underway

B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

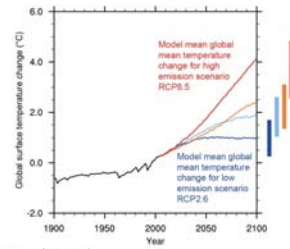
Carbon Emission Scenarios (Resource Concentration Pathways)

RCP2.5: Stop most CO_2 equivalent emissions immediately; negative emissions by 2020.
RCP4.5: Level off CO_2 equivalent 580-720 ppm by 2050, then fall
RCP6.0: Level off CO_2 equivalent 720-1000 ppm 2060-2080, then fall
RCP8.5: Mostly uncontrolled CO_2 equivalent emissions rise over 1000ppm by 2100

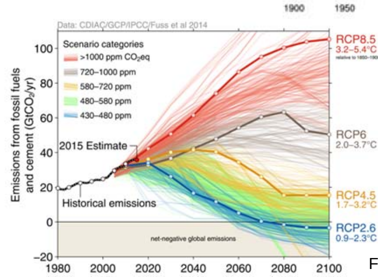
Range of *modeled* global warming by 2100:
- **Range: 1.7-5.4ºC (3.0-9.4°F)**
- **Average: 2.5ºC (4.5°F)**

We are currently near 410ppm for CO_2, and 490ppm for CO_2 equivalent

We are currently on the RCP8.5 pathway, but also pretty close to both RCP4.5 and 6.0 as long as emissions slow soon.



IPCC, 2013



Fuss, et al., 2014

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B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Regional Hydroregulation Studies

RMJOC-II

River Management Joint Operating Committee (RMJOC):
- Technical teams from Corps, Reclamation and BPA who jointly manage FCRPS operations
- RMJOC commissioned 2nd study in 2013 (previous study in 2009-2011)

Latest study commissioned with the University of Washington (Bart Nijssen and Oriana Chegwidden) and Oregon State University (David Rupp and Phil Mote)

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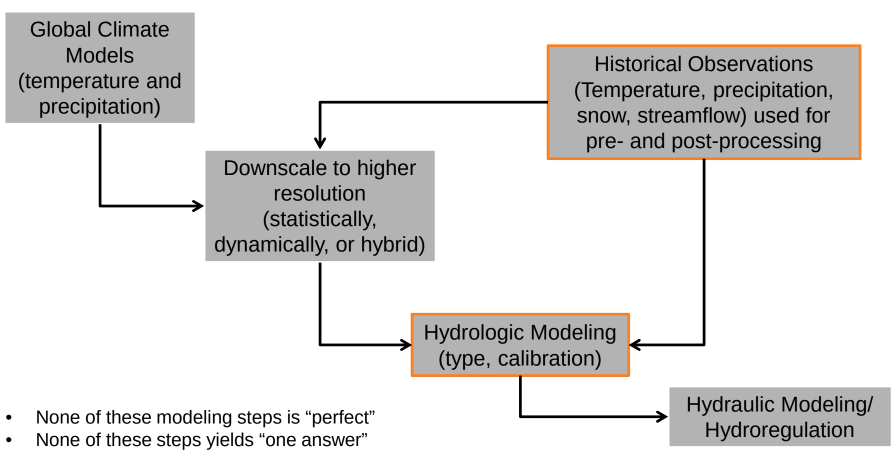
Project Objectives: RMJOC-II

- **Update climate change streamflow datasets used for regional long-range planning, using latest Global Climate Models (from IPCC-5, 2013)**
- **Better account for *range* of climate change outcomes:**
  - Global climate models agree on overall temperature trends, but indicate different precipitation and weather pattern changes
  - Previous study used a reasonable range of annual temperature and precipitation projections, but in hindsight was too narrow on future winter spreads
- **Better account for hydrologic modeling uncertainties:**
  - Each step in the modeling process introduces uncertainties – some larger/smaller than others
  - Previous study used only one downscaling method and one hydrologic model
  - **Even past “observed” temperature, precipitation, snowpack and streamflows have some uncertainty**
- **Provide realistic range of possible future scenarios for long range planning, while taking into account warmer global trends**

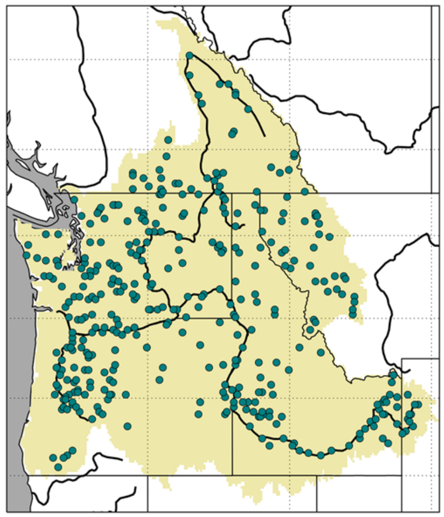
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Hydroclimate Modeling Steps

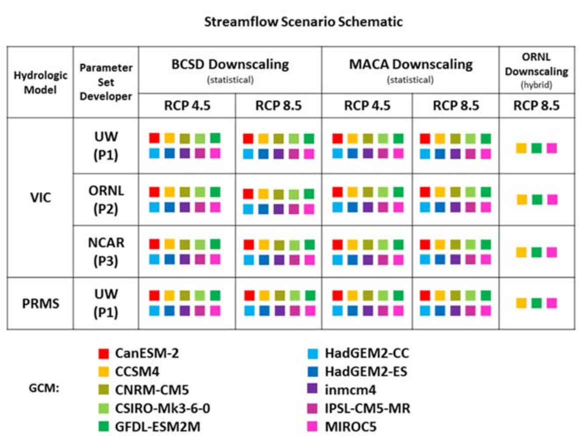


- None of these modeling steps is “perfect”
- None of these steps yields “one answer”
- These uncertainties should be included in climate change studies
- **These uncertainties are apparent in this study, particularly Historical Observations and Hydrologic Model Type/Calibration**

Streamflow Locations



Hydrometeorological Simulations



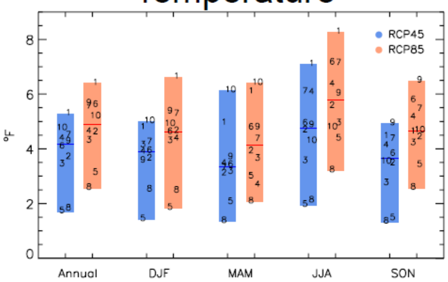
Each ■ represents a different hydrologic simulation based upon distinct meteorological forcings (172)

B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

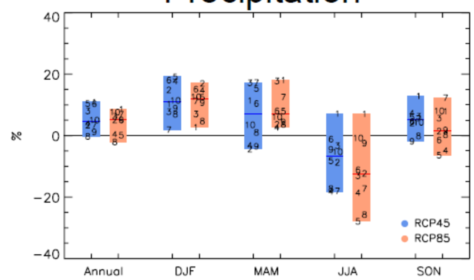
Temperature/Precipitation Projections for Columbia Basin

1970-1999 to 2030-2059

Temperature



Precipitation

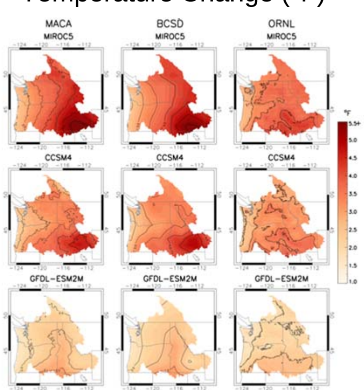


- Warming probably more pronounced in summers
- 9 of 10 best-performing climate models in PacNW show either increasing annual basin precipitation, or no change
- Good agreement for wetter winters; decent agreement for wetter springs
- Decent agreement on drier summers

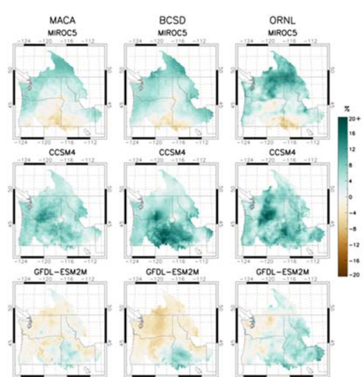
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

2030s Annual Temperature and Precipitation Trends

Temperature Change (°F)



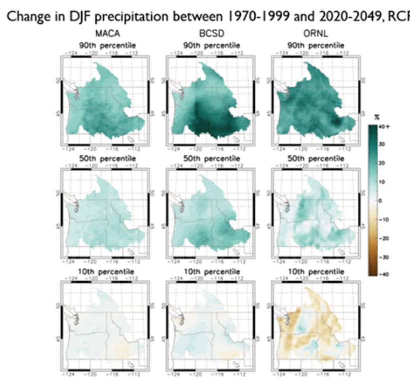
Precipitation Change (%)



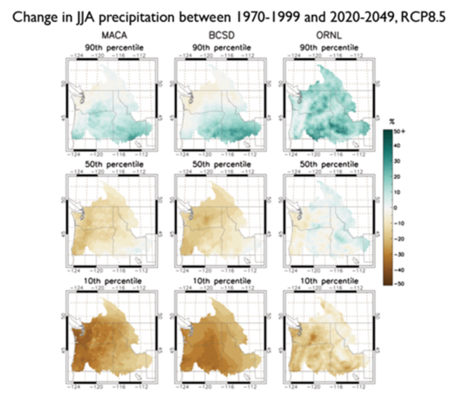
- More warming likely in the interior than the coasts, particularly in the upper Snake Basin
- Greatest uncertainty in amount of warming also in the interior
- Large model-to-model annual precipitation variability, but most are either no-change or wetter, especially in Canada

2030s Winter and Summer Precipitation Change in %

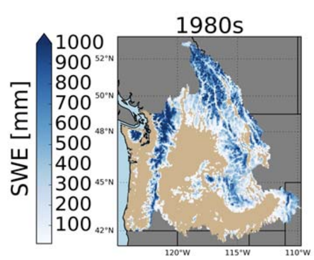
Winter



Summer

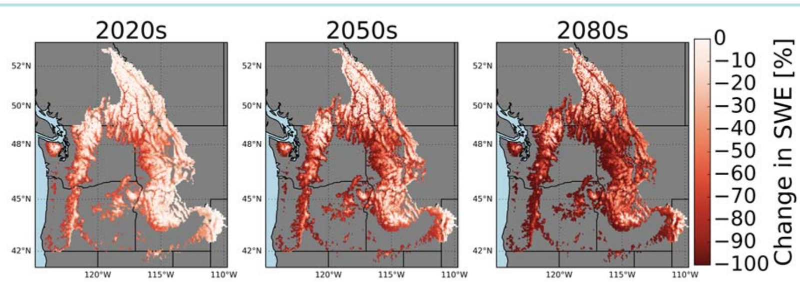


- Trend toward wetter winters
- Perhaps a drier summer trend (but July-August are generally the driest months in the Columbia Basin)



Historical April 1 SWE

Areas in tan: < 10 mm April 1 SWE

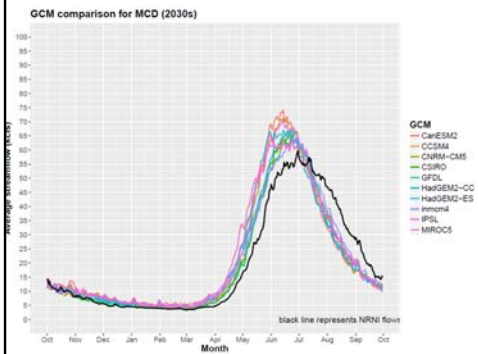


RCP8.5 – GCM mean – BCSD – VIC – UW

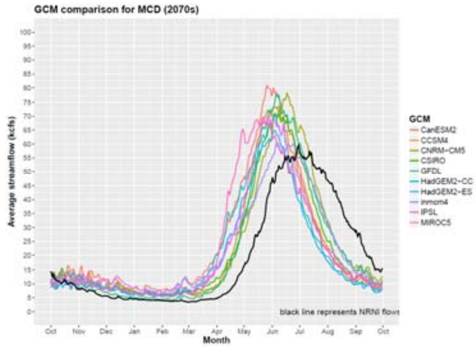
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Average Mica Inflows: 2030s and 2070s (All Hydro Models)

2030s



2070s

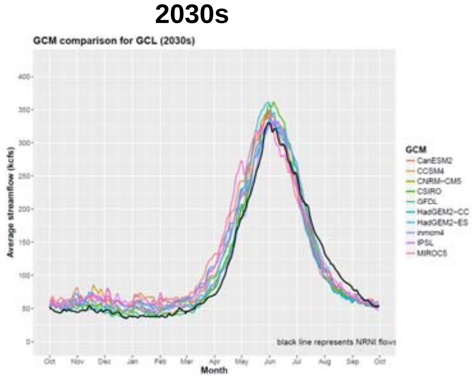


- Peak spring runoff 1-2 weeks earlier by the 2030s, and about 2-4 weeks earlier by the 2070s
- Higher spring peaks as winter/spring precipitation increases
- Little change in fall or winter natural flows until the 2070s
- Less mid Jul-Aug flows by the 2030s as glaciers continue to deplete and more snowpack reliably melts each year
- By 2070s, average higher March-May flows indicated, with more significant June-August decreases

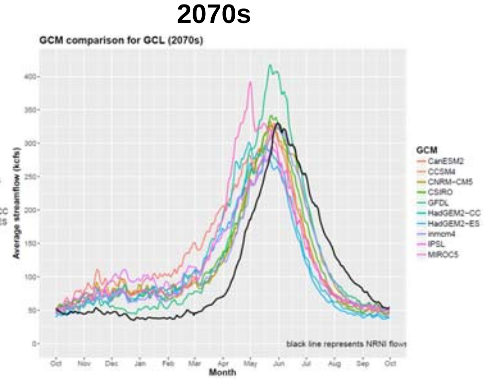
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Average Grand Coulee Inflows: 2030s and 2070s (All Hydro Models)

2030s



2070s

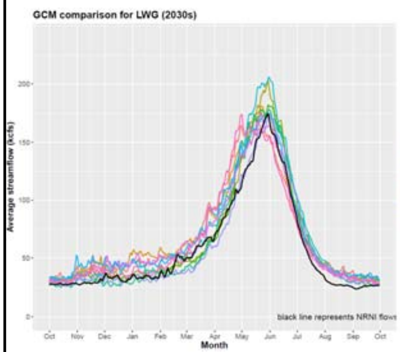


- Spring snowmelt shifts about 2 weeks earlier by the 2030s
- Higher natural flows in November-April
- Lower natural flows in July-August
- Higher annual volumes over time as precipitation increases

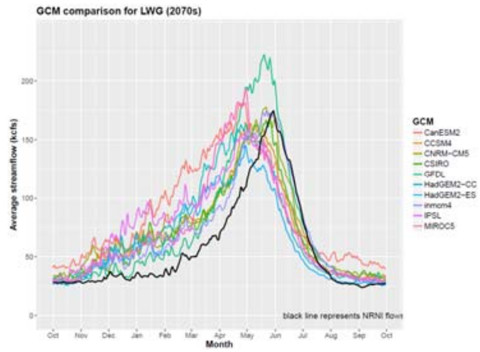
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Average Lower Granite Inflows: 2030s and 2070s (All Hydro Models)

2030s



2070s



- Larger changes compared to the rest of the Basin
- Spring snowmelt 2-3 weeks earlier in the 2030s, and about a month earlier by the 2070s.
- Multiple snowmelt peaks in any one year appear more often in January-May
- Higher average natural flows in November-March
- Longer periods of low summer natural flows
- Little change in September-October natural flows

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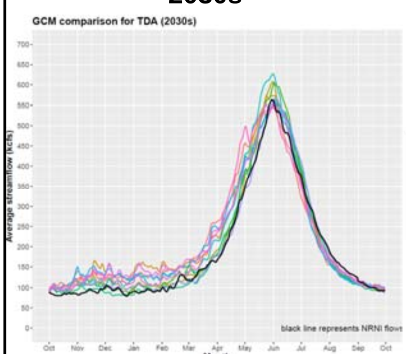
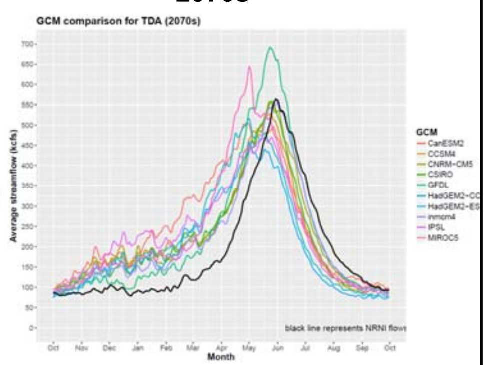
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Average The Dalles Inflows: 2030s and 2070s (All Hydro Models)

2030s



2070s



- Increased winter/spring Snake flows route through the Lower Columbia
- Flows from Grand Coulee keep peak runoff from shifting earlier in the 2030s; but
- Higher natural flows November-May
- Lower natural flows in July-August
- Higher annual volumes as precipitation increases

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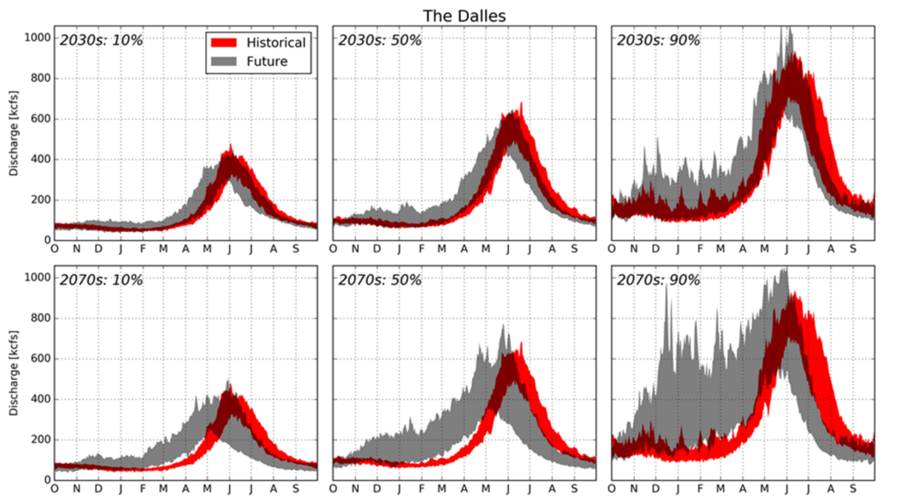
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

P10, 50 and 90 Flows at The Dalles
(80 RCP8.5 statistically downscaled scenarios)

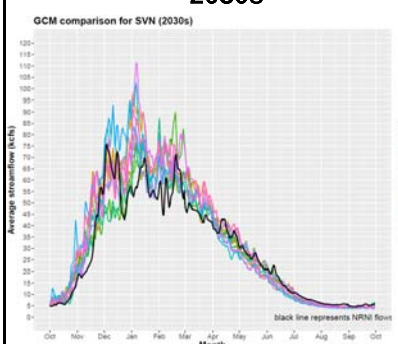


Images Produced by Chris Frans, USACE Seattle District

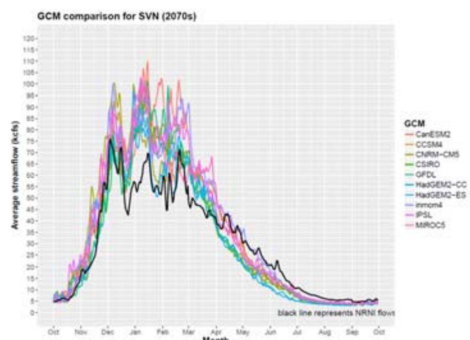
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Average Willamette Inflows: 2030s and 2070s (All Hydro Models)

2030s



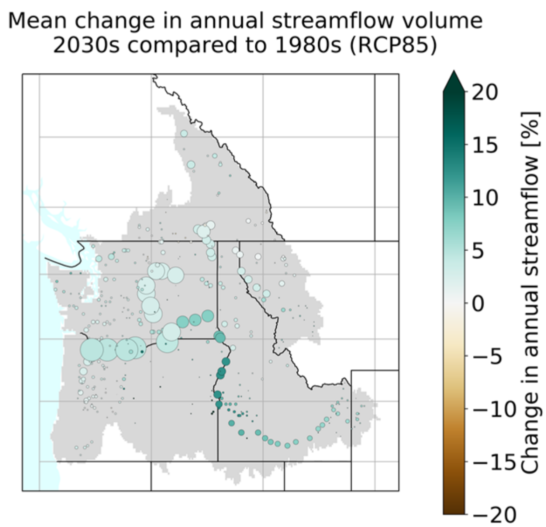
2070s



- Similar timing trends compared to historical/current
- Higher winter natural flows and peaks
- Slightly lower natural flows in May-July
- Higher winter Willamette natural flows likely to coincide more often with higher natural winter Columbia flows

B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Projected Mean Change in Annual Volume: 2030s



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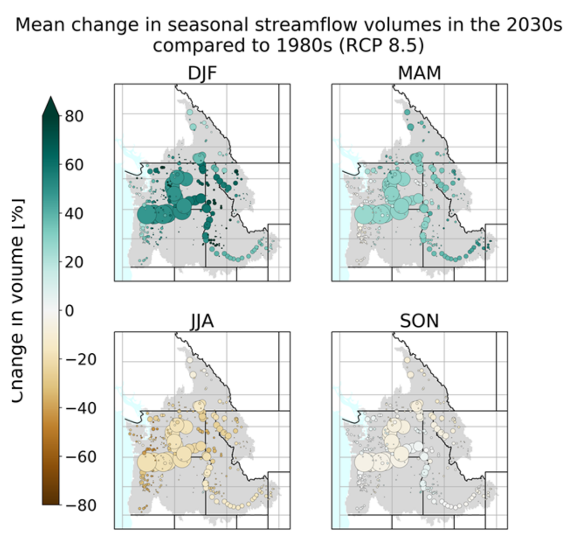
B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Projected Mean Change in Annual Volume by Season: 2030s



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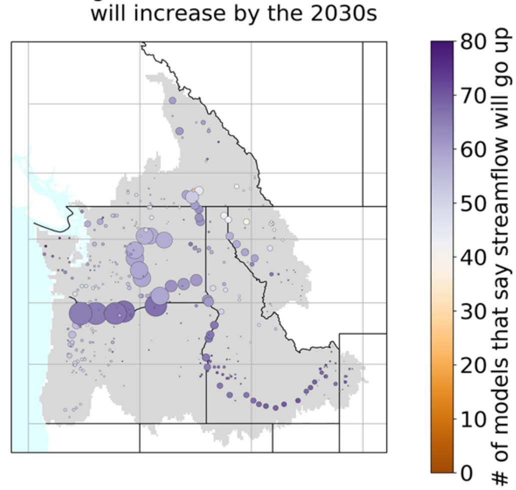
BONNEVILLE POWER ADMINISTRATION

Projection Agreement in Annual Volume: 2030s



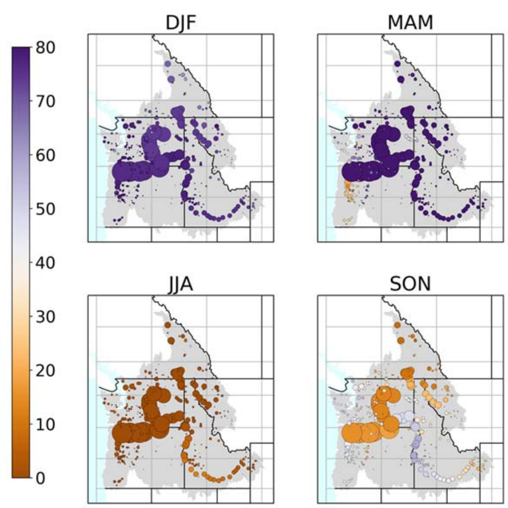
BONNEVILLE POWER ADMINISTRATION

Projection Agreement in Seasonal Volume: 2030s

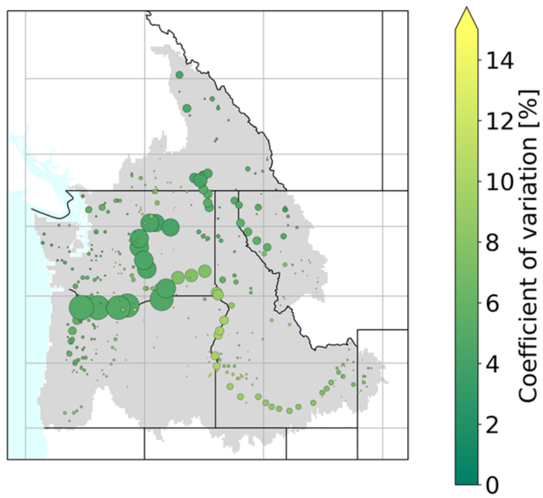
All say increase

Models disagree

All say decrease

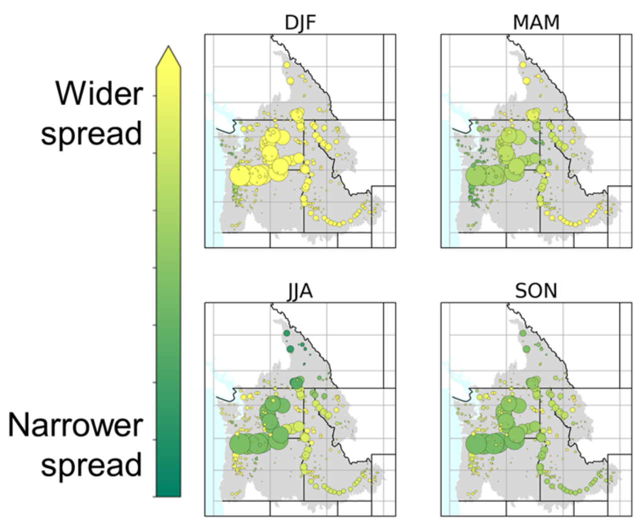


Projection Spread in Annual Volume: 2030s



B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

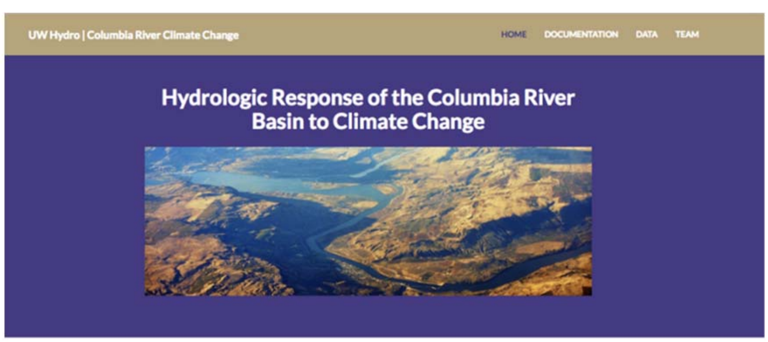
Projection Spread in Seasonal Volume: 2030s



BPA Climate Change Findings Statements

- BPA, and its Corps and Reclamation partners through the RMJOC, are fulfilling their promise to monitor climate change as part of our overall risk management. We have proactively worked with regional researchers and stakeholders to update the region's last study in 2011.
- Temperatures have already warmed about 1.5°F in the region since the 1970s, and are expected to warm another 1 to 4°F by the 2030s. Warming is likely to be greatest in the interior, with less warming near the coast.
- Future precipitation trends are more uncertain, but a general upward trend is likely, particularly in the winter months. Already dry summer months could become drier.
- Average winter snowpacks are very likely to decline over time as more winter precipitation falls as rain instead of snow, especially in the US side of the Columbia Basin.
- By the 2030s, higher average winter flows, earlier peak spring runoff, and longer periods of low summer flows are very likely. The greatest streamflow changes are likely to be in the Snake River Basin, although that is also the basin with the greatest modeling and forecast uncertainly.
- These changes may impact flood risk management, hydroelectric generation patterns, energy consumption and ecosystems. The results will be used in future studies.
- We will continue to monitor and support climate change science, and adapt as needed.

Data publicly available at: hydro.washington.edu/CRCC



UW HYDRO
COMPUTATIONAL HYDROLOGY

The short version: *Climate change is expected to affect temperature and precipitation in the Pacific Northwest and change the region's hydrology. This web site provides streamflow information for the Columbia River and coastal drainages in Washington and Oregon State for the 21st century based on a large number of climate scenarios and model experiments. Detailed information about the study can be found under* ***Documentation****, while model results can be found under* ***Data****. The* ***project team*** *consisted of researchers in the UW Hydro | Computational Hydrology research group at the University of Washington and the Oregon Climate Change Research Institute at Oregon State University.*

Upcoming Modeling Plans

- RMJOC-II, Part I Report: Published on June 19 on the BPA Website: https://www.bpa.gov/p/Generation/Hydro/Pages/Climate-Change-FCRPS-Hydro.aspx
- Now through 2019: RMJOC-II Hydroregulation Studies
  - 19 RCP8.5 Scenarios to be run through HydSim
- 2018-19: Inputs into CRSO and other studies
- Outreach continues at conferences, workshops, one-on-few stakeholder meetings