Washington State Climate Resilience Strategy

Appendix A:
Washington climate projections: Summary by region

Prepared by the University of Washington Climate Impacts Group

Summary by Region
Washington Climate Projections

This document presents key climate change stressors by region of Washington State based on the geographic variation in historical conditions and projected future changes in the climate. Geographic differences in risk also depend on the communities, infrastructure, and natural resources in each region and their degree of preparedness and capacity to adapt to expected changes.

Key Climate Stressors

Region	Reduced Water Availability and Drought	Marine and Coastal Changes	Flooding	Wildfire and Smoke	Extreme Heat
Pacific Coast	✓	✓	✓		
Olympic Mountains	✓		✓		
Puget Sound		✓	✓		✓
Southwestern Washington	✓	✓	✓	✓	✓
Cascade Mountains	✓		✓	✓	
Northeastern Washington	✓		✓	✓	✓
Southeastern Washington			✓	✓	✓

Extreme Heat

Indicator: Number of Hot Days

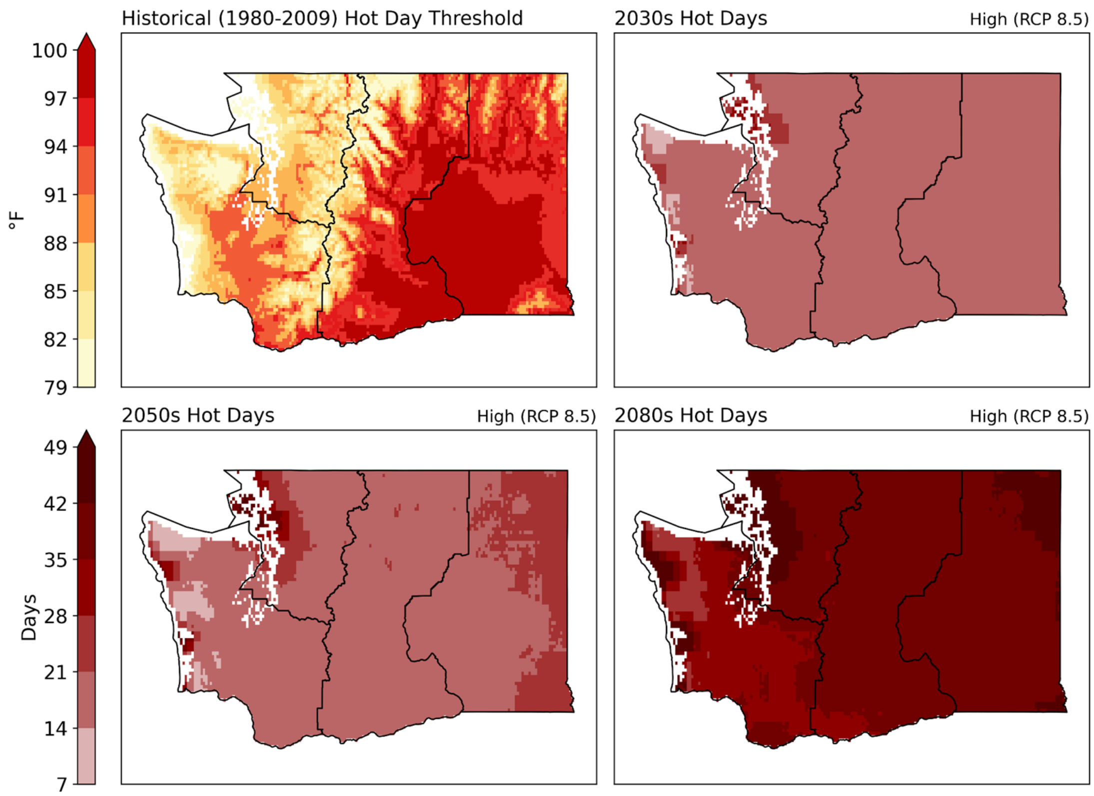
Washington Climate Projections

Historical Conditions and Observed Trend: Maximum temperatures are higher in eastern Washington and lower in most of western Washington because of the maritime influence. Since the beginning of the 20th century, temperatures in the state have risen almost 2°F. In recent decades, the number of hot days has been variable, but was above average in western and eastern Washington for the 2015–2020 period.[1]

Projected Change: **The number of hot days is projected to increase everywhere in Washington.** By the 2080s, different regions are projected to have 11 to 127 hot days per year, compared to about 1 day per year in the past.[2] *(more detail on the projections in the caption below)*

Geographic Variability of Projected Change: **Projected increases are greatest in northern Puget Sound, parts of the Pacific coast, and northeast Washington** and smallest in southwest Washington due to the influence of the Pacific Ocean.

Potential Impacts Without Adaptation: More hot days are expected to increase public health emergencies, concentrations of some air pollutants such as ozone, and heat stress of livestock and crops. Hot days are expected to dry soils and increase physiological stress for some plants and animals.



Modeled historical and future projected average number of hot days*(based on a high greenhouse gas scenario, relative to 1980-2009).* A "hot day" is one where the daily high temperature is in the top 1% of historical high temperatures for June through August. The historical hot day threshold is much larger in eastern Washington. The projected increase in hot days is also generally larger in eastern Washington, though the largest increases are in northern Puget Sound and a few locations on the coast. These coastal locations have temperature distributions that are more narrow and therefore more sensitive to warming relative to the hot day threshold. **Data Source:** MACAv2-METDATA[2] (*data available by request).*

River and Urban Flooding

Indicator: Extreme Precipitation

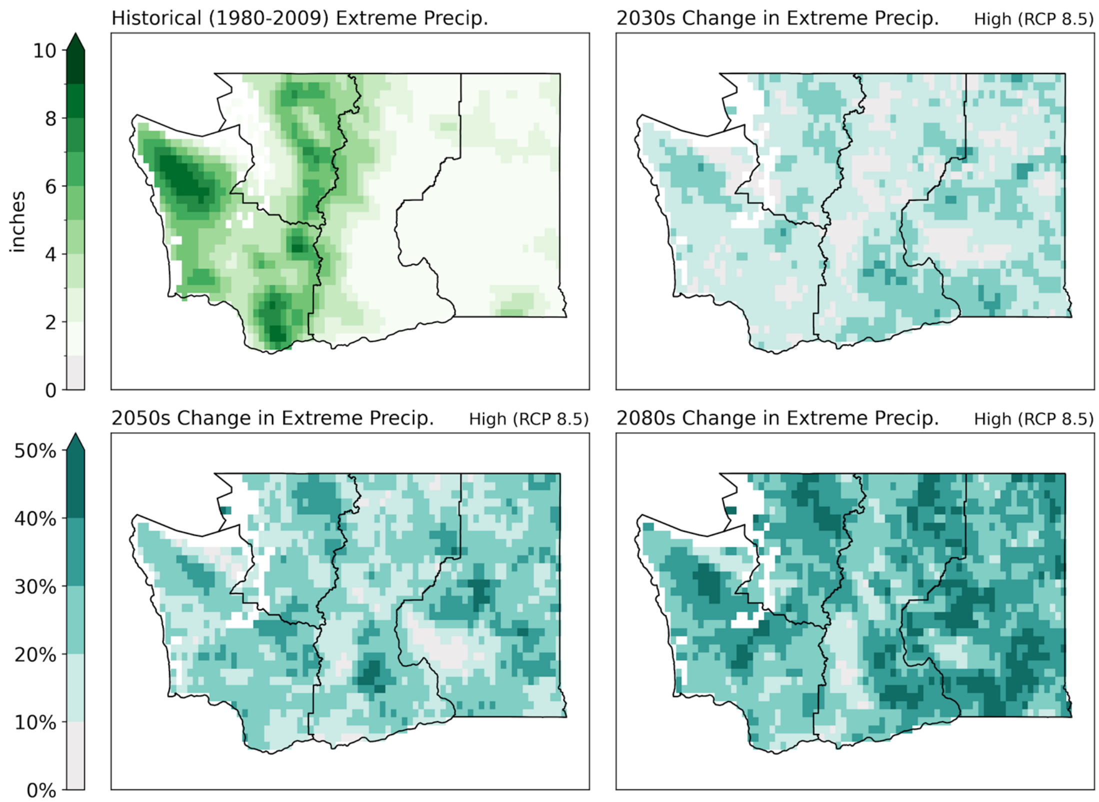
Washington Climate Projections

Historical Conditions and Observed Trend: The magnitude of extreme precipitation varies substantially across the state. In the Olympic and Cascade Mountains, extreme precipitation events exceed 8 inches in a 24-hour period. In eastern Washington, they rarely exceed 2 inches in a 24-hour period. **Due to high year-to-year variability, there is no significant observed trend.**

Projected Change: Extreme precipitation events are projected to become more intense for all of Washington. On average, models project about a 20% increase in the intensity of the biggest daily rain events each winter, by the 2080s.[3] *(More detail on the projections in the caption below.)*

Geographic Variability of Projected Change: Percentage changes are similar across the state. This means that **increases in precipitation totals are likely to be most pronounced in the western slopes of the Olympic and Cascade Mountains,** where extreme precipitation magnitudes are historically high.

Potential Impacts Without Adaptation: More extreme precipitation is expected to contribute to more flooding of infrastructure and communities, disrupting businesses, services and transportation routes. Extreme precipitation can also trigger landslides and increase erosion and sediment transport.



Modeled historical and future projected change in the magnitude of extreme precipitation events (based on a high greenhouse gas scenario, relative to 1980-2009). “Extreme precipitation” refers to the maximum 24-hour precipitation that occurs, on average, once every 25 years. The western slopes of the Olympic and Cascade Mountains have the largest precipitation totals. With climate change, extreme precipitation magnitude is expected to increase by roughly similar percentages across the state. Since precipitation varies a lot geographically, similar percent changes will result in larger precipitation increases for areas that are already wet. **Data Source:** PNW Regional WRF Projections[4]

River Flooding

Indicator: 2-year Flood

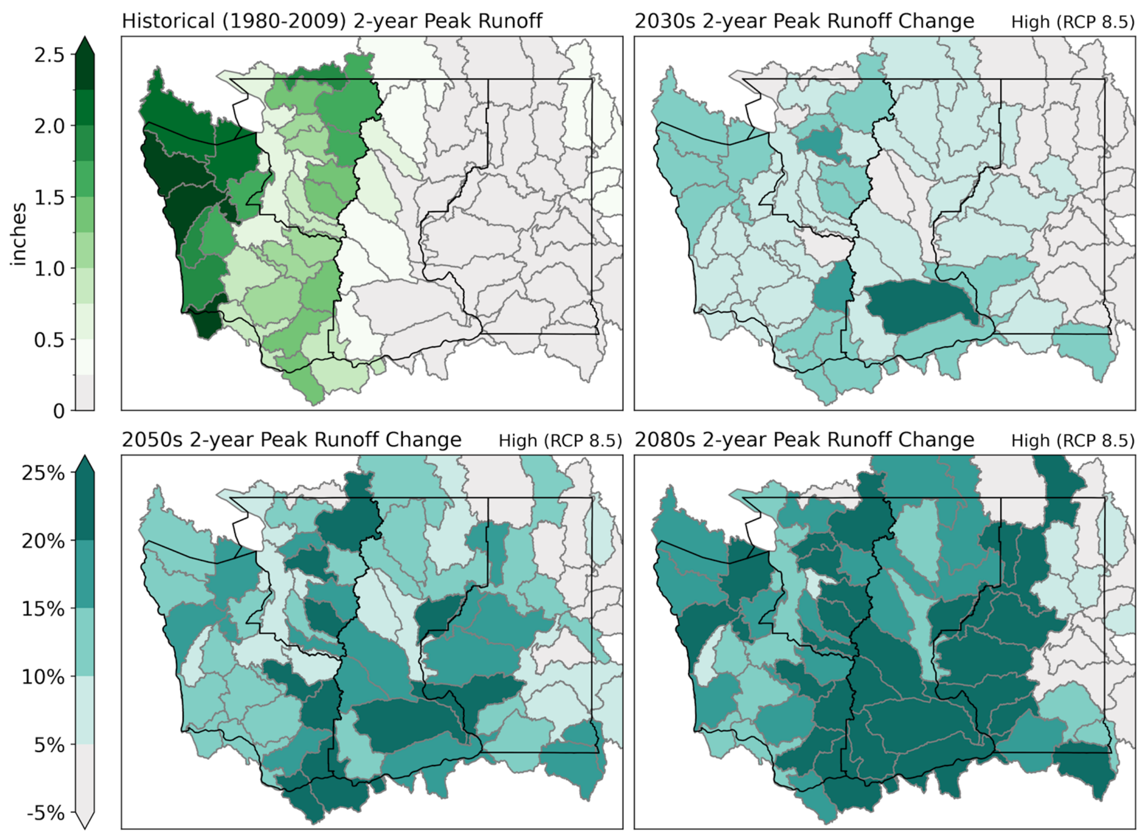
Washington Climate Projections

Historical Conditions and Observed Trend: The magnitude of the 2-year flood is greatest on the Olympic Peninsula, Pacific coast, and western Cascade Mountains due to more intense rainfall. **Given high year-to-year variability, there is no significant observed trend in the 2-year peak runoff.[5]**

Projected Change: The 2-year flood is projected to increase in magnitude for all of Washington. On average, models project a 14-15% increase in the 2-year flood, by the 2080s.[6] *(More detail on the projections in the caption below.)*

Geographic Variability of Projected Change: Percentage changes are greatest in the Olympic and Cascade Mountains, and in south central Washington. Similar percentage changes will result in larger magnitude increases in western Washington, where historical flows are largest.

Potential Impacts Without Adaptation: Larger peak flow events are expected to contribute to flooding and associated damage for communities, ecosystems, and infrastructure. Flooding is expected to be more frequent in areas that already flood and also reach new areas that have rarely flooded historically.



Modeled historical and future projected change in the magnitude of the 2 -year flood (based on a high greenhouse gas scenario, relative to 1980-2009). "Two-year flood" refers to the peak daily flow that occurs, on average, once every 2 years. These events are largest on the western slopes of the Cascade and Olympic Mountains. Projections show increases over much of Washington state, though similar percentage changes mean larger magnitude of increases for wetter parts of the state. **Data Source:** RMJOC-II Hydrologic Projections[6] (*data available by request*).

Snow Drought

Indicator: April 1 Snow Water Equivalent

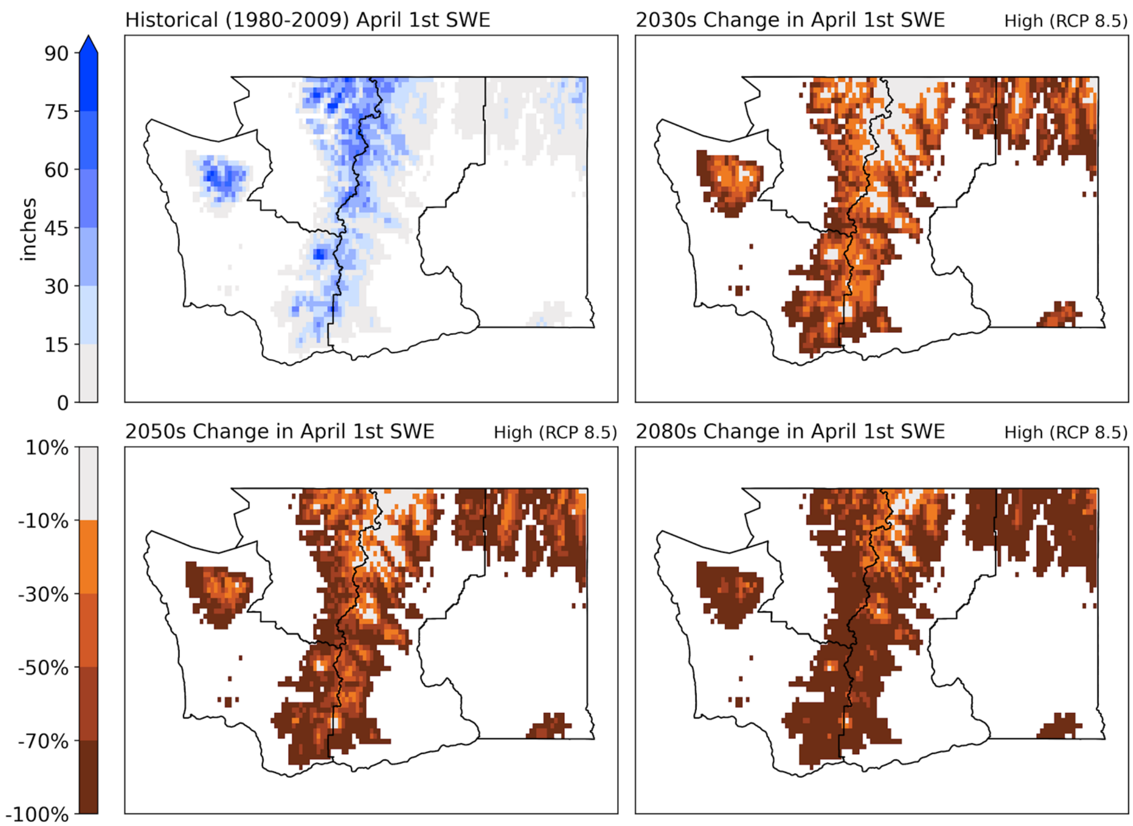
Washington Climate Projections

Historical Conditions and Observed Trend: Spring snowpack increases with elevation and latitude in the Olympic and Cascade Mountains. **Snowpack in the Cascade Mountains has decreased** by about 25% between the middle of the 20th century and 2006, with the largest decreases at low elevations.[7]

Projected Change: Declines in spring snowpack are projected to accelerate. Models project about a 40-60% decrease in spring snowpack, on average, by the 2080s.[6] *(More detail on the projections in the caption below.)*

Geographic Variability of Projected Change: Spring snowpack is projected to decrease substantially at lower and middle elevations, especially in southern latitudes and the Olympics. Only the highest elevations in the North Cascade Mountains will continue to have substantial spring snowpack.

Potential Impacts Without Adaptation: Declines in spring snowpack are expected to decrease water supply in summer and winter outdoor recreation opportunities with adverse effects on communities, ecosystems, and agriculture.



Modeled historical and future projected change in spring snowpack (based on a high greenhouse gas scenario, relative to 1980-2009). "Spring snowpack" refers to the Snow Water Equivalent (SWE; the amount of water stored in the snowpack) on April 1st. By the 2080s, only the highest elevations in the North Cascades are projected to maintain historical levels of spring snowpack. At mid- and low-elevations, April 1 SWE is projected to decline considerably. **Data Source:** RMJOC-II Hydrologic Projections[3] (*data available on request).*

Hydrologic Drought

Indicator: Late Summer (July-September) Runoff

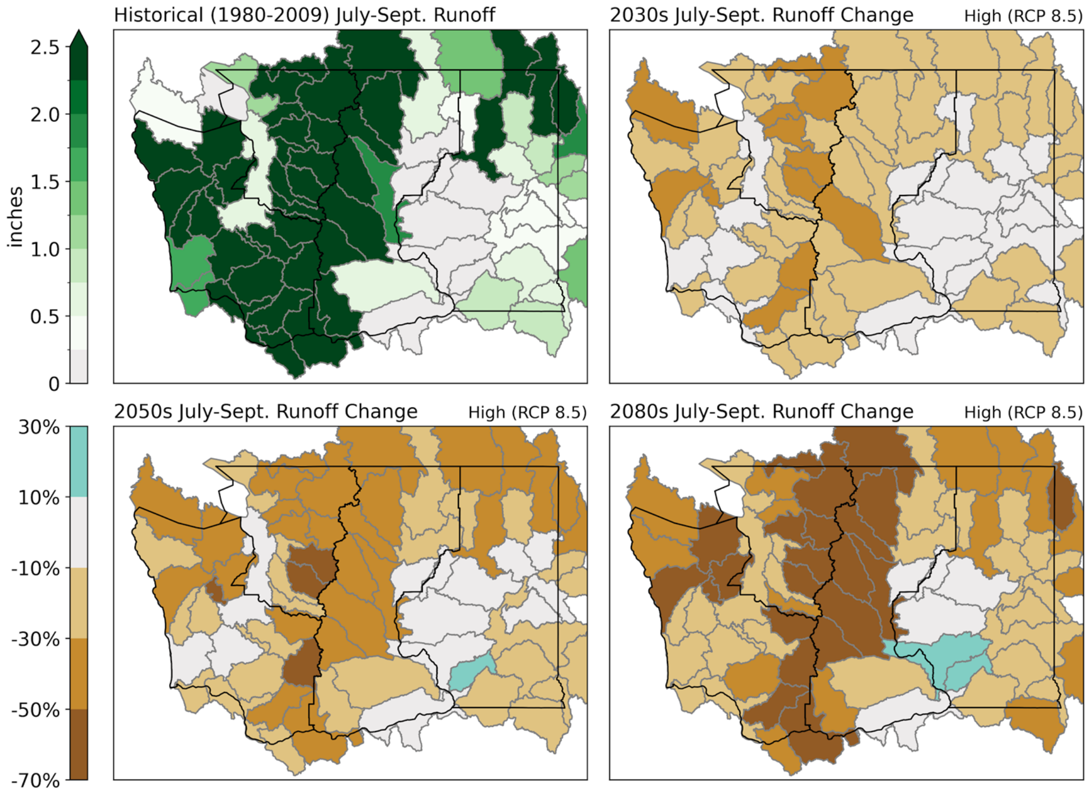
Washington Climate Projections

Historical Conditions and Observed Trend: The mountains and western Washington generally have more late summer runoff due to greater rainfall and cooler conditions. Most snow is melted by July, so the primary driver of late summer runoff is precipitation. **There is no significant observed trend in late summer runoff.**

Projected Change: Late summer runoff is projected to decrease for most of Washington. On average, models project a 7-14% decrease, by the 2080s.[6] *(More detail on the projections in the caption below.)*

Geographic Variability of Projected Change: Projected decreases in summer runoff are **largest in the Cascade and Olympic Mountains where precipitation is greatest and high elevations retain snowpack into early summer.** These changes may affect downstream low elevation areas with rivers that draw from the mountains, even if local decreases for these low-elevation areas are projected to be smaller. Areas in south central Washington are projected to have near zero change or even small increases in late summer runoff, likely associated with small increases in summer precipitation.

Potential Impacts Without Adaptation: Less runoff in summer will reduce water available for irrigation, residential and municipal use, streamflow, and ecosystems.



Modeled historical and future projected change in late summer runoff *(averaged for each 8-digit Hydrologic Unit Code, or HUC, based on a high greenhouse gas scenario, relative to 1980-2009).* "Late summer runoff" refers to average runoff for July-September. Historically the Cascade and Olympic Mountains have the most runoff in late summer. The largest decreases are projected for the mountains and western Washington. Although runoff is not projected to decrease as much at lower elevations, decreases in the upper watersheds will affect water availability in downstream low-elevation watersheds. **Data Source:** RMJOC-II Hydrologic Projections[6] (*data available by request*).

Coastal Flooding

Indicator: Sea Level Rise

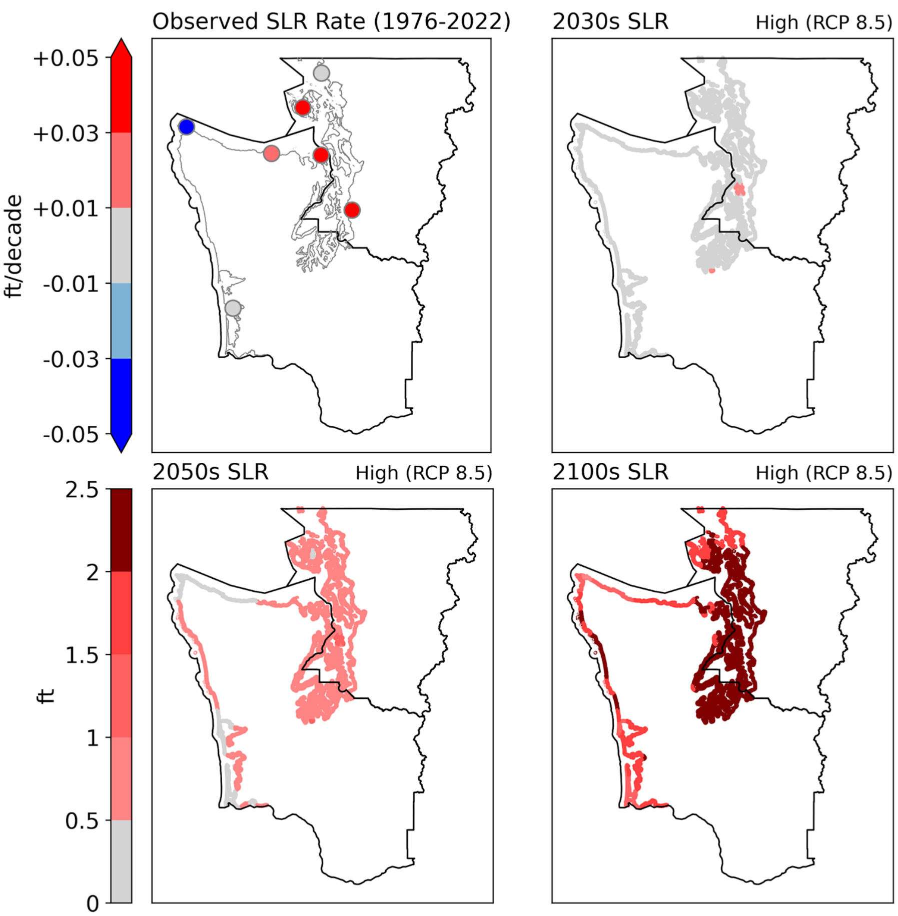
Washington Climate Projections

Historical Conditions and Observed Trend: Washington's coasts have experienced different rates of sea level rise due to the state's active geology. Although sea level has been rising for most of Washington's coastline, sea level is declining in a few locations on the Pacific coast where geologic factors are causing the land to rise faster than current rates of sea level rise. These geologic effects are minimal for the San Juan Islands, and **sea level rose over 4 inches at Friday Harbor between 1934 and 2018.[9]**

Projected Change: Sea level rise is projected to accelerate. By 2100, sea level is projected to rise about 1.5-2.5 ft, on average.[10] Projected changes are more than enough to overtake vertical land movement on the Pacific coast. *(More detail on the projections in the caption below.)*

Geographic Variability of Projected Change: Sea level rise is projected to be greatest in Puget Sound and parts of the Pacific coast. Natural variability in storm surge and waves will continue to contribute to coastal flooding in areas where these processes are substantial. Sea level rise will increase the reach of storm surge and waves, resulting in larger and more frequent floods.

Potential Impacts Without Adaptation: Coastal flooding of infrastructure and communities, and damage to coastal habitats that are adapted to specific tidal levels.



Observed historical and projected sea level rise. (Historical trend from 1976-2022 and projected future sea level rise, or SLR, with a 50% likelihood for 2100 relative to 2000, based on a high greenhouse gas scenario.) The Puget Sound region has experienced more SLR than elsewhere. The Pacific coast has experienced sea level decline due to uplift associated with the region's geology. Puget Sound is also projected to experience slightly more SLR than the surrounding regions. Future SLR more than outpaces high rates of uplift on the Pacific coast. SLR is the primary driver of future increases in coastal flooding, increasing the reach of storm surge and waves. **Data Source:** Projected Sea Level Rise for Washington State[10] (data available by request).

Wildfire and Smoke

Indicator: Likelihood of Wildfire Conditions

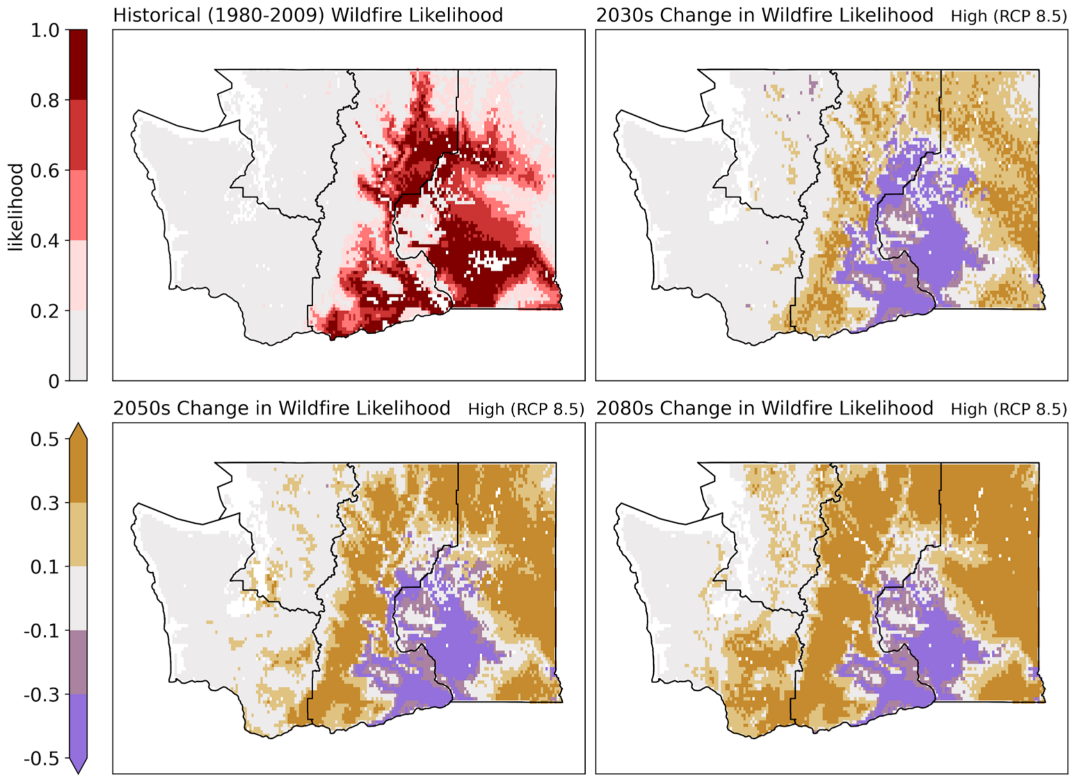
Washington Climate Projections

Historical Conditions and Observed Trend: The likelihood of fuel moisture and climate conditions conducive to wildfire are highest in the eastern Cascade Mountains and eastern Washington. Historically, the likelihood of wildfire conditions has been low in the Olympic Mountains, Puget Sound Region, Southwestern Washington, and western Cascade Mountains.

Projected Change: Fire risk is projected to increase for most of Washington. The likelihood of wildfire-favorable conditions is projected to increase for most of the state due to summer drying associated with snowpack loss and projected declines in summer precipitation.[11] *(more detail on the projections in the caption below)*.

Geographic Variability of Projected Change: Wildfire-favorable conditions are projected to increase in the central Cascade Mountains, southwestern Washington, and northeast Washington. The one exception is the Columbia Plateau, where wildfire-favorable conditions are projected to decrease, likely due to a combination of projected increases in precipitation and changes to vegetation.

Potential Impacts Without Adaptation: Increasing wildfire activity threatens infrastructure and communities, reduces air quality, and increases landslides and erosion in the subsequent wet seasons.



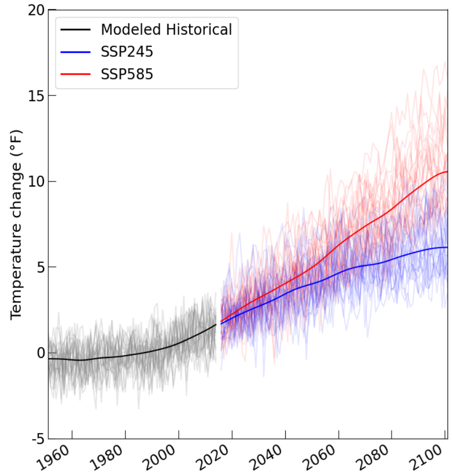
Modeled historical and projected change in the likelihood of wildfire conditions. *(Based on a high greenhouse gas scenario, relative to 1980-2009.)* "Likelihood of wildfire conditions" refers to the likelihood that a given year in each 30-year period will have instances when both vegetation and weather conditions are conducive to wildfire. High likelihoods of wildfire are historically confined to central and eastern Washington. With climate change, wildfire conditions are projected to become more likely at higher elevations in the Cascade Mountains and in southwestern Washington. Wildfire conditions are projected to become less likely in the Columbia Plateau. **Data Source:** Projected major fire and vegetation changes in the Pacific Northwest.[11]

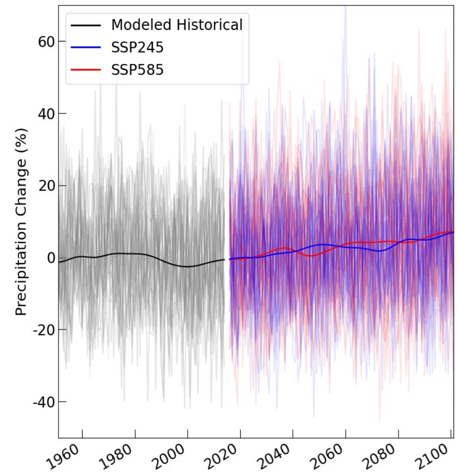
Washington State

Annual Temperature and Precipitation Projections

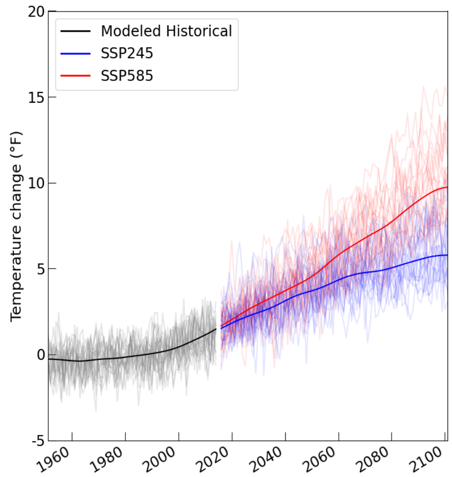
Average Annual Temperature | **Total Annual Precipitation**

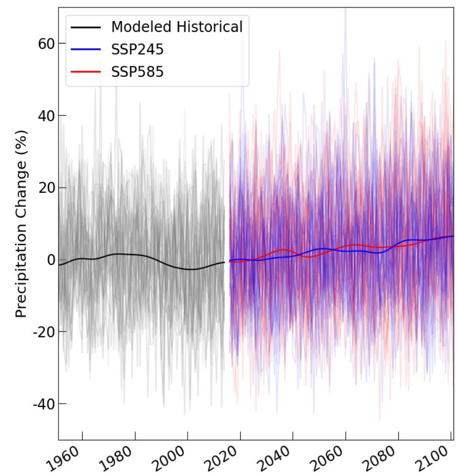
Washington State



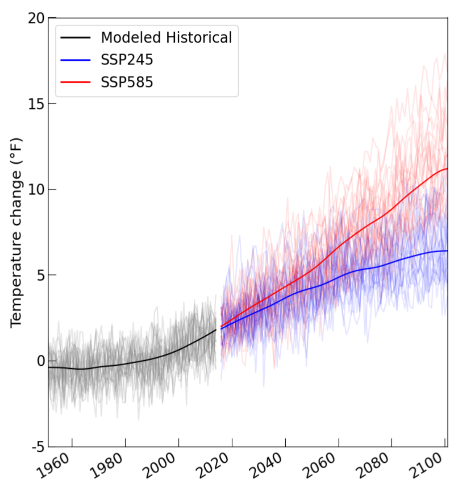


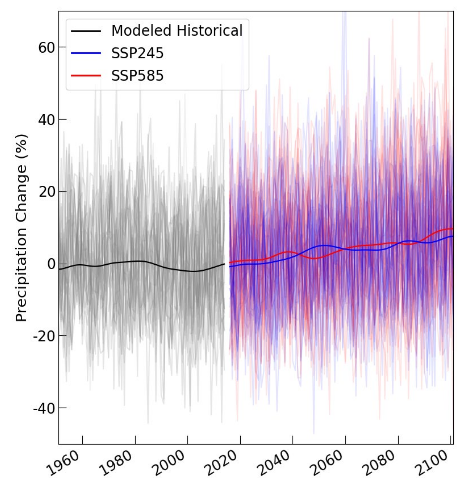
Western Washington





Eastern Washington





Modeled historical and projected change in average annual temperature and total annual precipitation for Washington State, western Washington, and eastern Washington**.** Thin lines are projections for individual climate models; bolded lines are the model median. For readability, the median lines are smoothed using an 11-year gaussian filter. All projections show temperature increases for Washington state, both east and west of the Cascades, with the high scenario (SSP585) projecting more warming than the low scenario (SSP245). The low and high scenario begin to diverge substantially around the year 2050. Though projections for annual precipitation suggest a slight increase throughout the next century, the changes are much smaller than year-to-year variability, and several models actually project a decrease. **Data Source:** LOCA2.[12] (data available by request).

Scenarios, References and Data Request

Climate Scenarios

All summaries of climate projections show changes for a high scenario of greenhouse gas emissions, RCP 8.5, a scenario for which greenhouse gas emissions continue to rise throughout the 21st century. A single scenario is shown in these summaries for simplicity. Results for lower scenarios show lower magnitudes of change, primarily after 2050 when future projections begin to diverge due to different greenhouse gas scenarios. Best practice when using climate projections is to view multiple scenarios and consider whether differences among the scenarios would affect the decision being made. Data for additional scenarios is available upon request.

With the release of the Fifth National Climate Assessment, updated projections of future temperature and precipitation are available for the United States. These updated projections are based on new scenarios of greenhouse gases and are shown in the annual temperature and precipitation projections for the 21st century. More information on these projections is available from the Fifth National Climate Assessment.

References

[1] Frankson, R., K.E. Kunkel, S.M. Champion, D.R. Easterling, L.E. Stevens, K. Bumbaco, N. Bond, J. Casola, and W. Sweet, 2022. Washington State Climate Summary 2022. NOAA Technical Report NESDIS 150-WA. NOAA/NESDIS, Silver Spring, MD, 5 pp. https://statesummaries.ncics.org/chapter/wa/

[2] Abatzoglou, J. T., & Brown, T. J. (2012). A comparison of statistical downscaling methods suited for wildfire applications. International journal of climatology, 32(5), 772-780. https://doi.org/10.1002/joc.2312

[3] Warner, M. D., Mass, C. F., & Salathé, E. P. (2015). Changes in winter atmospheric rivers along the North American west coast in CMIP5 climate models. Journal of Hydrometeorology, 16(1), 118-128. https://doi.org/10.1175/JHM-D-14-0080.1

[4] Mass, C. F., Salathé Jr, E. P., Steed, R., & Baars, J. (2022). The mesoscale response to global warming over the Pacific Northwest evaluated using a regional climate model ensemble. Journal of Climate, 35(6), 2035-2053. https://doi.org/10.1175/JCLI-D-21-0061.1

[5] Mastin, M. C., Konrad, C. P., Veilleux, A. G., & Tecca, A. E. (2016). Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014 (No. 2016-5118). US Geological Survey. https://doi.org/10.3133/sir20165118

[6] Chegwidden, O. S., Nijssen, B., Rupp, D. E., Arnold, J. R., Clark, M. P., Hamman, J. J., ... & Xiao, M. (2019). How do modeling decisions affect the spread among hydrologic climate change projections? Exploring a large ensemble of simulations across a diversity of hydroclimates. Earth's Future, 7(6), 623-637. https://doi.org/10.1029/2018EF001047

[7] Casola, J. H., Cuo, L., Livneh, B., Lettenmaier, D. P., Stoelinga, M. T., Mote, P. W., & Wallace, J. M. (2009). Assessing the impacts of global warming on snowpack in the Washington Cascades. Journal of Climate, 22(10), 2758-2772. https://doi.org/10.1175/2008JCLI2612.1

[8] Hegewisch, K.C. and Abatzoglou, J.T. (accessed 2024, July 12). 'Future Boxplots' web tool. Climate Toolbox. https://climatetoolbox.org/

[9] NOAA (National Oceanic and Atmospheric Administration). (accessed 2024, July 26). Relative Sea Level Trend; 944980 Friday Harbor, Washington. Tides and Currents. https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9449880

[10] Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E. 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. https://cig.uw.edu/projects/projected-sea-level-rise-for-washington-state-a-2018-assessment/

Scenarios, References and Data Request

References (continued)

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

[12] Pierce, D. W., Cayan, D. R., Feldman, D. R., & Risser, M. D. (2023). Future increases in North American extreme precipitation in CMIP6 downscaled with LOCA. Journal of Hydrometeorology, 24(5), 951-975. https://doi.org/10.1175/JHM-D-22-0194.1

For the data used to create these climate summaries, contact the Climate Impacts Group by completing this online data request and we will respond to your request.

Additional Resources

Snover, A.K., C.L. Raymond, H.A. Roop, H. Morgan, 2019. "No Time to Waste. The Intergovernmental Panel on Climate Change's Special Report on Global Warming of 1.5°C and Implications for Washington State." Briefing paper prepared by the Climate Impacts Group, University of Washington, Seattle. https://cig.uw.edu/projects/no-time-to-waste/

Snover, A.K, G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers. State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle.

Climate Mapping for a Resilient Washington