

## SECTION 5

# How is Pacific Northwest Climate Projected to Change?

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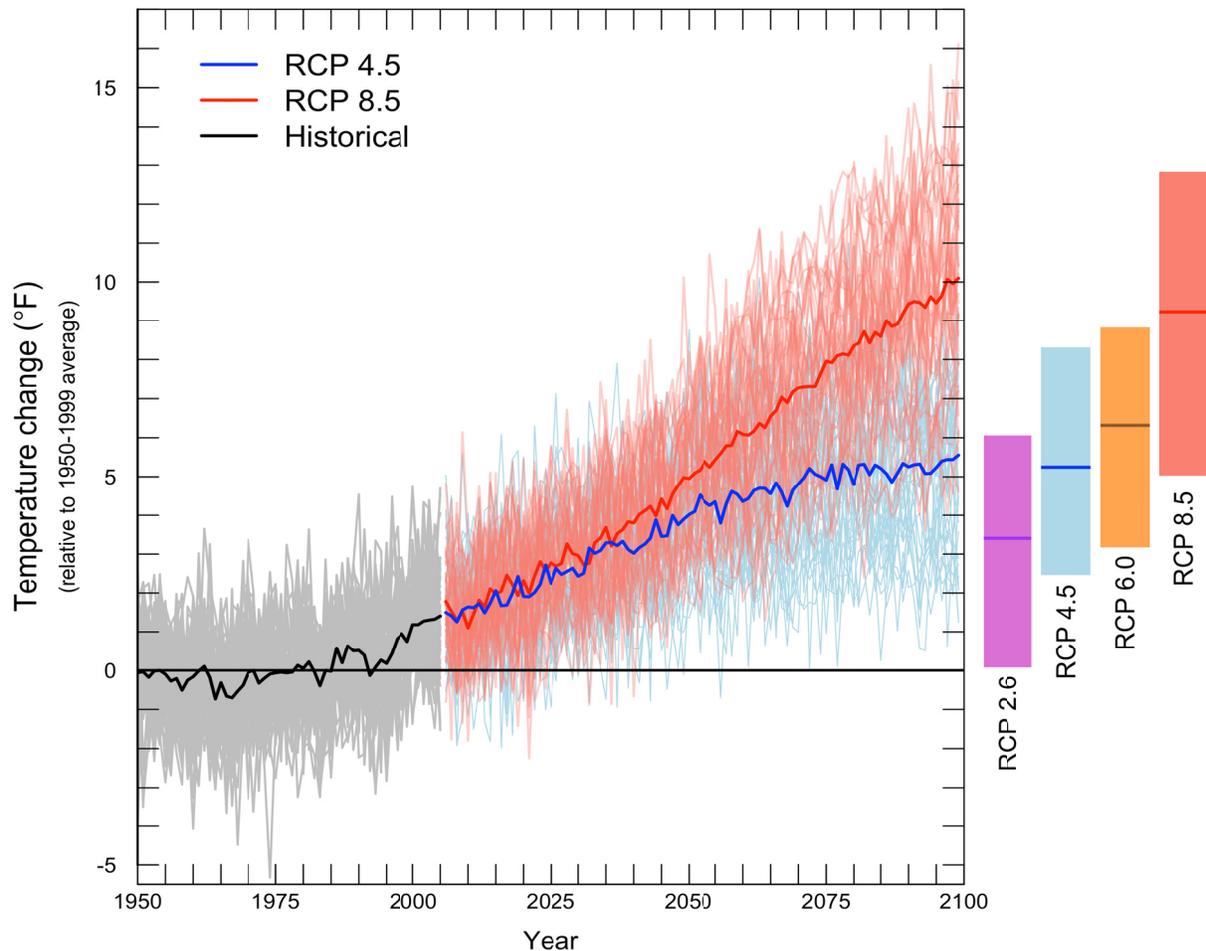
*Continued increases in average annual and seasonal Pacific Northwest temperatures are projected as a result of global warming, as well as increases in extreme heat. Projected changes in annual precipitation are small, although heavy rainfall events are projected to become more severe. Regionally, sea level will continue to rise in concert with global sea level. Locally, sea level is projected to rise in most locations, with the amount of rise varying by location and over time. Natural variability will continue to influence shorter-term (up to several decades) climate trends. New climate change projections are very similar to previous projections when similar greenhouse gas emissions are assumed.*

- 1. The Pacific Northwest is projected to warm rapidly during the 21<sup>st</sup> century, relative to 20<sup>th</sup> century average climate, as a result of greenhouse gases emitted from human activities.<sup>[A]</sup>** The actual amount of warming that occurs in the Pacific Northwest after about 2050 depends on the amount of greenhouse gases emitted globally in coming decades.<sup>[1]</sup>
  - *Continued rise in annual average temperature.* Warming is projected to continue throughout the 21<sup>st</sup> century (Figure 5-1). For the 2050s<sup>[B]</sup> relative to 1950-1999, temperature is projected to rise +5.8°F (range: +3.1 to +8.5°F) for a high greenhouse gas scenario (RCP8.5).<sup>[C][D]</sup> Much higher warming is possible after mid-century (Figure 5-1, Table 5-1).<sup>[1]</sup> Lower emissions of greenhouse gases will result in less warming.
  - *Warming is projected for all seasons.* The warming projected for summer is slightly larger than for other seasons.<sup>[1][2]</sup>
  - *More extreme heat.* There is strong agreement among climate models that extreme heat events will become more frequent while extreme cold events will become less frequent.<sup>[1]</sup>
  - *Ongoing variability.* Natural variability will remain an important feature of global and regional climate, at times amplifying or counteracting the long-term trends caused by rising greenhouse gas emissions. Important modes of natural variability for the Pacific Northwest include the El Niño/Southern Oscillation (i.e., El Niño and La Niña) and the Pacific Decadal Oscillation.
  - *The size of projected change is large compared to observed variability.* The Pacific Northwest is likely to regularly experience average annual temperatures by mid-century that exceed what was observed in the 20th century.<sup>[E][1]</sup>

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<sup>A</sup> Many characteristics of Washington’s climate and climate vulnerabilities are similar to those of the broader Pacific Northwest region. Results for Washington State are therefore expected to generally align with those provided for the Pacific Northwest, with potential for some variation at any specific location.

<sup>B</sup> Specifically, “2050s” refers to the 30-year average spanning from 2041 to 2070. Note that this section focuses on changes for the 2050s, because this is the only time period for which there are published results for the Pacific Northwest from the 2013 IPCC<sup>[2]</sup> projections.



**Figure 5-1.** All scenarios project warming for the 21<sup>st</sup> century. The graph shows average yearly temperatures for the Pacific Northwest relative to the average for 1950-1999 (gray horizontal line). The black line shows the average simulated temperature for 1950–2011, while the grey lines show individual model results for the same time period. Thin colored lines show individual model projections for two emissions scenarios (low: RCP 4.5, and high: RCP 8.5 – see Section 3 for details), and thick colored lines show the average among models projections for each scenario. Bars to the right of the plot show the mean, minimum, and maximum change projected for each of the four emissions scenarios for 2081-2100, ranging from a very low (RCP 2.6) to a high (RCP 8.5) scenario. Note that the bars are lower than the endpoints from the graph, because they represent the average for the final two decades of the century, rather than the final value at 2100. *Figure source: Climate Impacts Group, based on climate projections used in the IPCC 2013 report.*<sup>[2]</sup>

<sup>C</sup> Greenhouse gas scenarios were developed by climate modeling centers for use in modeling global and regional climate impacts. These are described in the text as follows: "very low" refers to the RCP 2.6 scenario; "low" refers to RCP 4.5 or SRES B1; "medium" refers to RCP 6.0 or SRES A1B; and "high" refers to RCP 8.5, SRES A2, or SRES A1FI – descriptors are based on cumulative emissions by 2100 for each scenario. See Section 3 for details.

<sup>D</sup> Scenarios used in this report range from a low (RCP 4.5) to a high (RCP 8.5) greenhouse gas scenario (both of which are used in the recent IPCC report,<sup>[2]</sup> see Section 3). The implications of the lowest greenhouse gas scenario – RCP 2.6, which assumes aggressive reductions in emissions – are not discussed in the text of this section

## 2. Changes in annual and seasonal precipitation will continue to be primarily driven by year-to-year variations rather than long-term trends, but heavy rainfall events are projected to become more severe.

- *Small changes in annual precipitation.* Projected changes in total annual precipitation are small (relative to variability)<sup>[F]</sup> and show increases or decreases depending on models, which project a change of -4% to +14% for the 2050s<sup>[D]</sup> (relative to 1950-1999).<sup>[1]</sup>
- *Seasonal changes in precipitation are mixed.* Most models project drier summers, with an average model projection of -6% to -8% for the 2050s for a low and a high greenhouse gas scenario, respectively (2041-2070, relative to 1950-1999).<sup>[D][G][2]</sup> Some individual model projections show as much as a -30% decrease in summer precipitation. A majority of models project increases in winter, spring, and fall precipitation for this same time period, ranging from +2 to +7%, on average.<sup>[1]</sup>
- *Increasing precipitation extremes.* Heavy rainfall events are projected to become more severe by mid-century. Specifically, the number of days with more than 1 inch of rain is projected to increase by +13% ( $\pm 7\%$ ) for the 2050s (relative to 1971-2000) for a high greenhouse gas scenario.<sup>[H][3]</sup>
- *Size of projected change is smaller than observed variability.* Projected changes in annual and seasonal precipitation are generally small – throughout the 21<sup>st</sup> century – compared to the range of precipitation caused by natural variability. In addition, projected changes are not consistent for all scenarios: some models project increases while others project decreases.<sup>[1]</sup>

## 3. Washington's coast will be affected by sea level rise, warmer ocean temperatures, and changing ocean chemistry.

- *Coastal areas in Washington will experience sea level rise, although some areas may continue to experience decreases due to trends in vertical land movement.* According to a recent report by the National Research Council, sea level is projected to rise an additional +4 to +56 inches in Washington by 2100 (relative to 2000).<sup>[4]</sup> Locally, however, sea level will increase by different amounts in different places. Previous research projects a decline

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because there are no published projections for the Pacific Northwest based on this scenario. In order to illustrate the full range of projections, Figures 5-1 and 5-2 nonetheless show results from the very low (RCP 2.6) greenhouse gas scenario, among other scenarios ranging up to the highest (RCP 8.5) scenario.

<sup>E</sup> Specifically, all scenarios project that, by mid-century (2041-2070), annual temperatures will be warmer than the warmest year historically (1950-1999).

<sup>F</sup> Year-to-year variations in precipitation are about  $\pm 10$  to 15%, on average.

<sup>G</sup> The RCP 4.5 (low) and RCP 8.5 (high) greenhouse gas scenarios (see Section 3 for more details).

<sup>H</sup> Projection based on regional climate model simulations, from the North American Regional Climate Change Program (NARCCAP) multi-model ensemble (<http://www.narccap.ucar.edu>). These simulations are based on results from 6 different regional models driven by 4 different global model projections, all based on the A2 greenhouse gas scenario, which is slightly lower than the RCP 8.5 scenario used in IPCC 2013. Values denote the average and the standard deviation among model projections. Results are averaged over a large area and may not be applicable to a given locale in Washington State.

in sea level for the northwest Olympic Peninsula through 2100, for scenarios that assume very low rates of global sea level rise and high rates of vertical uplift.<sup>[5][6]</sup> These projections differ from the NRC projections due to different study approaches. Although most global projections would result in sea level rise for the northwest Olympic Peninsula, it is not yet possible to conclusively rule out a decline in sea level for that region.

- *Short-term sea level variations can temporarily offset or accelerate trends.* Sea level can be temporarily elevated or depressed by up to a foot in winter as a result of natural periodic cycles in climate patterns such as El Niño and the Pacific Decadal Oscillation.<sup>[4]</sup> This variability will continue in the future.
- *Coastal ocean temperatures are projected to increase.* Ocean surface temperatures offshore of Washington are projected to rise by about +2°F by the 2040s (2030-2059, relative to 1970-1999) for a medium greenhouse gas scenario.<sup>[1][7]</sup> Projected changes in winter sea surface temperatures in the North Pacific are expected to be as large as the range of natural variability by 2030-2050 (relative to 1950-1999) under a medium greenhouse gas scenario.<sup>[3][8]</sup> However, coastal ocean temperatures are strongly affected by coastal upwelling of colder water from ocean depths, and by large scale climate variability such as El Niño – current research is unclear as to how these might be altered by climate change.
- *Acidification of Washington’s marine waters is projected to continue.* The acidity of Washington’s coastal waters is projected to increase due to increases in global ocean acidity (+38 to +109%<sup>[K]</sup> by 2100 relative to 1986-2005,<sup>[2]</sup> or roughly +150 to +200% relative to pre-industrial levels)<sup>[9]</sup>. Local conditions are also affected by seasonal upwelling of deeper Pacific Ocean water that is low in pH and high in nutrients, transport of nutrients and organic carbon from land, and oceanic absorption of other acidifying atmospheric gases.

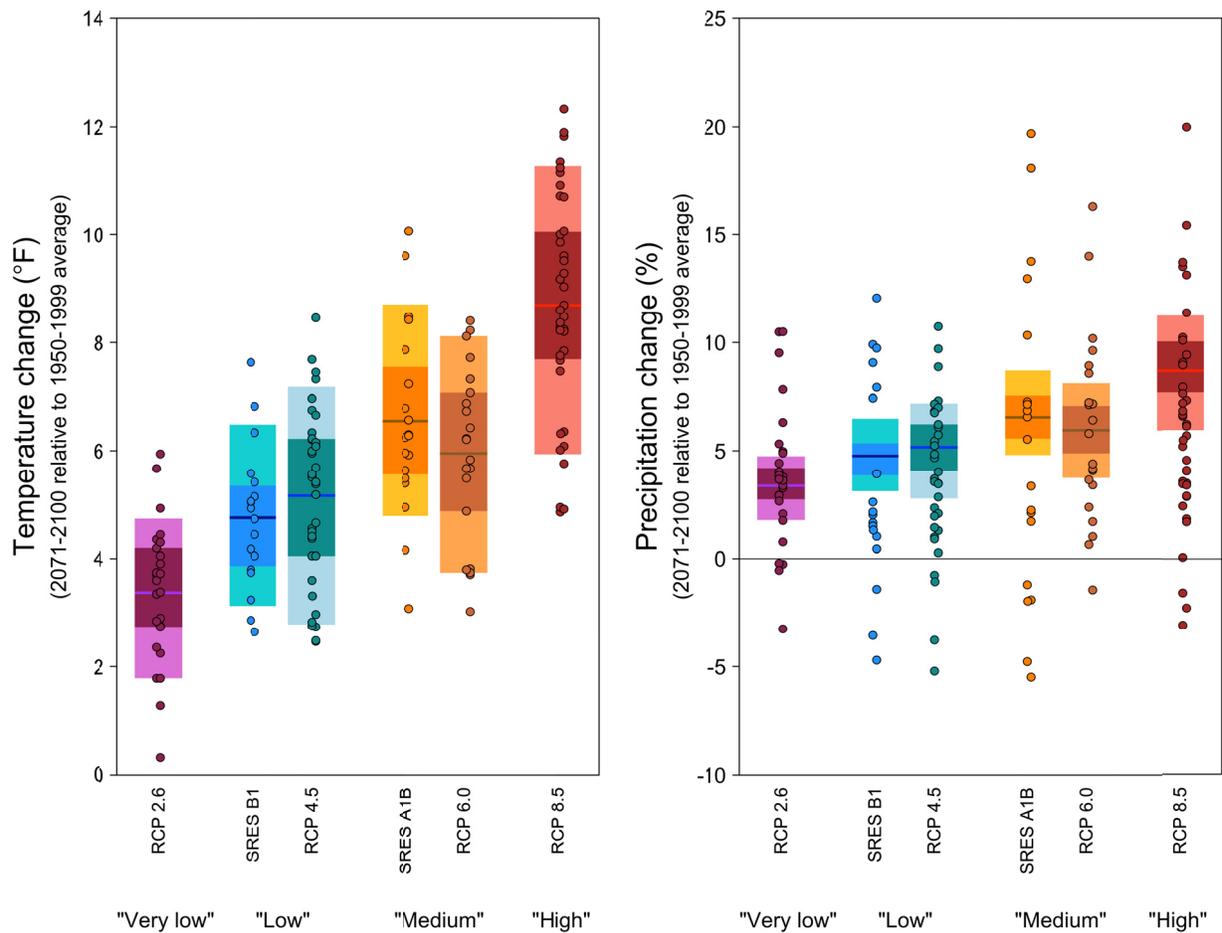
#### **4. The new climate projections<sup>[1]</sup> are very similar to the climate projections from 2007<sup>[7]</sup> when similar rates of greenhouse gas emissions are assumed.**

- *Projected Pacific Northwest climate change is similar for new (IPCC 2013)<sup>[2]</sup> and old (IPCC 2007)<sup>[10]</sup> scenarios of medium and low greenhouse gas emissions.<sup>[C]</sup>* The Washington Climate Change Impacts Assessment (WACCIA)<sup>[11]</sup> and many regional climate impact studies largely used the A1B and B1 greenhouse gas scenarios. These are comparable to RCP 6.0 and RCP 4.5, respectively, at the end of the century, in terms of both greenhouse gas concentrations (see Section 3) and resultant changes in NW climate (Figure 5-2).

<sup>I</sup> The A1B greenhouse gas scenario. See Section 3 for more details about scenarios.

<sup>J</sup> Based on analyses of 10 global climate models and the A1B greenhouse gas scenario.

<sup>K</sup> Although the acidity of the ocean is projected to increase, the ocean itself is not expected to become acidic (i.e., drop below pH 7.0). Global ocean pH has decreased from 8.2 to 8.1 (a 26% increase in hydrogen ion concentration, which is what determines a liquid's acidity) and is projected to fall to 7.8-7.9 by 2100. The term “ocean acidification” refers to this shift in pH towards the acidic end of the pH scale.



**Figure 5-2.** Differences among climate change projections for the Pacific Northwest are primarily due to differences among greenhouse gas scenarios. Projected changes in average annual temperature (left) and precipitation (right) for the Pacific Northwest for the 2080s (2071-2100, relative to 1950-1999). Projections are shown for all four new scenarios: RCP 2.6 (“very low”), 4.5 (“low”), 6.0 (“medium”), and 8.5 (“high”), along with the older projections based on the B1 (“low”) and A1B (“medium”) scenarios used in many Pacific Northwest impacts assessments. Individual climate model projections for each scenario are shown using colored dots. Boxes show the average projected change (in °F for temperature and percent change for precipitation), along with the 10<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup>, and 90<sup>th</sup> percentile values among all climate model projections. The black horizontal line on the precipitation graph denotes zero change. *Figure source: Climate Impacts Group, based on climate projections used in the IPCC 2013 report.<sup>[2]</sup> and figures 2.5b and 2.6 of Mote et al., 2013.<sup>[1]</sup>*

- *Newer scenarios for very low and high greenhouse gas emissions result in a wider range among late-century warming projections for the Pacific Northwest.* Previous regional assessments have typically considered a narrower range of greenhouse gas scenarios.
  - The new scenarios include an aggressive mitigation scenario (RCP 2.6), which would require about a 50% reduction in global emissions by 2050 relative to 1990 levels and near or below zero net emissions in the final decades of the 21<sup>st</sup> century. The older projections do not include a comparable scenario.
  - The highest scenarios commonly used in previous climate impacts assessments (A1B, A2) are much lower than the high-end scenario in the new projections (RCP 8.5).
- *The importance of differences between the old and new climate change projections will depend on the specific impact under consideration and the sensitivity of the decision being made.* For example, projected changes in annual average precipitation are likely to differ by less than 1°F under similar greenhouse gas scenarios from IPCC 2007 and 2013, while projected changes in annual average precipitation are likely to differ by only a few percentage points (Figure 5-2). Other differences between the scenarios have not yet been explored.

*For more details on projected changes in Pacific Northwest climate, see Table 5-1 at the end of this section. See next page for additional resources for evaluating regional climate change projections.*

***Additional Resources for Evaluating Regional Climate Change Projections***

The following resources provide location-specific information about climate change impacts to support identification and reduction of risks associated with a changing climate. Some resources are designed so that any user can easily browse, view, and download products; others assume more technical knowledge.

- **Climate and hydrologic scenarios.** The Climate Impacts Group provides downscaled daily historical data and future projections of temperature, precipitation, snowpack, streamflow, flooding, minimum flows, and other important hydrologic variables for all watersheds and 112 specific streamflow locations in Washington State, as well as for locations throughout the Columbia River basin and the western US. These are based on projections in IPCC 2007.<sup>[10]</sup> <http://warm.atmos.washington.edu/2860>,<sup>[11]</sup> <http://cses.washington.edu/cig/>.
- **Climate scenarios for the Western U.S.** This dataset provides future projections of daily temperature, precipitation, humidity, insolation and wind at a spatial resolution of about 2.5 miles, using new statistical downscaling methods and the new climate projections included in IPCC 2013.<sup>[2][11]</sup> <http://nimbus.cos.uidaho.edu/MACA/>
- **Fine scale climate scenarios for the lower 48 states.** Produced by NASA, this dataset provides future projections of monthly temperature and precipitation at a spatial resolution of about half a mile, using updated statistical downscaling methods and the new climate projections included in IPCC 2013.<sup>[2][13]</sup> [https://portal.nccs.nasa.gov/portal\\_home/published/NEX.html](https://portal.nccs.nasa.gov/portal_home/published/NEX.html)
- **Regional climate model projections for the Pacific Northwest.** Dynamically downscaled data are being developed at the Climate Impacts Group based on projections from both IPCC 2007<sup>[10]</sup> and 2013.<sup>[2]</sup> The data are produced using regional climate model simulations over the state of Washington and surrounding region, at a spatial resolution of about 9 miles. Among other advantages, these data are more accurate for projecting changes in extremes.<sup>[14][15]</sup>
- **Regional climate model projections for the Western U.S.** This dataset includes a large ensemble of regional climate model projections, based on a high greenhouse gas scenario (A2). Simulations are archived for numerous different regional and global climate models, all at a spatial resolution of about 30 miles. These are based on projections in IPCC 2007.<sup>[10]</sup> <http://narccap.ucar.edu/>

**Table 5-1.** Projected changes in the climate of Washington and the Pacific Northwest.

| <i>Variable</i>                  | <i>Projected Long-term Change</i>   |  |   |   |                    |   |   |                      |   |   |               |   |  |
|----------------------------------|---|--|---|---|--------------------|---|---|----------------------|---|---|---------------|---|--|
| <b>Temperature</b>               |   |  |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Annual</i>                    | <p>Warming</p> <ul style="list-style-type: none"> <li>▪ Warming projected for <i>all</i> greenhouse gas scenarios; amount of warming depends on the amount of greenhouse gases emitted.</li> <li>▪ Projected change in Pacific Northwest<sup>[A]</sup> average annual temperature for the 2050s (2041-2070),<sup>[B]</sup> relative to the average for 1950-1999: <ul style="list-style-type: none"> <li>Low emissions (RCP 4.5): +4.3°F (range: 2.0 to 6.7°F)</li> <li>High emissions (RCP 8.5): +5.8°F (range 3.1 to 8.5°F)<sup>[D][1]</sup></li> </ul> </li> </ul>   |  |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Seasonal</i>                  | <p>Warming in all seasons for 2041-2070, relative to 1950-1999:</p> <table border="0"> <tr> <td><i>Winter</i></td> <td>Low emissions (RCP 4.5): +4.5°F (range: 1.6 to 7.2°F)</td> <td>High emissions (RCP 8.5): +5.8°F (range 2.3 to 9.2°F)</td> </tr> <tr> <td><i>Spring</i></td> <td>Low emissions (RCP 4.5): +4.3°F (range: 0.9 to 7.4°F)</td> <td>High emissions (RCP 8.5): +5.4°F (range 1.8 to 8.3°F)</td> </tr> <tr> <td><i>Summer</i></td> <td>Low emissions (RCP 4.5): +4.7°F (range: 2.3 to 7.4°F)</td> <td>High emissions (RCP 8.5): +6.5°F (range 3.4 to 9.4°F)</td> </tr> <tr> <td><i>Fall</i></td> <td>Low emissions (RCP 4.5): +4.0°F (range: 1.4 to 5.8°F)</td> <td>High emissions (RCP 8.5): +5.6°F (range 2.9 to 8.3°F)<sup>[1]</sup></td> </tr> </table>                 | <i>Winter</i>  | Low emissions (RCP 4.5): +4.5°F (range: 1.6 to 7.2°F) | High emissions (RCP 8.5): +5.8°F (range 2.3 to 9.2°F) | <i>Spring</i>      | Low emissions (RCP 4.5): +4.3°F (range: 0.9 to 7.4°F) | High emissions (RCP 8.5): +5.4°F (range 1.8 to 8.3°F) | <i>Summer</i>        | Low emissions (RCP 4.5): +4.7°F (range: 2.3 to 7.4°F) | High emissions (RCP 8.5): +6.5°F (range 3.4 to 9.4°F) | <i>Fall</i>   | Low emissions (RCP 4.5): +4.0°F (range: 1.4 to 5.8°F) | High emissions (RCP 8.5): +5.6°F (range 2.9 to 8.3°F) <sup>[1]</sup> |
| <i>Winter</i>                    | Low emissions (RCP 4.5): +4.5°F (range: 1.6 to 7.2°F)   | High emissions (RCP 8.5): +5.8°F (range 2.3 to 9.2°F)                |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Spring</i>                    | Low emissions (RCP 4.5): +4.3°F (range: 0.9 to 7.4°F)   | High emissions (RCP 8.5): +5.4°F (range 1.8 to 8.3°F)                |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Summer</i>                    | Low emissions (RCP 4.5): +4.7°F (range: 2.3 to 7.4°F)   | High emissions (RCP 8.5): +6.5°F (range 3.4 to 9.4°F)                |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Fall</i>                      | Low emissions (RCP 4.5): +4.0°F (range: 1.4 to 5.8°F)   | High emissions (RCP 8.5): +5.6°F (range 2.9 to 8.3°F) <sup>[1]</sup> |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Geography of Change</i>       | <p>Overall, warming is expected to be fairly uniform across Washington State. However, there is slightly greater warming projected for the interior – east of the Cascade range.<sup>[1]</sup></p>  |  |   |   |                    |   |   |                      |   |   |               |   |  |
| <i>Extremes</i>                  | <p>More frequent extreme heat events and less frequent extreme cold events</p> <ul style="list-style-type: none"> <li>▪ Projected changes in Pacific Northwest annual temperature extremes for 2041-2070, relative to 1971-2000, for a high greenhouse gas scenario.<sup>[L][3]</sup> <table border="0"> <tr> <td>Length of freeze-free period:</td> <td>+35 days (± 6 days)</td> </tr> <tr> <td>Number of days above 90°F:</td> <td>+8 days (± 7 days)</td> </tr> <tr> <td>Number of nights below 10°F:</td> <td>-8 days (± 5 days)</td> </tr> <tr> <td>Heating degree days:</td> <td>-15% (± 2%)<sup>[M]</sup></td> </tr> <tr> <td>Cooling degree days:</td> <td>+105% (± 98%)</td> </tr> <tr> <td>Growing degree days (base 50°F):</td> <td>+51% (± 14%)</td> </tr> </table> </li> </ul> | Length of freeze-free period:  | +35 days (± 6 days)                                   | Number of days above 90°F:                            | +8 days (± 7 days) | Number of nights below 10°F:                          | -8 days (± 5 days)                                    | Heating degree days: | -15% (± 2%) <sup>[M]</sup>                            | Cooling degree days:                                  | +105% (± 98%) | Growing degree days (base 50°F):                      | +51% (± 14%)   |
| Length of freeze-free period:    | +35 days (± 6 days)   |  |   |   |                    |   |   |                      |   |   |               |   |  |
| Number of days above 90°F:       | +8 days (± 7 days)  |  |   |   |                    |   |   |                      |   |   |               |   |  |
| Number of nights below 10°F:     | -8 days (± 5 days)  |  |   |   |                    |   |   |                      |   |   |               |   |  |
| Heating degree days:             | -15% (± 2%) <sup>[M]</sup>  |  |   |   |                    |   |   |                      |   |   |               |   |  |
| Cooling degree days:             | +105% (± 98%)   |  |   |   |                    |   |   |                      |   |   |               |   |  |
| Growing degree days (base 50°F): | +51% (± 14%)  |  |   |   |                    |   |   |                      |   |   |               |   |  |

<sup>L</sup> Projection based on regional climate model simulations under a high greenhouse gas scenario (A2).<sup>[H]</sup>

<sup>M</sup> Cooling and heating degree days are measurements used in energy markets to estimate demand. In the United States, a cooling degree day is counted for each degree the average temperature for a day moves above 75°F. For example, if the average temperature for the day was 80°F, that would count as 5 cooling degree days. One heating degree day is counted for each degree that average daily temperature falls below 65°F.

| <i>Variable</i>            | <i>Projected Long-term Change</i>  |
|----------------------------|--|
| <b>Precipitation</b>       |  |
| <i>Annual</i>              | <p>Small changes</p> <ul style="list-style-type: none"> <li>Annual changes for all models are small relative to year-to-year variability.</li> <li>For all greenhouse gas scenarios, some models project wetter conditions while others project drier conditions.</li> <li>Projected change in annual Pacific Northwest precipitation for the 2050s (2041-2070,<sup>[B]</sup> relative to 1950-1999): <ul style="list-style-type: none"> <li>Low emissions (RCP 4.5): -4.3 to +10.1%</li> <li>High emissions (RCP 8.5): -4.7 to +13.5%<sup>[D][1]</sup></li> </ul> </li> </ul>   |
| <i>Seasonal</i>            | <p>Projected changes vary seasonally.</p> <ul style="list-style-type: none"> <li>A majority of models project increases in winter, spring, and fall precipitation for the Pacific Northwest for mid-century, as well as decreasing summer precipitation.</li> <li>For all scenarios and seasons, some models project wetter conditions while others project drier conditions.</li> <li>Projected summer drying is more consistent among models. Some models project more than a 30% decrease in summer precipitation for the 2050s (2041-2070, relative to 1950-1999), although the average projected change for summer is notably smaller: -6 to -8% for a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario, respectively.<sup>[1]</sup></li> </ul> |
| <i>Geography of Change</i> | Changes in precipitation are expected to be different from place to place.   |
| <i>Heavy Precipitation</i> | <p>Increasing</p> <ul style="list-style-type: none"> <li>Heavy rainfall events are expected to occur more frequently.</li> <li>Projected changes in Pacific Northwest precipitation extremes for 2041-2070, (relative to 1971-2000) for a high greenhouse gas scenario:<sup>[H][3]</sup> <ul style="list-style-type: none"> <li>Number of days with rain &gt; 1 inch: +13% (±7%)</li> <li>Number of days with rain &gt; 3 inches: +22% (±22%)</li> </ul> </li> </ul>   |
| <b>Oceans</b>              |  |
| <i>Ocean Temperature</i>   | <p>Warming</p> <ul style="list-style-type: none"> <li>Ocean surface temperatures off the coast of Washington<sup>[N]</sup> are projected to warm by +2.2°F by the 2040s (2030-2059, relative to 1970-1999).<sup>[4]</sup></li> <li>Projections of coastal ocean temperatures are unclear due to limited understanding of changes in coastal upwelling and the large influence of natural variability.</li> </ul>   |
| <i>Sea Level Change</i>    | <p>Rising in general, although considerable variations from location to location due to different rates of subsidence or uplift of land areas.</p> <ul style="list-style-type: none"> <li>Regionally, sea level is projected to rise substantially under all</li> </ul>  |

<sup>N</sup> Projected change in sea surface temperature for model grid points near the coast between 46° and 49°N.

| Variable                   | Projected Long-term Change  |
|----------------------------|---|
|                            | <p>greenhouse gas scenarios. Locally, however, sea level can rise or fall relative to land due to vertical uplift of land surfaces, primarily as a consequence of the high tectonic activity of the Pacific Northwest.</p> <ul style="list-style-type: none"> <li>▪ Projected sea level rise (for 2100 relative to 2000): <ul style="list-style-type: none"> <li>Seattle, WA: +4 to +56 inches</li> <li>Newport, OR: +5 to +56 inches<sup>[O][4]</sup></li> </ul> </li> </ul> |
| <i>Ocean Acidification</i> | <p>Increasing acidity</p> <ul style="list-style-type: none"> <li>▪ Regionally, coastal ocean acidity is projected to increase in tandem with global ocean acidification (see Section 4).<sup>[2]</sup></li> </ul>   |

- [1] Mote, P. W. et al., 2013. Climate: Variability and Change in the Past and the Future. Chapter 2, 25-40, in M.M. Dalton, P.W. Mote, and A.K. Snover (eds.) *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*, Washington D.C.: Island Press.
- [2] (IPCC) Intergovernmental Panel on Climate Change. 2013. *Working Group I, Summary for Policymakers*. Available at: [http://www.climatechange2013.org/images/uploads/WGIAR5-SPM\\_Approved27Sep2013.pdf](http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf)
- [3] Kunkel, K. E. et al., 2013: *Part 6. Climate of the Northwest U.S.*, NOAA Technical Report NESDIS 142-6.
- [4] National Research Council. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Washington, DC: The National Academies Press, 2012.
- [5] Mote, P.W. et al. 2008. *Sea Level Rise in the Coastal Waters of Washington State*. Report prepared by the Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, and the Washington Department of Ecology, Lacey, WA.
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<sup>O</sup> Range includes uncertainty in the estimated rate of melt for glaciers and ice sheets, vertical land motion, and greenhouse gas scenarios, spanning from the B1 (low emissions, similar to RCP 4.5) to the A1FI (high emissions, similar to RCP 8.5) greenhouse gas scenarios.