



## Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts

Prepared by the University of Washington Climate Impacts Group for the Washington Department of Ecology

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The information provided below is largely assembled from work completed for the 2009 Washington Climate Change Impacts Assessment. Other sources have been used where relevant but this summary should not be viewed as a comprehensive literature review of Pacific Northwest (PNW) climate change impacts. Confidence statements are strictly qualitative with the exception of IPCC text regarding rates of 20th century global sea level rise. Note that periods of months are abbreviated by each month's first letter, e.g., DJF = Dec, Jan, Feb.

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
<b>Temperature</b>	<p>Increasing temperatures expected through 21st century</p> <p>Variations in season and annual temperature associated with natural variability (e.g. El Niño and La Niña) will continue to occur even as long term average temperature increases. There is no consensus currently as to how El Niño and La Niña might be affected by climate change.</p>	<p>Projected multi-model change in average annual temperature (with range) for specific benchmark periods:</p> <ul style="list-style-type: none"> <li>• 2020s: +2°F (1.1 to 3.4°F)**</li> <li>• 2040s: +3.2°F (1.6 to 5.2°F)</li> <li>• 2080s: +5.3°F (2.8 to 9.7°F)</li> </ul> <p>These changes are relative to the average annual temperature for 1970-1999.</p> <p>The projected <i>rate</i> of warming is an average of 0.5°F per decade (range: 0.2-1.0°F).</p> <p>-----</p> <p><i>** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).</i></p>	<p>Projected warming by the end of this century is much larger than the regional warming observed during the 20th century (+1.5°F), even for the lowest scenarios.</p>	<p>Warming expected across all seasons with the largest warming in the summer months (JJA)</p> <p>Mean change (with range) in winter (DJF) temperature for specific benchmark periods, relative to 1970-1999:</p> <ul style="list-style-type: none"> <li>• 2020s: +2.1°F (0.7 to 3.6°F)**</li> <li>• 2040s: +3.2°F (1.0 to 5.1°F)</li> <li>• 2080s: +5.4°F (1.3 to 9.1°F)</li> </ul> <p>Mean change (with range) in summer (JJA) temperature for specific benchmark periods, relative to 1970-1999:</p> <ul style="list-style-type: none"> <li>• 2020s: +2.7°F (1.0 to 5.3°F)**</li> <li>• 2040s: +4.1°F (1.5 to 7.9°F)</li> <li>• 2080s: +6.8°F (2.6 to 12.5°F)</li> </ul>	<p>High confidence that the PNW will warm as a result of increasing greenhouse gas emissions. All models project warming in all scenarios (39 scenarios total) and the projected change in temperature is statistically significant.</p>	<p>Mote and Salathé 2010</p>

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<b>Precipitation</b> <i>(extreme precipitation addressed in separate field)</i>	<p>A small increase in average annual precipitation is projected (based on the multimodel average, Mote and Salathé 2010), although model-to-model differences in projected precipitation are large (see "Confidence").</p> <p>Potentially large seasonal changes are expected.</p>	<p>Projected change in average annual precipitation (with range) for specific benchmark periods:</p> <ul style="list-style-type: none"> <li>• 2020s: +1% (-9 to 12%)**</li> <li>• 2040s: +2% (-11 to +12%)</li> <li>• 2080s: +4% (-10 to +20%)</li> </ul> <p>These changes are relative to the average annual precipitation for 1970-1999.</p> <p>-----</p> <p><b>** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).</b></p>	<p>Projected increase in average annual precipitation is small relative to the range of natural variability observed during the 20th century and the model-to-model differences in projected changes for the 21<sup>st</sup> century</p>	<p><i>Summer:</i> Majority of global climate models (68-90% depending on the decade and emissions scenario) project decreases in summer (JJA) precipitation.</p> <p>Mean change (with range) in JJA precipitation for specific benchmark periods, relative to 1970-1999:</p> <ul style="list-style-type: none"> <li>• 2020s: -6% (-30% to +12%) **</li> <li>• 2040s: -8% (-30% to +17%)</li> <li>• 2080s: -13% (-38% to +14%)</li> </ul> <p><i>Winter:</i> Majority of global climate models (50-80% depending on the decade and emissions scenario) project increases in winter (DJF) precipitation.</p> <p>Mean change (with range) in DJF precipitation for specific benchmark periods, relative to 1970-1999:</p> <ul style="list-style-type: none"> <li>• 2020s: +2% (-14% to +23%)**</li> <li>• 2040s: +3% (-13% to +27%)</li> <li>• 2080s: +8% (-11% to +42%)</li> </ul>	<p>Low confidence. The uncertainty in future precipitation changes is large given the wide range of natural variability in the PNW and uncertainties regarding if and how dominant modes of natural variability may be affected by climate change. Additional uncertainties are derived from the challenges of modeling precipitation globally.</p> <p>Model to model differences are quite large, with some models projecting decreases in winter and annual total precipitation and others producing large increases.</p> <p>Expect that the region will continue to see years that are wetter than average and drier than average even as that average changes over the long term.</p>	<p>Mote and Salathé 2010; Salathé et al. 2010</p>

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<b>Extreme precipitation</b>	Precipitation intensity may increase but the spatial pattern of this change and changes in intensity is highly variable across the state.	<p>State-wide (<i>Salathé et al. 2010</i>): More intense precipitation projected by two regional climate model simulations but the distribution is highly variable; substantial changes (increases of 5-10% in precipitation intensity) are simulated over the North Cascades and northeastern Washington. Across most of the state, increases are not significant.</p> <p>For sub-regions (<i>Rosenberg et al. 2010</i>): Projected increases in the magnitude (i.e., the amount of precipitation) of 24-hour storm events in the Seattle-Tacoma area over the next 50 years are 14.1%-28.7%, depending upon the data employed. Increases for Vancouver and Spokane are not statistically significant and therefore cannot be distinguished from natural variability</p> <p>An increase in the intensity of the winter season midlatitude storm track in the Northern Hemisphere is expected globally, however there is considerable variation in model results at the regional scale (<i>O’Gorman 2010, Ulbrich et al. 2008</i>).</p>	Projected increases in the magnitude of 24-hour precipitation events for the period 2020-2050 for the Seattle-Tacoma area (14.1 to 28.7%) is comparable to the observed increases for 24-hour events over the past 50 years (24.7%) ( <i>Rosenberg et al. 2009</i> ).	<p>The ECHAM5 simulation produces significant increases in precipitation intensity during winter months (Dec-Feb), although with some spatial variability. The CCSM3 simulation also produces more intense precipitation during winter months despite reductions in total winter and spring precipitation (<i>Salathé et al. 2010</i>)</p> <p>Projections for increases in coastal precipitation intensity are for the winter season. There is little information on how summer precipitation intensity may change along the coast or in the interior PNW.</p>	<p>Low confidence for increases in precipitation intensity. Anthropogenic changes in extreme precipitation are difficult to detect given the wide range of natural precipitation variability in the PNW. Computational requirements limit the analysis of sub-regional impacts within Washington to two scenarios, reducing the robustness of possible results. Simulated changes from those two scenarios are statistically significant only over northern Washington.</p> <p>Low confidence for increasing coastal storm track intensity. While there is good agreement across models at the global scale that the intensity of mid-latitude storm tracks is likely to increase, there is considerable variation in model results (and therefore considerable uncertainty) as you move to the regional scale.</p>	Salathé et al. 2010 Rosenberg et al. 2009 Rosenberg et al. 2010 O’Gorman 2010 Ulbrich, U. et al. 2008
<b>Extreme heat</b>	More extreme heat events expected	<p>Increases in extreme heat events are projected for the 2040s, particularly in south central WA and the western WA lowlands (<i>Salathé et al. 2010</i>).**</p> <p>Changes in specific regions vary with time period (2025, 2045, and 2085), scenario (low, moderate, high), and region (Seattle, Spokane, Tri-Cities, Yakima) but all four regions and all scenarios show increases in the mean annual</p>	<p>Projected increases in number and duration of events is significantly larger than the number and duration of events between 1980-2006 (specific values vary with location, warming scenario, and time period).</p> <p>In western</p>	n/a (relevant to summer only)	Medium confidence. There is less confidence in sub-regional changes in extreme heat events due to the limited number of scenarios used to evaluate changes in extreme heat events in Jackson et al. 2010 (9 scenarios) and Salathé et al. 2010 (2 scenarios), although confidence in warmer summer temperatures	Salathé et al. 2010 Jackson et al. 2010

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		<p>number of heat events, mean event duration, and maximum event duration (<i>Jackson et al. 2010, Table 4</i>).</p> <p>-----</p> <p><i>** Definitions of extreme heat varied between the two studies cited here. Salathé et al. 2010 defined a heat wave as an episode of three or more days where the daily heat index (humidex) value exceeds 90°F. Jackson et al. 2010 defined heat events as one or more consecutive days where the humidex was above the 99th percentile.</i></p>	<p>Washington, the frequency of exceeding the 90th percentile daytime temperature (Tmax) increases from 30 days per year in the current climate (1970-1999) to 50 days per year in the 2040s (2030-2059).</p>		<p>overall is high (see previous entry for temperature).</p>	
<b>Snowpack (SWE)</b>	Decline in spring (April 1) snowpack expected	<p>The multi-model means for projected changes in mean April 1 SWE for the B1 and A1B greenhouse gas emissions scenarios are:</p> <ul style="list-style-type: none"> <li>• 2020s: -27% (B1), -29% (A1B)</li> <li>• 2040s: -37% (B1), -44% (A1B)</li> <li>• 2080s: -53% (B1), -65% (A1B)</li> </ul> <p>All changes are relative to 1916-2006. Individual model results will vary from the multi-model average.</p>	<p>Projected declines for the 2040s and 2080s are greater than the snowpack decline observed in the 20th century (based on a linear trend from 1916-2006).</p>	n/a (relevant to cool season [Oct-Mar] only)	<p>High confidence that snowpack will decline even though specific projections will change over time. Projected changes in temperature, for which there is high confidence, have the most significant influence on SWE (relative to precipitation).</p>	Elsner et al. 2010
<b>Glaciers</b>	Decline in glacial volume and summer runoff	<p>Projected declines in the area-averaged volume, or cumulative net balance, of Washington's seven monitored glaciers are as follows:</p> <ul style="list-style-type: none"> <li>• 2020s: -10 meters, or -3% (<i>equivalent water loss: 900 billion gallons</i>)</li> <li>• 2040s: - 20 meters, or -9% (<i>equivalent water loss: 2 trillion gallons</i>)</li> <li>• 2060s: - 30m, or -15% (<i>equivalent water loss: 4 trillion gallons</i>)</li> </ul> <p>All changes are relative to the mid-to late-20<sup>th</sup> century (roughly 1950s</p>	<p>Projected rate of decline in cumulative net mass balance through mid-century is comparable to the rate of decline observed since the mid-1950s.</p>	<p>Glacial contributions to summer runoff ultimately decline with loss of glacial volume, although increases may be observed in the near-term as summer melt accelerates.</p>	<p>High confidence that glaciers will decline given projected increases in 21<sup>st</sup> century temperature and detailed glacier monitoring data from that past 50 years showing glacial sensitivity to warming.</p>	<p>Jon Riedel, National Park Service; personal communication based on data published in:</p> <ul style="list-style-type: none"> <li>- Granshaw and Fountain, 2006</li> <li>- Riedel and Larrabee, 2011a</li> <li>- Riedel and Larrabee, 2011b</li> </ul>

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		<p>through 2007, depending on the glacier).</p> <p>These projections are considered preliminary estimates given 1) data limitations on total glacial volume, and 2) the expectation that changes in volume are nonlinear, meaning the rate of volume change per 1°F of warming is likely to become greater as temperatures increase.</p>				
<b>Streamflow volume</b>	<p>Expected seasonal changes include increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow dominant and rain/snow mix (transient) basins, and decreases in summer streamflow.</p> <p>Increasing risk of extreme high and low flows also expected.</p> <p>In all cases, results will vary by location and basin type.</p>	<p>The multi-model averages for projected changes in mean annual runoff for Washington state for the B1 and A1B greenhouse gas emissions scenarios are:</p> <ul style="list-style-type: none"> <li>• 2020s: +2% (B1), 0% (A1B)</li> <li>• 2040s: +2% (B1), +3% (A1B)</li> <li>• 2080s: +4% (B1), +6% (A1B)</li> </ul> <p>All changes relative to 1916-2006; numbers rounded to nearest whole value (<i>Elsner et al. 2010</i>)</p> <p>The risk of lower low flows (e.g., lower 7Q10** flows) increases in all basin types to varying degrees. The decrease in 7Q10 flows is greater in rain dominant and transient basins relative to snow-dominant basins, which generally see less snowpack decline and, as a result, a smaller decline in summer streamflow than transient basins. (<i>Mantua et al. 2010; Tohver and Hamlet 2010</i>)</p> <p>Changes in flood risk vary by basin type. Spatial patterns for the 20-year and 100-year flood ratio (future/historical) indicate slight or no increases in flood risk for snowmelt dominant basins due to declining spring snowpack. There is a progressively higher flood risk through the 21st century for</p>	<p>During the period from 1947-2003, runoff occurred earlier in spring throughout snowmelt influenced watersheds in the western U.S. (<i>Hamlet et al. 2007</i>).</p>	<p>Projected changes in mean cool season (Oct-Mar) runoff for WA state:</p> <ul style="list-style-type: none"> <li>• 2020s: +13% (B1), +11% (A1B)</li> <li>• 2040s: +16% (B1), +21% (A1B)</li> <li>• 2080s: +26%(B1), +35% (A1B)</li> </ul> <p>Projected changes in mean warm season (Apr-Sept) runoff for WA state:</p> <ul style="list-style-type: none"> <li>• 2020s: -16% (B1), -19% (A1B)</li> <li>• 2040s: -22% (B1), -29% (A1B)</li> <li>• 2080s: -33%(B1), -43% (A1B)</li> </ul> <p>All changes relative to 1916-2006; numbers rounded to nearest whole value. (<i>Elsner et al. 2010</i>)</p>	<p><i>Regarding changes in total annual runoff:</i> There is high confidence in the direction of projected change in total annual runoff but low confidence in the specific amount of projected change due to the large uncertainties that exist for changes in winter (Oct-Mar) precipitation. The large uncertainties in winter precipitation are due primarily to uncertainty about the timing of, and any changes in, dominant models of natural decadal variability that influence precipitation patterns in the PNW (e.g. the Pacific Decadal Oscillation) as well as changes in precipitation caused by climate change.</p> <p><i>Regarding streamflow timing shifts:</i> There is high confidence that peak streamflow will shift earlier in the season in transient and snow-dominant systems due to projected warming and loss of April 1 SWE. There is less confidence in the specific</p>	<p>Elsner et al. 2010 Hamlet et al. 2007 Mantua et al. 2010 Tohver and Hamlet 2010</p>

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		<p>transient basins, although changes in risk in individual transient basins will vary. Projections of flood risk for rain dominant basins do not indicate any significant change under future conditions, although increases in winter precipitation in some scenarios nominally increase the risk of flooding in winter. <i>(Tohver and Hamlet 2010, in draft)</i></p> <p>-----</p> <p><i>** 7Q10 flows are the lowest stream flow for seven consecutive days that would be expected to occur once in ten years.</i></p>			<p>size of the shift in any specific basin given uncertainties about changes winter precipitation <i>(see previous comment)</i>.</p> <p><i>Regarding summer streamflows:</i> Overall, there is high confidence that summer streamflow will decline due to projected decreases in snowpack (relevant to snow dominant and transient basins) and increasing summer temperatures (relevant to all basin types). There is medium confidence that late summer streamflow will decline given 1) the sensitivity of late summer streamflow to uncertain precipitation changes, and 2) uncertainties about if and how groundwater contributions in any given basin may affect late summer flows.</p> <p>For all changes in streamflow, confidence in <i>specific</i> projected values is low due to high uncertainty about changes in precipitation and decadal variability.</p>	
<b>Stream temperature</b>	<p>Summer stream temperatures are expected to increase and to remain elevated for longer periods of the summer.</p> <p>Impacts on juvenile</p>	<p>Annual maximum temperature for the B1 and A1B scenarios is projected to increase less than 1.8°F at most stations by the 2020s. By the 2080s, many stations both east and west of the Cascades are likely to warm by 3.6°F to 9°F. Because baseline water temperatures in eastern Washington are generally</p>	<p>In eastern Washington, the percentage of streams analyzed by Mantua et al. 2010 with temperatures lethal to juvenile salmon (&gt;71°F) increases from 20%</p>	<p><i>For spring temperatures:</i> Warmer average temperatures in streams that currently experience cool spring temperatures <i>increases</i> juvenile growth, while warmer average temperatures in streams that already</p>	<p>High confidence that stream temperatures will increase, although there will be significant variation in location and magnitude of change.</p>	<p>Mantua et al. 2010 Beer and Anderson 2011</p>

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	salmon will vary depending on the species and location.	<p>warmer than in western Washington, more streams in eastern Washington become stressful to salmon than in western Washington (Mantua et al. 2010).</p> <p>Periods where water temperatures exceed 69°F, a threshold where water temperatures become especially unfavorable for salmon, are projected to lengthen from 1-5 weeks historically (1980s) to 10-13 weeks by the 2080s (Mantua et al. 2010).</p>	<p>to 41% by the 2080s, relative to the 1980s.</p> <p>In western, Washington, the percentage of streams with temperatures lethal to juvenile salmon (&gt;71°F) increases from approximately 2% to approximately 14% by the 2080s, relative to the 1980s.</p>	<p>experience warm spring temperatures <i>reduces</i> the duration of optimal conditions for growth (Beer and Anderson 2011).</p> <p><i>For summer temperatures:</i> A loss of snow enhances growth in cool summer streams and decreases growth in warm summer streams (Beer and Anderson 2011).</p> <p>Increases in summer water temperature will be exacerbated by loss of glaciers as sources of particularly cold water.</p>		
<b>Sea level</b>	Varying amounts of sea level rise (or decline) projected in Washington due to regional variations in land movement and coastal winds.	<p>Projected global change (2090-2099) according to the IPCC: 7-23", relative to 1980-99 average (Solomon et al. 2007)**</p> <p>2050: Projected medium change in Washington sea level (with low to high range) (Mote et al. 2008):</p> <ul style="list-style-type: none"> <li>• NW Olympic Pen: 0" (-5-14")</li> <li>• Central &amp; So. Coast: 5" (1-18")</li> <li>• Puget Sound: 6" (3-22")</li> </ul> <p>2100: Projected medium change in WA sea level (with low to high range) (Mote et al. 2008):</p> <ul style="list-style-type: none"> <li>• NW Olympic Peninsula: 2" (-9-35")</li> <li>• Central &amp; So. Coast: 11" (2-43")</li> <li>• Puget Sound: 13" (6-50")</li> </ul> <p>-----</p> <p>** Since 2008, numerous peer-</p>	<p>Relative change in Washington varies by location. Globally, the average rate of sea level rise during the 21st century very likely<sup>‡</sup> (&gt;90%) exceeds the 1961-2003 average rate (0.07 ± 0.02 in/year) (Solomon et al. 2007)</p> <p>-----</p> <p><sup>‡</sup> = as defined by the IPCC's treatment of uncertainties (Solomon et al. 2007, Box TS1)</p>	<p>Wind-driven enhancement of PNW sea level is common during winter months (even more so during El Niño events). On the whole, analysis of more than 30 scenarios found minimal changes in average wintertime northward winds in the PNW. However, several models produced strong increases. These potential increases contribute to the upper estimates for WA sea level rise. (Mote et al. 2008)</p>	<p>High confidence that sea level will rise globally.</p> <p>Confidence in the amount of change at any specific location in Washington varies depending on the amount of uncertainty associated with the global and local/regional factors affecting rates of sea level rise.</p> <p>Regionally, there is high confidence that the NW Olympic Peninsula is experiencing uplift at &gt;2 mm/yr. There is less confidence about rates of uplift along the central and southern WA coast due to sparse data, but available data generally indicate</p>	<p>Mote et al. 2008 Solomon et al. 2007</p>

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		<p><i>reviewed studies have offered alternate estimates of global sea level rise. The basis for these updates are known deficiencies in the IPCC's 2007 approach to calculating of global sea level rise, including assumptions of a near-zero net contribution from the Greenland and Antarctic ice sheets to 21st century sea level rise. A comparison of several studies in Rahmstorf 2010 (Figure 1) shows projections in the range of 1.5ft to over 6ft. Overall, recent studies appear to be converging on projected increases in the range of 2-4ft (e.g., Vermeer and Rahmstorf (2009), Pfeffer et al. 2008, Grinsted et al. 2009, Jevrejeva et al. 2010).</i></p>			<p>uplift in range of 0-2mm/yr. There is high uncertainty about subsidence, and rates of subsidence where it exists, in the Puget Sound region.</p> <p>Although annual rates of current and future uplift and subsidence (a.k.a. "VLM") are well-established at large geographic scales, determining rates at specific locations requires additional analysis and/or monitoring. Uncertainties around future rates are unknown and would be affected by the occurrence of a subduction zone earthquake.</p>	
<p><b>Wave Heights</b></p>	<p>Increase in "significant wave height" ** and extreme significant wave heights (98<sup>th</sup> or 99<sup>th</sup> percentile) expected based on research showing that a future warmer climate may contain fewer overall extra-tropical cyclones but an increased frequency of very intense extra-tropical cyclones (which may affect the extreme wave climate).</p> <p>-----  ** "Significant wave height" is defined as the average of</p>	<p>No quantified projected changes available at this time.</p>	<p>Positive long-term trends in the range of +2 to +4 cm/yr in extreme significant wave heights (98th percentile) were observed between 1985-2007 along the west coast of the U.S., particularly in California and to a lesser degree Oregon and Washington (Menendez et al. 2008). These increases are due at least in part to El Niño and the Pacific/North American pattern of climate variability. Similar results were found by Mendez et al. 2010 and Young et al. 2011 for the</p>	<p>Winter season (Oct-March) is the dominant season of strong storms and significant wave events.</p>	<p>There is low confidence that significant wave height will increase given the dependence of this increase on a limited number of studies showing potential increases in the intensity of the extra-tropical cyclones that can affect the extreme wave climate.</p>	<p>Menendez et al. 2008  Mendez et al. 2010  Ruggiero et al. 2010</p>



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	<i>the highest 1/3 of the measured wave heights within a (typically) 20 minute period</i>		same or similar time periods. Mendez et al. 2010 also found that the rate of increase in extreme wave heights was greater than the rate of increase in mean monthly wave heights, which were also found to be increasing but not in a statistically significant way.			
<b>Sea surface temperature (SST)</b>	Warmer SST expected	Increase of +2.2°F projected for the 2040s (2030-59) for coastal ocean between 46°N and 49°N. Changes are relative to 1970-99 average.	Projected change is substantially outside the range of 20th century variability.	<i>No information currently available</i>	Medium to low confidence in the degree of warming expected for the summertime upwelling season. Global climate models do not resolve the coastal zone and coastal upwelling process very well, and uncertainty associated with summertime upwelling winds also brings uncertainty to coastal SSTs in summer.	Mote and Salathé 2010
<b>Coastal upwelling</b>	Little change in coastal upwelling expected	The multimodel average mean change in winds that drive coastal upwelling is minimal	Comparable to what has been observed in the 20th century	Little change in seasonal patterns.	Low confidence given the fact that this hasn't been evaluated with dynamical downscaling of many climate model scenarios at this point.	Mote and Salathé 2010
<b>Ocean acidification</b>	Continuing acidification expected in coastal Washington and Puget Sound waters	The global surface ocean is projected to see a 0.2 - 0.3 drop in pH by the end of the 21 <sup>st</sup> century (in addition to observed decline of 0.1 units since 1750) (Feely et al. 2010).  pH in the North Pacific, which includes the coastal waters of	Projected global changes are larger than the decrease of 0.1 units since 1750, and greater than the trend in last 20 years (0.02 units/decade).	The contribution of ocean acidification to Dissolved Inorganic Carbon (DIC) concentrations within the Puget Sound basin can vary seasonally. Ocean acidification has a	For global changes, confidence that oceans will become more acidic is high.  Results from large-scale ocean CO <sub>2</sub> surveys and time-series studies over	Feely et al. 2009 Feely et al. 2010

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		<p>Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO<sub>2</sub> to 560 and 840 ppm, respectively (Feely et al. 2009). This decrease in pH is equivalent to a 100-150% increase in the acidity of the oceans.</p> <p>pH in Puget Sound is projected to decrease, with ocean acidification accounting for an increasingly large part of that decline. Feely et al. 2010 estimated that ocean acidification accounts for 24-49% of the pH decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial values. Over time, ocean acidification from a doubling of atmospheric CO<sub>2</sub> could account for 49-82% of the pH decrease in Puget Sound subsurface waters.</p>	The observed decrease of 0.1 units since 1750 is equivalent to a 26% increase in the hydrogen ion concentration or "acidity".	smaller contribution to the subsurface increase in DIC concentrations in the summer (e.g., 24%) compared to winter (e.g., 49%) relative to other processes (Feely et al. 2010).	<p>the past two decades show that ocean acidification is a predictable consequence of rising atmospheric CO<sub>2</sub> that is independent of the uncertainties and outcomes of climate change (Feely et al. 2009).</p> <p>For Puget Sound, estimates of the contribution of ocean acidification to future pH decreases in Puget Sound have very high uncertainty since other changes that may occur over the intervening time were not taken into account when calculating that estimate (a percentage) (Feely et al. 2010).</p>	

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