SECTION 2
How Is Puget Sound's Climate Changing?

Puget Sound is experiencing a suite of long-term changes that are consistent with those observed globally as a result of human-caused climate change. These include increasing air temperatures, a longer frost-free season, nighttime warming, and a possible increase in the intensity of heavy rainfall events. Continued increases in average annual and seasonal Puget Sound air temperatures are projected as a result of climate change, as well as increases in extreme heat. Projected changes in annual precipitation are generally small, although summer precipitation is projected to decrease and heavy rainfall events are projected to become more severe. Natural variability can have a strong effect on trends – as evidenced by recent regional cooling – and will continue to influence shorter-term (up to several decades) climate trends in the future.

Observed Changes

OBSERVED ***The Puget Sound region[A] has experienced long-term warming, a lengthening of the frost-free season, and more frequent nighttime heat waves.***

- *Air temperatures are increasing in the Puget Sound region.* The lowland areas surrounding Puget Sound warmed about +1.3°F (range: +0.7°F to +1.9°F)[B] between 1895 and 2014, with statistically significant warming occurring in all seasons except for spring.[C,D,1] All but six of the years from 1980 to 2014 were warmer than the 20th century average (Figure 2-1, Table 2-1).[1] This trend is consistent with the observed warming over the Pacific Northwest as a whole.[2,3]

A Throughout this report, the term "Puget Sound" is used to describe the marine waters of Puget Sound and the Strait of Juan de Fuca, extending to its outlet near Neah Bay. The term "Puget Sound region" is used to describe the entire watershed, including all land areas that ultimately drain into the waters of Puget Sound (see "How to Read this Report").

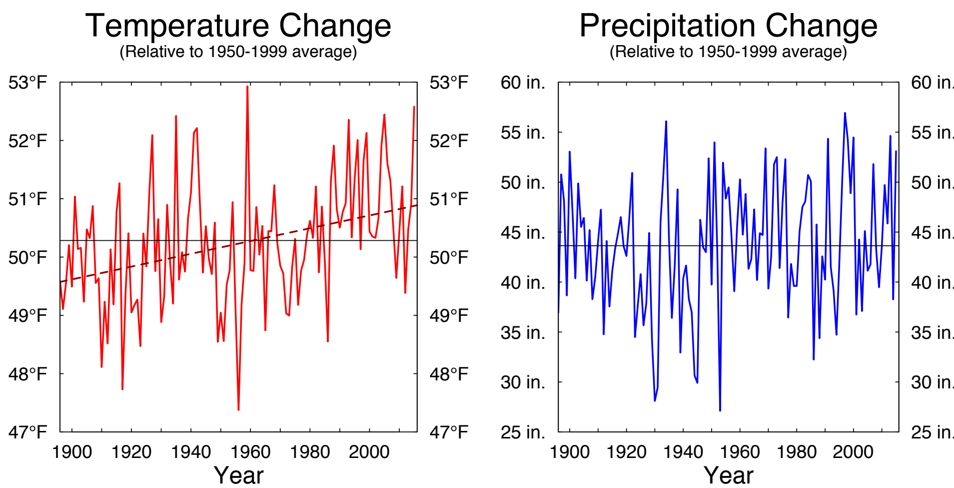
B The range shows the 95% confidence limits for the trend estimate.

C In this section, trends are only reported if they are statistically significant at or above the 95% confidence level. All trends are reported for the full length of the available observed record.

D These trends were determined using data from the U.S. Climate Divisional Dataset, developed by the National Centers for Environmental Information (NCEI). NCEI provides long-term climate summaries for each of the country's 344 climate divisions. Results for the "Puget Sound Lowlands" climate division (see inset in Figure 2-1) were used in the present analysis, which includes all of the low-lying land areas surrounding Puget Sound, where most of the historical weather observations are concentrated. For more information, see: http://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php

- *Nighttime air temperatures are rising faster than daytime air temperatures in the Puget Sound lowlands.* Daily minimum air temperatures (which generally occur at night) have increased by +1.8°F between 1895 and 2014, while daily maximum air temperatures (generally occurring in afternoon) warmed by +0.8°F over the same time period.[D,1]

- *The frost-free season has lengthened.* The frost-free season (and the associated growing season) in the Puget Sound region lengthened by +30 days (range: +18 to +41 days) from 1920 to 2014.[E,3,4]



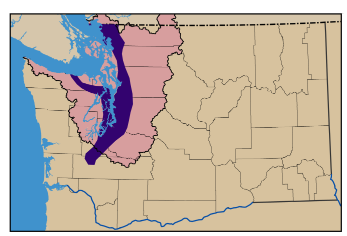


Figure 2-1. Temperature is rising in the Puget Sound lowlands, and there is no long term trend in precipitation. Average annual air temperature (top left, red, in °F) and total annual precipitation (top right, blue, in %) for the Puget Sound Lowlands climate division[D] (dark blue shading in map), shown relative to the average for 1950-1999 (black horizontal line in both graphs, corresponding to 50.3°F for annual aveage temperature and 43.6 inches for annual total precipitation). The dashed line in the temperature plot is the fitted trend, indicating a warming of +1.3°F (range: +0.7°F to +1.9°F)[B] from 1895 to 2014. The trend for precipitation is not statistically significant, and therefore is not shown. *Data source: Vose et al. 2014.[D,1]*

E Trends are based on an average of the anomalies (difference between each year and the long-term average) for the eight Puget Sound stations used by Abatzoglou et al. (2014).[3] Stations were only included in the analysis if at least 75% of years of monitoring data available, with each year missing no more than 20% of days within a year, from 1920-2014. Data were obtained from John Abatzoglou, with trends estimated using a standard linear regression. The range gives the 95% confidence limits.

- *Warm nights have become more frequent, but daytime heat waves have not changed.* Nighttime heat events have become more frequent west of the Cascade Mountains in Oregon and Washington[F] (1901-2009).[5] No significant trend has been found for daytime heat events.

- *Short-term trends can differ substantially from the long-term trend.* The Puget Sound region's highly variable climate often results in short-term cooling trends, as well as warming trends larger than the long-term average (Figure 2-1, Table 2-1). The cooling observed from about 2000 to 2011, for example, is similar to cooling observed at other times in the 20th century, despite overall long-term warming.

- *Long-term air temperature trends are affected by natural variability, although there is continued debate about the extent of its influence.* Natural climate variability has a strong influence on trends: one previous study estimated that about half of the observed increase in air temperature in the northern hemisphere (1900-1990) is a result of random natural variability.[6] A more recent study has presented evidence that over 80% of the observed trend in surface air temperature for Washington, Oregon, and California (1900-2012) can be explained by changes in atmospheric circulation (specifically, variations in surface pressure and winds), which may or may not result from human-induced warming.[7] Others have repeated the analysis using different datasets and found no evidence for the long-term change in circulation.[8,9]

- *Measurement biases can affect local trends, but will have a much smaller effect on regional trends.* Estimates of air temperature changes over time can be affected by changes in the location, the number of measurements made, and in the instruments used to make the measurements. The air temperature datasets reported here include corrections for these factors.[10] Even with these corrections, trend estimates can still be affected by measurement biases, and the effect will be greater when considering smaller regions or areas with sparse observations. Although potentially important for individual stations, the effect on regional average trend estimates is likely to be small: one published study analyzed annual average air temperature trends for the contiguous U.S., and found that these issues had a very small effect on long-term trends, and that the bias actually led to an underestimate of the warming trend.[11]

OBSERVED ***There has been no discernible long-term trend in precipitation for the Puget Sound region.***

- *Year-to-year variability in total precipitation is large compared to long-term trends.* Natural variability has a large influence on regional precipitation, causing ongoing fluctuations between wet years and dry years and wet decades and dry decades.

[F] Many characteristics of Puget Sound's climate and climate vulnerabilities are similar to those of the broader Pacific Northwest region. Results for Puget Sound are expected to generally align with those for western Oregon and Washington, and in some instances the greater Pacific Northwest, with potential for some variation at any specific location.

- *Spring precipitation is increasing, but no other trends are statistically significant.* Seasonal and annual precipitation trends are generally not statistically significant, and in all cases are smaller than natural year-to-year variations. The one exception is spring (Mar-May) precipitation, which increased by +27% in the Puget Sound lowlands, from 1895 to 2014.[D,1]

- *Modest increases in heavy rainfall have been documented in Western Washington.* Most studies find increases in both the frequency and intensity of heavy precipitation in Western Washington.[12,13,14] For example, one study found a statistically-significant +23% increase in the annual-maximum 48-hour event for the Puget Sound region (1981-2005 relative to 1956-1980).[14] Not all trends are statistically significant – results depend on the dates and methods of the analysis.

Natural Climate Variability

NATURAL VARIABILITY ***Large-scale fluctuations in weather patterns and ocean conditions drive short-term (up to several decades) natural variability in Puget Sound's climate.*** Two of the dominant patterns are the El Niño – Southern Oscillation (ENSO, otherwise known as El Niño and La Niña) and the Pacific Decadal Oscillation (PDO). These climate patterns are associated with variations in ocean temperatures, local surface winds, air temperatures, and precipitation.[15] ENSO and PDO are just two examples: other fluctuations in weather patterns can have an effect on the climate of Puget Sound.

- *ENSO and PDO are both large-scale patterns of climate variability in which sea surface temperatures over large parts of the Pacific Ocean are unusually warm in some places and unusually cool in others.* The two patterns are not entirely independent.[15,16] The main difference between them is that for ENSO, the largest changes in ocean temperatures are in the tropics, while the associated changes in the North Pacific are much smaller. The opposite is true for the PDO: larger changes in the North Pacific, smaller changes in the tropics. In addition, typical ENSO events are more seasonal and much shorter in duration: ENSO events usually persist for 6-18 months, whereas PDO events can persist for 20-30 years.[17]

- *Warm ENSO (El Niño) and warm PDO events generally increase the likelihood of warmer coastal ocean and higher air temperatures in winter for the Puget Sound region.* Conversely, cool ENSO (La Niña) and cool PDO events generally produce cooler winters. Precipitation is not strongly related to ENSO and PDO events.[15,18,19,20]

- *It is not known how ENSO might change with warming.* Some climate models project increases while others project decreases in the frequency of ENSO events. Global model projections of ocean surface temperature show a pattern of change that resembles the changes observed during an El Niño. However, the magnitude of the warming due to climate change is much lower. In addition, the global patterns of temperature and precipitation resulting from global warming (e.g., the associated changes in Puget Sound's climate) do not resemble those observed in El Niño years.[21]

- *Recent research has found that a new type of El Niño, the so-called "El Niño Modoki" (or "Central Pacific El Niño"), has become more common in the 20th century, and is projected to become still more common in the 21st century.* The changes in large-scale weather patterns brought on by an El Niño Modoki, including those affecting Puget Sound's climate, are very different than those that occur with a typical El Niño event.[G,22]

Projected Changes

PROJECTED ***The Puget Sound region is projected to warm rapidly during the 21st century.*** Prior to mid-century, the projected increase in air temperatures is about the same for all greenhouse gas scenarios, a result of the fact that a certain amount of warming is already "locked in" due to past emissions. After about 2050, projected warming depends on the amount of greenhouse gases emitted globally in the coming decades (see Section 1).[23,24]

- *All scenarios project warming.* Warming is projected to continue throughout the 21st century (Figure 2-2, Table 2-2). For the 2050s (2040-2069, relative to 1970-1999), annual average air temperature is projected to rise +4.2°F to +5.5°F, on average, for a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario.[H,I,J] Much higher warming is possible after mid-century (Figure 2-2, Table 2-2).[23] Lower emissions of greenhouse gases will result in less warming.

- *Warming is projected for all seasons.*[K] The projected increase in summer air temperature is greater than for other seasons.[23]

G Based on an analysis of 6 global climate model projections and a moderate (A1b) greenhouse gas scenario.

H 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; "moderate" 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 1 for details.

I Greenhouse gas scenarios used in this report generally 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,[27] see Section 1). 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 because there are no published projections specific to the Puget Sound region that are based on this scenario.

J Projections stem from 10 global climate model projections, based on both a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. The 10 global climate models were selected for their ability to accurately represent the climate of the Pacific Northwest.[25]

K Unless otherwise noted, seasons are defined as follows in this report: Winter (December-February), Spring (March-May), Summer (June-August), Fall (September-October).

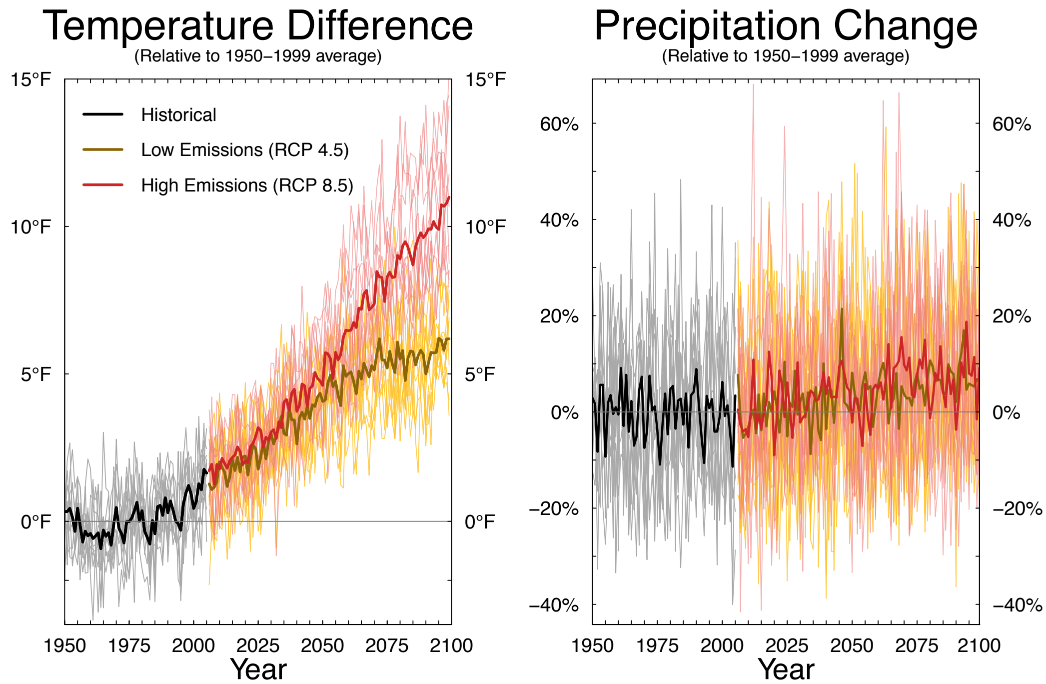


Figure 2-2. All scenarios project warming in the Puget Sound region for the 21st century; projected changes in annual precipitation are small compared to year-to-year variability. The graphs show average yearly air temperature and precipitation for the Puget Sound region, relative to the average for 1950-1999 (horizontal gray line, corresponding to an annual average temperature of 44°F and an annual total precipitation of 78 inches). The black line shows the average simulated air temperature or precipitation for 1950–2005, based on the individual model results indicated by the thin grey lines. The thick colored lines show the average among model projections for two emissions scenarios (low: RCP 4.5, and high: RCP 8.5 – see Section 1), while the thin colored lines show individual model projections for each scenario. *Data source: Downscaled climate projections developed by Abatzoglou and Brown (2011).*[26,23,27]

- *More extreme heat is likely, although the increase may be moderated by changes in weather patterns.* There is strong agreement among climate models that extreme heat events will become more frequent while extreme cold events will become less frequent.[23,24] Recent research has suggested that changes in atmospheric circulation will cause heat waves to increase less rapidly (in terms of both the frequency and intensity of heat events) in coastal areas such as the Puget Sound region.[28,29]

- *Ongoing variability will continue to play a role in regional climate.* 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 Puget Sound region include the El Niño/Southern Oscillation (ENSO, otherwise known as El Niño and La Niña) and the Pacific Decadal Oscillation (PDO). Current research is inconclusive as to how ENSO and other modes of climate variability may change as a result of warming (see

Section 6).[30,31]

- *The projected warming for the Puget Sound region is large compared to year-to-year variability.* The Puget Sound region is likely to regularly experience average annual air temperatures by mid-century that exceed what was observed in the 20th century.[L,23]

PROJECTED ***Changes in annual and fall, winter, and spring precipitation will continue to be primarily driven by year-to-year variations rather than long-term trends. All models project a decline in summer precipitation for the Puget Sound region.***

- *Small changes in annual precipitation are projected.* Projected changes in total annual precipitation are small (relative to historical variability)[M] and show increases or decreases depending on models. The projected changes for the 2050s (2040-2069, relative to 1970-1999) range from a decline of −2% to an increase of +13%.[J,23]

- *Summer precipitation is projected to decline.* In contrast to annual precipitation, all scenarios project drier summers (June-August),[K] for the Puget Sound region.[25] Models project a decline of −22%, on average, for the 2050s (2040-2069, relative to 1970-1999) for both a low and a high greenhouse gas scenario.[J,23] One individual model projection shows a −50% decrease in summer precipitation. Because only about 10% of annual precipitation falls in this season, these reductions would not represent a large change in rainfall. However, summer rains help reduce both municipal and agricultural water demand at a time when water availability is limited.

- *Projected changes in fall, winter, and spring precipitation are mixed.* Although some models project decreases, a majority of models project increases in winter, spring, and fall precipitation for the 2050s (2040-2069, relative to 1970-1999), ranging from +2 to +11%, on average.[J,23]

- *Winter precipitation extremes are projected to increase.* Heavy rainfall events – so-called "Atmospheric River" events – are expected to become more severe*.* Global models project that the heaviest 24-hour rain events in western Oregon and Washington[F] will intensify by +22%, on average, by the 2080s (2070-2099, relative to 1970-1999). These high intensity events are also projected to occur more frequently: occurring about seven days per year (range: four to nine days per year)

L Specifically, all scenarios project that, by mid-century (2040-2069), average annual air temperature will be warmer than the warmest year historically (1950-1999).

M Year-to-year variations in precipitation are about ±10 to 15%, on average.

by the 2080s in comparison to two days per year historically.[N,32] Another study evaluating extreme rainfall projections for the Sea-Tac weather station reported similar results.[14]

- *Research is lacking regarding the effect of climate change on thunderstorms and lightning in the Puget Sound region.* Thunderstorms are rare in the Puget Sound region due to cold ocean temperatures and warm upper air. Climate change results in competing effects: reductions in summer precipitation may cause thunderstorm activity to decrease, while increased land surface temperatures may trigger more thunderstorms. Changes in atmospheric circulation could also affect thunderstorm activity.[33,34] It is not known how these effects will combine to affect the frequency and intensity of thunderstorms.

- *Projected shifts in the storm track are small.* Possible increases in variability in the speed or position of the jet stream are speculative and may not significantly affect precipitation in the Puget Sound region. Warming is expected to cause the storm tracks to shift towards the poles, and possibly alter the frequency and magnitude of high and low pressure events. The climate model projections used in IPCC 2013[26] project a northward shift of about 1° latitude in the average position of the North Pacific storm track – this is a small shift and would not substantially alter the precipitation reaching the Puget Sound region.[35] Similarly, climate models do not project a change in wind speed or the strength of low pressure systems. Although some studies suggest that warming will result in a "wavier" (i.e., more variable) storm track,[35,36,37] this is considered highly speculative. The behavior of the jet stream is governed by many factors; understanding how these combine to drive changes in its behavior is still an active area of research.[38,39] In addition, it is unclear how such changes might affect the Puget Sound region.[40]

Although the projected change in annual and seasonal precipitation is smaller than historic variability, the change in heavy precipitation is not. Projected changes in annual and seasonal precipitation are generally small, throughout the 21st century, compared to the variability in precipitation resulting from natural year-to-year fluctuations. In addition, projected changes are not consistent among models: some project increases while others project decreases.[24] This is in contrast with the large changes projected for heavy precipitation events, which are expected to exceed the range of variability shortly after mid-century.[32]

For more details on observed and projected changes in Puget Sound climate, see Tables 2-1 and 2-2.

[N] The study evaluated precipitation totals on days with the top 1% (99th percentile) in daily water vapor transport, the principal driver of heavy rain events in the Pacific Northwest. Projections are based on an analysis of 10 global climate model projections and a high greenhouse gas scenario (RCP 8.5). Projected changes in intensity were evaluated for latitudes ranging from 40 to 49N. Although global models are coarse in spatial scale, previous research has shown that they can adequately capture the dynamics that govern West coast storms and heavy precipitation events.

Online Tools and Resources

The following tools and resources are suggested in addition to the reports and papers cited in this document.

Historical Observations:

- Trends in temperature, precipitation, and snowpack for individual weather stations across the Pacific Northwest: http://www.climate.washington.edu/trendanalysis/
- Trends in temperature and precipitation for Washington State and specific regions within the state: http://charts.srcc.lsu.edu/trends/
- Centralized resource for observed climate trends and data in Washington State: http://climate.washington.edu/
- Centralized resource for observed climate in the Western U.S.: http://www.wrcc.dri.edu/

Climate Variability:

- **NOAA Climate Prediction Center:** Provides information on seasonal weather predictions and large-scale weather patterns such as El Niño. http://www.cpc.ncep.noaa.gov/
- **Joint Institute for the Study Atmosphere and Ocean PDO website:** Provides a brief overview, along with figures, links, and references on the Pacific Decadal Oscillation (PDO). http://research.jisao.washington.edu/pdo/

Climate Change Projections:

- **Global Climate Model (GCM) projections:** Interactive tool to explore global climate model projections of changing temperature and precipitation in the Pacific Northwest, including separate results for coastal and inland areas: http://cig.uw.edu/resources/analysis-tools/projections/
- **Time of Emergence:** This dataset serves data and figures that show the "Time of Emergence" of climate trends throughout the region, defined as the year in which a particular climate trend emerges from natural year-to-year variability. http://toe.cig.uw.edu
- **Local-Scale Projections:** Interactive tools to visualize MACA (Multivariate Adaptive Constructed Analogs) statistically downscaled climate projections: http://maca.northwestknowledge.net/

Downscaled Climate Change Projections

The following datasets provide location-specific information about climate change effects 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, hydrologic, and vegetation change scenarios.** The Pacific Northwest Climate Impacts Research Consortium recently completed a new set of projections, which include changes in climate, hydrology, and vegetation. The projections are produced at a daily time step and a spatial resolution of about four miles, and are based on the newest set of climate model projections (IPCC 2013,[27] see Section 1).
http://climate.nkn.uidaho.edu/IntegratedScenarios/index.php

- **Climate and hydrologic scenarios.** The Climate Impacts Group provides downscaled daily historical data and projected future temperature, precipitation, snowpack, streamflow, flooding, minimum flows, and other important hydrologic variables for all watersheds and specific streamflow locations throughout the Columbia River basin and the western U.S. The projections are produced at a daily time step and a spatial resolution of about four miles, and are based on the previous set of climate model projections (IPCC 2007).[Error! Bookmark not defined.]
http://warm.atmos.washington.edu/2860,[Error! Bookmark not defined.]
http://cig.uw.edu/datasets/wus/[Error! Bookmark not defined.]

- **Fine scale climate scenarios for the lower 48 states.** Produced by NASA, this dataset provides projections of future monthly air temperature and precipitation, developed using updated statistical downscaling methods. The projections are produced at a daily time step and a spatial resolution of about half a mile, and are based on the new climate projections included in IPCC 2013.[26,27] https://portal.nccs.nasa.gov/portal_home/published/NEX.html

- **Regional climate model projections for the Pacific Northwest.** Regional climate model simulations (dynamical downscaling) over the Pacific Northwest are currently archived and under development at the Climate Impacts Group. Among other advantages, these data are more accurate for projecting changes in extremes.[Error! Bookmark not defined.] The projections are produced at a 6-hourly time step and a spatial

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resolution of about seven miles, and are based on projections from both IPCC 2007[Error! Bookmark not defined.] and 2013.[27] http://cig.uw.edu/datasets/wrf/

- **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.[26] http://narccap.ucar.edu/

Table 2-1. Observed trends in Puget Sound climate.

Variable	Observed Change [C]
Temperature	
Annual	Warming: +1.3°F (range: +0.7°F to +1.9°F for 1895-2014)[B,C,D,1]
Seasonal	Warming in most seasons (1895-2014)[D,1]
	Fall Warming: +0.12°F/decade (range: +0.07 to +0.17)
	Winter Warming: +0.13°F/decade (range: +0.02 to +0.24)
	Spring No significant change
	Summer Warming: +0.13°F/decade (range: +0.07 to +0.19)
Extremes	Statistically significant increase in nighttime heat events west of the Cascade Mountains in Oregon and Washington (1901-2009).[5] No significant trends in daytime heat events.
Freeze-free Season	Lengthening: +30 days (+3 days/decade for 1920–2014).[E,3,4]
Precipitation	
Annual	No significant change (1895-2014) [D,1]
Seasonal	Wetter springs (1895-2014)[D,1]
	Winter No significant change
	Spring Increasing: +2.3%/decade
	Summer No significant change
	Fall No significant change
Extremes	Most studies find increases in the frequency and intensity of heavy precipitation events, but few are statistically significant. Results depend on the dates and methods of the trend analysis. [12,13,14]

Table 2-2. Projected trends in Puget Sound climate.

Variable	*Projected Long-term Change*
Temperature	
Annual	Annual average air temperatures are projected to increase. Warming is projected for all greenhouse gas scenarios, and the amount of warming depends on the amount of greenhouse gases emitted. *Projected change in Puget Sound average annual air temperature:* **2050s** (2040-2069, relative to the average for 1970-1999):[J,23] Low emissions (RCP 4.5): +4.2°F (range: +2.9 to +5.4°F) High emissions (RCP 8.5): +5.5°F (range +4.3 to +7.1°F) **2080s** (2070-2099, relative to the average for 1970-1999):[J,23] Low emissions (RCP 4.5): +5.5°F (range: +4.1 to +7.3°F) High emissions (RCP 8.5): +9.1°F (range: +7.4 to +12°F)
Seasonal	Warming is projected for all seasons for the Puget Sound. *Projected change in Puget Sound seasonal air temperature:* **2050s** (2040-2069, relative to 1970-1999):[J,23] *Fall* Low emissions (RCP 4.5): +4.1°F (range: +2.6 to +5.6°F) High emissions (RCP 8.5): +5.6°F (range: +3.9 to +7.2°F) *Winter* Low emissions (RCP 4.5): +3.9°F (range: +2.8 to +5.0°F) High emissions (RCP 8.5): +4.9°F (range: +3.2 to +6.5°F) *Spring* Low emissions (RCP 4.5): +3.9°F (range: +2.4 to +5.3°F) High emissions (RCP 8.5): +4.8°F (range: +3.0 to +7.6°F) *Summer* Low emissions (RCP 4.5): +5.1°F (range: +3.3 to +7.5°F) High emissions (RCP 8.5): +6.8°F (range: +4.8 to +9.7°F) **2080s** (2070-2099, relative to the average for 1970-1999):[J,23] *Fall* Low emissions (RCP 4.5): +5.2°F (range: +3.7 to +7.1°F) High emissions (RCP 8.5): +9.0°F (range: +6.5 to +11°F) *Winter* Low emissions (RCP 4.5): +5.0°F (range: +4.3 to +6.3°F) High emissions (RCP 8.5): +8.3°F (range: +6.0 to +10°F) *Spring* Low emissions (RCP 4.5): +5.3°F (range: +3.8 to +8.2°F) High emissions (RCP 8.5): +7.9°F (range: +5.2 to +11°F)

Variable	*Projected Long-term Change*
	Summer Low emissions (RCP 4.5): +6.4°F (range: +4.6 to +9.1°F) High emissions (RCP 8.5): +11°F (range: +8.8 to +15°F)
Extremes	Heat waves are projected to intensify, while cold snaps are projected to become less severe. *Projected changes in Puget Sound air temperature extremes:* **2050s** (2040-2069, relative to 1970-1999):[O,23] Temperature of hottest days: +6.5°F (+4.0 to +10.2°F)[P] Temperature of coolest nights: +5.4°F (+1.3 to +10.4°F)[Q] Heating degree days: −1600 deg-days (−2300 to −1000)[R] Cooling degree days: +17 deg-days (+5 to +56) Growing degree days: +800 deg-days (+500 to +1300) **2080s** (2070-2099, relative to 1970-1999):[O,23] Temperature of hottest days: +9.8°F (+5.3 to +15.3°F)[P] Temperature of coolest nights: +8.3°F (+3.7 to +14.6°F)[Q] Heating degree days: −2306 deg-days (−3493 to −1387)[R] Cooling degree days: +52 deg-days (+6 to +200) Growing degree days: +1280 deg-days (+591 to +2295)
Precipitation	
Annual	Projected changes in precipitation are small. All models project changes that are small relative to year-to-year variability.

O Projections are based on 10 global models and two greenhouse gas scenarios (RCP 4.5 and 8.5), statistically downscaled following the procedures described by Mote et al. 2015.[23] For each metric, the average among all twenty scenarios is listed, along with the range in parentheses.

P Projected change in the 99th percentile of daily maximum temperature.

Q Projected change in the 1st percentile of daily minimum temperature.

R 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. Growing degree days are calculated in the same way as cooling degree days, using a base temperature of 50°F.

Variable	*Projected Long-term Change*
	Projected change in annual Puget Sound precipitation: **2050s** (2040-2069, relative to 1970-1999):[J,23] Low emissions (RCP 4.5): +4.2% (range: +0.6 to +12%) High emissions (RCP 8.5): +5.0% (range: −1.9 to +13%) **2080s** (2070-2099, relative to the average for 1970-1999):[J,23] Low emissions (RCP 4.5): +6.4% (range: −0.2 to +10%) High emissions (RCP 8.5): +6.9% (range: +1.0 to +9.4%)
Seasonal	Precipitation is generally projected to decrease in summer and increase in fall, winter, and spring. For all seasons except summer, most models project wetter conditions while others project drier conditions. All models project decreases in summer precipitation. *Projected change in Puget Sound seasonal temperature:* **2050s** (2040-2069, relative to 1970-1999):[J,23] *Fall* Low emissions (RCP 4.5): +5.5% (range: −5.7 to +13%) High emissions (RCP 8.5): +6.3% (range: −2.4 to +19%) *Winter* Low emissions (RCP 4.5): +9.9% (range: −1.6 to +21%) High emissions (RCP 8.5): +11% (range: +1.8 to +19%) *Spring* Low emissions (RCP 4.5): +2.4% (range: −9.4 to +13%) High emissions (RCP 8.5): +3.8% (range: −7.7 to +13%) *Summer* Low emissions (RCP 4.5): −22% (range: −45 to −6.1%) High emissions (RCP 8.5): −22% (range: −50 to −1.6%) **2080s** (2070-2099, relative to 1970-1999):[J,23] *Fall* Low emissions (RCP 4.5): +12% (range: +1.6 to −21%) High emissions (RCP 8.5): +10% (range: +1.9 to +15%) *Winter* Low emissions (RCP 4.5): +11% (range: +1.3 to +16%) High emissions (RCP 8.5): +15% (range: +6.2 to +23%) *Spring* Low emissions (RCP 4.5): +1.6% (range: −3.2 to +9.3%) High emissions (RCP 8.5): +2.5% (range: −6.7 to +11%) *Summer* Low emissions (RCP 4.5): −20% (range: −37 to −10%) High emissions (RCP 8.5): −27% (range: −53 to +10%)

Variable	***Projected Long-term Change***
Geography of Change	*Changes in precipitation are expected to be different from place to place, but it is not known how patterns will shift with warming.*
Heavy Precipitation	*Heavy precipitation events are projected to become more intense.* Projected changes in western Oregon and Washington precipitation extremes for the 2080s (2070-2099, relative to 1970-1999) for a high (RCP 8.5) greenhouse gas scenario:[N,32] Annual 99th percentile of 24-hour precipitation: +22% (range: +5 to +34%) Frequency of exceeding the historical 99th percentile of 24-hour precipitation: Historical (1970-1999): 2 days / year Future (2070-2099): 7 days / year (range: 4 to 9 dys/yr)

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