# Maps of Climate and Hydrologic Change for the Nooksack River Watershed

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Prepared by the University of Washington Climate Impacts Group as technical input for Nooksack Indian Tribe Natural Resources Climate Change Vulnerability Assessment.


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# Maps of Climate and Hydrologic Change for the Nooksack River Watershed

This document includes maps of historical and projected changes in climate and hydrology for the Nooksack River watershed. Spatial resolution of the downscaled projections is 0.0625 degrees, or approximately 6 km. Projections are from Integrated Scenarios for the Future Northwest Environment. This set of projections were developed by Mote et al. 2015[1], which are derived from the 2013 IPCC report.[2]

Projections are shown for two time horizons (2050s and 2080s) and for a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario.

Projections are included for the following climate and hydrologic variables:



[1] Mote, P.W., Rupp, D.E., Abatzoglou, J.T., Hegewisch, K.C., Nijssen, B., Lettenmaier, D.P., Stumbaugh, M., Lee, S. Y., & Bachelet, D., 2015. Integrated Scenarios for the Future Northwest Environment. USGS ScienceBase. Data set accessed at https://www.sciencebase.gov/catalog/item/5006eb9de4b0abf7ce733f5c

[2] (IPCC) Intergovernmental Panel on Climate Change. 2013. Working-Group-1, Summary for Policymakers. Available at: http://www.climatechange2IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis.Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

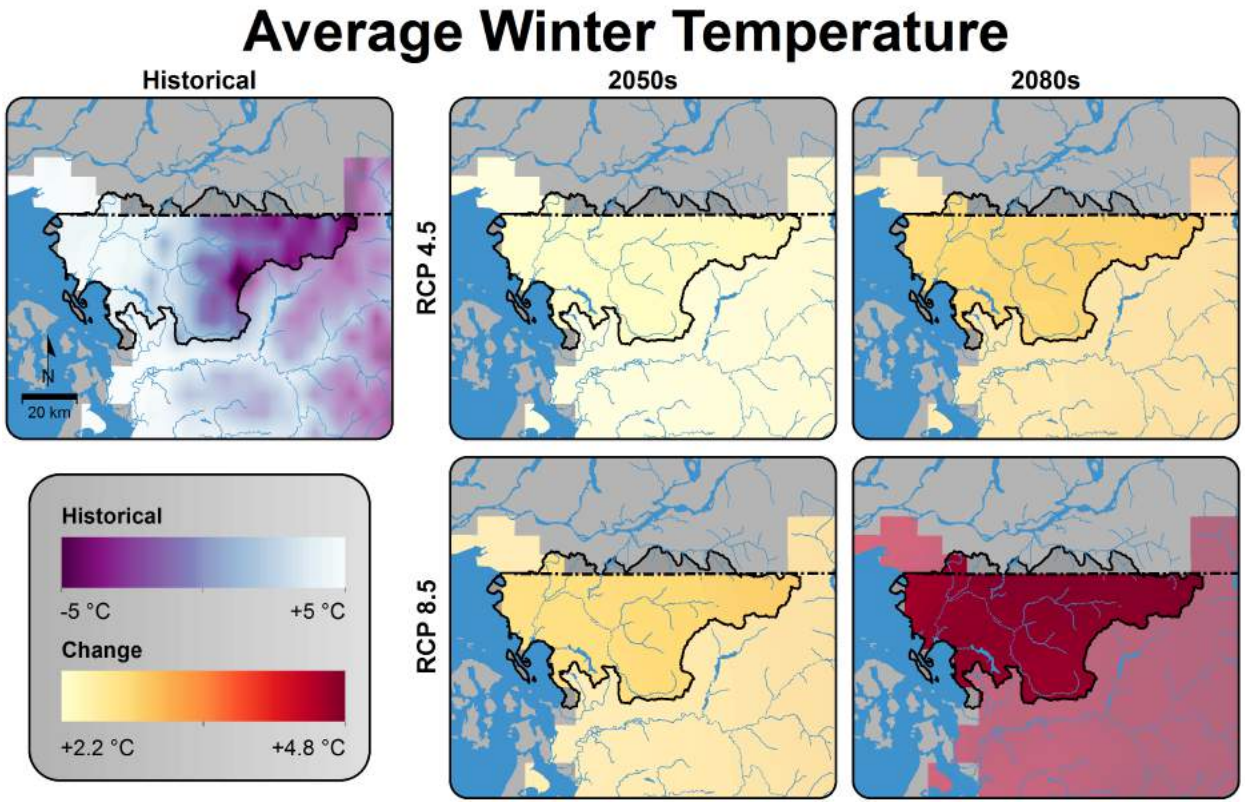


**Figure 1. Average Winter Temperature.** Maps show the historical and projected change in average winter (December–February) temperature, in °C. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark purple shading on the historical map indicates areas with the lowest average winter temperature. Projected increases in average winter temperature are depicted by the yellow to red shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[1] Data source: Integrated Scenarios.[2]

| **Variable** | **Projected Change for the 2050s**[3] | **Projected Change for the 2080s**[4] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Average winter temperature | +2.2°C for RCP 4.5 (range: +1.7°C to 2.9°C) and +2.8°C (range: +1.9 to 3.8°C) for RCP 8.5 relative to 1970-1999. | +2.8°C for RCP 4.5 (range: +2.2°C and +3.7°C) and +4.8 (range: +3.5°C to 5.6°C) for RCP 8.5 relative to 1970-1999. |

[3] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069

[4] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

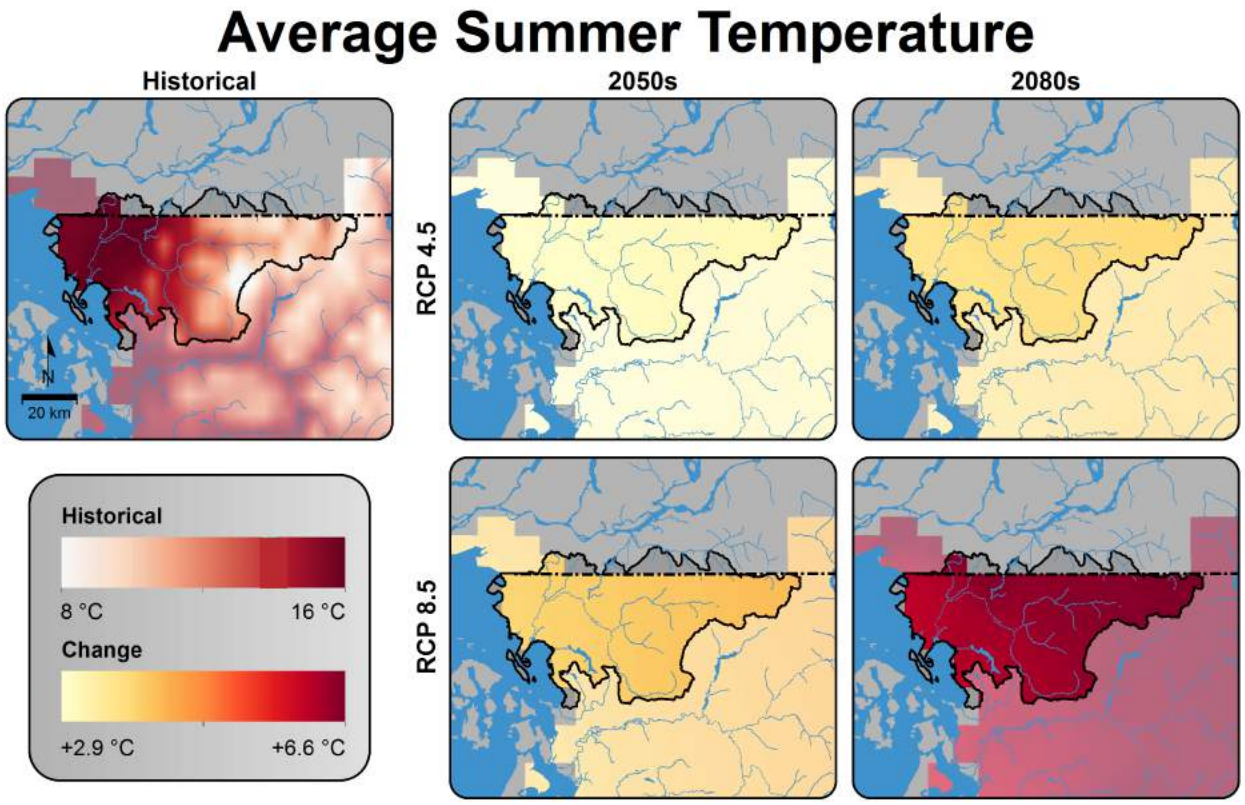


**Figure 2. Average Summer Temperature.** Maps show the historical and projected change in average summer (June– August) temperature, in °C. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark red shading on the historical map indicates areas with the highest average summer temperature. Projected increases in average summer temperature are depicted by the yellow to red shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| **Variable** | **Projected Change for the 2050s**[5] | **Projected Change for the 2080s**[6] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Average summer temperature | +3.0°C for RCP 4.5 (range: +1.9°C to +4.3°C) and +4.0°C (range: +2.7 to 5.5°C) for RCP 8.5 relative to 1970-1999. | +3.7°C for RCP 4.5 (range: +2.6°C and +5.2°C) and +6.4 (range: +5.0°C to 8.5°C) for RCP 8.5 relative to 1970-1999. |

[5] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069

[6] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

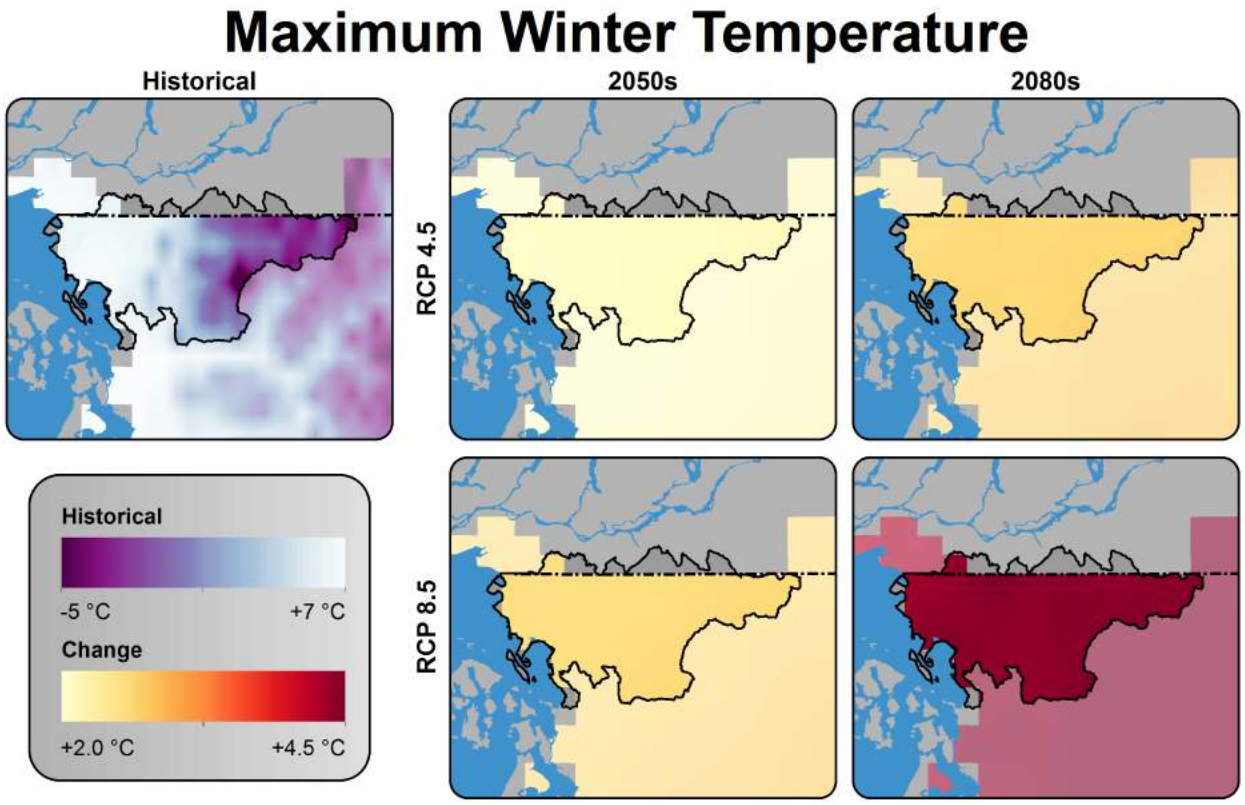


**Figure 3. Maximum Winter Temperature.** Maps show the historical and projected change in maximum winter (December–February) temperature, in °C. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. White shading on the historical map indicates areas with the warmest maximum winter temperature. Projected increases in maximum winter temperature are depicted by the yellow to red shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| **Variable** | **Projected Change for the 2050s**[7] | **Projected Change for the 2080s**[8] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Maximum winter temperature | +2.0°C for RCP 4.5 (range: +1.5°C to +2.6°C) and +2.5°C (range: +1.7 to 3.4°C) for RCP 8.5 relative to 1970-1999. | +2.6°C for RCP 4.5 (range: +1.8°C and +3.4°C) and +4.5 (range: +3.3°C to 5.3°C) for RCP 8.5 relative to 1970-1999. |

[7] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069

[8] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

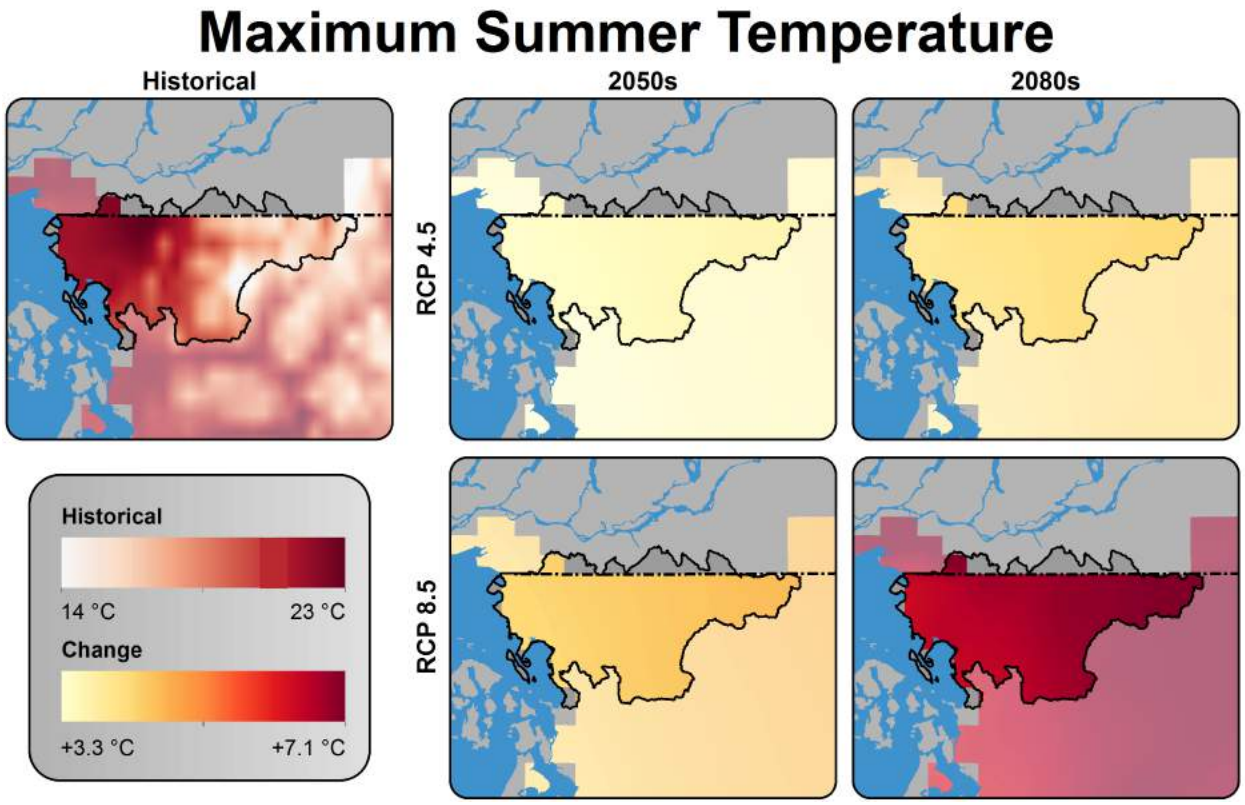


**Figure 4. Maximum Summer Temperature.** Maps show the historical and projected change in maximum summer (June–August) temperature, in °C. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark red shading on the historical map indicates areas with the warmest maximum summer temperature. Projected increases in maximum summer temperature are depicted by the yellow to red shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[9] | Projected Change for the 2080s[10] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Maximum summer temperature | +3.3°C for RCP 4.5 (range: +2.0°C to +4.7°C) and +4.3°C (range: +2.9 to 5.8°C) for RCP 8.5 relative to 1970-1999. | +4.0°C for RCP 4.5 (range: +2.8°C and +5.7°C) and +6.9 (range: +5.3°C to 8.9°C) for RCP 8.5 relative to 1970-1999. |

[9] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069

[10] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

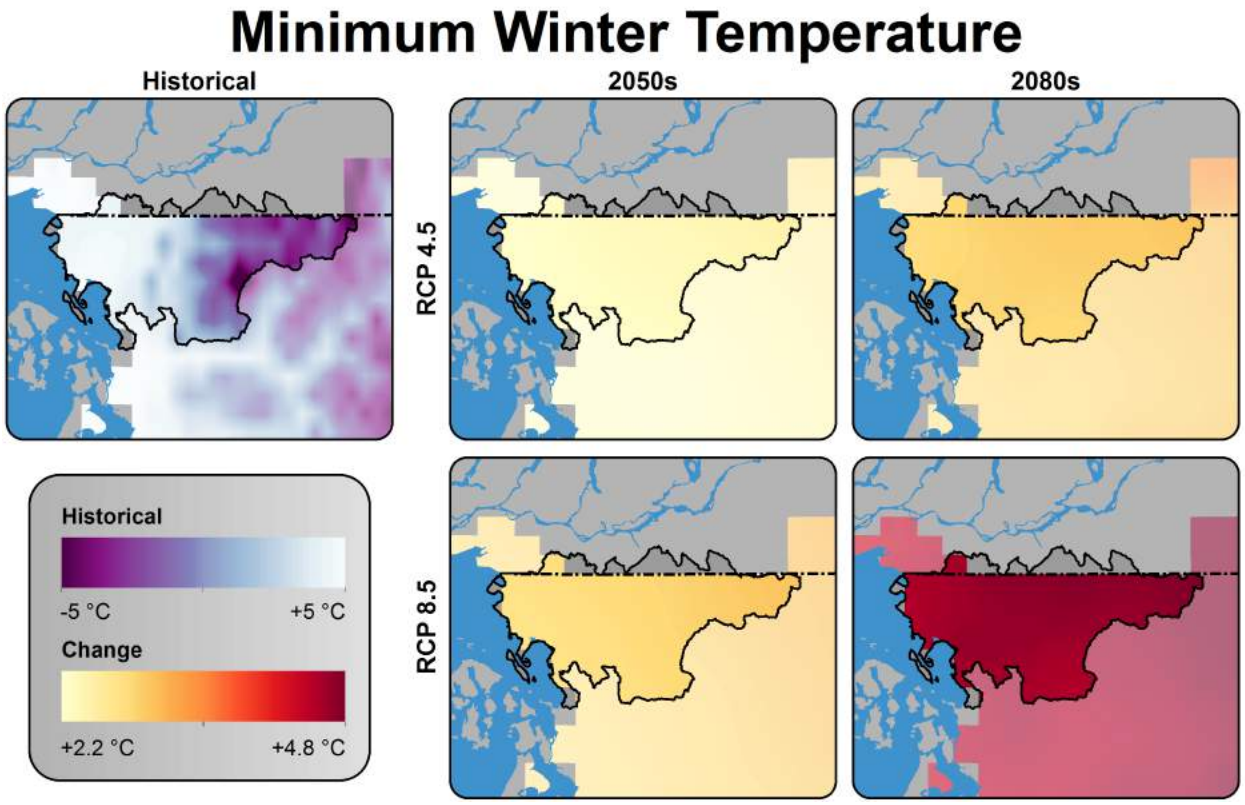


**Figure 5. Minimum Winter Temperature.** Maps show the historical and projected change in minimum winter (December–February) temperature, in °C. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark purple shading on the historical map indicates areas with the coldest minimum winter temperatures. Projected increases in minimum winter temperature are depicted by the yellow to red shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[11] | Projected Change for the 2080s[12] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Minimum winter temperature | +2.4°C for RCP 4.5 (range: +1.9°C to +3.3°C) and +3.0°C (range: +2.0 to 4.3°C) for RCP 8.5 relative to 1970-1999. | +3.1°C for RCP 4.5 (range: +2.7°C and +4.1°C) and +5.0 (range: +3.7°C to 6.1°C) for RCP 8.5 relative to 1970-1999. |

[11] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[12] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

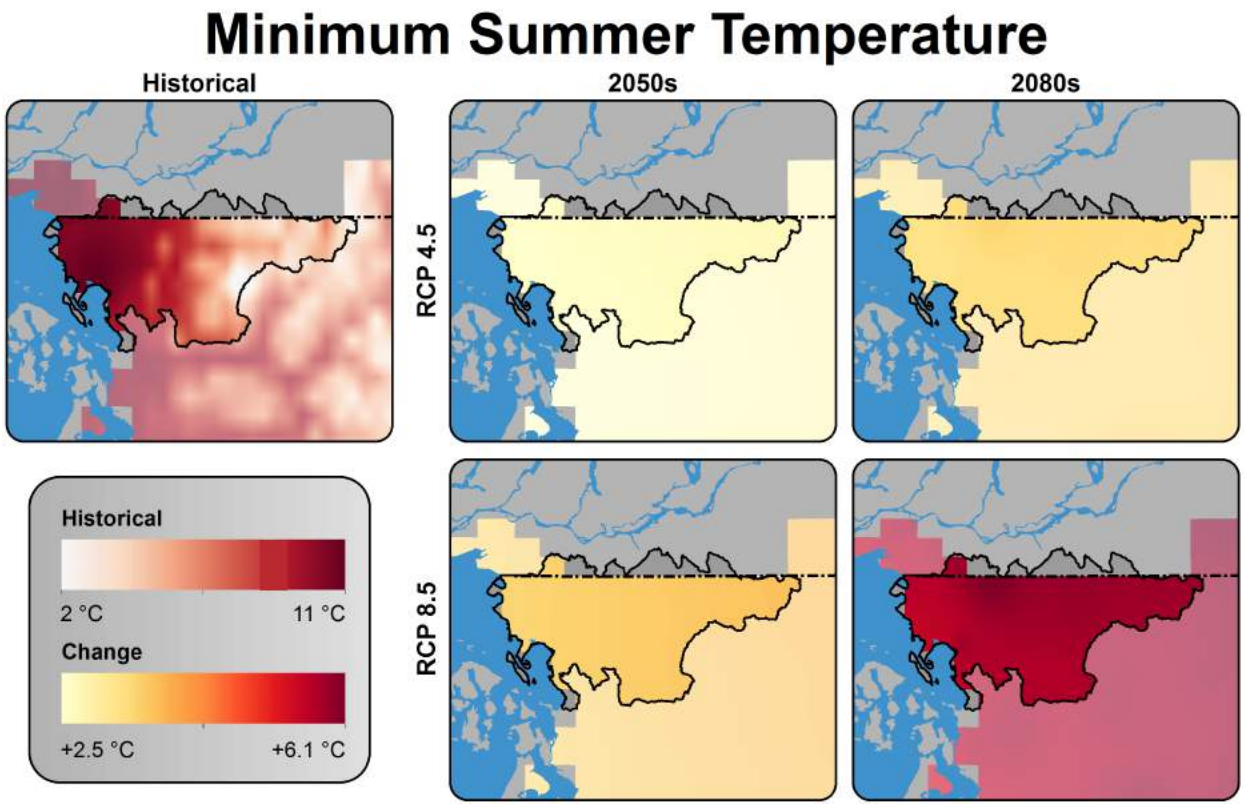


**Figure 6. Minimum Summer Temperature.** Maps show the historical and projected change in minimum summer (June– August) temperature, in °C. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Very light red shading on the historical map indicates areas with the coolest minimum summer temperature. Projected increases in minimum summer temperature are depicted by the yellow to red shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[13] | Projected Change for the 2080s[14] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Minimum summer temperature | +2.6°C for RCP 4.5 (range: +1.6°C to +3.9°C) and +3.6°C (range: +2.5 to 5.2°C) for RCP 8.5 relative to 1970-1999. | +3.3°C for RCP 4.5 (range: +2.0°C and +4.7°C) and +6.0 (range: +4.5°C to 8.1°C) for RCP 8.5 relative to 1970-1999. |

[13] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[14] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

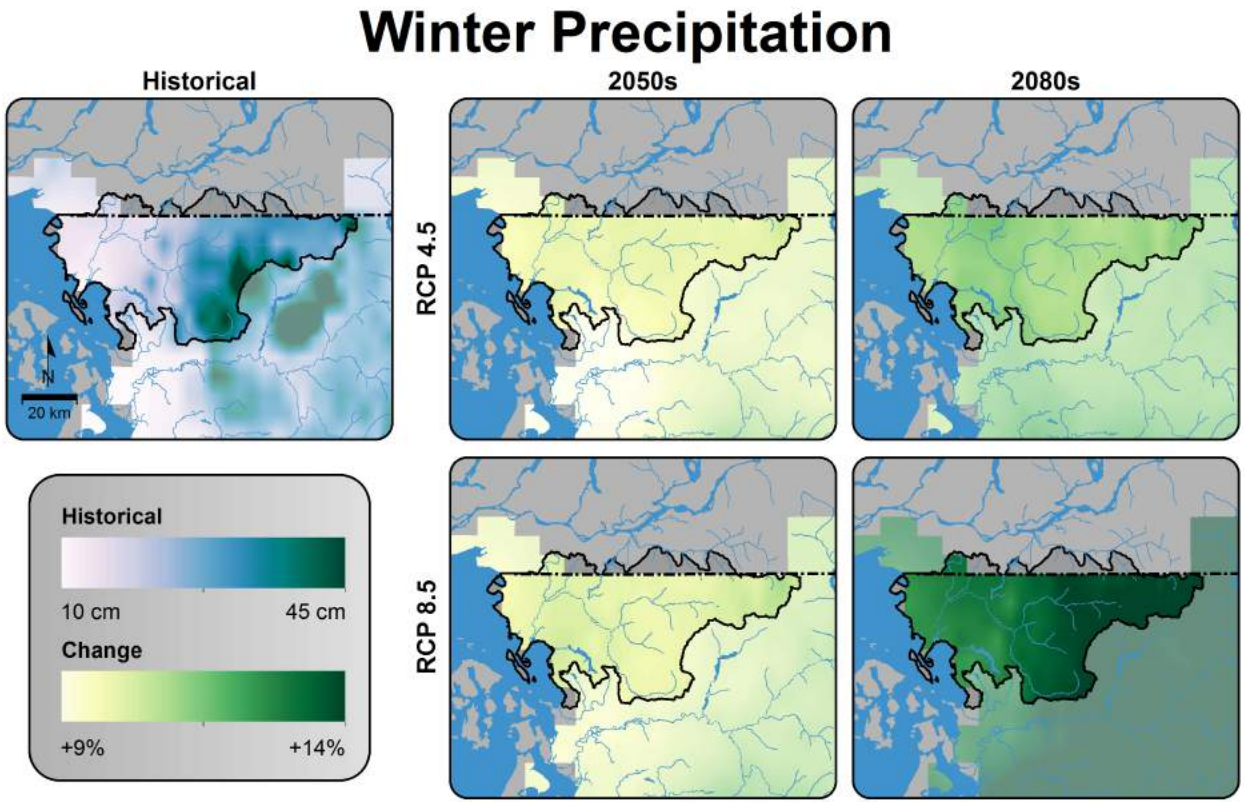


**Figure 7. Average Winter Precipitation.** Maps show the historical and projected change in average winter (December–February) precipitation, in percent. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark green shading on the historical map indicates areas with the highest average winter precipitation. Projected increases in average winter precipitation are depicted by the light yellow to green shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[15] | Projected Change for the 2080s[16] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Average winter precipitation | +9.5% for RCP 4.5 (range: –2.8% to +20.8%) and +9.7% (range: +2.0% to +20.8%) for RCP 8.5 relative to 1970-1999. | +10.8% for RCP 4.5 (range: +0.8% and +16.2%) and +13.2% (range: +5.0% to 21.7%) for RCP 8.5 relative to 1970-1999. |

[15] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[16] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

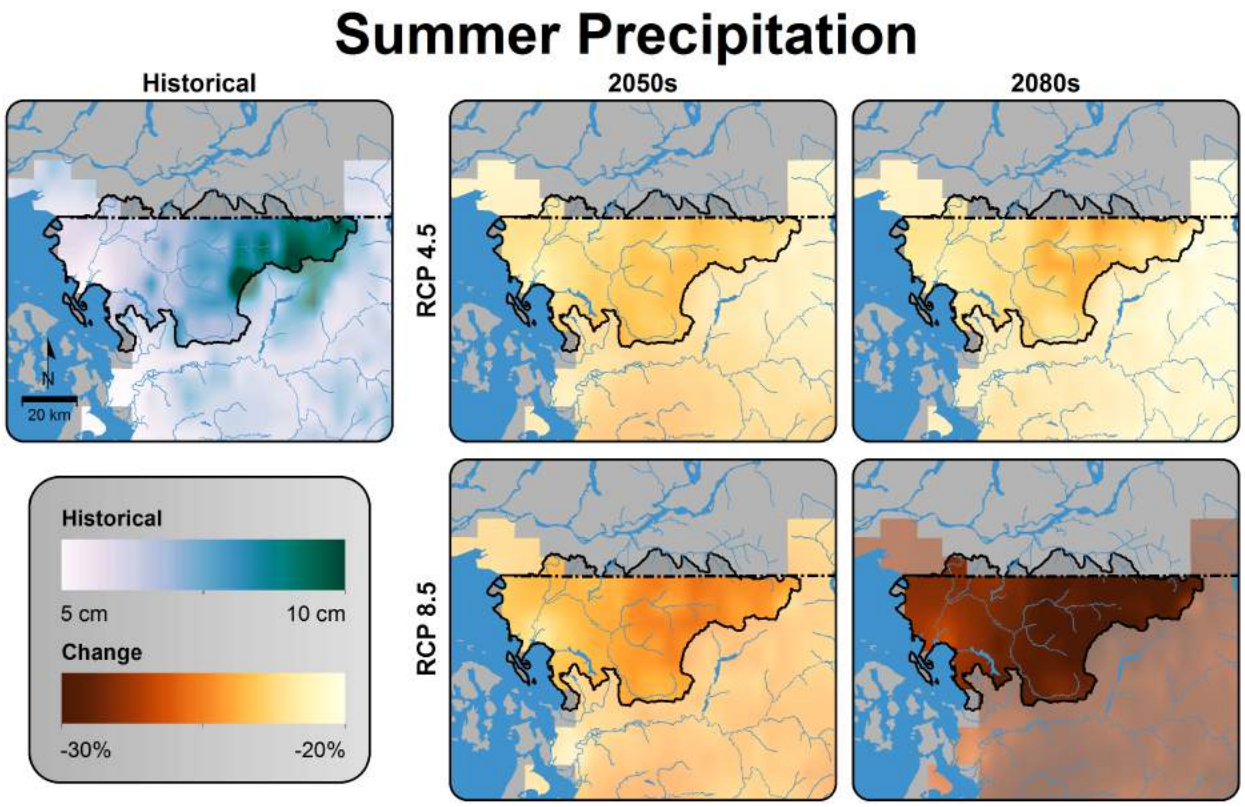


**Figure 8. Average Summer Precipitation.** Maps show the historical and projected change in average summer (June– August) precipitation, in percent. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark green shading on the historical map indicates areas with the highest average summer precipitation. Projected declines in average summer precipitation are depicted by the dark red to light yellow shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| **Variable** | **Projected Change for the 2050s**[17] | **Projected Change for the 2080s**[18] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Average summer precipitation | –21.3% for RCP 4.5 (range: –39.6% to –7.2%) and –22.9% (range: –49.9% to –2.2%) for RCP 8.5 relative to 1970-1999. | –21.1% for RCP 4.5 (range: –34.1% and –9.9%) and –29% (range: –52% and –+2.3%) for RCP 8.5 relative to 1970-1999. |

[17] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[18] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

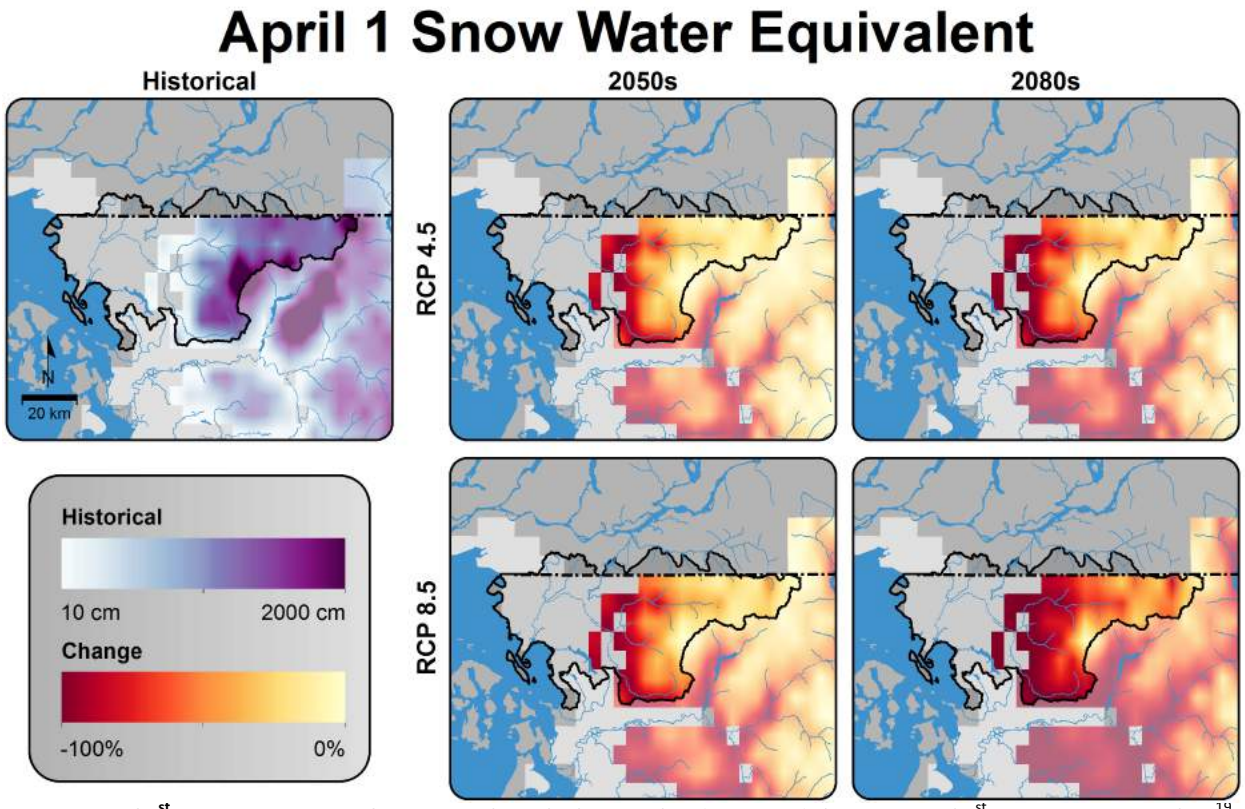


**Figure 9. April 1st Snow Water Equivalent.** Maps show the historical and projected change in April 1st snow water equivalent[19], in percent. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark purple shading on the historical map indicates areas with the highest April 1st SWE. Projected declines in April 1st SWE are depicted by the dark red to light yellow shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[20] | Projected Change for the 2080s[21] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| April 1st SWE | –44.5% for RCP 4.5 (range: –52.0% to –34.2%) and –51.3% (range: –63.6% to –38.1%) for RCP 8.5 relative to 1970-1999. | –54.7% for RCP 4.5 (range: –62.3% and –47.2%) and –72.3% (range: –81.2% and –57.6%) for RCP 8.5 relative to 1970-1999. |

[19] Snow water equivalent (SWE) is a measure of the total amount of water contained in the snowpack. April 1st is currently the approximate timing of peak annual snowpack in the mountains of the Northwest. Changes calculated for locations that regularly accumulate snow (i.e., historical April 1st SWE of at least 10 mm, or about 0.4 inch, on average) (Mauger et al. 2015).

[20] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069

[21] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

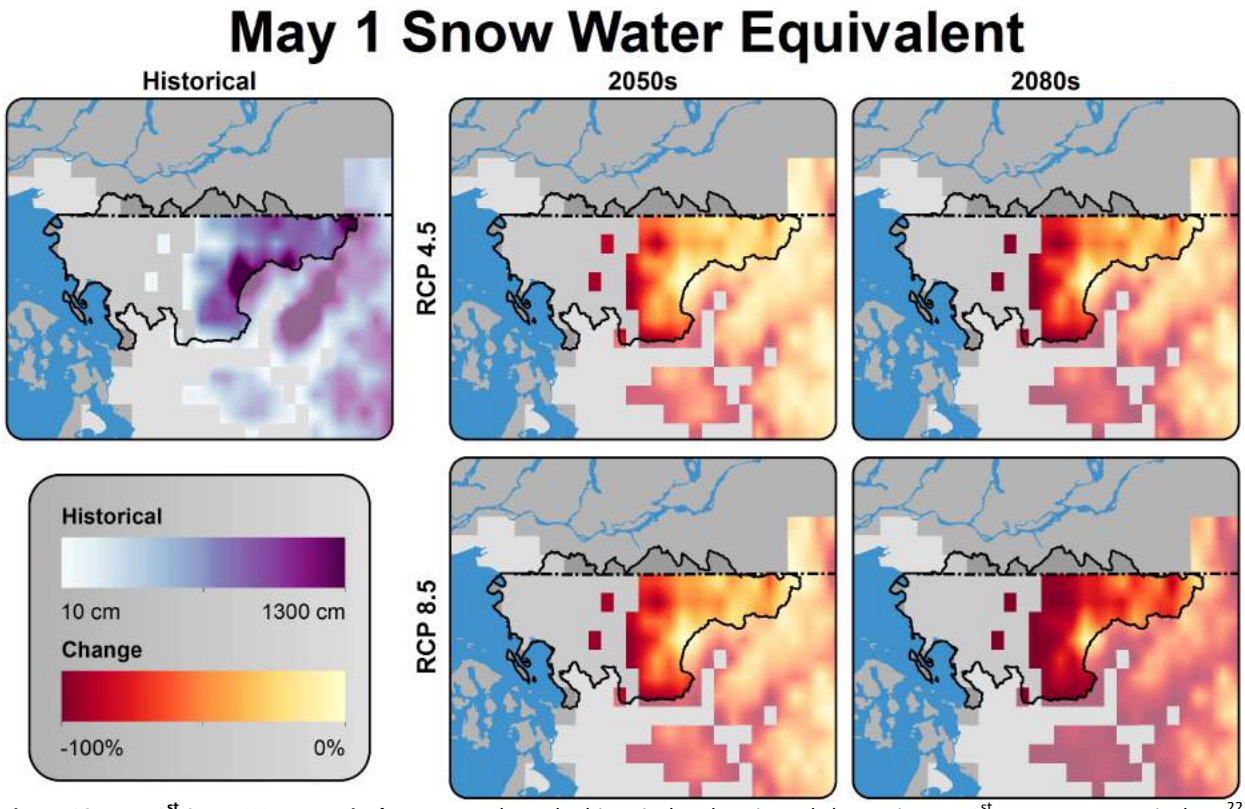


**Figure 10. May 1st Snow Water Equivalent.** Maps show the historical and projected change in May 1st snow water equivalent,[22] in percent. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Dark purple shading on the historical map indicates areas with the highest May 1st SWE. Projected declines in May 1st SWE are depicted by the dark red to light yellow shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[23] | Projected Change for the 2080s[24] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| May 1st SWE | –49.1% for RCP 4.5 (range: –56.5% to –37.9%) and –56.9% (range: –69.5% to –41.3%) for RCP 8.5 relative to 1970-1999. | –60.9% for RCP 4.5 (range: –72.5% and –54.9%) and –78.3% (range: –89.7% and –63.3%) for RCP 8.5 relative to 1970-1999. |

[22] Snow water equivalent (SWE) is a measure of the total amount of water contained in the snowpack. Changes calculated for locations that regularly accumulate snow (i.e., historical May 1st SWE of at least 10 mm, or about 0.4 inch, on average).

[23] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069

[24] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

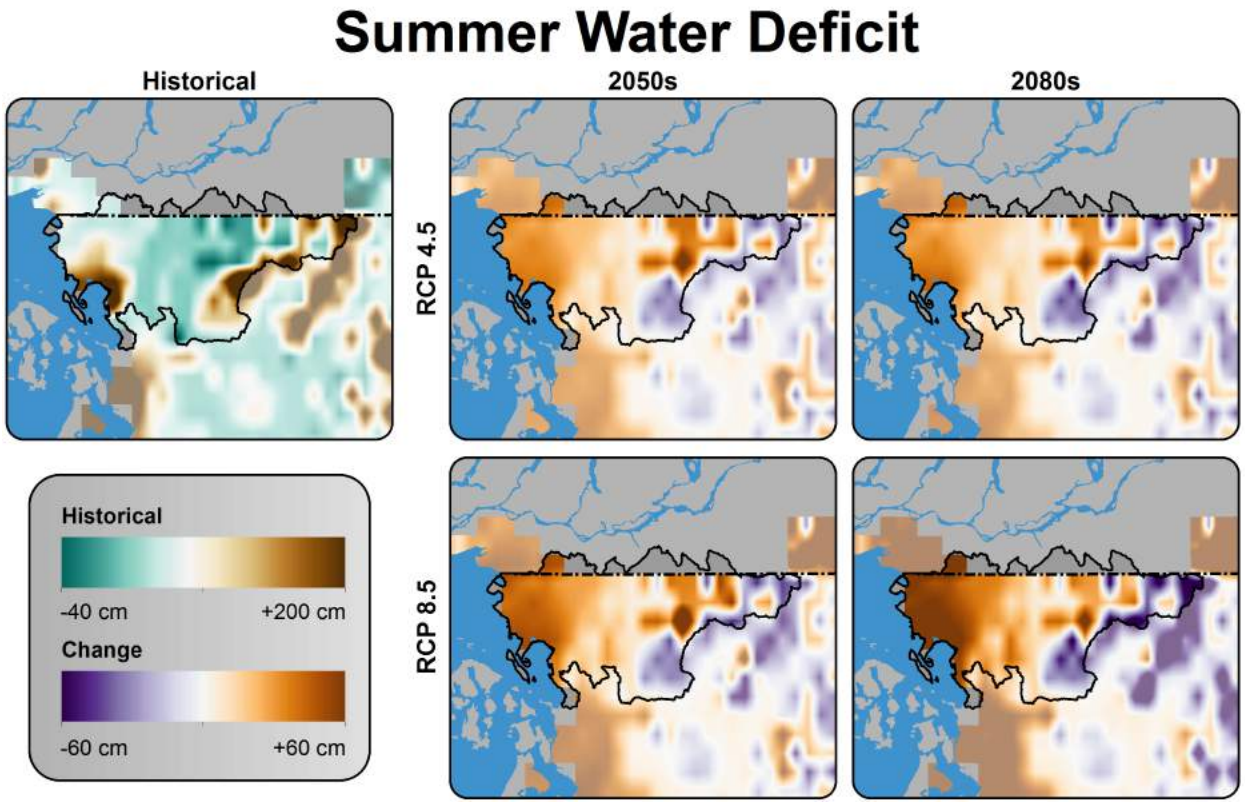


**Figure 11. Summer Water Deficit.** Maps show the historical and projected change in summer (July-September) water deficit, in centimeters, based on the amount of soil moisture available relative to atmospheric demand for water via evaporation, either from water sources or vegetation. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Teal shading on the historical map indicates areas where water availability exceeds water demand, and brown shading indicates areas where water demand exceeds water availability. Projected change in summer water deficit is depicted by the purple to dark orange shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| **Variable** | **Projected Change for the 2050s**[25] | **Projected Change for the 2080s**[26] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Summer water deficit | +14.9 cm for RCP 4.5 (range: +7.5 cm to +22.3 cm) and +18.6 cm (range: +3.4 cm to +34.9 cm) for RCP 8.5 relative to 1970-1999. | +11.7 cm for RCP 4.5 (range: +0.5 cm and +19.9 cm) and +20.9 cm (range: +7.3 cm and +33.5 cm) for RCP 8.5 relative to 1970-1999. |

[25] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[26] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

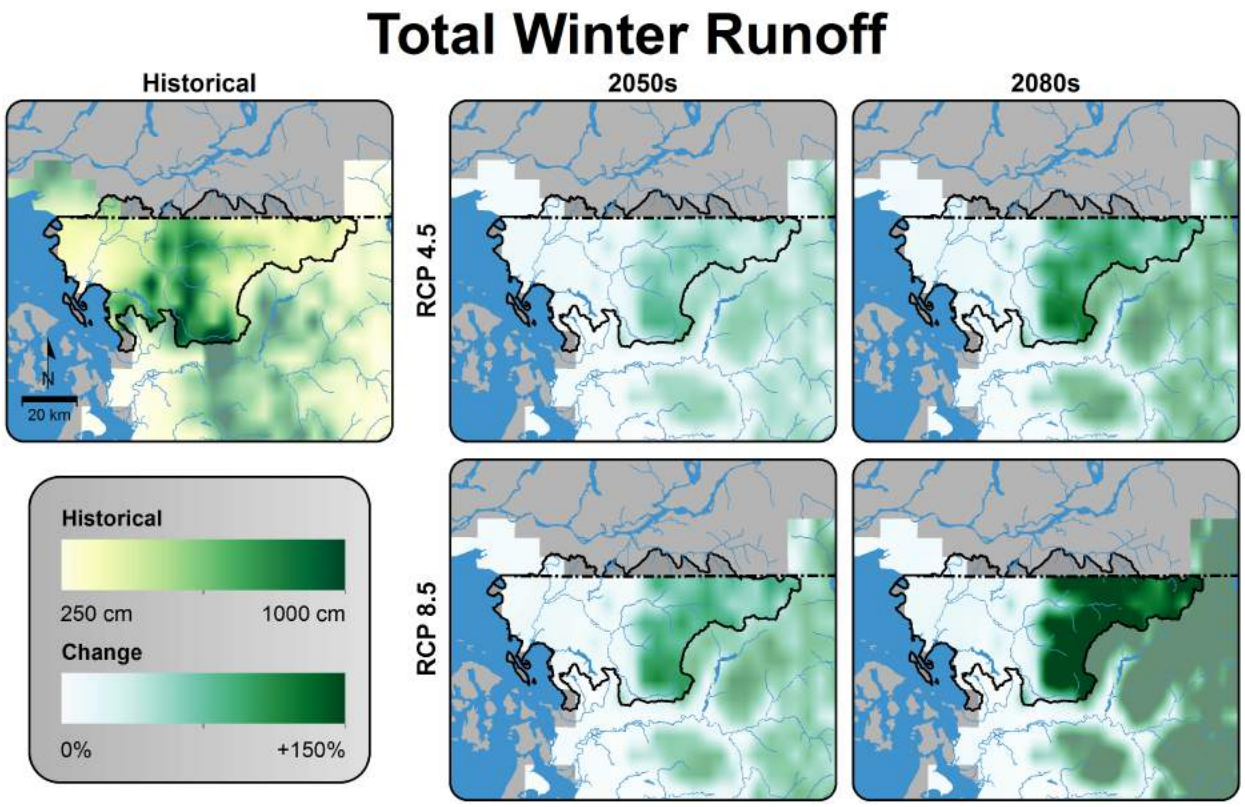


**Figure 12. Total Winter Runoff.** Maps show the historical and projected change in total winter (October-March) runoff, in percent change. Runoff includes any overland water flows in addition to subsurface runoff in shallow groundwater. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Projected change in total winter runoff is depicted by the light to dark green shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| Variable | Projected Change for the 2050s[27] | Projected Change for the 2080s[28] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Total winter runoff | +24.0% for RCP 4.5 (range: +11.2% to +44.3%) and +29.4% (range: +17.3% to +45.4%) for RCP 8.5 relative to 1970-1999. | +37.5% for RCP 4.5 (range: +19.2% and +54.6%) and +50.8% (range: –5.3% and +75.6%) for RCP 8.5 relative to 1970-1999. |

[27] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[28] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.

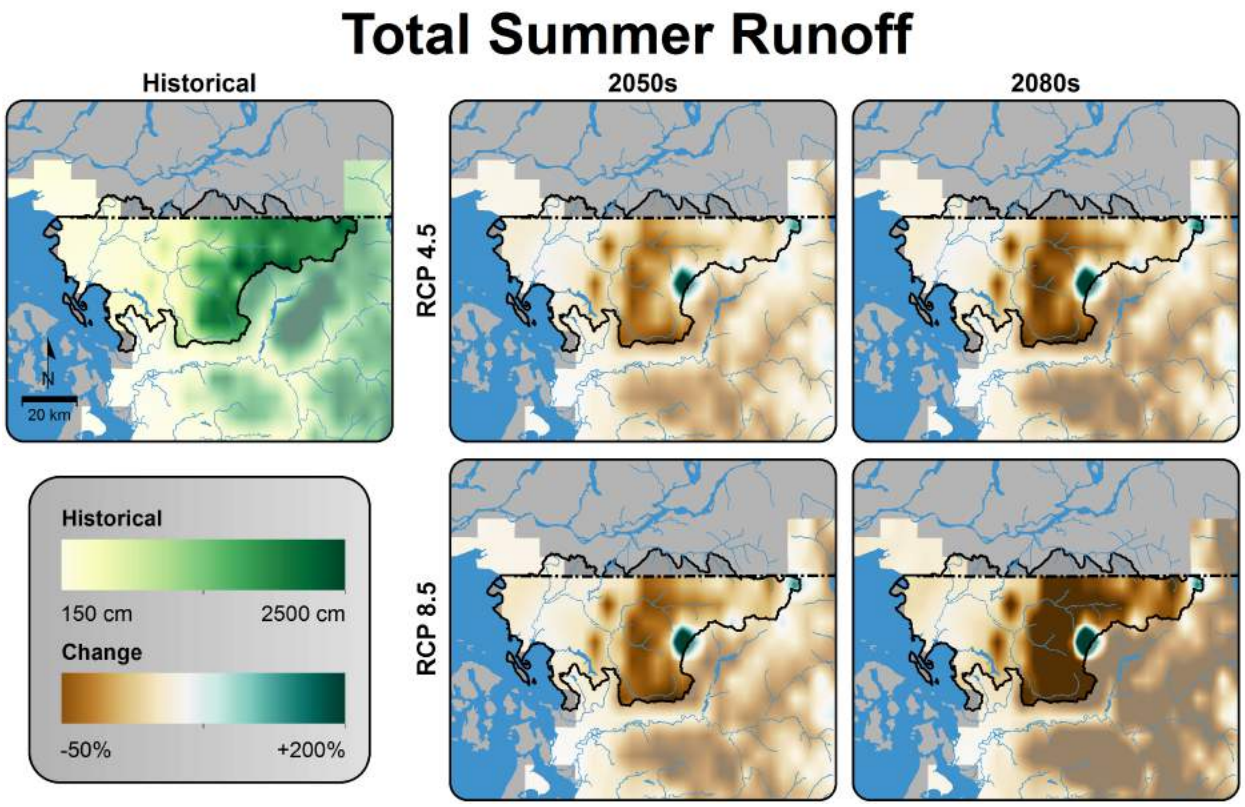


**Figure 13. Total Summer Runoff.** Maps show the historical and projected change in total summer (April-September) runoff, in percent change. Runoff includes any overland water flows in addition to subsurface runoff in shallow groundwater. Maps compare historical conditions (1970-1999) with the projected change for ten global models. Projections are shown for two time periods: the 2050s (2040-2069) and the 2080s (2070-2099), based on a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Projected change in total summer runoff is depicted by the brown to teal shading. Figure created by Robert Norheim University of Washington Climate Impacts Group, based on the CMIP5 projections used in the IPCC 2013 report.[2] Data source: Integrated Scenarios.[1]

| **Variable** | **Projected Change for the 2050s**[29] | **Projected Change for the 2080s**[30] |
|---|---|---|
| ***Nooksack River Watershed*** | | |
| Total summer runoff | –12.5% for RCP 4.5 (range: –16.2% to –5.6%) and –16.1% (range: –22.4% to –7.4%) for RCP 8.5 relative to 1970-1999. | –15.9% for RCP 4.5 (range: –20.3% to –4.3%) and –18.6% (range: –35.1% to –51.0%) for RCP 8.5 relative to 1970-1999. |

[29] Specifically, "2050s" refers to the 30-year average spanning from 2040 to 2069
[30] Specifically, "2080s" refers to the 30-year average spanning from 2070 to 2099.