II. CO_2 CONCENTRATIONS, TEMPERATURE, AND PRECIPITATION

Box 1. Summary of observed trends and future projections for greenhouse gas concentrations, temperature, and precipitation.

Observed Trends

- Atmospheric CO_2 concentrations in March 2011 were approximately 392 parts per million (ppm),[29] higher than any level in the past 650,000 years[30] and 41% higher than the pre-industrial value (278 ppm).[31] From 2000-2004, the emissions growth rate (>3%/yr) exceeded that of the highest-emissions IPCC scenario (A1F1), and the actual emissions trajectory was close to that of the A1F1 scenario.[32]
- Annual average temperatures in the NPLCC region increased, in general, 1-2°F (~0.6-1°C) over the 20th century.[33] Alaska is an exception – a 3.4°F (~1.9°C) increase was observed from 1949-2009.[34]
- In the 20th century and early 21st century, the largest increase in seasonal temperature occurred in winter (January-March): +3.3°F (+1.83°C) in western BC, OR, and WA[35] and +1.8-2.0ºF (+1.0-1.1ºC) in northwestern CA.[36] These increases tend to drive the annual trends, particularly in AK (+6.2°F or 3.4°C from 1949-2009 near Juneau).[37]
- In the 20th century and early 21st century, average annual precipitation trends are highly variable, with increases of 2 to approximately 7 inches (~5-18 cm) observed in WA, OR,[38] and northwestern CA,[39] and both small increases and decreases (±1inch or ±2.54 cm) observed in BC's Georgia Basin and coastal areas, depending on the time period studied.[40] Precipitation trends in Alaska were not available. However, precipitation was 32-39 inches (80-100cm) in southcentral Alaska and at least 39 inches (100cm) in southeast Alaska from 1949-1998.[41]
- In the 20th century and early 21st century, seasonal precipitation trends are highly variable, with increases in winter and spring precipitation observed in WA, OR,[42] and northwestern CA,[43] and both increases and decreases observed in BC, depending on location and time period.[44] Specifically, in WA and OR, spring precipitation increased +2.87 inches (7.29cm) and winter precipitation increased 2.47 inches (6.27cm) from 1920 to 2000.[45]

A summary of future projections can be found on the next page.

Note to the reader: In Boxes, we summarize the published and grey literature. The rest of the report is constructed by combining sentences, typically verbatim, from published and grey literature. Please see the Preface: Production and Methodology for further information on this approach.

[29] National Oceanic and Atmospheric Administration (NOAA). (2011c)
[30] CIG. (2008)
[31] Forster et al. (2007, p. 141)
[32] Raupach et al. (2007)
[33] Mote (2003, p. 276); Butz and Safford (Butz and Safford 2010, 1). Butz and Safford refer the reader to Figures 1 & 2 in the cited report.
[34] Karl, Melillo and Peterson. (2009, p. 139). The authors cite Fitzpatrick et al. (2008) for this information.
[35] Mote. (2003, p. 276)
[36] Butz and Safford (Butz and Safford 2010, 1). The authors refer the reader to Figures 1 & 2 in the cited report.
[37] Alaska Climate Research Center (ACRC). (2009)
[38] Mote. (2003, p. 279)
[39] Killam et al. (2010, p. 2)

Future projections

- Projected atmospheric CO_2 concentrations in 2100 range from a low of about 600 ppm under the A1T, B1, and B2 scenarios to a high of about 1000 ppm in the A1F1 scenario.[46] Recent emissions trajectories are close to that of the A1F1 scenario.[47]
- By 2100, average annual temperatures in the NPLCC region are projected to increase 3.1-6.1°F (1.7-3.4°C) (excluding AK & BC, where temperatures are projected to increase 2.5-2.7°F (1.4-1.5°C) by 2050 and 5-13°F (2.8-7.2°C) after 2050, respectively).[48] The range of projected increases varies from 2.7 to 13°F (1.5-7.2°C); the largest increase is projected in AK.[49] Baselines for projections are: 1960s-1970s in AK, 1961-1990 in BC, 1970-1999 in the Pacific Northwest (PNW), and 1971-2000 in northwest CA.
- By 2100, seasonal temperatures are projected to increase the most in summer (region-wide: 2.7-9.0°F, 1.5-5°C): in BC, 2.7°F to 5.4˚F (1.5-3˚C) along the North Coast and 2.7°F to 9.0˚F (1.5-5˚C) along the South Coast. In WA and OR, 5.4-8.1˚F (3.0-4.5˚C).[50] The exception is AK, where seasonal temperatures are projected to increase the most in winter.[51] The baseline for projections varies by study location: 1960s-1970s in Alaska, 1961-1990 on the BC coast and northern CA, 1970-1999 in the PNW.
- Precipitation may be more intense, but less frequent, and is more likely to fall as rain than snow.[52] Annual precipitation is projected to increase in AK,[53] BC (2050s: +6% along the coast, no range provided),[54] and WA and OR (2070-2099: +4%, range of -10 to +20%),[55] but is projected to decrease in CA (2050: -12 to -35%, further decreases by 2100).[56] Increases in winter and fall precipitation drive the trend (+6 to +11% [-10 to +25% in winter] in BC and +8% [small decrease to +42%] in WA and OR), while decreases in summer precipitation mitigate the upward trend (-8 to -13% in BC [-50 to +5%] and -14% [some models project -20 to -40%] in WA and OR).[57] In southeast AK a 5.7% increase in precipitation during the growing season is projected (no range or baseline provided).[58] Baselines for BC, WA, OR, and CA are the same as those listed in the previous bullet.

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[40] Pike et al. (2010, Table 19.1, p. 701)
[41] Stafford, Wendler and Curtis. (2000, p. 41). Information obtained from Figure 7.
[42] Mote. (2003, p. 279)
[43] Killam et al. (2010, p. 4)
[44] Pike et al. (2010, Table 19.1, p. 701)
[45] Mote. (2003, p. 279)
[46] Meehl et al. (2007, p. 803). This information was extrapolated from Figure 10.26 by the authors of this report.
[47] Raupach et al. *Global and regional drivers of accelerating CO_2 emissions.* (2007)
[48] For BC, Pike et al. (2010, Table 19.3, p. 711). For AK, U.S. Karl, Melillo and Peterson. (2009, p. 139). For WA and OR, CIG. *Climate Change (website).* (2008, Table 3) and Mote et al. (2010, p. 21). For CA, California Natural Resources Agency (NRA). (2009, p. 16-17), Port Reyes Bird Observatory (PRBO). (2011, p. 8), and Ackerly et al. (2010, Fig. S2, p. 9).
[49] For AK, Karl, Melillo and Peterson. (2009, p. 139). For WA and OR, CIG. *Climate Change (website).* (2008, Table 3) and Mote et al. (2010, p. 21). For CA, CA NRA.. (2009, p. 16-17) and PRBO. (2011, p. 8).
[50] For BC, BC Ministry of Environment (MoE). (2006, Table 10, p. 113). For OR and WA, Mote and Salathé, Jr. (2010, Fig. 9, p. 42).For CA, PRBO. (2011, p. 8).
[51] Karl, Melillo and Peterson. (2009)
[52] Karl, Melillo and Peterson. (2009)
[53] Karl, Melillo and Peterson. (2009, p. 139)
[54] Pike et al. (2010, Table 19.3, p. 711)
[55] Climate Impacts Group (CIG). *Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts (draft document; pdf).* (2010, p. 2)
[56] California Natural Resources Agency. (2009, p. 16-17)
[57] For BC, BC MoE. (2006, Table 10, p. 113). For OR & WA, Mote & Salathé, Jr. (2010, 42-44).
[58] Alaska Center for Climate Assessment and Policy. (2009, p. 31)

1. CARBON DIOXIDE (CO_2) CONCENTRATIONS – *global observed trends and future projections*

Observed Trends

- Overall change: Atmospheric CO_2 concentrations in March 2011 were approximately 392 parts per million (ppm),[59] higher than any level in the past 650,000 years[60] and 41% higher than the pre-industrial value (278 ppm).[61] Current CO_2 concentrations are about 3.4 percent higher than the 2005 concentration reported by the IPCC's Fourth Assessment Report (AR4: 379 ± 0.65 ppm).[62] From 2000-2004, the actual emissions trajectory was close to that of the high-emissions A1F1 scenario.[63]
- Annual growth rates
    - 1960-2005: CO_2 concentrations grew 1.4 ppm per year, on average.[64]
    - 1995-2005: CO_2 concentrations grew 1.9 ppm per year, on average.[65] This is the most rapid rate of growth since the beginning of continuous direct atmospheric measurements, although there is year-to-year variability in growth rates.[66]
    - 2000-2004: the emissions growth rate (>3%/yr) exceeded that of the highest-emissions IPCC scenario (A1F1).[67]
    - 2010: the annual mean rate of growth of CO_2 concentrations was 2.68 ppm.[68]

[59] NOAA. *Trends in Atmospheric Carbon Dioxde (website).* (2011c)
[60] CIG. *Climate Change: Future Climate Change in the Pacific Northwest (website).* (2008)
[61] Forster et al. (2007, p. 141)
[62] Forster et al. (2007, p. 141)
[63] Raupach et al. *Global and regional drivers of accelerating CO_2 emissions.* (2007)
[64] IPCC. "Summary for Policymakers." In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* (2007f, p. 2)
[65] IPCC. (2007f, p. 2)
[66] *IPCC. (2007f, p. 2)
[67] Raupach et al. (2007)
[68] NOAA. (2011c)

Box 2. The Special Report on Emissions Scenarios (SRES).

Changes in greenhouse gas (GHG, e.g. carbon dioxide, CO_2) and sulfate aerosol emissions are based on different assumptions about future population growth, socio-economic development, energy sources, and technological progress. Because we do not have the advantage of perfect foresight, a range of assumptions about each of these factors are made to bracket the range of possible futures, i.e. scenarios. Individual scenarios, collectively referred to as the IPCC Special Report on Emissions Scenarios or SRES scenarios, are grouped into scenario "families" for modeling purposes. Forty individual emissions scenarios are grouped into six families: A1F1, A1B, A1T, A2, B1, and B2. The "A" families are more economic in focus than the "B" families, which are more environmentally focused. The A1 and B1 families are more global in focus compared to the more regional A2 and B2. All scenarios are assumed to be equally valid, with no assigned probabilities of occurrence. While the scenarios cover multiple GHGs and multiple drivers are used to project changes, this report focuses on CO_2 because it is the major driver of climate change impacts and is tightly coupled with many ecological processes.

- The A1 scenarios (A1F1, A1B, and A1T) assume rapid economic growth, a global population that peaks in mid-century, and rapid introduction of new and more efficient technologies. They are differentiated by assumptions about the dominant type of energy source: the fossil-intensive A1F1, non-fossil intensive A1T, and mixed energy source A1B scenarios. Cumulative CO_2 emissions from 1990 to 2100 for the A1T, A1B, and A1F1 scenarios are 1061.3 Gigatons of carbon (GtC), 1492.1 GtC, and 2182.3 GtC, respectively. These correspond to a low-, medium-high, and high-emissions scenario, respectively.
- The B1 scenario assumes the same population as A1, but with more rapid changes toward a service and information economy. This is a low-emissions scenario: cumulative CO_2 emissions from 1990 to 2100 are 975.9 GtC.
- The B2 scenario describes a world with intermediate population and economic growth, emphasizing local solutions to sustainability. Energy systems differ by region, depending on natural resource availability. This is a medium-low emissions scenario: cumulative CO_2 emissions from 1990 to 2100 are 1156.7 GtC.
- The A2 scenario assumes high population growth, slow economic development, and slow technological change. Resource availability primarily determines the fuel mix in different regions. This is a high-emissions scenario: cumulative CO_2 emissions from 1990 to 2100 are 1855.3 GtC.

Scenario	Cumulative CO_2 emissions (GtC), 1990-2100	Population Growth Rate	Economic Development Rate	Fuels used
A1F1	2182.3	Peaks in mid-21st century	Rapid	Fossil fuel intensive
A1B	1492.1	Peaks in mid-21st century	Rapid	Mixed energy sources
A1T	1061.3	Peaks in mid-21st century	Rapid	Non-fossil fuel intensive
A2	1855.3	High	Slow	Determined by resource availability
B2	1156.7	Intermediate	Intermediate	Determined by resource availability
B1	975.9	Peaks in mid-21st century	Rapid – toward service & information economy	Non-fossil fuel intensive

Source: IPCC. *Climate Change 2007: Synthesis Report.* (2007); IPCC. *The SRES Emissions Scenarios (website).* (2010); IPCC. *IPCC Special Report on Emissions Scenarios: Chapters 4.3 & 5.1 (website).* (2010); IPCC. *SRES Final Data (version 1.1) Breakdown (website).* (2000); CIG. *Climate Change (website).* (2008).

Future Projections

- Compared to the concentration in 2005 (~379 ppm), atmospheric CO_2 concentrations are projected to increase over the period 2000-2100 across all six SRES scenarios,[69] from a low of about 600 ppm under the A1T, B1, and B2 scenarios to a high of about 1000 ppm in the A1F1 scenario.[70]
- *Note: Most projections in this chapter are based on climate modeling and a number of emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES, see Box 2 and Appendix 3 for further information).*[71]

Box 3. Why are atmospheric CO_2 concentrations, temperature, and precipitation important for a discussion of climate change effects on freshwater ecosystems?

- Increasing carbon dioxide concentrations in the atmosphere contribute to the greenhouse effect, leading to increases in global average air temperature.
- Changes in air temperature are reflected in water temperature, although there is a lag time due to the temperature-moderating effect of groundwater on surface waters.
- Warmer air holds more water vapor.
- Air temperature affects the timing of key hydrological events (e.g. snowmelt) as well as the amount of precipitation falling as rain and snow: increases in air temperature correspond to more rain, and less snow. Higher temperatures drive higher evapotranspiration and increase drying (even when precipitation is constant).
- Precipitation is important because its type (e.g. rain vs. snow), amount, frequency, duration, and intensity affect other hydrological processes such as the amount of snowpack, timing of snowmelt, amount and timing of streamflow, and frequency and intensity of flooding.
- Together, temperature, precipitation, and CO_2 concentrations affect the land (e.g. erosion), water (e.g. scour, flow), freshwater environment (e.g. nutrient cycling, disturbance regimes), and the habitats and biological communities dependent on each.

Sources: Allan, Palmer, and Poff (2005); Hamlet et al. (2007); Pew Center on Global Climate Change (2011); Rieman & Isaak (2010); Trenberth et al. (2007).

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[69] Meehl et al. *Climate Change 2007: The Physical Science Basis: Global Climate Projections.* (2007, p. 803). This information has been extrapolated from Figure 10.26 by the authors of this report.
[70] Meehl et al. (2007, p. 803). This information has been extrapolated from Figure 10.26 by the authors of this report.
[71] IPCC. *Climate Change 2007: Synthesis Report.* (2007c, p. 44)

2. TEMPERATURE – *global and regional observed trends and future projections*

Observed Trends

Globally

- In 2010, the combined land and ocean global surface temperature was 58.12°F (14.52°C; NCDC dataset).[72] This is tied with 2005 as the warmest year on record, at 1.12°F (0.62°C) above the 20th century average of 57.0°F (13.9°C; NCDC dataset).[73] The range associated with this value is plus or minus 0.13°F (0.07°C; NCDC dataset).[74]
    - From 1850 through 2006, 11 of the 12 warmest years on record occurred from 1995 to 2006.[75]
    - In 2010, Northern Hemisphere combined land and ocean surface temperature was the warmest on record: 1.31°F (0.73°C) above the 20th century average (NCDC dataset).[76]
- From 1906 to 2005, global average surface temperature increased ~1.34°F ± 0.33°F (0.74°C ± 0.18°C).[77]
    - From the 1910s to 1940s, an increase of 0.63°F (0.35°C) was observed.[78] Then, about a 0.2°F (0.1°C) decrease was observed over the 1950s and 1960s, followed by a 0.99°F (0.55°C) increase between the 1970s and the end of 2006 (Figure 2).[79]
- The 2001-2010 decadal land and ocean average temperature trend was the warmest decade on record for the globe: 1.01°F (0.56°C) above the 20th century average (NCDC dataset).[80]
    - From 1906-2005, the decadal trend increased ~0.13°F ± 0.04°F (0.07°C ± 0.02°C) per decade.[81] From 1955-2005, the decadal trend increased ~0.24°F ± 0.05°F (0.13°C ± 0.03°C) per decade.[82]
- Warming has been slightly greater in the winter months from 1906 to 2005 (December to March in the northern hemisphere; June through August in the southern hemisphere).[83] Analysis of long-term changes in daily temperature extremes show that, especially since the 1950s, the number of very cold days and nights has decreased and the number of extremely hot days and warm nights has increased.[84]

[72] NOAA. *State of the Climate Global Analysis 2010 (website).* (2011b)
[73] NOAA. (2011b)
[74] NOAA. (2011b)
[75] *IPCC. *Climate Change 2007: Synthesis Report: Summary for Policymakers.* (2007g, p. 2)
[76] NOAA. *State of the Climate Global Analysis 2010 (website).* (2011b)
[77] *Trenberth et al. *Climate Change 2007: The Physical Science Basis: Observations: Surface and Atmospheric Climate Change.* (2007, p. 252)
[78] Trenberth et al. (2007, p. 252)
[79] Trenberth et al. (2007, p. 252)
[80] NOAA. (2011b)
[81] Trenberth et al. (2007, p. 237)
[82] Trenberth et al. (2007, p. 237)
[83] *Trenberth et al. (2007, p. 252)
[84] *Trenberth et al. (2007, p. 252)

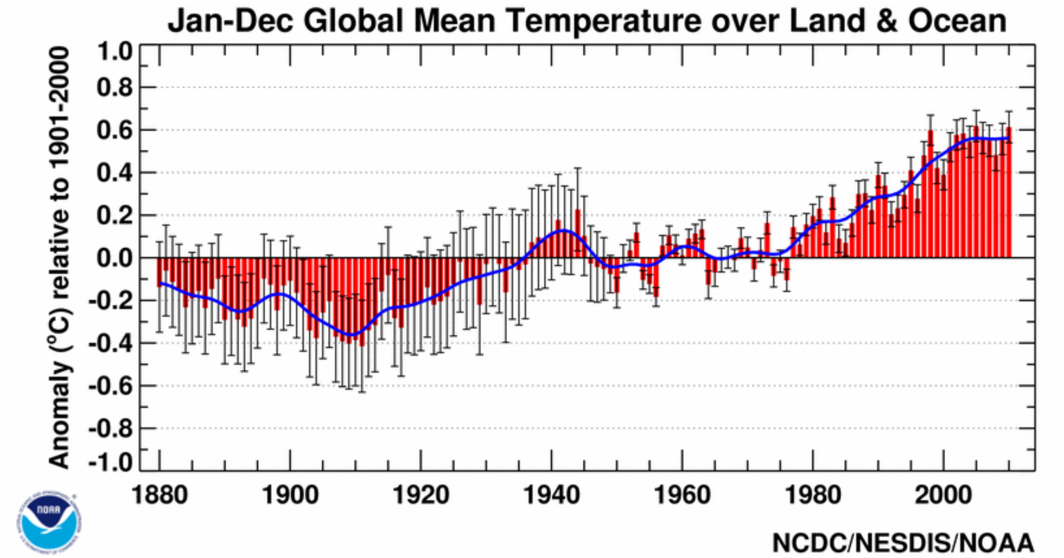

Figure 2. Jan-Dec Global Mean Temperature over Land & Ocean. *Source: NCDC/NESDIS/NOAA. Downloaded from http://www.ncdc.noaa.gov/sotc/service/global/global-land-ocean-mntp-anom/201001-201012.gif (7.27.2011).*

Southcentral and Southeast Alaska

- Annual average temperature has increased 3.4°F (~1.9°C) over the last fifty years, while winters have warmed even more, by 6.3°F (3.5°C).[85] The time period over which trends are computed is not provided. However, compared to a 1960s-1970s baseline, the average temperature from 1993 to 2007 was more than 2°F (1.1°C) higher.[86]
  - Annual average temperature increased 3.2°F (1.8°C) in Juneau over 1949-2009.[87] From 1971 to 2000, temperatures in Anchorage increased by 2.26°F (1.27°C).[88]
- From 1949 to 2009, winter temperatures increased the most, followed by sprng, summer, and autumn temperatures.[89] For example, in Juneau, winter temperatures increased by 6.2°F (3.4°C), spring temperatures increased by 2.9°F (1.6°C), summer temperatures increased by 2.2°F (1.2°C), and autumn temperatures increased 1.4°F (0.8°C).[90]

[85] *Karl, Melillo and Peterson. *Global Climate Change Impacts in the United States.* (2009, p. 139). The report does not provide a year range for this information. The authors cite Fitzpatrick et al. (2008) for this information.
[86] Karl, Melillo and Peterson. (2009, p. 139). See the figure entitled *Observed and Projected Temperature Rise*.
[87] Alaska Climate Research Center. *Temperature Change in Alaska (website).* (2009)
[88] Alaska Center for Climate Assessment and Policy. *Climate Change Impacts on Water Availability in Alaska (presentation).* (2009, p. 4)
[89] Alaska Climate Research Center. (2009)
[90] Alaska Climate Research Center. (2009)

- A comparison of official data from the National Climatic Data Center (NCDC) for 1971-2000 and unofficial National Weather Service (NWS) data for 1981-2010 for Juneau, Alaska indicates average annual, warm season (April – September), and cold season (October – March) temperatures have increased from 1971-2000 to 1981-2010 (Table 1):[91]
    - Annual: +0.6°F (+0.33°C), from 41.5°F (5.28°C) to 42.1°F (5.61°C).[92]
    - April-September: +0.2°F (+0.1°C), from 50.9°F (10.5°C) to 51.1°F (10.6°C).[93]
    - October-March: +0.8°F (+0.444°C), from 32.1°F (0.0556°C) to 32.9°F (0.500°C).[94]

Table 1. Annual and seasonal temperature trends for Juneau, AK over two thirty-year time periods.

		1971-2000* °F (°C)	1981-2010* °F (°C)	Absolute Change °F (°C)	Percent Change†
Annual	Average	41.5 (5.28)	42.1 (5.61)	+0.6 (+0.33)	+1.45
	Average maximum	47.6 (8.67)	48.1 (8.94)	+0.5 (+0.27)	+1.05
	Average minimum	35.3 (1.83)	36.1 (2.28)	+0.8 (+0.45)	+2.27
Warm season (April – Sept)	Average	50.9 (10.5)	51.1 (10.6)	+0.2 (+0.1)	+0.393
	Average maximum	58.2 (14.6)	58.3 (14.6)	+0.1 (0.06)	+0.172
	Average minimum	43.5 (6.39)	44.0 (6.67)	+0.5 (+0.28)	+1.15
Cold season (Oct – March)	Average	32.1 (0.0556)	32.9 (0.500)	+0.8 (+0.444)	+2.49
	Average maximum	37.0 (2.78)	37.7 (3.17)	+0.7 (+0.39)	+1.89
	Average minimum	27.2 (-2.67)	28.1 (-2.17)	+0.9 (+0.50)	+3.31

*Data for 1971-2000 are official data from the National Climatic Data Center (NCDC). Data for 1981-2010 are preliminary, unofficial data acquired from Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on May 12, 2011. The official data for 1981-2010 are scheduled for release by NCDC in July 2011. The table was created by the authors of this report and approved by Tom Ainsworth and Rick Fritsch on June 10, 2011.
†Percent change reflects the relative increase or decrease from 1971-2000 to 1981-2010.

Western British Columbia

- Observed trends in the annually averaged daily minimum, mean, and maximum temperatures from 1950 to 2006 are available for four stations along the BC coast (Table 2).[95]

[91] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[92] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[93] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[94] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[95] BC Ministry of Environment (MoE). *Environmental Trends in British Columbia: 2007: Climate Change.* (2007, p. 7)

Table 2. Trends in the average daily minimum, mean, and maximum temperatures per decade in °F (°C) in southern coastal British Columbia, 1950-2006.

	Temperature	Annual	Winter	Spring	Summer	Autumn
Abbotsford Airport, near Vancouver	Minimum	0.72 (0.40)	1.58 (0.88)	0.86 (0.48)	0.58 (0.32)	0.23 (0.13)
	Average	0.59 (0.33)*	0.52 (0.29)*	0.68 (0.38)*	0.74 (0.41)*	0.27 (0.15)*
	Maximum	0.20 (0.11)	1.13 (0.63)	-0.41 (-0.23)	1.21 (0.67)	-0.76 (-0.42)
Comox Airport, east Vancouver Island	Minimum	0.58 (0.32)*	0.40 (0.22)*	0.79 (0.44)*	0.65 (0.36)*	0.38 (0.21)*
	Average	0.41 (0.23)*	0.40 (0.22)*	0.50 (0.28)*	0.45 (0.25)*	0.22 (0.12)*
	Maximum	0.23 (0.13)*	0.31 (0.17)*	0.23 (0.13)	0.27 (0.15)	0.11 (0.06)
Port Hardy Airport, NE Vancouver Island	Minimum	0.38 (0.21)*	0.43 (0.24)*	0.50 (0.28)*	0.45 (0.25)*	0.04 (0.02)
	Average	0.34 (0.19)*	0.49 (0.27)*	0.36 (0.20)	0.31 (0.17)	0.07 (0.04)
	Maximum	0.27 (0.15)*	0.52 (0.29)*	0.41 (0.23)*	0.14 (0.08)	0.05 (0.03)
Victoria Airport, near Victoria	Minimum	0.40 (0.22)*	0.36 (0.20)*	0.63 (0.35)*	0.45 (0.25)*	0.20 (0.11)*
	Average	0.45 (0.25)*	0.40 (0.22)*	0.58(0.32)*	0.52 (0.29)*	0.22 (0.12)*
	Maximum	0.43 (0.24)*	0.52 (0.29)*	0.43 (0.24)*	0.49 (0.27)*	0.18 (0.10)

Note: Asterisks indicate a statistically significant difference, meaning there is at least a 95% probability that the trend is not due to chance.
Source: Adapted from B.C. MoE. (2007, Table 1, p. 7-8) by authors of this report.

Pacific Northwest (Figure 3)

- Average 20th century warming was 1.64°F (0.91°C; the linear trend over the 1920-2000 period, expressed in degrees per century).[96]
- Warming over the 20th century varied seasonally, with average warming in winter being the largest (+3.3°F, +1.83°C), followed by summer (+1.93°F, +1.07°C), spring (+1.03°F, +0.57°C), and autumn (+0.32°F, +0.18°C).[97] Data reflect the linear trend over the 1920-2000 period, expressed in degrees per century; data for summer are significant at the 0.05 level.[98]
- Increases in maximum and minimum temperatures in the cool (October-March) and warm (April-September) seasons from 1916 to 2003 and from 1947 to 2003 have been observed (Table 3).[99]
- When comparing the 1981-2010 climate normals (i.e., the 30-year average) to the 1971-2000 climate normals, both maximum and minimum temperatures are about 0.5°F (~0.3°C) warmer on average in the new normals across the United States.[100] The averaged annual statewide increases in maximum and minimum temperatures observed over this period are:
    - **Maximum:** +0.3 to +0.5°F (~+0.2-0.3°C) in Washington and Oregon.[101]

[96] Mote. *Trends in temperature and precipitation in the Pacific Northwest during the Twentieth Century.* (2003, Fig. 6, p. 276)
[97] Mote (2003, Fig. 6, p. 276)
[98] Mote (2003, Fig. 6, p. 276)
[99] Hamlet et al. *Twentieth-century trends in runoff, evapotranspiration, and soil moisture in the western United States.* (2007, Table 1, p. 1475).
[100] *NOAA. *NOAA Satellite and Information Service: NOAA's 1981-2010 Climate Normals (website).* (2011a)
[101] *NOAA. (2011a, Fig. 1)

  - **Minimum:** +0.3 to +0.5°F (~+0.2-0.3°C) in Washington and +0.1 to +0.3°F (~+0.06-0.3°C) in Oregon.[102]

<u>Northwestern California</u>

- PRISM data (a climate-mapping system) suggest that most of the Six Rivers National Forest area, located in northwestern California, experienced increases in mean annual temperature of about 1.8ºF (1ºC) between the 1930s and 2000s, although some coastal areas have seen a slight decrease in temperature.[103] Average temperatures at the Orleans station increased approximately 2ºF (1.1ºC) in the period from 1931 to 2009 (1931 baseline: ~56.2ºF, or ~13 ºC).[104] The trend is driven by a highly significant increase in mean minimum (i.e., nighttime) temperature, which rose by almost 4ºF (2.2ºC) between 1931 and 2009 (1931 baseline: ~42ºF, or ~5.5ºC).[105] *Note: For a figure showing mean annual temperature and annual temperature seasonality from 1971 to 2000, please see Figure S1 in the link included in the footnote.*[106]

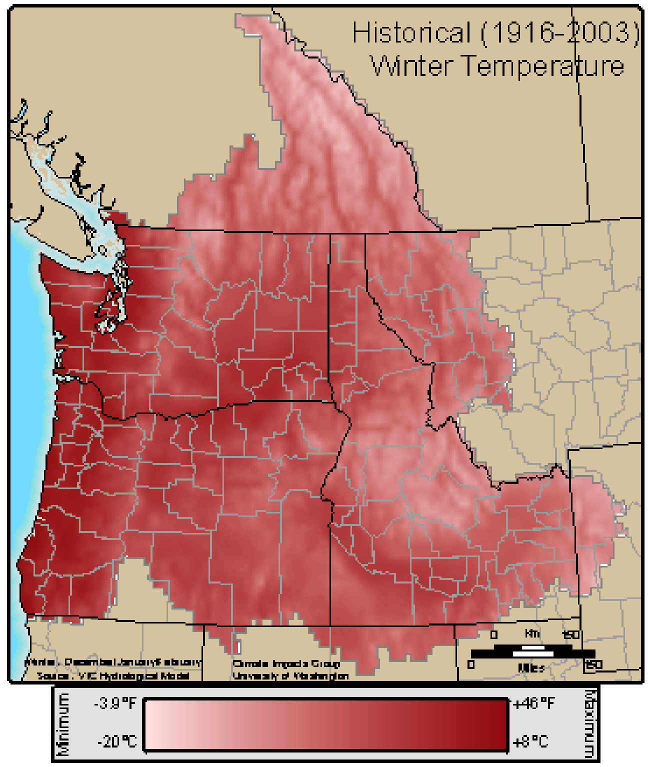

Figure 3. Historical average (1916-2003) winter temperature in the Pacific Northwest.
Source: Downloaded with permission from Center for Science in the Earth System August 13, 2011. (http://cses.washington.edu/cig/maps/index.shtml).

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102 *NOAA. (2011a, Fig. 2)

103 *Butz and Safford. *A summary of current trends and probable future trends in climate and climate-driven processes for the Six Rivers National Forest and surrounding lands (pdf).* (2010, p. 1). Butz and Safford refer the reader to Figure 1 in the cited report.

104 *Butz and Safford. (2010, p. 1). Butz and Safford refer the reader to Figure 1 in the cited report. For the 1931 baseline, please see Figure 2 in the cited report.

105 *Butz and Safford. (2010, p. 1). Butz and Safford refer the reader to Figure 2 in the cited report.

106 Ackerly et al. *The geography of climate change: implications for conservation biogeography (Supplemental Information)*. (2010). http://onlinelibrary.wiley.com/store/10.1111/j.1472-4642.2010.00654.x/asset/supinfo/DDI_654_sm_Data_S1andFig_S1-S8.pdf?v=1&s=93f8310b31bb81d495bae87579a8d7f4d710ca3e (accessed 6.8.2011).

- When comparing the 1981-2010 climate normals (i.e., the 30-year average) to the 1971-2000 climate normals, both maximum and minimum temperatures are about 0.5°F (~0.3°C) warmer on average in the new normals across the United States.[107] The averaged annual increase in maximum and minimum temperatures in California observed over this period are:
  - **Maximum:** +0.3 to +0.5°F (~+0.2-0.3°C).[108]
  - **Minimum:** +0.3 to +0.5°F (~+0.2-0.3°C).[109]

Table 3. Regional-scale maximum and minimum temperature trends during 1916-2003 and 1947-2003 for the cool season (October-March) and warm season (April-September) in the Pacific Northwest.
(°F per century with °C per century in parentheses; trends extrapolated from 1916-2003 and 1947-2003 data records)
Source: Modified from Hamlet et al. (2007, Table 1, p. 1475) by authors of this report.

Maximum temperature	October-March	1916-2003	1.82 (1.01)
		1947-2003	3.47 (1.93)
	April-September	1916-2003	0.40 (0.22)
		1947-2003	2.68 (1.49)
Minimum temperature	October-March	1916-2003	3.01 (1.67)
		1947-2003	4.09 (2.27)
	April-September	1916-2003	2.43 (1.35)
		1947-2003	3.47 (1.93)

Future Projections

Note: The studies presented here differ in the baseline used for projections. Baselines include 1980-1999 (IPCC), 1961-1990 (BC, CA), 1970-1999 (WA, OR), 1971-2000 (CA) and 1960-1970s (AK).

<u>Globally (1980-1999 baseline)</u>

- Even if greenhouse gas (GHG) concentrations were stabilized at year 2000 levels (not currently the case), an increase in global average temperature would still occur: 0.67°F (0.37°C) by 2011-2030, 0.85°F (0.47°C) by 2046-2065, 1.01°F (0.56°C) by 2080-2099, and 1.1°F (0.6°C) by 2090-2099 (all compared to a 1980-1999 baseline).[110,111]
- Global average temperatures are projected to increase at least 3.2°F (1.8°C) under the B1 scenario and up to 7.2°F (4.0°C) under the A1F1 scenario by 2090-2099 compared to a 1980-1999 baseline.[112] The range of projected temperature increases is 2.0°F (1.1°C) to 11.5°F (6.4°C) by 2090-2099, compared to a 1980-1999 baseline (Figure 4).[113]

[107] *NOAA. (2011a)
[108] *NOAA. (2011a, Fig. 1)
[109] *NOAA. (2011a, Fig. 2)
[110] *IPCC. (2007g, p. 8). See Figure SPM.1 for the information for 2090-2099.
[111] Meehl et al. (2007). Data for 2011-2030, 2046-2065, 2080-2099, and 2180-2199 were reproduced from Table 10.5 on p. 763. Data for 2090-2099 were obtained from p. 749.
[112] IPCC. (2007g, p. 8). See Figure SPM.1.
[113] IPCC. (2007, Table SPM.3, p. 13). AOGCMs are Atmosphere Ocean General Circulation Models.

- A study by Arora et al. (2011) suggests that limiting warming to roughly 3.6°F (2.0°C) by 2100 is unlikely since it requires an immediate ramp down of emissions followed by ongoing carbon sequestration after 2050.[114]

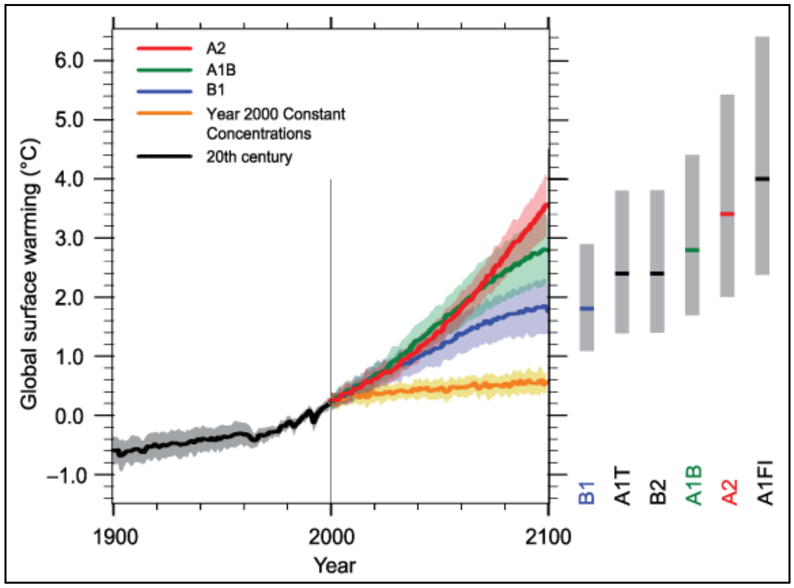

Figure 4. Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the **likely** range assessed for the six SRES marker scenarios. The assessment of the best estimate and **likely** ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and10.29} *Source: Reproduced from IPCC.* (2007, Fig. SPM.5, p. 14) *by authors of this report.*

<u>Southcentral and Southeast Alaska (1960s-1970s baseline)</u>

- By 2020, compared to a 1960-1970s baseline, average annual temperatures in Alaska are projected to rise 2.0°F to 4.0°F (1.1-2.2°C) under both the low-emissions B1 scenarios and higher-emissions A2 scenario.[115]
- By 2050, average annual temperatures in Alaska are projected to rise 3.5°F to 6°F (1.9-3.3°C) under the B1 scenario, and 4°F to 7°F (2.2-3.9°C) under the A2 scenario (1960-1970s baseline).[116] Later in the century, increases of 5°F to 8°F (2.8-4.4°C) are projected under the B1 scenario, and increases of 8°F to 13°F (4.4-7.2°C) are projected under the A2 scenario (1960-1970s baseline).[117]
- On a seasonal basis, Alaska is projected to experience far more warming in winter than summer, whereas most of the United States is projected to experience greater warming in summer than in winter.[118]
- No data were found for mean temperatures associated with the ranges reported here.

[114] *Arora et al. *Carbon emission limits required to satisfy future representative concentration pathways of greenhouse gases.* (2011)
[115] Karl, Melillo and Peterson. (2009, p. 139). See the figure titled *Observed and Projected Temperature Rise* (section on Regional Impacts: Alaska)
[116] Karl, Melillo and Peterson. (2009, p. 139)
[117] Karl, Melillo and Peterson. (2009, p. 139)
[118] *Karl, Melillo and Peterson. (2009)

Western British Columbia (1961-1990 baseline)

- Along the North Coast by the 2050s, annual air temperature is projected to increase 2.5˚F (1.4˚C) compared to a 1961-1990 baseline (multi-model average; scenarios not provided).[119] Along the South Coast, annual air temperature is projected to increase 2.7˚F (1.5˚C) compared to a 1961-1990 baseline (multi-model average; scenarios not provided).[120] The North Coast extends from the border with Alaska to just north of Vancouver Island; the South Coast extends to the Washington border.[121]
- Along the North Coast by 2050, seasonal projections are as follows compared to a 1961-1990 baseline (multi-model average; scenarios not provided):
  - In winter, temperatures are projected to increase 0°F to 6.3˚F (0-3.5ºC), and
  - In summer, temperatures are projected to increase 2.7°F to 5.4˚F (1.5-3˚C).[122]
- Along the South Coast by 2050, seasonal projections are as follows compared to a 1961-1990 baseline (multi-model average; scenarios not provided):
  - In winter, temperatures are projected to increase 0°F to 5.4˚F (0-3˚C), and
  - In summer, temperatures are projected to increase 2.7°F to 9.0˚F (1.5-5˚C).[123]

Pacific Northwest (1970-1999 baseline)

- Average annual temperature could increase beyond the range of year-to-year variability observed during the 20th century as early as the 2020s.[124] Annual temperatures, averaged across all climate models under the A1B and B1 scenarios, are projected to increase as follows (1970-1999 baseline):
  - By the 2020s: 2.0˚F (1.1°C), with a range of 1.1˚F to 3.4˚F (0.61-1.9°C),
  - By the 2040s: 3.2˚F (1.8°C), with a range of 1.6˚F to 5.2˚F (0.89-2.89°C), and
  - By the 2080s: 5.3˚F (~3.0°C), with a range of 2.8˚F to 9.7˚F (1.56-5.4°C).[125]
- Seasonal temperatures, averaged across all models under the B1 and A1B scenarios, are projected to increase as described in Table 4 (compared to a 1970-1999 baseline).
- In another look at the Pacific Northwest by the 2080s, temperatures are projected to increase 2.7 to 10.4 °F (1.5-5.8 °C), with a multi-model average increase of 4.5˚F (2.5°C) under the B1 scenario and 6.1˚F (3.4°C) under the A1B scenario (1970-1999 baseline).[126]

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[119] Pike et al. *Compendium of forest hydrology and geomorphology in British Columbia: Climate Change Effects on Watershed Processes in British Columbia.* (2010, Table 19.3, p. 711).
[120] Pike et al. (2010, Table 19.3, p. 711)
[121] Please see the map available at http://pacificclimate.org/resources/publications/mapview (accessed 3.16.2011).
[122] B.C. Ministry of Environment. *Alive and Inseparable: British Columbia's Coastal Environment: 2006*. (2006, Table 10, p. 113). The authors make the following note: From data in the Canadian Institute for Climate Studies, University of Victoria (*www.cics.uvic.ca*) study of model results from eight global climate modelling centres. A total of 25 model runs using the eight models were used to determine the range of values under different IPCC emission scenarios (Nakicenovic and Swart 2000).
[123] B.C. Ministry of Environment. (2006, Table 10, p. 113). The authors make the following note: From data in the Canadian Institute for Climate Studies, University of Victoria (*www.cics.uvic.ca*) study of model results from eight global climate modelling centres. A total of 25 model runs using the eight models were used to determine the range of values under different IPCC emission scenarios (Nakicenovic and Swart 2000).
[124] *CIG. *Climate Change Scenarios: Future Northwest Climate (website).* (2008)
[125] CIG. *Climate Change: Future Climate Change in the Pacific Northwest (website).* (2008, Table 3)
[126] Mote, Gavin and Huyer. *Climate change in Oregon's land and marine environment.* (2010, p. 21)

Table 4. Projected multi-model average temperature increases, relative to the 1970-1999 mean. (°F with °C in parentheses) *Source: Modified from Mote and Salathé, Jr. (2010, Fig. 9, p. 42) by authors of this report. Please see Figure 9 in the cited report for the range of each average shown below.*

	2020s		2040s		2080s	
	B1	A1B	B1	A1B	B1	A1B
Winter (Dec-Feb)	2.0 (1.1)	2.2 (1.2)	2.9 (1.6)	3.4 (1.9)	4.9 (2.7)	5.9 (3.3)
Spring (March-May)	1.8 (1.0)	1.8 (1.0)	2.5 (1.4)	3.1 (1.7)	3.8 (2.1)	5.0 (2.8)
Summer (June-Aug)	2.3 (1.3)	3.1 (1.7)	3.4 (1.9)	4.9 (2.7)	5.4 (3.0)	8.1 (4.5)
Fall (Sept-Nov)	1.8 (1.0)	2.0 (1.1)	2.7 (1.5)	3.6 (2.0)	4.3 (2.4)	6.1 (3.4)

Northwestern California (1961-1990 and 1971-2000 baselines)

- Compared to a 1961-1990 baseline under the B1 and A2 scenarios, California-wide annual average temperatures are projected to increase as follows:
  - By 2050: 1.8 to 5.4 ˚F (1-3 °C), and
  - By 2100: 3.6 to 9 ˚F (2-5 °C).[127]
- In northwestern California, regional climate models project mean annual temperature increases of 3.1 to 3.4°F (1.7-1.9°C) by 2070 (no baseline provided).[128] In contrast, Ackerly et al. (2010) project a mean annual temperature increase of more than 3.6˚F (2°C) but less than 5.4˚F (3°C) by 2070-2099 (Figure 5; 1971-2000 baseline).[129]
  - By 2070, mean diurnal (i.e., daily) temperature range is projected to increase by 0.18 to 0.36˚F (0.1-0.2°C) based on two regional climate models.[130] No baseline was provided.
- In northern California, Cayan et al. (2008) project average annual temperature increases of 2.7°F (1.5°C) or 4.9°F (2.7°C) under the B1 scenario (PCM and GFDL models, respectively) and 4.7°F (2.6°C) or 8.1°F (4.5°C) (PCM and GFDL models, respectively) under the A2 scenario by 2070-2099 (1961-1990 baseline).[131]
- Seasonally, the projected impacts of climate change on thermal conditions in northwestern California will be warmer winter temperatures, earlier warming in the spring, and increased summer temperatures.[132] Average seasonal temperature projections in northern California are as follows (1961-1990 baseline):[133]
  - Winter projections:
    - 2005-2034: at least ~0.18°F (0.1°C; A2, PCM model) and up to 2.5°F (1.4°C; A2, GFDL model).

[127] California Natural Resources Agency. *2009 California Climate Adaptation Strategy: A Report to the Governor of the State of California in Response to Executive Order S-13-2008*. (2009, p. 16-17). Figure 5 (p. 17) indicates projections are compared to a 1961-1990 baseline.
[128] *Port Reyes Bird Observatory. *Projected effects of climate change in California: Ecoregional summaries emphasizing consequences for wildlife. Version 1.0 (pdf).* (2011, p. 8)
[129] Ackerly et al. (2010, Fig. S2, p. 9). Ackerly et al. use bias-corrected and spatially downscaled future climate projections from the CMIP-3 multi-model dataset. Data are downscaled to 1/8th degree spatial resolution (see p. 2).
[130] *Port Reyes Bird Observatory. (2011, p. 8). This data was based on two regional climate models presented in Stralberg et al. (2009).
[131] Cayan et al. *Climate change scenarios for the California region*. (2008, Table 1, p. S25)
[132] *Port Reyes Bird Observatory. (2011, p. 8)
[133] Cayan et al. (2008, Table 1, p. S25)

        - 2035-2064: at least 1.6°F (0.9°C; A2, PCM model) and up to 4.3°F (2.4°C; B1, PCM model).
        - 2070-2099: at least 3.1°F (1.7°C; B1, PCM model) and up to 6.1°F (3.4°C; A2, GFDL model).
    - Summer projections:
        - 2005-2034: at least ~1°F (0.6°C; B1, PCM model) and up to 3.8°F (2.1°C; A2, GFDL model).
        - 2035-2064: at least ~2.0°F (1.1°C; B1, PCM model) and up to 6.1°F (3.4°C; A2, GFDL model).
        - 2070-2099: at least 2.9°F (1.6°C; B1, PCM model) and up to ~12°F (6.4°C; A1, GFDL model).
- Coastal regions are likely to experience less pronounced warming than inland regions.[134]

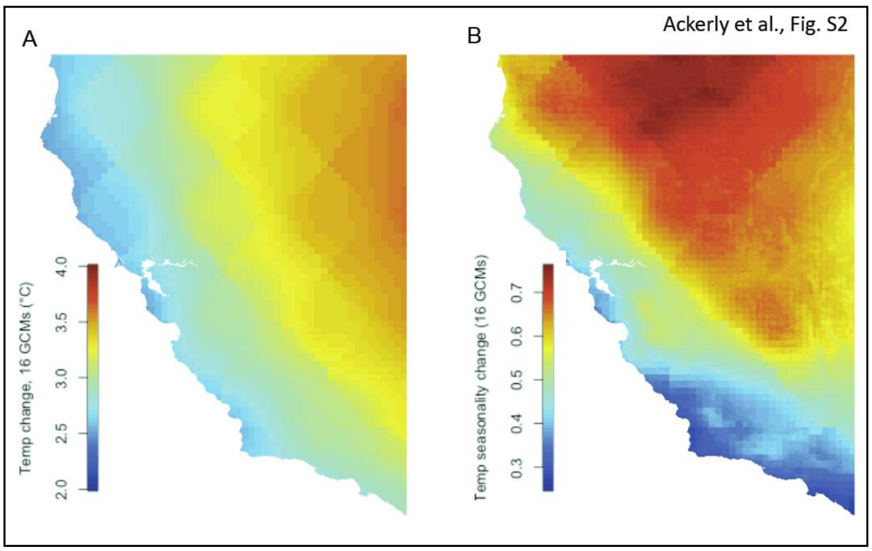

Figure 5. Changes in (A) mean annual temperature and (B) temperature seasonality, averaged over 16 GCMs, A1B scenario, for 2070-2099 (1971-2000 baseline).
Source: Reproduced from Ackerly et al. (2010, Fig. S2, p. 9) by authors of this report.
Note: Temperature seasonality is the standard deviation of monthly means. Lower values indicate temperature varies less throughout the year, i.e. temperature is more constant throughout the year in blue areas than in yellow and red areas.

[134] *California Natural Resources Agency. (2009, p. 17)

3. PRECIPITATION – *global and regional observed trends and future projections*

Observed Trends

Note: Please see Box 4 for information on extreme precipitation in the NPLCC region.

Global (see also: projections below)

- Atmospheric moisture amounts are generally observed to be increasing after about 1973 (prior to which reliable atmospheric moisture measurements, i.e. moisture soundings, are mostly not available).[135]
- Most of the increase is related to temperature and hence to atmospheric water-holding capacity,[136] i.e. warmer air holds more moisture.

Southcentral and Southeast Alaska

- In southeast Alaska from 1949 to 1998, mean total annual precipitation was at least 39 inches (1000 mm).[137] The maximum annual precipitation over this period was 219 inches (5577 mm) at the Little Port Walter station on the southeast side of Baranof Island about 110 miles (177 km) south of Juneau.[138]
- In southcentral Alaska from 1949 to 1998, mean total annual precipitation was at least 32 inches (800 mm) and up to 39 inches (1000 mm).[139]
- A comparison of official data from the National Climatic Data Center (NCDC) for 1971-2000 and unofficial National Weather Service (NWS) data for 1981-2010 for Juneau, Alaska indicates annual, warm season, and cold season precipitation increased.[140] The official NCDC record indicates average snowfall increased from 1971-2000 to 1981-2010, but the local NWS database indicates average snowfall decreased over the same time periods (Table 5, see notes).[141] In addition:
    - The date of first freeze occurred, on average, one day earlier over 1981 to 2010 than over 1971 to 2000, on October 3 instead of October 4.[142]
    - The date of last freeze occurred two days earlier, on average, over 1981 to 2010 than over 1971 to 2000, on May 6 instead of May 8.[143]

[135] *Trenberth et al. *The changing character of precipitation.* (2003, p. 1211). The authors cite Ross and Elliott (2001) for this information.
[136] *Trenberth et al. (2003, p. 1211).
[137] Stafford, Wendler and Curtis. *Temperature and precipitation of Alaska: 50 year trend analysis.* (2000, Fig. 7, p. 41).
[138] Stafford, Wendler and Curtis. (2000, Fig. 7, p. 41)
[139] Stafford, Wendler and Curtis. (2000, Fig. 7, p. 41)
[140] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[141] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[142] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.
[143] This information was obtained from and approved by Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on June 10, 2011.

Table 5. Annual and seasonal precipitation and date of freeze trends for Juneau, AK over two thirty-year time periods.

		1971-2000* inches (cm)	1981-2010* inches (cm)	Absolute Change inches (cm)	Percent Change†
Annual and date of freeze trends	Total annual precipitation (including melted snow)	58.33 (148.2)	62.17 (157.9)	+3.84 (+9.75)	+6.58
	Average snowfall (Jan-Dec, NWS/Juneau)	93.0# (236)	86.8 (220)	-6.2 (-16)	-6.7
	Average snowfall (Jan-Dec, NCDC/Asheville)	84.1# (214)	N/A*	N/A	N/A
	Date of first freeze, on average	October 4	October 3	One day earlier	N/A
	Date of last freeze, on average	May 8	May 6	Two days earlier	N/A
Warm season (April – Sept)	Average seasonal precipitation (mostly rain)	26.85 (68.20)	28.52 (72.44)	+1.67 (+4.24)	+6.22
	Average snowfall (NWS/Juneau)	1.0 (2.5)	1.1 (2.8)	+0.1 (+0.3)	+10
	Average snowfall (NCDC/Asheville)	1.0 (2.5)	N/A*	N/A	N/A
Cold season (Oct – March)	Average seasonal precipitation	31.48 (79.96)	33.65 (85.47)	+2.17 (+5.51)	+6.89
	Average snowfall (NWS/Juneau)	92.0# (234)	85.7 (218)	-6.3 (-16)	-6.8
	Average snowfall (NCDC/Asheville)	83.1# (211)	N/A*	N/A	N/A

*Data for 1971-2000 are official data from the National Climatic Data Center (NCDC). Data for 1981-2010 are preliminary, unofficial data acquired from Tom Ainsworth and Rick Fritsch (Meteorologists, NOAA/National Weather Service, Juneau) on May 12, 2011. The official data for 1981-2010 are scheduled for release by NCDC in July 2011. The table was created by the authors of this report and approved by Tom Ainsworth and Rick Fritsch on June 10, 2011.
†Percent change reflects the relative increase or decrease from 1971-2000 to 1981-2010.
#Two values for average snowfall for 1971-2000 are reported due to differences between the locally held National Weather Service (NWS) database in Juneau and the official NWS database in Asheville, North Carolina. Differences represent the quality assurance processing and filtering that occurs at the National Climatic Data Center (NCDC) in Asheville (the source of official U.S. climate data) as well as missing data in the NCDC record. The Juneau office of the NWS is investigating the discrepancy.

Western British Columbia

- Annual and seasonal precipitation trends over thirty, fifty, and 100-year time periods in the Georgia Basin and remaining coastal regions of B.C. within the NPLCC region are summarized in Table 6.[144] The Georgia Basin includes eastern Vancouver Island and a small portion of the mainland east of Vancouver Island; the coastal region includes all remaining areas in B.C. within the NPLCC region.[145]

[144] Pike et al. *Compendium of forest hydrology and geomorphology in British Columbia: Climate Change Effects on Watershed Processes in British Columbia.* (2010, Table 19.1, p. 701)
[145] Pike et al. *Compendium of forest hydrology and geomorphology in British Columbia: Climate Change Effects on Watershed Processes in British Columbia.* (2010, Fig. 19.1, p. 702)

Table 6. Historical trends precipitation in 30-, 50-, and 100-year periods, calculated from mean daily values as seasonal and annual averages.
(inches per month per decade, with millimeters per month per decade in parentheses)
Source: Modified from Pike et al. (2010, Table 19.1, p. 701) by authors of this report.

	Time period	*Coastal B.C.*	*Georgia Basin*
Annual	30-year: 1971-2004	0.064 (1.63)	-0.017 (-0.42)
	50-year: 1951-2004	0.040 (1.01)	-0.017 (-0.43)
	100-year: 1901-2004	0.089 (2.25)	0.047 (1.20)
Winter (Dec-Feb)	30-year: 1971-2004	-0.24 (-6.08)	-0.32 (-8.06)
	50-year: 1951-2004	-0.12 (-3.06)	-0.21 (-5.35)
	100-year: 1901-2004	0.13 (3.39)	0.070 (1.78)
Summer (June-Aug)	30-year: 1971-2004	0.14 (3.50)	-0.071 (-1.80)
	50-year: 1951-2004	0.083 (2.11)	-0.011 (-0.27)
	100-year: 1901-2004	0.036 (0.91)	0.034 (0.93)

Pacific Northwest

- Annual precipitation increased 12.9% (6.99"; 17.76cm) from 1920 to 2000.[146]
- Observed relative increases were largest in the spring (+37%; +2.87"; 7.29cm), followed by winter (+12.4%; 2.47"; 6.27cm), summer (+8.9%; +0.39"; 0.99cm), and autumn (+5.8%; +1.27"; 3.22cm) from 1920 to 2000.[147] The spring trend (April-June) is significant at the $p < 0.05$ level.[148]
- From about 1973 to 2003, clear increases in the variability of cool season precipitation over the western U.S. were observed.[149]
- *Note: For the reader interested in trends in mean temperature, maximum temperature, minimum temperature, and precipitation annually, seasonally, and monthly, an online mapping tool produced by the Office of the Washington State Climatologist is available at http://www.climate.washington.edu/trendanalysis/ (accessed 6.8.2011).*

[146] Mote. *Trends in temperature and precipitation in the Pacific Northwest during the Twentieth Century*. (2003, p. 279)
[147] Mote. (2003, p. 279)
[148] Mote. (2003, p. 279)
[149] Hamlet and Lettenmaier. *Effects of 20th century warming and climate variability on flood risk in the western U.S*. (2007, p. 15)

Box 4. Trends and projections for extreme precipitation in the NPLCC region.

Trends. In the Pacific Northwest, trends in extreme precipitation are ambiguous.[150] Groisman et al. (2004) find no statistical significance in any season in the Pacific Northwest (1908-2000).[151] Madsen and Figdor (2007) find a statistically significant increase of 18% (13-23%) in the Pacific states (WA, OR, CA), a statistically significant increase of 30% (19-41%) in Washington, and a statistically significant decrease of 14% (-4 to – 24%) in Oregon (1948-2006).[152] In southern British Columbia and along the North Coast, Vincent and Mekis (2006) report some stations showed significant increases in very wet days (the number of days with precipitation greater than the 95th percentile) and heavy precipitation days (≥0.39", 1.0cm).[153] A limited number of stations also showed significant decreases.

Projections. Precipitation patterns in the Northwest are expected to become more variable, resulting in increased risk of extreme precipitation events, including droughts.[154] In northern California, daily extreme precipitation occurrences (99.9 percentile) are projected to increase from 12 occurrences (1961-1990) to 25 (+108%) or 30 (+150%) occurrences by 2070-2099 under A2 simulations in the PCM and GFDL models, respectively.[155]

Northwestern California

- A preliminary study found annual precipitation increased 2 to 6 inches (~5-15cm) from 1925 to 2008.[156] There also appears to be a shift in seasonality of precipitation: an increase in winter and early spring precipitation and a decrease in fall precipitation from 1925 to 2008.[157]
- From 1925 to 2008, the daily rainfall totals show a shift from light rains to more moderate and heavy rains that is especially evident in northern regions.[158] The increase in precipitation intensity over this time period is similar to results from other regions of the United States.[159]

Future Projections

Note: The studies presented here differ in the baseline used for projections. Baselines include 1961-1990 (BC, CA) and 1970-1999 (WA, OR).

Note: Please see Box 4 for information on extreme precipitation in the NPLCC region.

Global

- Global precipitation patterns are projected to follow observed recent trends, increasing in high latitudes and decreasing in most subtropical land regions.[160] Overall, precipitation may be more intense, but less frequent, and is more likely to fall as rain than snow.[161]
- *Note: There is greater confidence overall in projected temperature changes than projected changes in precipitation given the difficulties in modeling*

[150] Mote, Gavin and Huyer. (2010, p. 17)
[151] Groisman et al. *Contemporary changes in the hydrological cycle over the contiguous United States: Trends dervied from in situ observations.* (2004, Fig. 8, p. 71)
[152] Madsen and Figdor. *When it rains, it pours: Global warming and the rising frequency of extreme participation in the United States (pdf).* (2007, App. A & B, p. 35-37)
[153] Vincent and Mekis. *Changes in daily and extreme temperature and precipitation indices for Canada over the twentieth century*. (2006, Fig. 5, p. 186)
[154] Capalbo et al. *Toward assessing the economic impacts of climate change on Oregon.* (2010, p. 374)
[155] Cayan et al. (2008, Table 4, p. S30). For the 99 percentile, the occurrence of extreme precipitation is projected to increase from 111 (1961-1990) to 161 (45%) or 127 (~14%) occurrences by 2070-2099 under A2 simulations in the PCM and GFDL models, respectively.
[156] Killam et al. *California rainfall is becoming greater, with heavier storms*. (2010, p. 2)
[157] *Killam et al. (2010, p. 4)
[158] *Killam et al. (2010, p. 3)
[159] *Killam et al. (2010, p. 3)
[160] *IPCC. (2007g, p. 8)
[161] *Karl, Melillo and Peterson. (2009)

precipitation[162] and the relatively large variability in precipitation (both historically and between climate model scenarios) compared with temperature.

Southcentral and Southeast Alaska (1961-1990 and 2000 baseline)

- Climate models project increases in precipitation over Alaska.[163] Simultaneous increases in evaporation due to higher air temperatures, however, are expected to lead to drier conditions overall, with reduced soil moisture.[164]
  - Using a composite of five Global Circulation Models (GCMs) under the A1B scenario,[165] one study projects an average increase of 0.59 inches (15 mm) by 2090-2099 (1961-1990 baseline), from a mean of 3.1 inches (78 mm) in the 1961-1990 period to a mean of 3.7 inches (93 mm) in the 2090-2099 period, an approximately 19% increase from the 1961-1990 mean at the rate of approximately 0.059 inches per decade (+1.5 mm/decade).[166]
- In the coastal rainforests of southcentral and southeast Alaska, precipitation during the growing season (time period between last spring freeze and first fall frost) is projected to increase approximately four inches (~100 mm, or 5.7%) from 2000 to 2099, from approximately 69 inches (~1750 mm) in 2000 to approximately 73 inches (1850 mm) in 2099 using a GCM composite (scenario not provided).[167]
- The University of Alaska – Fairbanks Scenarios Network for Alaska Planning (SNAP) has web-based mapping tools for viewing current and future precipitation under the B1, A1B, and A2 scenarios for the 2000-2009, 2030-2039, 2060-2069, and 2090-2099 decades (baseline not provided). Tools are available at http://www.snap.uaf.edu/web-based-maps (accessed 3.16.2011).[168]

Western British Columbia (1961-1990 baseline)

- By the 2050s, annual precipitation is projected to increase 6% (range not provided) along the B.C. coast compared to a 1961-1990 baseline (multi-model average; scenarios not provided).[169]
- Along the North Coast by the 2050s, seasonal projections are as follows compared to a 1961-1990 baseline (multi-model average; scenarios not provided):
  - In winter, precipitation is projected to increase 6%[170] (0 to +25%),[171]
  - In spring, precipitation is projected to increase 7% (range not provided),
  - In summer, precipitation is projected to decrease 8%[172] (-25 to +5%),[173] and
  - In fall, precipitation is projected to increase 11% (range not provided).[174]

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162 CIG. (2008) The authors cite the IPCC AR4, Chapter 8 of the Working Group I report, for this information.
163 Karl, Melillo and Peterson. (2009, p. 139)
164 *Karl, Melillo and Peterson. (2009, p. 139). The authors cite Meehl et al. (2007) for this information.
165 Alaska Center for Climate Assessment and Policy. (2009, p. 10-11)
166 Alaska Center for Climate Assessment and Policy. (2009, p. 13)
167 Alaska Center for Climate Assessment and Policy. (2009, p. 31)
168 Maps are also available for current and future mean annual temperature, date of thaw, date of freeze up, and length of growing season. The scenario and decadal options are the same as those described for precipitation.
169 Pike et al. (2010, Table 19.3, p. 711)
170 Pike et al. (2010, Table 19.3, p. 711)
171 B.C. Ministry of Environment. (2006, Table 10, p. 113). B.C. Ministry of Environment makes the following note: "From data in the Canadian Institute for Climate Studies, University of Victoria (*www.cics.uvic.ca*) study of model results from eight global climate modelling centres. A total of 25 model runs using the eight models were used to determine the range of values under different IPCC emission scenarios (Nakicenovic and Swart 2000)."
172 Pike et al. (2010, Table 19.3, p. 711)
173 B.C. Ministry of Environment. (2006, Table 10, p. 113)

- Along the South Coast by the 2050s, seasonal projections are as follows compared to a 1961-1990 baseline (multi-model average; scenarios not provided):
  - In winter, precipitation is projected to increase 6%[175] (-10 to +25%),[176]
  - In spring, precipitation is projected to increase 7% (range not provided),[177]
  - In summer, precipitation is projected to decrease 13%[178] (-50 to 0%),[179] and
  - In fall, precipitation is projected to increase 9% (range not provided).[180]

Pacific Northwest (1970-1999 baseline)

- Annual average precipitation is projected to increase as follows (1970-1999 baseline):
  - By 2010-2039, precipitation is projected to increase 1% (-9 to +12%),
  - By 2030-2059, precipitation is projected to increase increase 2% (-11 to +12%), and
  - By 2070-2099, precipitation is projected to increase 4% (-10 to +20%).[181]
- Winter projections are as follows (1970-1999 baseline):
  - In 2010-2039 and 2030-2059, 58 to 90% of models project increases in precipitation.[182]
  - In 2070-2099, an 8% increase in precipitation is projected (small decrease to +42%; 1.2 inches; ~3cm).[183]
- Summer precipitation is projected to decrease 14% by the 2080s, although some models project decreases of 20 to 40% (1.2-2.4 inches; 3-6cm) compared to a 1970-1999 baseline.[184]
- These regionally averaged precipitation projections reflect all B1 and A1B simulations, along with the weighted reliability ensemble average (REA, an average that gives more weight to models that perform well in simulating 20th century climate).[185]

Northwestern California (1961-1990 baseline)

- Annual average precipitation is projected to decrease 12 to 35% by mid-century, with further decreases expected by 2070-2099 compared to a 1961-1990 baseline. [186] Over 2005-2034, small to moderate decreases are projected compared to a 1961-1990 baseline.[187] These projections are based on six climate models using the A2 and B1 emissions scenarios.[188]

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174 Pike et al. (2010, Table 19.3, p. 711)
175 Pike et al. (2010, Table 19.3, p. 711)
176 B.C. Ministry of Environment. (2006, Table 10, p. 113)
177 Pike et al. (2010, Table 19.3, p. 711)
178 Pike et al. (2010, Table 19.3, p. 711)
179 B.C. Ministry of Environment. (2006, Table 10, p. 113)
180 Pike et al. (2010, Table 19.3, p. 711)
181 The range of precipitation reported here was obtained from the Climate Impacts Group. It can be found in a document titled *Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts.* A draft version is available online at http://www.ecy.wa.gov/climatechange/2010TAGdocs/20100521_projecteddrivers.pdf (last accessed 1.5.2011).
182 Mote and Salathé Jr. *Future climate in the Pacific Northwest.* (2010, p. 43-44)
183 Mote and Salathé Jr. (2010, p. 43-44)
184 Mote and Salathé Jr. (2010, p. 42)
185 Mote and Salathé Jr. (2010, p. 39)
186 *California Natural Resources Agency. (2009, p. 17-18)
187 *California Natural Resources Agency. (2009, p. 17-18)
188 California Natural Resources Agency. (2009, p. 17-18)

Information Gaps

- Information on seasonal temperature projections in California is needed.
- One reviewer suggested updated regional runs could be made for Oregon and Washington. Another reviewer stated precipitation extremes are generally not well captured due to the spatial scale of the GCMs. Regional scale models are providing some guidance (e.g., Salathe et al., 2010), but additional research is needed.
- Peterson and Schwing (2008) identify four categories of information needs for the California Current region (south of Vancouver, B.C.) – climate data, monitoring, models, and climate products and forecasts:
    - Climate data are needed to provide the climate forcing and environmental context for climate impacts on the CCE, for developing science-based operational indicators, and to provide continuity of satellite data and products.[189]
    - Monitoring needs include large-scale monitoring to provide information on gyre-scale circulation, monitoring in the coastal region, and maintaining NDBC monitoring and data archives.[190]
    - Modeling of climate and atmospheric and oceanic physics needs to be linked with similar work being carried out by NOAA and its partners.[191]
    - Climate product and forecasting needs include indicators and indices of climate variability, seasonal and longer-term forecasts and projections, and additional research to understand the mechanisms linking equatorial ENSO processes and teleconnections with California Current conditions and their populations.[192]

[189] *Peterson and Schwing. *Climate Impacts on U.S. Living Marine Resources: National Marine Fisheries Service Concerns, Activities and Needs: California Current Ecosystem.* (2008, p. 49)
[190] *Peterson and Schwing. (2008, p. 49)
[191] *Peterson and Schwing. (2008, p. 49)
[192] *Peterson and Schwing. (2008, p. 50)