The UW Climate Impacts Group

Science for climate resilience

Working since 1995 to.....

• Produce scientific information that is both useful to and used by decision makers

• Conduct decision-relevant climate research

• Support the interpretation and application of climate science in decision making
We’re changing the climate...
Global mean concentration of carbon dioxide in the atmosphere, April 2016 (*varies monthly*)

407.42 ppm

parts per million

Increase relative to pre-Industrial Revolution (1750): +40%

http://www.esrl.noaa.gov/gmd/ccgg/trends/
“It is unequivocal that the current concentrations of atmospheric CO$_2$ [carbon dioxide], CH$_4$ [methane], and N$_2$O [nitrous oxide] exceed any level measured for at least the past 800,000 years...”

– IPCC 2013, Working Group 1 report, Chapter 6
…in ways that have committed our climate to change for the next several centuries, if not longer.
Different scenarios result in different climate change projections.

- RCP2.6 (Very low)
- RCP4.5 (Low)
- RCP6 (Moderate)
- RCP8.5 (High)

Figure source: van Vuuren 2011
Key Climate Impact “Drivers”

- Substantial warming
- Increasing heavy rainfall
- Changes in hydrology (snow, streamflow)
- Sea level rise
- Changes in ocean conditions
- Natural variability
Rapid Warming Projected

All scenarios indicate warming in the 21st century. Warming is expected in all seasons.

<table>
<thead>
<tr>
<th>2050s</th>
<th>2040-2069, relative to 1950-1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low emissions</td>
<td>RCP 4.5</td>
</tr>
<tr>
<td></td>
<td>+4.2°F (2.9-5.4°F)</td>
</tr>
<tr>
<td>High emissions</td>
<td>RCP 8.5</td>
</tr>
<tr>
<td></td>
<td>+5.5°F (4.3-7.1°F)</td>
</tr>
</tbody>
</table>

Figure source: Climate Impacts Group; Data source: Downscaled climate projections developed by Abatzoglou and Brown (2011).
**Continued Variability in Precipitation**

Modest increases in average *annual* precipitation. *Seasonal* patterns are reinforced.

<table>
<thead>
<tr>
<th>2050s (2040-2069, relative to 1950-1999)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low emissions</strong> RCP 4.5</td>
</tr>
<tr>
<td><strong>High emissions</strong> RCP 8.5</td>
</tr>
</tbody>
</table>

**Projected Change in Average Annual Precipitation, Puget Sound Region**
*(relative to 1950-1999 average)*

Figure source: Climate Impacts Group; Data source: Downscaled climate projections developed by Abatzoglou and Brown (2011).
Increased frequency, intensity of extremes

For the Thurston County region, 2080s:

Heaviest 24-hour rain events become **+20% to +33% more intense** for a high (RCP 8.5) greenhouse gas scenario, depending on location.

Extreme high temperature (top 5%) **increases +10 to +12°F** for a high (RCP 8.5) greenhouse gas scenario.

Changes relative to 1970-1999
Mauger et al. 2015, Appendix B (figs 4b, 8b)
## Projected Range, Seattle
Relative to 2000 (NRC 2012)

<table>
<thead>
<tr>
<th>Year</th>
<th>Projected Rise</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>+2.6 in.</td>
<td>-1.5 to +8.8 in.</td>
</tr>
<tr>
<td>2050</td>
<td>+6.5 in</td>
<td>-1.0 to +18.8 in</td>
</tr>
<tr>
<td>2100</td>
<td>+24.3</td>
<td>+3.9 to +56.3 in</td>
</tr>
</tbody>
</table>

![Chart showing projected sea level rise in inches for 2030, 2050, and 2100.](chart.png)
Are these changes in climate big enough to matter?
Climate Change Affects Many Local Government Functions

Land use planning
Infrastructure design
Operations and maintenance
Regulations *(coming in and going out)*
Compliance with NPDES permits, CSOs
Non-point source management
Energy supply, transmission
Recreation & tourism
Habitat restoration
Emergency services
Risk management
Water supply
All Scenarios Indicate Less Snow

<table>
<thead>
<tr>
<th>Historical (inches)</th>
<th>Change (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 15</td>
<td>-100% to -75%</td>
</tr>
<tr>
<td>15 to 30</td>
<td>-75% to -62.5%</td>
</tr>
<tr>
<td>30 to 35</td>
<td>-62.5% to -50%</td>
</tr>
<tr>
<td>35 to 45</td>
<td>-50% to -37.5%</td>
</tr>
<tr>
<td>45 to 55</td>
<td>-37.5% to -25%</td>
</tr>
<tr>
<td>55 to 68</td>
<td>-25% to 0%</td>
</tr>
</tbody>
</table>

April 1st Snow Water Equivalent

Puget Sound: 2050s: -29%; 2080s: -55%

Changes relative to 1970-1999
Mauger et al. 2015, Appendix B (fig 11a)
Hydrology is most affected in basins that historically accumulated snow.

**Important caveats:**

Naturalized flows (flows without the influence of dams)

Does not include atmospheric river events (important in rain, mixed rain-and-snow basins)

Mauger et al. 2015
Higher Winter, Lower Summer Flows – Nisqually River

Source: CMIP3

- Historical
- Moderate Emissions (A1B)
- Moderate Emissions range (A1B)

**2040s Flow (cfs)**

**2080s Flow (cfs)**

Month
The Puget Sound region is almost entirely rain-dominant by end of century.

Percent of winter precipitation captured in peak snowpack:

- < 10%: Rain dominant
- 10% to 40%: Mixed rain and snow
- > 40%: Snow dominant

Mauger et al. 2015
Glaciers will continue to recede, exacerbating hydrologic impacts

Affects:

- Summer streamflow volume
- Stream temperature
- Sediment supply
Impacts: Water
Direct and indirect impacts of climate on salmon

- Stream temperature
- Streamflow volume
- Sediment
- Food availability, quality
- Predation
- Disease
- Ocean conditions

- Habitat quality, connectivity
- Reservoir management
- Floodplain management
- Community responses to sea level rise
- Changes in land cover
- Toxics
Salmon Impacted Across Full Life-Cycle

- Early peak flows
- Floods
- Warm, low streamflow
- Ocean Acidification? Warmer sea surface temps?

- Timing of migration to spawning grounds depends on species and race
- Fish spawning in freshwater stream
- Eggs in stream gravel hatch in 1-3 months
- Alevins in stream gravel 1-5 months
- Fry emerge in spring or summer
- Juvenile fish in freshwater a few days to 4 years, depending on species and locality
- Smolt migration to ocean usually in spring or early summer
- Fish spend 1-4 years in ocean
Increased Fire Risk

Historically, Puget Sound wildfires have been rare, but large.

By the 2080s, the area burned by wildfire in Puget Sound is projected to increase by +150 to +1000%.

Stream temperature, sediment/nutrient loading rates affected

Relative to 1970-1999, for a low (B1) and moderate (A1b) GHG scenario; Mauger et al. 2015
Sea Level Rise: Low-lying Areas at Risk

Sea Level Rise Estimates
- 88" High + Storm
- 60" High
- 13" Medium

LEGEND
Flooding Depth (ft.)
- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
Sea level rise increases storm surge and the risk of:

- flooding,
- erosion,
- habitat loss
- toxics mobilization

These impacts will affect coastal areas long before permanent inundation.
## Changing Flood Risk: Olympia

<table>
<thead>
<tr>
<th>Sea level rise amount</th>
<th>0 inches</th>
<th>+3 inches</th>
<th>+6 inches</th>
<th>+12 inches</th>
<th>+24 inches</th>
<th>+50 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return frequency for a storm tide reaching the current 100-year flood level</td>
<td>100-yr event</td>
<td>40-yr event</td>
<td>18-yr event</td>
<td>2-yr event</td>
<td>&lt; 1-yr event</td>
<td>&lt;&lt; 1-yr event</td>
</tr>
<tr>
<td>Equivalent annual probability of occurrence</td>
<td>1%</td>
<td>2.5%</td>
<td>5.5%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

City of Olympia
Erosion, inundation, and flooding will affect:

- Public and private property along the coast
- Infrastructure, including wastewater treatment plants
- Stormwater outfalls
- Ferry terminals
- Coastal roads and rail transportation
- Coastal aquifers (groundwater level, salinity)
- Ability to drain low-lying areas

**Additional Considerations**
Key Summary Points

• Regional climate is changing and continued rapid change is expected, absent significant reductions in greenhouse gas emissions. Natural variability will also continue.

• Climate change will have important implications for the build and natural environment in the Puget Sound region.

• We have the knowledge, tools, data, and need to start preparing for climate change.
For More Details...

Available for download at https://cig.uw.edu/