

Climate Variability and Change in the Pacific Northwest

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*Climate Science in
the Public Interest*

The Mountaineers Leadership Conference
December 5, 2015

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



W COLLEGE OF THE ENVIRONMENT
UNIVERSITY of WASHINGTON



Northwest Climate
Science Center



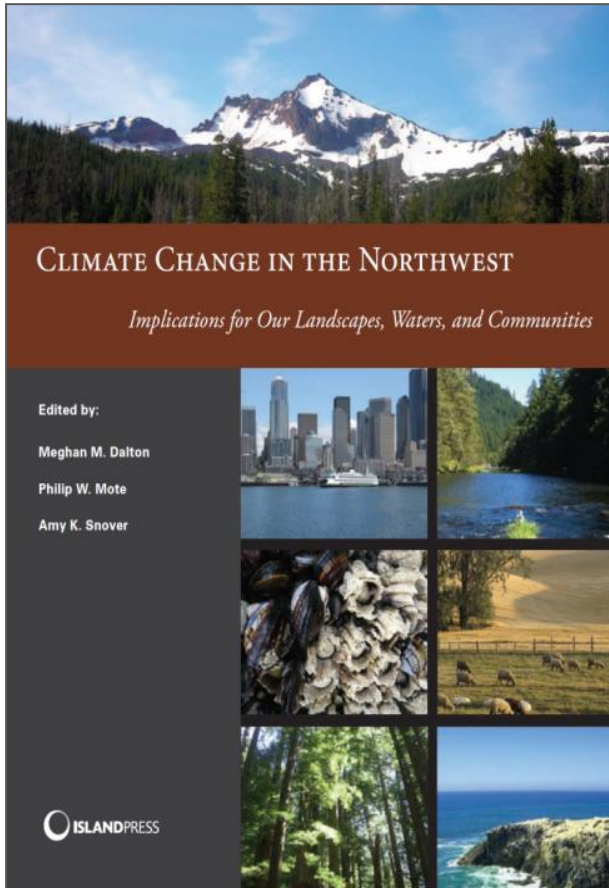
Objectives for Today

- Share what we've learned from 20 years of research on Pacific Northwest climate and climate impacts
- Address and questions you might have

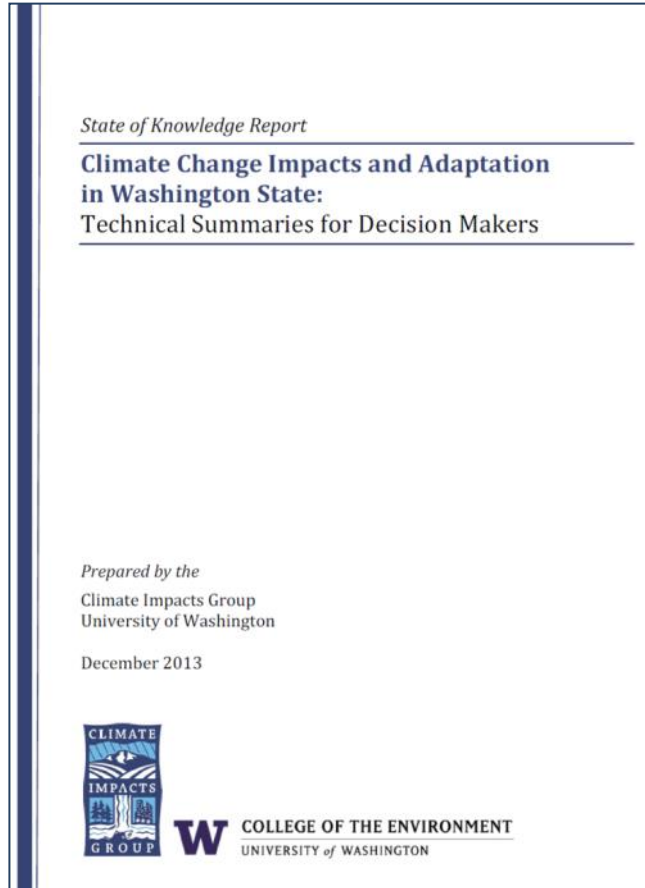
But hopefully not leaving you feeling like this...



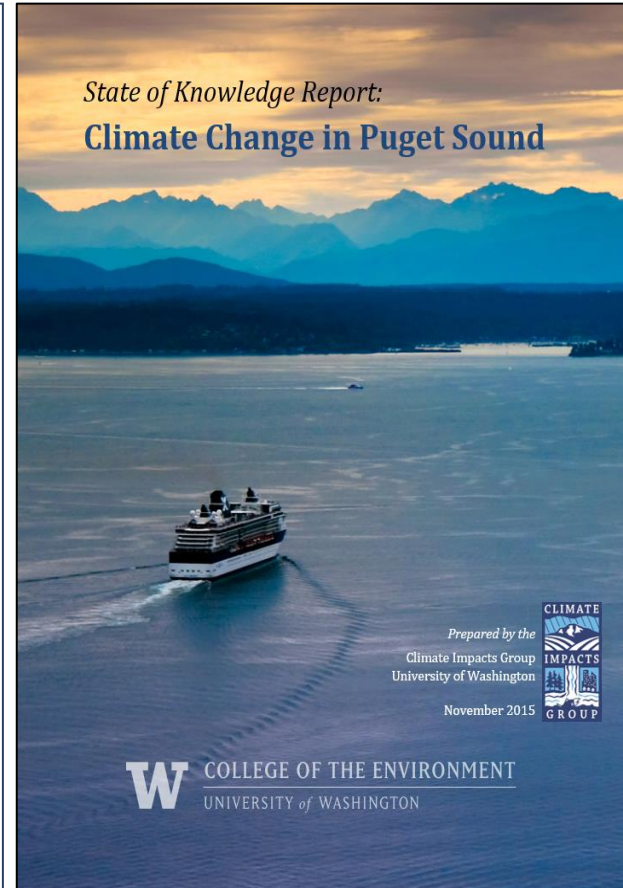
For More Details...



Dalton et al. 2013



Snover et al. 2013



Mauger et al. 2015

"You can observe a lot just by watching"
– *Yogi Berra*





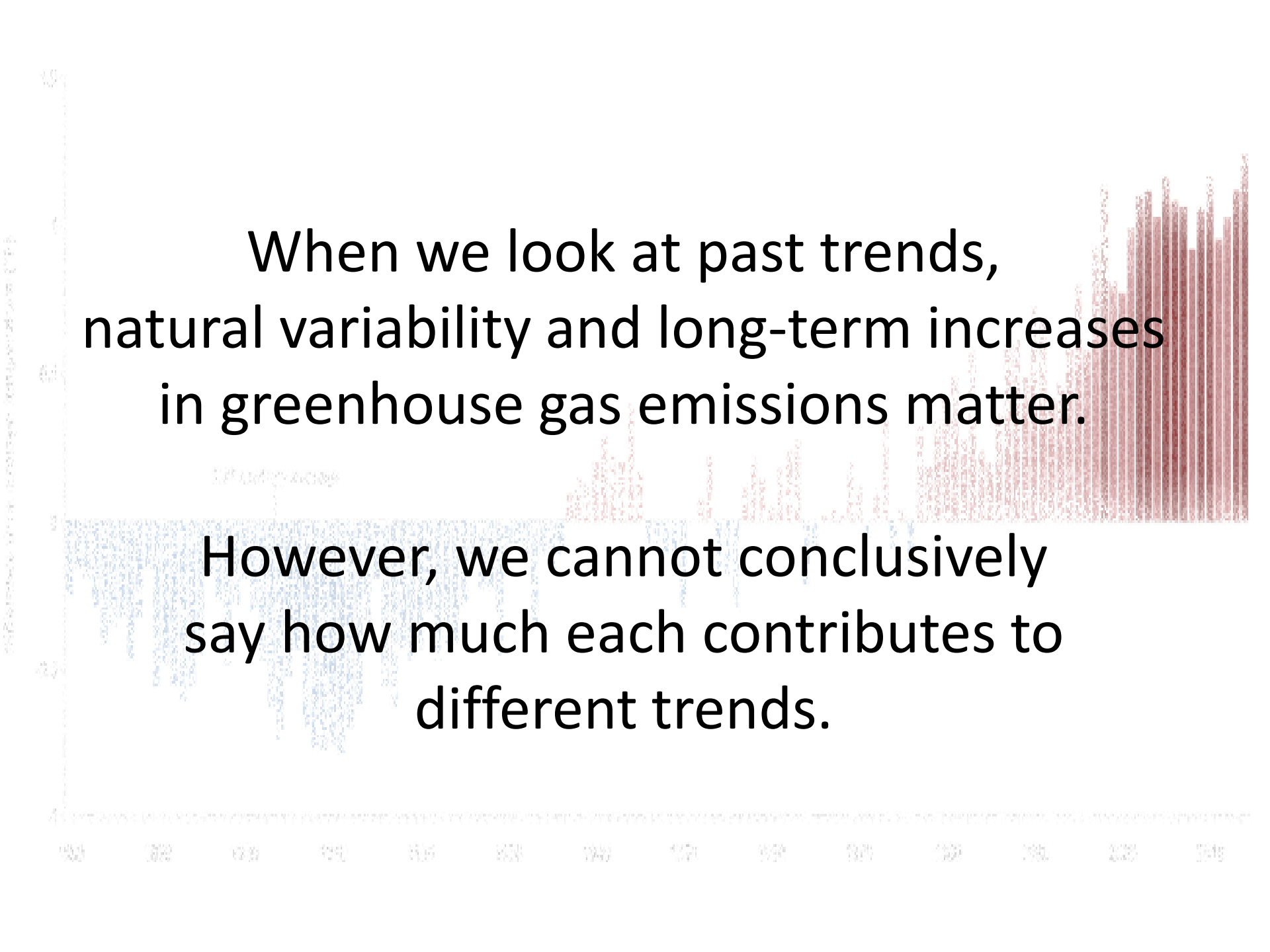
Observed changes in PNW climate

Climate. Washington and the Pacific Northwest have experienced long-term warming (+1.3°F between 1895 and 2011), a lengthening of the frost-free season, and more frequent nighttime heat waves.

Hydrology. Snowpack in the WA/OR Cascades declined ~25% between mid-20th century through 2006. Most glaciers are in decline (Mt. Rainier: -27%, 1913-1994). Spring peak streamflow shifted earlier by up to 20 days, depending on location (1948-2002)

Sea level. Sea level is rising along some parts of the Washington coastline and falling in others. Increased +8 inches in Seattle, 1898-2013.

Oceans. The coastal ocean is acidifying and some local inshore coastal waters are warming.



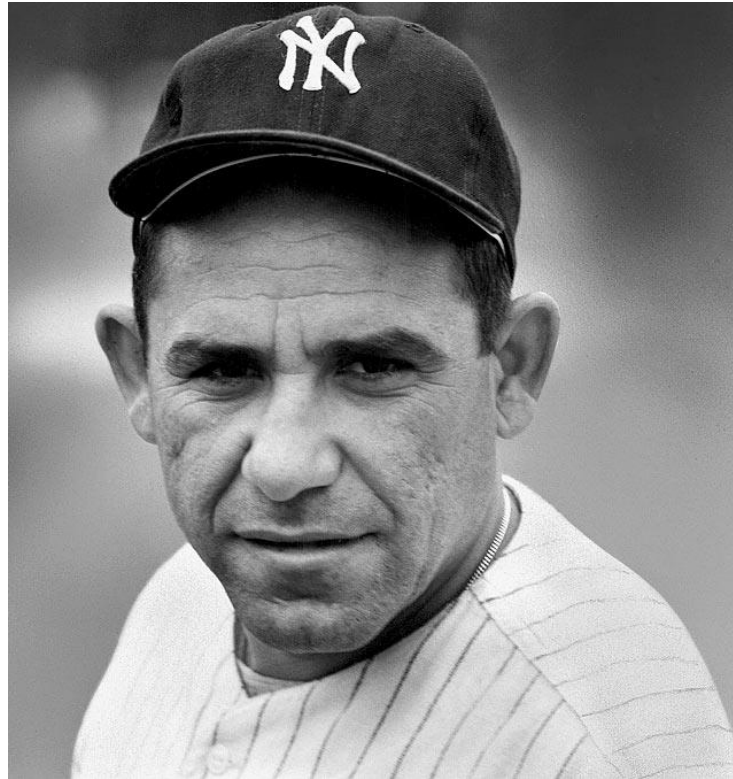
When we look at past trends,
natural variability and long-term increases
in greenhouse gas emissions matter.

However, we cannot conclusively
say how much each contributes to
different trends.

Over time, greenhouse gas emissions play a larger and larger role...

...but we'll always have natural variability





“The future ain’t what it used to be”

Yogi Berra



Key Drivers of Change

Substantial warming

Increasing heavy rainfall

Sea level rise

Ocean acidification

Natural variability



Rapid Warming Projected

All scenarios indicate warming in the 21st century.

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

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

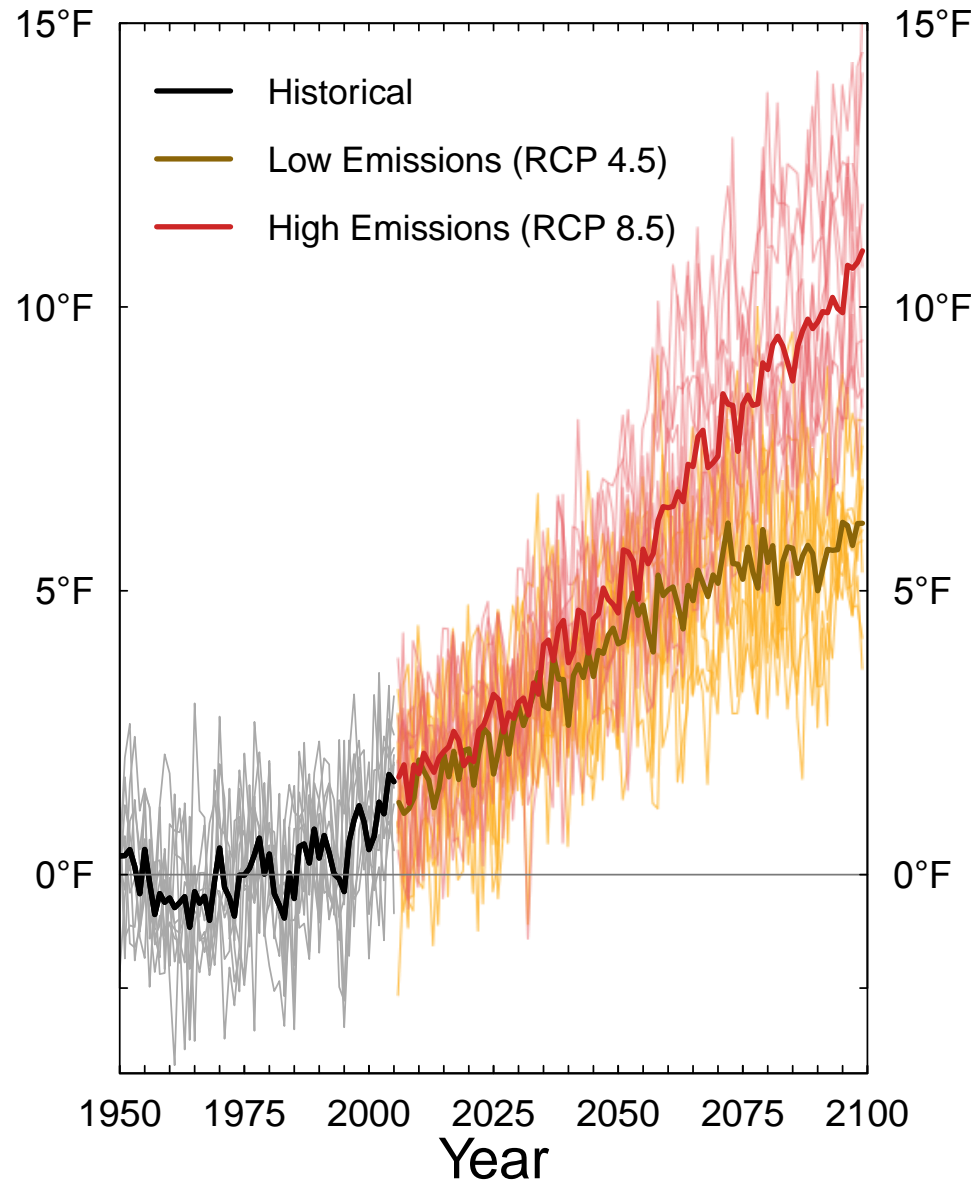


Figure source: Climate Impacts Group; Data source: Downscaled climate projections developed by Abatzoglou and Brown (2011).



Continued Variability in Precipitation

Modest increases in average
annual precipitation.

Seasonal patterns
reinforced.

2050s (2040-2069, relative to 1950-1999)	
Low emissions <i>RCP 4.5</i>	+4.2% (+0.6% to +12%)
High emissions <i>RCP 8.5</i>	+6.9% (-1.9% to +13%)

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

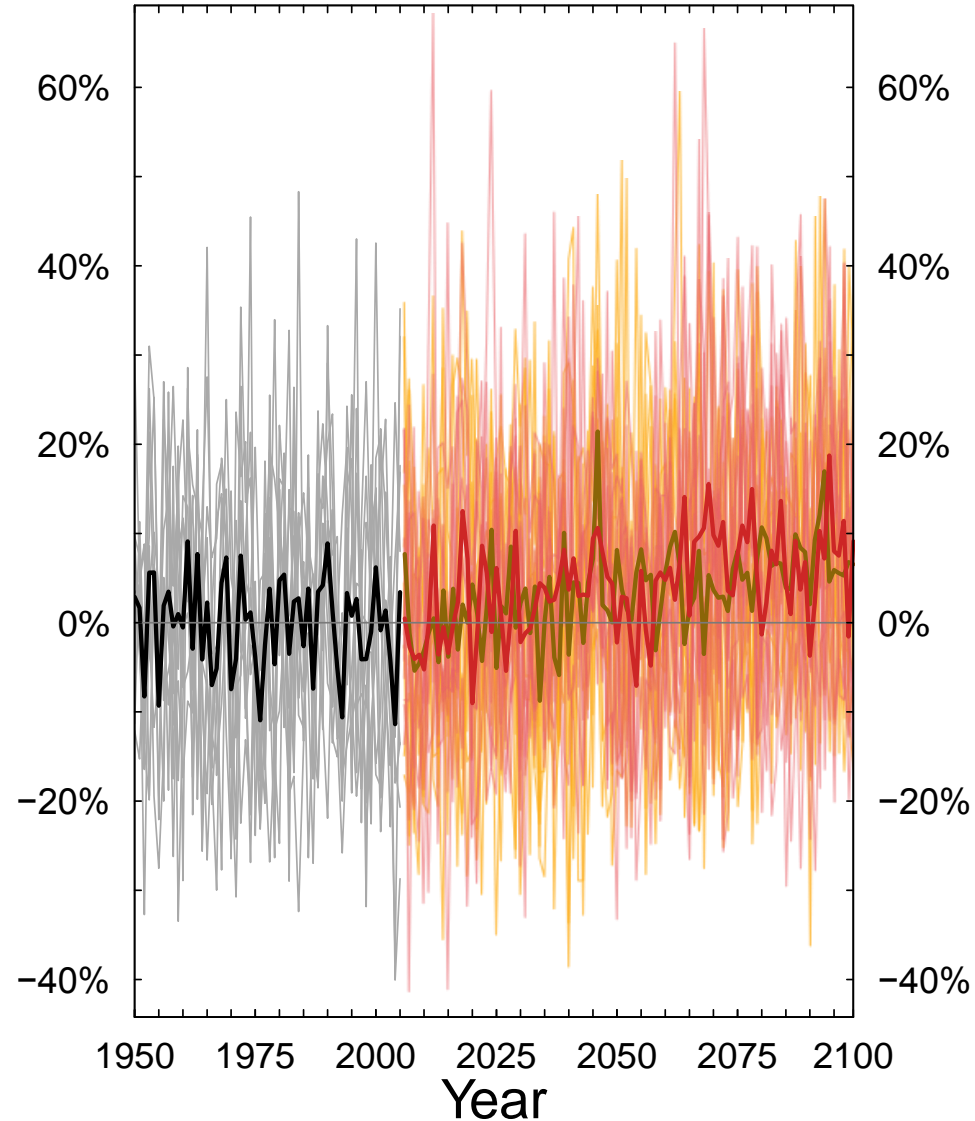


Figure source: Climate Impacts Group; Data source: Downscaled climate projections developed by Abatzoglou and Brown (2011).

Projected Sea Level Rise: Seattle

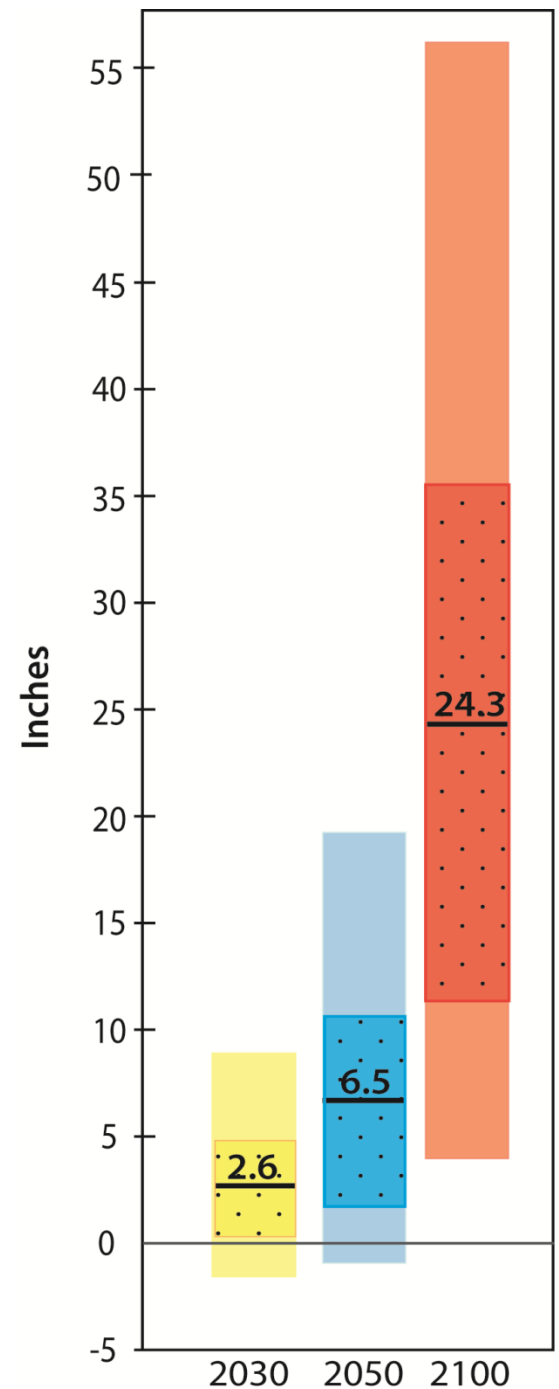
(NRC 2012)

Projected Mean (mean for the A1B scenario)

- 2030: +2.6 in. (+/- 2.2 in)
- 2050: +6.5 in. (+/- 4.1 in)
- 2100: +24.3 in. (+/- 11.5 in)

Projected Range (mean of B1 scenarios, A1FI scenarios)

- 2030: -1.5 in. to +8.8 in.
- 2050: - 1 in. to +18.8 in.
- 2100: +4 in. to +56.3 in.



What Does 2 Feet of SLR Look Like?

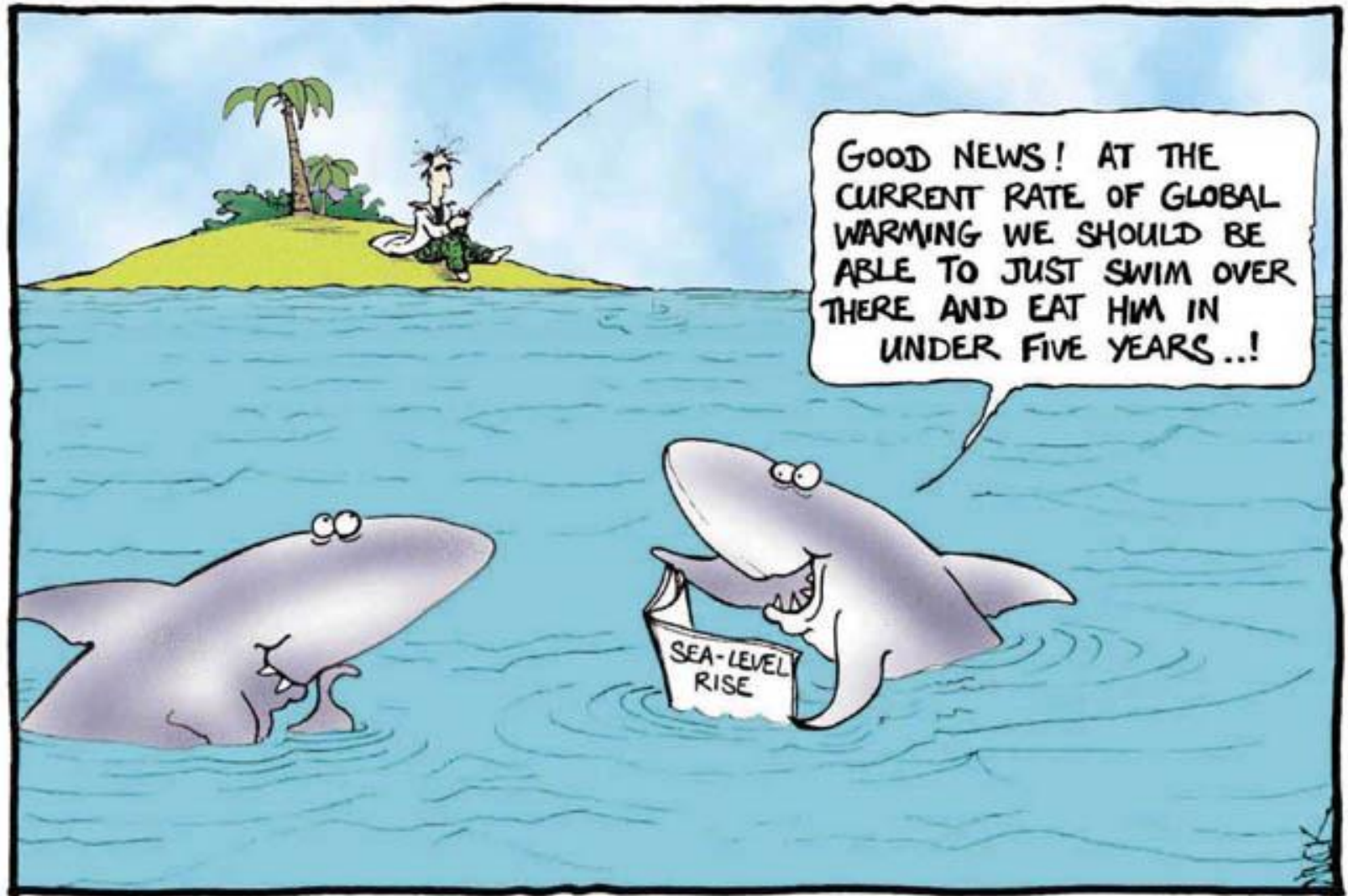


**Alki Beach, West Seattle
Photo by Hugh Shipman, WA Dept of Ecology**

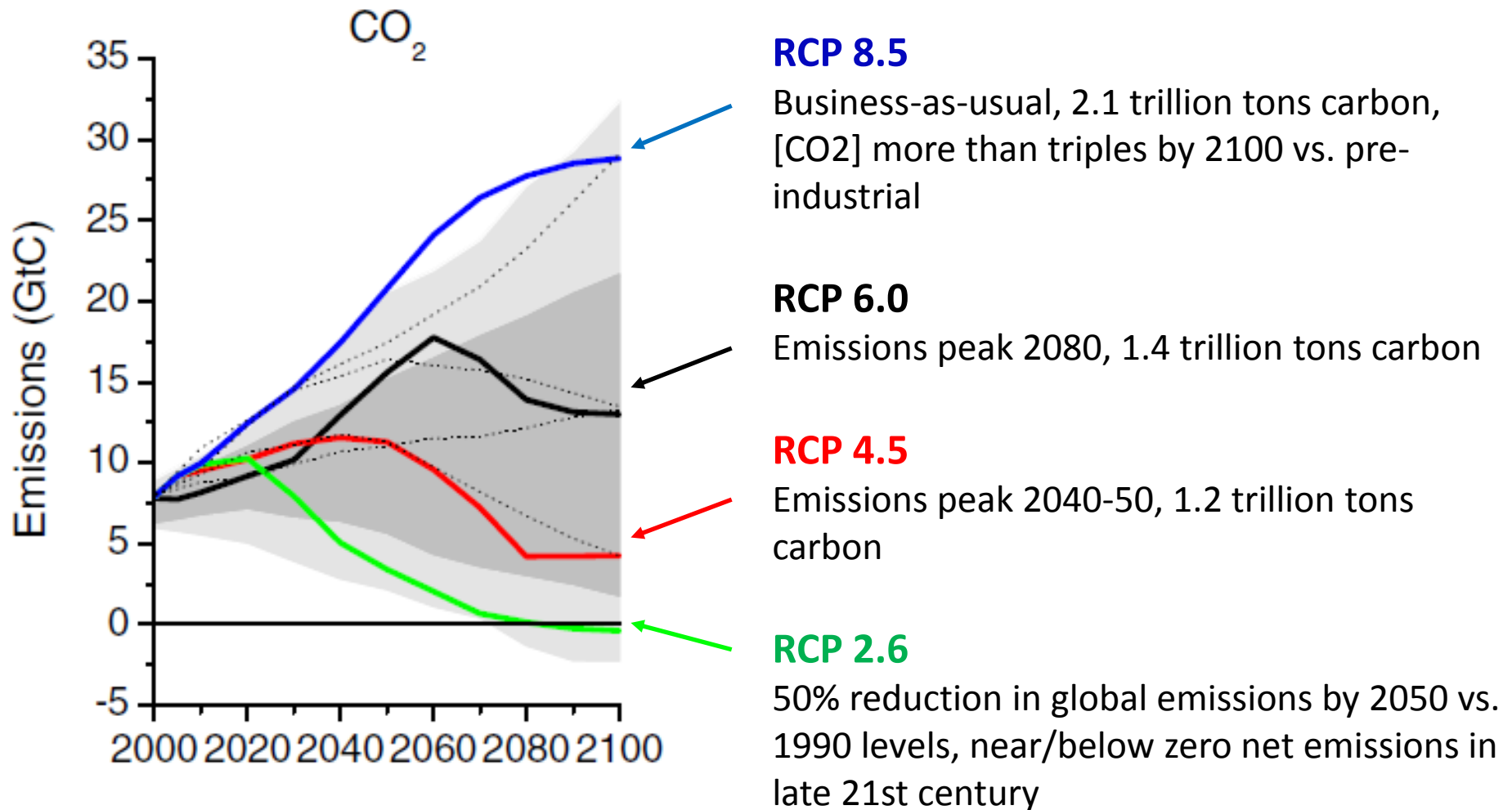


Alki Beach, West Seattle, January 21, 2010
Photo by Hugh Shipman, WA Dept. of Ecology

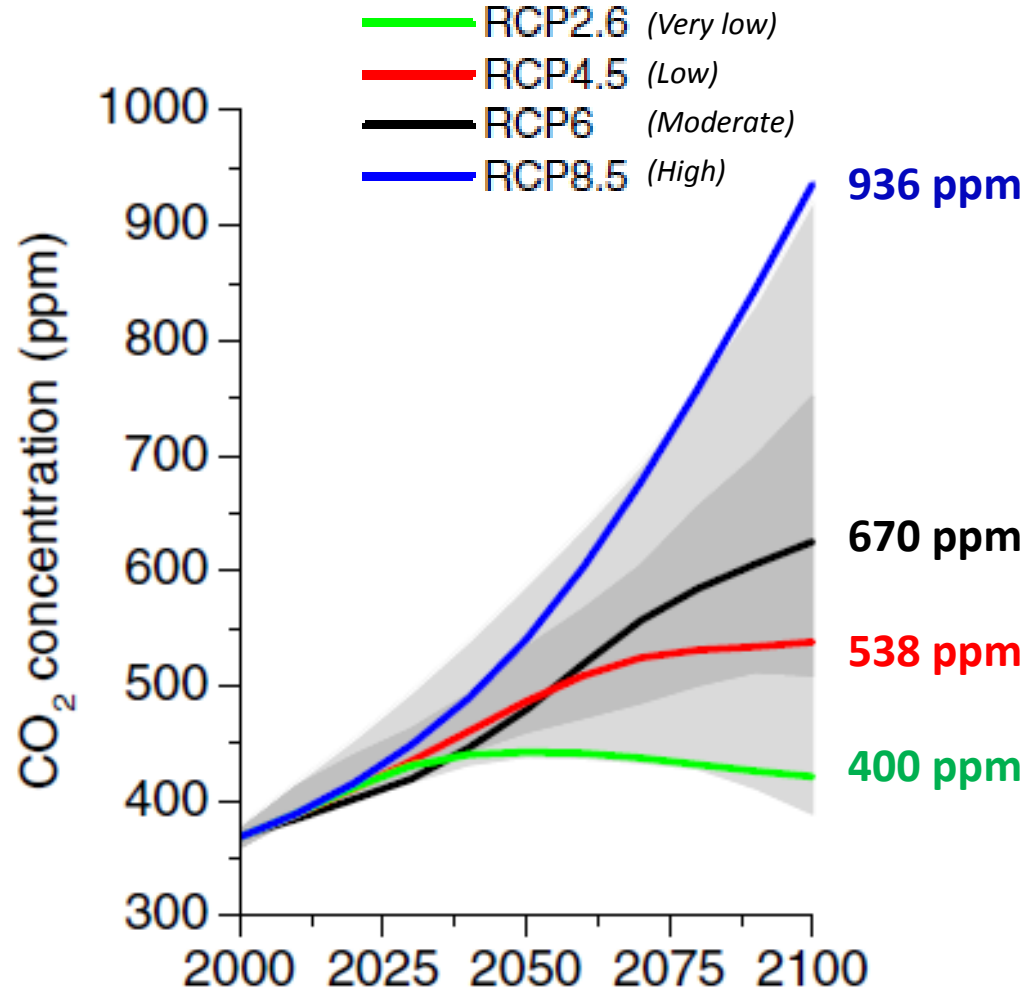
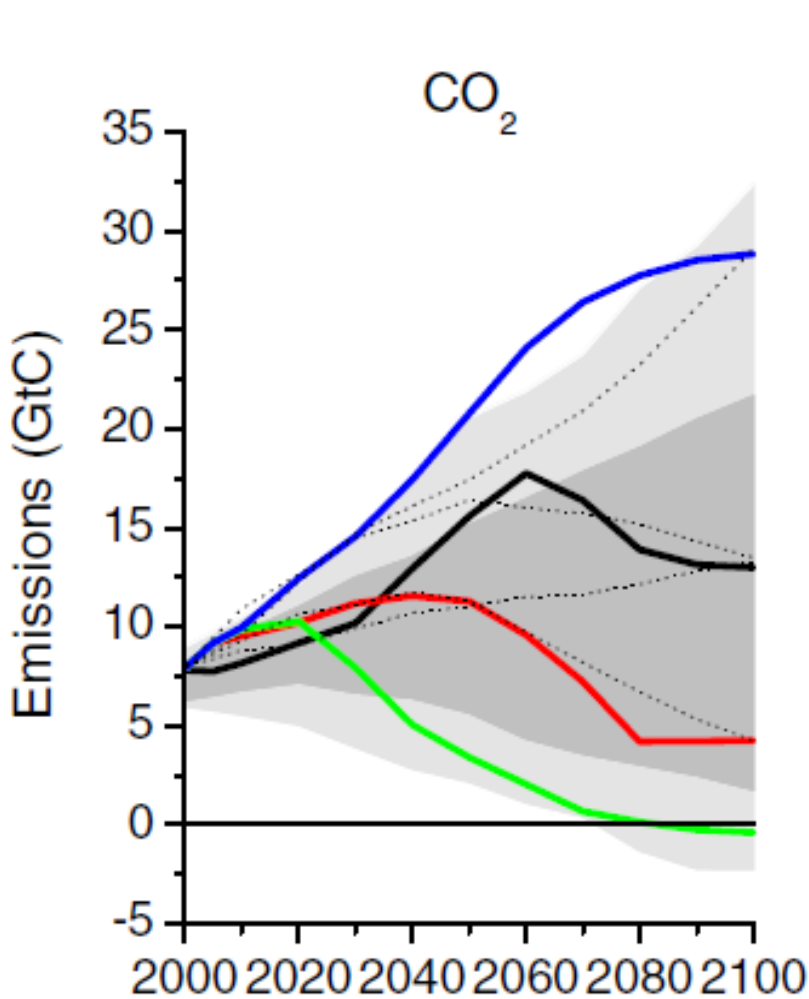
What's "the number"?




Projections Vary Depending on Future Greenhouse Gas Emissions



Projections Vary Depending on Future Greenhouse Gas Emissions – cont'd



A black and white photograph of a snowy mountain road. The road is covered in a thick layer of snow, with visible tire tracks. On the right side, there is a steep, rocky cliff face that has been partially covered in snow. In the distance, a small dark car is driving away on the road. The sky is overcast and grey.

Snow

Sometimes you've got it....

...and sometimes you don't.

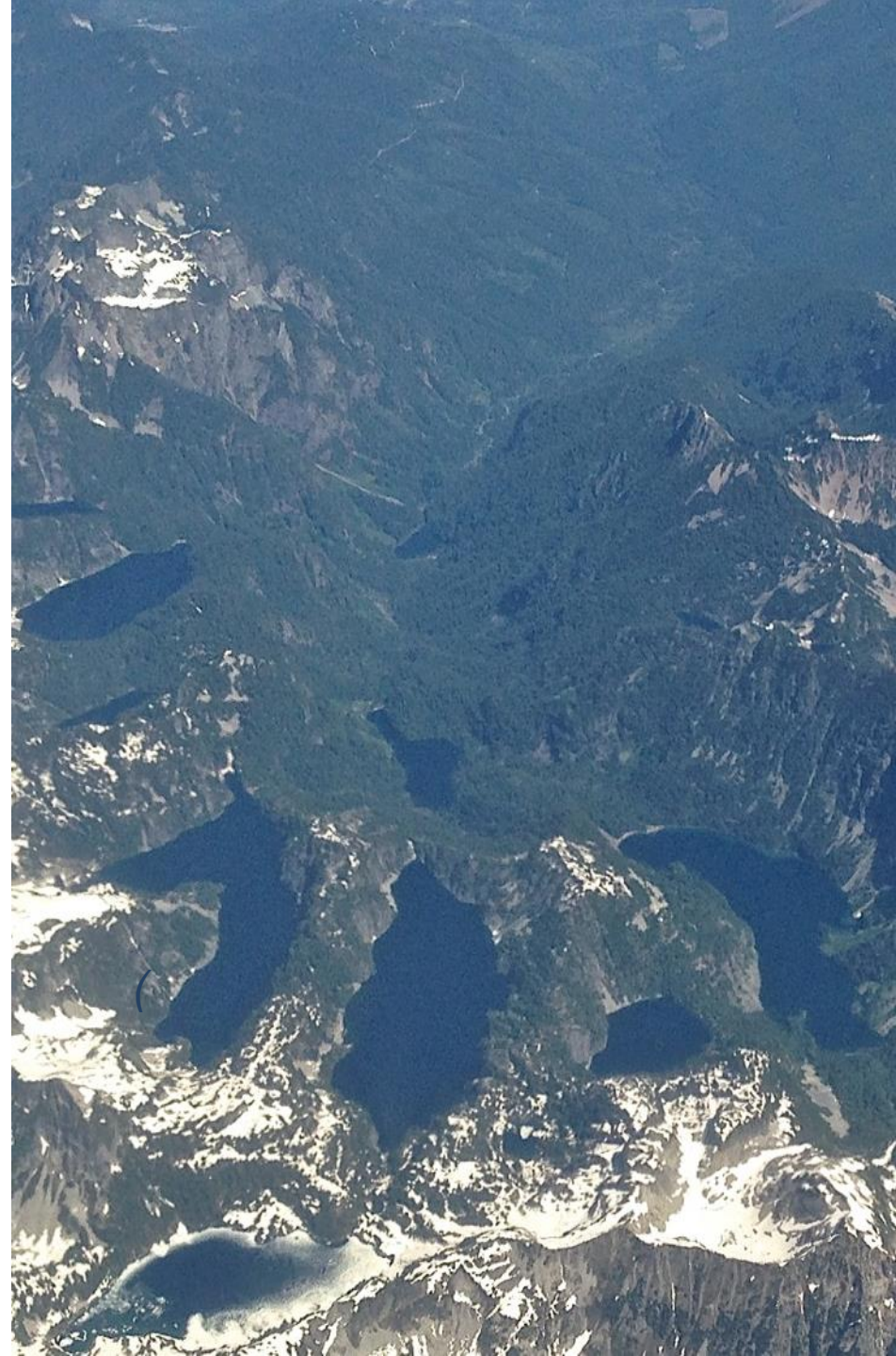


Photo source: World Meteorological Organization

Our primary mechanism
for storing water – snow
– is sensitive to
warming.

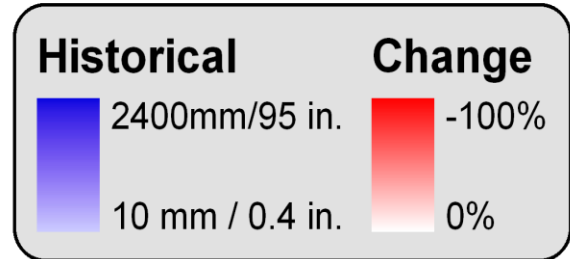
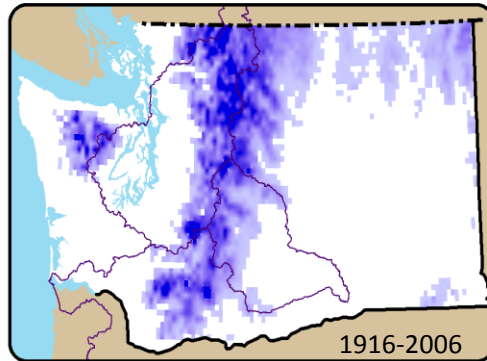
The Cascade and Olympic
Mountains have the highest
fraction of “warm snow”
(snow falling between 27-32°F)
in the continental U.S.

(Mote et al. 2008)



All Scenarios Indicate Less Snow

Historical

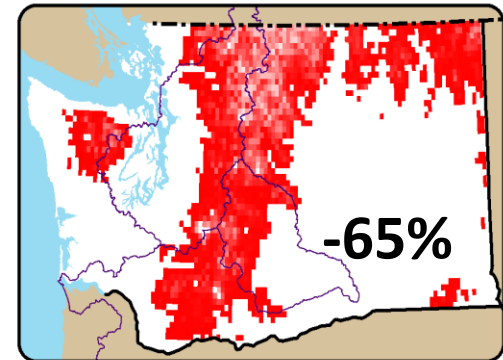
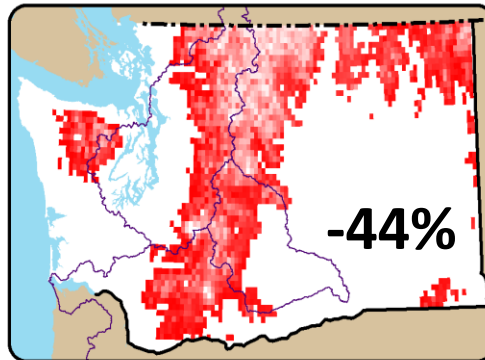
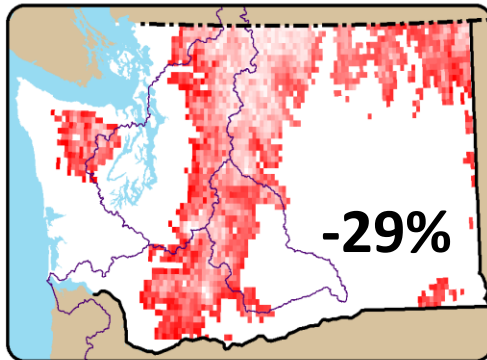


Apr. 1 Snow Water Equivalent

2020s

2040s

2080s



Medium Emissions Scenario

A1B

Elsner et al. 2010

Why? Spring snowpack is projected to decline as more winter precipitation falls as rain rather than snow, especially in warmer mid-elevation basins. Also, snowpack will melt earlier with warmer spring temperatures.



When will the temperatures of winter 2015 be "the new normal" (for winter)?

Dec-Feb 2015 was +5.6°F above average

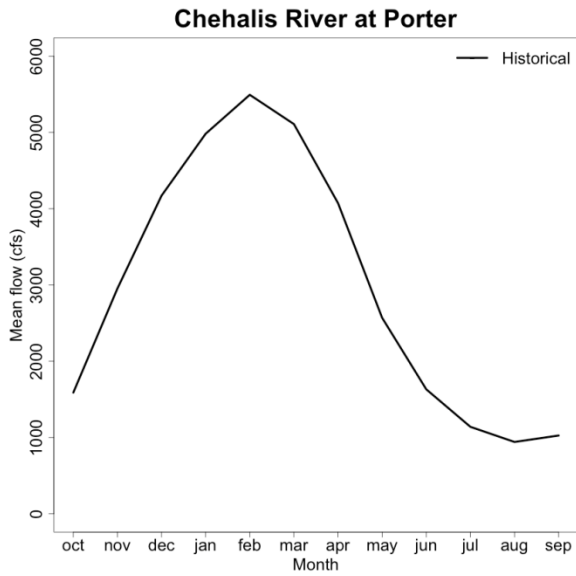
	Low emissions (RCP 4.5)	High emissions (RCP 8.5)
Minimum (earliest):	2045	2040
10th percentile:	2049	2041
25th percentile:	2055	2048
50th percentile:	2061	2056
75th percentile:	2075	2061
90th percentile:	2088	2080
Maximum (latest):	>2099	2084

Natural variability not included here!

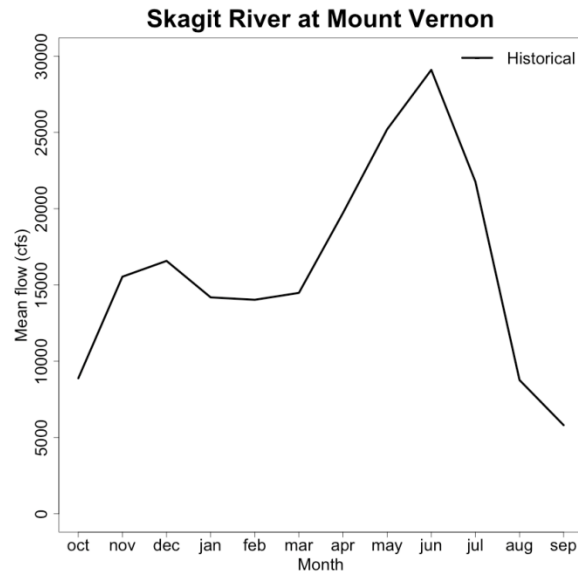
All results are for the PNW, relative to the average for 1970-1999. Based on evaluation of 40 climate model scenarios. The year listed for each model is the year when the future 30-year average is 5.6°F warmer than the average for 1970-1999 (i.e.: when will the conditions we saw this year be "the new normal").

Rivers will respond differently

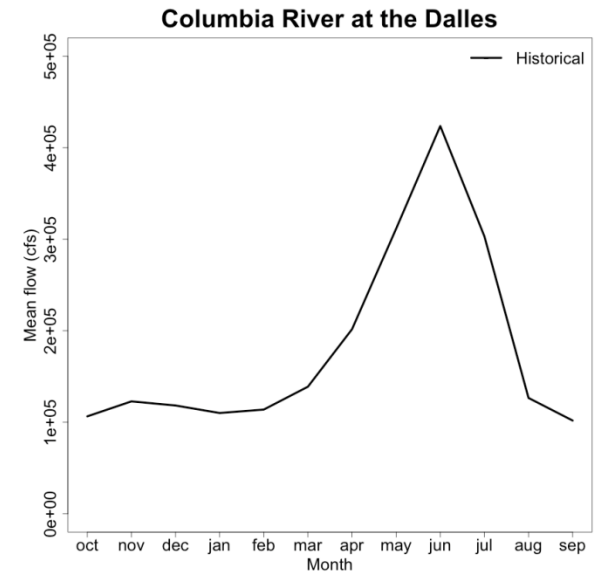
rain-dominant



“transient” – double peaked

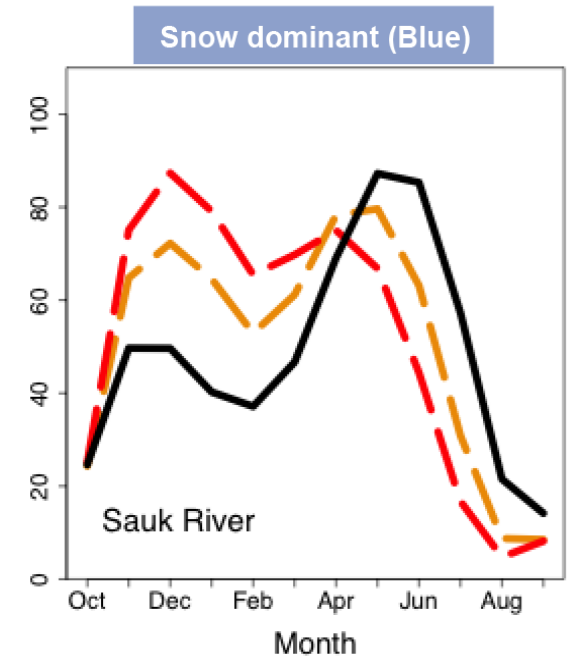
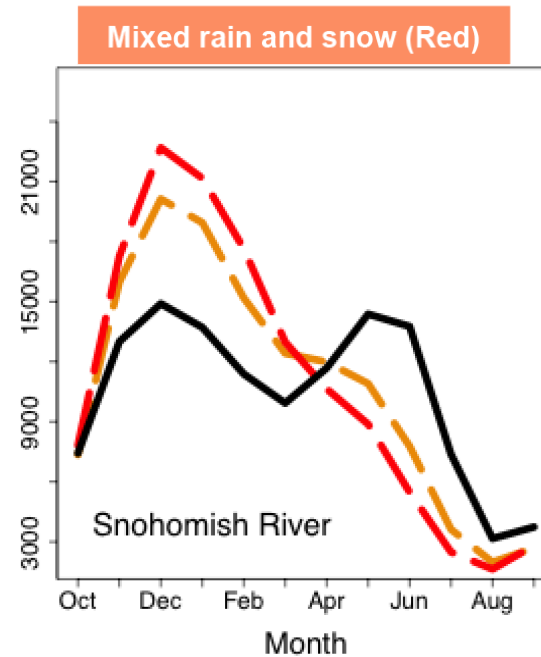
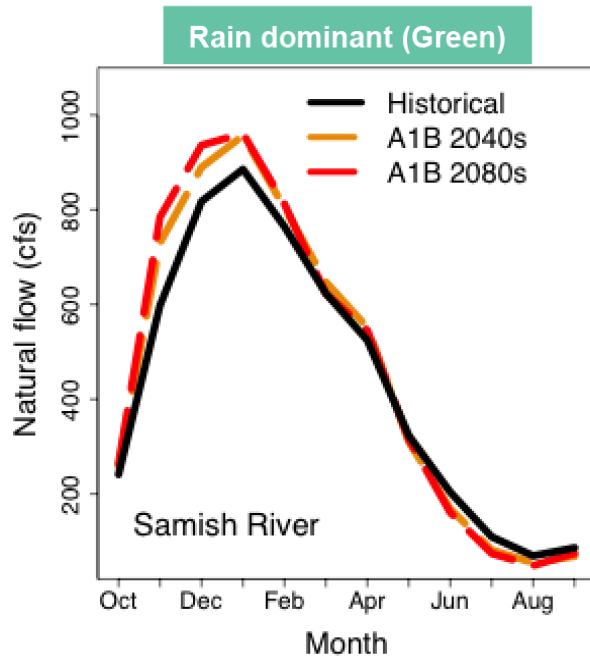


snowmelt-dominant








Basins that historically accumulated snow are most sensitive to warming



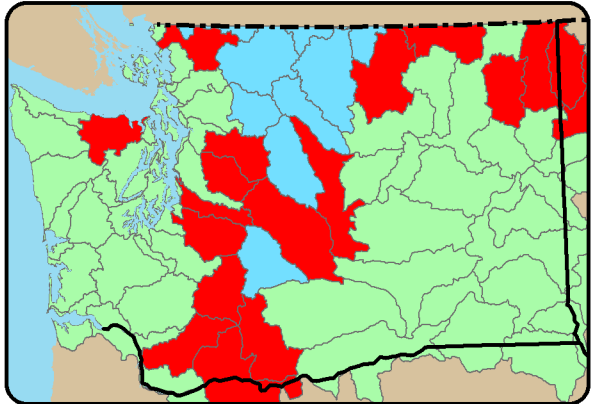
Examples from Puget Sound

Watershed Classification

Ratio of April 1 SWE to
October - March Precipitation

-  < 0.1 Rain dominant
-  0.1 - 0.4 Transition
-  > 0.4 Snow dominant

Historical

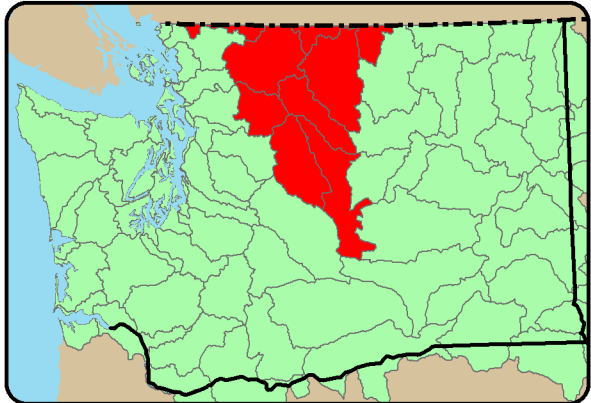
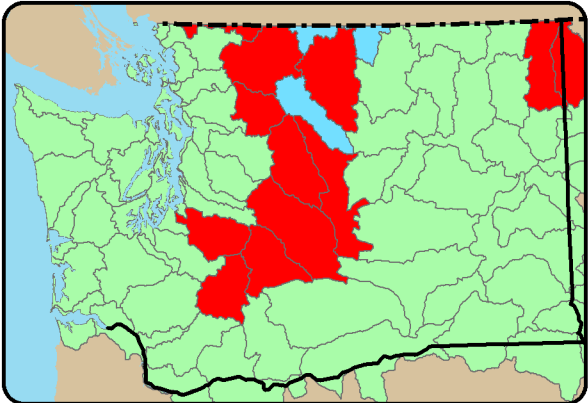
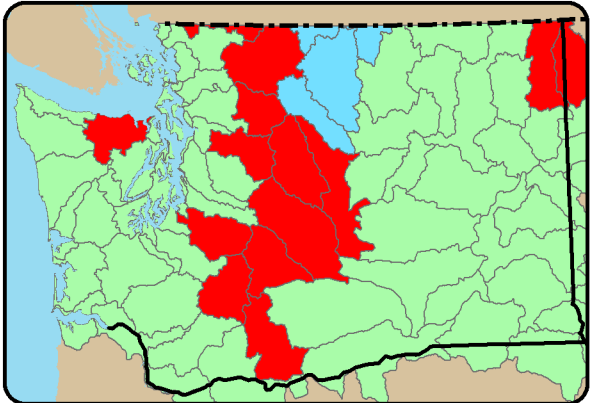


2020s

2040s

2080s

A1B



Glaciers will continue to recede, exacerbating hydrologic impacts

South Cascade Glacier, 1979 (left) and 2003 (right)





Increasing Landslide Risk



Due to projected increases in winter precipitation, more extreme precipitation, and decreasing snow/glacial recession.

These factors lead to more saturated soils and increased landslide risk during winter. Slide material also affects water quality and streambeds.



Decreased summer
hydropower production



More intensive management
of municipal water supplies
(*groundwater - unknown*)



Increased stress for salmon
& many coldwater
ecosystems



Increased challenges for stormwater management



Increased flood risk west of the Cascades



Reduced water quality
(*e.g., temp, turbidity*)



Winter: Shortened ski season

Increased risk of shortened ski season at lower elevation ski areas due to lack of snow or poor snow quality. More rain events. (*Hamlet et al. 2000, Mote et al. 2008*)



Spring/Fall: Longer hiking season

Snowmelt occurs up to 45 days earlier throughout N Cascades, altering access, landslides, safety, operations & maintenance (*Strauch et al. 2013*). Fires/forest closures can affect summer tourism.

Increased wildfire risk

Area burned by fire in the Columbia River Basin is projected to double by 2020s, triple by 2040s, x5 by 2080s (relative to median for 1916-2006).
(Littell et al. 2010, 2012)



Discovery Fire burns near volatile stands of insect-damaged trees, 2009, DNR



Increased risk of insect outbreaks

Near-term increased risk of mountain pine beetle outbreaks in drier forests will exacerbate fire risk.
(Littell et al. 2010, 2012)



Photo: DNR



Additional considerations: Climate Change, Tribes, and Tribal Health

Psychological stress from loss of cultural identity in Native cultures due to:

- decline or loss of key plant and animal species,
- loss of reservation land,
- loss of cultural sites to sea level rise
- loss or changes in traditional foods



What are our choices
for dealing with this
reality?





Mitigation and adaptation are required



Mitigation

Reducing emissions of greenhouse gases

Adaptation

Preparing for and managing the change that occurs as mitigation strategies are implemented.

Who is Working on Adaptation in WA?



DEPARTMENT OF
ECOLOGY
State of Washington



Washington
Department of
**FISH and
WILDLIFE**



City of
OLYMPIA



City of Seattle



King County



WASHINGTON STATE DEPARTMENT OF
Natural Resources



SOUNDTRANSIT



**WATER SUPPLY
FORUM**

Serving Snohomish, King & Pierce Counties



Tacoma



Washington State Department of
Health



PORT OF BELLINGHAM
Washington State



**US ARMY
CORPS OF ENGINEERS**



Snohomish County



TACOMA POWER
TACOMA PUBLIC UTILITIES



Swinomish Indian
Tribal Community



**JAMESTOWN
S'KLALLAM
TRIBE**



**U.S.
FISH & WILDLIFE
SERVICE**
DEPARTMENT OF THE INTERIOR



**NATIONAL MARINE
SANCTUARIES**



NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE



**NATIONAL
PARK
SERVICE**



**The Nature
Conservancy**
Protecting nature. Preserving life.



**NATIONAL
WILDLIFE
FEDERATION**



**NORTH PACIFIC LANDSCAPE
CONSERVATION COOPERATIVE**



**CONFEDERATED
TRIBES AND BANDS
YAKAMA NATION
TREATY OF 1855**



**FOREST SERVICE
U.S.
DEPARTMENT OF AGRICULTURE**



**UNITED STATES • AGENCY
ENVIRONMENTAL PROTECTION**



FTA

Key Points

- We have now had 20 years of active climate impacts research in the Pacific Northwest. There are a number of robust findings, and the picture is getting clearer over time.
 - *Changes in snow and hydrology drive a large number of impacts in the region*
 - *Recreation will be affected by changes in snow, glaciers, fire, and sea level rise*
- The Northwest is a leader in addressing climate change – but will it be fast enough?



The Climate Impacts Group

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