Climate Change: What is the current understanding and what to expect

Jessica Halofsky and David L. Peterson
University of Washington, School of Environmental and Forest Sciences and USDA Forest Service, Pacific Northwest Research Station
Some recent statistics:
Some recent statistics:

• In Seattle, the five hottest years on record since 1948 were:
  – 2015 (63.4 degrees)
  – 2014 (62.6 degrees)
  – 2016 (62.5 degrees)
  – 1992 (62.5 degrees)
  – 2018 (62.3 degrees)
Some recent statistics:

In 2014, a record was set for the largest wildfire in Washington State history, the 256,100-acre Carlton Complex Fire.
Some recent statistics:

In 2015, 1.7 million acres were burned in Oregon and Washington, with over 9 million acres burned in the western United States.
Several fires in 2015 occurred in west-side conifer forests, including a rare fire event in coastal temperate rainforest on the Olympic Peninsula.
Carbon dioxide is increasing

Atmospheric CO\textsubscript{2} is now 409 ppm.

It was 260 ppm in 1850.

Source: https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html
Greenhouse gases (water vapor, CO$_2$, CH$_4$, N$_2$O) play a critical role in determining global temperature. Rapid increases in greenhouse gases are changing this natural balance.
Radiative forcing

2.3 Watts
X 500 trillion
for the entire Earth
In 2100?

X 500 trillion
Global temperature trend

Source: https://www.ncdc.noaa.gov/cag/time-series/global
Temperature trends by station

Average annual temperature has increased +1.6°F since 1920.

Almost every station shows warming.

Extreme cold conditions have become rarer.

Minimum temperatures rose faster than maximum temperatures.
Projected temperature in Pacific Northwest

Trends diverge here

Business as usual

Global cooperation
What about precipitation?

Global climate models do not project precipitation reliably.

Most models project a small increase in winter or no change.
What will future climate feel like?

Olympia, WA
What will future climate feel like?

Sacramento, CA
This is what we know…

There is a natural greenhouse effect.

Humans are increasing the greenhouse effect by adding carbon dioxide and other gases to the atmosphere.

Effects of a changing climate are already apparent.

There will be more global warming to come.
Climate controls ecosystem processes

The hydrologic cycle
Climate controls ecosystem processes

The hydrologic cycle

Plant establishment, growth, and mortality

growing season
Climate controls ecosystem processes

The hydrologic cycle

Plant establishment, growth, and mortality

Disturbance
Nearly every glacier in the Cascade Range has retreated during the past 100 years.

South Cascade Glacier, 1928 (top) 2016 (right)
Nearly every glacier in the Cascade Range has retreated during the past 100 years.

Since 1900, glacial area in the North Cascades has decreased by 46%.

South Cascade Glacier, 1928 (top) 2016 (right)
Snowpack is decreasing

Snow-water equivalent
1955-2016

Mote et al. 2018
Snowpack is decreasing

Snow-water equivalent
1955-2016

Snow-dominant watersheds

Rain-dominant watersheds

Mote et al. 2018
Watershed types will shift

- Snow dominant watersheds become transitional (mixed rain and snow).
- Transitional watersheds become rain dominant.

Hamlet et al. 2013
Streamflow will change

Simulated Natural Flows (cfs)

Chehalis River
Streamflow will change

Simulated Natural Flows (cfs)

Elwha River
Future projections of flood risk in the PNW

Hamlet et al. 2013
Changes in Hydrologic Extremes
Changes in Hydrologic Extremes

Jan 2009 Flood, Hwy 97 – Blewett Pass
Future projections of low flow risks in the PNW

Hamlet et al. 2013
Higher temperatures will stress salmon

13°C: Spawning, incubation and optimal growth temperature

16°C: Core salmon habitat temperature

Mantua et al. 2010
Extreme weather + increased disturbance: Our primary challenge
Extremes matter

Frequency, extent, and severity of disturbances may be affected by climate change, altering the mean and variability of disturbance properties.

A shift of 1 standard deviation changes a 1 in 40 yr event to a 1 in 6 yr event.

A shift in distribution of disturbance properties has a larger relative effect at the extremes than near the mean.

It’s all about the tail!
U.S. Drought Monitor

Washington

August 25, 2015
(Released Thursday, Aug. 27, 2015)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

<table>
<thead>
<tr>
<th>Current</th>
<th>None</th>
<th>D0-D4</th>
<th>D1-D4</th>
<th>D2-D4</th>
<th>D3-D4</th>
<th>D4</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.00</td>
<td>100.00</td>
<td>100.00</td>
<td>99.99</td>
<td>84.64</td>
<td>0.00</td>
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<tr>
<td>Last Week</td>
<td>0.00</td>
<td>100.00</td>
<td>100.00</td>
<td>99.99</td>
<td>60.80</td>
<td>0.00</td>
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<tr>
<td>3 Months Age</td>
<td>9.77</td>
<td>90.23</td>
<td>51.81</td>
<td>23.76</td>
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<td>0.00</td>
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<tr>
<td>Start of Calendar Year</td>
<td>51.87</td>
<td>43.13</td>
<td>36.15</td>
<td>14.83</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Start of Water Year 92014</td>
<td>34.22</td>
<td>65.78</td>
<td>40.27</td>
<td>20.17</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>One Year Age 92014</td>
<td>32.61</td>
<td>67.33</td>
<td>40.32</td>
<td>19.99</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Intensity:
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Exceptional Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Anthony Artusa
NOAA/NWS/NCEP/CPC

http://droughtmonitor.unl.edu/
Environmental Research Letters

LETTER

The 2015 drought in Washington State: a harbinger of things to come?

Miriam E Marlier\textsuperscript{1,5}, Mu Xiao\textsuperscript{1\#}, Ruth Engel\textsuperscript{1}, Ben Livneh\textsuperscript{2,3}, John T Abatzoglou\textsuperscript{4} and Dennis P Lettenmaier\textsuperscript{1}

\textsuperscript{1} Department of Geography, University of California, Los Angeles, CA, United States of America
\textsuperscript{2} Department of Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder, CO, United States of America
\textsuperscript{3} Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO, United States of America
\textsuperscript{4} Department of Geography, University of Idaho, Moscow, ID, United States of America
\textsuperscript{5} Author to whom any correspondence should be addressed.

E-mail: mmarlier@ucla.edu

Keywords: drought, climate change, fire risk, hydrology

Supplementary material for this article is available online

Abstract

Washington State experienced widespread drought in 2015 and the largest burned area in the observational record, attributable in part to exceptionally low winter snow accumulation and high summer temperatures. We examine 2015 drought severity in the Cascade and Olympic mountains relative to the historical climatology (1950–present) and future climate projections (mid-21st century)
It’s official: Seattle breaks record for most consecutive days without rain

Originally published August 9, 2017 at 7:06 am | Updated August 9, 2017 at 1:37 pm

A haze continues to hang over Seattle, as viewed Monday from Kerry Park on Seattle’s Queen Anne Hill. (Ken Lambert / The Seattle Times)

Also, the city's air quality is at unhealthy levels as of Wednesday morning, according to the Department of Ecology.
2018: a very dry summer

Seattle Monthly Precipitation, 2018

Year-to-date through Oct. 4: 20.76" (Average: 22.37")

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>2018</td>
<td>8.12</td>
<td>2.16</td>
<td>2.44</td>
<td>5.69</td>
<td>0.12</td>
<td>0.63</td>
<td>0.05</td>
<td>0.20</td>
<td>1.04</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>5.57</td>
<td>3.50</td>
<td>3.72</td>
<td>2.71</td>
<td>1.94</td>
<td>1.57</td>
<td>0.70</td>
<td>0.88</td>
<td>1.50</td>
<td>3.48</td>
<td>6.57</td>
<td>5.35</td>
</tr>
</tbody>
</table>
Droughts were formerly more common

Columbia River reconstruction

Gedalof et al. 2004
Climate change affects insects

*Mountain pine beetle*

Warmer temperature has favored MPB by:

- Increasing its reproductive rate
- Allowing an expanded geographic range
Mountain pine beetle outbreak since 1990

50 million acres
Trees killed by mountain pine beetles (Okanogan-Wenatchee NF)
How will climate change affect wildfire?
How will climate change affect wildfire?

Anacortes – August 26, 2016
How will climate change affect wildfire?

Goodell Creek Fire, Newhalem (August 2015)
Washington wildfires — 2015

- 1,541 fires
- 1 million acres burned (387,000 acres in 2014)
- $253 million fire suppression cost
- Large economic losses in rural communities
Climatic change and regional wildfires

• As temperature increases, more water evaporates from the landscape and plant tissues

• Larger areas of low fuel moisture

• Regional synchronization of fires occurs

Pacific Northwest, August 30, 2015

MODIS, NASA
More fires = more smoke

Seattle (August 2018)
Wildfires are colliding

Southwest Washington
Fires have burned some areas 3 times since 2008

Map by R. Norheim
Wildfires are colliding

Southwest Washington
Fires have burned some areas 3 times since 2008
Disturbances will interact

Figure by R. Loehman
Interacting disturbances

Map by R. Norheim
Wildfire area burned, 2050

Projected increase in median area burned with 1°C warming

- 600% or more
- 500 - 599%
- 400 - 499%
- 300 - 399%
- 200 - 299%
- 100 - 199%
- 0 - 99%
- Not modeled

From J. Littell
Wildfire area burned, 2050

In the western United States, for a 2°C increase, annual area burned will be 2-3 times higher.

From J. Littell
Warming affects stress complexes

Global warming

- Higher temperatures & more severe and extended droughts
  - Bark beetles and defoliators
    - Lodgepole pine mortality
      - Large severe fires
        - Salvage logging
          - Changes in species composition (including exotics)

- Stand-replacing fire regime
  - Extensive mature cohorts (70-80 yrs)
    - Fuel accumulation

Lodgepole pine

McKenzie et al. (2009)
In summary — What to expect

• **High certainty:** Higher temperature, more wildfire, less snowpack, less water in summer

• **Less certainty:** Precipitation

• **Extreme events** (drought, wildfire, insects) will have the biggest effects on ecosystems.

• Things may change quickly after 2050.

• There will be **surprises**.
Thank you

For more information:
jhalo@uw.edu; wild@uw.edu
www.adaptationpartners.org