Changing Flood Risk: Extreme precipitation and Atmospheric Rivers

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Climate Change Pathways: Physical Drivers

- Global Sea Level Rise
- Increased Storminess
- Extreme Precipitation
- Warmer Temperatures
- Storm Surge
- Higher Peak Flows
- Inundation
- Reduced Snowpack
Atmospheric Rivers
More Intense
Heavy Rains

Heaviest rain events are projected to become +22% more intense (range: +5 to +34%) by the 2080s.

Warner, Mass, Salathé, J Hydromet, 2014
Substantial Warming, Variable Rainfall

Temperature Difference
(Relative to 1950–1999 average)

Year

Temperature Difference
(Relative to 1950–1999 average)

Year

Extreme Precipitation Change
(Relative to 1950–1999 average)

Top 10 Wettest Days in Seattle, 1948-2013

<table>
<thead>
<tr>
<th>Rank</th>
<th>Date</th>
<th>Precipitation (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oct. 20, 2003</td>
<td>5.02</td>
</tr>
<tr>
<td>2</td>
<td>Dec. 3, 2007</td>
<td>3.77</td>
</tr>
<tr>
<td>3</td>
<td>Nov. 20, 1959</td>
<td>3.41</td>
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<tr>
<td>4</td>
<td>Nov. 6, 2006</td>
<td>3.29</td>
</tr>
<tr>
<td>5</td>
<td>Feb. 8, 1996</td>
<td>3.06</td>
</tr>
<tr>
<td>6</td>
<td>Nov. 25, 1998</td>
<td>3.04</td>
</tr>
<tr>
<td>7 (tie)</td>
<td>Jan. 18, 1986</td>
<td>2.98</td>
</tr>
<tr>
<td>7 (tie)</td>
<td>Feb. 9, 1951</td>
<td>2.98</td>
</tr>
<tr>
<td>9</td>
<td>Nov. 9, 1990</td>
<td>2.95</td>
</tr>
<tr>
<td>10</td>
<td>Nov. 24, 1990</td>
<td>2.93</td>
</tr>
</tbody>
</table>
extreme precipitation and climate change

Global **extreme** increases by *~7.5% per Degree C of warming*
Closely follows thermodynamic increase in Water Vapor

Allen and Ingram (2002)
Atmospheric Rivers and Extreme Precipitation

Neiman et al. (2008b)
Dynamical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America

Geophysical Research Letters
Volume 42, Issue 17, pages 7179-7186, 12 SEP 2015 DOI: 10.1002/2015GL065435
Dynamical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America

Geophysical Research Letters
Clear increase in heavy precipitation with warming
Uncertainties in important regional details

Mean IVT

Std Dev IVT
**MOTIVATION AND AIM**

- **Heavy precipitation events are increasing** in many regions worldwide such as parts of the West Coast
- **Uncertainties** about how observed local changes are connected to large-scale climate change
- **Pacific North West** has strong vulnerability of flood risk under climate change

- Identify the regions with different temporal variability in **extreme precipitation**.
- Identify the **large-scale drivers** that promote differences in spatial variability of local heavy precipitation.
METHODS: REGIONAL CLIMATE SIMULATION

- Regional climate simulation using Weather Research Forecast (WRF) model
- Initial and boundary conditions: NCEP/NCAR Reanalysis Project (NNRP)
- 40 year period (1970-2010)
- Two nested domains with 30 and 10 km spatial resolution

Physical parameterizations
- PBL: YSU
- Cumulus: Kain-Fritsch
- Microphysics: Thompson
- Land: Noah
- Radiation: CAM

Orography of outer and inner domains
REGIONS with different DAILY PREC. variability

Daily prec. from Oct. to Marc
Top 5% Extreme Events:
- 14 mm at Puget Sound (~1/2 in)
- 55 mm at Olympics (~2 in)
- 235 events are simultaneous
- 140 events are unique
Extreme Precipitation in Puget Sound versus the Olympic Mts

Average Precipitation for Top 5% of Daily Events
Puget Sound ARs are quite different from Olympic ARs.

Large-scale Water Vapor Transport from 36-km WRF

- **Puget Sound**
- **Common**
- **Olympic**

**magnitude**

**direction**
Moisture needs to come through **Terrain Gaps** to supply Puget Sound Precipitation

High-resolution Winds and Terrain from WRF 12-km

- Puget Sound Events
- Olympic Events
- Common Events
Conclusions

• Projected changes in Atmospheric Rivers yield increases in local intense precipitation directly connected to warming temperatures

• Orographic effects likely contribute to unique responses in different regions

• The changes in large-scale climate likely fully determine the local response

• Pathways for Climate Change and Heavy Precipitation:
  – Connection to Global Climate – Atmospheric Rivers
  – Thermodynamics – Warming and increased Water Vapor
  – Orographic Enhancement – Unique local responses