Changing Flood Risk: Extreme precipitation and Atmospheric Rivers

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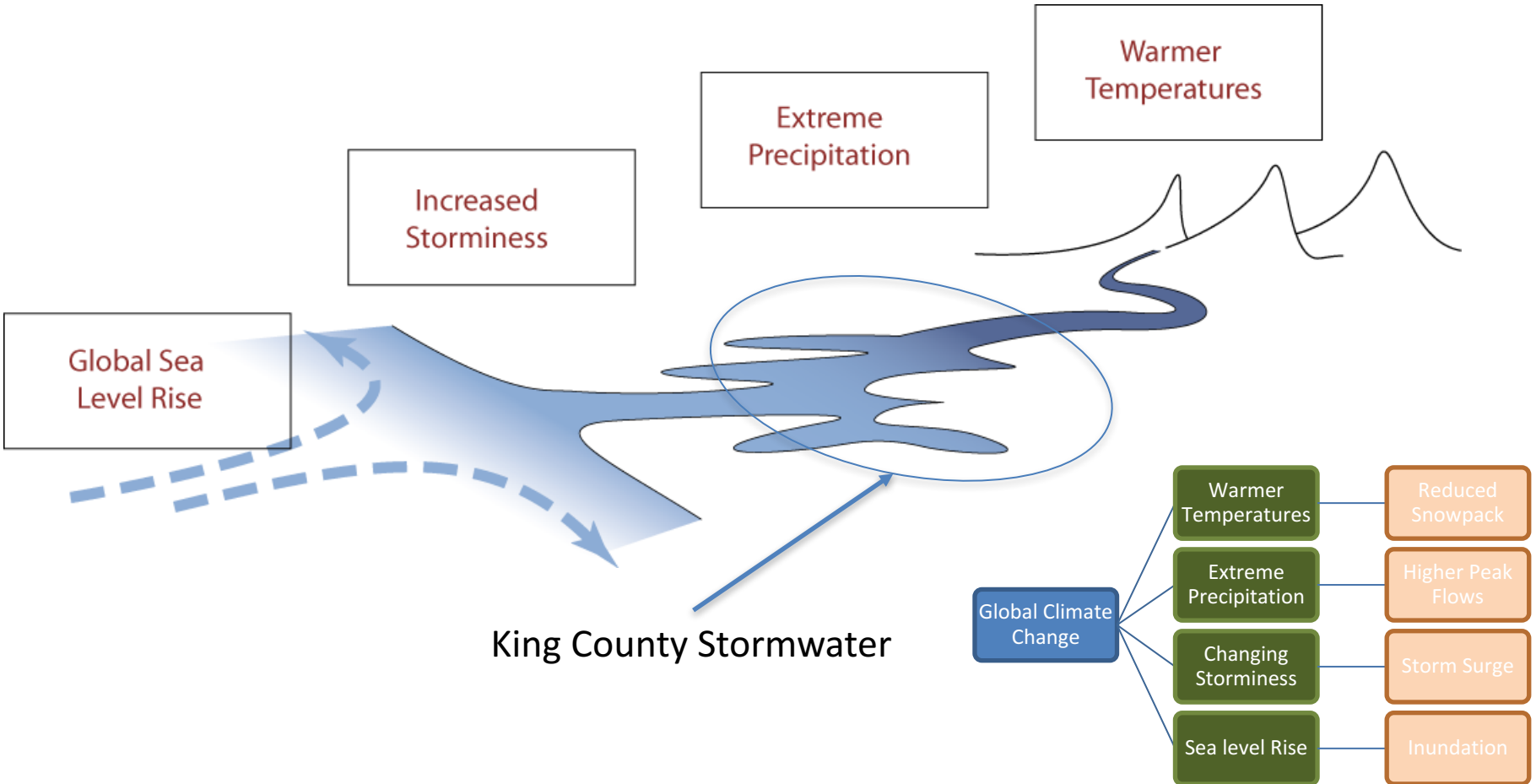
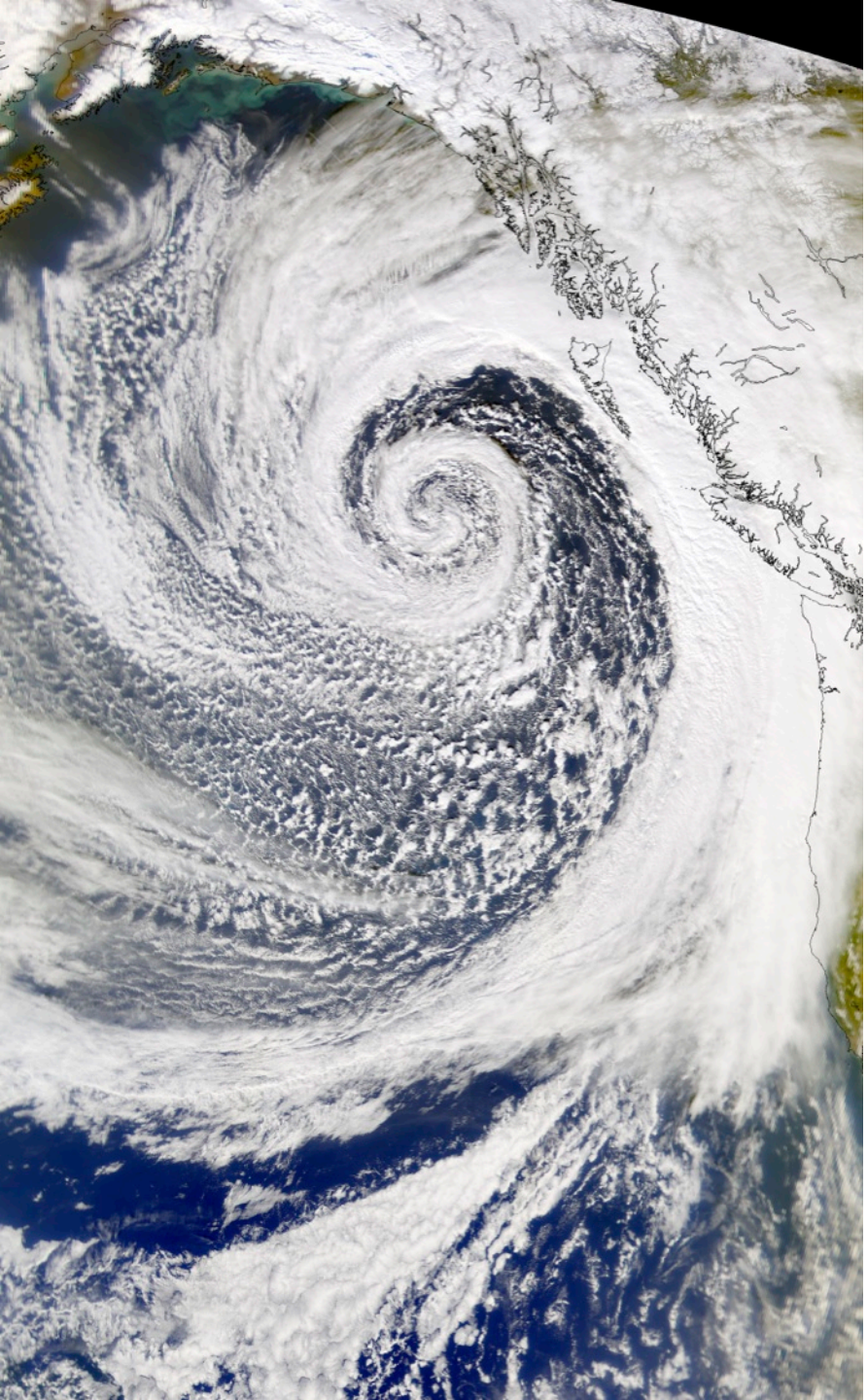
Photo credit: Marli Miller

Climate Change Pathways: Physical Drivers





Atmospheric Rivers More Intense Heavy Rains

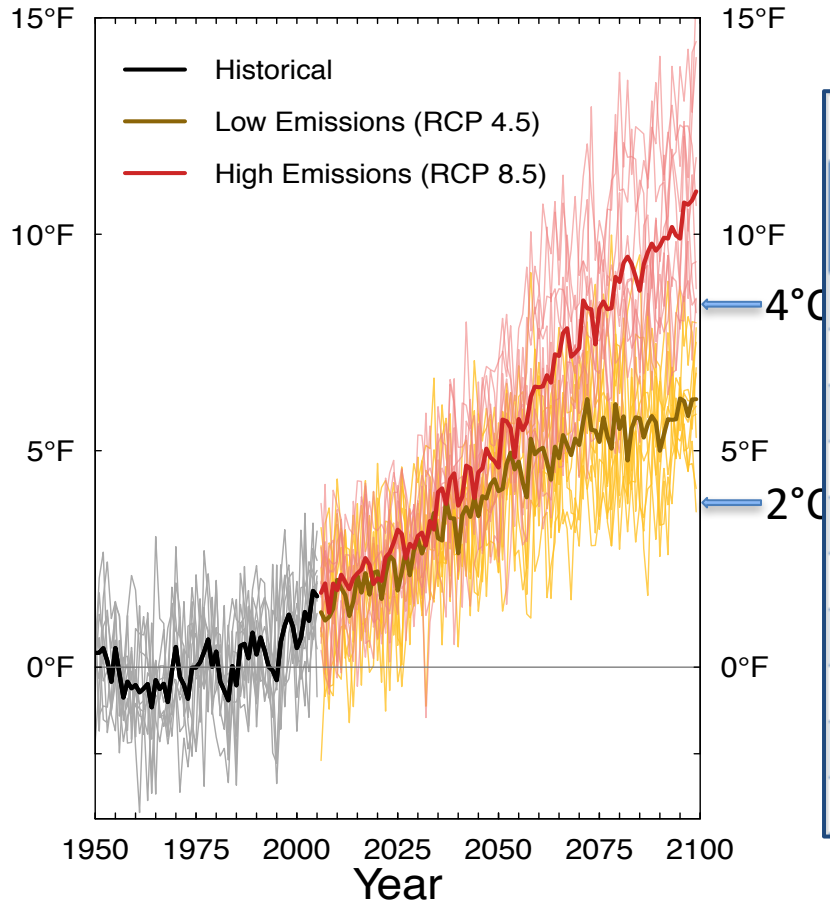
Heaviest rain events are projected to become **+22% more intense** (*range:* +5 to +34%) by the 2080s.

Warner, Mass, Salathé, J Hydromet, 2014

Substantial Warming, Variable Rainfall

Temperature Difference

(Relative to 1950–1999 average)



Extreme Precipitation Change

(Relative to 1950–1999 average)

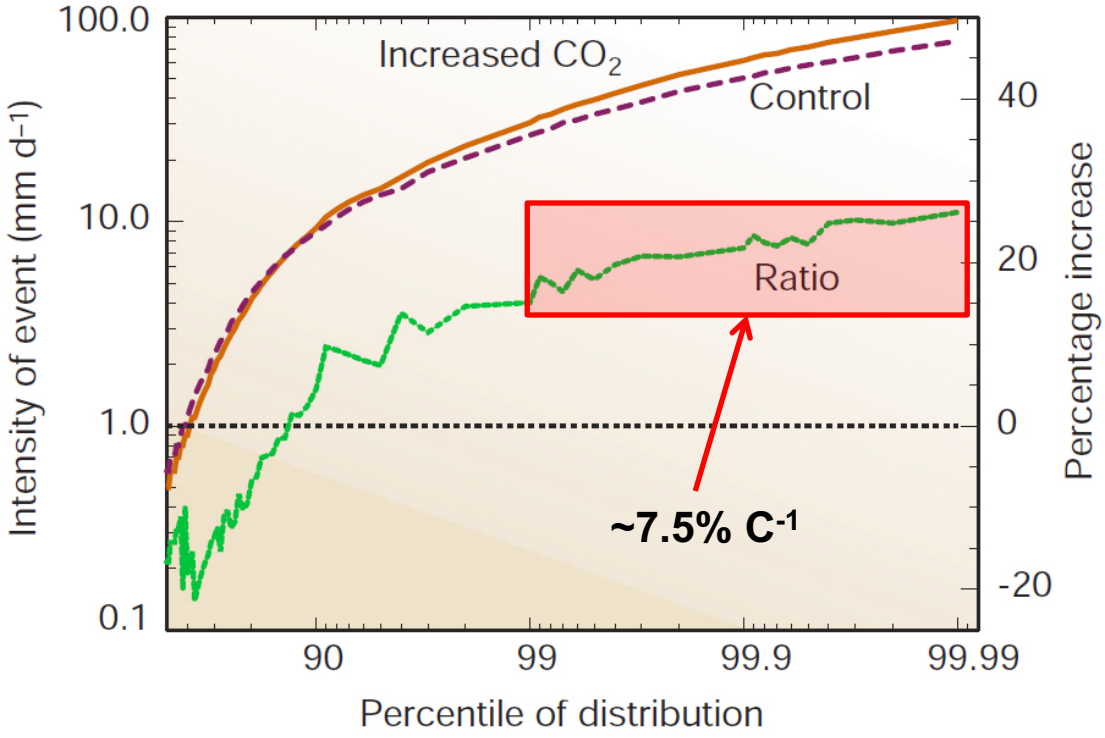
Top 10 Wettest Days in Seattle, 1948-2013

Rank	Date	Precipitation (inches)
1	Oct. 20, 2003	5.02
2	Dec. 3, 2007	3.77
3	Nov. 20, 1959	3.41
4	Nov. 6, 2006	3.29
5	Feb. 8, 1996	3.06
6	Nov. 25, 1998	3.04
7 (tie)	Jan. 18, 1986	2.98
7 (tie)	Feb. 9, 1951	2.98
9	Nov. 9, 1990	2.95
10	Nov. 24, 1990	2.93

SeaTac

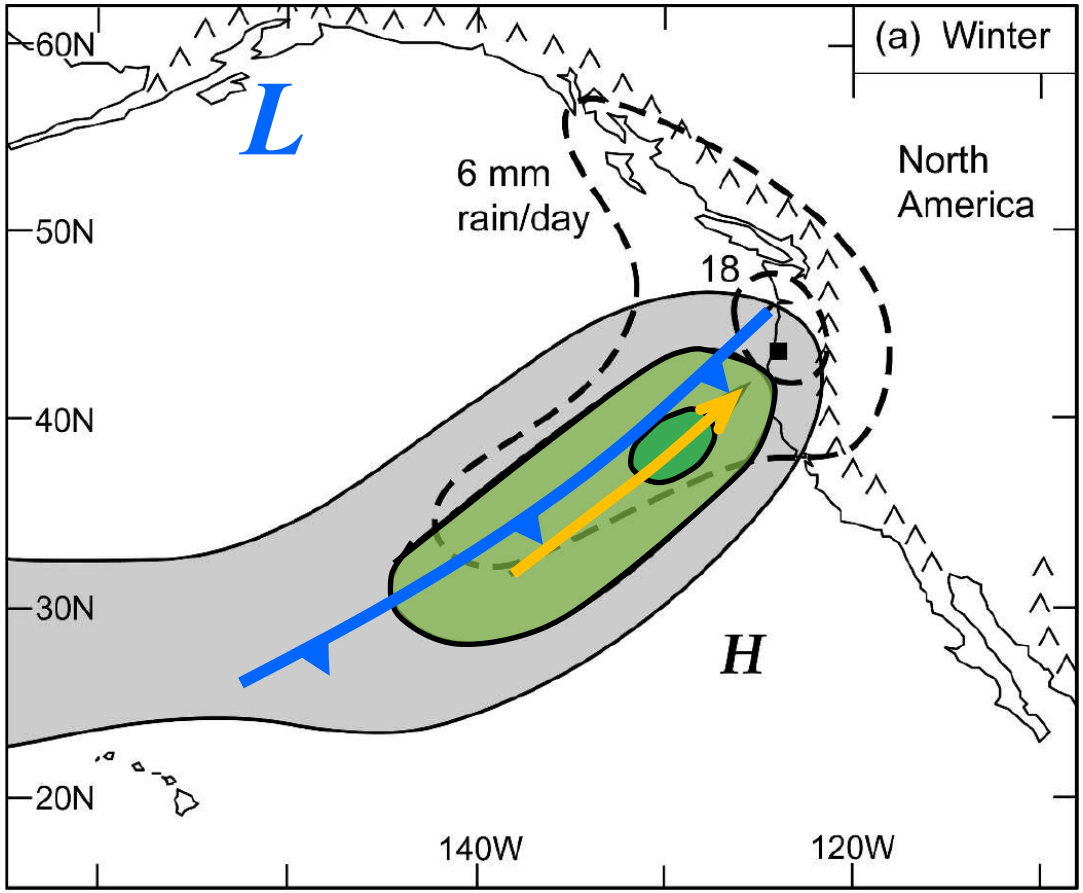
extreme precipitation and climate change

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

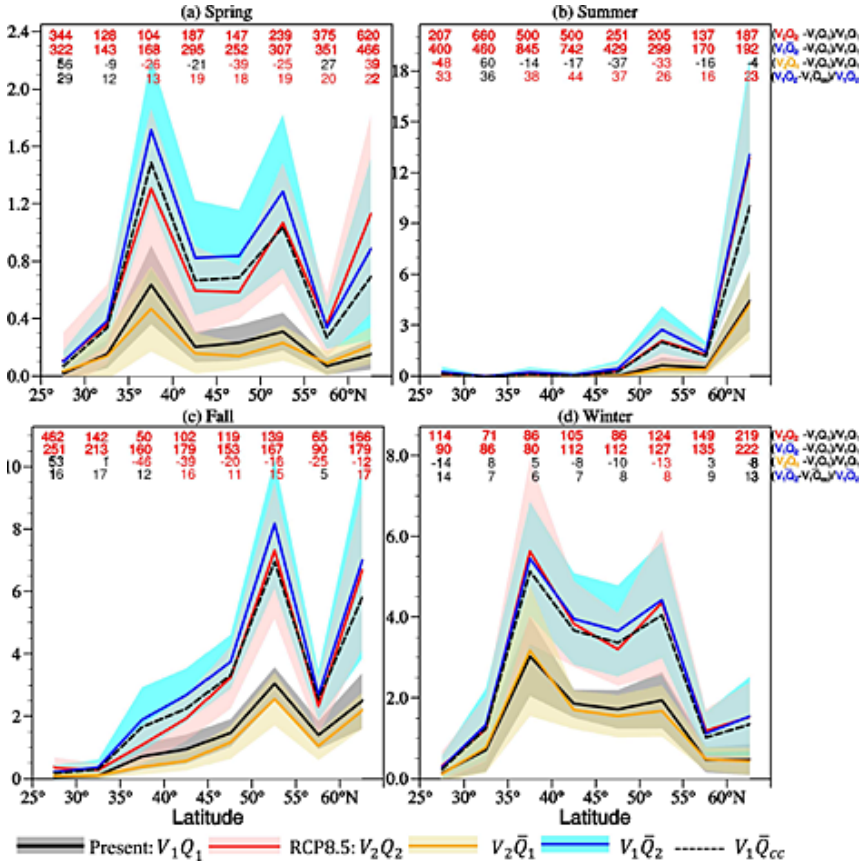


precipitation

integrated water vapor (IWV)

Neiman et al. (2008b)

Dynamical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America



Geophysical Research Letters
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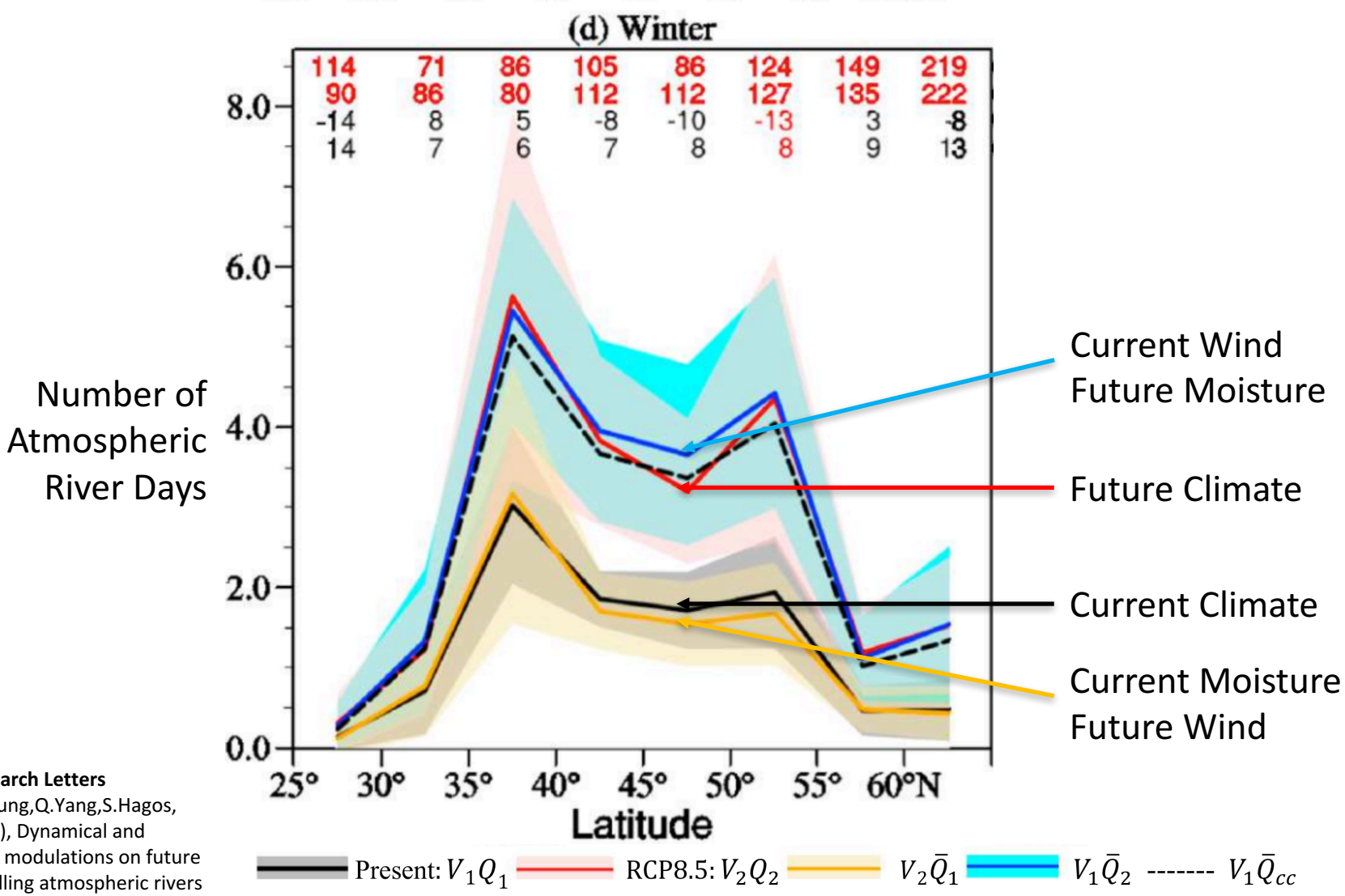
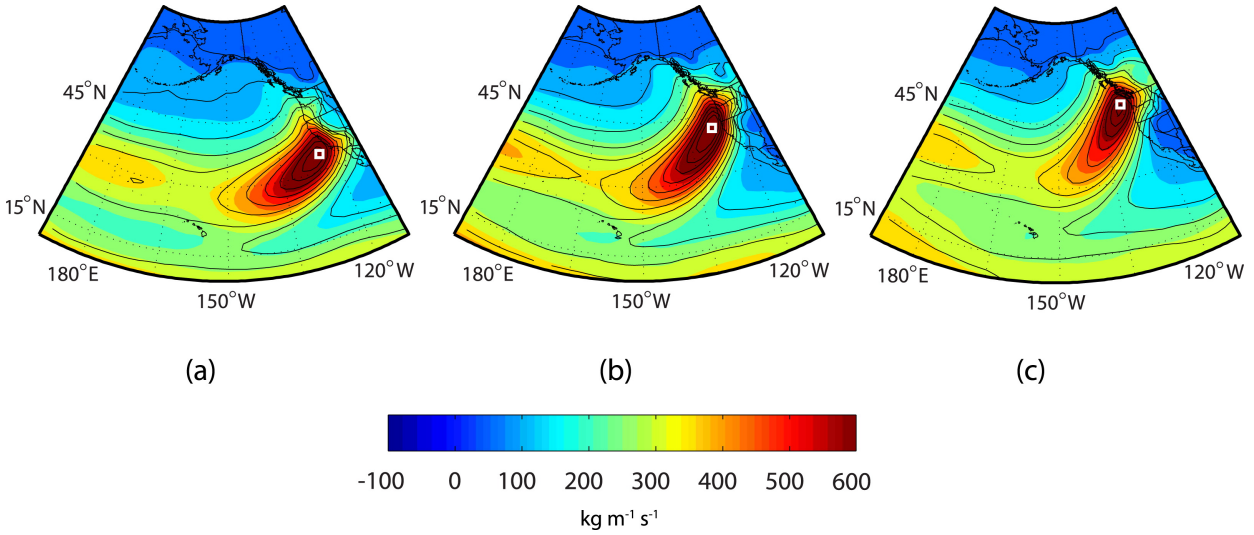
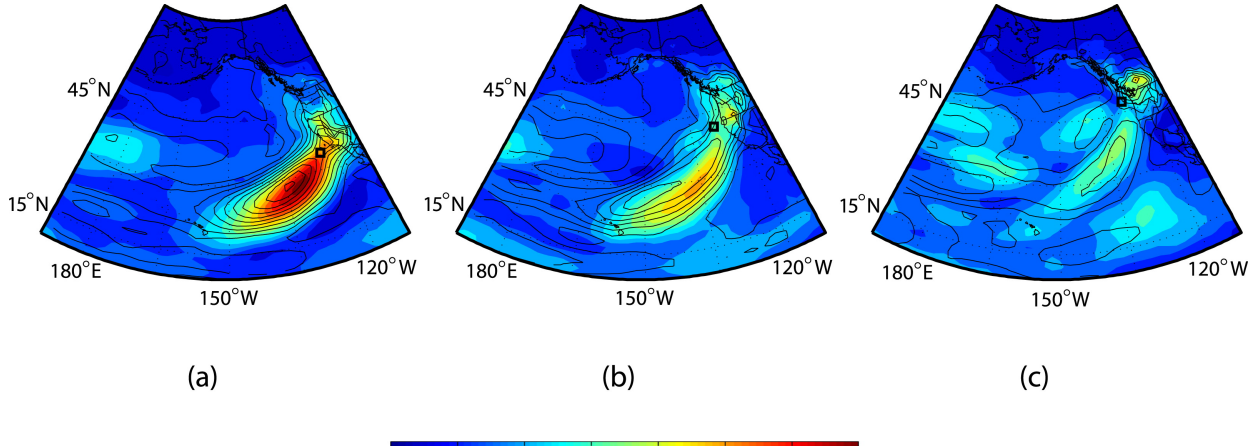


Geophysical Research Letters
Gao,Y.,J.Lu,L.R.Leung,Q.Yang,S.Hagos, and Y. Qian (2015), Dynamical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America, Geophys. Res. Lett., 42, 7179–7186, doi:10.1002/2015GL065435.

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.

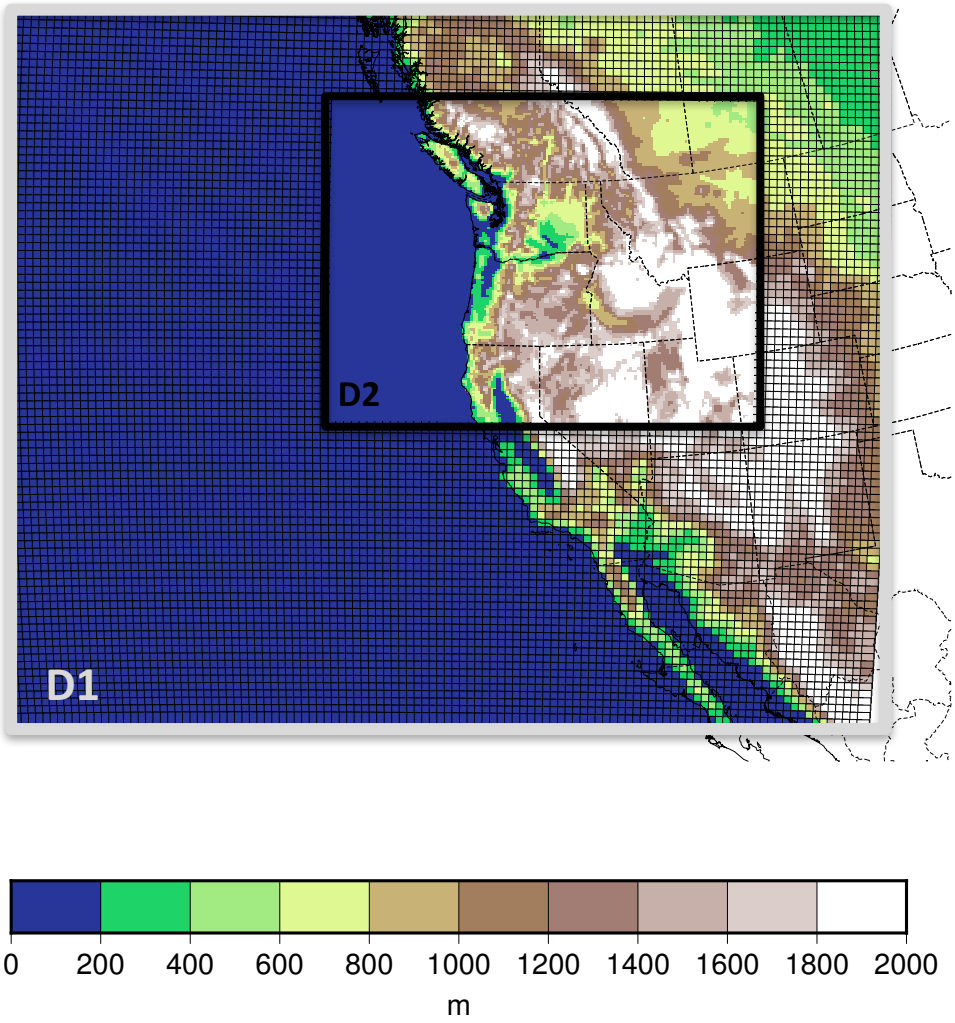
METHODS: REGIONAL CLIMATE SIMULATION

- 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

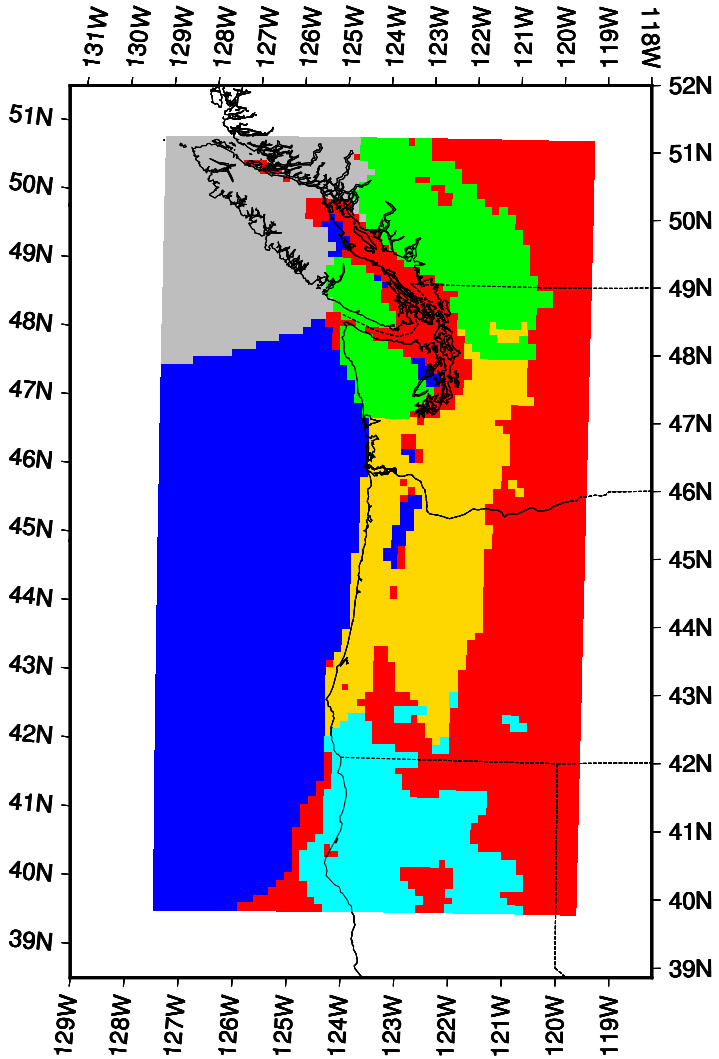
Orography of outer and inner domains



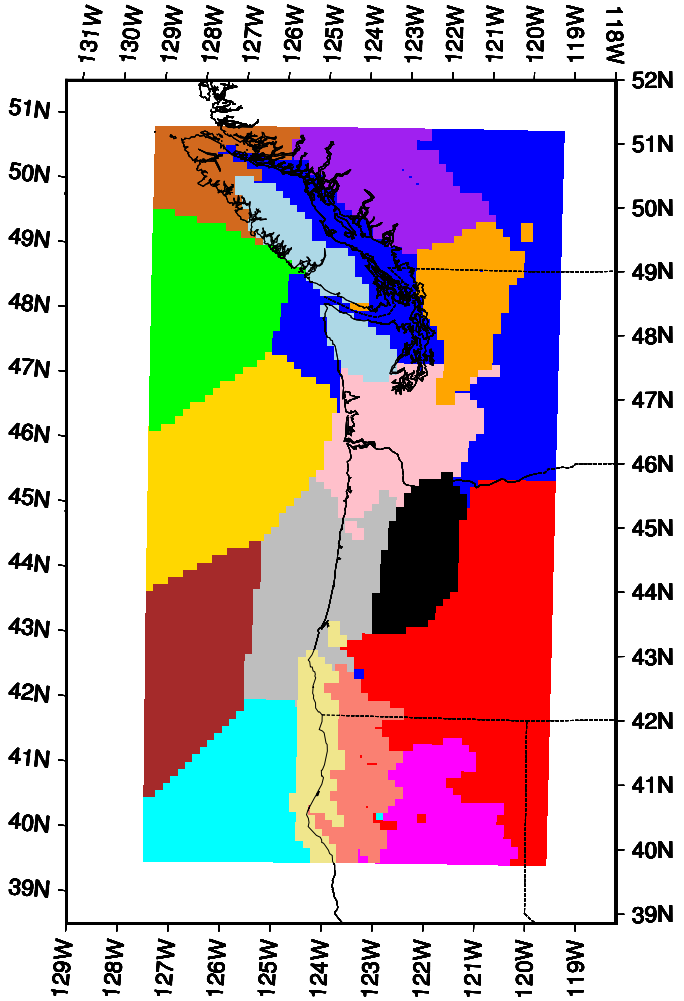
REGIONS with different DAILY PREC. variability

Daily prec. from Oct. to Marc

5modes - 6 regiones



20 modes - 16 regiones



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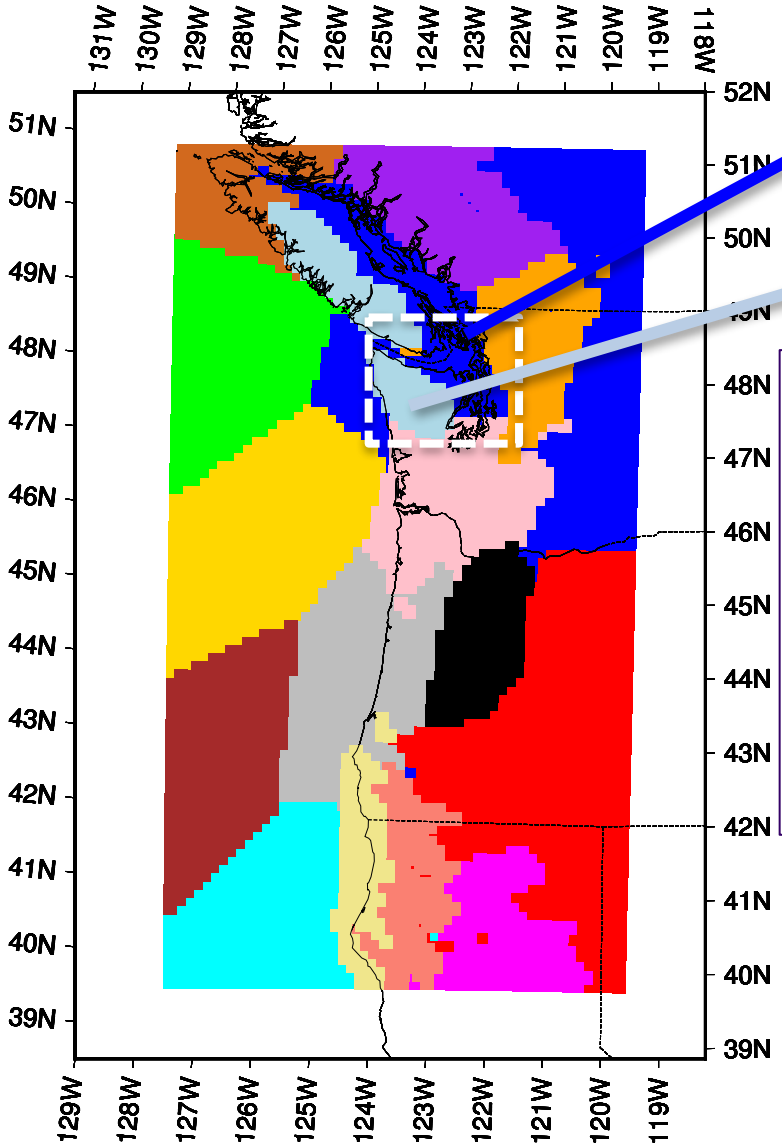


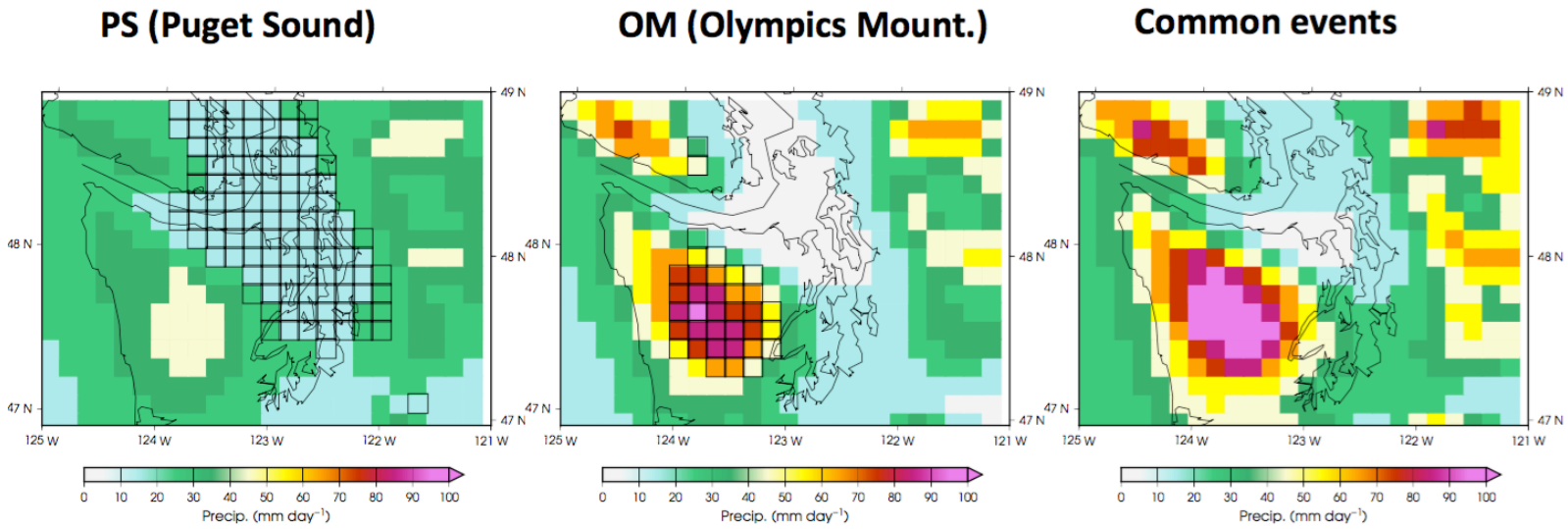
Puget sound

Olympic mountains

- 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

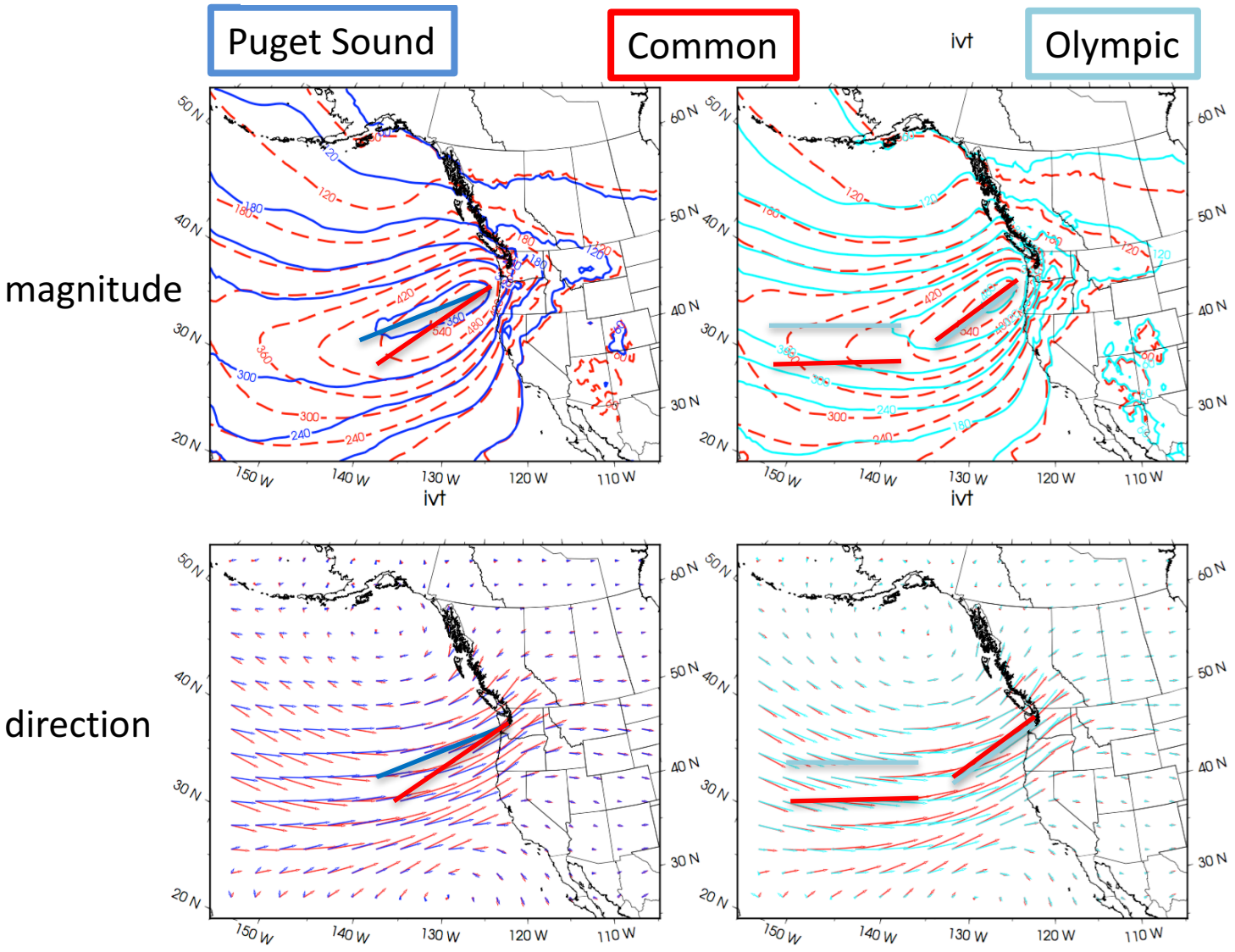
Extreme Precipitation in Puget Sound versus the Olympic Mts

Average Precipitation for Top 5% of Daily Events



Puget Sound ARs are quite different from Olympic ARs

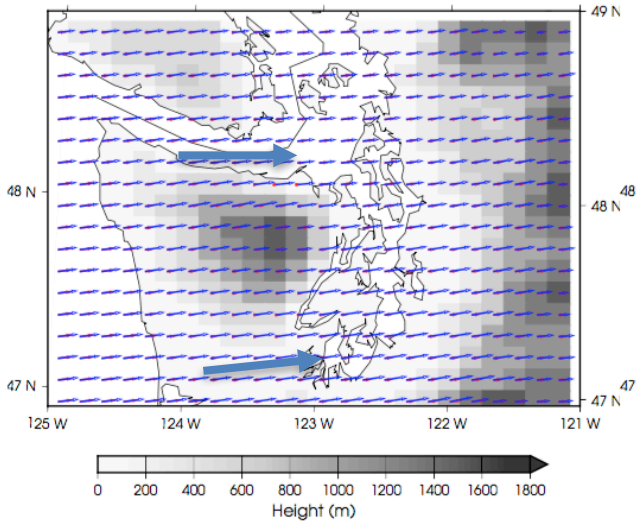
Large-scale Water Vapor Transport from 36-km WRF



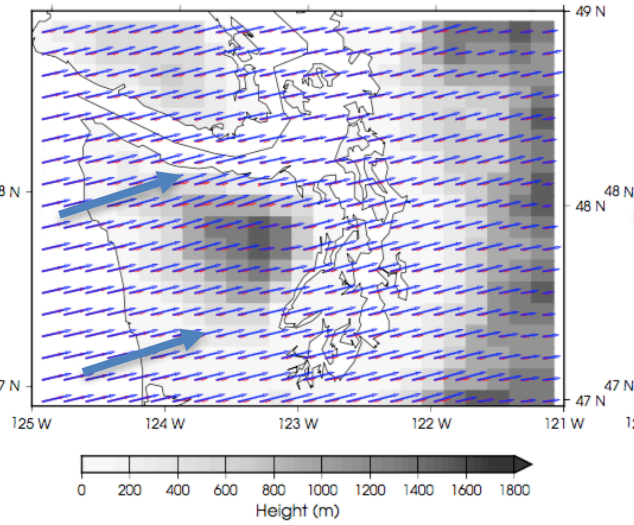
Moisture needs to come through **Terrain Gaps** to supply Puget Sound Precipitation

High-resolution Winds and Terrain from WRF 12-km

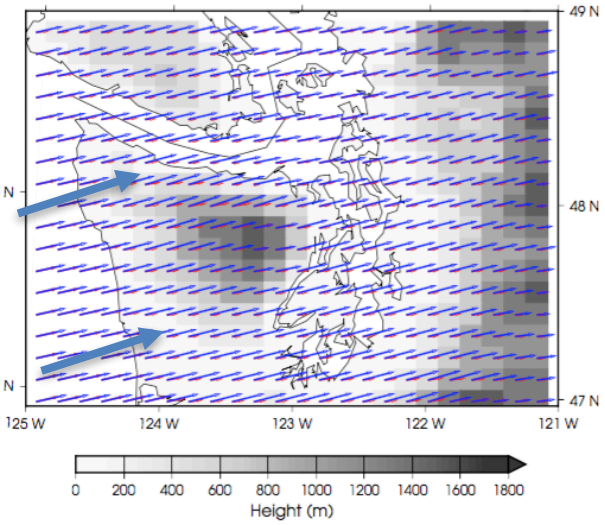
Puget Sound Events



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