

# Extreme Weather Trends over the Pacific Northwest

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Northwest  
Climate  
Conference  
September 2014

# There is a lot of interest and contradictory information about changes in the frequency of extreme weather over the Pacific Northwest

- Heavier rain?
- More flooding?
- Heat waves
- Stronger windstorms?
- More drought?
- Collapsing snowpack?



**This talk will provide a fresh view  
based on peer-reviewed literature  
and the latest modeling research**

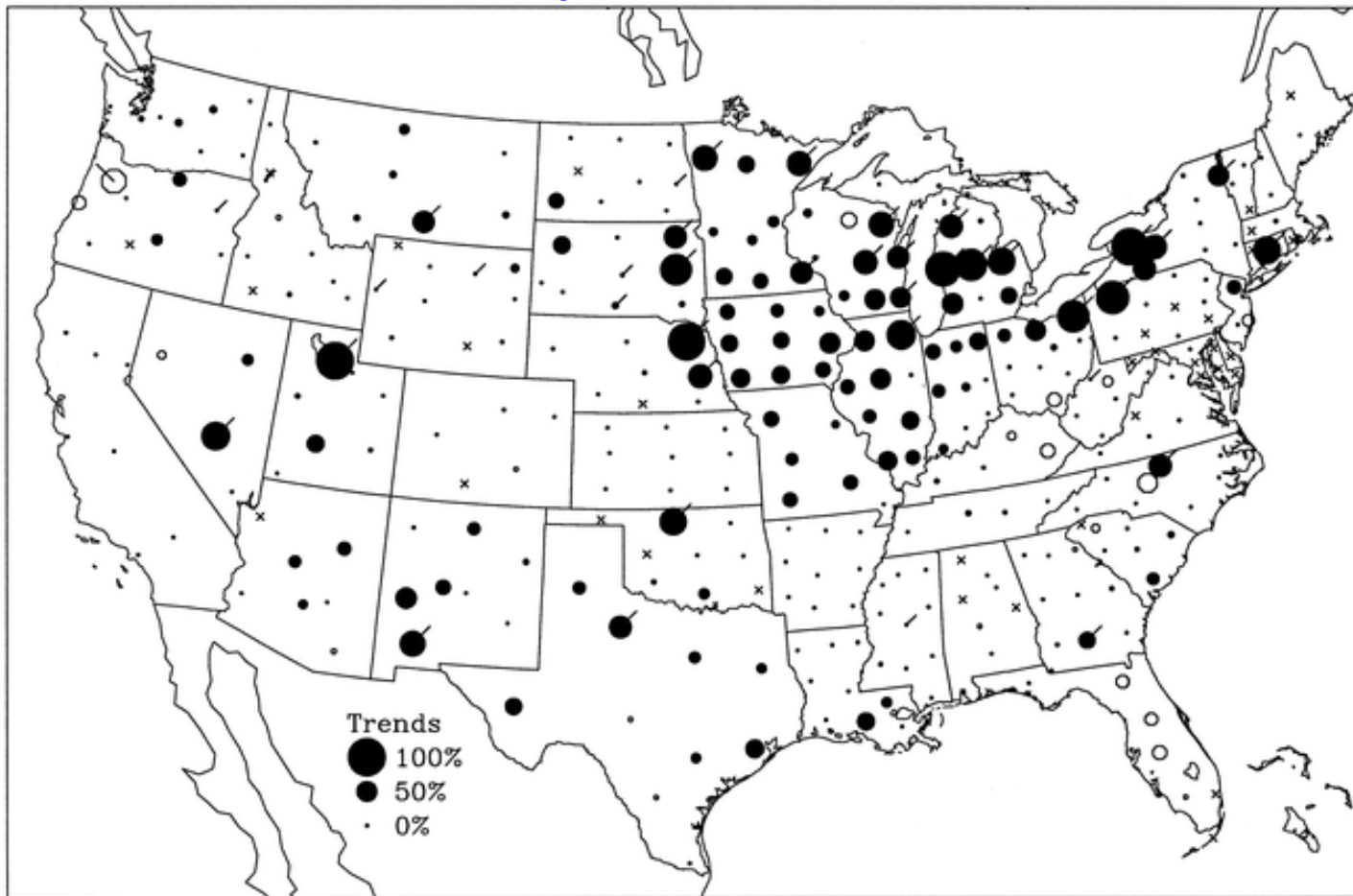
# Heavy Precipitation Trends



# **Historical Trends During the Past Half-Century**

# Trends of 7-day extreme: 1931-96

## 3 and 1-day extremes were similar



Kunkel,  
Andsager, and  
Easterling, J.  
of Climate,  
1999

Little trend in the NW. Suggesting of small increases in western WA and decreases in western Oregon (tail indicates significant at 5% level)

# **Extreme Precipitation over the West Coast of North America: Is There a Trend?**

CLIFFORD MASS, ADAM SKALENAKIS, AND MICHAEL WARNER

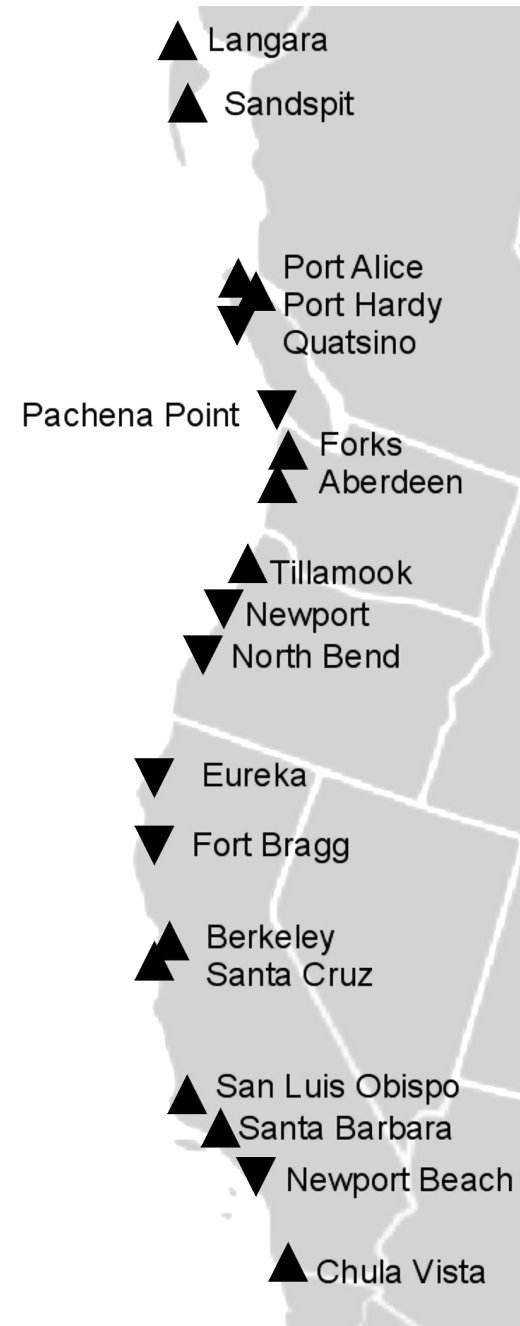
*Department of Atmospheric Sciences, University of Washington, Seattle, Washington*

(Manuscript received 10 August 2010, in final form 27 October 2010)

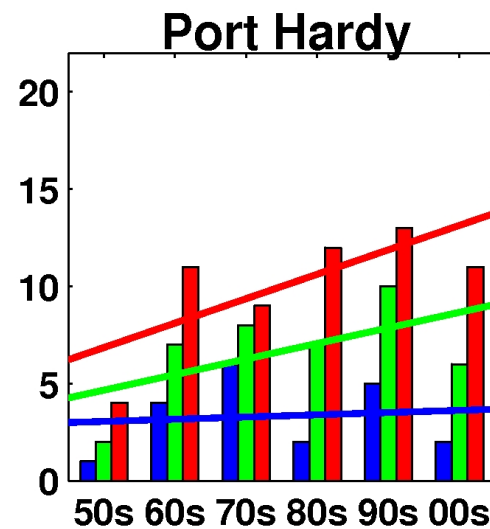
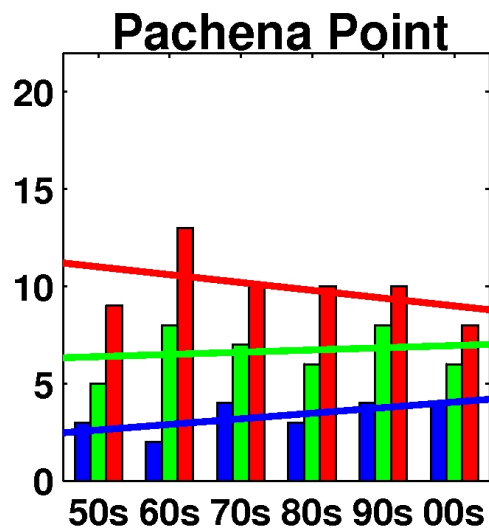
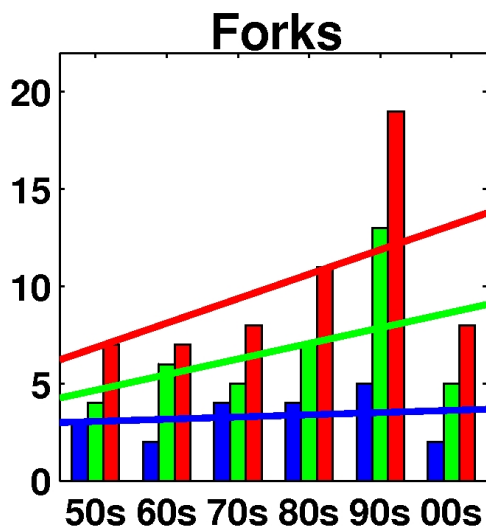
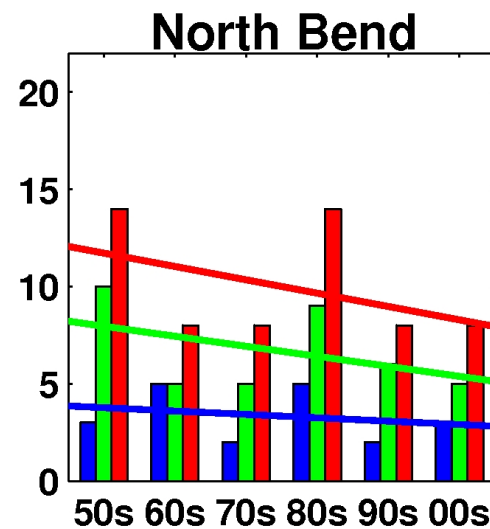
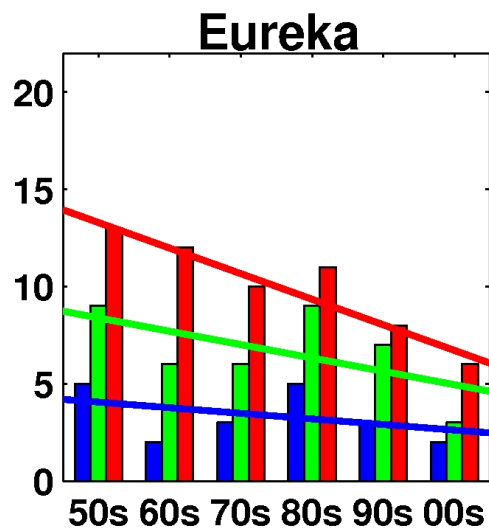
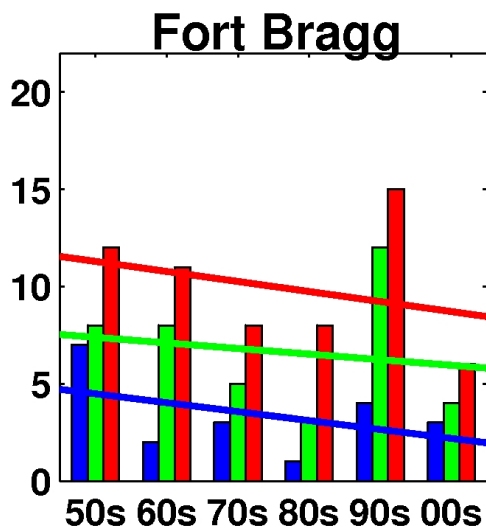


# Are there trends in major precipitation events?

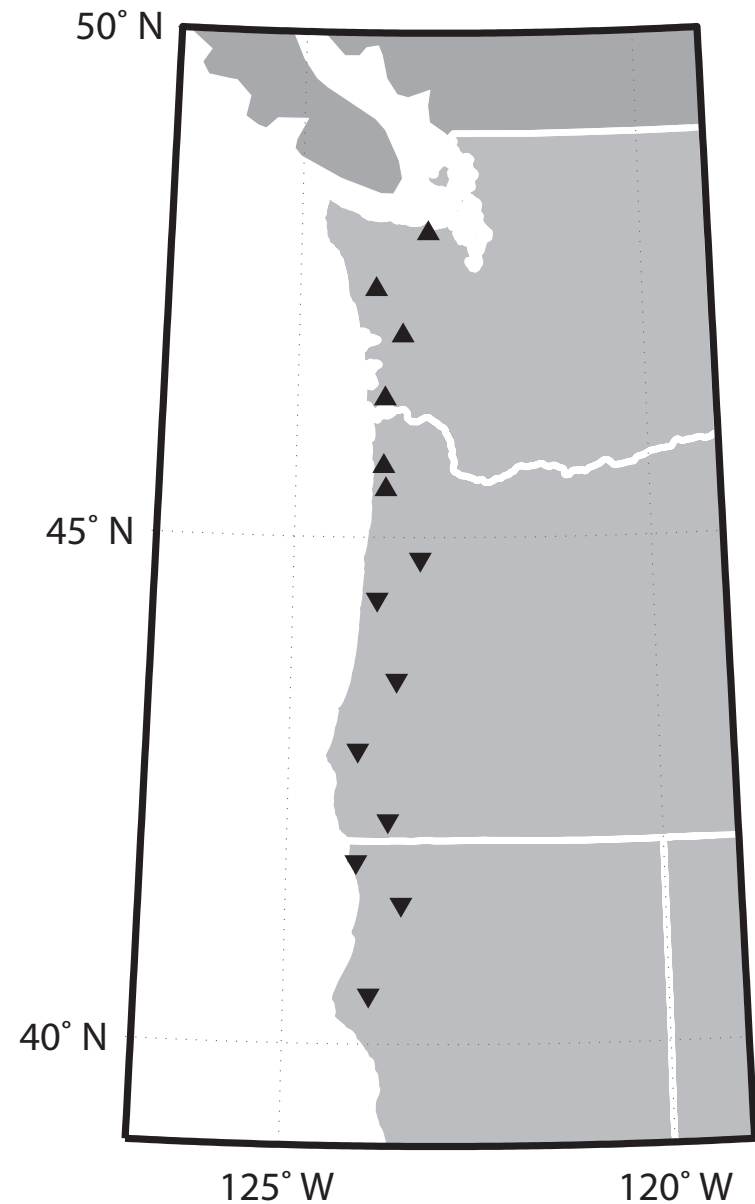
- Examined top 20, 40, 60 two-day precipitation events at stations along the coast for 1950-2008.







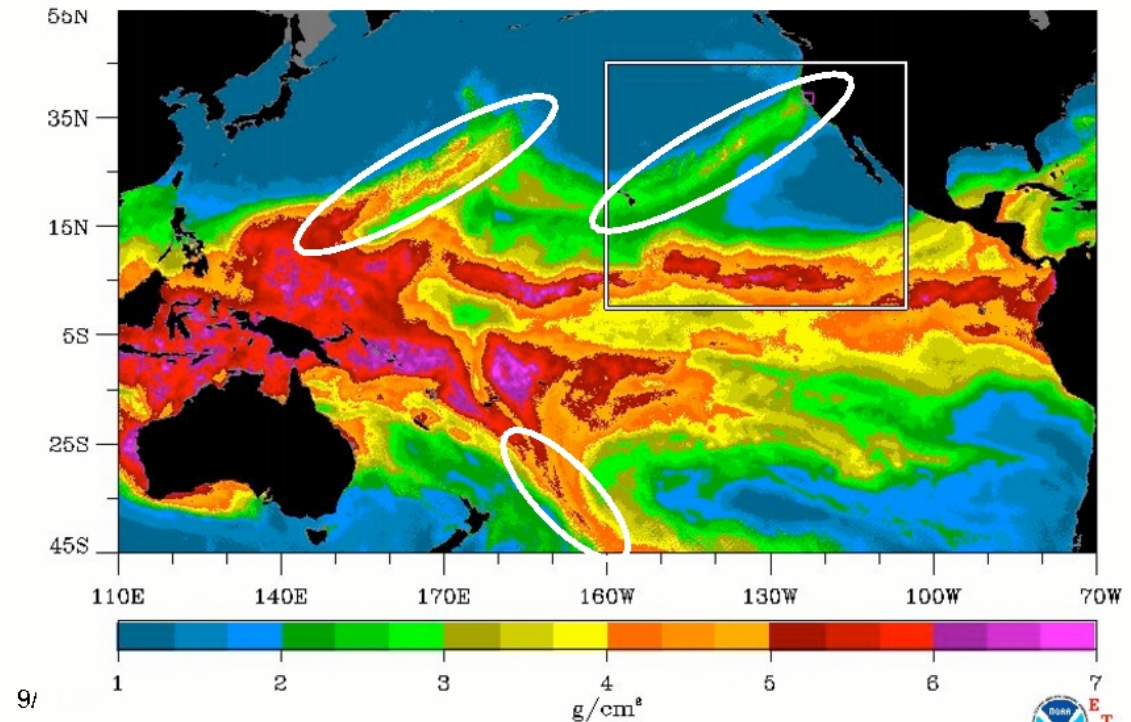
**Trends on  
Unregulated  
Rivers  
1950-2009:  
Max Annual  
Daily Discharge**



# What will happen to extreme precipitation over the Northwest under global warming?

To get the answer must answer another question:

**What will happen to atmospheric rivers under global warming?**



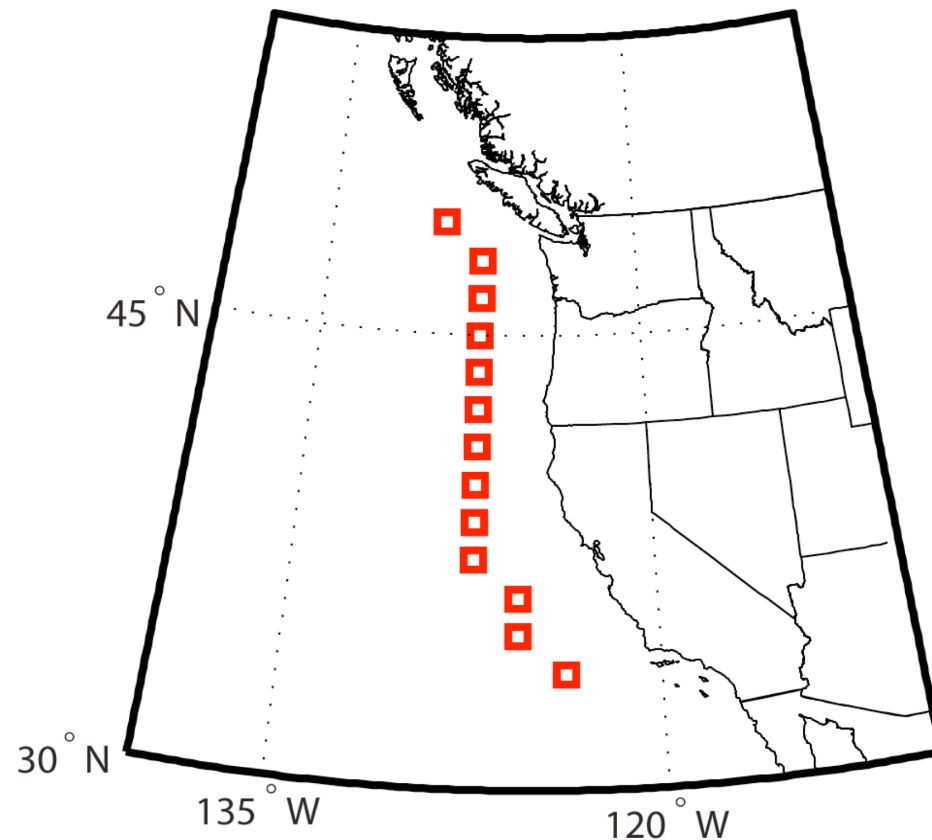
# One Answer

**Changes in wintertime atmospheric rivers along the North American west coast in CMIP5 climate models**

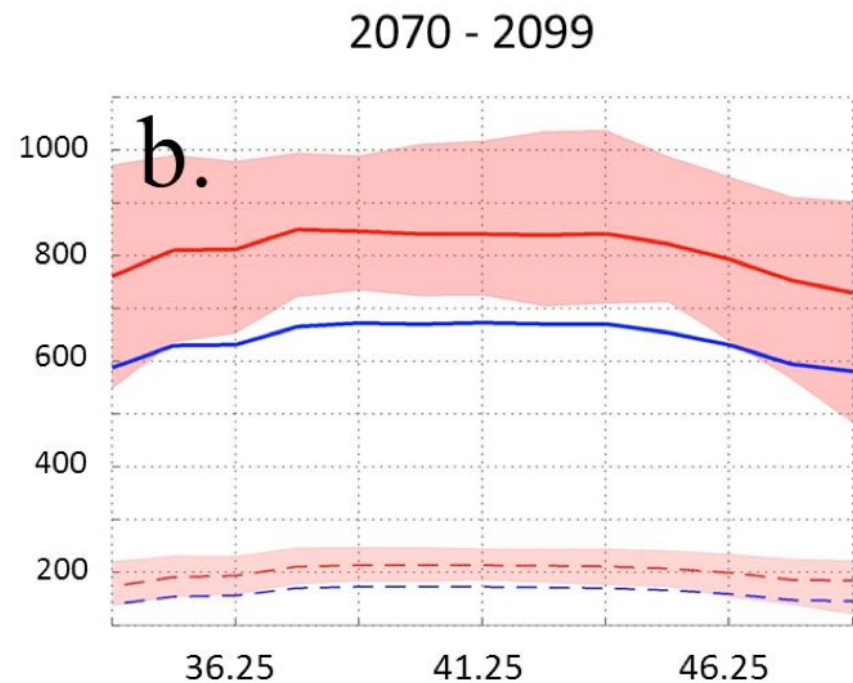
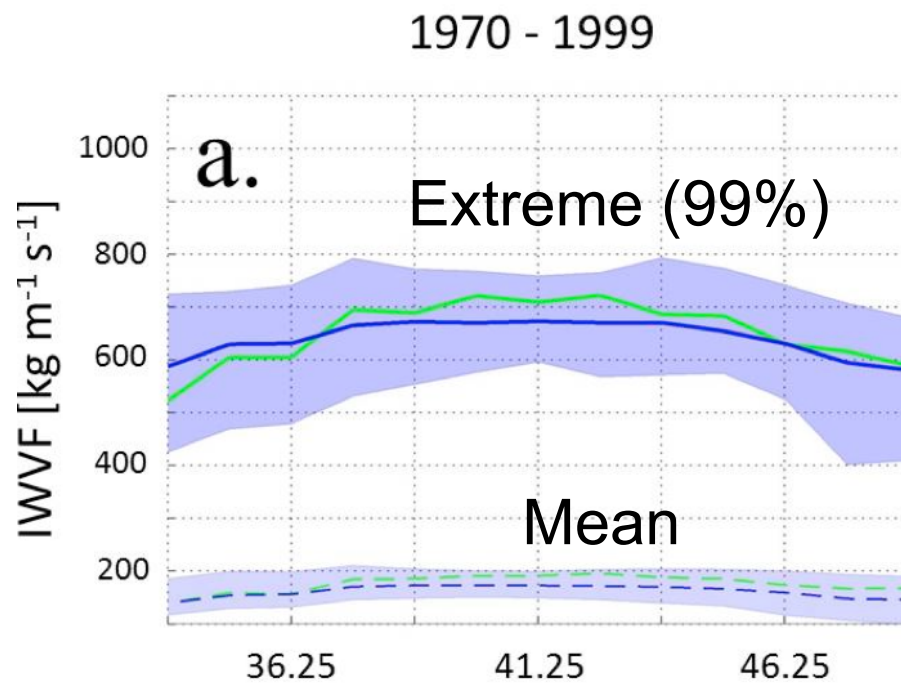
Michael D. Warner, Clifford F. Mass, Eric Salathé, Jr.

Geophysical Research Letters (in review)

# What do the latest CMIP climate models say about changes in atmospheric rivers?

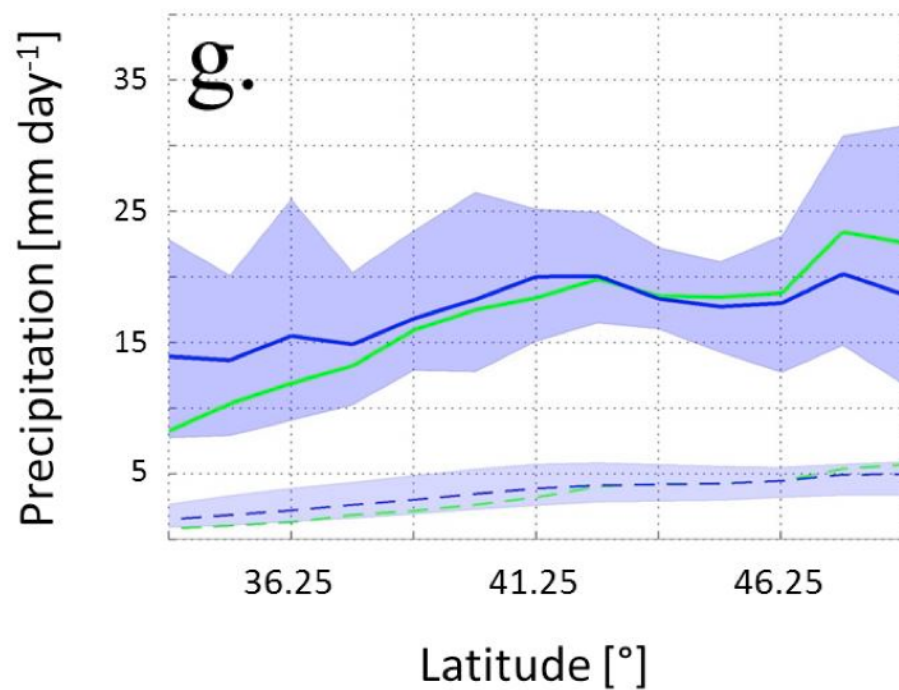


# Integrated Water Vapor Flux

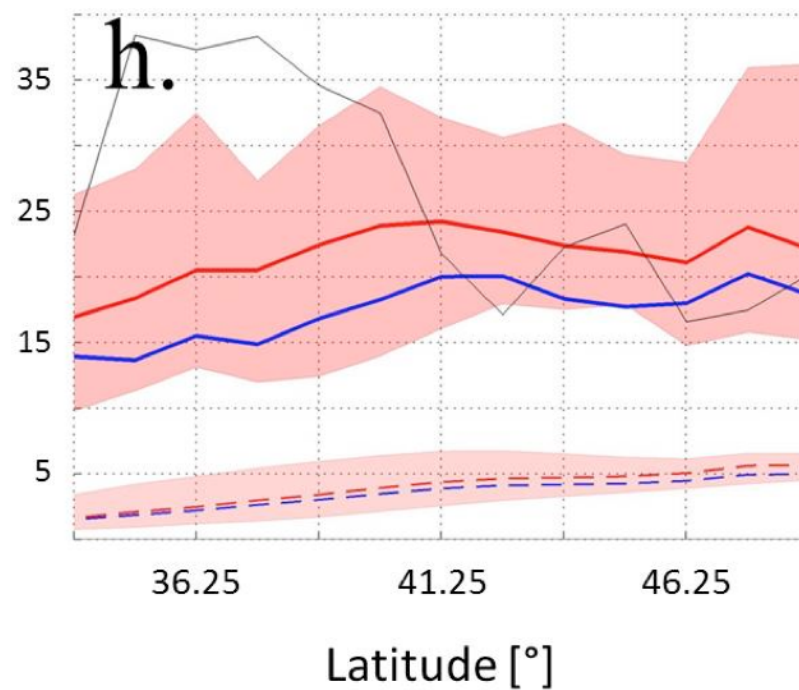


# Precipitation (offshore)

1970-1990



2070-2099





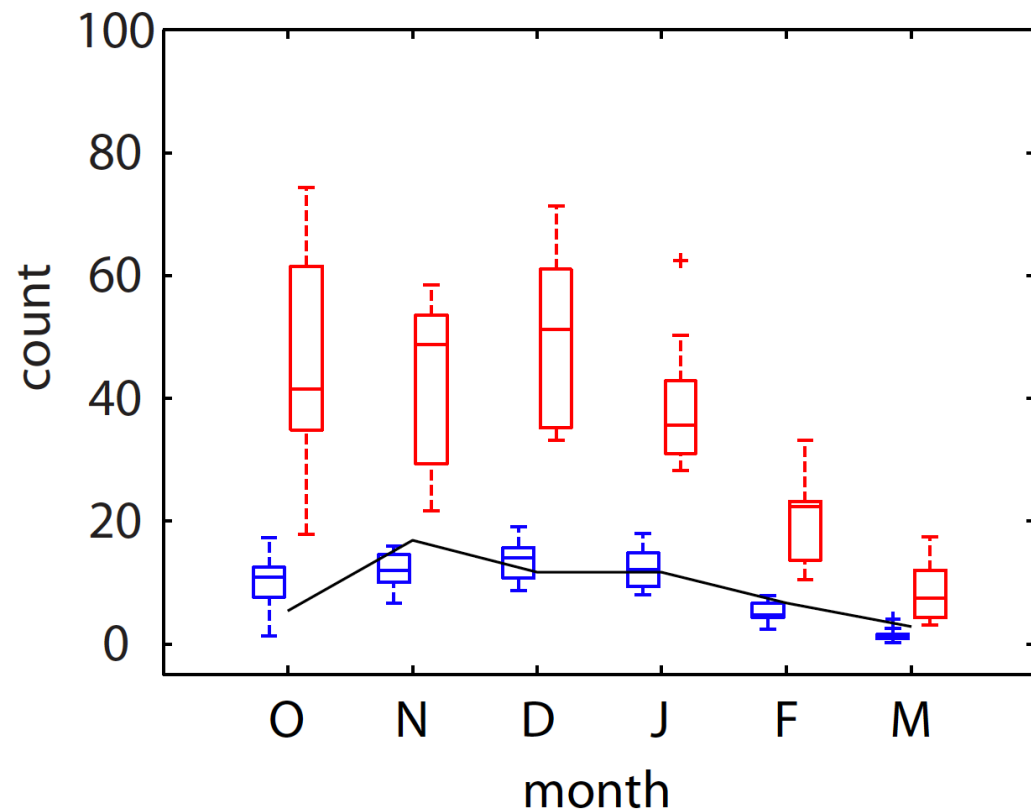
# Results

- Winter-mean precipitation along the West Coast increases by 11-18% while precipitation on extreme atmospheric river days increases by 15-39% .
- The frequency of days above the historical 99<sup>th</sup> percentile threshold in water vapor flux increases as much as 290% by the end of this century.

# Other Results from Mike Warner's Thesis

There is a shift of heavier precipitation events to earlier in the season

10-model winter mean (October-March) climatology of AR events defined by historical (1970-1999) 99th percentile IVT and averaged over the northwest coast. Red (2070-99) and blue (1970-99) NCEP reanalysis events are represented in black solid line.

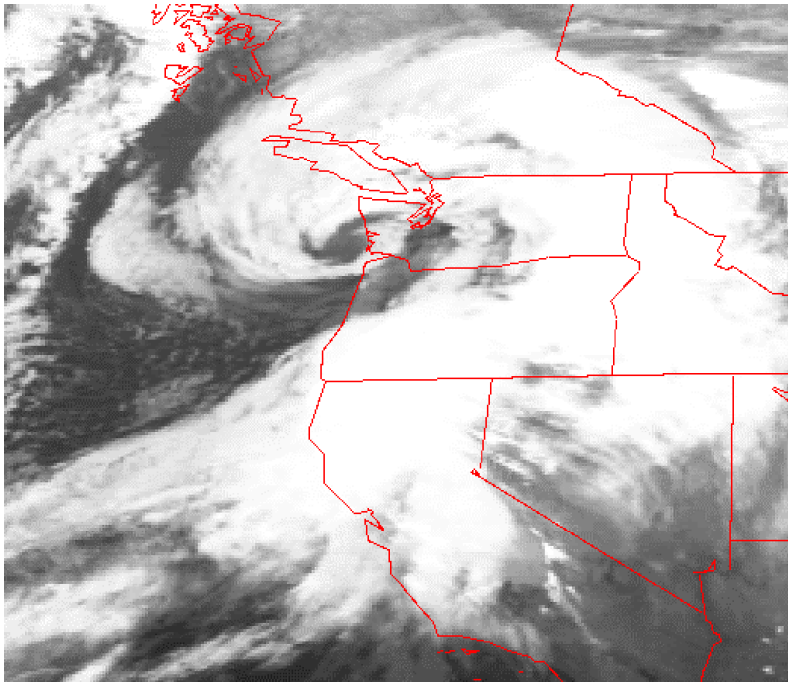


**Bottom Line:**  
**Be prepared for more of this**



# Northwest Windstorms

- Will there be more of them?
- Will they become more intense?



The Inauguration Day Storm  
1993

# Northwest Windstorms

- The answer appears to be no. There will **not** be an increasing trend.
- But first, what has been the trend over the past half-century?



# West Coast windstorm trend since 1950

JULY 2010

MASS AND DOTSON

2499

## **Major Extratropical Cyclones of the Northwest United States: Historical Review, Climatology, and Synoptic Environment**

CLIFFORD MASS AND BRIGID DOTSON

*Department of Atmospheric Sciences, University of Washington, Seattle, Washington*

(Manuscript received 3 September 2009, in final form 14 January 2010)

### ABSTRACT

- Increasing number of major windstorms from northern Oregon into southern BC
- Decreasing numbers to the south.

**But what about the rest of the  
century?**



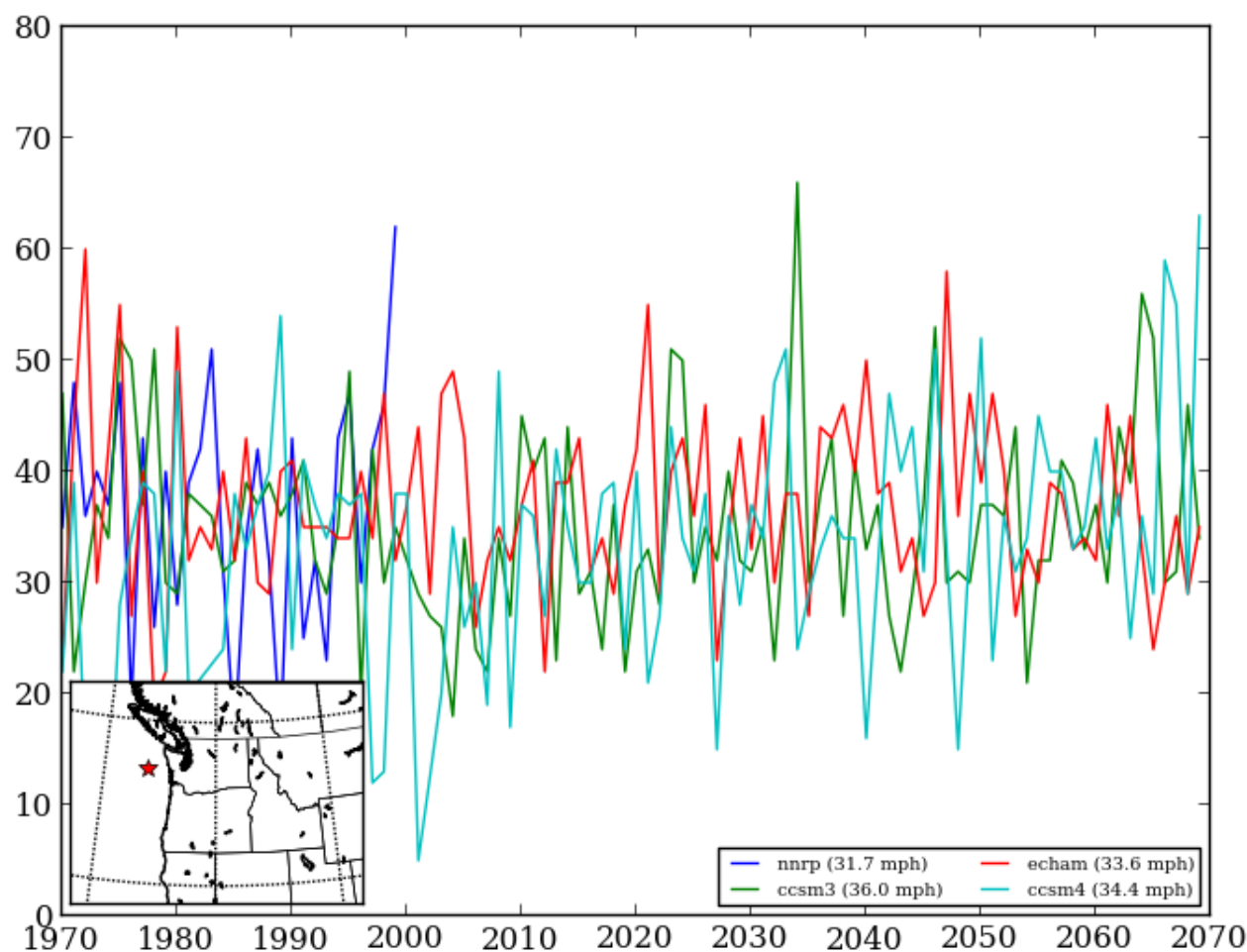
# Seattle City Light sponsored study

- Researchers: Bri Dotson, Eric Salathe, Guillaume Mauger, Rick Steed, Me
- Looked at dynamically downscaled (WRF) runs driven by global climate models.
- And looked at wind trends in CMIP5 climate models.

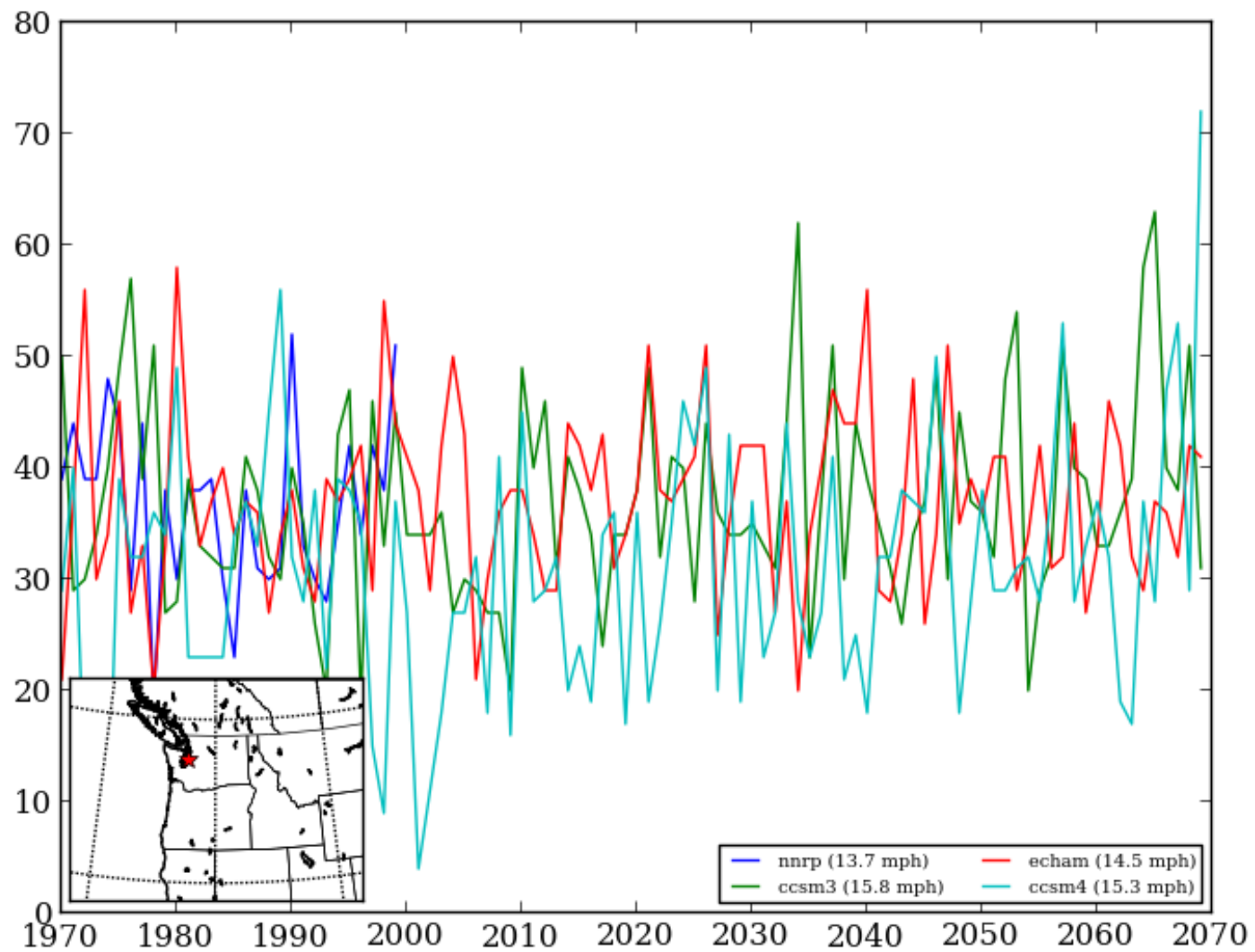
# Number of times per year above the 90 percentile wind speed for 1970-2000 (DJF)

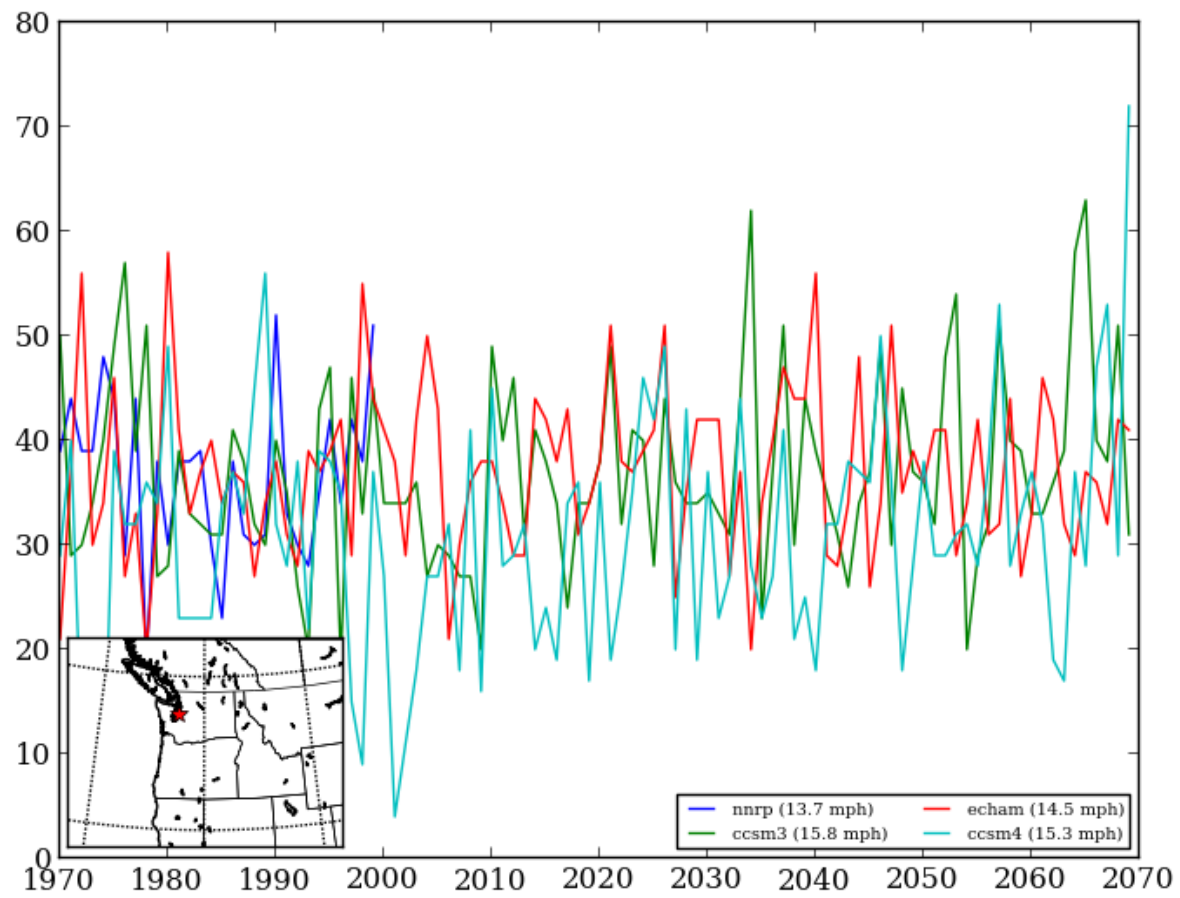
Just offshore  
of  
Washington  
Coast

No Trend

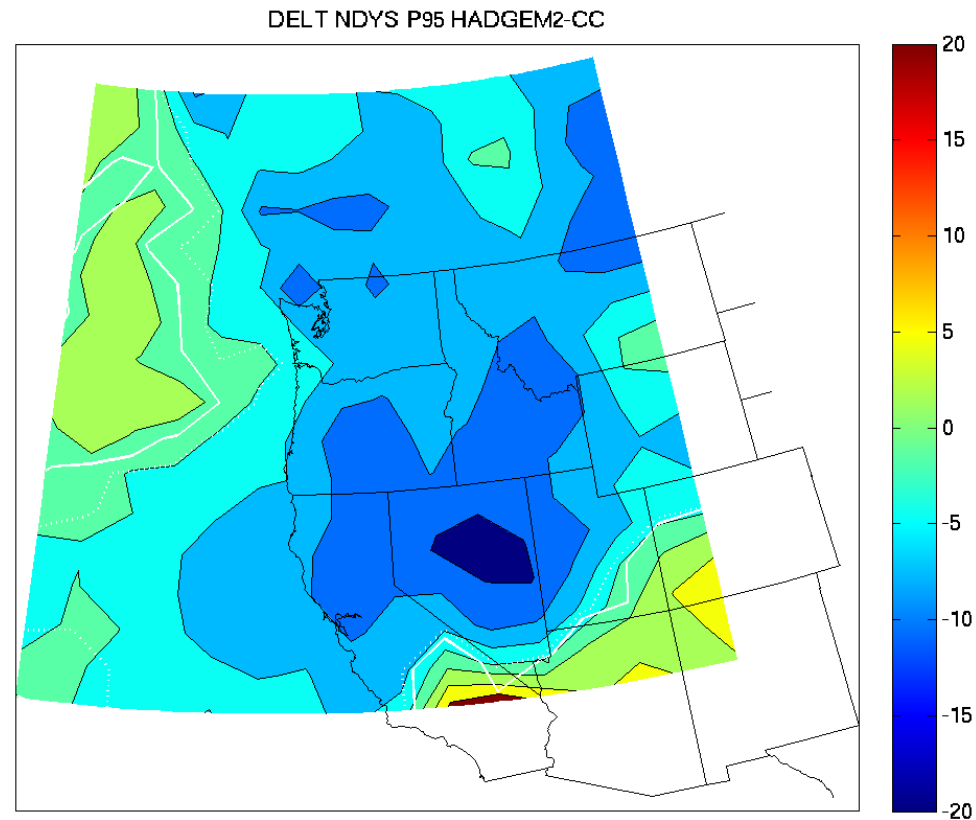


# Seattle

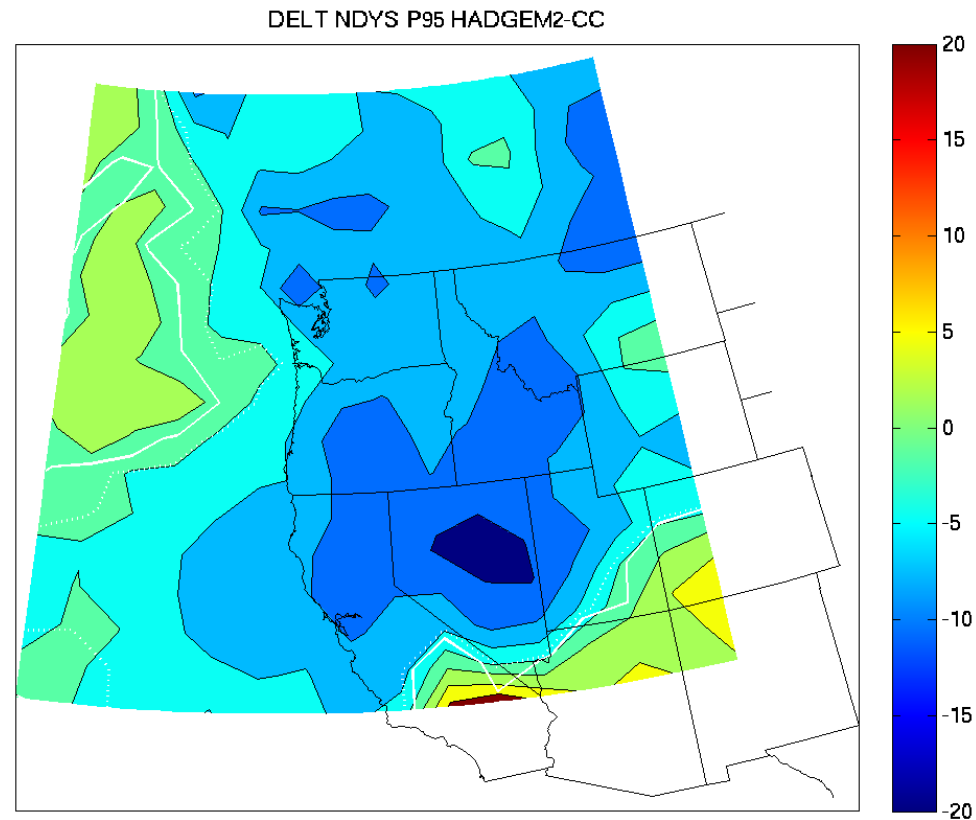




# Raw CMIP5 models are all over the place!

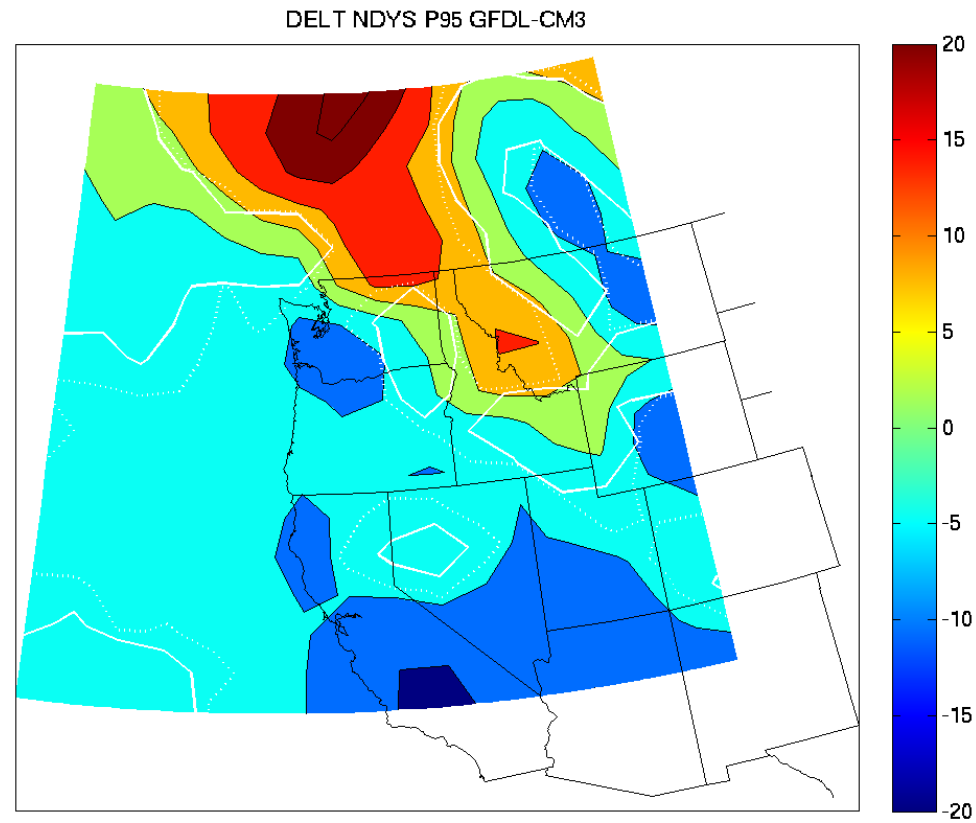


# Raw CMIP5 models are all over the place!



HADGEM Model

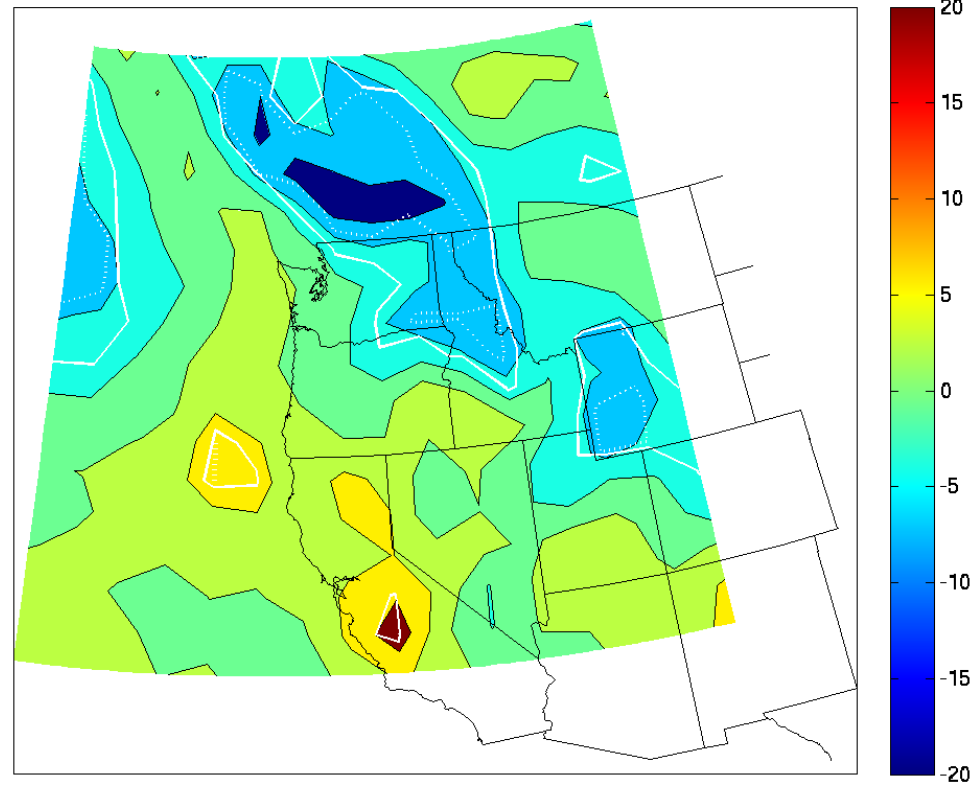
# GFDL Model





# CM5

DELT NDYS P95 CNRM-CM5



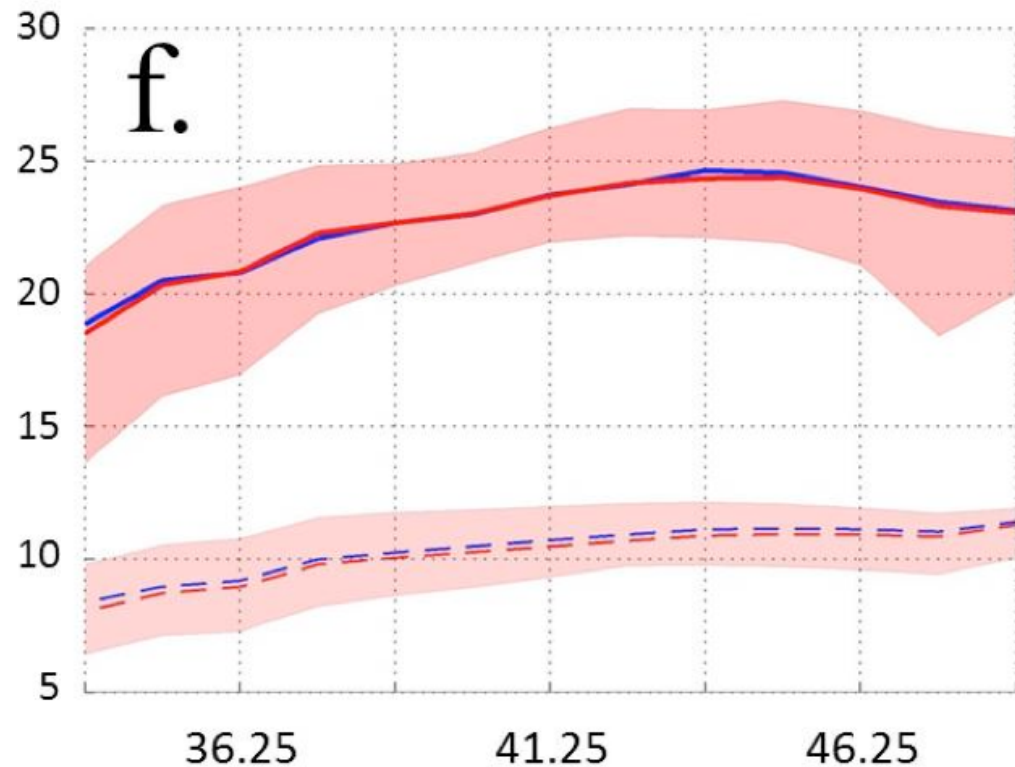
# **Why SHOULD we expect Northwest windstorms to change?**

- Their energy source is the jet stream and the strong horizontal temperature gradients associated with it.
- Most global climate models suggest that the temperature gradients will weaken at low levels as the Arctic heats up more than the poles.
- But the temperature gradient increases in upper troposphere.

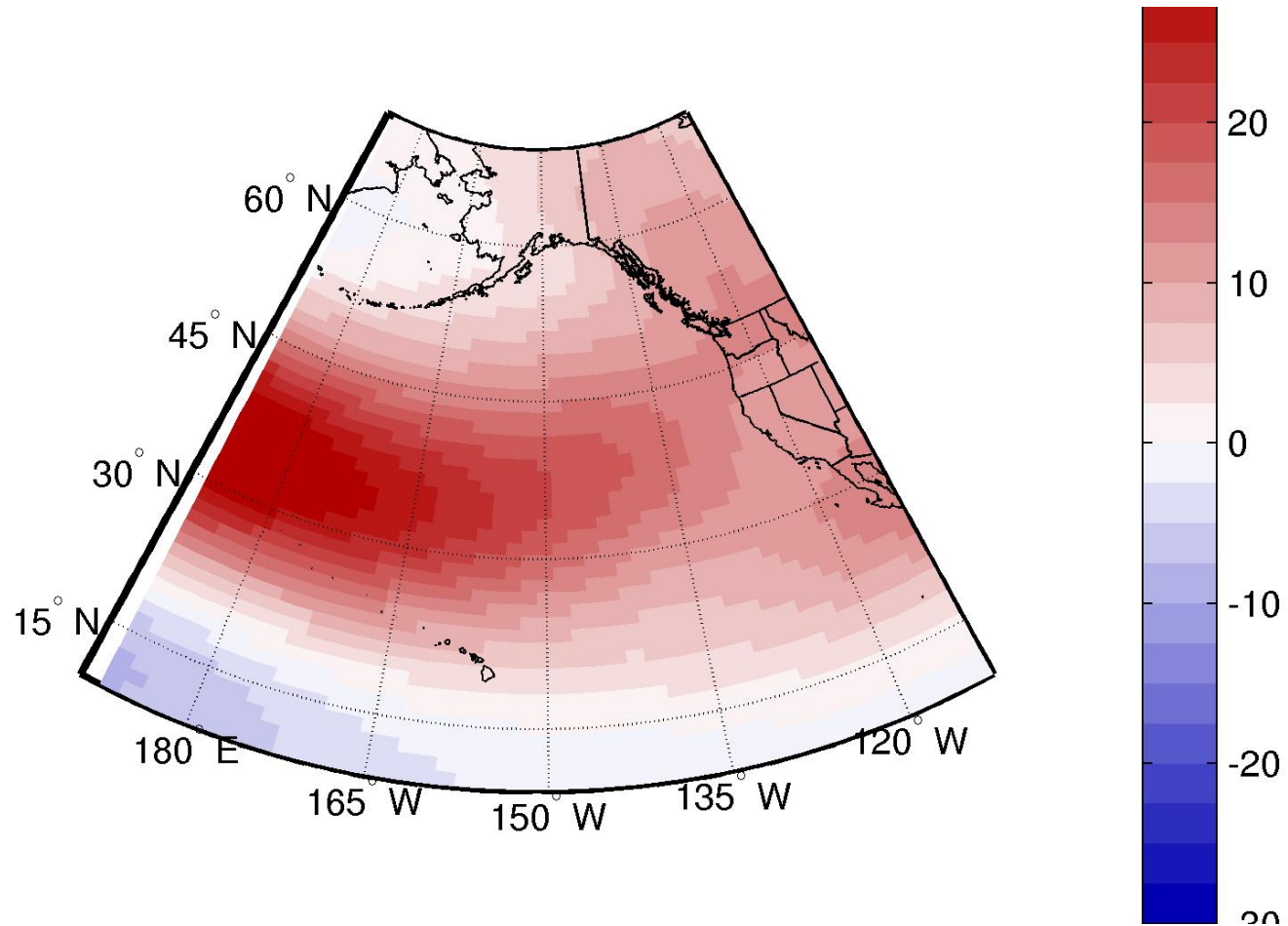
# Little change in the integrated temperature gradient in the lower troposphere

- Thus, only small changes in the jet and windstorms that derive their energy from it.

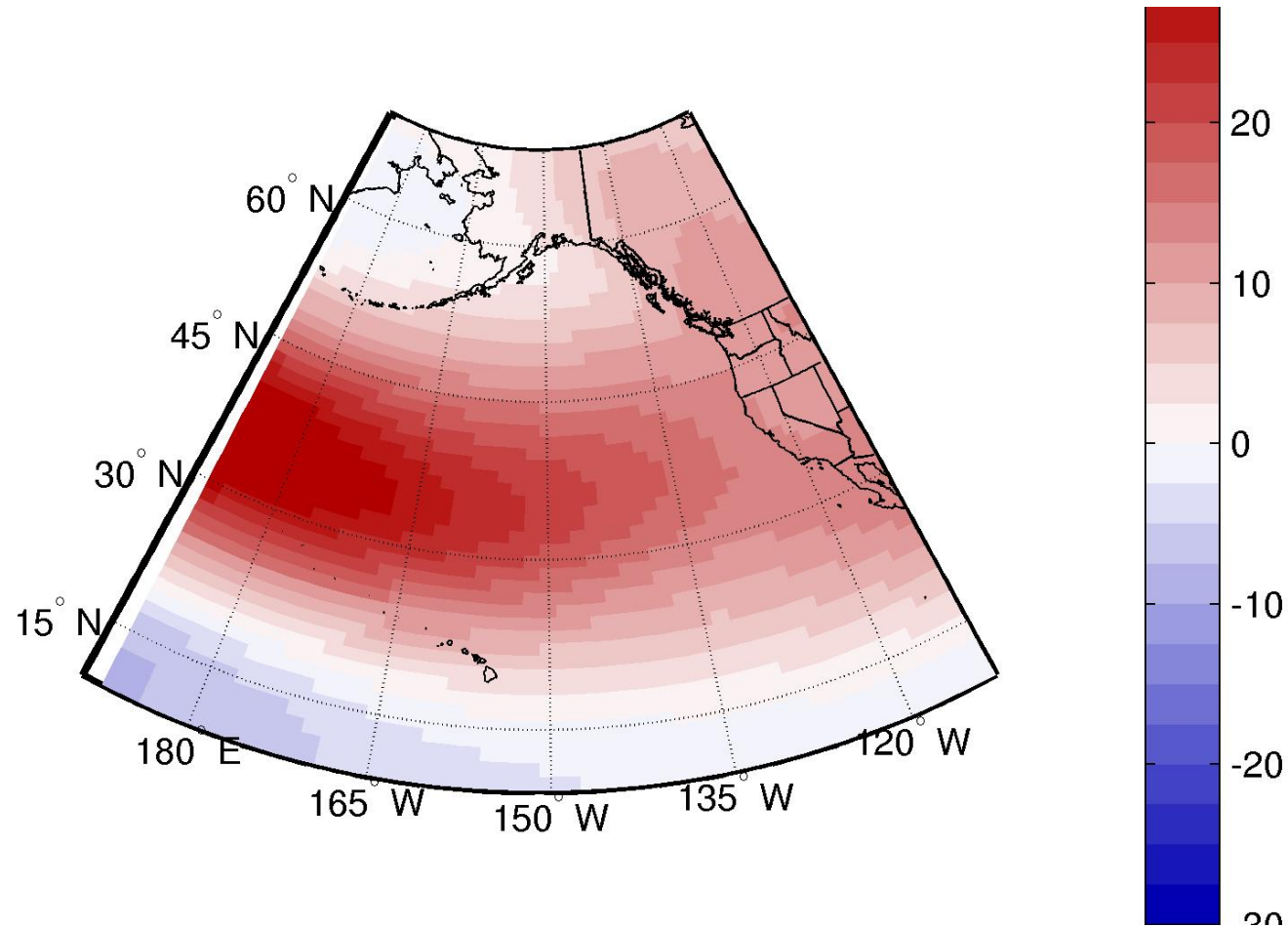
850 hPa total wind for the contemporary (blue) and end of century (red) periods. From Warner et al., (2015)



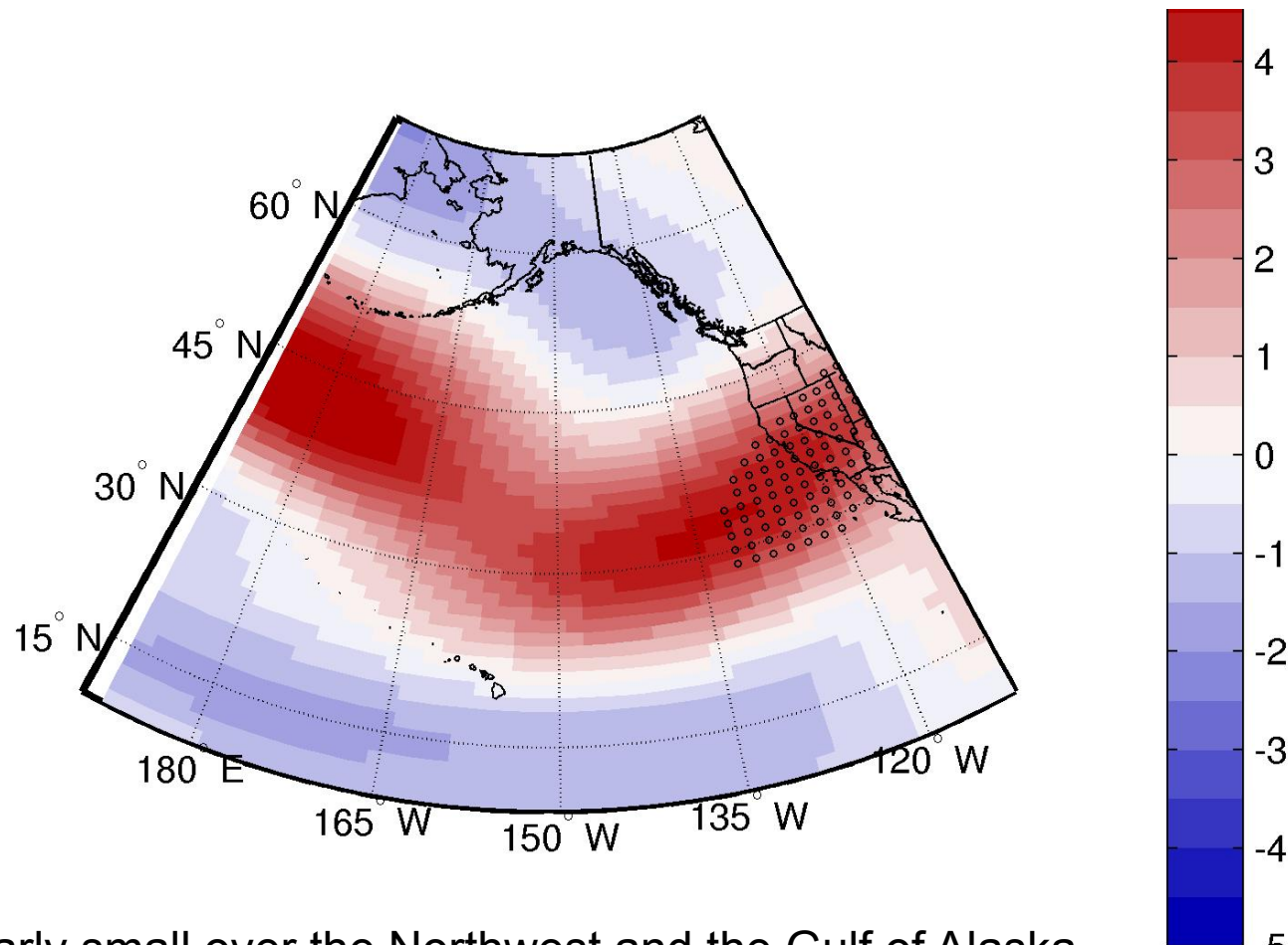
# Zonal Wind Component: CMIP5 Average (1970-1999)



# Future (2070-2099)



# Difference (small everywhere)



Particularly small over the Northwest and the Gulf of Alaska

# Hurricanes hitting the Northwest?

Forget it, even a warmed eastern Pacific will be far too cold.





# Northwest heat waves?

- A very complex story with our mountains and land/water contrasts.
- True heat waves only occur over the western, populous side of the region when there is **offshore (easterly) flow**.
- Matt Brewer, a UW Ph.D. candidate has done several papers on heat waves.

# **T<sub>max</sub> heat waves are not increasing in frequency**

## **History of Pacific Northwest Heat Waves: Synoptic Pattern and Trends\***

**KARIN A. BUMBACO**

*Office of the Washington State Climatologist, Joint Institute for the Study of Atmosphere and Ocean,  
University of Washington, Seattle, Washington*

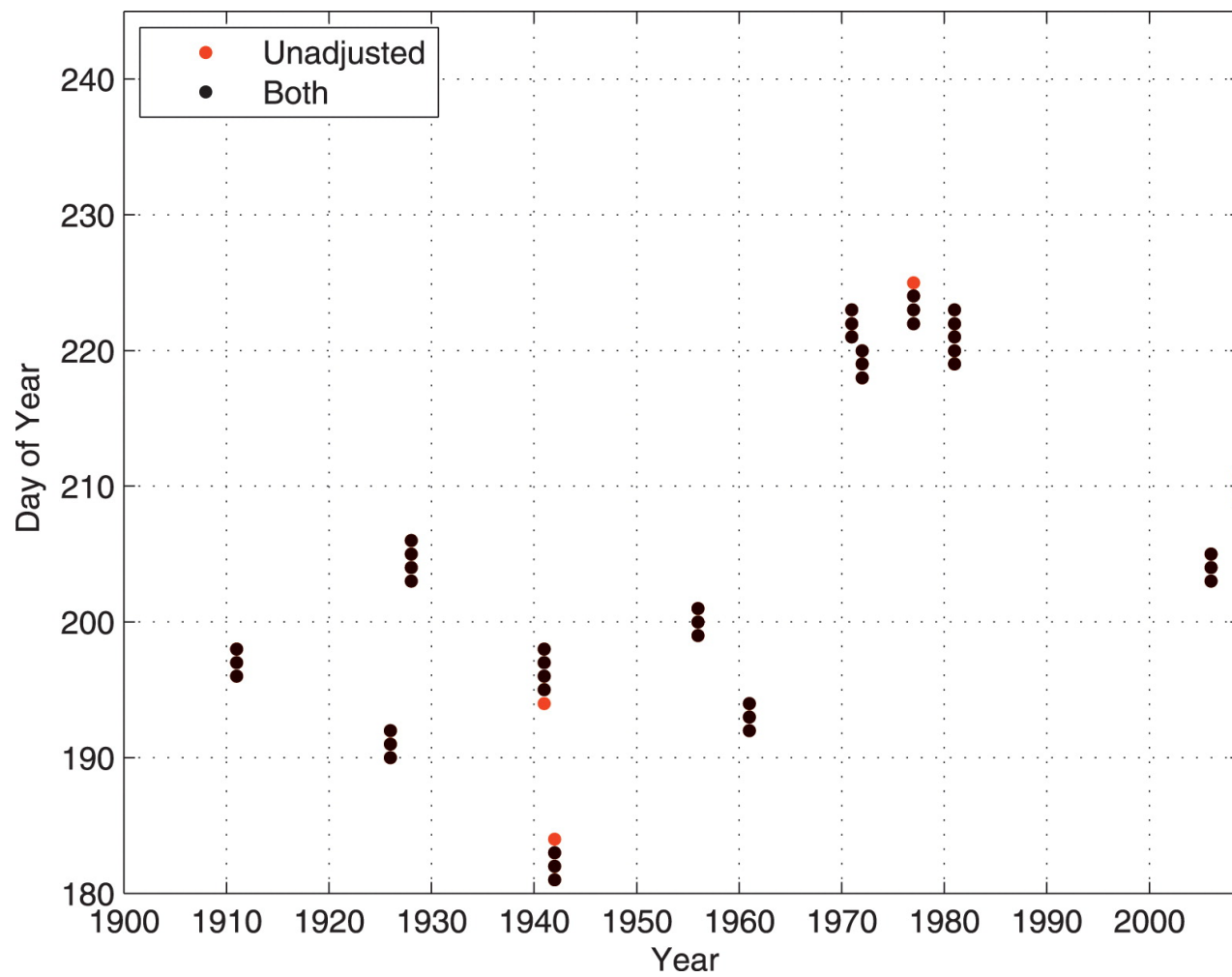
**KATHIE D. DELLO**

*Oregon Climate Service, Oregon Climate Change Research Institute, College of Earth, Ocean,  
and Atmospheric Sciences, Oregon State University, Corvallis, Oregon*

**NICHOLAS A. BOND**

*Office of the Washington State Climatologist, Joint Institute for the Study of Atmosphere and Ocean,  
University of Washington, Seattle, Washington*

# $T_{\max}$ Heat Waves

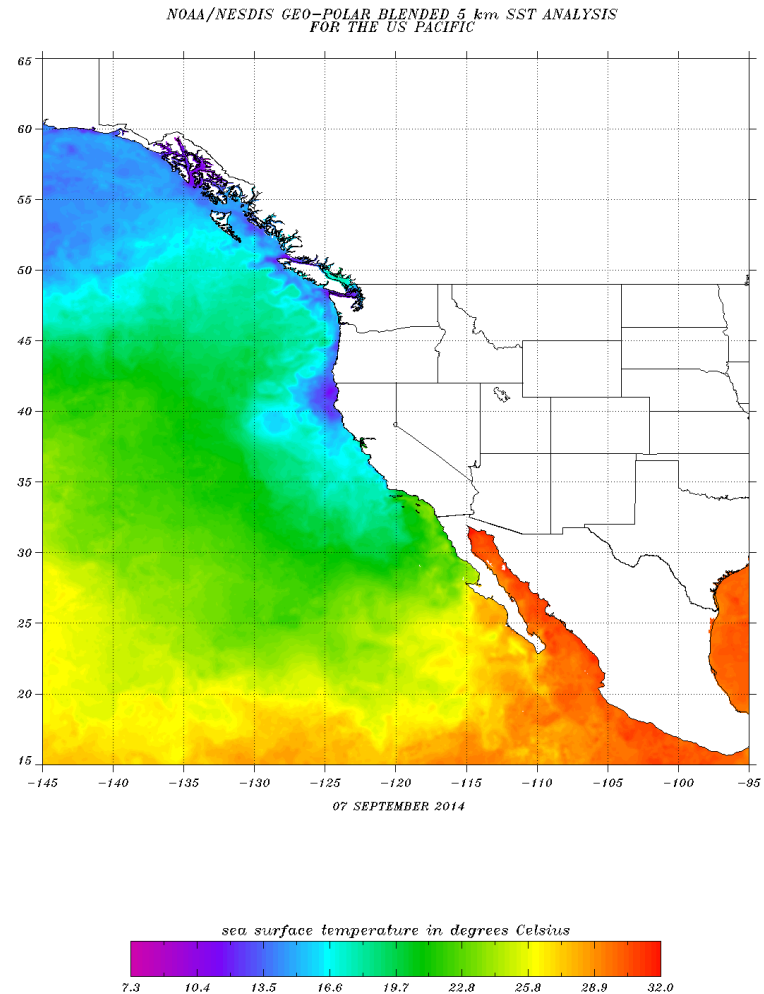


# Heat waves distributed through the historical period

Year	Start date	Avg anomaly (°C)	Intensity rank	Duration (days)	Duration rank
Tmax event					
1911	15 Jul	10.5	11	3	—
1926	9 Jul	10.6	9	3	—
1928	22 Jul	11.0	6	4	3
1941	13 Jul	11.5	4	5	1
1942	30 Jun	11.6	3	4	3
1956	18 Jul	10.4	12	3	—
1961	11 Jul	11.5	4	3	—
1971	9 Aug	9.9	13	3	—
1972	6 Aug	10.7	7	3	—
1977	10 Aug	10.7	7	4	3
1981	7 Aug	12.5	1	5	1
2006	22 Jul	10.6	9	3	—
2009	28 Jul	12.1	2	3	—

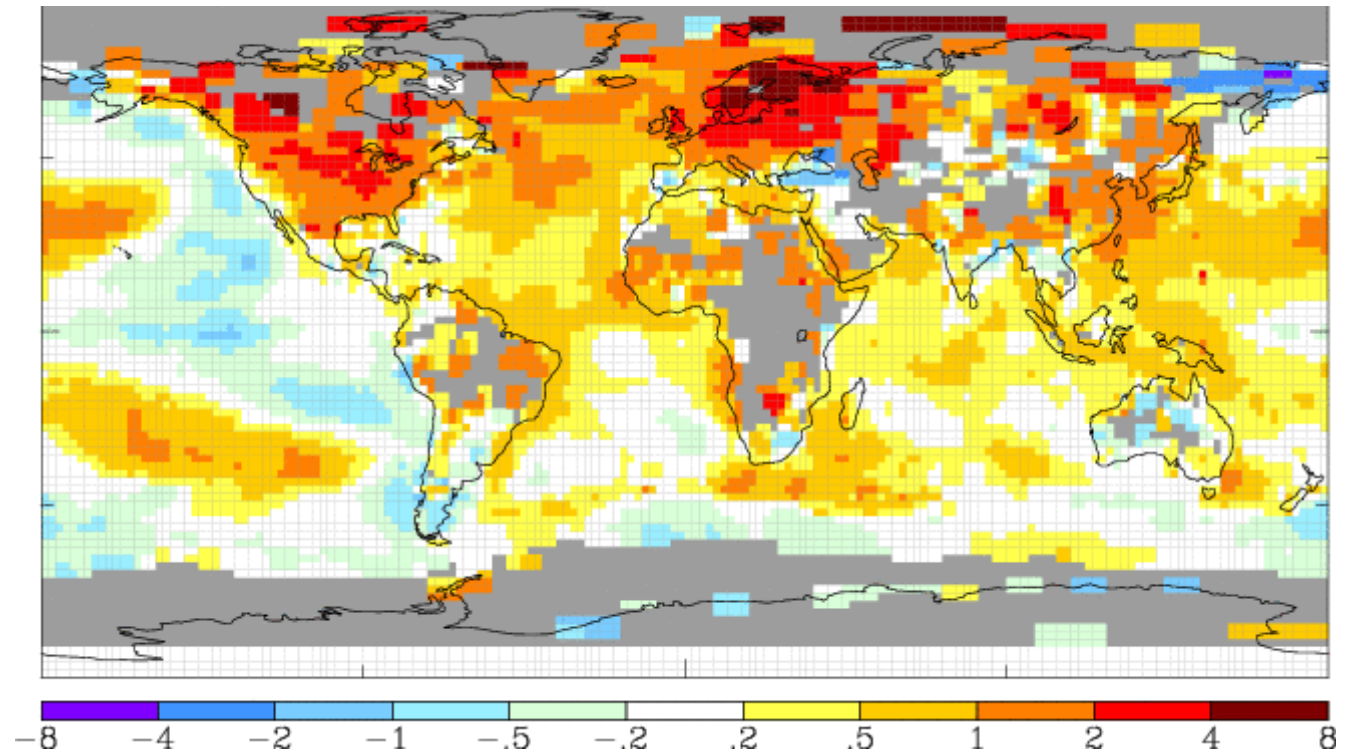
**But what about future heat  
waves?**

The cool  
eastern Pacific  
protects the  
west side from  
extreme heat  
most of the  
summer: this  
will not change



**And recent decadal trends and most coupled climate models suggest the eastern Pacific will warm up less and slower than most locations**

Change in  
Winter  
Surface Air  
Temperature  
(°C) for  
1979-2008



# **But there is something else. Could the mesoscale meteorology of the region work AGAINST heat waves?**

- Most models indicate more warming over land than water.
- Might the greater heating cause more pressure falls over land and thus larger onshore pressure gradients.
- Could this bring in MORE cool air and mitigate the warming?

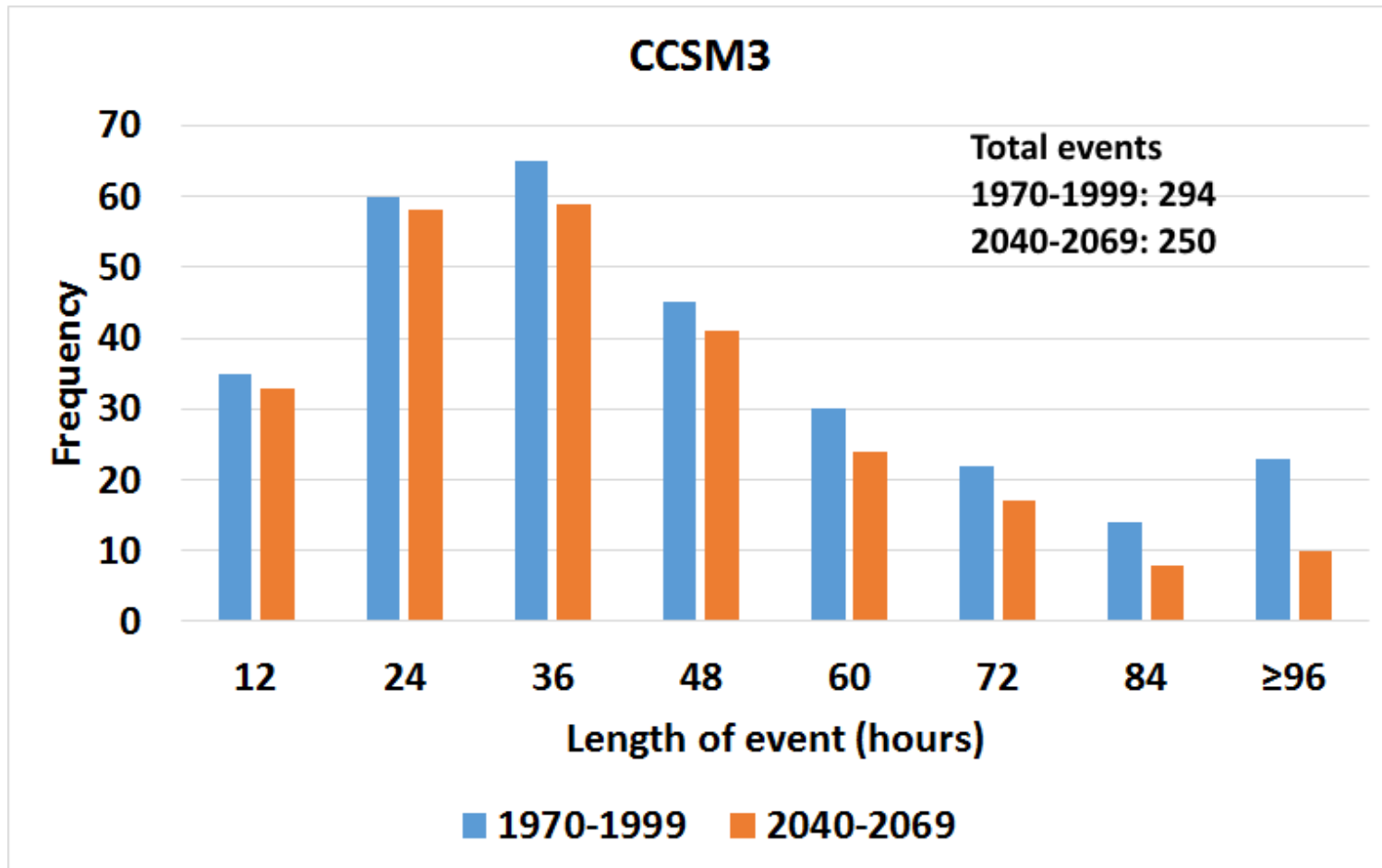


# **Major New Finding**

(Matt Brewer, next talk)

**Might strong easterly flow events  
decline under global warming?**

# Dynamically Downscaled CCSM3 climate model (using WRF at 12-km)



**Could fewer offshore flow events  
reduce the potential for regional  
heat waves?**

# **Critical need for understanding changes in NW extremes under global warming**

High-resolution century-long  
dynamically downscaled climate  
runs.

# A substantial deficiency and opportunity

- Downscale 10-20 CMIP5 climate models using a mesoscale model (WRF)
- Must get to 12-km or less. Needs bias correction and statistical post-processing
- Can **not** be done efficiently on distributed computing on folks pcs...need big machines.
- Computer resources are available. Mainly people time.
- *Can the community come together to do this?*

# Conclusions

- Under global warming there is the potential for stronger atmospheric river events, and thus flooding near major rivers.
- No reason to expect major Northwest windstorms to become more frequent or intense.
- The region will warm slowly during the next century, but changes in extremes may be moderated due to the Pacific and our terrain.

**The END**