Historical and Future Trends in *Precipitation Extremes*…

…and Their Impacts on the Stormwater Infrastructure of Washington State

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Introduction

House Bill 1303

- Passed spring 2007
- Assessed impacts of climate change on:
  - Agriculture
  - Coasts
  - Energy
  - Forests
  - Human Health
  - Salmon
  - Water
  - **Urban Stormwater Infrastructure**

The Seattle Times JANUARY 12, 2009

JANUARY FLOC

When disast utine

Crisis repeats as appear

Lynda V. Mapes

Disaster Declarations

Federal Emergency Management Agency disaster declarations in King County in connection with flooding:

January 1990
November 1990
December 1990
November 1995
February 1996
December 1996
March 1997
November 2003
December 2006
December 2007

Stationarity

"A time series is stationary if it is free of trends, shifts, or periodicity, implying that the statistical parameters of the series (e.g., mean and variance) remain constant through time."

Salas 1993, *Handbook of Hydrology*

Urban Stormwater Infrastructure

Minor Infrastructure

Roadside swales, gutters, and sewers typically designed to convey runoff events of 2- or 5-year return periods.

Major Infrastructure

Larger flood control structures designed to manage 50- or 100-year events.

Urbonas and Roesner 1993

Objectives

1. What are the historical trends in precipitation extremes across Washington State?
2. What are the projected trends in precipitation extremes over the next 50 years in the state's urban areas?
3. What are the likely consequences of future changes in precipitation extremes on urban stormwater infrastructure?

Historical Precipitation Analysis

Literature Review

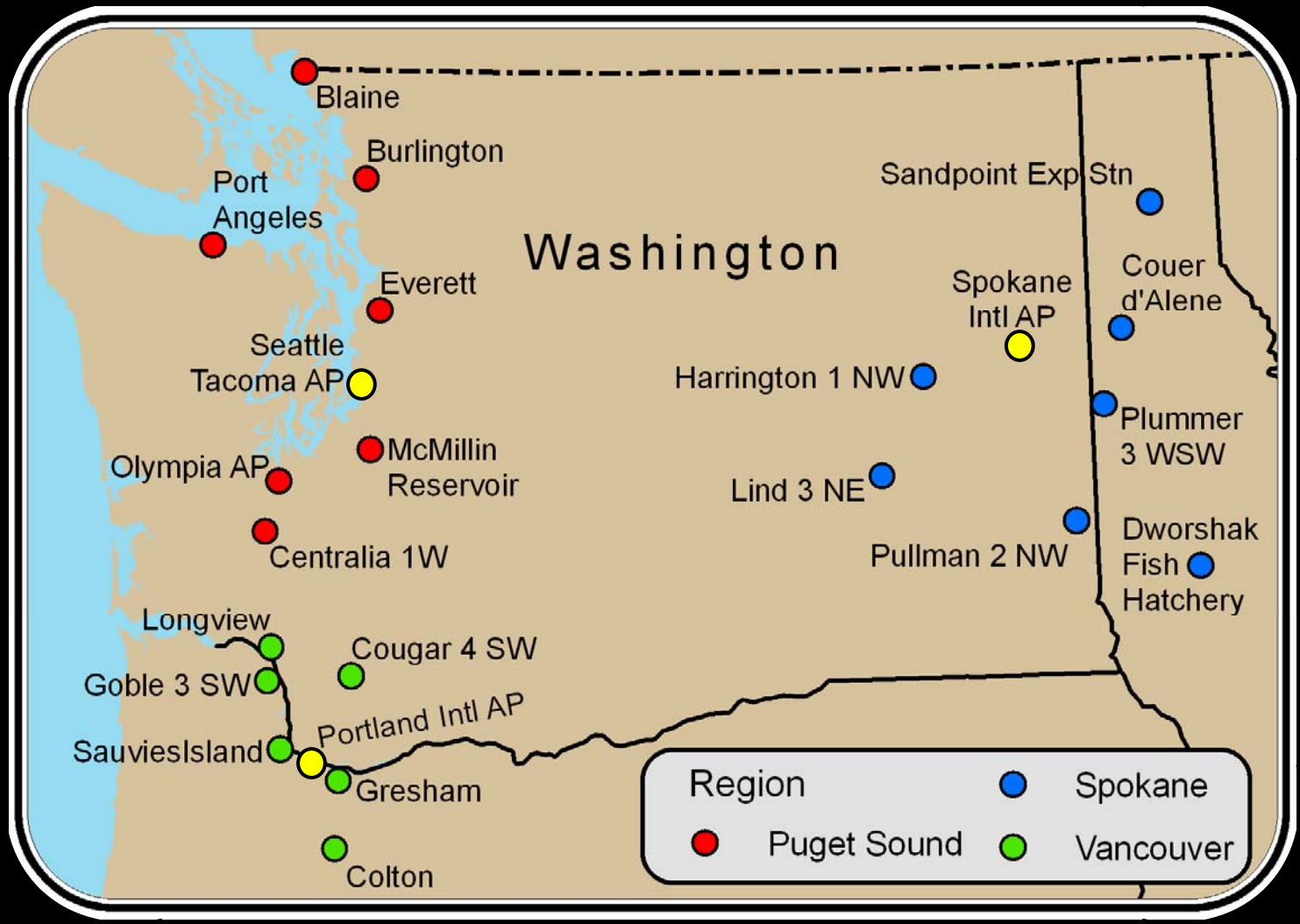
- Several studies have found increases in the frequency of extreme precipitation events throughout the US over the last 100 years.
- Two main drawbacks with prior research:

1. Not focused on *sub-daily* extremes most critical to urban stormwater infrastructure
2. Not focused on changes in event *intensity* most critical to urban stormwater infrastructure

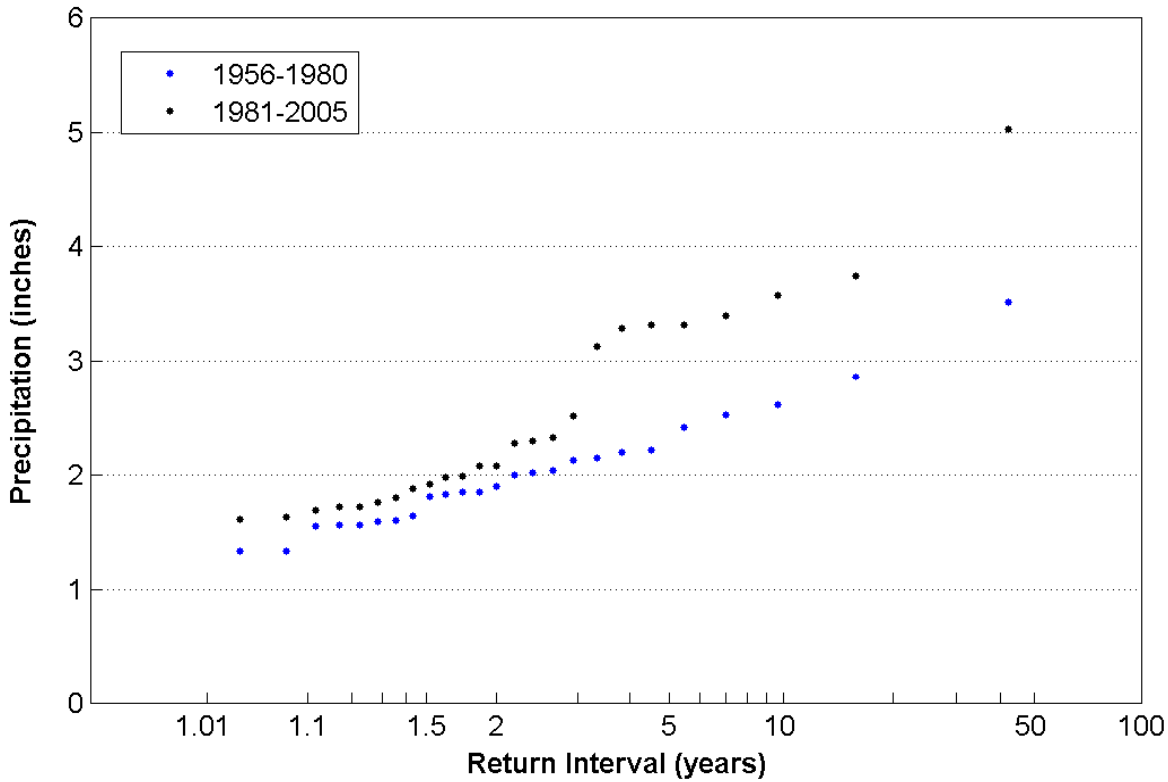
Regional Frequency Analysis

- Used by *Fowler and Kilsby (2003)* to determine changes in design storm magnitudes from 1960 to 2000 in the United Kingdom
- Based on principle that annual precipitation maxima from all sites in a region can be described by common probability distribution after site data are divided by their at-site means.
- Larger pool of data results in less variable estimates of design storm magnitudes, particularly for longer return periods.

Study Locations



Precipitation Distributions at SeaTac



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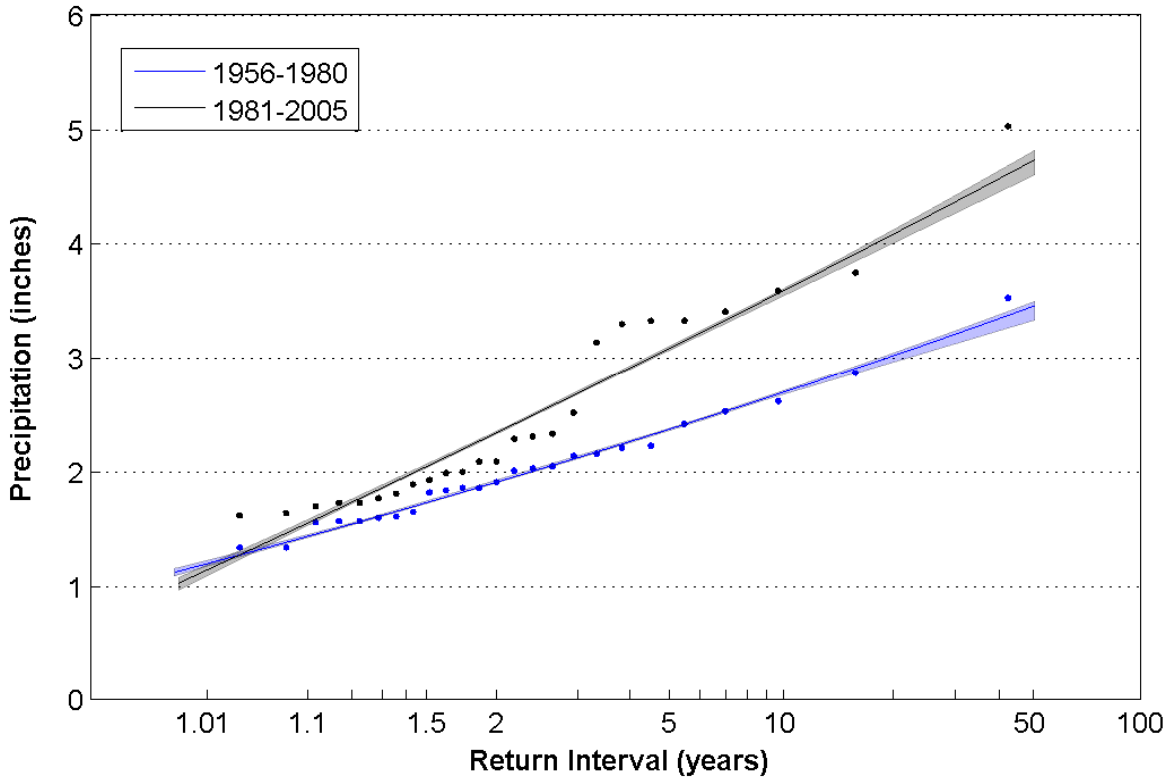
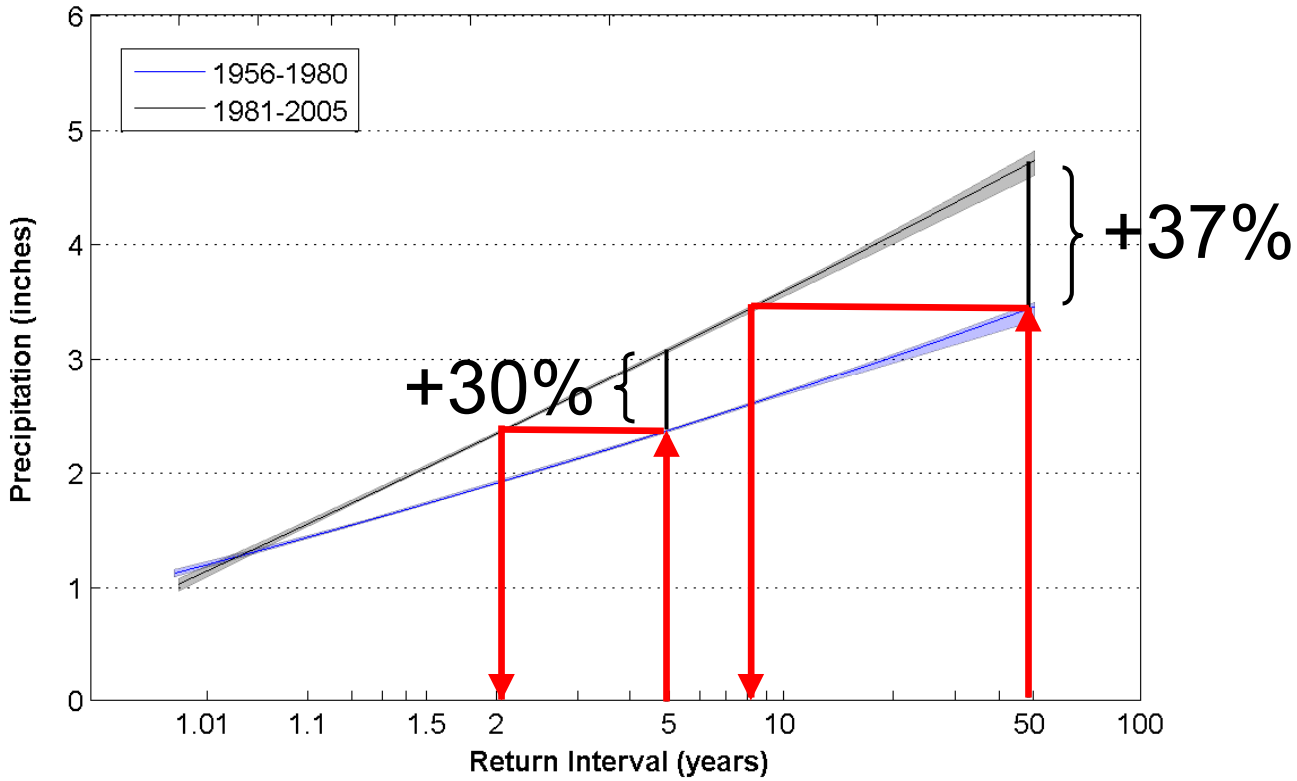


Precipitation Distributions at SeaTac

Change in Average Annual Maximum = +25%



Results of Historical Analysis

Changes in average precipitation annual maxima between 1956–1980 and 1981–2005:

	SeaTac	Spokane	Portland
1-hour	+7%	-1%	+4%
24-hour	+25% *	+7%	+2%

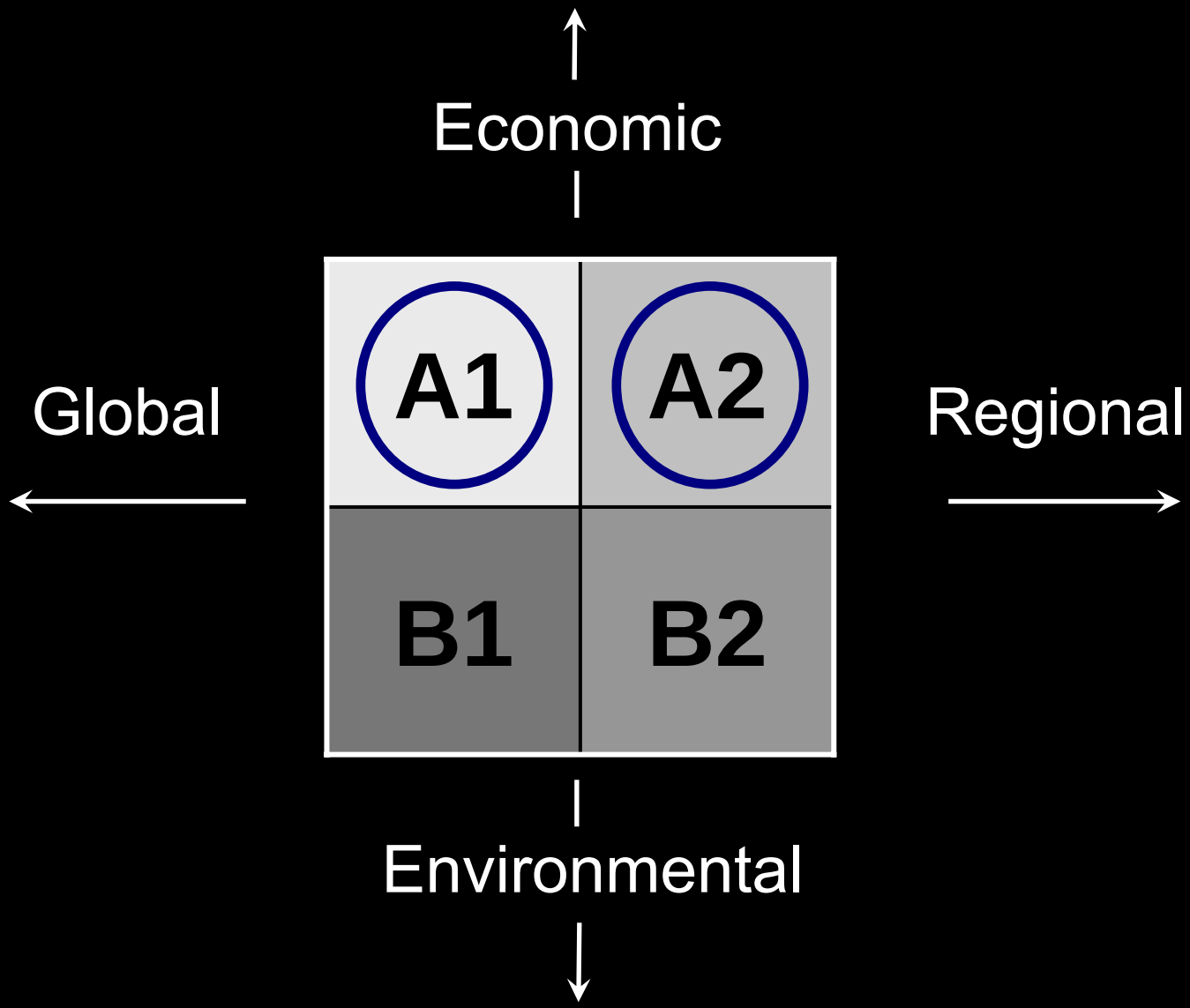
* Statistically significant for difference in means

Statistical Significance

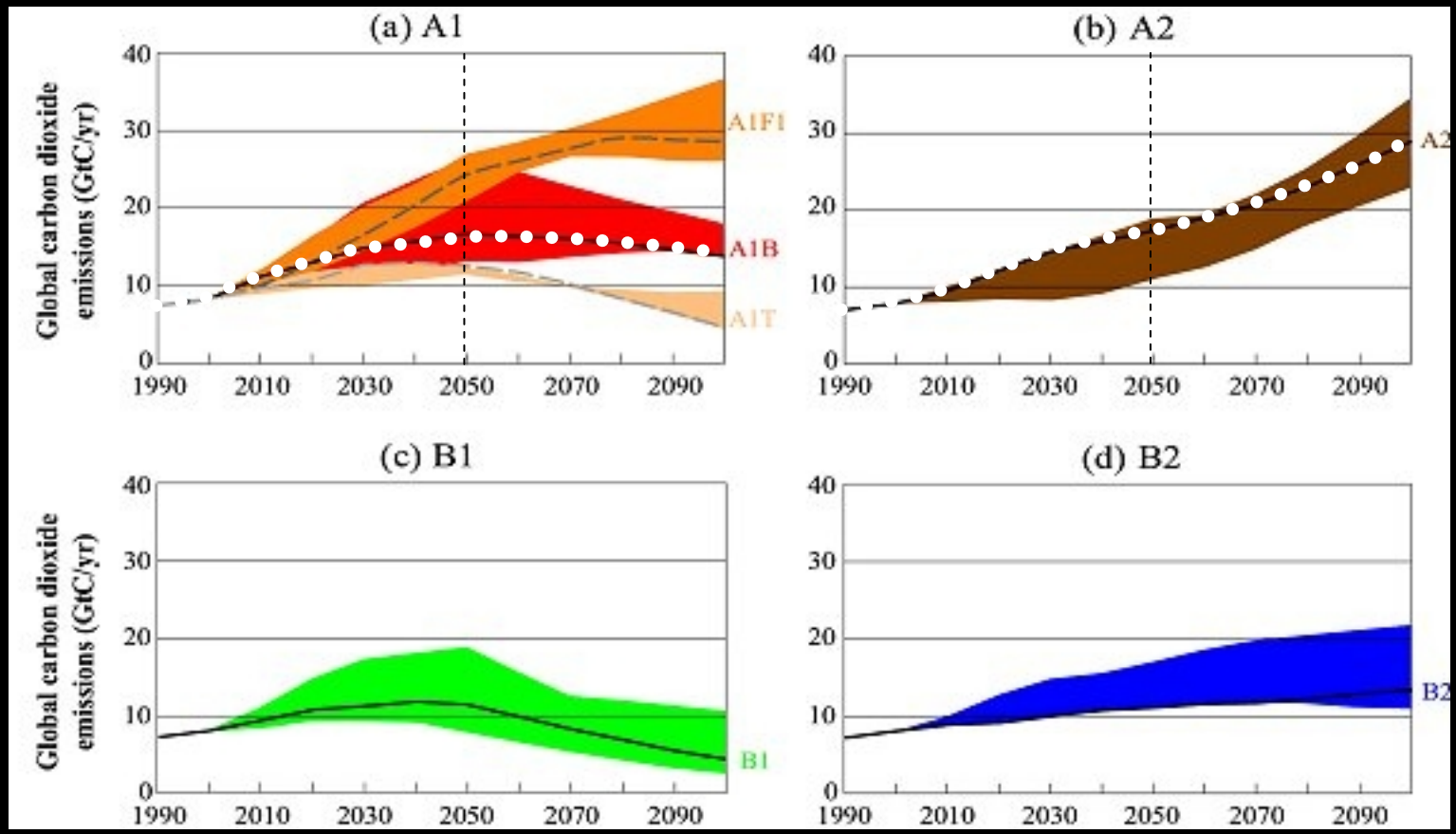
- General indication of how likely a sample statistic is to have occurred by chance.
- A statistically significant result indicates that we are at least 95% confident that the means of the underlying populations are not equal.
- A statistically significant result does NOT imply that the means of the underlying populations are different by the same amount as the difference in the sample means, only that they are different by SOME amount.

Future Precipitation Projections

Emissions Scenarios



Emissions Scenarios



Nakicenovic and Swart 2000

Global Climate Models

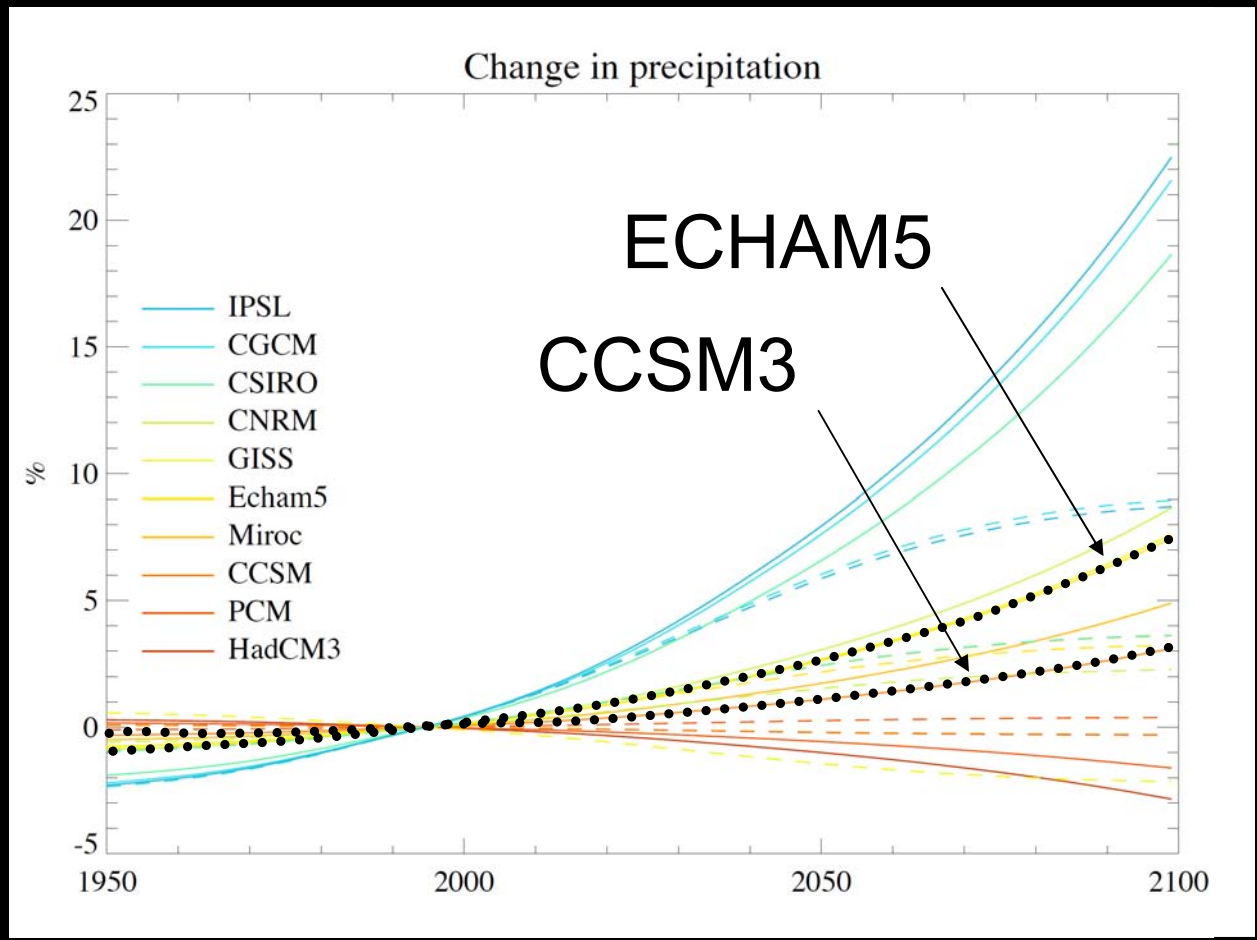
ECHAM5

- Developed at Max Planck Institute for Meteorology (Hamburg, Germany)
- Used to simulate the A1B scenario in our study

CCSM3

- Developed at National Center for Atmospheric Research (NCAR; Boulder, Colorado)
- Used to simulate the A2 scenario in our study

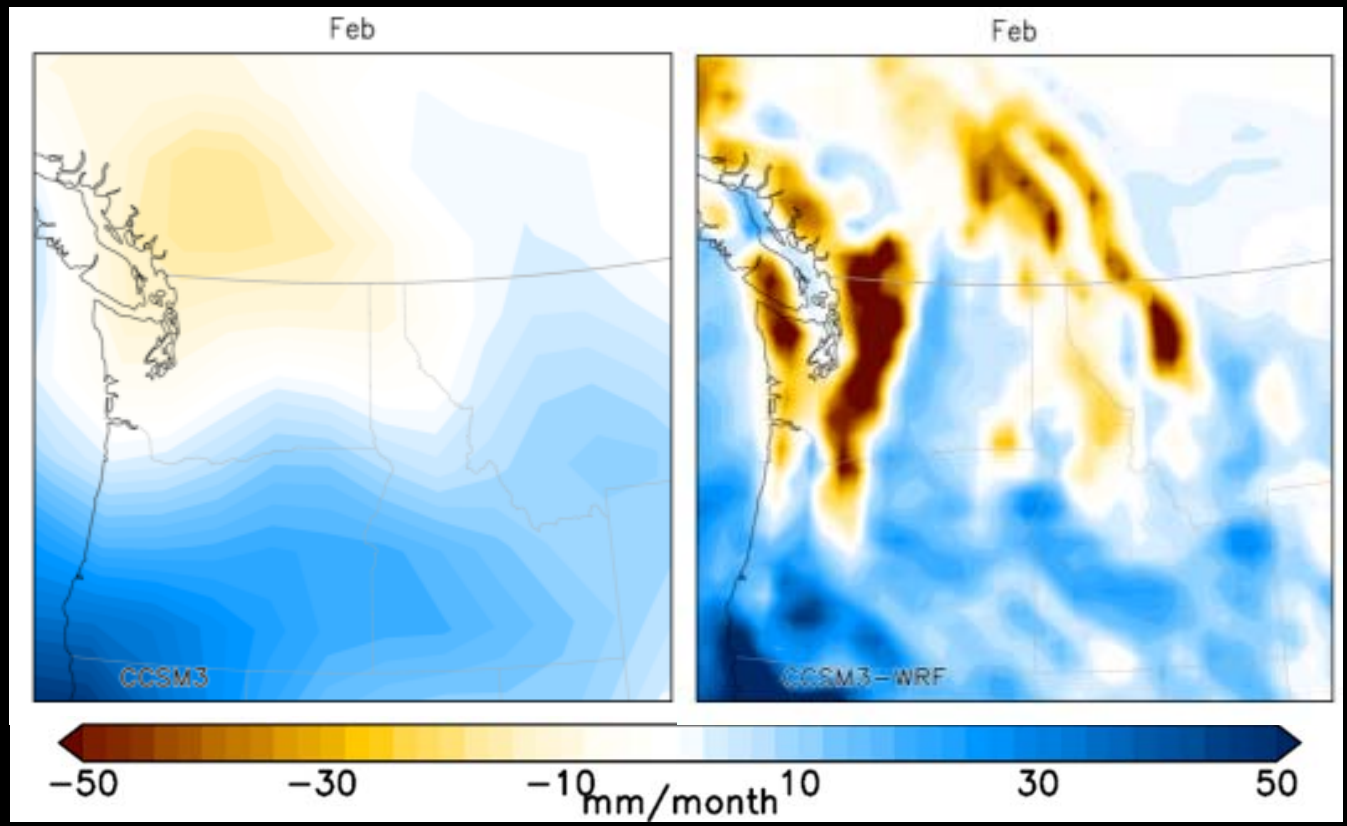
Global Climate Models



Mote et al 2005

Dynamical Downscaling

Global Model Regional Model



Courtesy Eric Salathé

Results of Future Analysis

Changes in average precipitation annual maxima between 1970–2000 and 2020–2050:

		SeaTac	Spokane	Portland
CCSM3	1-hour	+16% *	+10%	+11% *
	24-hour	+19%	+4%	+5%
ECHAM5	1-hour	-5%	-7%	+2%
	24-hour	+15% *	+22% *	+2%

* Statistically significant for difference in means

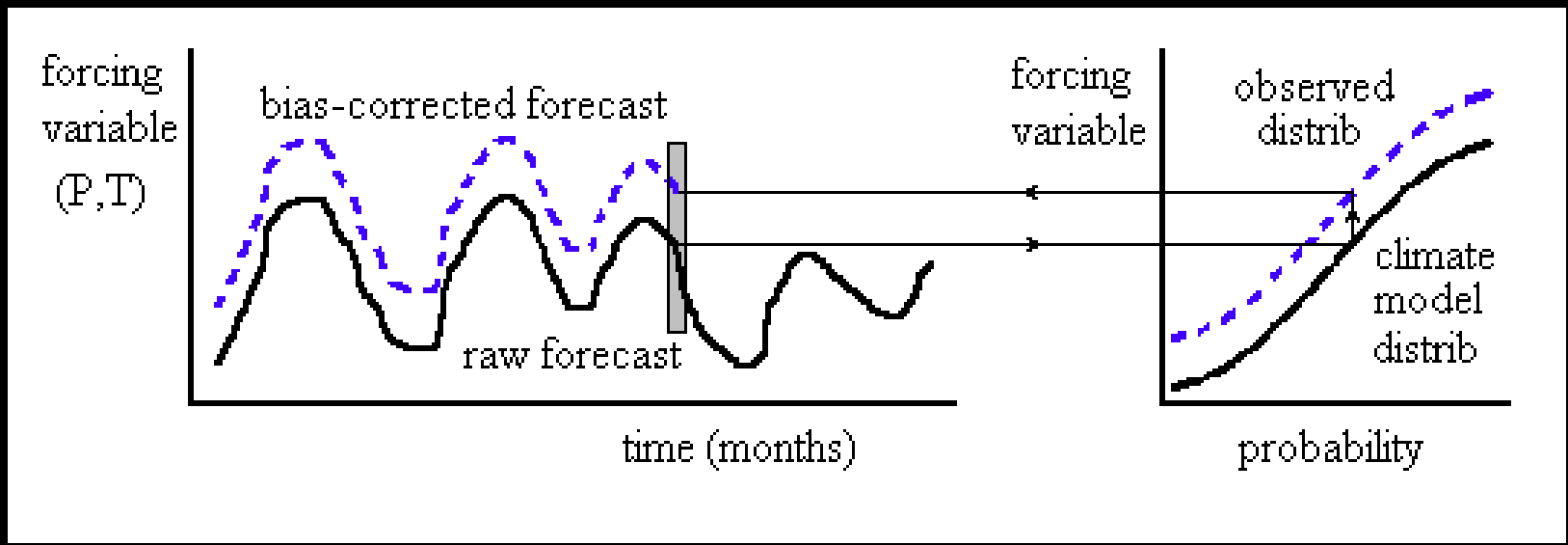
Future Runoff Simulations

Bias Correction and Statistical Downscaling

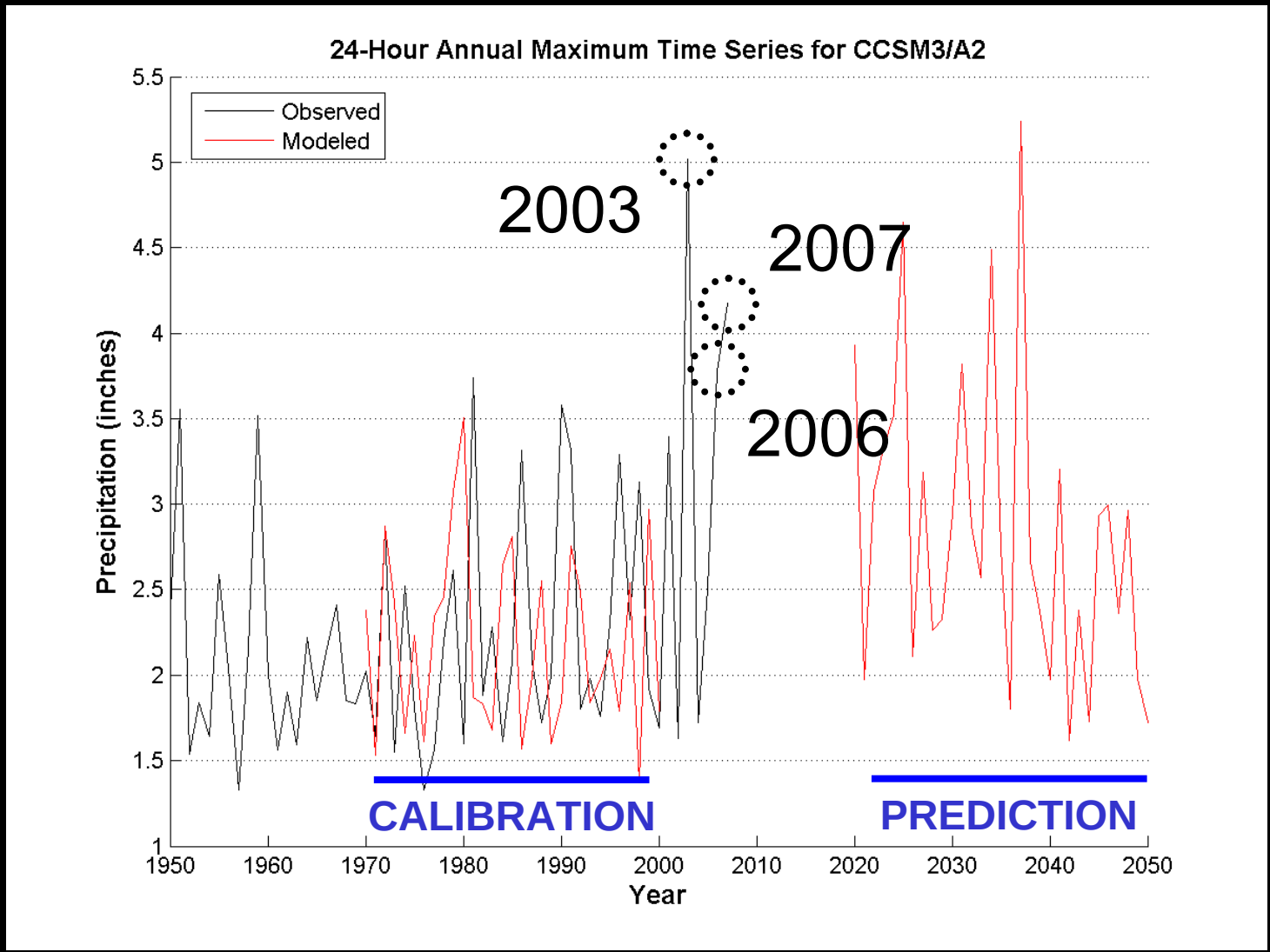
- Performed at the grid point from each simulation that was closest to SeaTac Airport
- Bias corrected data used to drive hydrologic modeling of Thornton Creek (Seattle) and Juanita Creek (Kirkland) watersheds.

Bias Correction and Statistical Downscaling

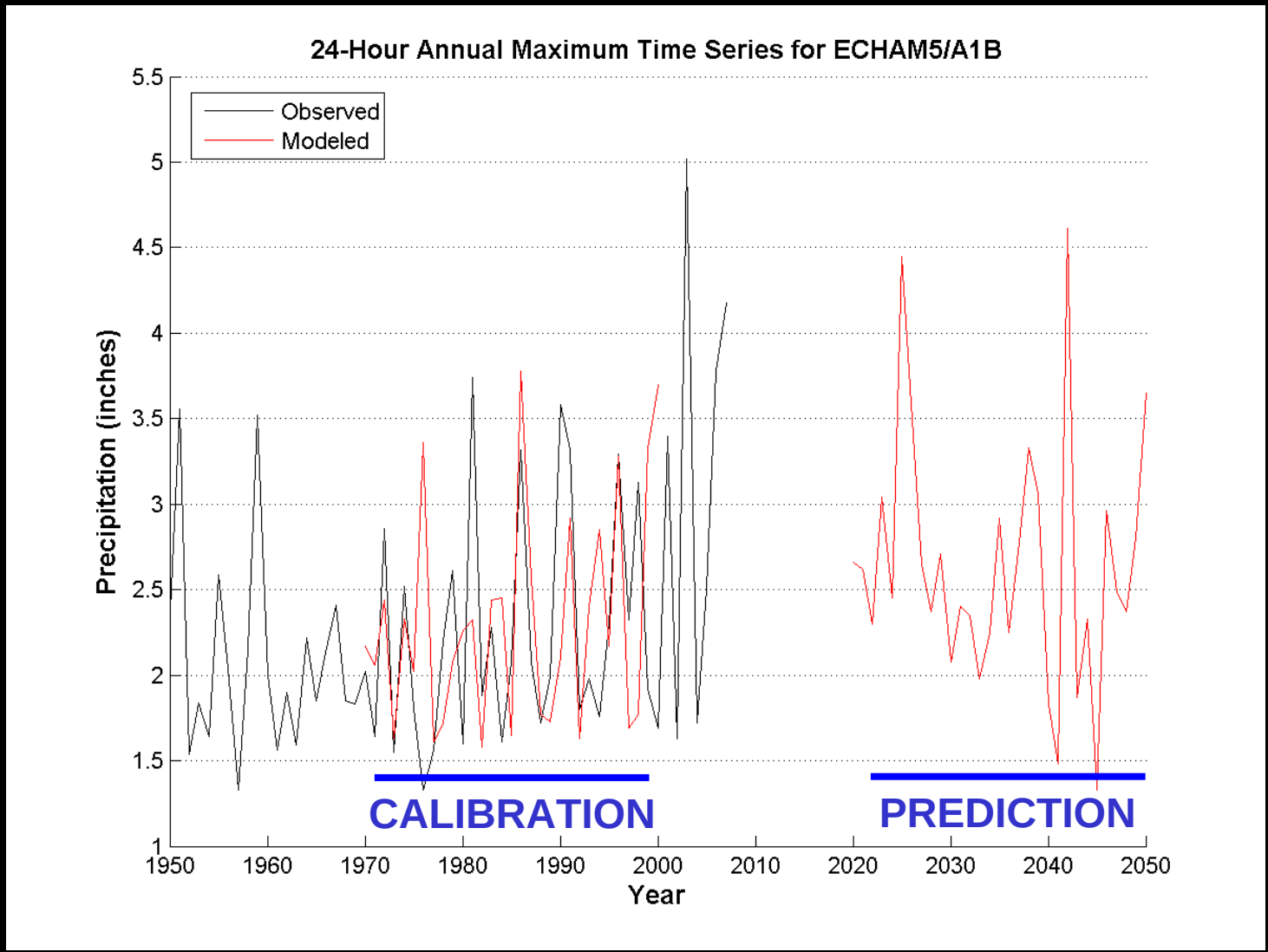
- Despite biases in modeled data, projections may still prove useful if interpreted relative to the modeled climatology rather than the observed climatology.
- Performed separately for each calendar month.



Bias-Corrected Time Series (CCSM3/A2)



Bias-Corrected Time Series (ECHAM5/A1B)



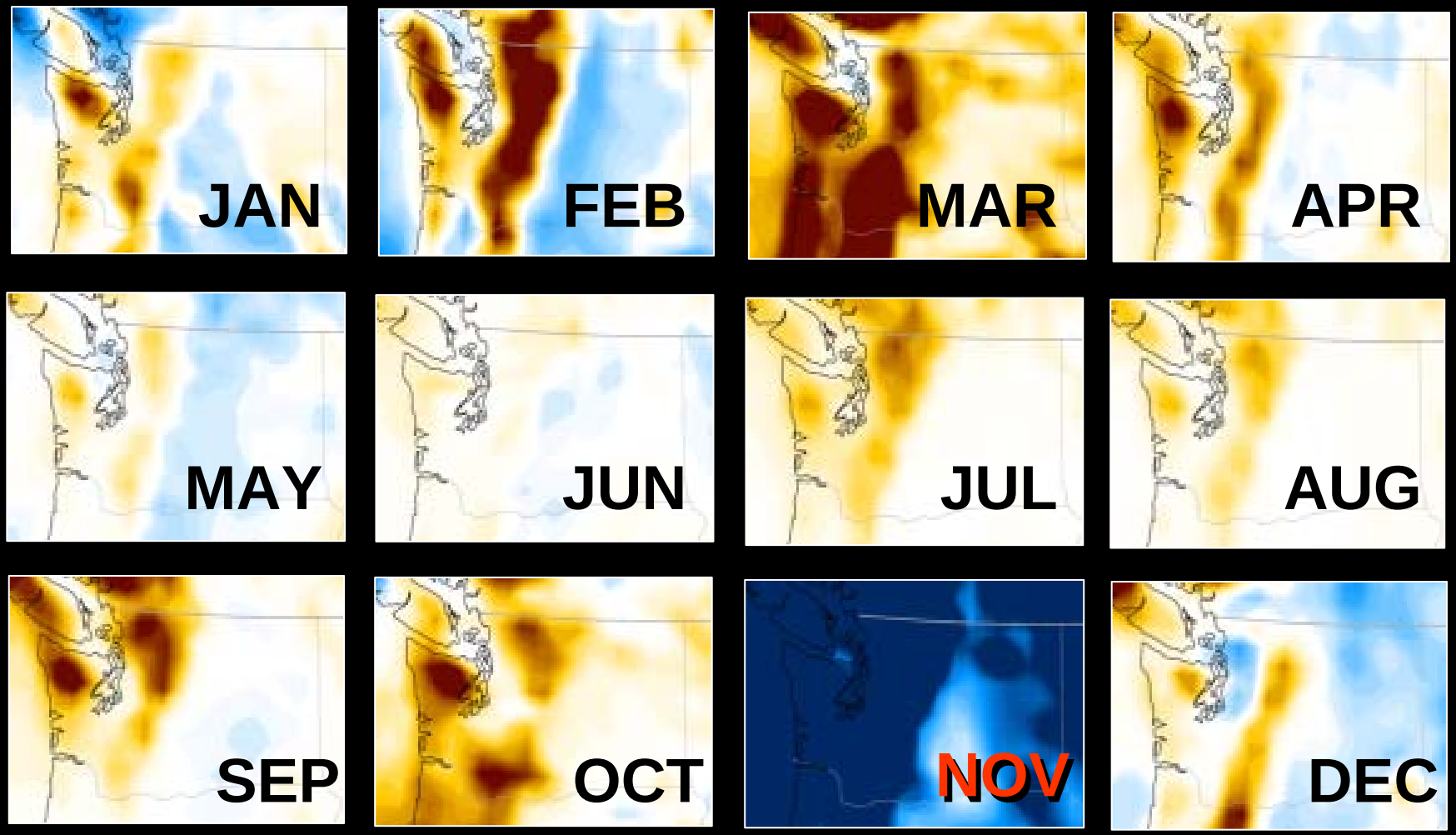
Results of Hydrologic Modeling

Changes in average streamflow annual maxima between 1970-2000 and 2020-2050:

	Juanita Creek	Thornton Creek
CCSM3	+25% *	+55% *
ECHAM5	+11%	+28%

* Statistically significant for difference in means

The November Surprise



Courtesy Eric Salathé

Conclusions

Conclusions

- Few statistically significant changes in extreme precip have been observed in the last 50 years, with the possible exception of the Puget Sound.
- Simulations generally indicate increases in extreme magnitudes throughout the state over the next 50 years, but their projections vary by model and region, and actual changes may be difficult to distinguish from natural variability.
- Hydrologic modeling of two urban creeks in the Seattle area suggest overall increases in peak annual discharge over the next 50 years.

What the Study Does Not Address

- Projections from the other 2 families of scenarios *or* the other 20+ global climate models
- What percentage of past trends was due to climate *change* and what percentage was due to climate *variability*
- The relative influence of changes in land use or more complex climate-related phenomena (e.g., rain-on-snow events) on future runoff

What Do We Do Now?

- Insufficient confidence in future projections to recommend changes to design standards right now
- Regardless of climate change, our stormwater infrastructure is *currently* underperforming and in need of improvement and repair
- Low Impact Development strategies are likely to be most practical, economical, and effective options
- Accounting for future increases in runoff is still a matter of risk. For large capital projects, robust cost-benefit analyses can determine the most efficient use of money over the projects' intended design lives.

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Thank You