

# Climate model assessment of changes in winter-spring streamflow timing over North America

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# Short Biography

## At GFDL/NOAA (Post-doc)

### Climate Impacts and Extremes Group

The Climate Impacts and Extremes Group works to improve scientific understanding of climate impacts and extremes in a changing climate. The group conducts research to produce and effectively communicate high-quality information on climate impacts and extremes, including the influence of climate variability and change, and with assessment of uncertainties.

#### Members

##### NOAA



**Tom Knutson**  
Group Leader  
Bibliography



**Thomas Delworth**  
Bibliography



**Keith Dixon**  
Bibliography



**Kirsten Findell**  
Bibliography



**John Lanzante**  
Bibliography



**Mary Jo Nath**  
Bibliography



**Jeff Ploshay**  
Bibliography



**Joe Sirutis**  
Bibliography



**Fanrong Zeng**  
Bibliography



**Rong Zhang**  
Bibliography

#### Collaborators



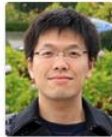
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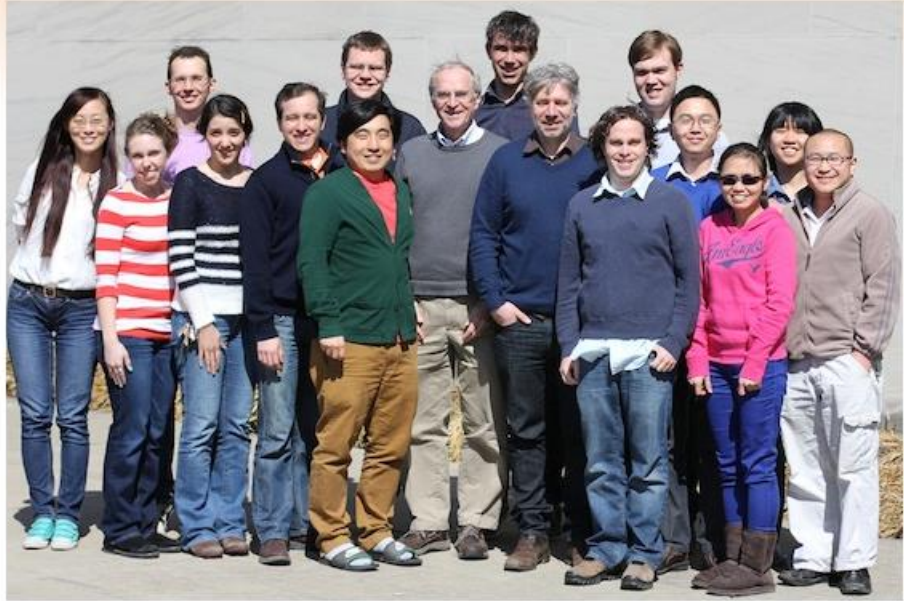
**Krista Dunne**  
USGS  
Bibliography



**Christopher Milly**  
USGS  
Bibliography

## At Princeton U.(Ph.D)

### Terrestrial Hydrology Research Group Princeton University



#### Welcome

Welcome to the home page of the Terrestrial Hydrology Research Group in the Department of Civil and Environmental Engineering at Princeton University. Our research includes land surface - atmosphere interactions for climate models and watershed models; impacts of climate change on hydrologic and water resource systems; and remote sensing of hydrologic systems. This web site describes our current research projects, the people in our research group, the models and the data that we use, our recent publications and our resources.

# Short Biography

## At Tuscaloosa, AL



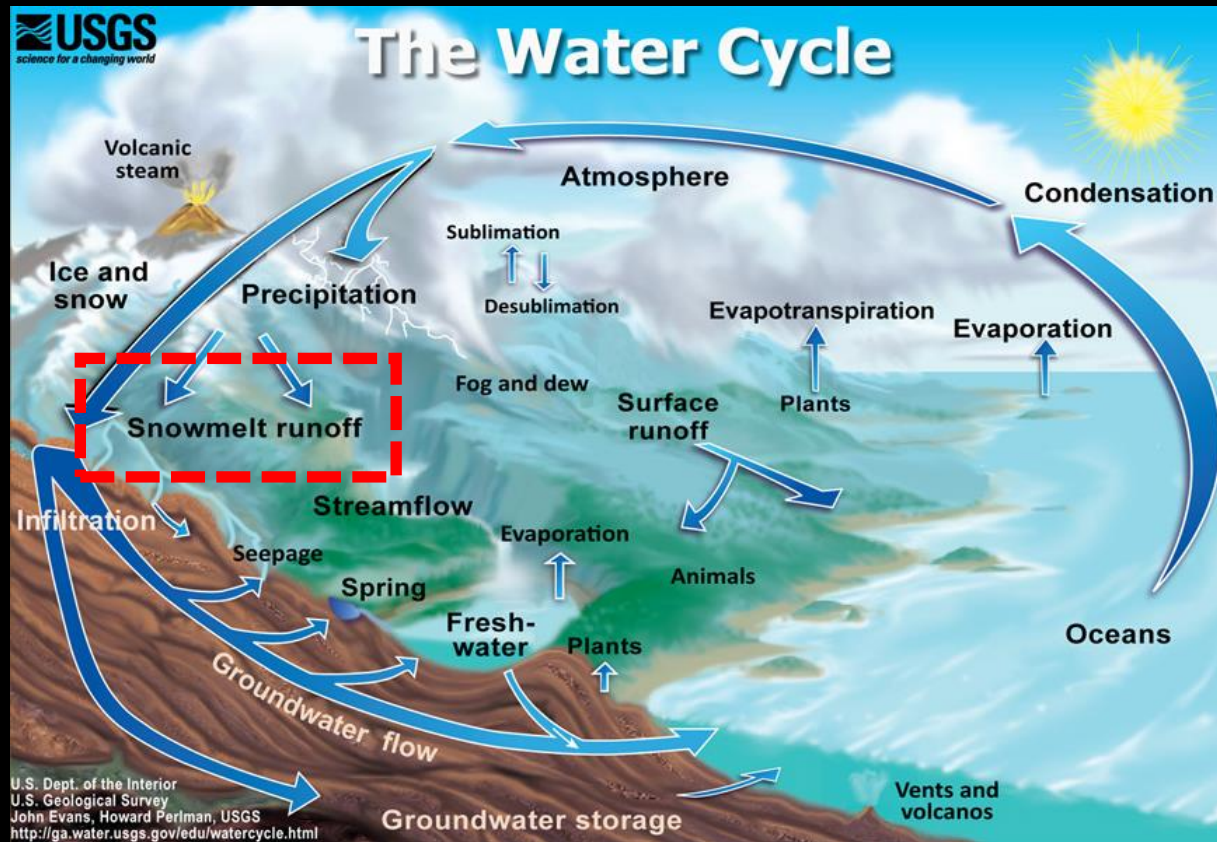
## National Water Center/NOAA



### 2016 College Football Rankings - Week 11 AP Top 25

RK	TEAM	REC	PTS	TREND
1	 Alabama (60)	9-0	1524	—
2	 Michigan (1)	9-0	1432	—
3	 Clemson	9-0	1408	—
4	 Washington	9-0	1364	—
5	 Louisville	8-1	1255	—

# Global warming can change the hydrological cycle



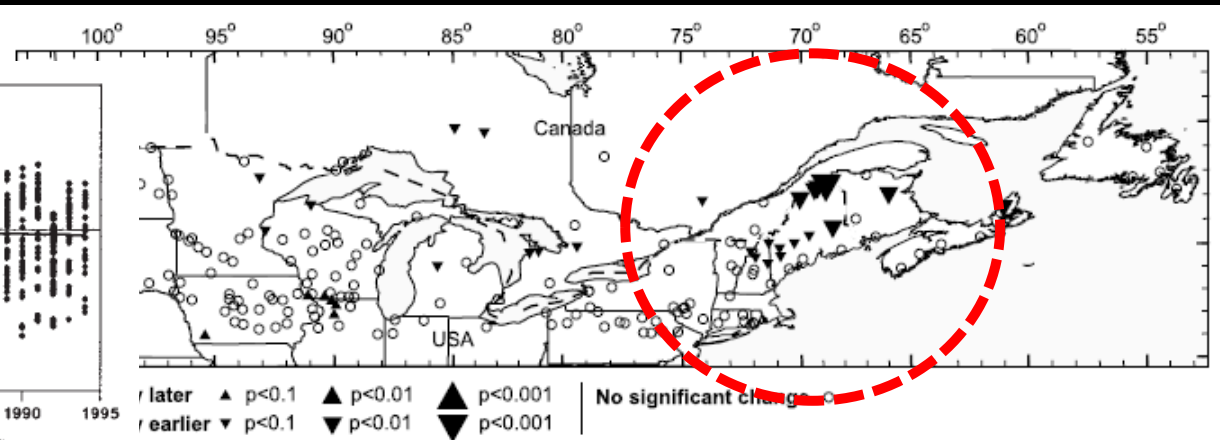
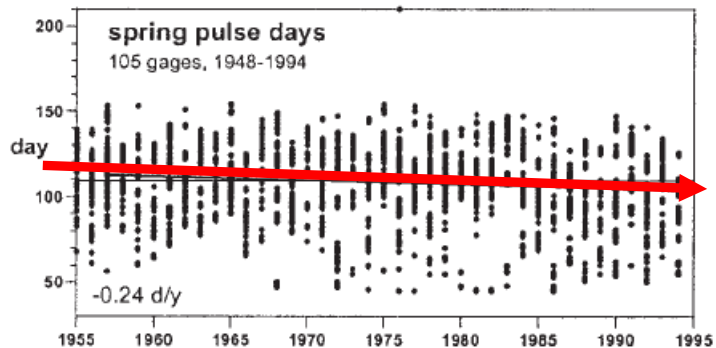
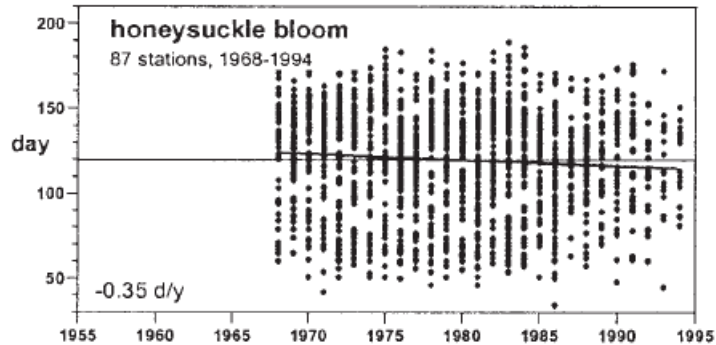
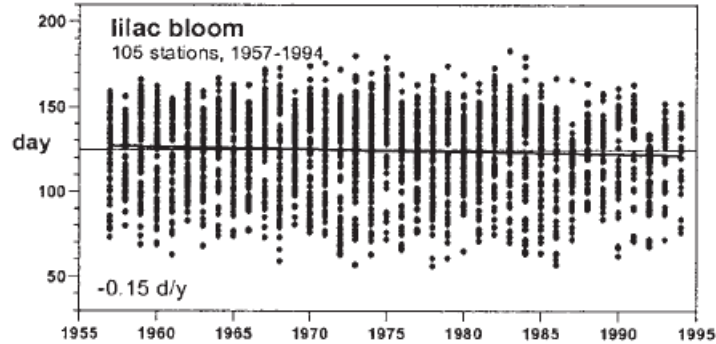
Over extratropical and mountainous regions,

- **Snowmelt runoff**
- Sensitive to surface temperature

Impact of global warming,

- Increase winter-spring runoff due to early snow-melting processes
- Decrease summertime runoff due to lack of natural water storage
- Changes in peak streamflow timing

# Changes in Timing of Winter-Spring Streamflows (1951-2000)



Hodgkins and Dudley, WRR, 2006

Over the U.S.,

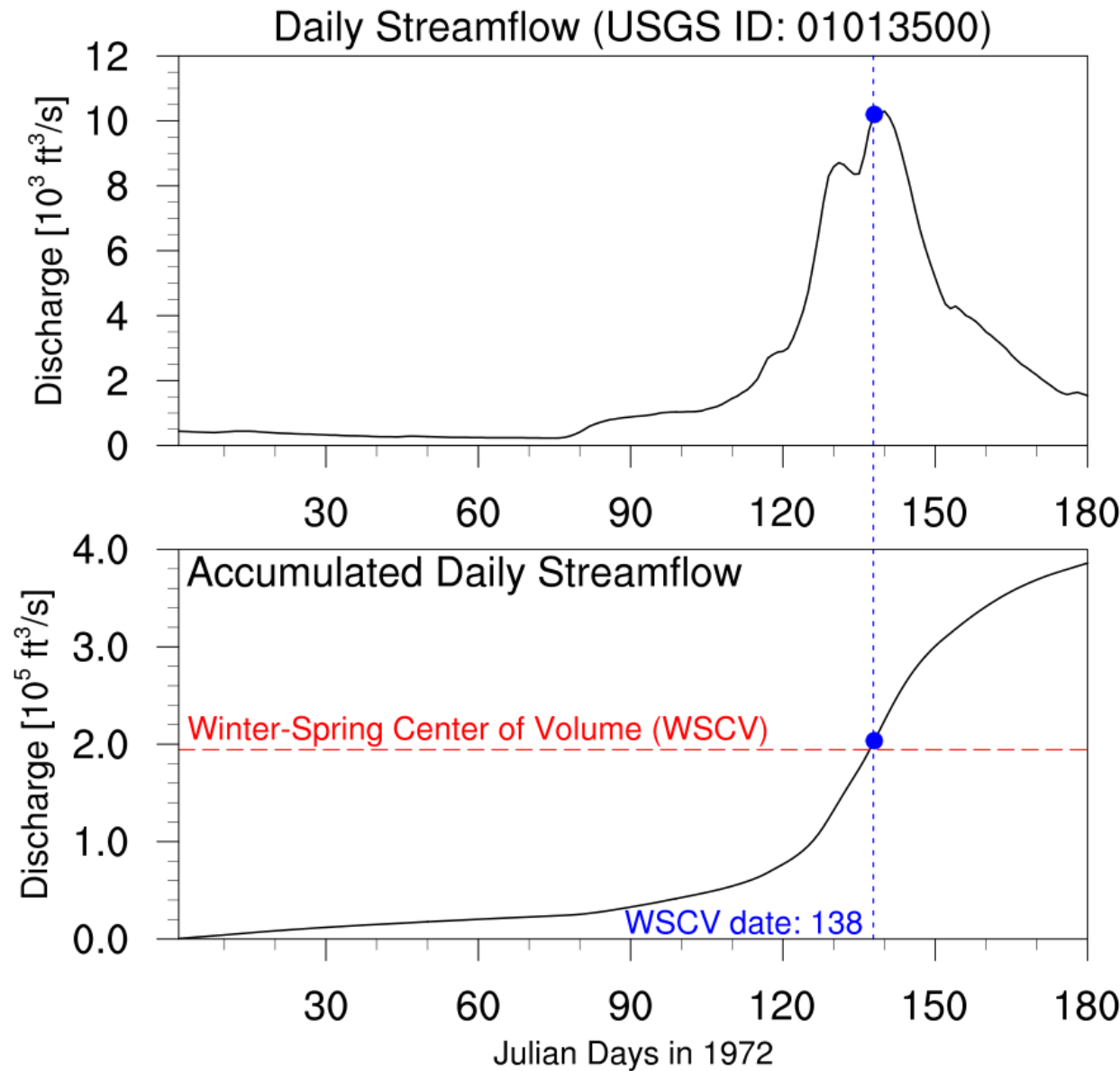
- Advance the onset of spring
- Related to early snowmelt runoff
- Increase spring streamflows

Adverse effects:

- Flash Flood (mid-winter ice jam)
- Drought (lack of natural water storage)
- Ecological impacts (salmon survival rate, blooming season)

1. Changes in timing of winter-spring streamflow over North America is still detectable?
2. What are key drivers of the changes in timing of spring-winter streamflow? Global warming or internal (multi-decadal) variability?

# How to Define Timing of Winter-Spring Streamflows



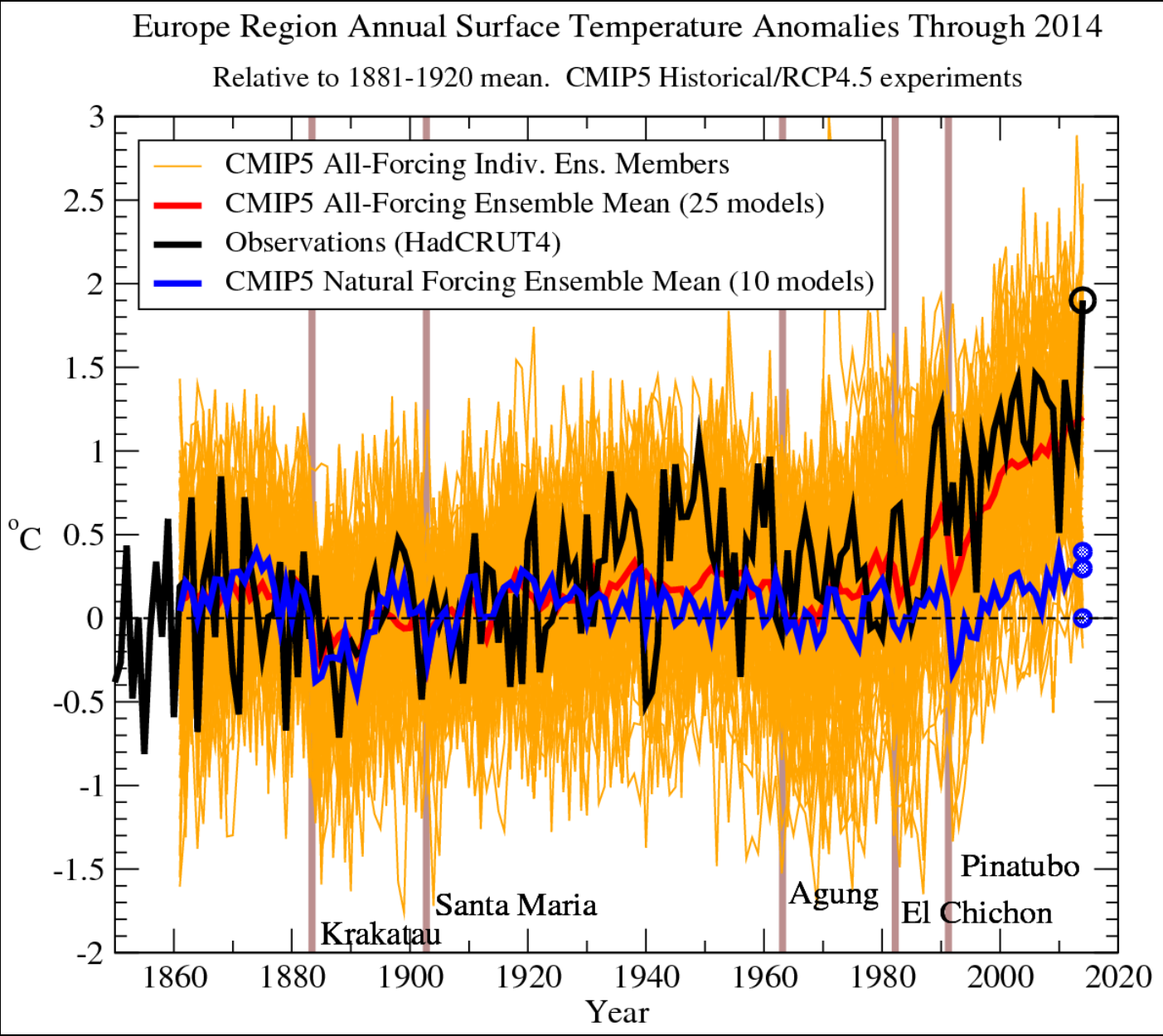
Winter-Spring Center of Volume:

- Half of accumulated daily discharge volume from the start to the end of a year or season.
- Accumulating period: January through June of a calendar year

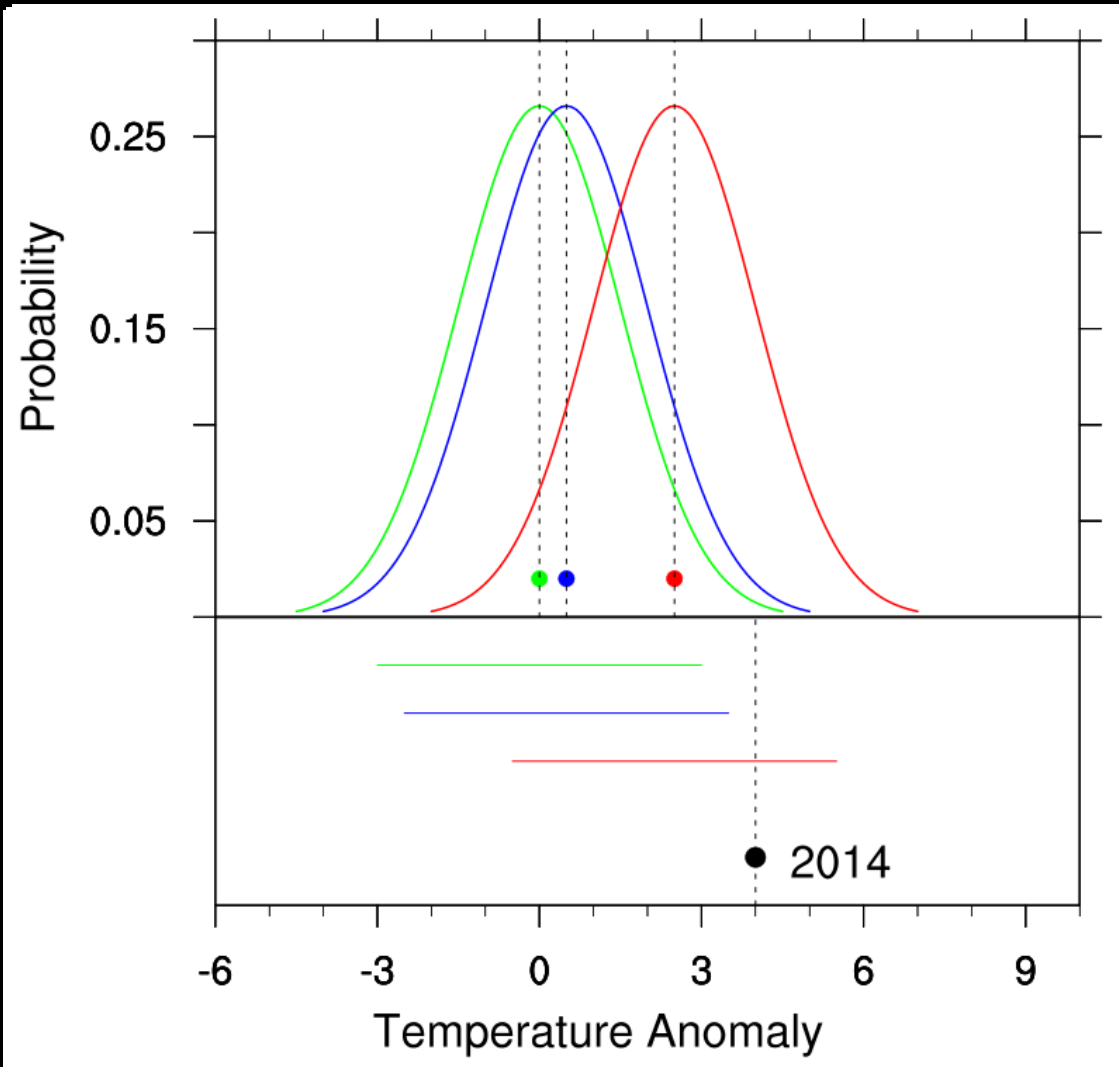
Winter-Spring Time of Center Volume:

- the first date by which winter-spring center of volume or more passes by a gauge station

# Climate Model Experiment Design: CMIP5



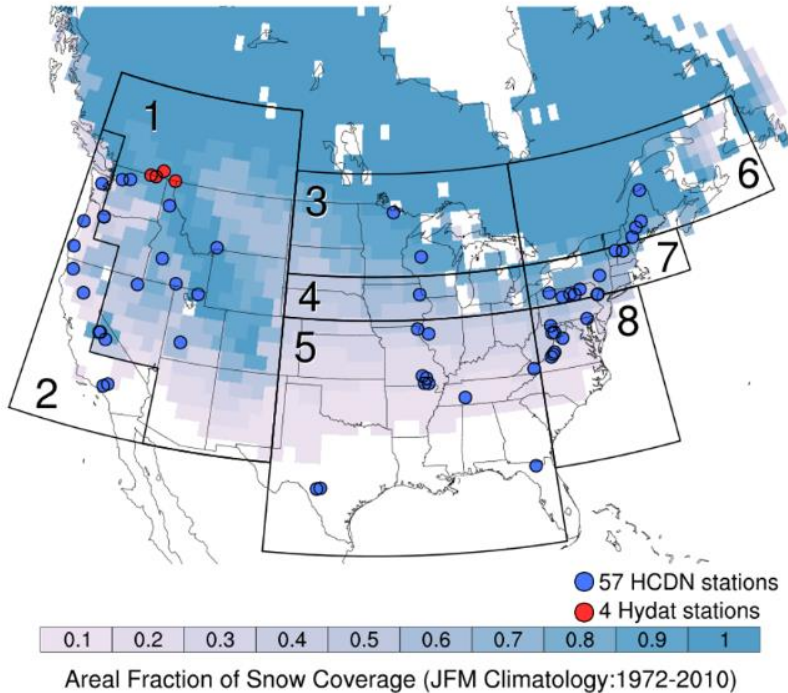
# Detection and Attribution of Anthropogenic Influence



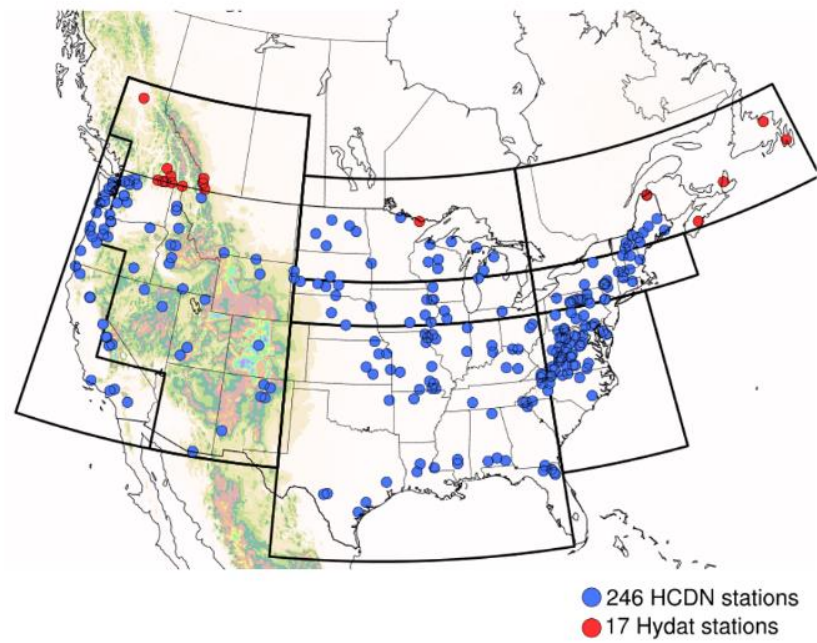
**Obs**  
**piCont (unforced)**  
**historicalNat (natural forcing)**  
**Historical (natural forcing + anthropogenic forcing)**

# Observed and Simulated Monthly Runoff Data

(a) 61 HCDN & Hydat Stations (1933-2012)



(b) 263 HCDN & Hydat Stations (1951-2000)



Monthly discharge records: USGS HCDN and HYDAT (Canada) stations

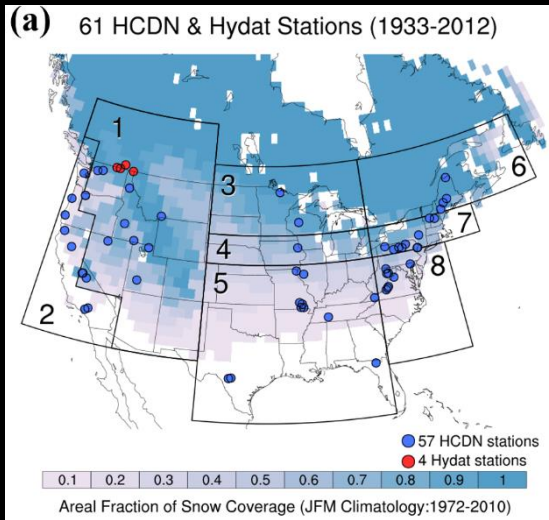
Winter-spring Streamflow Center Time (WSCT):

$$WSCT = \frac{0.5*q_1 + 1.5*q_2 + 2.5*q_3 + 3.5*q_4 + 4.5*q_5 + 5.5*q_6}{\sum_{i=1}^6 q_i} \text{ [months] Eqn. 1}$$

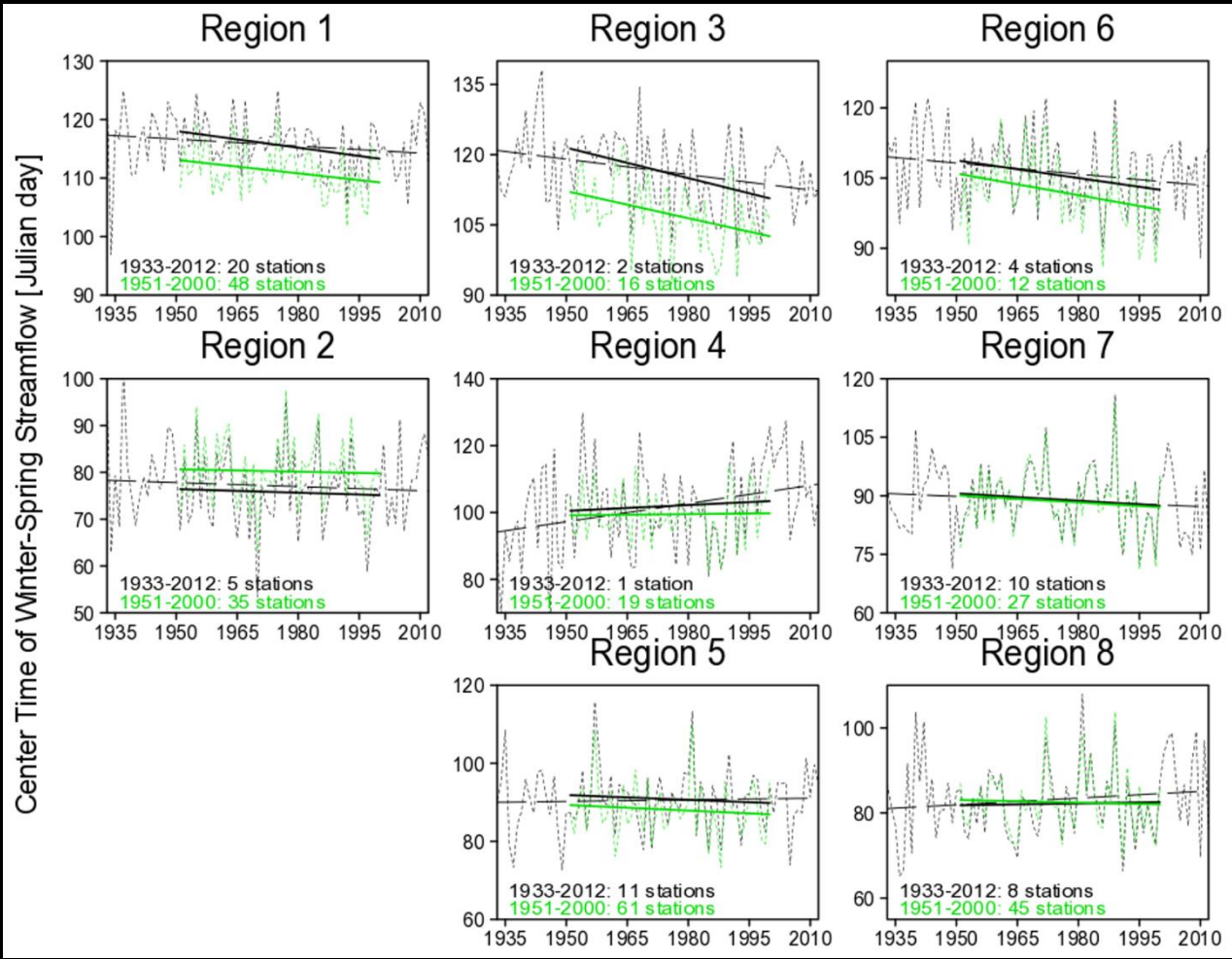
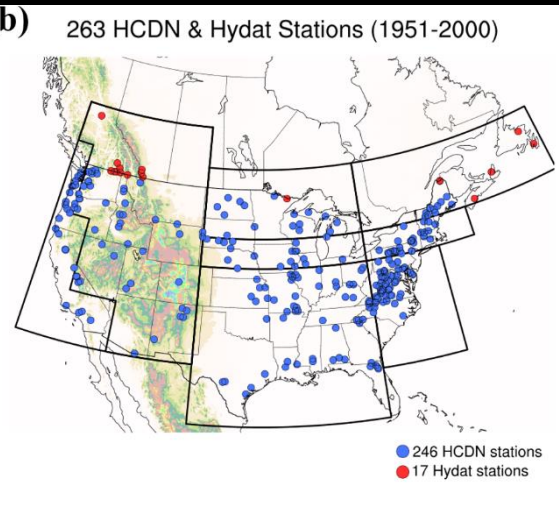
$$= \frac{\sum_{i=1}^6 (t_i - 0.5)q_i}{\sum_{i=1}^6 q_i} * \left(\frac{181 \text{ days}}{6 \text{ month}}\right) \text{ [DOY] Eqn. 2}$$

# Longer records but fewer gage stations?

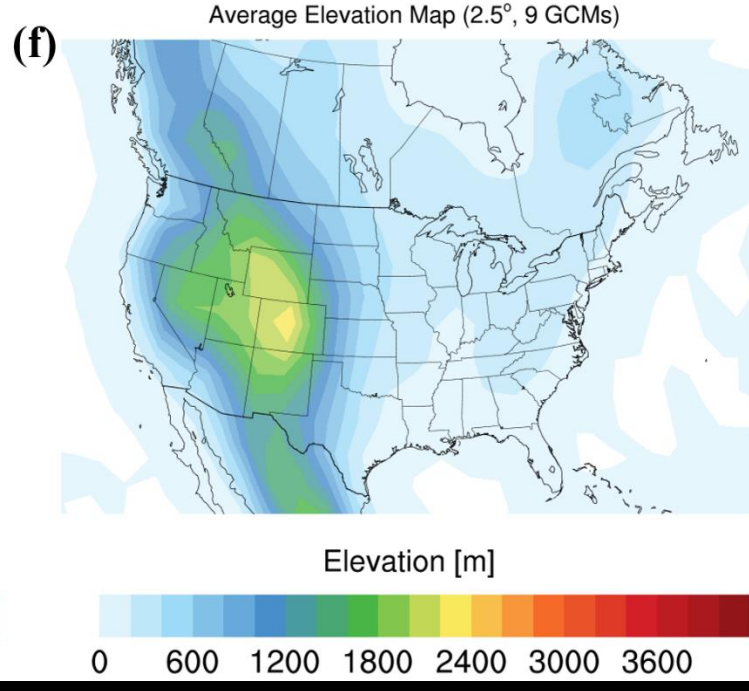
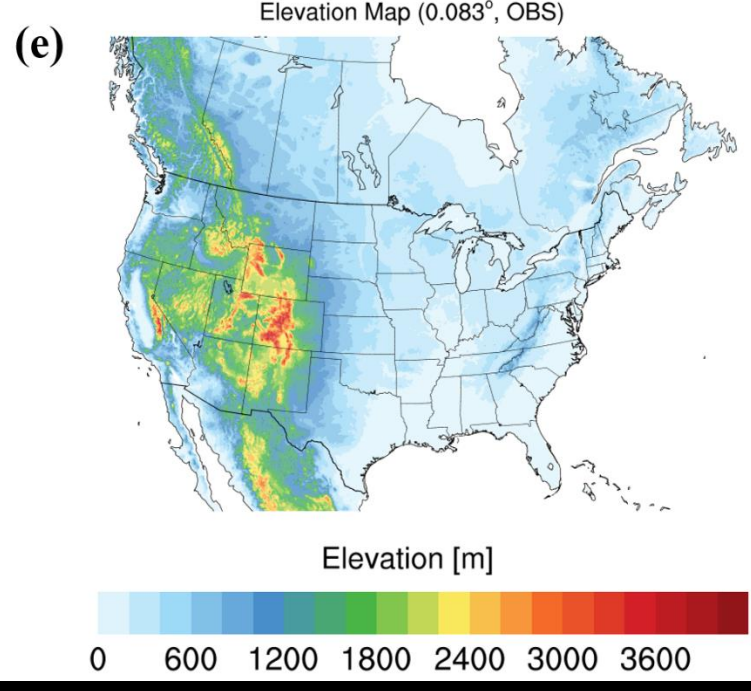
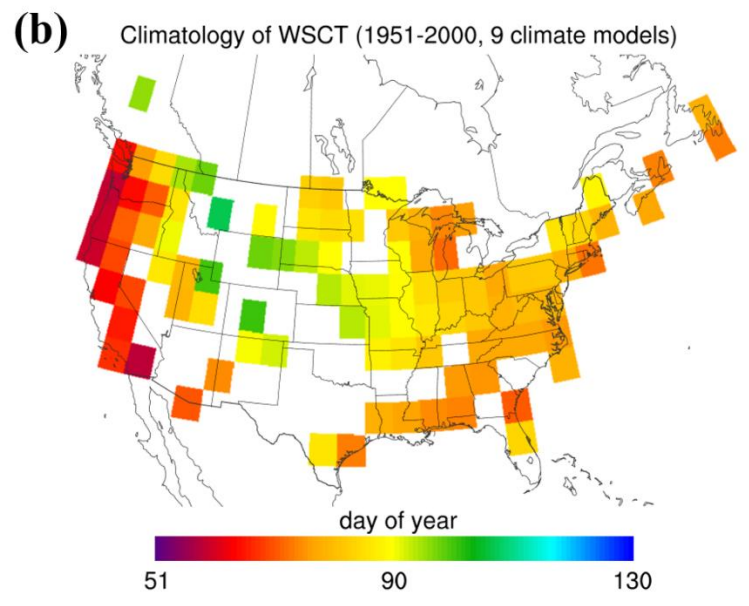
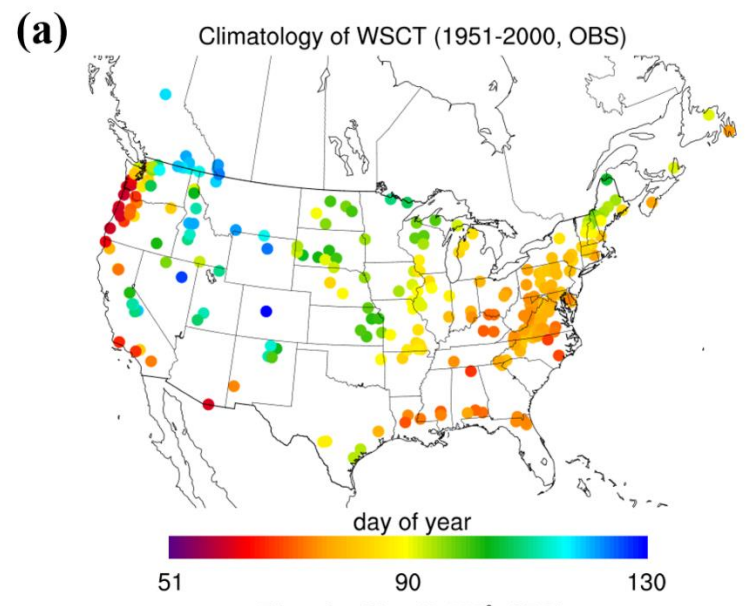
## 80 years (1933-2012; black)



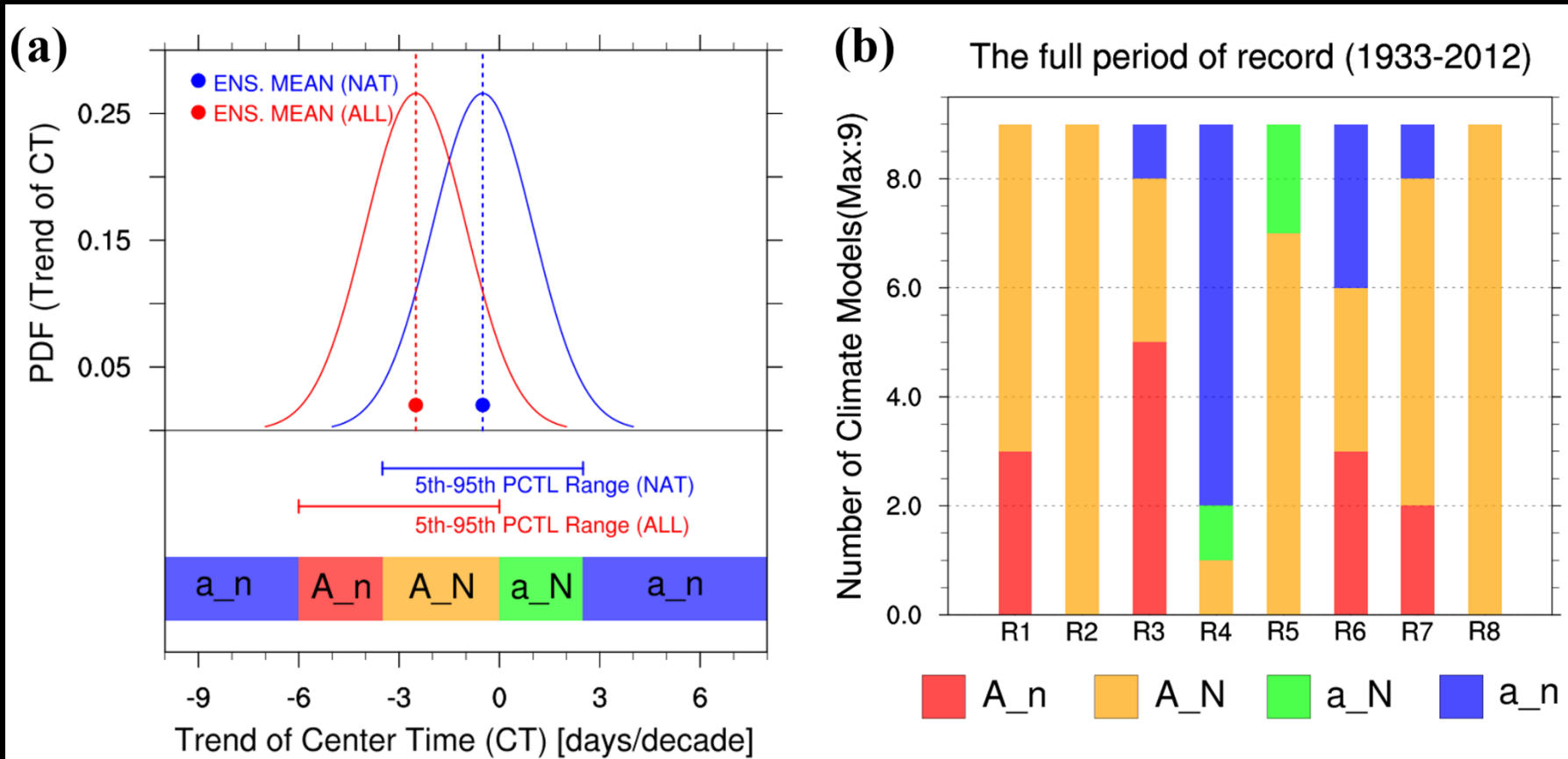
## 50 years (1951-2000; green)



# WSCT Climatology and Elevation Map: Obs. vs CMIP5



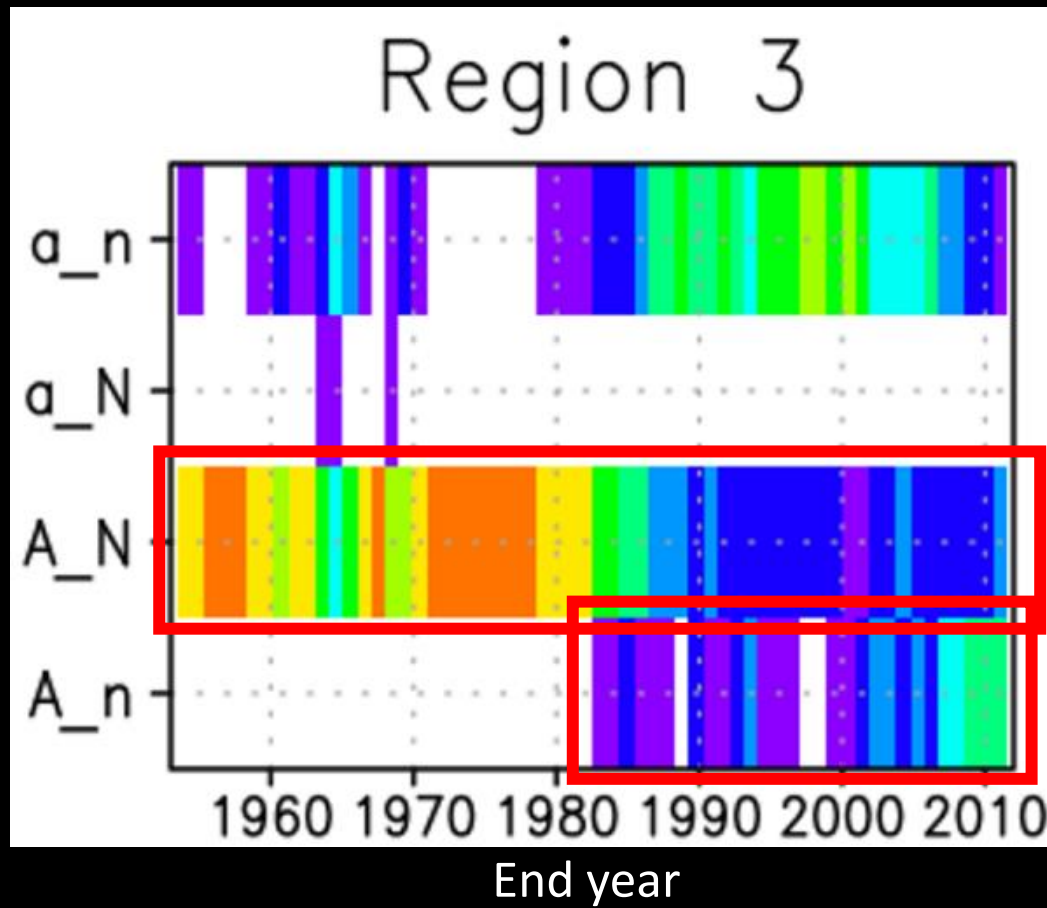
# Detection and Attribution of Changes in WSCT



Definition of a robust evidence for detectable anthropogenic influence: five of nine models are in **A\_n**.

The robust evidence are found in R3.

# Sliding Trend Analysis of WSCT: An Example



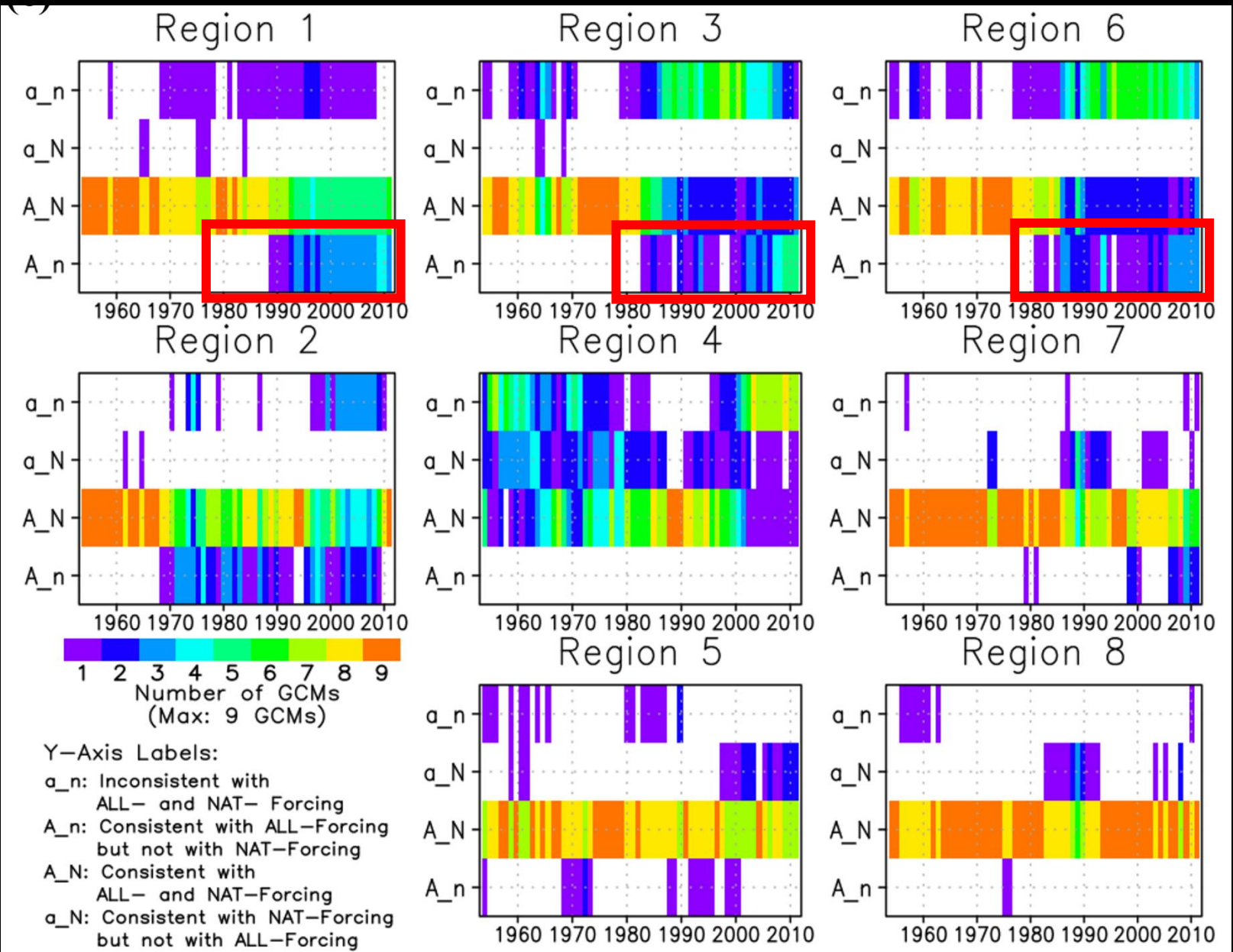
A\_N: Insensitive to anthropogenic forcings

A\_n: Sensitive to anthropogenic forcings

(with a common start year, 1933)



# Sliding Trend Analysis of WSCT: 8 Regions



# Summary

1. The most robust evidence for detectable anthropogenic influence (five of nine models) is in north-central U.S., where streamflows have been coming earlier.

2. Marginal evidence for a detectable anthropogenic influence was found in the mountainous western U.S./southwestern Canada and in extreme northeastern U.S./Canadian Maritimes.

3. In the mountainous western U.S./southwestern Canada, a recent shift toward later streamflow onset was rendered the full-record trend toward earlier onset significant.

4. In extreme northeastern U.S./Canadian Maritimes, the forced responses from several models are inconsistent with the detectable observed earlier streamflow onset.

**Take-Home Message:** North-central U.S. is more vulnerable for drought and flood in next decades likely due to the anthropogenic influence.

# Question?

## **Increased Drought and Pluvial Risk over California due to Changing Oceanic Conditions**

JONGHUN KAM AND JUSTIN SHEFFIELD

*Department of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey*

(Manuscript received 10 December 2015, in final form 18 August 2016)

J. Climate 2016

### **References:**

Kam et al., Record annual-mean warmth over Europe, the northeast Pacific, and the northwest Atlantic during 2014: Assessment of anthropogenic influence, *Bull. Amer. Meteor. Soc.*, 96, S61-S65 (2015).

Kam, J., T. R. Knutson, and P. C. D. Milly, 2016, Climate model assessment of changes in winter-spring streamflow timing over North America. (in review)

Cayan, D. R., Kammerdiener, S. A., Dettinger, M. D., Caprio, J. M. & Peterson, D. H., Changes in the Onset of Spring in the Western United States. *Bulletin of the American Meteorological Society* 82, 399-415 (2001).

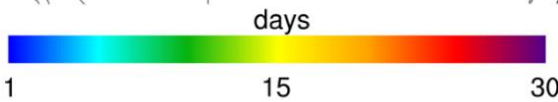
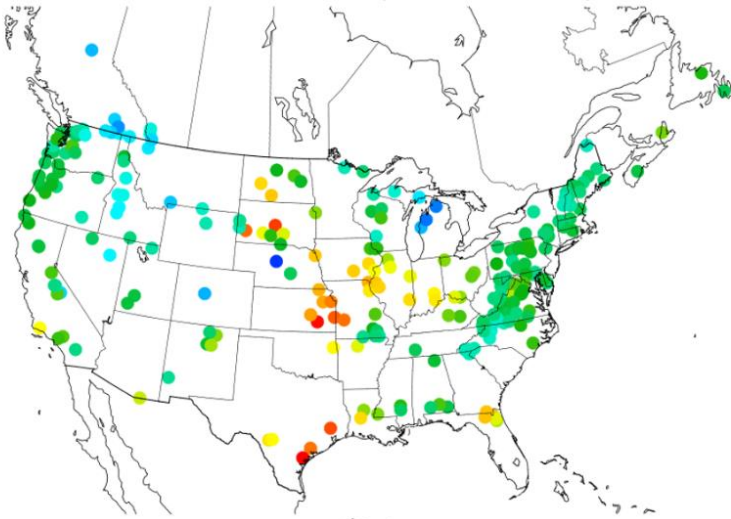
Hodgkins, G. A. & Dudley, R. W., Changes in the timing of winter-spring streamflows in eastern North America, 1913-2002. *Geophysical Research Letters* 33, L06402 (2006).



# WSCT Inter-annual Variability: Obs. vs CMIP5

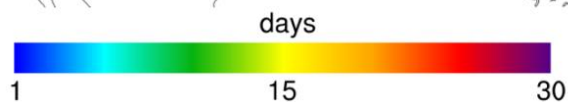
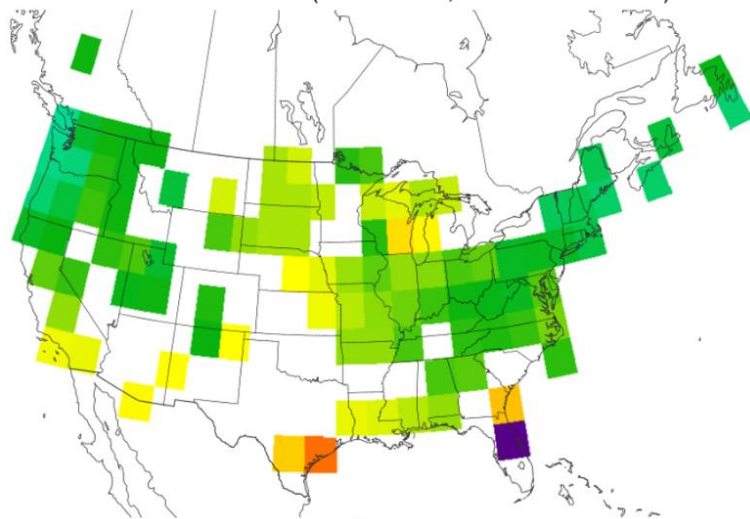
(c)

Std. Dev. of WSCT (1951-2000, OBS)

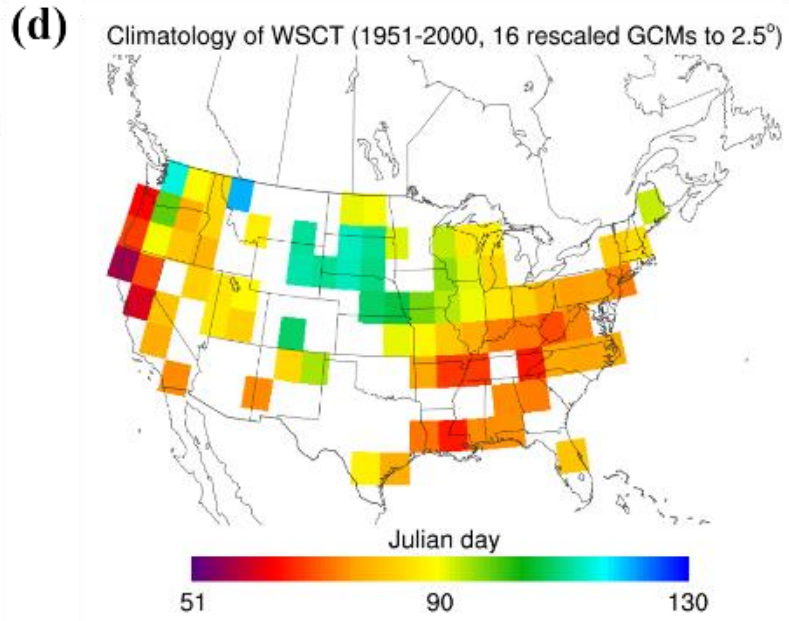
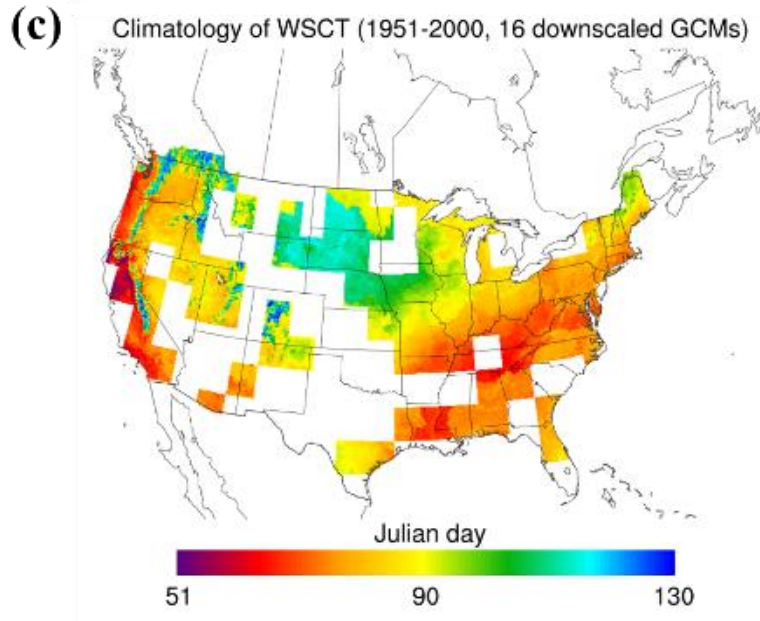
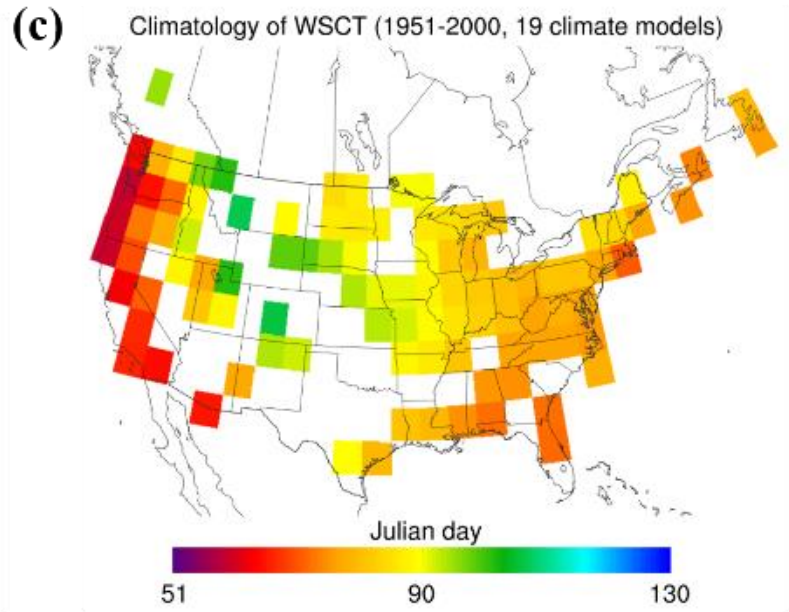
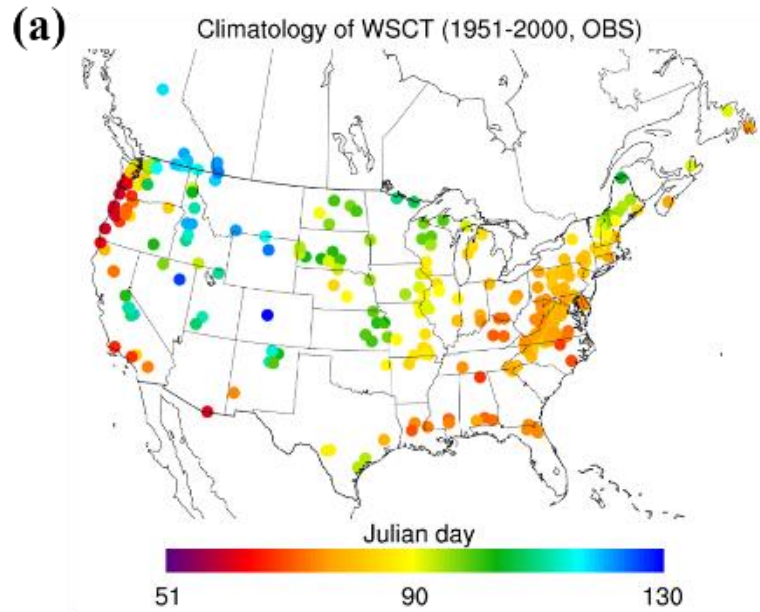


(d)

Std. Dev. of WSCT (1951-2000, 9 climate models)

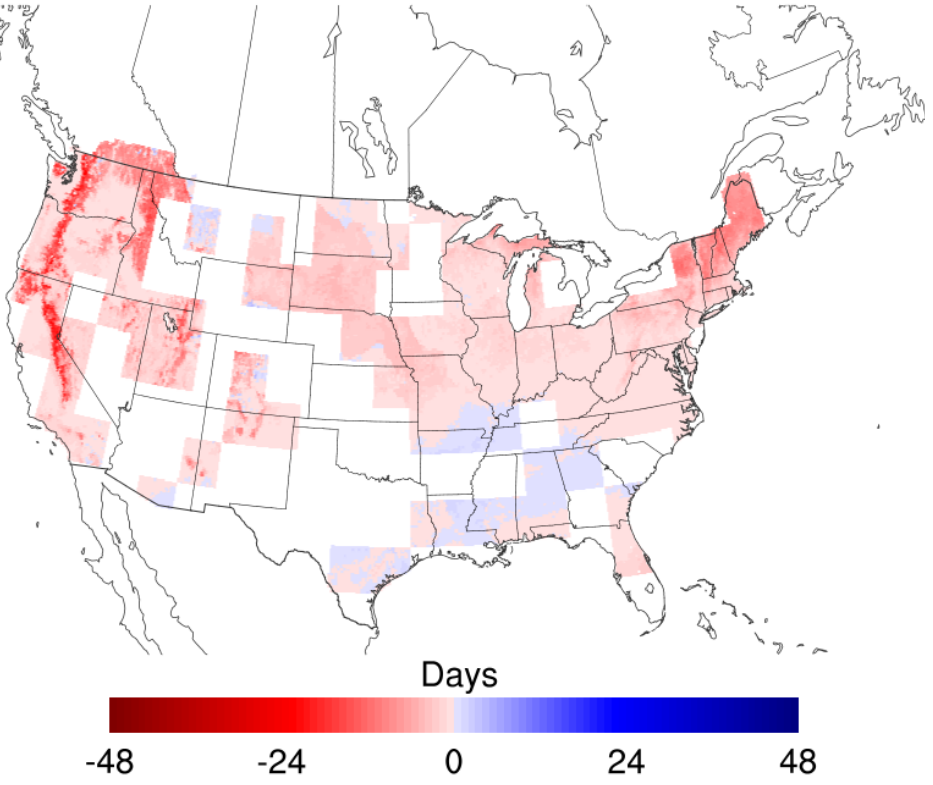


# Impact of downscaling

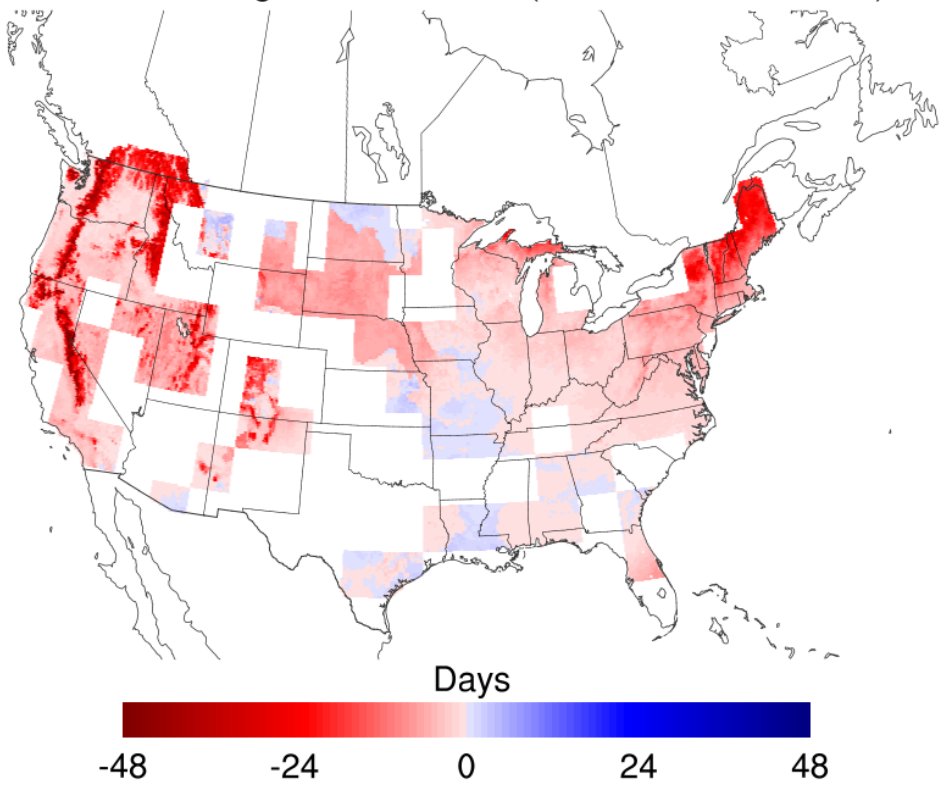


# Future Changes in WSCT from Downscaled CMIP5

WSCT Changes in 2006-2050 (16 downscaled GCMs)



WSCT Changes in 2056-2099 (16 downscaled GCMs)



# Temperature dominant vs Rainfall dominant?

