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***31 May - 11 June, 2010***

# Future hydrological changes in United States: Methods and projections

M. Ashfaq and N. Diffenbaugh

*Stanford University*
*USA*

Near term

# Future hydrological changes in United States: Methods and projections

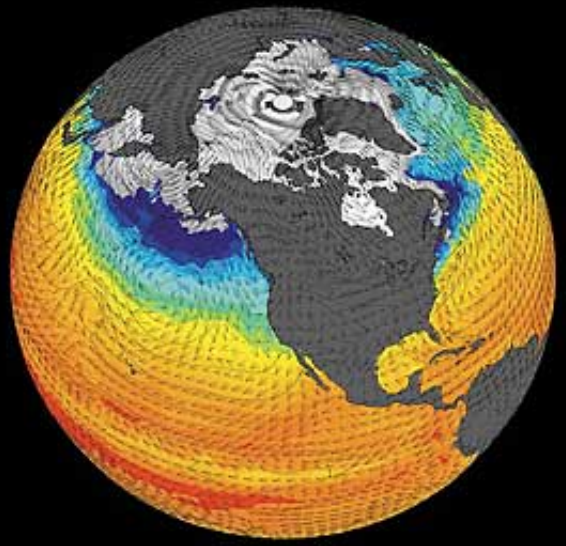
Moetasim Ashfaq, Noah Diffenbaugh

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

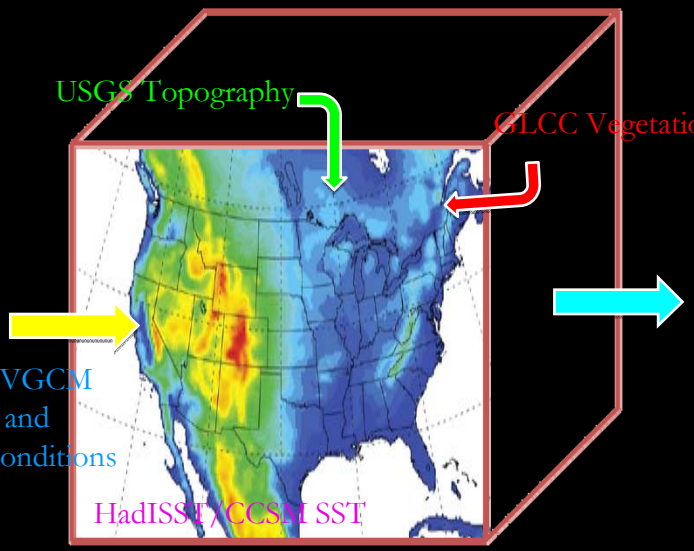
STANFORD UNIVERSITY
SCHOOL OF EARTH SCIENCES

PURDUE
UNIVERSITY

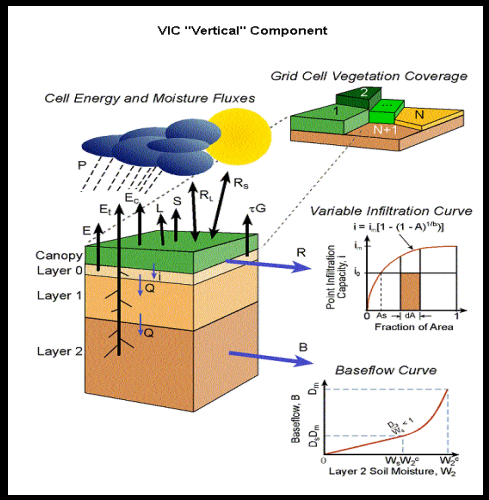
## GCM



## RegCM3




## VIC



# PART ONE - Methods

# Science Questions

How do

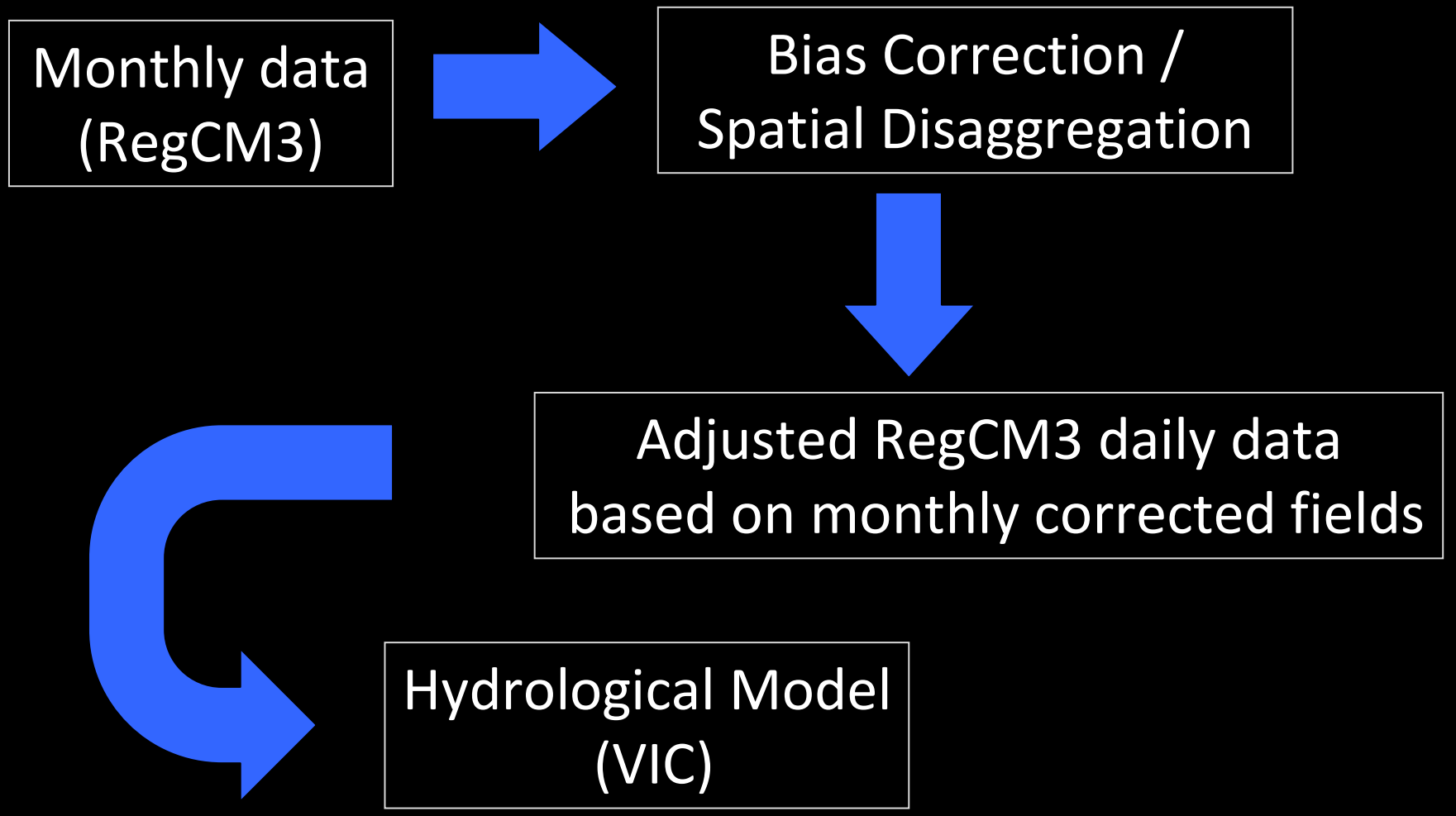
1) "Biases" in climate model data
2) Changes in the "occurrence and intensity" of daily extremes
3) Changes in the "daily distributions"

affect process-based hydrological assessments

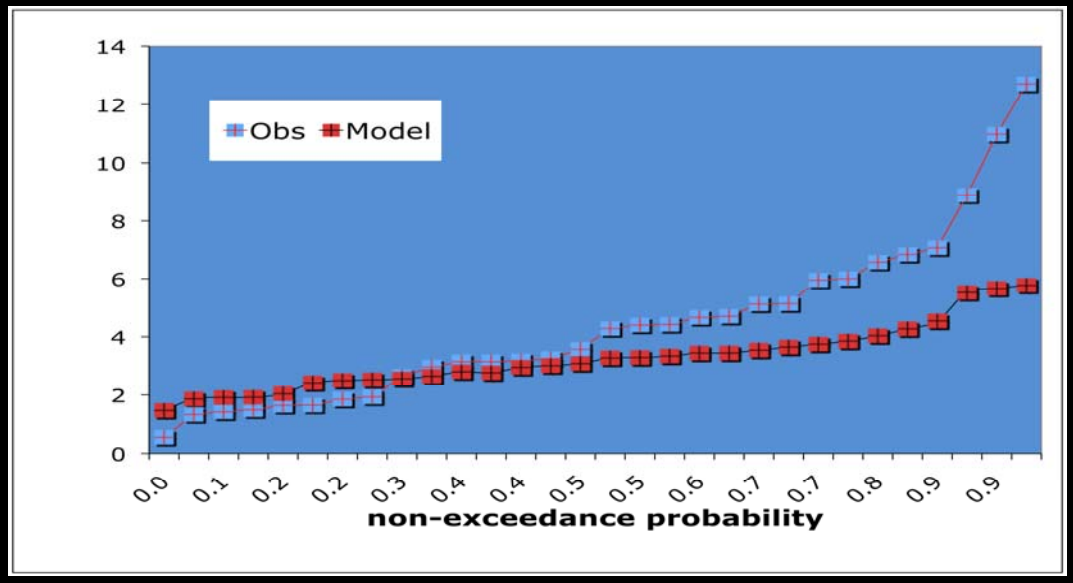
# Experimental Details

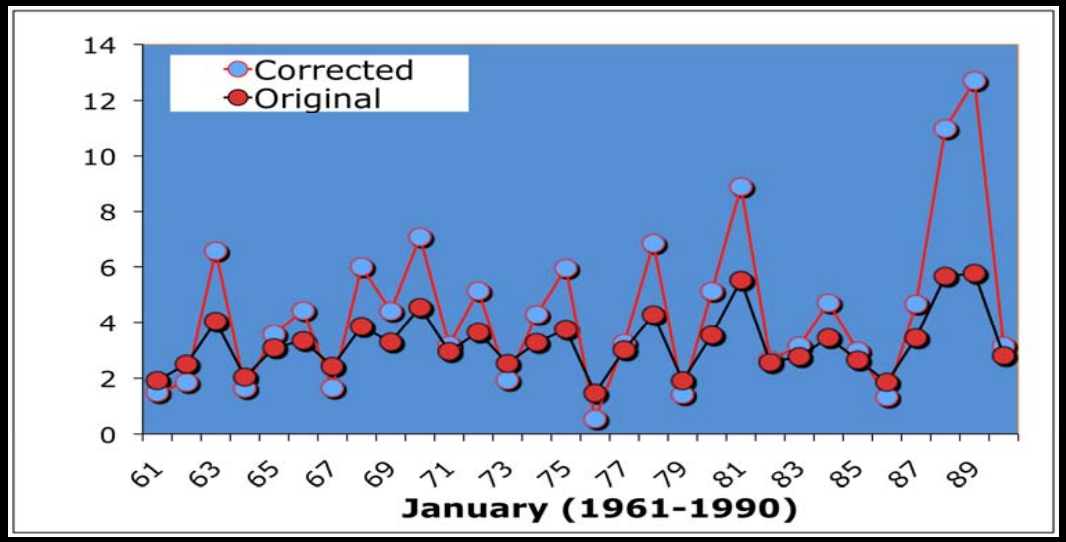
| | Historic Period (**1961-1990**) | Future Period (**2071-2100**) |
|---|---|---|
| Driving Data | | |
| RegCM3-***ORG*** | ***Original*** daily precipitation, minimum temperature, maximum temperature, surface winds | ***Original*** daily precipitation, minimum temperature, maximum temperature, surface winds |
| RegCM3-***BC*** | ***Bias-corrected*** daily precipitation, minimum temperature, maximum temperature, original surface winds | ***Bias-corrected*** daily precipitation, minimum temperature, maximum temperature, original surface winds (***Bias correction applied to the future period daily values***) |
| RegCM3-***BCD*** | Same as RegCM3-***BC*** | Bias-corrected daily precipitation, minimum temperature, maximum temperature, original surface winds (***Bias correction applied to the historic period daily values***) |
| ***OBS*** | Maurer et al, 2002 | |
| | | |
| Experiments | | |
| VIC-***ORG*** | RegCM3-***ORG*** | RegCM3-***ORG*** |
| VIC-***BC*** | RegCM3-***BC*** | RegCM3-***BC*** |
| VIC-***BCD*** | RegCM3-***BC*** | RegCM3-***BCD*** |
| VIC-***OBS*** | ***OBS*** | |

# Bias Correction Methodology

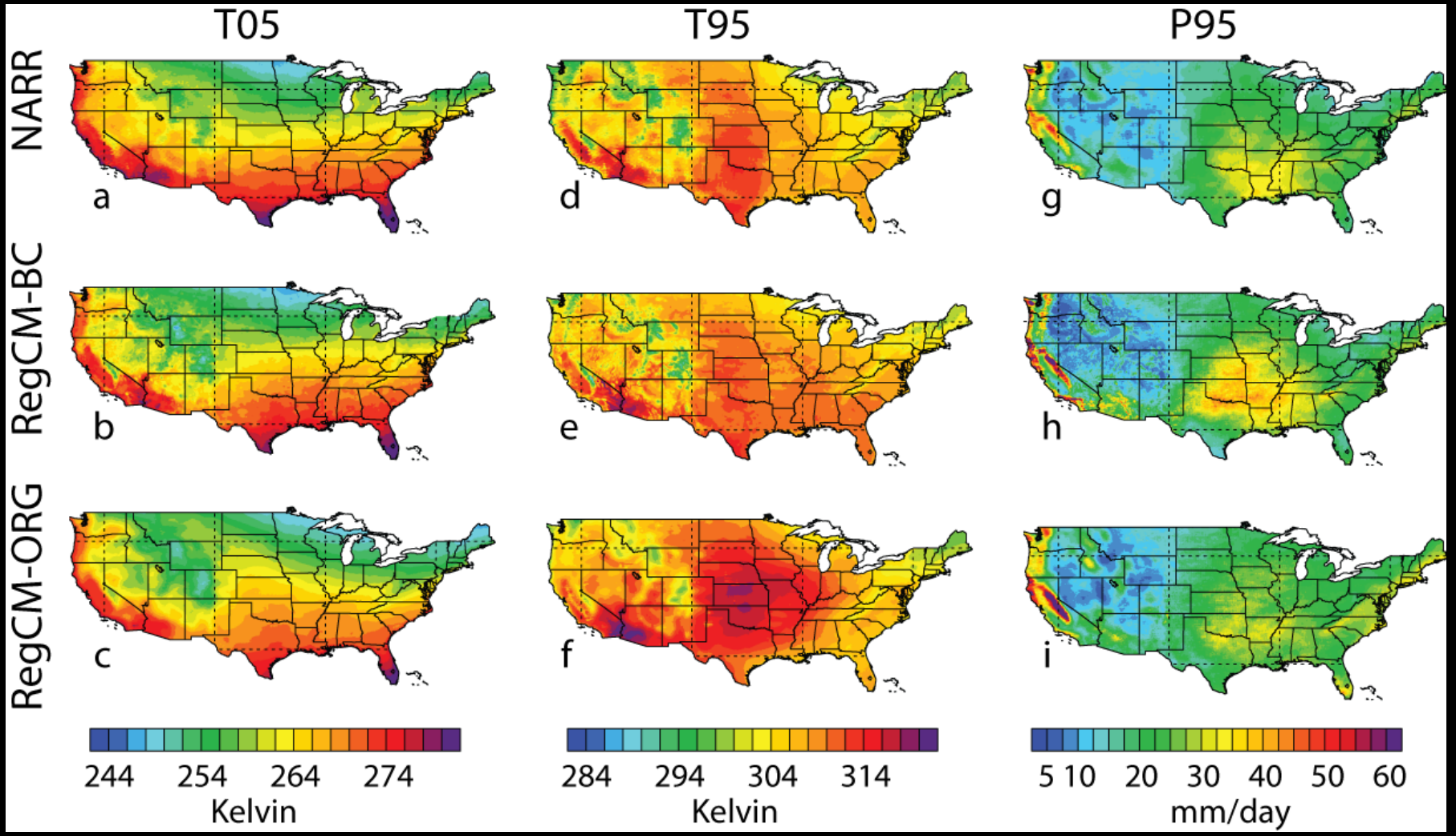


# Bias Correction Methodology



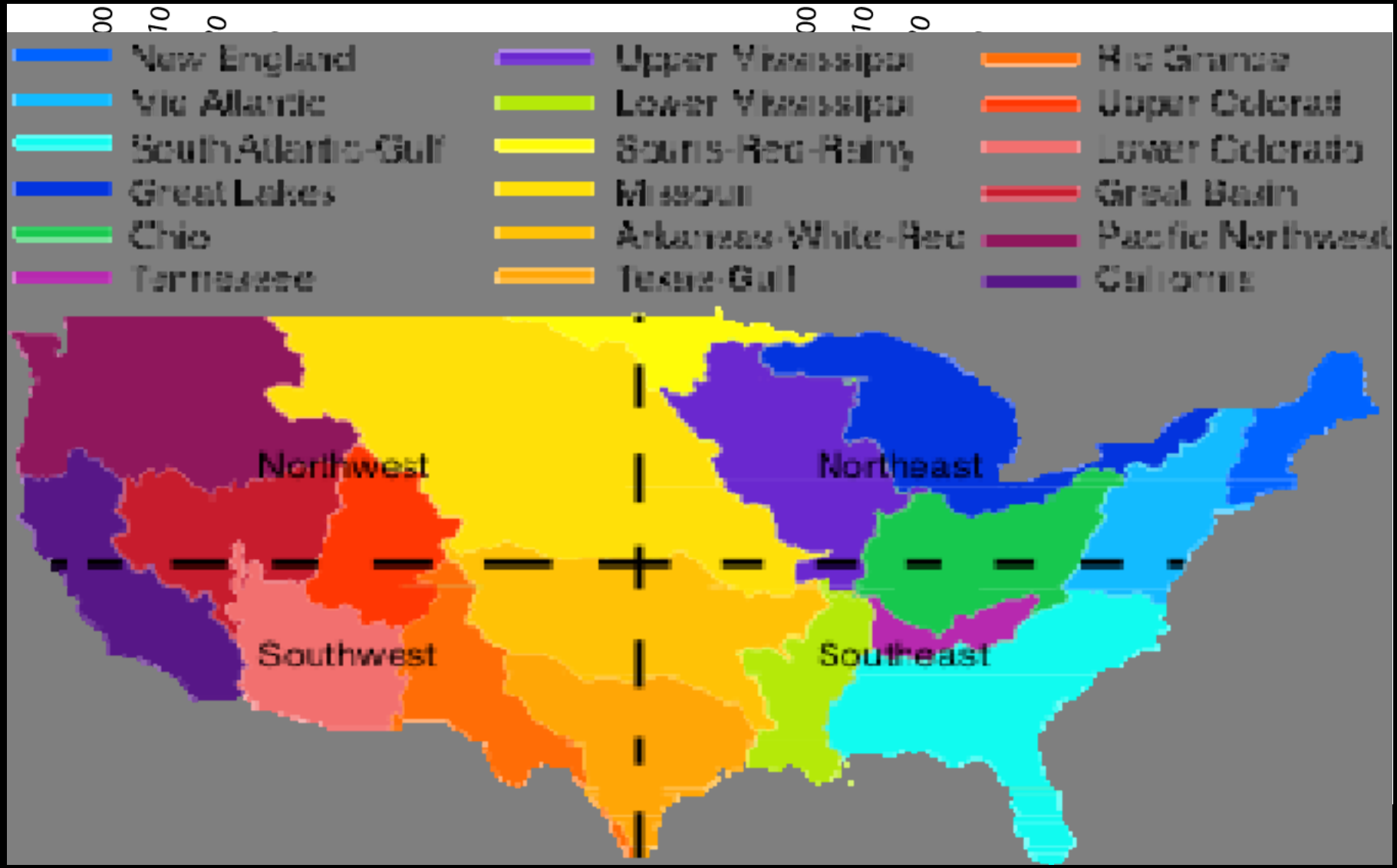



# Comparison of daily extremes in RegCM-BC and RegCM-ORG with daily extremes in NARR

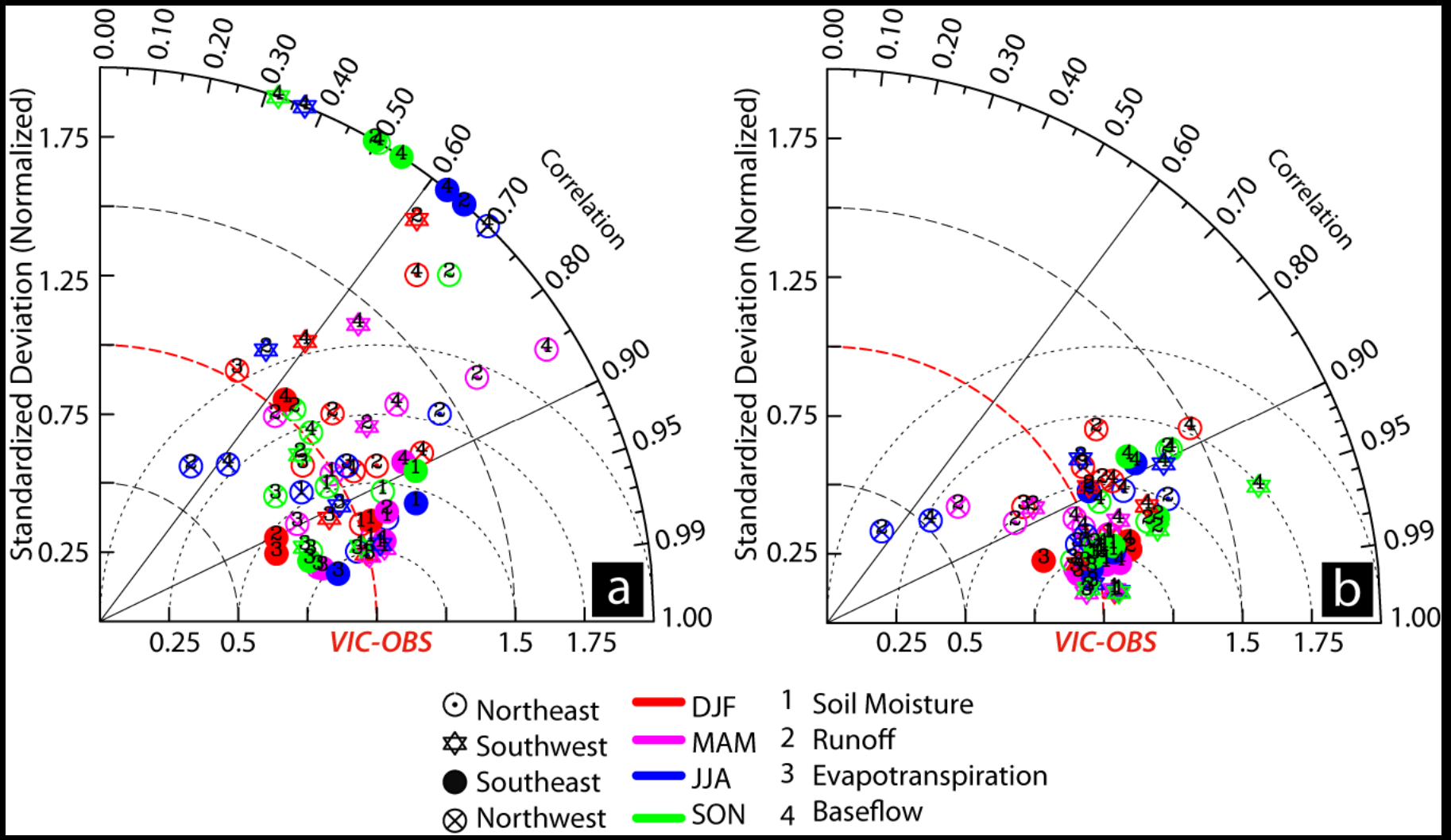


# Role of climate model biases

# Statistical comparison of VIC-OBS with VIC-ORG and VIC-BC – Taylor diagram



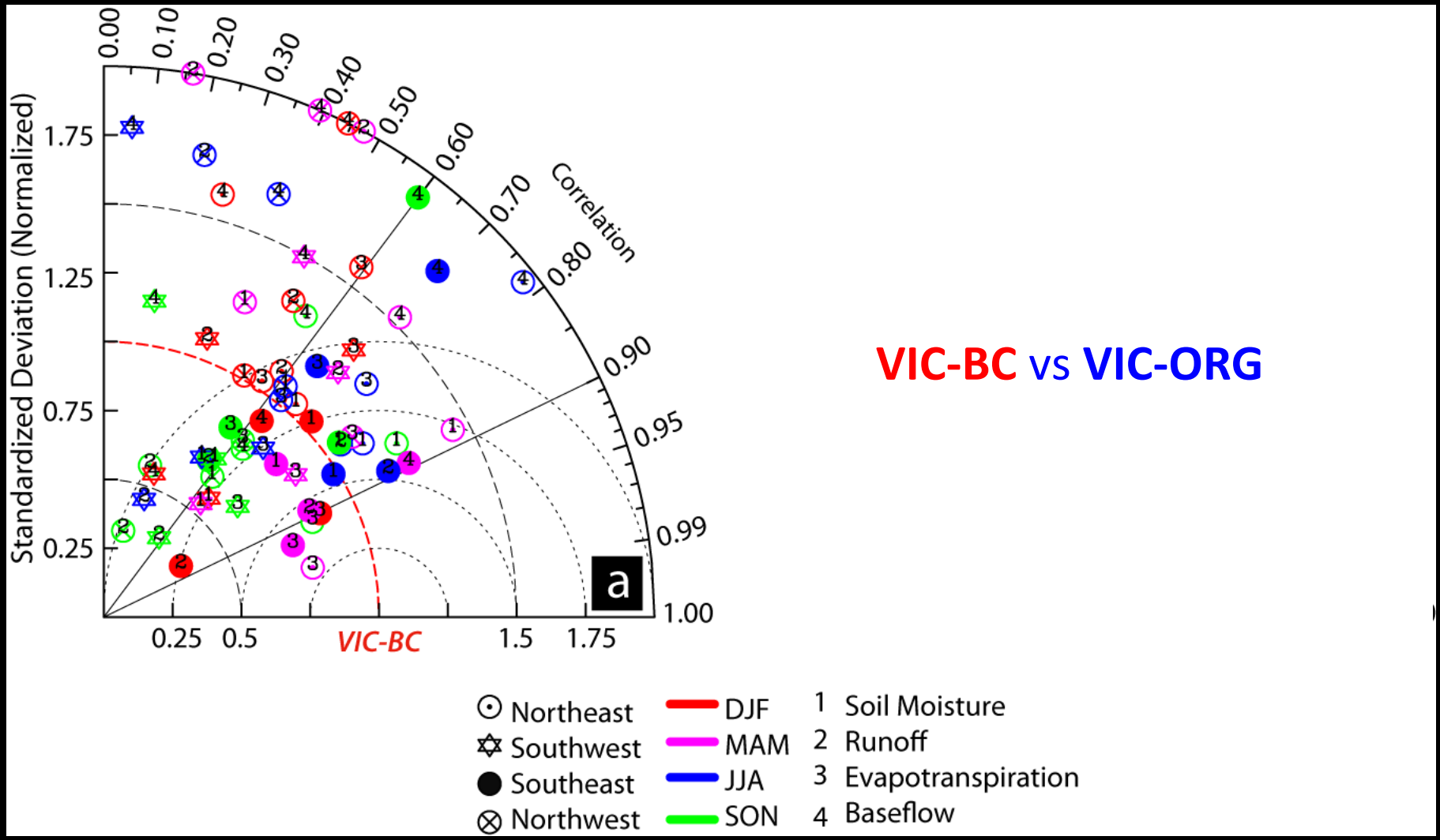
# Statistical comparison of VIC-OBS with VIC-ORG and VIC-BC – Taylor diagram




VIC-OBS vs VIC-ORG

VIC-OBS vs VIC-BC

# Statistical comparison of VIC-BC simulated changes with VIC-ORG simulated **changes** – Taylor diagram

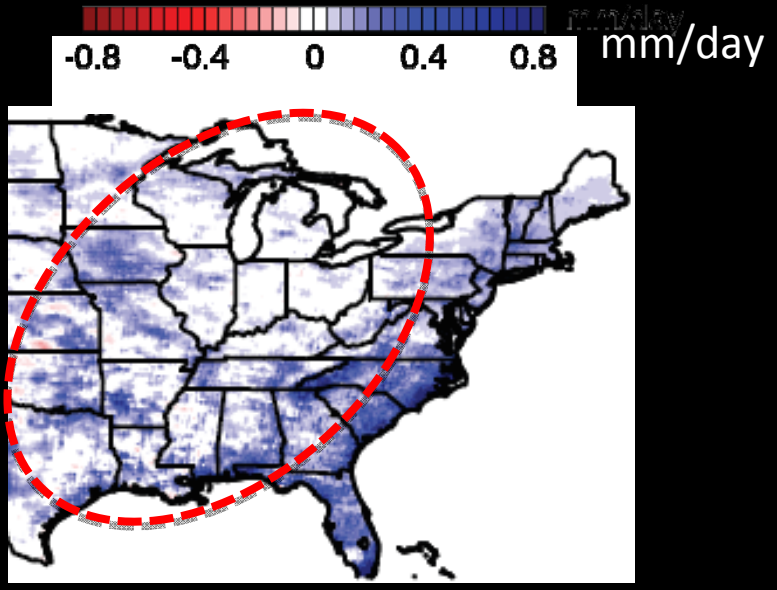



**VIC-BC** vs **VIC-ORG**

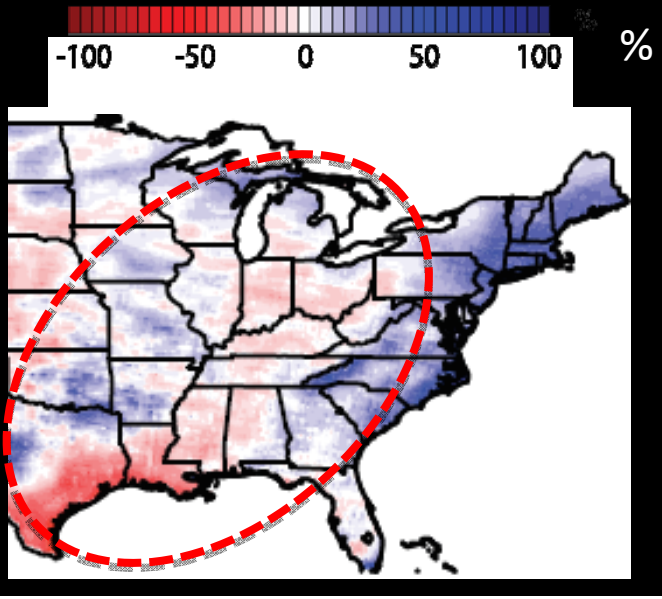
# Role of daily extremes

SPRING

## Surface Runoff

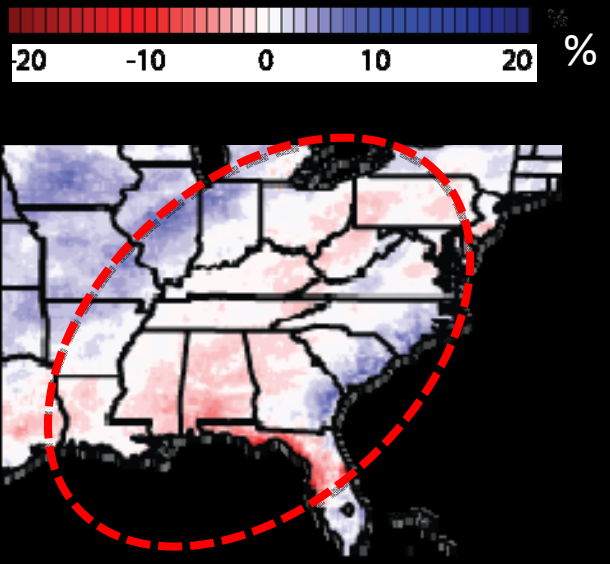



## Precipitation

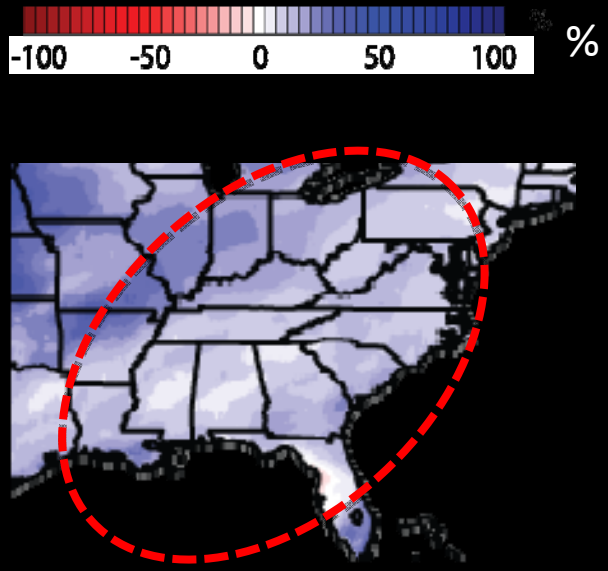



SUMMER

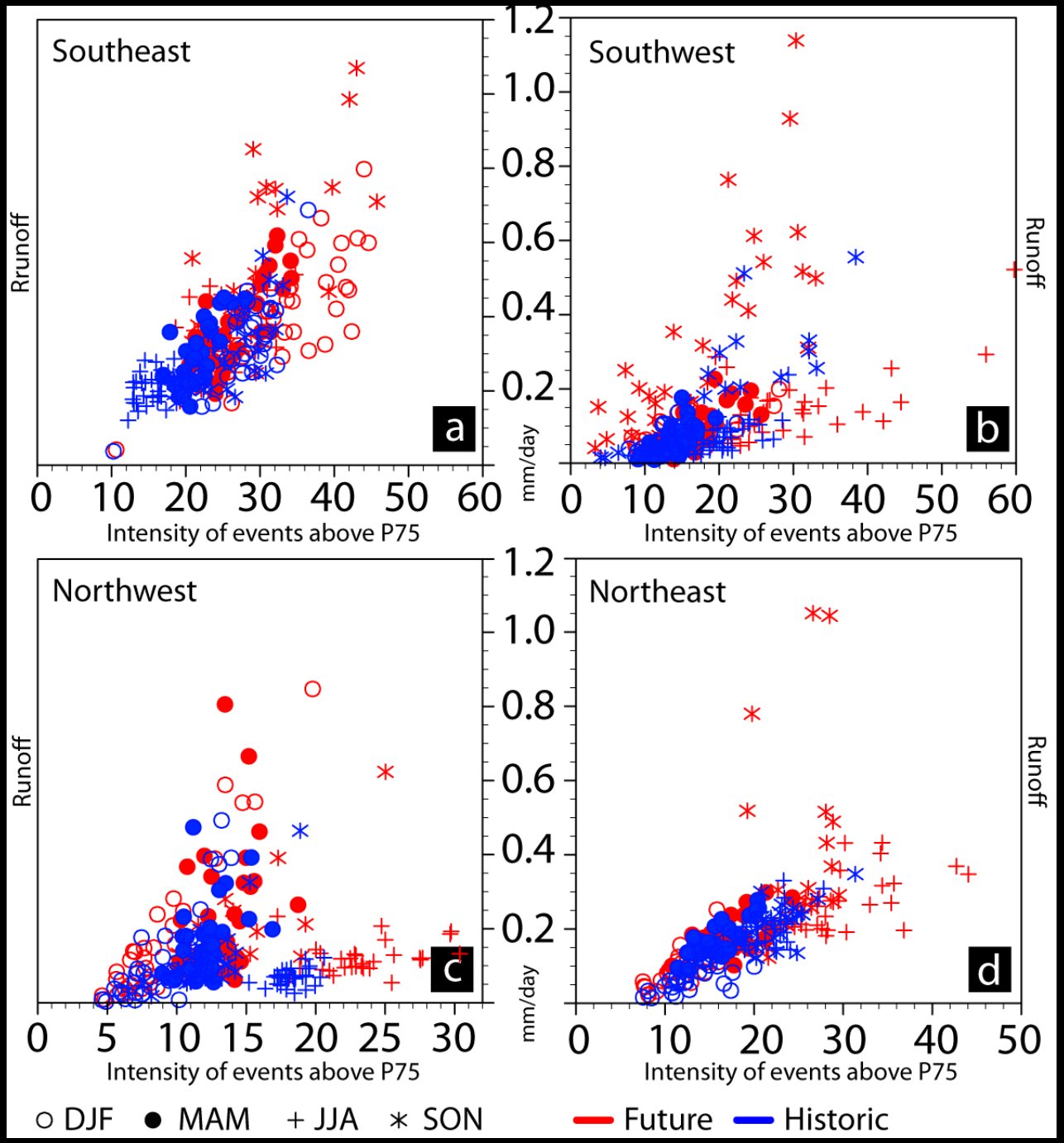
## Soil Moisture




## Precipitation

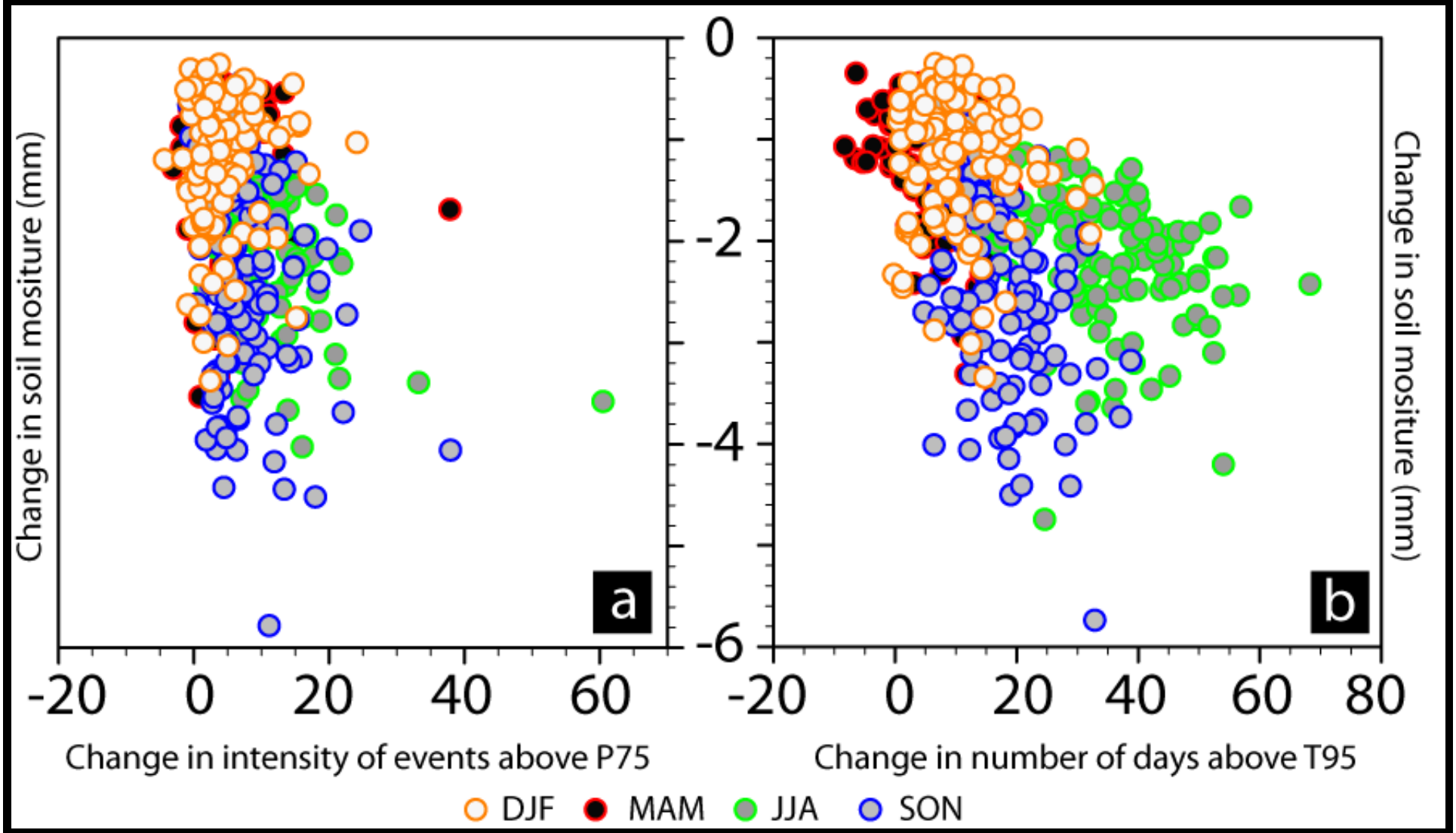


**“Runoff”** versus **“Intensity of heavy precipitation events”**



“Changes in the Soil Moisture”
versus
“changes in the intensity of heavy precipitation events”

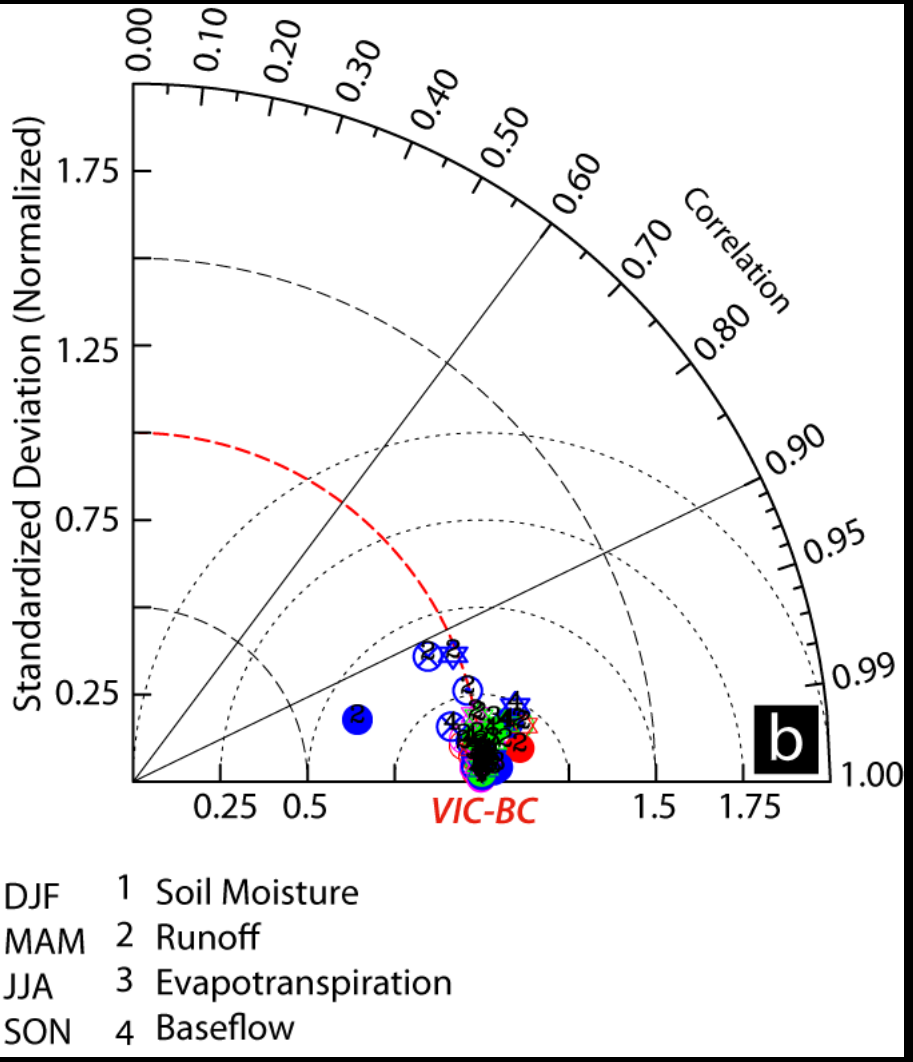
“Changes in the Soil Moisture”
versus
“changes in the occurrences of extreme hot days”



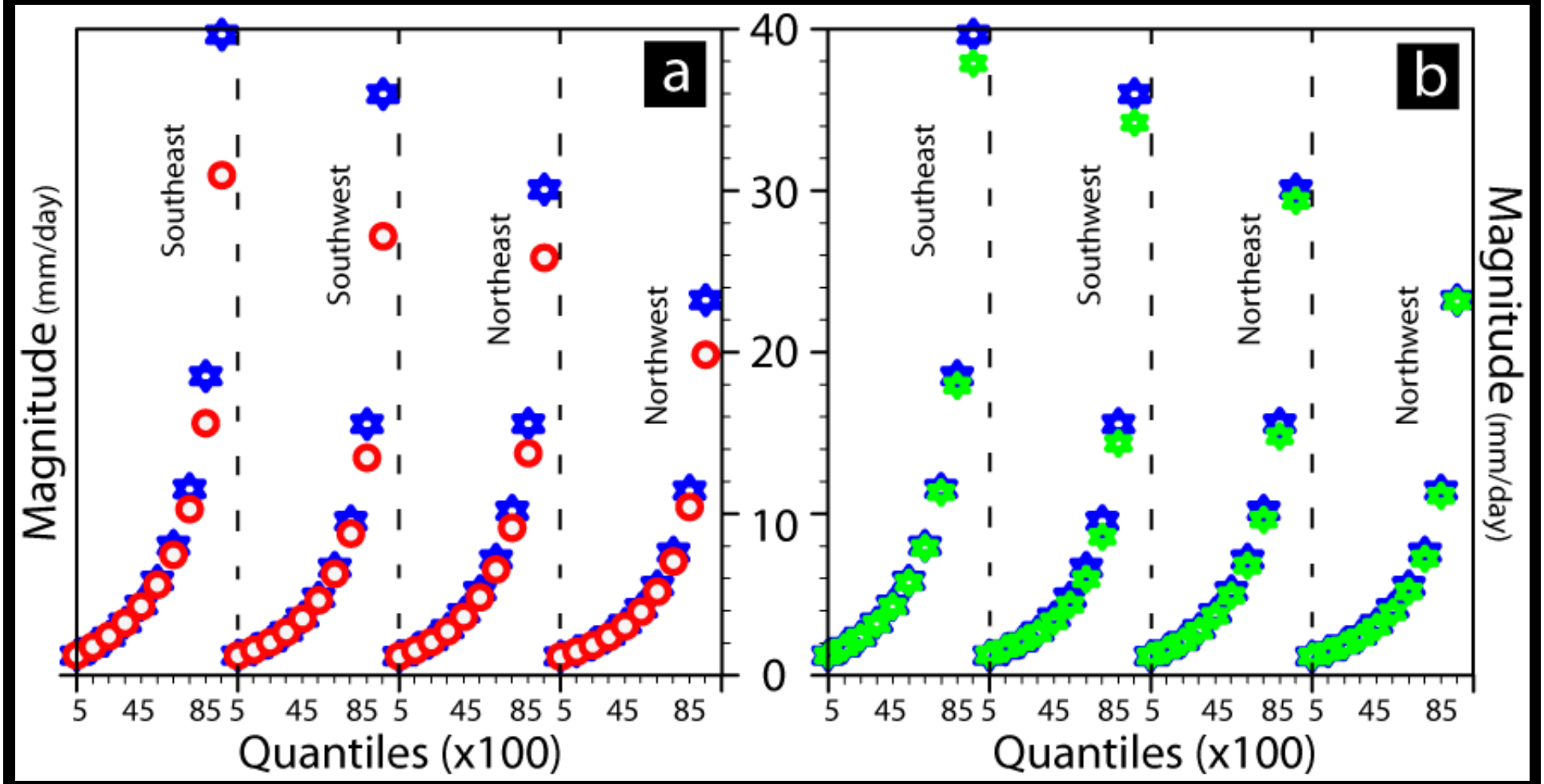
# Role of changes in daily distributions

# Statistical comparison of VIC-BC simulated changes with VIC-BCD simulated **changes** – Taylor diagram

**VIC-BC** vs **VIC-BCD**



# Why are the "**simulated hydrologic changes**" NOT sensitive to the "**changes in daily distribution**"?




**Blue** = RegCM-BC "future period"

**Red** = RegCM-BC "historic period"

**Green** = RegCM-BCD "future period"

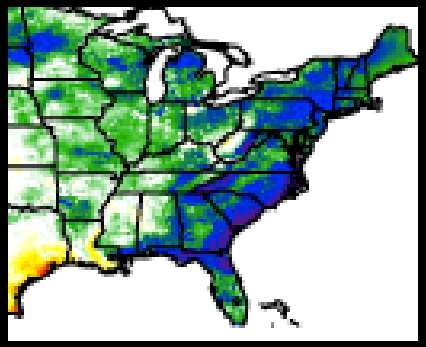
# However, ……

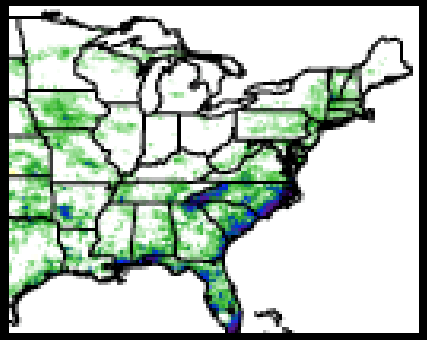
Evapotranspiration

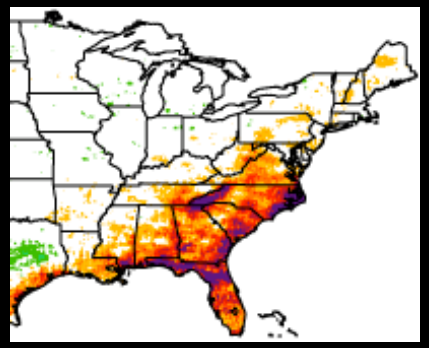
Runoff

Difference in P75 days
RegCM-BC minus RegCM-BCD

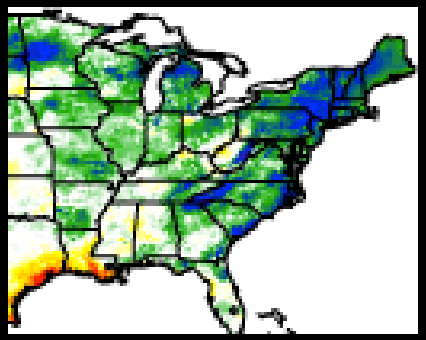
VIC-BC

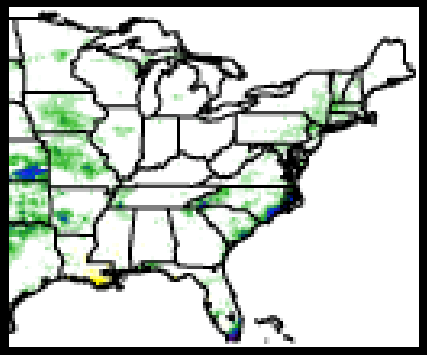




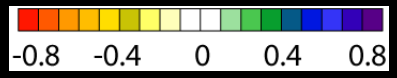


VIC-BCD

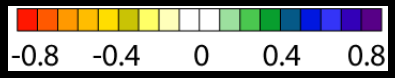





days/season




mm/day

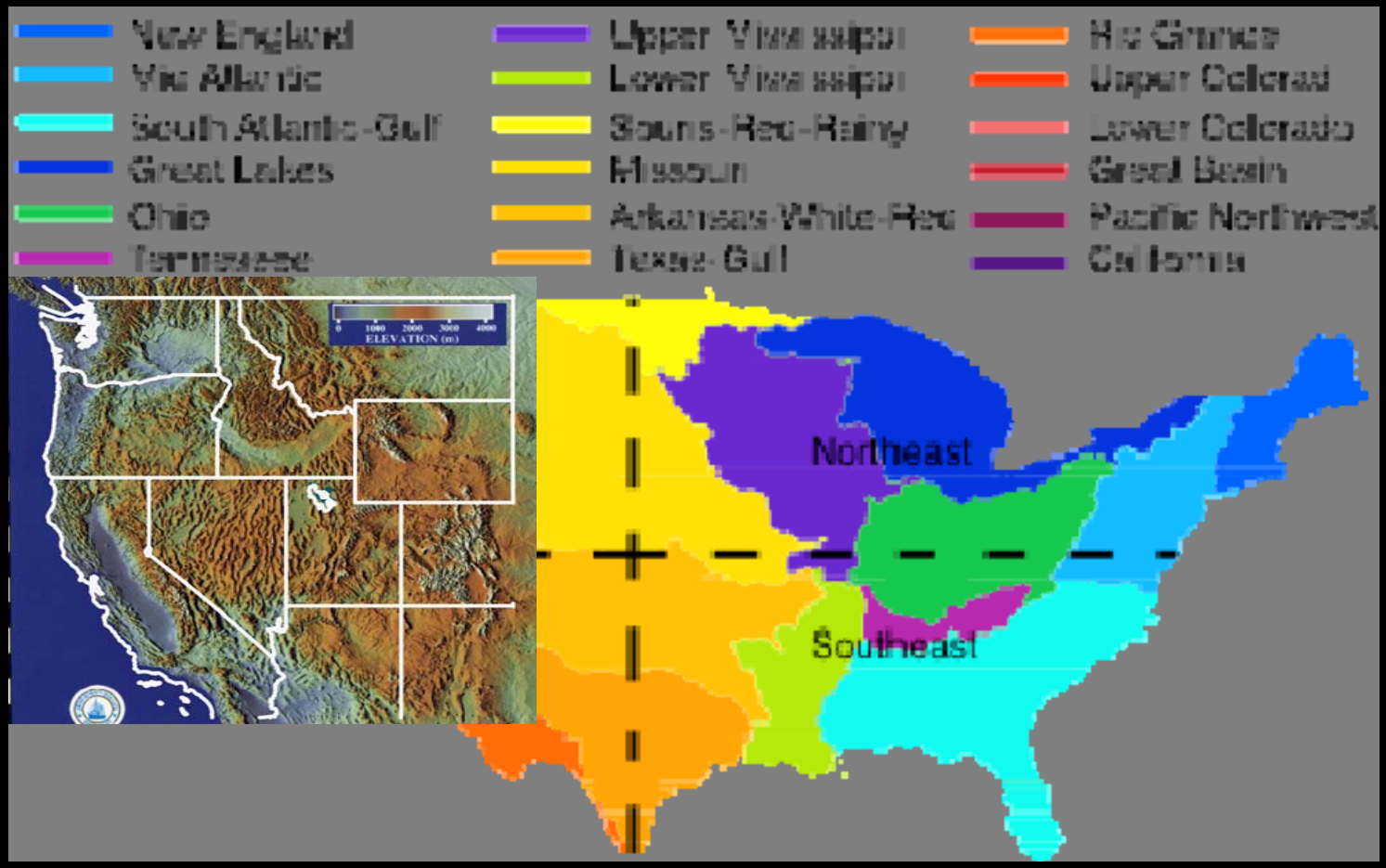



mm/day

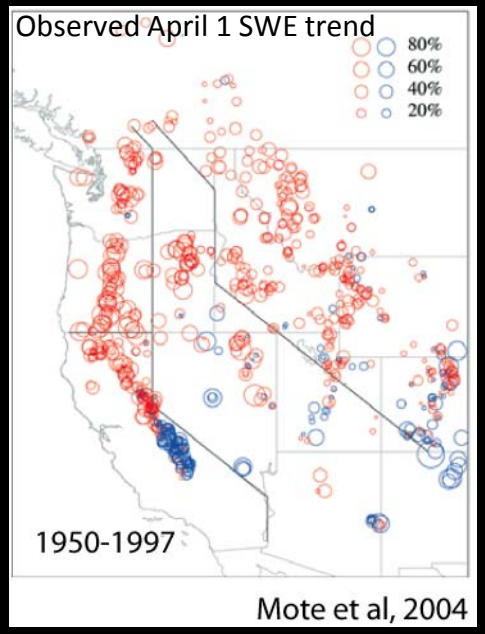
# PART II – **Projections**

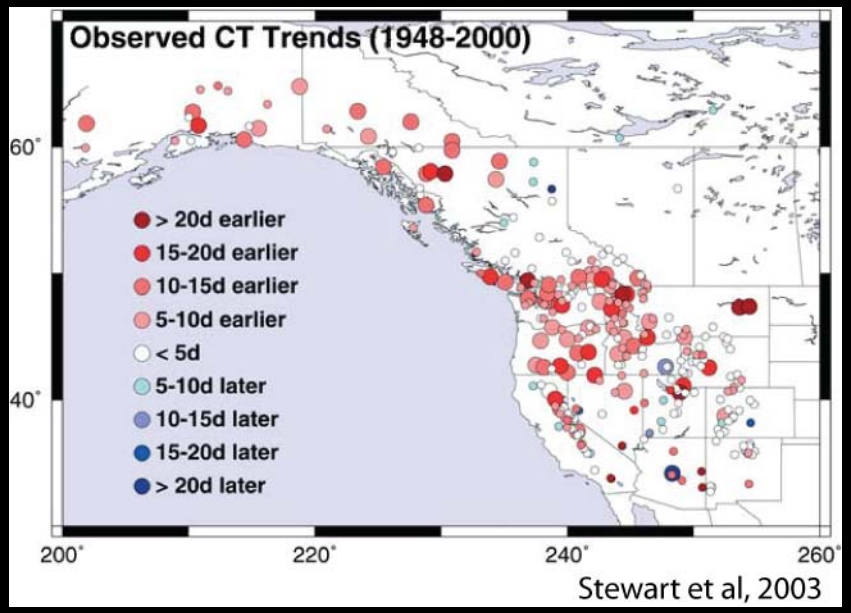
# Experimental Details

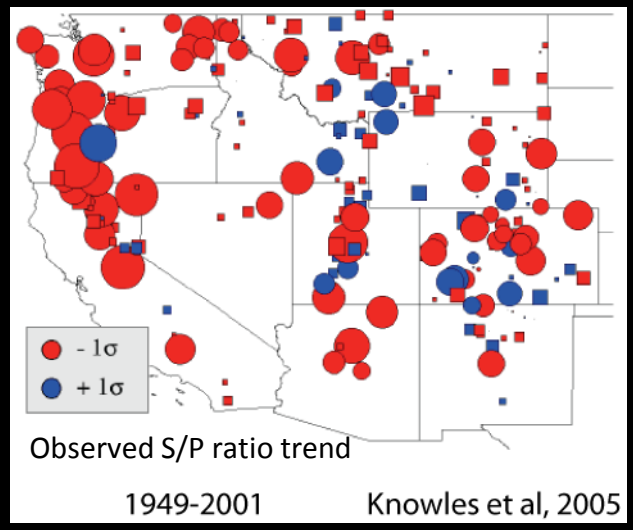
- Five member ensemble VIC simulations at 1/8 degree grid spacing
- Simulation periods
  - Historic 1960-1999
  - Future 2000-2040
- Driving Fields :: Bias corrected P, TMIN, TMAX and original RegCM3 winds
- RegCM3 was driven with five CCSM ensemble members. Each simulation was driven at 25km horizontal grid spacing

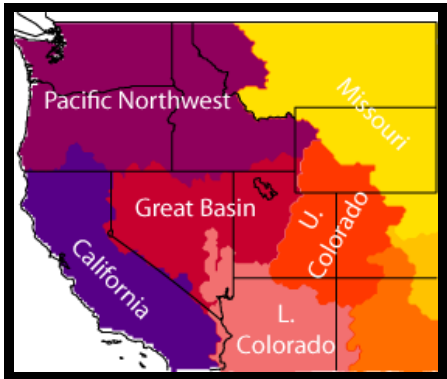

New England
Mid Atlantic
South Atlantic-Gulf
Great Lakes
Ohio
Tennessee
Upper Mississippi
Lower Mississippi
Souris-Red-Rainy
Missouri
Arkansas-White-Red
Texas-Gulf
Rio Grande
Upper Colorado
Lower Colorado
Great Basin
Pacific Northwest
California
0 1000 2000 3000 4000
ELEVATION (m)
Northeast
Southeast

# What is so special about Western US Snow cover ?



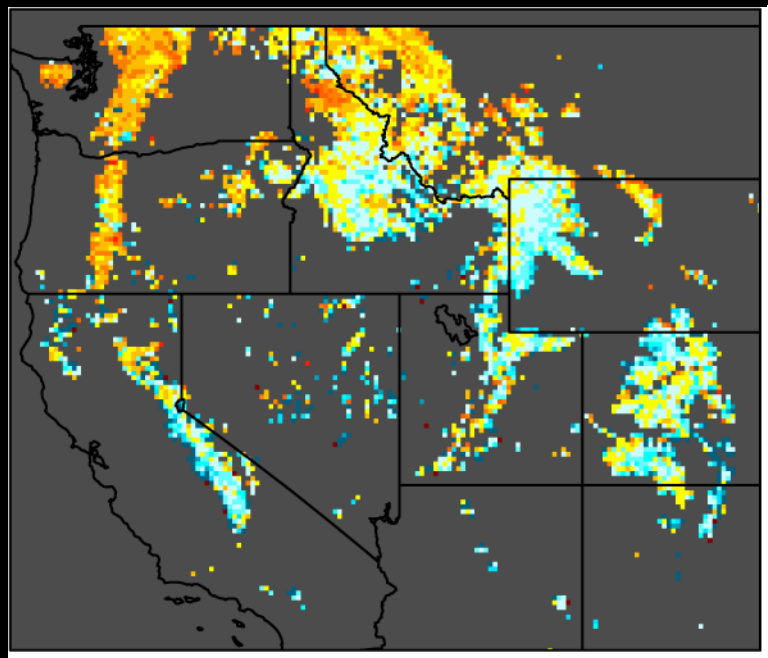



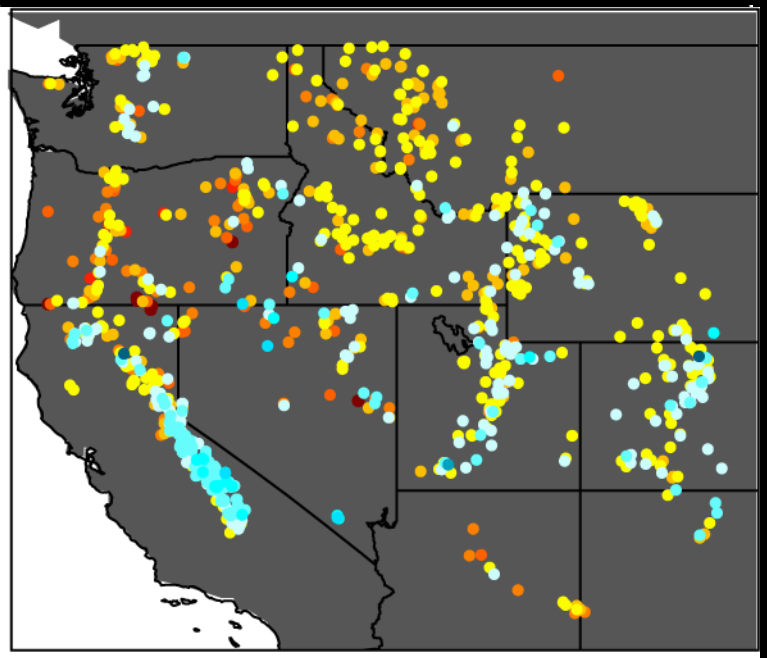



# Historic trends in April 1 SWE

Simulated Trend (1960-1999)



Observed Trend (1960-1999)

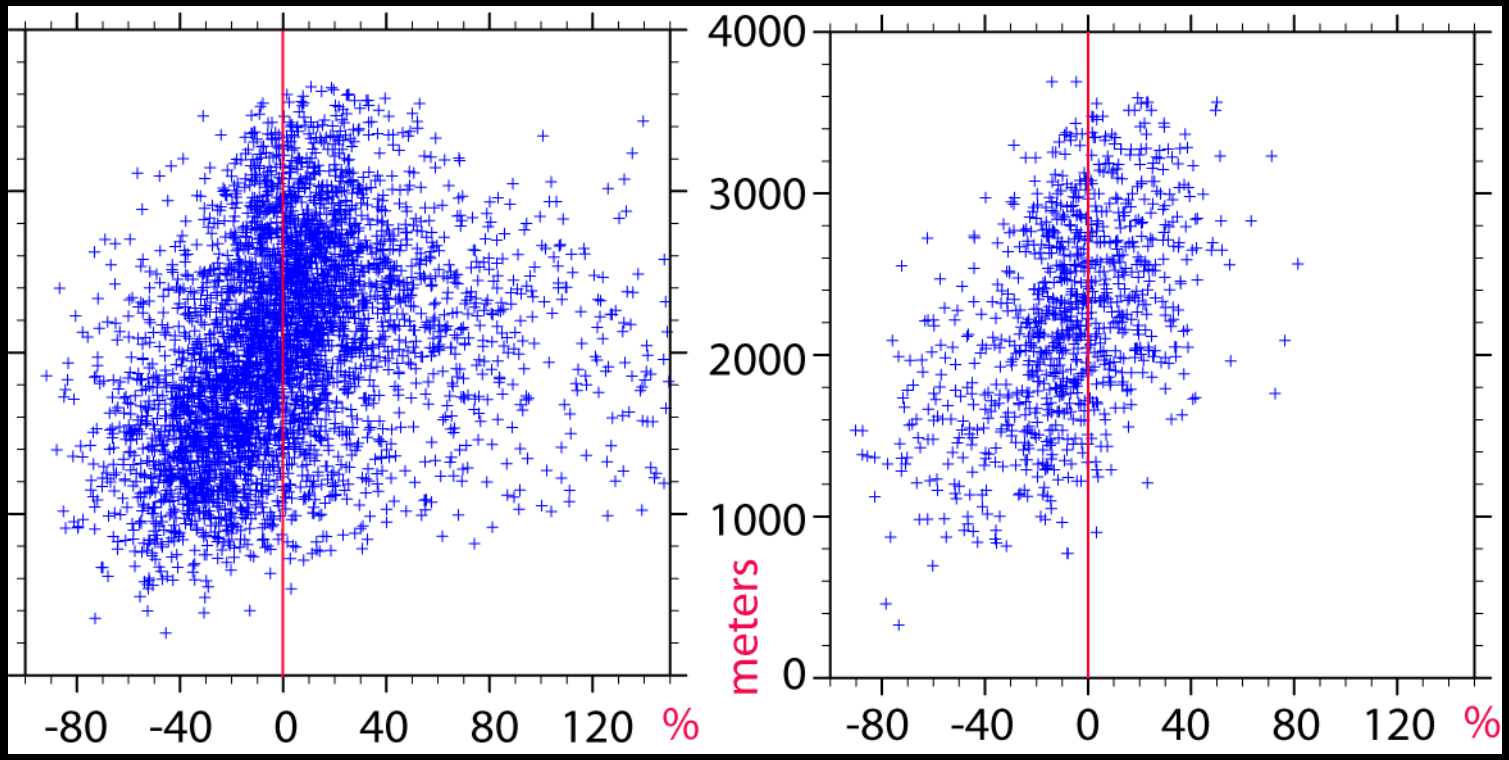



Trend is shown as % change relative to the 1960 value on the linear fit line

# April 1 SWE Trend versus Elevation

Simulated Trend (1960-1999)

Observed Trend (1960-1999)

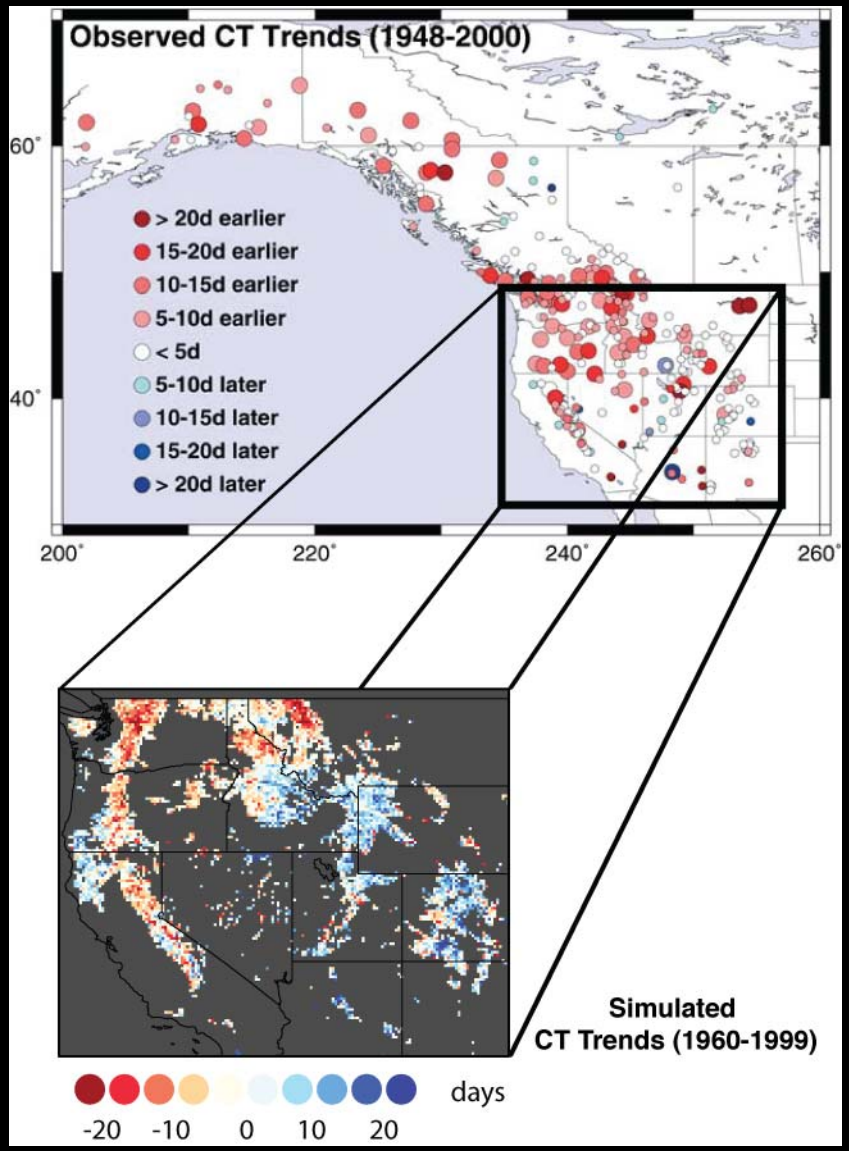


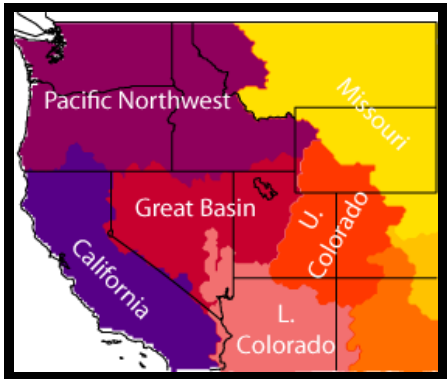

Trend is shown as % change relative to the 1960 value on the linear fit line

# Historical trends in the timing of center of mass flow

RED represents trend towards earlier melt

BLUE represents trend towards earlier melt

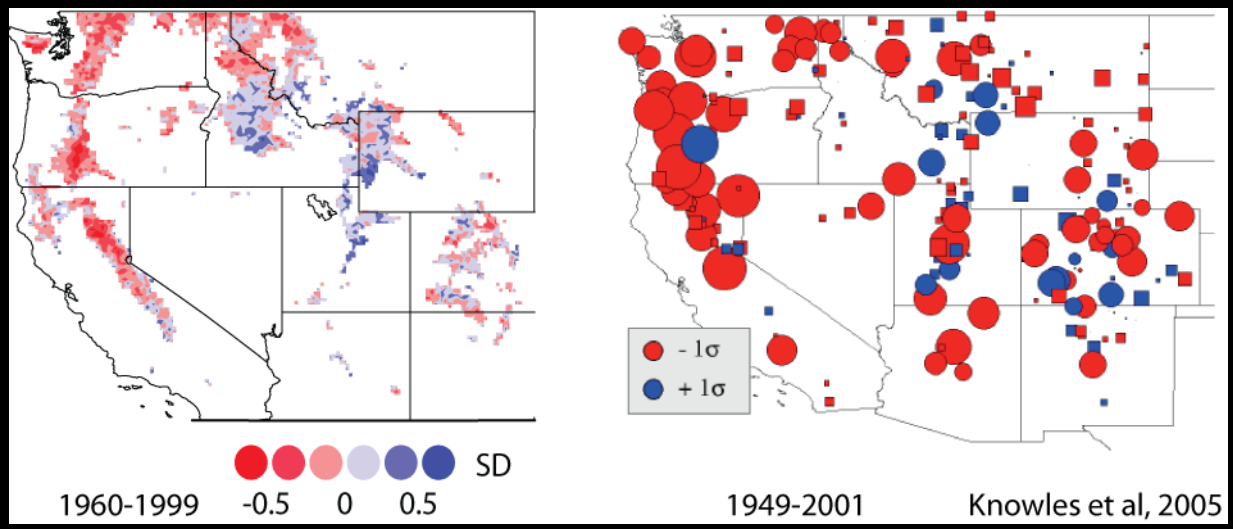





# Historic trends in snow to precipitation ratio

Simulated Trend (1960-1999)

Observed Trend (1949-2001)

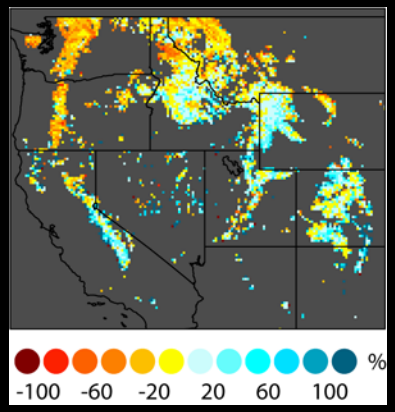


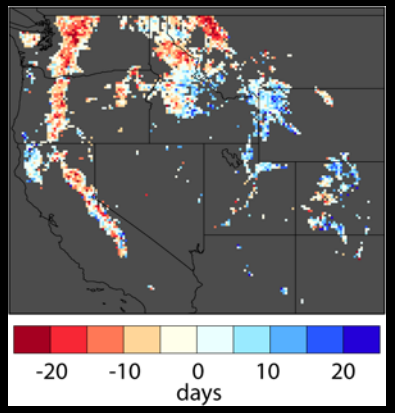

**RED** represents **less** snowfall and **more** liquid precipitation.

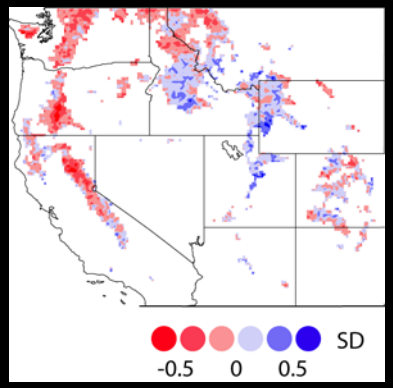
**BLUE** represents **more** snowfall and **less** liquid precipitation.

Trend is shown in terms of Standard Deviation relative to the base value on the linear fit line

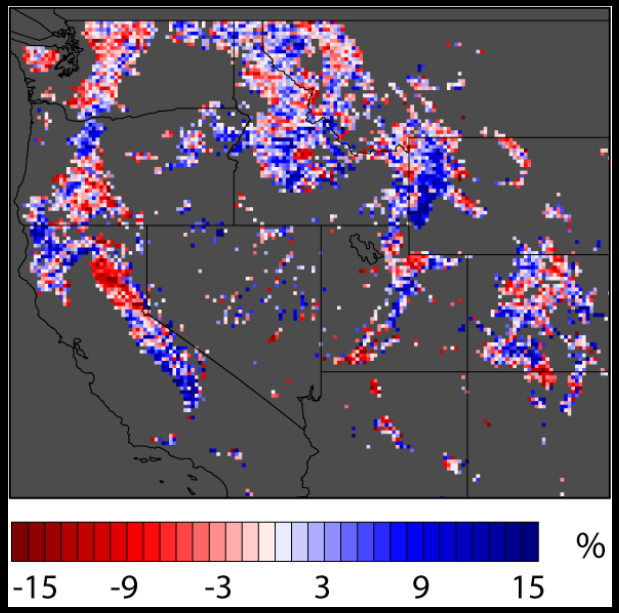
# Driving forces….



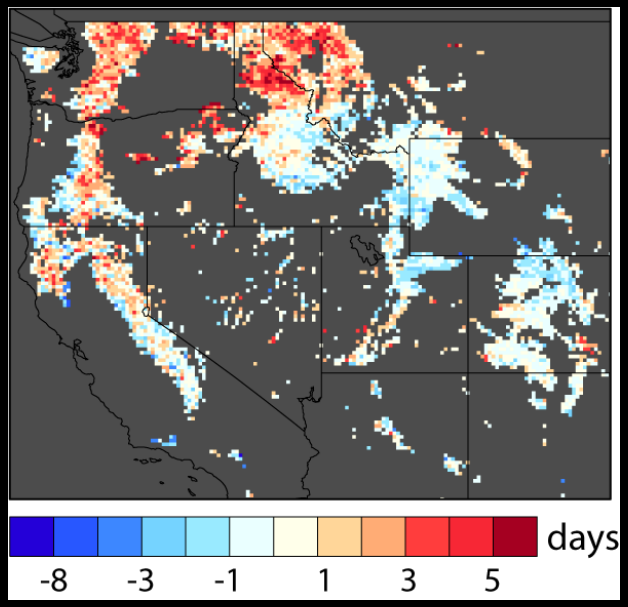



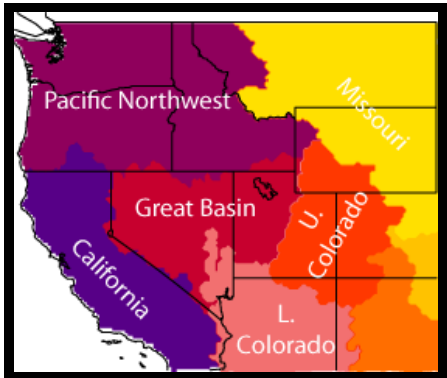




Precipitation Trends NDJFM

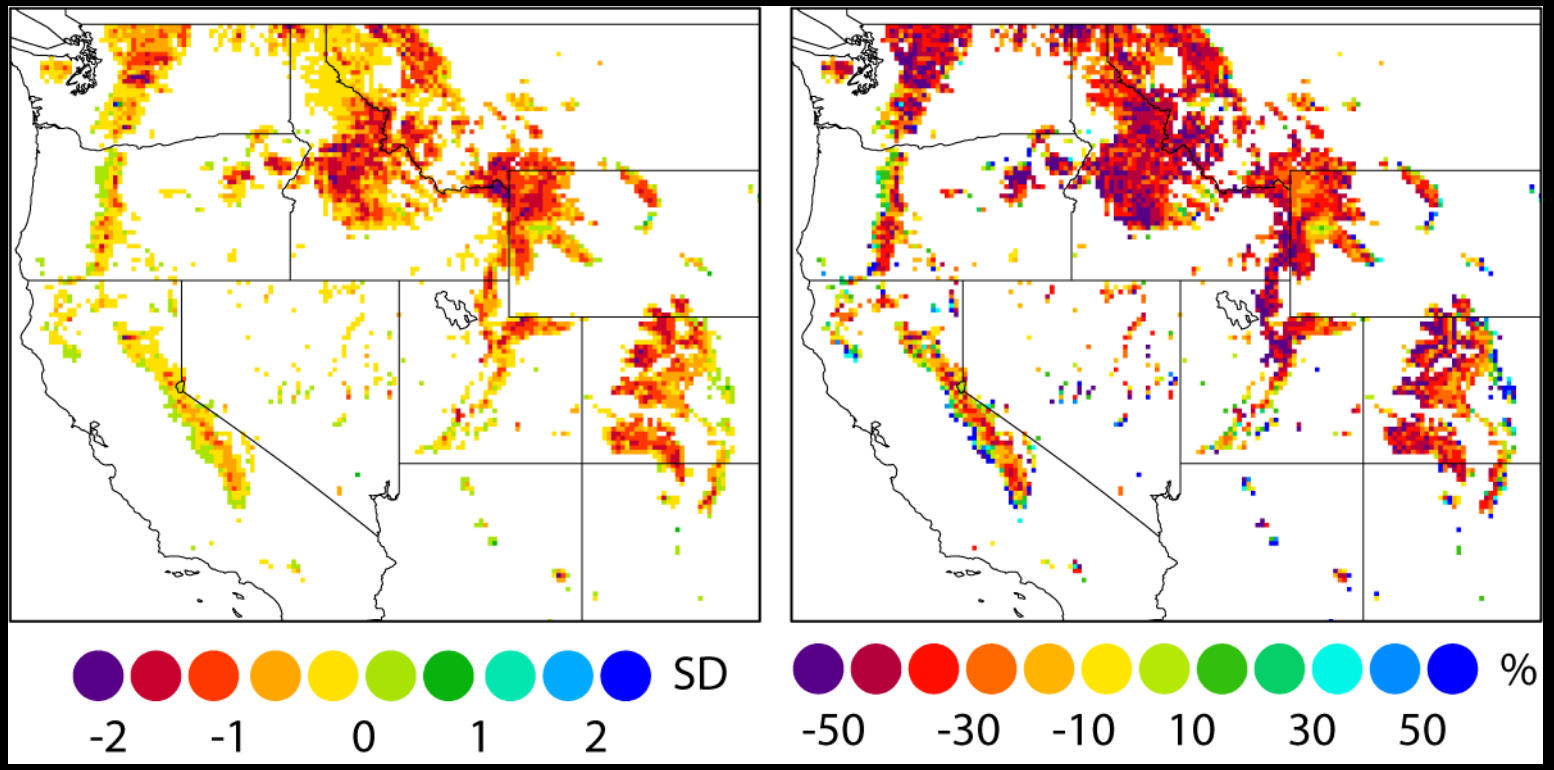



TMIN>0 Trends NDJFM





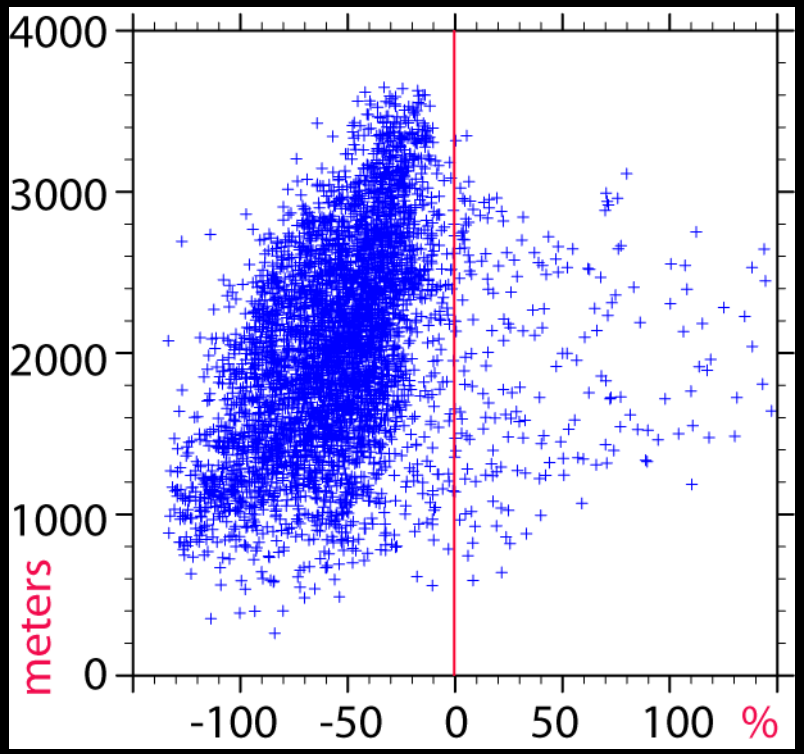

# Future Trends in April 1 SWE (2000-2039)




Trend is shown in terms of Standard Deviation relative to the base value (average of 1960-1999) on the linear fit line.

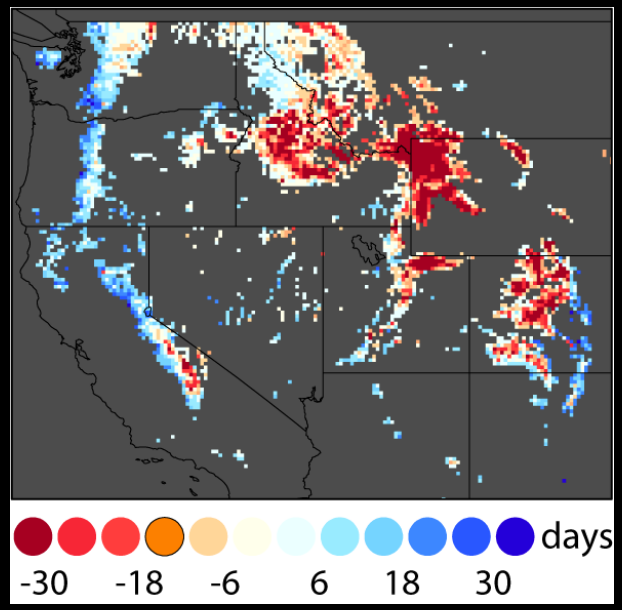
Trend is shown in terms of percent change relative to the base value (average of 1960-1999) on the linear fit line.

# Future Trends in April 1 SWE versus Elevation

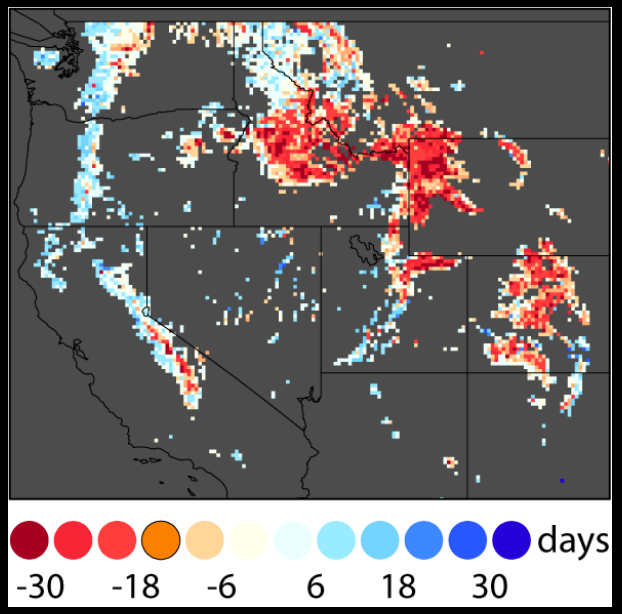


# Future Changes (days) in the timing of snow melt (2000-2039)

Q25

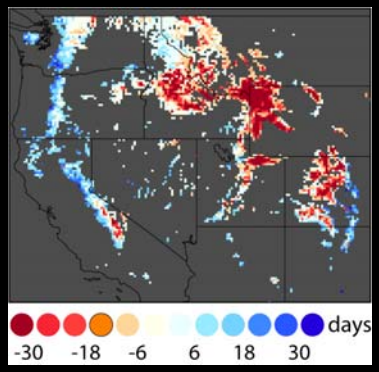



Q50

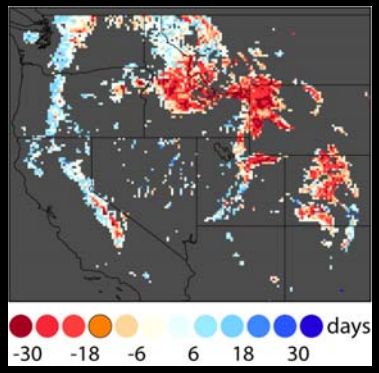



Changes are shown relative to the baseline (1960-1999)

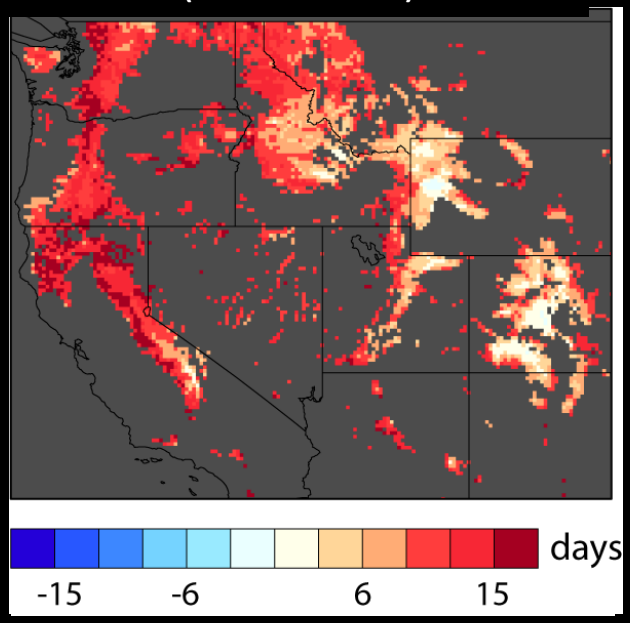
Q25



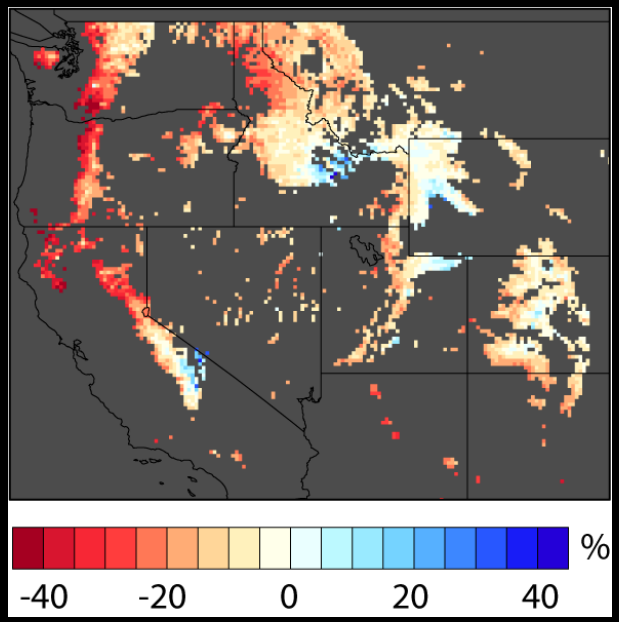

Q50



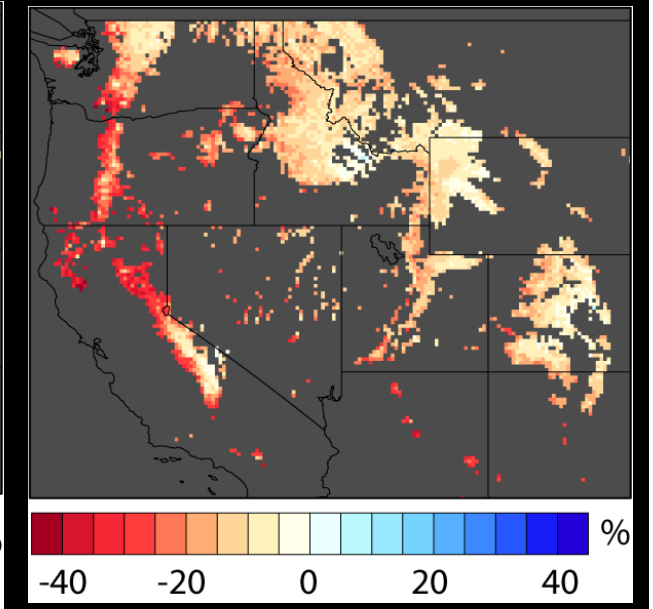

Days with TMIN > 0 NDJFM (2000-2039)



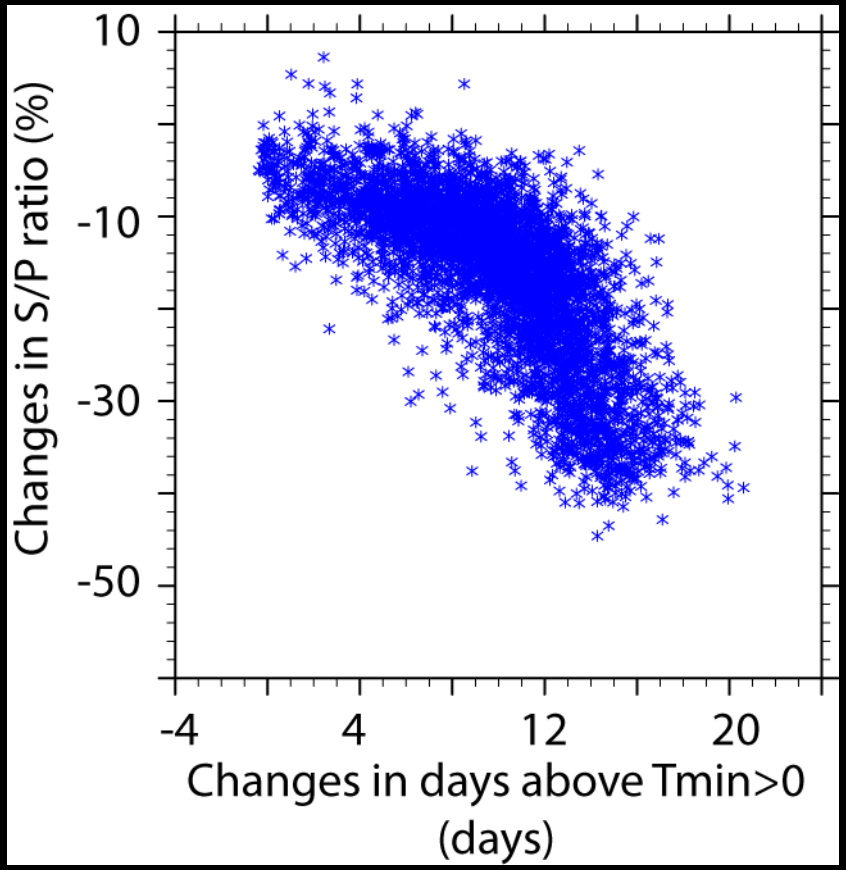

Snow melt Trend Water Year (2000-2039)




Snow to precipitation ratio NDJFM (2000-2039)



# S/P ratio versus Days with TMIN > 0

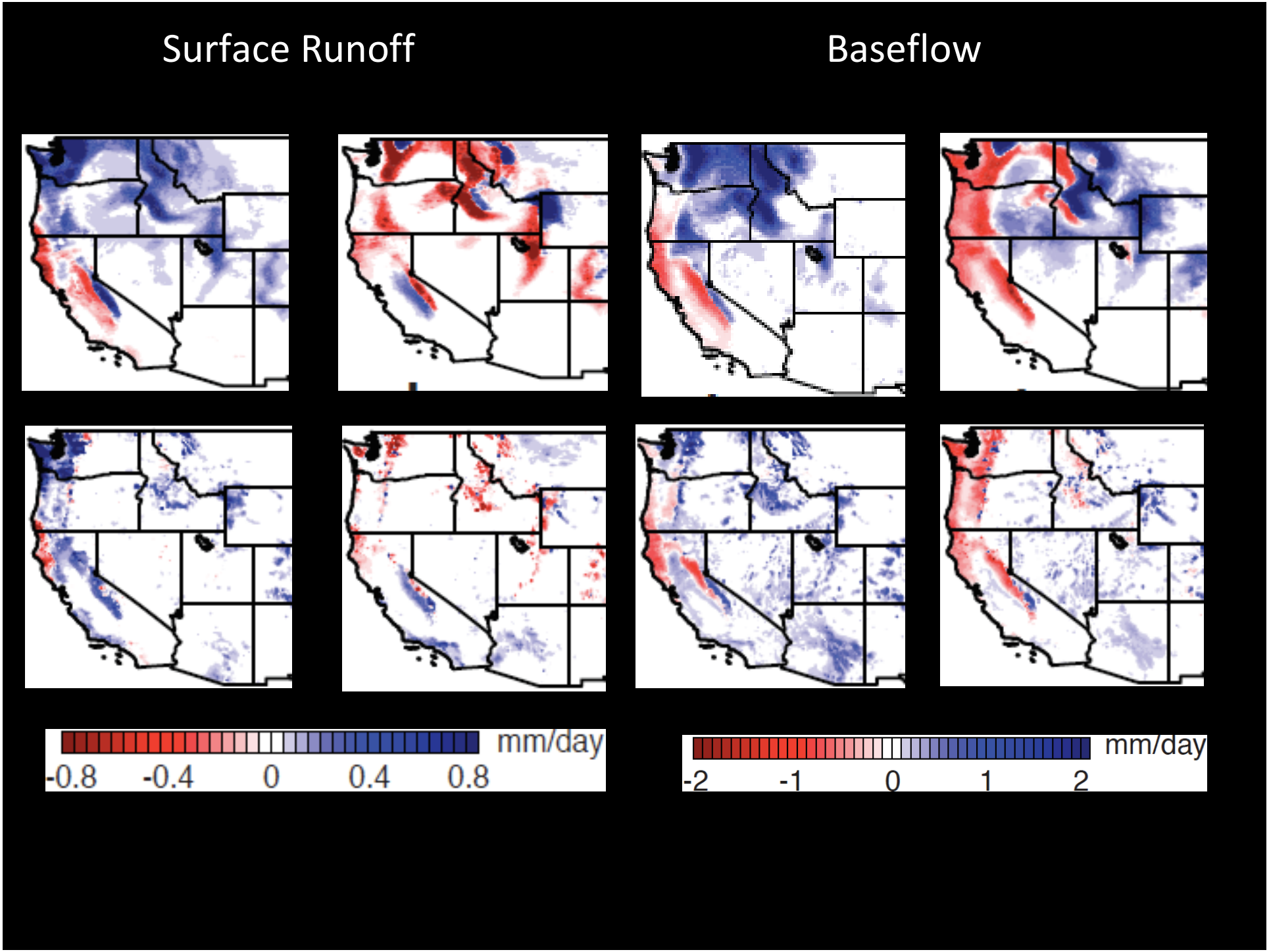


# Summary

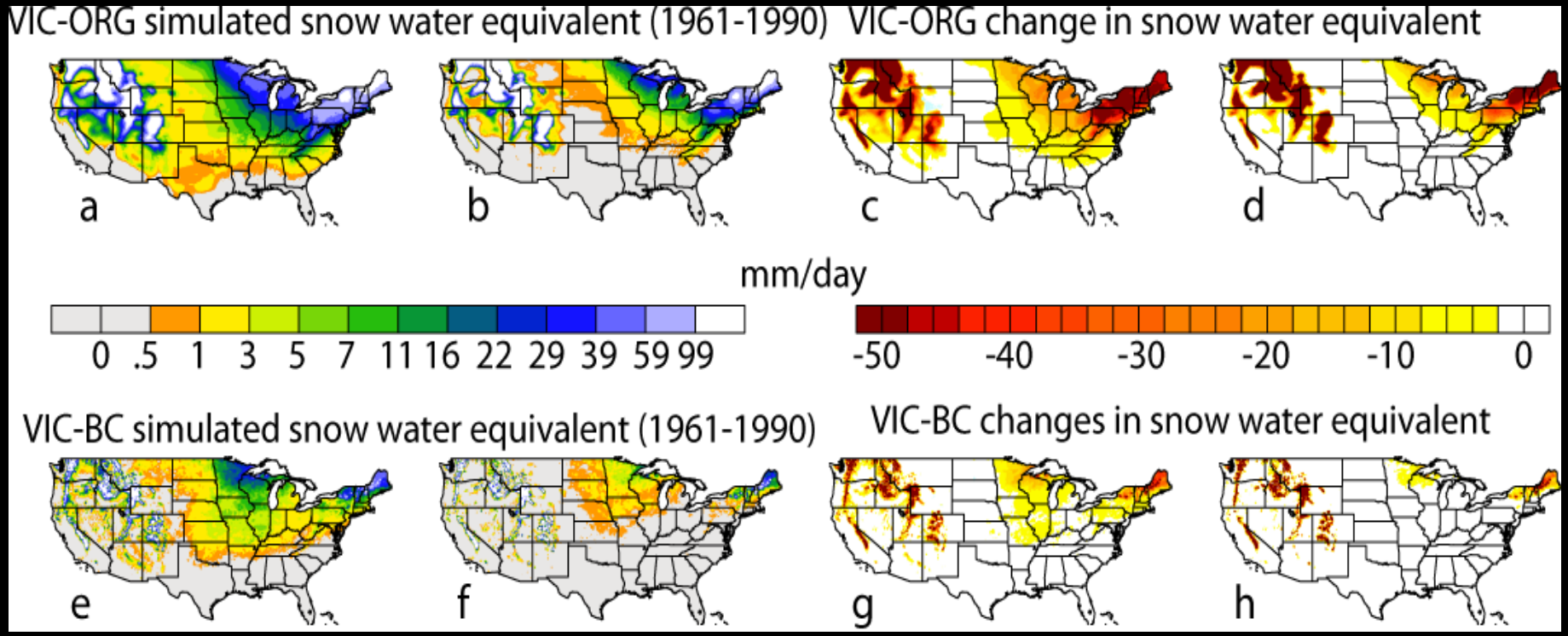
- Multi-ensemble high-resolution hydrological modeling system is able to simulate historic western US hydrological trends

- Simulated changes show further strengthening of historic trends over the next few decades, which may lead to substantial decrease in the late season snow-melt driven runoff.

# Role of fine spatial scales


Surface Runoff
Baseflow
mm/day
-0.8
-0.4
0
0.4
0.8
mm/day
-2
-1
0
1
2


0
1000
2000
3000
4000
ELEVATION (m)


VIC-ORG simulated snow water equivalent (1961-1990)
VIC-ORG change in snow water equivalent
a
b
c
d
mm/day
0 .5 1 3 5 7 11 16 22 29 39 59 99
-50 -40 -30 -20 -10 0
VIC-BC simulated snow water equivalent (1961-1990)
VIC-BC changes in snow water equivalent
e
f
g
h