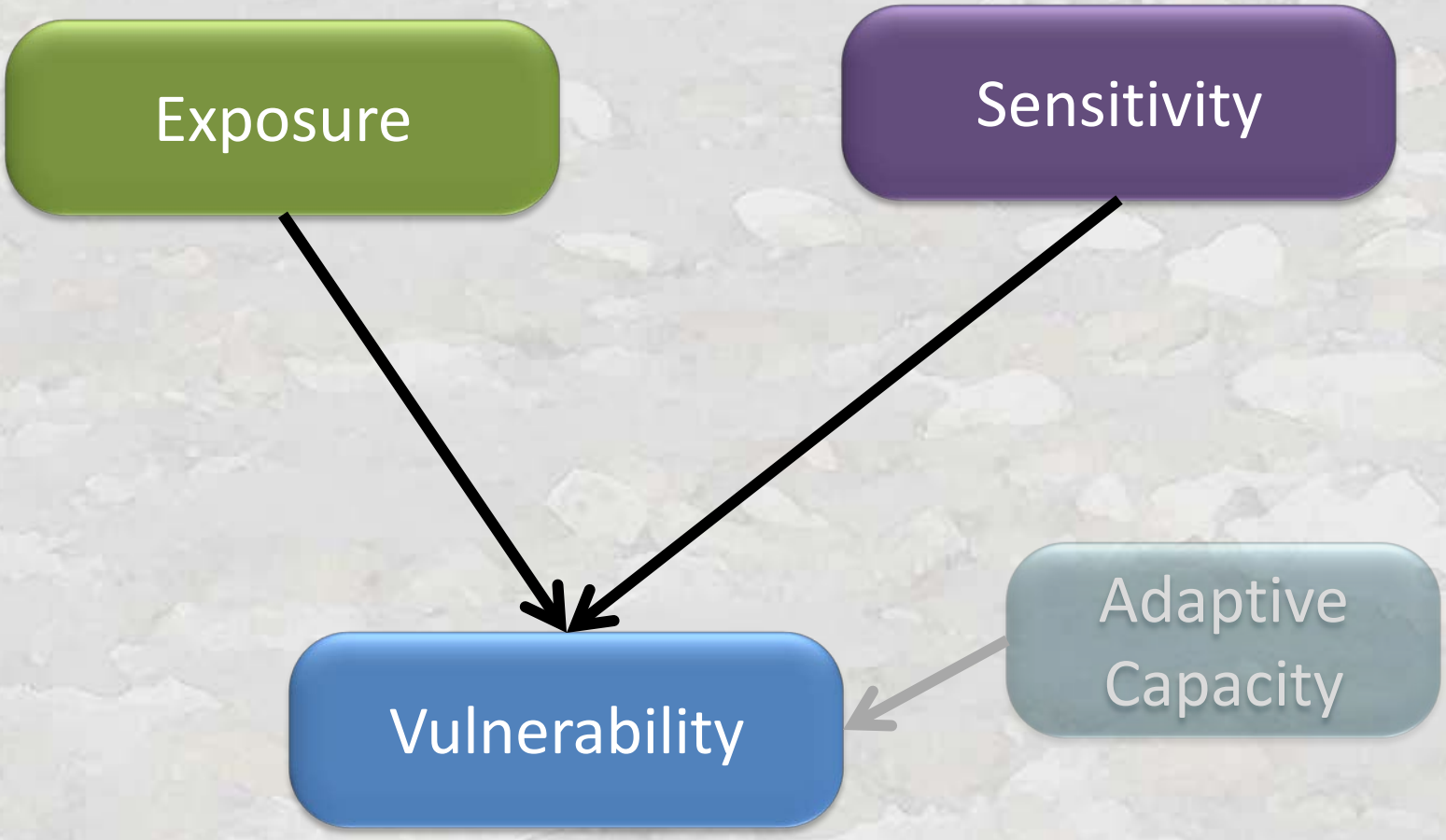
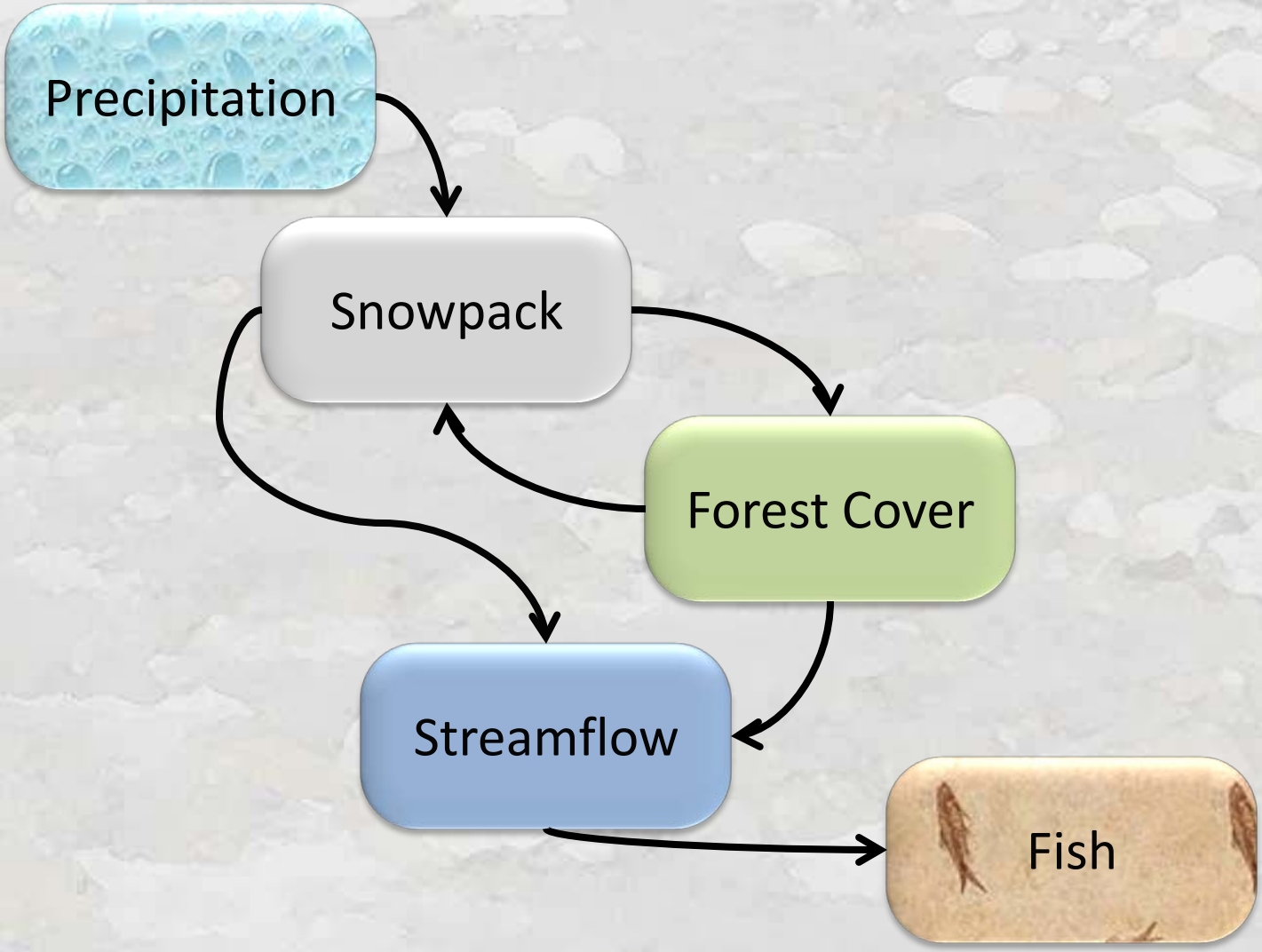
Climate Change, Streamflow, and Connections to Ecology

Charles Luce
U.S. Forest Service
Boise, ID

Climate Change Vulnerability



Cascading Vulnerability and Exposure



Hydrologic Connections

Precipitation

Temperature

Snowmelt Timing

Runoff Timing

Peak Snow

Flood Seasonality

Soil Moisture

Flood Magnitude

Summer Low Flow

Stream Temperature

Water Supply

Tree Growth

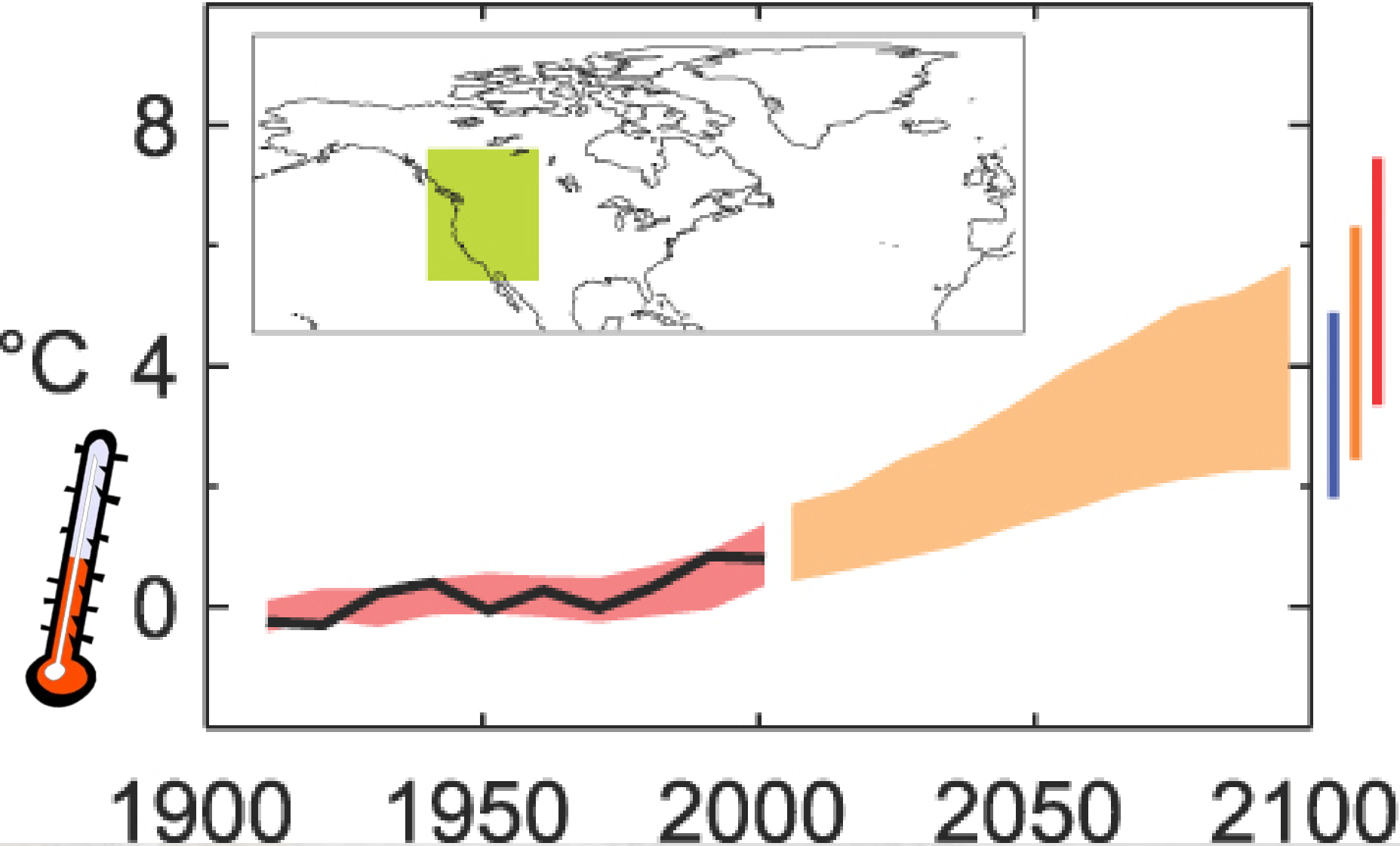
Fire Extent

Mortality

Spawning Success

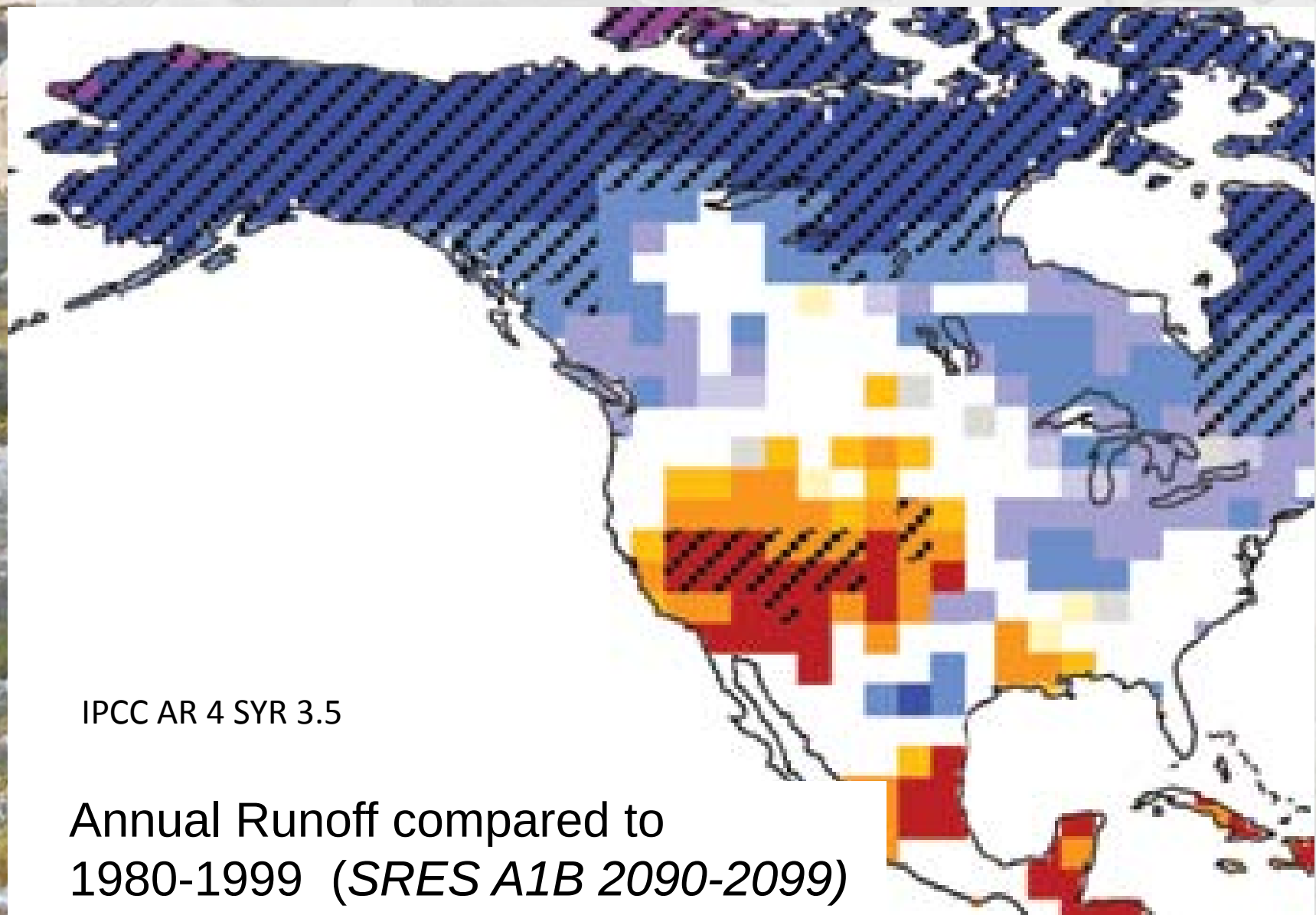
Habitat Quality

Western North America Temperature



IPCC AR 4 WGI 11.11

Water Supply: GCM Projection

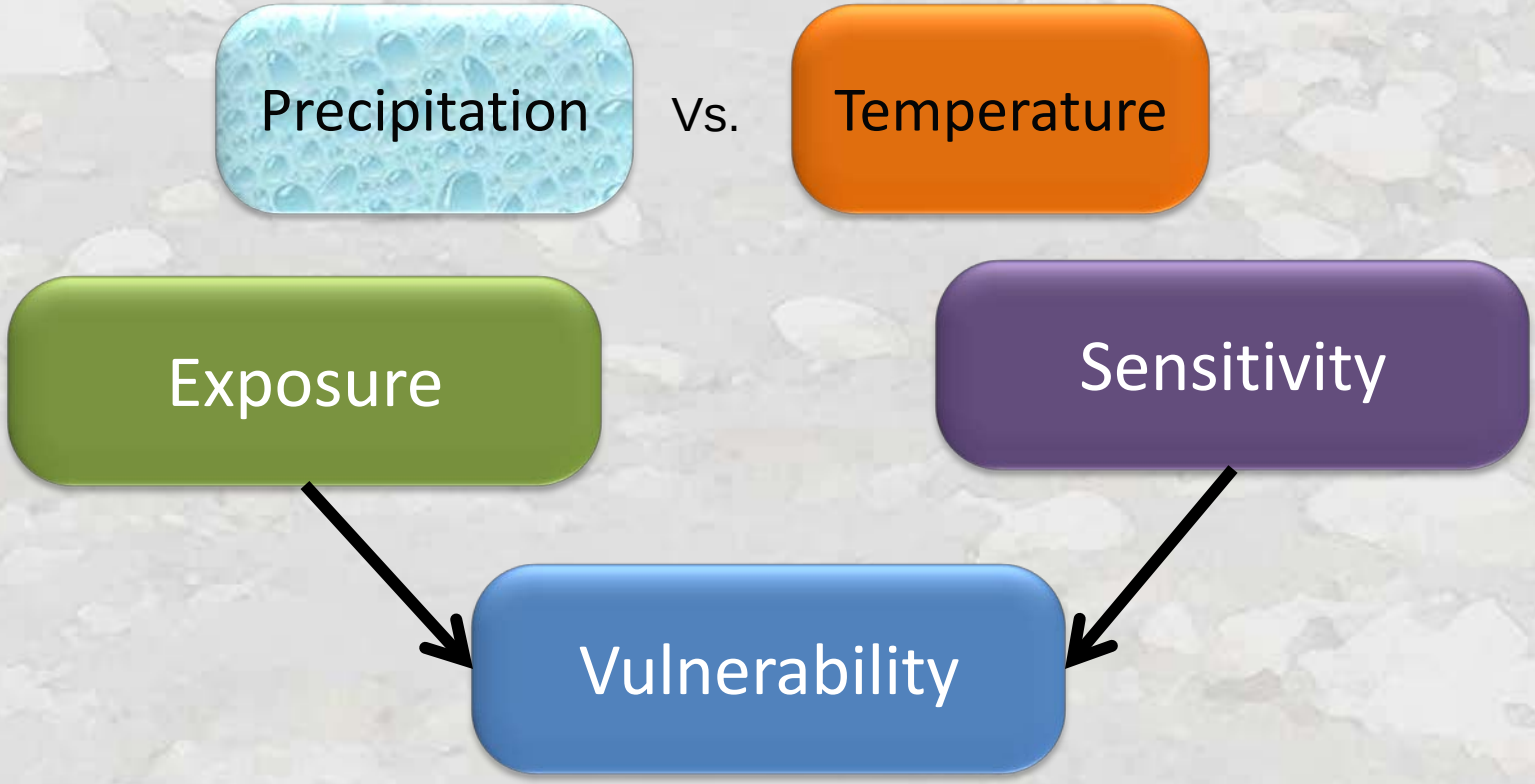


IPCC AR 4 SYR 3.5

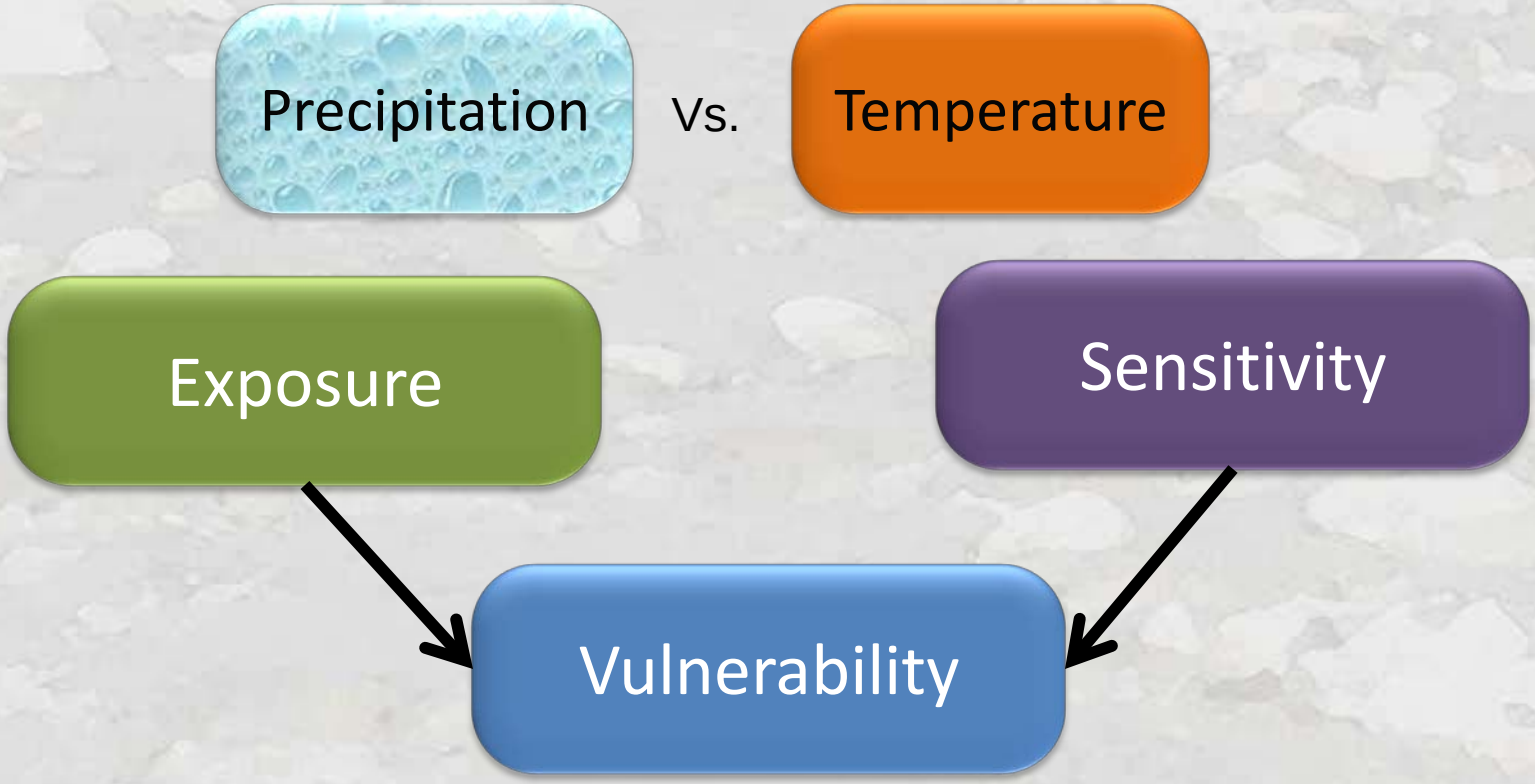
Annual Runoff compared to 1980-1999 (*SRES A1B 2090-2099)*

Future Precipitation

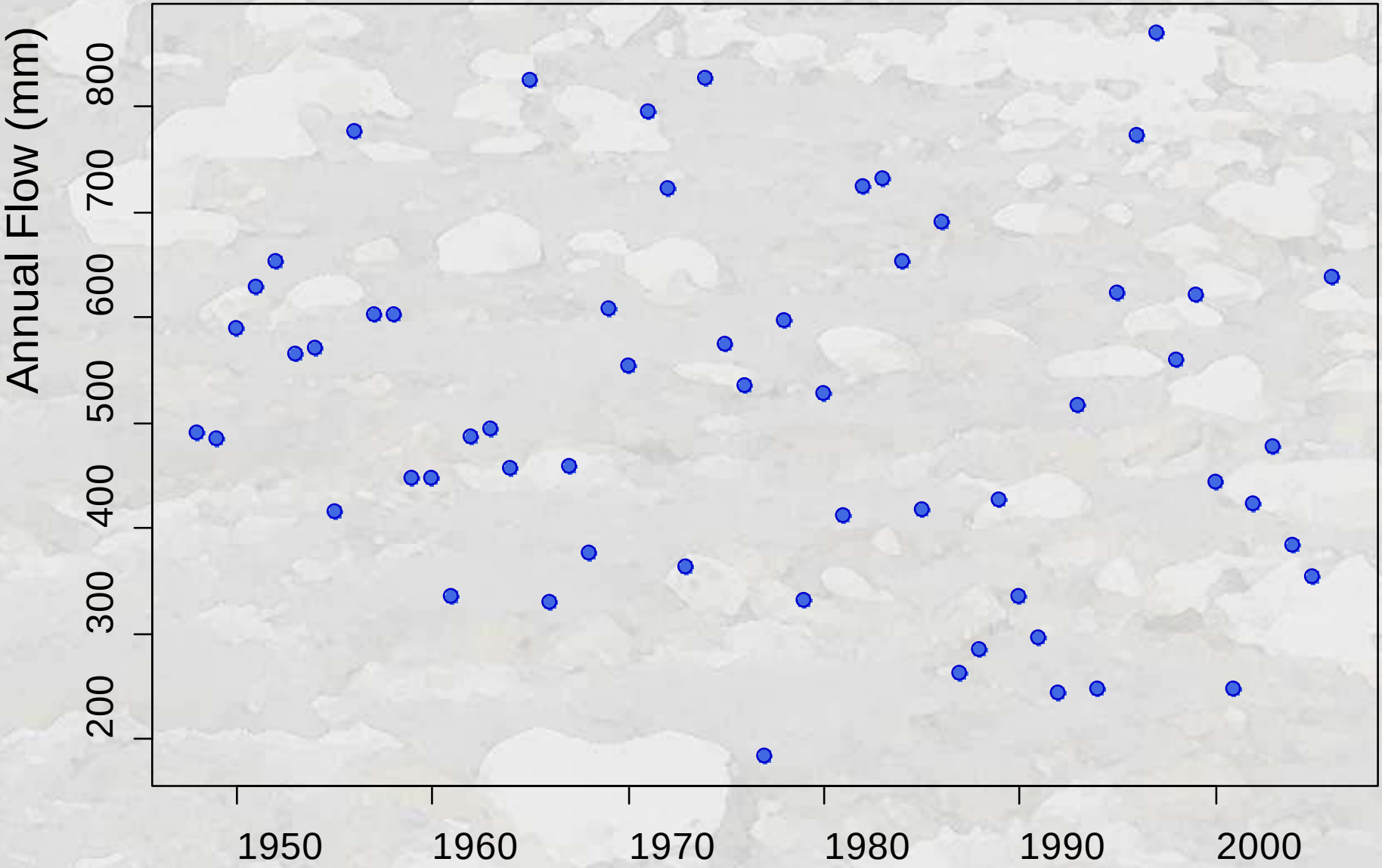
Relative Sensitivity



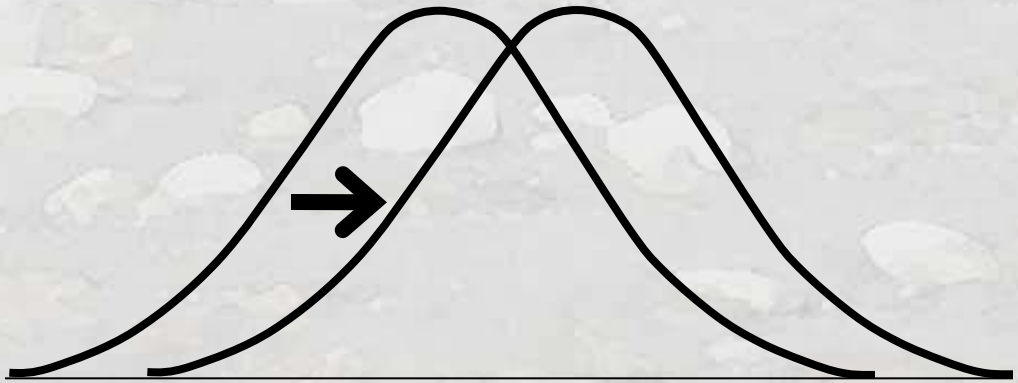
Relative Sensitivity



If sensitivity is small,
uncertainty about exposure is less important!

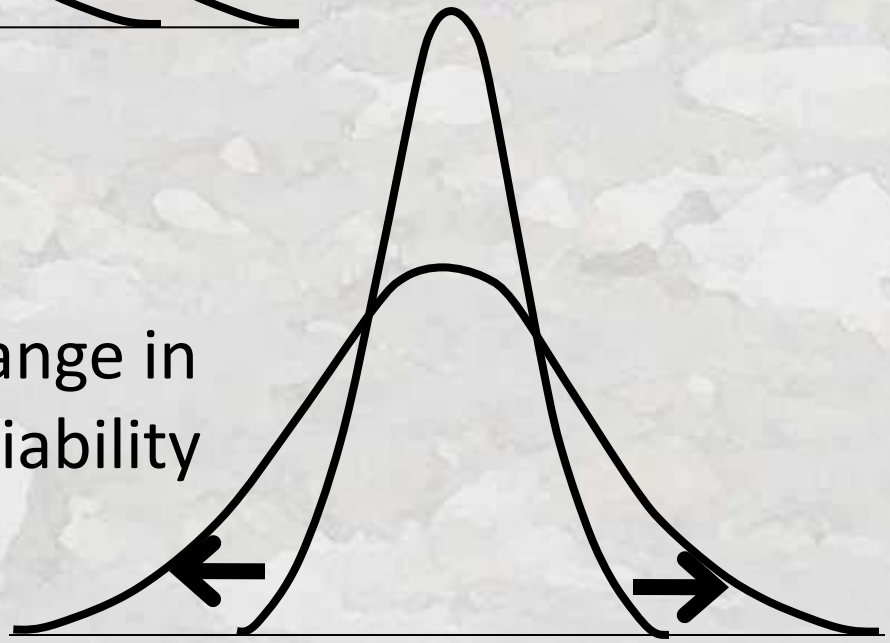

Annual Flow (mm)
200
300
400
500
600
700
800
1950
1960
1970
1980
1990
2000

Two Kinds of “Non-Stationarity”



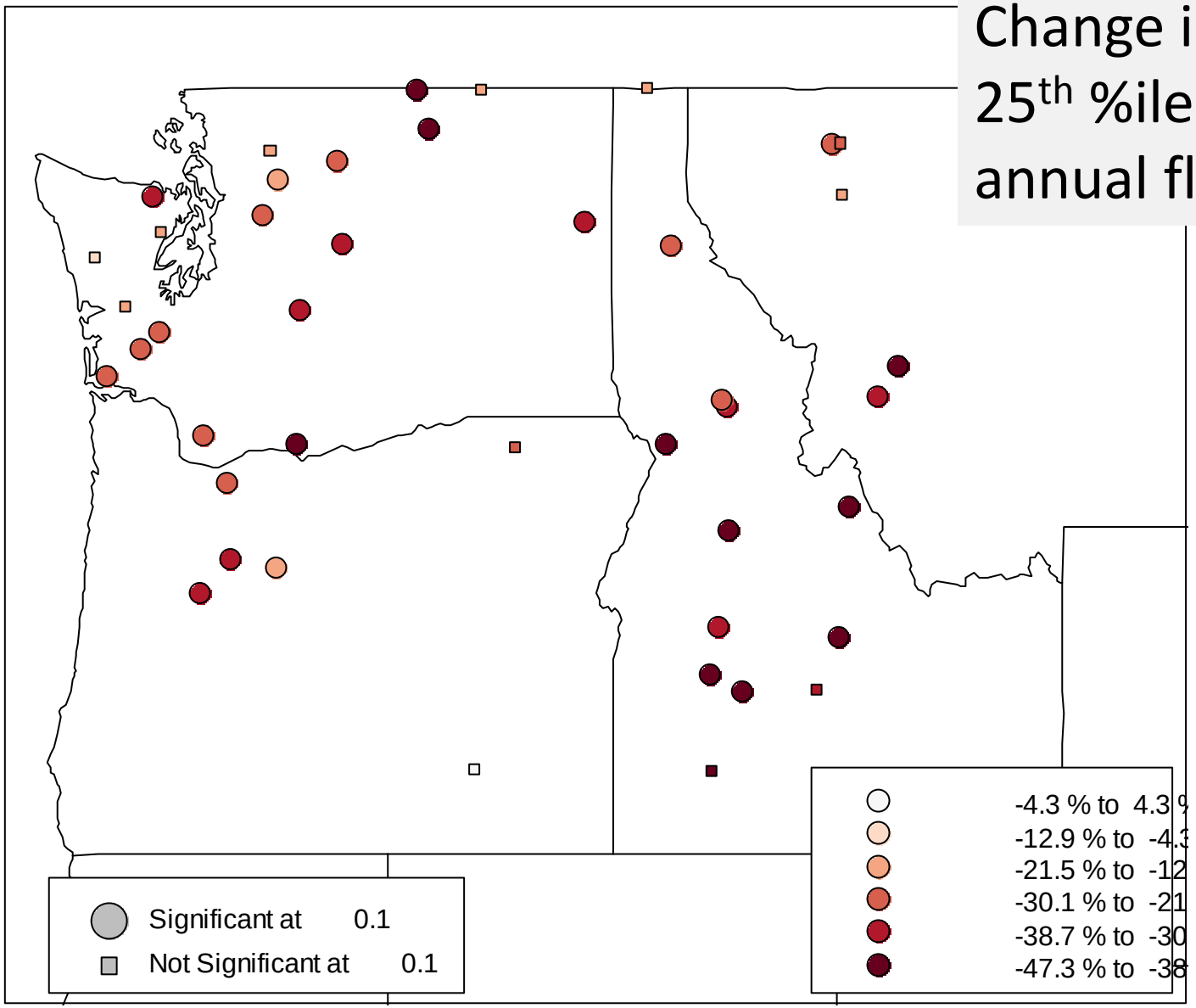
Change in
Mean

Change in
Variability

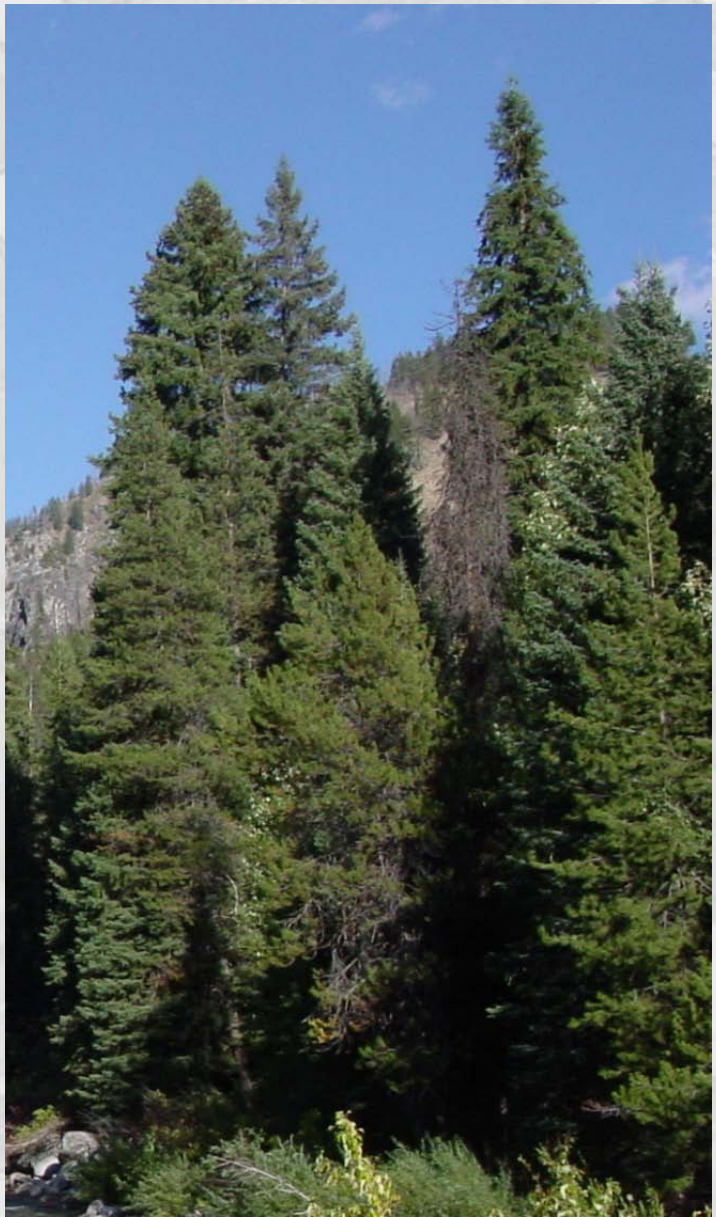


Water Supply: Historical Trends

Change in 25th %ile annual flow



ET or Precipitation?



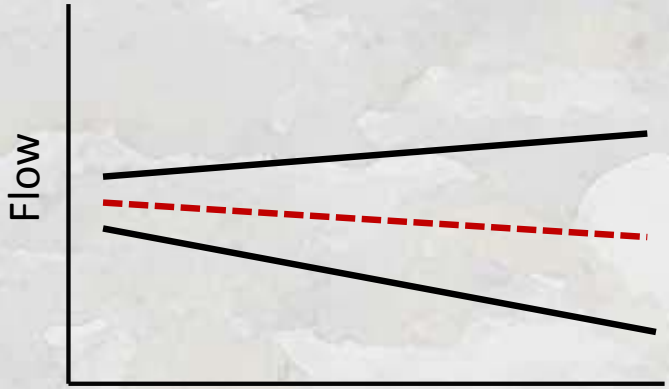
Precipitation!

1. Changes too big to be accounted for by increased radiant forcing.

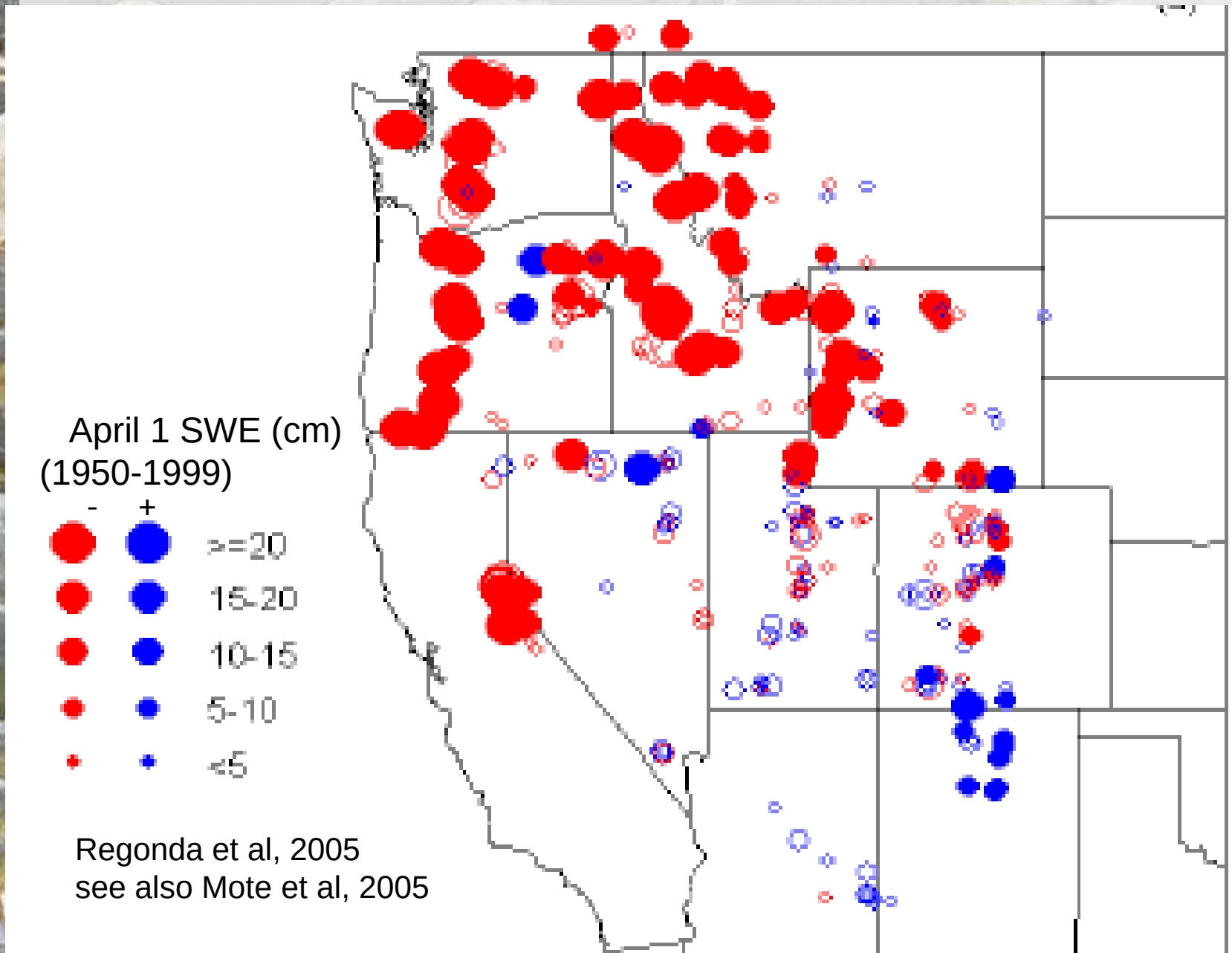
Precipitation!

1. Changes too big to be accounted for by increased radiant forcing.

2. Changes in wet years inconsistent with increased ET.

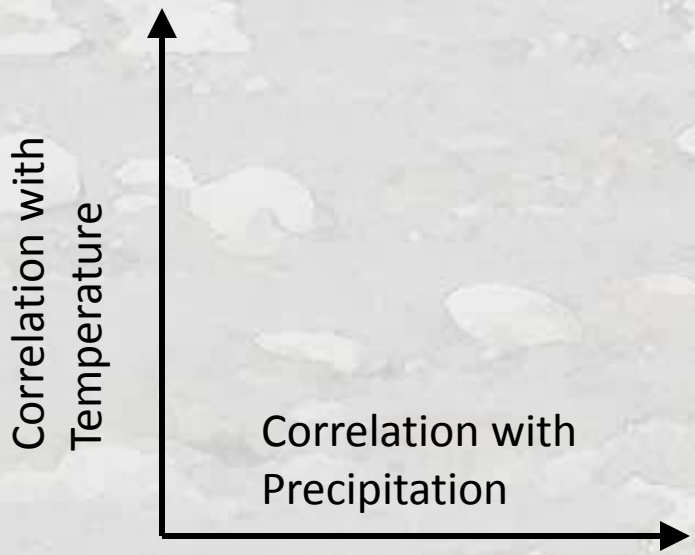


Historical April 1 Snowpack (SWE)

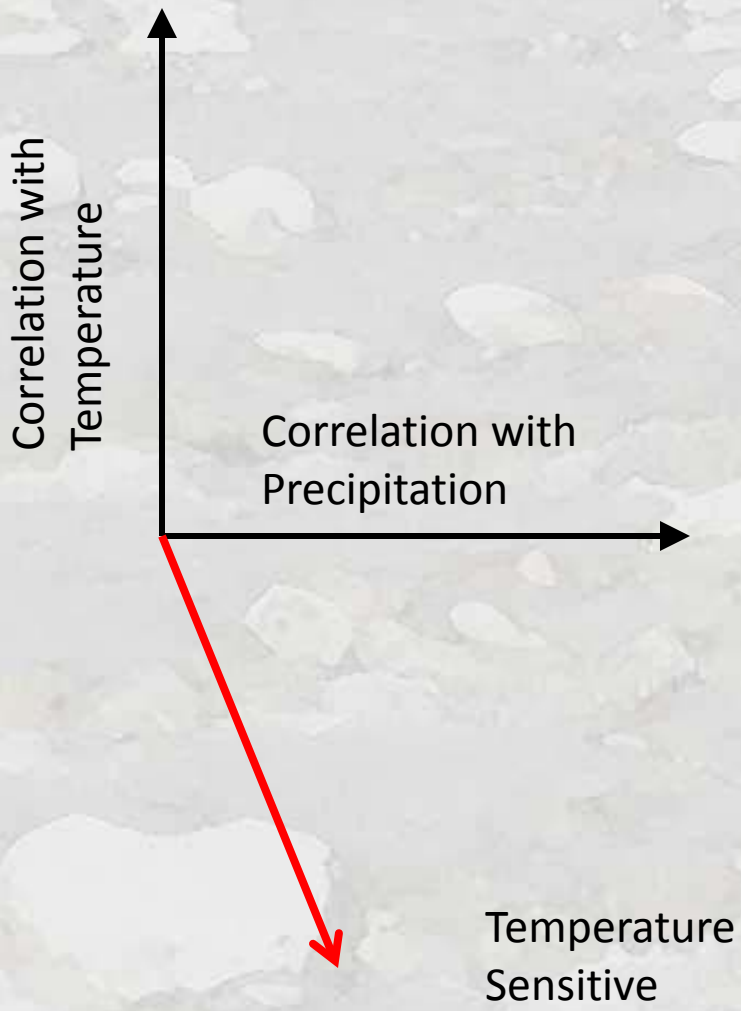


Regonda et al, 2005
see also Mote et al, 2005

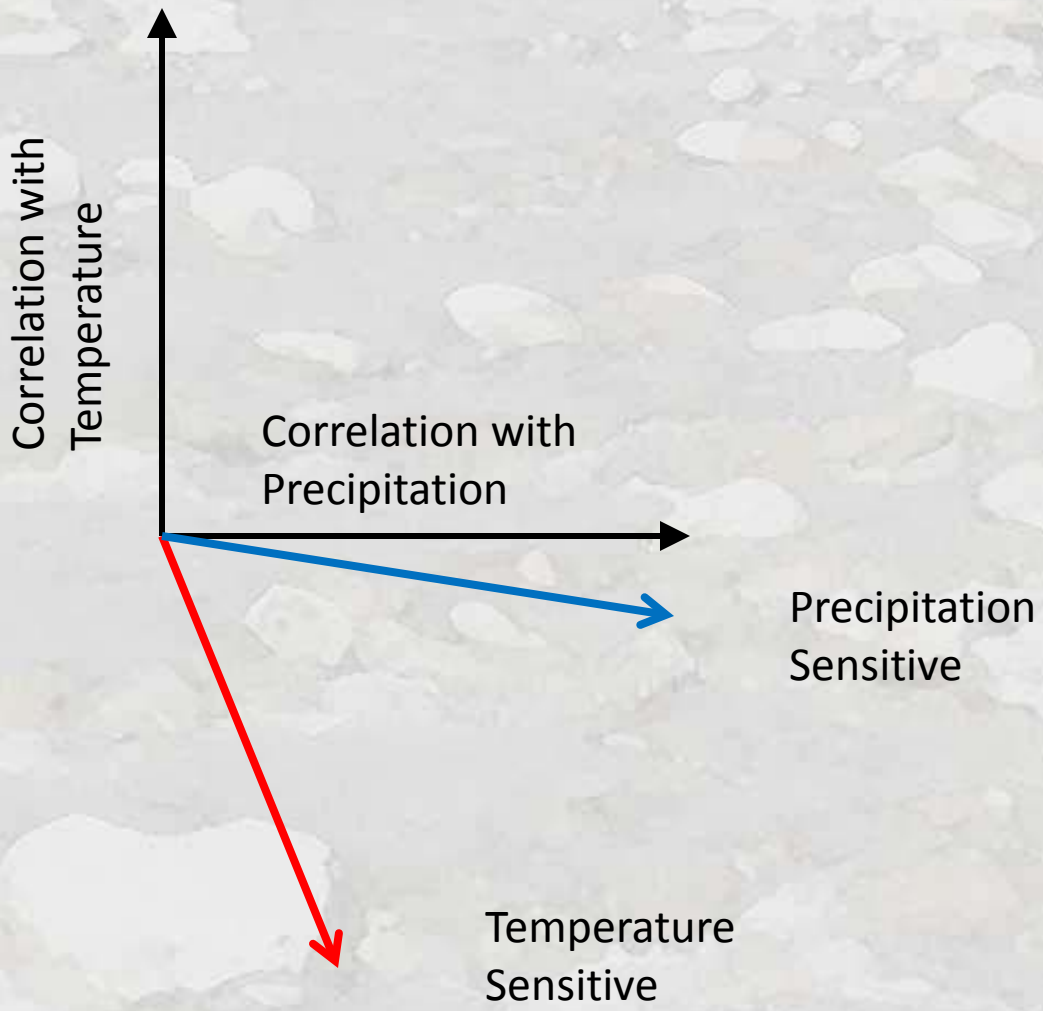
Snowpack Sensitivity Diagram



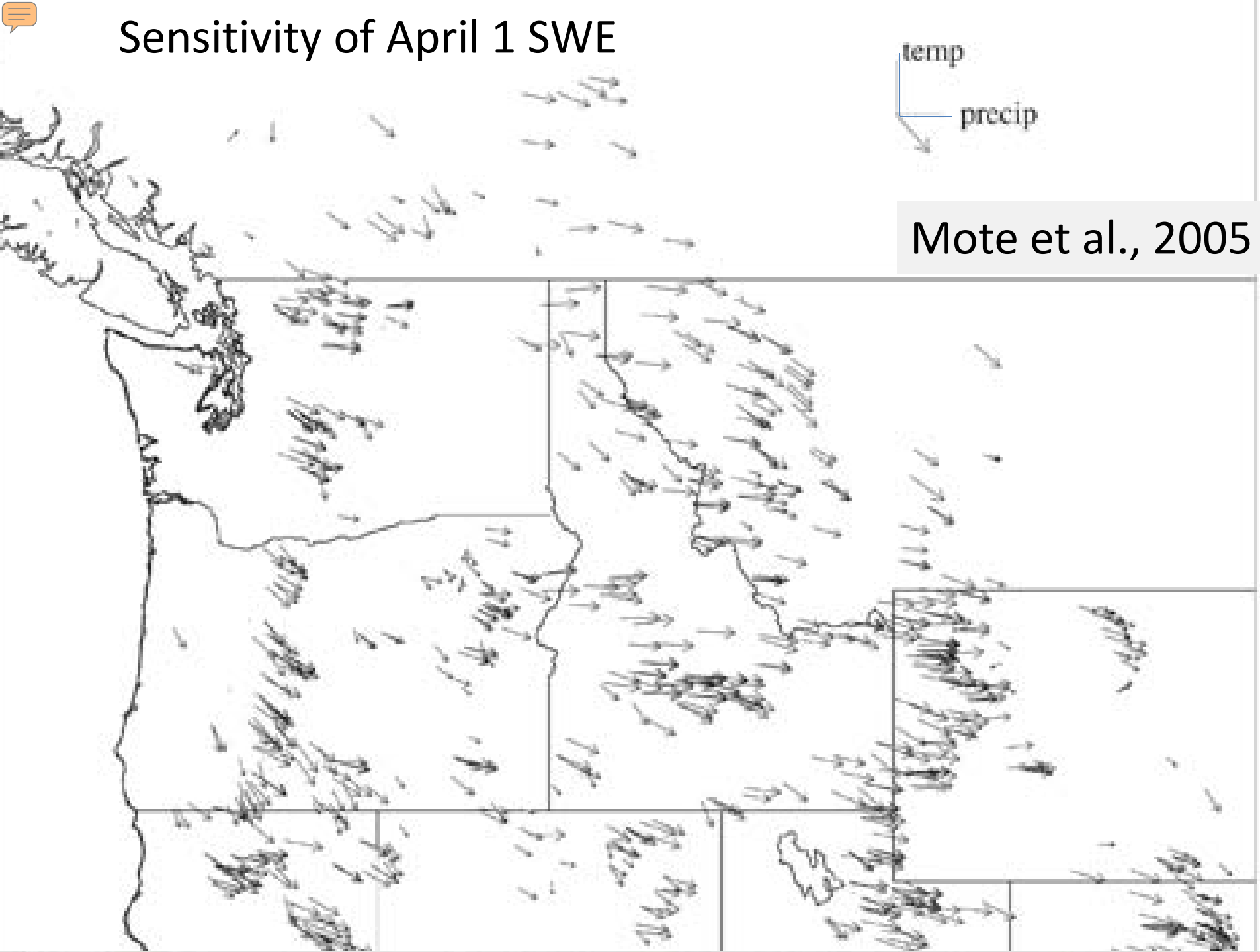
Snowpack Sensitivity Diagram



Snowpack Sensitivity Diagram

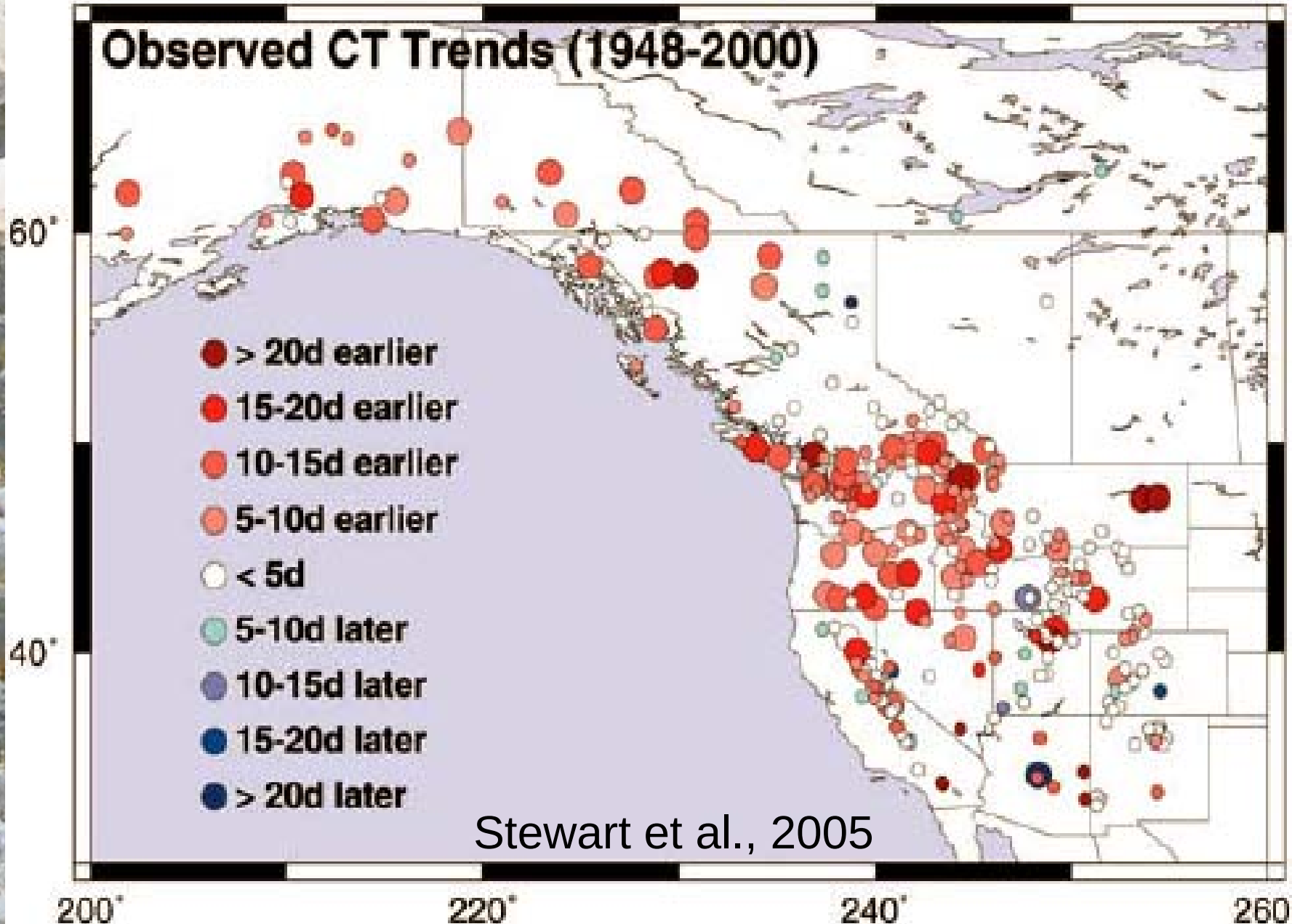


Sensitivity of April 1 SWE



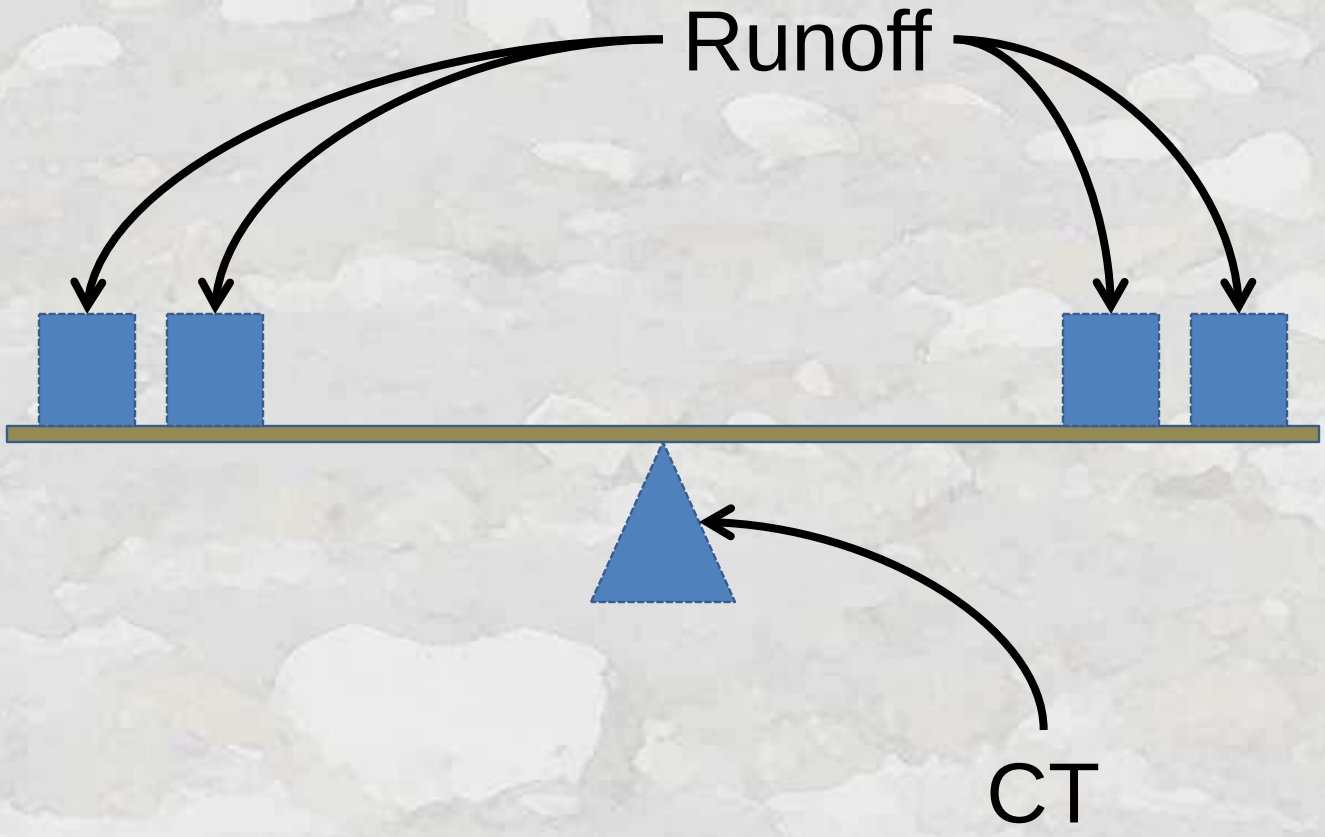
Mote et al., 2005

Streamflow Timing



Stewart et al., 2005

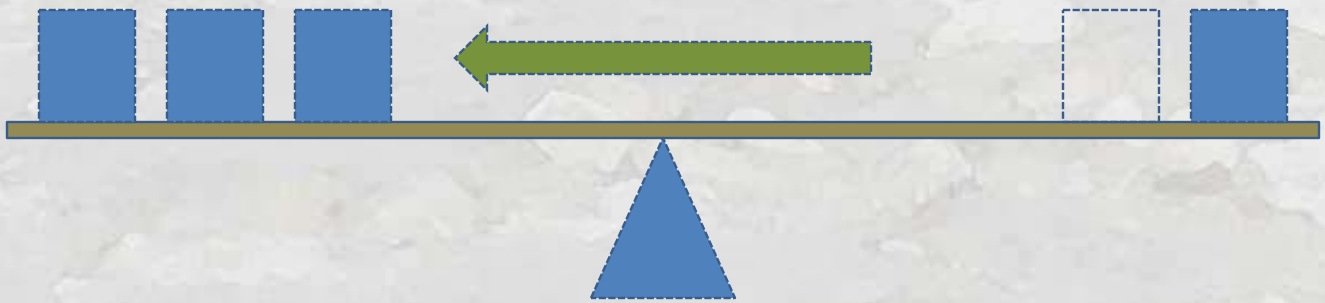
Seasonality Seesaw



Seasonality Seesaw

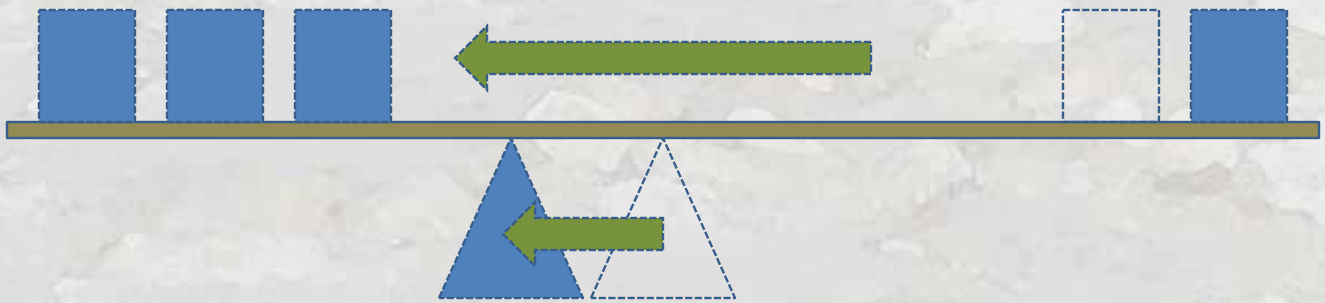
Seasonality Seesaw

Volume same
Timing change



Seasonality Seesaw

Volume same
Timing change



Seasonality Seesaw

Volume same
Timing change

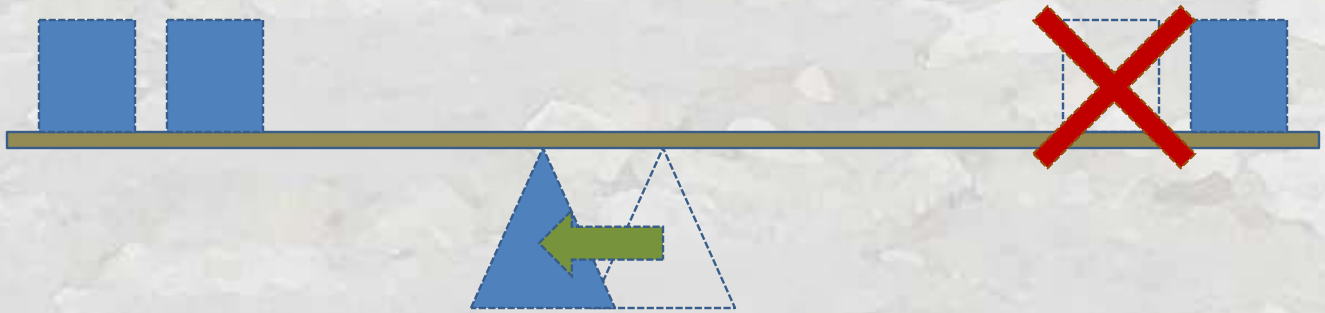
Seasonality Seesaw

Seasonality Seesaw

Volume decreased in melt season

Seasonality Seesaw

Volume decreased in melt season

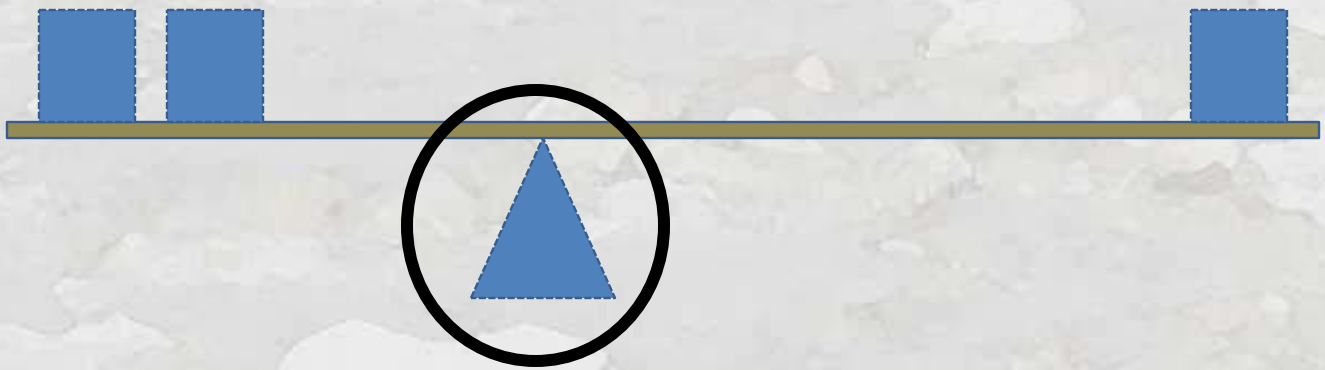


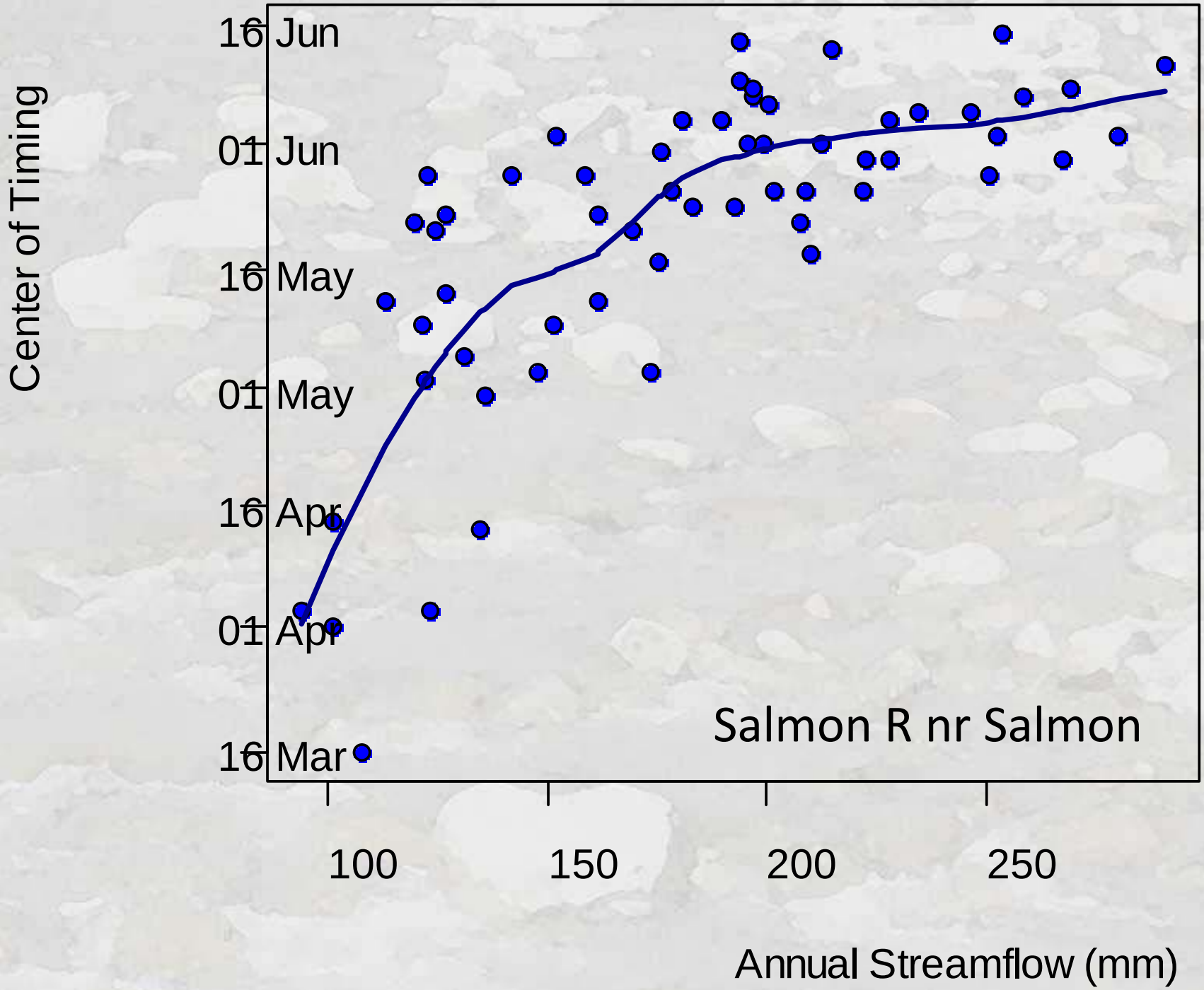
Seasonality Seesaw

Volume decreased in melt season

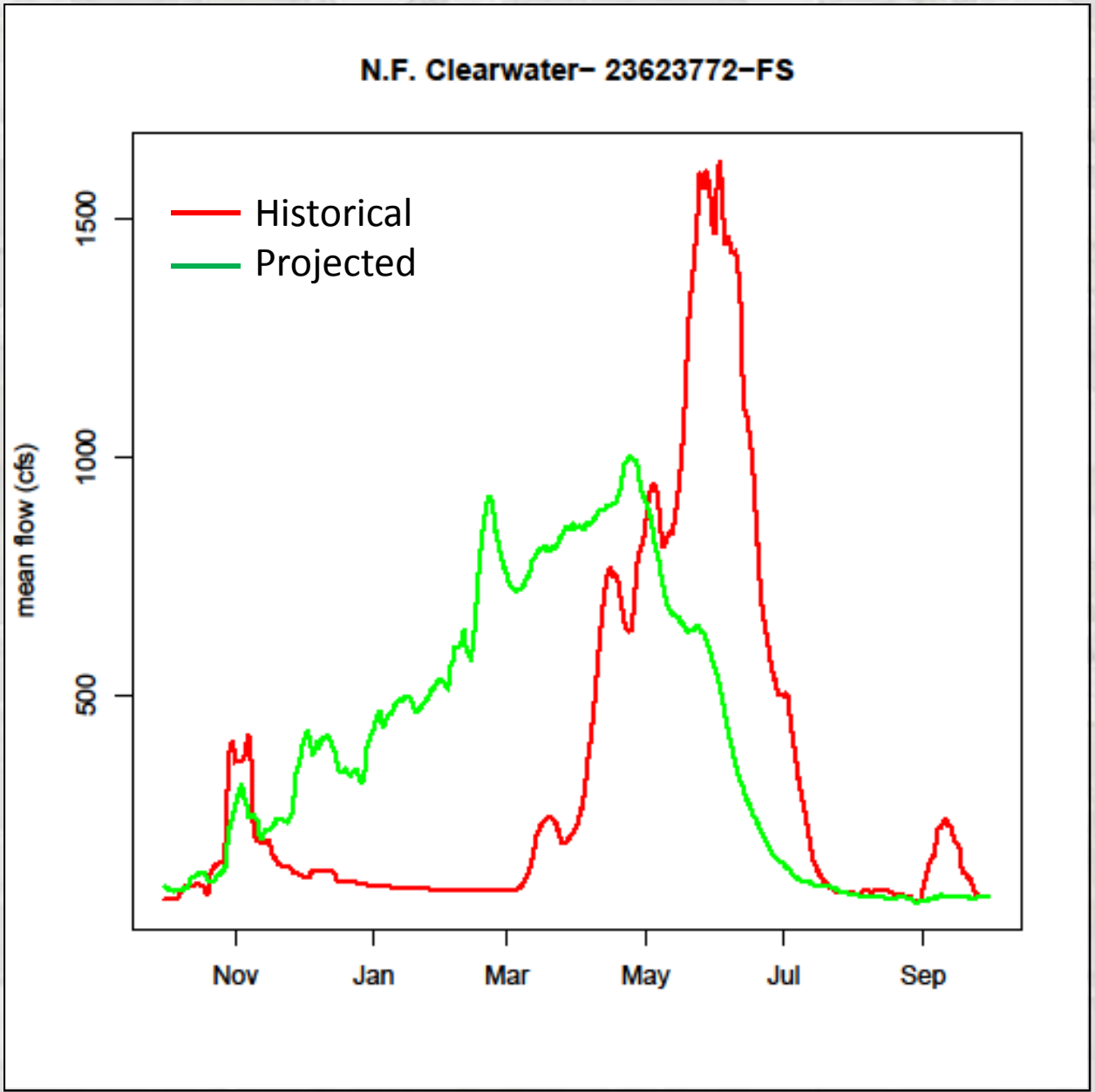
Seasonality Seesaw

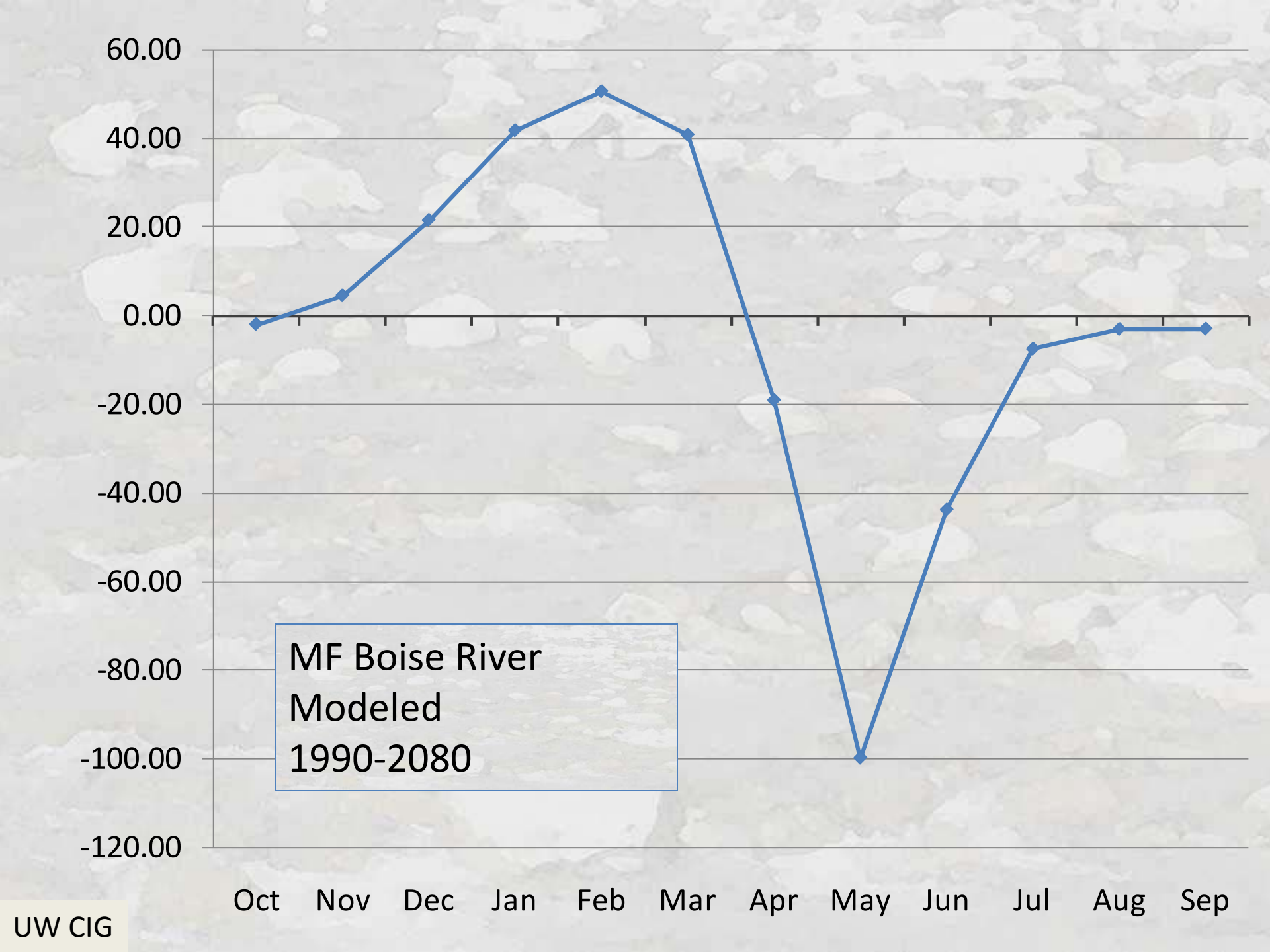
Volume decreased in melt season

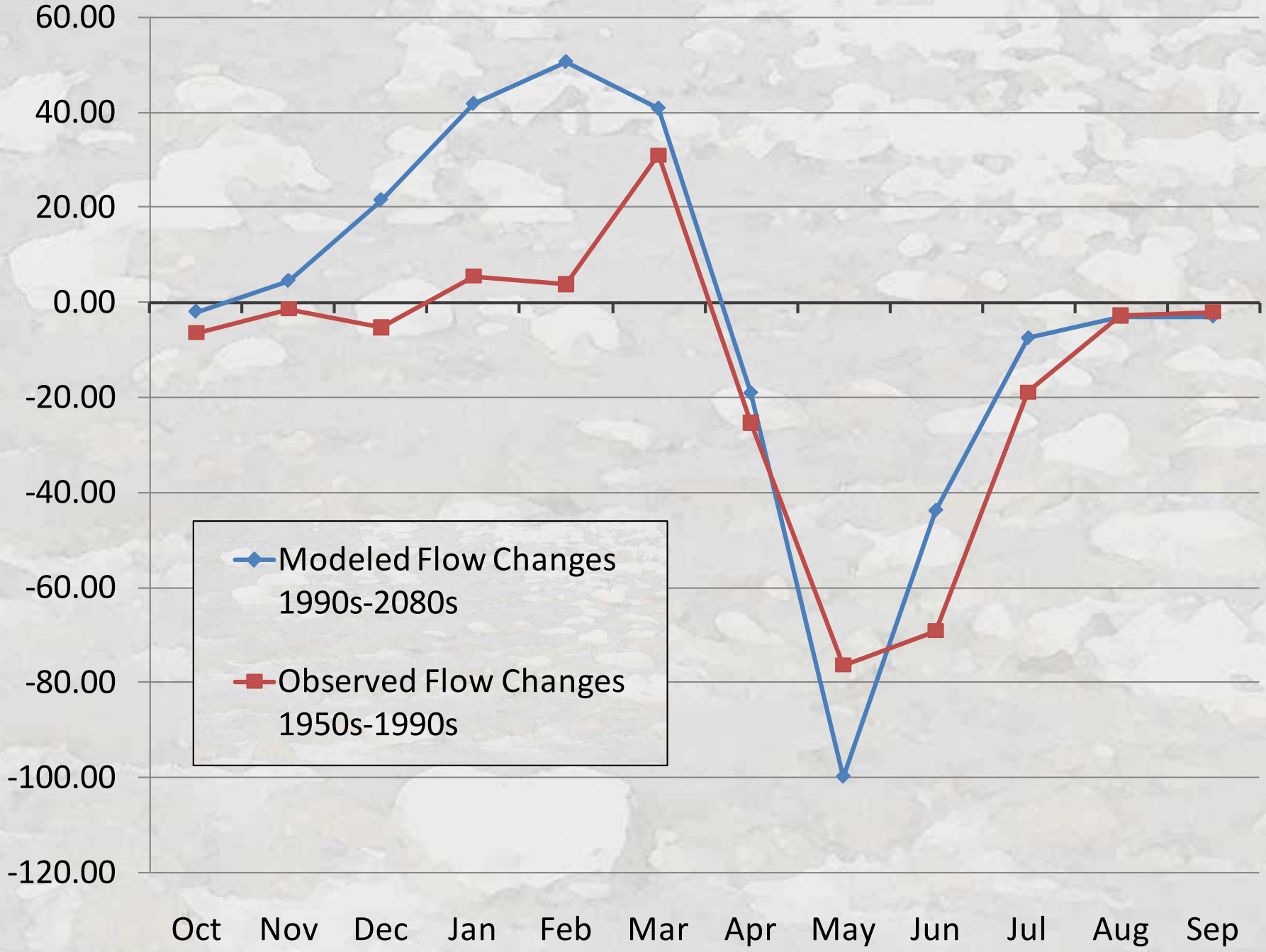



Center of Timing
16 Jun
01 Jun
16 May
01 May
16 Apr
01 Apr
16 Mar
Salmon R nr Salmon
100
150
200
250
Annual Streamflow (mm)

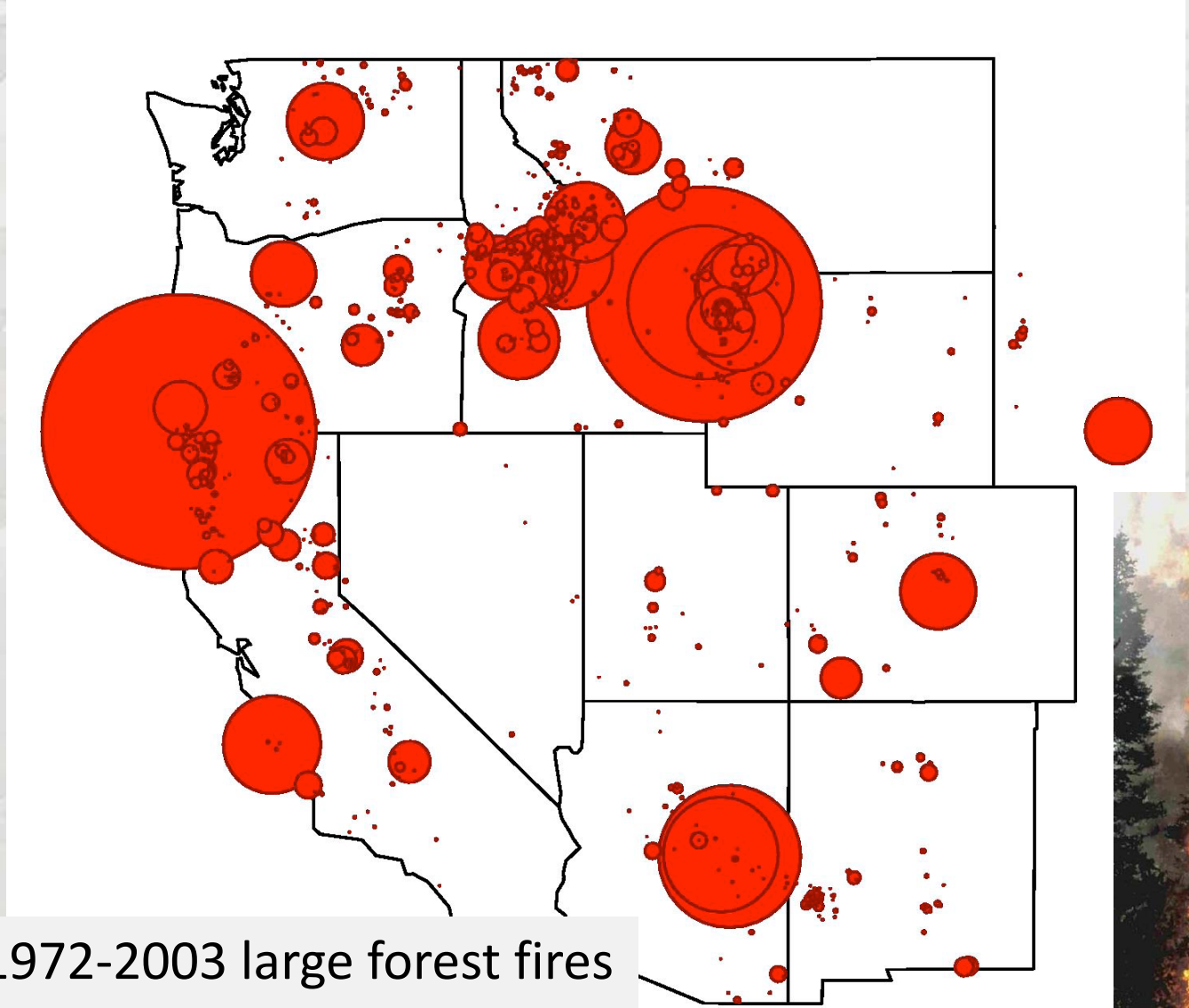
Past and 'Future' Hydrographs




60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
MF Boise River
Modeled
1990-2080
UW CIG

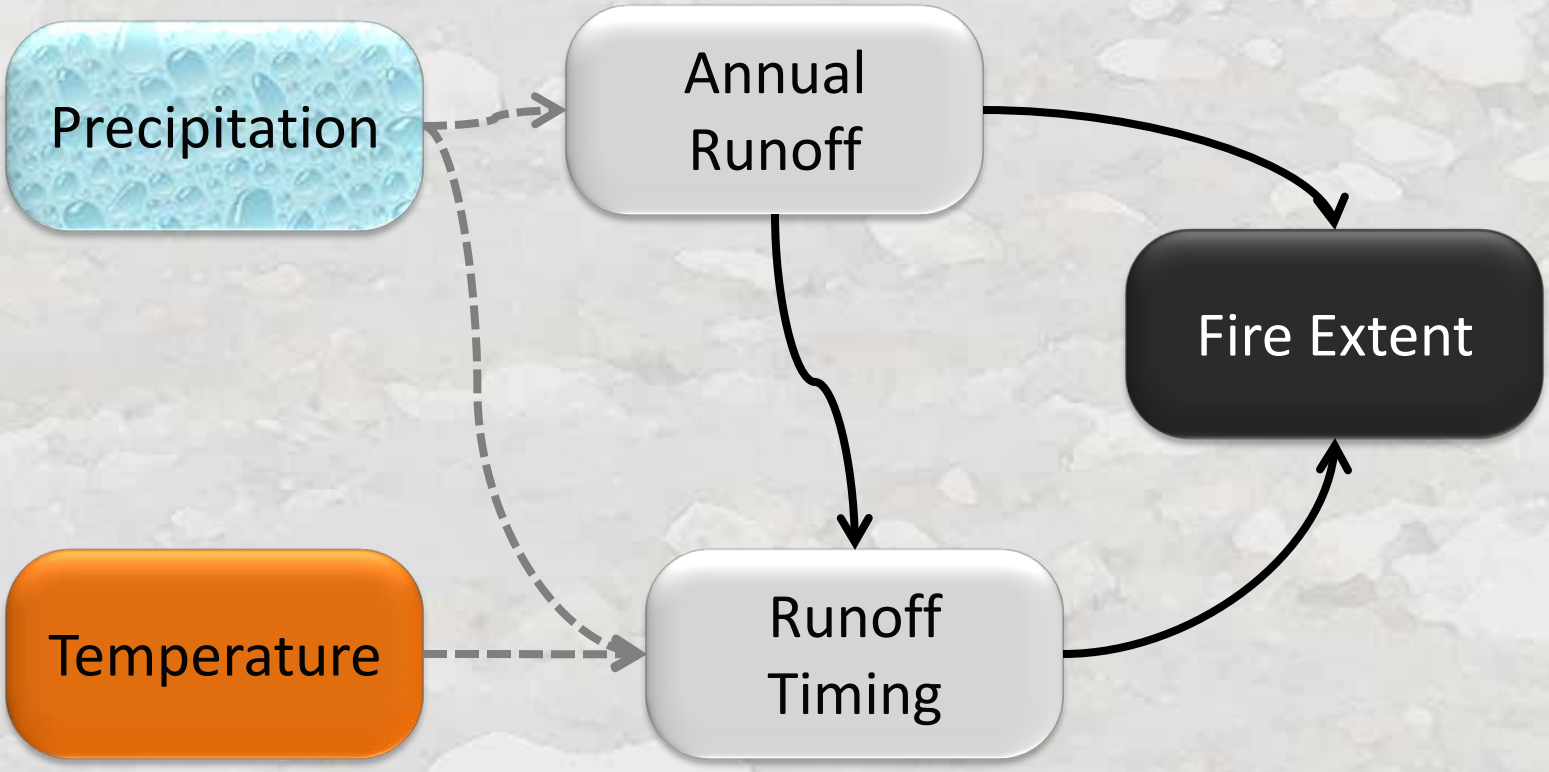

60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Modeled Flow Changes 1990s-2080s
Observed Flow Changes 1950s-1990s

Longer Fire Season Effect?



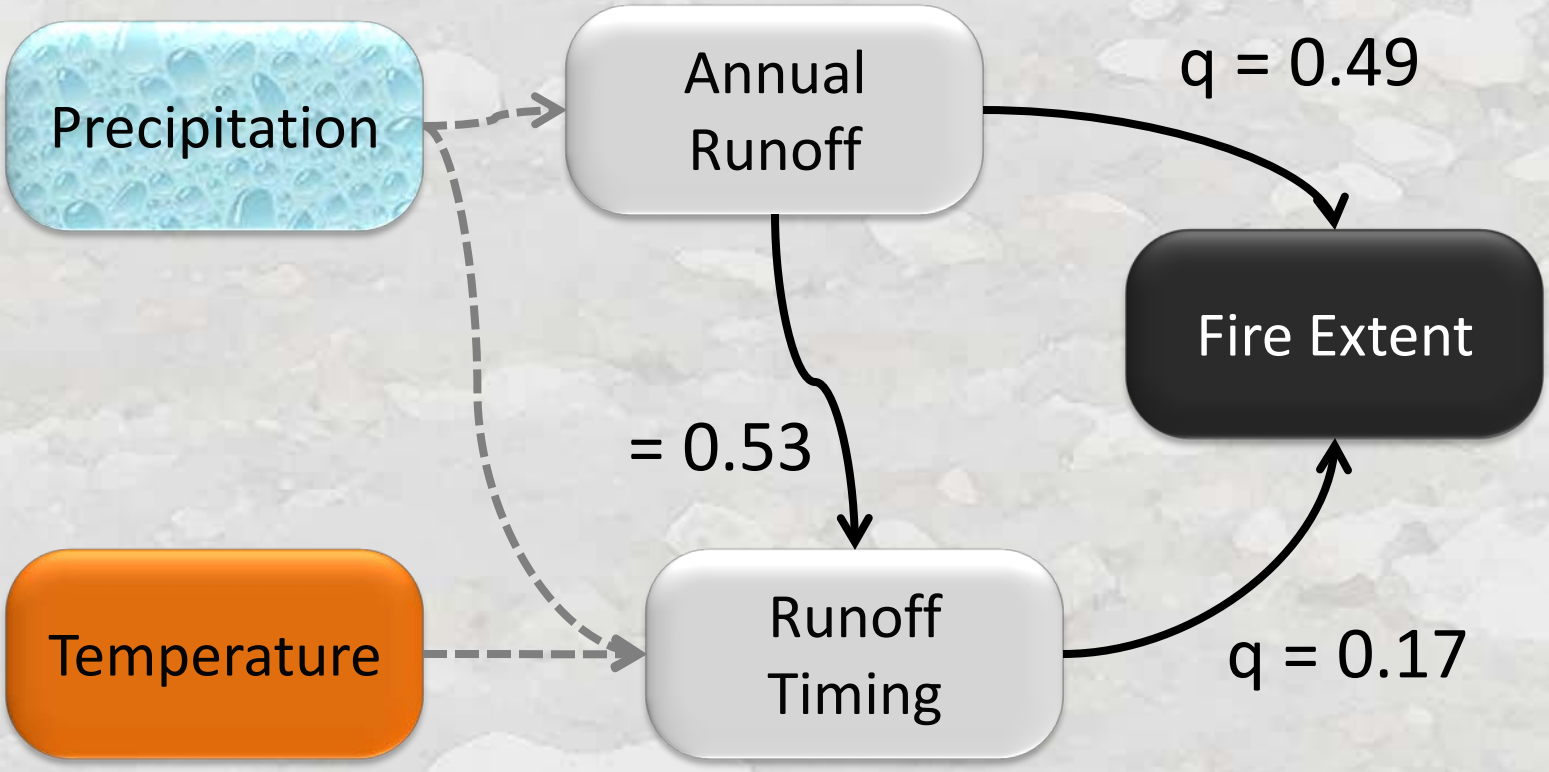
1972-2003 large forest fires
Westerling et al, 2006

Burned Area Sensitivity



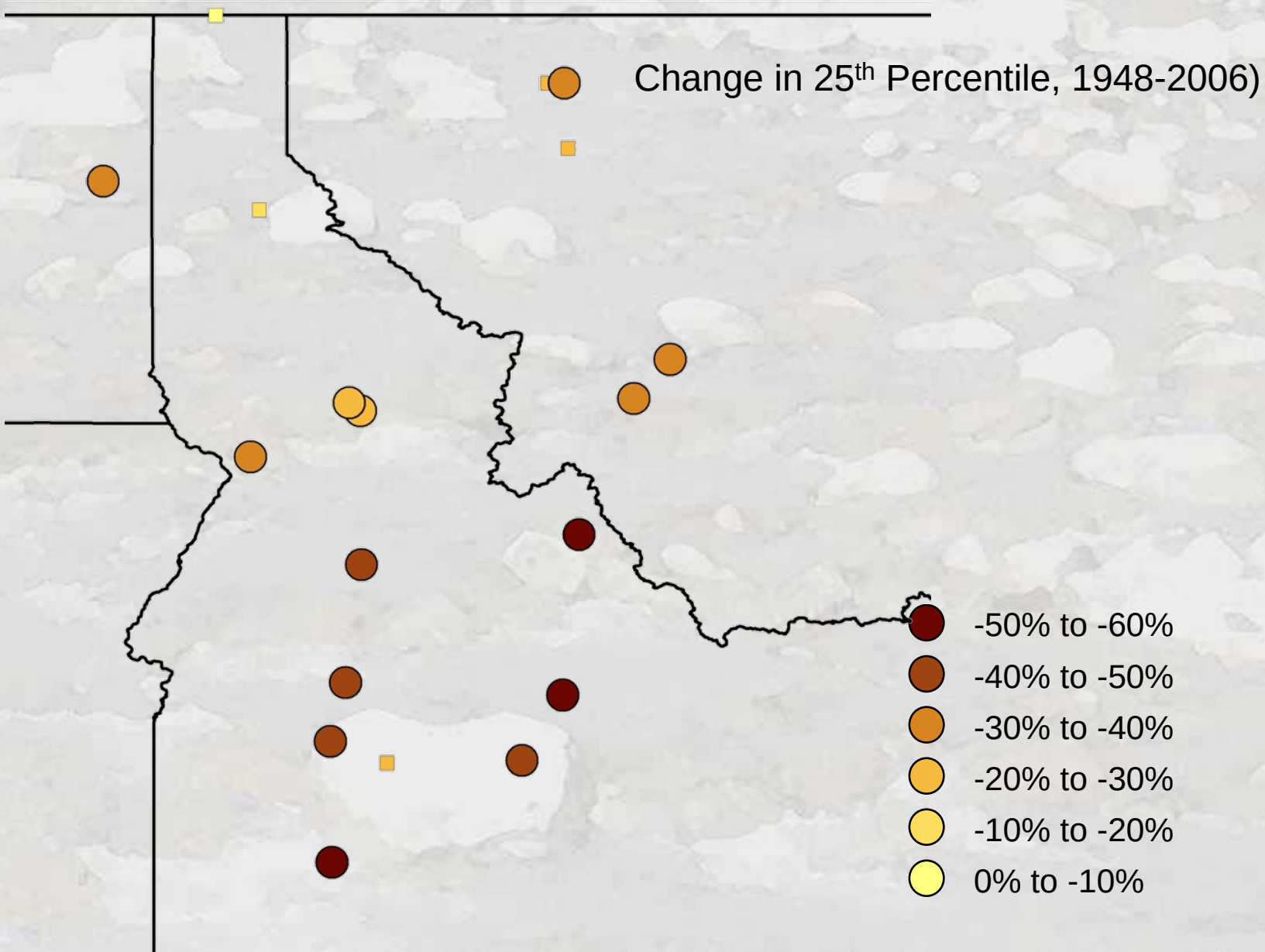
Holden et al., in revision

Burned Area Sensitivity

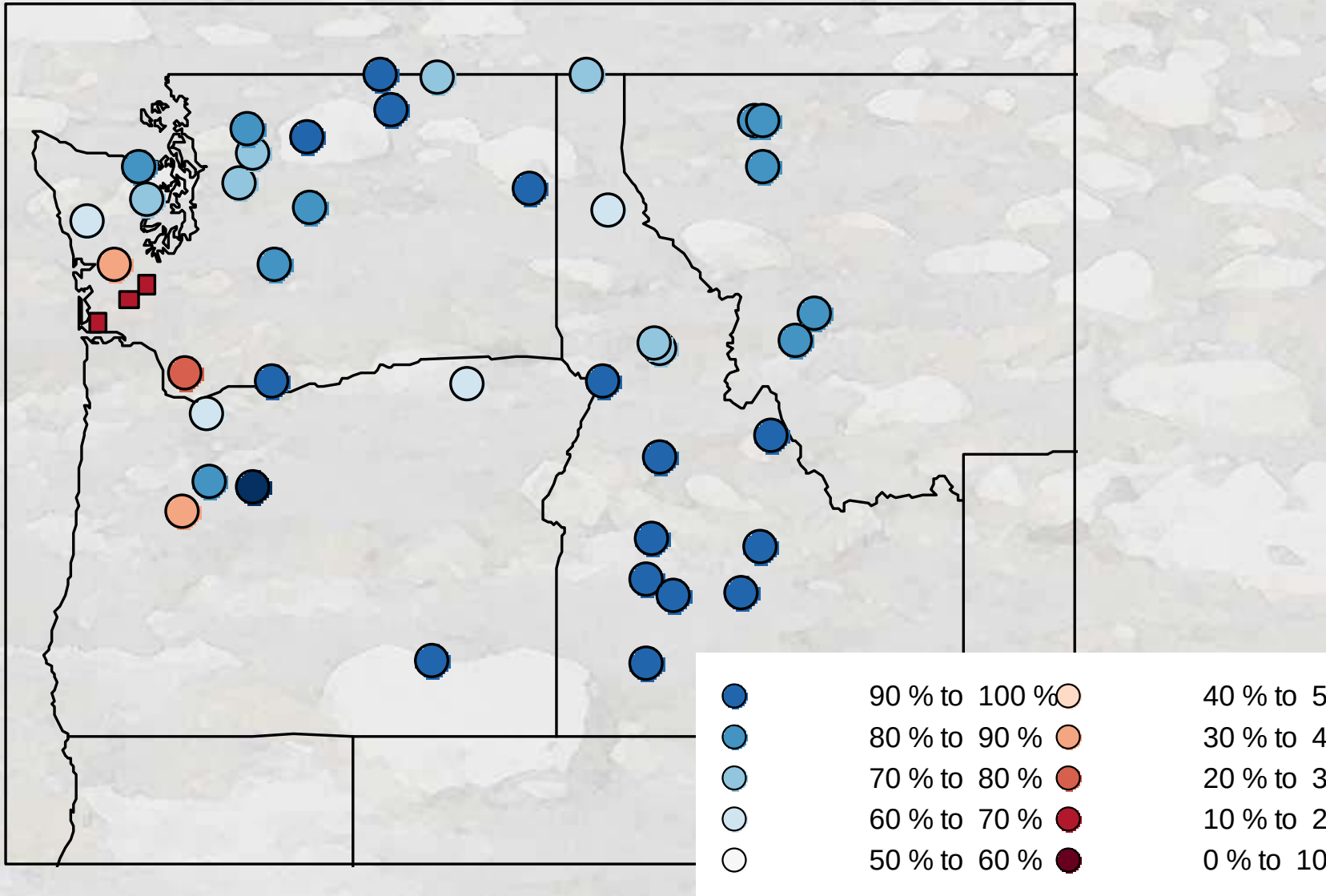


Holden et al., in revision

Summer Flows (July 15-Sep15)

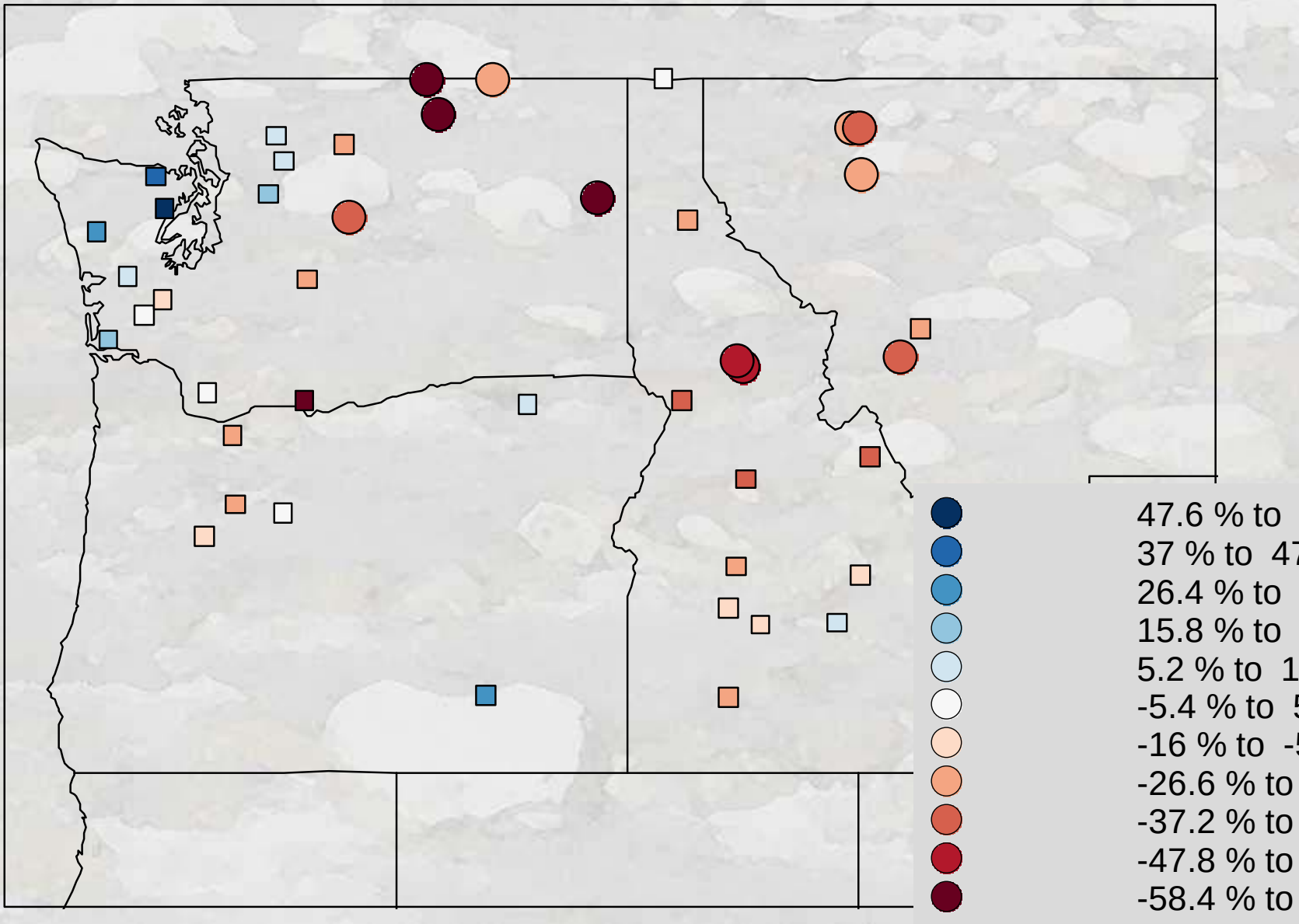


Summer Flow to Annual Flow Correlation



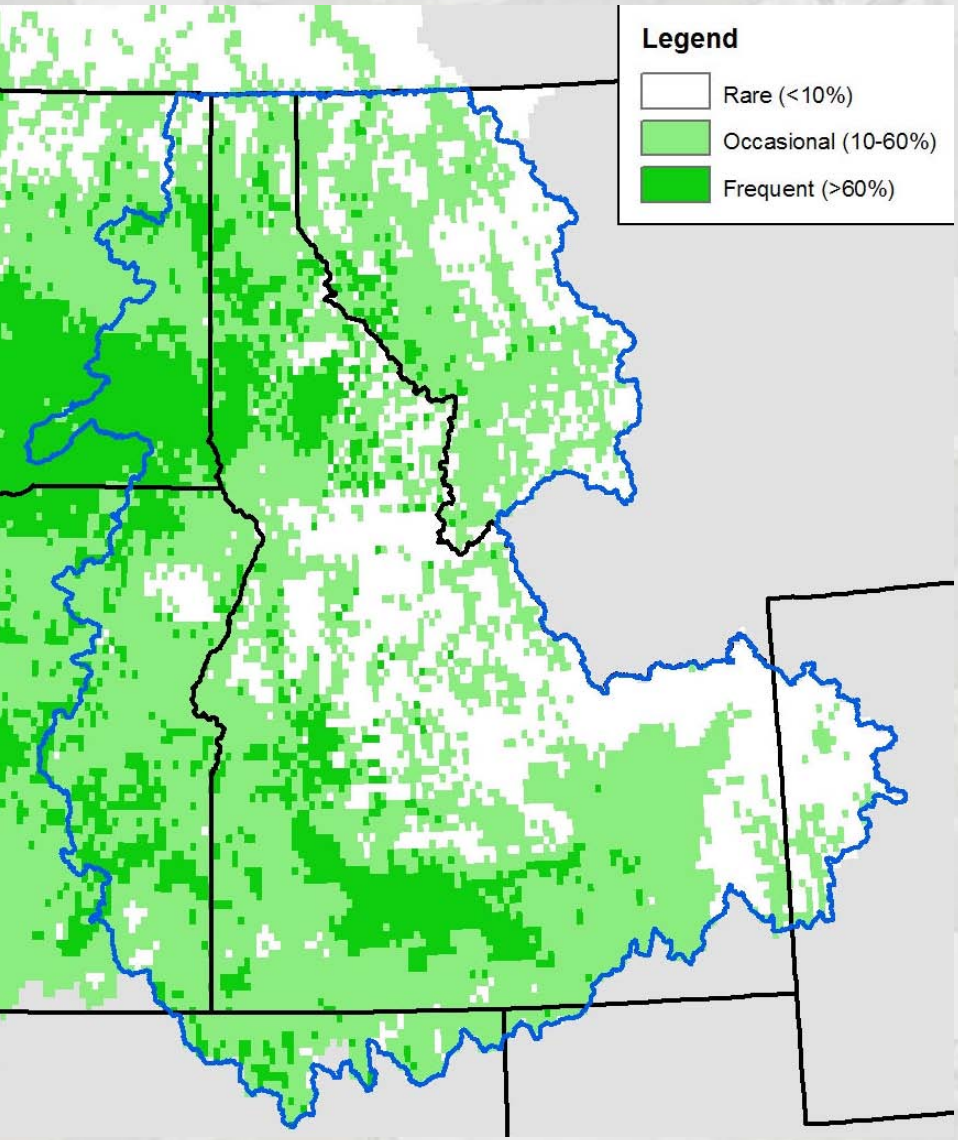
Floods

Historical 2-yr Flood Trend

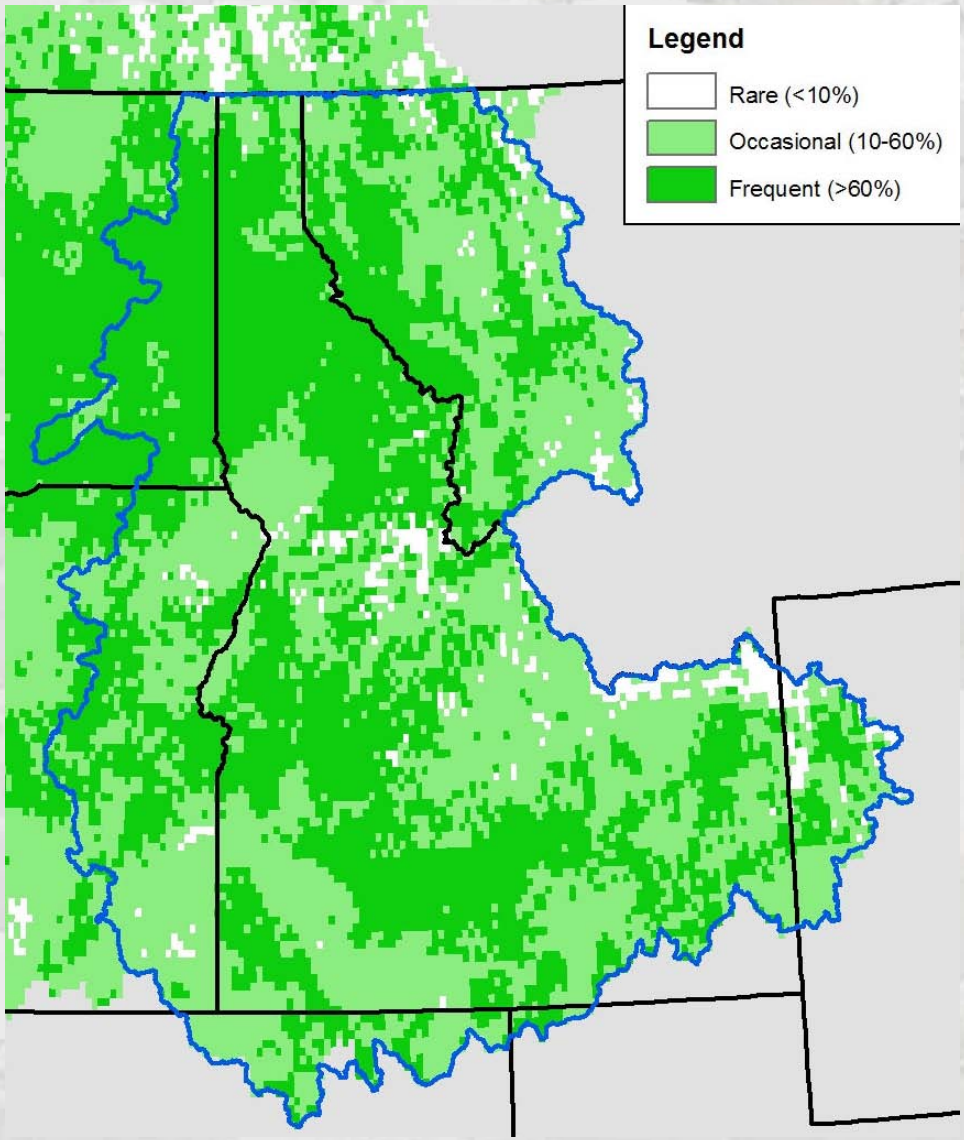


Midwinter Flood Frequency

Wenger et al, submitted
From UW CIG data

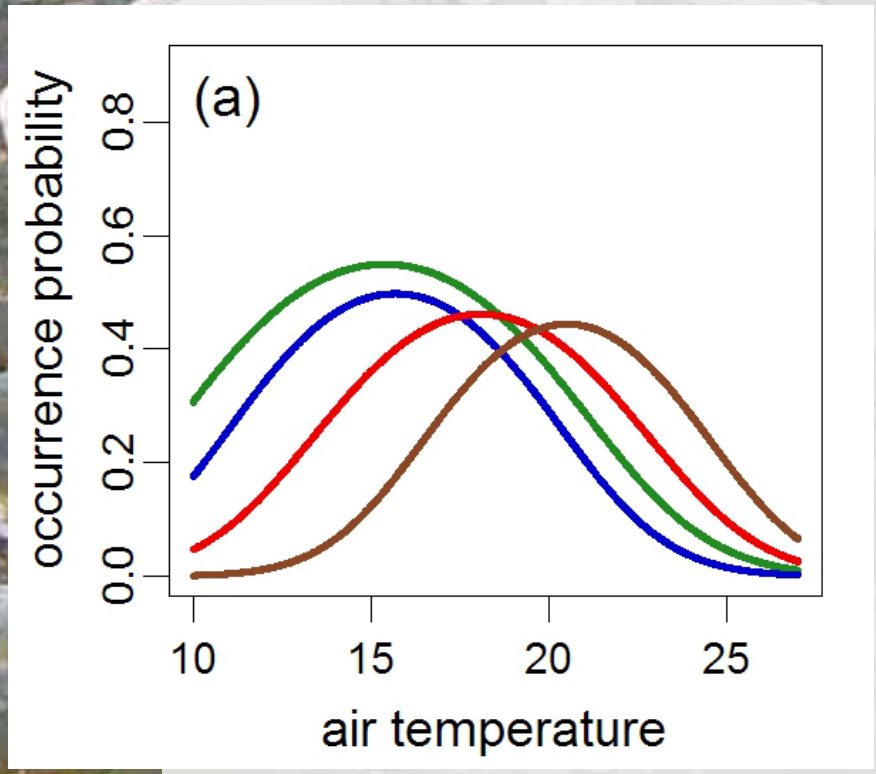


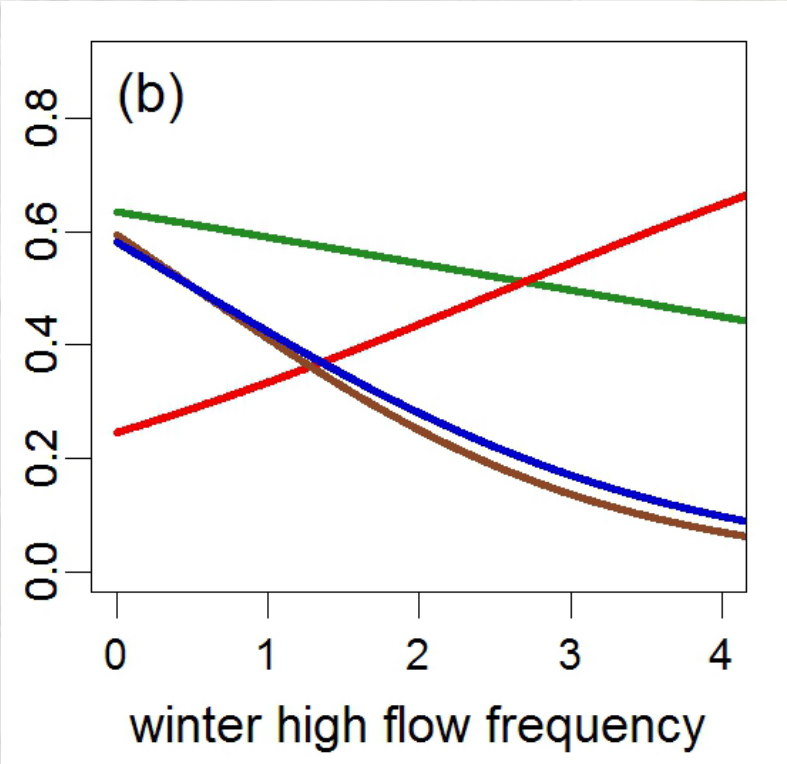
Present



2080 A1b

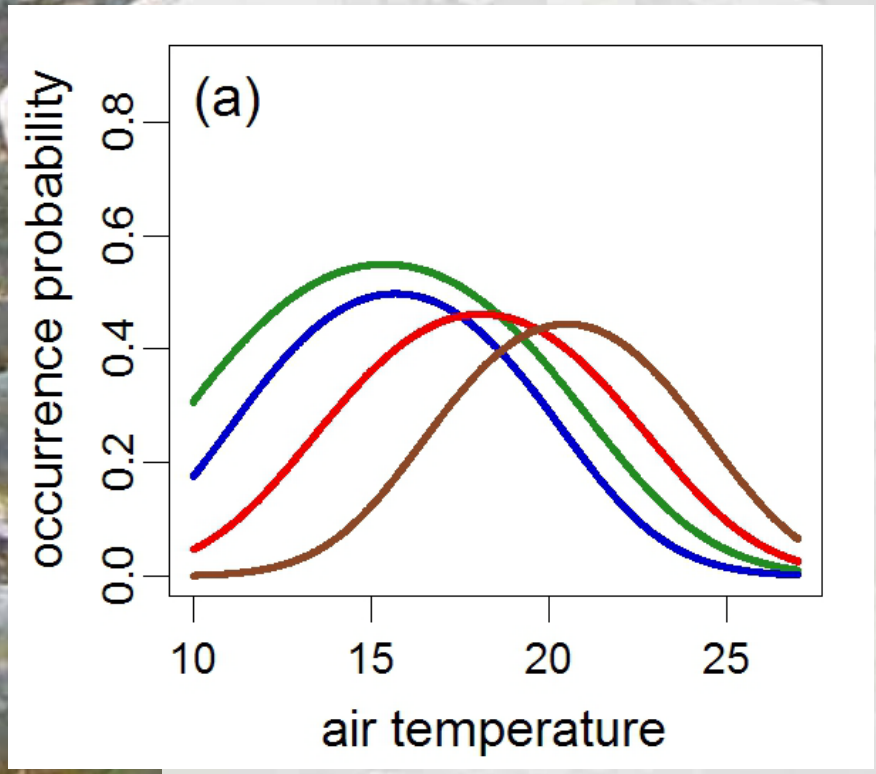
Aquatic Species Sensitivity



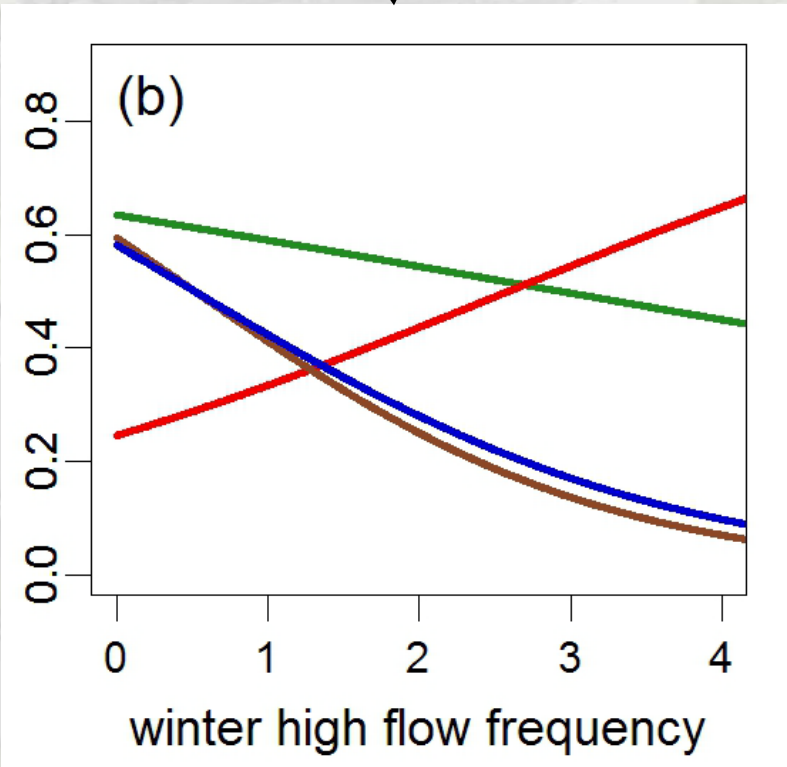


Wenger et al., submitted

Aquatic Species Sensitivity



Both metrics primarily Temperature sensitive



Wenger et al., submitted

Sensitivity

Precipitation

Temperature

Water Supply

Peak Snow

Runoff Timing

Fire Extent

Flood Seasonality

Spawning Success

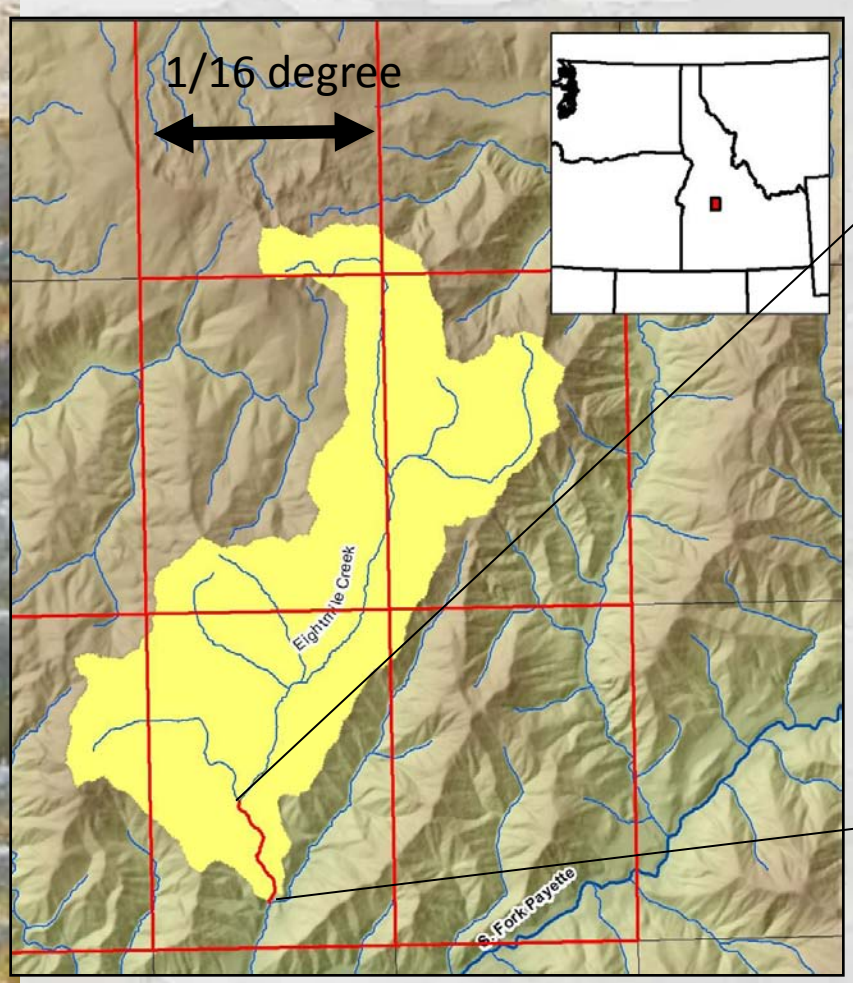
Flood Magnitude

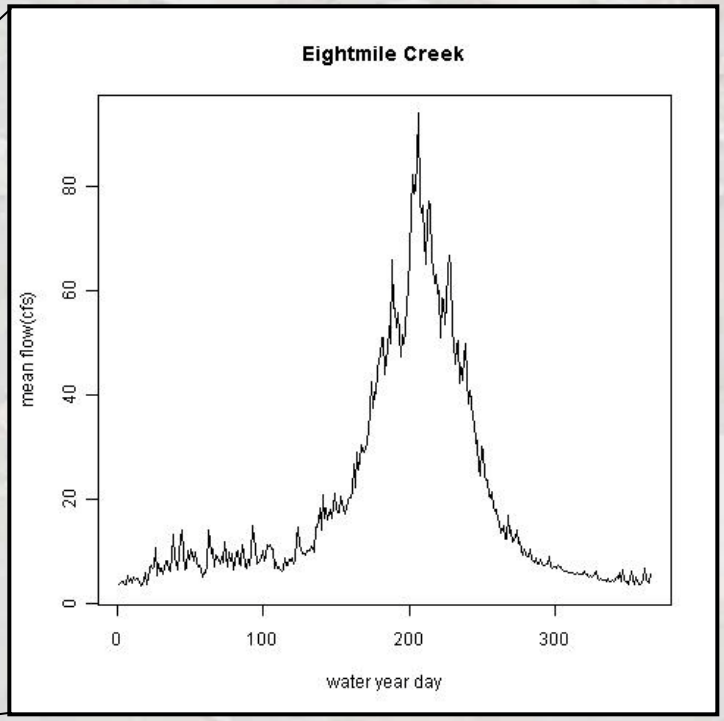
Summer Low Flow

Key Items

- Projections as temperature sensitivity
  - Projections are a partial description of vulnerability
- Need for more explicit discussion of uncertain precipitation
  - Big differences in adapting to drier vs. wetter future

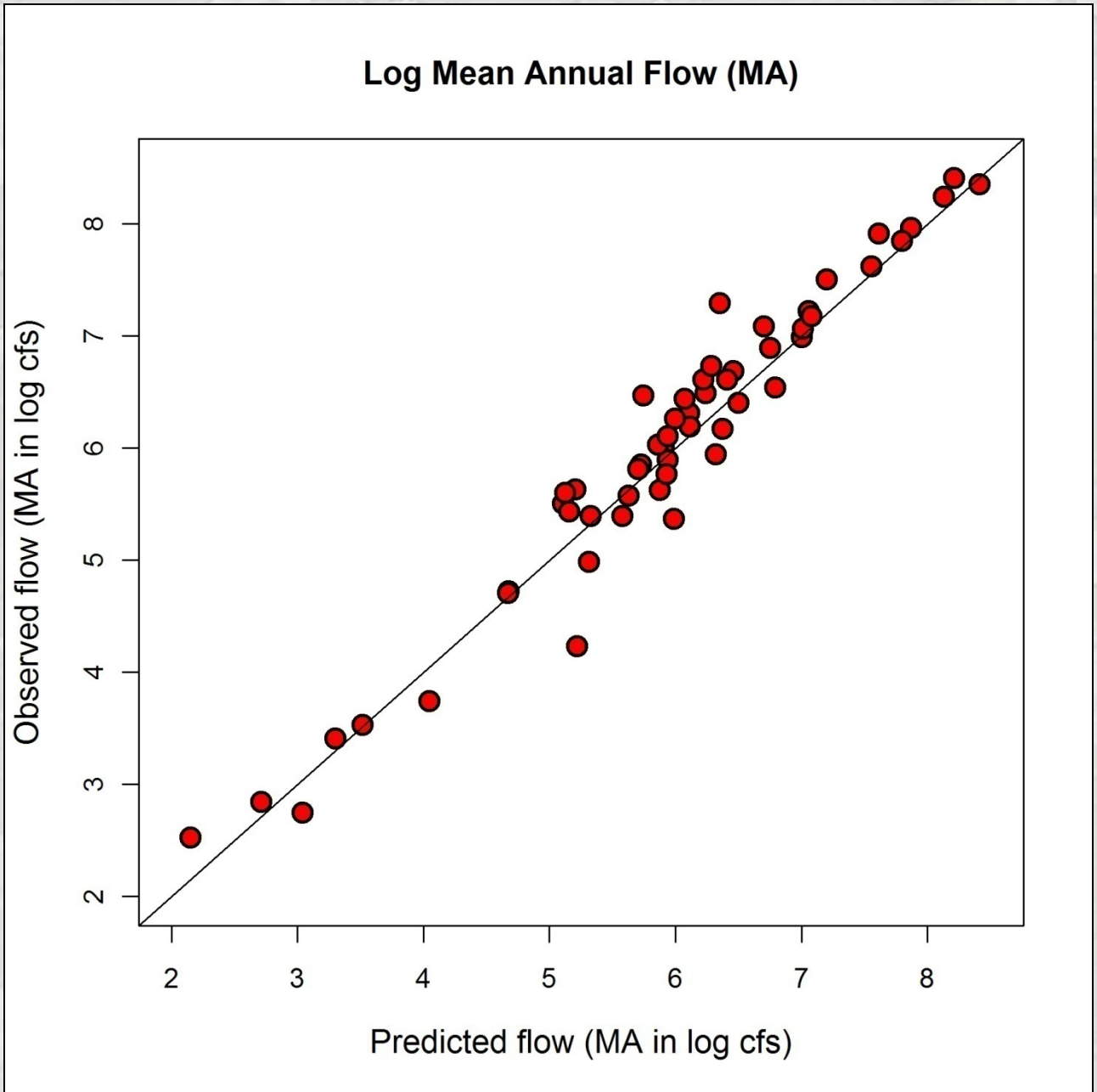
VIC Streamflow Downscaling





Wenger et al., 2010

PNW VIC Validation



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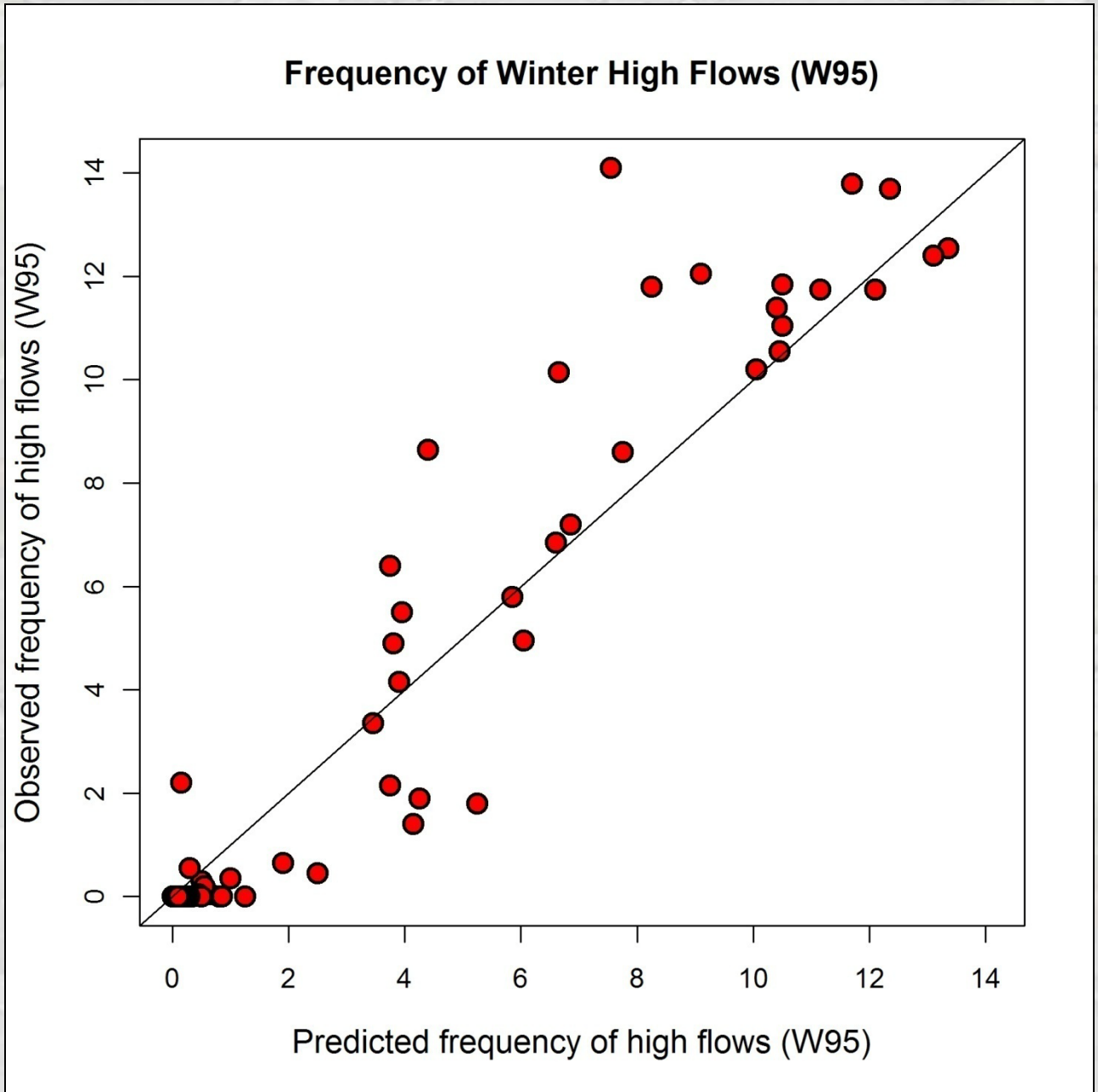

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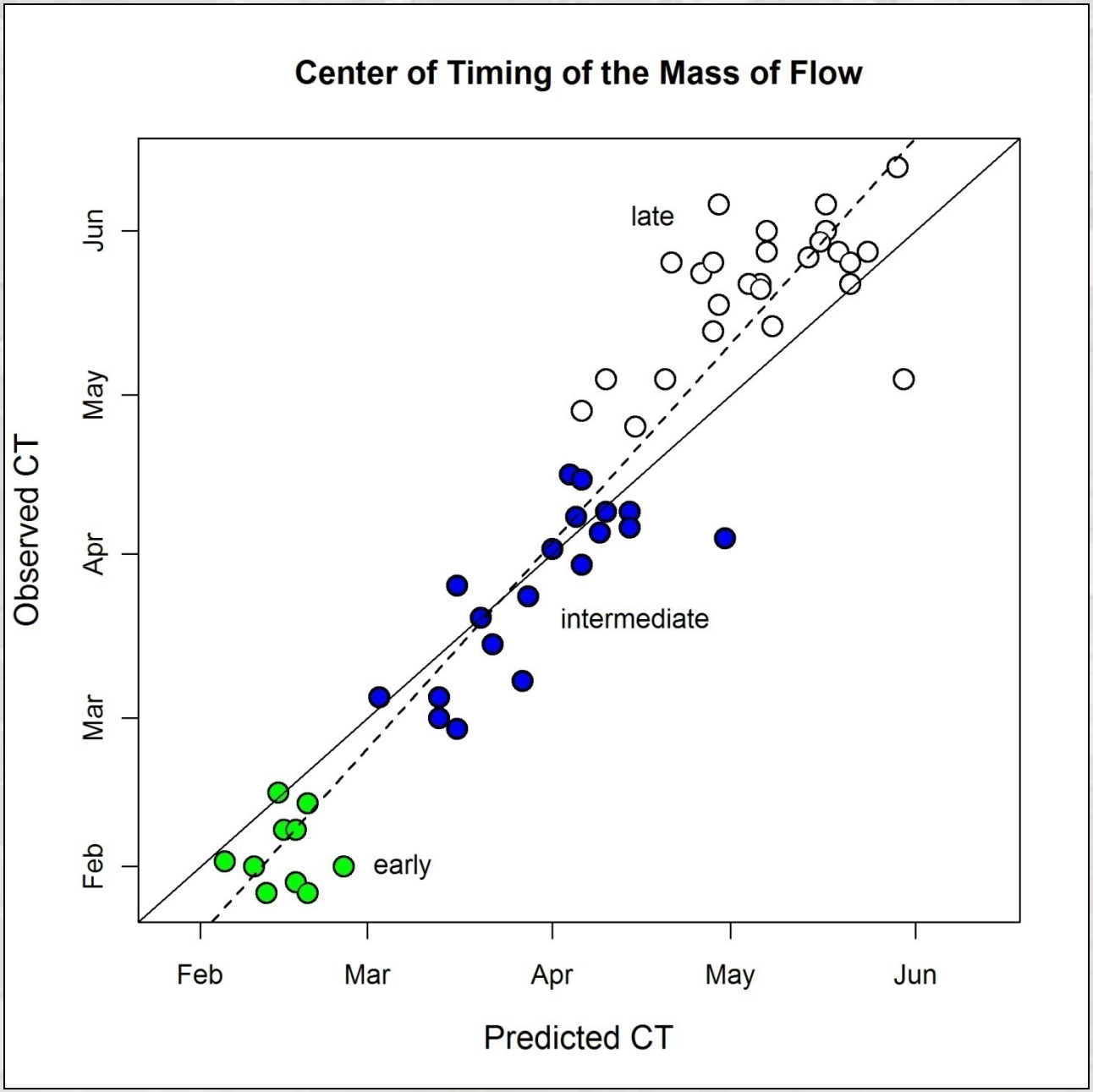

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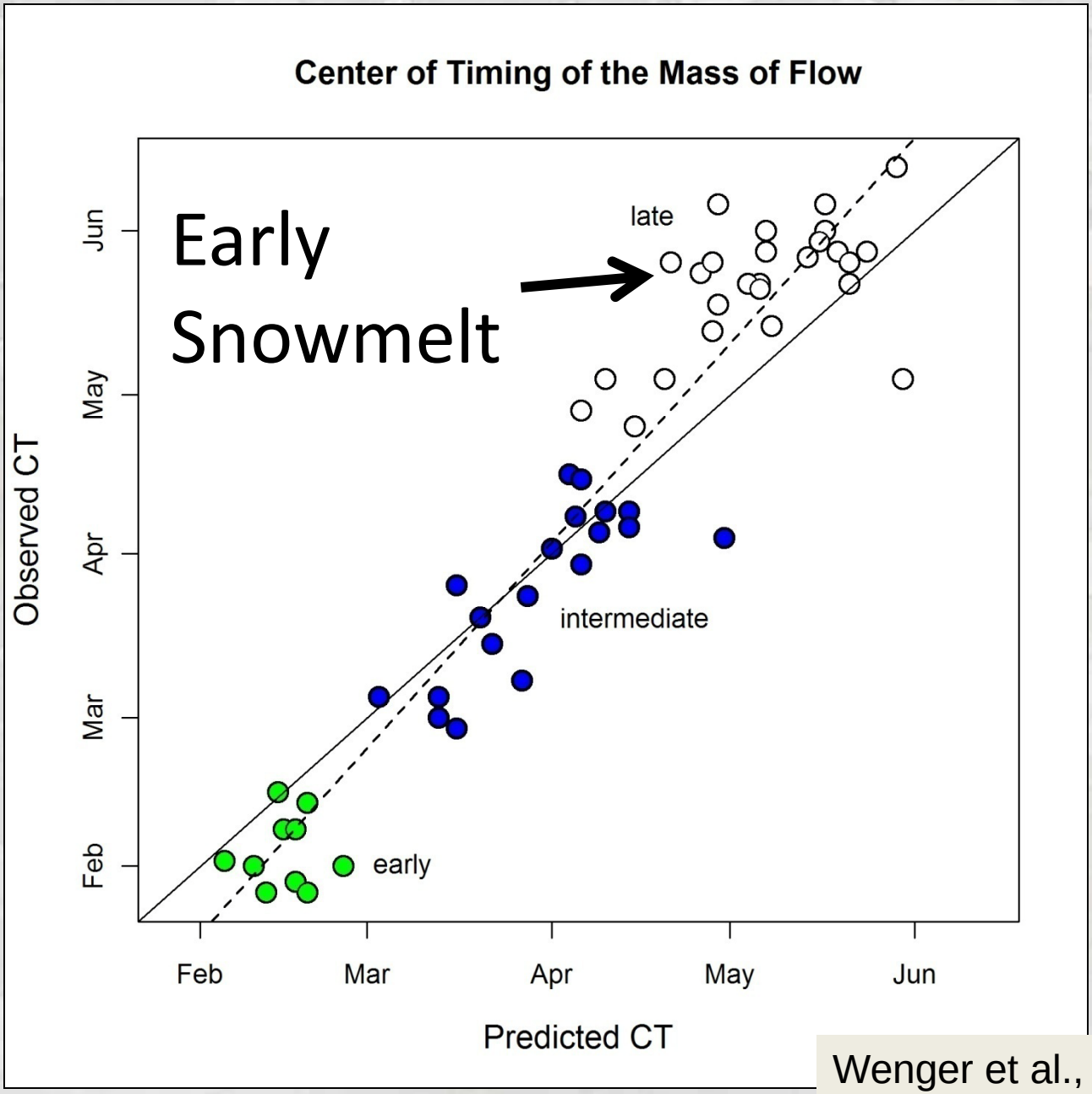
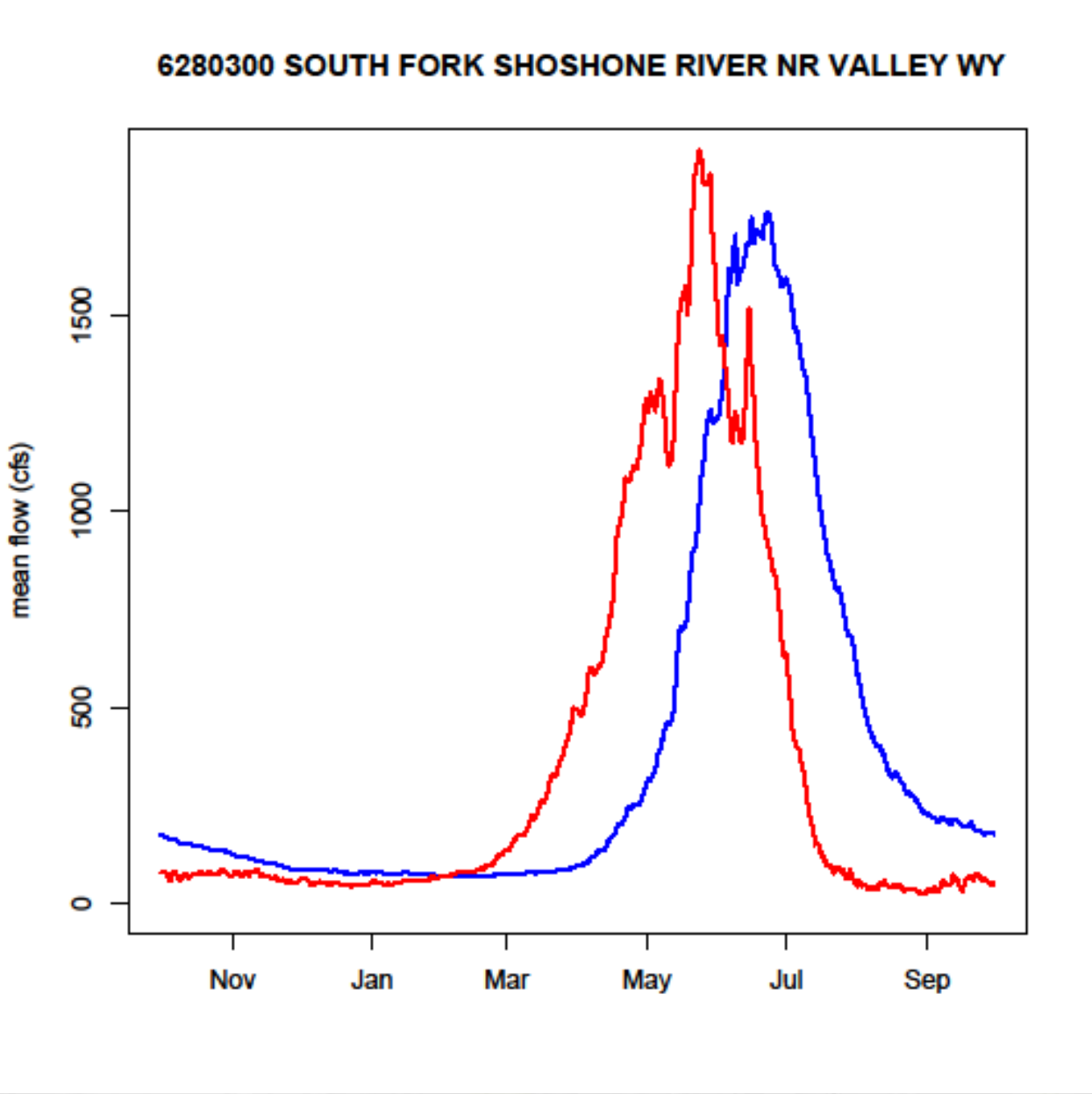


Wenger et al., 2010

Snowmelt Bias Example



Available Downscaled Streamflow Metrics

Historical
2040s A1b
2080s A1b

Ensemble
Miroc
PCM

http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml