Changing Water Resources in the Western US

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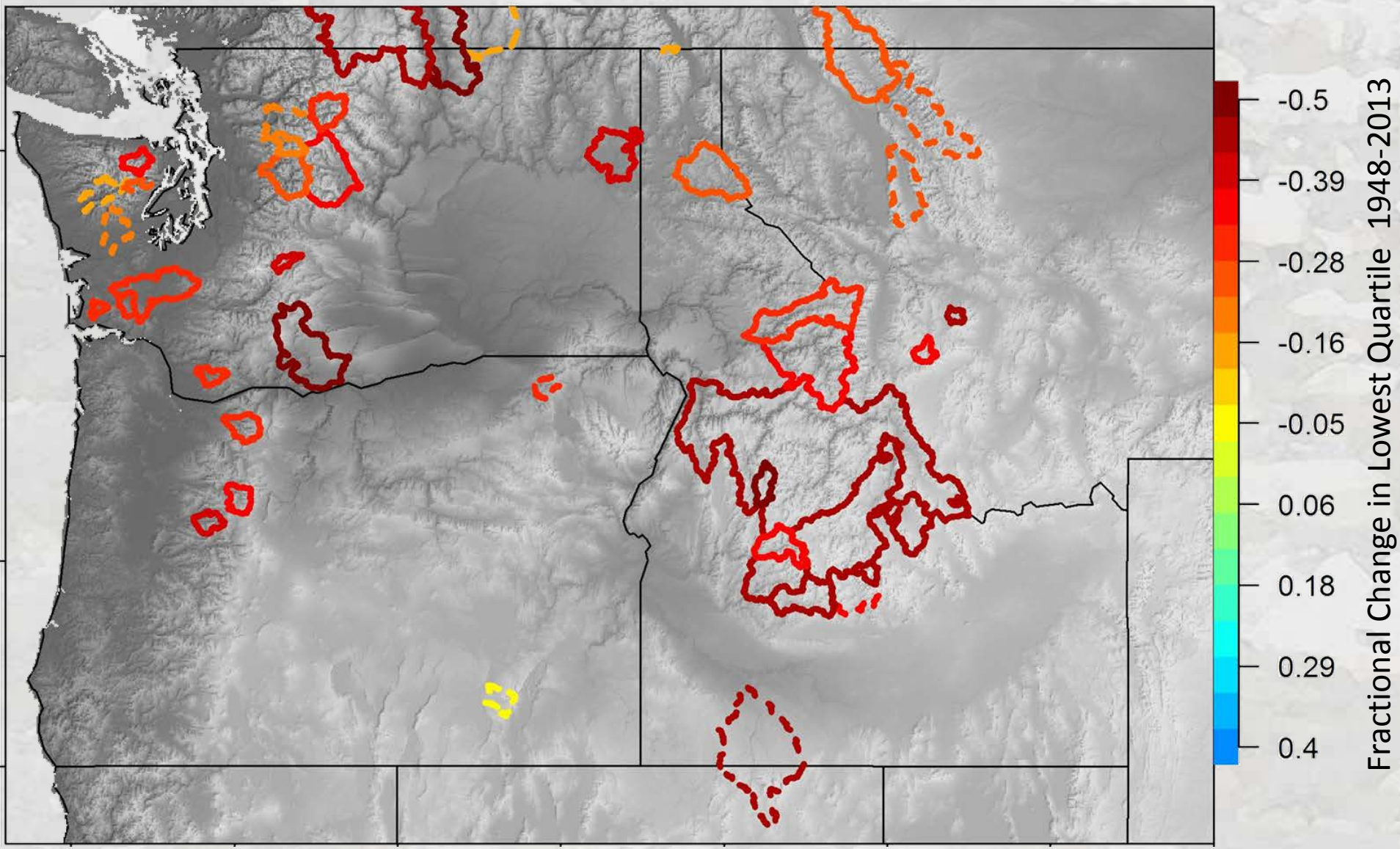
Water Resources

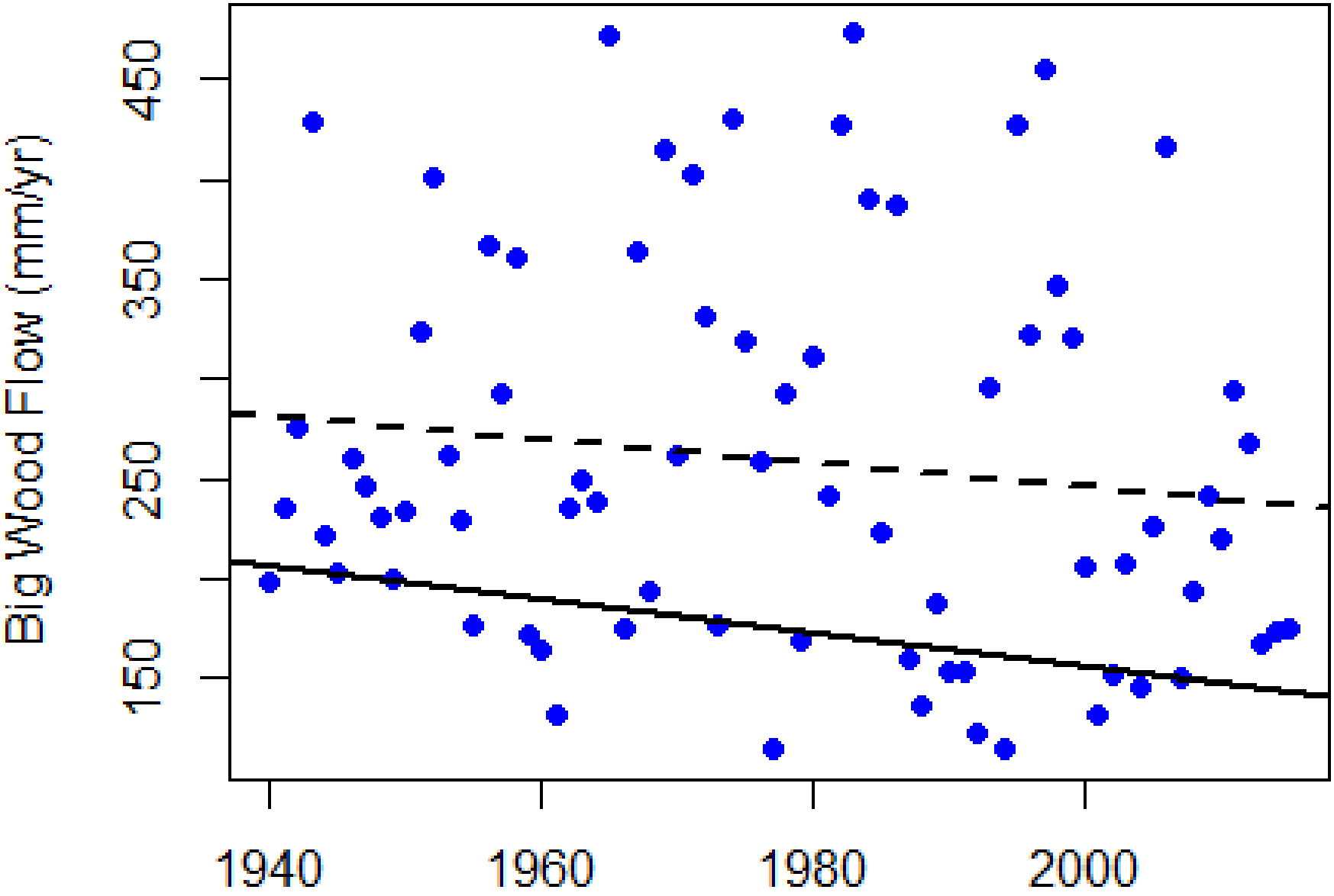
- Climate Context
  - Orography in NW
- Snow
  - April 1 SWE
  - Residence time
- Runoff
  - Amount, timing, floods

Declines in Mountain Runoff 1948-2013

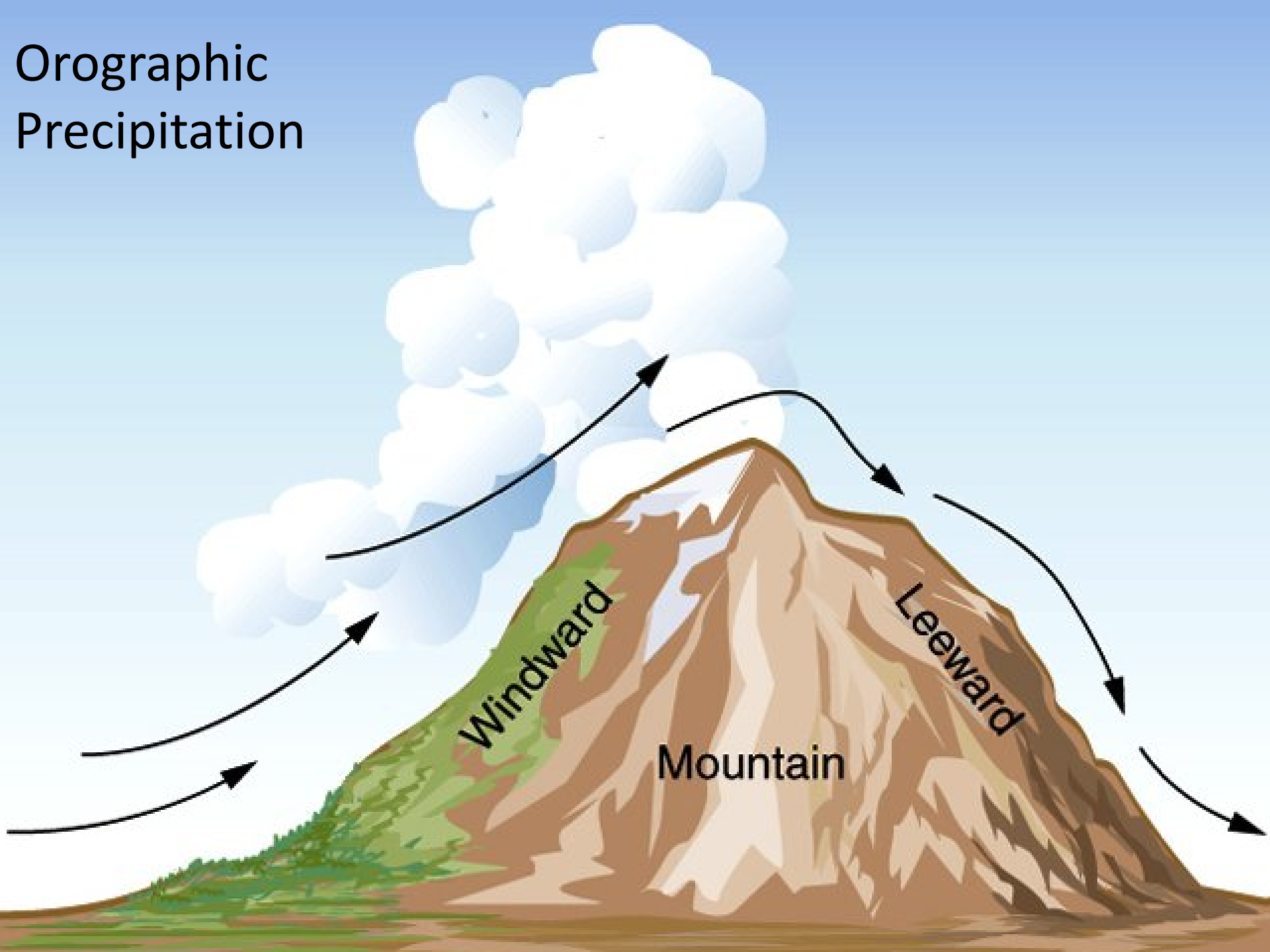


Luce, Abatzoglou, Holden 2013

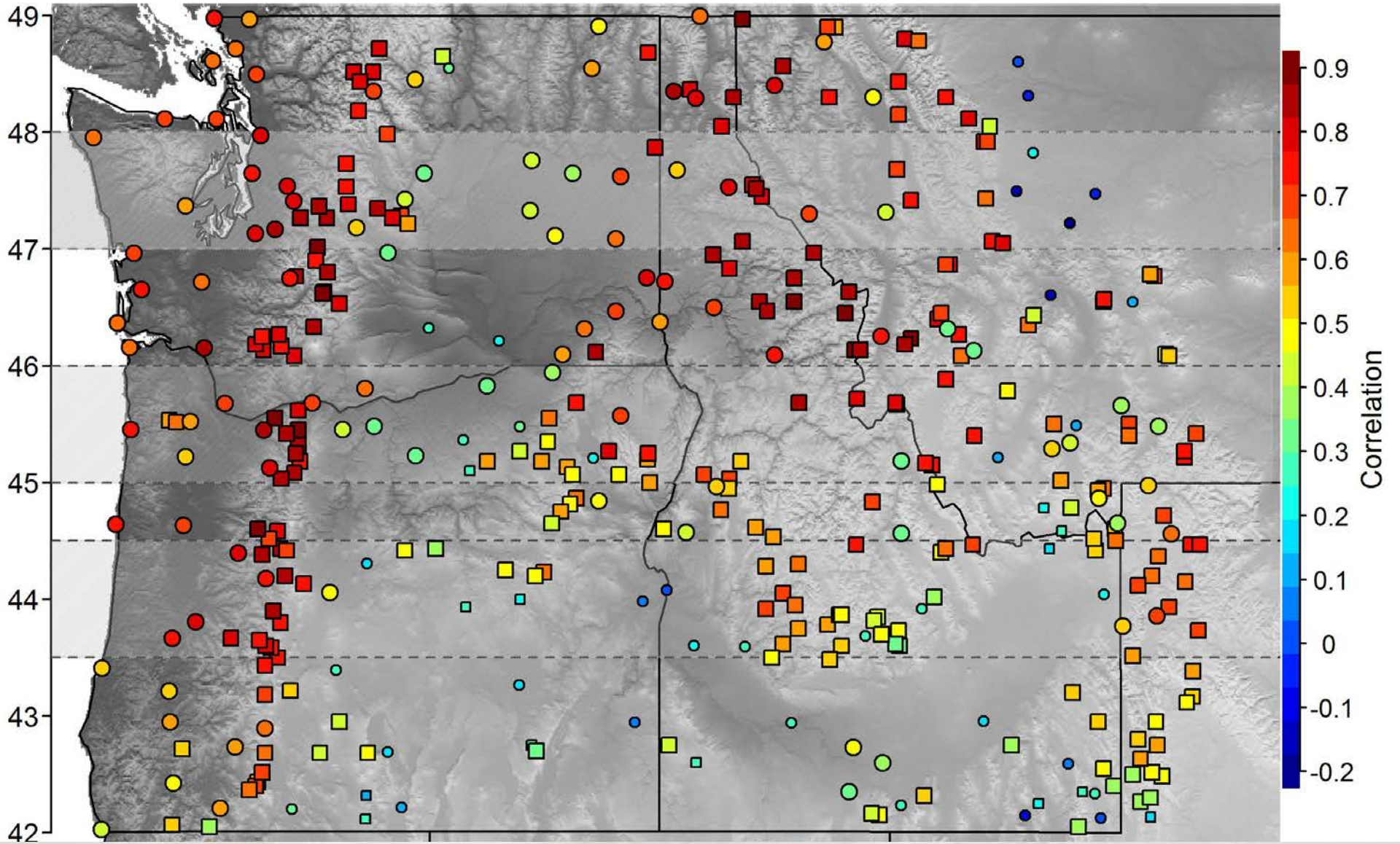
Big Wood River Flow Trend



Orographic Precipitation



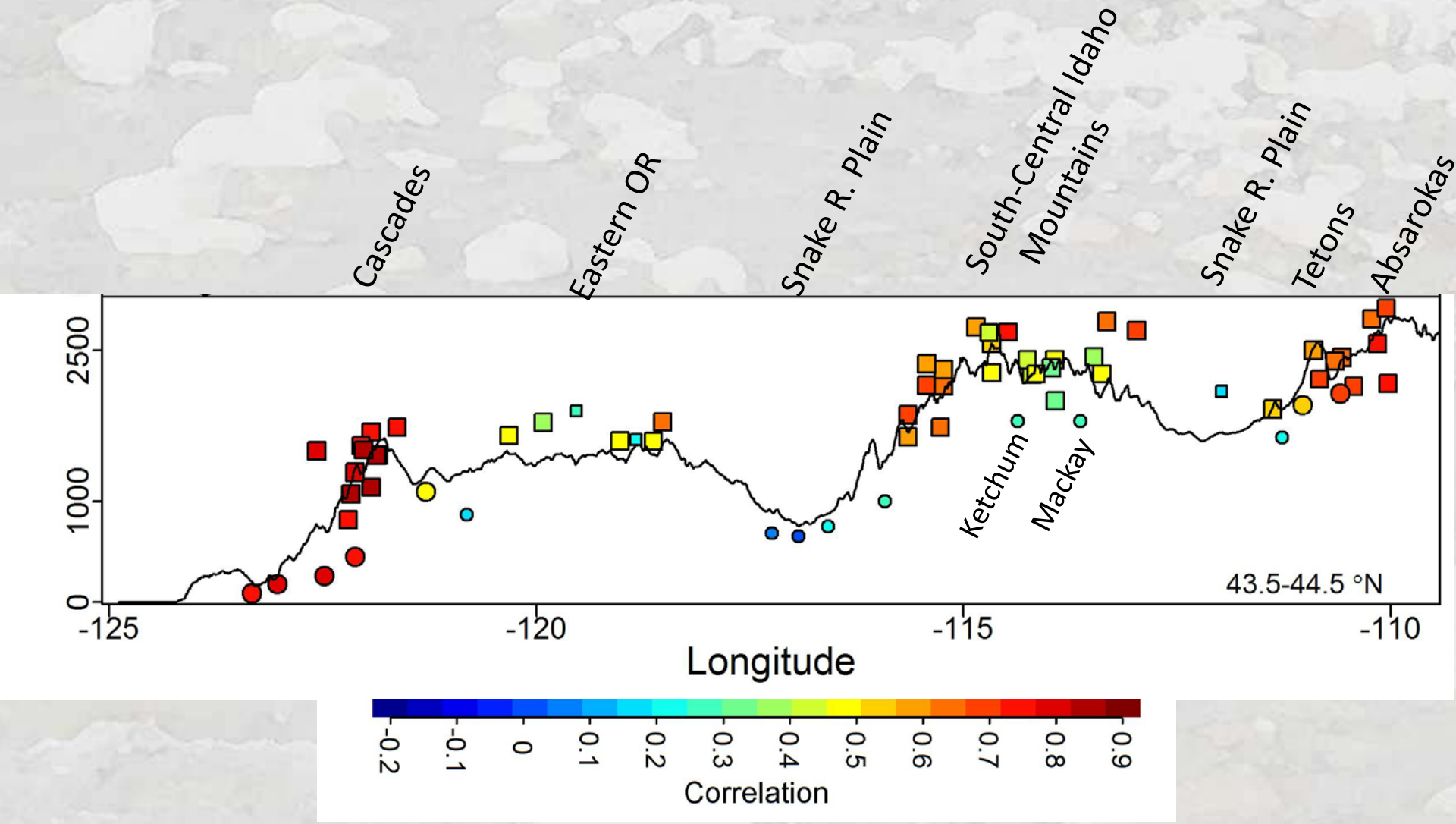
Precipitation Correlation with Regional Westerly Wind Speed

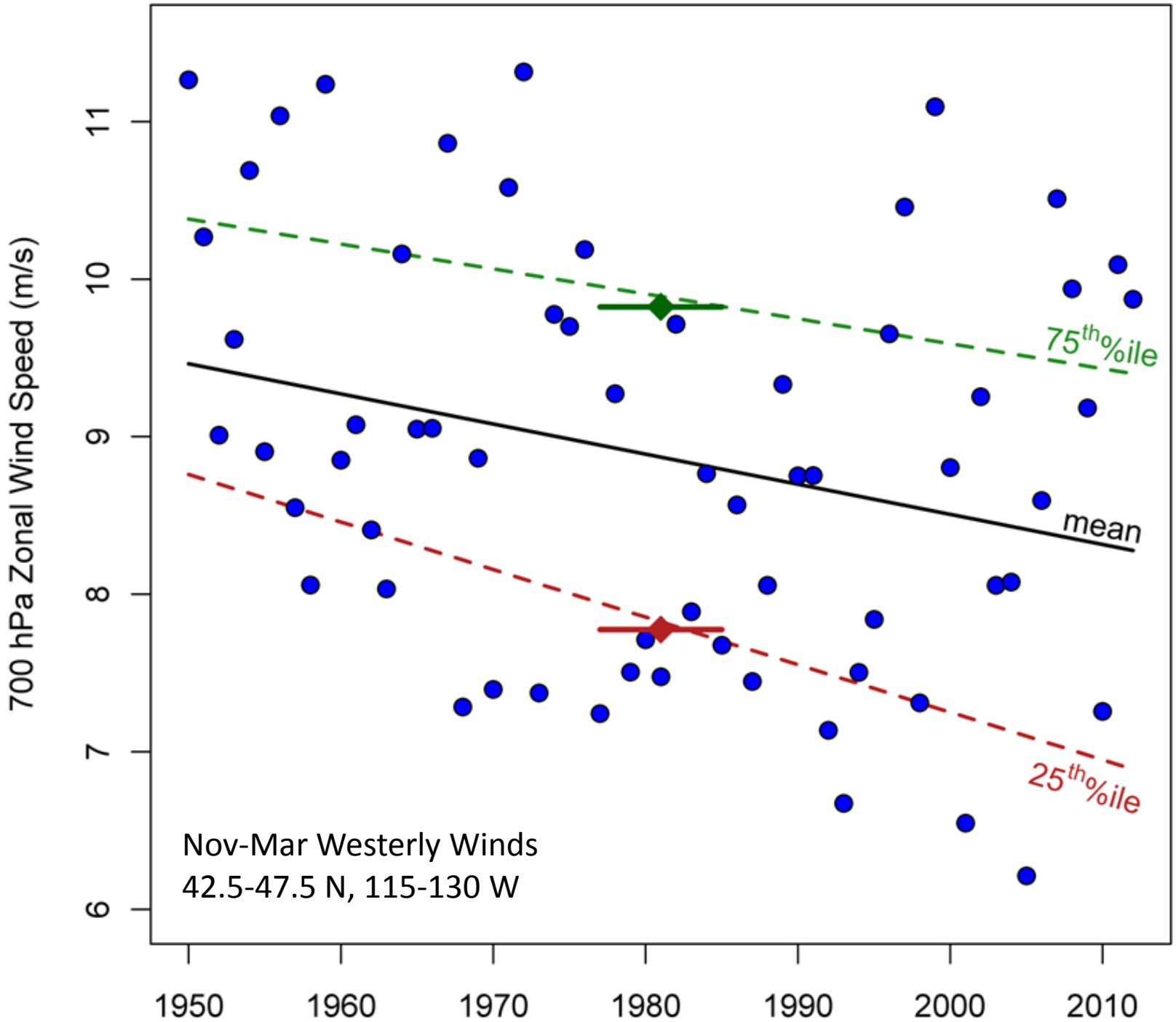


Snotel Station

HCN Station

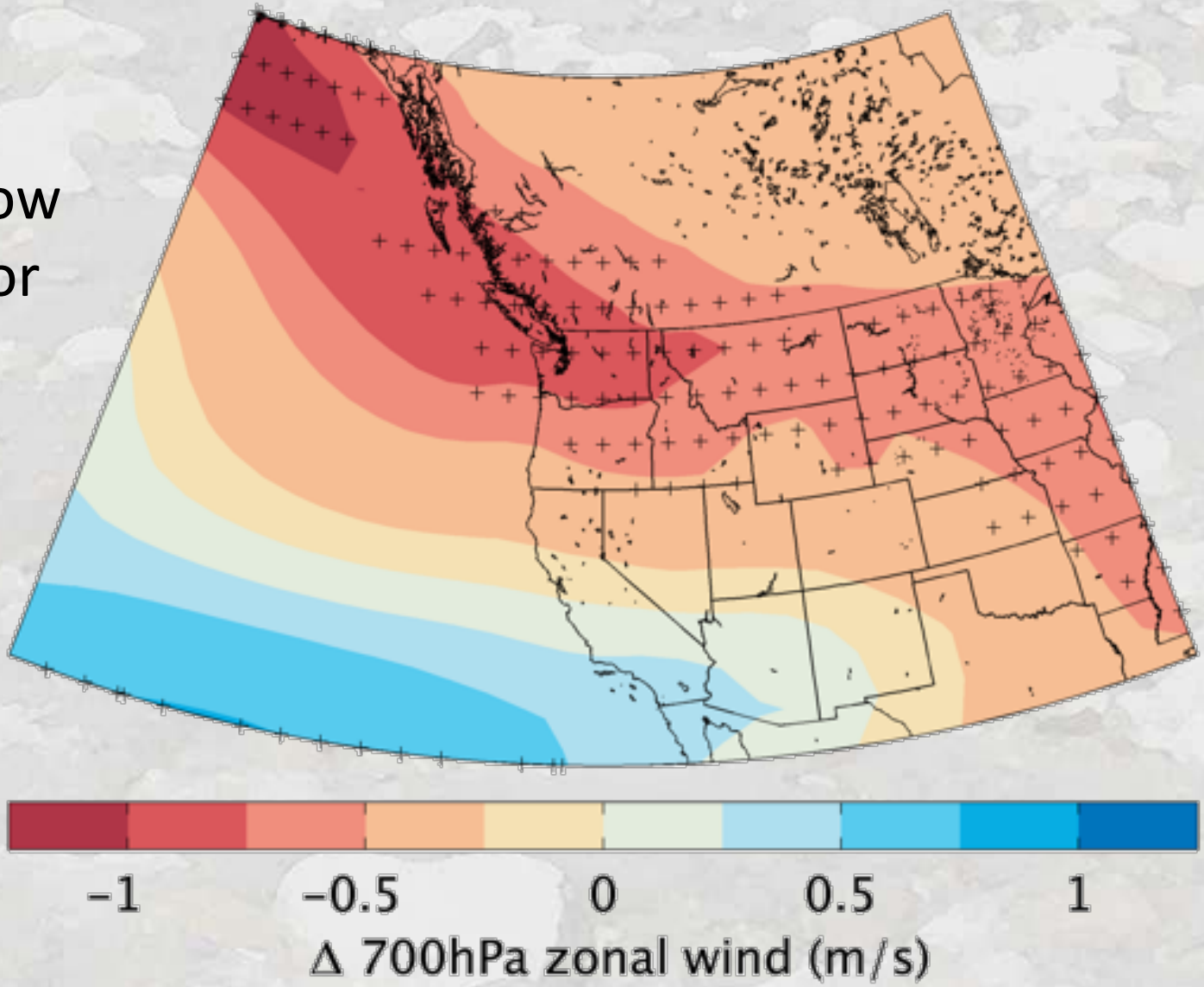
Precipitation Correlation with Regional Westerly Wind Speed




700 hPa Zonal Wind Speed (m/s)
6
7
8
9
10
11
1950
1960
1970
1980
1990
2000
2010
75th%ile
mean
25th%ile
Nov-Mar Westerly Winds
42.5-47.5 N, 115-130 W

Future Wind Changes – from GCMs

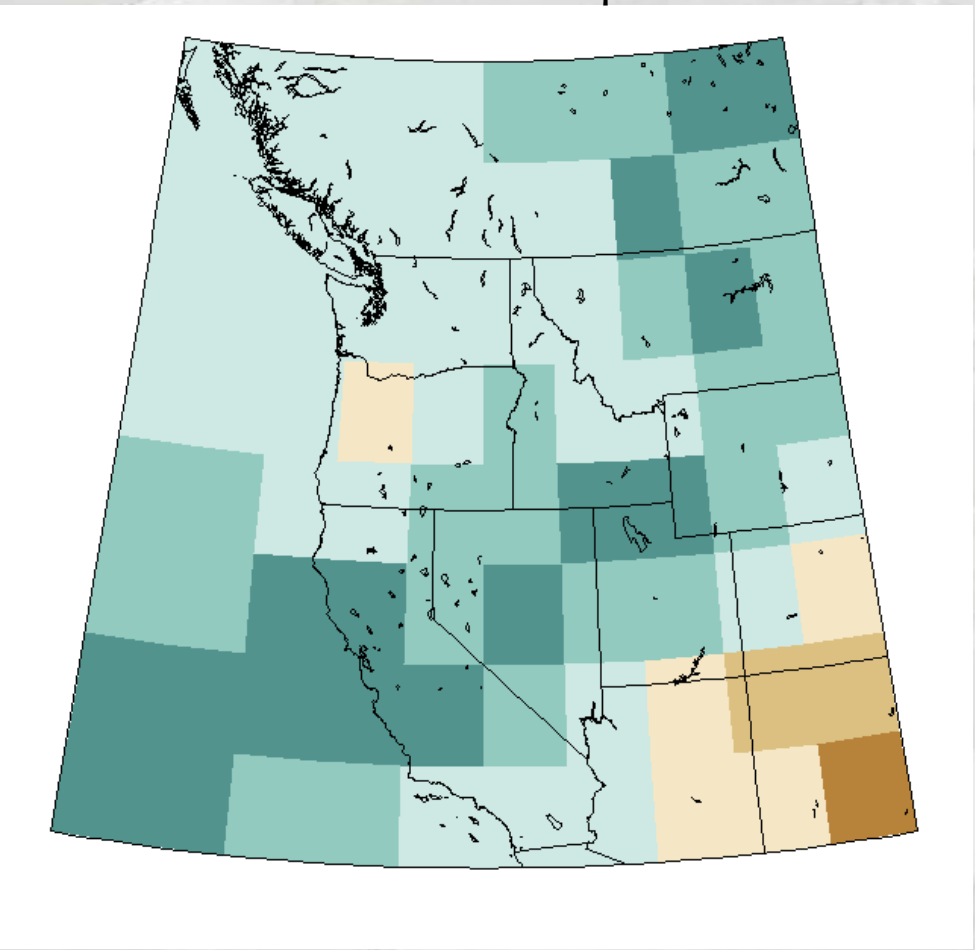
20 of 24 models show a decline for the region studied!



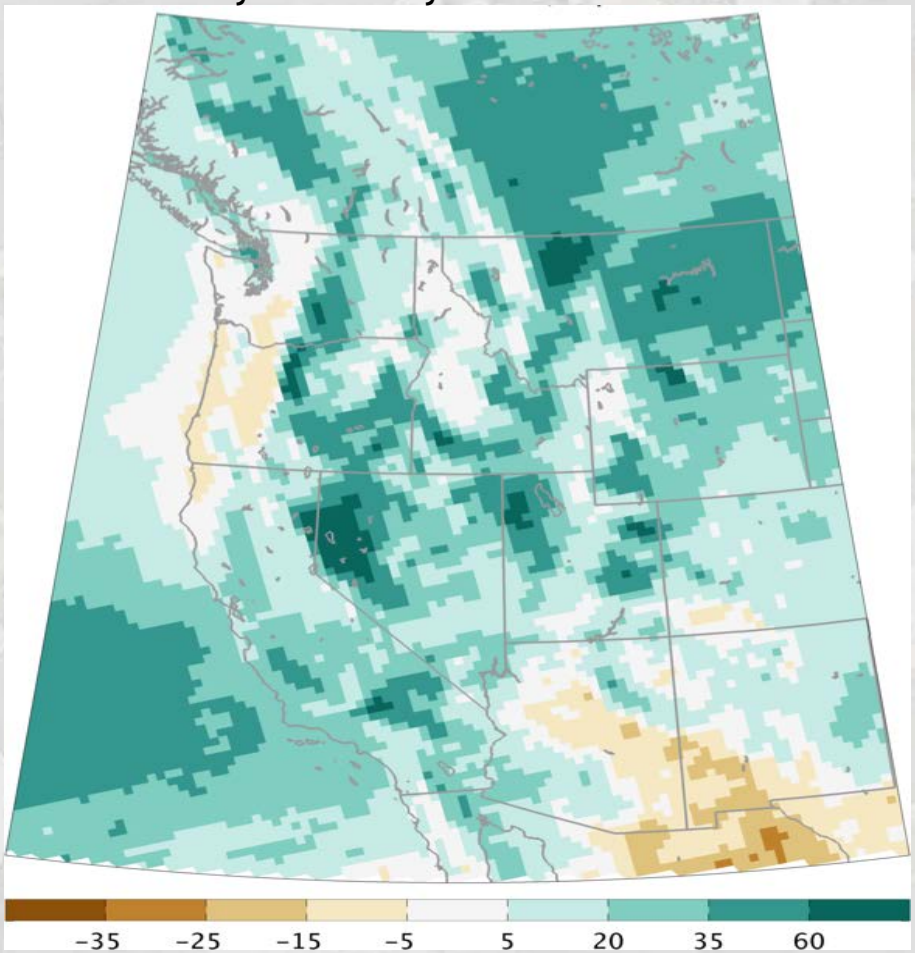
Luce, Abatzoglou, Holden 2013

CanESM2 Oct-Mar Precipitation Change 2041-2070 vs 1971-2000

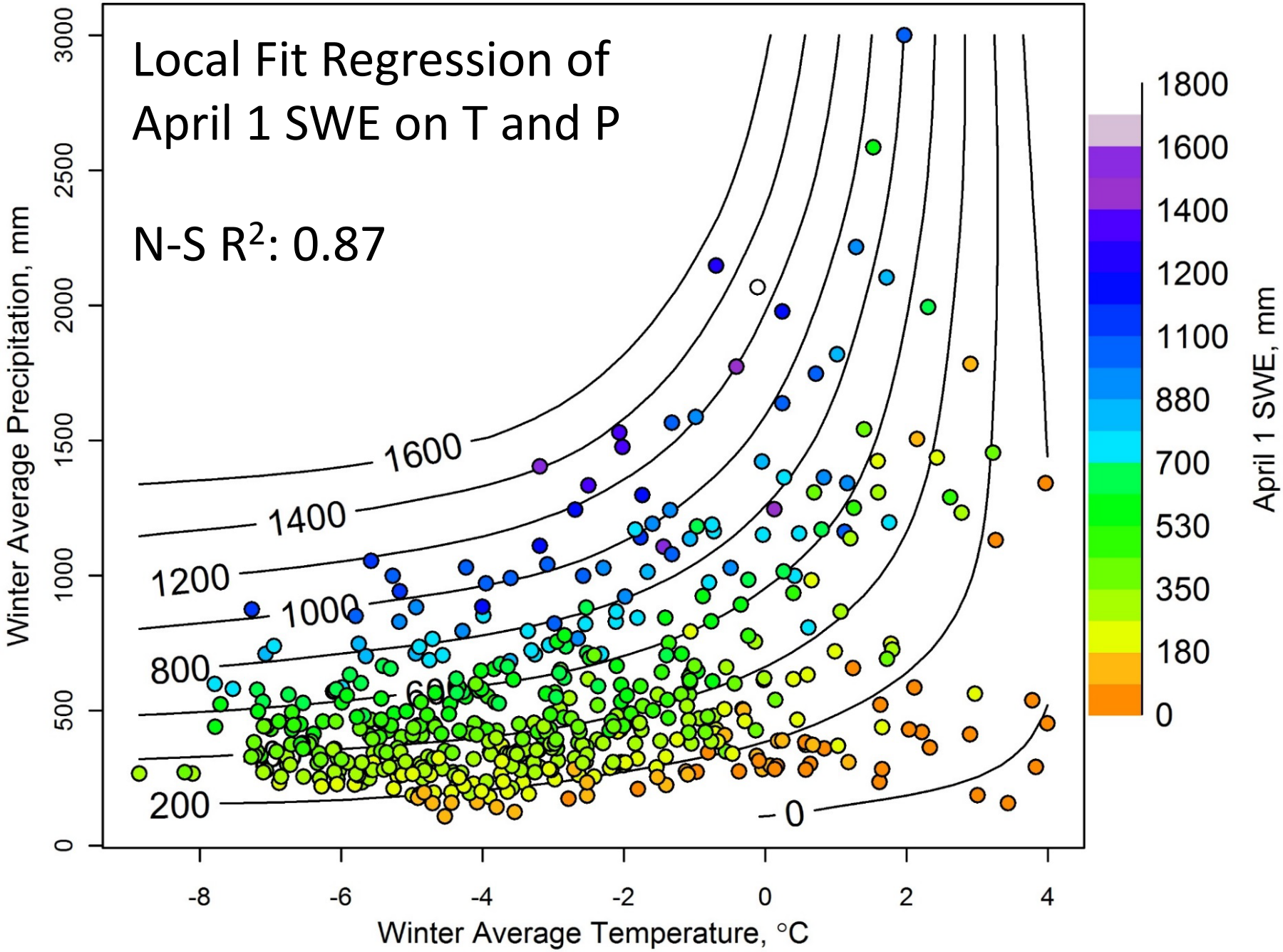
Raw GCM output

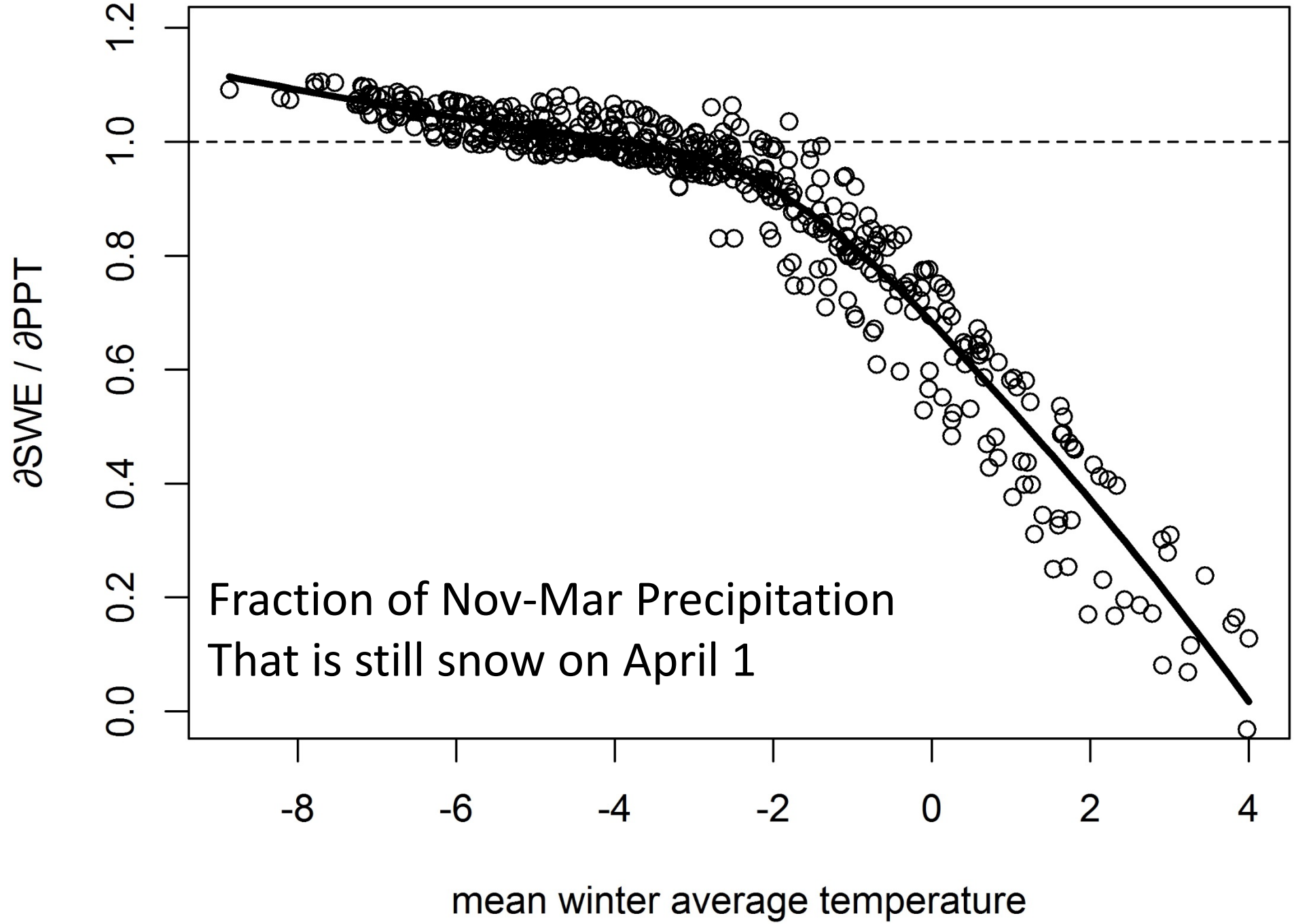


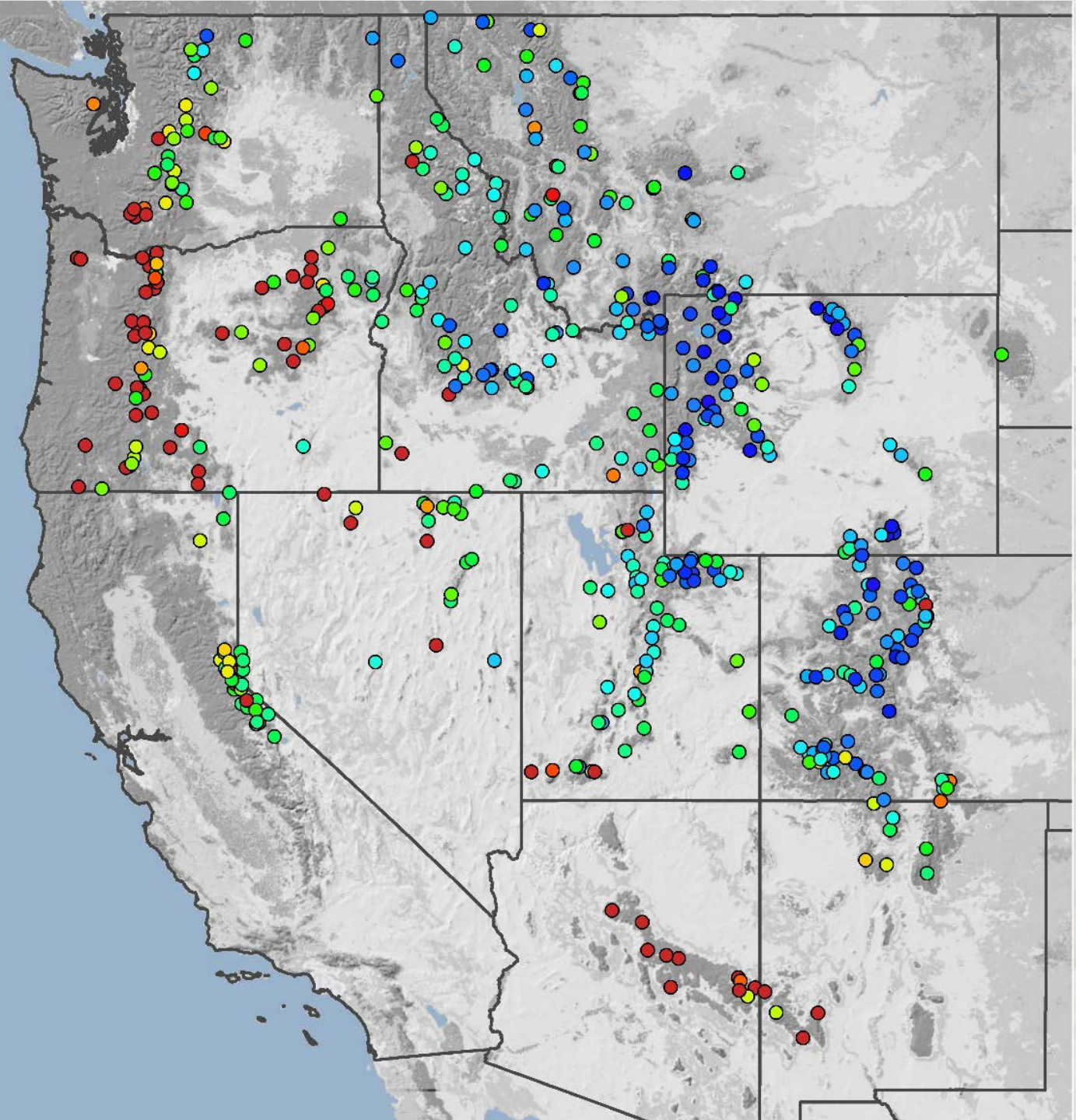
Dynamically Downscaled



Snow


Local Fit Regression of
April 1 SWE on T and P
N-S R²: 0.87
Winter Average Precipitation, mm
Winter Average Temperature, °C
April 1 SWE, mm
1600
1400
1200
1000
800
600
200
0
1800
1600
1400
1200
1100
880
700
530
350
180
0
-8
-6
-4
-2
0
2
4
0
500
1000
1500
2000
2500
3000


Fraction of Nov-Mar Precipitation
That is still snow on April 1
∂SWE / ∂PPT
mean winter average temperature
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-8
-6
-4
-2
0
2
4



April 1 SWE Sensitivity

Percent Change April 1 SWE

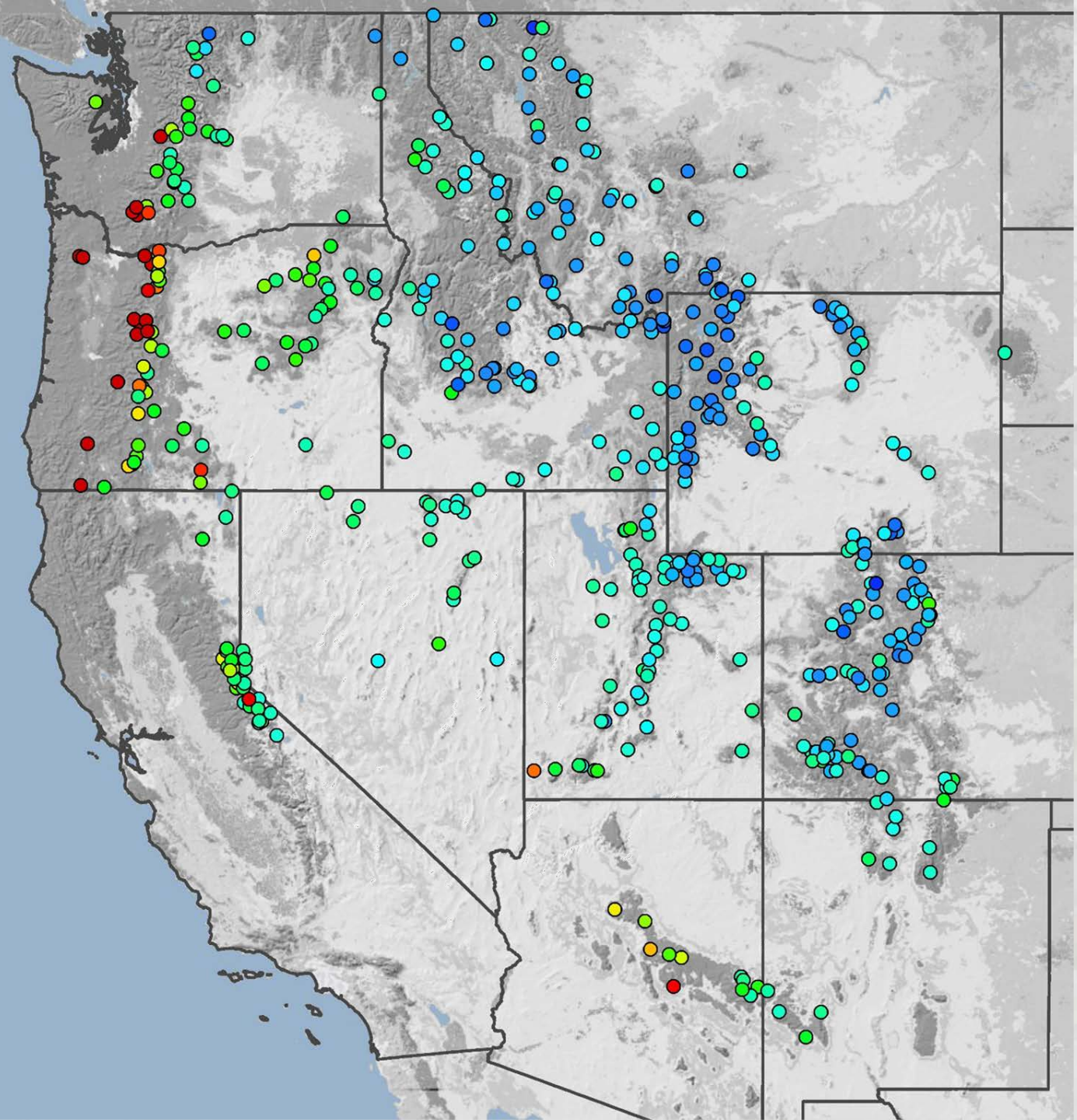
-25

-50

-75

-100

3°C Temperature Increase



Residence Time Sensitivity

Percent Change

SRT

0

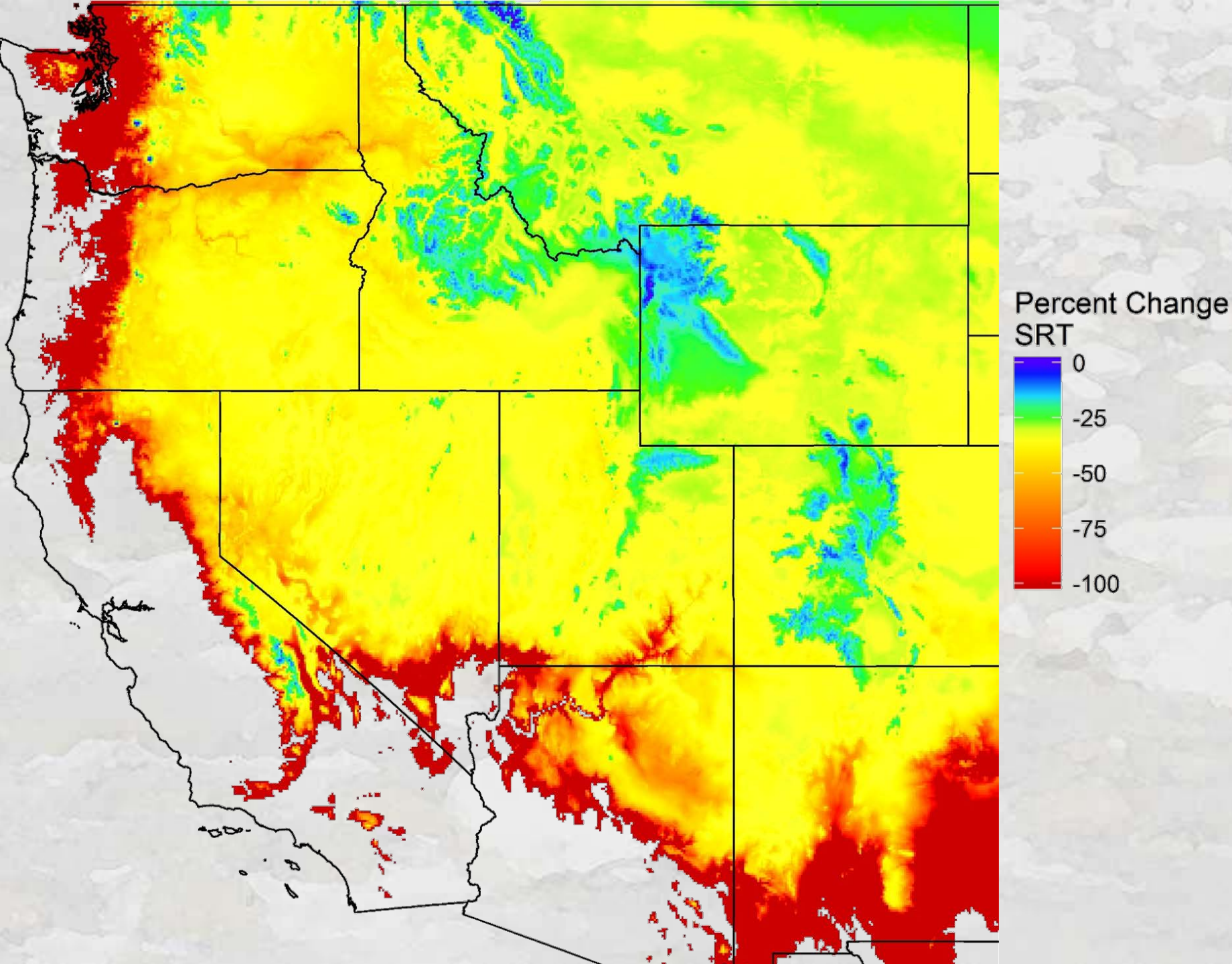
-25

-50

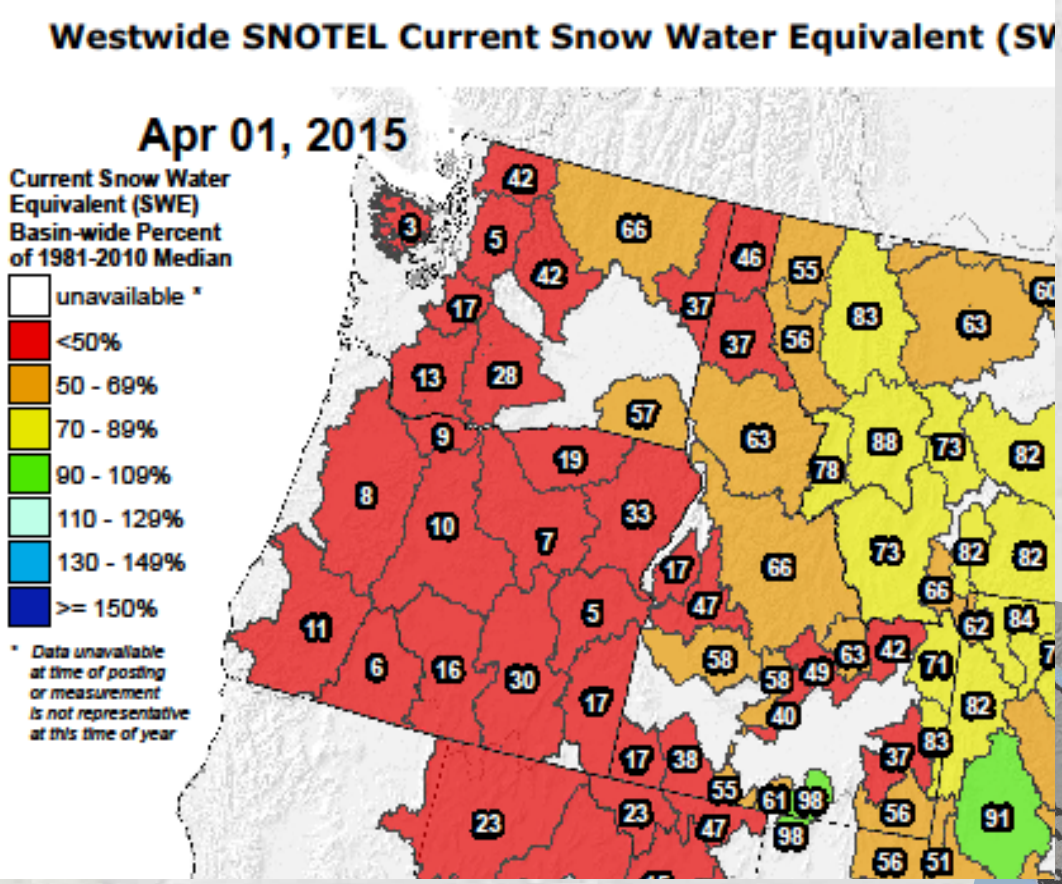
-75

-100

3°C Temperature Increase

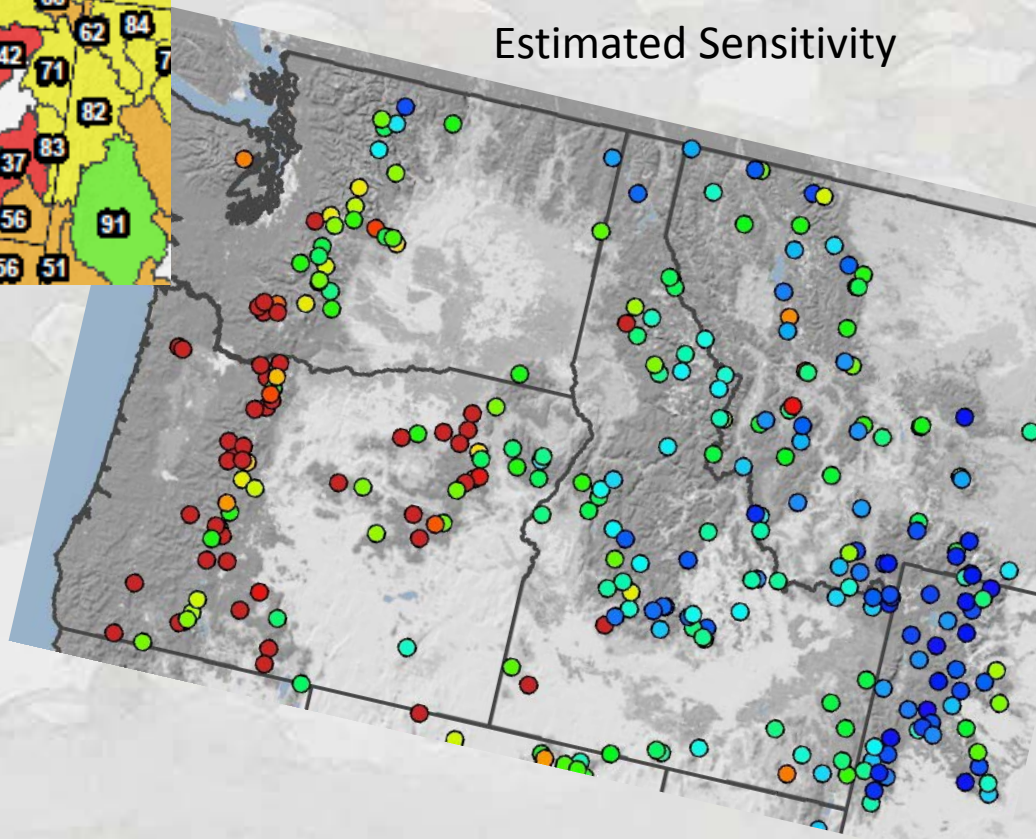

Percent Change
SRT
0
-25
-50
-75
-100

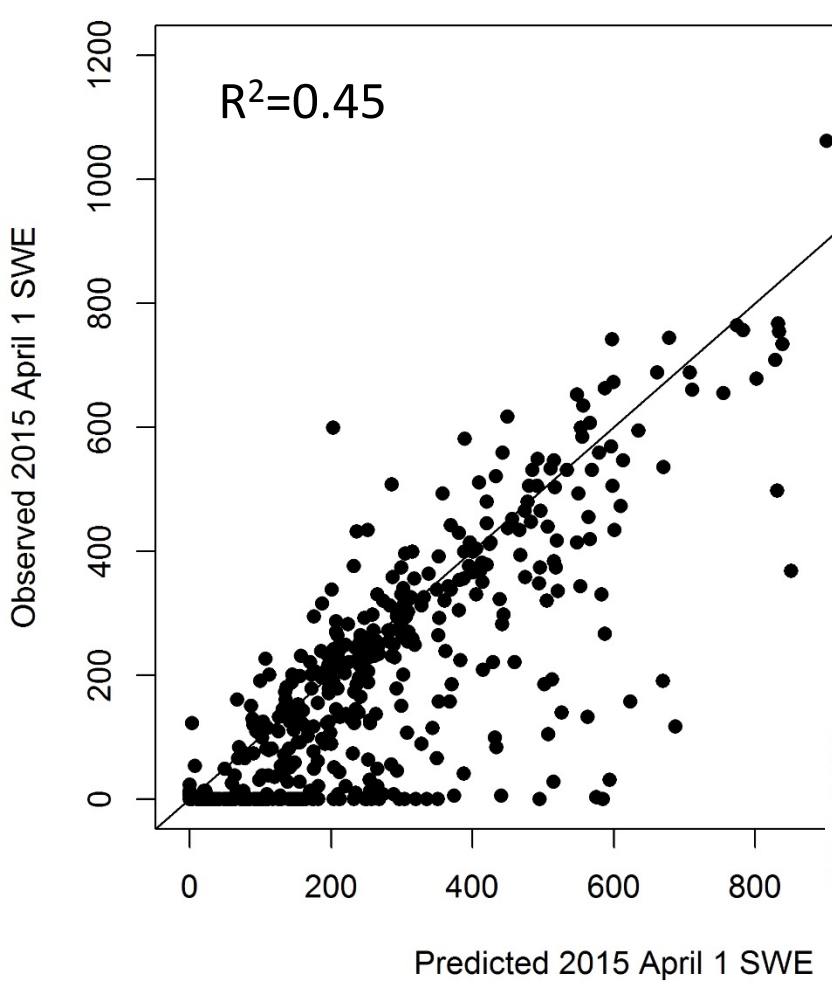
2015 Analogy?

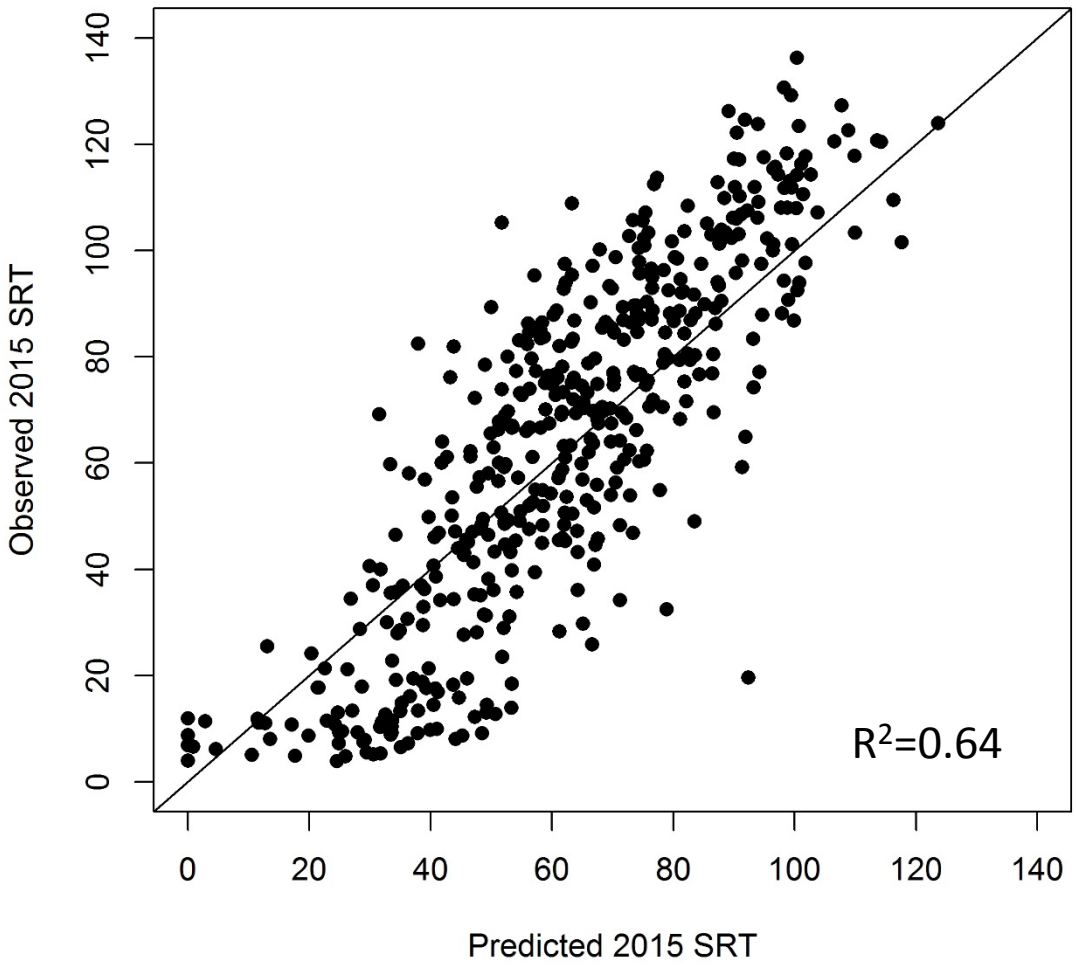


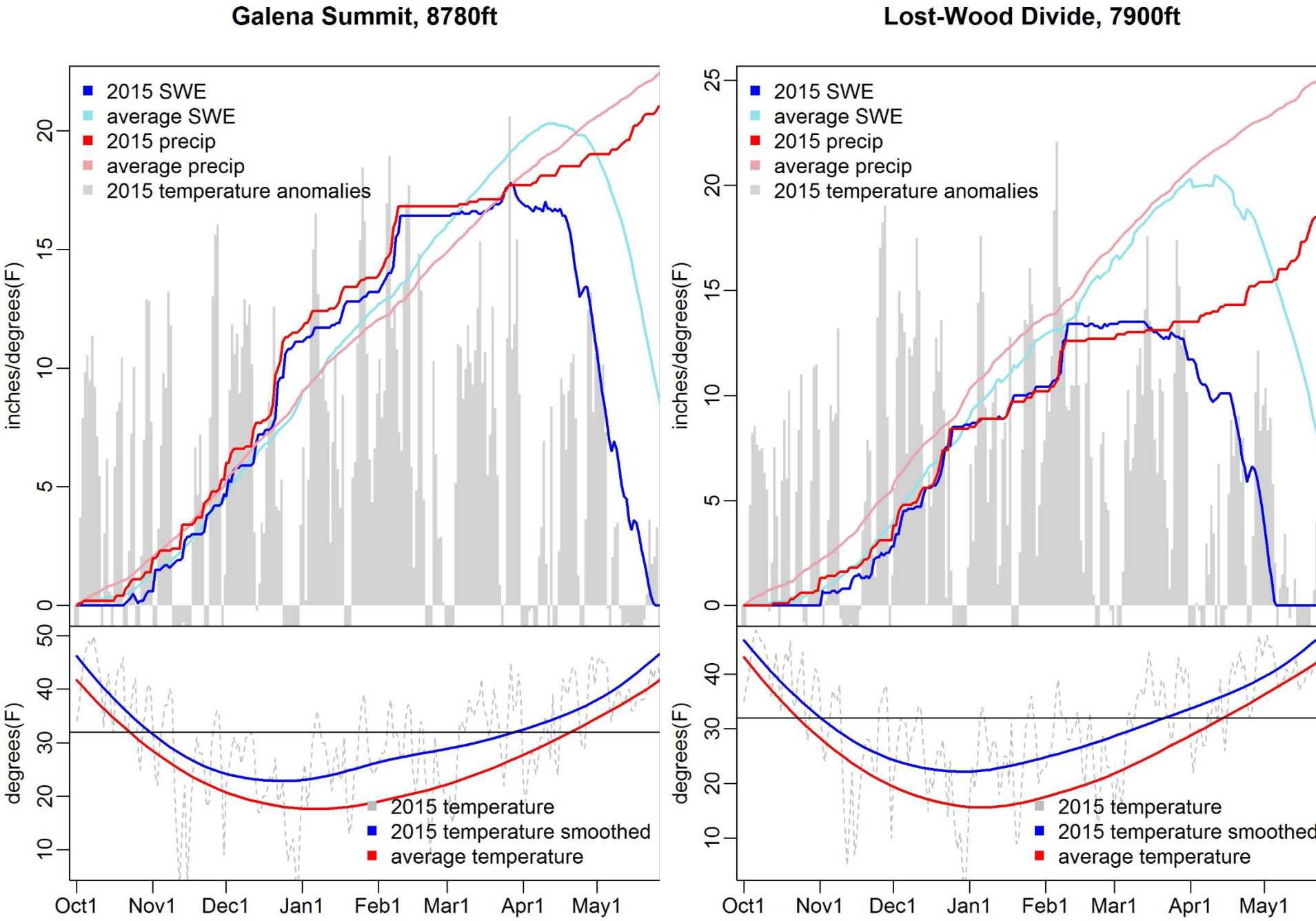
NRCS Snow Conditions Report

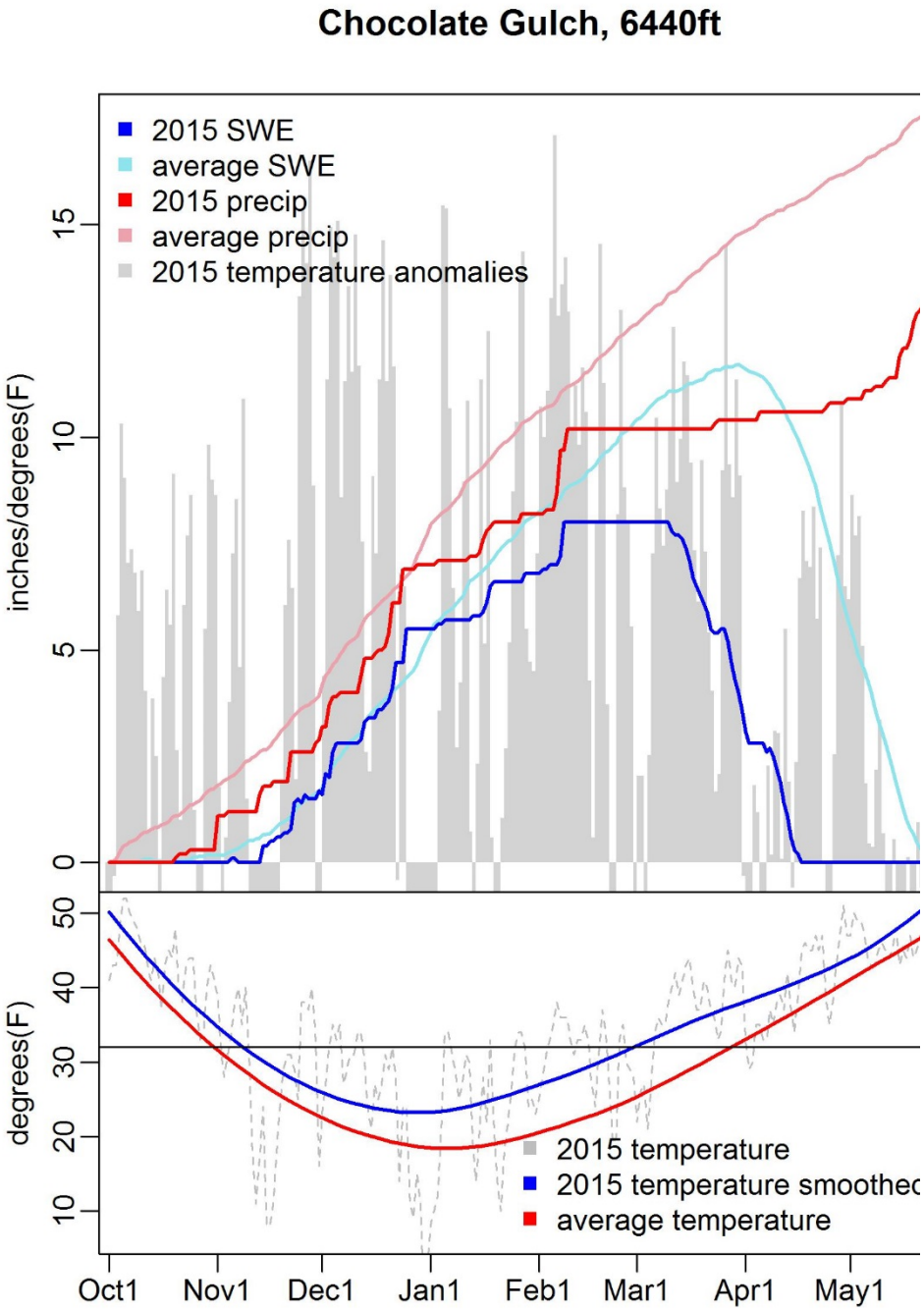
Estimated Sensitivity

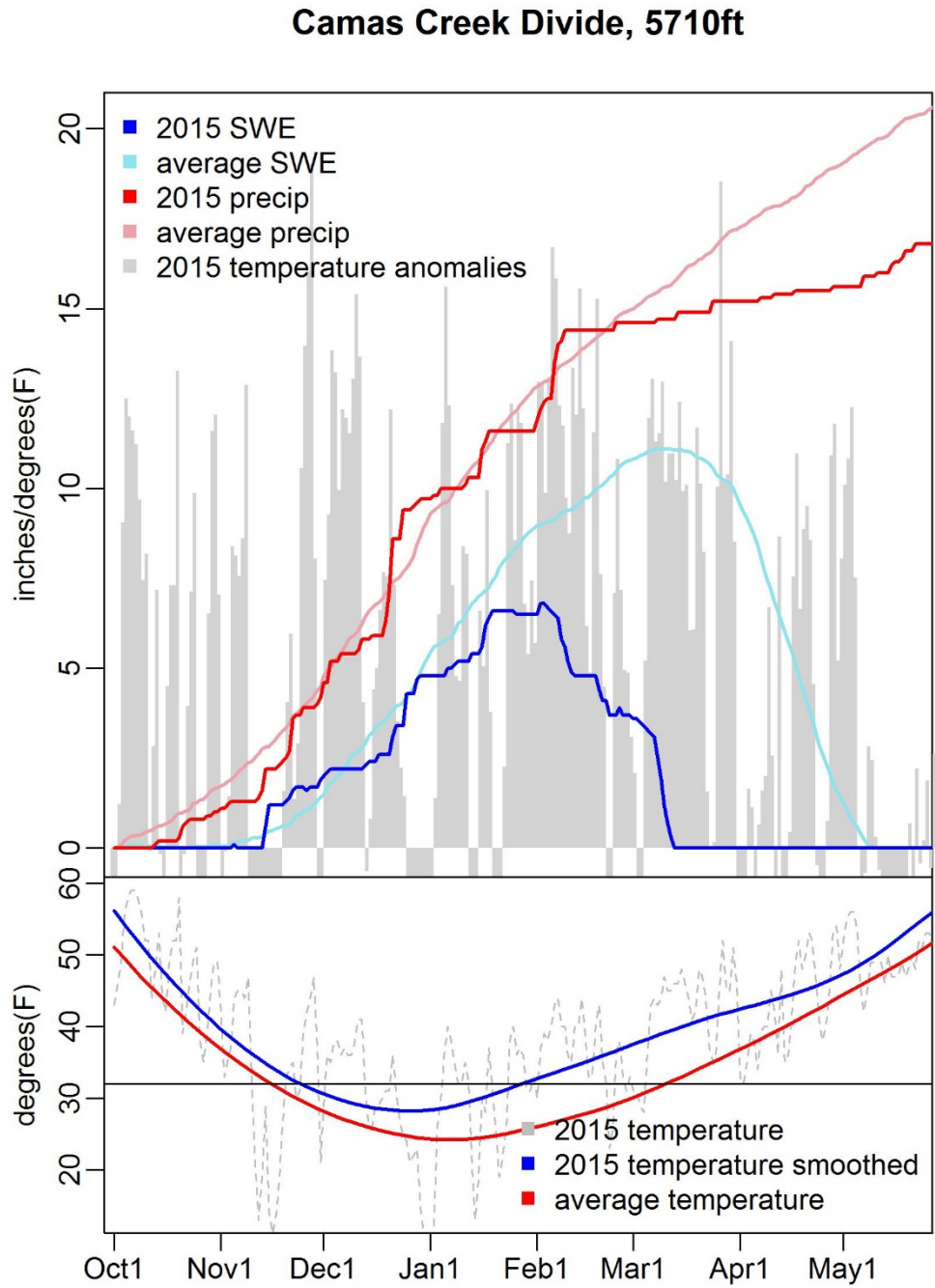



R^2=0.45
Observed 2015 April 1 SWE
Predicted 2015 April 1 SWE
0
200
400
600
800
1000
1200


R^2=0.64
Observed 2015 SRT
Predicted 2015 SRT
0
20
40
60
80
100
120
140

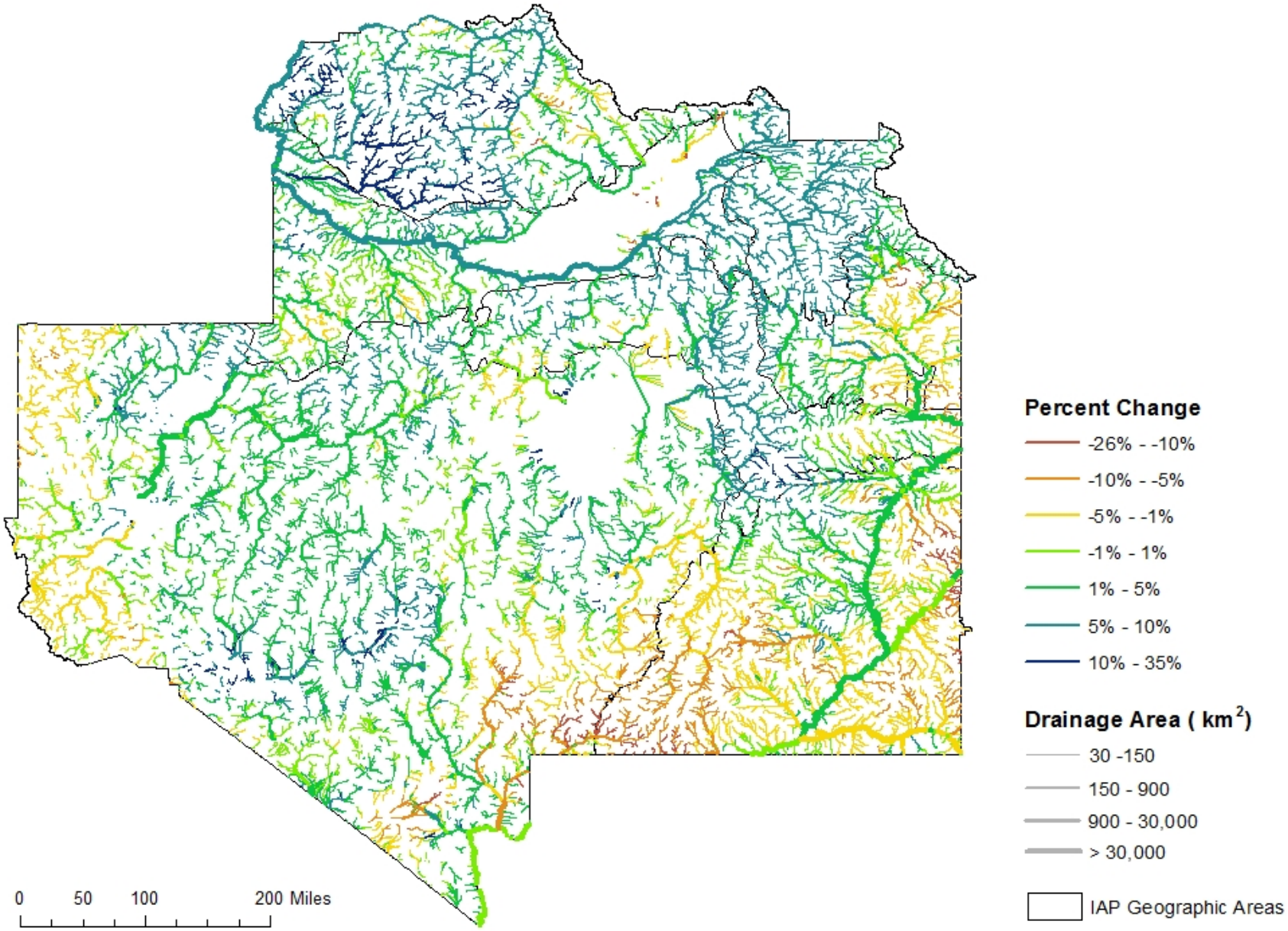

Galena Summit, 8780ft
Lost-Wood Divide, 7900ft
2015 SWE
average SWE
2015 precip
average precip
2015 temperature anomalies
inches/degrees(F)
degrees(F)
2015 temperature
2015 temperature smoothed
average temperature
Oct1
Nov1
Dec1
Jan1
Feb1
Mar1
Apr1
May1


Chocolate Gulch, 6440ft
2015 SWE
average SWE
2015 precip
average precip
2015 temperature anomalies
inches/degrees(F)
0
5
10
15
degrees(F)
10
20
30
40
50
2015 temperature
2015 temperature smoothed
average temperature
Oct1
Nov1
Dec1
Jan1
Feb1
Mar1
Apr1
May1

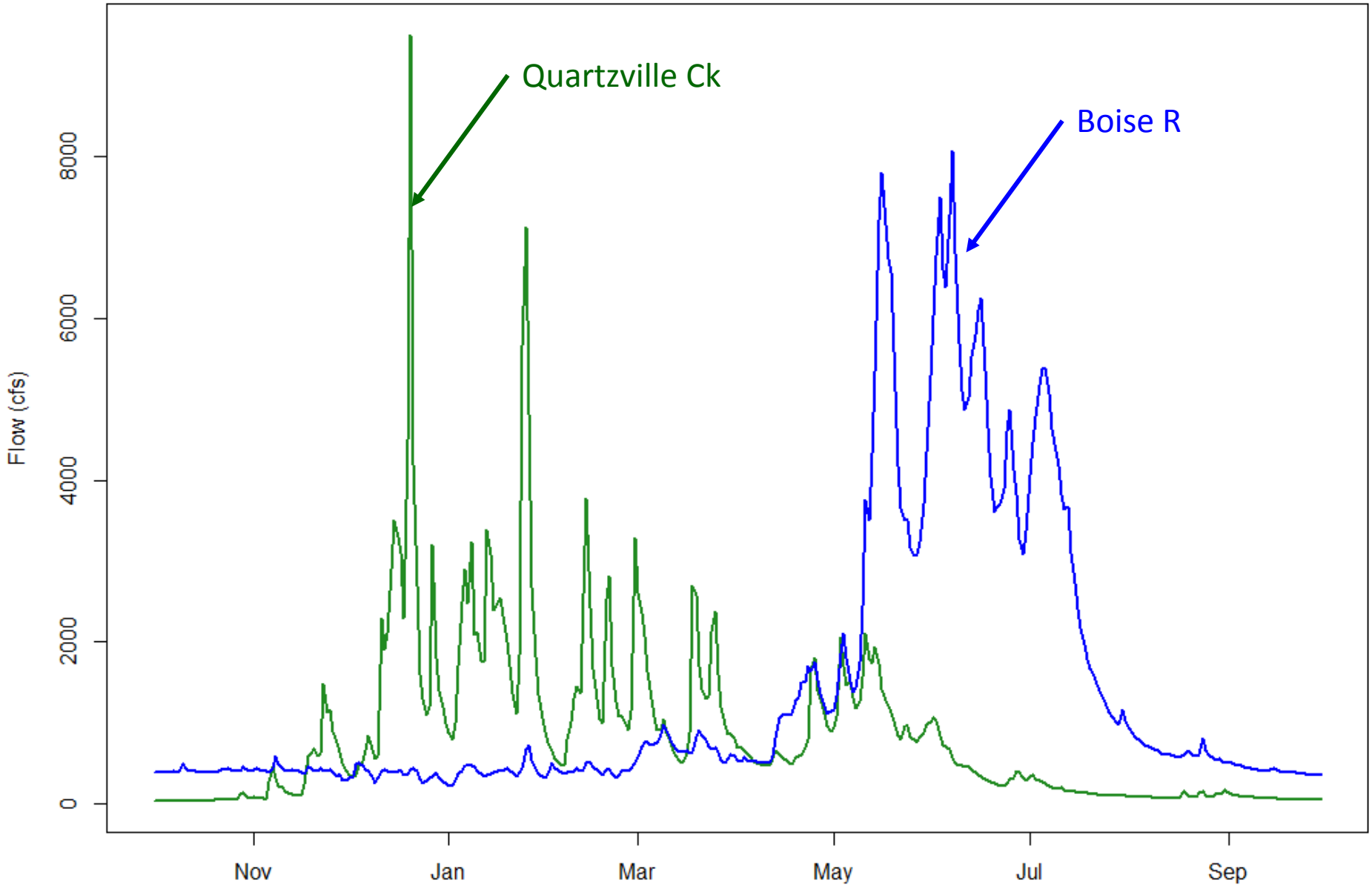

Camas Creek Divide, 5710ft
2015 SWE
average SWE
2015 precip
average precip
2015 temperature anomalies
inches/degrees(F)
0
5
10
15
20
degrees(F)
20
30
40
50
60
2015 temperature
2015 temperature smoothed
average temperature
Oct1
Nov1
Dec1
Jan1
Feb1
Mar1
Apr1
May1

Runoff

Percent Change in Mean Annual Flow (historic-2040s)

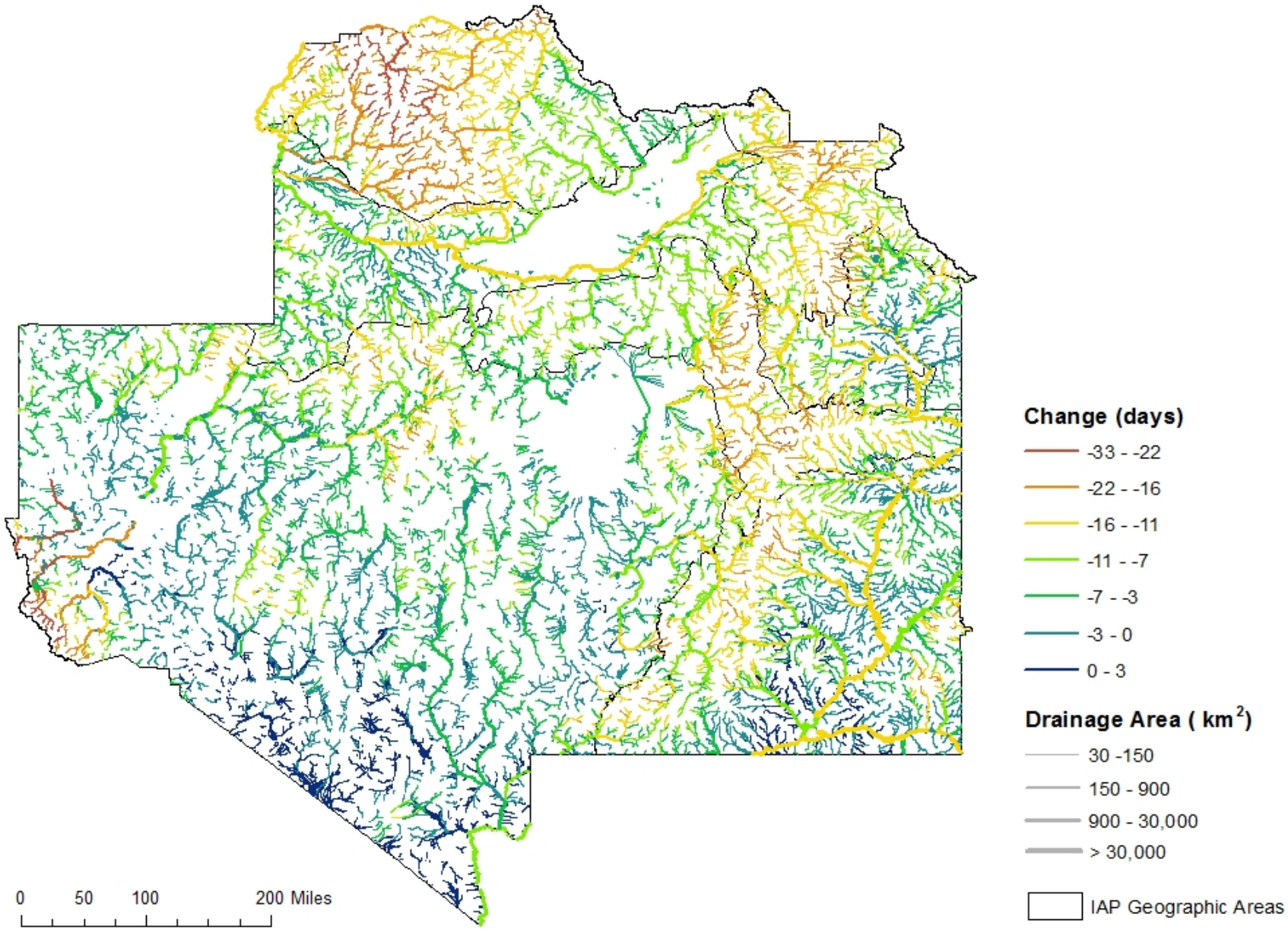


Contrasting Snowmelt Contributions

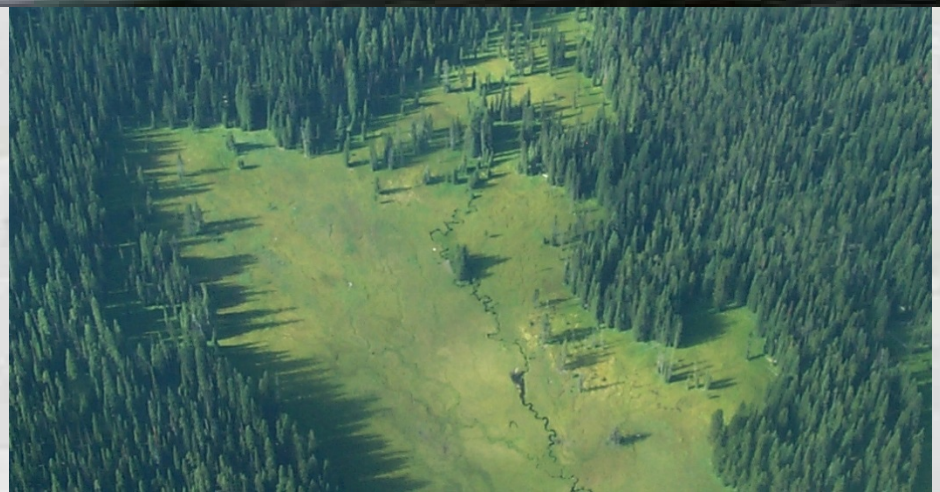


WY 2004

Change in Center of Flow Mass (historic-2040s)

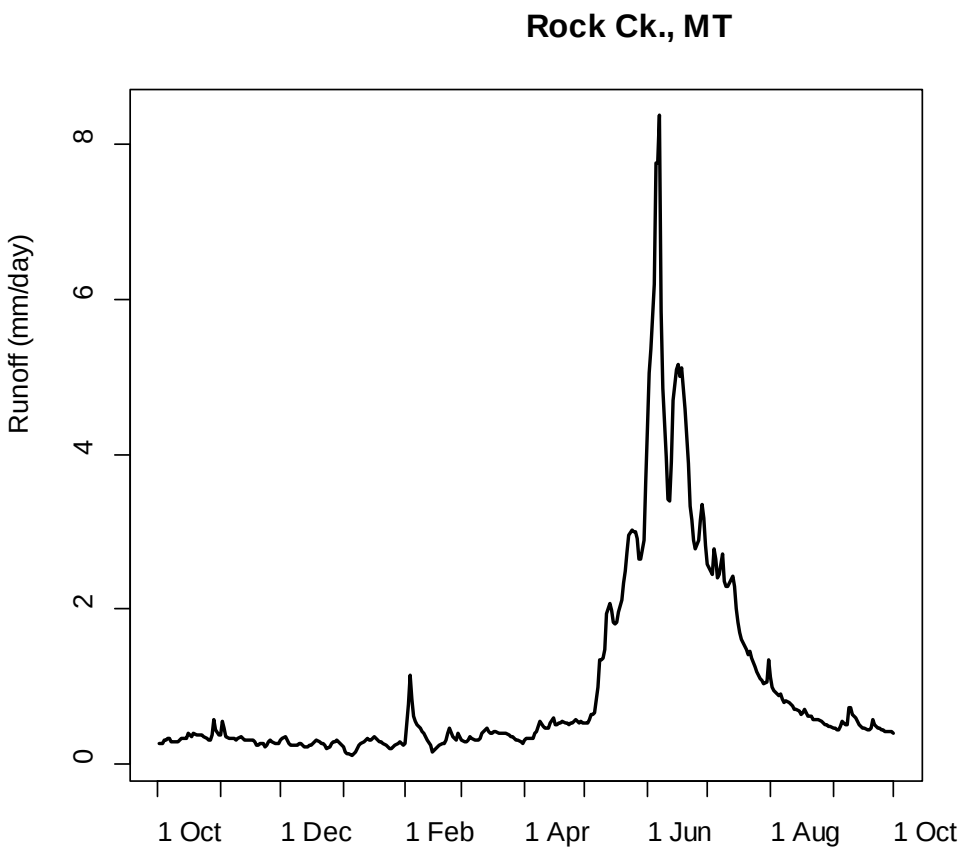


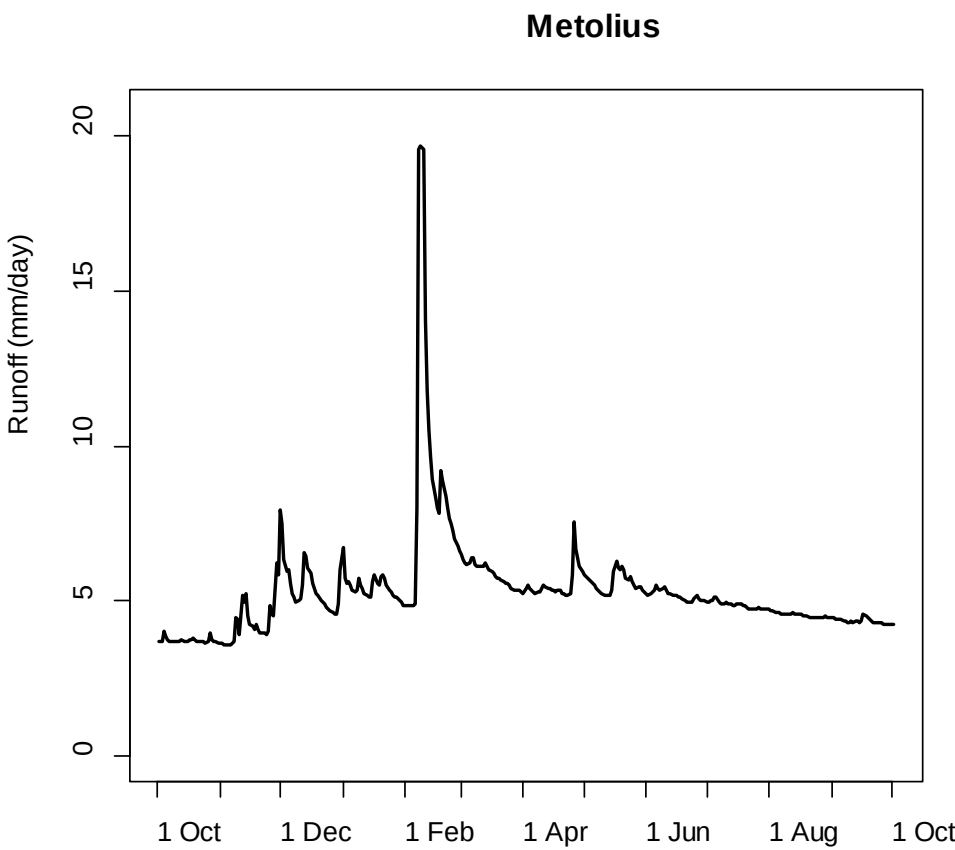
Groundwater Dependent Systems

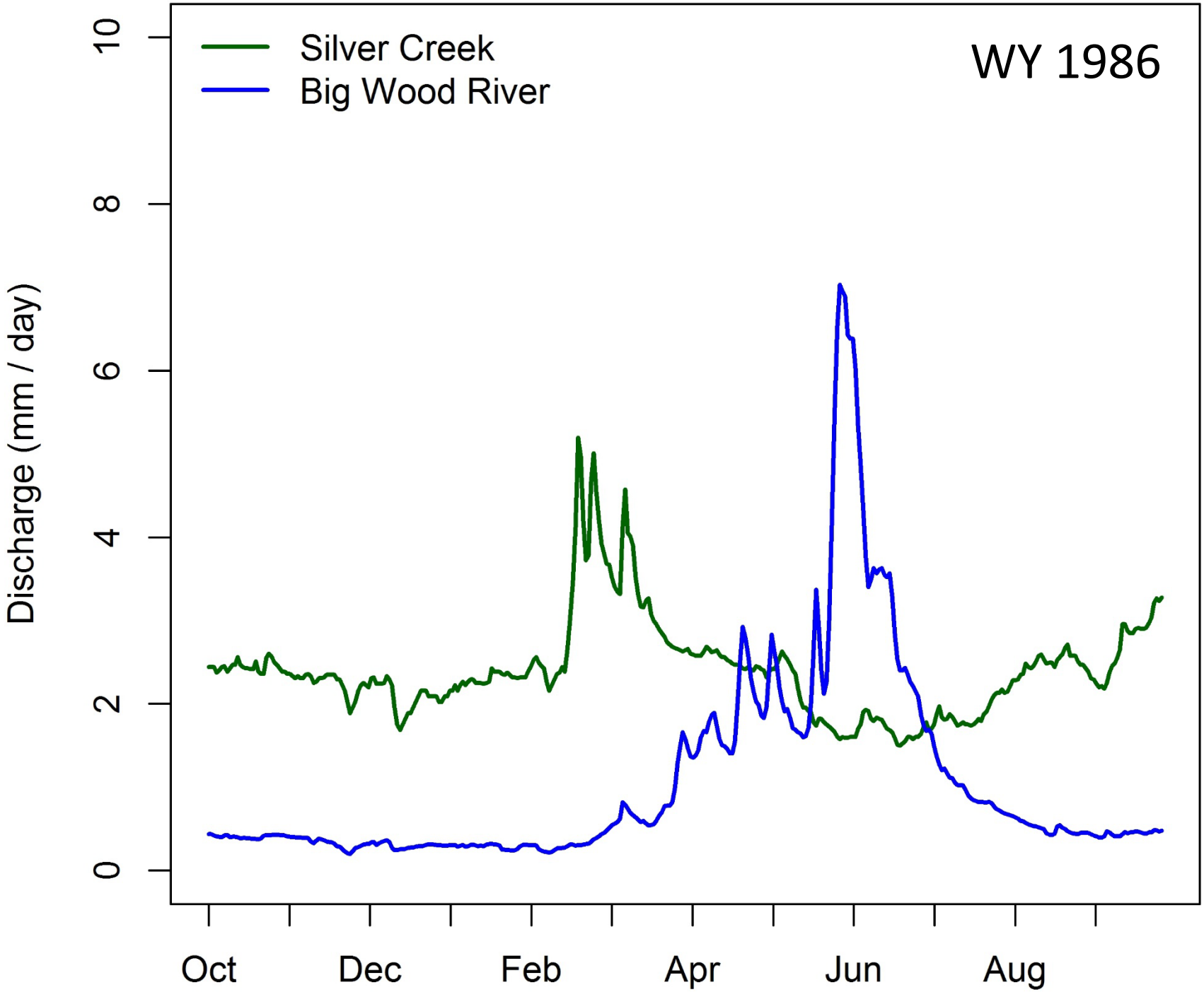


Low Groundwater Storage

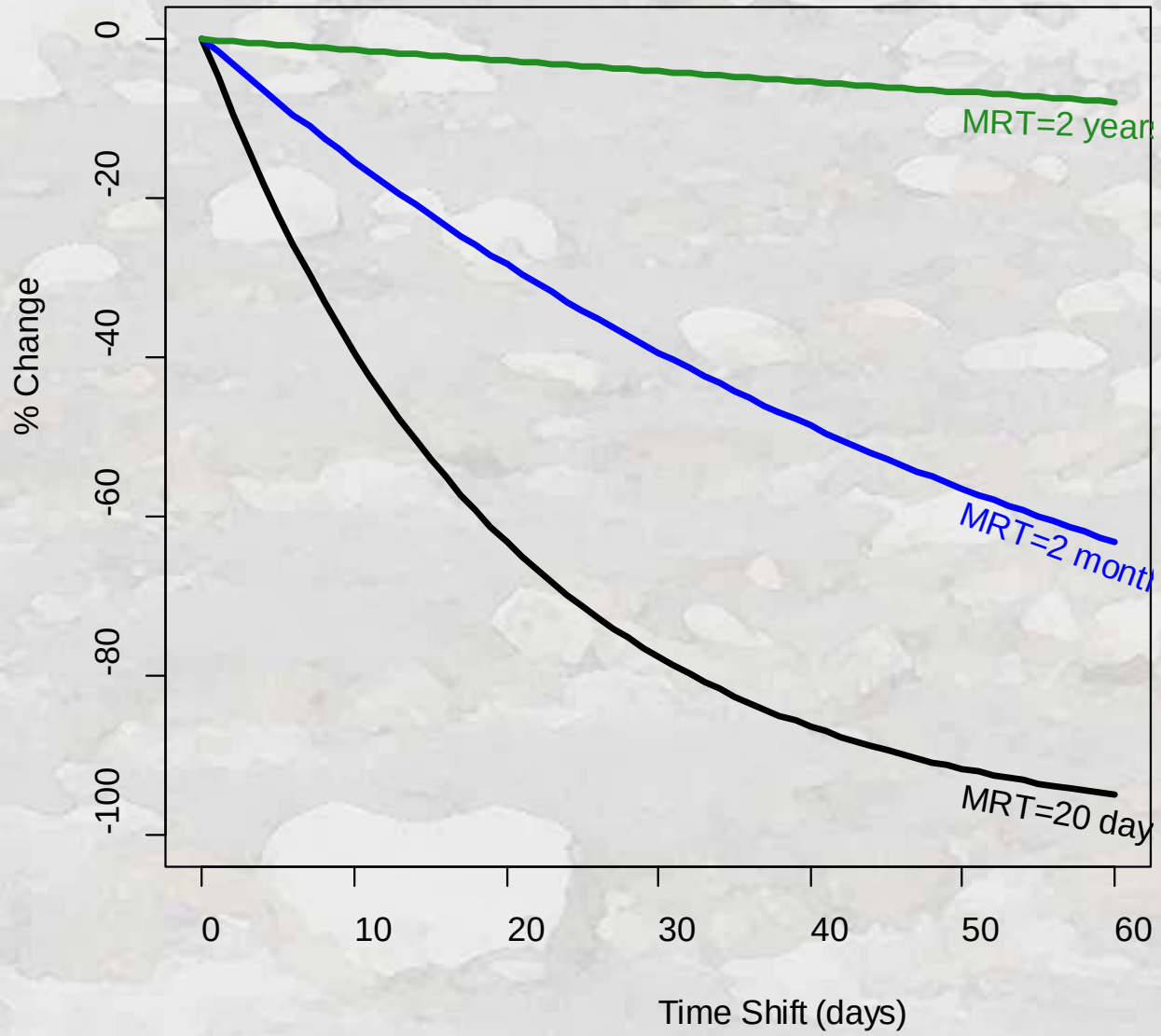
HIgh Groundwater Storage






Silver Creek
Big Wood River
WY 1986
Discharge (mm / day)
0
2
4
6
8
10
Oct
Dec
Feb
Apr
Jun
Aug

Low Flow Fractional Decline

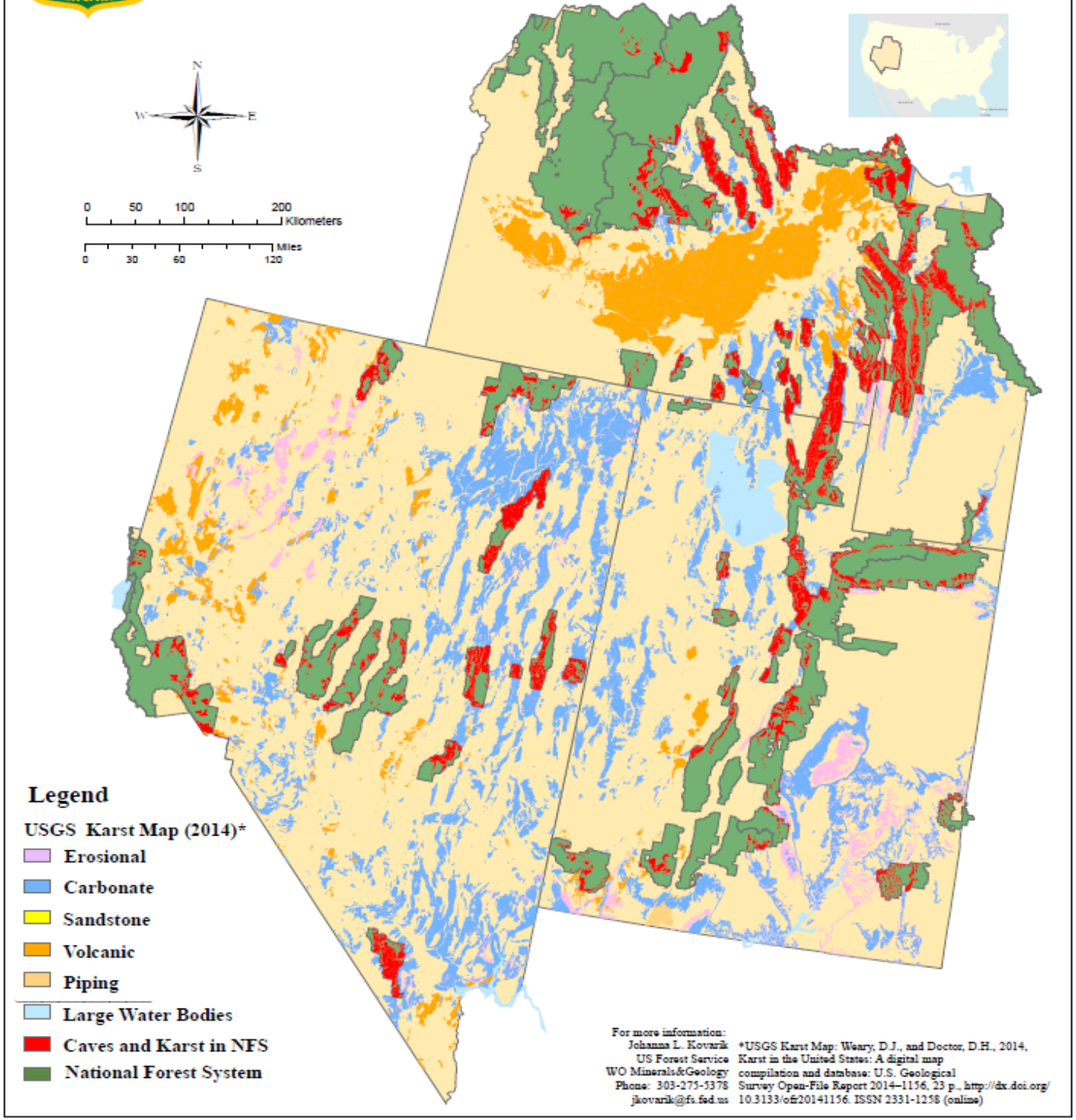


*Using linear reservoir theory

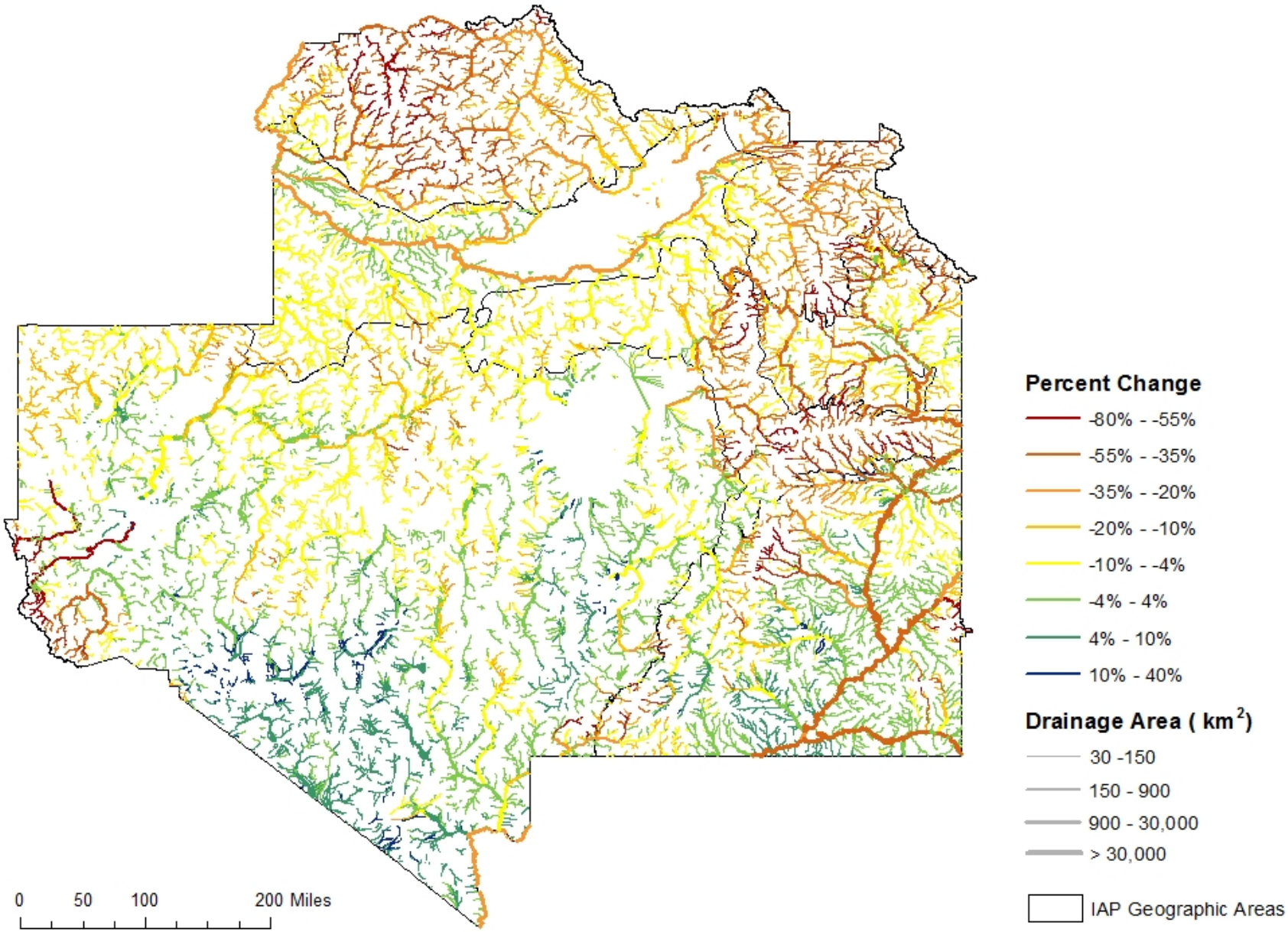
MRT=Mean Residence Time

Karst and Related Resources in the Intermountain Region

Courtesy of Johanna Kovarik



Percent Change in Mean Summer Flow (historic-2040s)

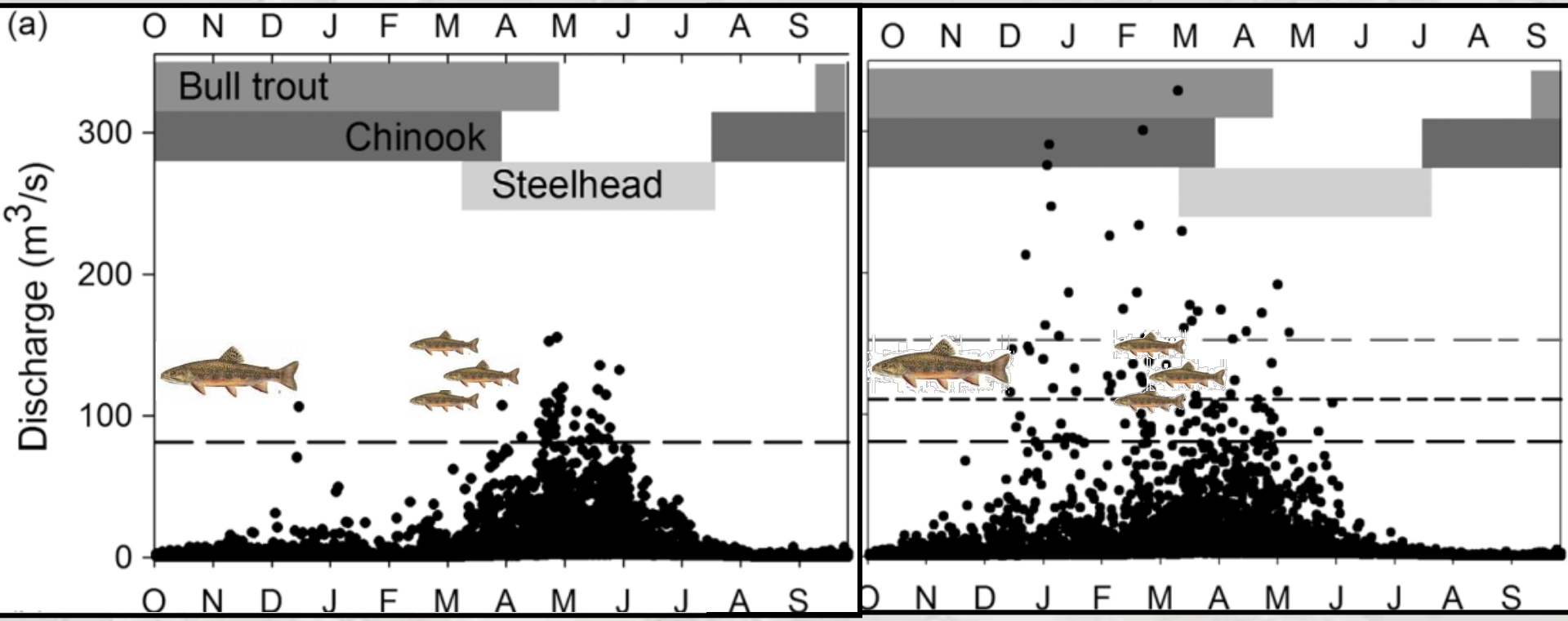


More Midwinter Flooding

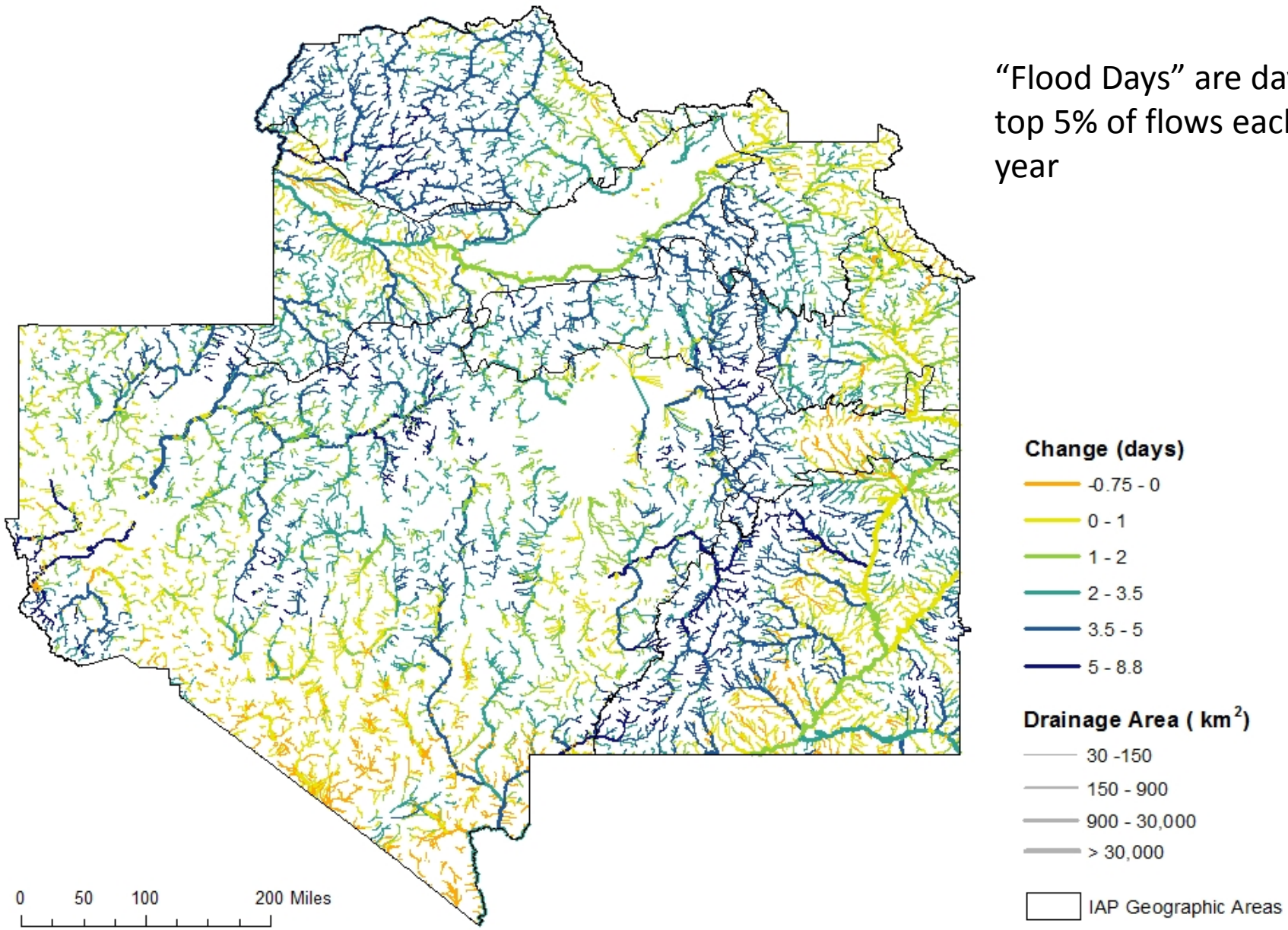
Goode et al. 2013

Historical

Future

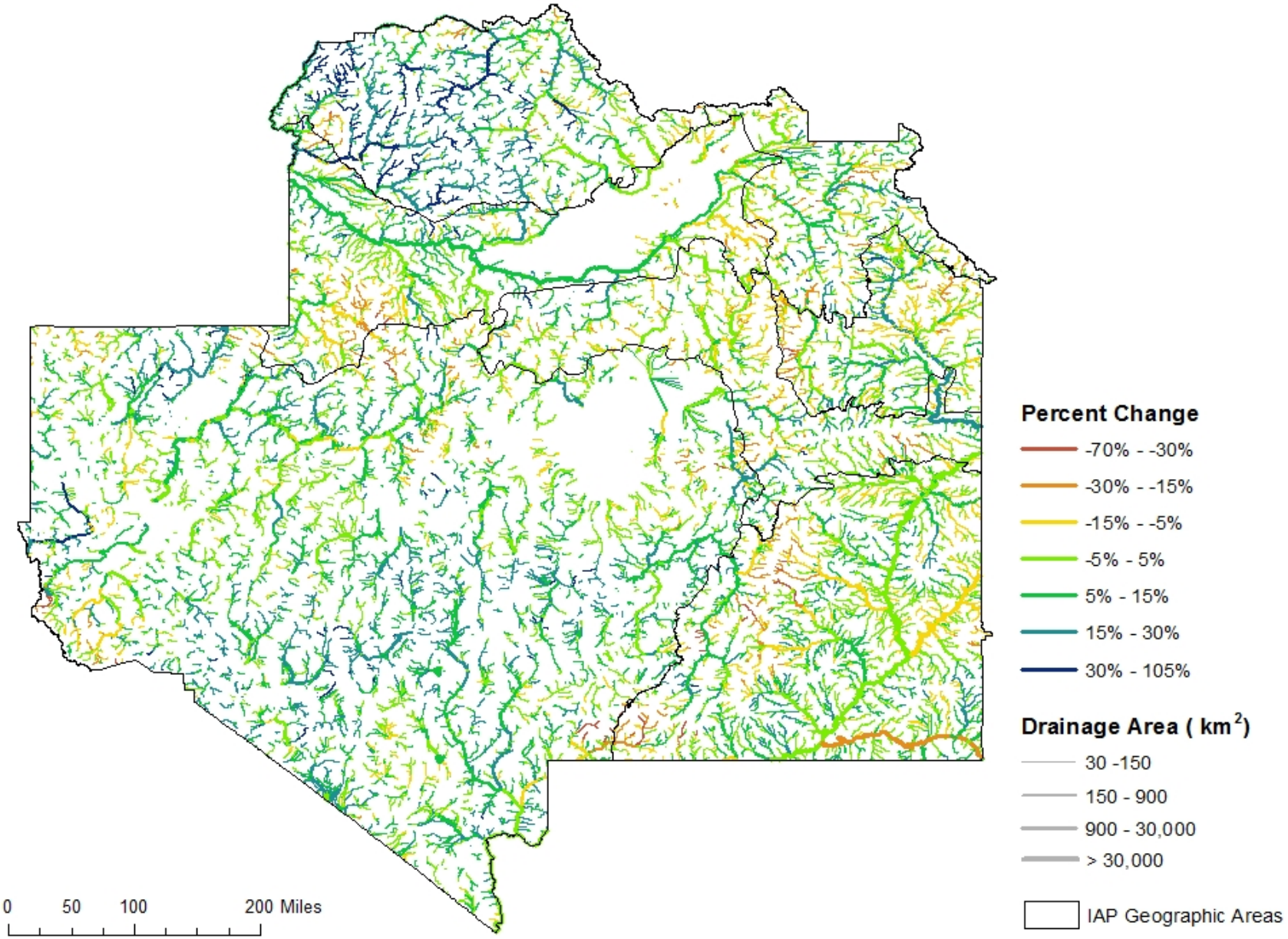


Change in Number of Winter Floods (historic-2040s)



"Flood Days" are days in top 5% of flows each year

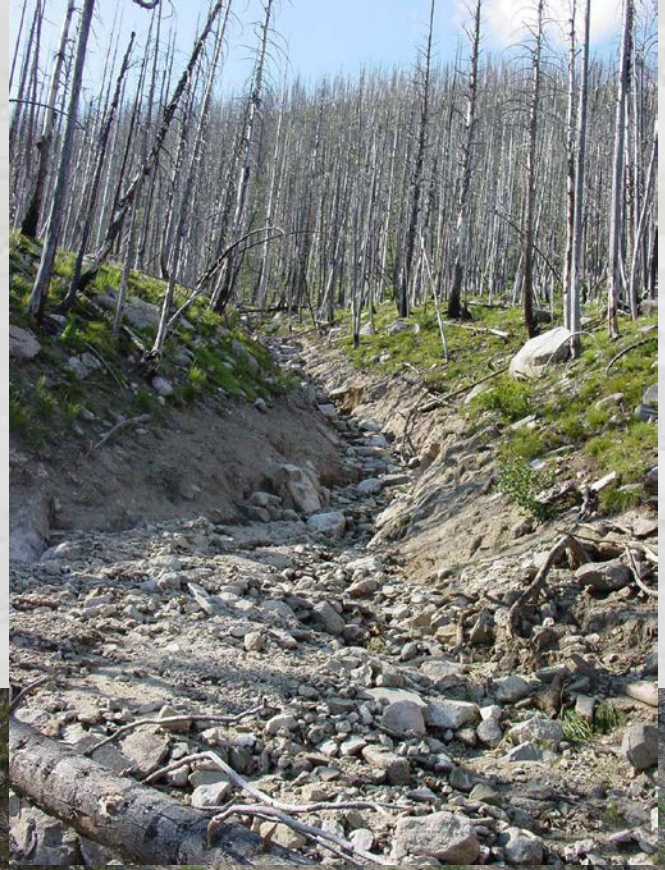
Percent Change in 1.5 Year Flood (historic-2040s)

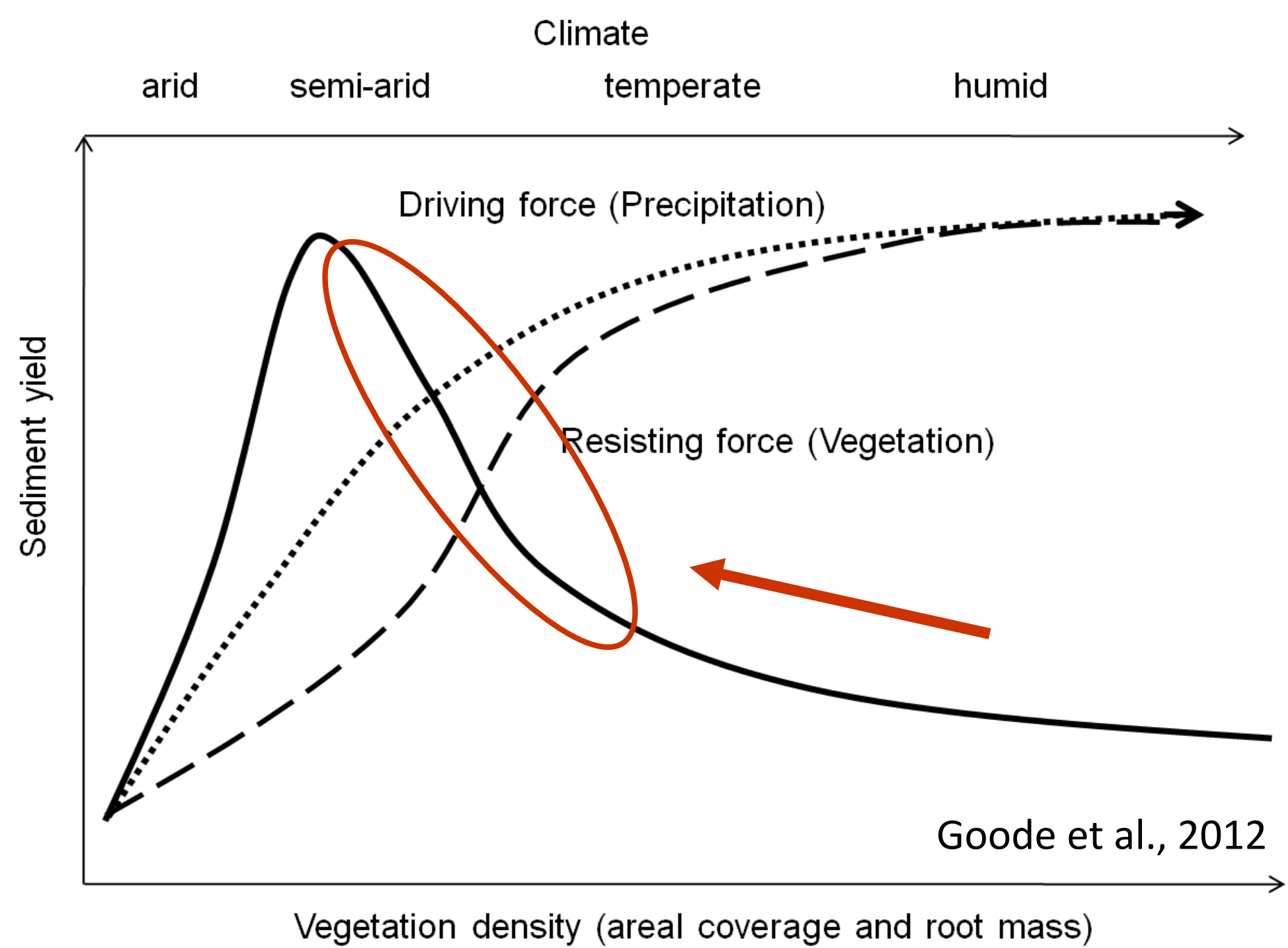


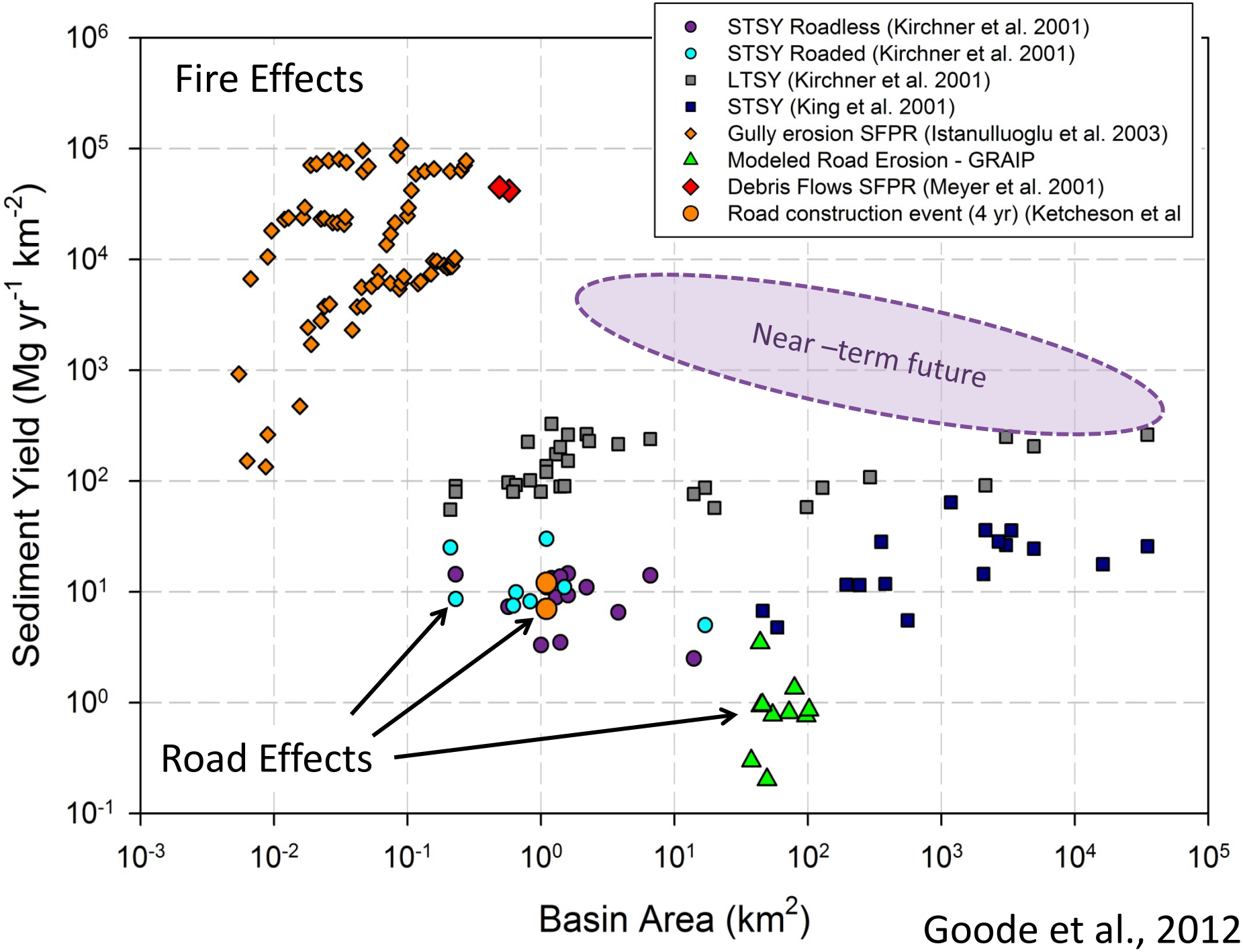
Summary

- Precipitation uncertain – don’t count on more … consider what might happen if less
- Less snow – cold places affected less
- Lower low flows, bigger floods
  - Bad timing for some fishes (chinook, bull trout)

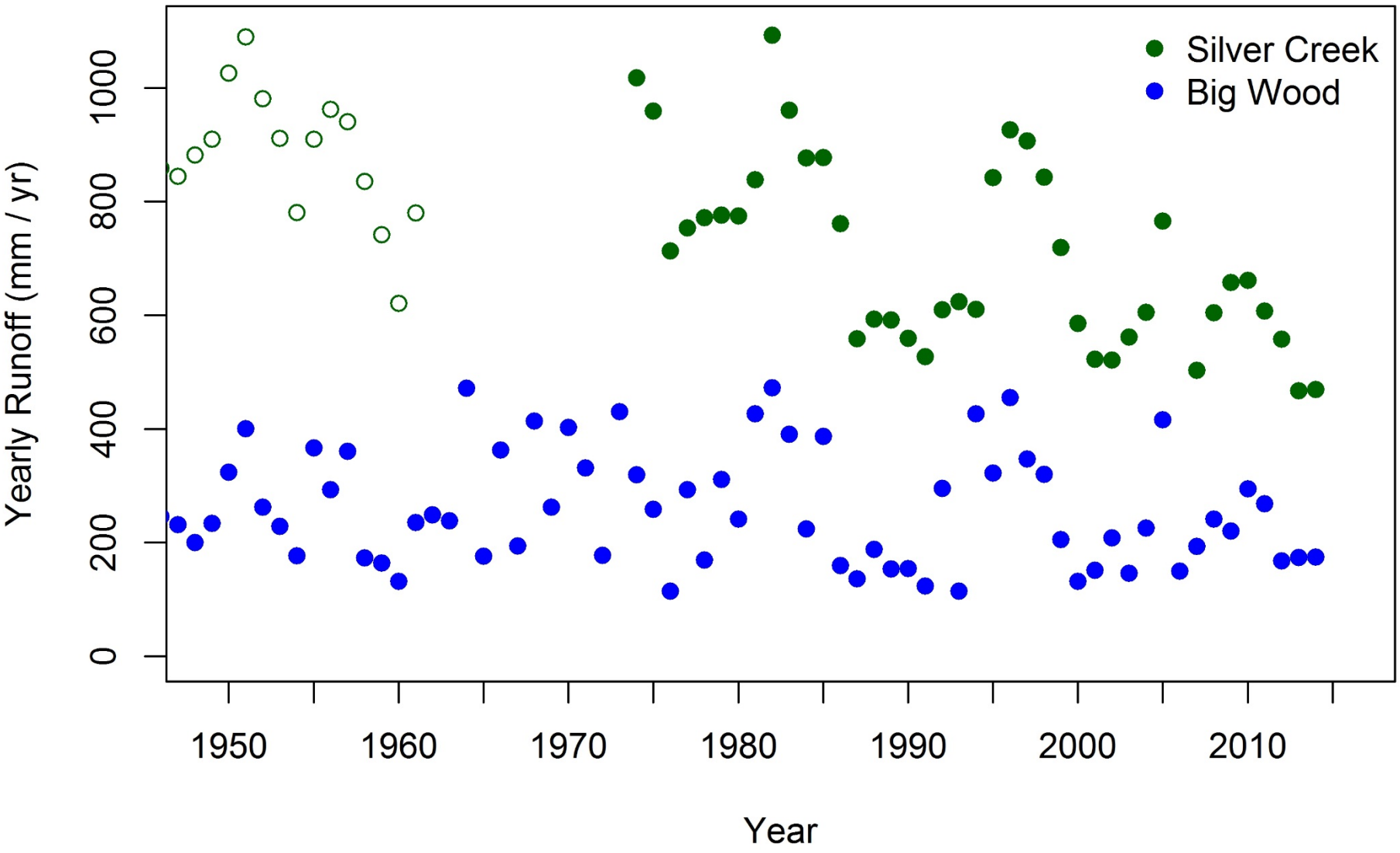
Sediment and Climate Change




Climate
arid
semi-arid
temperate
humid
Driving force (Precipitation)
Resisting force (Vegetation)
Sediment yield
Goode et al., 2012
Vegetation density (areal coverage and root mass)



Goode et al., 2012


Silver Creek
Big Wood
Yearly Runoff (mm / yr)
0
200
400
600
800
1000
1950
1960
1970
1980
1990
2000
2010
Year