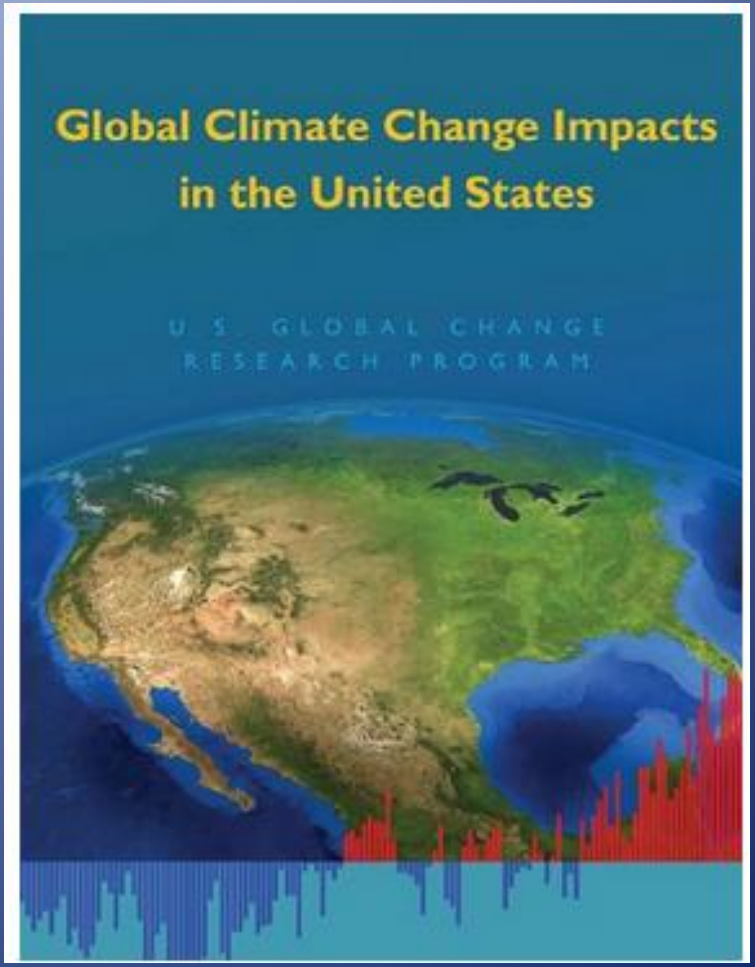
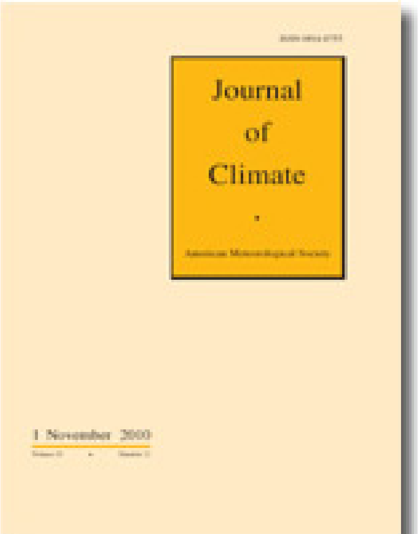
Utah's Climate - Our current understanding of past and current climate and, future prospects

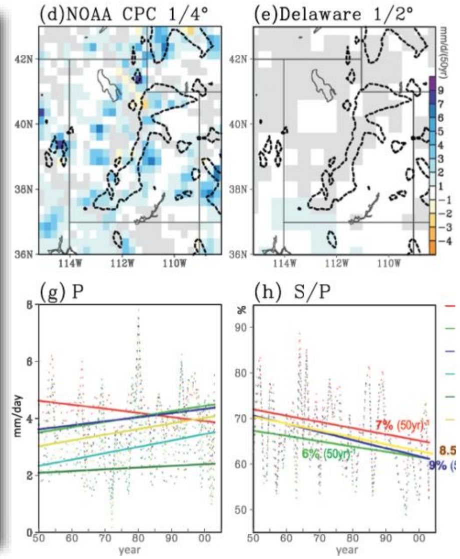
Dr. Robert R. Gillies

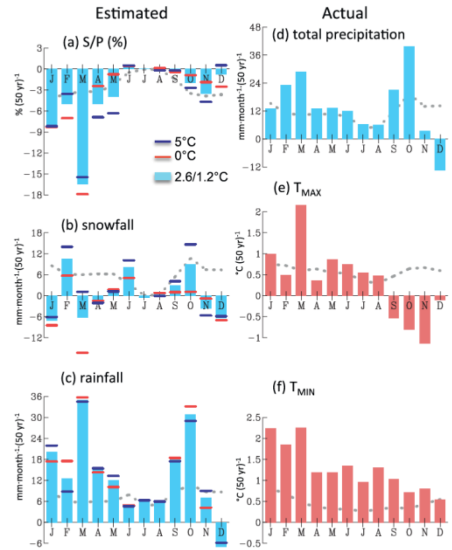
UTAH CLIMATE CENTER

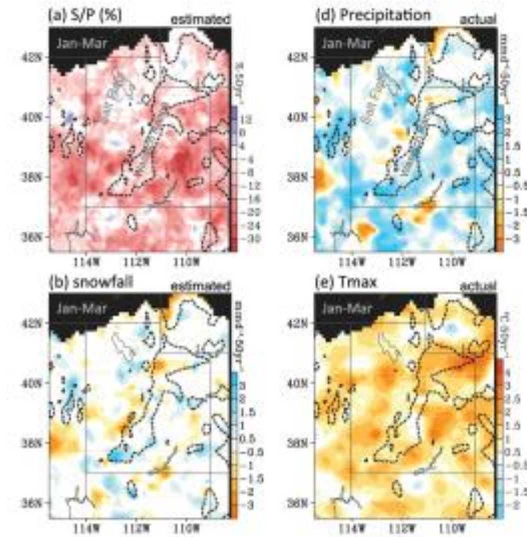
Is Climate Change Real? The Pentagon Sure Thinks So

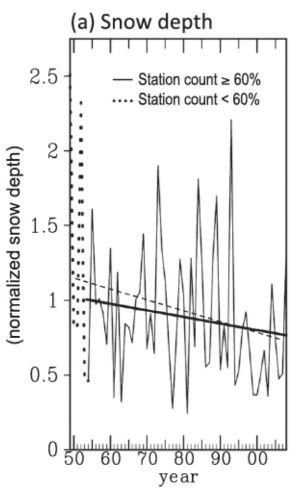


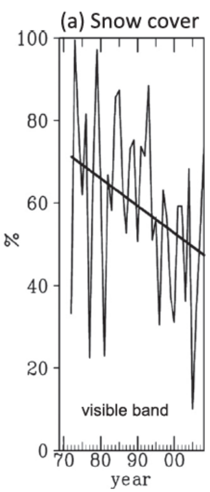

Journal
of
Climate
American Meteorological Society
1 November 2000

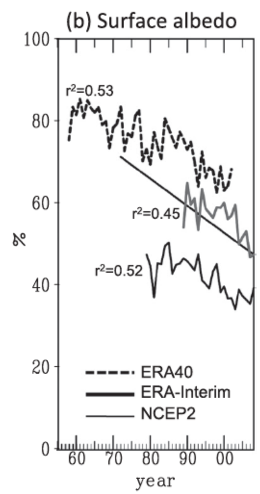

(d)NOAA CPC 1/4°
(e)Delaware 1/2°
(g) P
(h) S/P
mm/day
year
7% (50yr)
6% (50yr)
9%

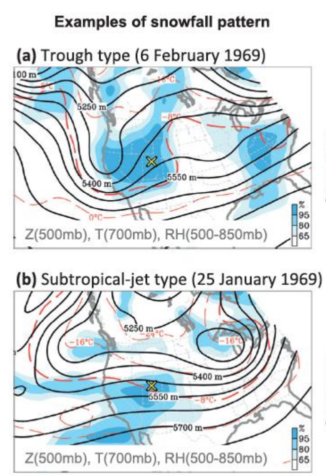

Estimated
Actual
(a) S/P (%)
(b) snowfall
(c) rainfall
(d) total precipitation
(e) T_{MAX}
(f) T_{MIN}
5°C
0°C
2.6/1.2°C

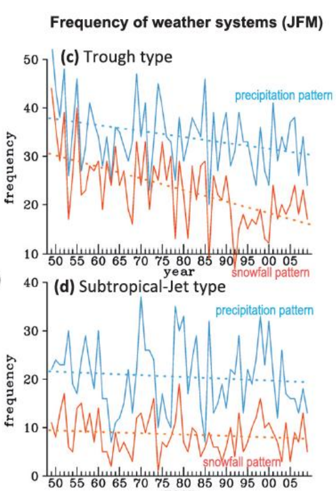

(a) S/P (%)
estimated
(d) Precipitation
actual
(b) snowfall
estimated
(e) Tmax
actual
Jan-Mar

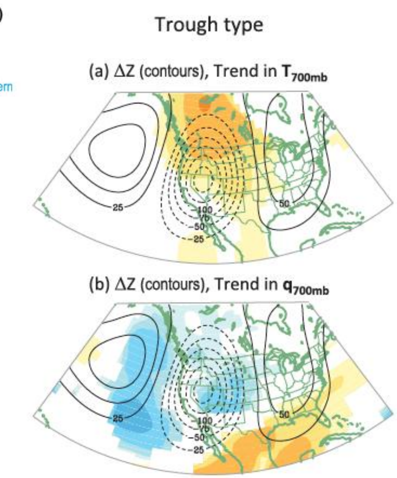

(a) Snow depth
Station count ≥ 60%
Station count < 60%
(normalized snow depth)
year


(a) Snow cover
%
visible band
year


(b) Surface albedo
r^2=0.53
r^2=0.45
r^2=0.52
%
ERA40
ERA-Interim
NCEP2
year


Examples of snowfall pattern
(a) Trough type (6 February 1969)
Z(500mb), T(700mb), RH(500-850mb)
(b) Subtropical-jet type (25 January 1969)
Z(500mb), T(700mb), RH(500-850mb)


Frequency of weather systems (JFM)
(c) Trough type
precipitation pattern
snowfall pattern
(d) Subtropical-Jet type
precipitation pattern
snowfall pattern
frequency
year


Trough type
(a) ΔZ (contours), Trend in T_{700mb}
(b) ΔZ (contours), Trend in q_{700mb}

Climate
Science

~~Average Weather~~

The statistics
of the environment
over time.

Long-Term Trends

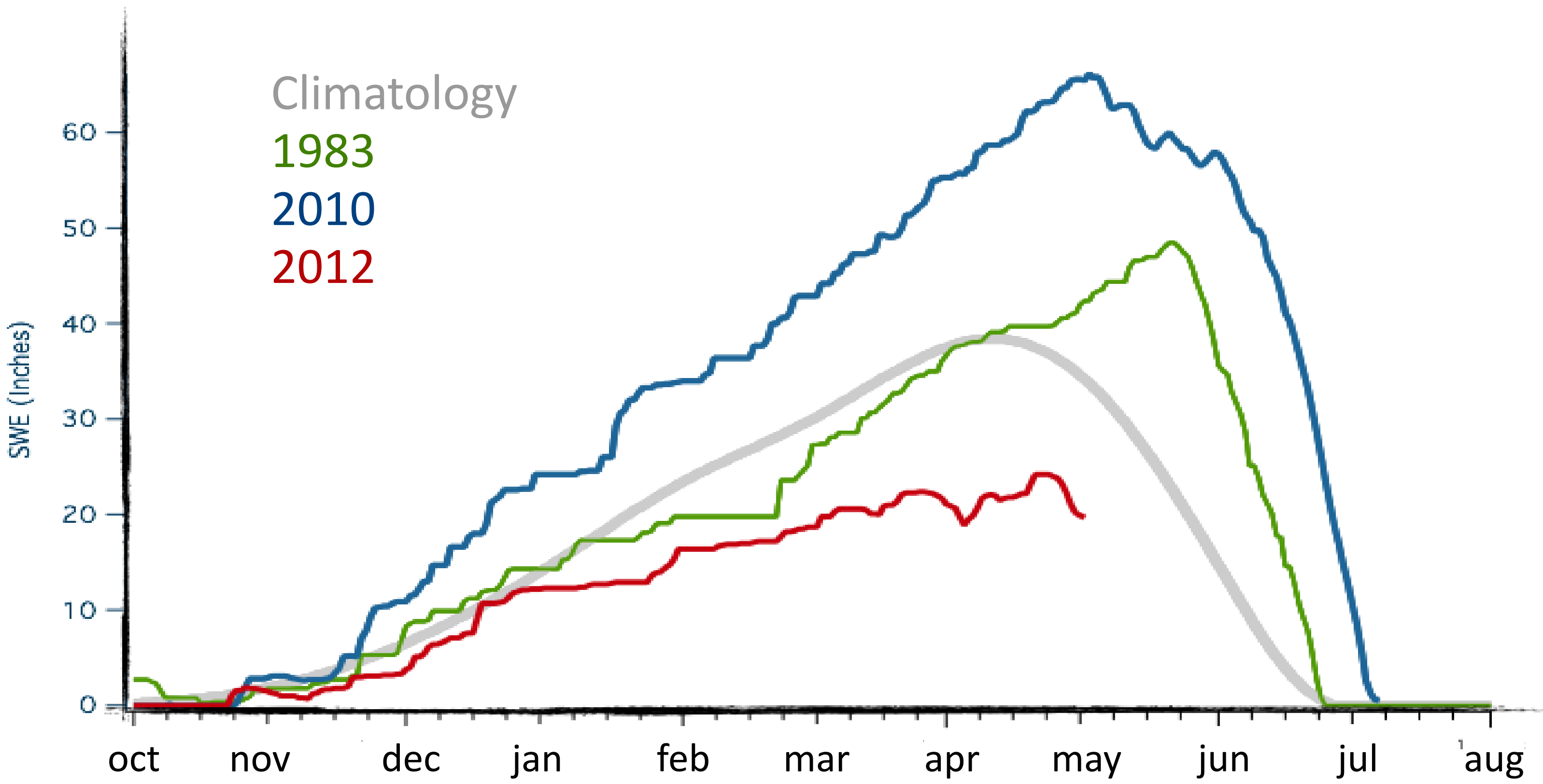
+

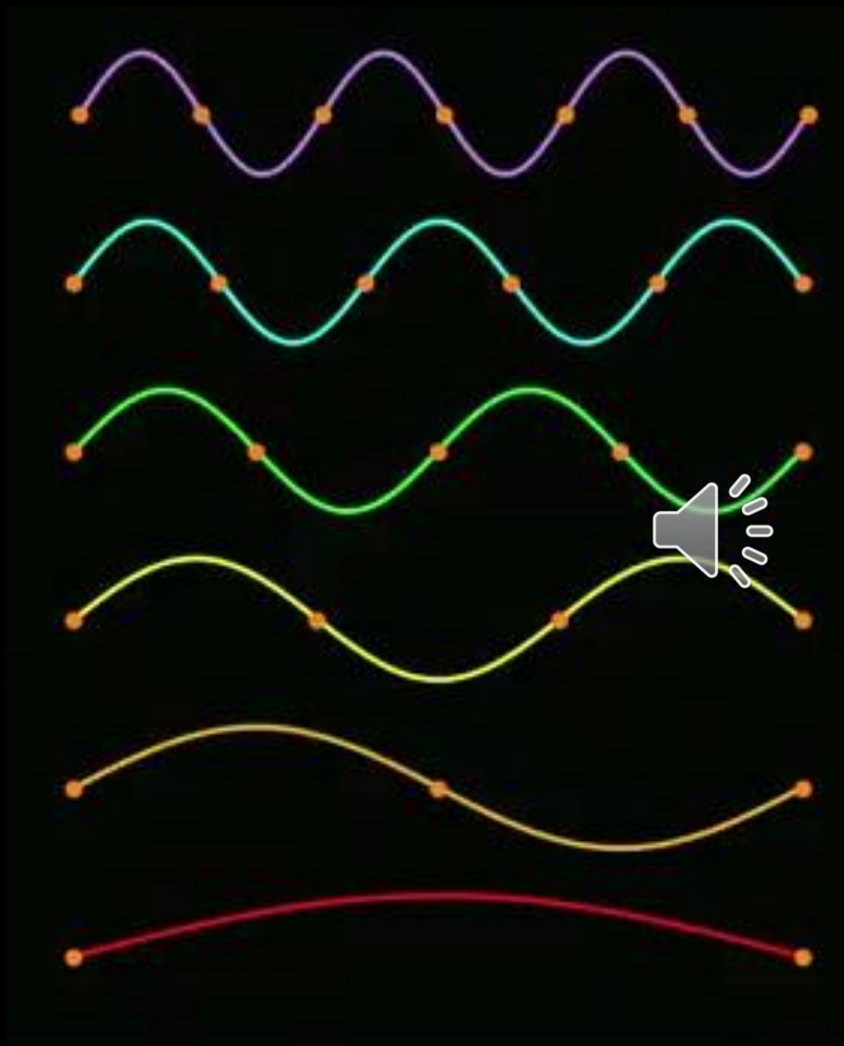
Short-Term Variability

Let’s Start with Variability

Snow Water

Tony Grove Snotel





Madden-Julian

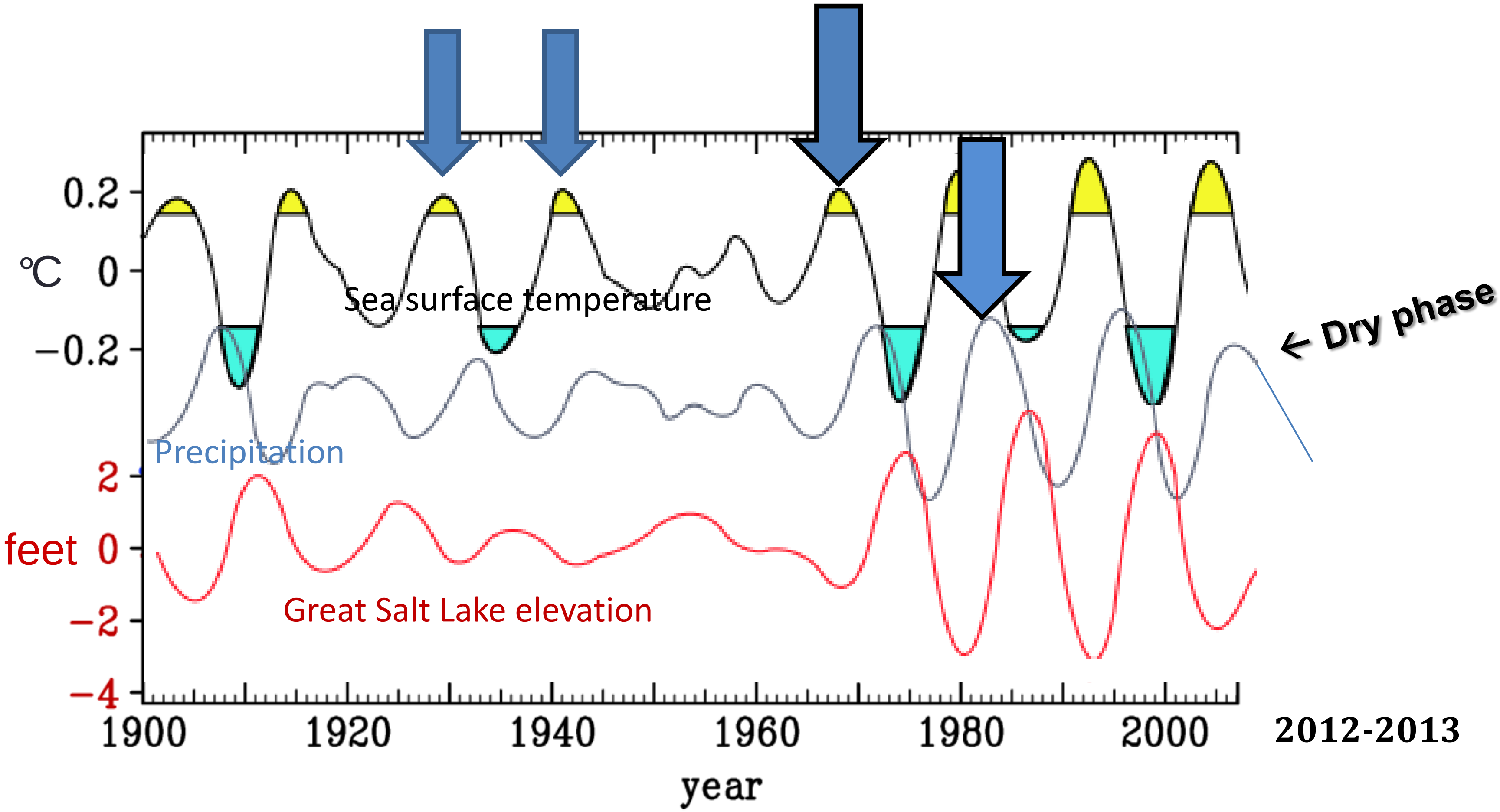
El Niño Southern

North Atlantic

Quasi-Decadal

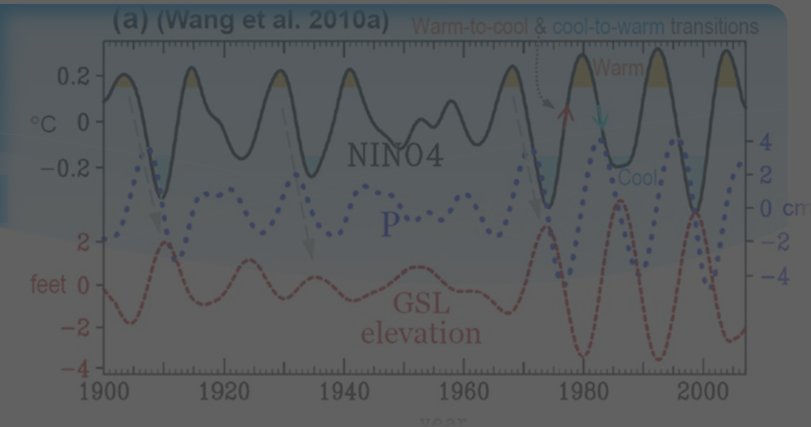
Pacific-Decadal

Arctic e Bass

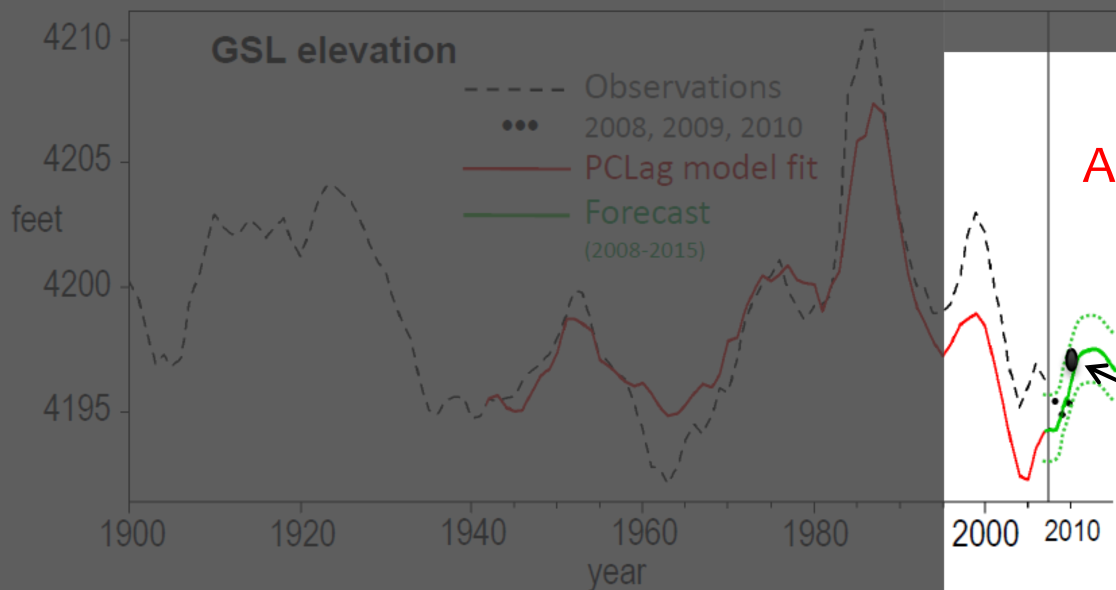


0.2
℃ 0
−0.2
Sea surface temperature
Precipitation
2
feet 0
−2
−4
Great Salt Lake elevation
← Dry phase
1900
1920
1940
1960
1980
2000
2012-2013
year

Principal Component (PC) – Lagged Regression Combined Model
to forecast GSL elevation tendency



$$G_t = \beta_0 G_{t-1} - \beta_1 PC1_{t-8} + \beta_2 PC1_{t-17} + \beta_3 PC1_{t-42} + \beta_4 PC2_{t-18} \cdots$$



Able to forecast “turnarounds”

Forecast out to 8 years

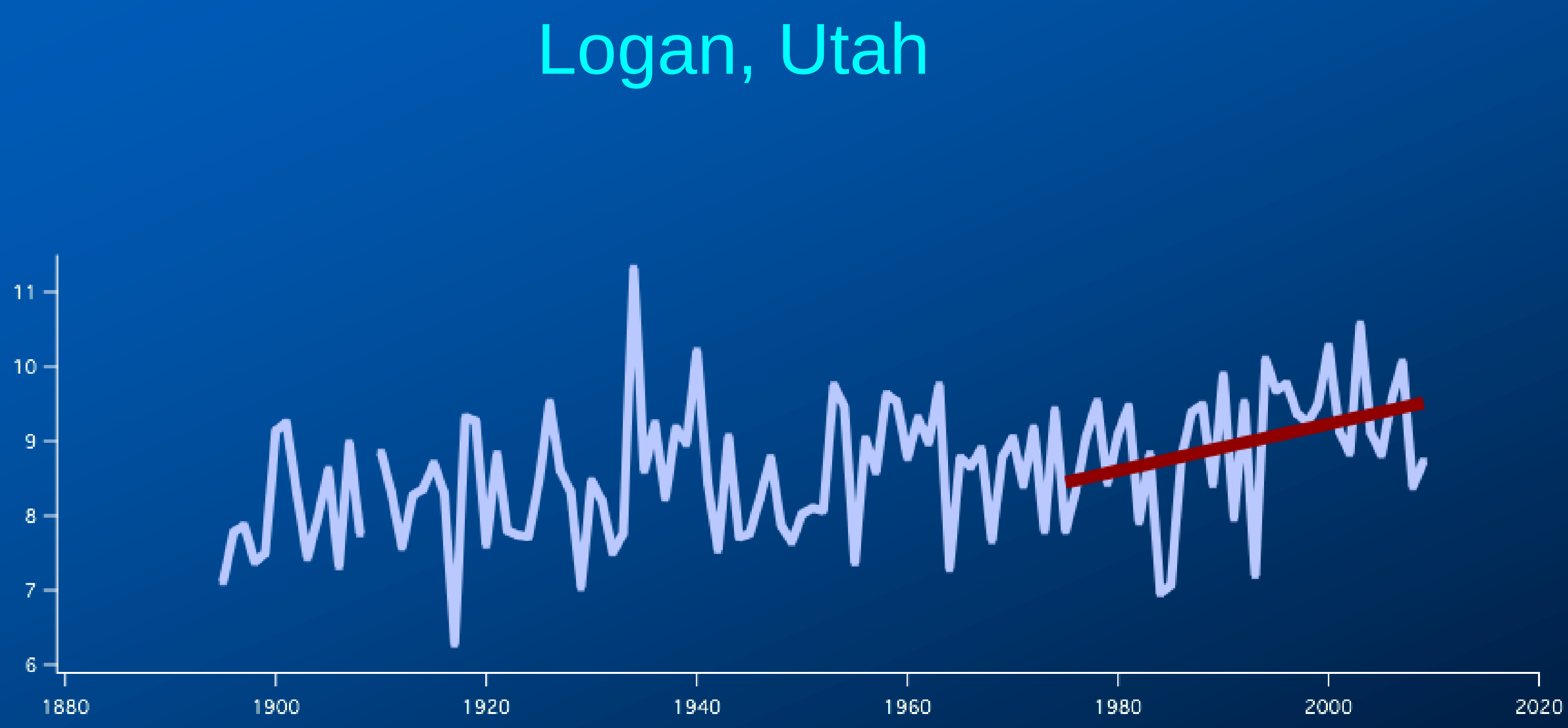
(Gillies et al. 2011; JHM)

And now Trends

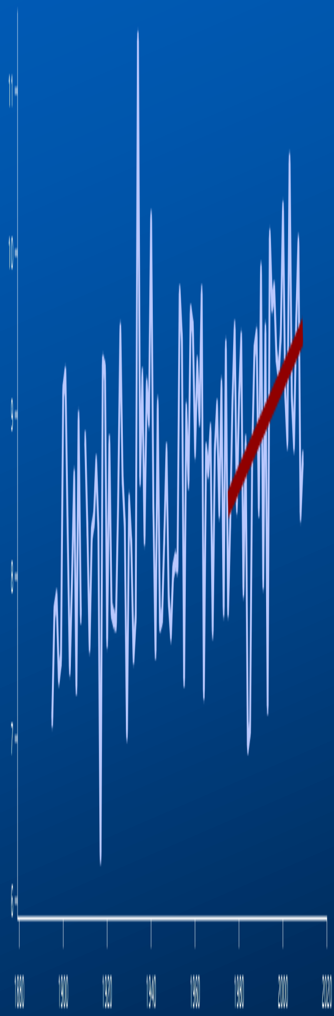
Temperature Change

Utah

utah's warming climate

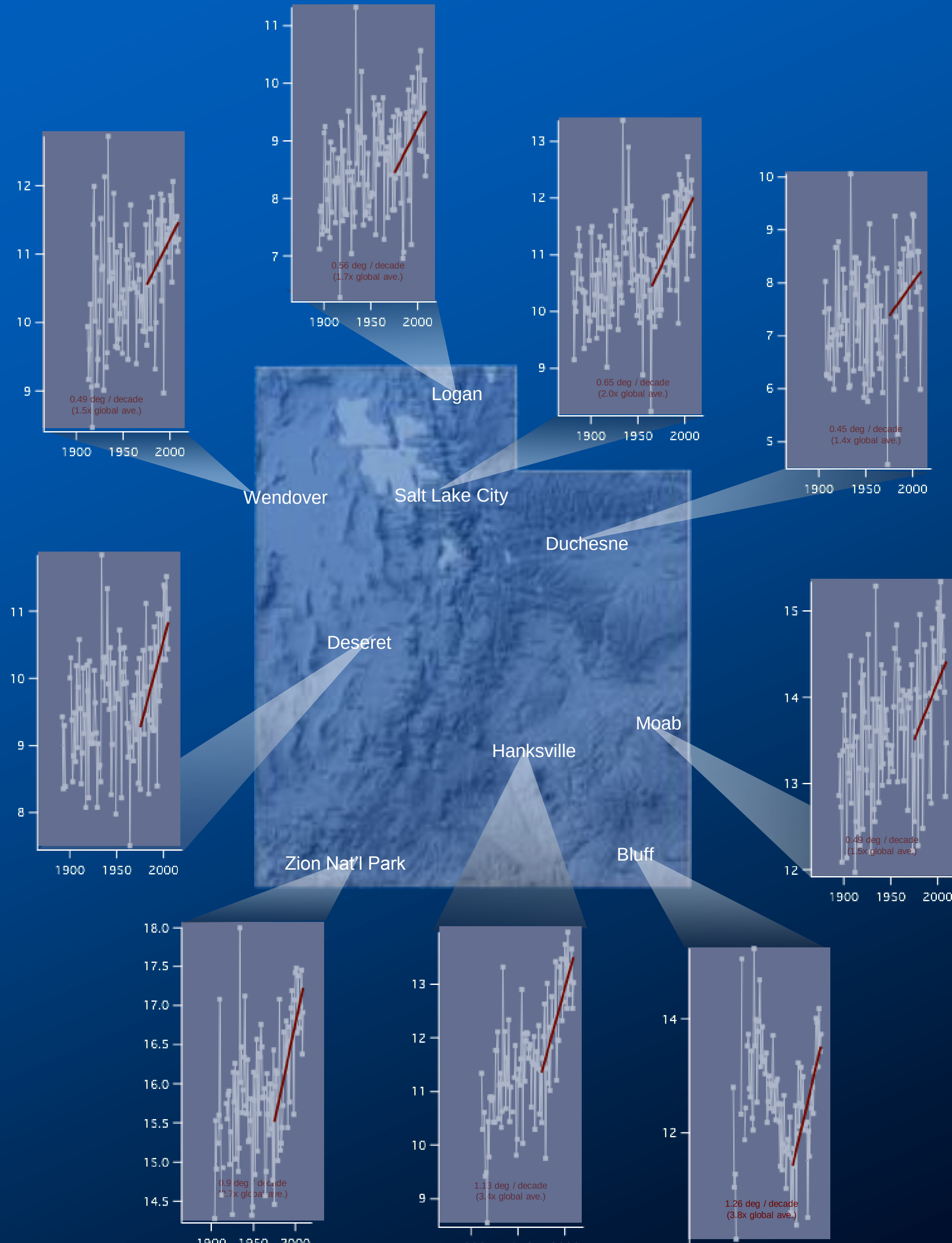


utah’s warming climate



Logan, Utah

utah's warming climate



utah's warming climate

Bluff
1.26 deg / decade
(3.8x global ave.)

Hanksville
1.13 deg / decade
(3.4x global ave.)

Zion Nat'l Park
0.9 deg / decade
(2.7x global ave.)

Salt Lake City
0.65 deg / decade
(2.0x global ave.)

Logan
0.56 deg / decade
(1.7x global ave.)

Moab
0.45 deg / decade
(1.4x global ave.)

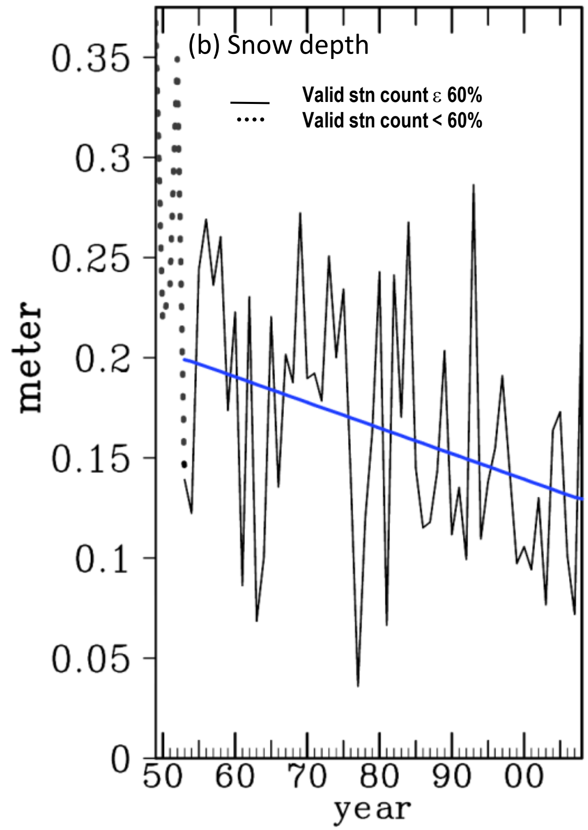
Precipitation Change

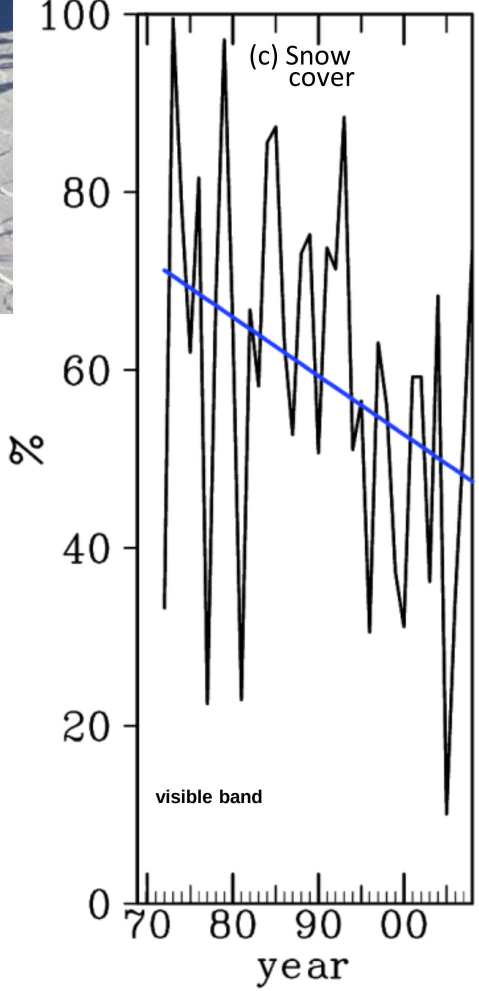
Utah


We’re getting more precipitation!


Less of it is falling as snow
but more as rain

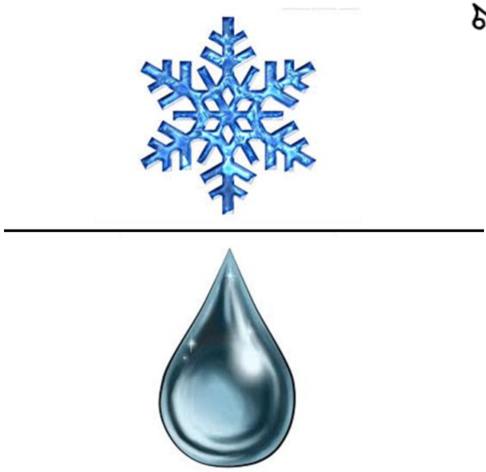
COOP snow depth

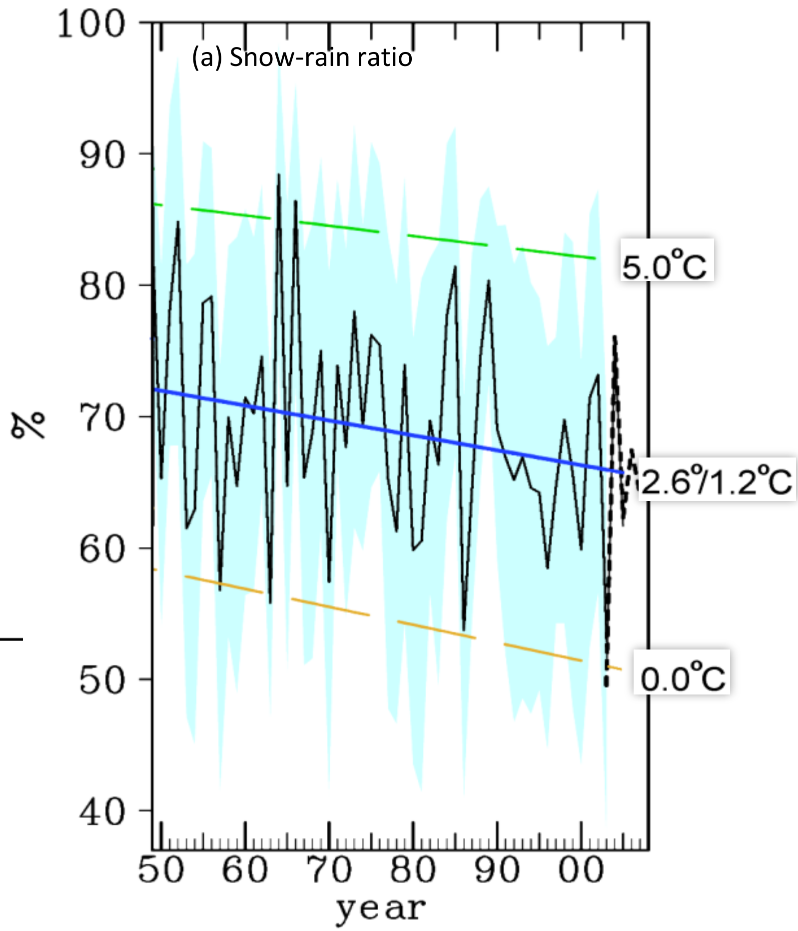




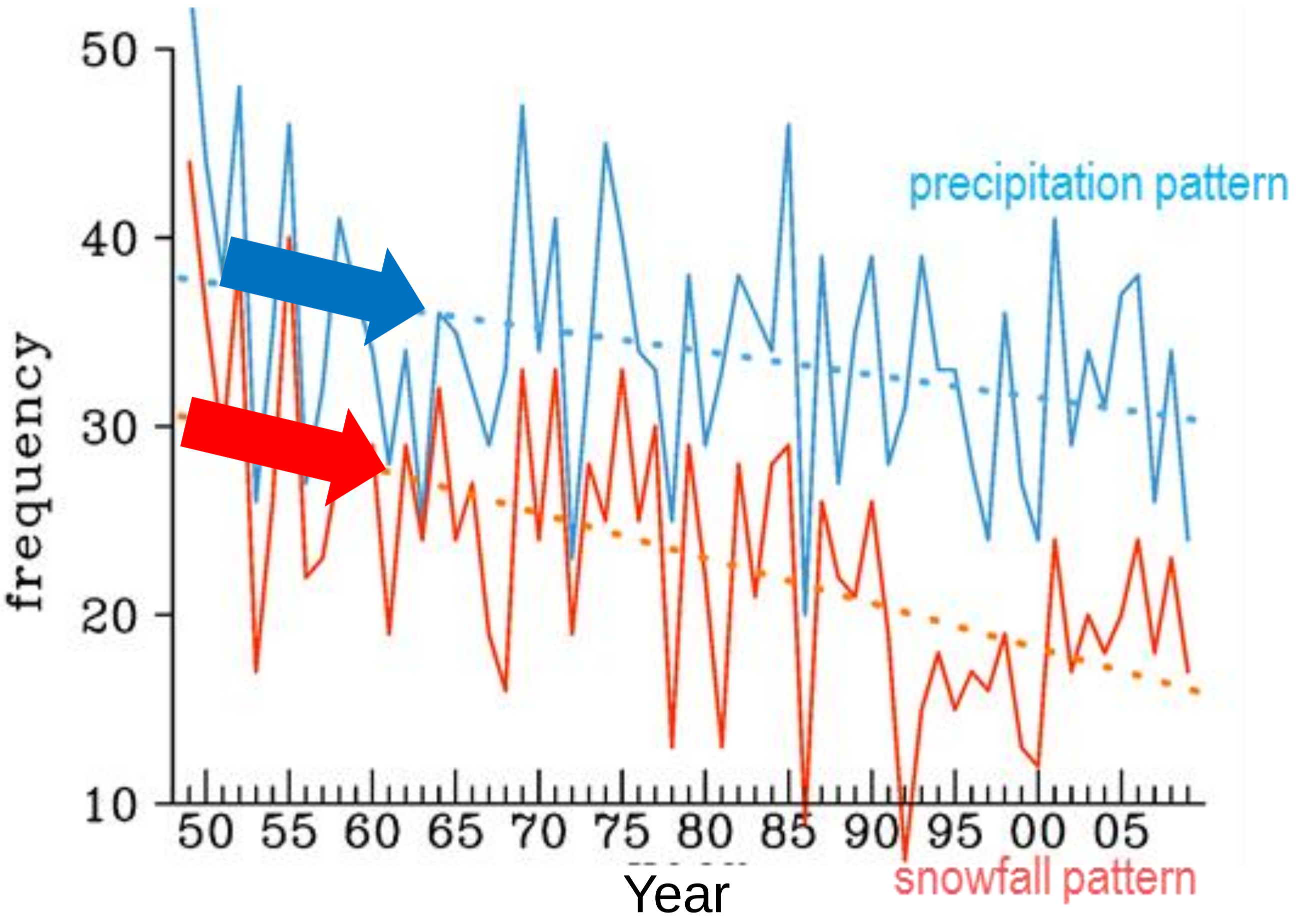
(c) Snow cover
visible band
%
100
80
60
40
20
0
70
80
90
00
year

COOP snow-to-rain ratio





Winter storms have become less frequent



precipitation pattern
snowfall pattern
frequency
Year
50
40
30
20
10
50 55 60 65 70 75 80 85 90 95 00 05

But each storm dumps more precipitation

MORE
INTENSE

What does the future hold?

Models


$$f_v(v_i) = \sqrt{\frac{m}{2\pi kT}} \exp\left[\frac{-mv_i^2}{2kT}\right]$$

$$\rho\left(\frac{\partial \vec{v}}{\partial t} + \vec{v} \cdot \nabla \vec{v}\right) = -\nabla p + \nabla \cdot \vec{T} + \vec{f}$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \cdot D = \rho_f$$

$$\nabla \times B = \mu_0 J + \mu_0 \varepsilon_0 \frac{\partial E}{\partial t}$$

$$\left(\beta mc^2 + \sum_{k=1}^{3} \alpha_k p_k c\right) \psi(x,t) = i\hbar \frac{\partial \psi}{\partial t}(r,t)$$

$$S = k \log W$$

$$\nabla \cdot B = 0$$

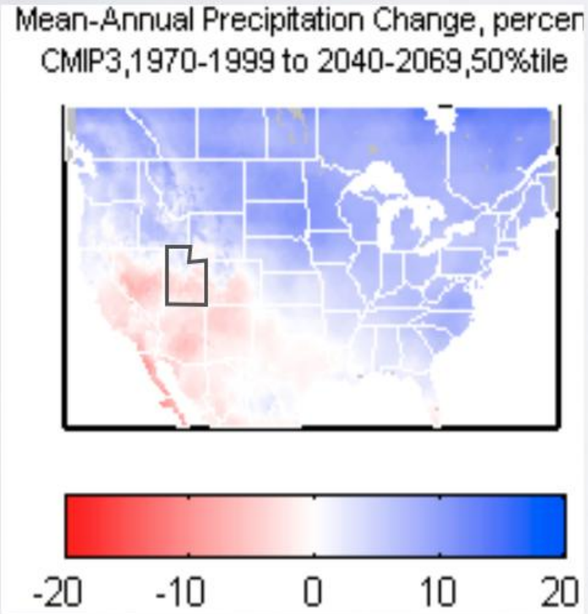
$$i\hbar \Psi(r,t) = -\frac{\hbar^2}{2m} \nabla^2 \Psi(r,t) + V(r,t)$$

$$\partial_t \phi + \partial_x^3 \phi + 6\phi \partial_x \phi = 0$$

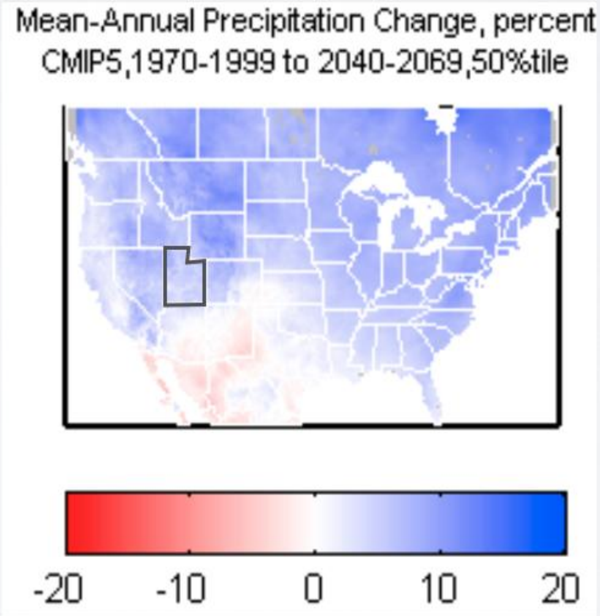
Model Projections
Trends

Future?

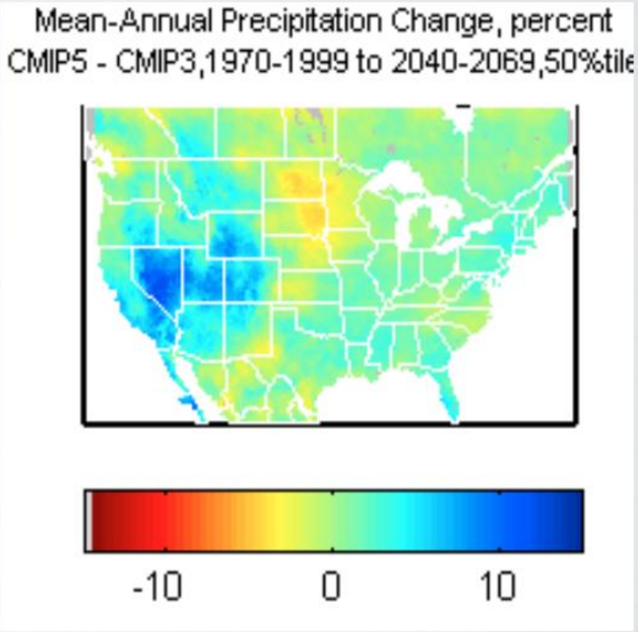
CMIP3
(older models)



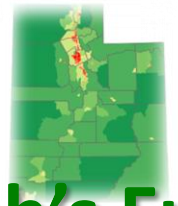
CMIP5
(newer models)



CMIP5 - CMIP3



Levi Brekke (BoR; 2013)

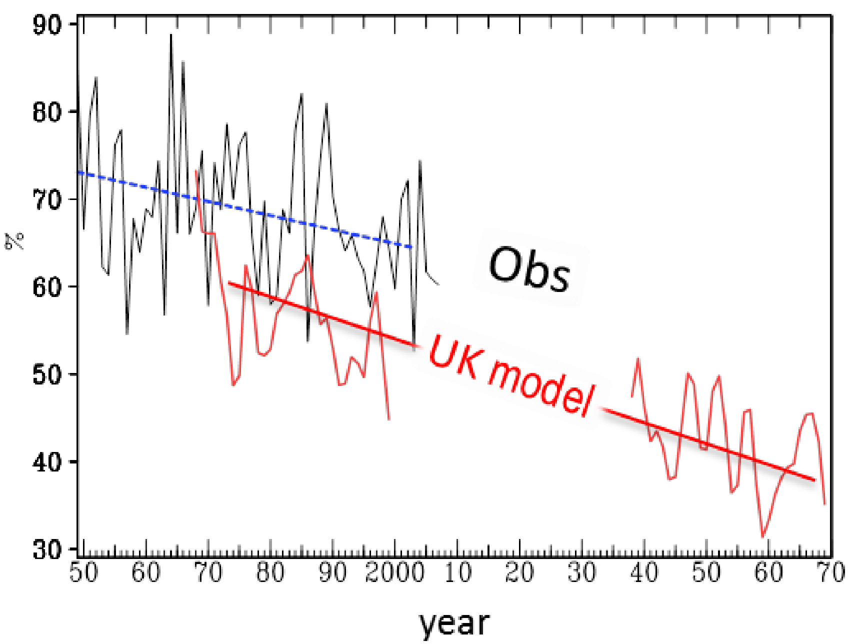


Utah's Future

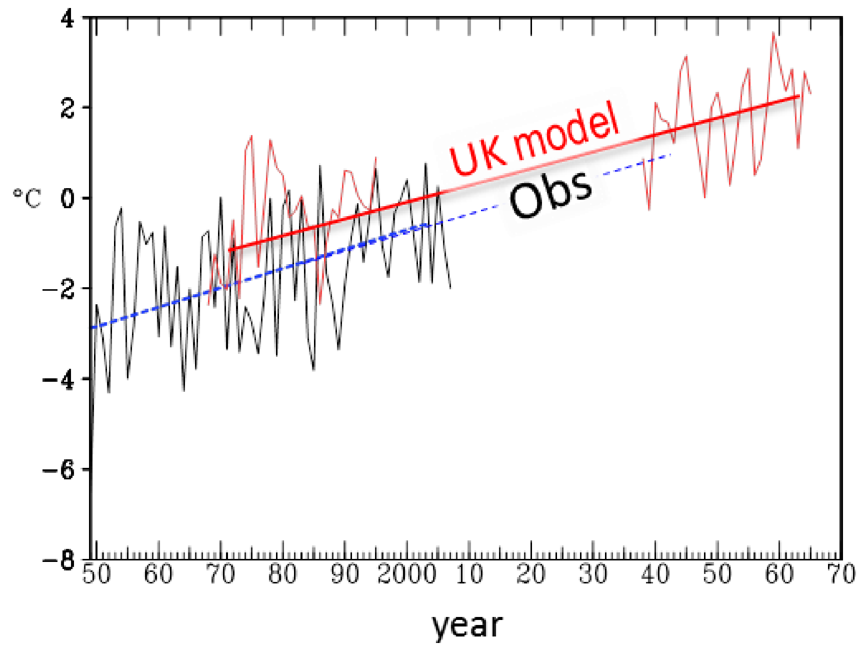
Climate model simulations

NARCCAP (North American Regional Climate Change Assessment Program**)**

Snow-to-precipitation ratio



Temperature

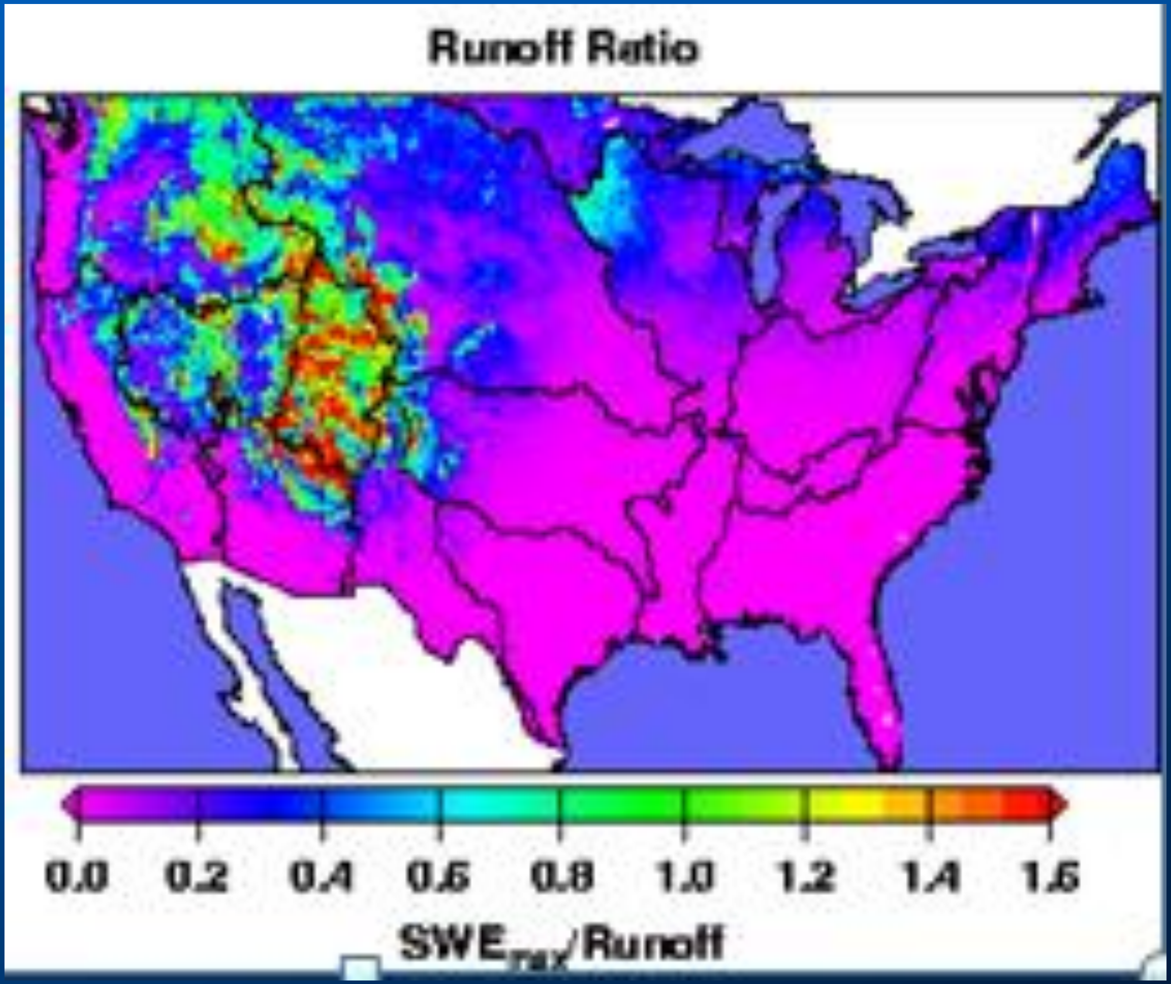



A QUESTION of Timing


UTAH
LIFE ELEVATED
S.J. & JESSIE E. QUINNEY COLLEGE of NATURAL RESOURCES
UtahStateUniversity
REMOTE SENSING/GIS LABORATORY
INCREASED
Air temperature over land
INCREASED
Precipitation as rain
SNOWPACK
Declining over land

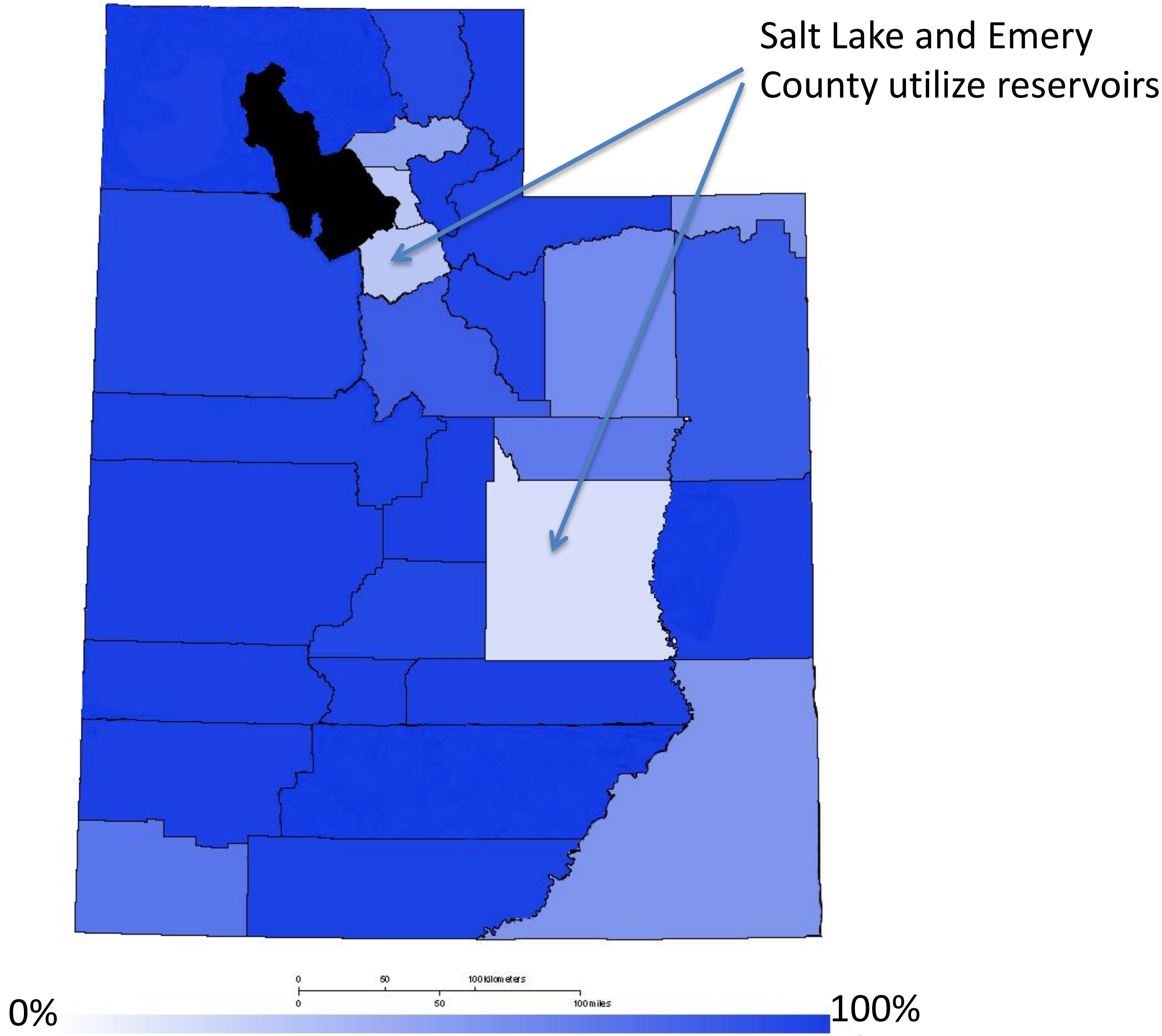
Why Should We Care

Hydroclimate of the West



Utah Groundwater Dependence

(color = % dependence on groundwater for public supply for 2005)



CCSM4
Spring (March-April)
Snow Depth

RCP8.5 High Emissions Scenario

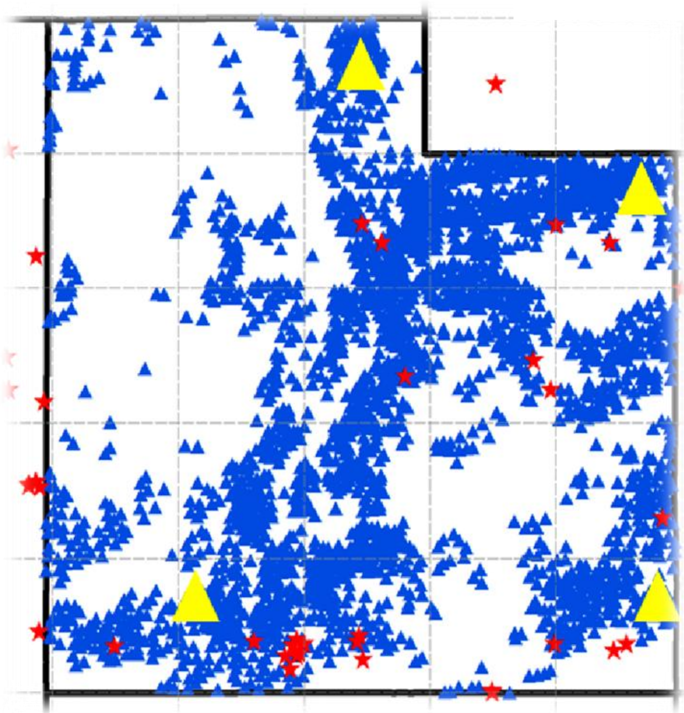
1850-2100 Four Year Running Average

Postscript

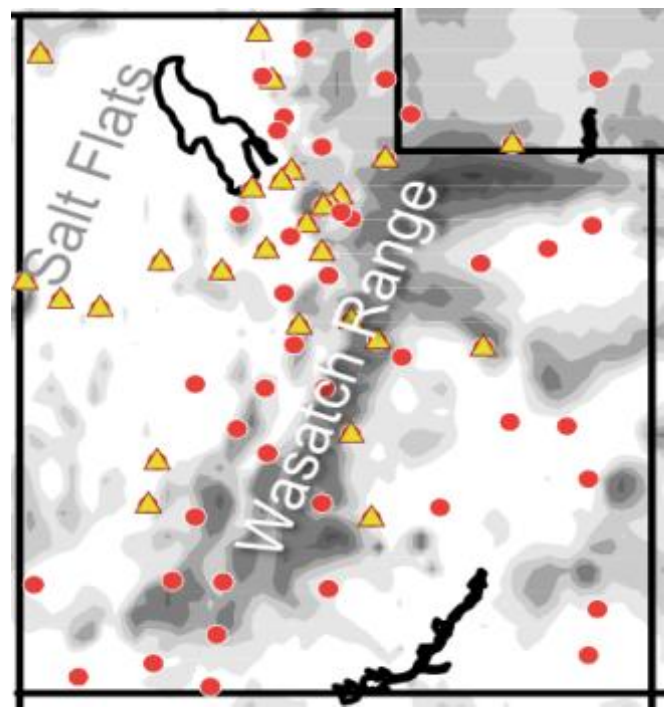
Tree ring power!

USFS: Forest Inventory and Analysis (FIA) Program

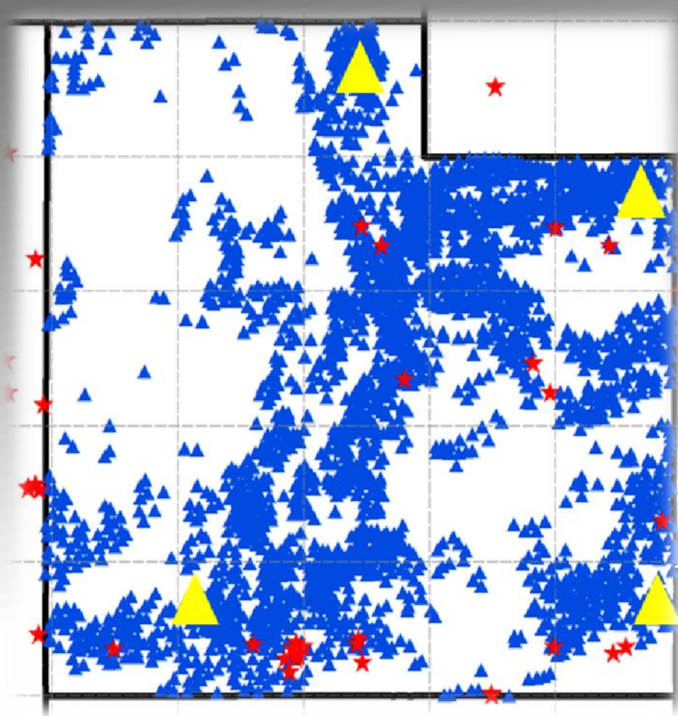
from Justin DeRose

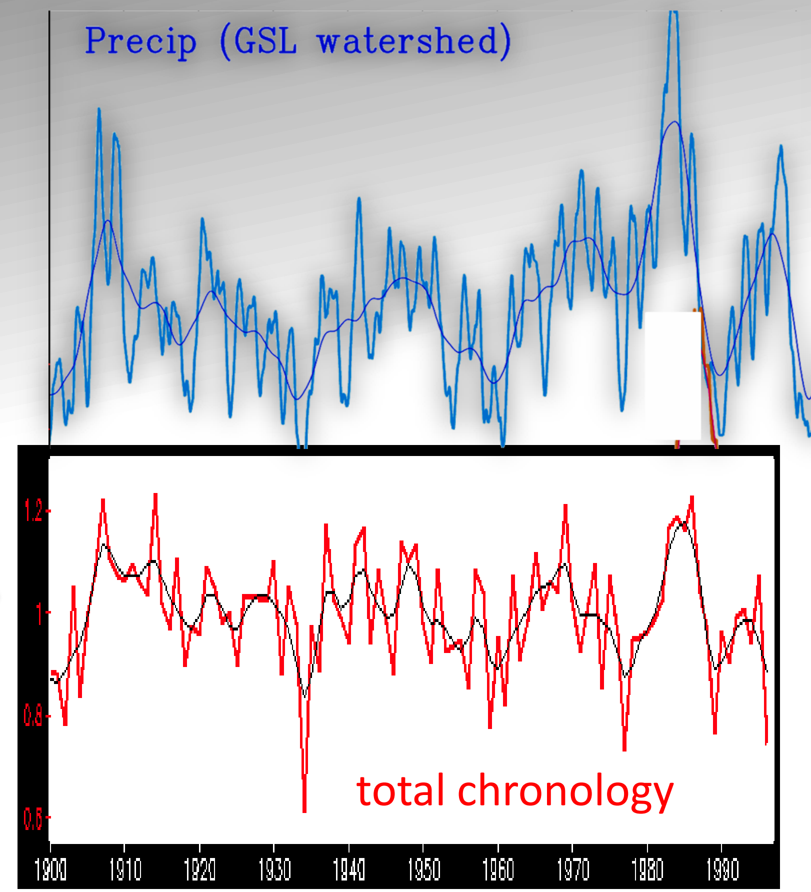


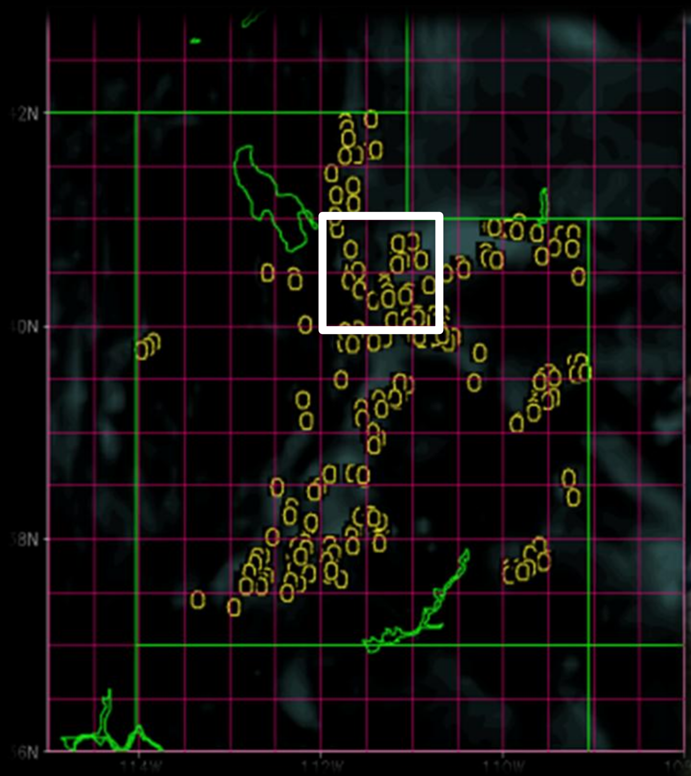
COOP stations

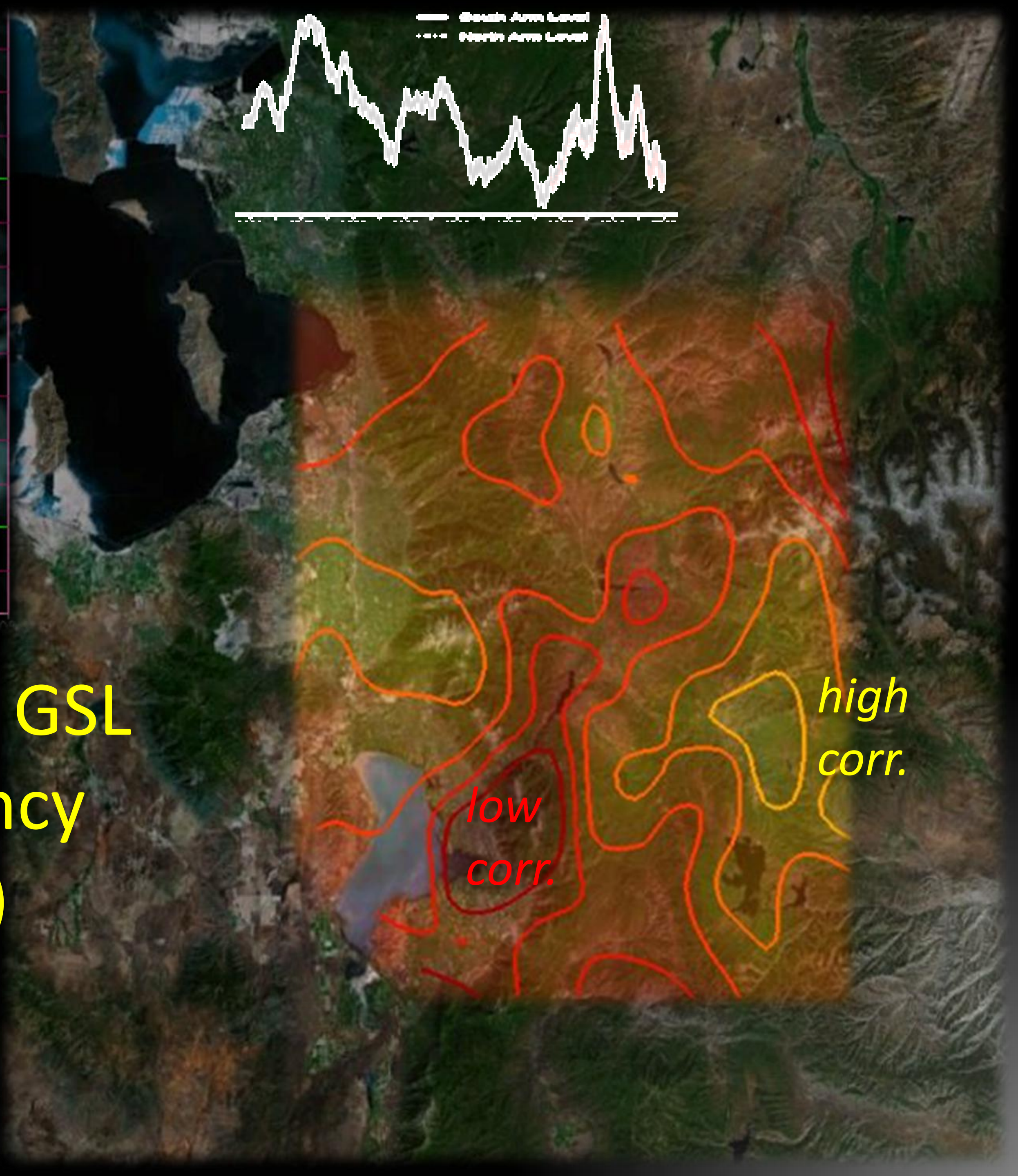


Detection of decadal cycles

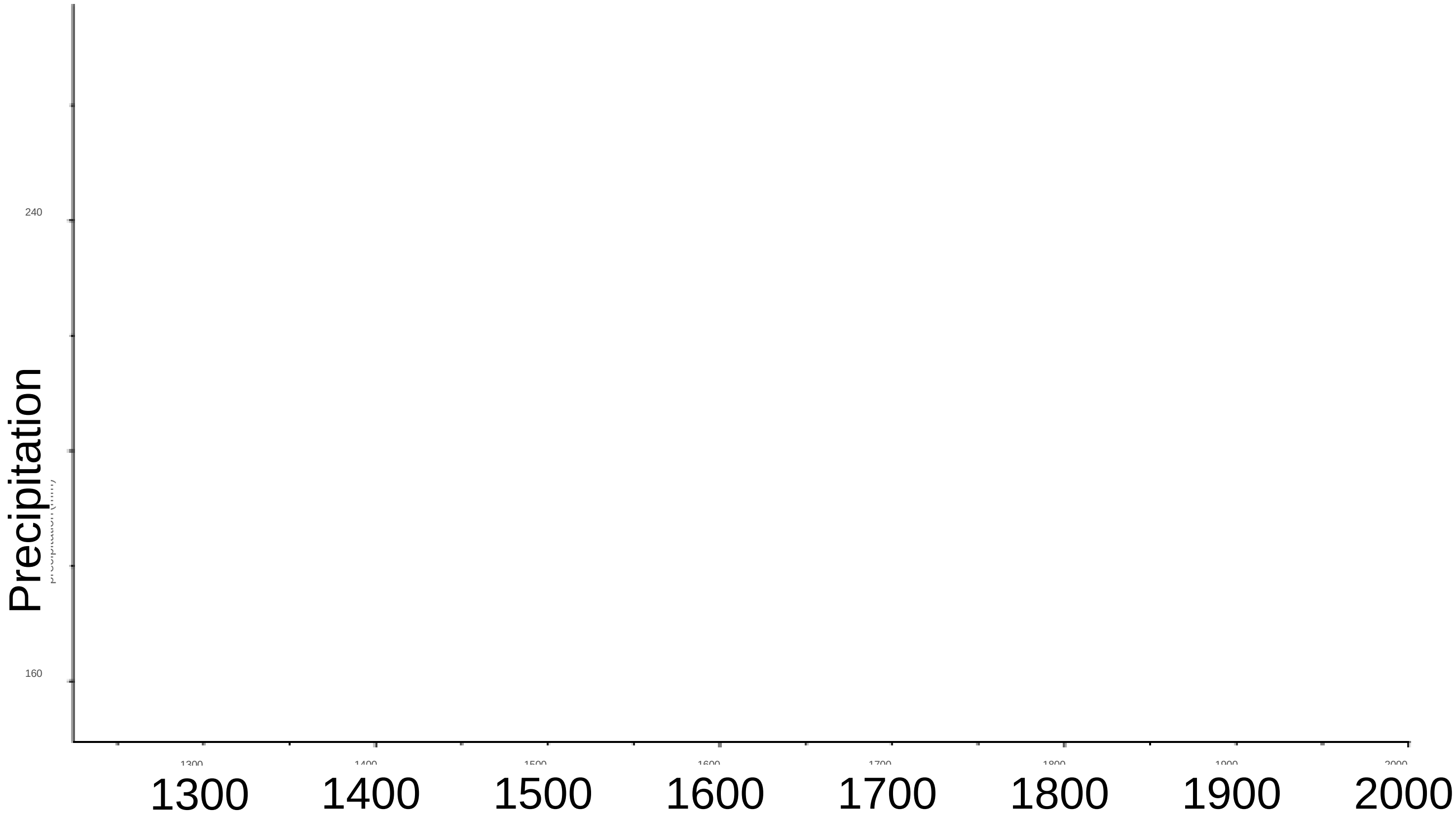


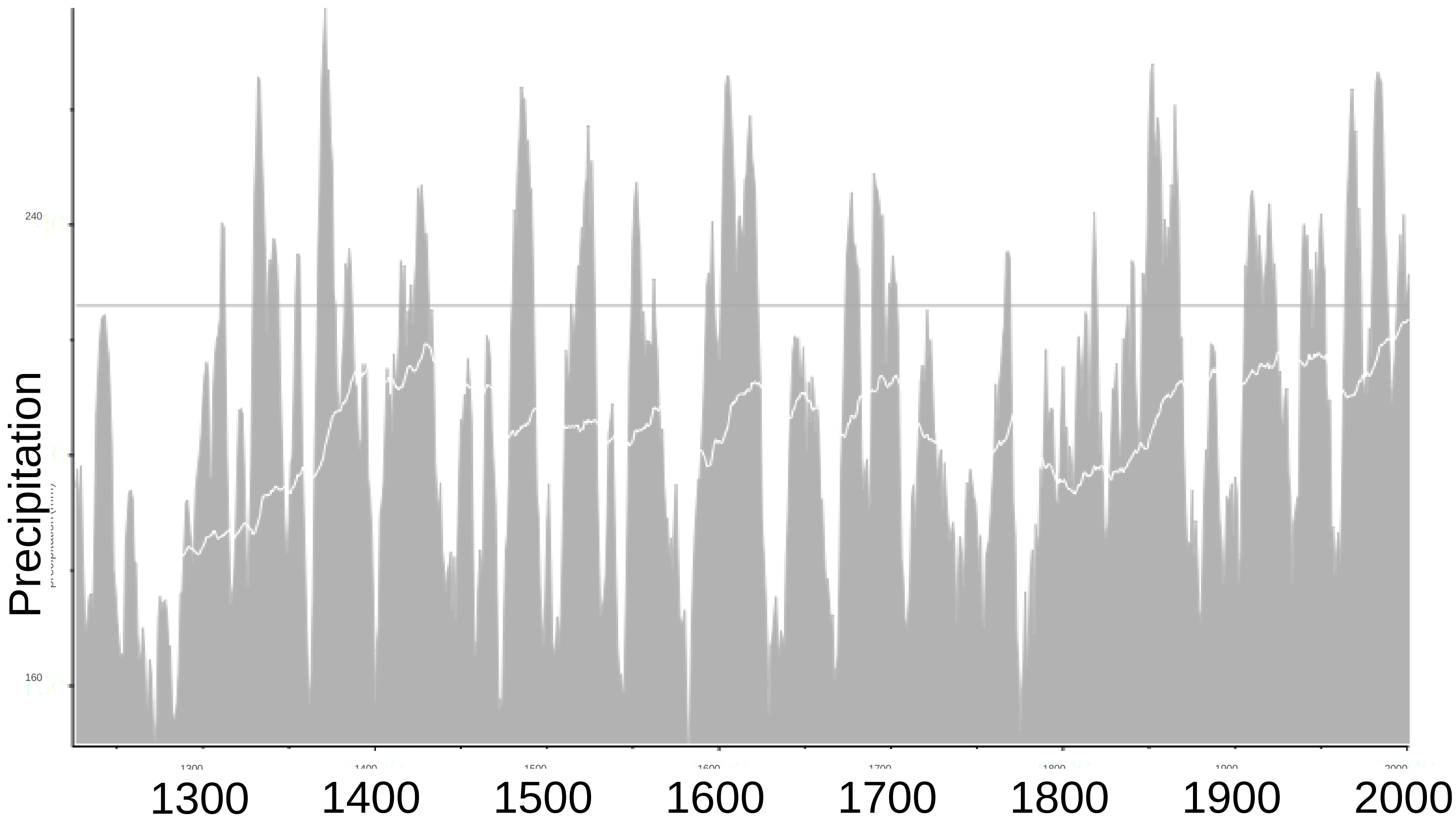


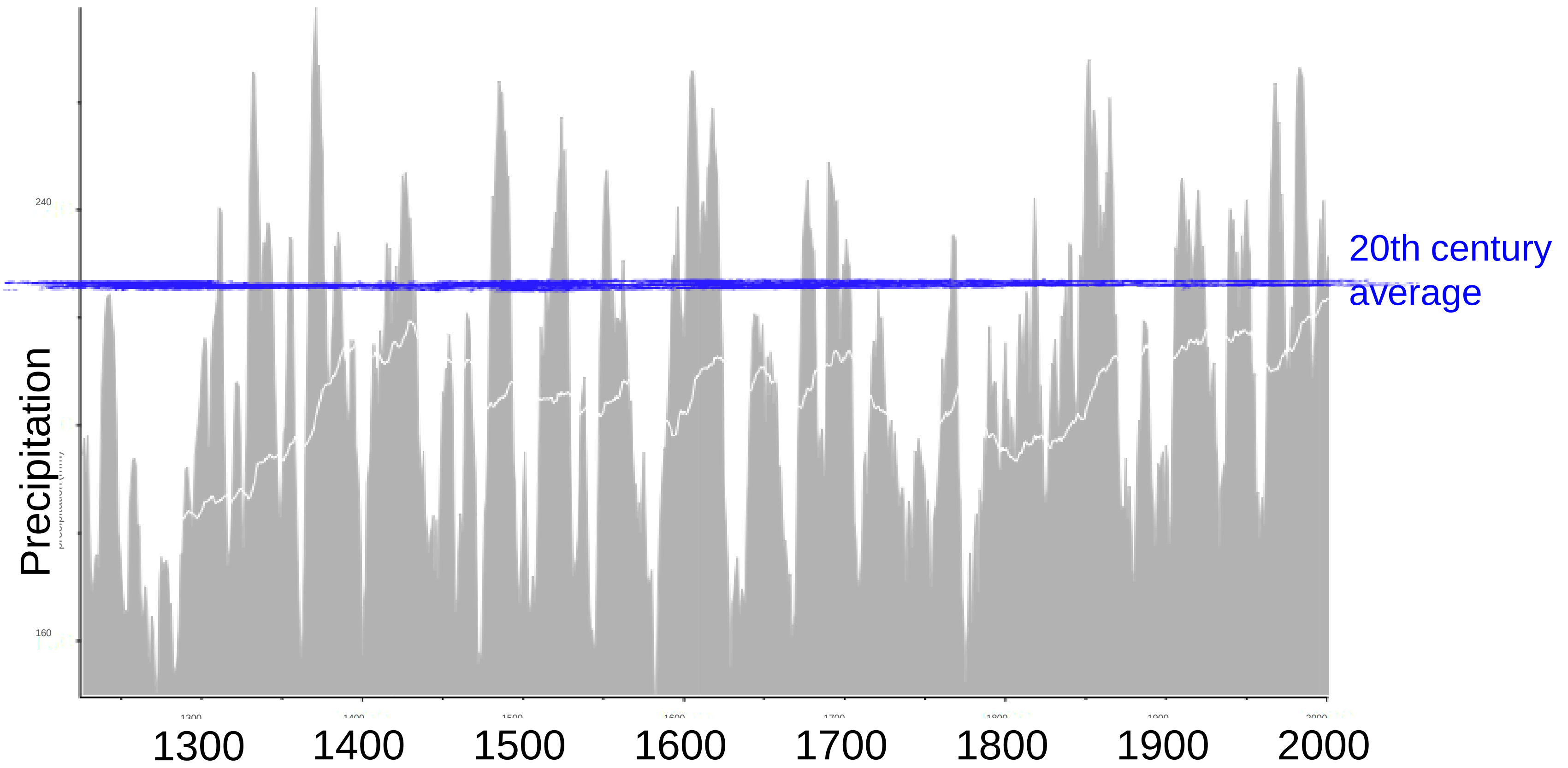




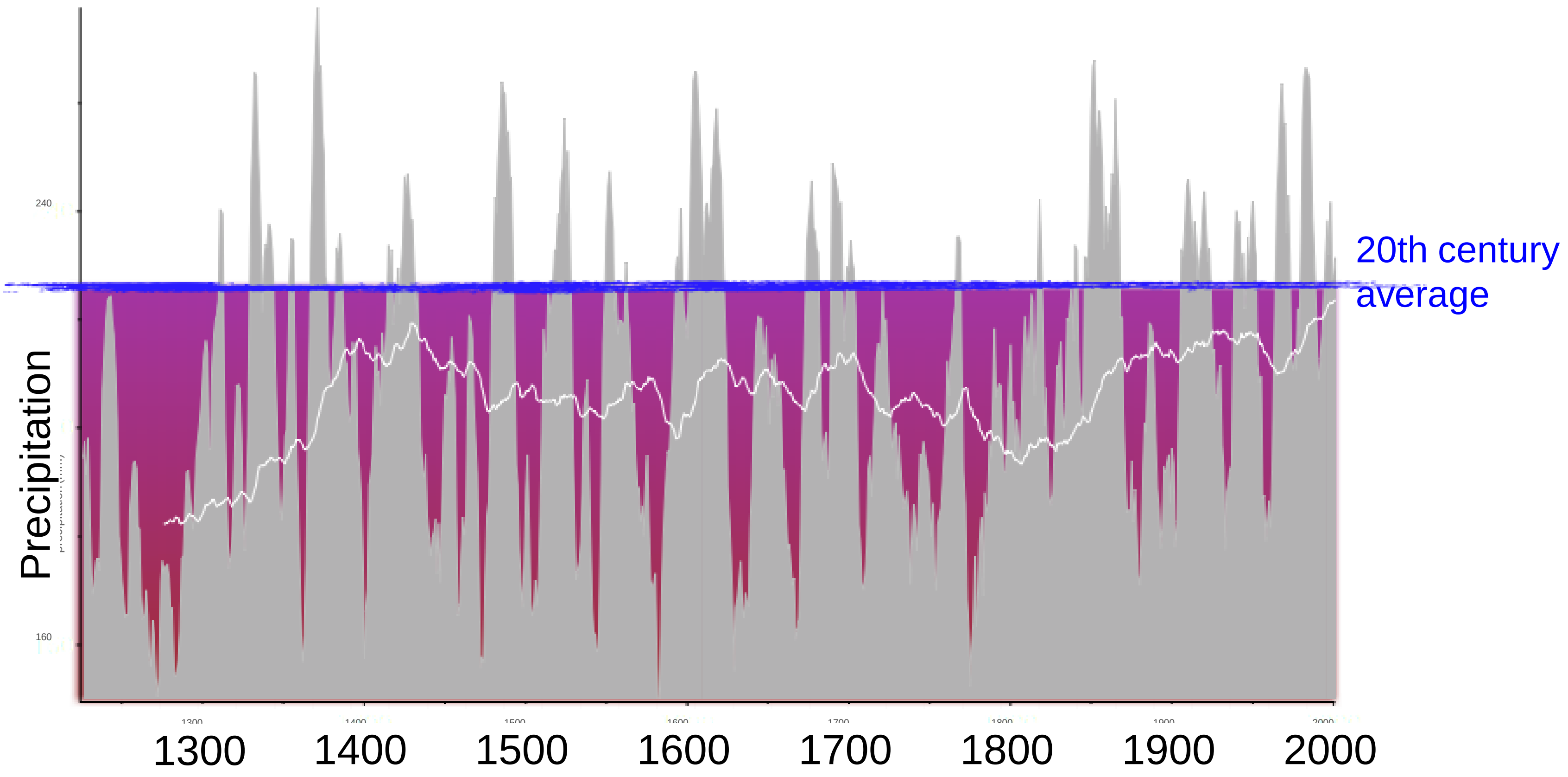
Correlation with GSL elevation tendency (1/8° resolution)

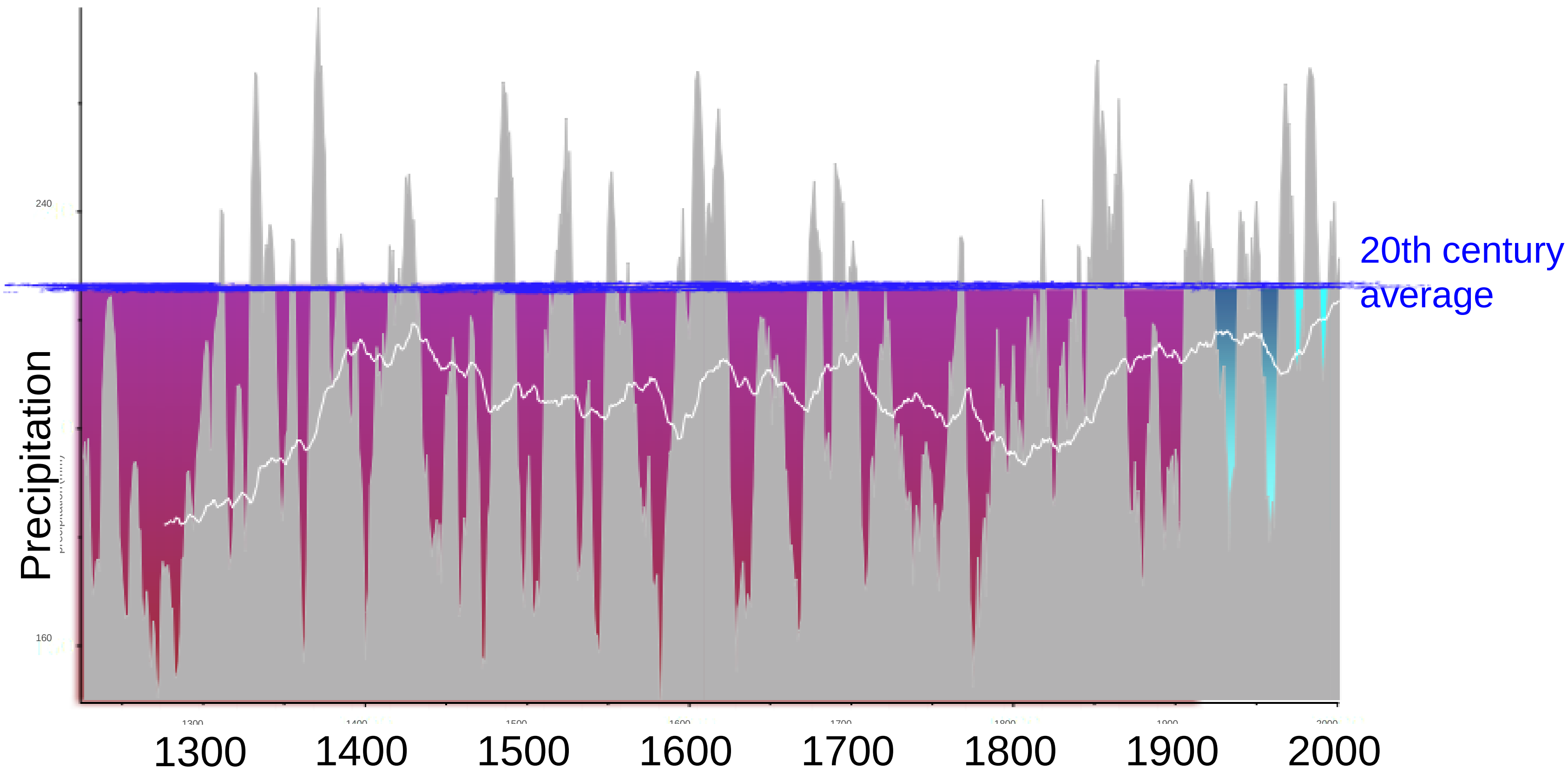

240
160
Precipitation
1300
1400
1500
1600
1700
1800
1900
2000


Precipitation
240
160
1300
1400
1500
1600
1700
1800
1900
2000

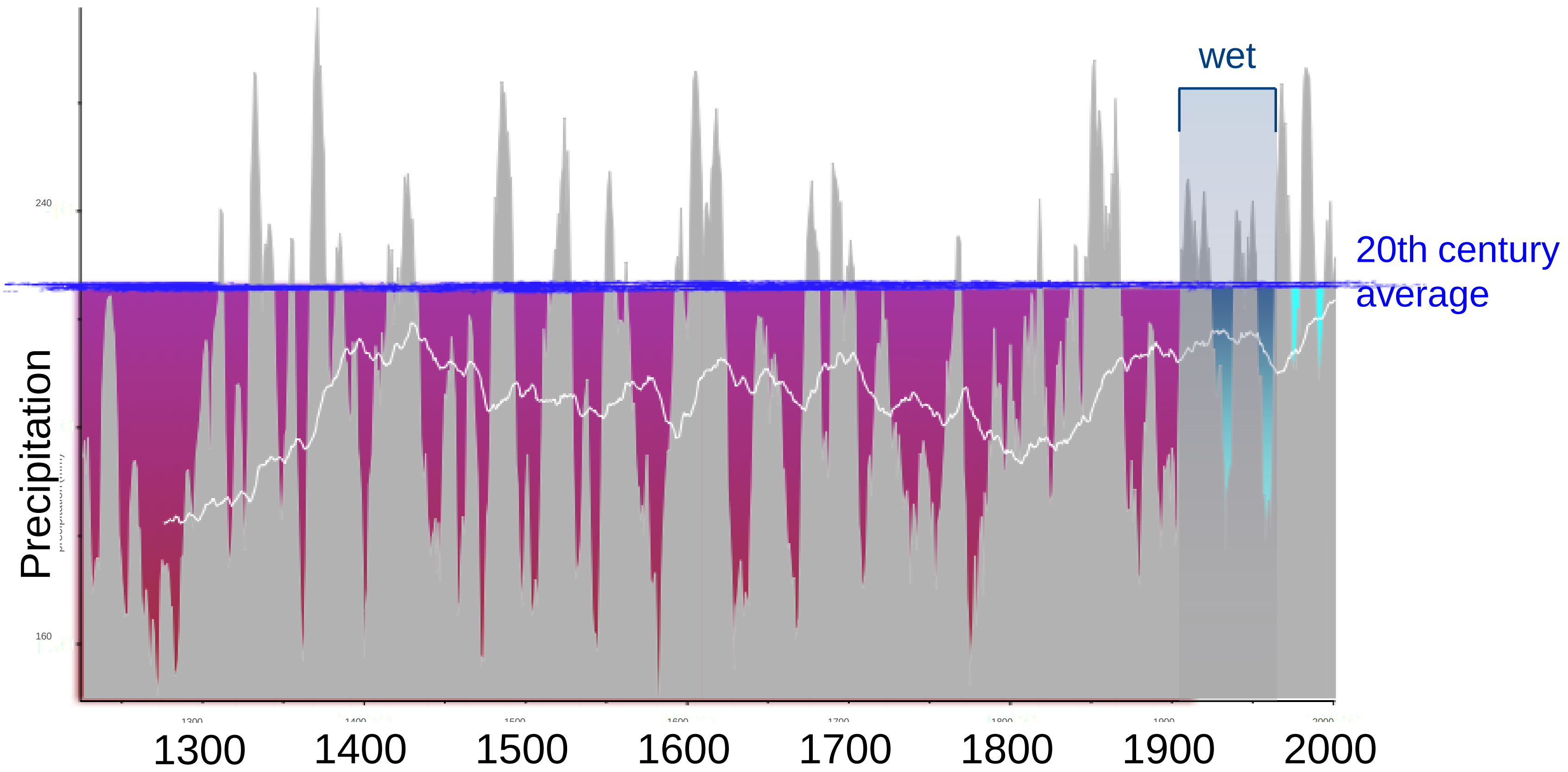


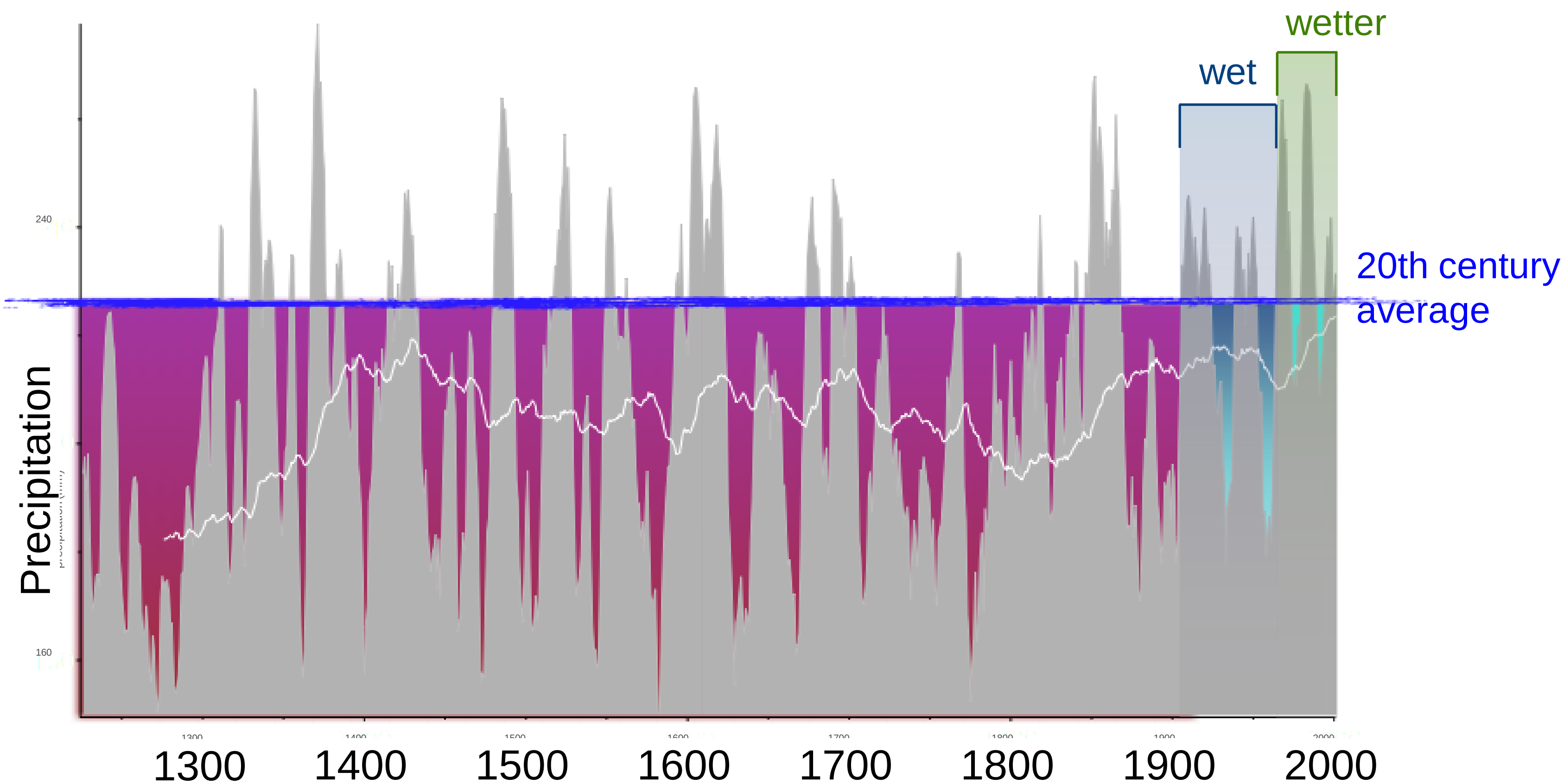
240
160
Precipitation
20th century average
1300
1400
1500
1600
1700
1800
1900
2000


20th century average
Precipitation
240
160
1300
1400
1500
1600
1700
1800
1900
2000



20th century
average
Precipitation
240
160
1300
1400
1500
1600
1700
1800
1900
2000


wet
20th century average
Precipitation
240
160
1300
1400
1500
1600
1700
1800
1900
2000


wetter
wet
20th century average
Precipitation
240
160
1300
1400
1500
1600
1700
1800
1900
2000