# Utah State University

# The Changing Winter Precipitation Regime in Utah

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Journal
of
Climate
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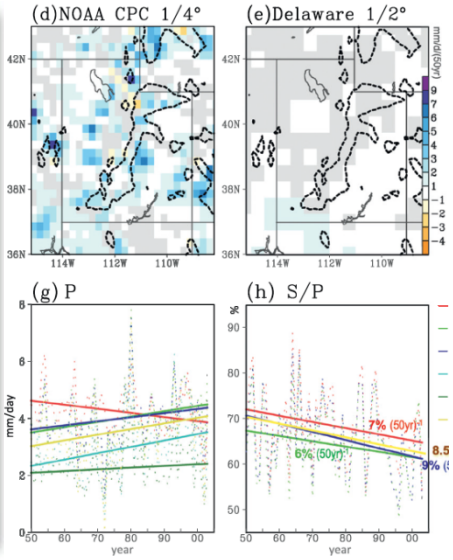
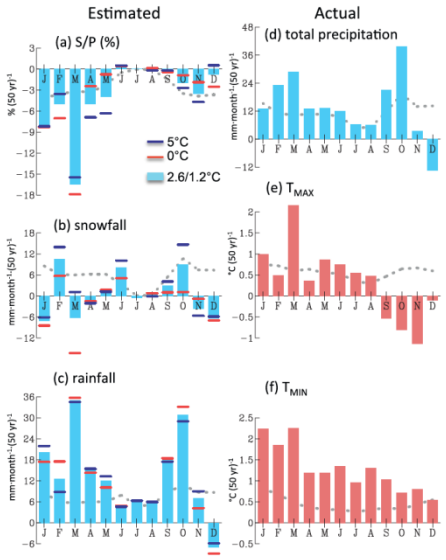
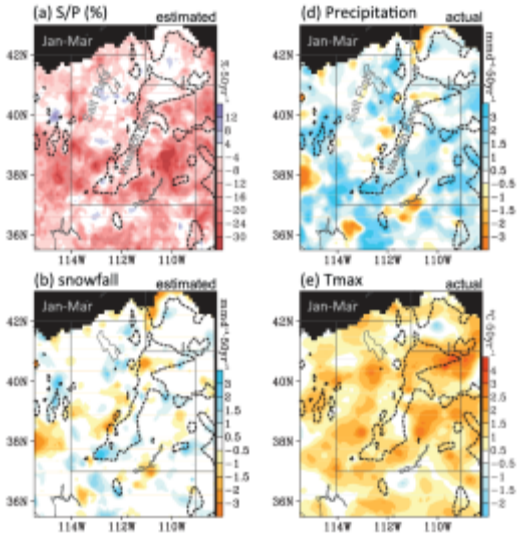
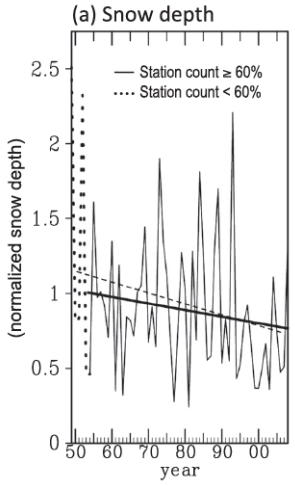
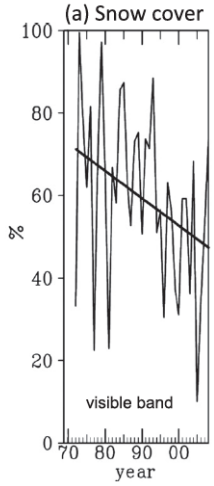
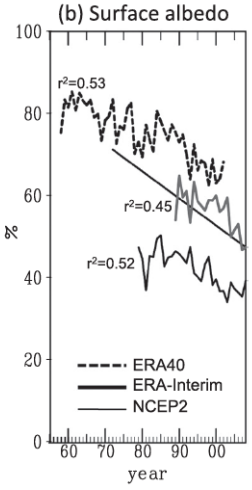

(d)NOAA CPC 1/4°
(e)Delaware 1/2°
(g) P
(h) S/P
mm/day
%
year
7% (50yr)-1
6% (50yr)-1

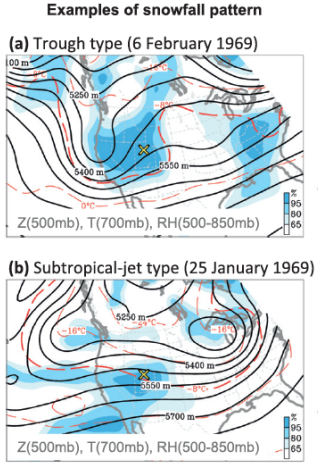

Estimated
Actual
(a) S/P (%)
(d) total precipitation
(b) snowfall
(e) TMAX
(c) rainfall
(f) TMIN
5°C
0°C
2.6/1.2°C

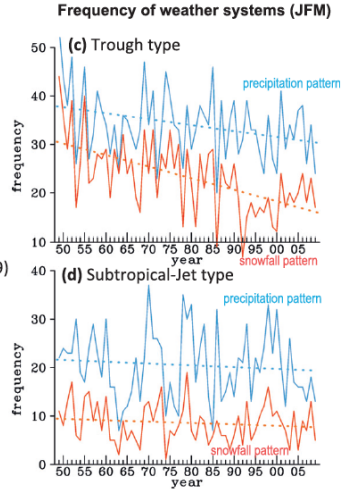

(a) S/P (%)
estimated
(d) Precipitation
actual
(b) snowfall
estimated
(e) Tmax
actual
Jan-Mar

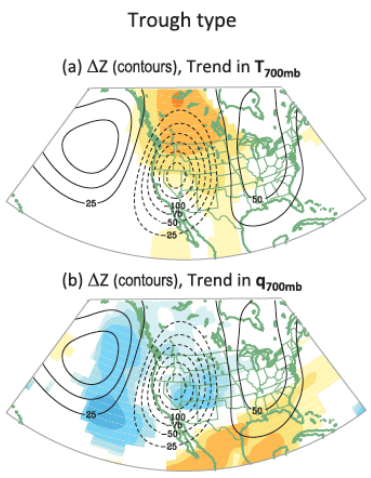

(a) Snow depth
Station count ≥ 60%
Station count < 60%
(normalized snow depth)
year


(a) Snow cover
%
visible band
year


(b) Surface albedo
r²=0.53
r²=0.45
r²=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
frequency
year


Trough type
(a) ΔZ (contours), Trend in T700mb
(b) ΔZ (contours), Trend in q700mb

# Climate Science

Shorter-Term Variability

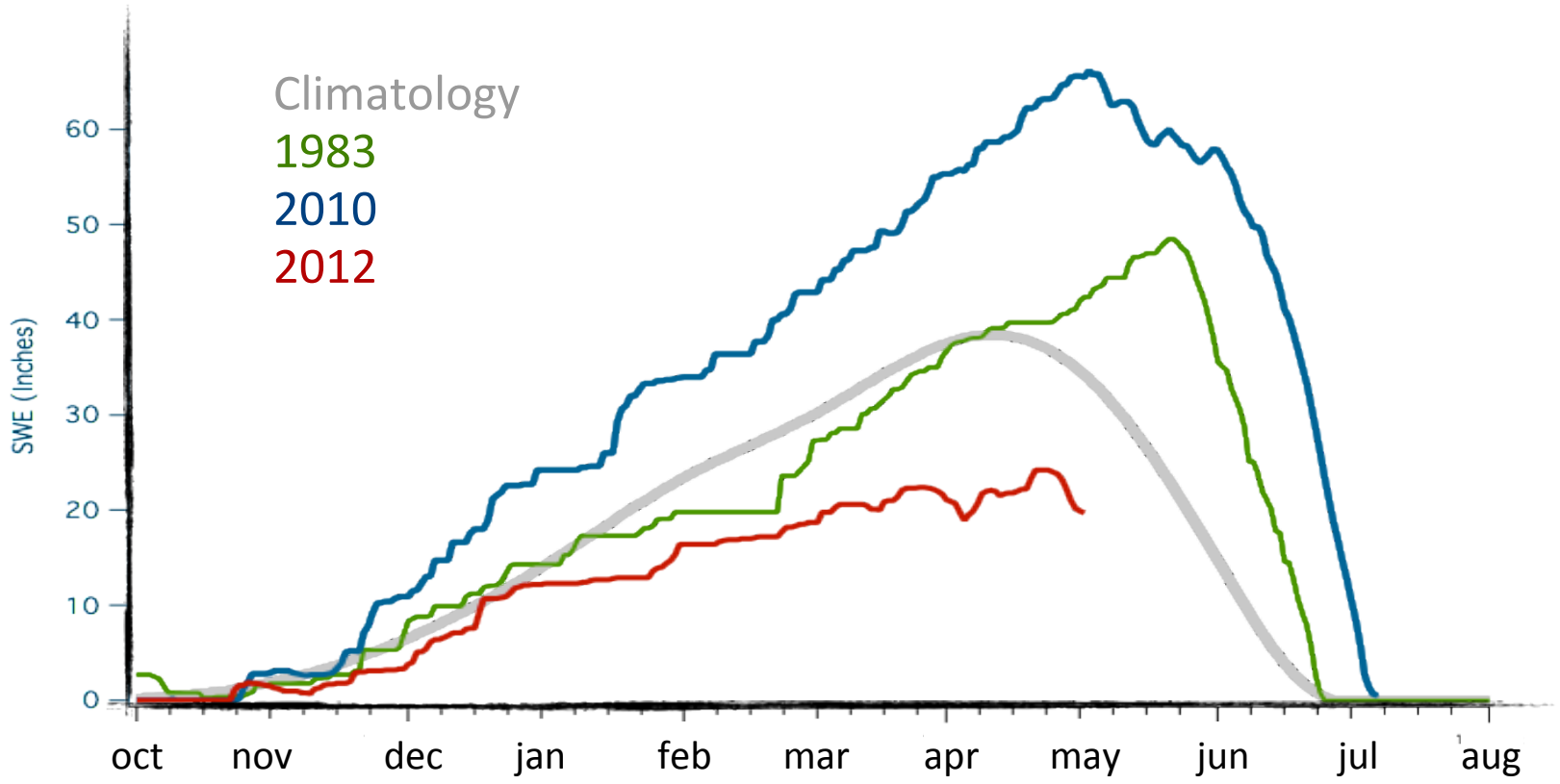
+

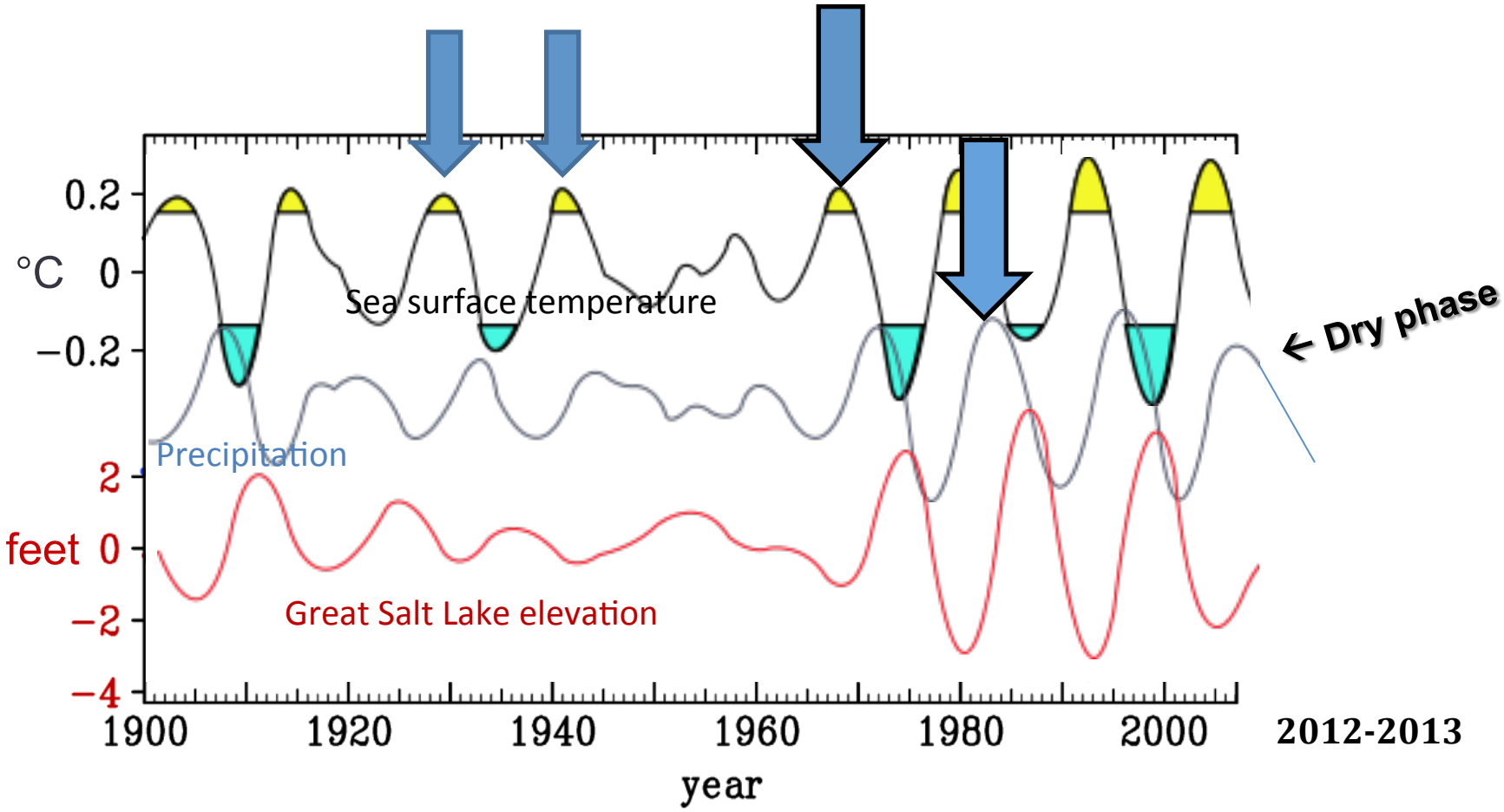
Long-Term Trends

# Let’s Start with Variability

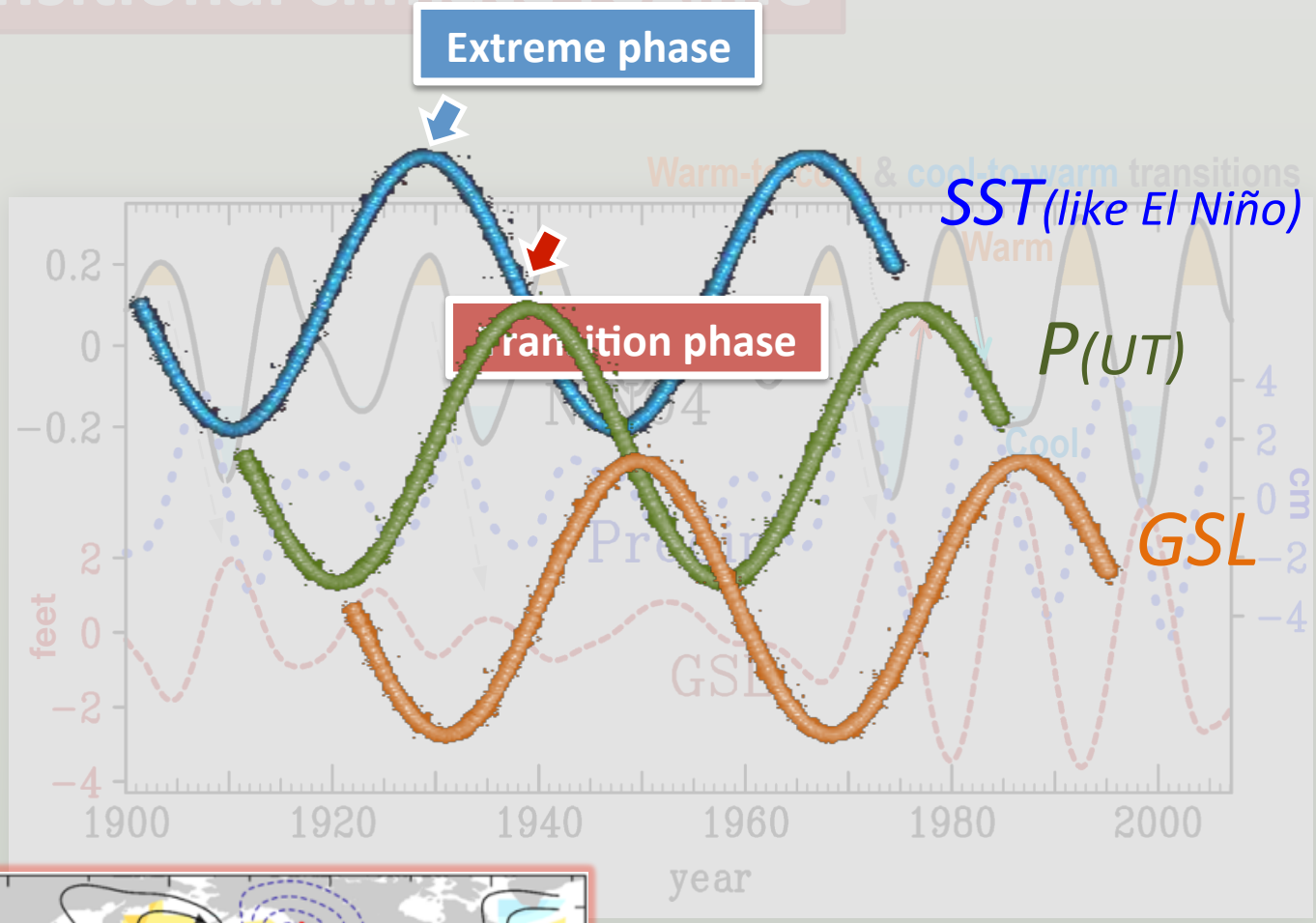
# Snow Water

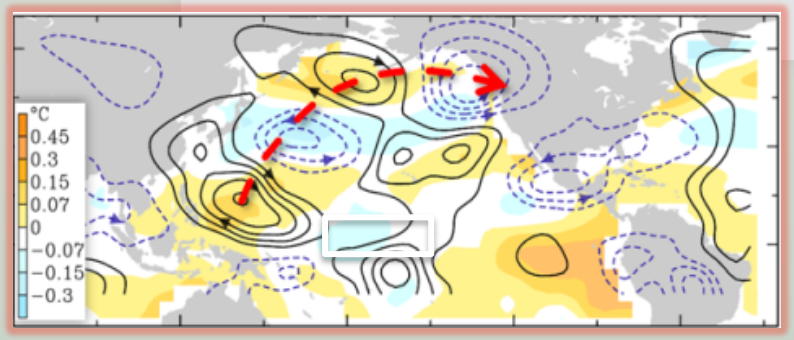
Tony Grove Snotel




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

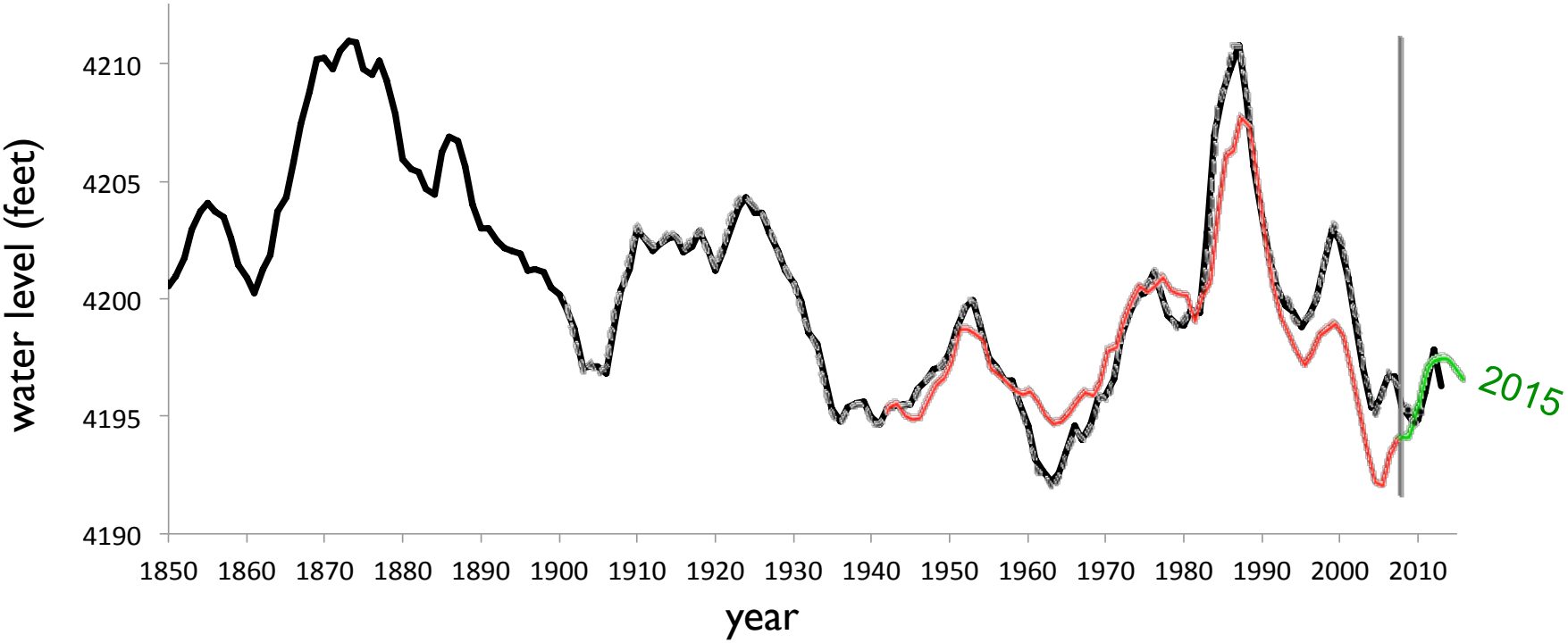
# Transitional climate regime

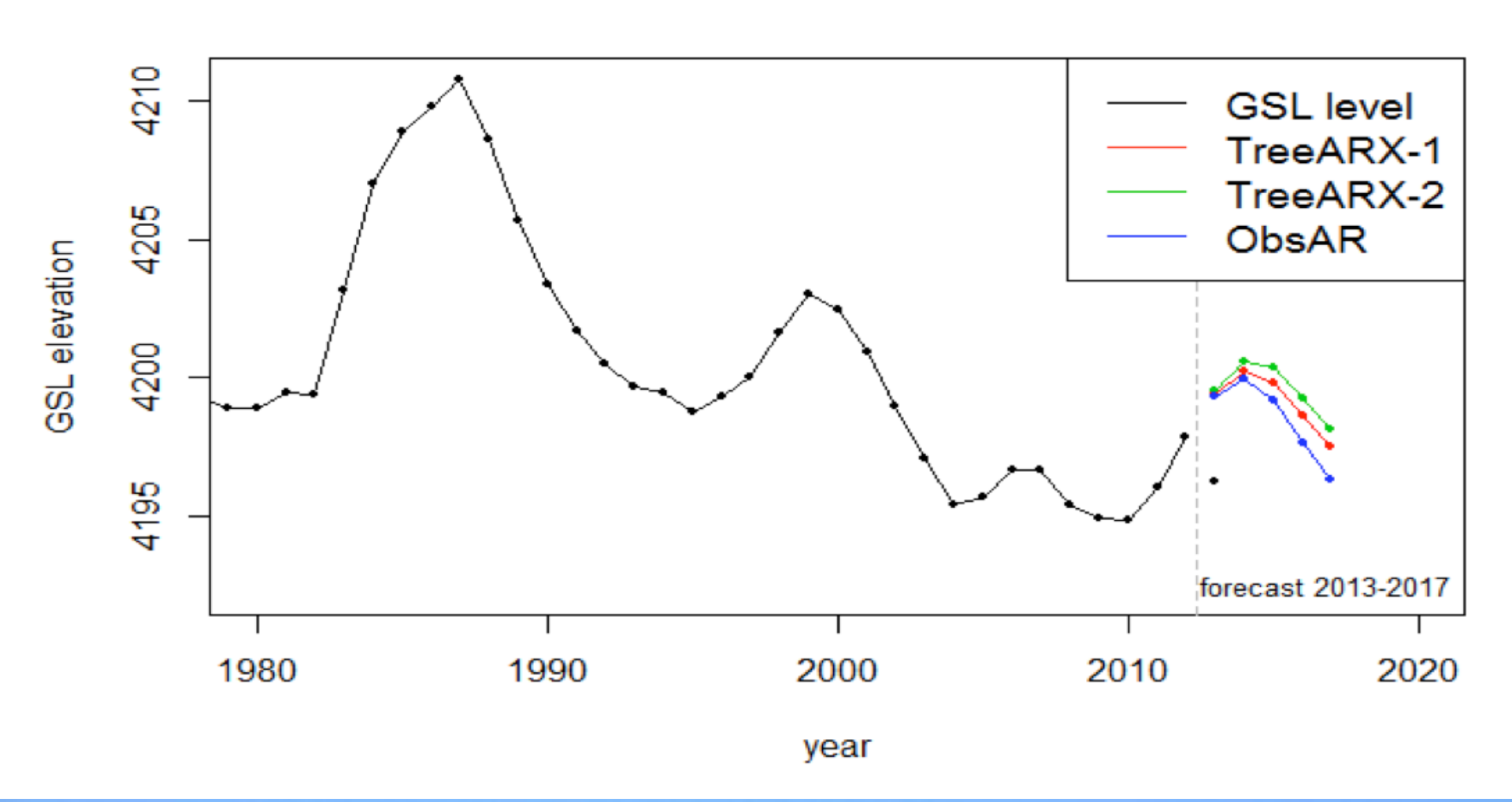


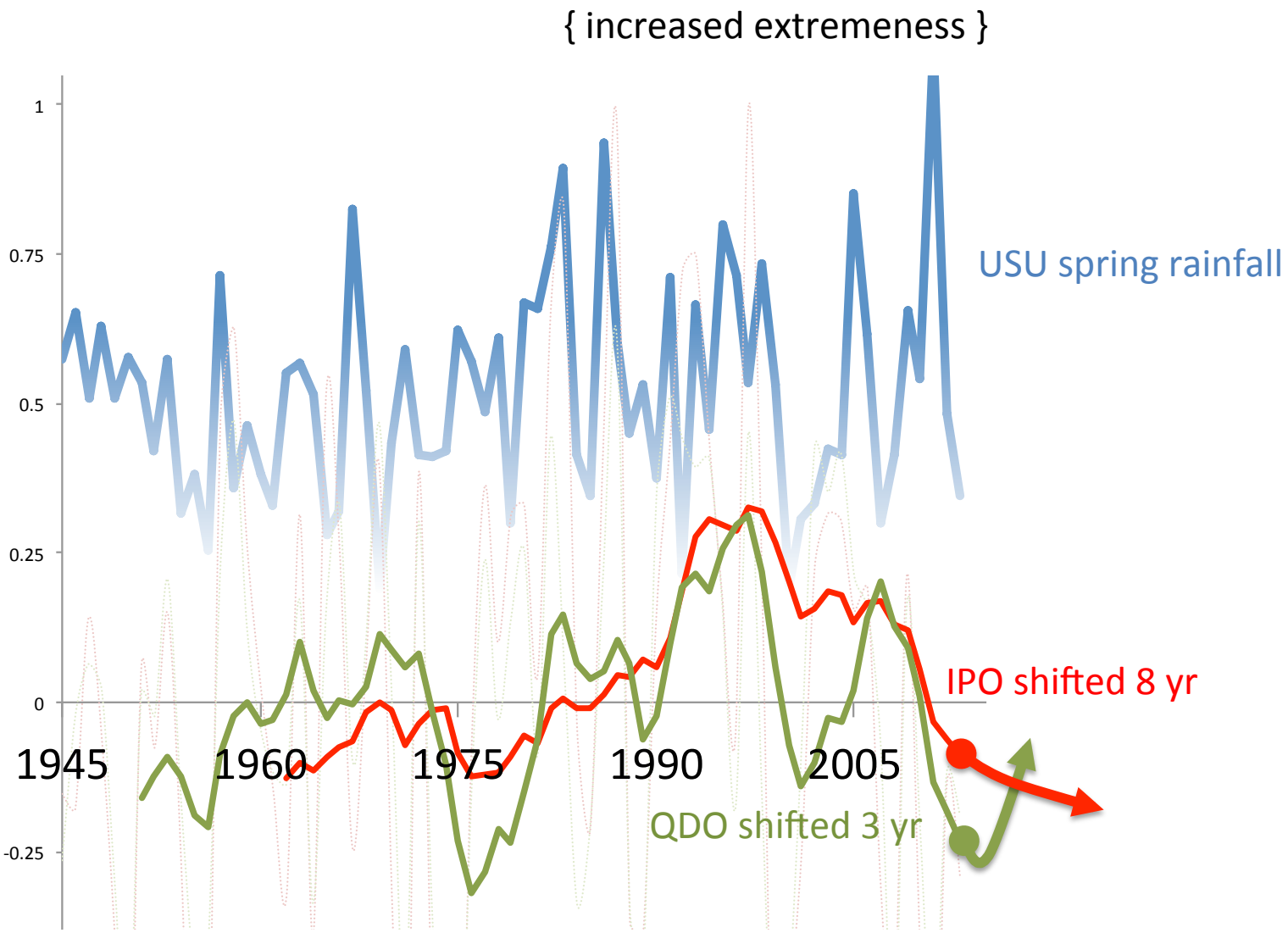




Physical process: Ocean temperatures & atmospheric circulations in transition

*Forecast out to 8 years, published in 2010*




GSL level
TreeARX-1
TreeARX-2
ObsAR
GSL elevation
4195
4200
4205
4210
1980
1990
2000
2010
2020
year
forecast 2013-2017


{ increased extremeness }
1
0.75
0.5
0.25
0
-0.25
1945
1960
1975
1990
2005
USU spring rainfall
IPO shifted 8 yr
QDO shifted 3 yr

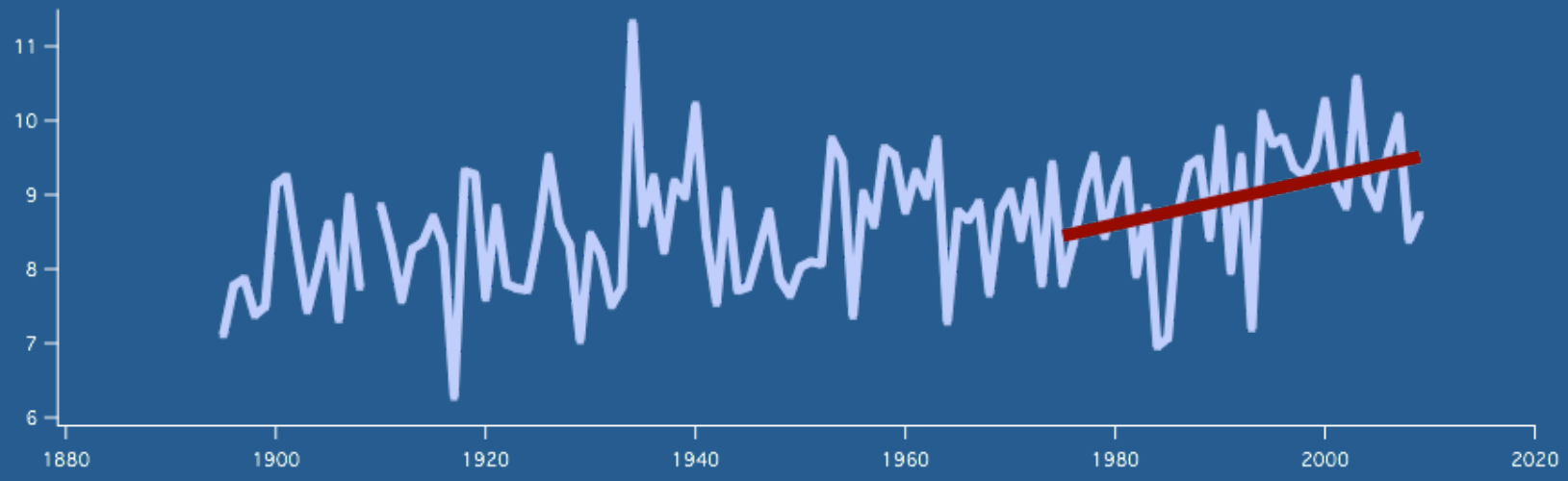
# And now Trends

# Temperature Change

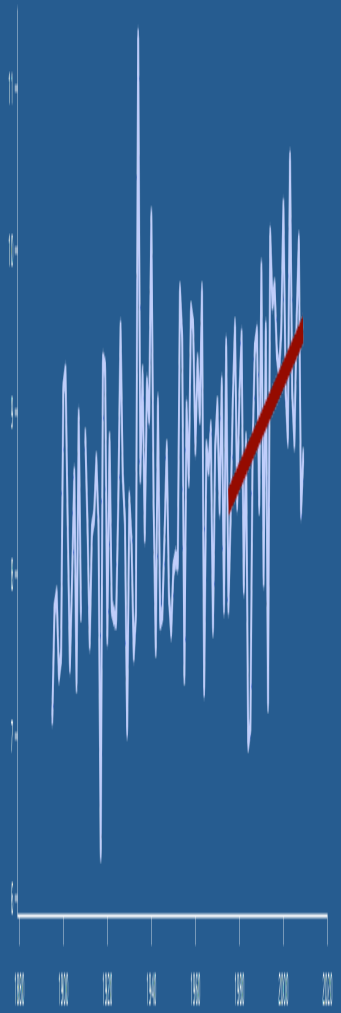
Utah

# Utah’s warming climate

## Logan, Utah

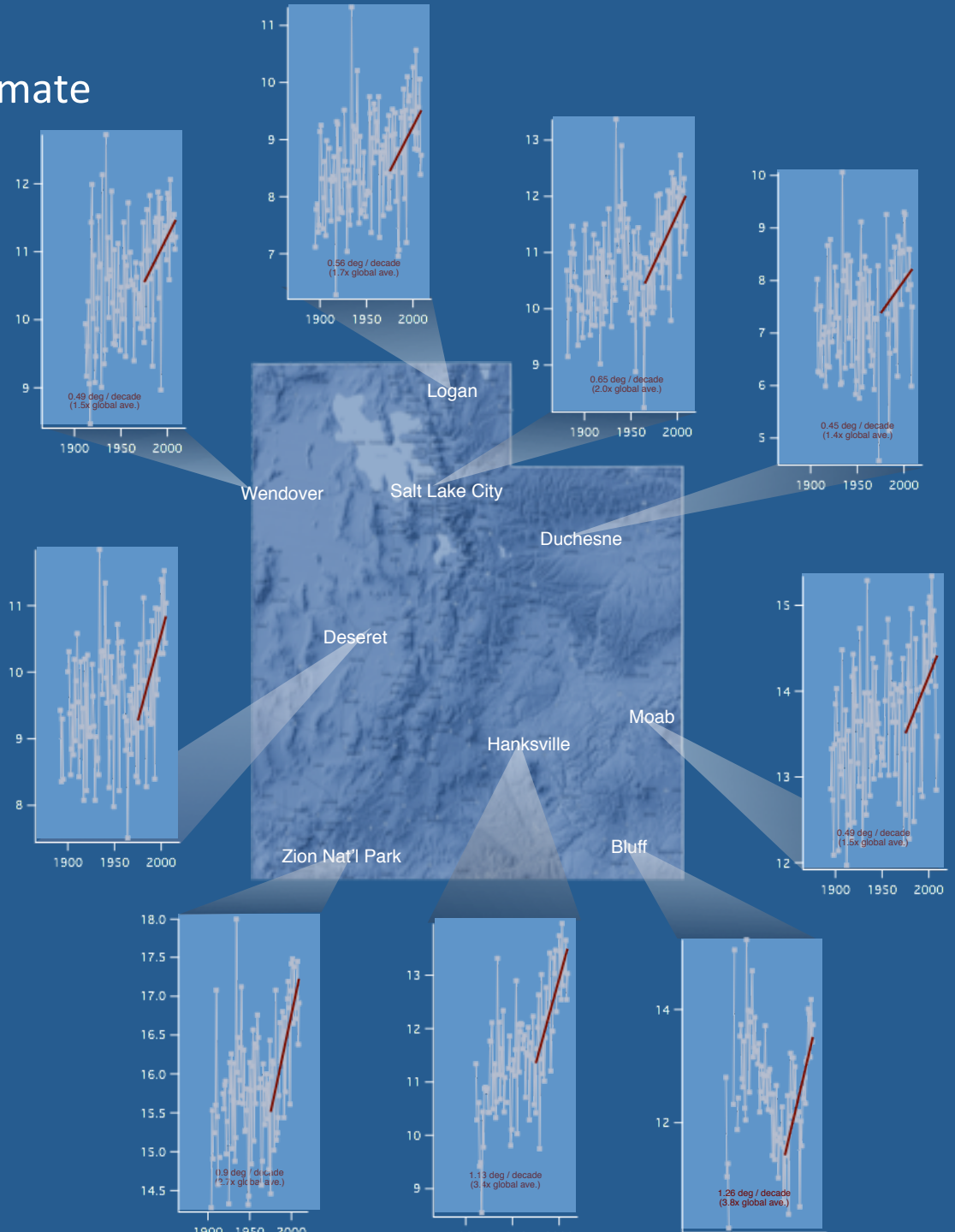


# Utah’s warming climate

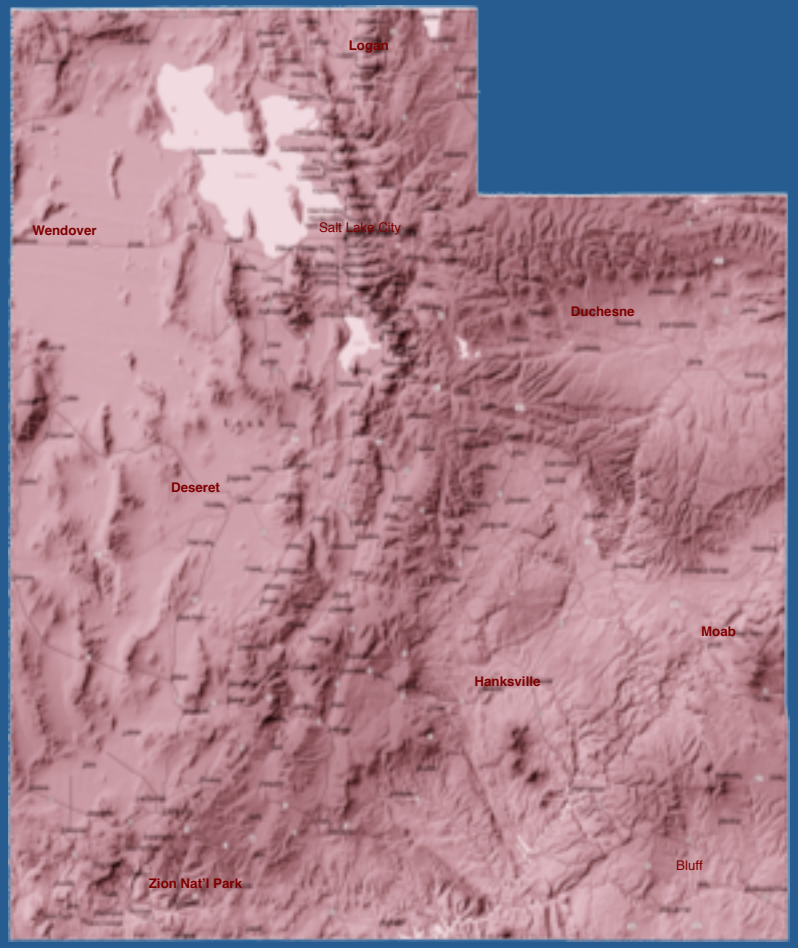


Logan, Utah

# 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.)

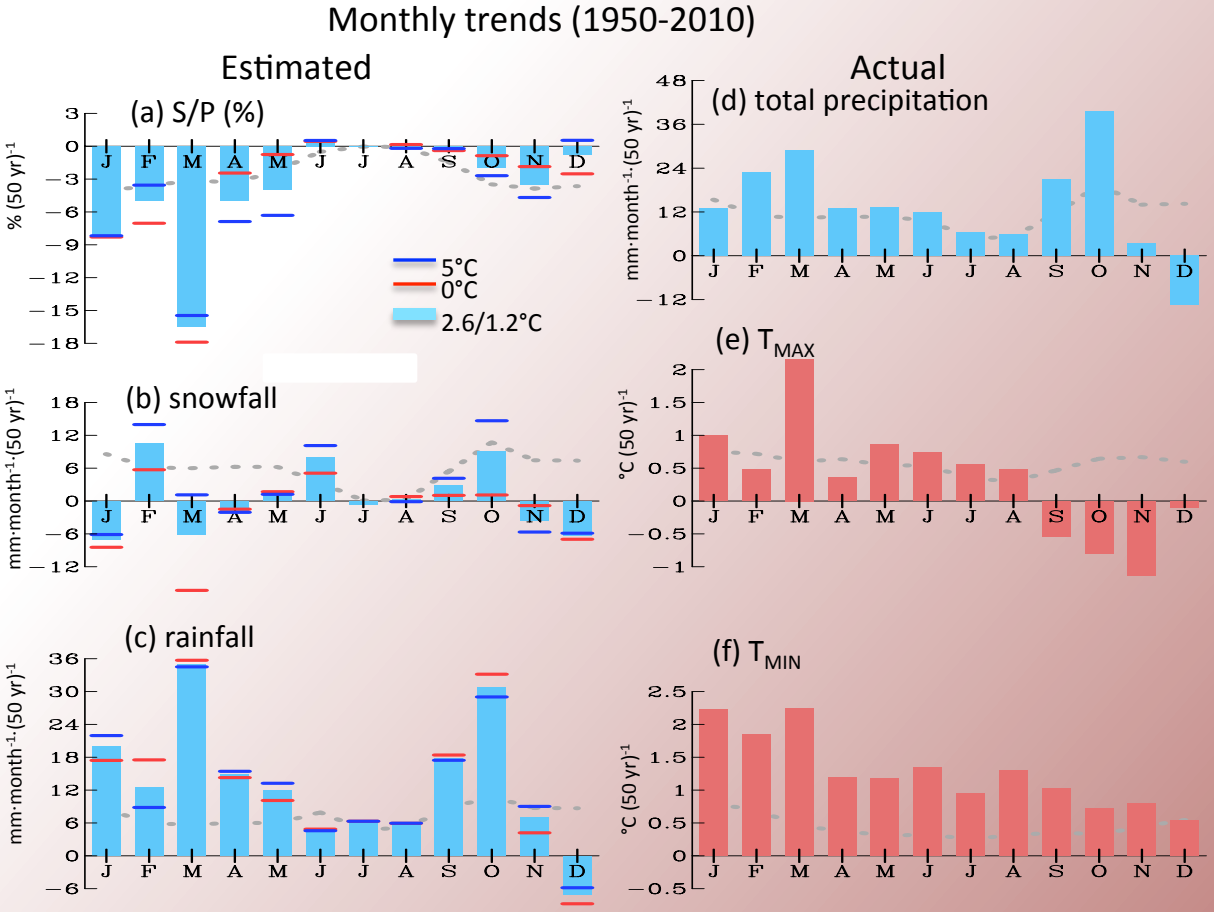
# Precipitation Change

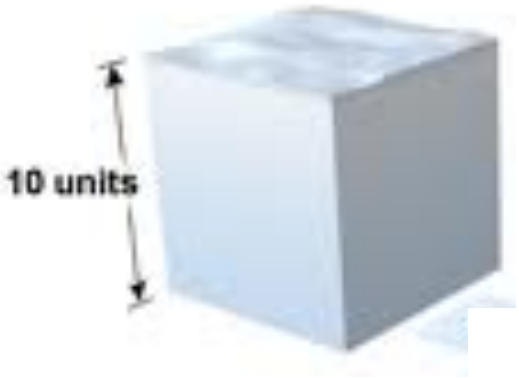
Utah

We’re getting more precipitation!

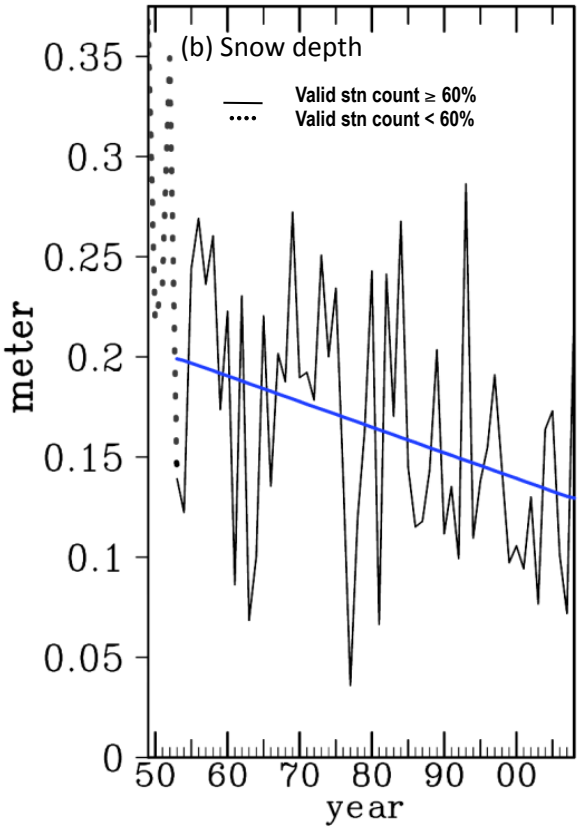
Less of it is falling as snow
but more as rain

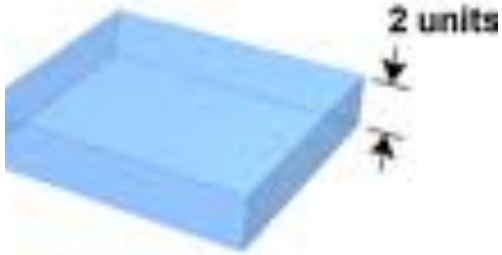
# Utah Future

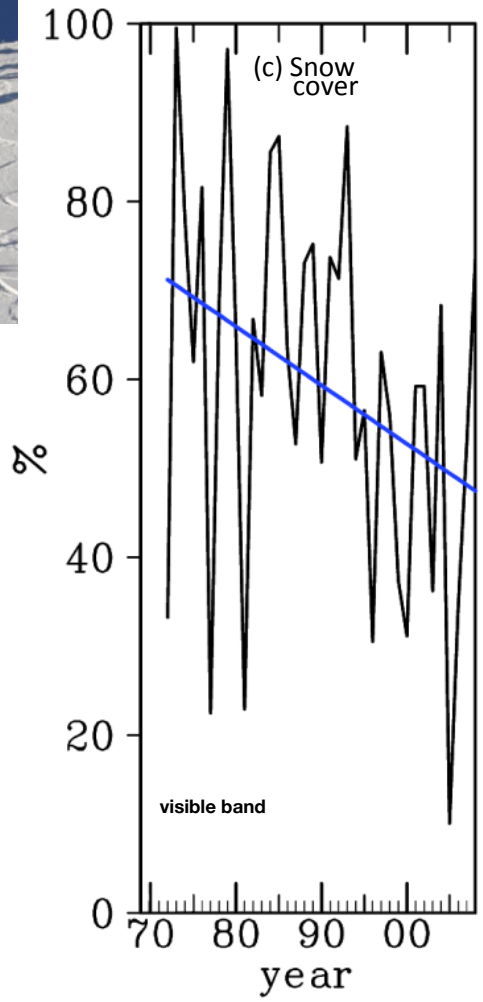

Monthly trends (1950-2010)
Estimated
Actual
(a) S/P (%)
% (50 yr)-1
5°C
0°C
2.6/1.2°C
(b) snowfall
mm·month-1·(50 yr)-1
(c) rainfall
mm·month-1·(50 yr)-1
(d) total precipitation
mm·month-1·(50 yr)-1
(e) TMAX
°C (50 yr)-1
(f) TMIN
°C (50 yr)-1
J F M A M J J A S O N D


10 units

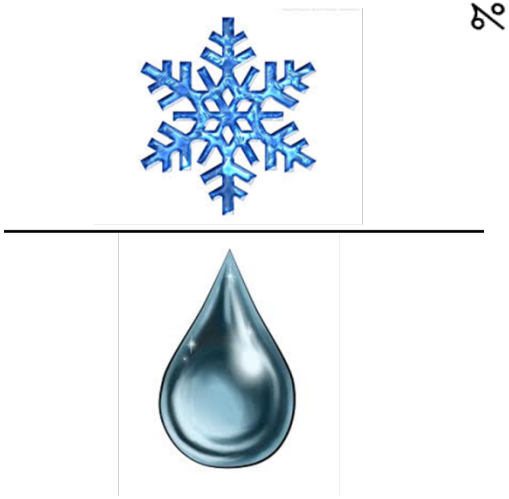
COOP snow th

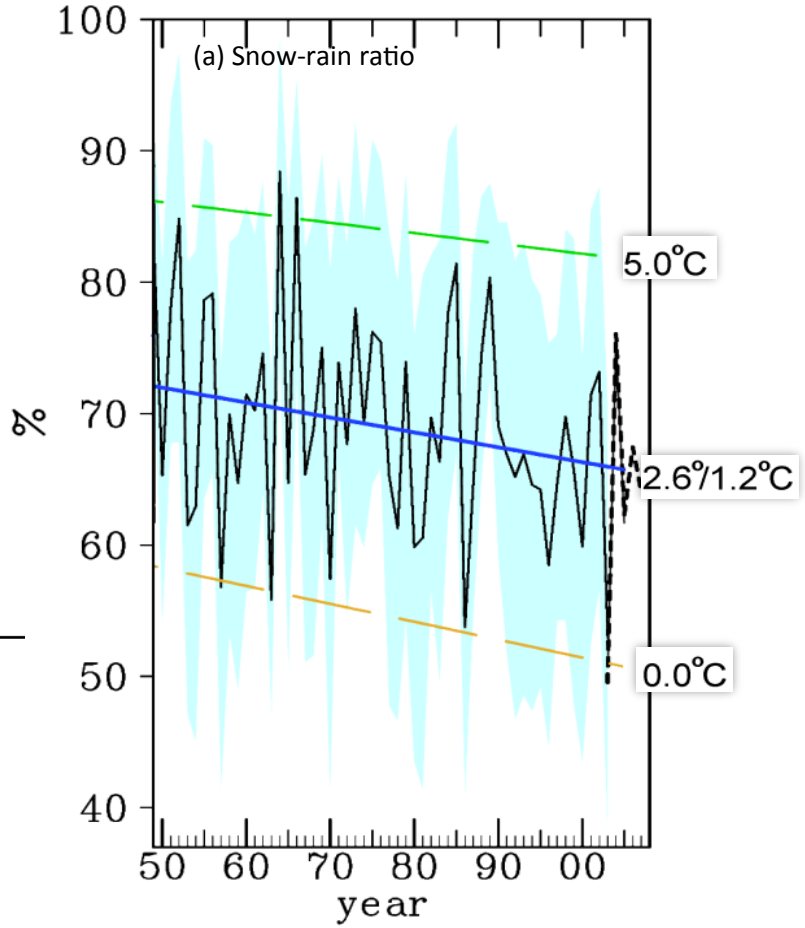

(b) Snow depth
Valid stn count ≥ 60%
Valid stn count < 60%
meter
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
50
60
70
80
90
00
year


2 units

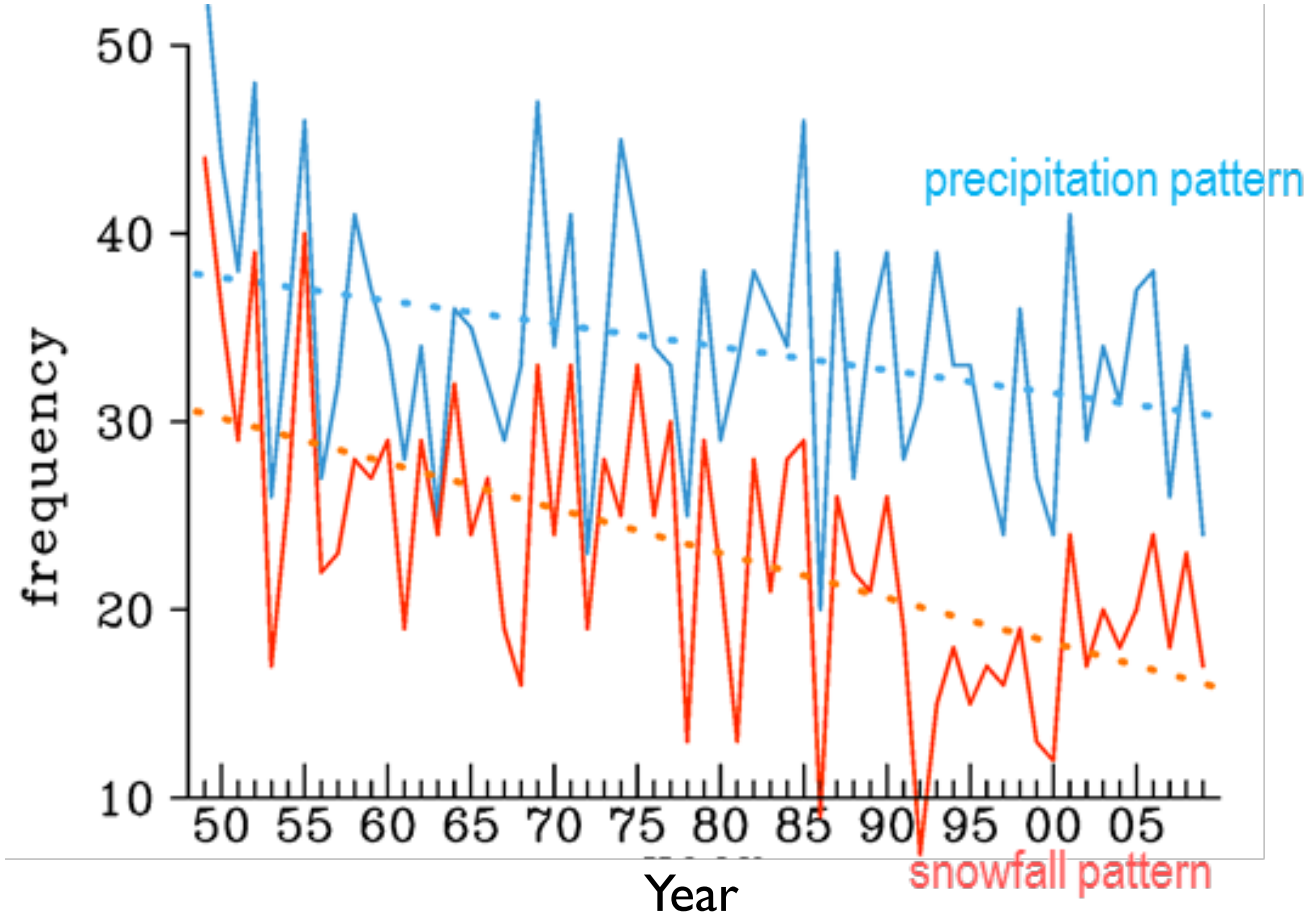

(c) Snow cover
100
80
60
40
20
0
%
visible band
70
80
90
00
year

COOP snow-to-rain ratio





# Winter storms have become less frequent


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

But each storm dumps more precipitation

MORE INTENSE

# What does the future hold?

# Models

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

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

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

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

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

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

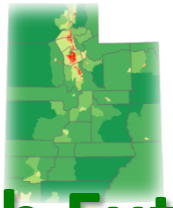
$$S = k \log W$$

$$\nabla \cdot B = 0$$

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

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

# Model Projections Trends

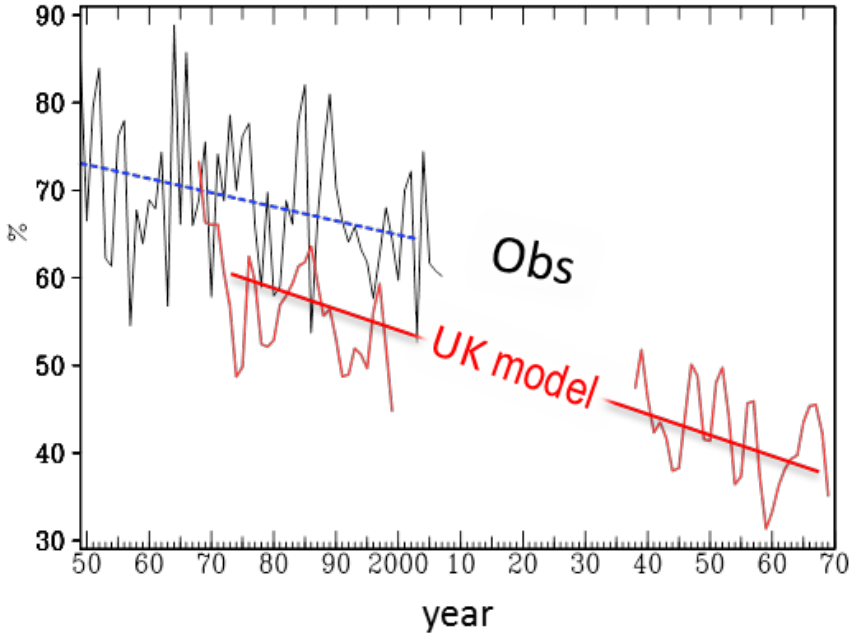


# Utah Future

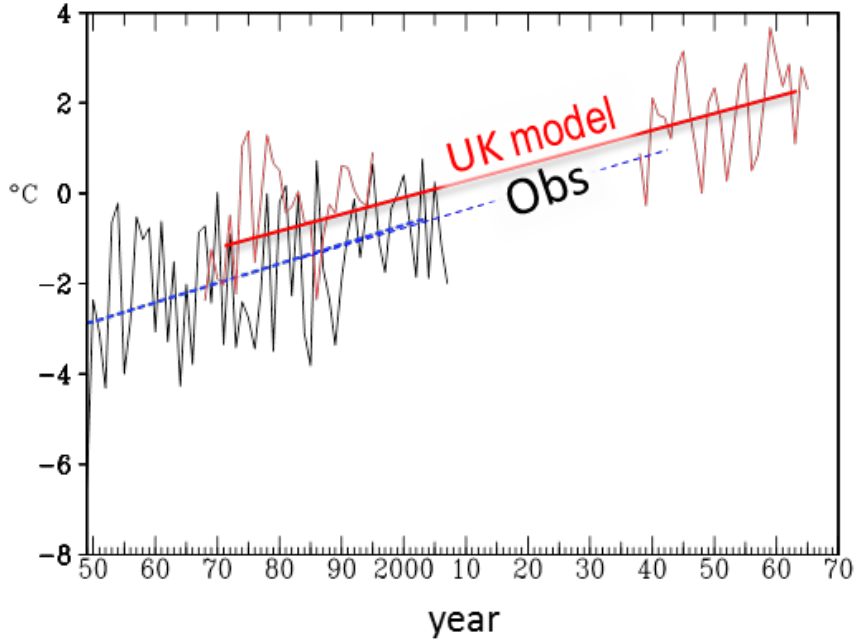
## Climate model simulations

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

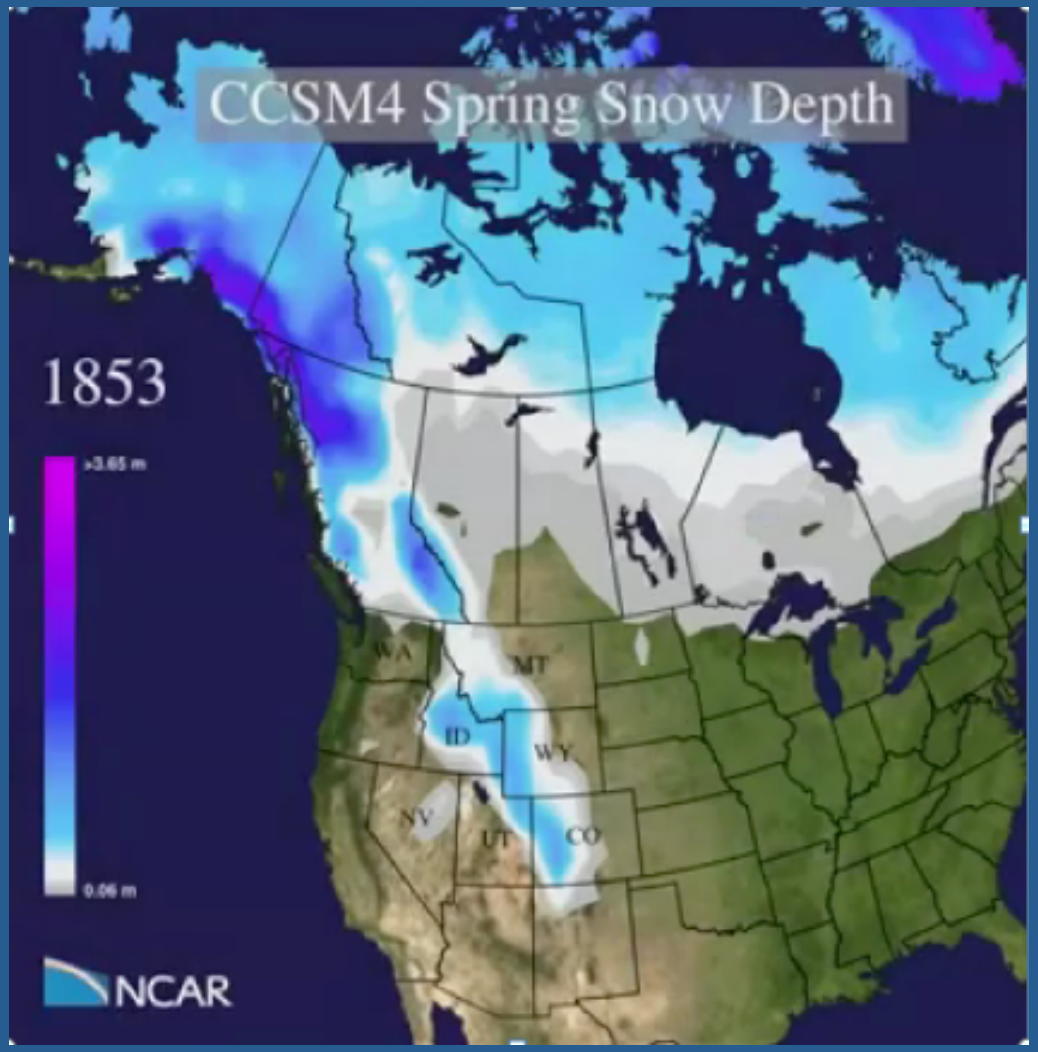
Snow-to-precipitation ratio




Temperature



CCSM4
Spring (March-April)
Snow Depth
RCP8.5 High Emissions Scenario
1850-2100 Four Year Running Average


CCSM4 Spring Snow Depth
1853
>3.65 m
0.06 m
WA
MT
ID
WY
NV
UT
CO
NCAR

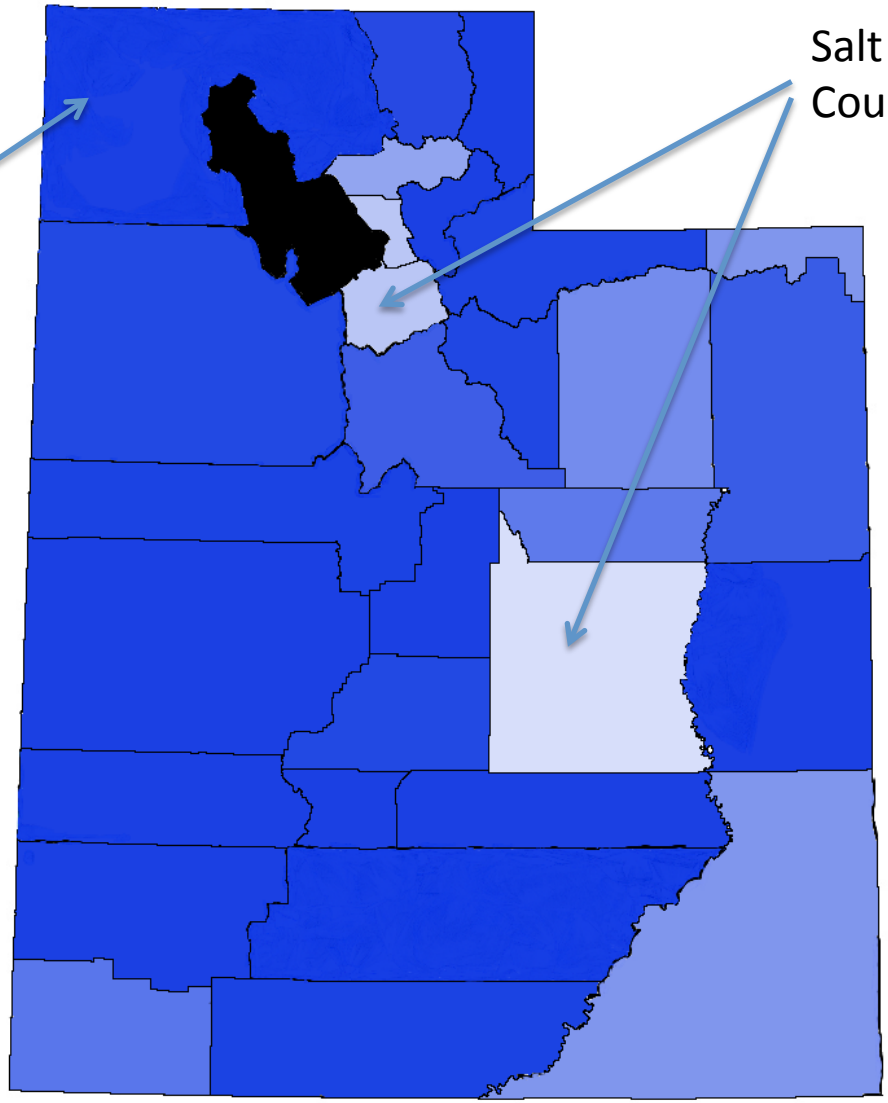
CCSM4 Spring Snow Depth
2100
>3.65 m
0.06 m
WA
MT
ID
WY
NV
UT
CO
NCAR

Why Should We Care

# Utah Groundwater Dependence

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

| County | % Dependence |
|---|---|
| Beaver | 100.00% |
| Box Elder | 100.00% |
| Cache | 98.92% |
| Carbon | 69.07% |
| Daggett | 53.85% |
| Davis | 36.42% |
| Duchesne | 57.17% |
| Emery | 22.83% |
| Garfield | 100.00% |
| Grand | 100.00% |
| Iron | 100.00% |
| Juab | 100.00% |
| Kane | 100.00% |
| Millard | 100.00% |
| Morgan | 100.00% |
| Piute | 100.00% |
| Rich | 100.00% |
| Salt Lake | 29.03% |
| San Juan | 54.75% |
| Sanpete | 100.00% |
| Sevier | 98.83% |
| Summit | 99.30% |
| Tooele | 98.92% |
| Uintah | 89.76% |
| Utah | 82.83% |
| Wasatch | 99.23% |
| Washington | 75.50% |
| Wayne | 100.00% |
| Weber | 47.86% |

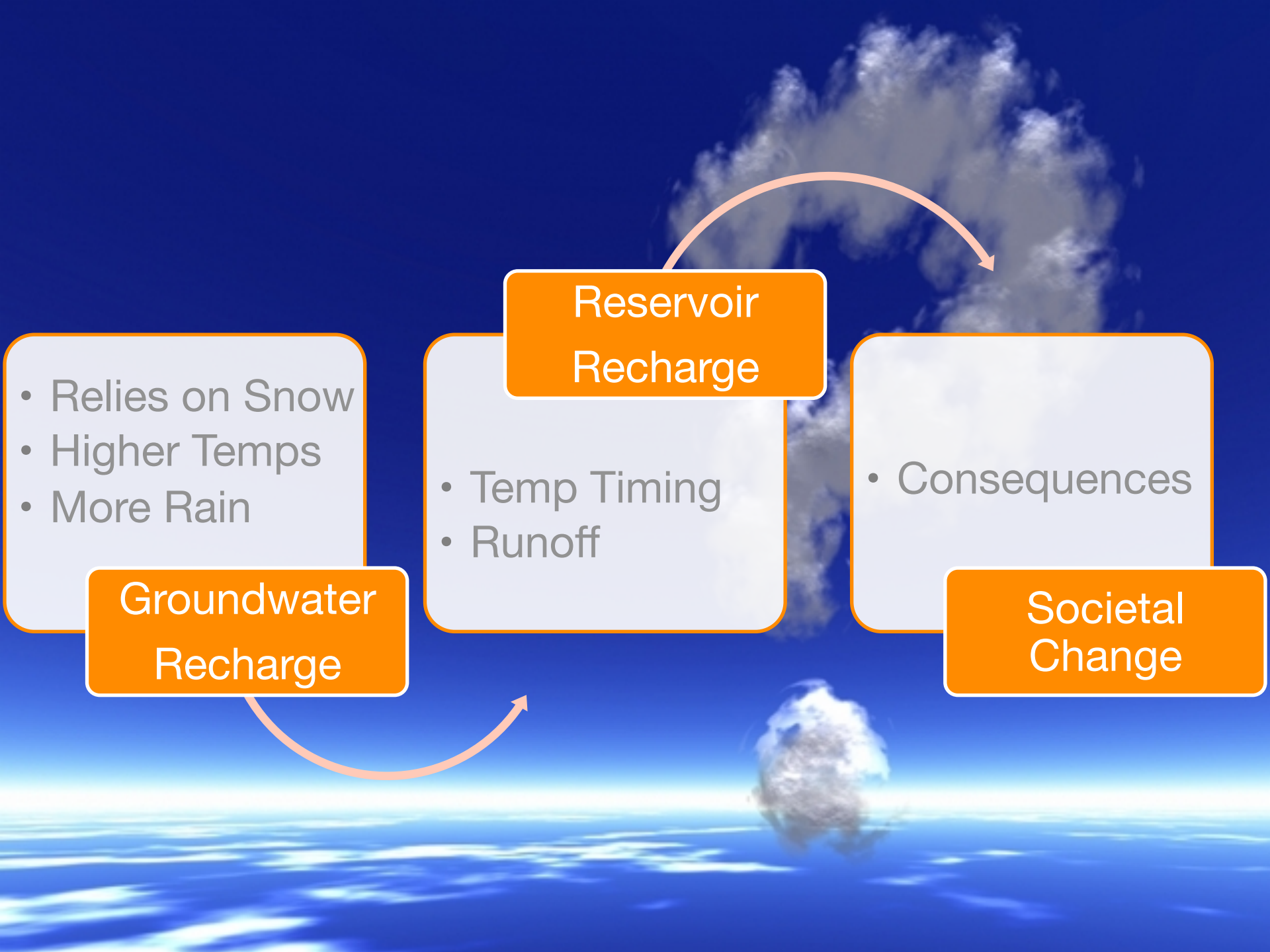


Salt Lake and Emery County utilize reservoirs

0 50 100 kilometers

0 50 100 miles

0% 100%


Groundwater Recharge
• Relies on Snow
• Higher Temps
• More Rain
Reservoir Recharge
• Temp Timing
• Runoff
Societal Change
• Consequences

Thank You
UTAH CLIMATE
CENTER
climate.usu.edu