

Snow and water resources of the Great Salt Lake Basin: historical perspective and projections for the future



Court Strong

Jim Steenburgh, Carolyn Stwertka, Kimberly Smith
*University of Utah Department of Atmospheric
Sciences*



Outline

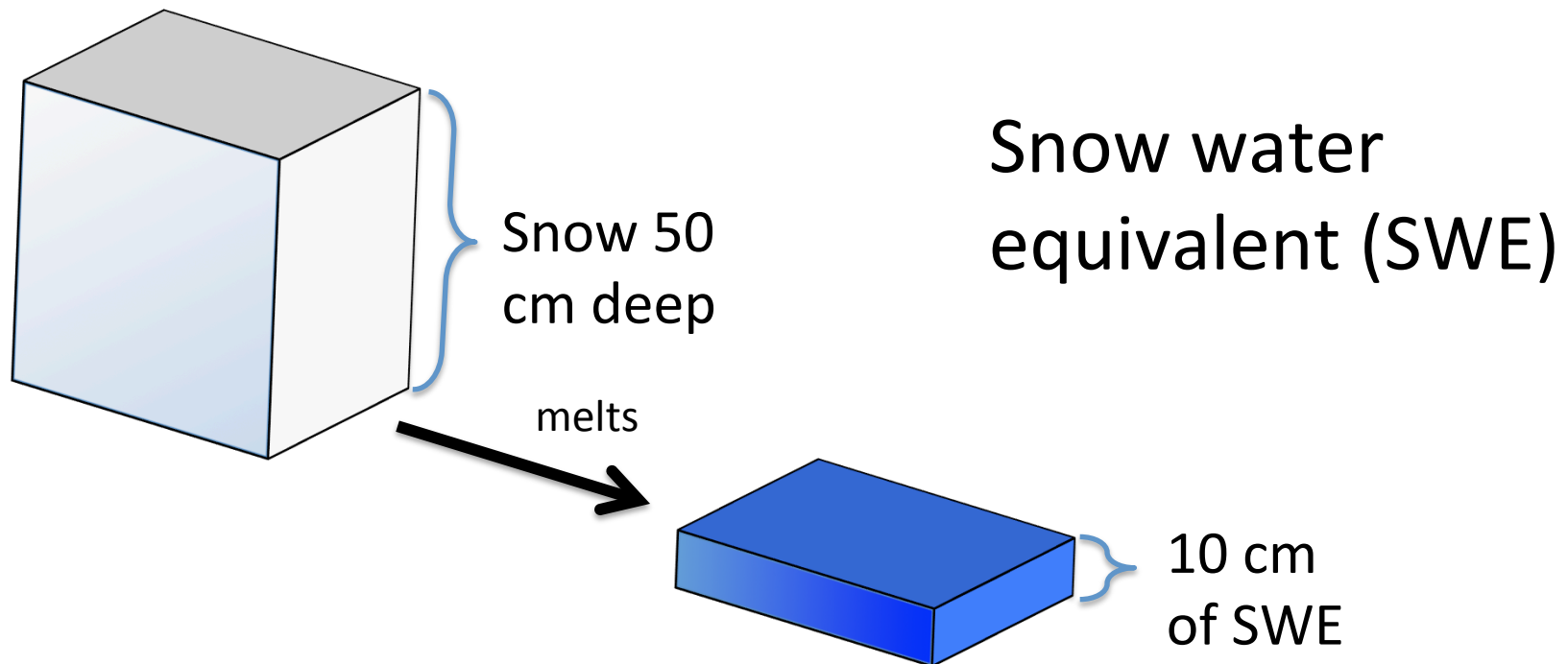
- Introduction
 - Definitions
 - Study region
 - Diversity of data
- Precipitation and snowpack in the Great Basin and Wasatch Range
 - Historical perspective (back to 1200)
 - Future projections (forward to 2100)
- Climate wild card: dust
- Summary

Definitions

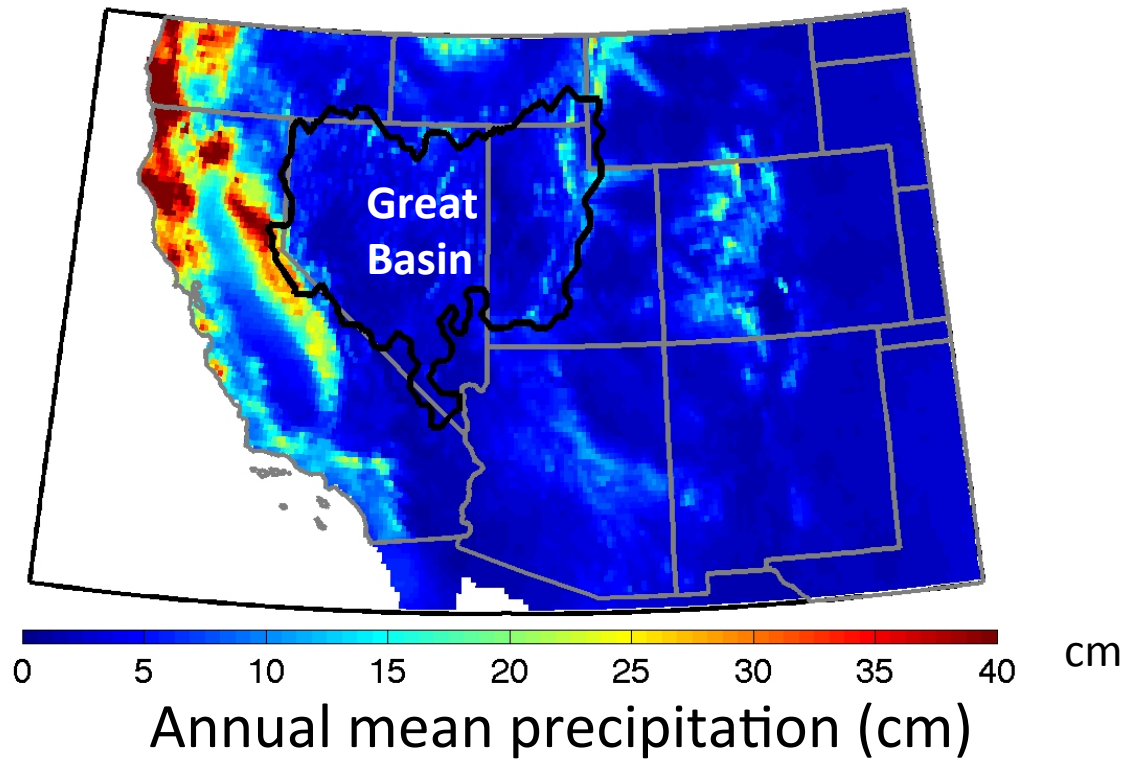
Precipitation here is a “liquid equivalent depth.” This value includes the depth of rainfall plus the melted depth of any snowfall (or hail, sleet ,etc.).

Definitions

Snowpack: snow currently sitting on ground reported as a “snow water equivalent” (SWE)

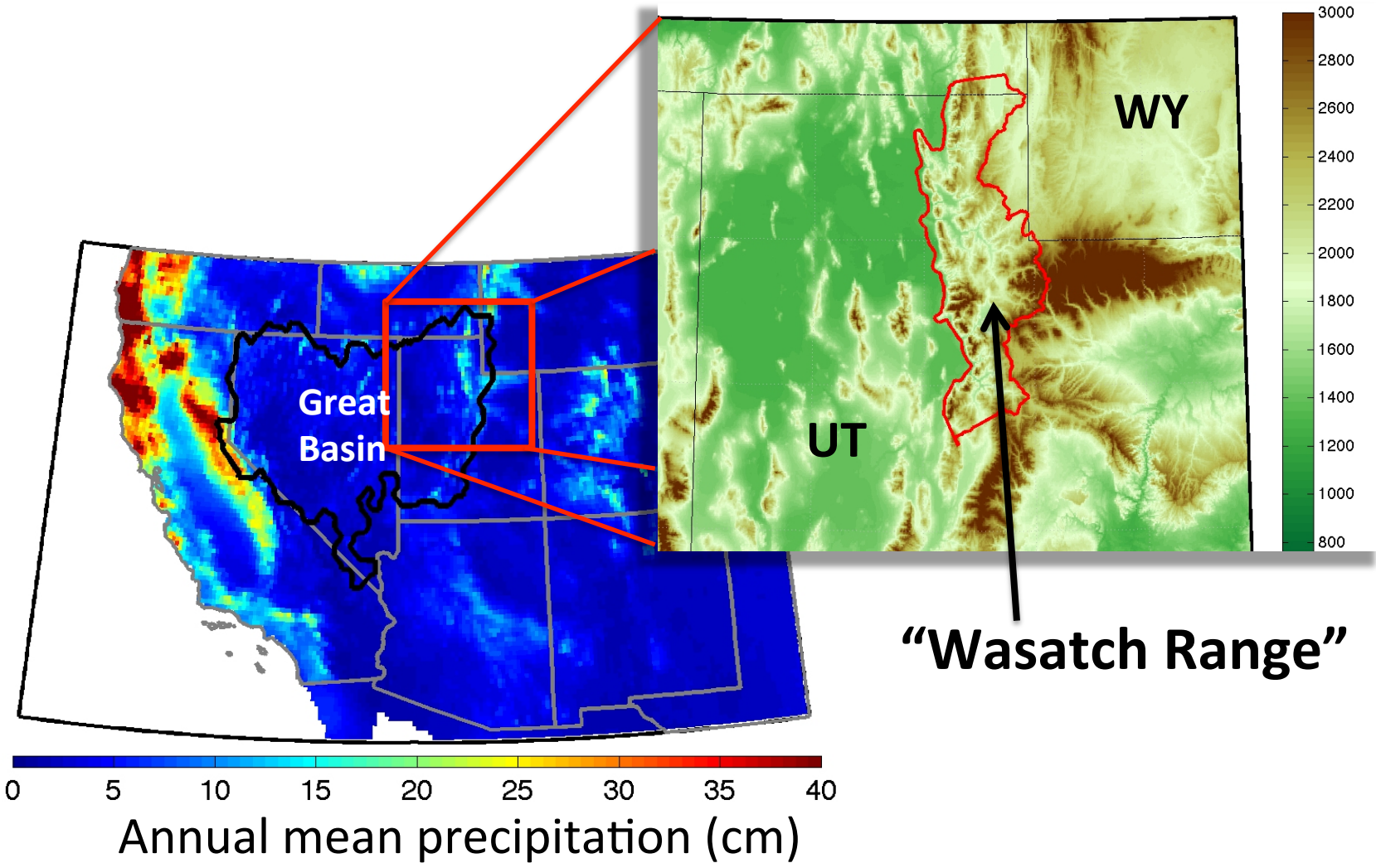


Study region



Study region

Elevation (m)



Diversity of data: gauges



Hawaii, 1933
USGS archives



Appalachian Mountains
1953
US Forest Service



National Weather Service
Modern
NOAA



Global Precipitation Climatology Centre (GPCC)
has estimated precipitation over land from available gauges 1900-2010

Diversity of data: **proxies**



Trees

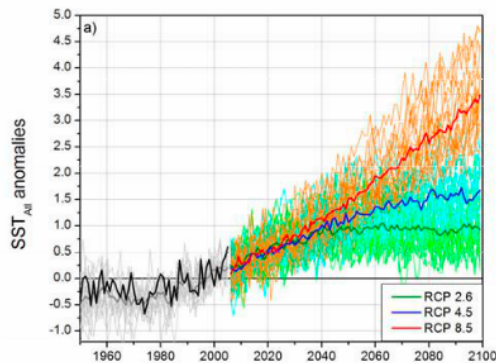
ring width varies with
environmental
conditions



Piñon Pine

Diversity of data: modeling

- **Climate models** represent components of the climate system mathematically, allowing us to make predictions about their future state.



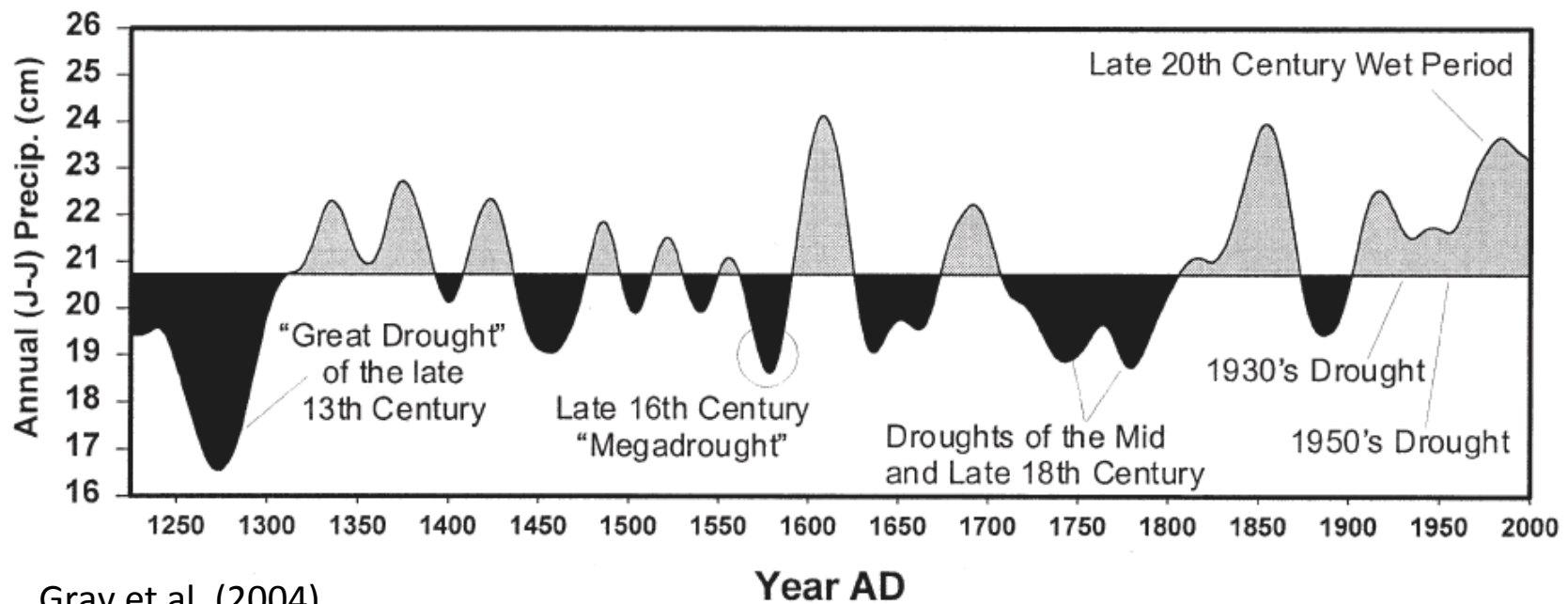
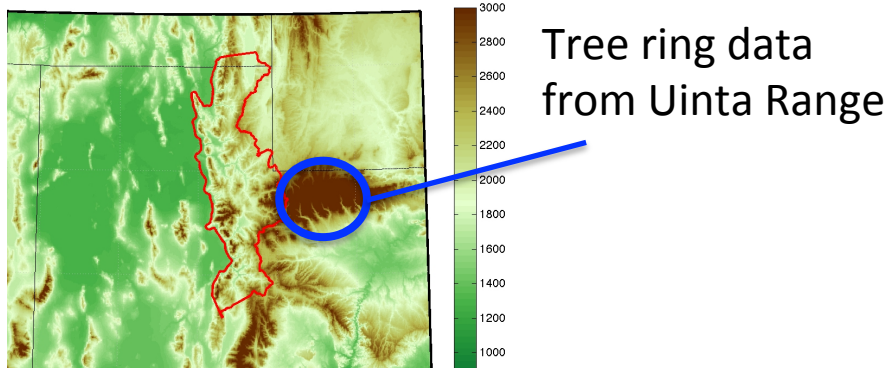
$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla \Phi - 2\Omega \times \mathbf{u} - \frac{1}{\rho} \nabla p + \mathbf{F}$$



```
! Accumulate first and second terms
!  
do j=beginlatpair(m),plat/2  
do n=1,nlen(m),2  
zwdalp = ztdtrw(j)*ldalp(lmr+n,j)  
zwalp = zw(j) *lalp (lmr+n,j)  
do kv=1,plev*6  
tmpSPEodd(kv,n) = tmpSPEodd(kv  
zwalp*tmpGRlodd(kv,j) + z  
end do  
end do  
end do  
do j=beginlatpair(m),plat/2  
do n=2,nlen(m),2  
zwdalp = ztdtrw(j)*ldalp(lmr+n,j)  
zwalp = zw(j) *lalp (lmr+n,j)
```



Historical perspective: precipitation



Gray et al. (2004)

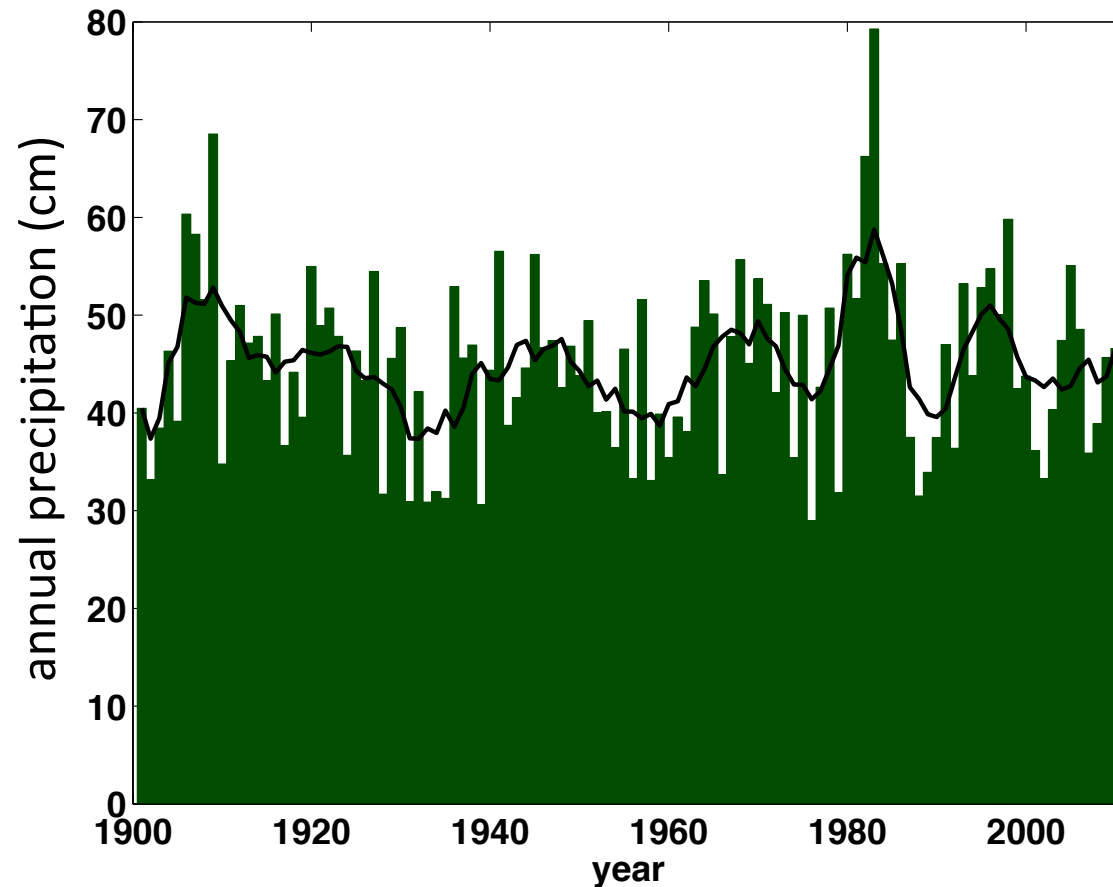
J. American Water Resources Assoc.

Historical perspective: precipitation

- Average approximately 45 cm (18") annually.
- Wet and dry decades with no trend.



Wasatch Range total annual precipitation

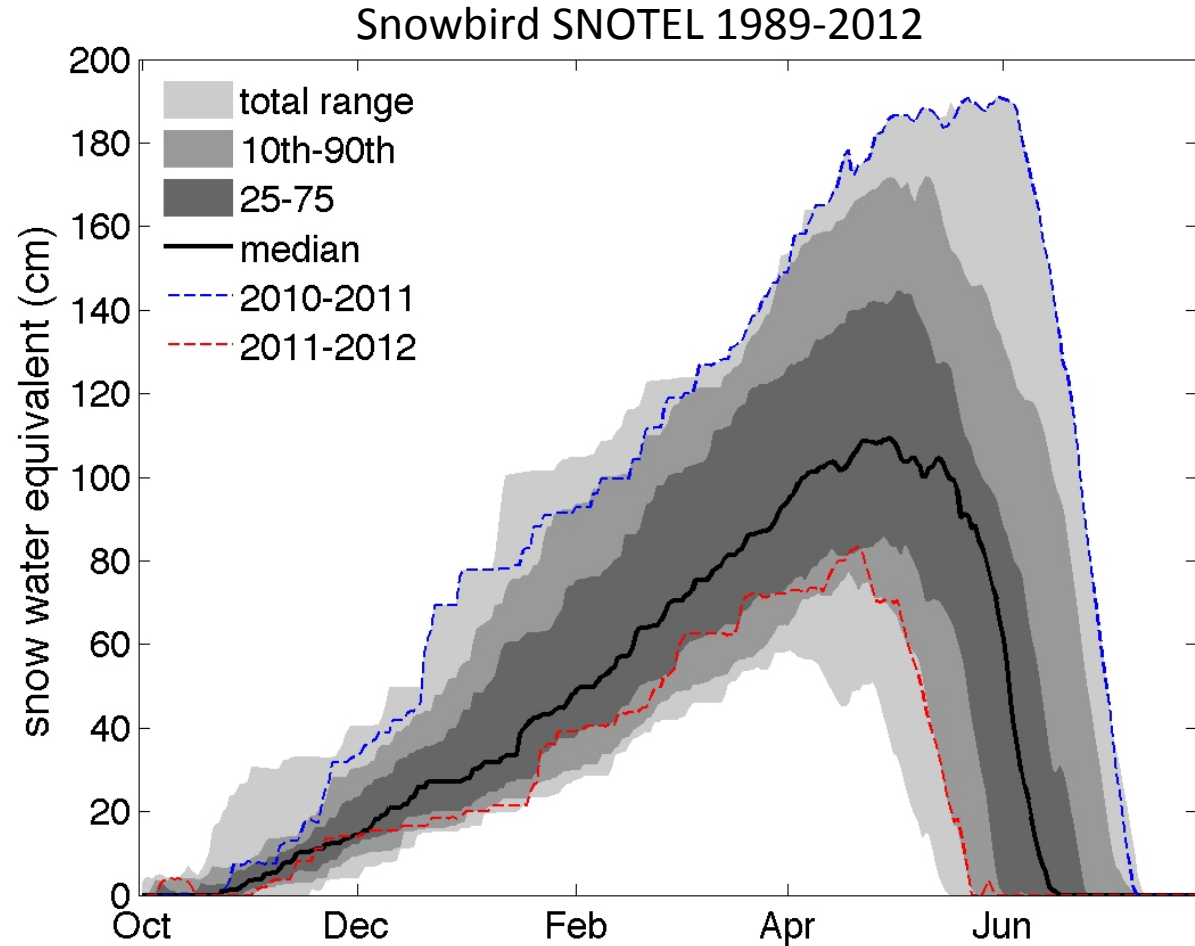


data from Global Precipitation Climatology Centre
Rudolf et al. (2005); <http://gpcc.dwd.de/>

Historical perspective: snowpack

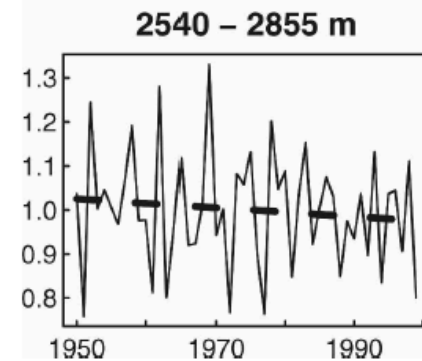
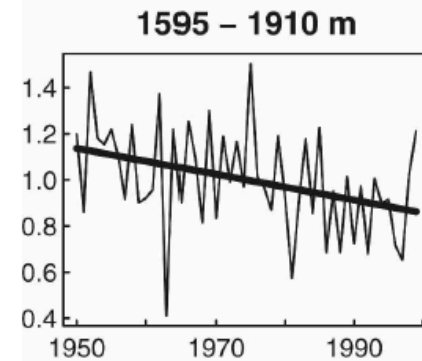
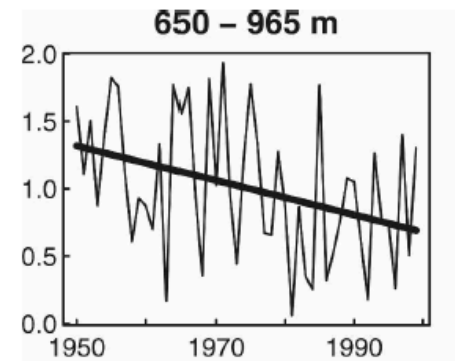
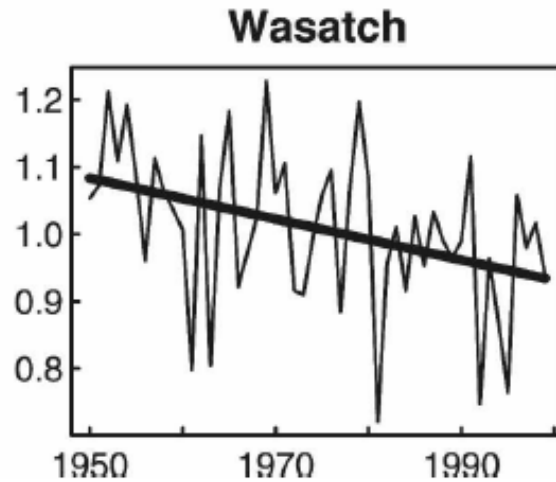
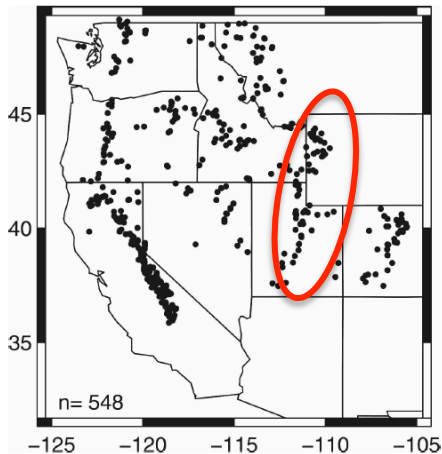


Extremely high and very low years just occurred back to back.



Historical perspective: snow fraction

Fraction of precipitation that fell as snow during water year



Pierce et al. (2008)
Journal of Climate

Future projections

- Bias Corrected and Downscaled Climate and Hydrology Projections
- Coarse-scale information (111-km resolution) from 16 major climate models was converted to 14-km data using statistical methods

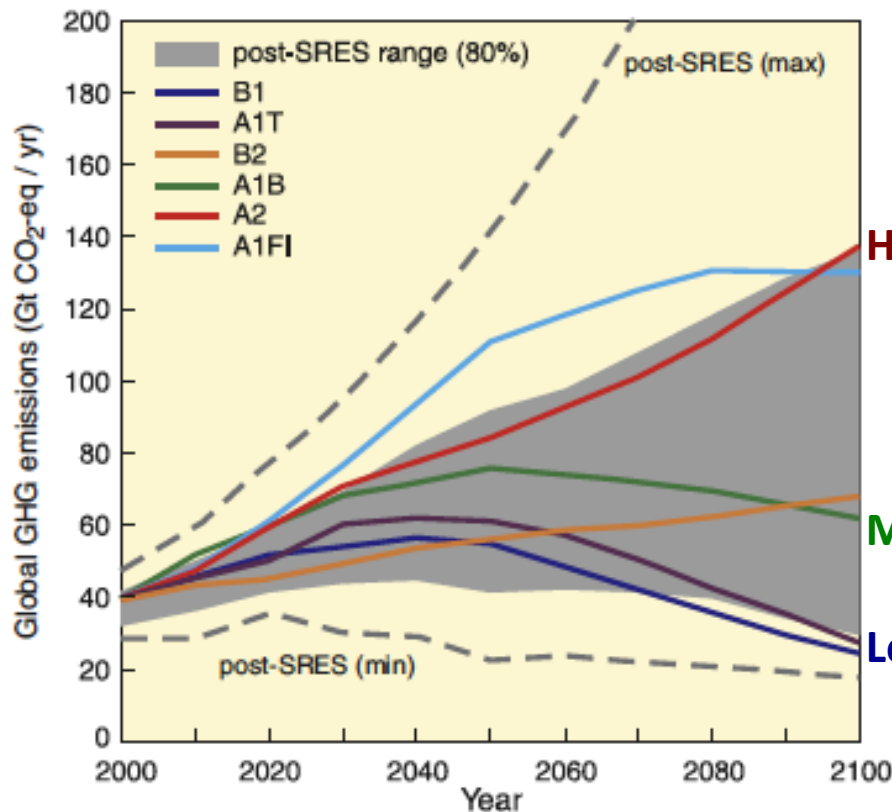


CMIP3
simulations
completed
2006-2007

Maurer et al. (2007),
Eos Trans. AGU

Future projections

- Three greenhouse gas emission scenarios were considered



High emission (A2)

Moderate emission (A1B)

Low emission (B1)

Image from IPCC AR4 Report

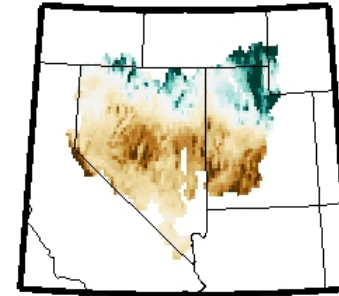
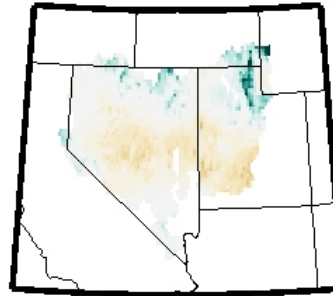
Future projections

Change in annual precipitation

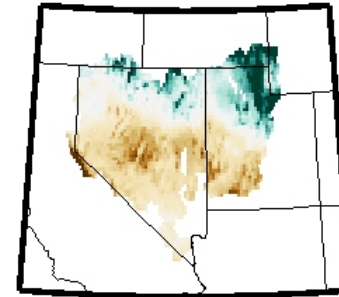
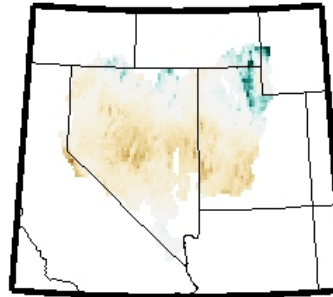
2000-2049
minus 1950-1999

2050-2099
minus 1950-1999

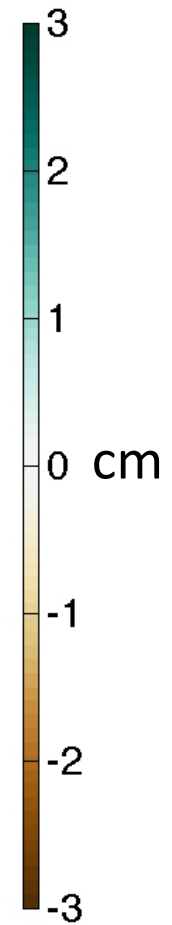
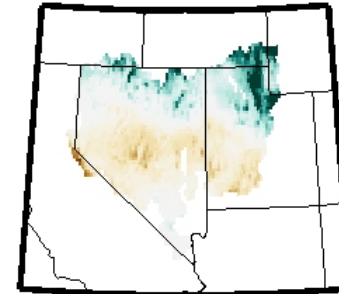
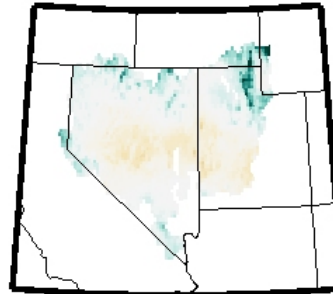
High emission (A2)



Moderate emission (A1B)

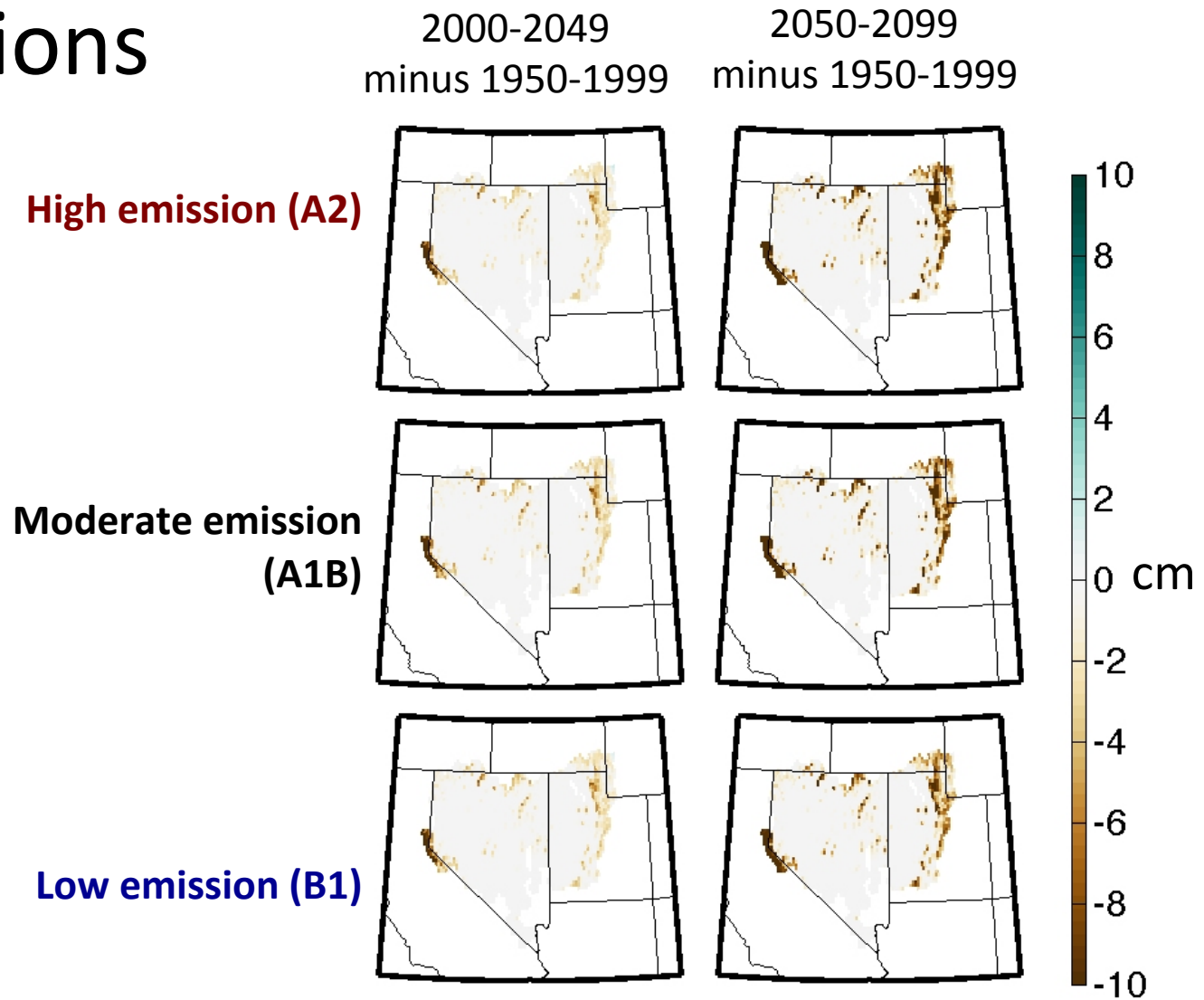


Low emission (B1)



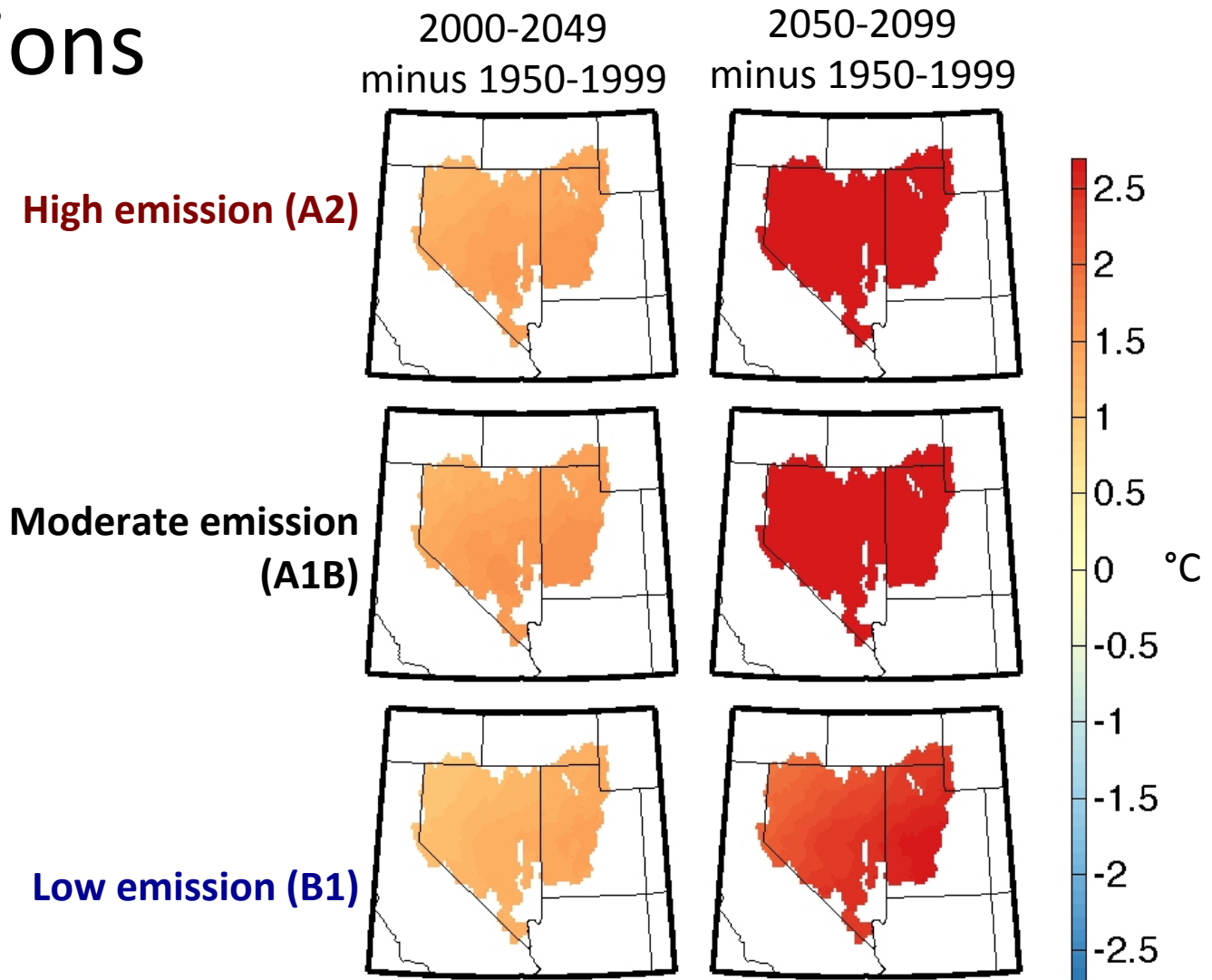
Future projections

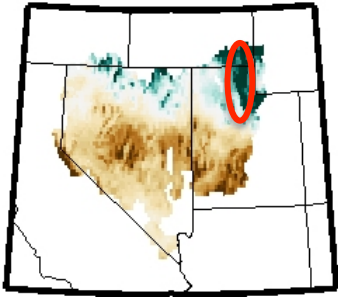
Change in snowpack April 1 (SWE)



Future projections

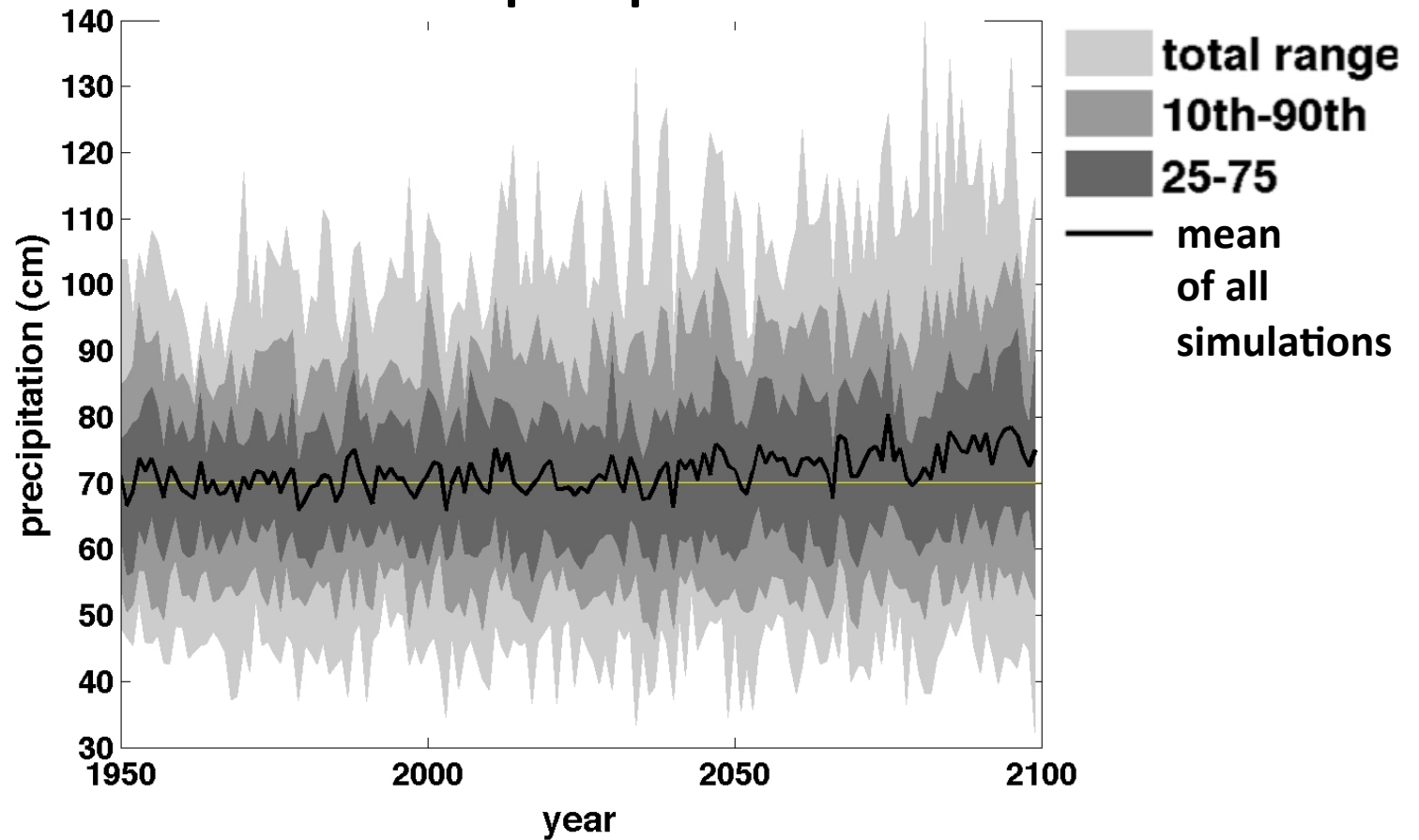
Change in average maximum air temperature March-April

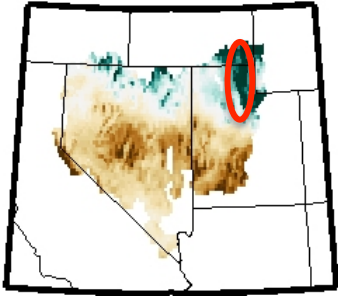




Future projections: Wasatch

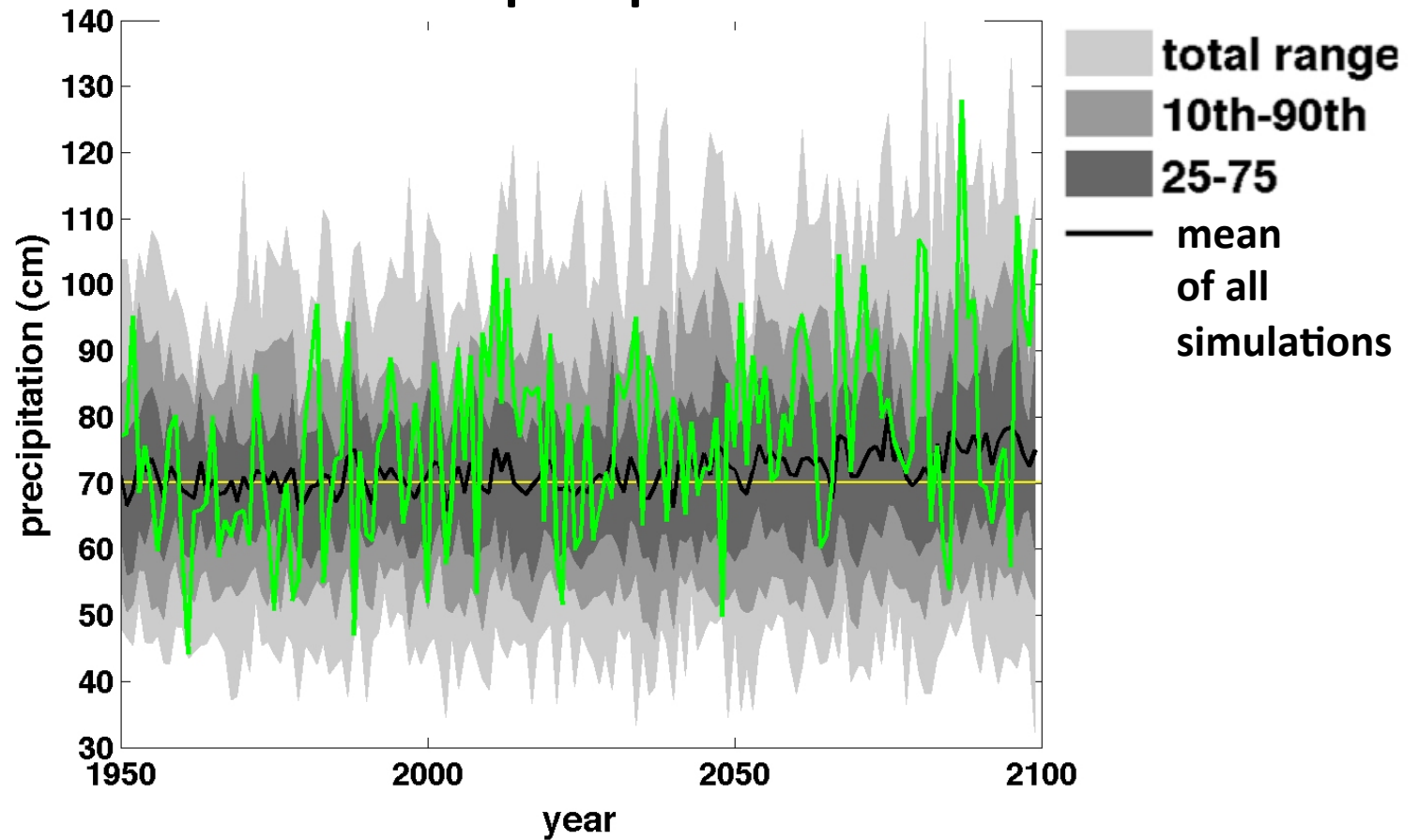
Moderate emission (A1B)
annual precipitation

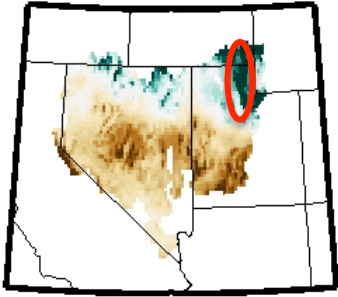




Future projections: Wasatch

Moderate emission (A1B)
annual precipitation

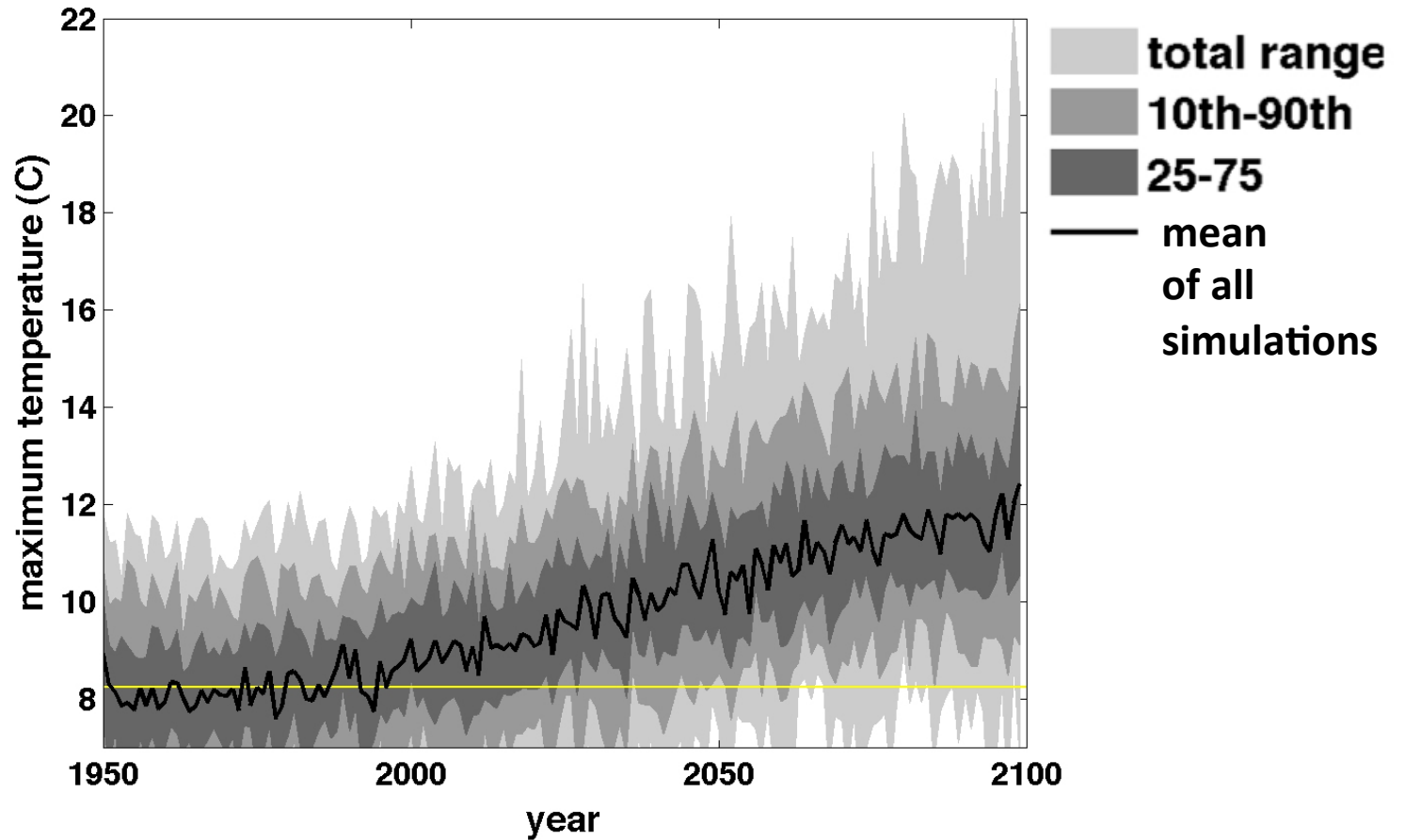


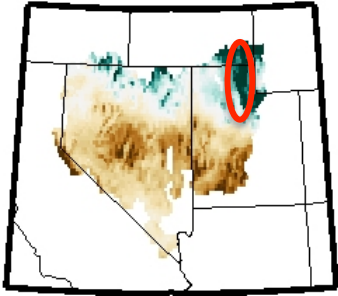


Future projections: Wasatch

Moderate emission (A1B)

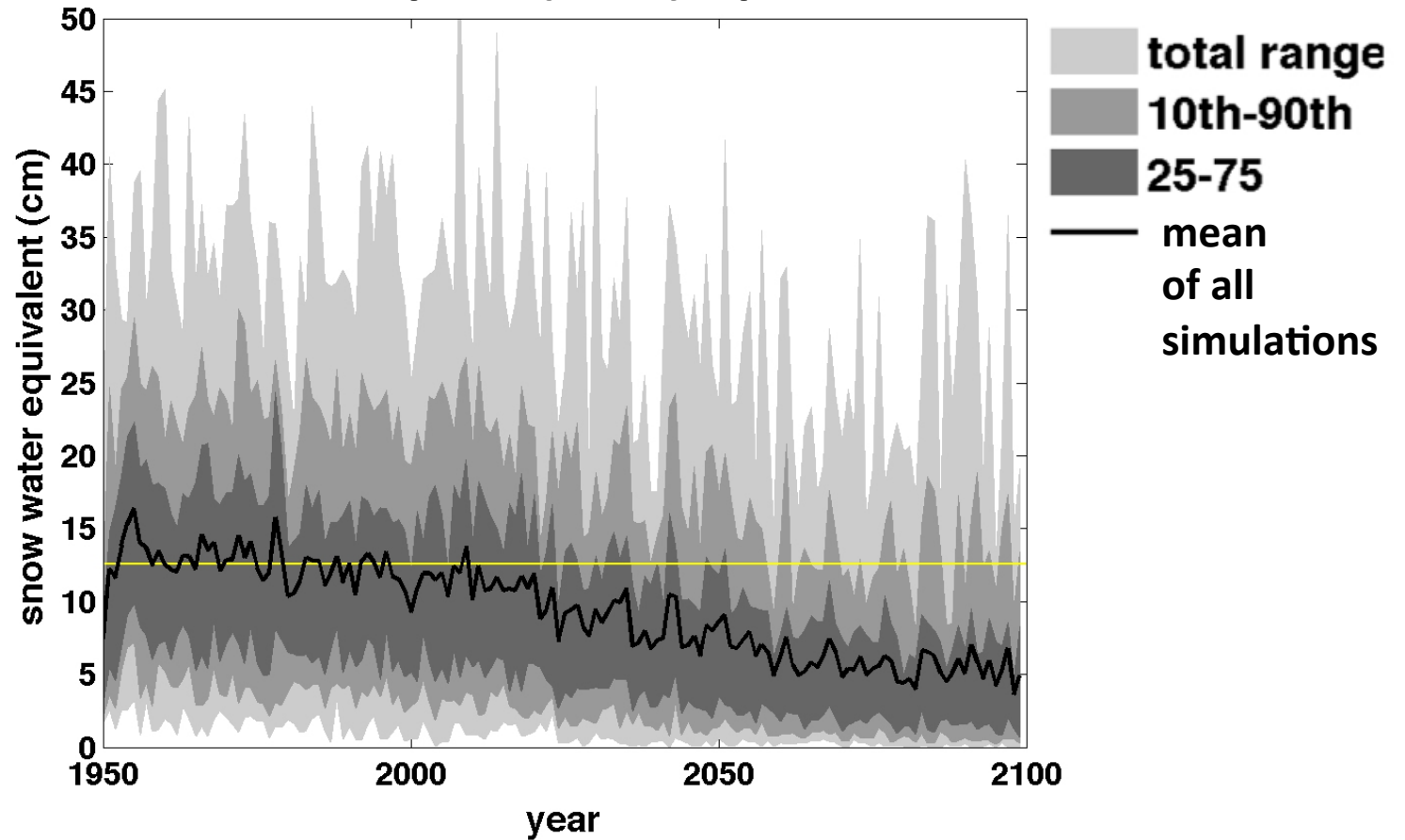
average maximum air temperature: March-April

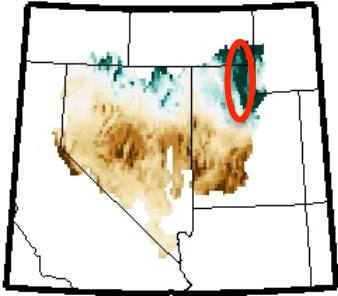




Future projections: Wasatch

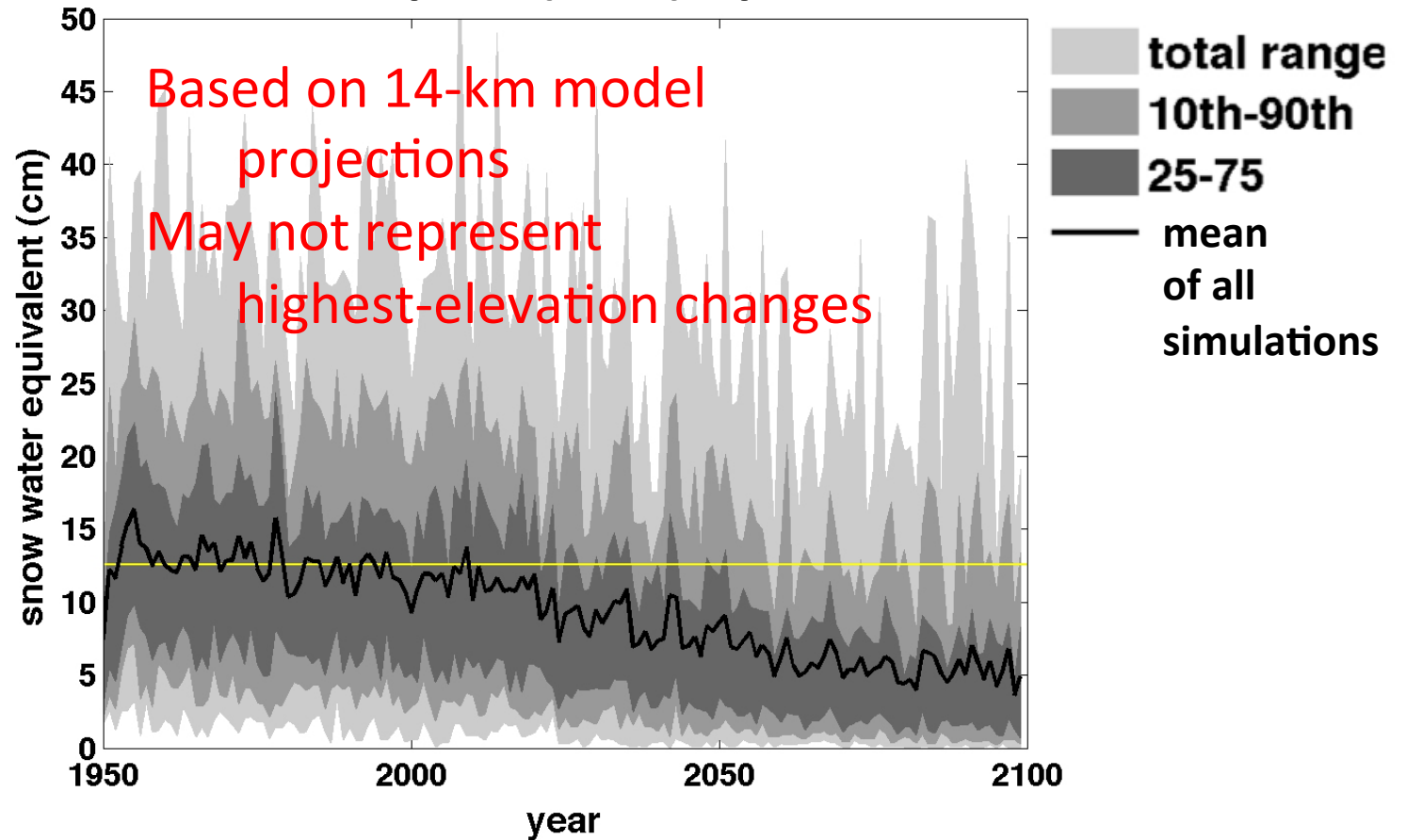
Moderate emission (A1B)
snowpack (SWE) April 1

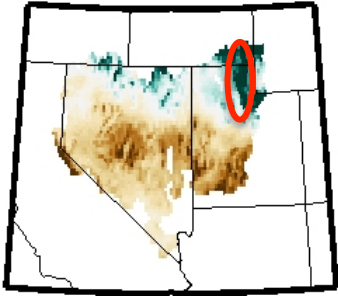




Future projections: Wasatch

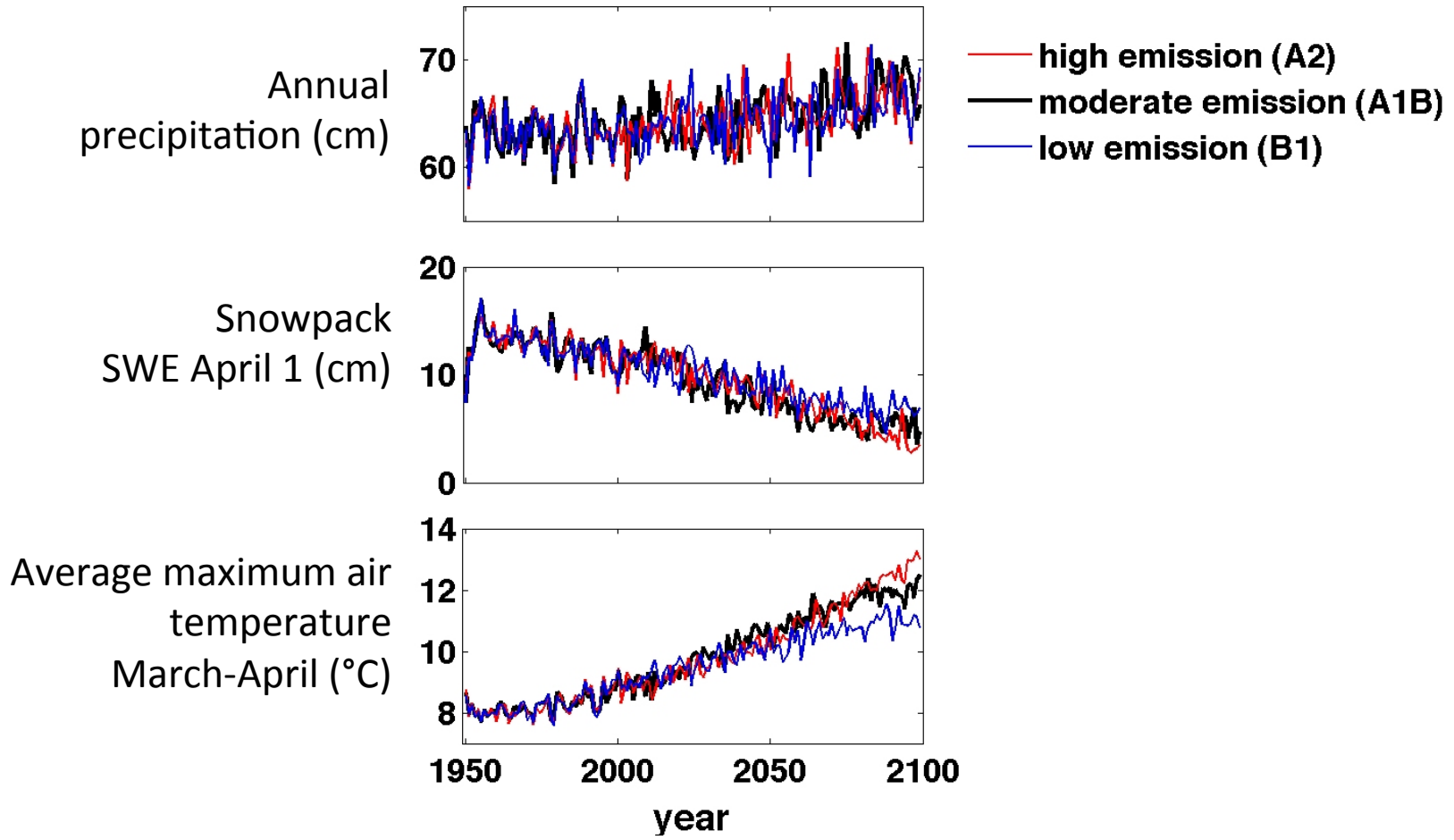
Moderate emission (A1B)
snowpack (SWE) April 1





Future projections: Wasatch

Wasatch Range



Climate wildcard

Dust: reduces the amount of sunlight that is reflected, leading to faster and earlier snow melt



Summary for **Wasatch Range**

- Historically
 - dry and wet decades with no trend
 - Large year-to-year variations in snowpack
- By the end of this century
 - Precipitation increases by 6 cm (2.5")
 - 40% to 50% decrease in April 1 snowpack
 - March-April maximum air temperature increase by 3 to 5°C
- Our current work
 - Consideration of elevation effects on projected snowpack
 - High-resolution modeling based on newest climate projections (CMIP5)