Climate change and the Delaware River Basin

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Science of Source Water Workship
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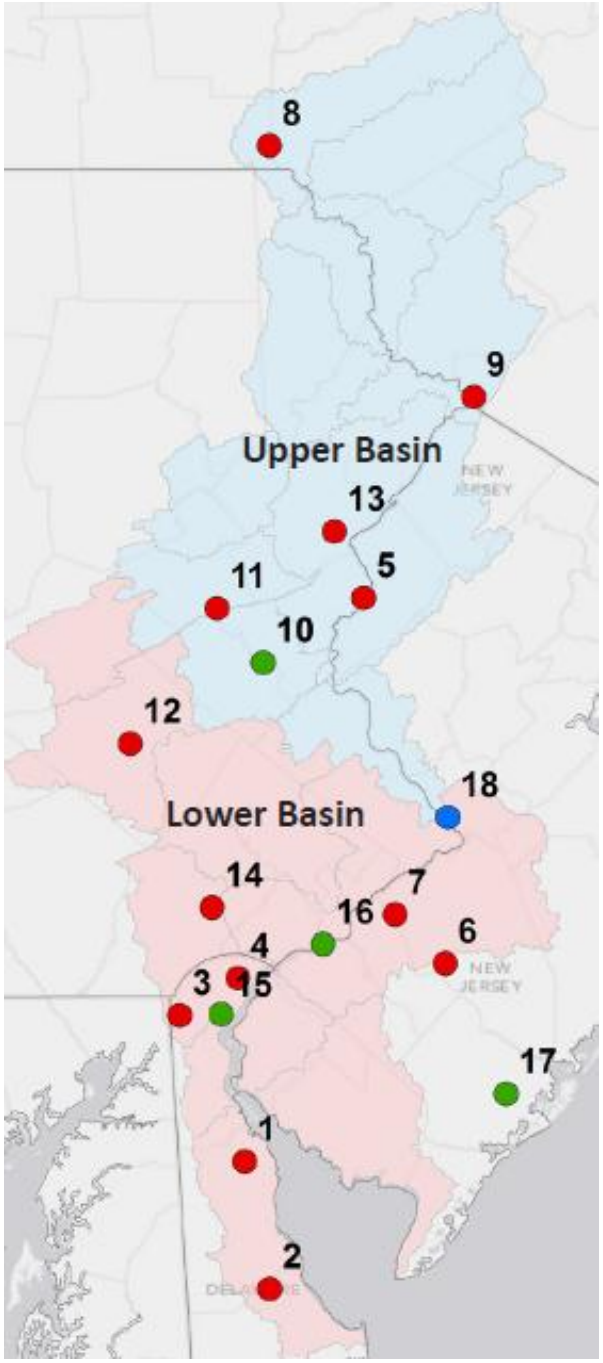
Outline

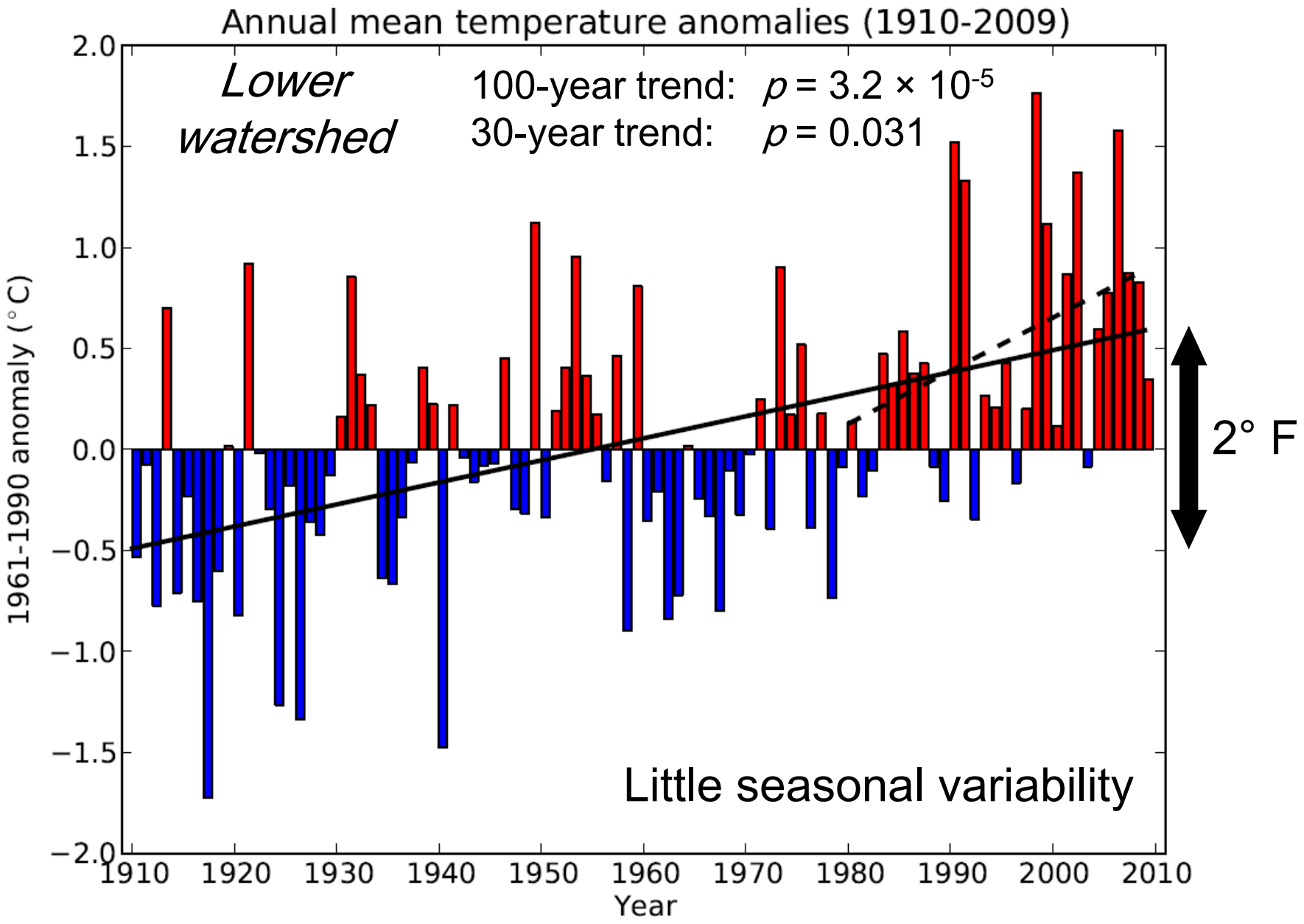
- Past climate
- Future climate: global & regional models
- Runoff change
- Salinity change



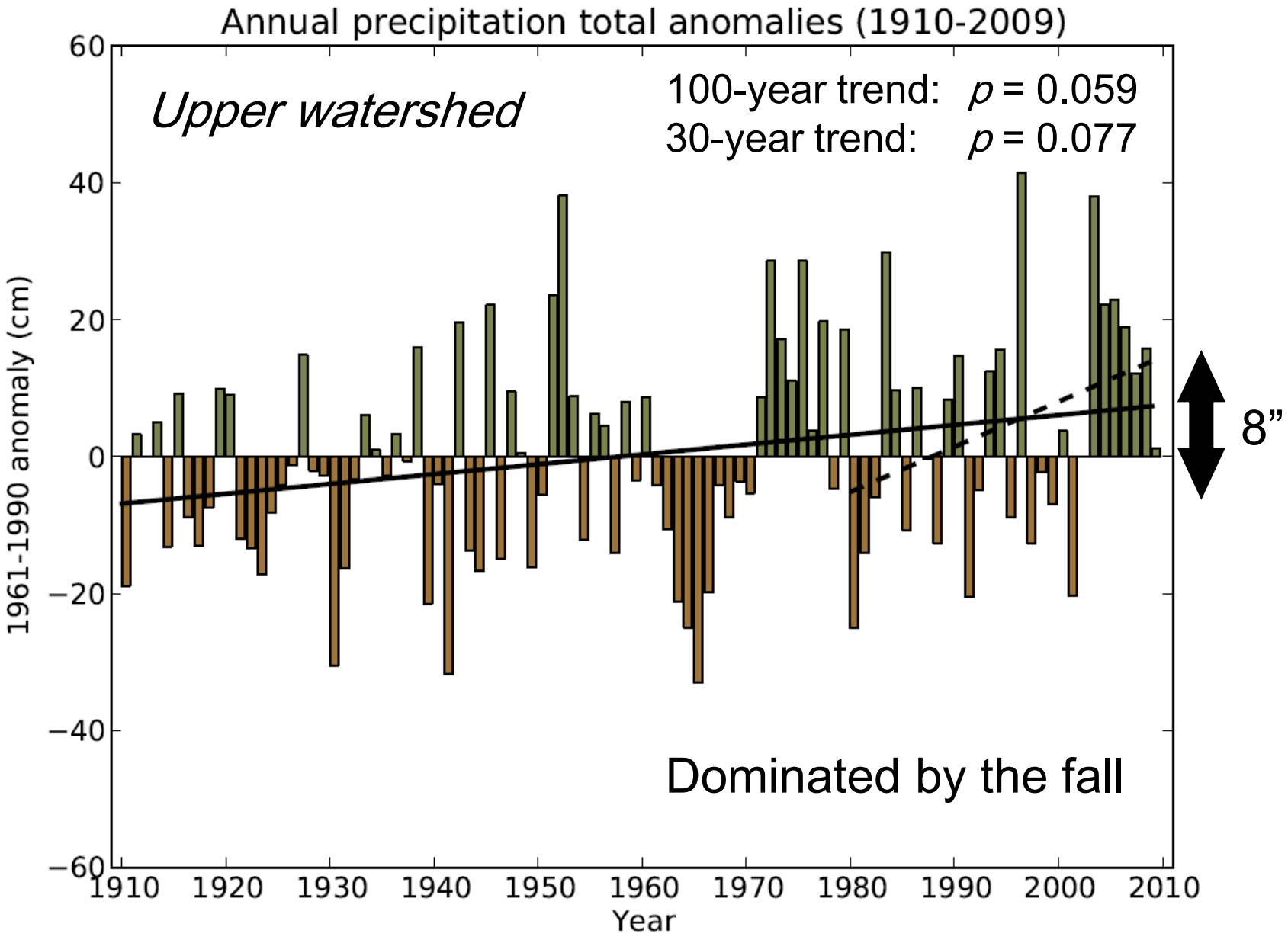
Goal: Comprehensively document changing climate of the Delaware River Basin

- Temperature
- Precipitation
- Snow cover
- Wind speed
- Streamflow
- Ice jams
- Low-pressure systems

HCN monthly temperature data (adjusted)



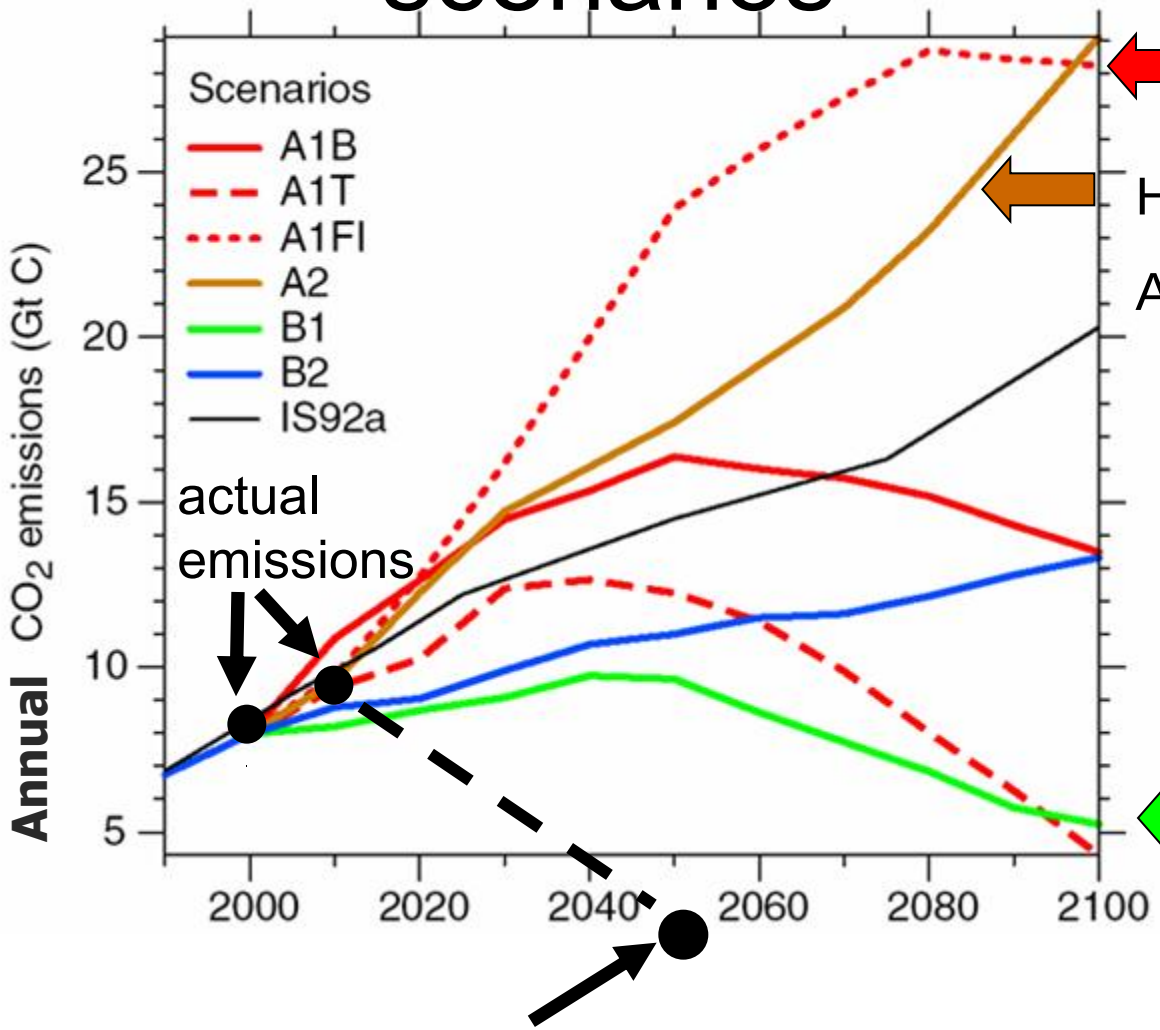
HCN monthly precipitation data



Trends in Temperature and Precipitation Extremes

1. Days per year above 90° F **NS**
2. Days per year below 32° F 
3. Annual maximum # consecutive dry days **NS**
4. Days per year of heavy (>4.5 cm) precip. 
5. Annual maximum 5-day precip. total 

IPCC Emissions scenarios



HIGHER

A1FI (CO_2 = 940 ppm)

HIGHER

A2 (CO_2 = 840 ppm)

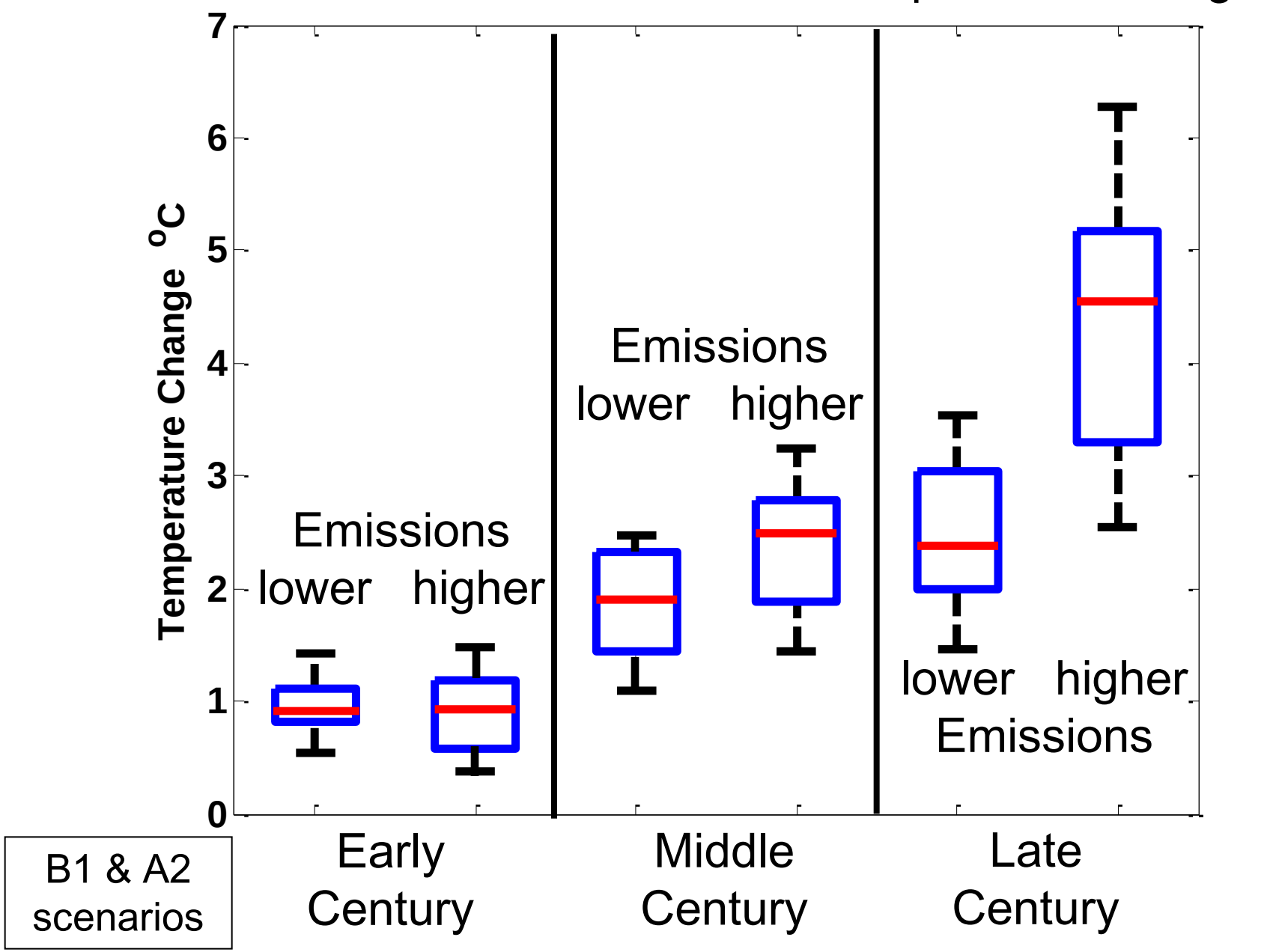
pre-industrial CO_2 = 280 ppm

LOWER

B1 (CO_2 = 550 ppm)

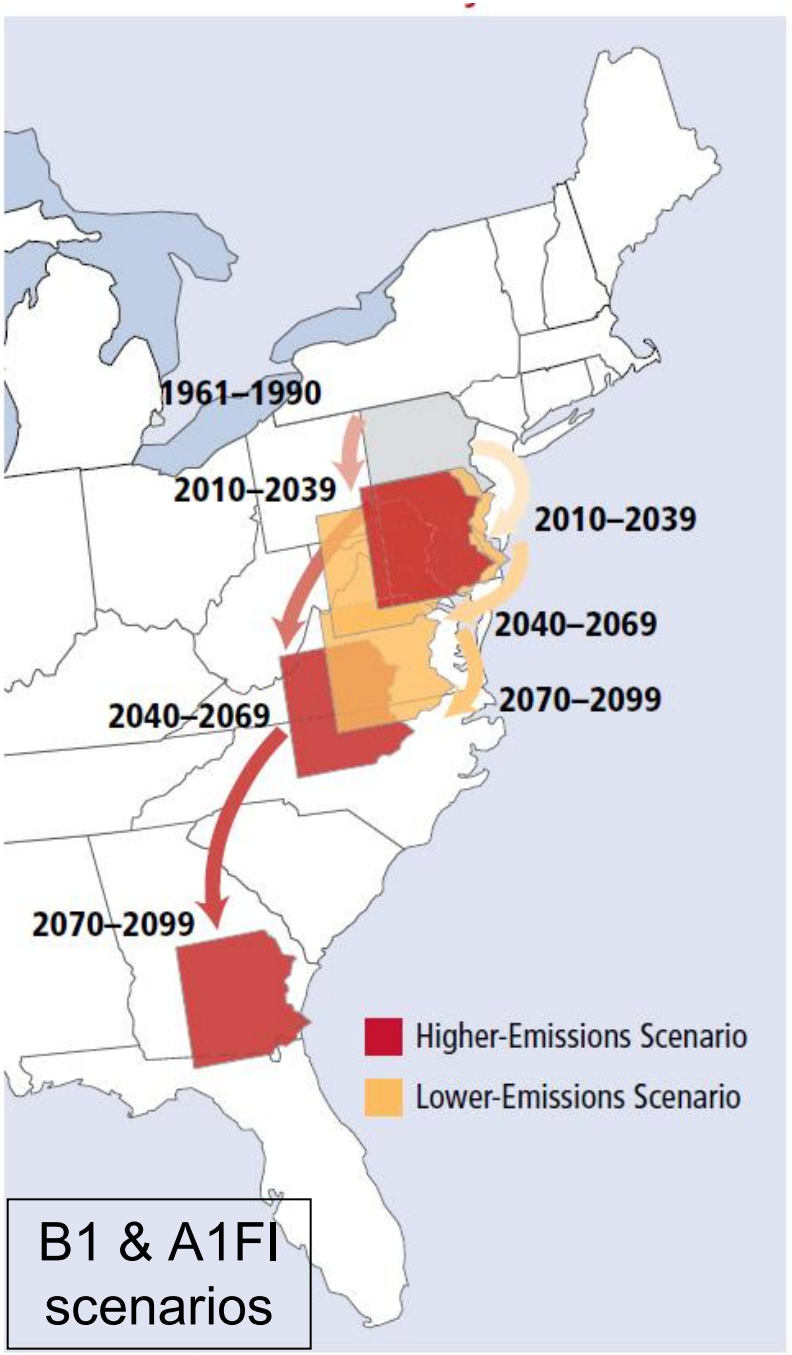
Commonly proposed target: 20% of current emissions by 2050—estimated warming of 2° C.

Source: Nakićenović & Swart (2000)


Delaware River Basin summer temperature change
Temperature Change °C
0
1
2
3
4
5
6
7
Emissions
lower higher
Emissions
lower higher
lower higher
Emissions
Early Century
Middle Century
Late Century
B1 & A2 scenarios

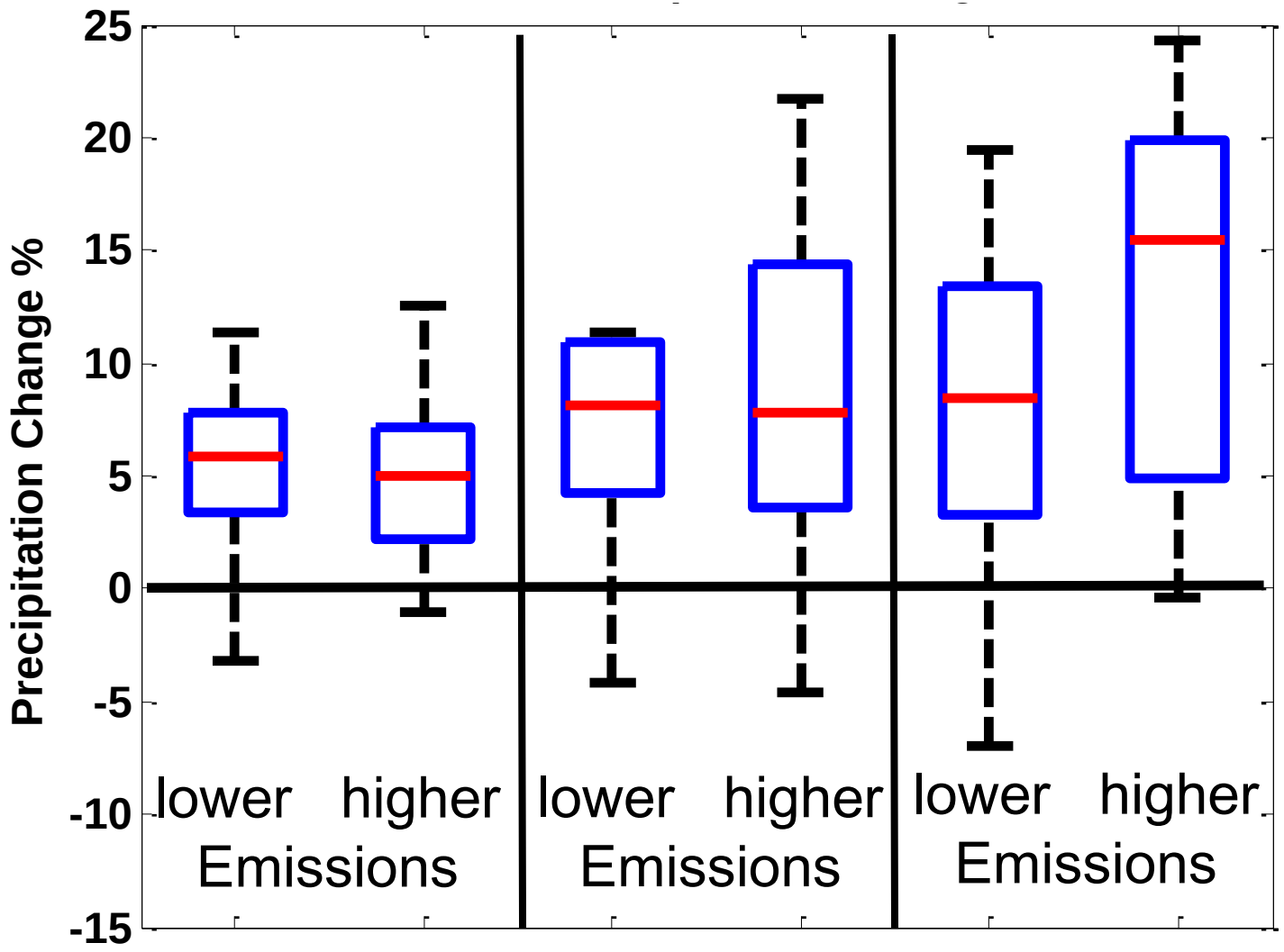
Summer heat index change

Heat index depends on temperature and humidity



Source: Union of Concerned Scientists (2008)

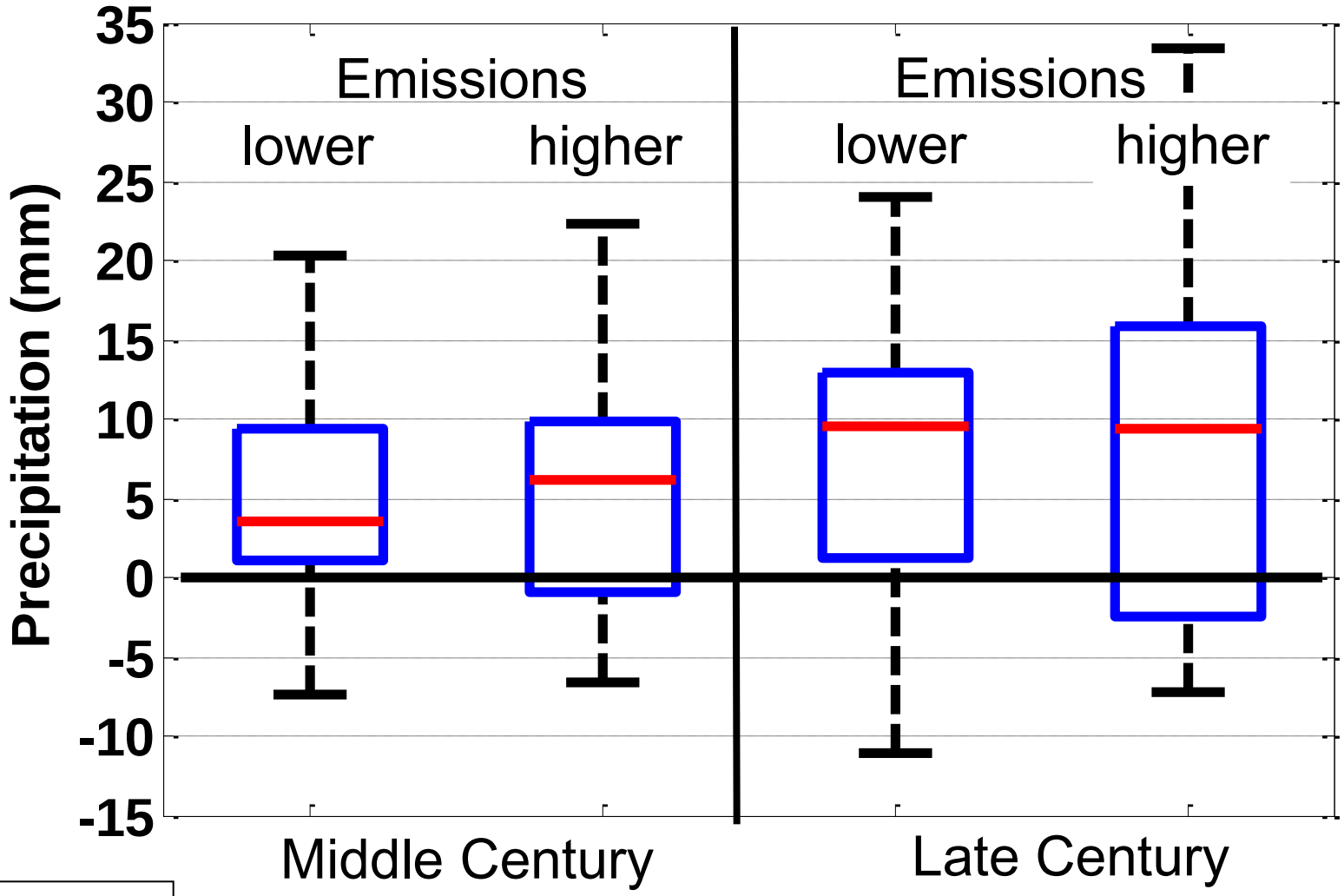
Delaware River Basin winter precipitation change



B1 & A2 scenarios

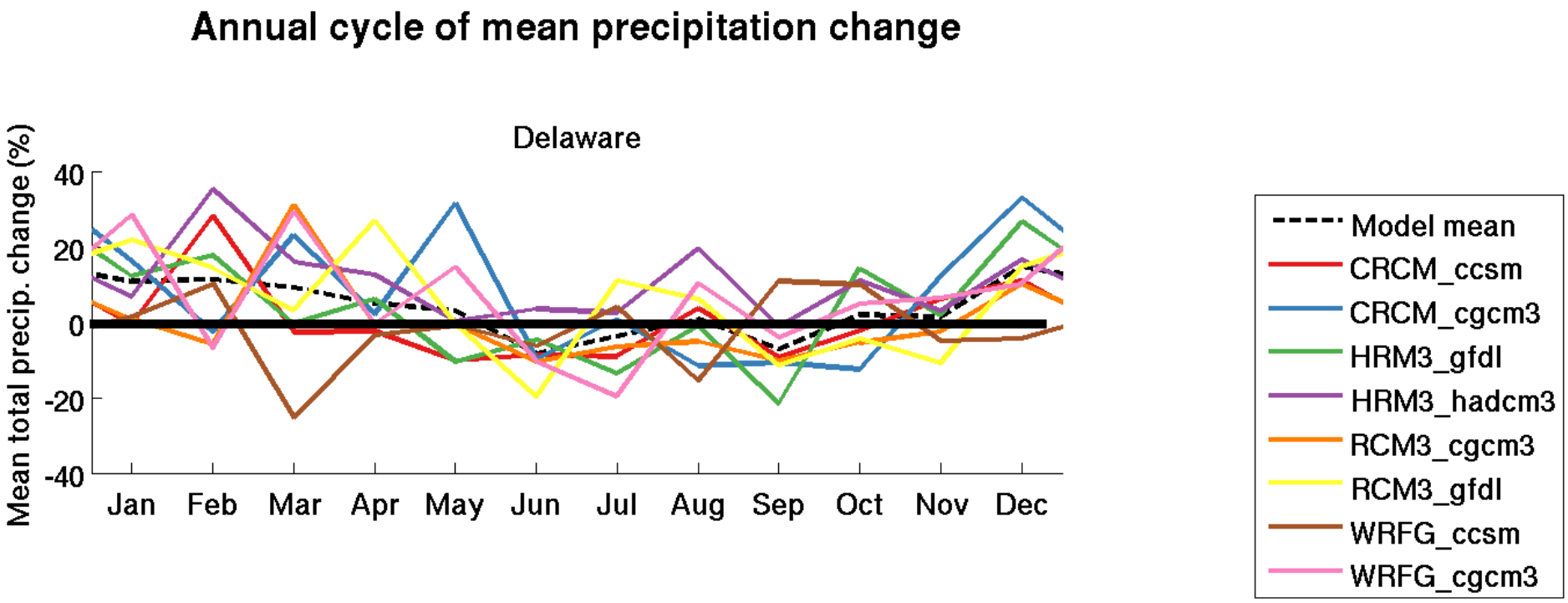
Delaware River Basin

Change in Annual Maximum 5 Day Precipitation Total (Baseline = 63 mm)



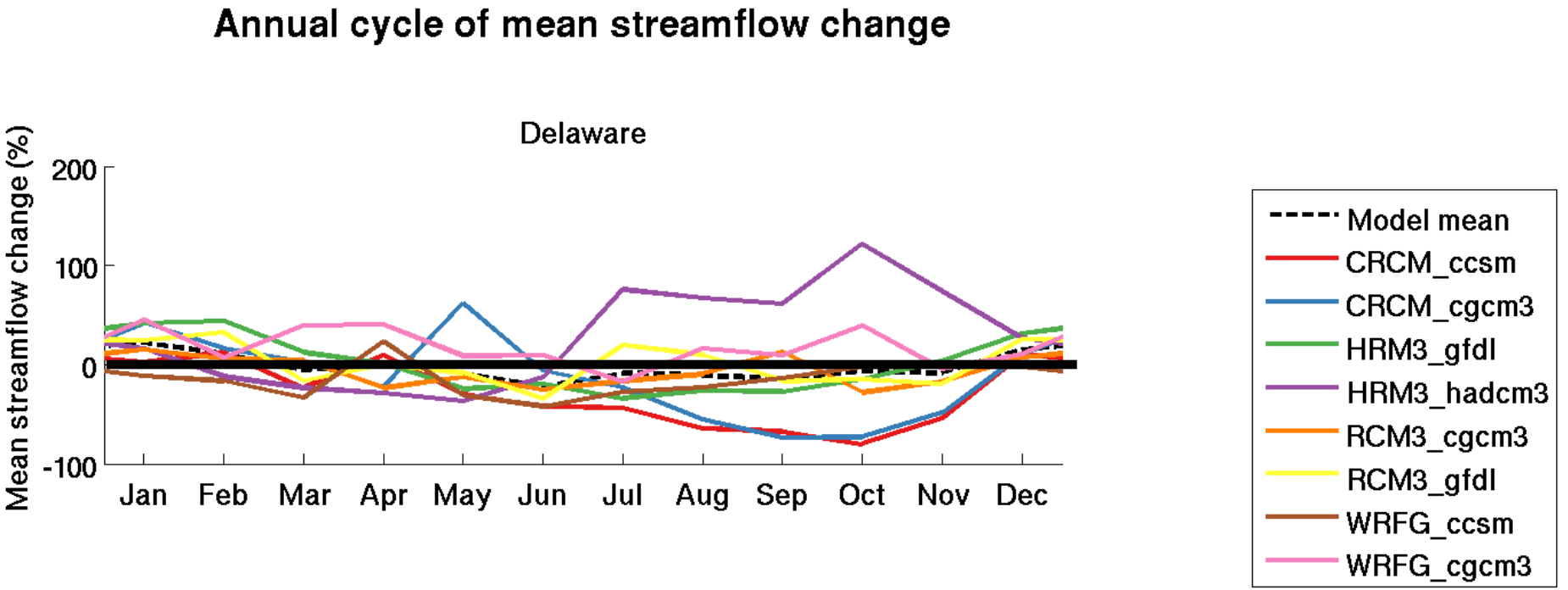
B1 & A2 scenarios

New results from regional climate models: precipitation



A2, mid-century

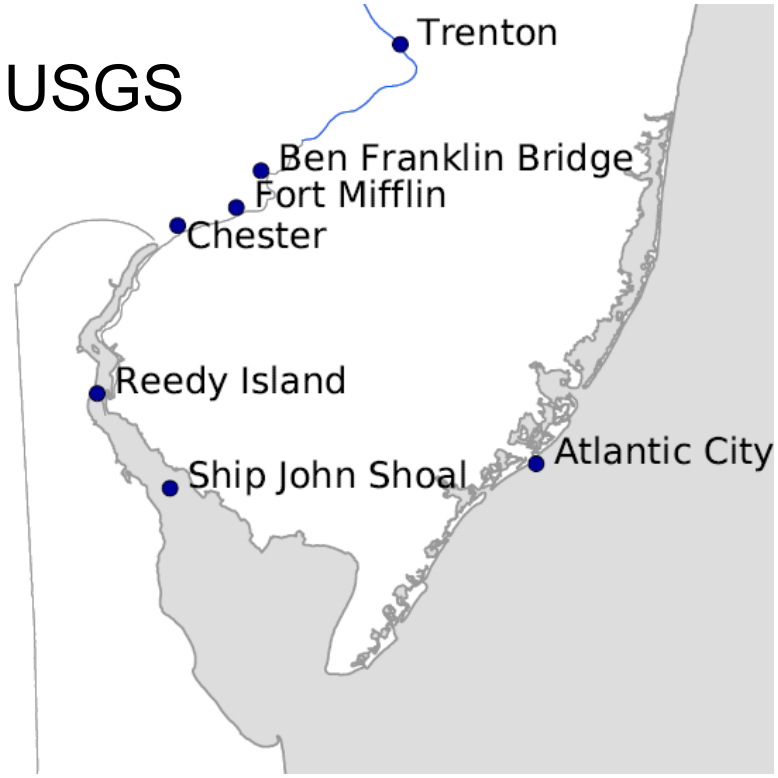
New results from regional climate models: streamflow

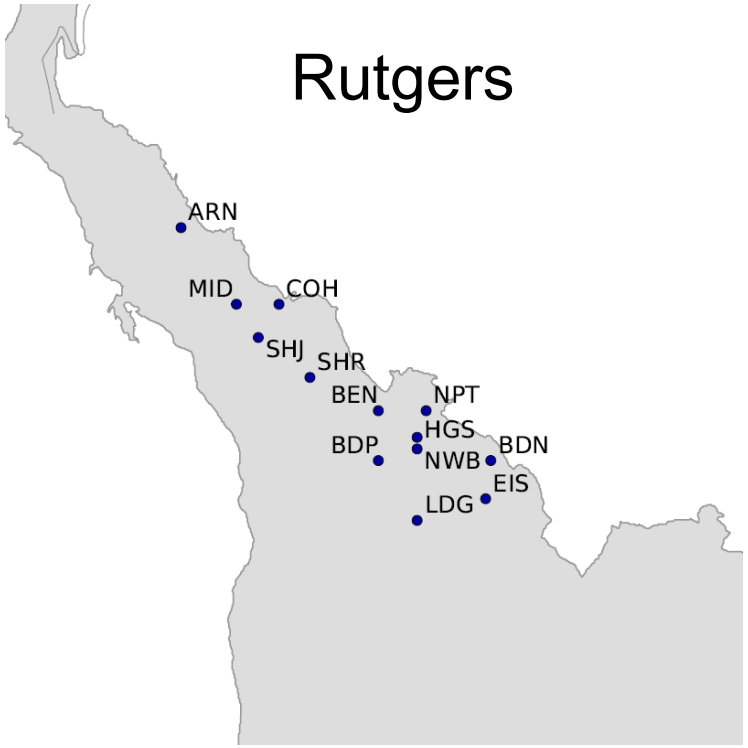


A2, mid-century

Salinity change

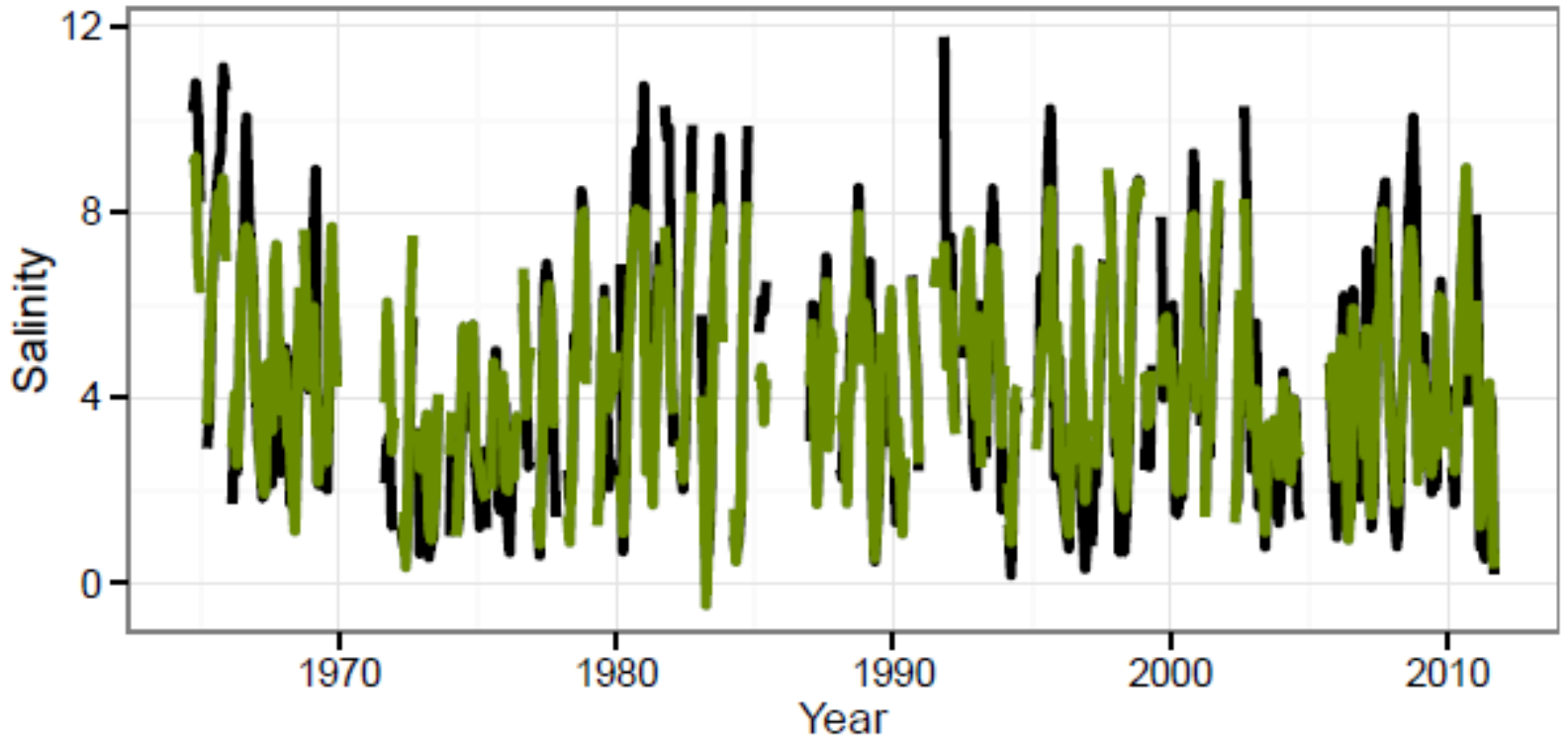
- Ross Masters thesis
- Analysis of USGS and Rutgers data
- Statistical modeling using GAMMs





The model closely fits the observed salinity

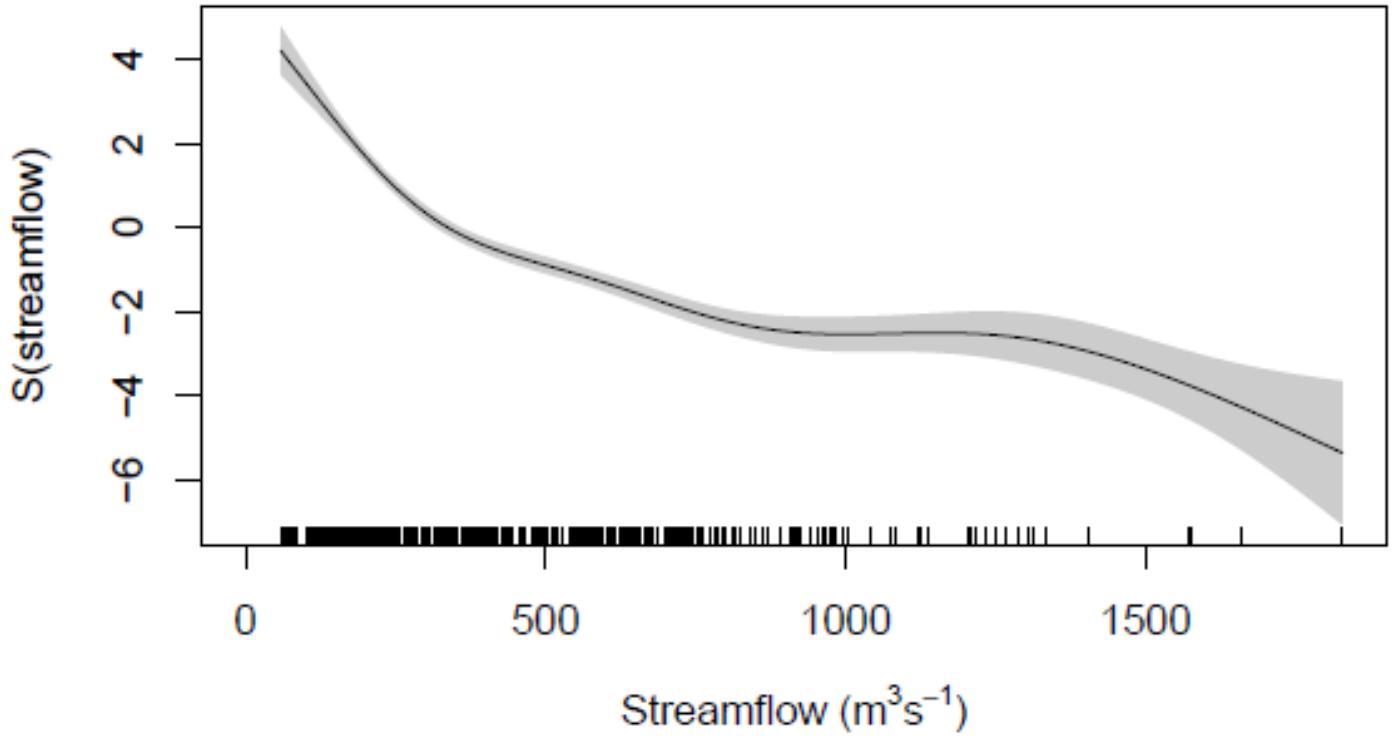
Black: observed Reedy Island salinity. **Green:** modeled Reedy Island salinity.



- The fits upstream in the Estuary are not as good.

Streamflow has the largest effect

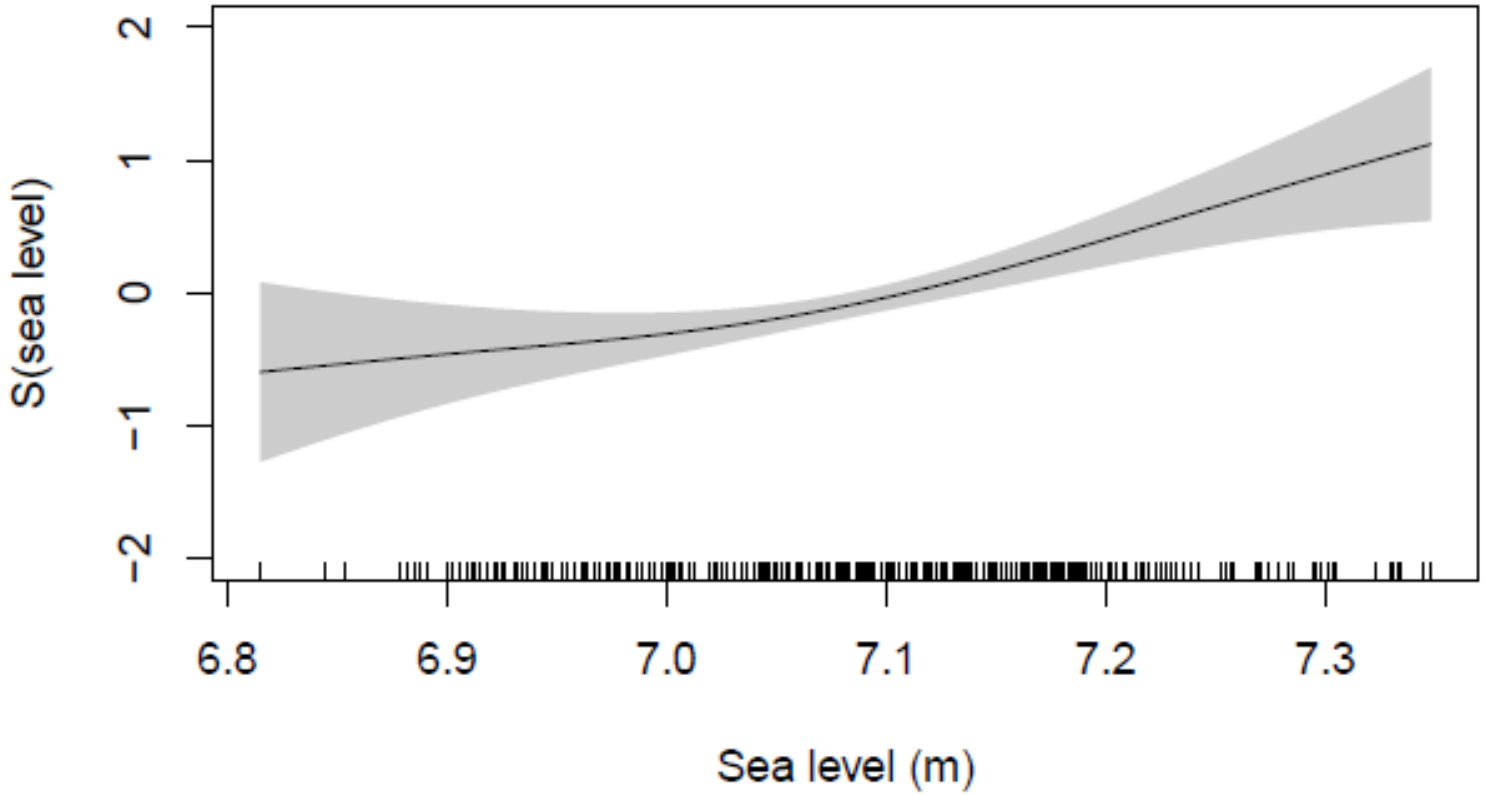
Reedy Island Jetty



- The results are similar at the other locations.

Sea level is also important

Reedy Island Jetty



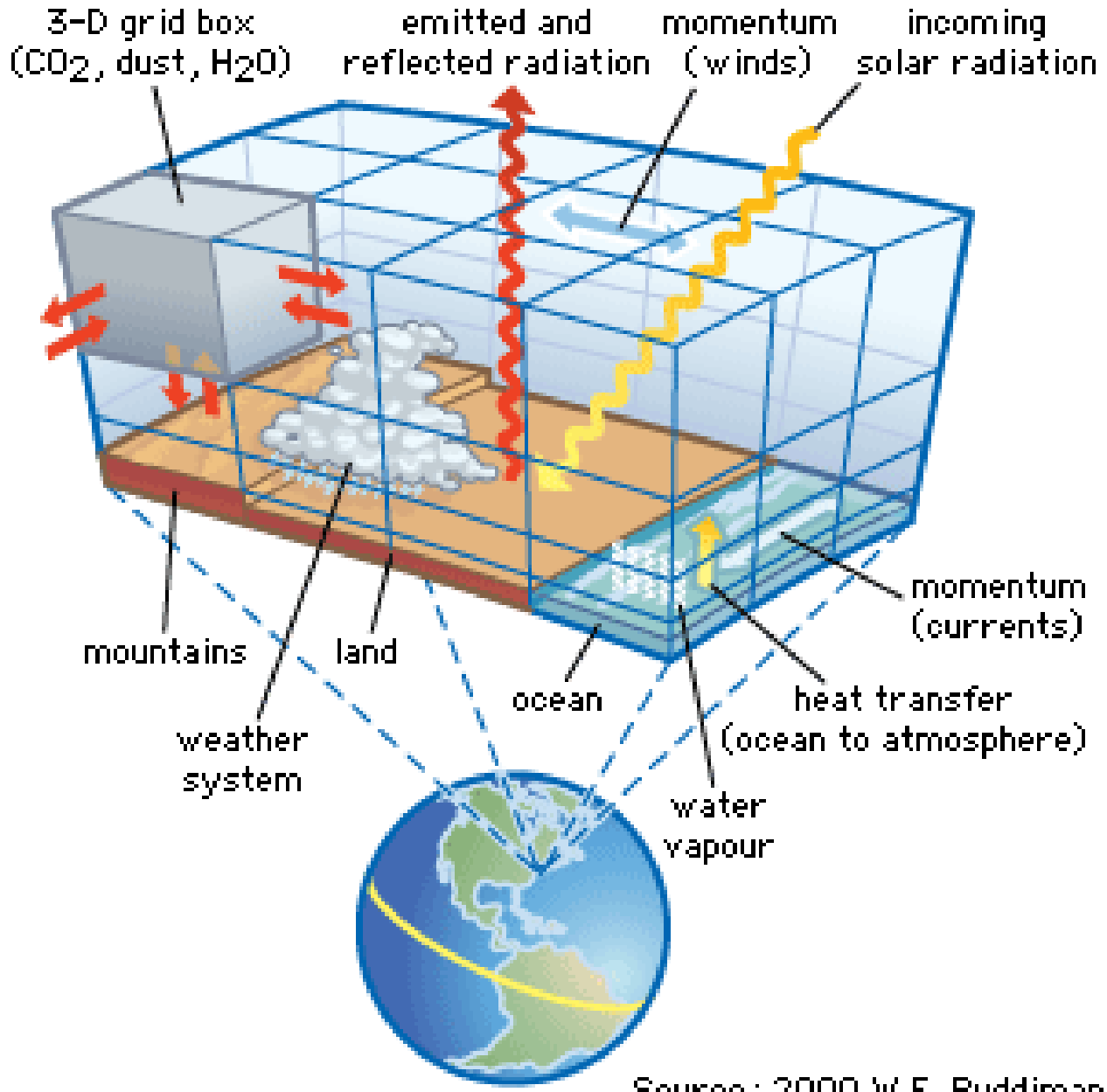
Summary

- DRB is getting warmer and wetter, sea-level is rising, salinity (flow corrected) is increasing
- Future climate-change impacts on DRB water resources should be considered in planning

Thank you

Extra slides

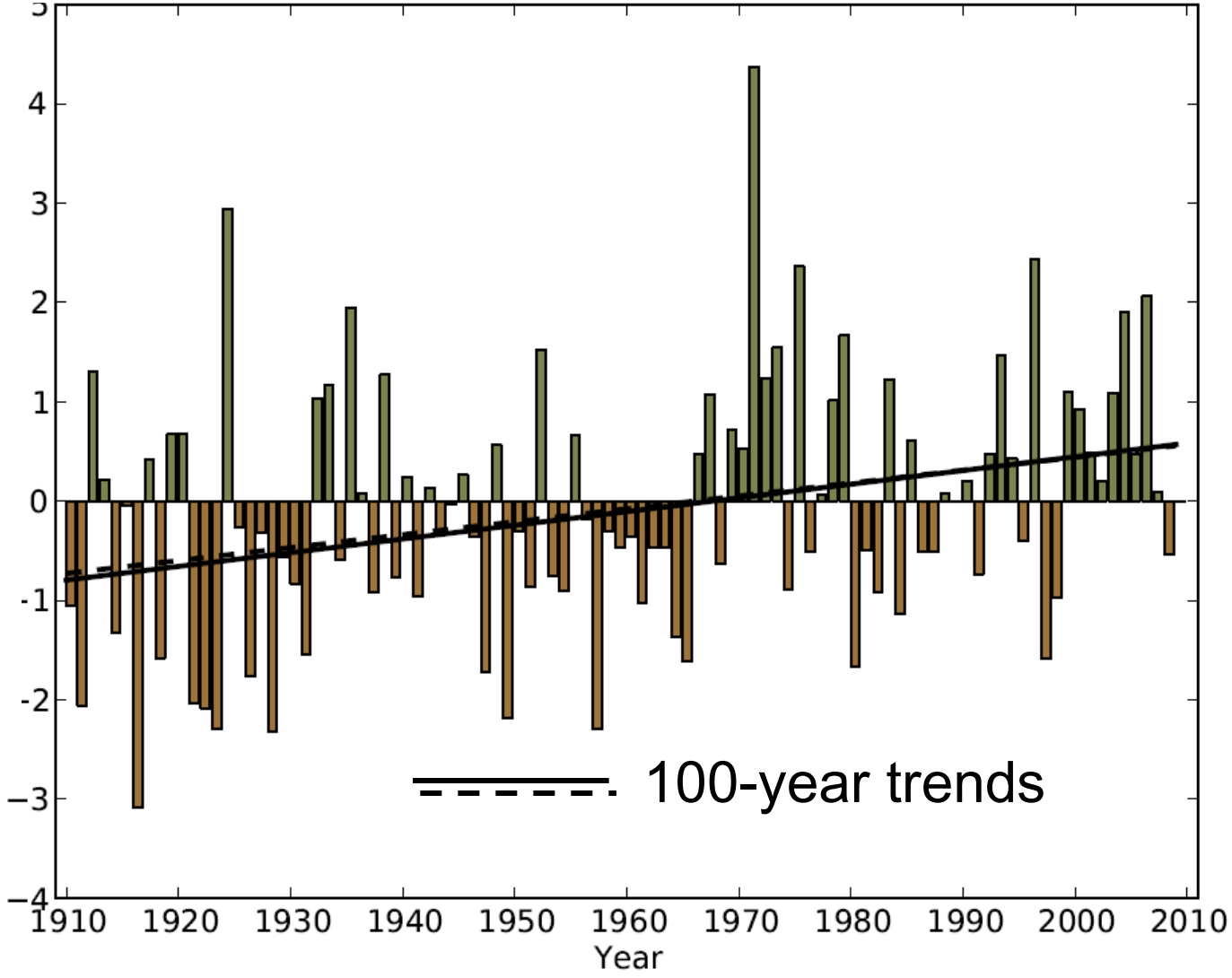
Concept diagram of climate modeling



Source : 2000 W.F. Ruddiman

Heavy precipitation change in the lower Delaware River Basin

Number of days per year with precipitation more than 4.5 cm (anomaly)



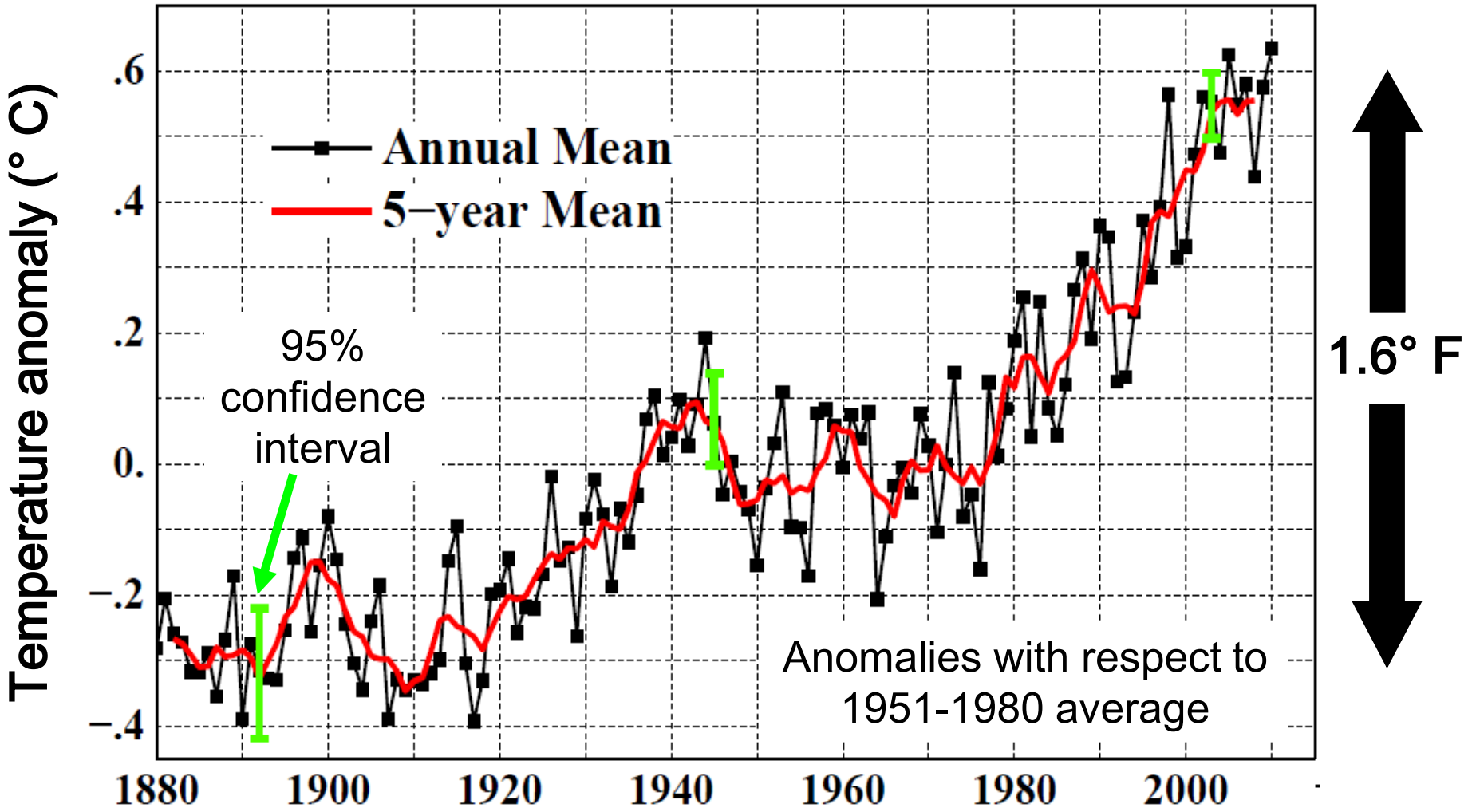
Drought implications

- Flooding
- Water quality declines
- Treatment plant overflows

Implications of increased intense precipitation

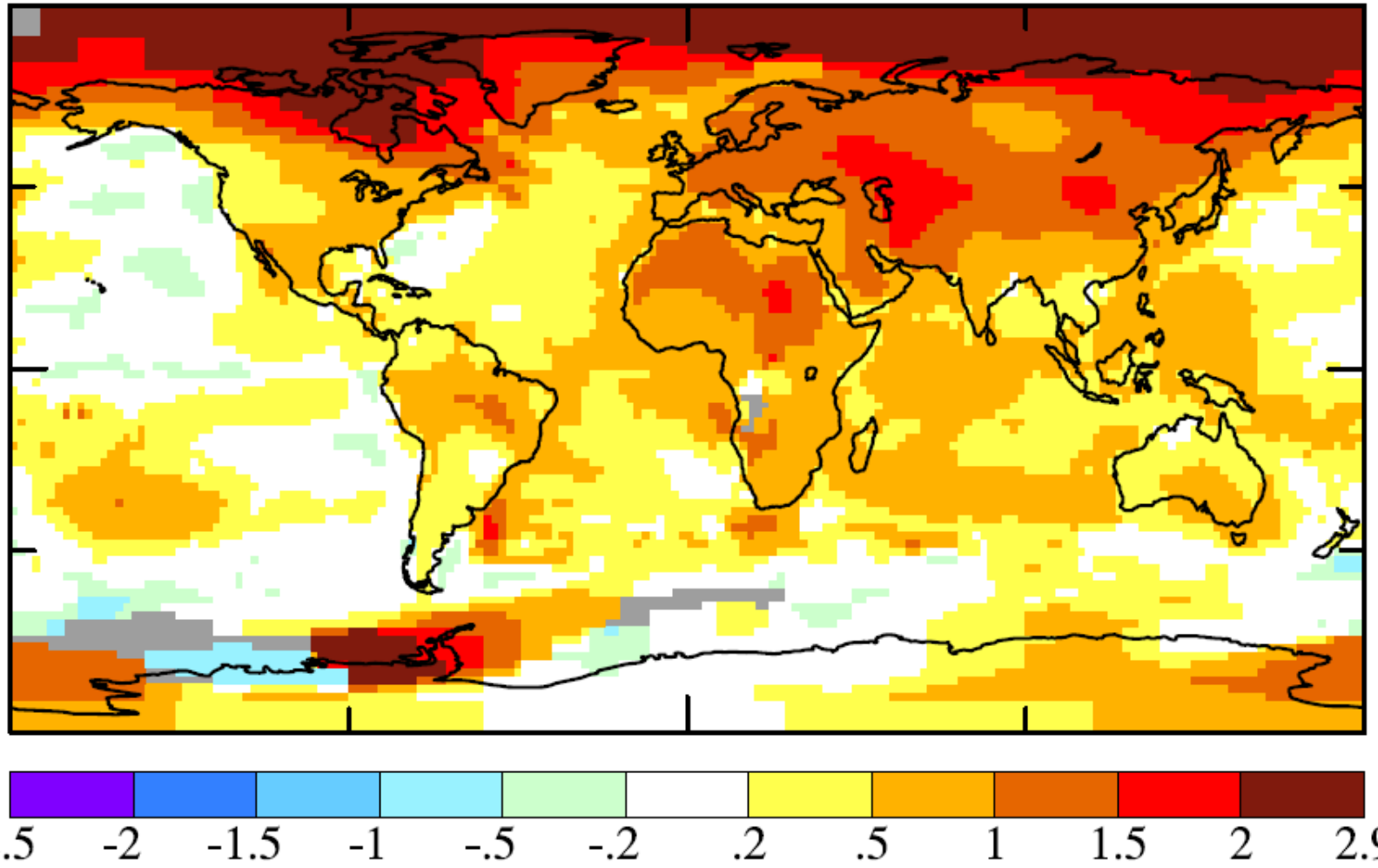
- Water availability
- Reservoir storage
- Salt water intrusion

Global mean temperature change



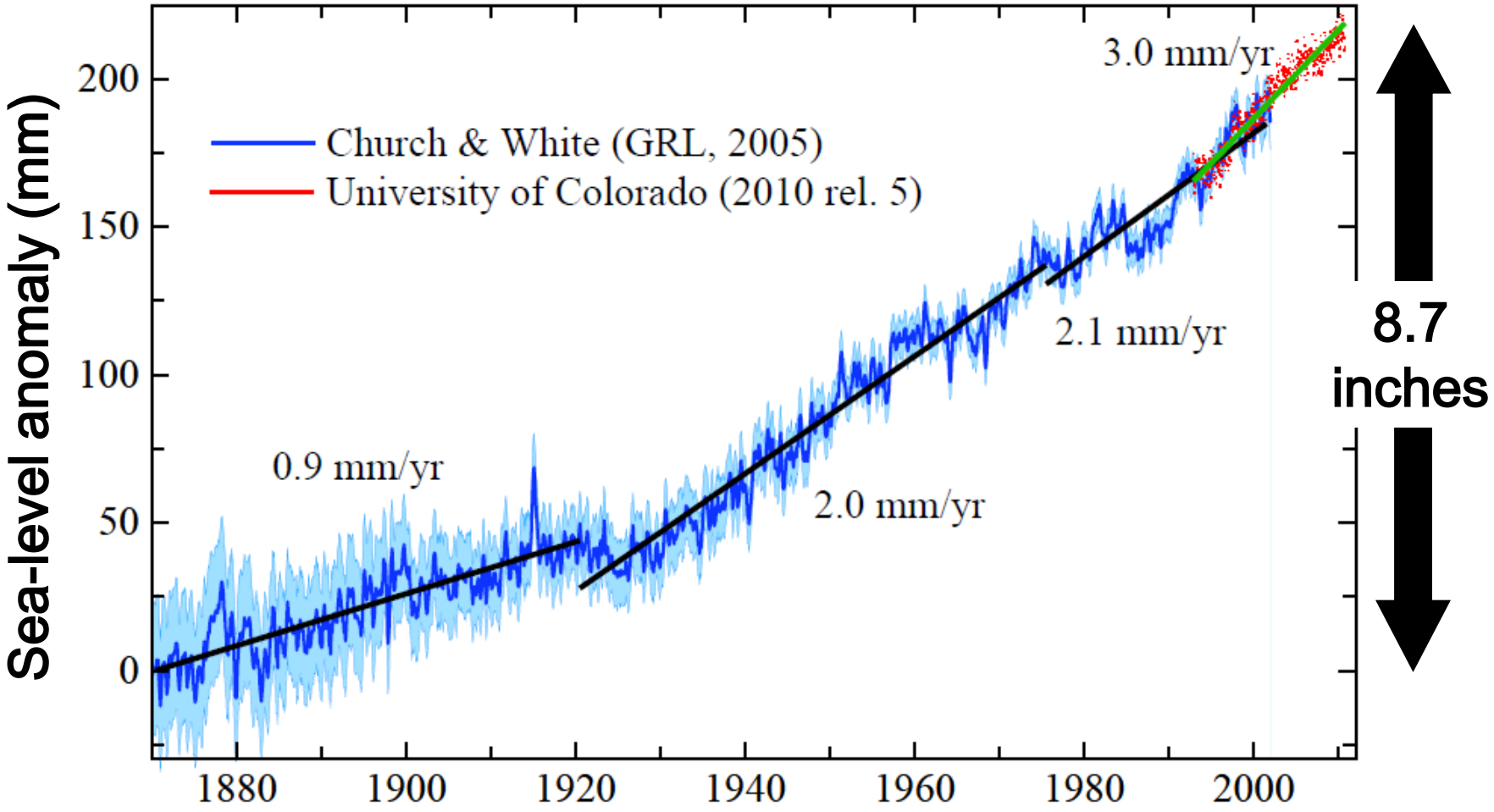
Source: Sato and Hansen (2011)

Surface temperature change (° C)
2006-2010 minus 1951-1980



Source: Sato and Hansen (2011)

Global average sea-level change

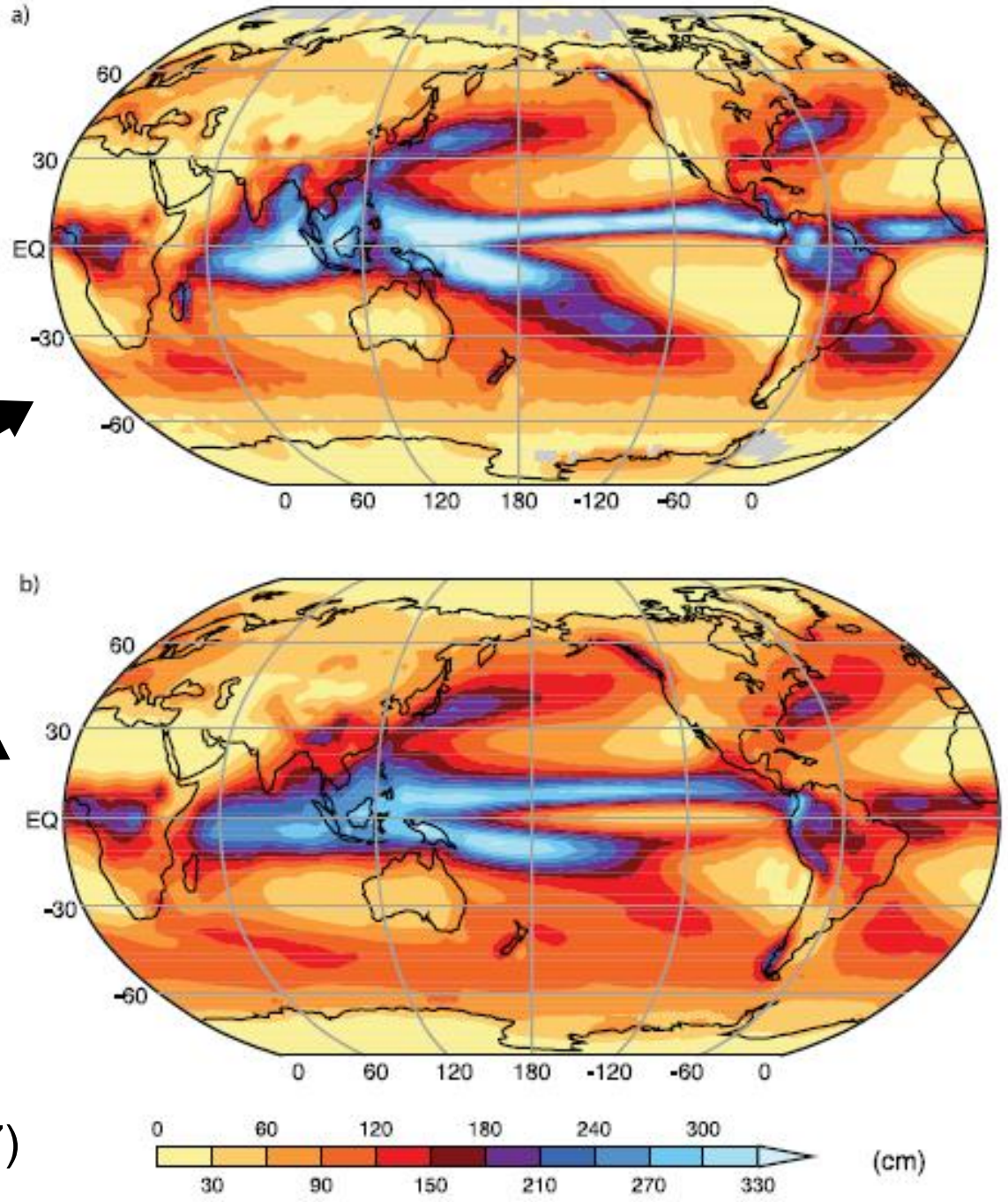


Source: Sato and Hansen (2011)

Annual precipitation

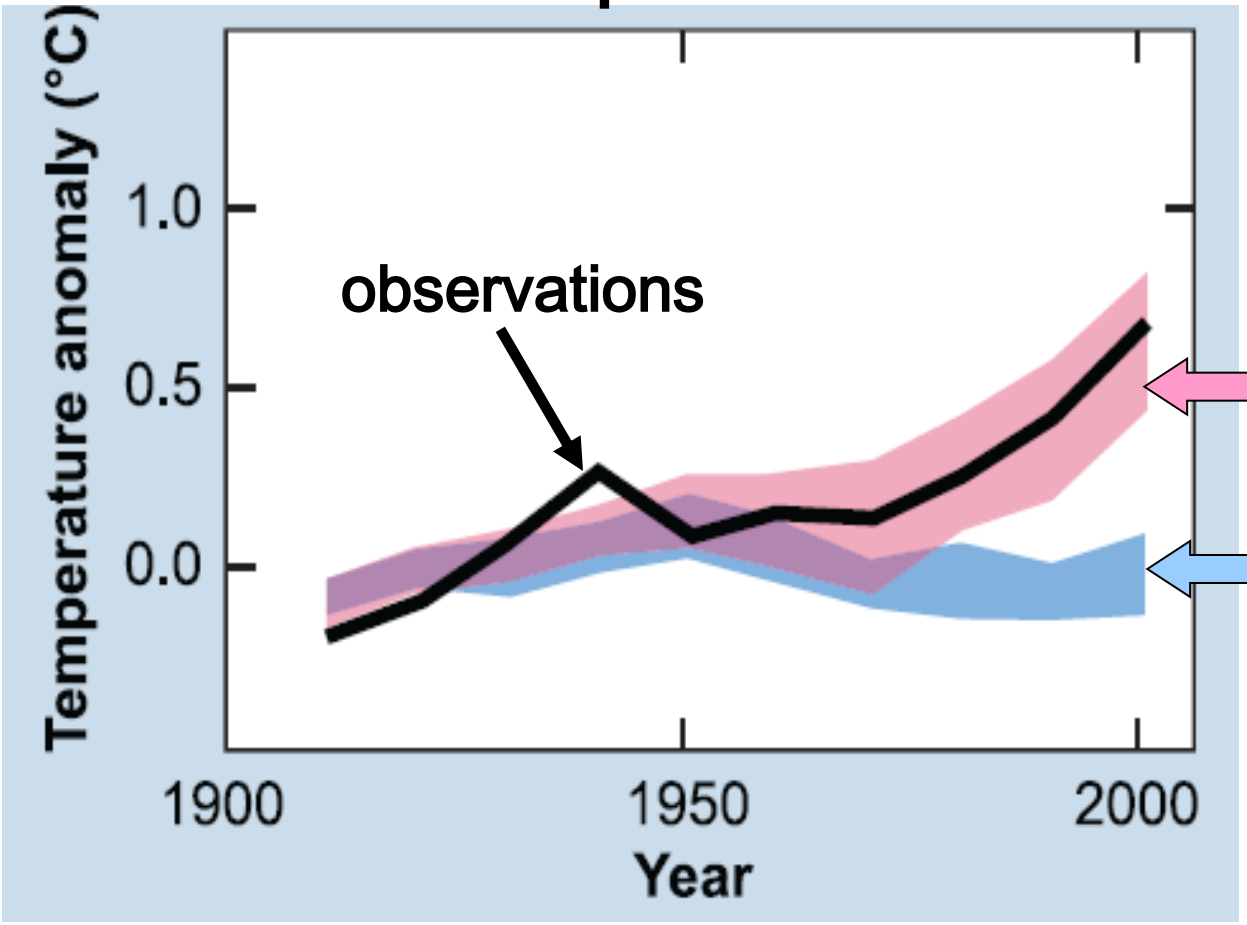
Simulated
(multi-model average)

observed



Source: Randall et al. (2007)

Observed and simulated global temperature change



Models using both natural and anthropogenic forcings

Models using only natural forcings

Shading indicates 5-95% range of models

Source: Hegerl et al. (2007)

Authoritative sources for climate change reports and position statements

- Intergovernmental Panel on Climate Change
- National Science Foundation
- National Oceanic and Atmospheric Administration
- Environmental Protection Agency
- United States Geological Survey
- Department of Energy
- National Aeronautical and Space Administration
- U.S. Global Change Research Program
- The National Academy of Sciences
- American Meteorological Society
- American Geophysical Union
- Geological Society of America
- American Association for the Advancement of Science
- American Physical Society
- American Chemical Society

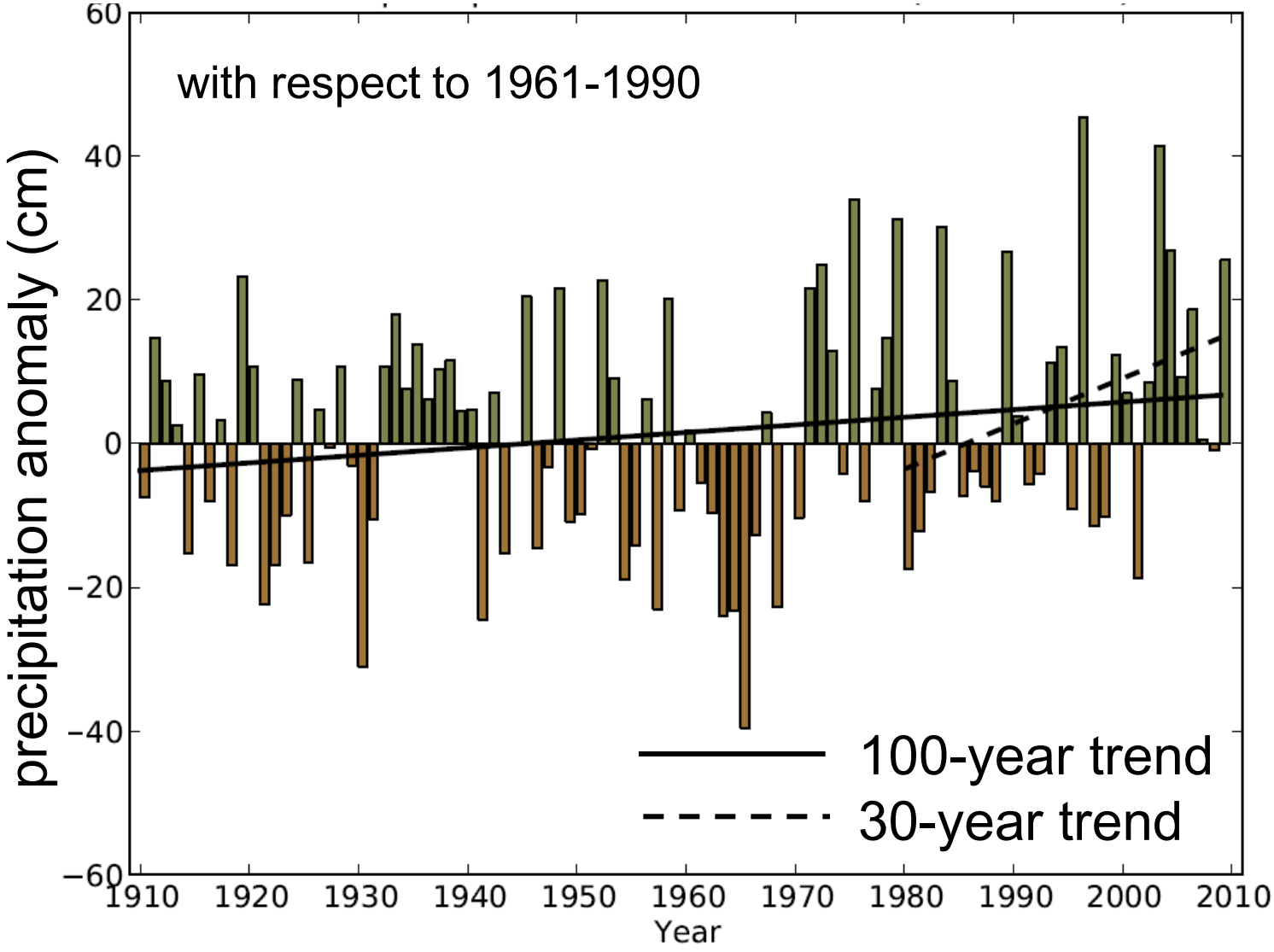
Is global warming mostly human-induced?

Survey says …

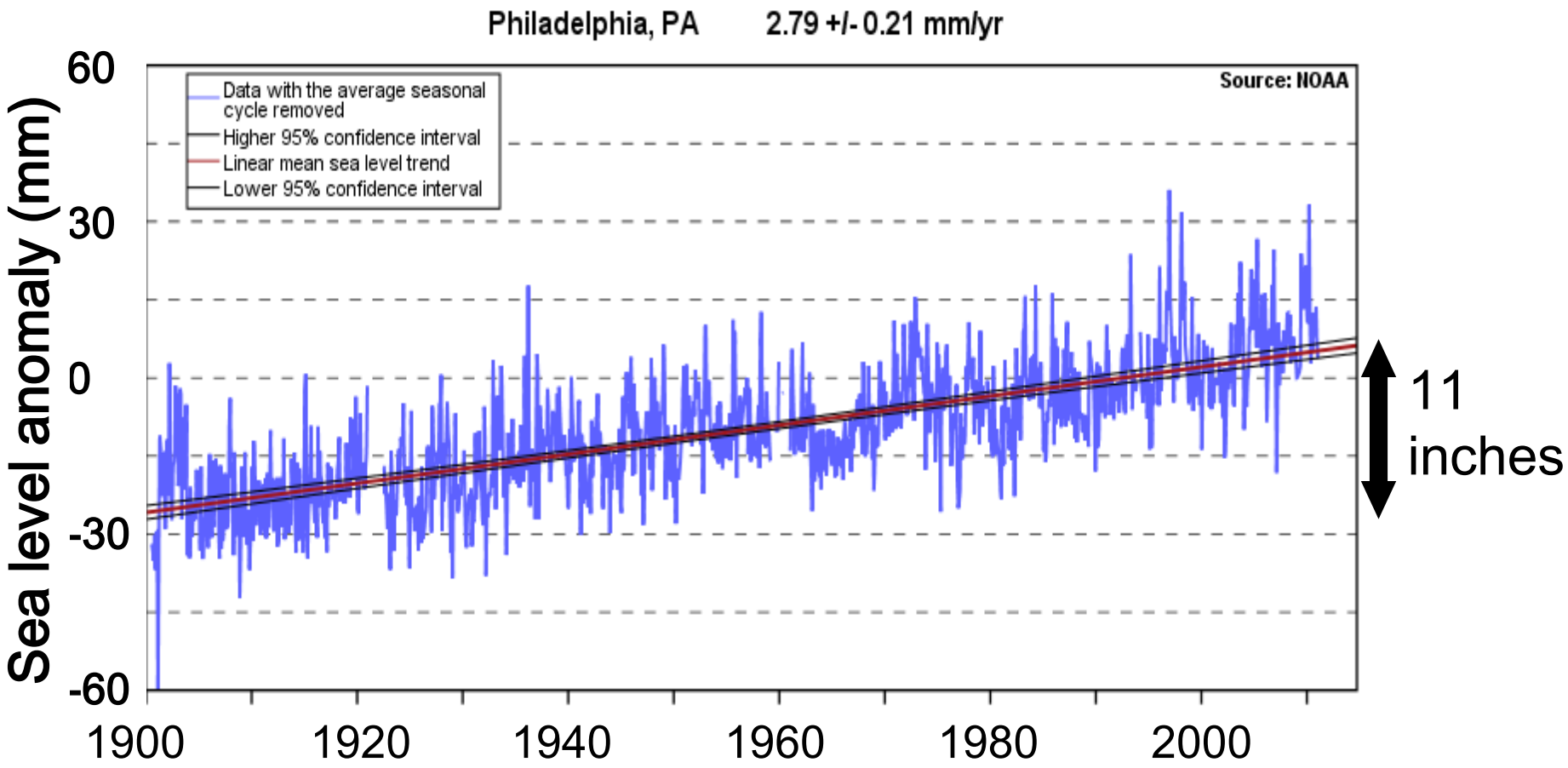
American public	34%
Active climate scientists	97%

Sources: Pew Research Center (2010), Doran and Kimmerman (2009)

Precipitation change in the lower Delaware River Basin



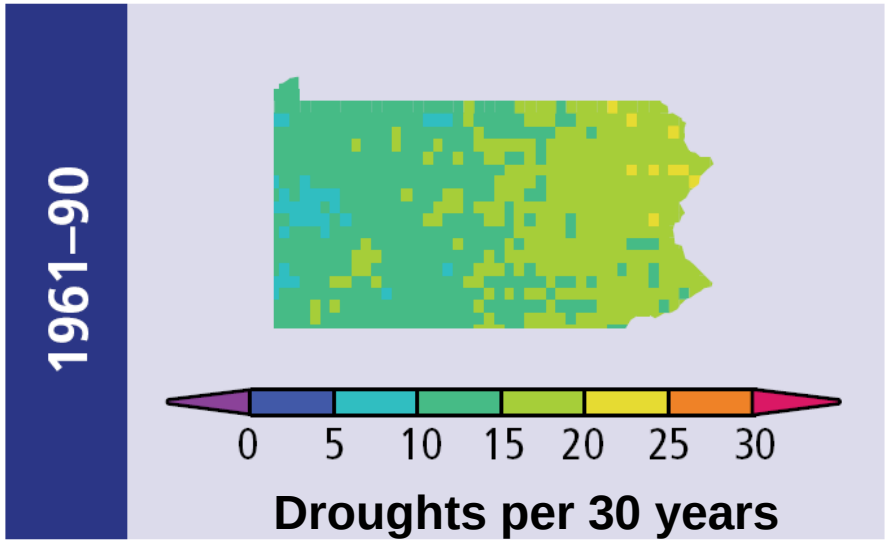
Water-level change at Philadelphia

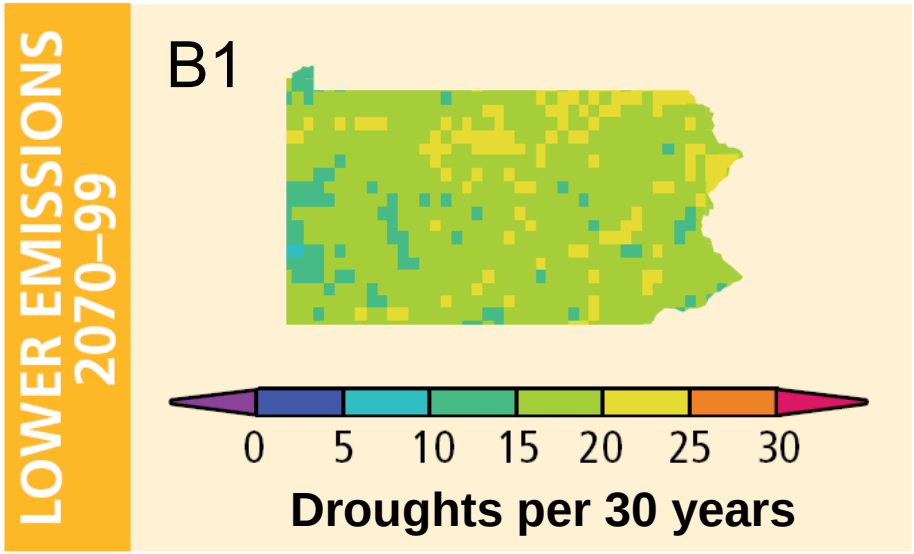


Source: NOAA (2011)

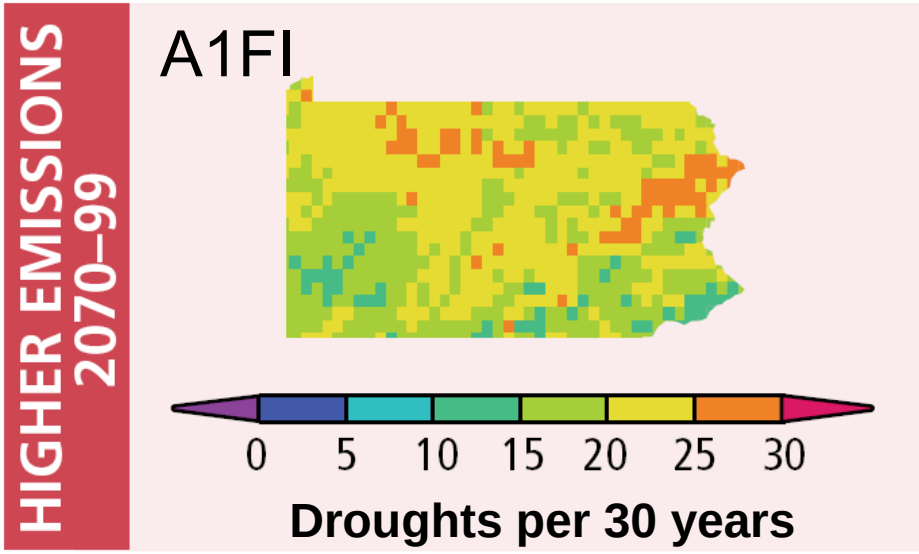

Odense Steel Shipyard Ltd.

Increasing summer drought



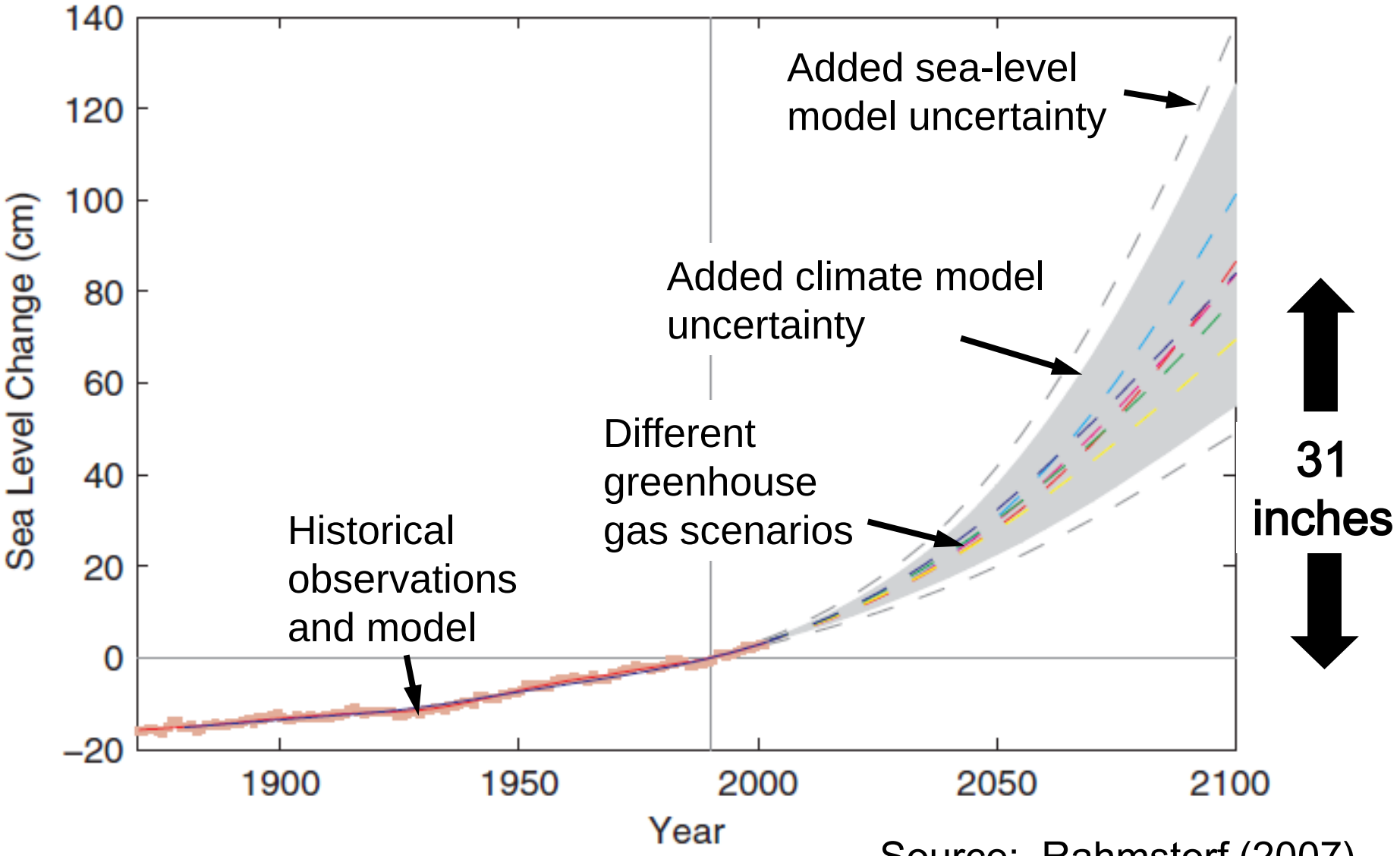


Under higher emissions, short-term drought frequency increases 50% by late century



Union of Concerned Scientists (2008)

Projected global sea-level change



Source: Rahmstorf (2007)

Subsidence: add 1-2 cm per decade

Other likely changes from heat-trapping emissions

- Increases in intense storms
- Increases in tidal range
- Flashier streamflow
- Reduced snowfall and snow cover
- Shifts in runoff from spring to winter
- Greater salinity variability in estuary

Sources: Najjar et al. (2010), Kreeger et al. (2010)

Implications for water resources

- *Manage the unavoidable*
  - Improve infrastructure
  - Reduce impervious surface
  - Increase efficiency
- *Avoid the unmanageable*
  - Dramatically reduce emissions

References

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