

What global warming means for water resources in the Delaware River Basin

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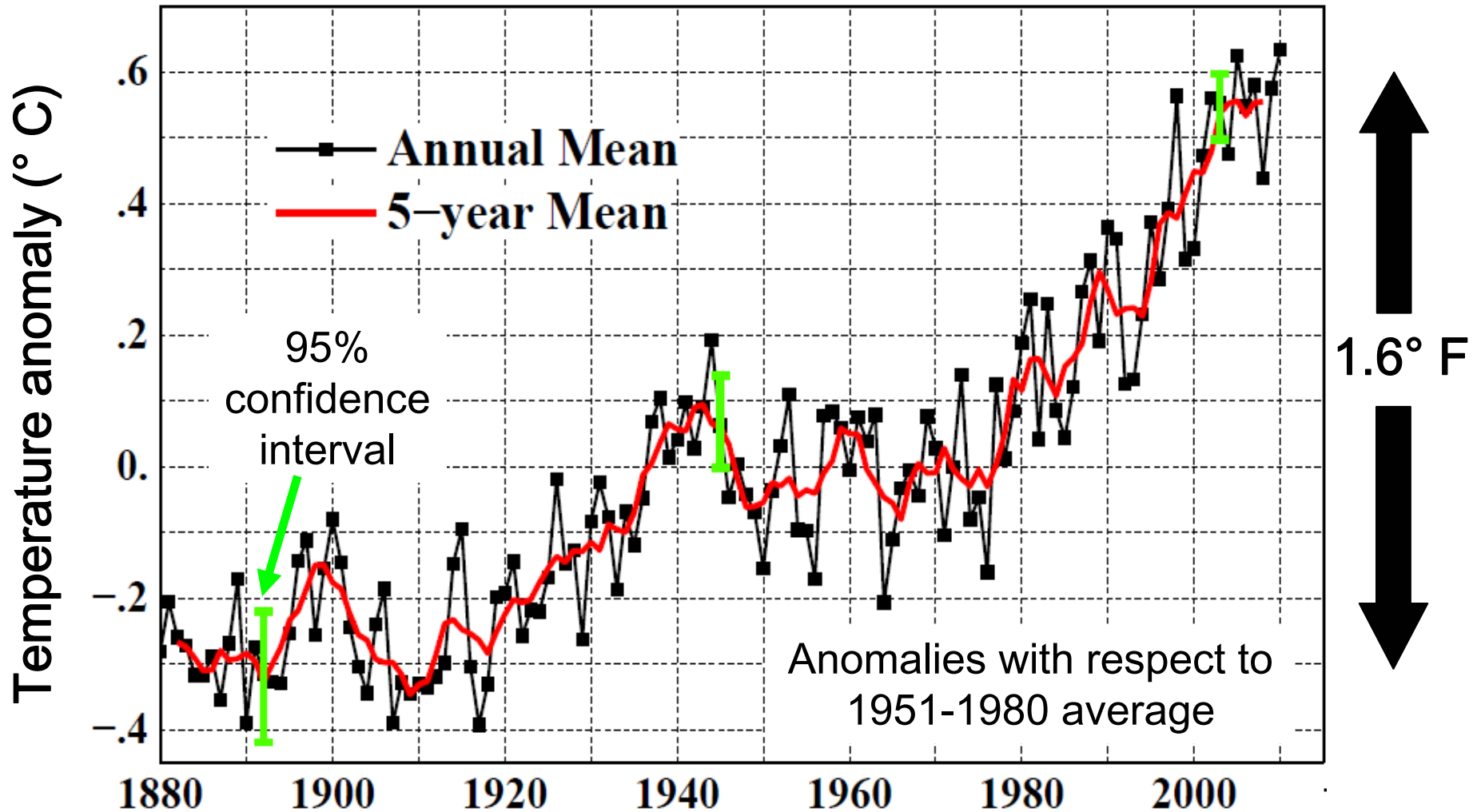
Department of Meteorology

The Pennsylvania State University

Delaware River Basin Forum

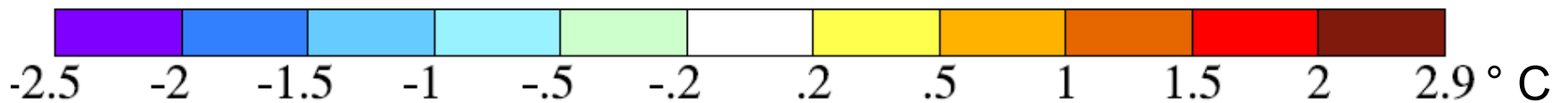
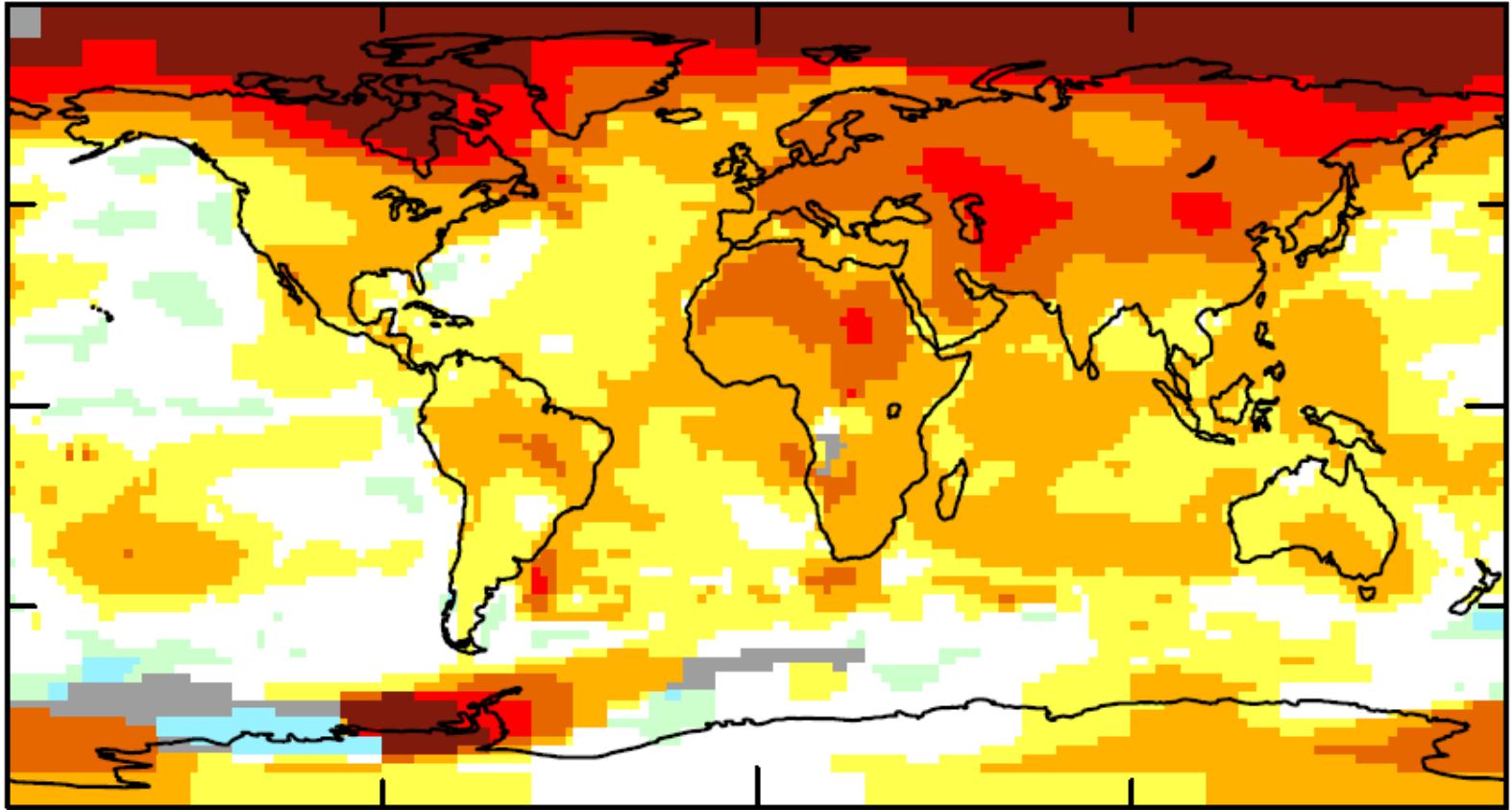
March 10, 2011

Global mean temperature change



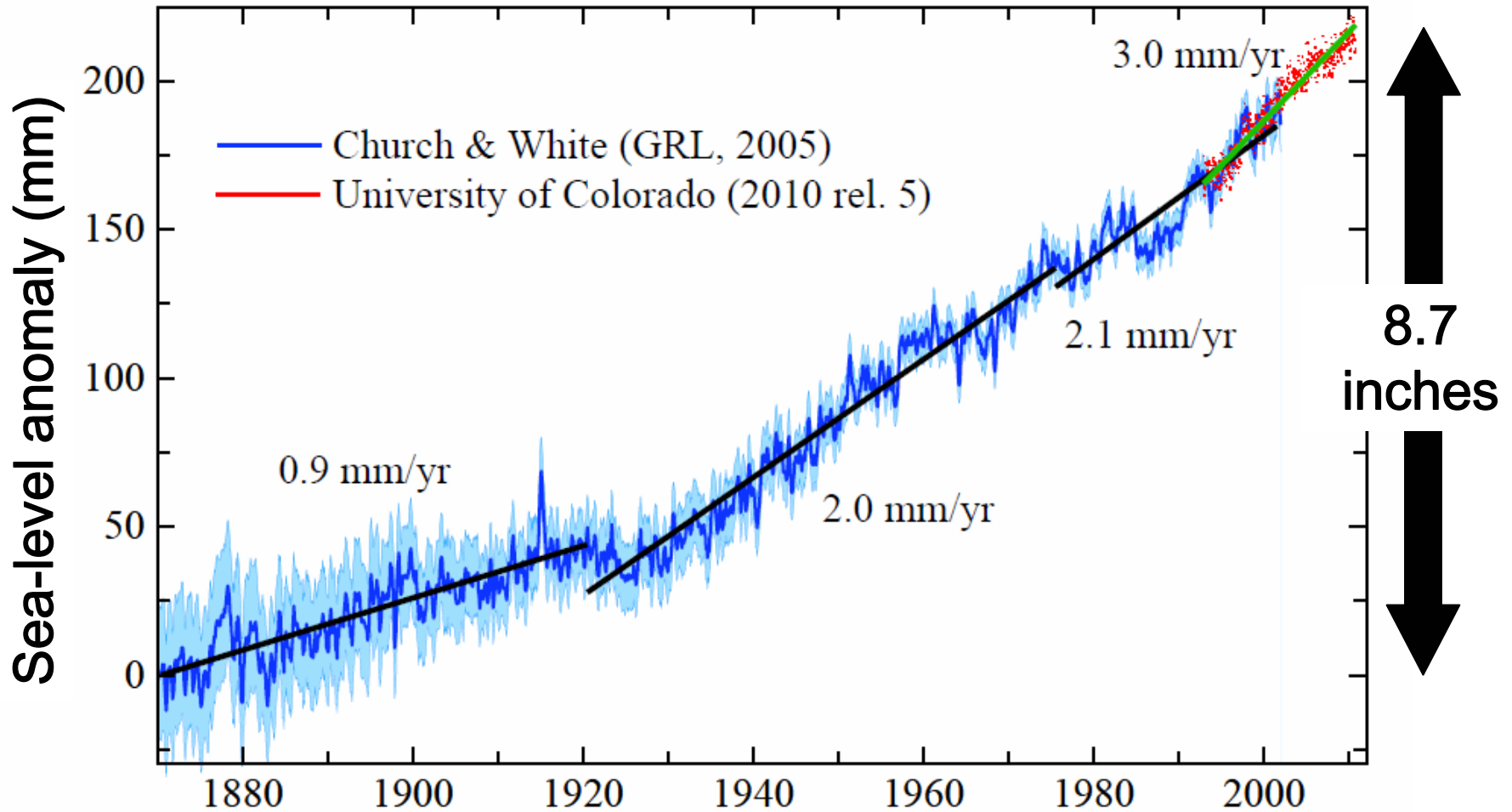
Source: Sato and Hansen (2011)

Surface temperature change ($^{\circ}$ C) 2006-2010 minus 1951-1980



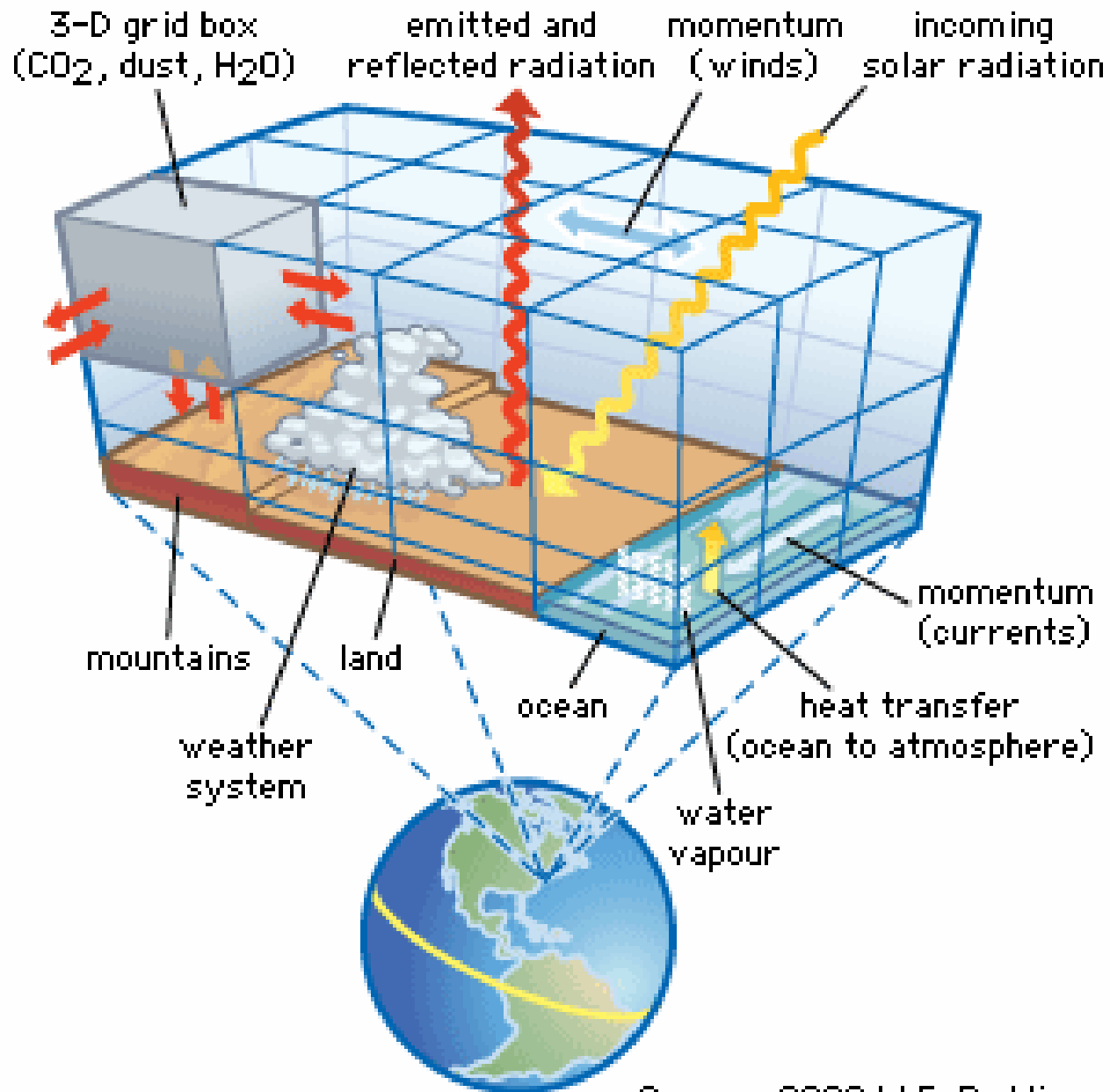
Source: Sato and Hansen (2011)

Global average sea-level change



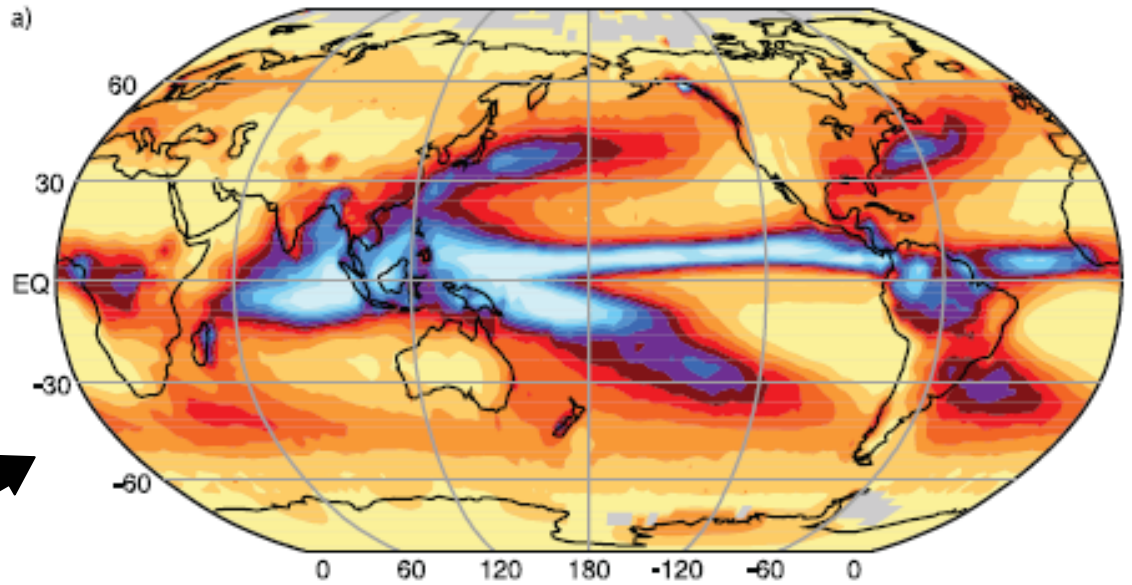
Source: Sato and Hansen (2011)

Concept diagram of climate modeling

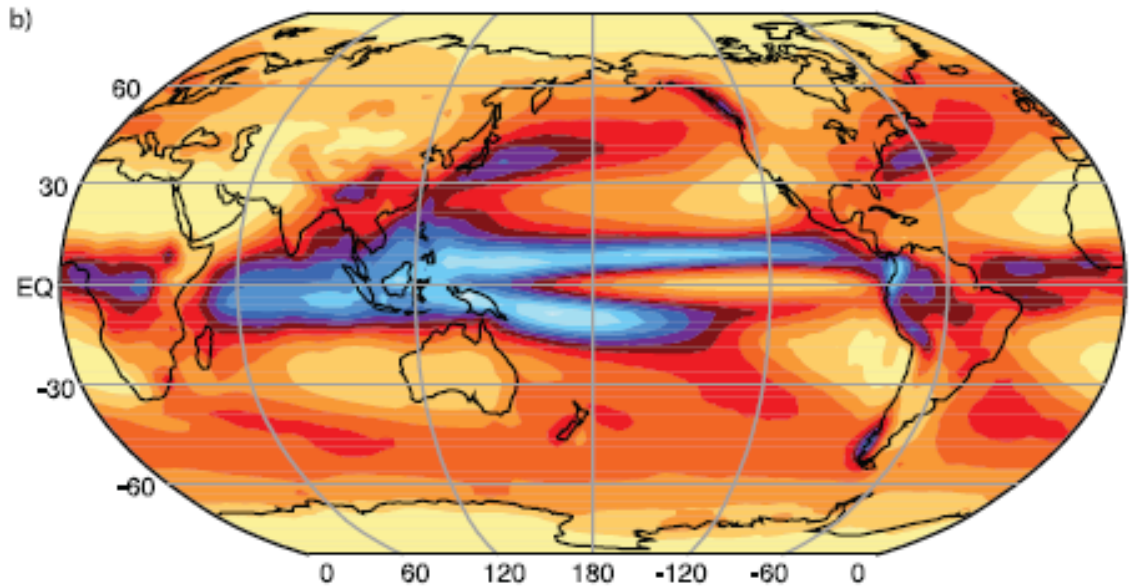


Annual precipitation

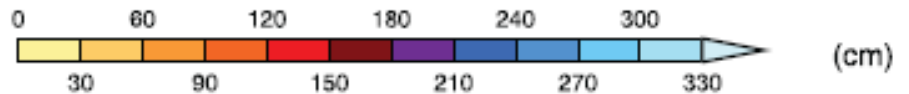
Simulated
(multi-model average)



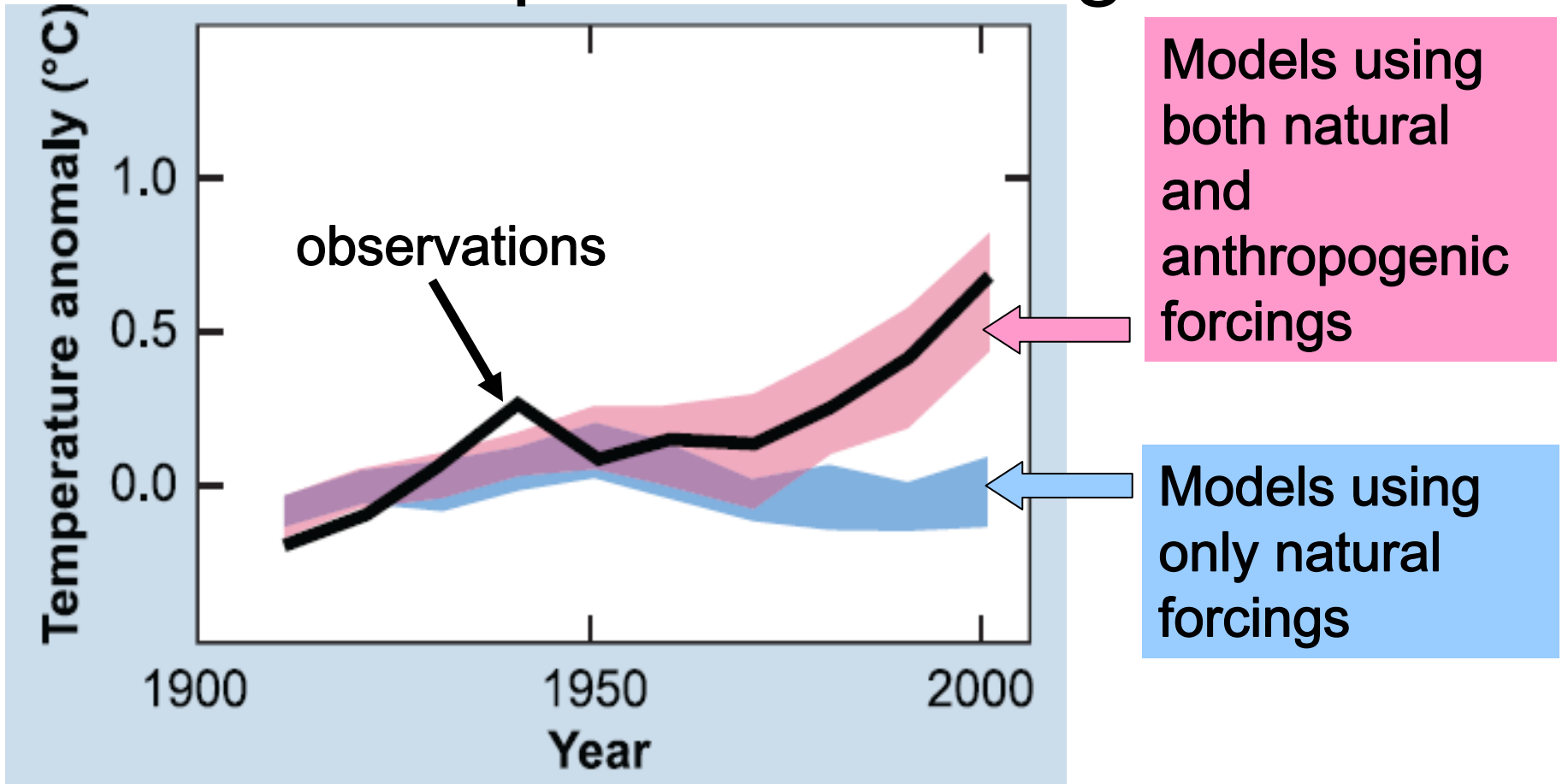
observed



Source: Randall et al. (2007)



Observed and simulated global temperature change



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

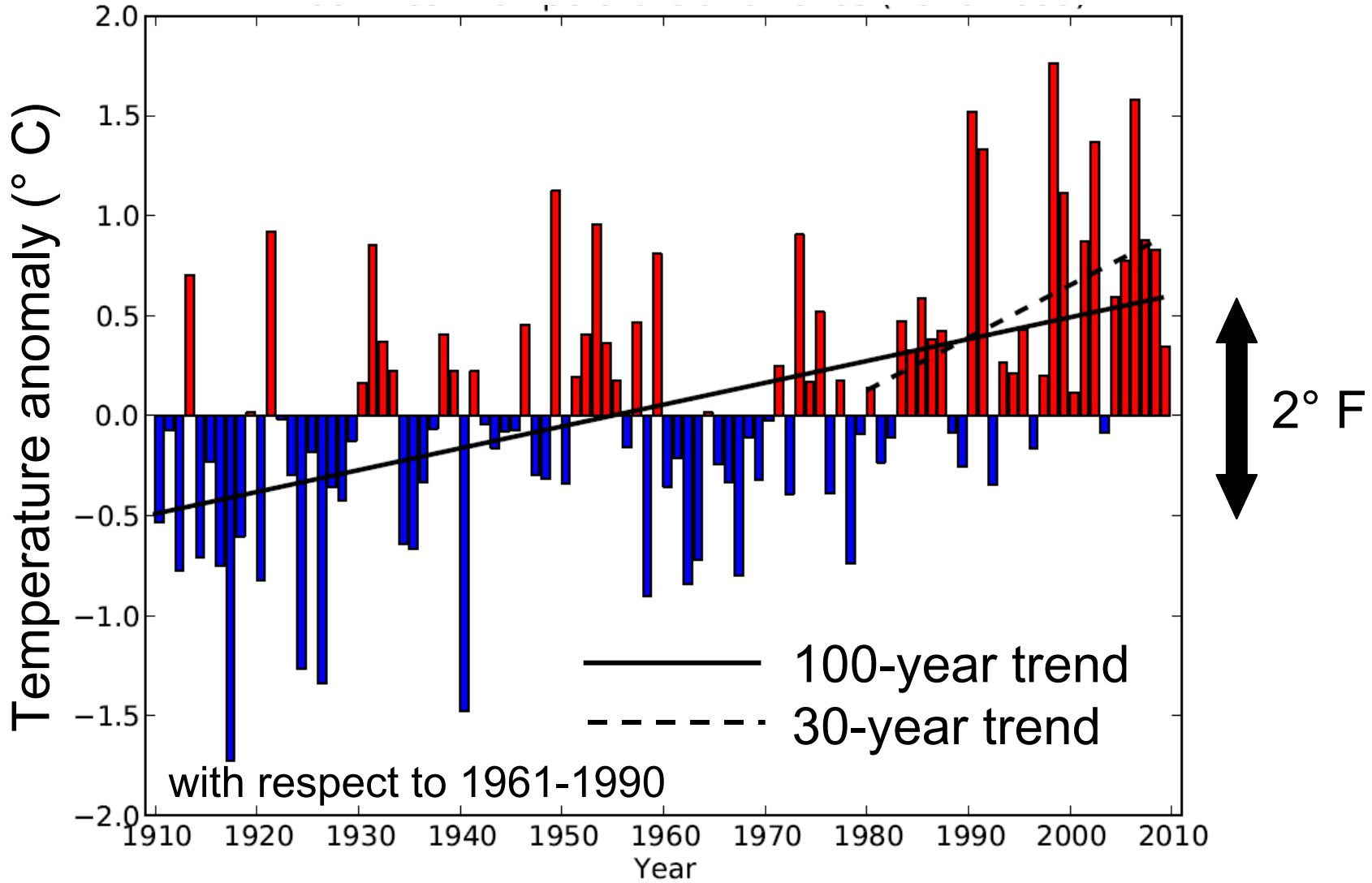
Is global warming mostly human-induced?

Survey says ...

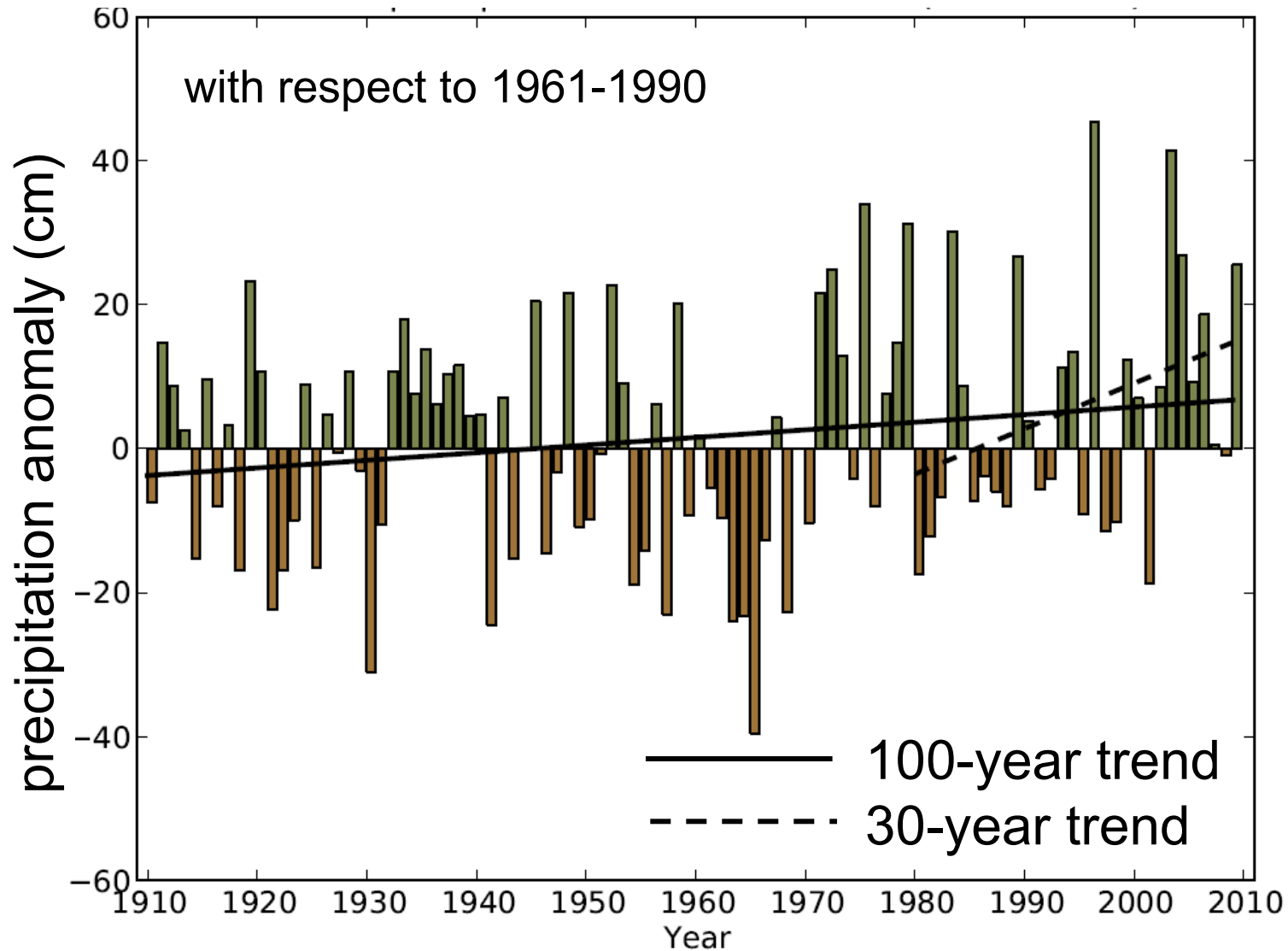
American public	34%
Active climate scientists	97%

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

Temperature change in the lower Delaware River Basin

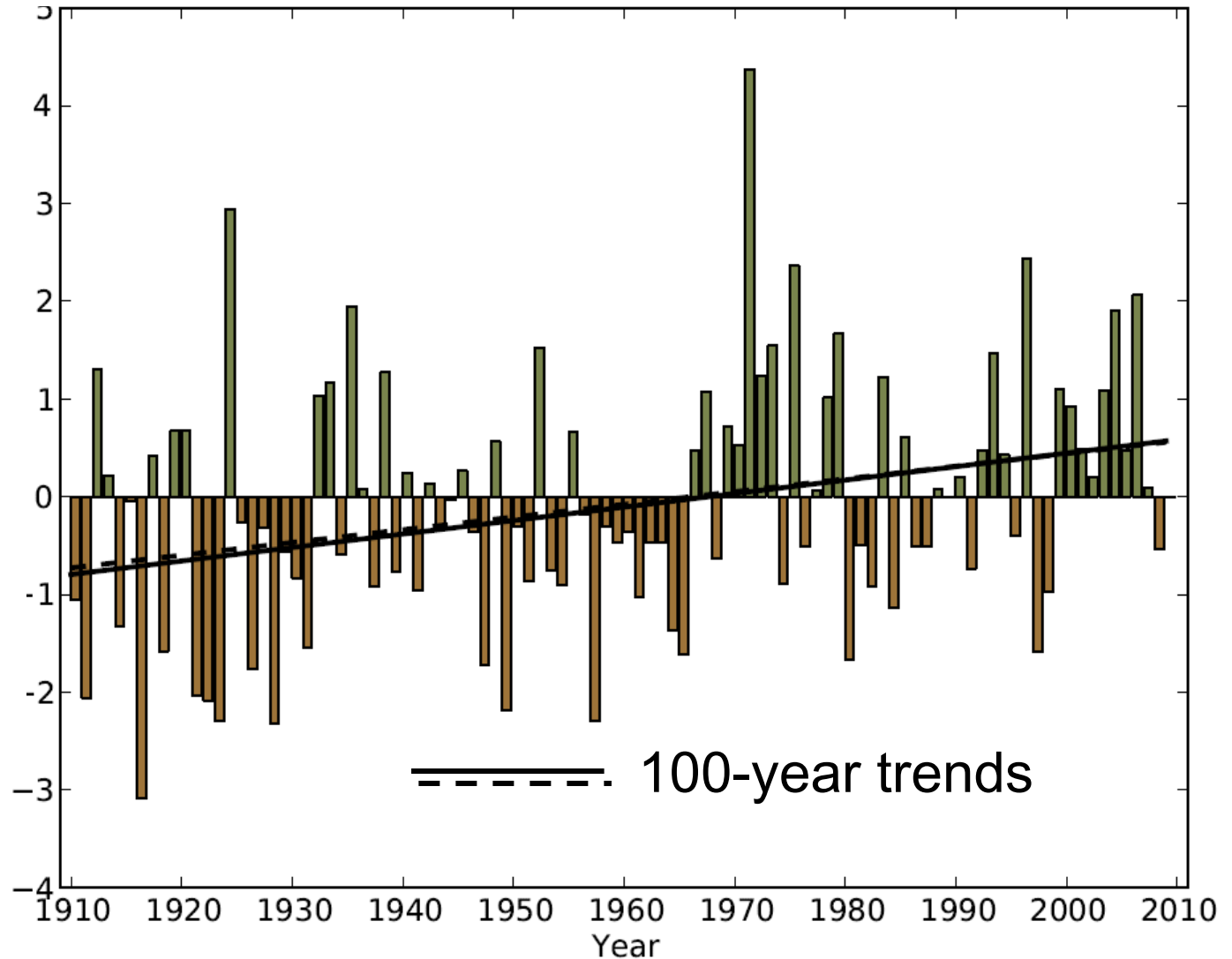


Precipitation change in the lower Delaware River Basin



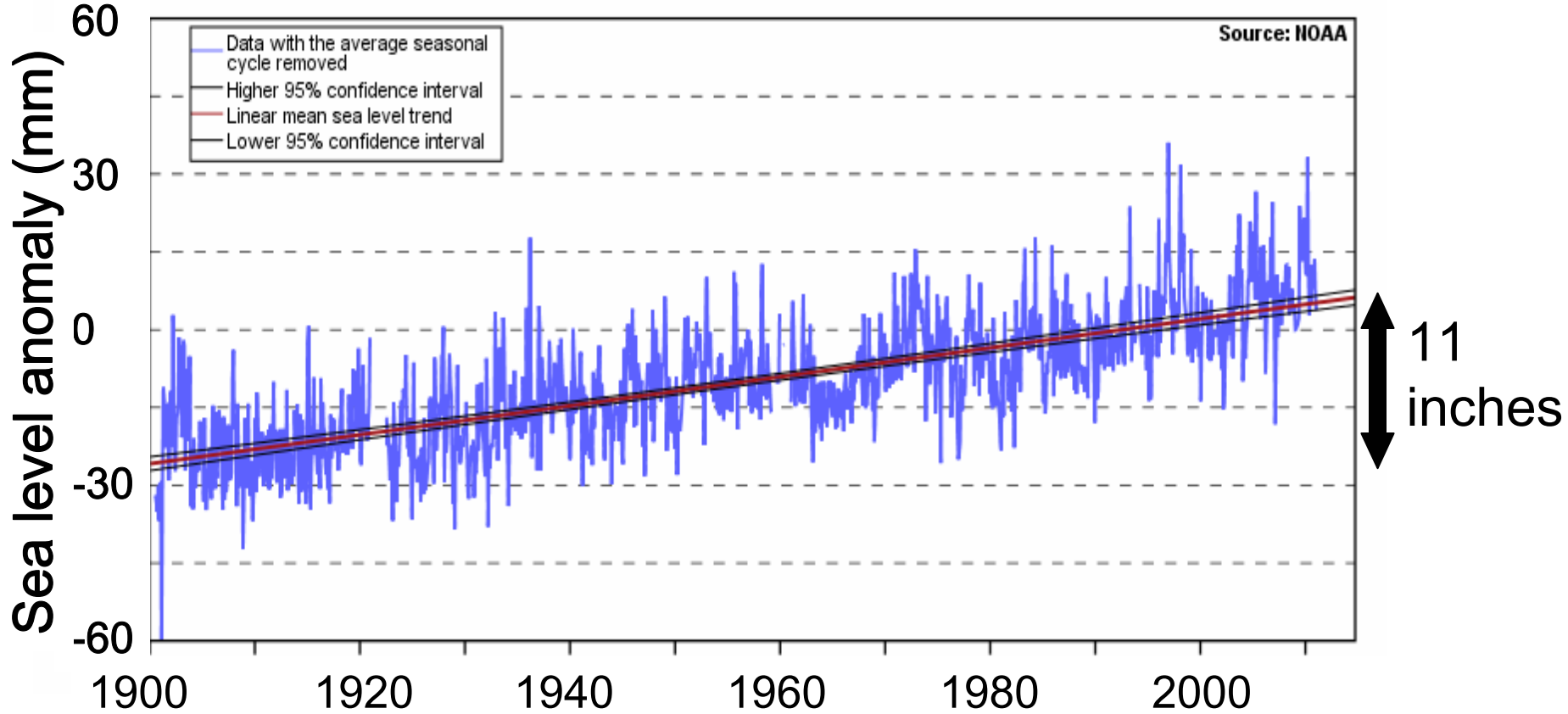
Heavy precipitation change in the lower Delaware River Basin

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



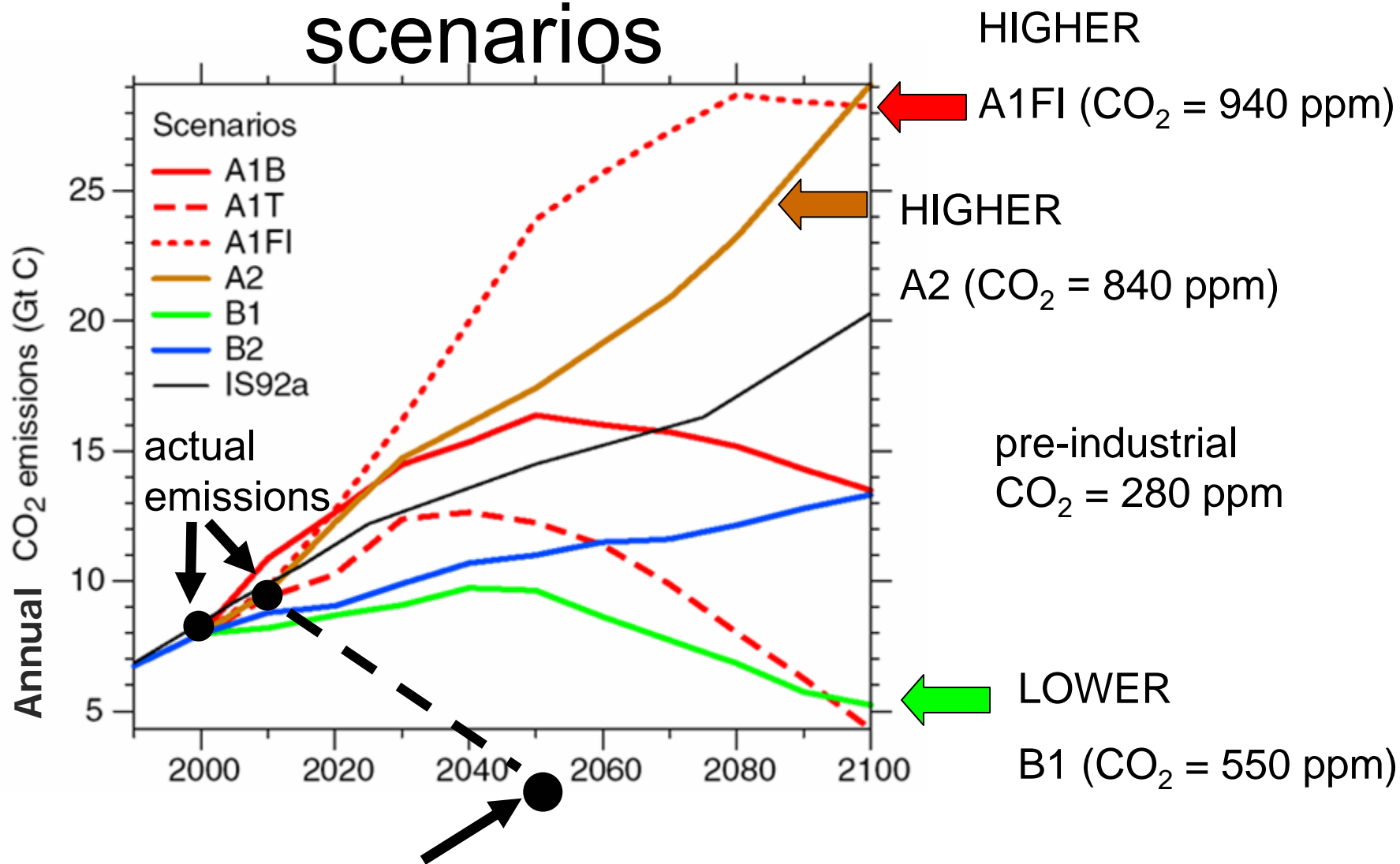
Water-level change at Philadelphia

Philadelphia, PA 2.79 ± 0.21 mm/yr



Source: NOAA (2011)

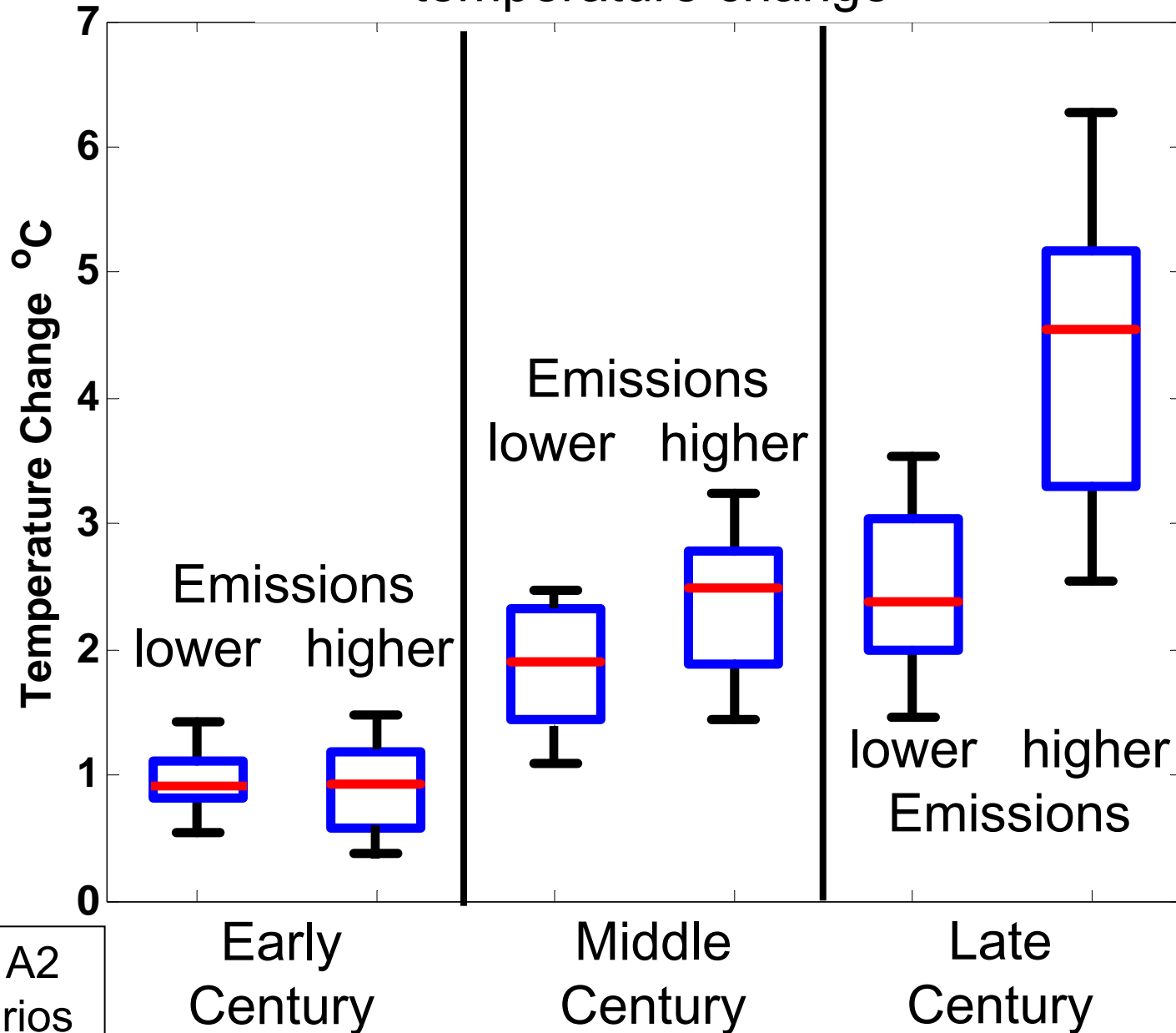
IPCC Emissions scenarios



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

Source: Nakićenović & Swart (2000)

Delaware River Basin summer temperature change



B1 & A2 scenarios

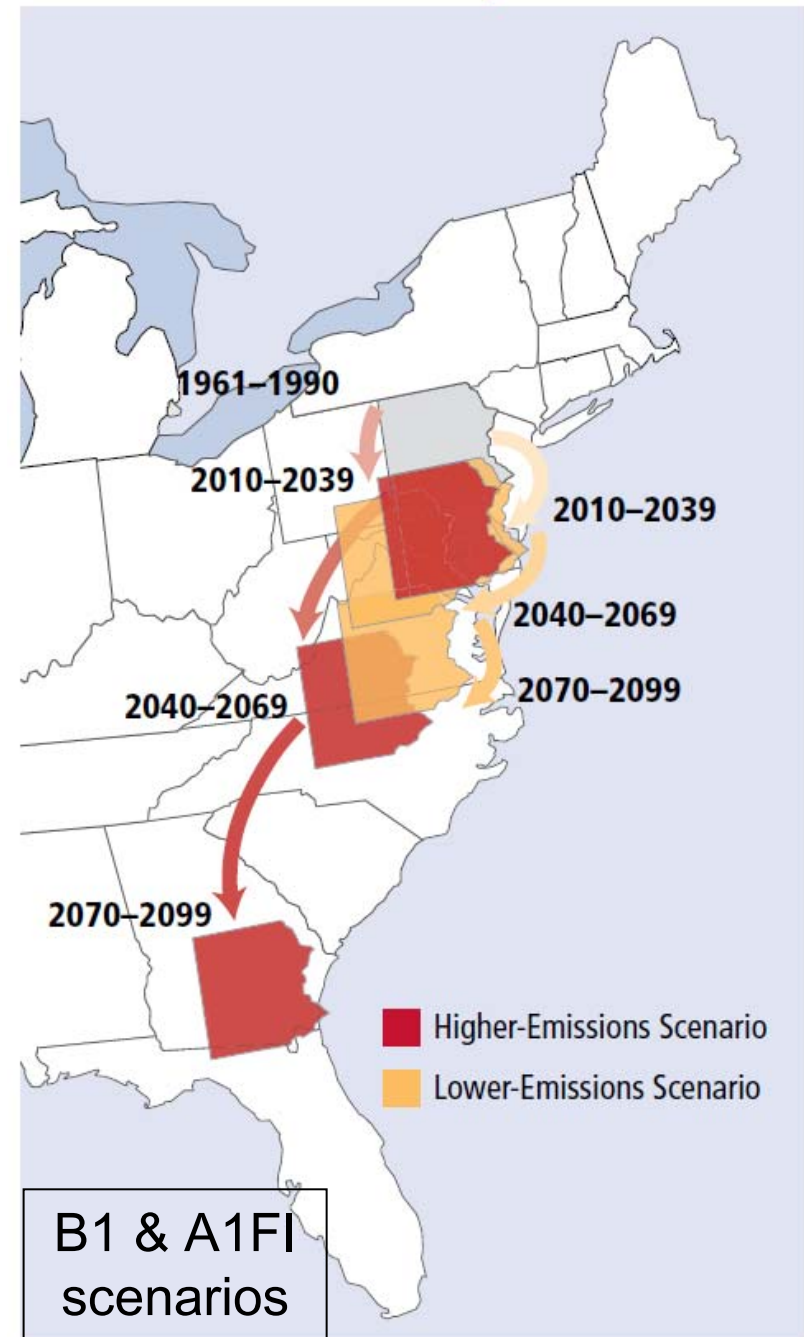


Odense Steel Shipyard Ltd.

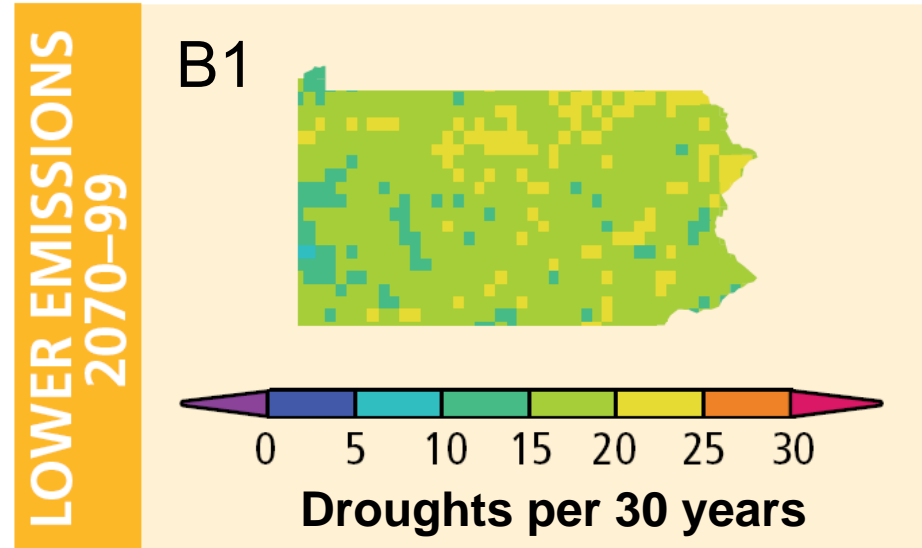
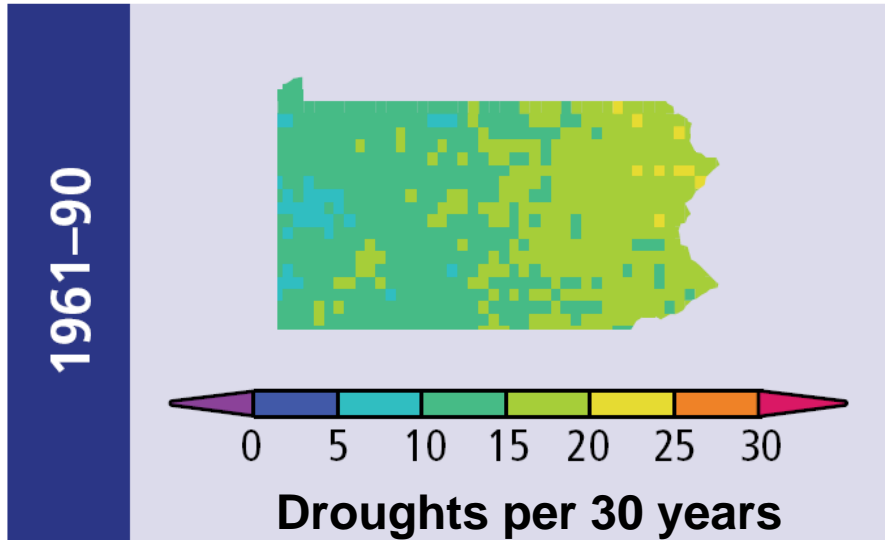
Summer heat index change

Heat index depends on temperature and humidity

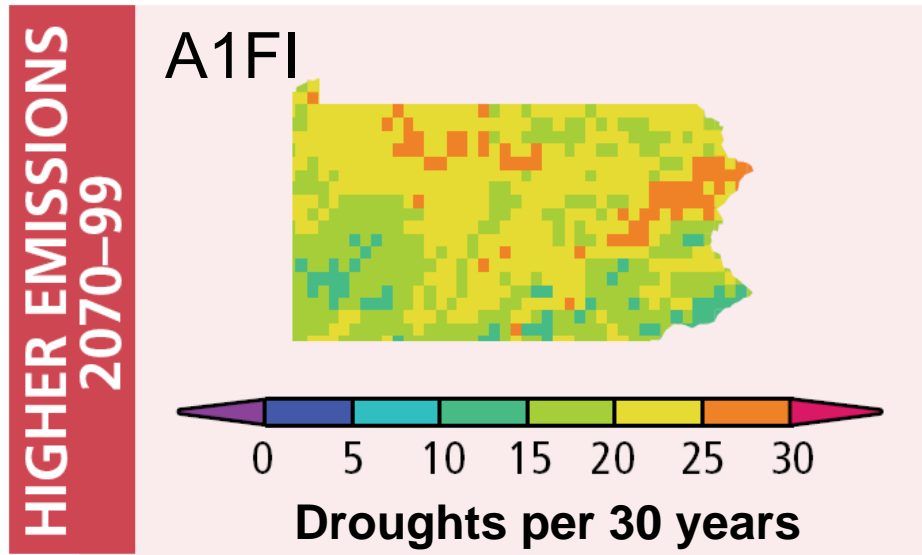
Source: Union of Concerned Scientists (2008)



Increasing summer drought



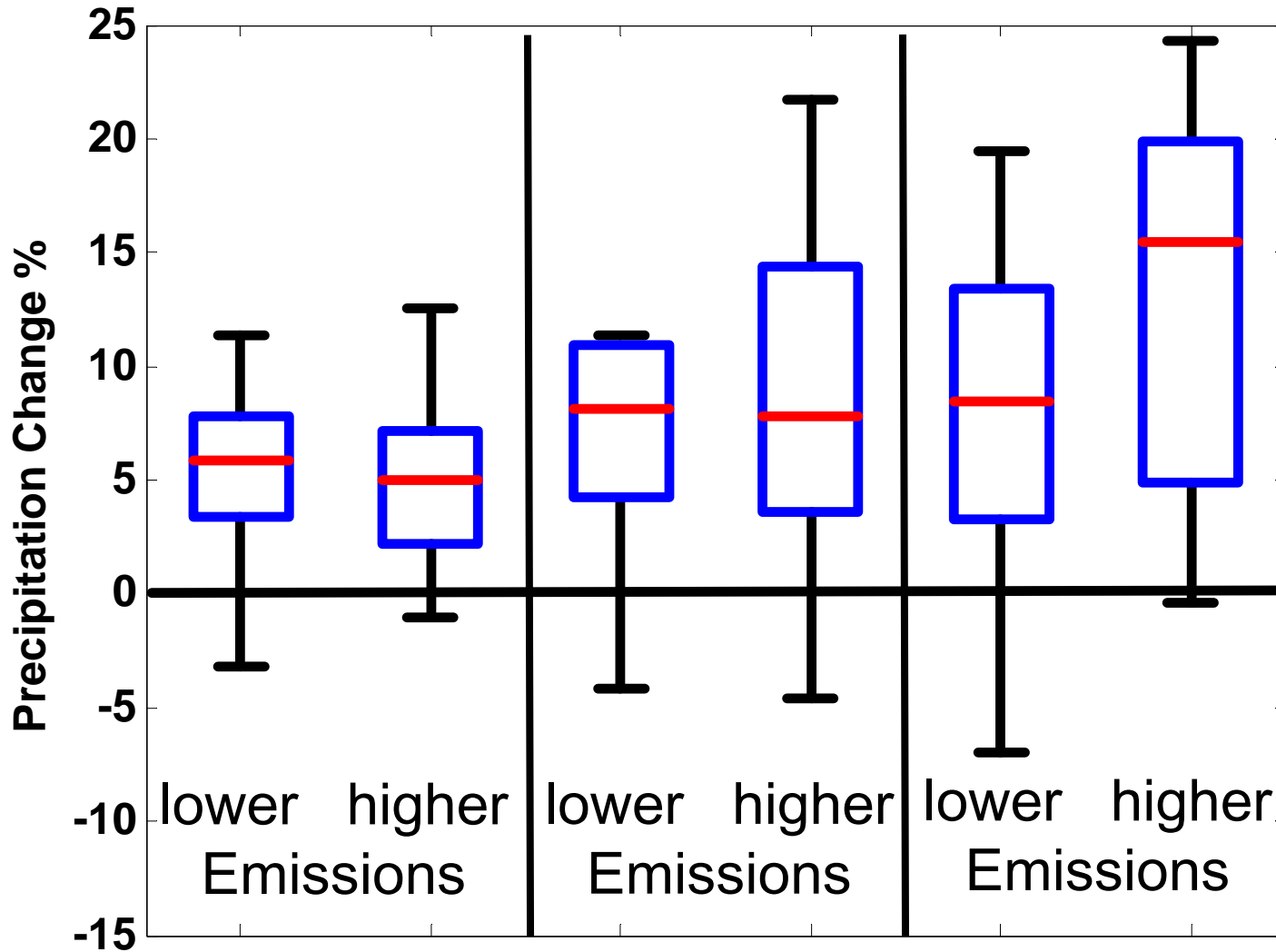
Under higher emissions, short-term drought frequency increases 50% by late century



Drought implications

- Water availability
- Reservoir storage
- Salt water intrusion

Delaware River Basin winter precipitation change



B1 & A2 scenarios

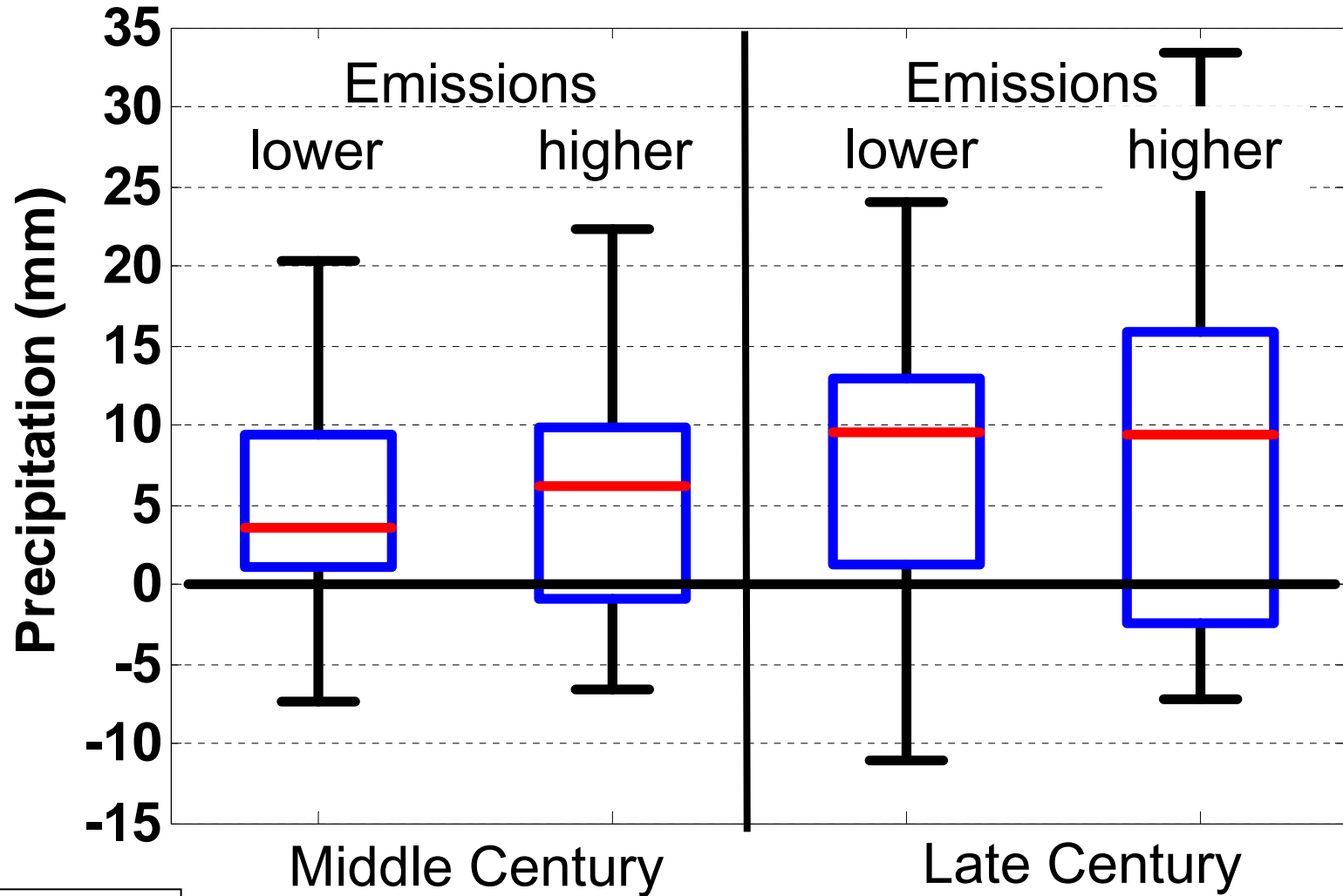
Early Century

Middle Century

Late Century

Delaware River Basin

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

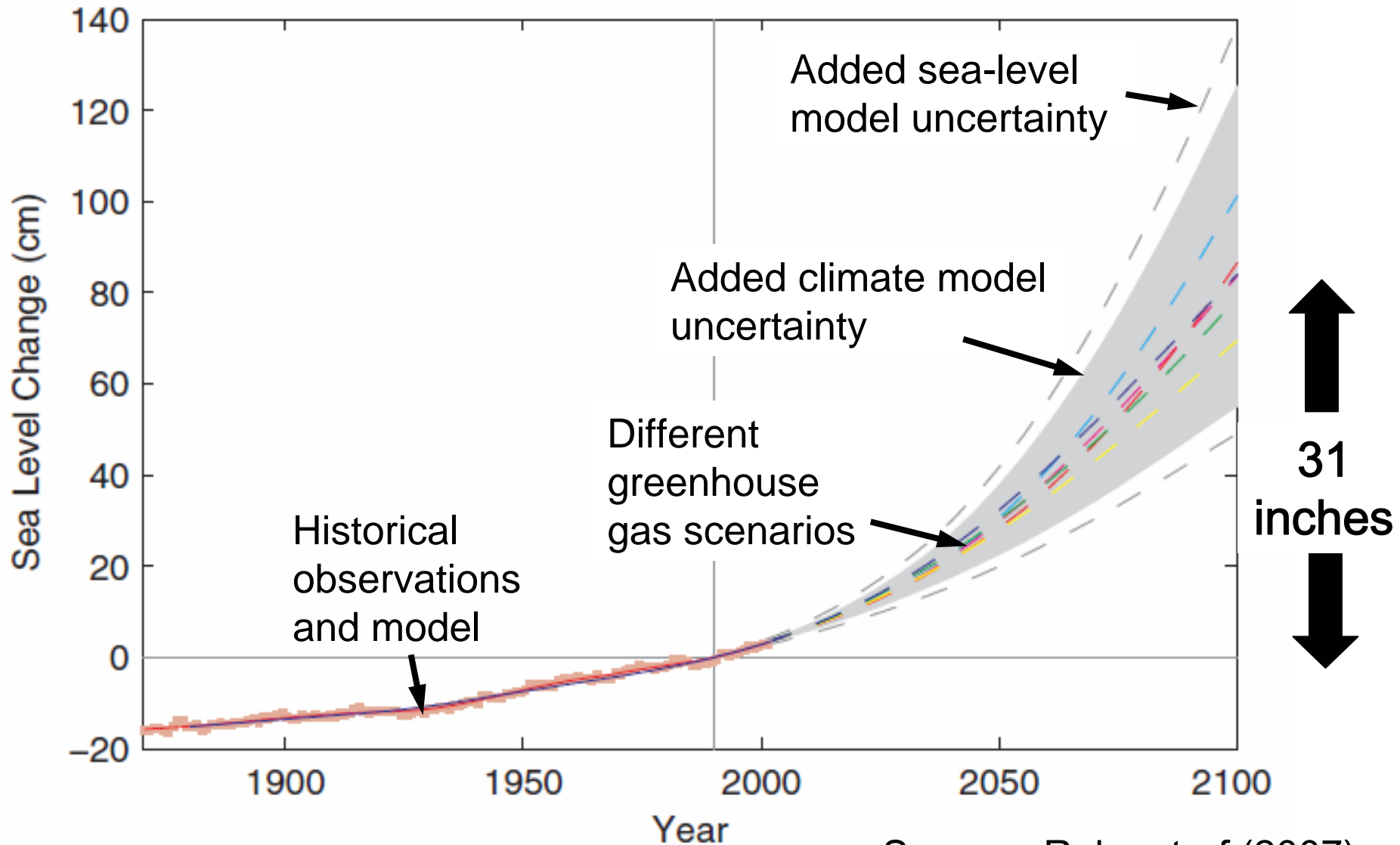


B1 & A2
scenarios

Implications of increased intense precipitation

- Flooding
- Water quality declines
- Treatment plant overflows

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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Thank you