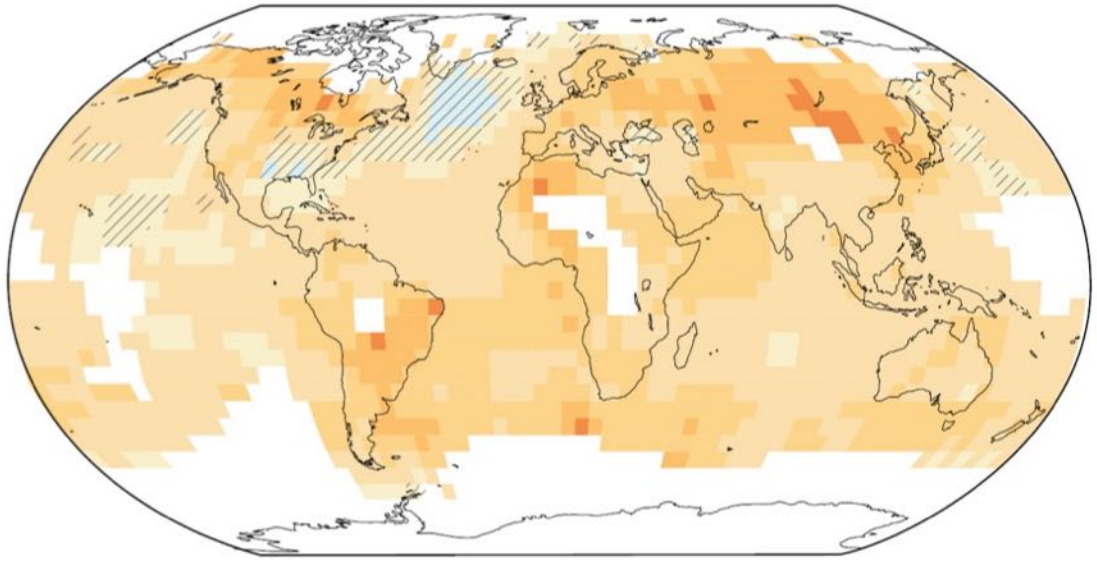
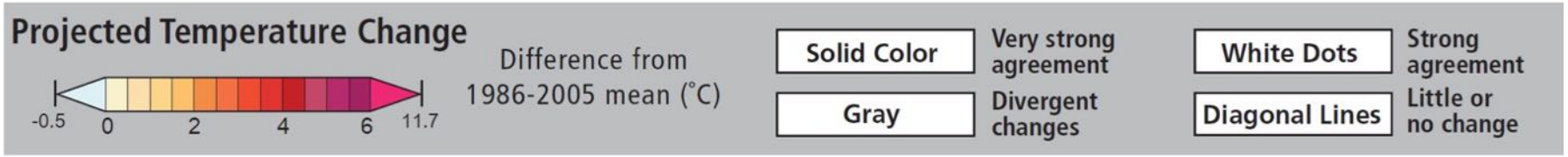
Future Climate Change

Module 8

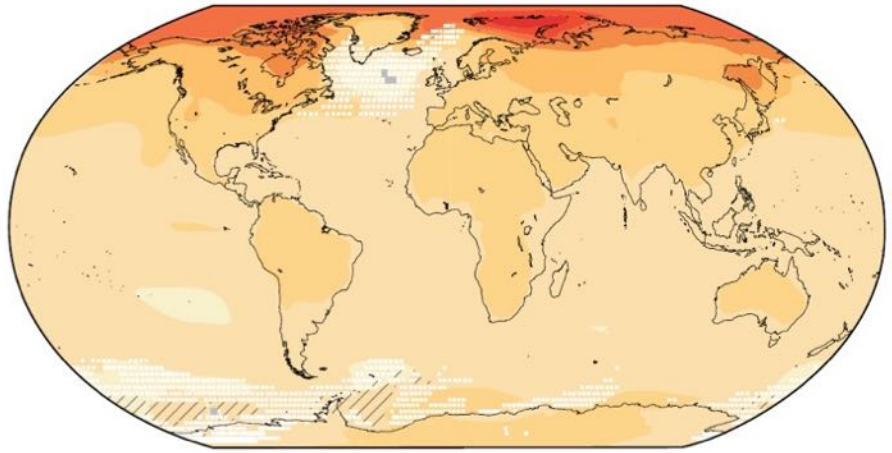
Observed Change 1901-2012



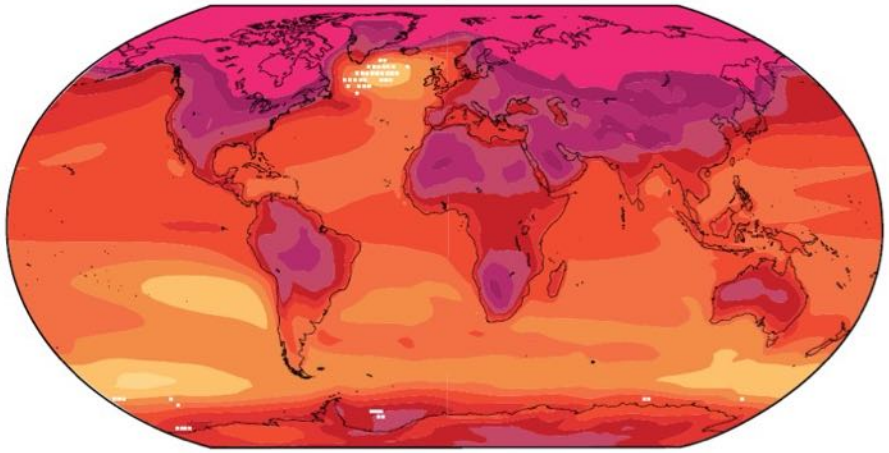
Big Choices



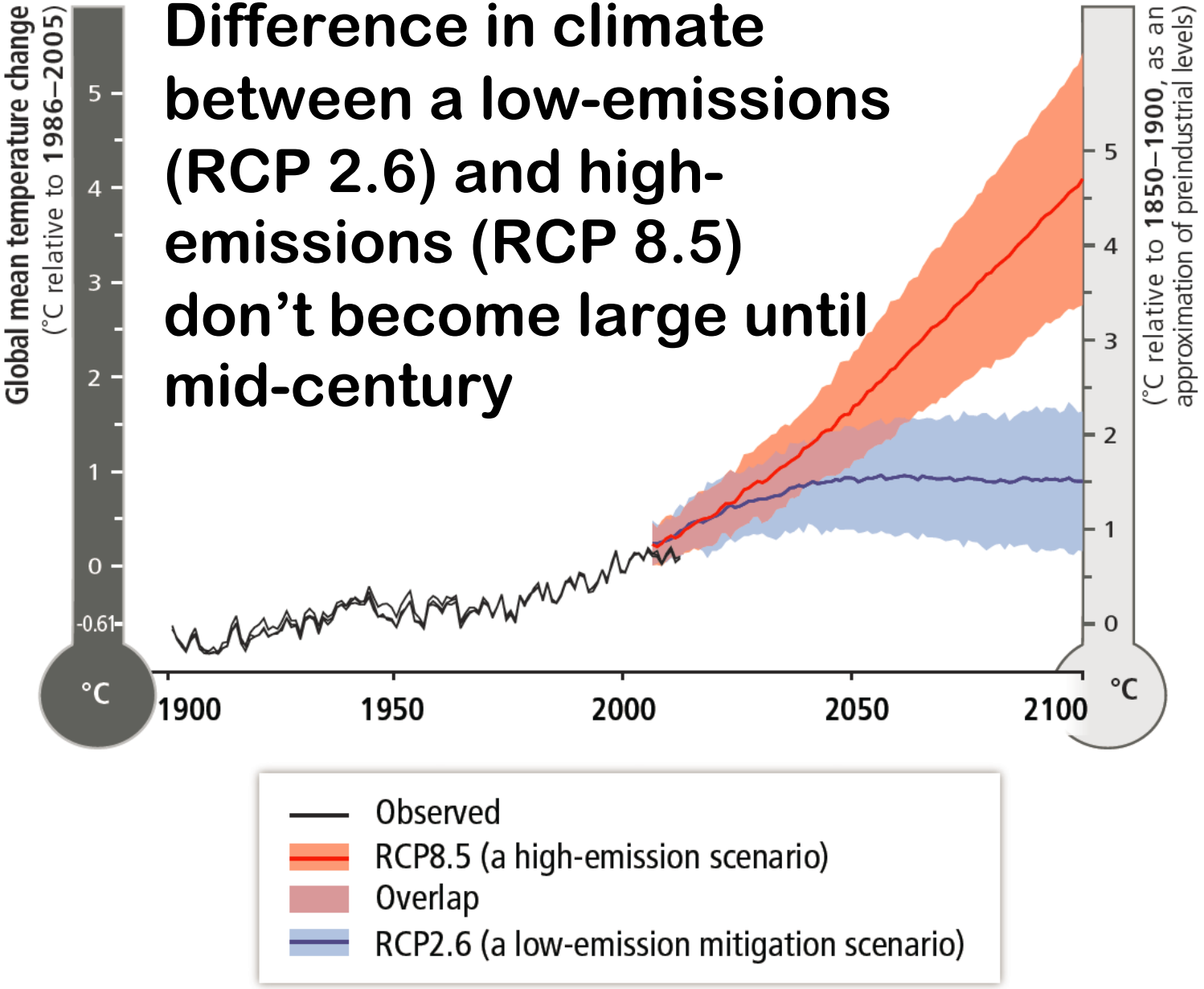
RCP2.6 2081 - 2100



RCP8.5 2081 - 2100

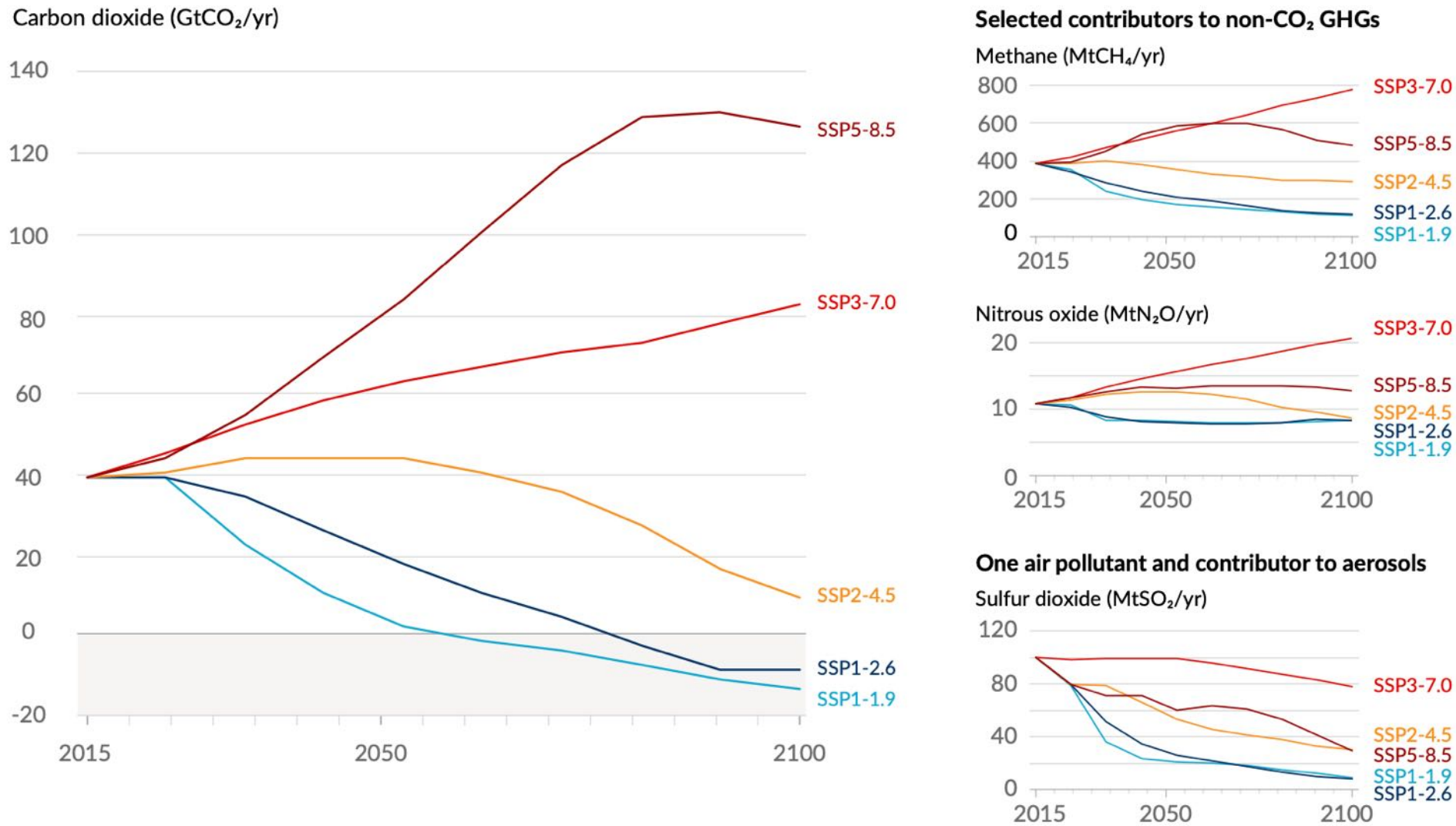


Past and Future



Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios

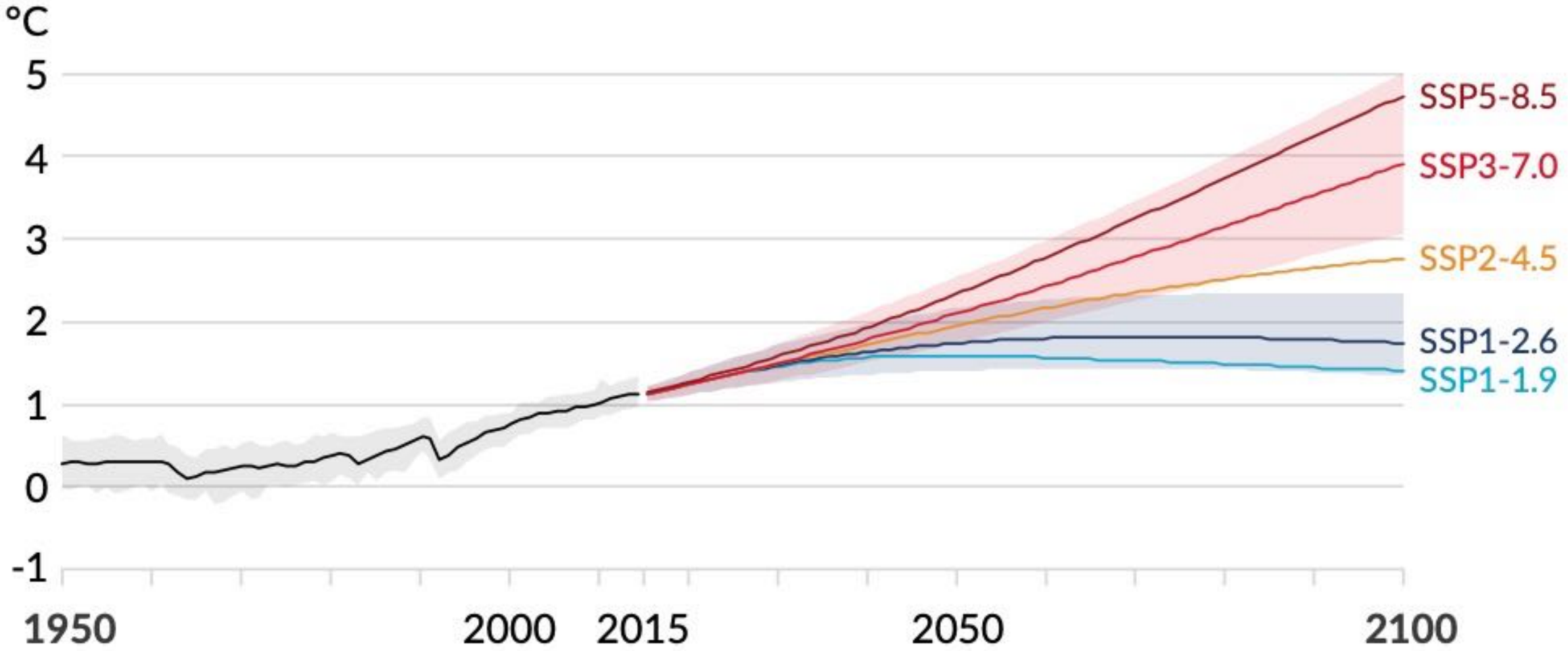


How much warmer?

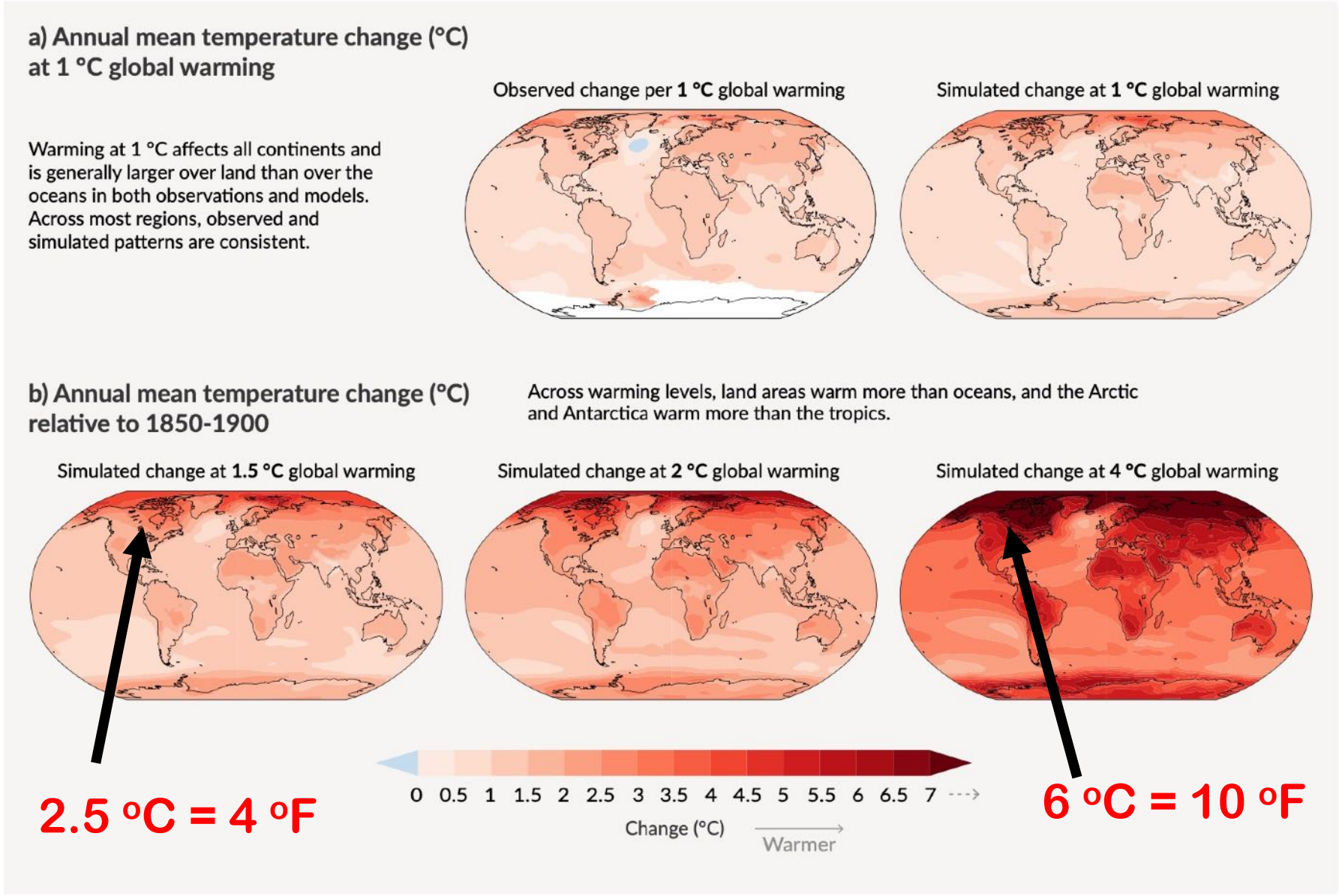
	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

How much warmer?

a) Global surface temperature change relative to 1850-1900



With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture



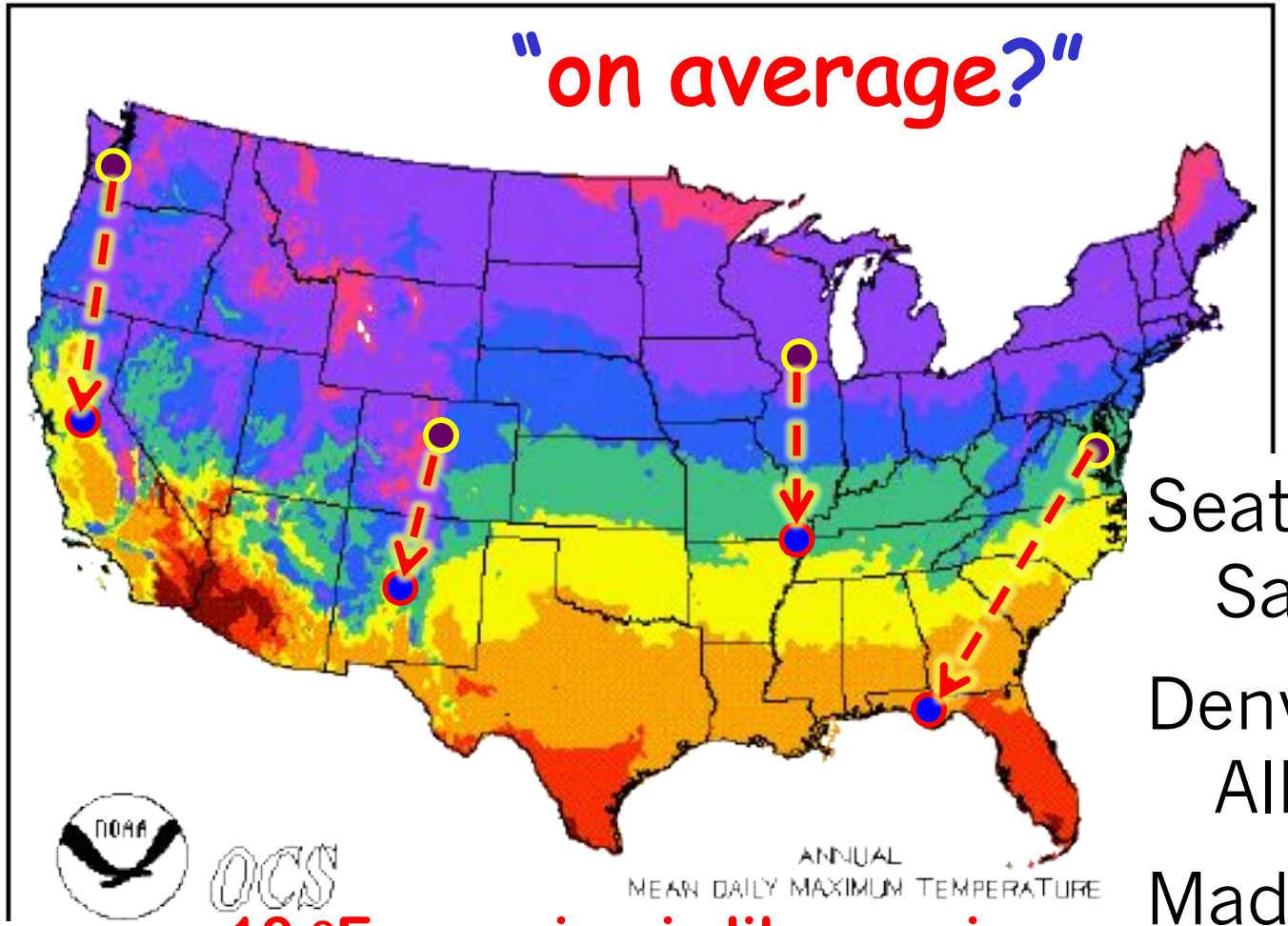
- Models reproduce observed spatial pattern
- Land vs Oceans
- N vs S
- Arctic!

Interior North America

- 4 °F with low emissions
- 10 °F with high emissions!

Where is it 10º F Warmer

"on average?"



10 ºF warming is like moving 600 – 800 miles South!

Water? *Crops?*

Real Estate? *Health?*

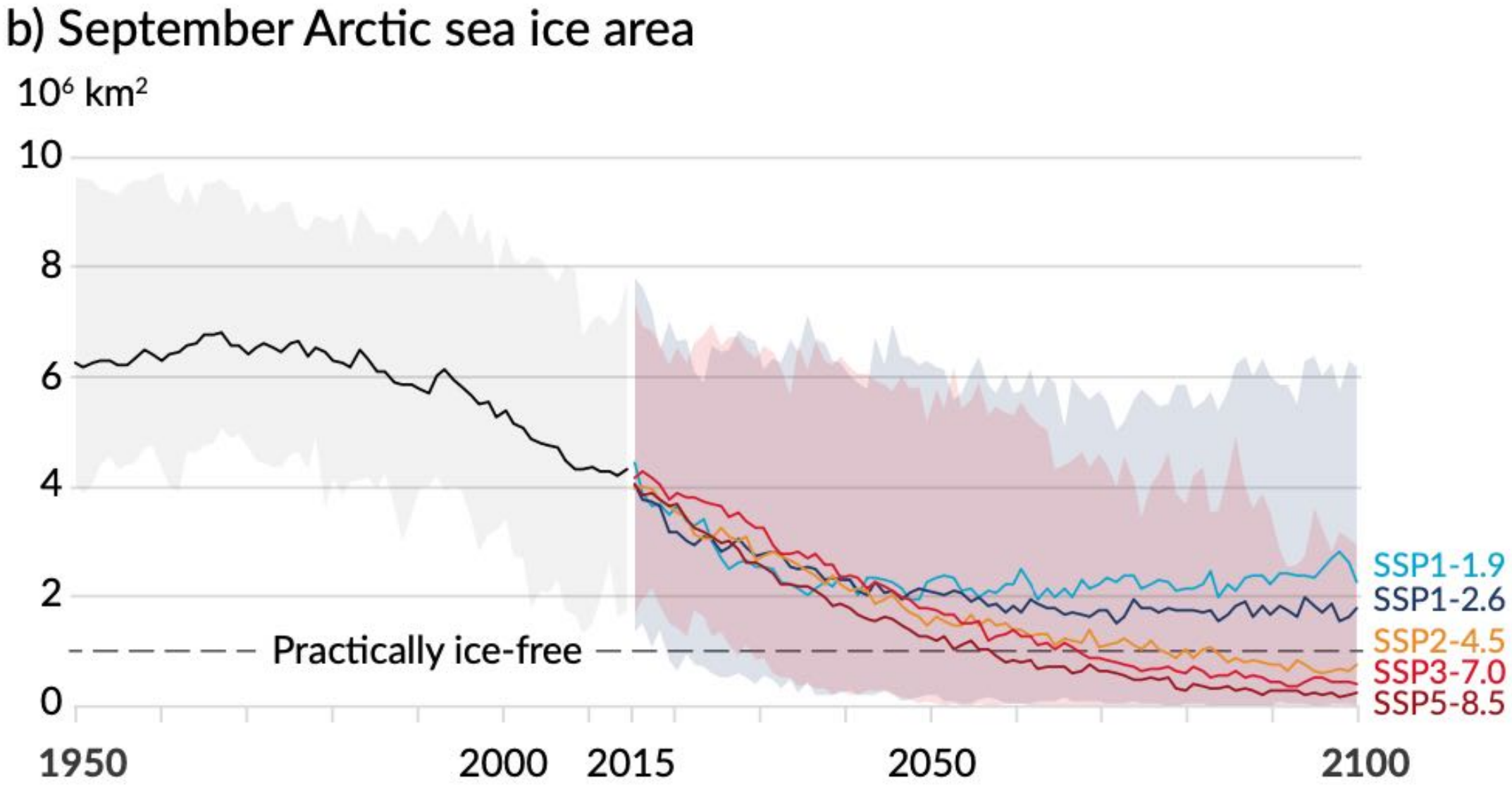
Seattle ➔ Sacramento

Denver ➔ Albuquerque

Madison ➔ Memphis

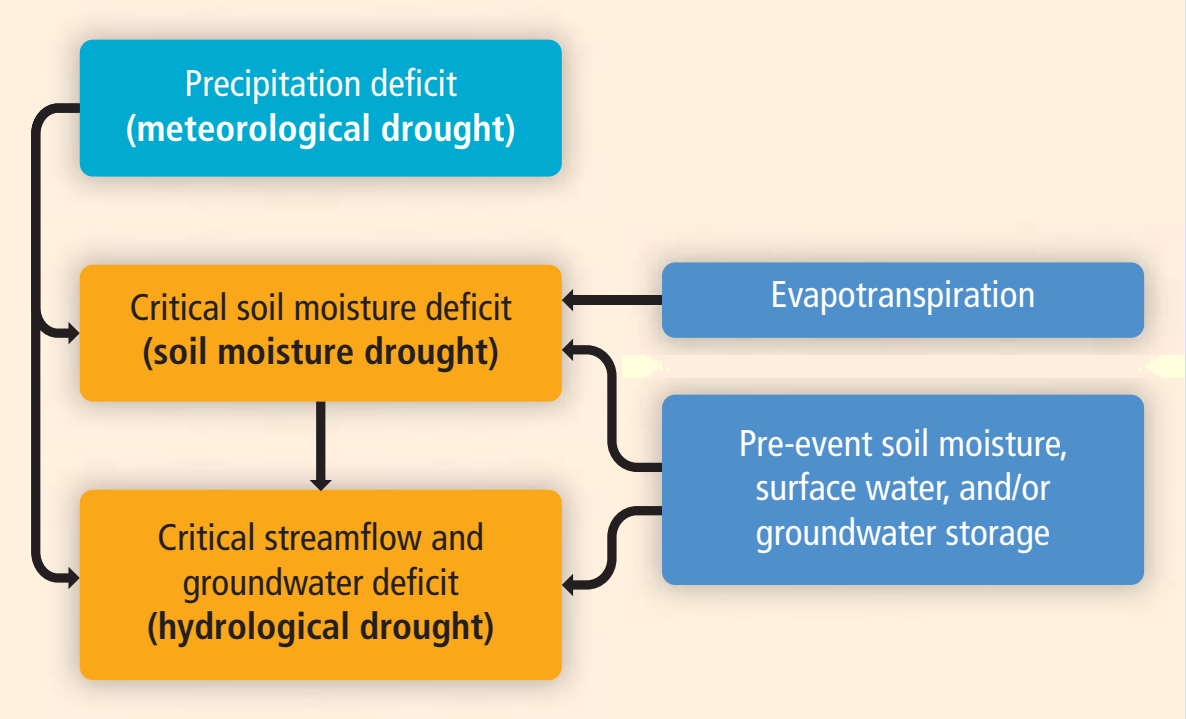
Washington DC ➔ Tallahassee

Sea Ice Changes



Drought and Water Stress

What is Drought?



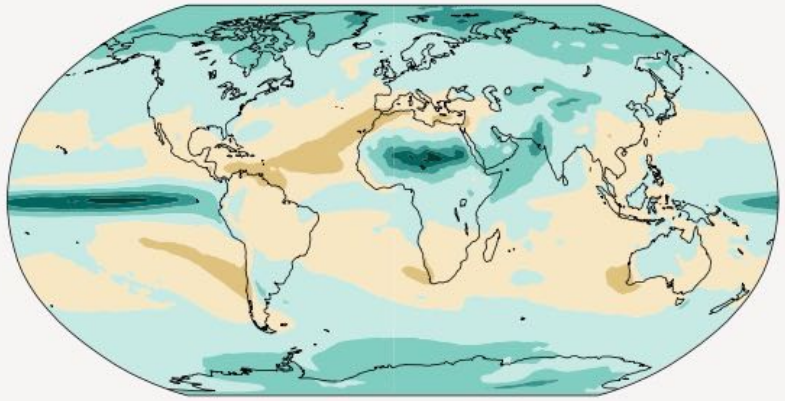
- Drought doesn’t just happen when it doesn't rain enough
- Also depends on evaporation losses and our ability to tap stored water in wells and reservoirs

Precipitation Changes

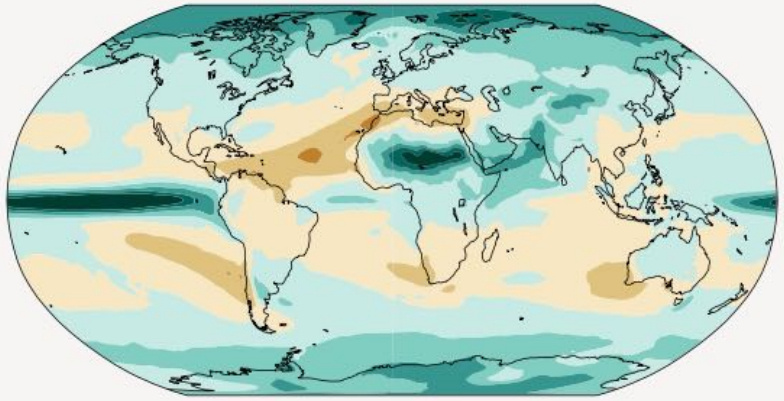
c) Annual mean precipitation change (%) relative to 1850-1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

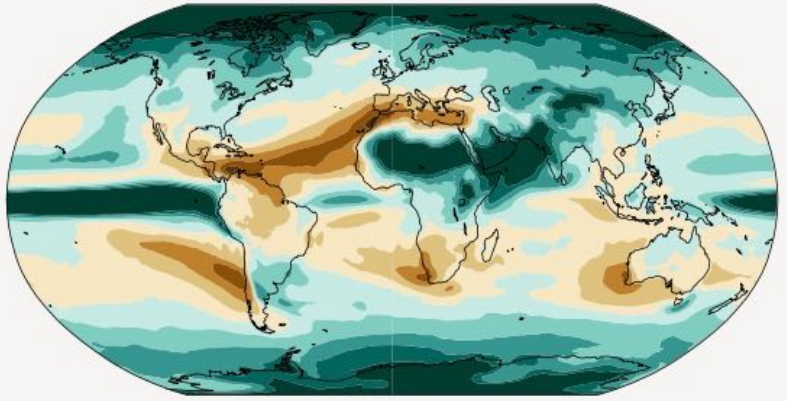
Simulated change at **1.5 °C** global warming



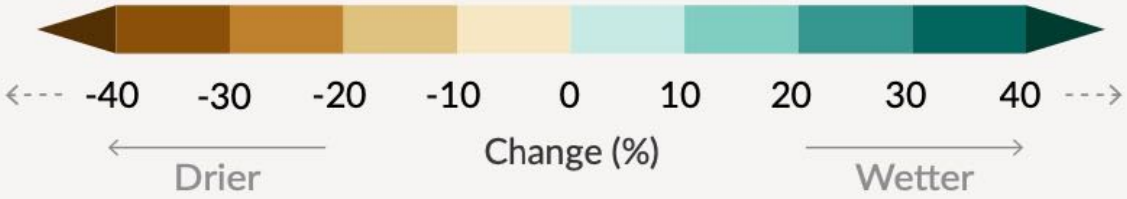
Simulated change at **2 °C** global warming



Simulated change at **4 °C** global warming

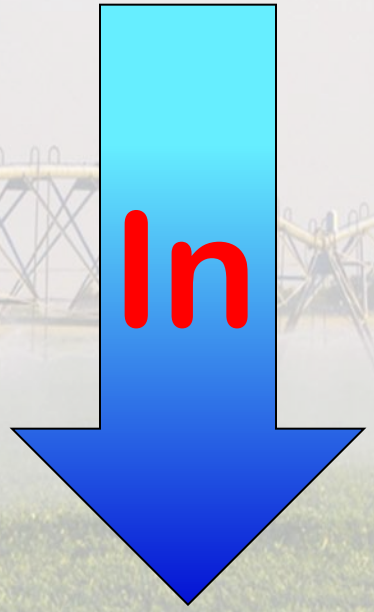


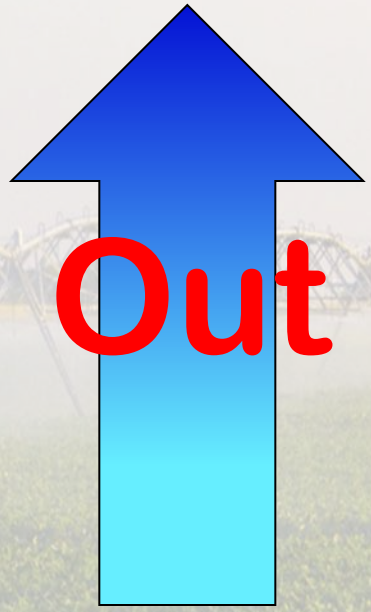
Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions



Water Budgets

Evaporative demand increases w/ temperature





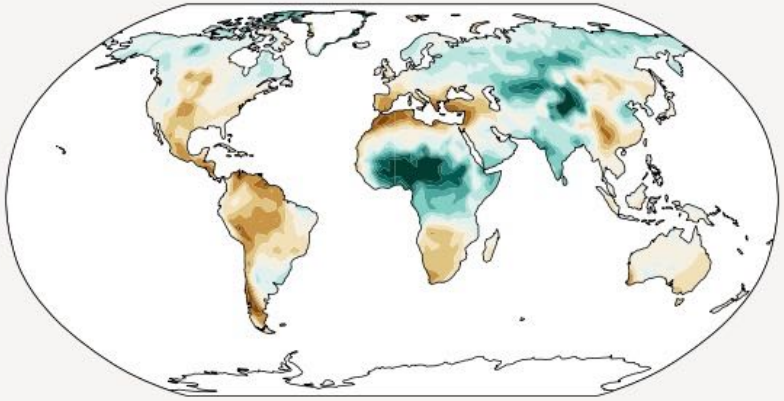
Drought is the *running sum* of water out minus water in

Changes in Soil Moisture

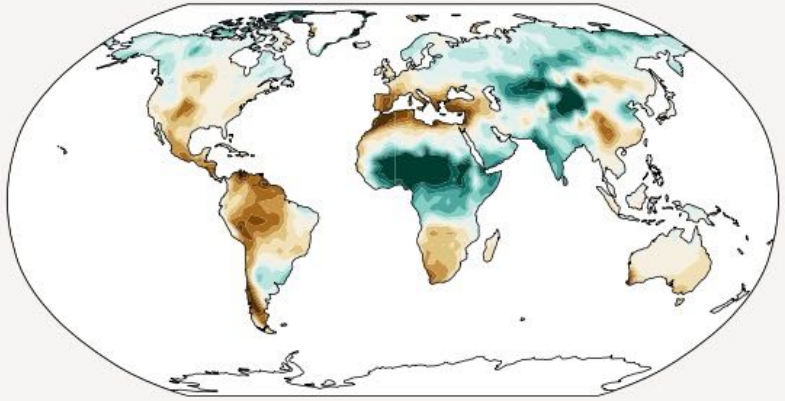
d) Annual mean total column soil moisture change (standard deviation)

Across warming levels, changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.

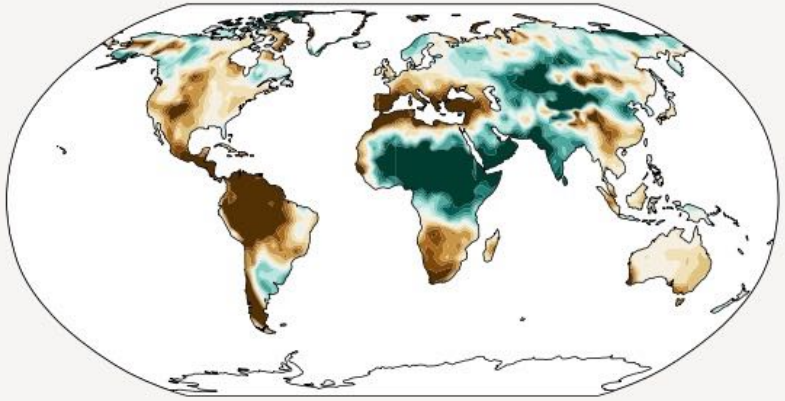
Simulated change at **1.5 °C** global warming



Simulated change at **2 °C** global warming

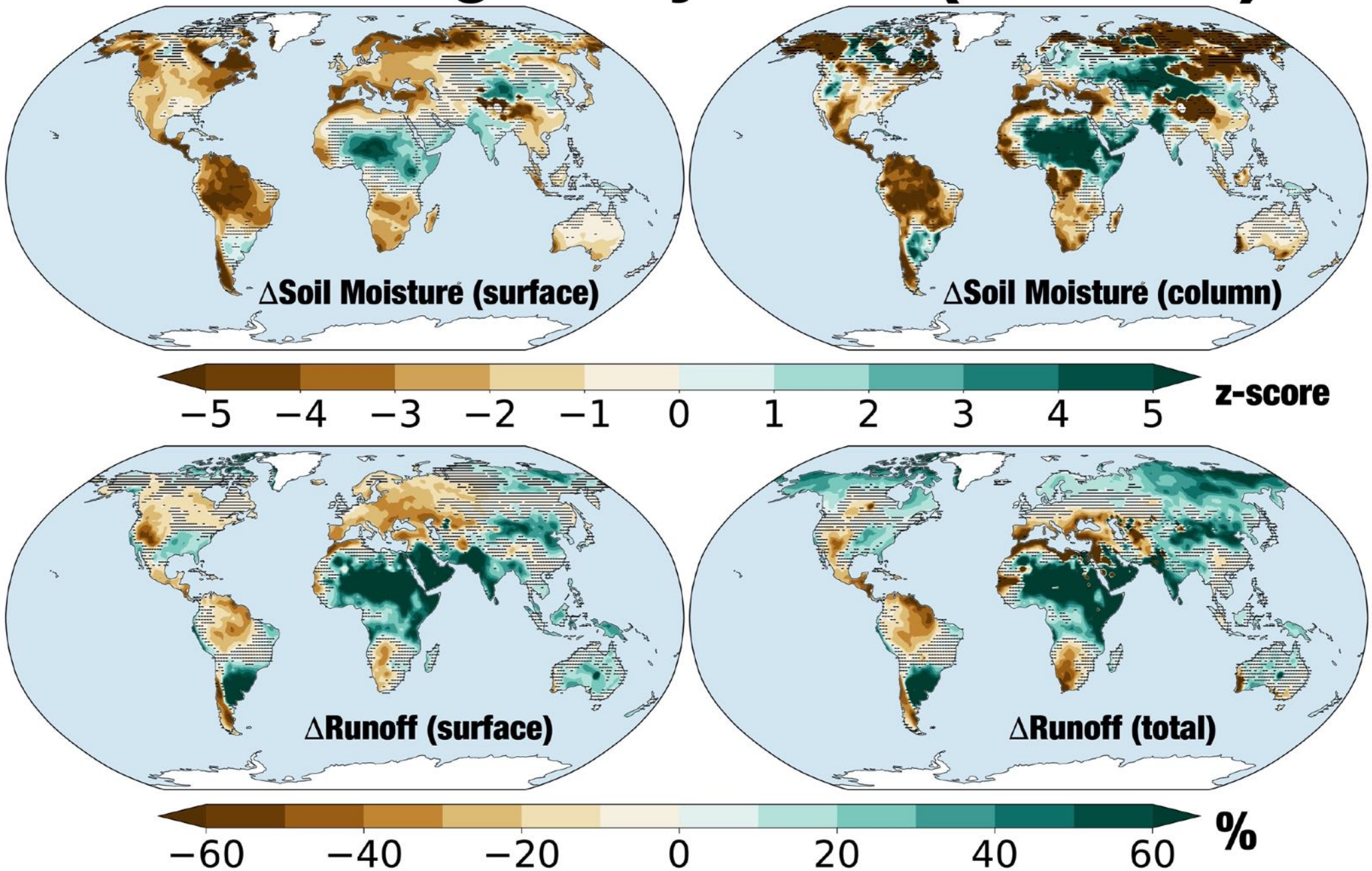


Simulated change at **4 °C** global warming



Relatively small absolute changes may appear large when expressed in units of standard deviation in dry regions with little interannual variability in baseline conditions

CMIP6 Drought Projections (SSP3-7.0)

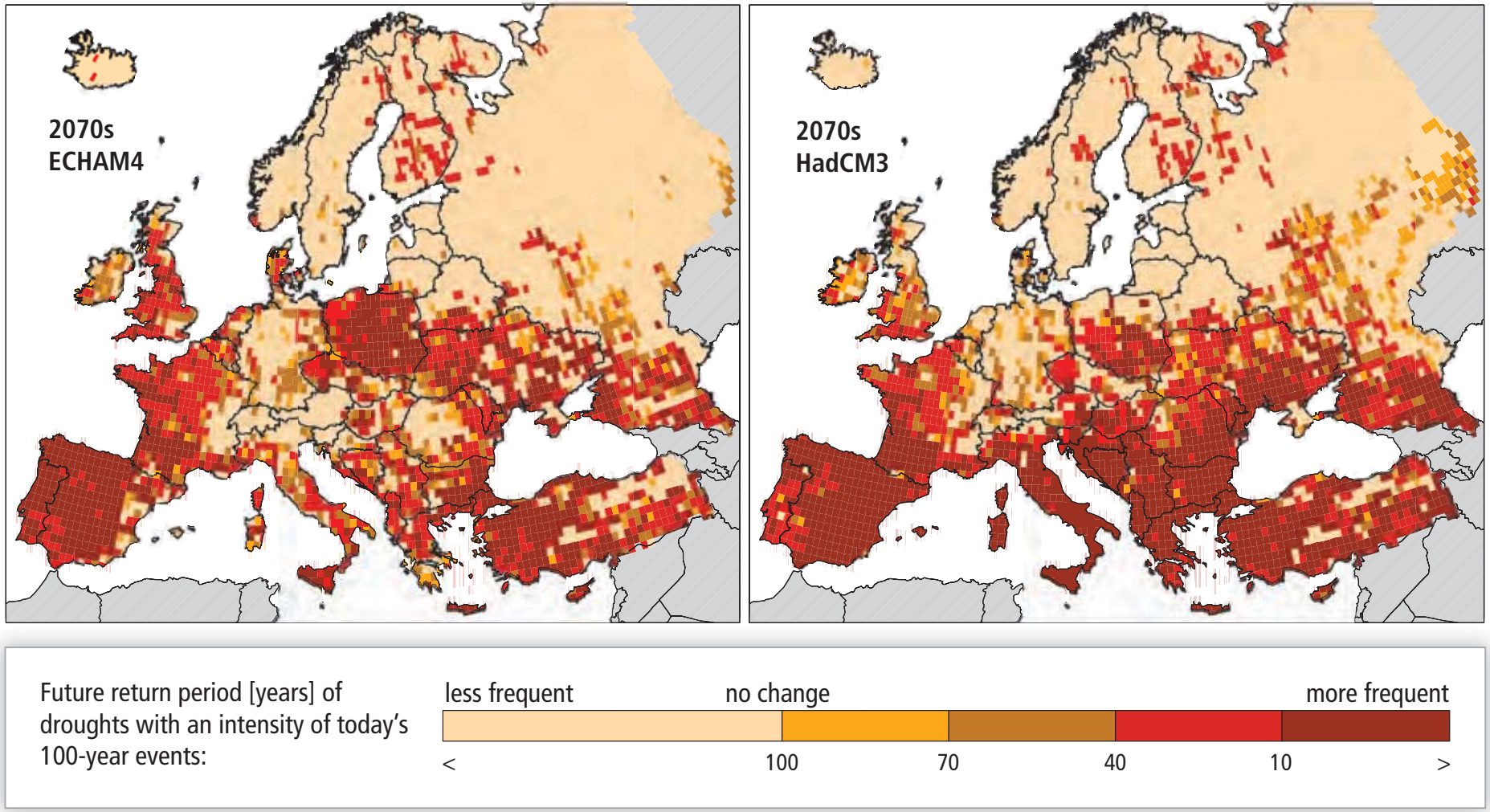


Droughts Past & Future

Climate models

Coming droughts *much* worse than any in past 1000 years

100-Year Drought

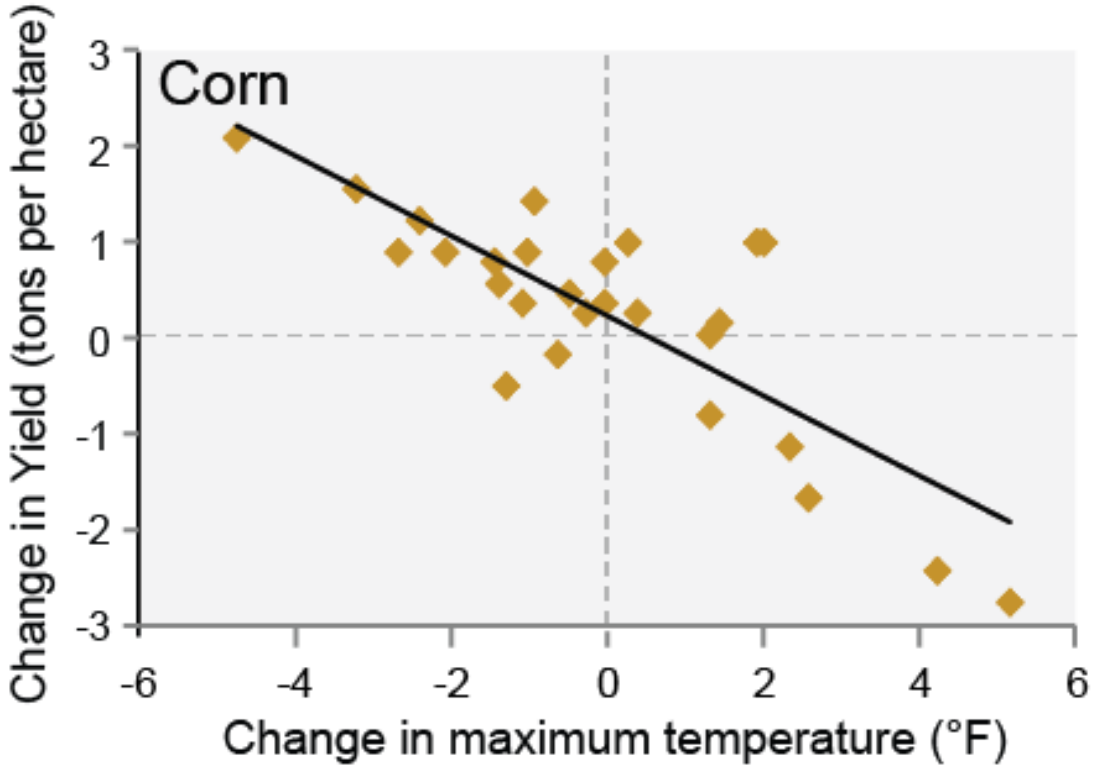


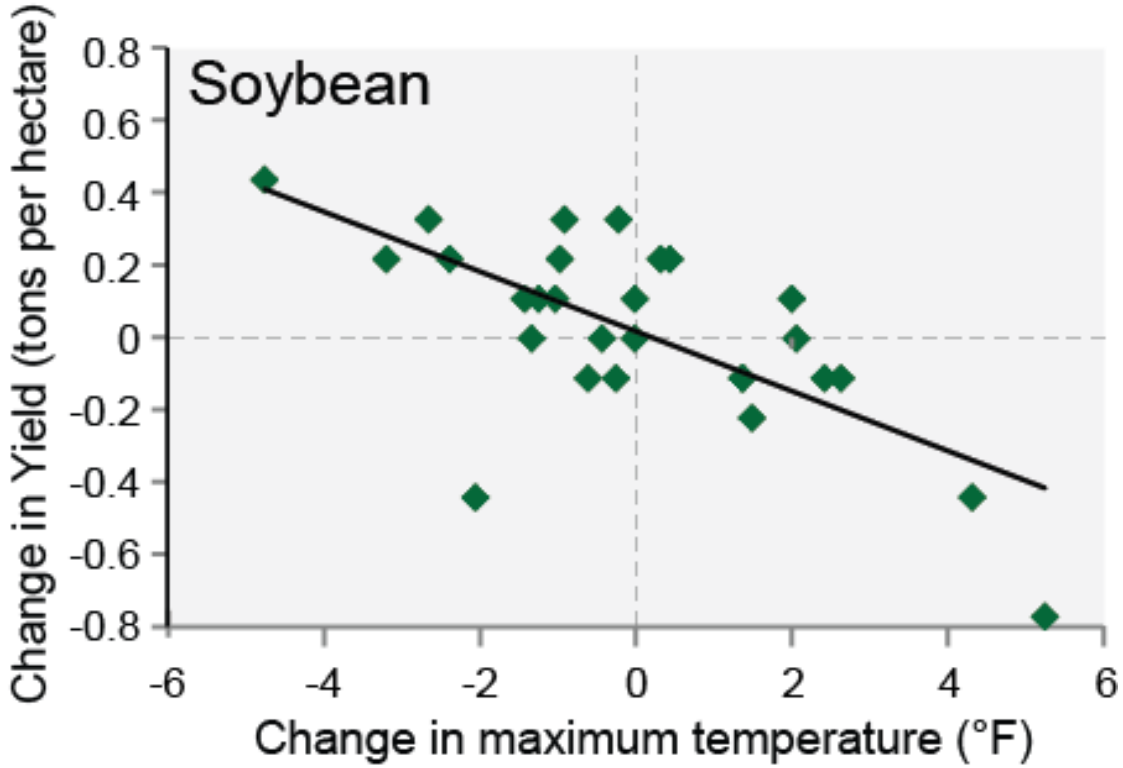
Two different models, med-high emissions, return time

Reduced Crop Yields

Projected Change in Corn and Soy Yield

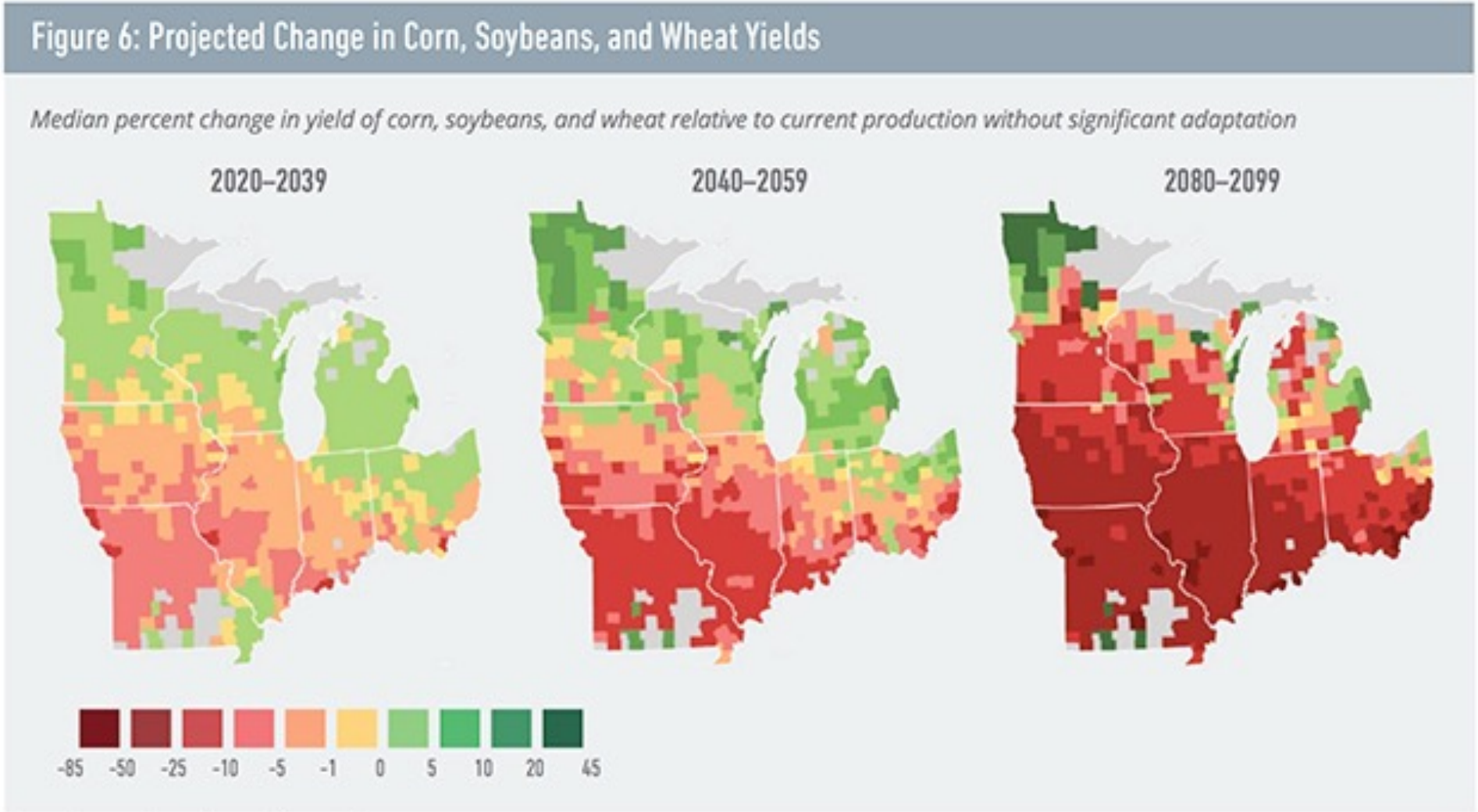
Crop Yields Decline under Higher Temperatures



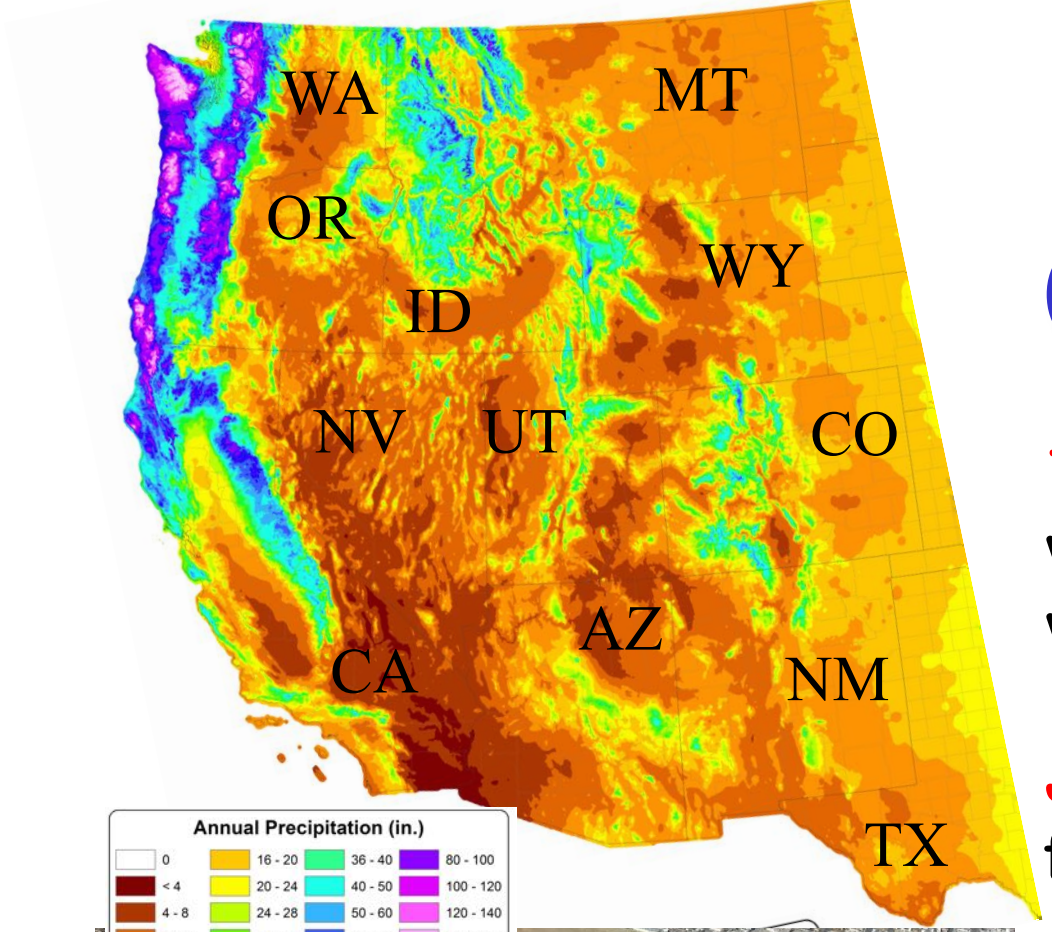


Reduced Crop Yields

Projected Change in Corn, Soy, & Wheat Yield



Data Source: American Climate Prospectus



A Region On the Edge

75 million people in the western US live in a region with **marginal precipitation**

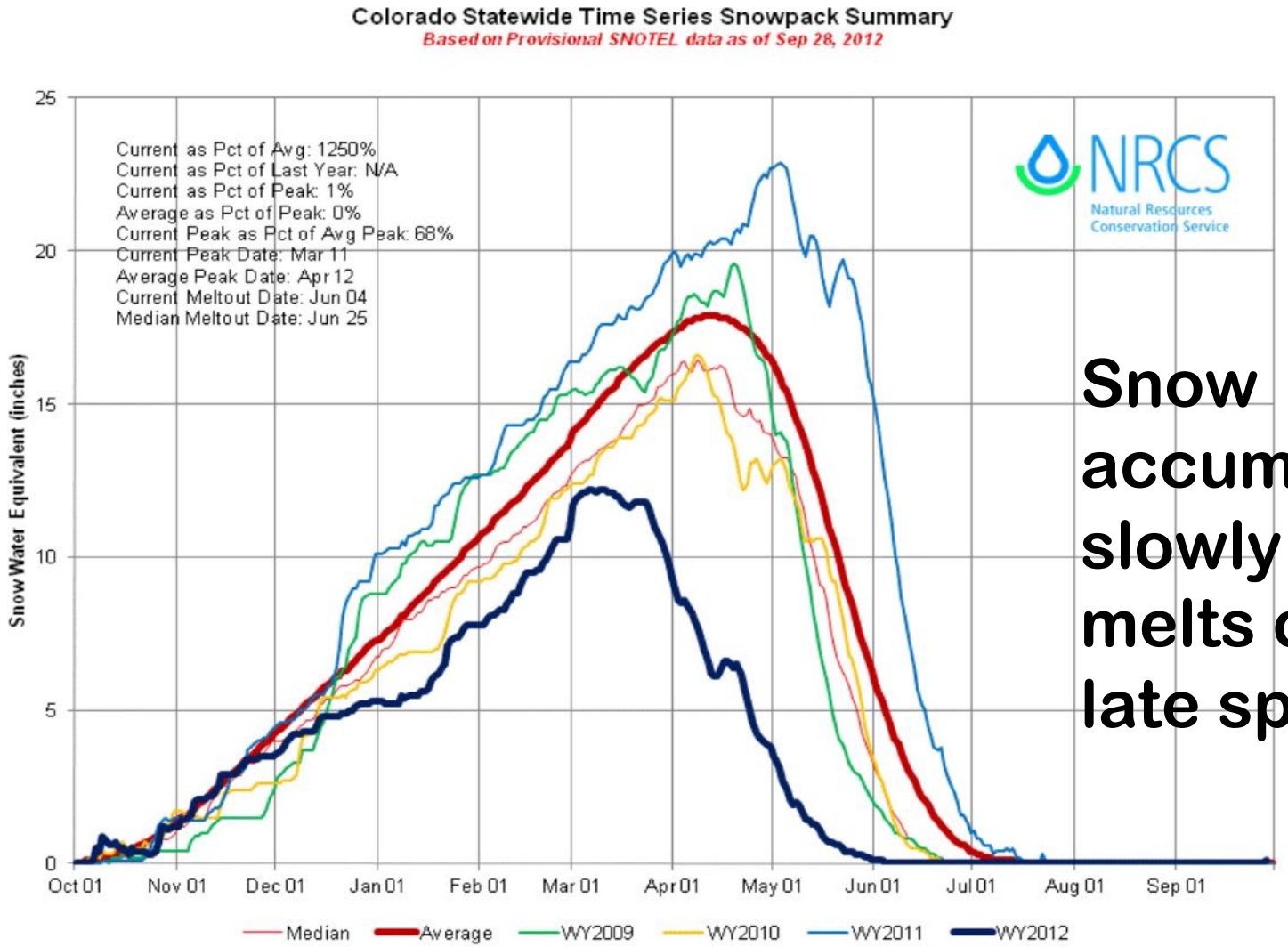
Just enough snow to support forests and reservoirs

Just enough irrigation water to support farming

Just enough **water for cities and towns**

Water Supply

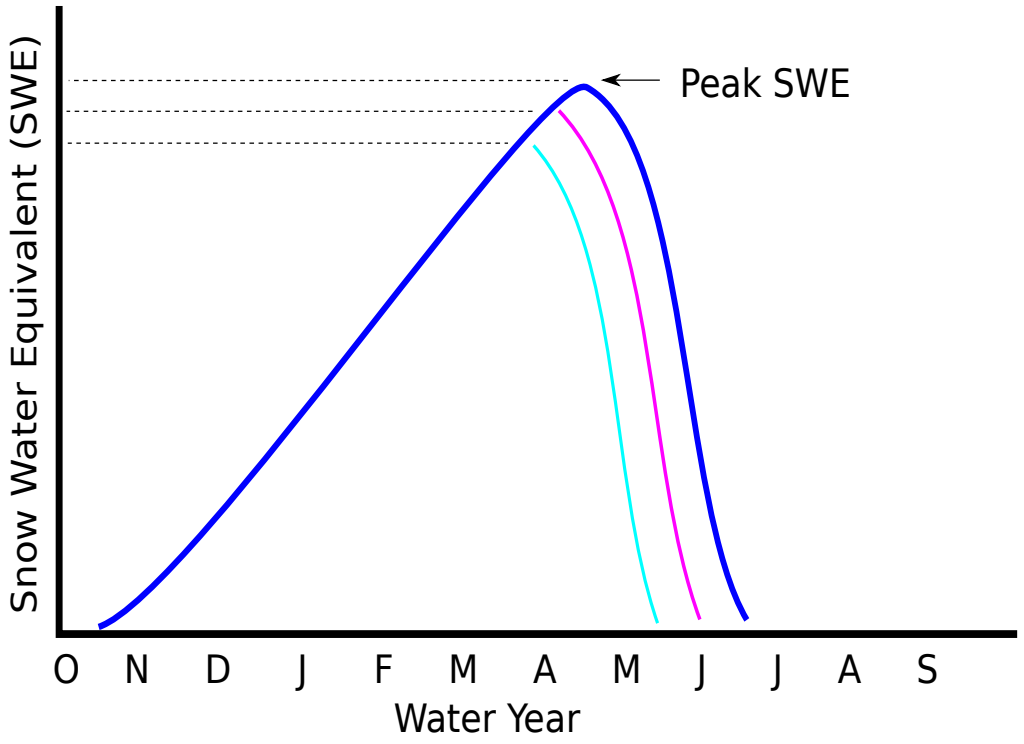
Snowpack



Snow accumulates slowly all winter, melts quickly in late spring

Figure 7 Graph of Colorado statewide snowpack water content for water years (WY) 2009, 2010, 2011, and 2012 with average plotted in bold red. WY2011 was well above average and the very next year WY2012 was below average, peaking in early March instead of early April. (For reference, WY2012 is October 1, 2011 – September 30, 2012.) Graphs and data are available at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/co/snow/?cid=nrcs144p2_063323.

Snowpack & Warming Climate

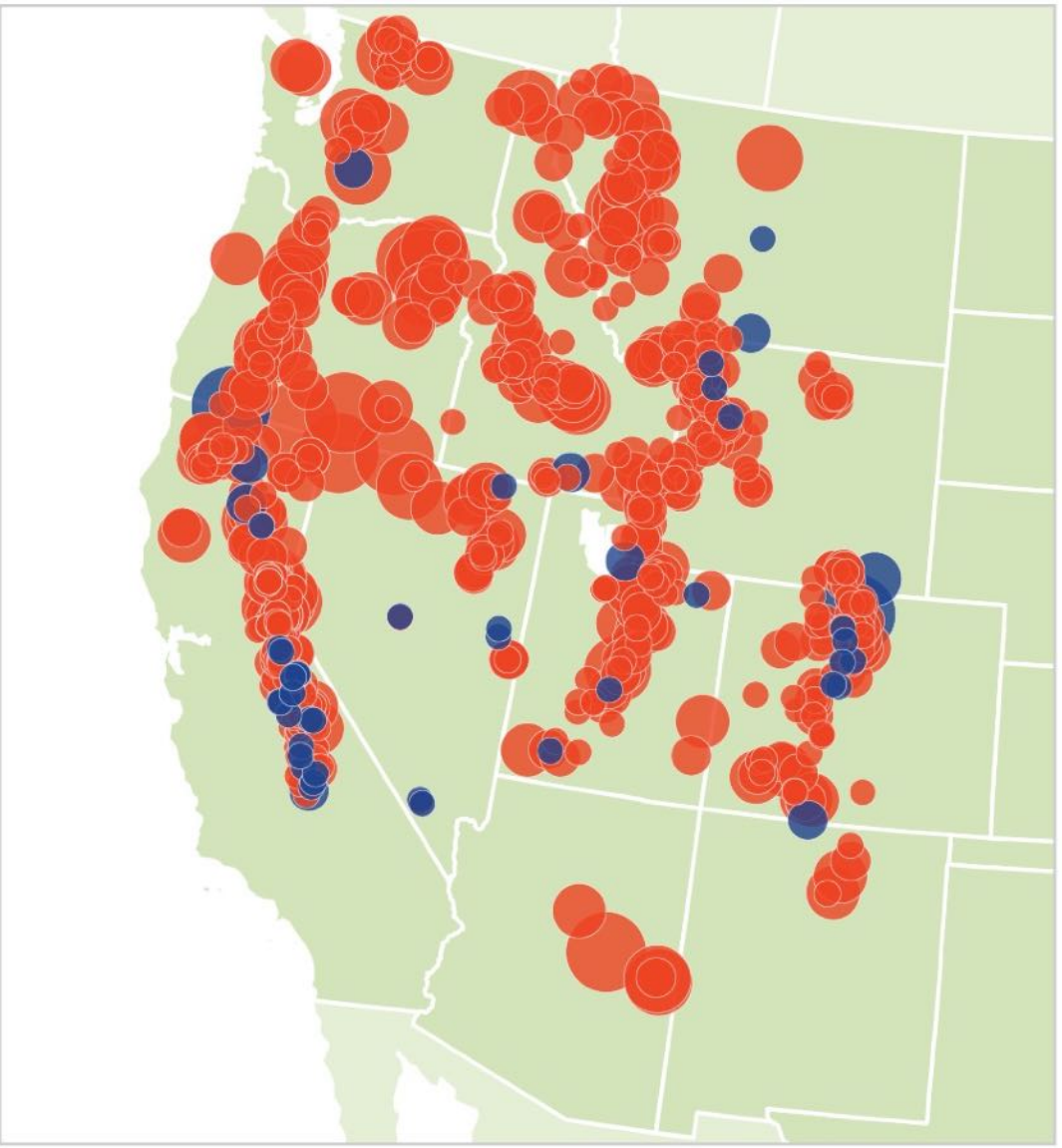


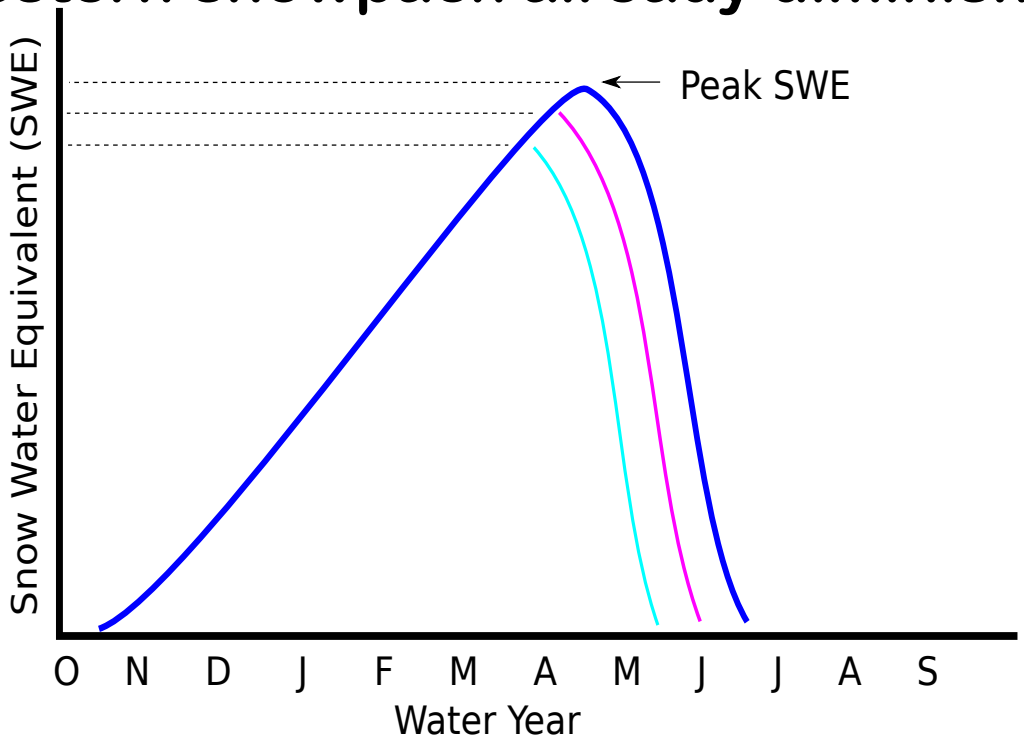
- Colorado peak snowmelt now 3 weeks earlier than in 1980
- Earlier melt "eats into" accumulation season

- Peak snowpack down about 20% so far
- Only 2 °F warming to date, 10 °F by 2100

Declining Snowpack

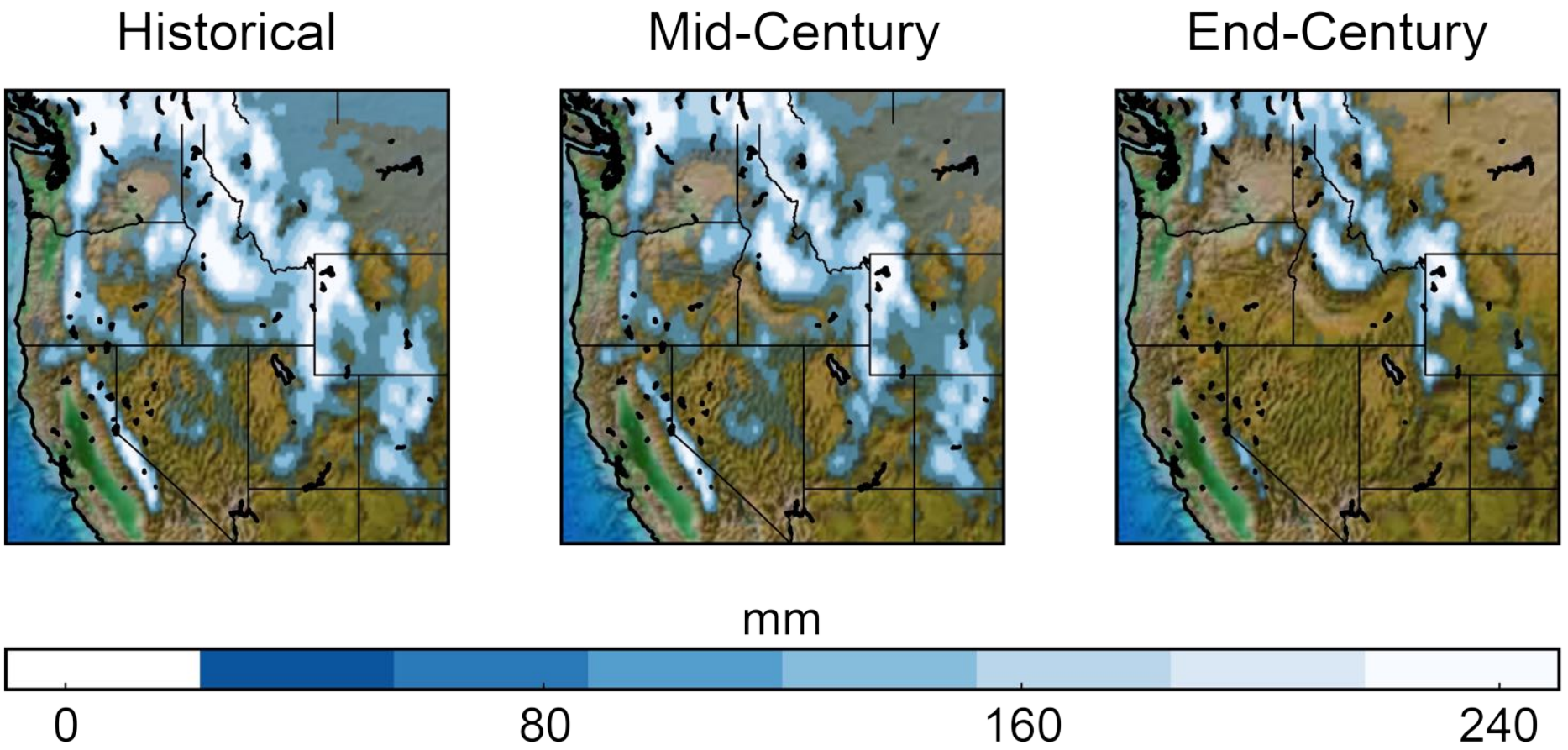
- Warmer winters, earlier springs, less runoff
- Only 1 C of global warming so far
- Western snowpack already diminished





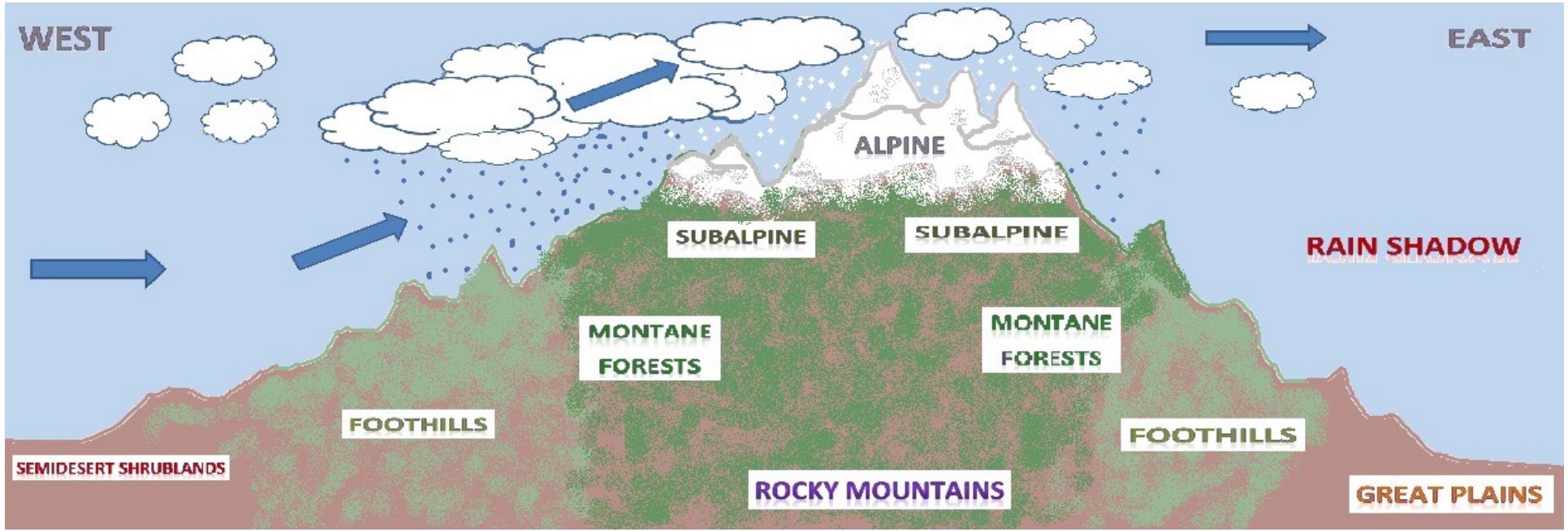
Declines in peak snowpack water equivalent since 1955 (Mote and Sharp 2016)

Projected Loss of Mountain Snowpack



"Water Towers of the West"

Zones Marching Up



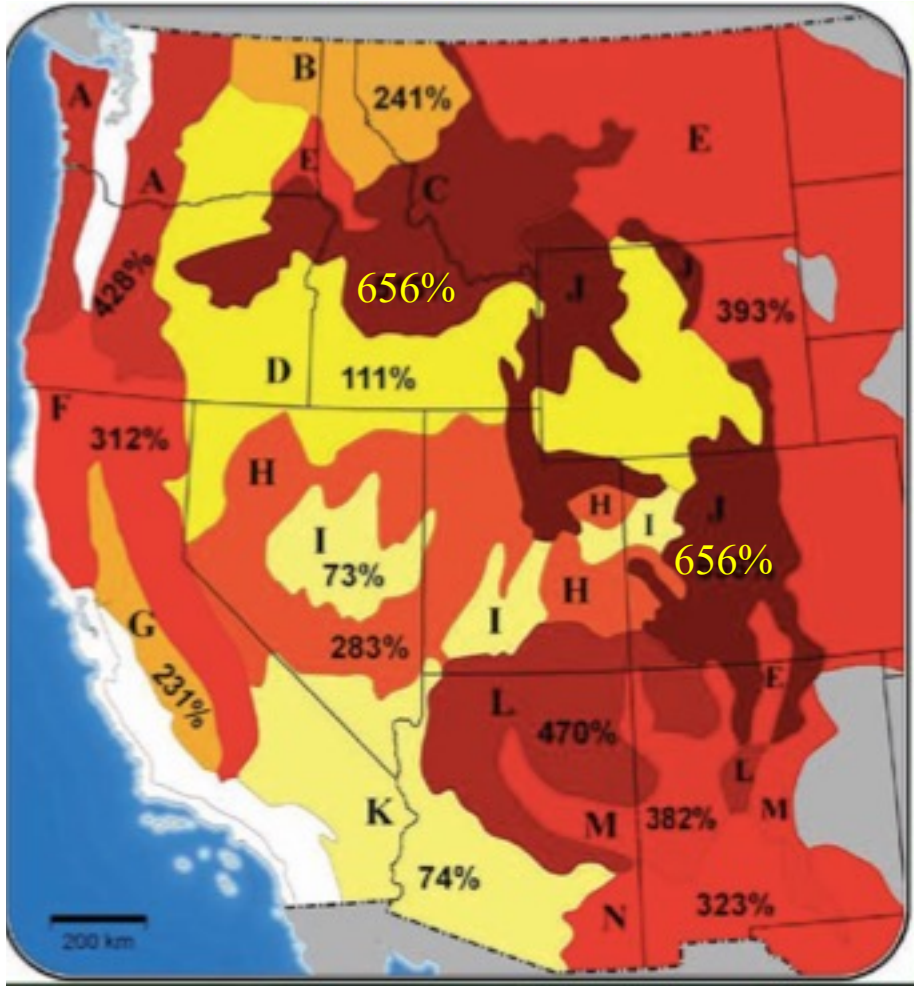
- In Colorado, temps drop about 10 F for each 3000 feet of elevation
  - Denver -> Estes Park
  - Estes Park -> Trail Ridge Road
- But in 100 years instead of 100 centuries!


Wildfire

Warming Promotes Wildfire

1. Warmer air increases **evaporative demand** on forests
2. Longer **warm season** depletes soil moisture
3. More frequent extremely **hot, dry, windy days** when fires are uncontrollable

Projected Increase in Area Burned



NRC 2011

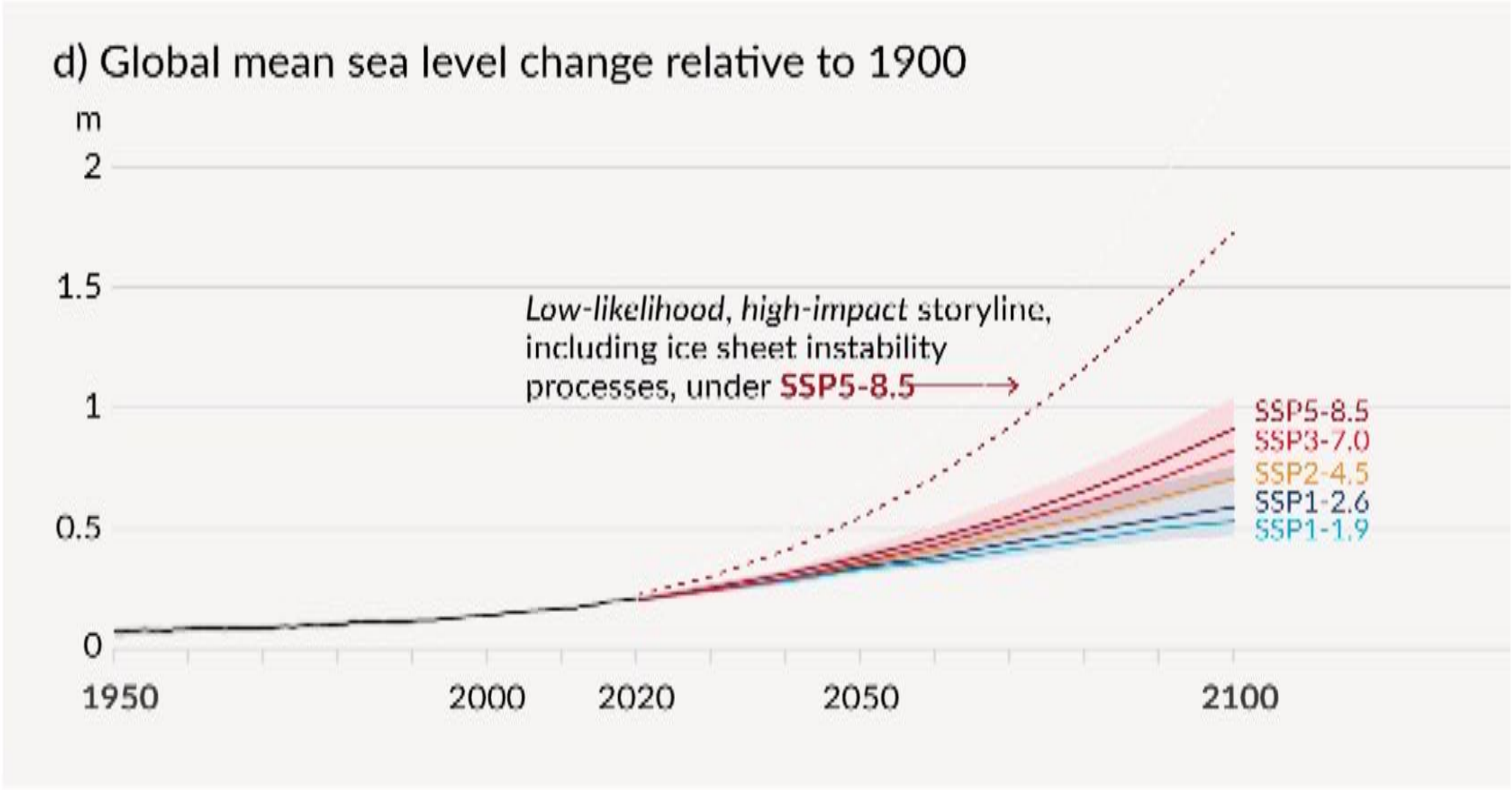

LandscapeTransition
Forest

LandscapeTransition

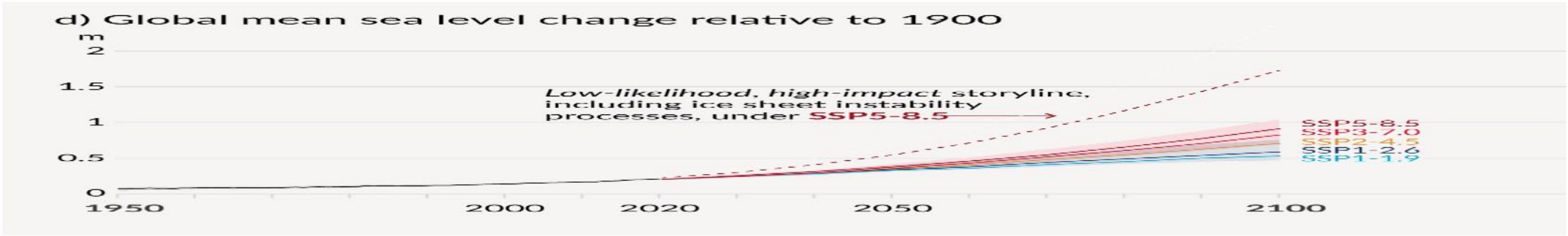
Gradual Conversion to Semi-Arid Landscape?


Sudden
Landscape Conversion

Sea Level & Coastal Flooding

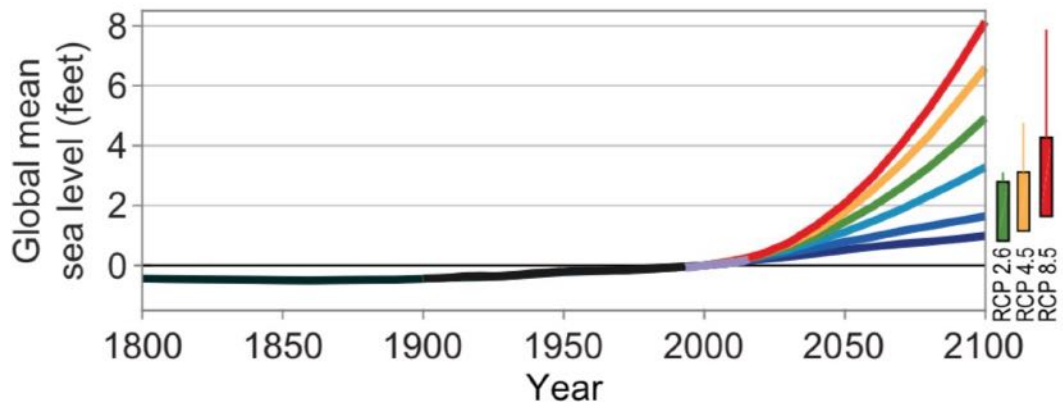

d) Global mean sea level change relative to 1900
m
2
1.5
1
0.5
0
1950
2000
2020
2050
2100
Low-likelihood, high-impact storyline, including ice sheet instability processes, under SSP5-8.5
SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Global Mean Sea Level

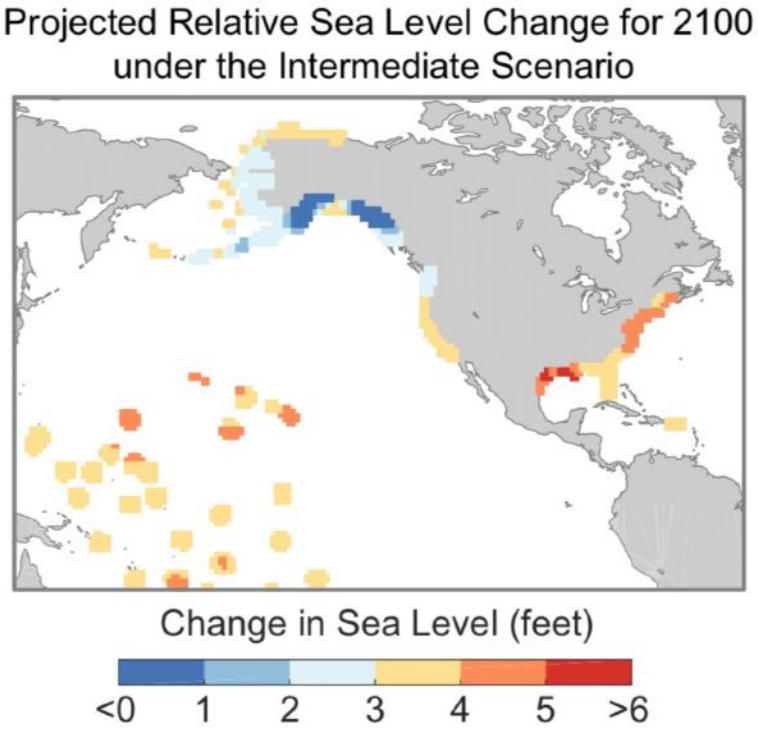


Future Sea-Level

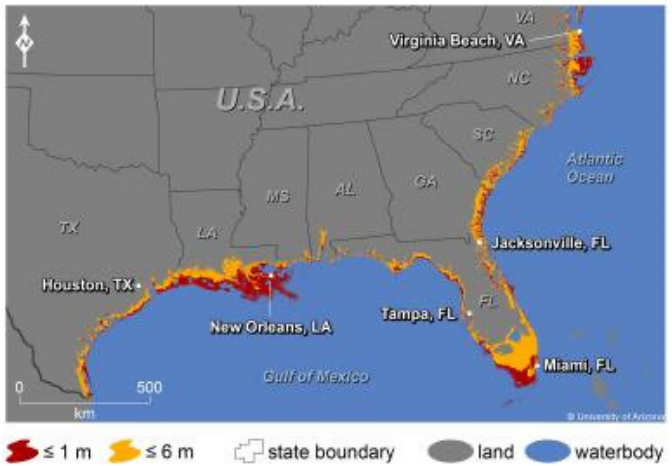
(a)



(b)

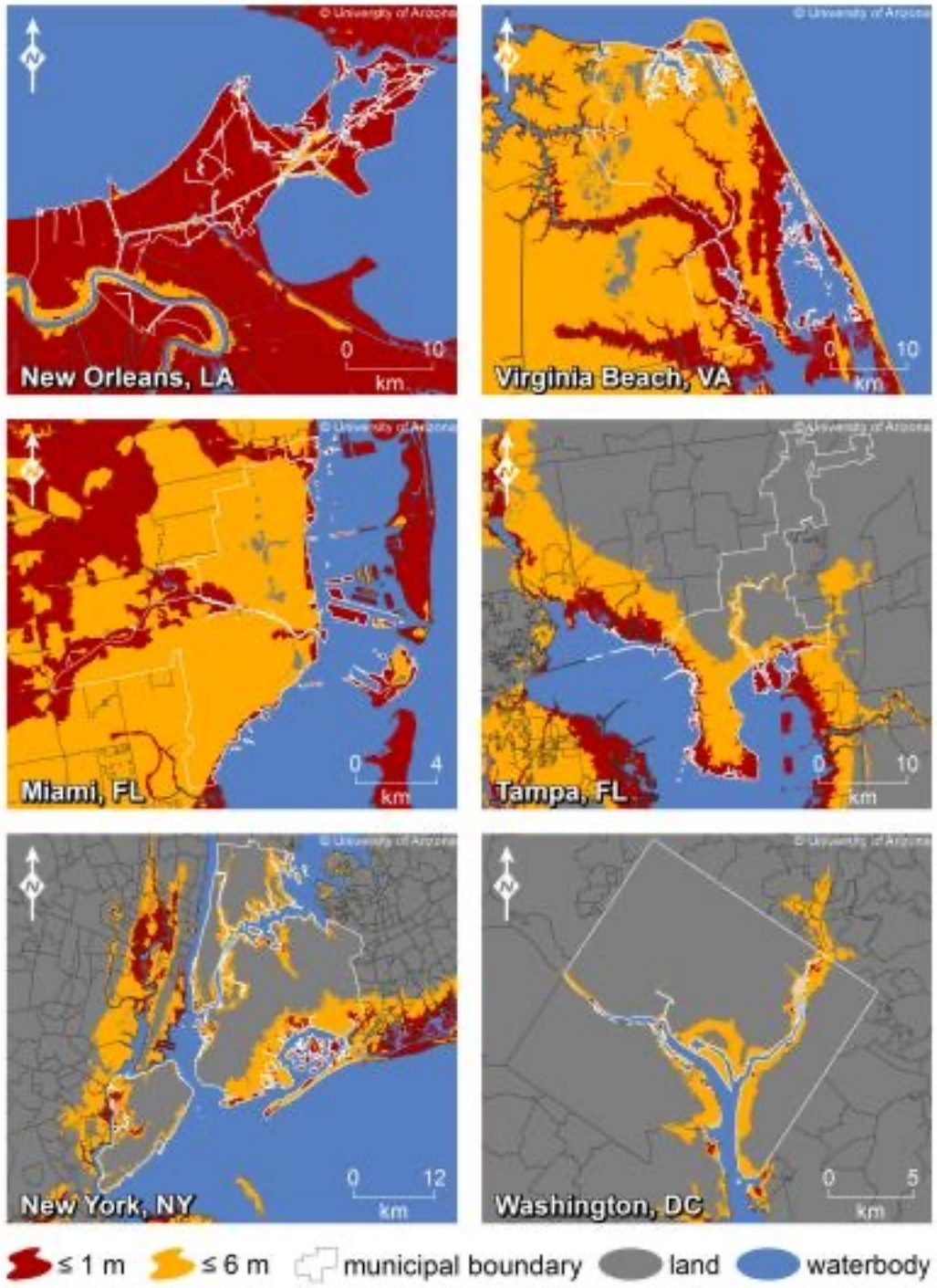


- All models show substantial and accelerating rise in sea-level
- Big differences depending on future emissions
- Equilibrium sea level will take many centuries

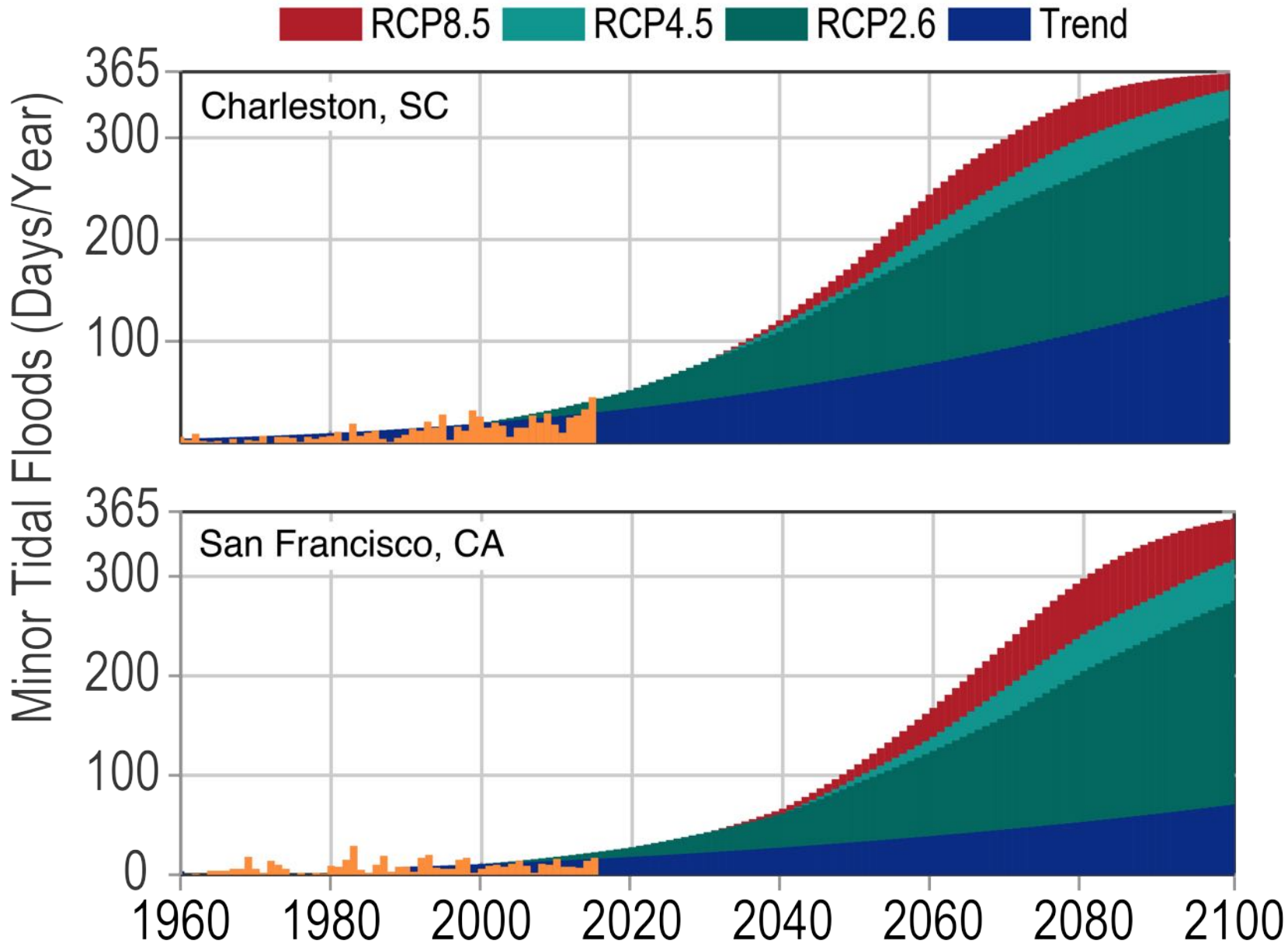


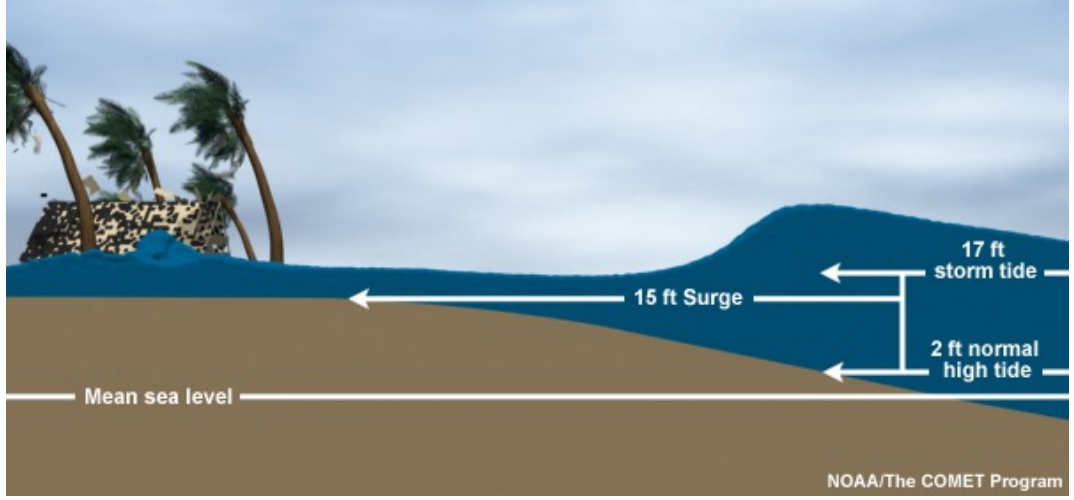
Changes in Mean Sea Level

- 1 meter is a high-end estimate for 2100
- 6 m is loss of Greenland



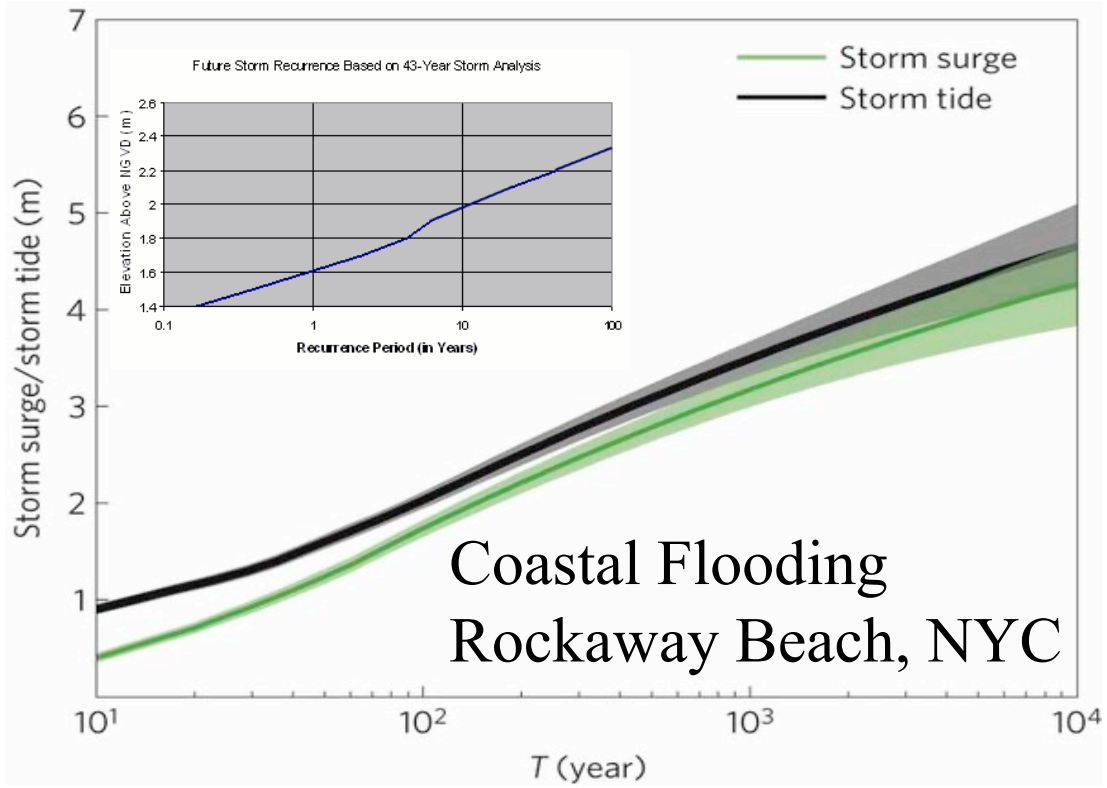
“Nuisance” Tidal Flooding



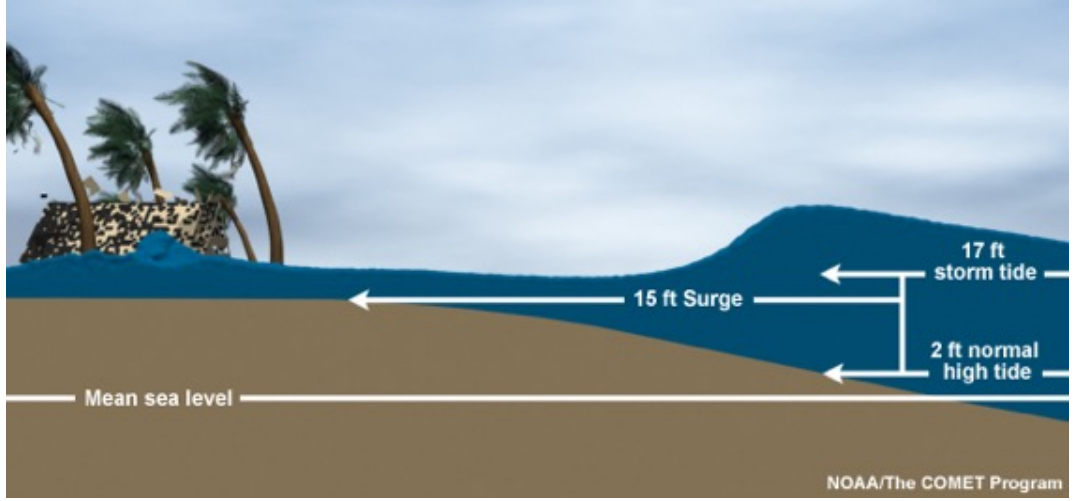


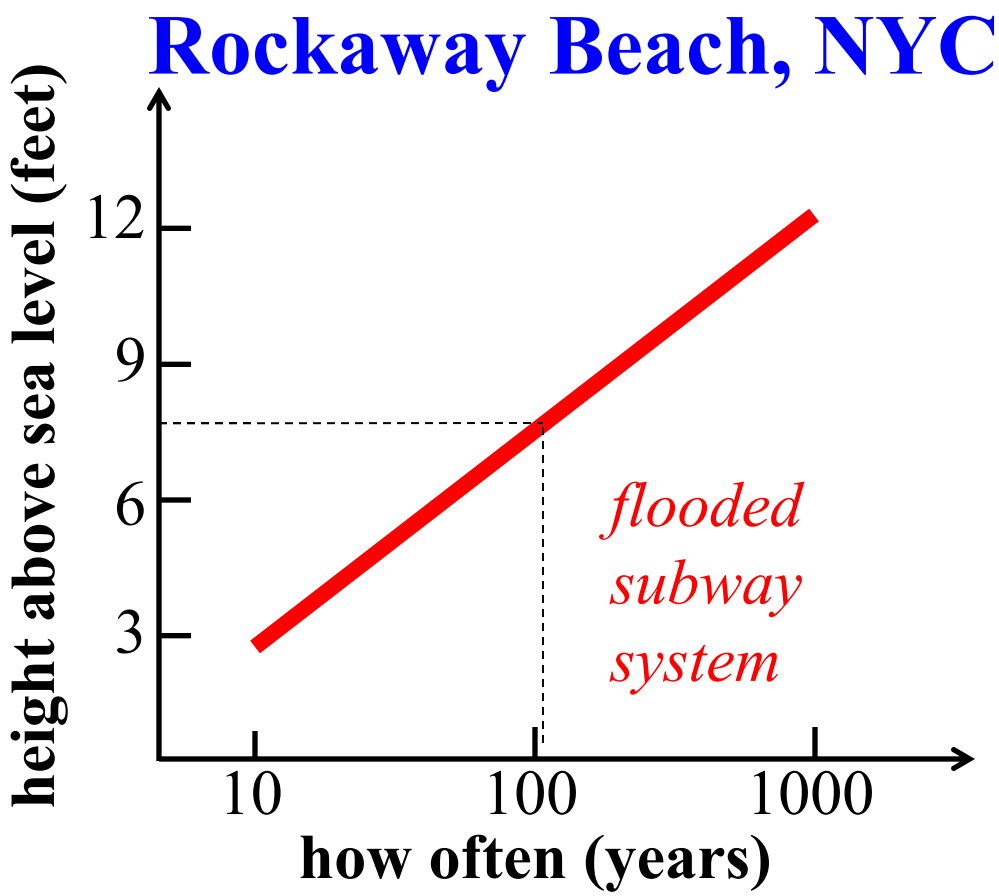
Storm Surge Frequency

- Return frequency for flood drops off exponentially
- Sea level rise shifts the curves up
- What was a 100-year flood becomes a 10-year flood!

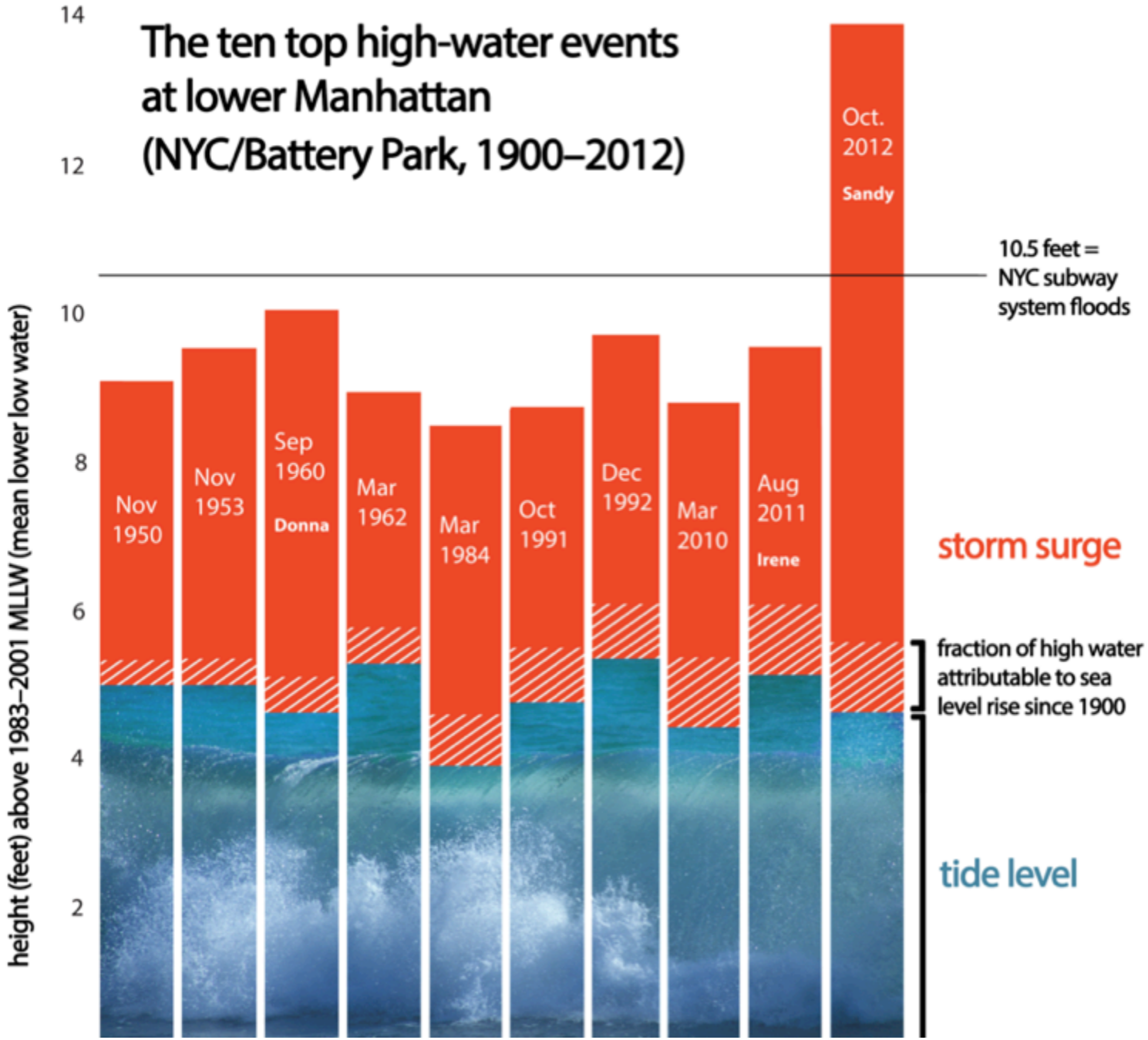


Coastal Flooding





- Small floods are common, big floods are rare
- **Sea level rise shifts the line up**
- **What was a 100-year flood becomes a 10-year flood!**


The ten top high-water events at lower Manhattan (NYC/Battery Park, 1900–2012)
height (feet) above 1983–2001 MLLW (mean lower low water)
14
12
10
8
6
4
2
Nov 1950
Nov 1953
Sep 1960
Donna
Mar 1962
Mar 1984
Oct 1991
Dec 1992
Mar 2010
Aug 2011
Irene
Oct. 2012
Sandy
10.5 feet = NYC subway system floods
storm surge
fraction of high water attributable to sea level rise since 1900
tide level


Mon 65 : Newark Selectable
Cam 1420 : 1420-HBKN-E and D Elevator Platform
10/29/2012
20:23:34

Storm-Surge Exposure

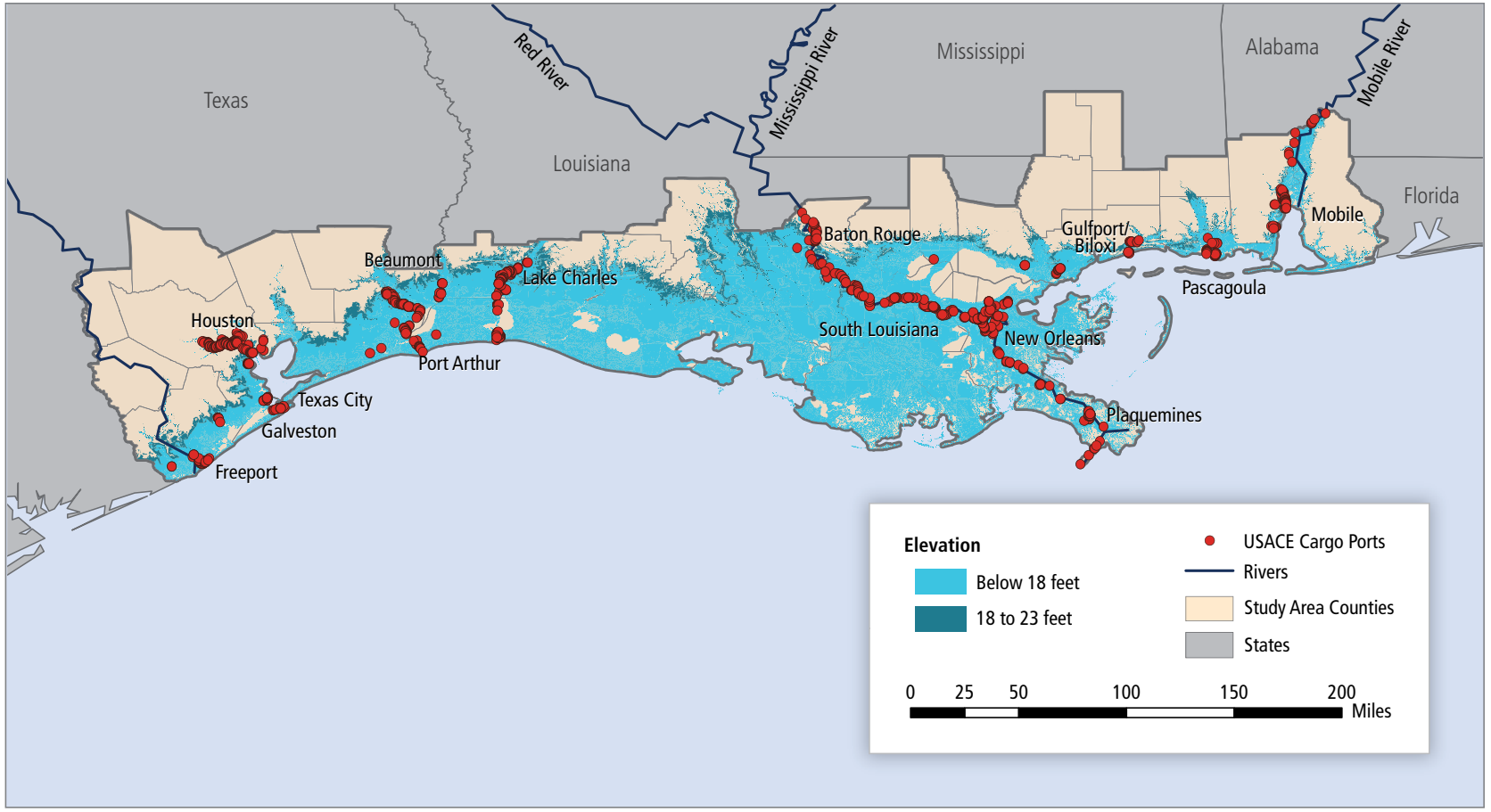


Figure 4-6 | Freight-handling port facilities at risk from storm surge of 5.5 and 7 m on the US Gulf Coast. Adapted from CCSP, 2008.