Climate Change

What we know
What we expect

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Climate Change 2013: The Physical Science Basis

IPCC Working Group I, 2013

- "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased." [SPM, p. 3]

- "Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system." [SPM, p. 10]

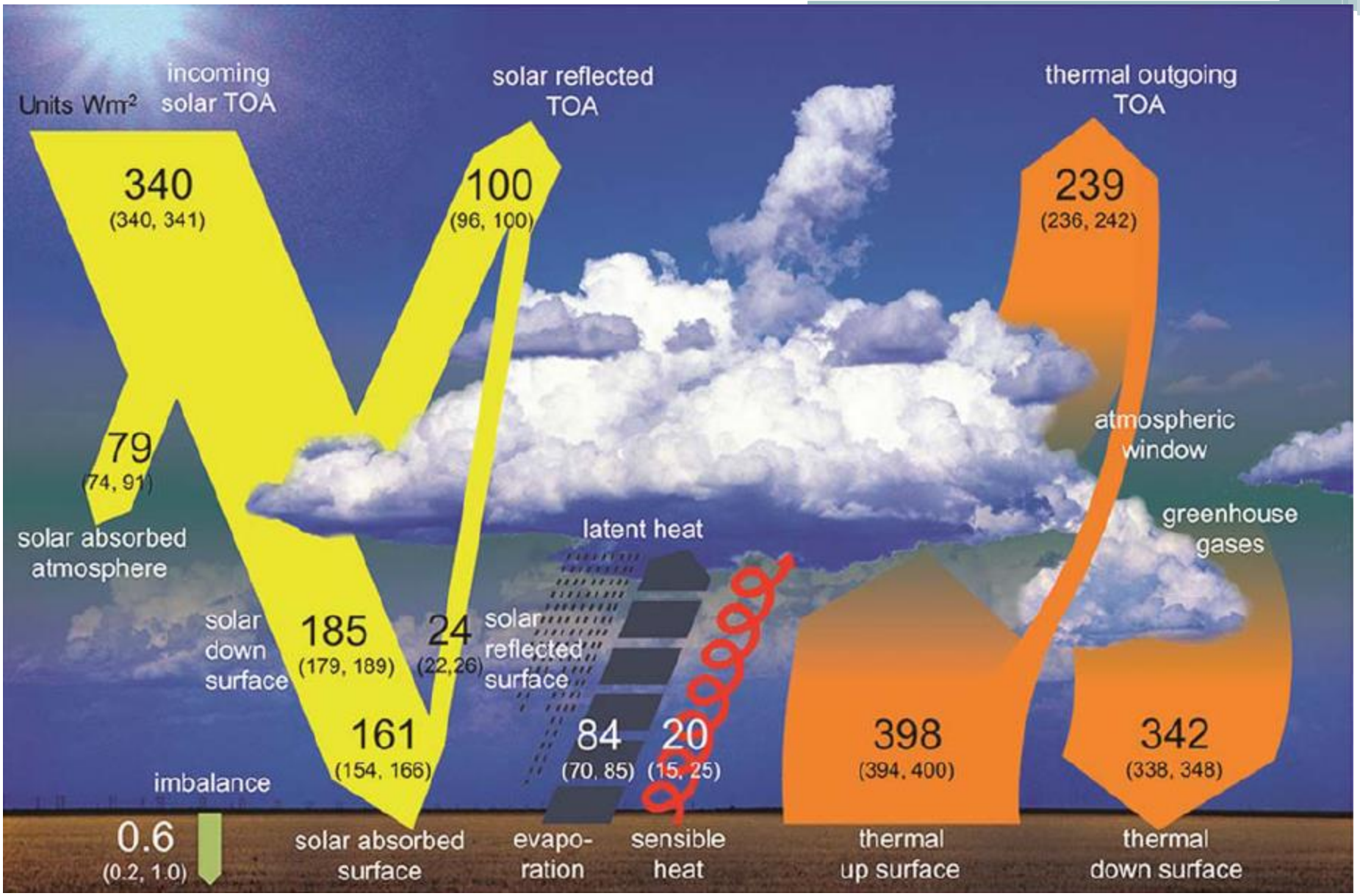
Advancing the Science of Climate Change, National Research Council, 2010

- "… scientific evidence that the Earth is warming is now overwhelming. There is also a multitude of evidence that this warming results primarily from human activities, especially burning fossil fuels and other activities that release heat-trapping greenhouse gases (GHGs) into the atmosphere." [p. 19]

- "Although the details of how the future impacts of climate change will unfold are not as well understood as the basic causes and mechanisms of climate change, we can reasonably expect that the consequences of climate change will be more severe if actions are not taken to limit its magnitude and adapt to its impacts." [p. 19]

The “greenhouse” effect

- greenhouse gases (such as water vapor, carbon dioxide, methane, nitrous oxide) absorb radiation and radiate energy back toward the surface
  - keeps Earth’s average surface temperature warmer
    - about 33°C (59°F) higher



IPCC 2013; WG-I, Fig. 2.11

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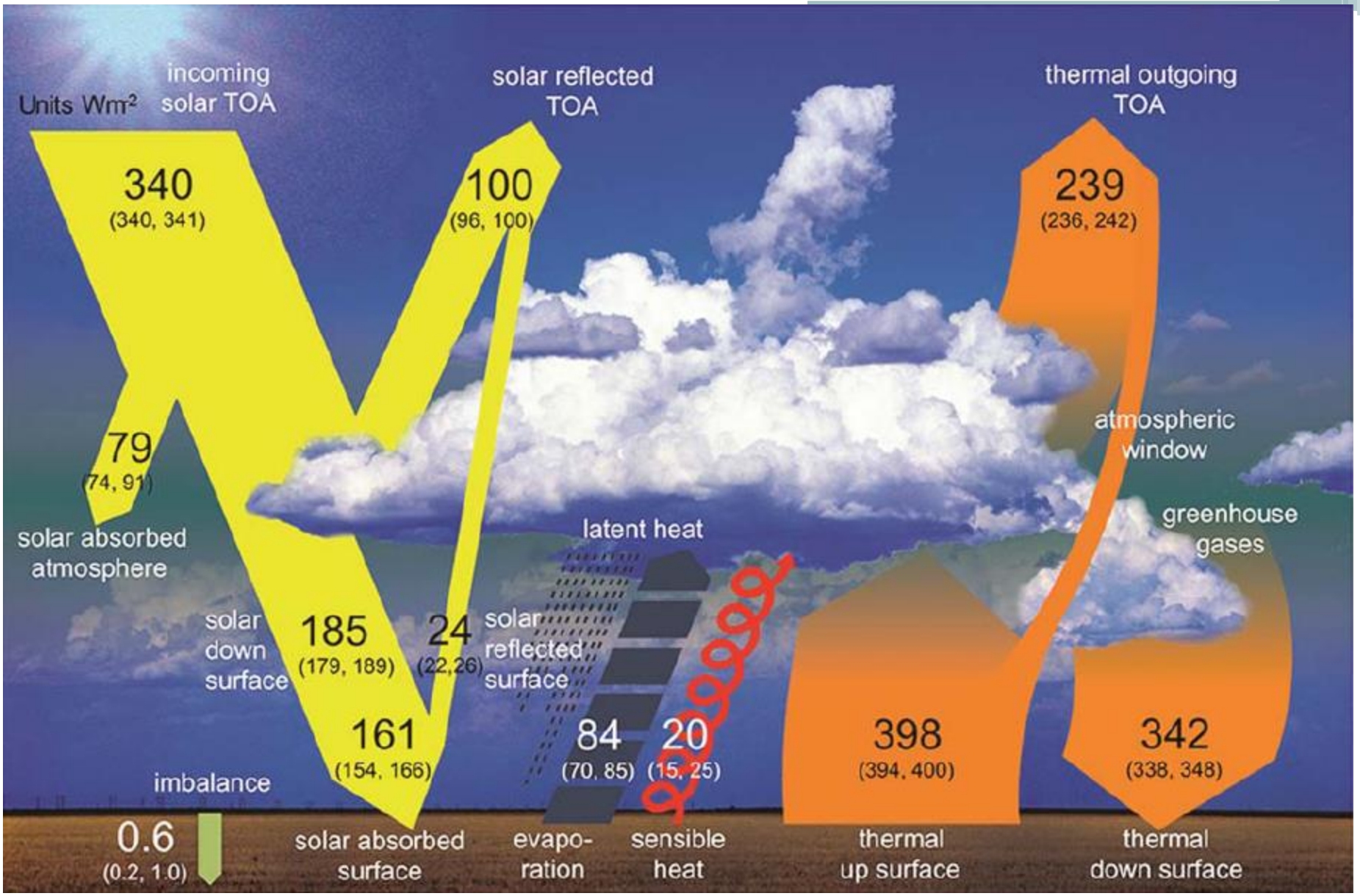
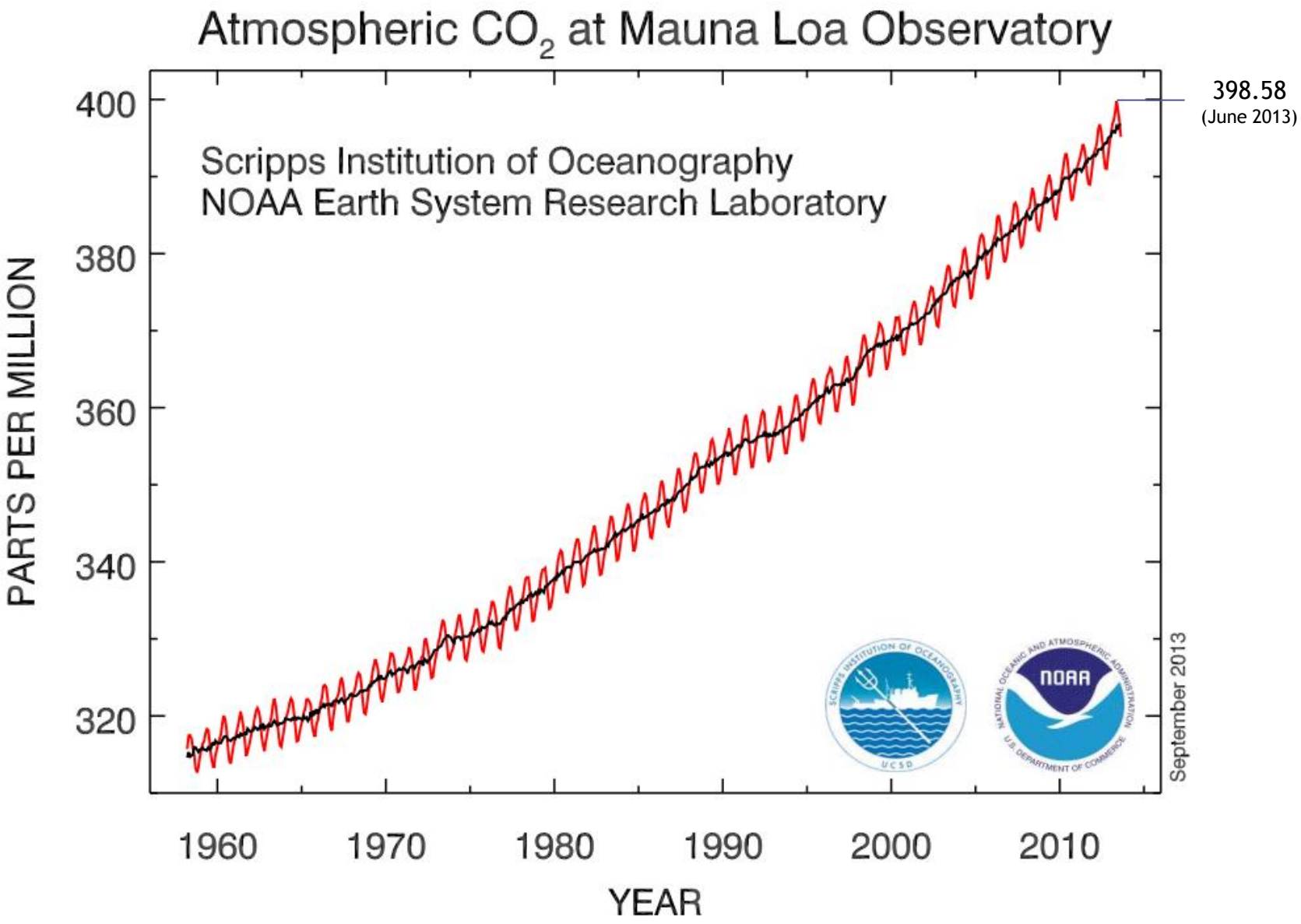
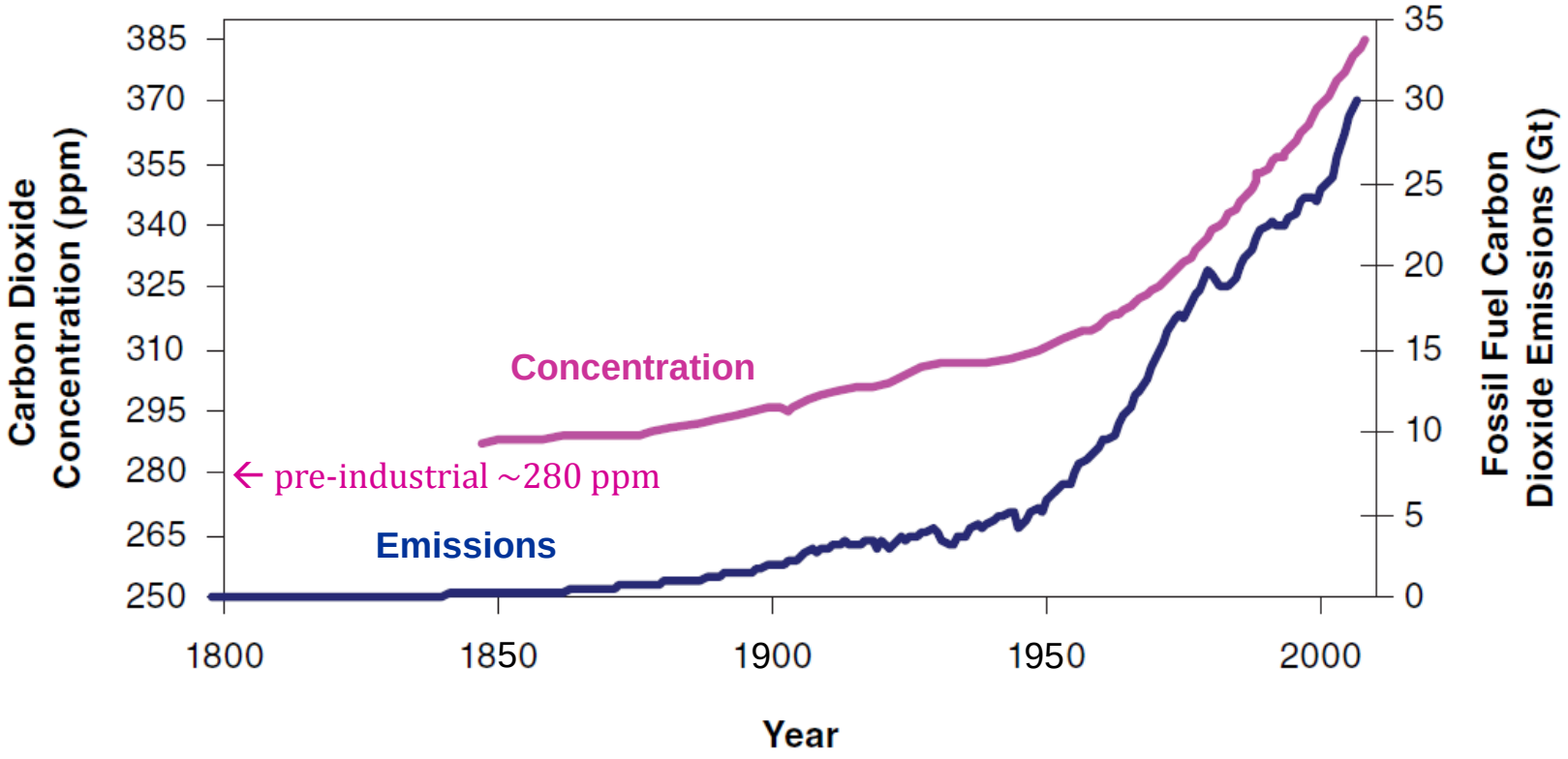
- increasing concentrations of GHGs from human activities cause Earth’s temperature to rise (enhanced “greenhouse” effect)



IPCC 2013; WG-I, Fig. 2.11



http://www.esrl.noaa.gov/gmd/ccgg/trends/


Carbon Dioxide Concentration (ppm)
385
370
355
340
325
310
295
280
265
250
Concentration
← pre-industrial ~280 ppm
Emissions
1800
1850
1900
1950
2000
Year
35
30
25
20
15
10
5
0
Fossil Fuel Carbon Dioxide Emissions (Gt)

NRC, 2010

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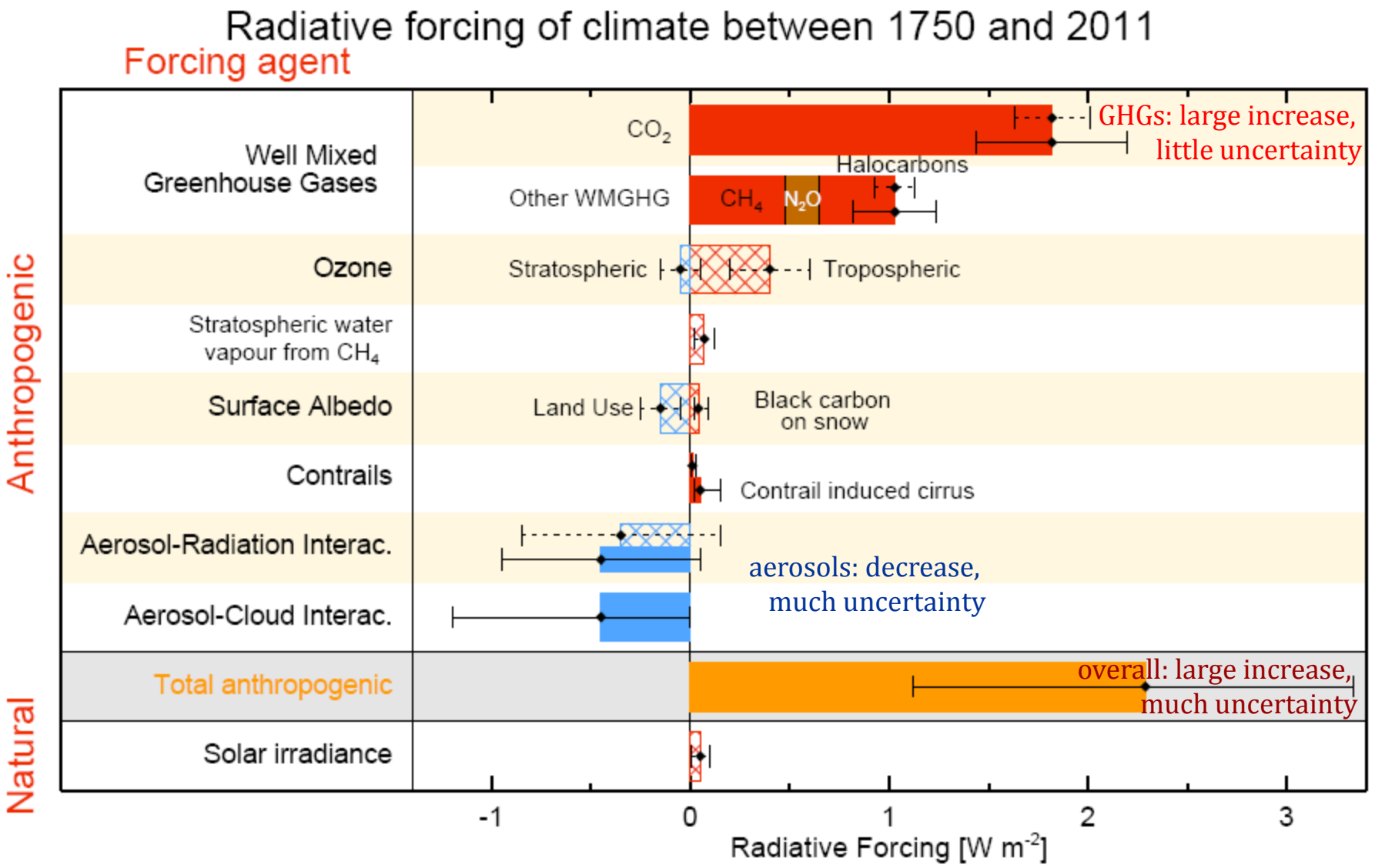
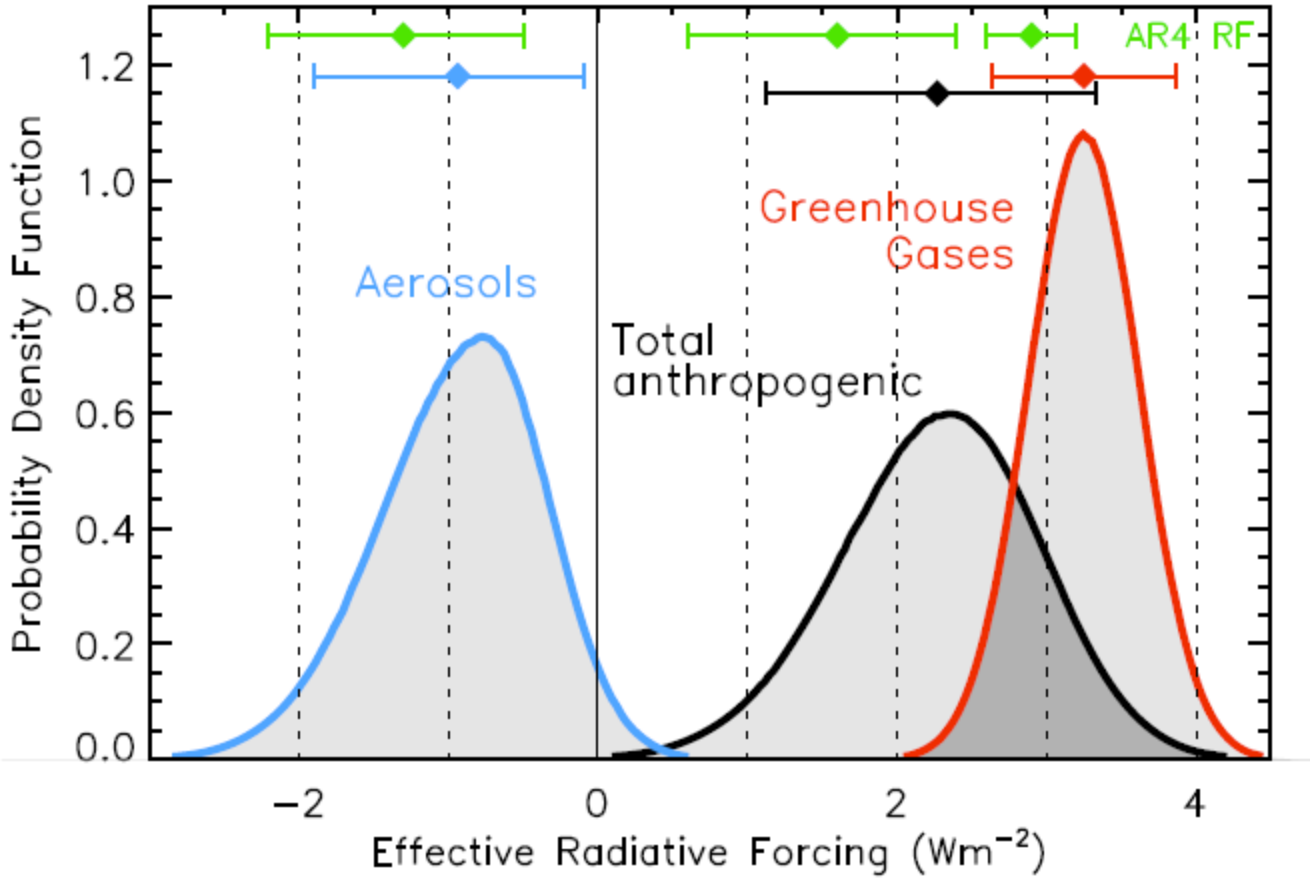
    - about 33°C (59°F) higher
- increasing concentrations of GHGs from human activities cause Earth’s temperature to rise (enhanced “greenhouse” effect)
- increasing concentrations of some aerosols could offset part (but not all) of this warming by increasing reflection of sunlight



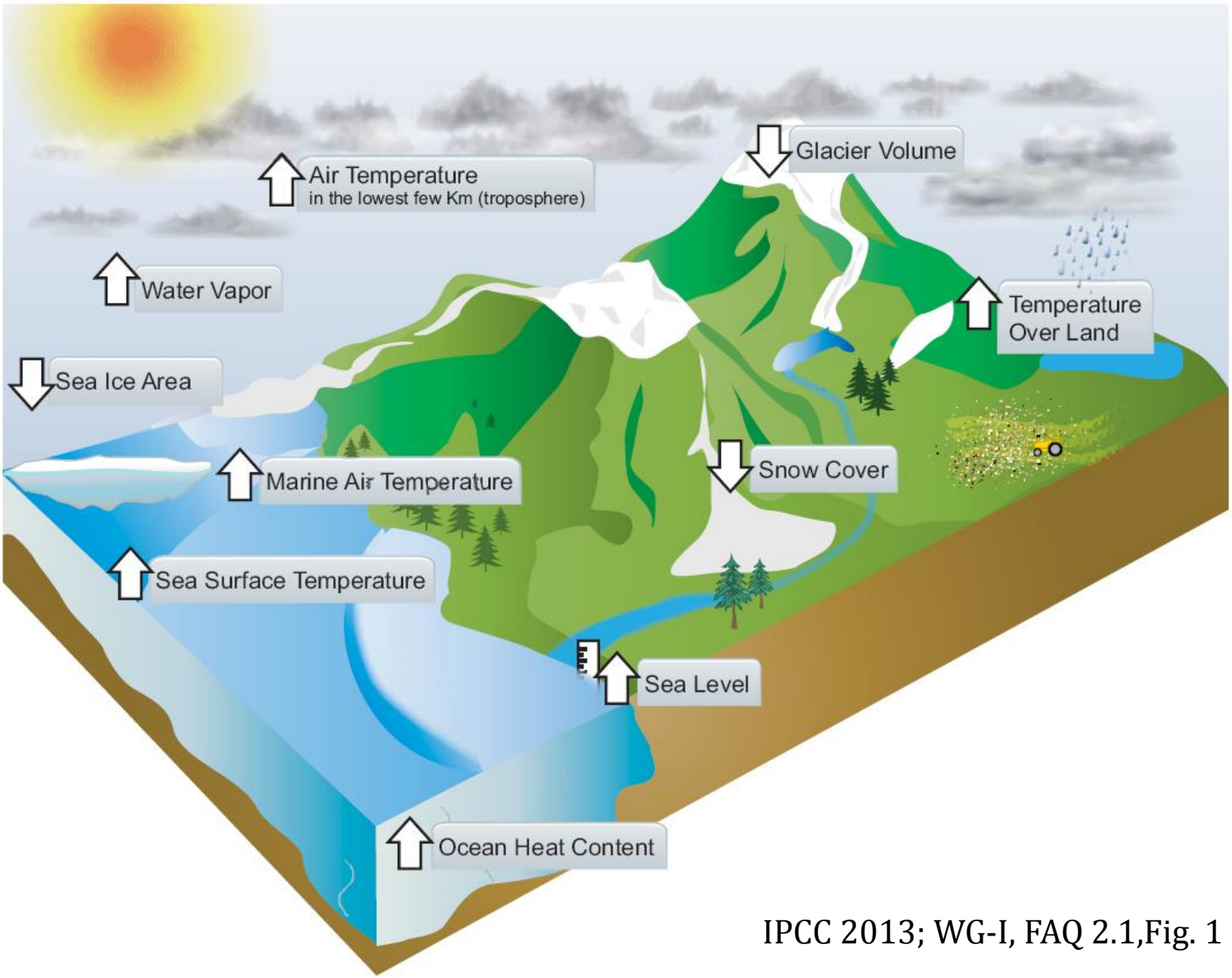
IPCC 2013; WG-I, Fig. 8.15



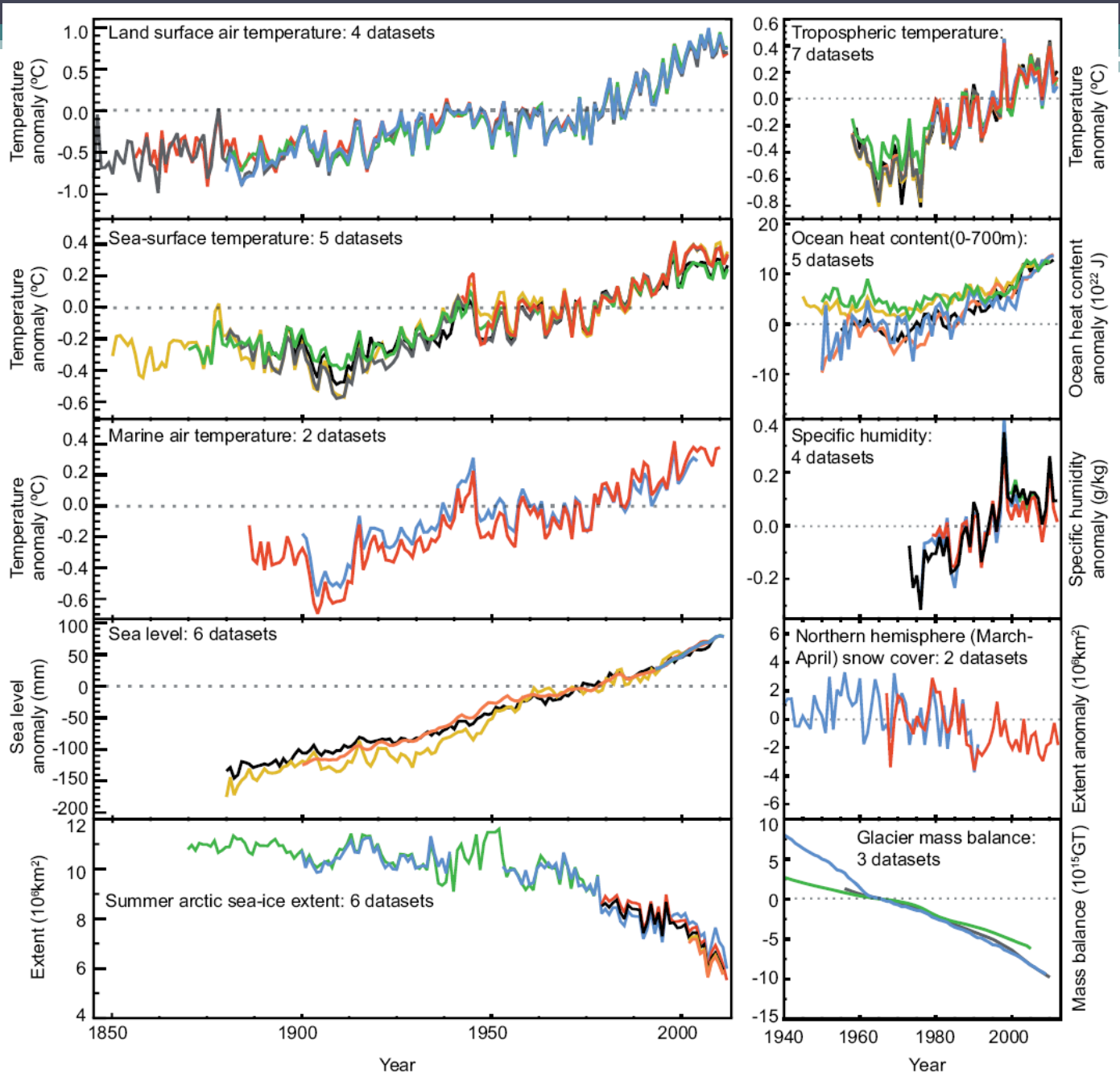
IPCC 2013; WG-I, Fig. 8.15

Temperatures are increasing …

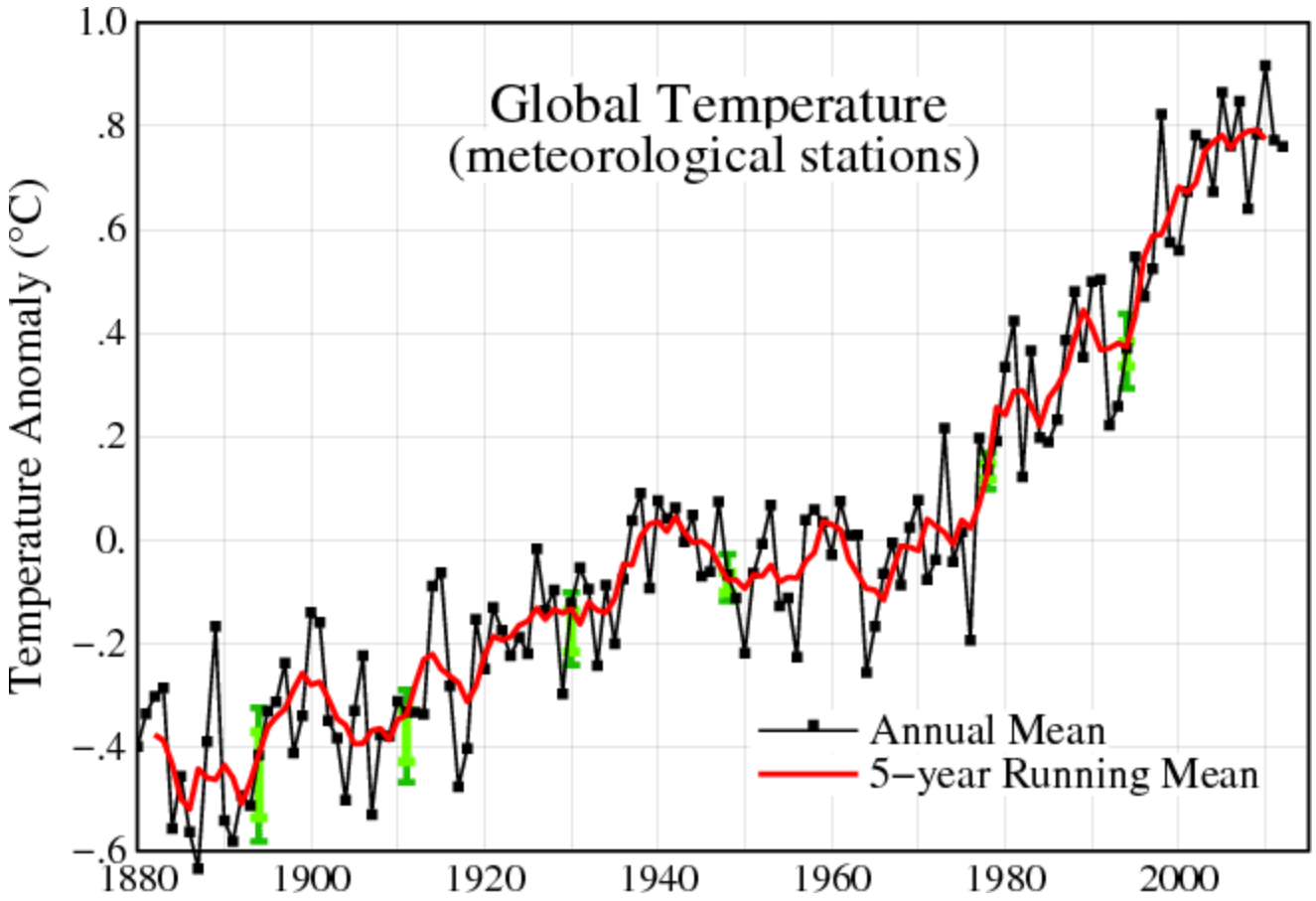
- Surface thermometer measurements show the first decade of the 21st century was 0.8°C (1.4°F) warmer than the first decade of the 20th century
- Each of the past three decades has been warmer than all the previous decades in the instrumental record, and the decade of the 2000's has been the warmest.
- Oceans show a warming trend over the past several decades that is similar to the atmospheric warming trend
- Hot days and nights have become warmer and more frequent
- Cold snaps have become milder and less frequent
- Northern Hemisphere snow cover is decreasing
- Northern Hemisphere sea ice is declining in both extent and average thickness
- Rivers and lakes are freezing later and thawing earlier
- Glaciers and ice caps are melting in many parts of the world
- Precipitation, ecosystems, and other environmental systems are changing in ways that are consistent with global warming



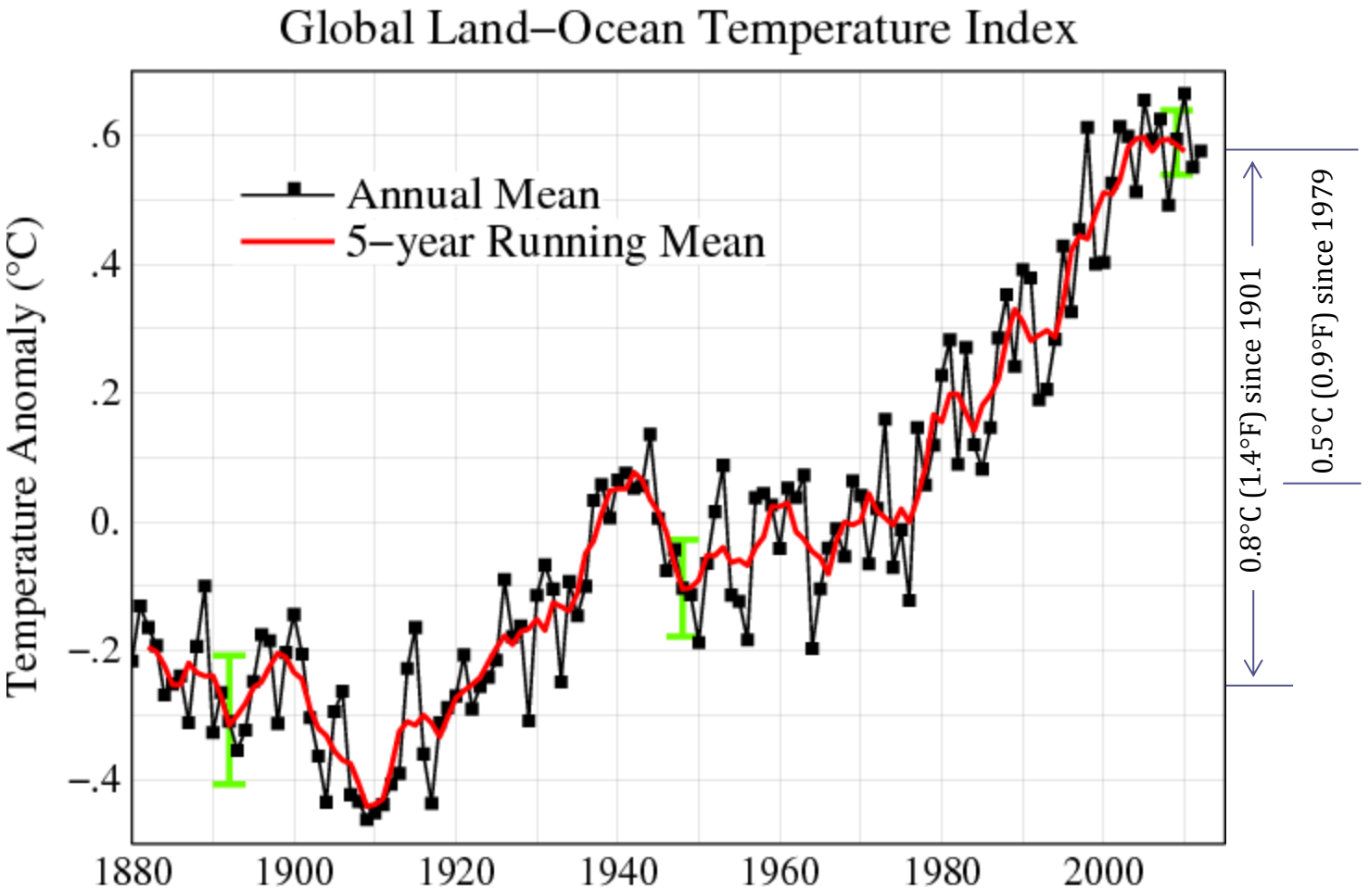
IPCC 2013; WG-I, FAQ 2.1,Fig. 1



IPCC 2013; WG-I, FAQ 2.1,Fig. 2



http://data.giss.nasa.gov/gistemp/graphs_v3/Fig.A.gif



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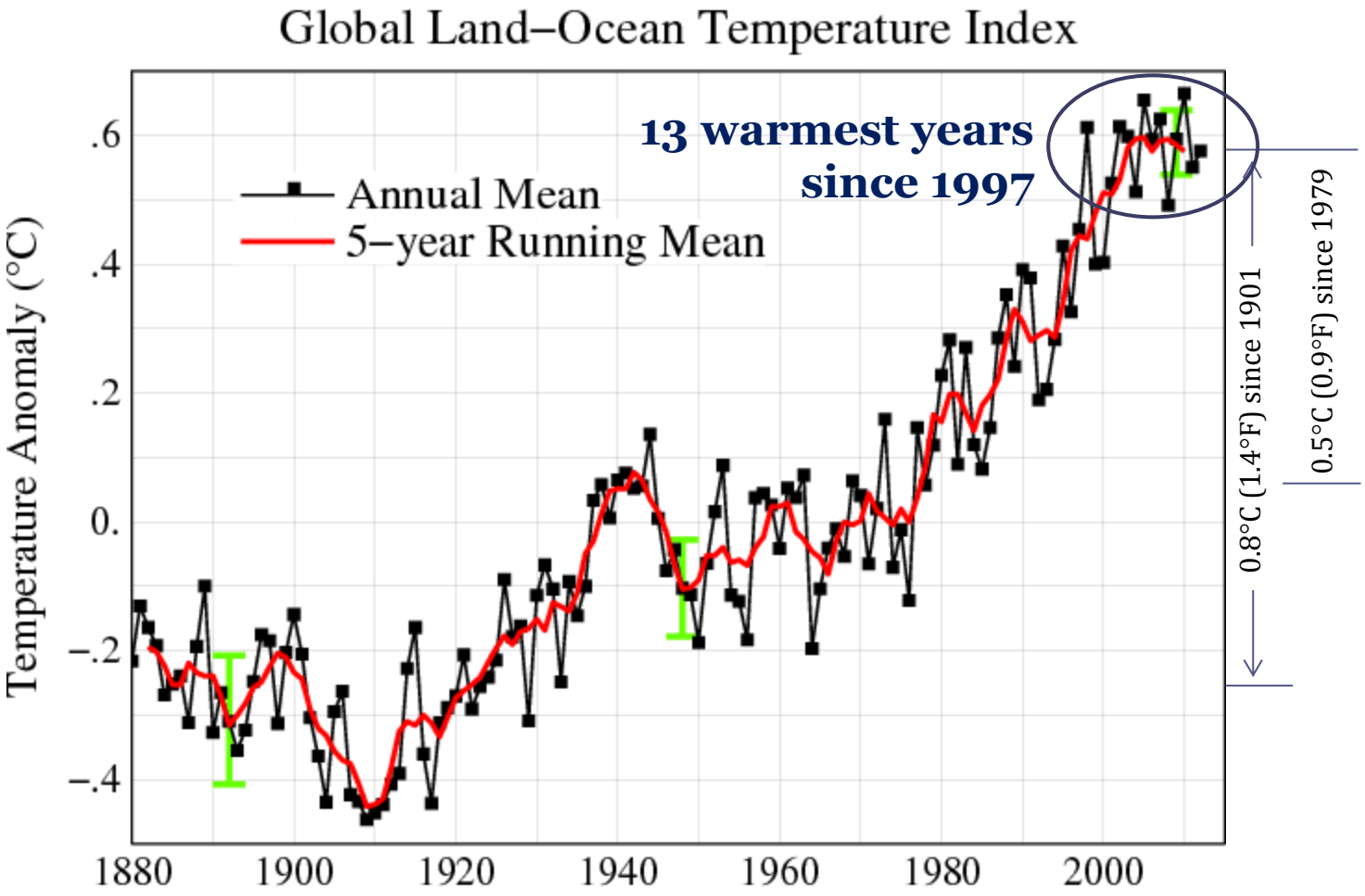

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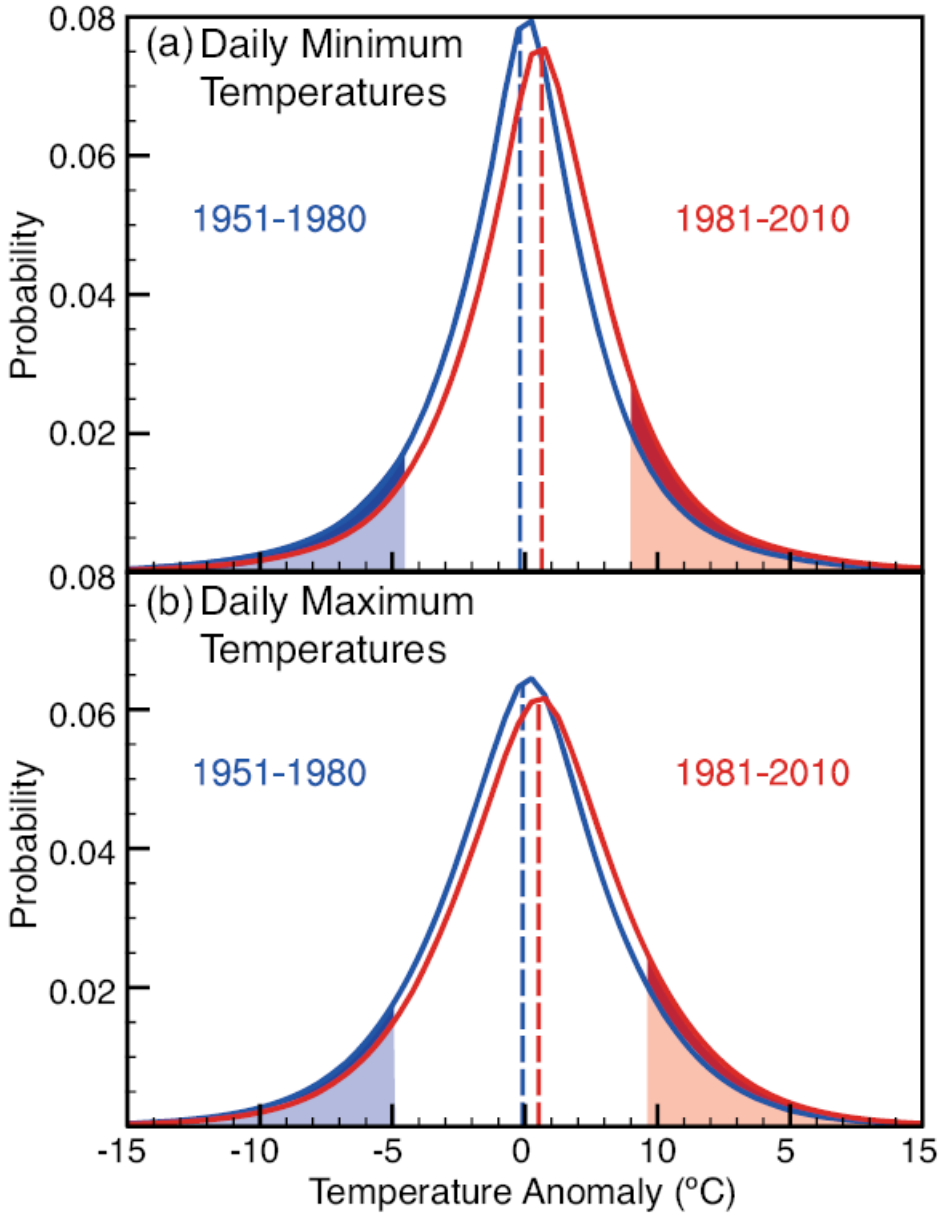
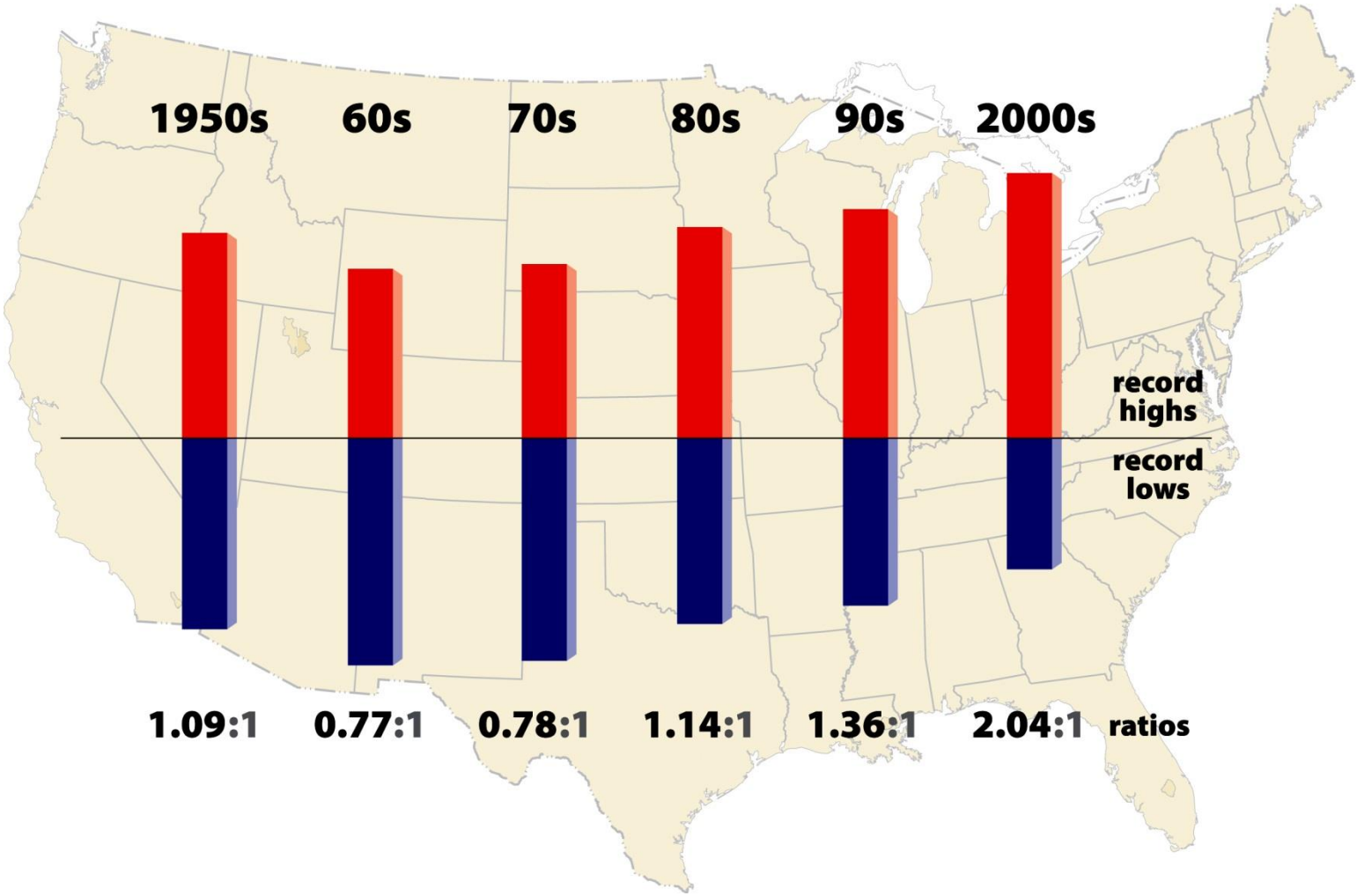
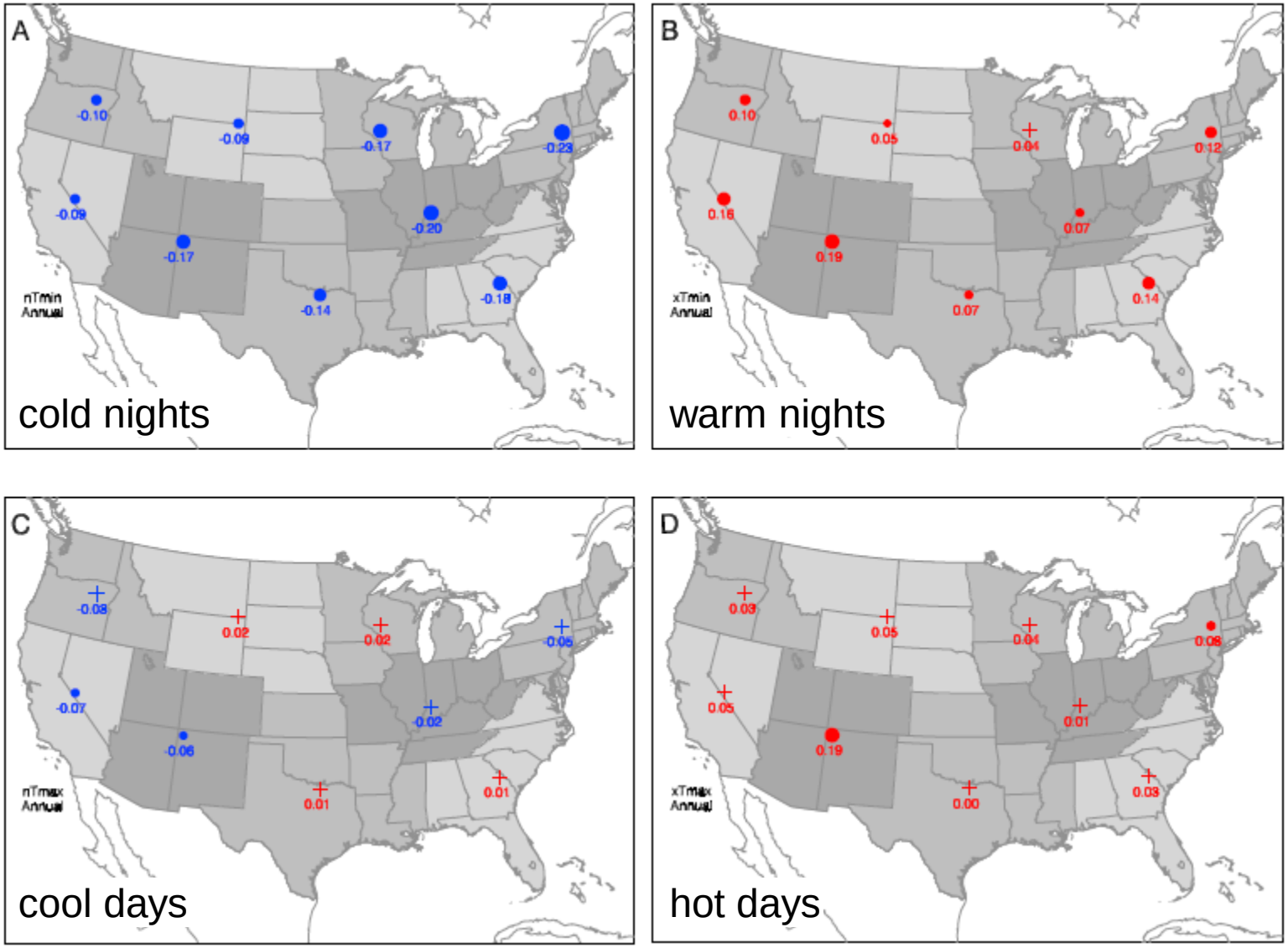


IPCC 2013; WG-I, FAQ 2.2, Fig. 1



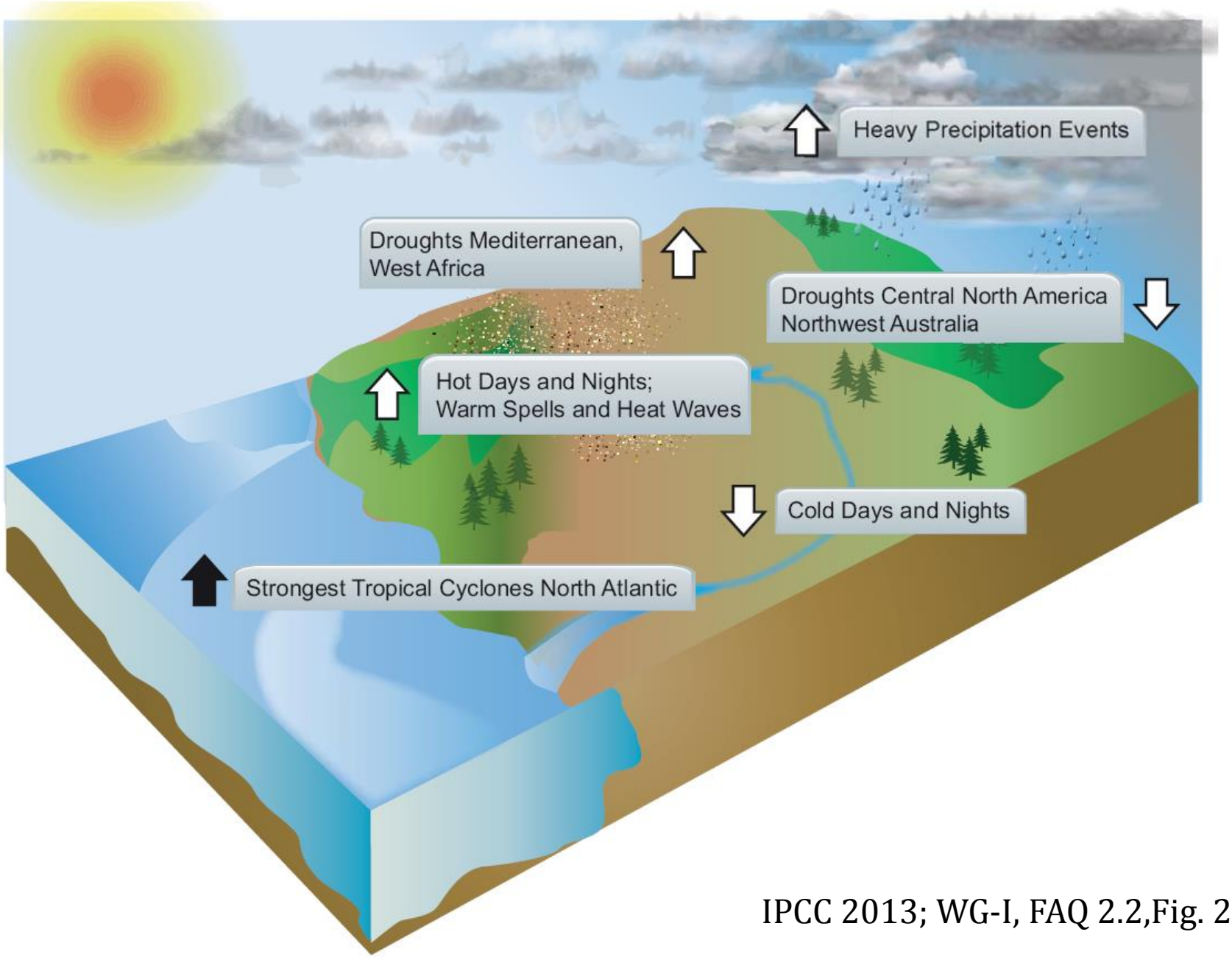
Meehl et al., 2009

Trends in record*-breaking temperatures

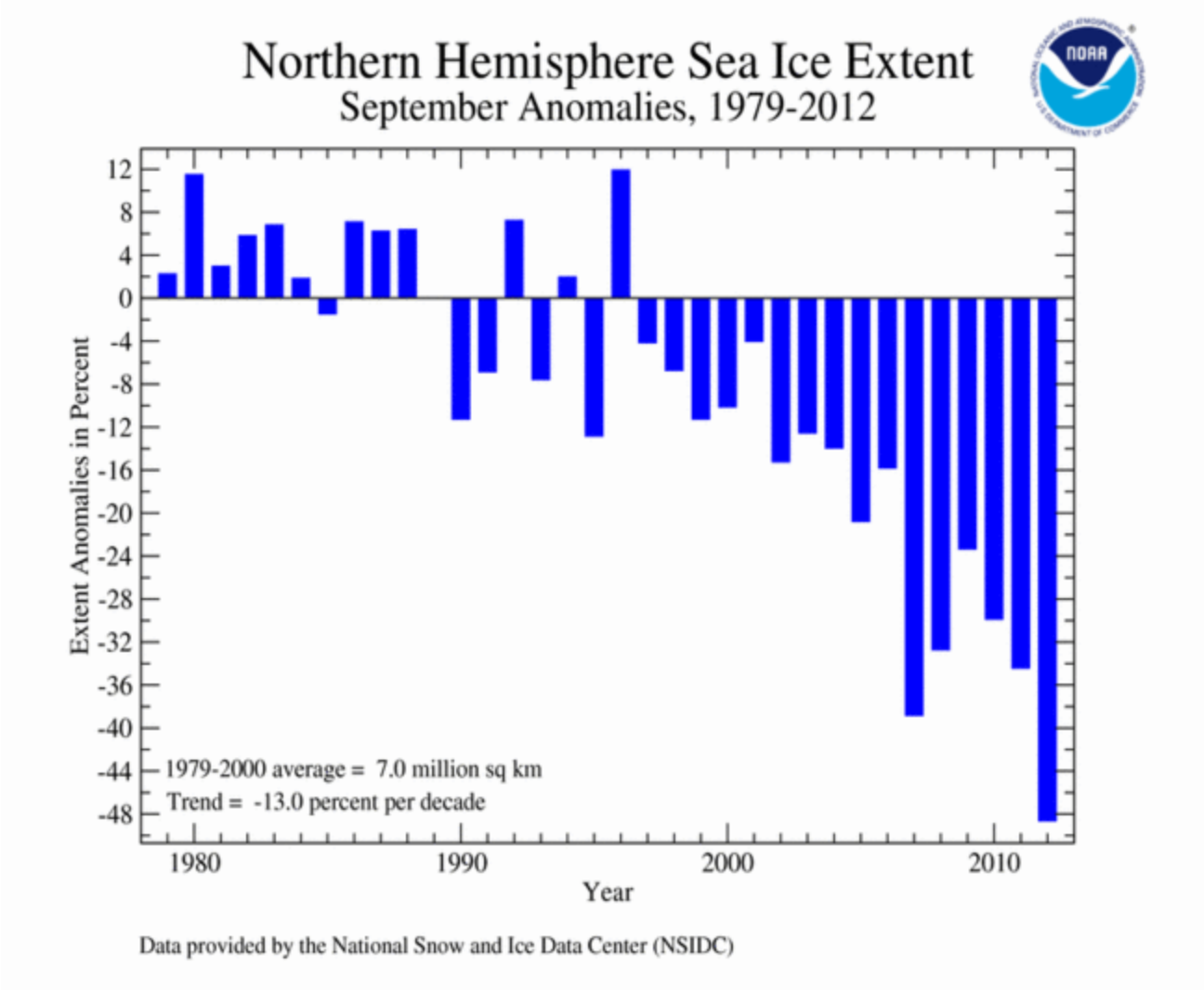


● increasing trend ● decreasing trend

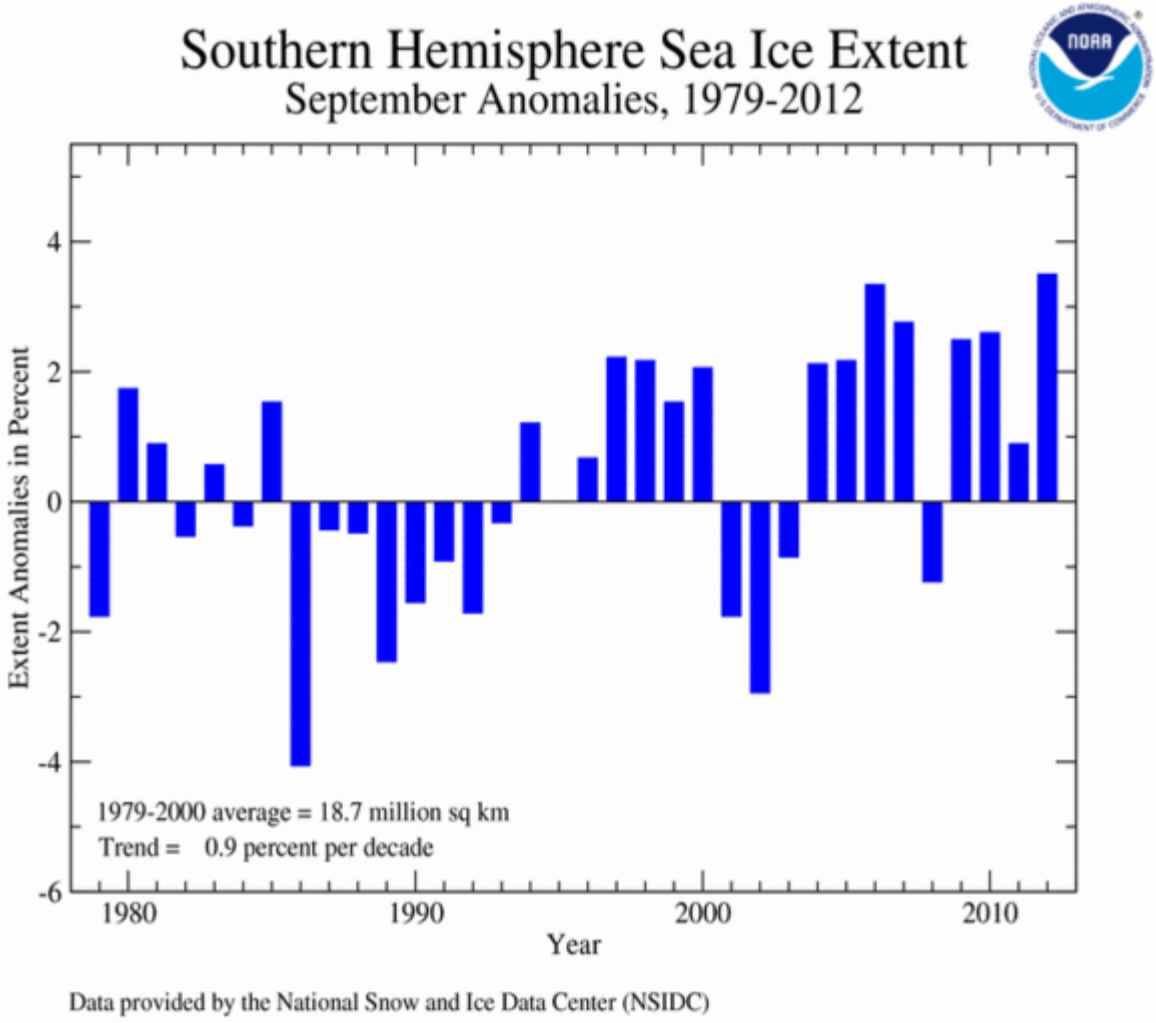
Rowe & Derry, 2012



IPCC 2013; WG-I, FAQ 2.2,Fig. 2



http://www.ncdc.noaa.gov/sotc/global-snow/2012/9.



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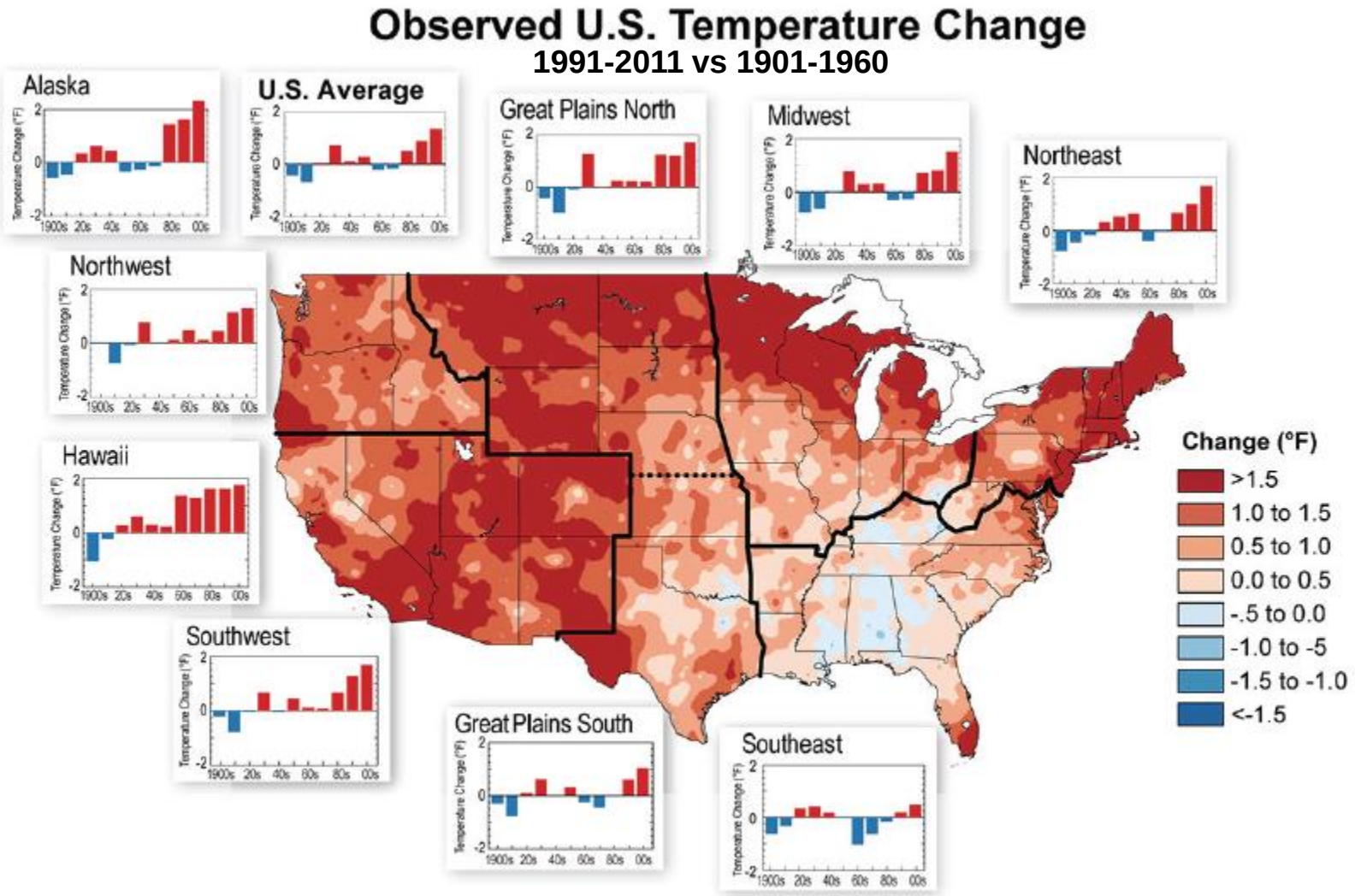
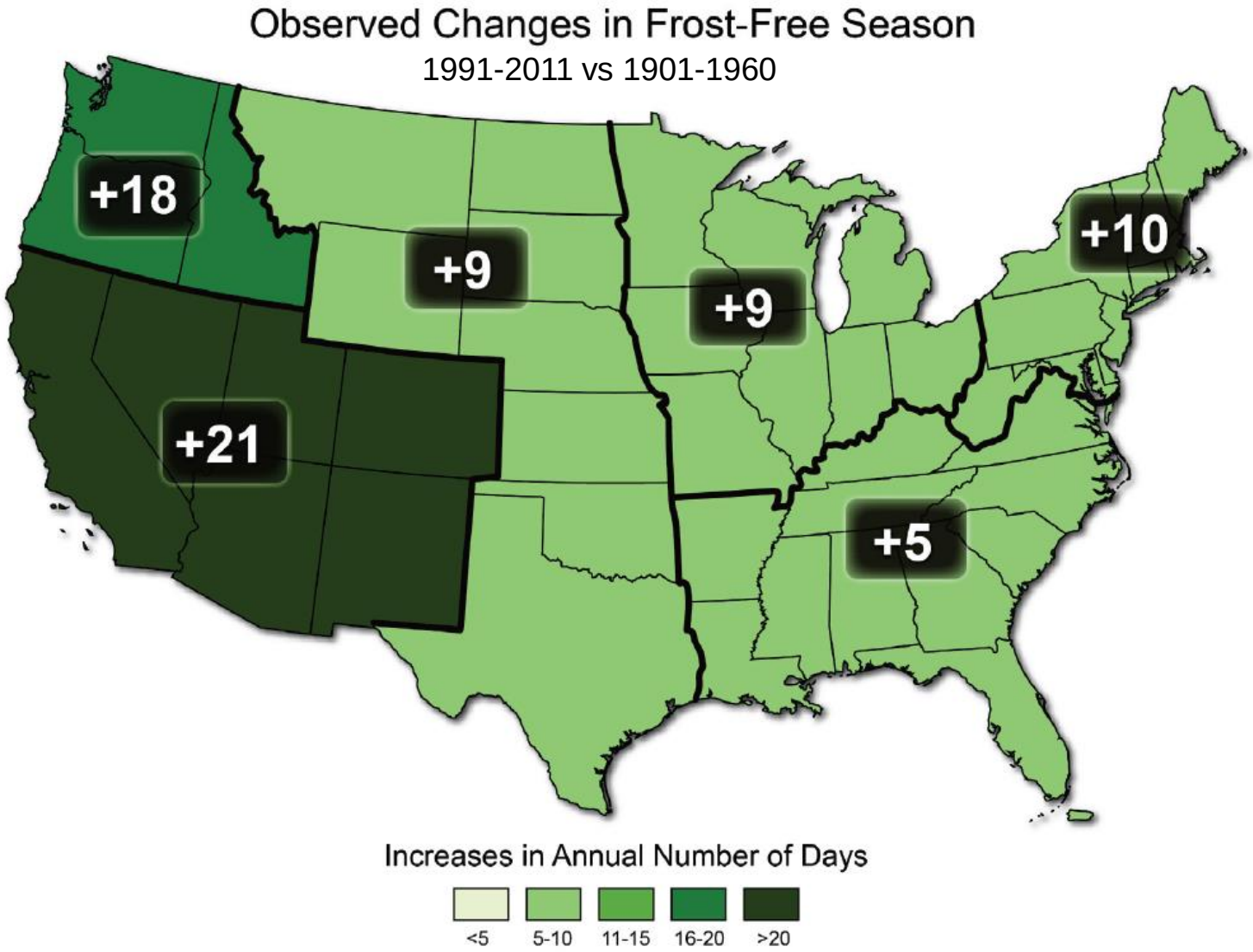


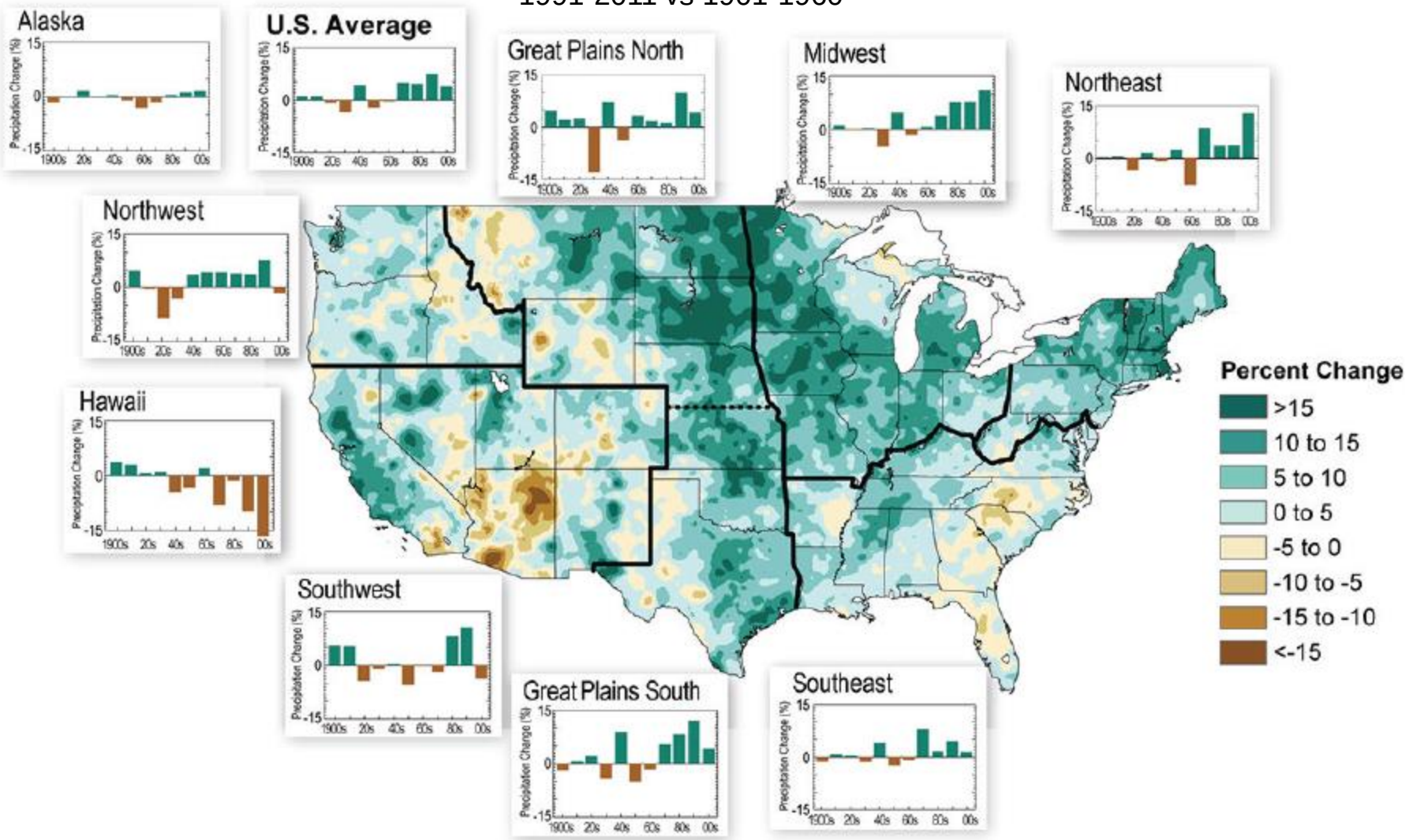
Third National Climate Assessment (NCA) - 11 Jan 2013 draft



Third National Climate Assessment (NCA) - 11 Jan 2013 draft

Observed U.S. Precipitation Change

1991-2011 vs 1901-1960



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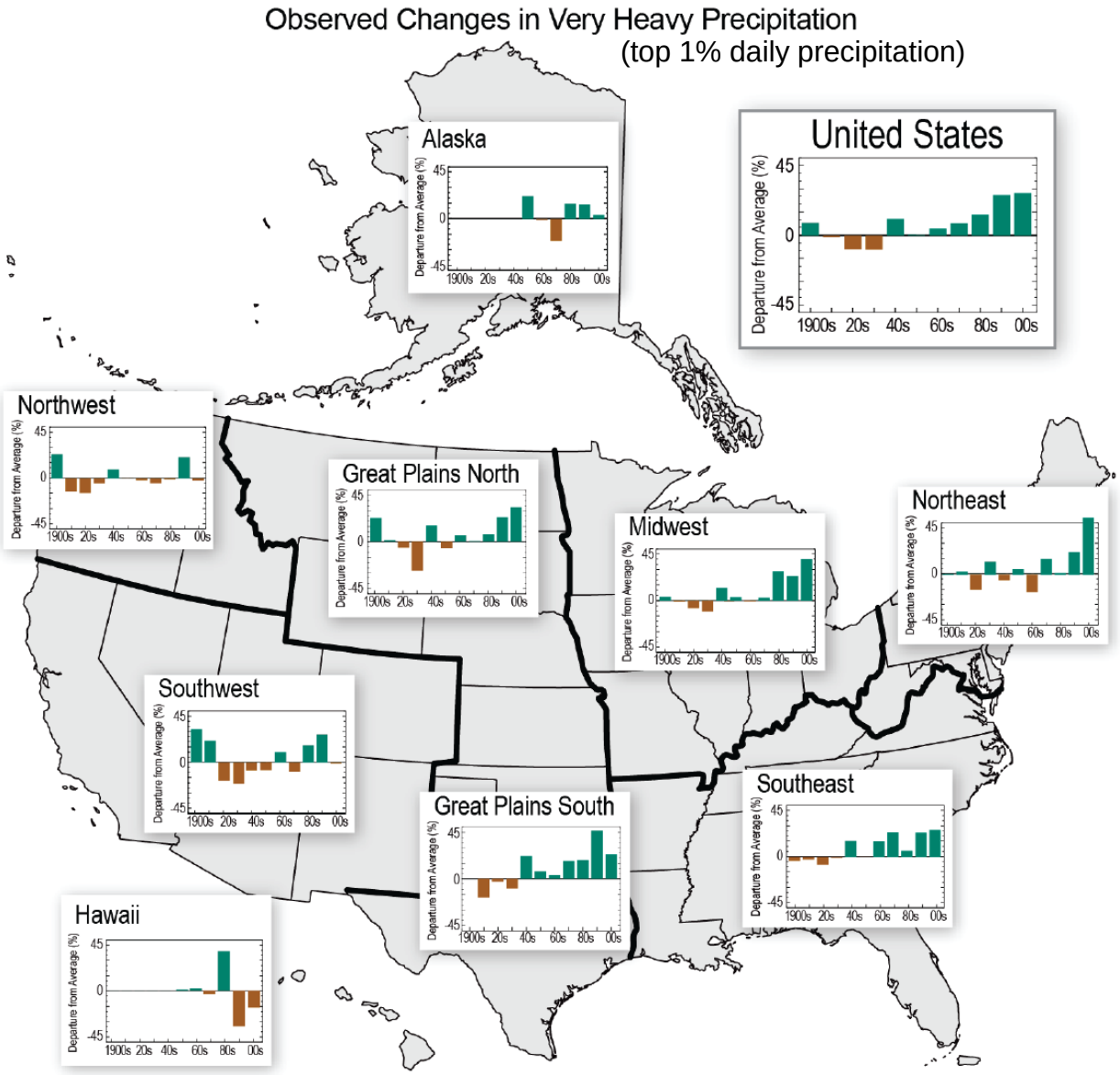

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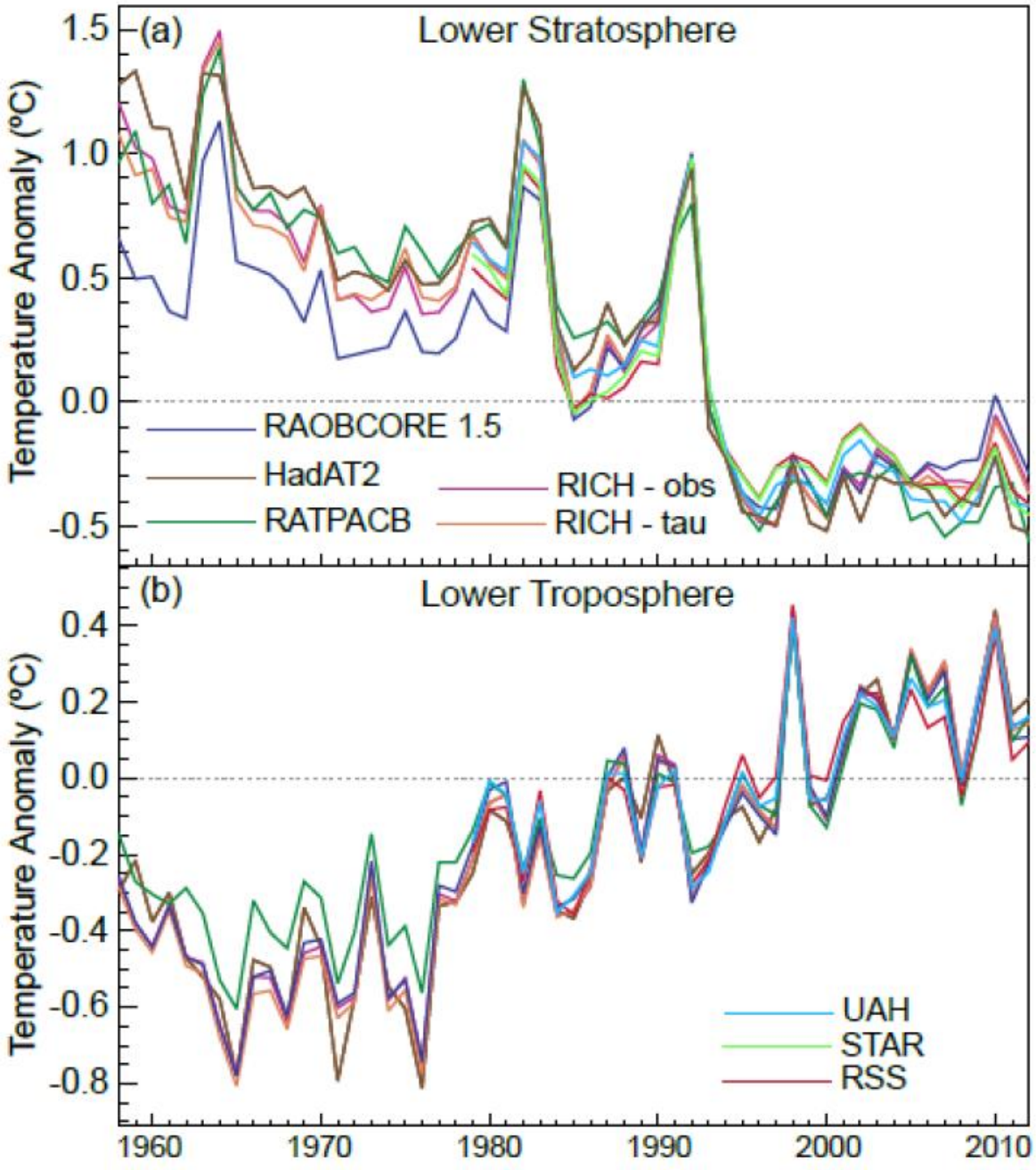
How do we know it's humans?

- Many lines of evidence support the conclusion that most of the observed warming since the start of the 20th century, and especially over the last several decades, can be attributed to human activities, including the following:
  - Earth's surface temperature has clearly risen over the past 100 years, at the same time that human activities have resulted in sharp increases in CO_2 and other GHGs.
  - Both the basic physics of the greenhouse effect and more detailed calculations dictate that increases in atmospheric GHGs should lead to warming of Earth's surface and lower atmosphere.
  - The vertical pattern of observed warming—with warming in the bottommost layer of the atmosphere and cooling immediately above—is consistent with warming caused by GHG increases and inconsistent with other possible causes.
  -

NRC, 2010



IPCC 2013; WG-I, Fig. 2.24

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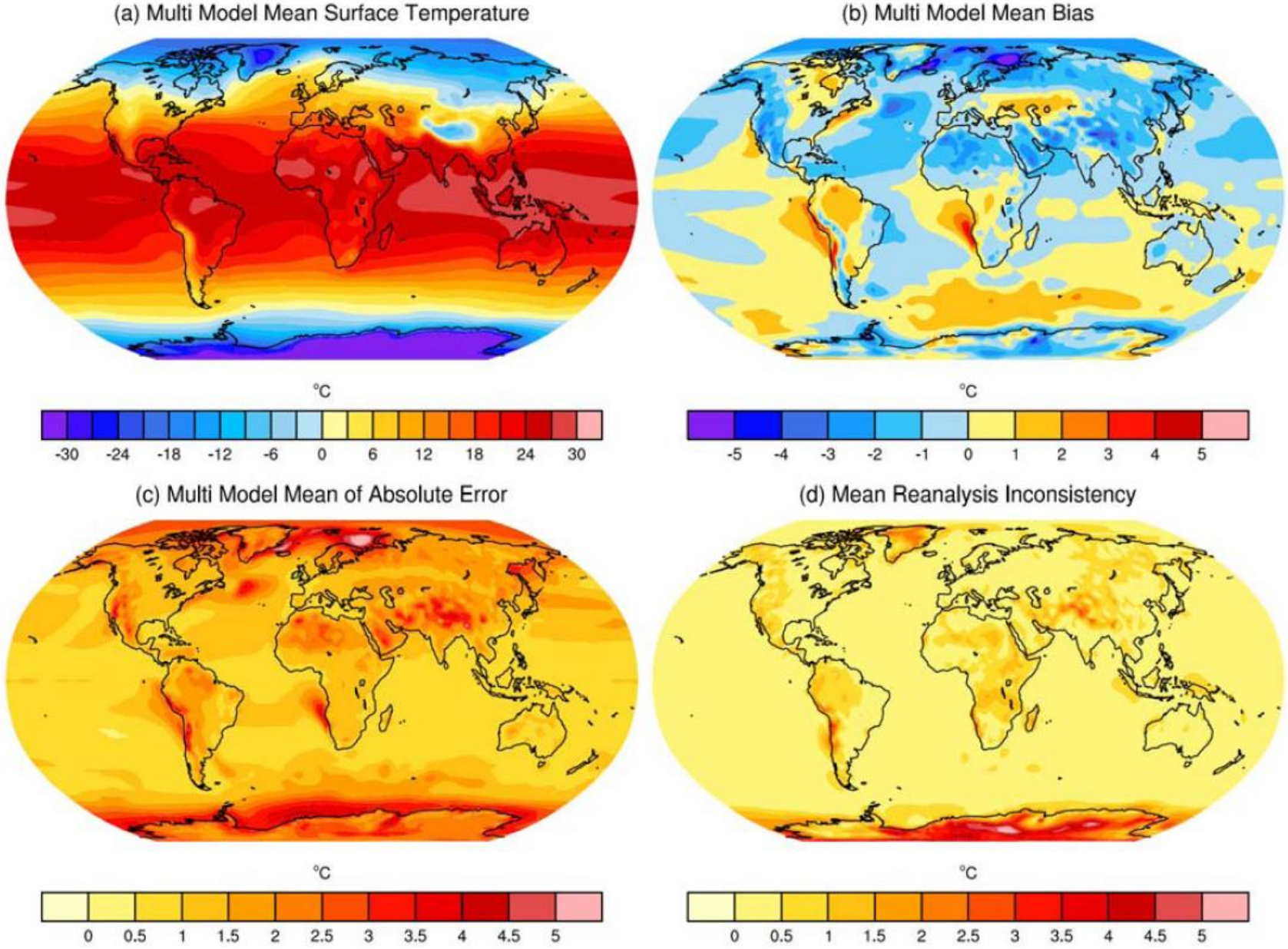
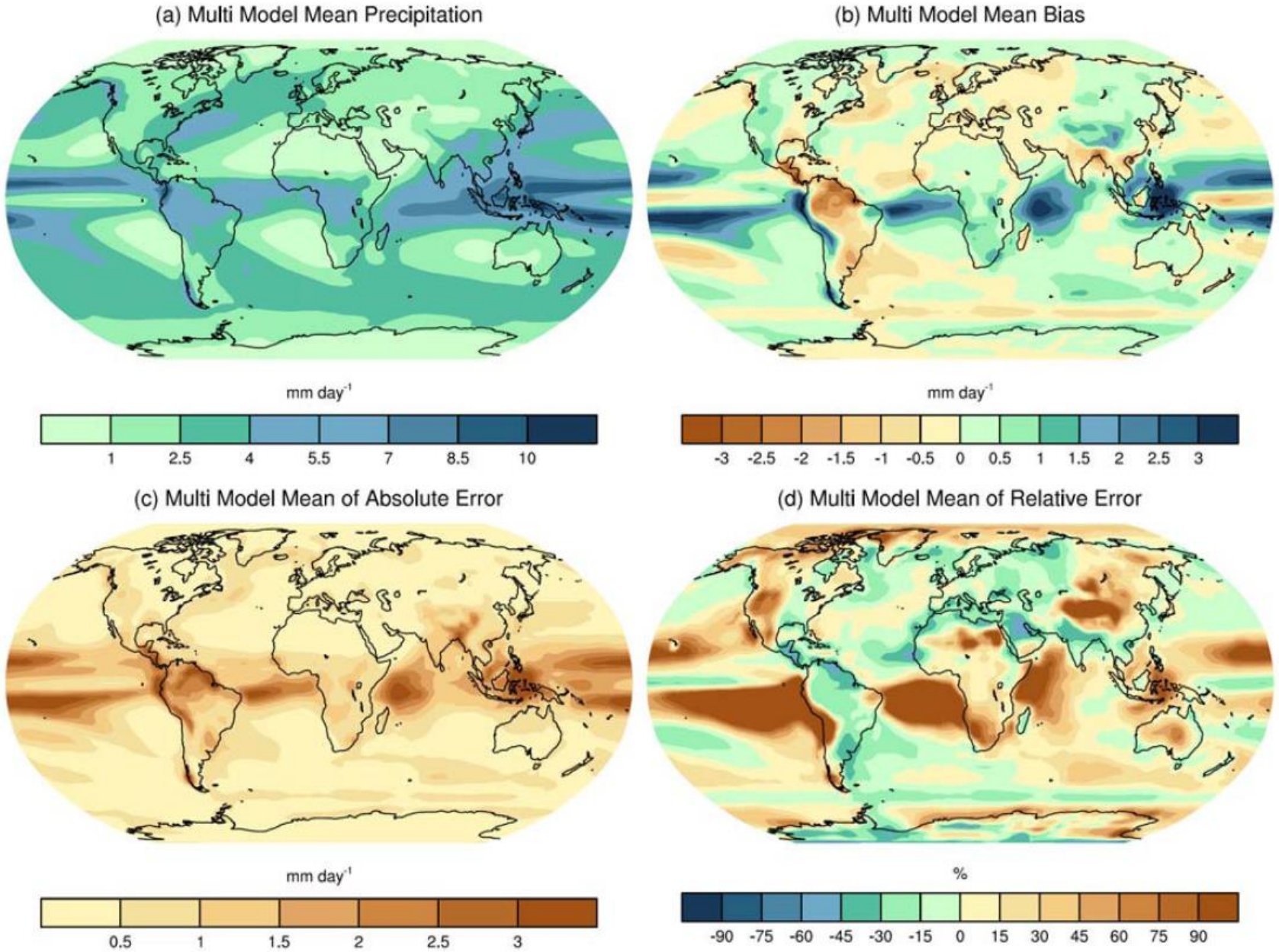
  - The vertical pattern of observed warming—with warming in the bottommost layer of the atmosphere and cooling immediately above—is consistent with warming caused by GHG increases and inconsistent with other possible causes.
  - Detailed simulations with state-of-the-art computer-based models of the climate system are only able to reproduce the observed warming trend and patterns when GHG emissions are included.

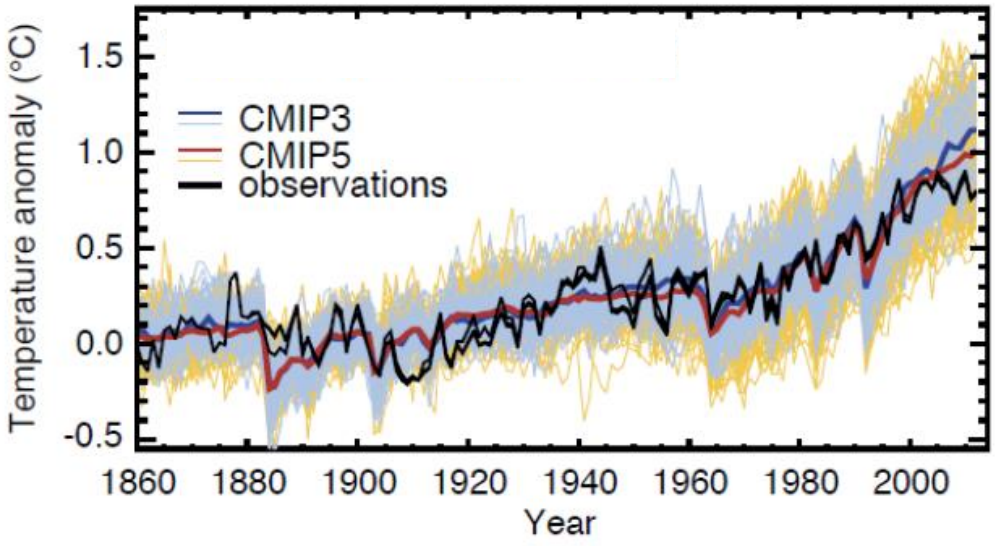
NRC, 2010

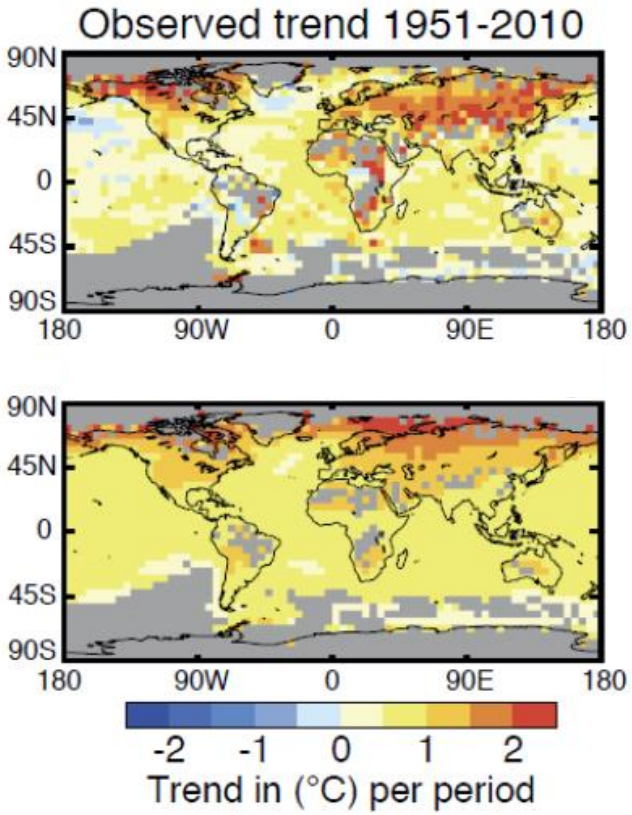


IPCC 2013; WG-I, Fig. 9.2

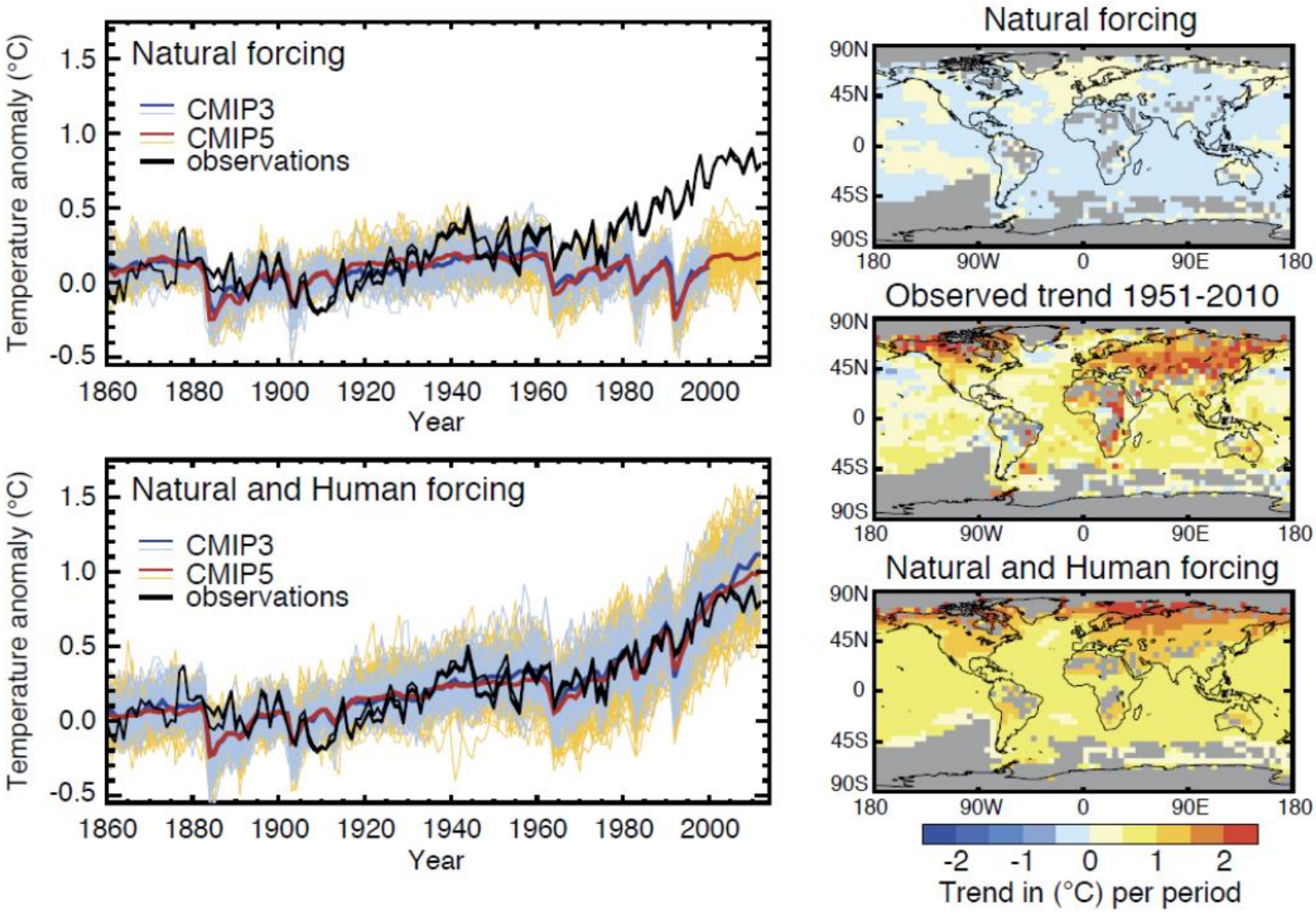


IPCC 2013; WG-I, Fig. 9.4

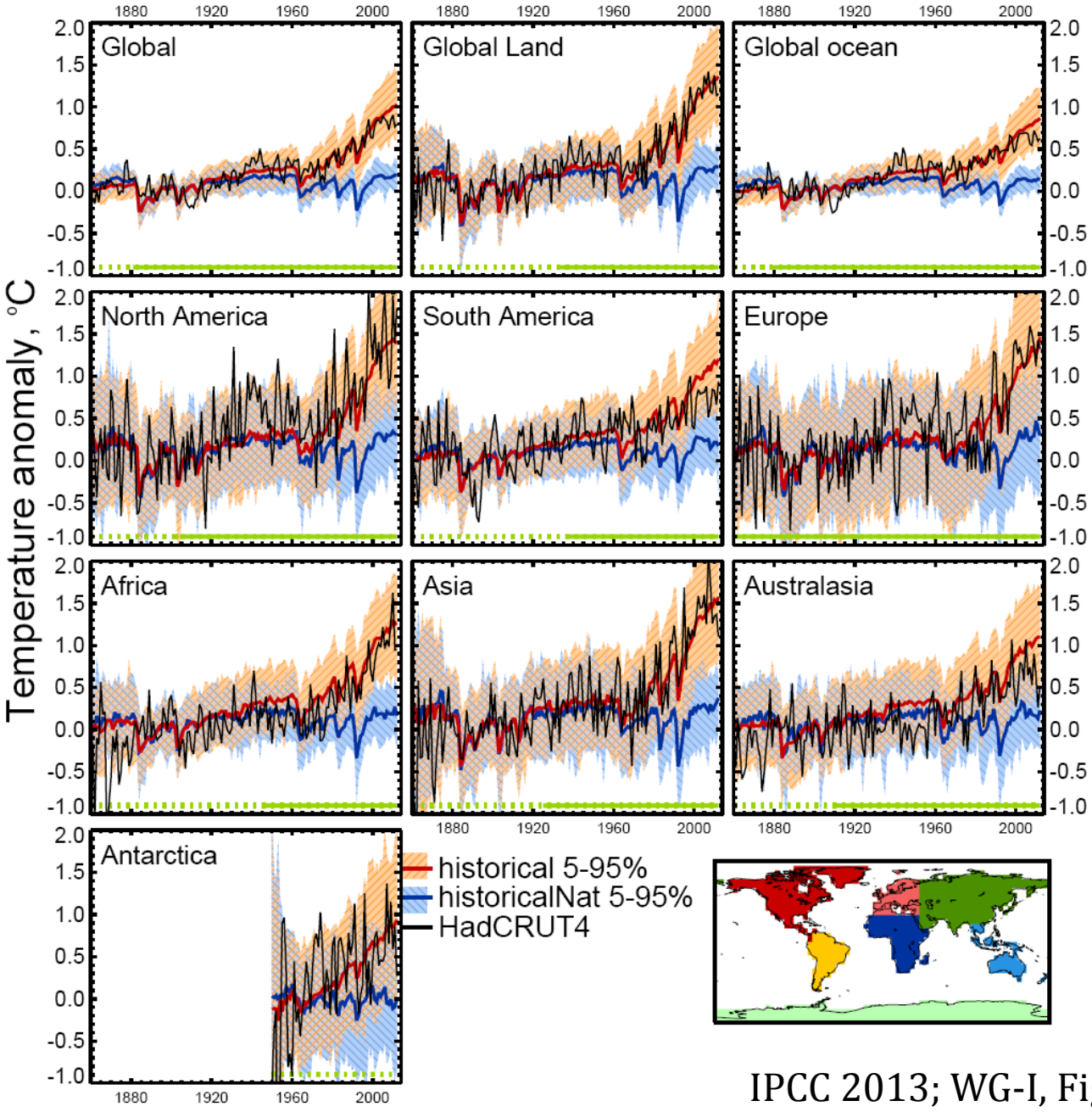




IPCC 2013; WG-I, FAQ 10.1, Fig. 1



IPCC 2013; WG-I, FAQ 10.1, Fig. 1



IPCC 2013; WG-I, Fig. 10.7

How do we know it's humans?

- In addition, other possible causes of the observed warming have been rigorously evaluated:
  - The climate system varies naturally on a wide range of time scales, but a rigorous statistical evaluation of observed climate trends, supported by analyses with climate models, indicates that the observed warming, especially the warming since the late 1970s, **cannot be attributed to natural variations**.
  - Satellite measurements conclusively show that solar output has not increased over the past 30 years, so **an increase in energy from the Sun cannot be responsible for recent warming**. There is evidence that some of the warming observed during the first few decades of the 20th century may have been caused by a slight uptick in solar output, although this conclusion is much less certain.
  - Direct measurements likewise show that the number of cosmic rays, which some scientists have posited might influence cloud formation and hence climate, have neither declined nor increased during the last 30 years. Moreover, **a plausible mechanism by which cosmic rays might influence climate has not been demonstrated**.

NRC, 2010

Estimated contributions to global mean temperature change (°C)

Observations

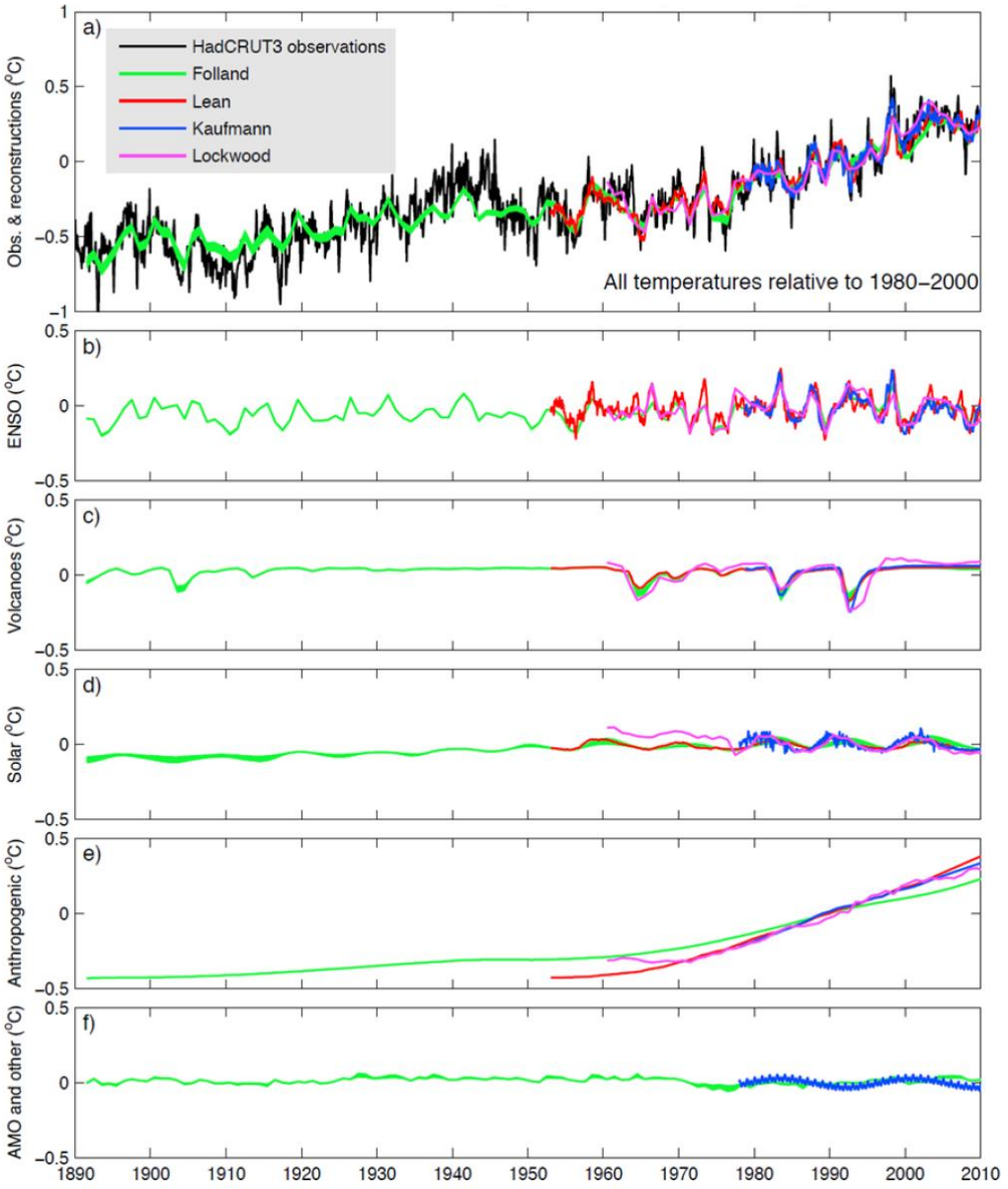
ENSO

Volcanoes

Solar

Anthropogenic

Other factors
(AMO, SAO, AO)

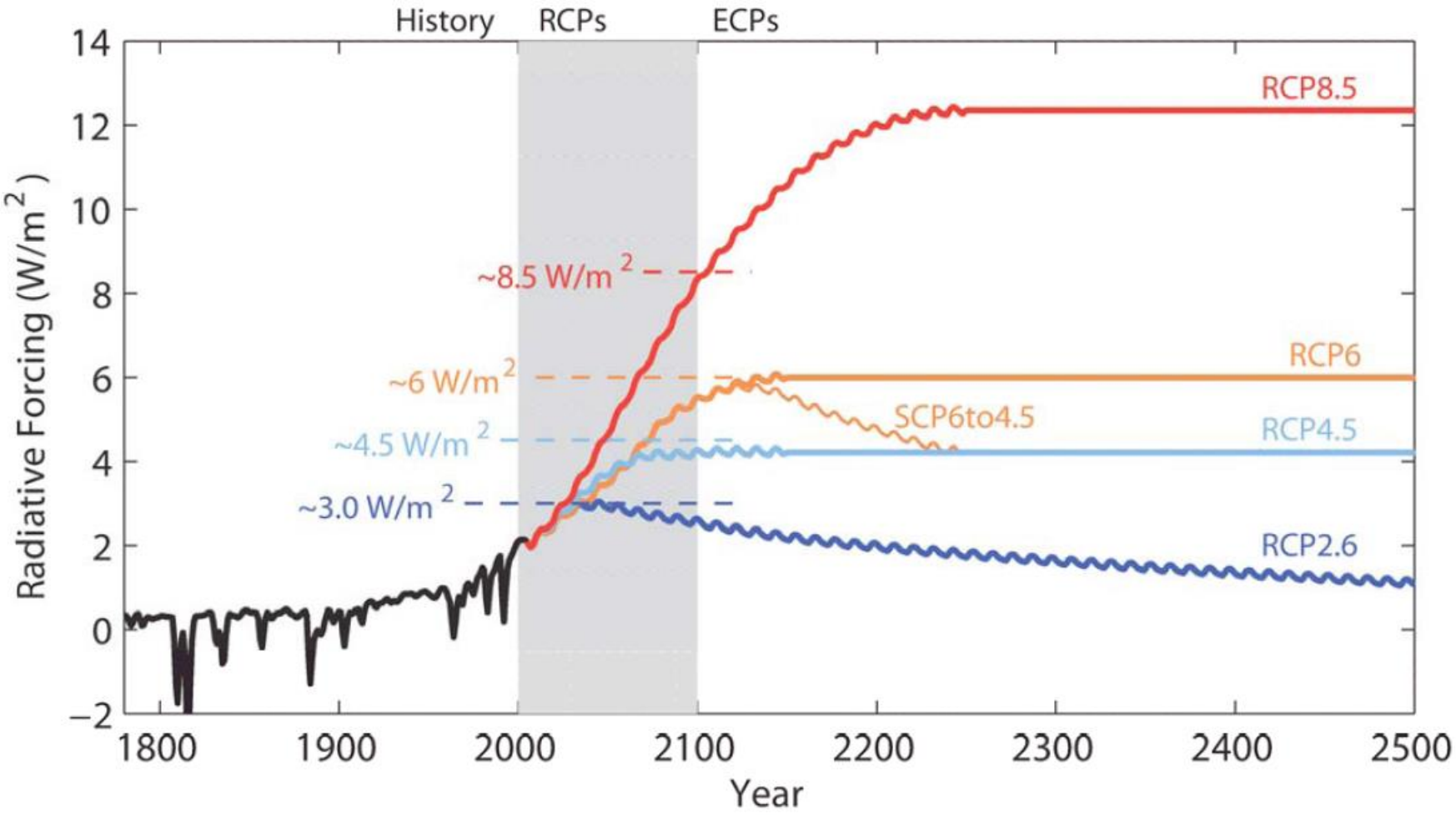


IPCC 2013; WG-I, Fig. 10.6

What is going to happen?

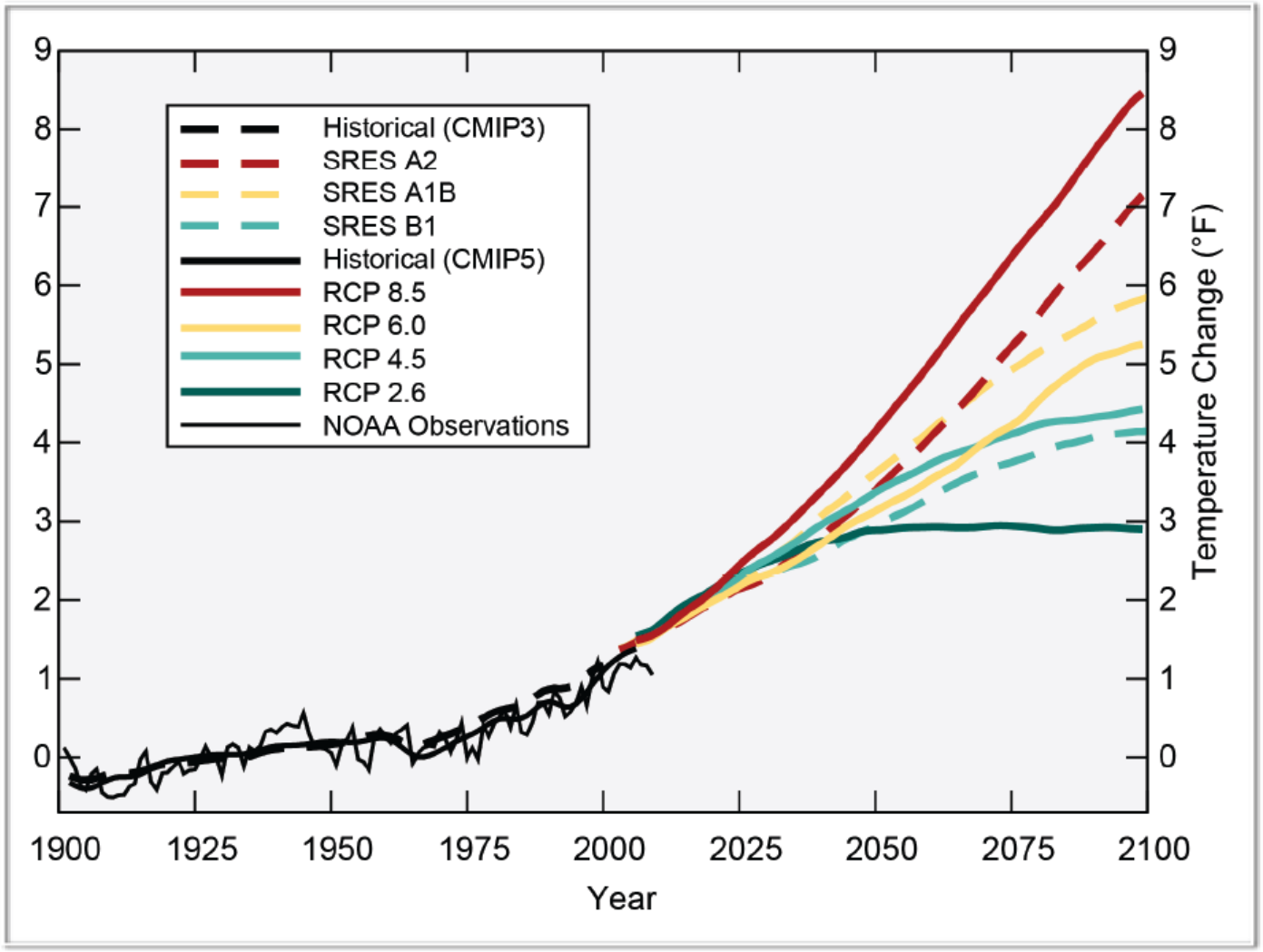
- Need to create scenarios of how CO2 emissions and atmospheric concentrations will change in the future
  - SRES (A2, A1B, B2, …)
    - used for AR4, tried to account for economic and social trends
  - RCP (2.6, 4.5, 6, 8.5, …)
    - used for AR5, represent radiative forcing at (or near) end of 21st century
  - regardless of choice of method, scenarios contain uncertainty

- Use best computer models to project climate change in response to GHG forcings
  - include all known additional forcings and feedbacks
  - model uncertainty due to incomplete scientific understanding and lack of data



IPCC 2013; WG-I, Box 1.1,Fig. 1

Average Global Temperature Projections



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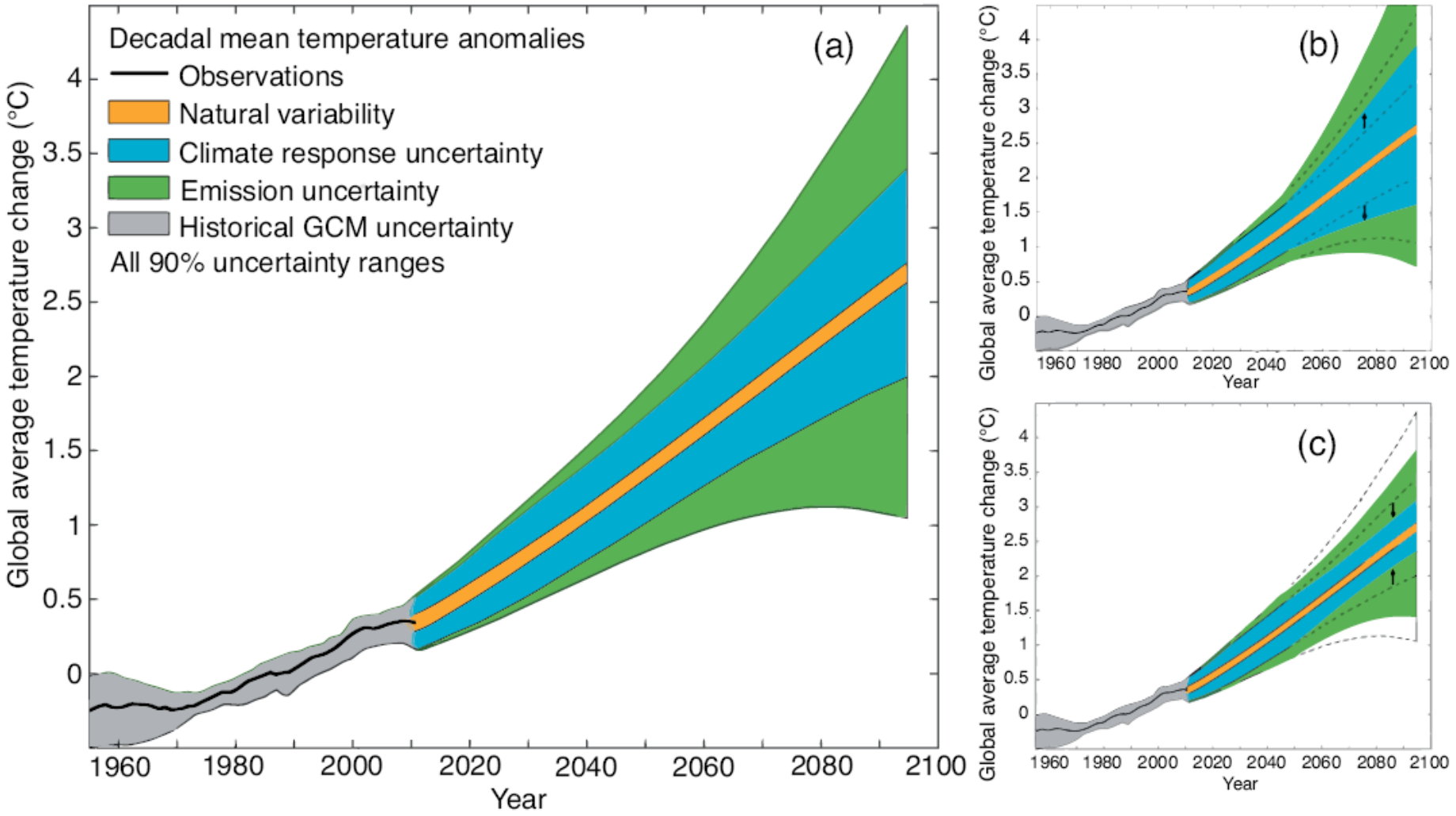
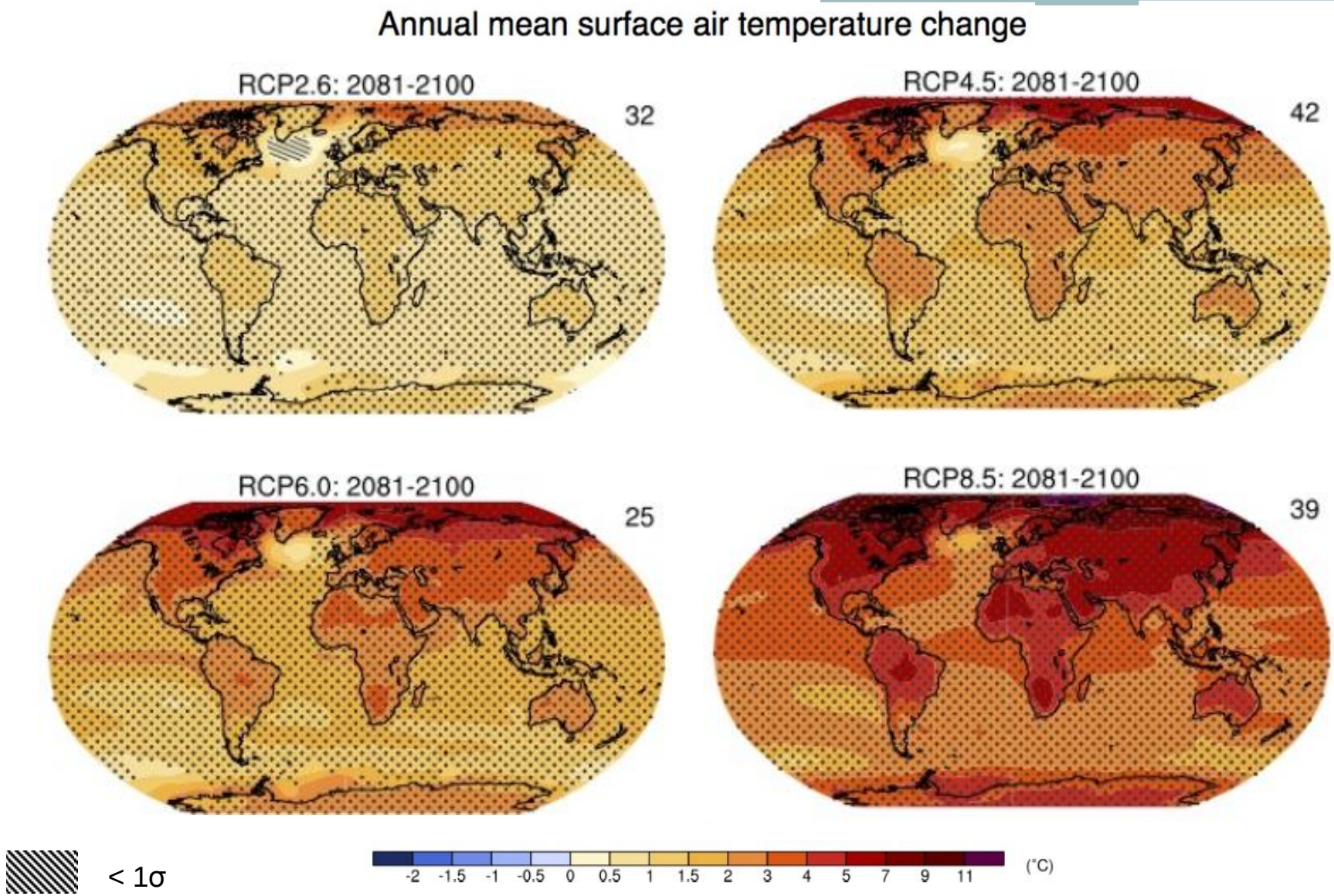
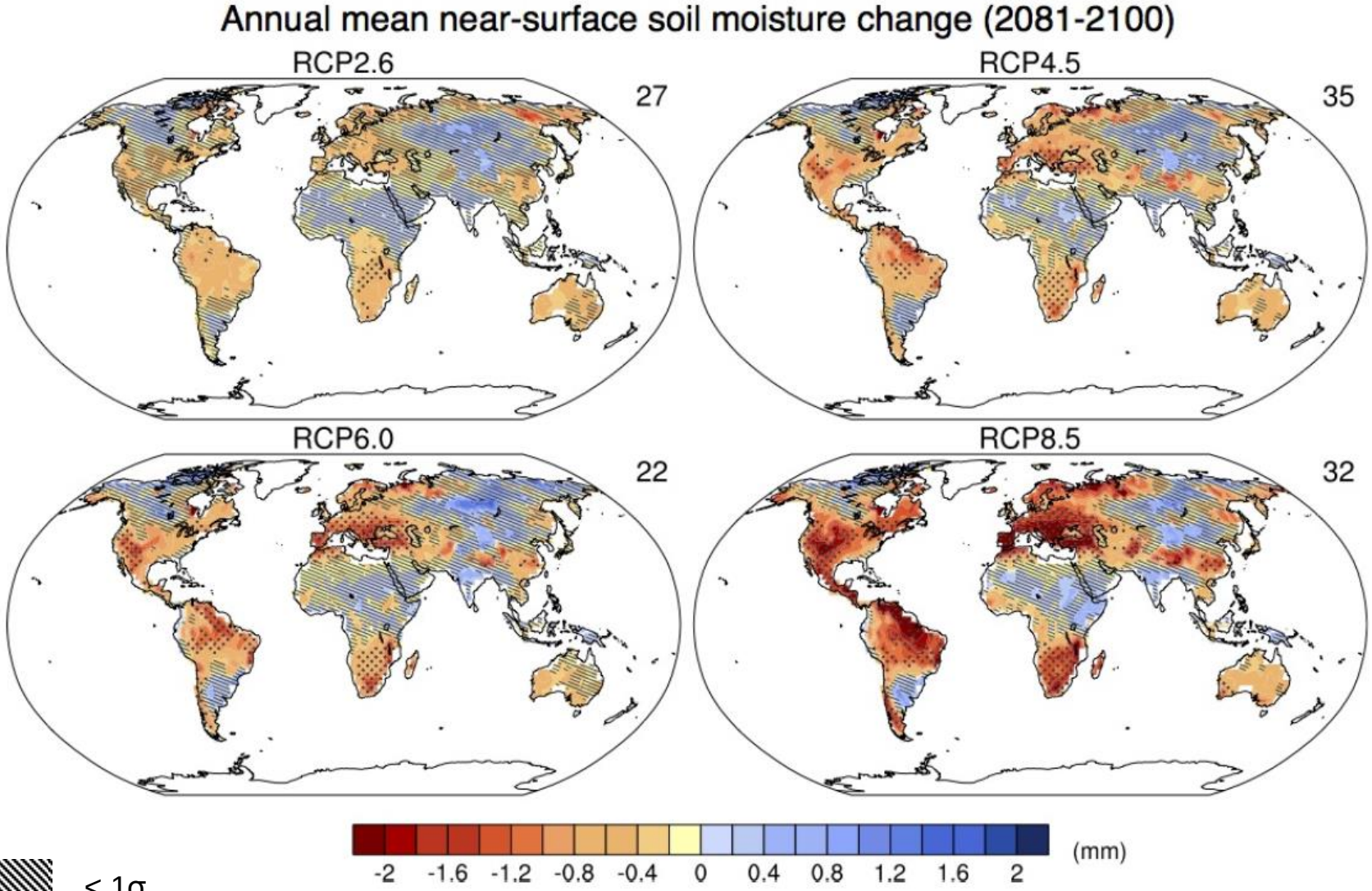


Climate response uncertainty is based on climate model spread, along with added uncertainties from the carbon cycle, as well as rough estimates of additional uncertainty from poorly-modeled processes.

IPCC 2013; WG-I, FAQ 1.1,Fig. 1

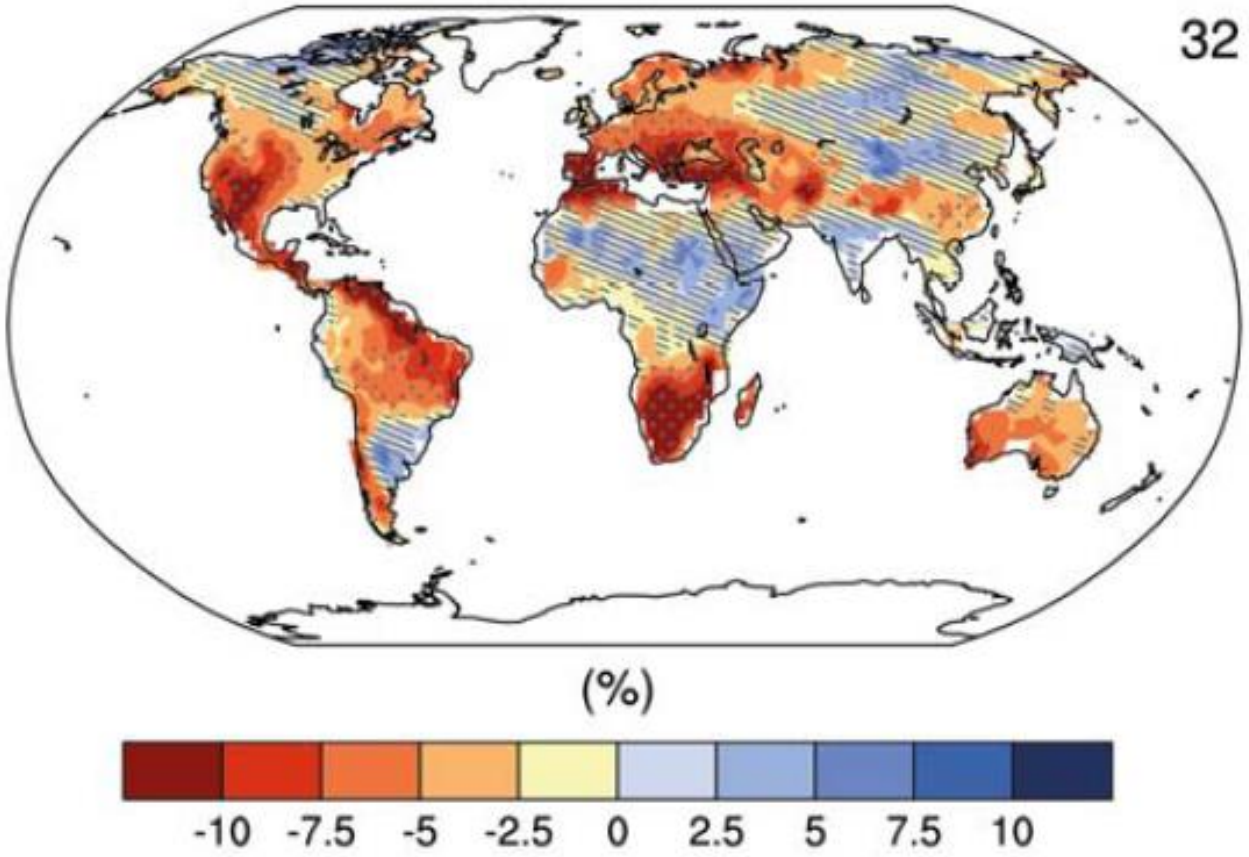


IPCC 2013; WG-I, Fig. 12.11



IPCC 2013; WG-I, Fig. 12.23

Annual mean near-surface soil moisture change (2081-2100)



< 1σ

≥ 2σ and ≥ 90% sign agreement

IPCC 2013; WG-I, Fig. 12.23

in summary …

- **Global and US climate is changing and is observable.**
  - **Majority of change over the past 50 years is due to human activities, predominantly the burning of fossil fuels.**
- **Some extreme weather and climate events have increased in recent decades.**
  - **Emerging evidence that many of these increases are related to human activities.**
- **Reliability of water supplies is reduced by climate change.**
  - **Even where precipitation is projected to increase, seasonal distribution may change in adverse ways.**
- **Impacts related to climate change are already evident.**
  - **Expected to increase through the 21st century and beyond.**

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Additional resources

- **National Research Council, National Academy of Sciences**
  - *Advancing the Science of Climate Change*
  - *Limiting the Magnitude of Future Climate Change*
  - *Adapting to the Impacts of Climate Change*
  - *Informing an Effective Response to Climate Change*
  - *America's Climate Choices*
- **Intergovernmental Panel on Climate Change**
  - *Climate Change 2013 - The Physical Science Basis*
  - *Climate Change 2007 - Impacts, Adaptation and Vulnerability*
  - *Climate Change 2007 - Mitigation of Climate Change*
- **U.S. Global Change Research Program**
  - www.globalchange.gov
  - National Climate Assessment (http://ncadac.globalchange.gov/)
- *What We Know About Climate Change, 2nd edition*, **Kerry Emanuel**
- **Nature Conservancy**
  - www.climatewizard.org