BASICS OF CLIMATE CHANGE

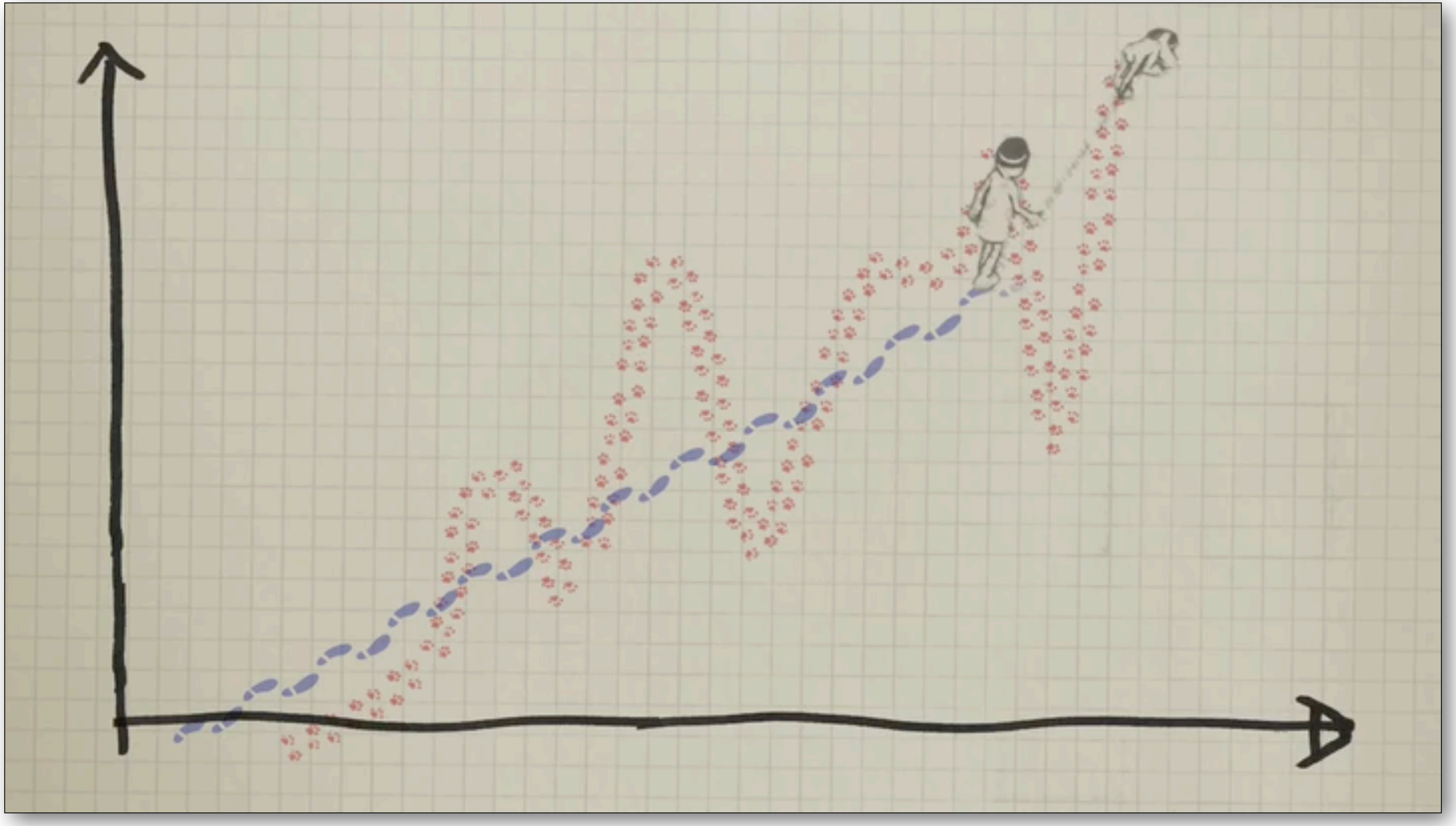
Dr. Renee A. McPherson

Associate Professor, Geography & Environmental Sustainability

University Director, South Central Climate Adaptation Science Center, University of Oklahoma

SOUTH CENTRAL
CLIMATE ADAPTATION SCIENCE CENTER

WEATHER VS. CLIMATE



WEATHER VS. CLIMATE

Weather – **state of the atmosphere** with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness; **short-term**

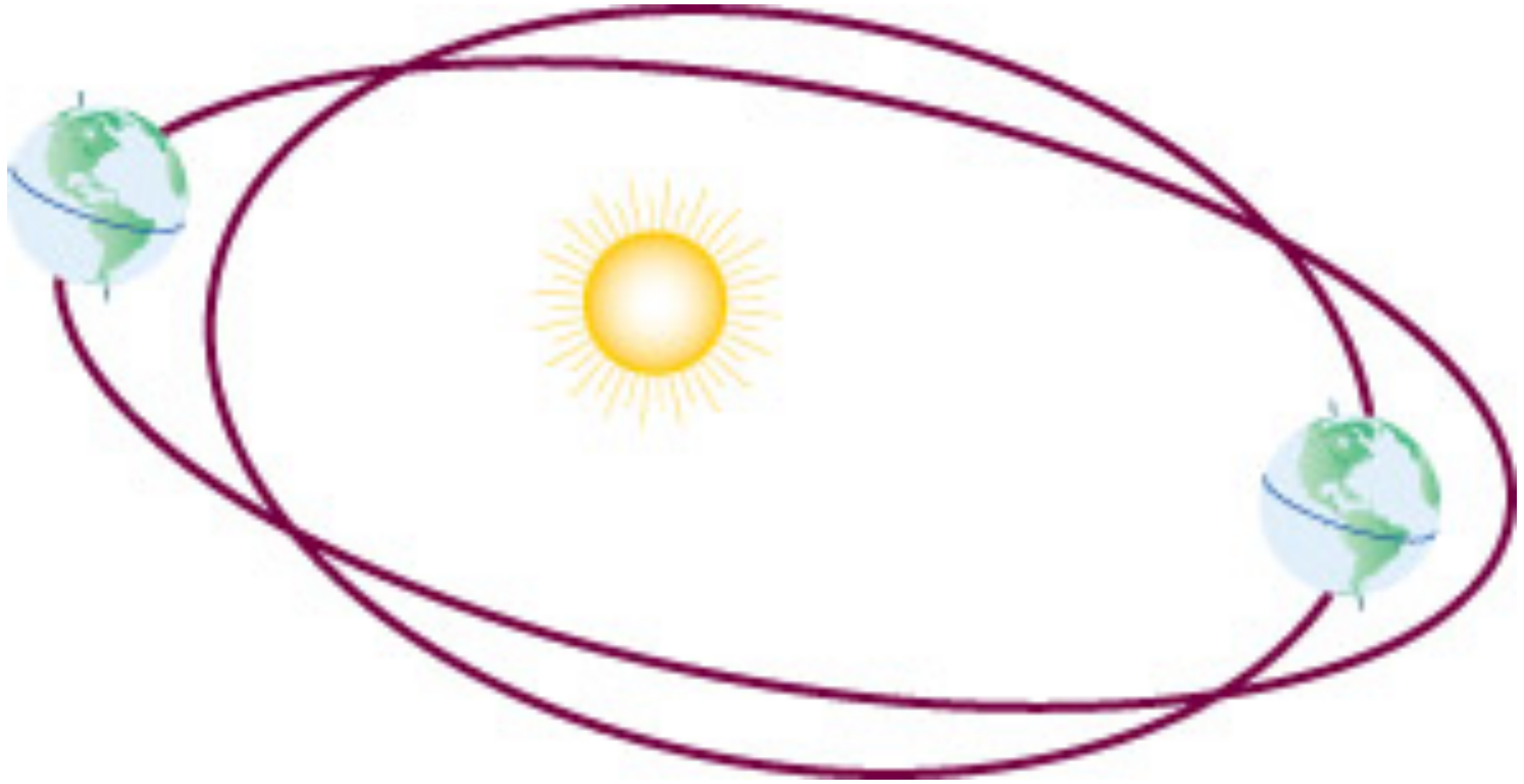
Climate – **statistical collection of weather conditions** at a place over a period of years; **long-term**

“Climate is what you expect. Weather is what you get.”

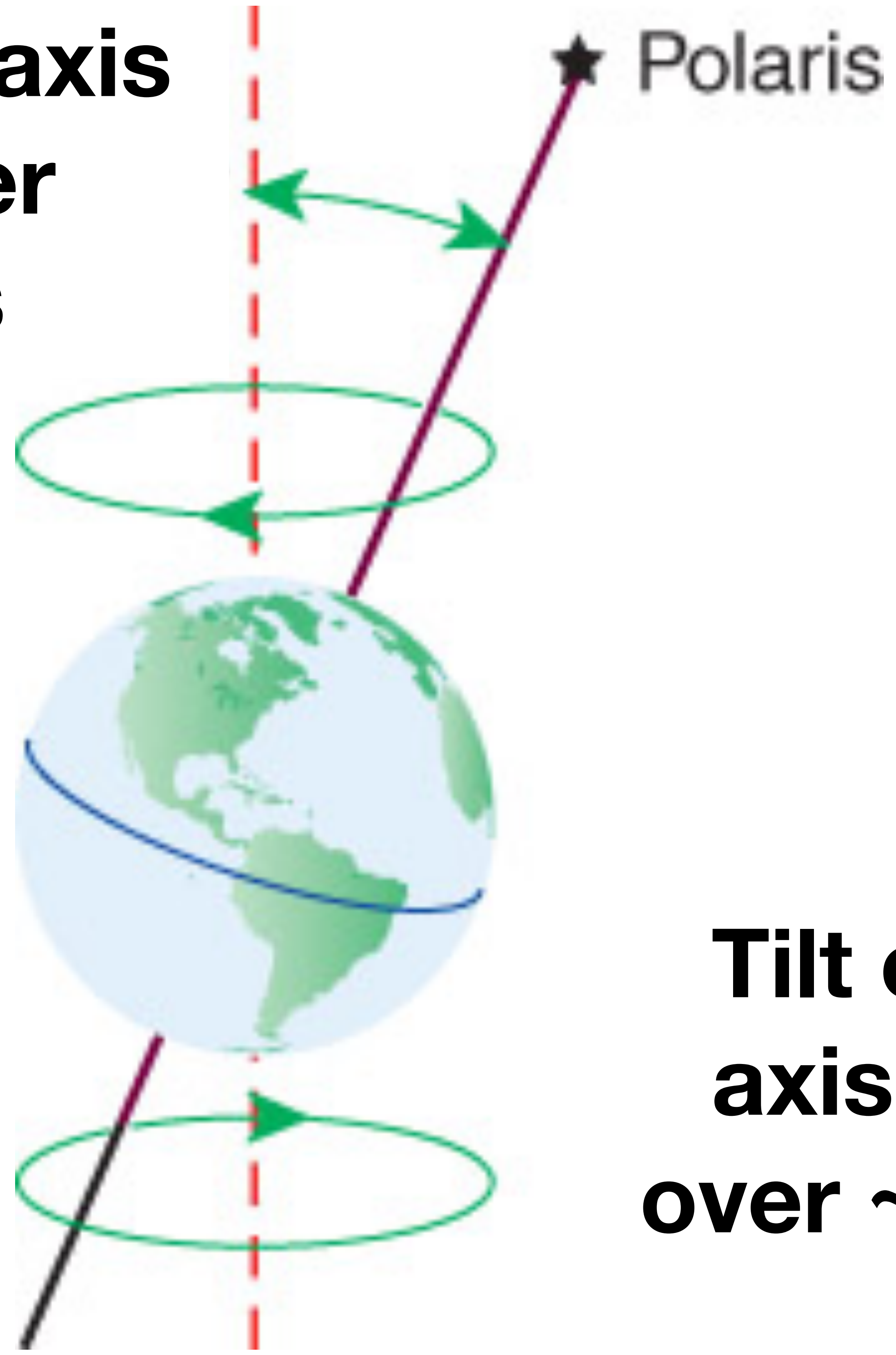
CLIMATE VARIABILITY VS. CHANGE

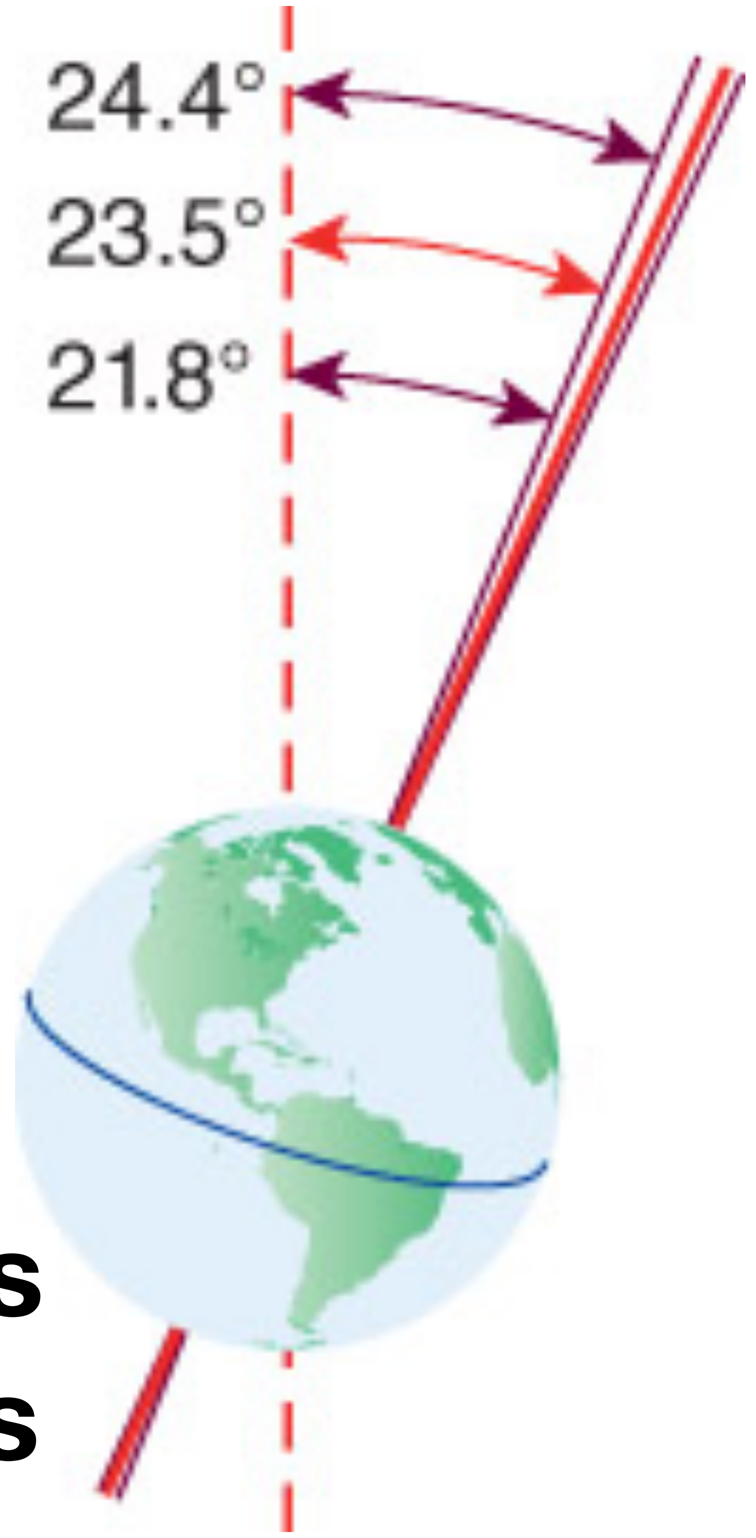
REALLY LONG-TERM CLIMATE CHANGE

Shape of Earth's orbit changes over ~100,000 yrs



Wobble (precession) of Earth on its axis changes over ~22,000 yrs



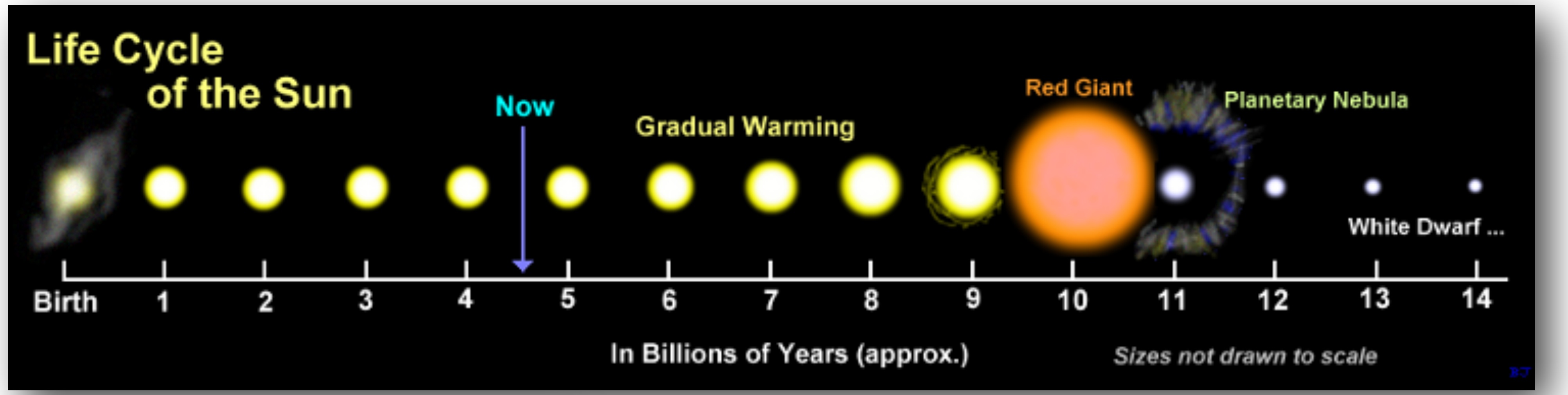


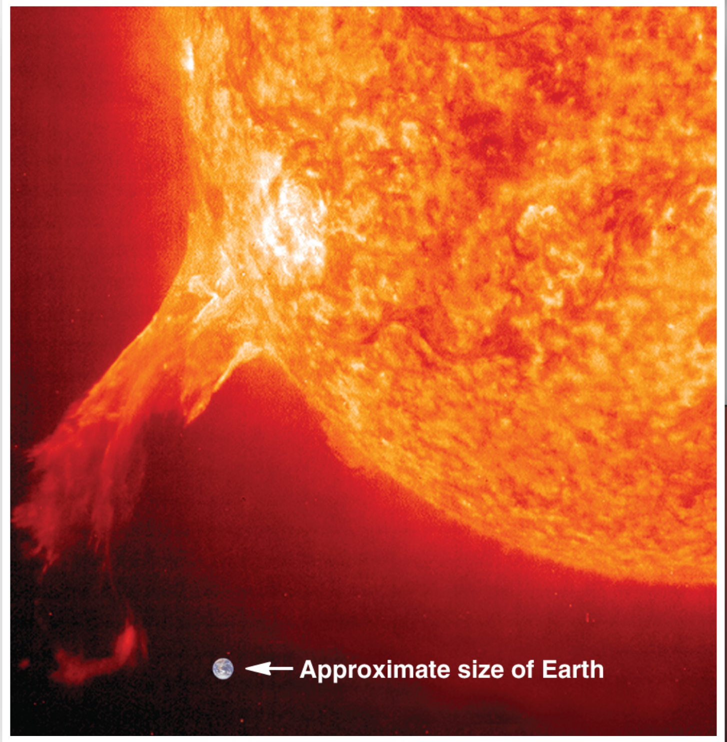
Tilt of Earth's axis changes over ~41,000 yrs

NATURAL CAUSES OF CLIMATE CHANGE

External factors: (1) **luminosity** of sun (amount of incoming radiation), (2) Earth's **orbital mechanics** (tilt, precession, orbit shape) & (3) comet, meteorite, or asteroid **impact event**

Internal factors: (1) **plate tectonics** (location of land, weathering), (2) **ocean** temperatures & currents, & (3) natural changes in **atmospheric composition**

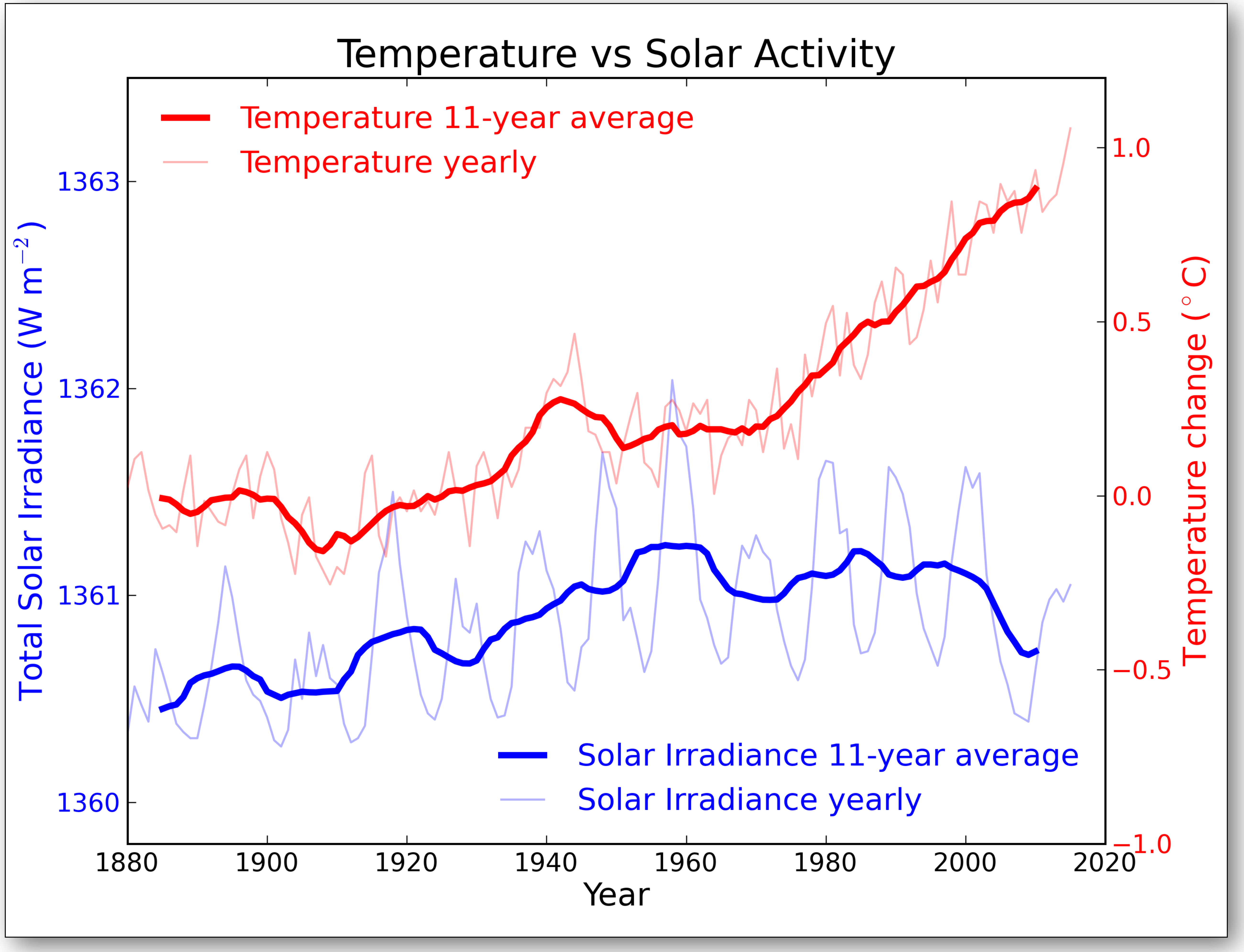




TEMPERATURE VS. LUMINOSITY OF SUN

Sun's energy output has been decreasing over past few decades

Energy from the sun cycles with sunspot activity (~11 yrs)



SOUTH CENTRAL
CLIMATE ADAPTATION SCIENCE CENTER

KEY POINTS

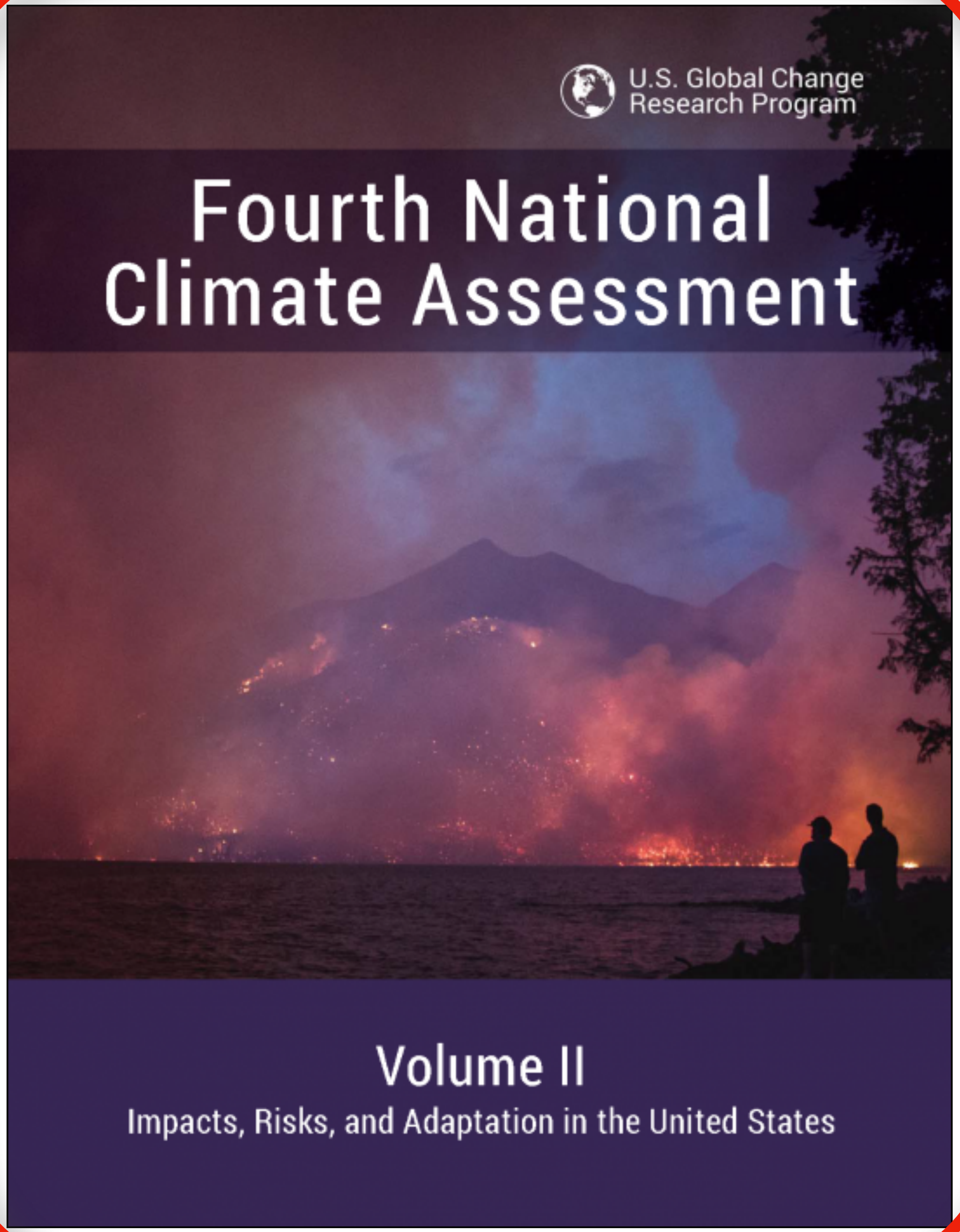
No single weather event (e.g., early autumn blizzard, December heat wave, landfalling hurricane) **is a sign of climate change**, but a **higher frequency** of certain events or **trend** toward **higher intensity events may be**.

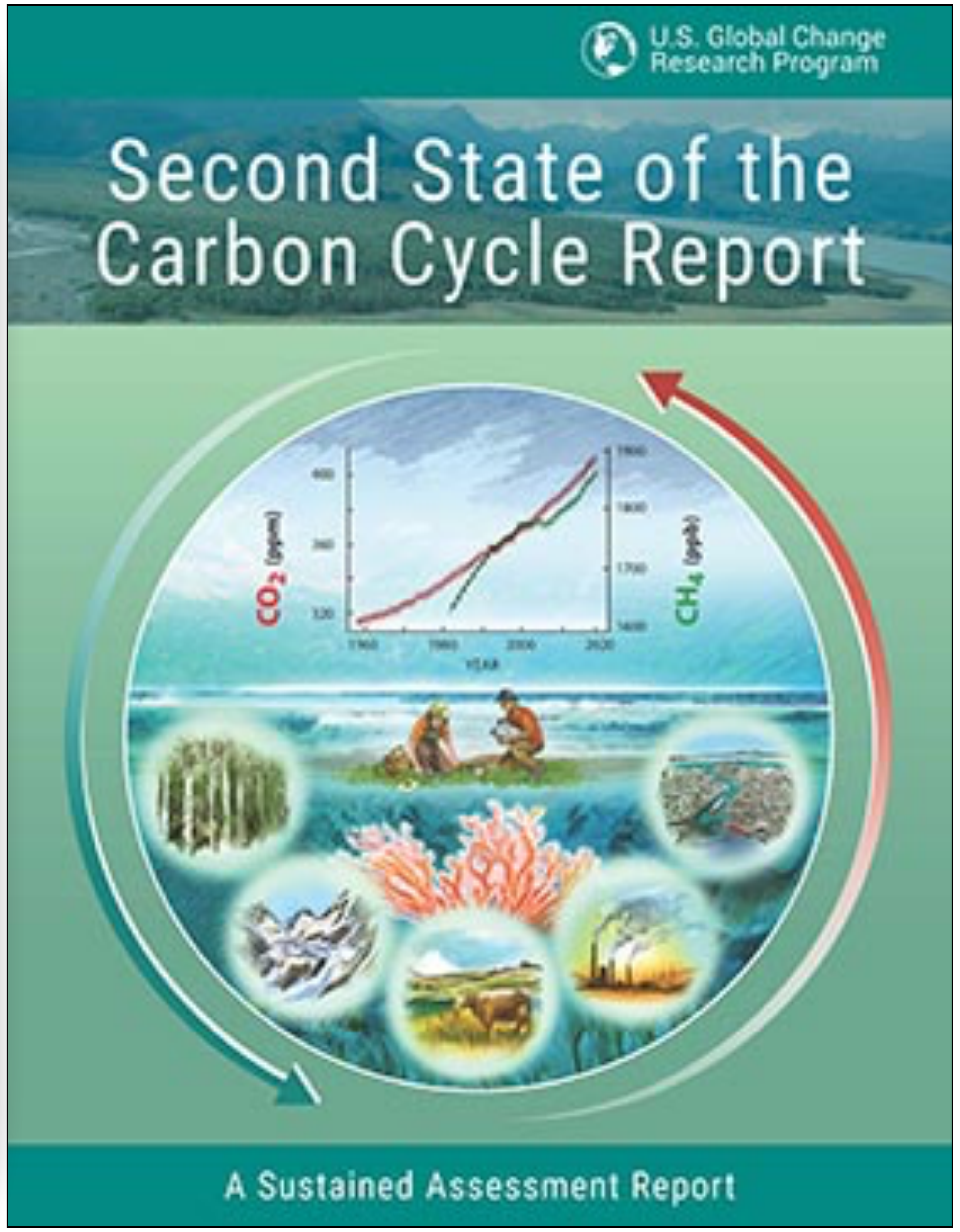
There are natural drivers to climate change, but they typically **occur over 1000s to 100,000s of years**. Faster changes, like those that occur with volcanic eruptions, usually last only a few years and are part of climate variability, not climate change.

FROM THE 4TH NATIONAL CLIMATE ASSESSMENT (2017)

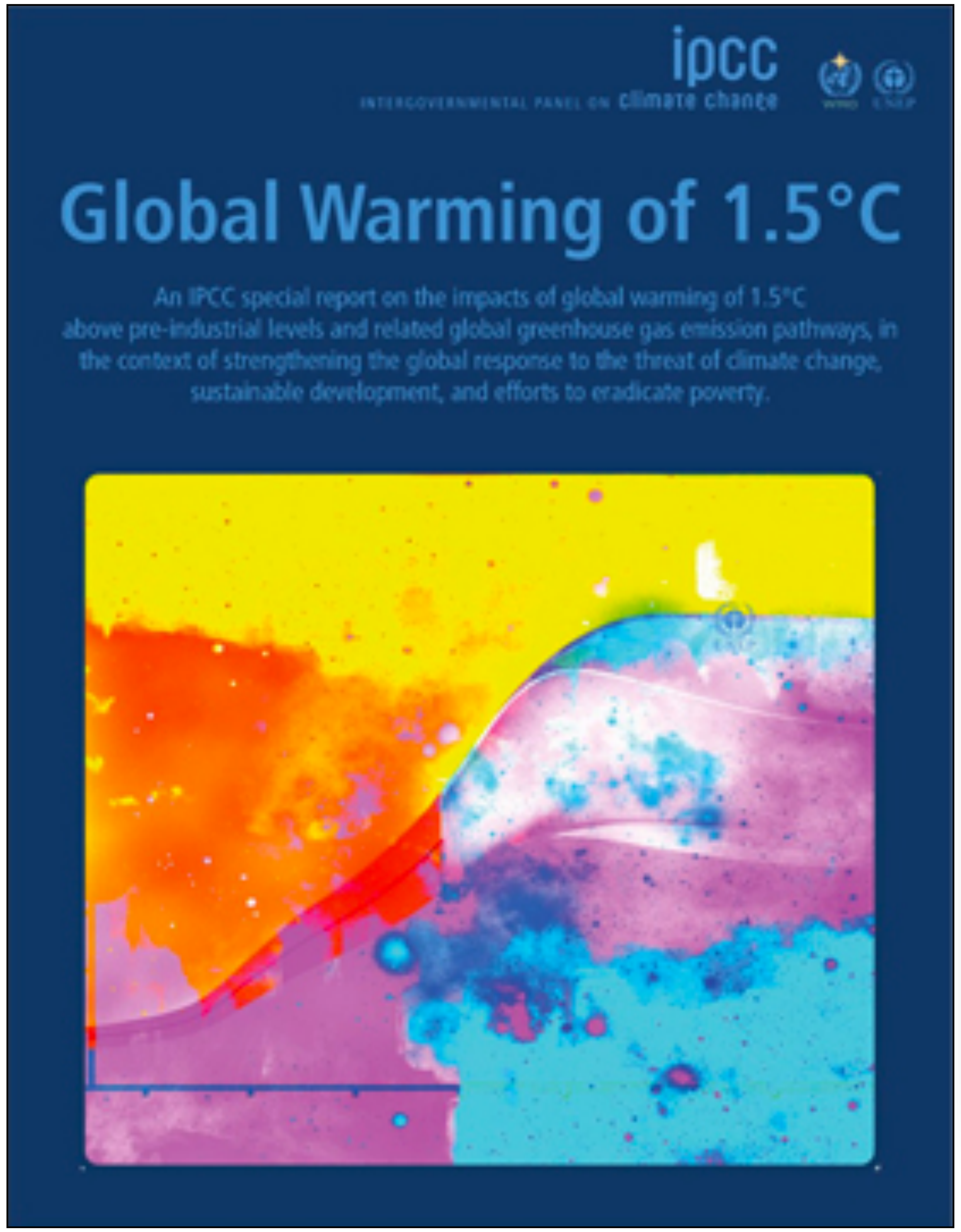
"Since NCA3 [Third National Climate Assessment], **stronger evidence has emerged for continuing, rapid, human-caused warming of the global atmosphere and ocean**. This report concludes that 'it is **extremely likely** that **human influence has been the dominant cause** of the observed warming since the mid-20th century. For the warming over the last century, **there is no convincing alternative explanation** supported by the extent of the observational evidence.'" – Climate Science Special Report

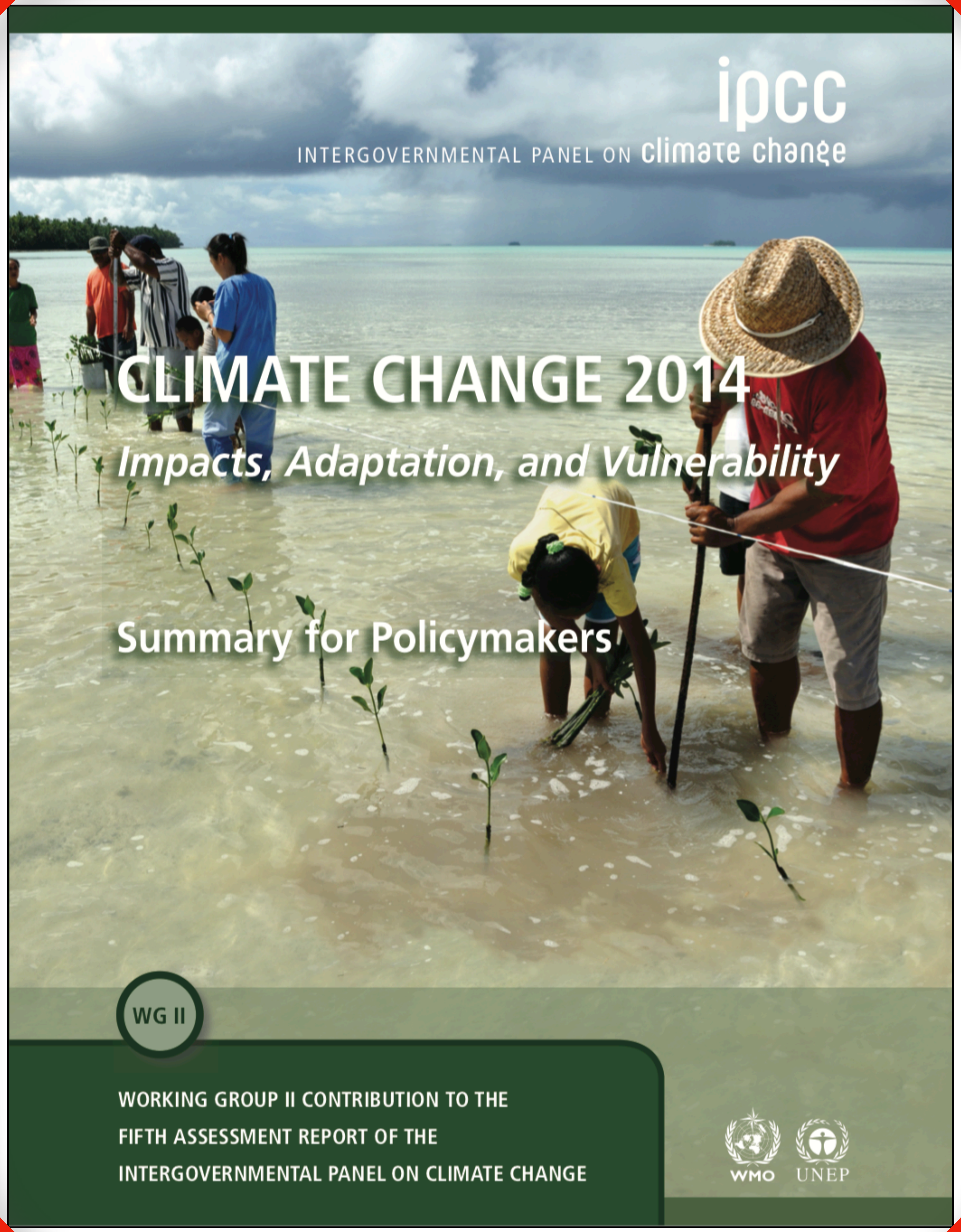
U.S. NATIONAL CLIMATE ASSESSMENT (NCA)

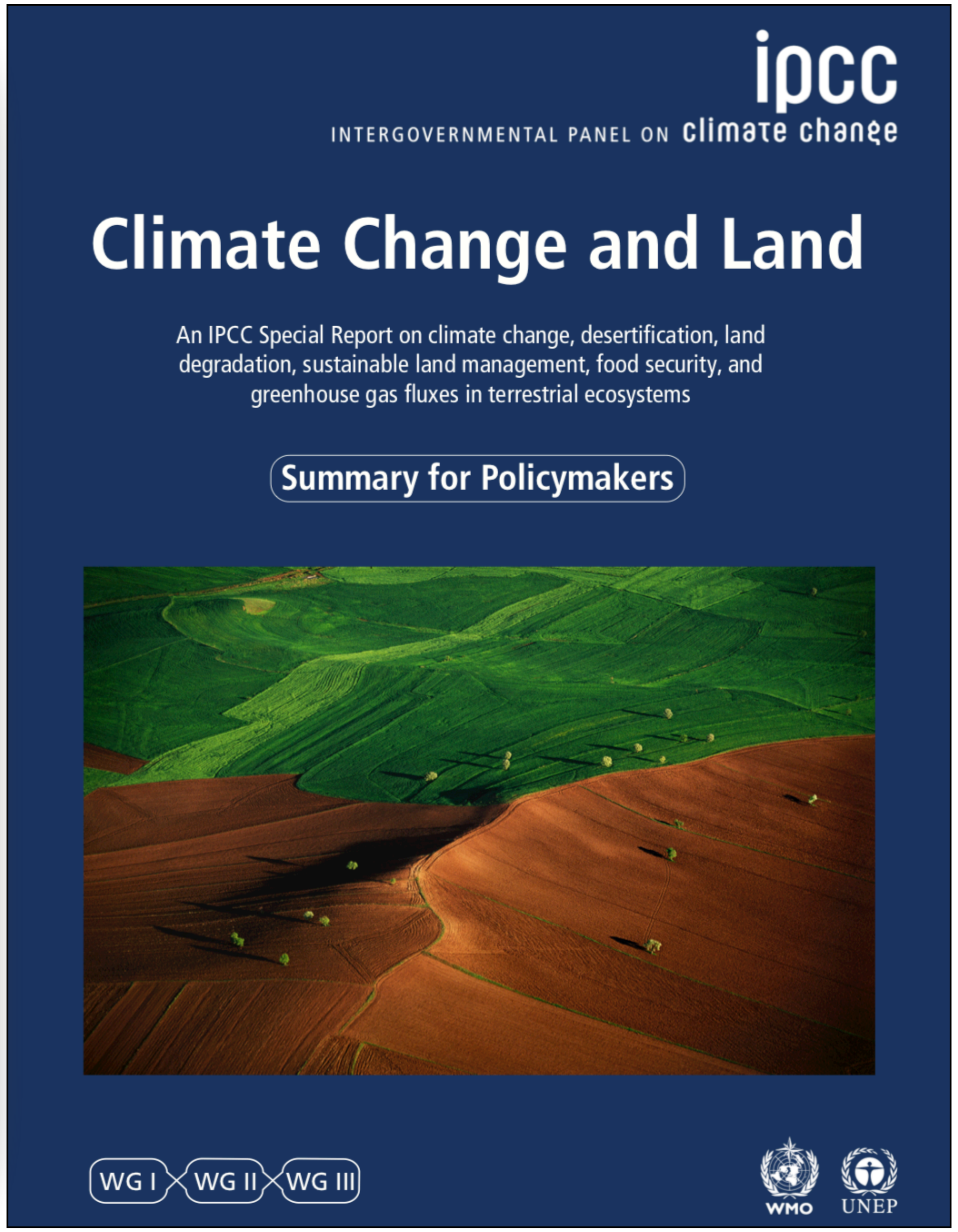




INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)







WHY ARE THESE REPORTS IMPORTANT?

Rigorous & transparent review process focusing on climate change, its impacts, and our ability to adapt and mitigate

IPCC main assessment reports **summarize almost 10,000 peer-reviewed scientific papers** in both an easy-to-read format (**Summary for Policymakers**) & in a detailed manner (for researchers); **NCA reports focus on the United States**, its regions, and sectors of the environment & economy

Policy relevant but not policy prescriptive

IPCC REASONS FOR CONCERN

Aggregate impacts & damages

Risks of large-scale discontinuities & disruptions

Uneven distribution of climate change impacts

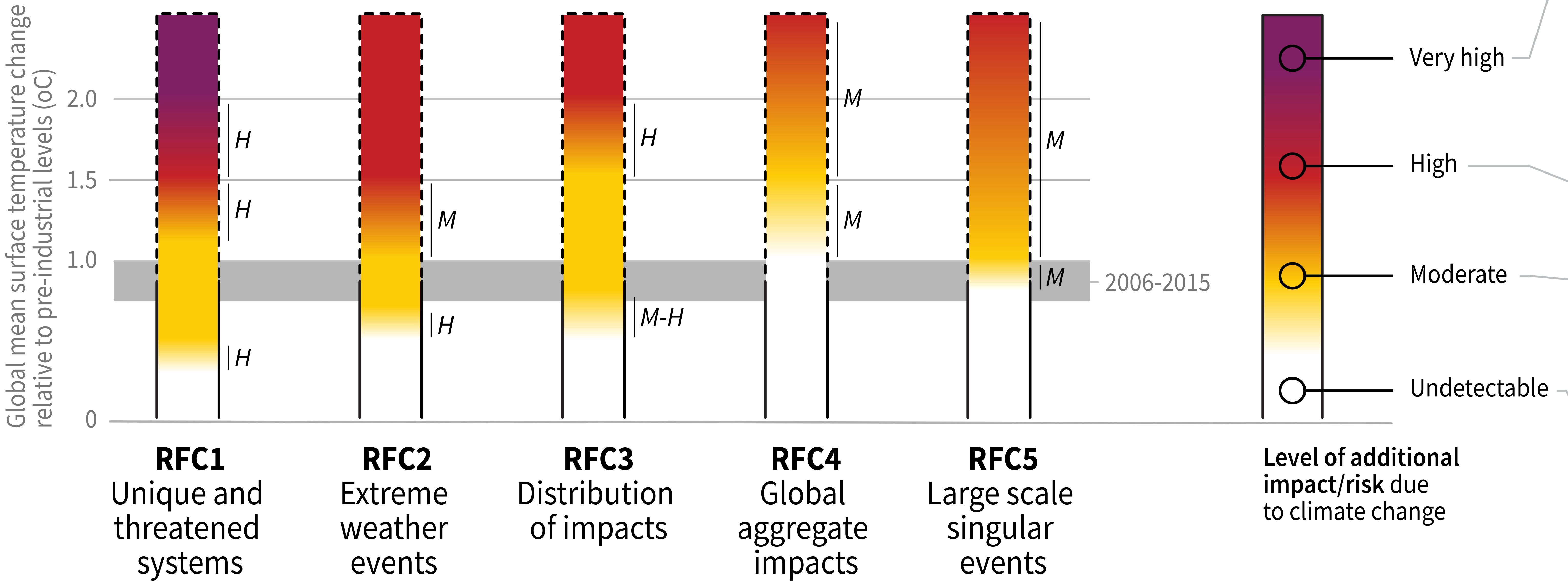
Risks of extreme weather events

Risks to unique & threatened systems

IPCC: GLOBAL WARMING OF 1.5°C (OCT. 2018)

Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)



Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.
Red indicates severe and widespread impacts/risks.
Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.
White indicates that no impacts are detectable and attributable to climate change.

IPCC 2018

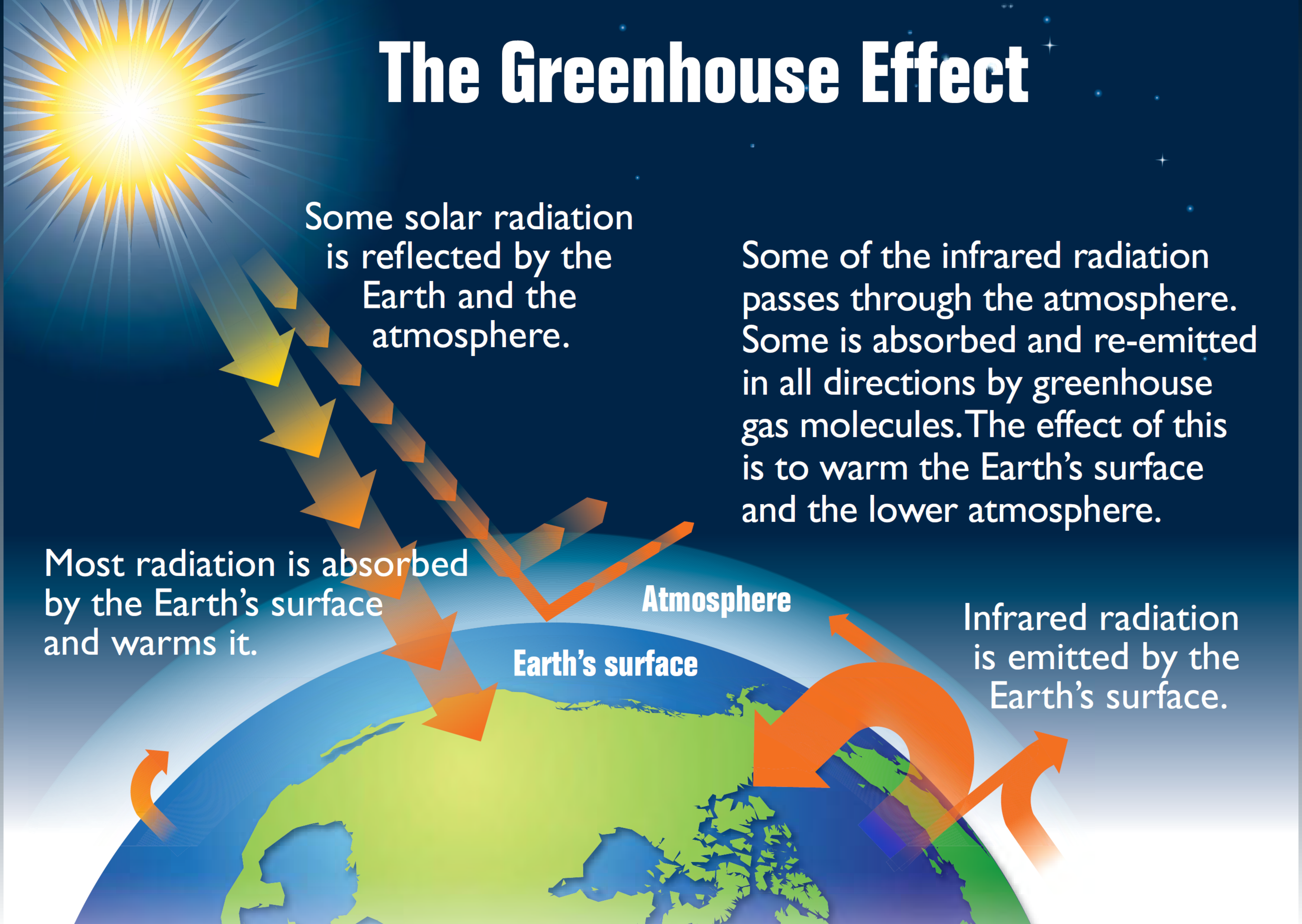
KEY POINT

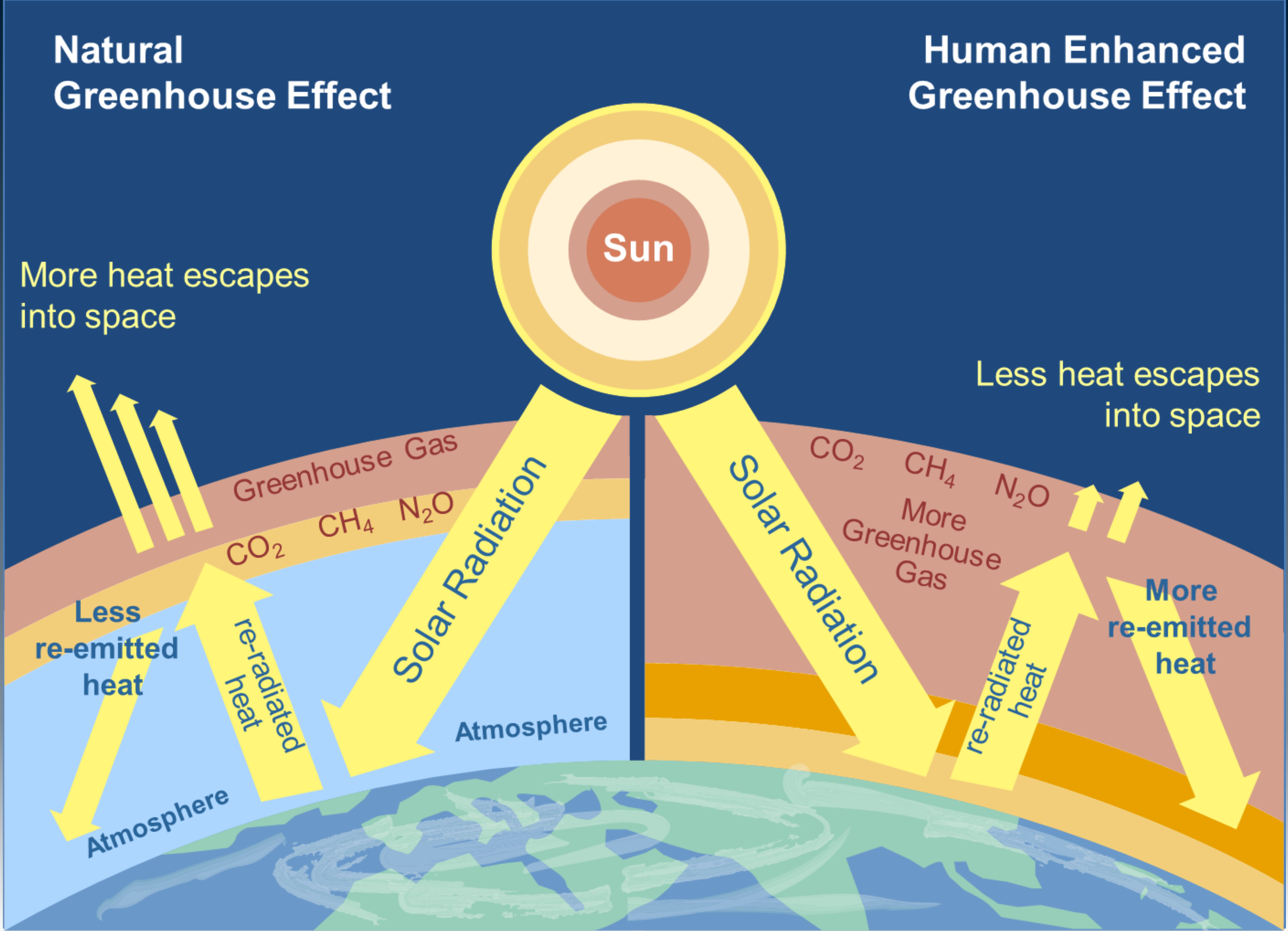
The **Intergovernmental Panel on Climate Change** (IPCC) reports and the **National Climate Assessment** (NCA) are the **two best sources** for expert assessments of climate change worldwide and across the United States.

Available at:

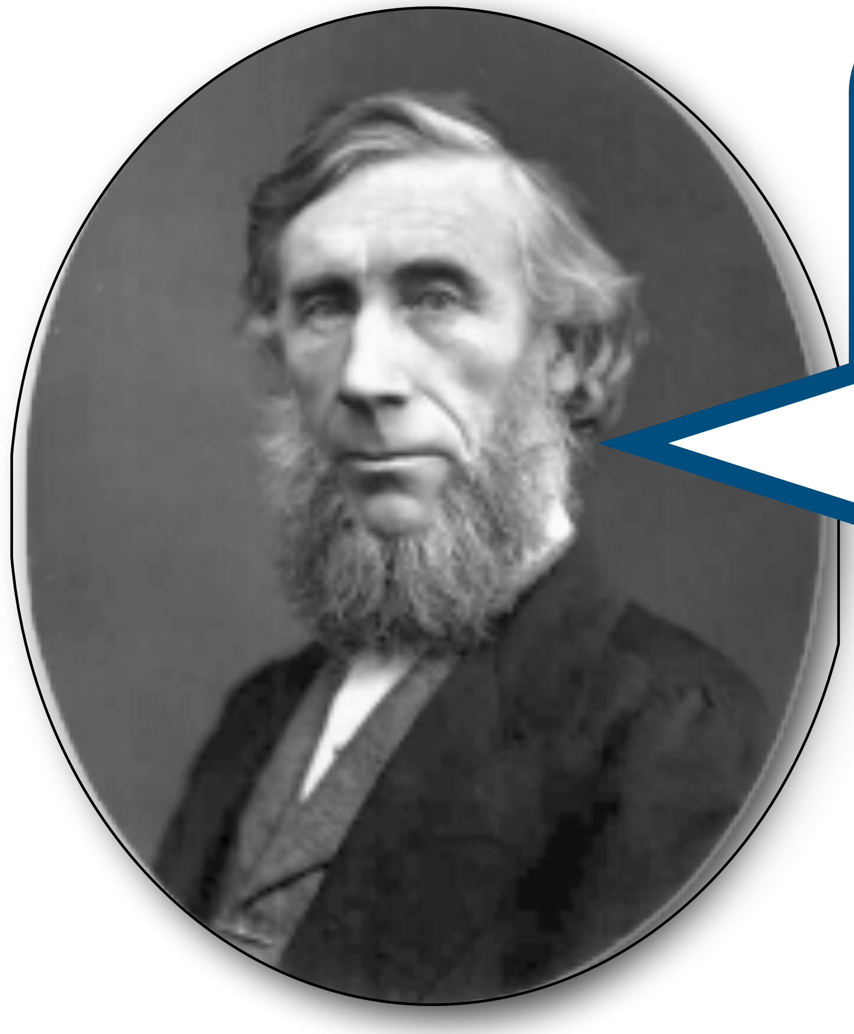
http://www.ipcc.ch (IPCC)

http://www.globalchange.gov (NCA)


The Greenhouse Effect
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere. Some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Most radiation is absorbed by the Earth's surface and warms it.
Atmosphere
Earth's surface
Infrared radiation is emitted by the Earth's surface.

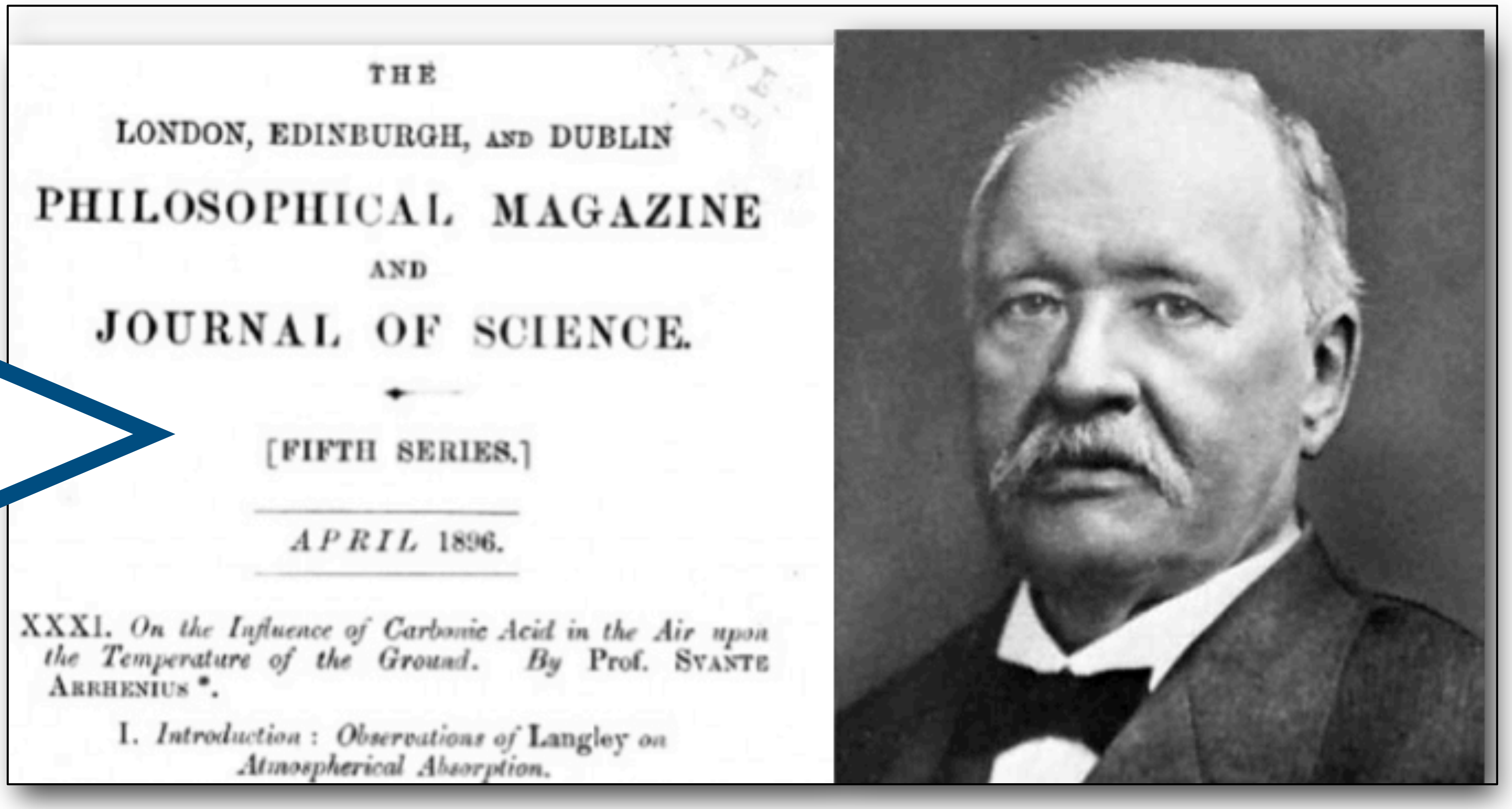

Natural Greenhouse Effect
Human Enhanced Greenhouse Effect
Sun
More heat escapes into space
Greenhouse Gas
CO_2 CH_4 N_2O
Less re-emitted heat
re-radiated heat
Solar Radiation
Atmosphere
Atmosphere
Less heat escapes into space
Solar Radiation
CO_2 CH_4 N_2O
More Greenhouse Gas
re-radiated heat
More re-emitted heat

WE'VE KNOWN THIS FACT FOR 160 YEARS



"The atmosphere admits of the entrance of the solar heat, but checks its exit; and the **result is a tendency to accumulate heat at the surface of the planet.**" — John Tyndall, 1859

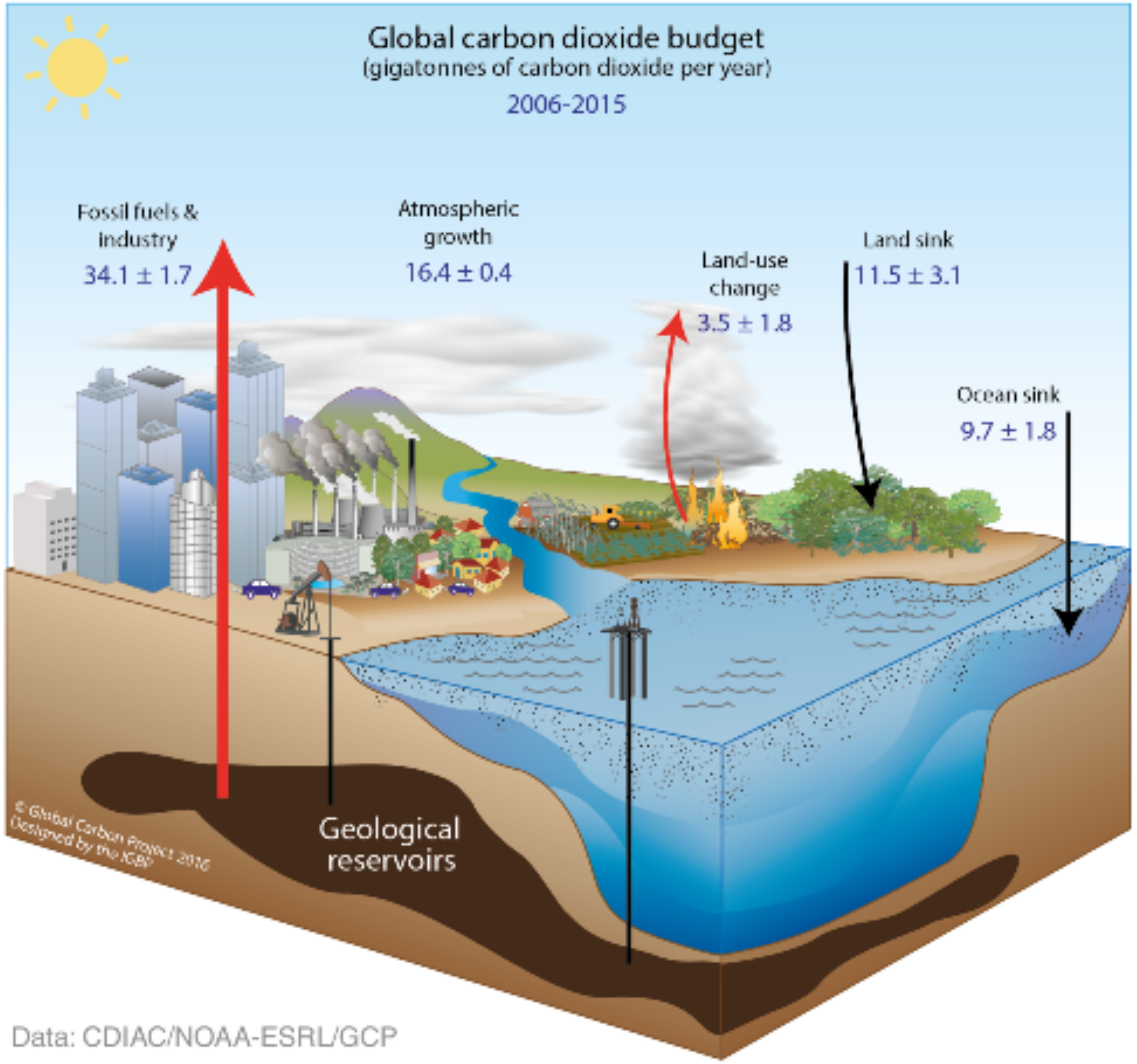
"**Doubling of CO_2 would raise surface temperature** by 5-6°C, or 9-11°F, above pre-industrial temperatures." — Svante Arrhenius,1896



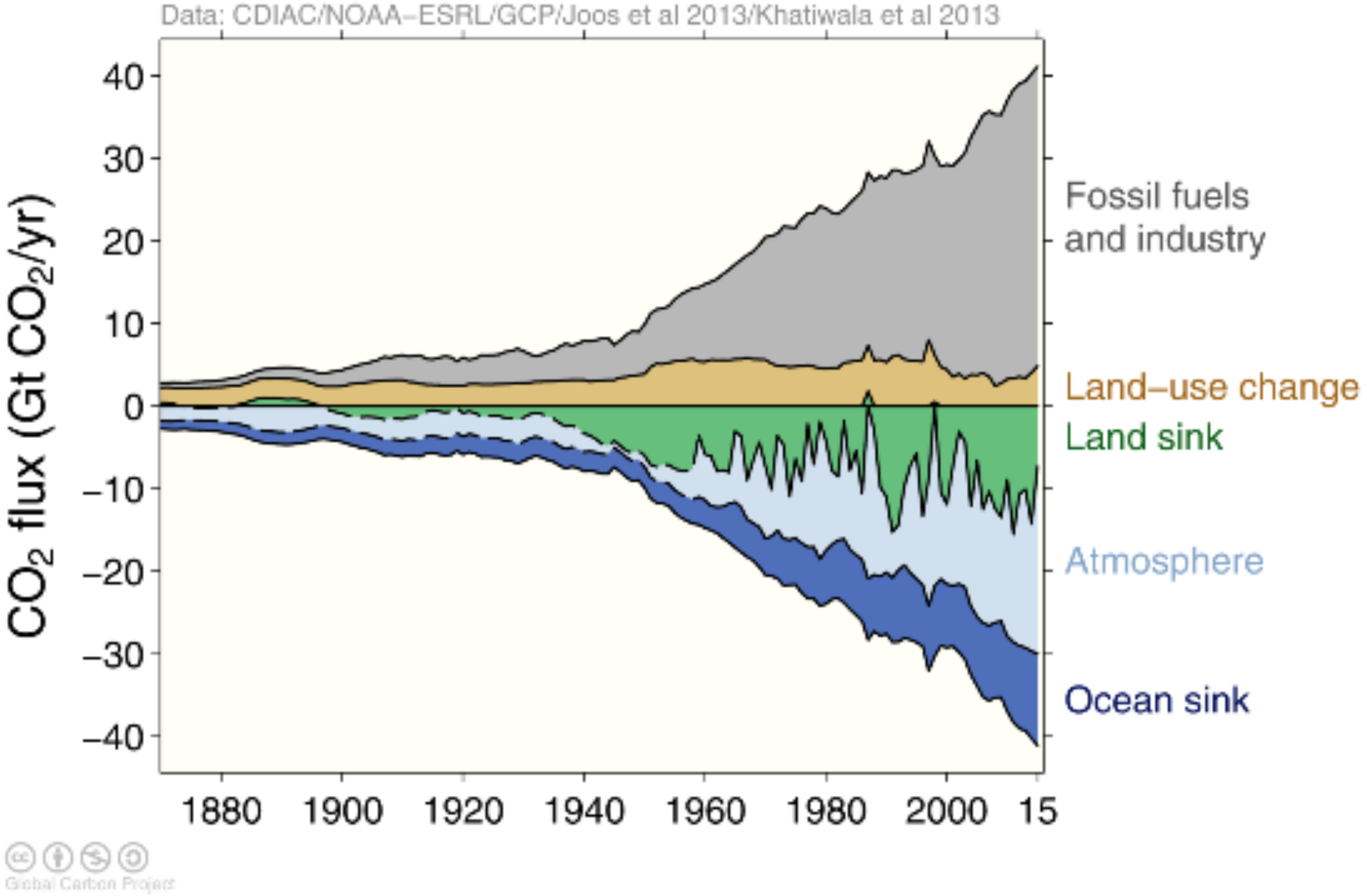
KEY POINT

Greenhouse gases are necessary for Earth to be livable, **but adding too much into the atmosphere will disrupt** the long-term energy balance, **increasing the thermal energy** in the atmosphere.

GLOBAL CARBON DIOXIDE BUDGET

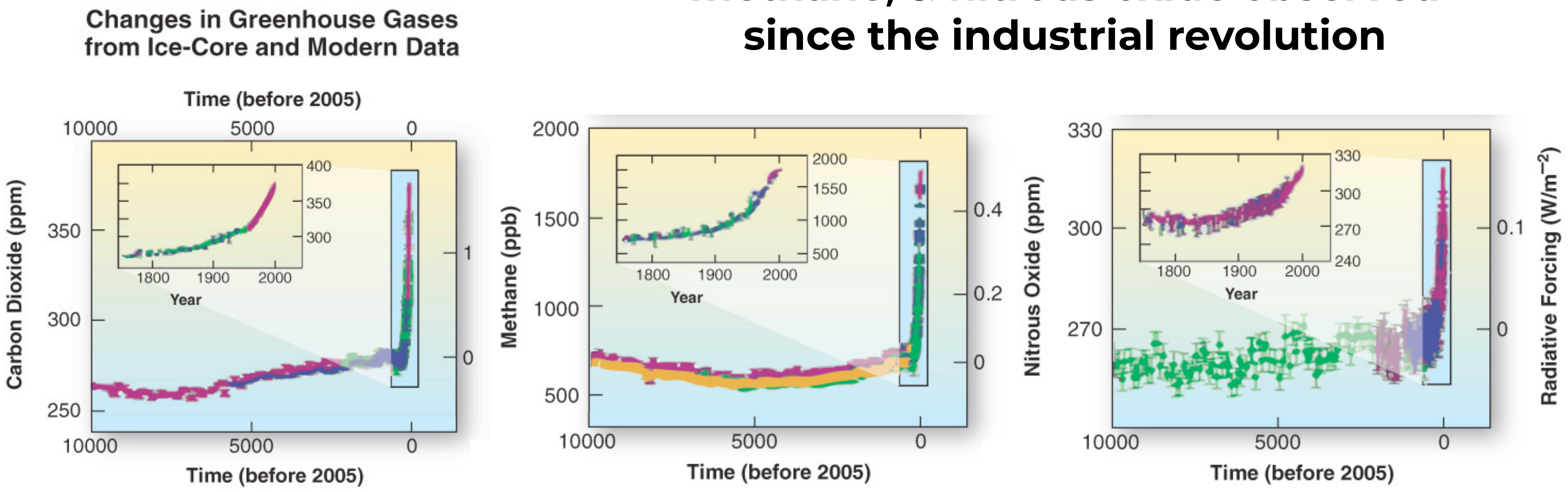


Data: CDIAC/NOAA-ESRL/GCP



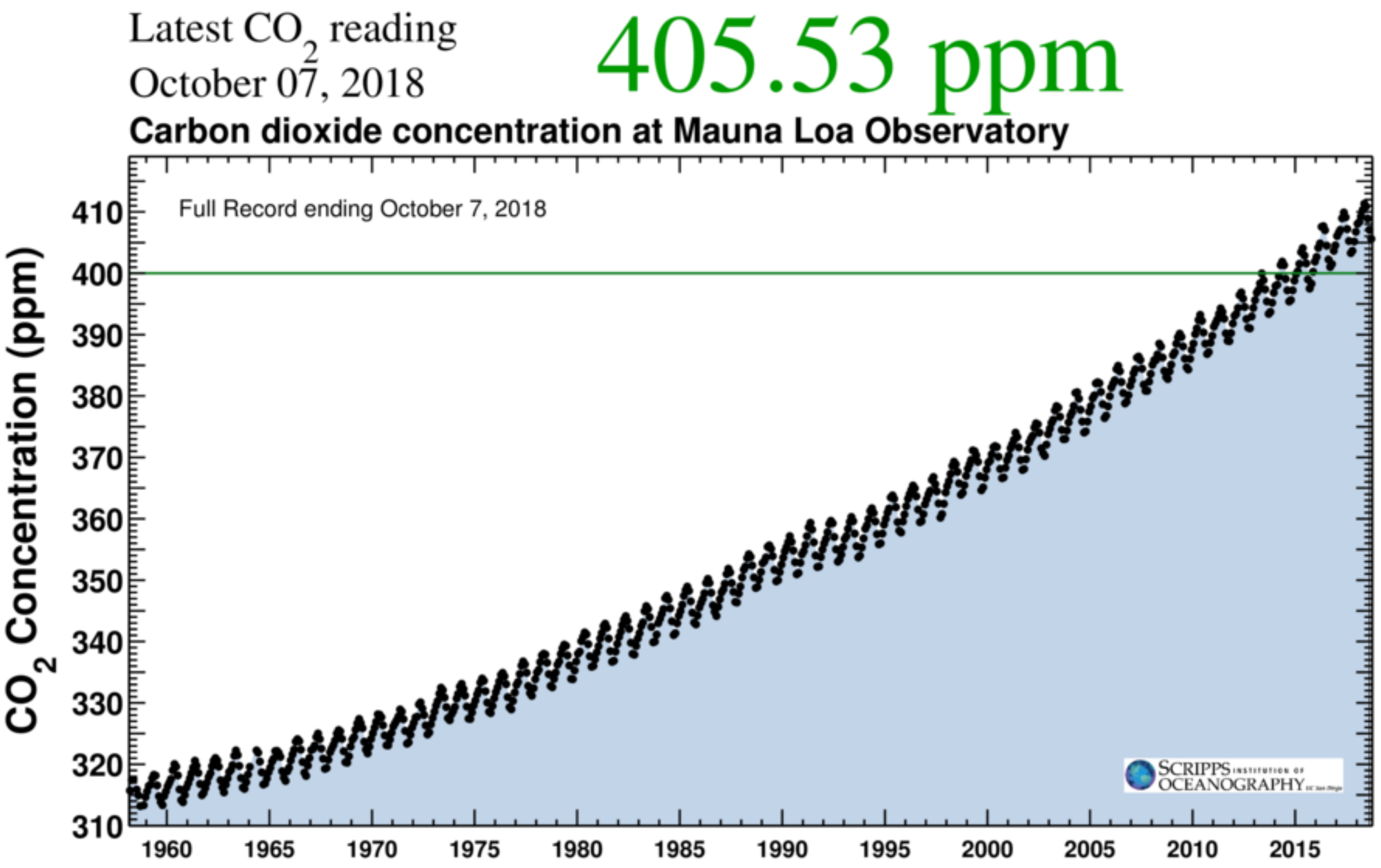
GREENHOUSE GASES INCREASING

Significant increases in carbon dioxide, methane, & nitrous oxide observed since the industrial revolution

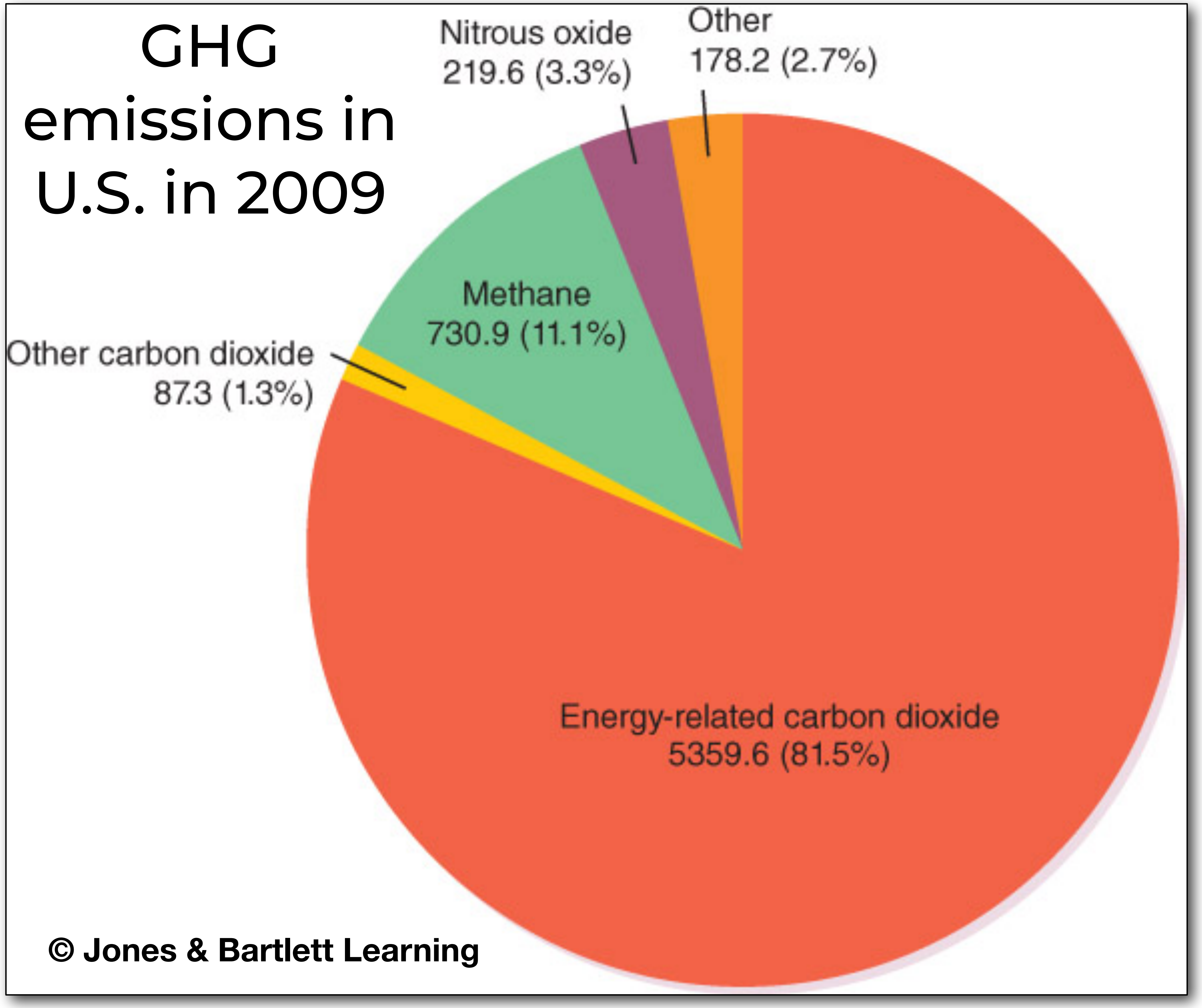


OBSERVATIONS OF CARBON DIOXIDE (CO_2)

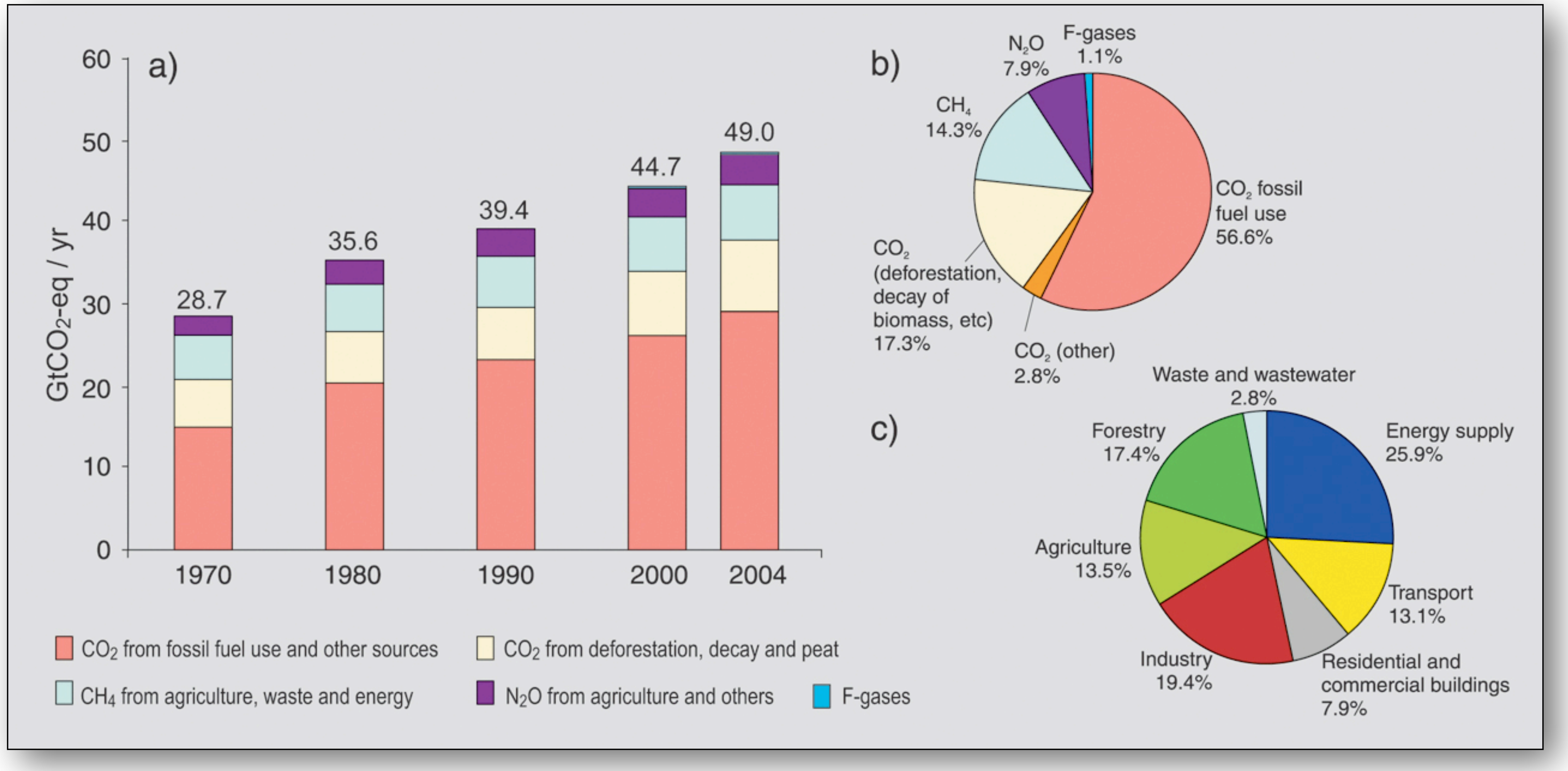
Charles Keeling first measured CO_2 at the Mauna Loa Observatory, leading the scientific community to notice the human contribution to the greenhouse effect



GREENHOUSE GAS EMISSIONS BY GAS



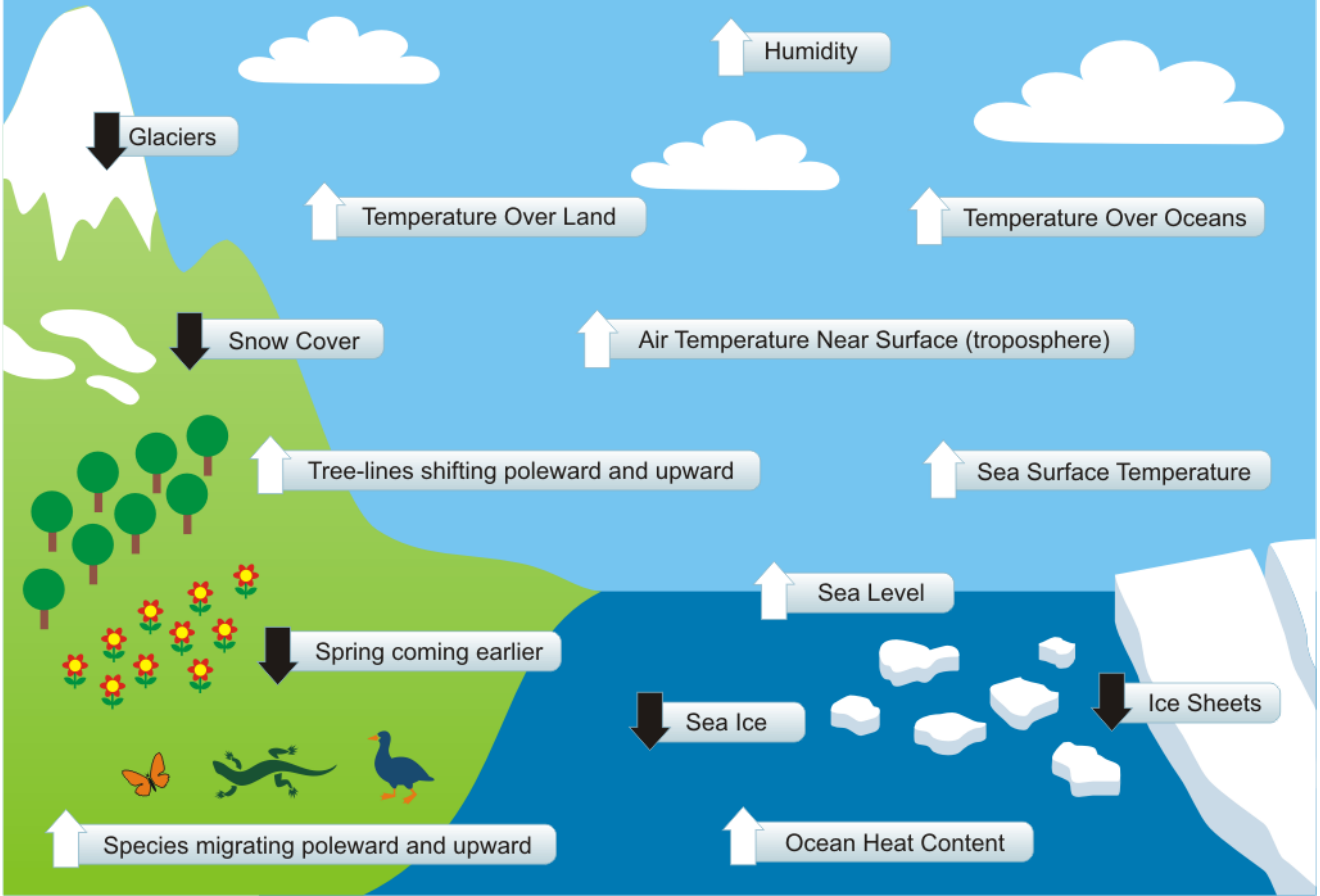
Largest contributor is CO_2 from fossil fuel use



KEY POINT

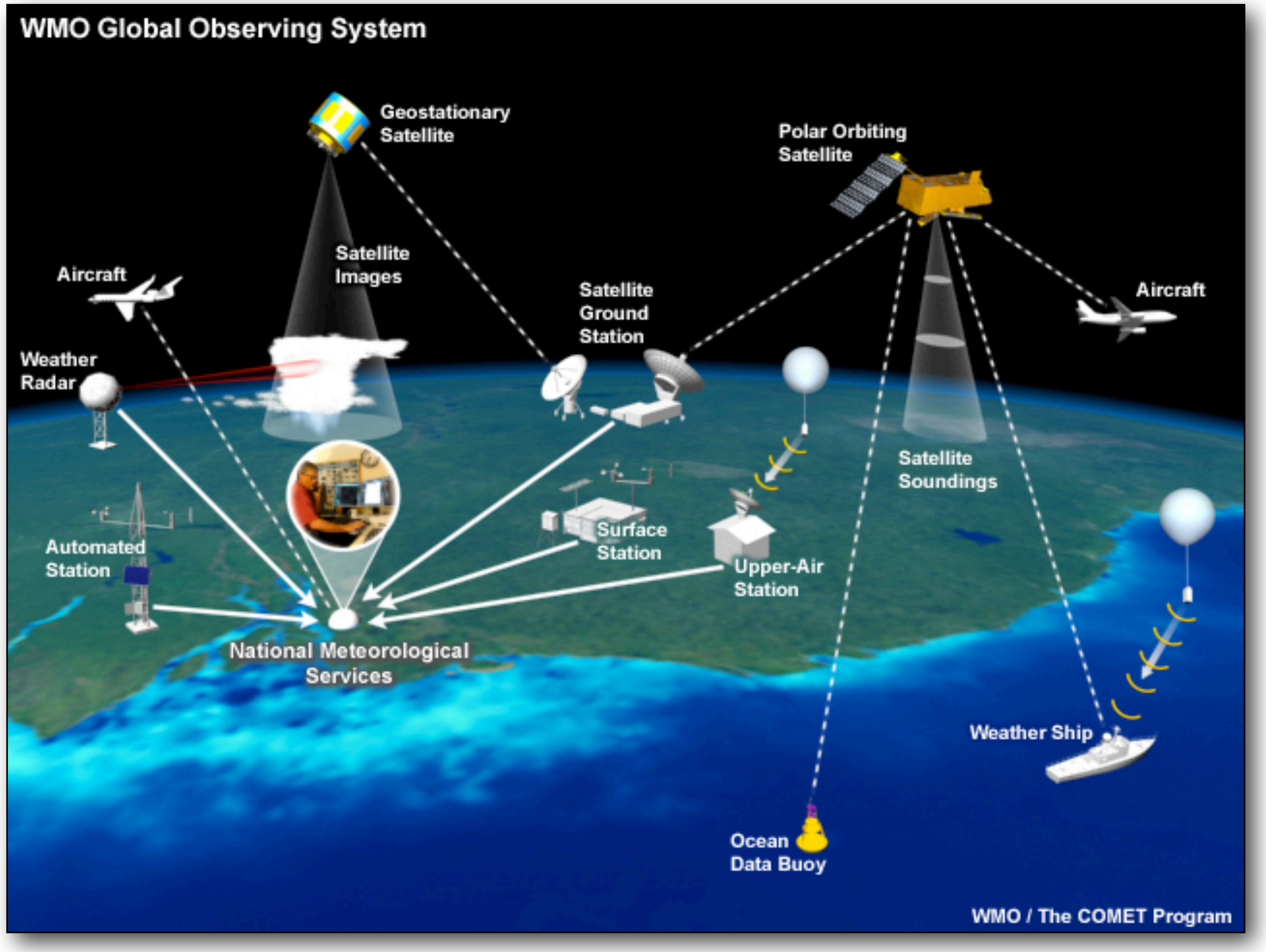
Greenhouse gases have been increasing at an abnormally fast rate, primarily as a result of human activity (i.e., fossil fuel use, deforestation, agriculture, etc.). Our oceans and ecosystems cannot absorb CO_2 quickly enough to keep up. Except for water vapor, **these greenhouse gases are long-lived** and will remain in our atmosphere for decades.

Indicators of a Warming World

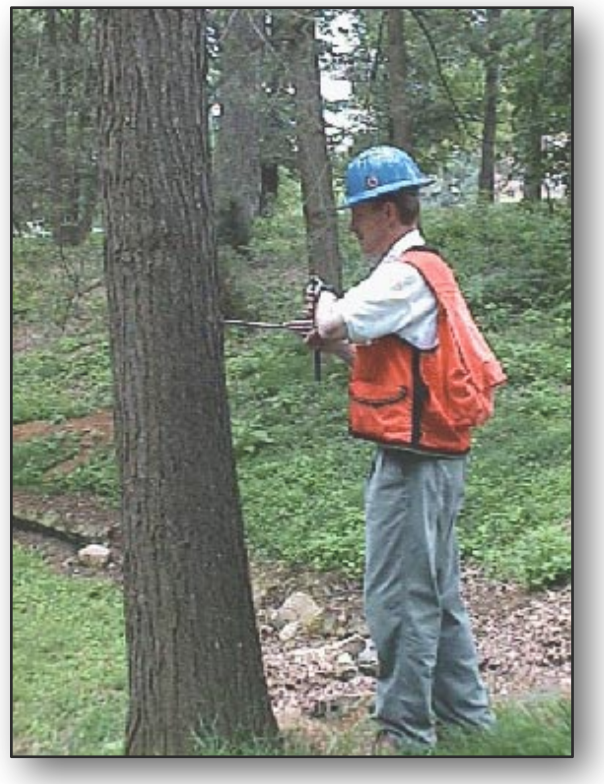


Skeptical Science

TECHNIQUES TO OBSERVE THE CLIMATE



Creative Commons



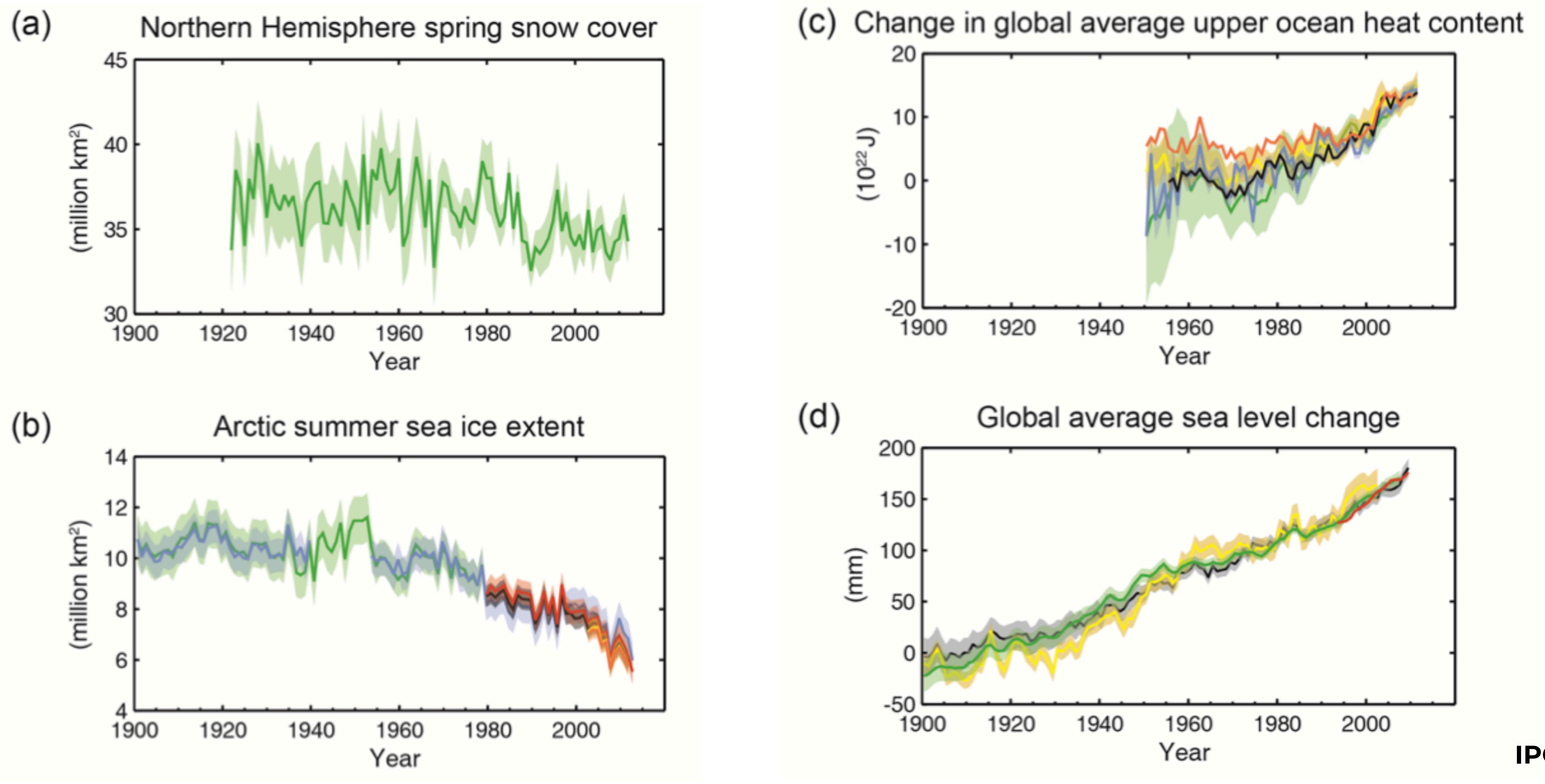
USGS

Kathy Krucker

Nat’l Park Service

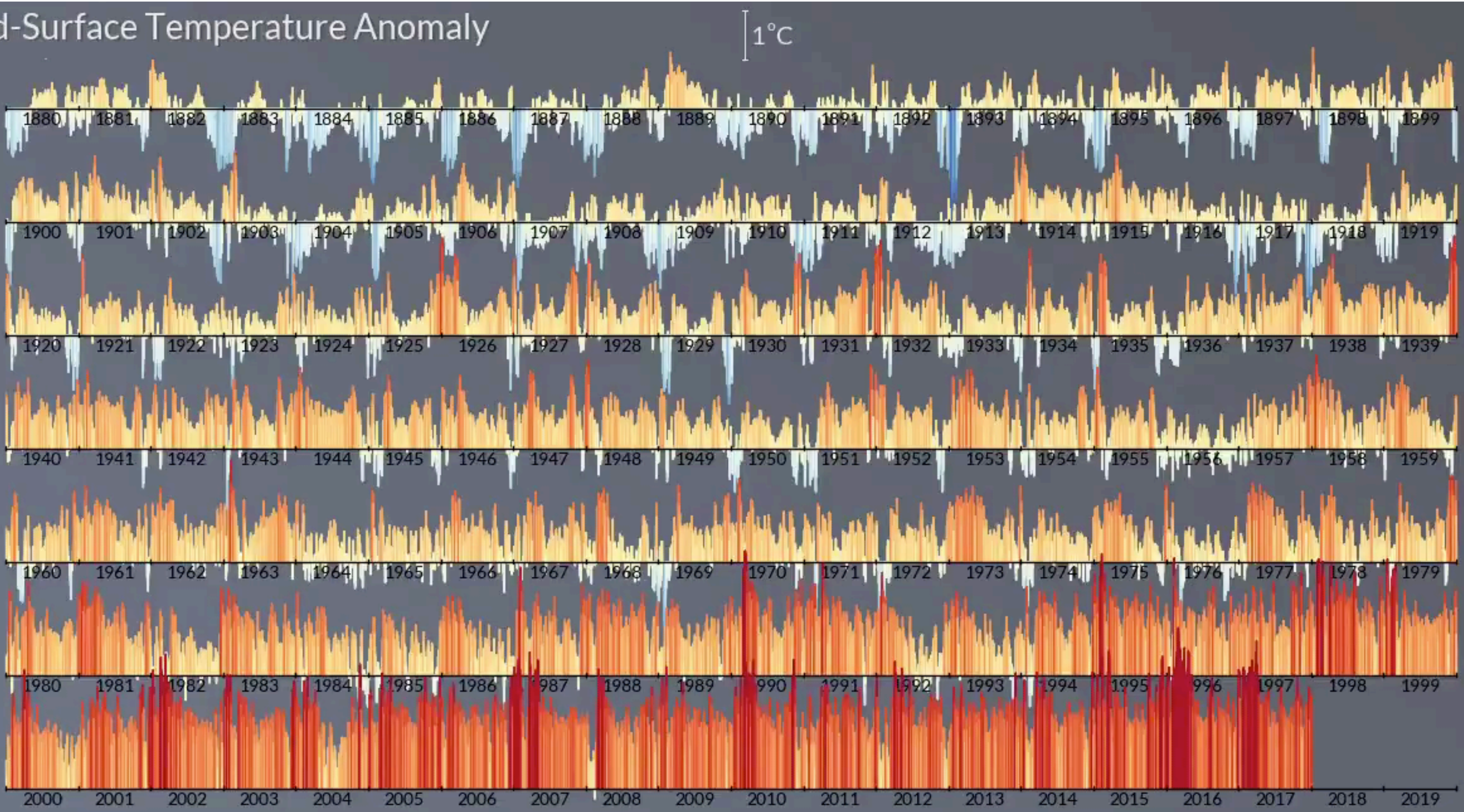
Carlye Calvin

OBSERVATIONAL EVIDENCE FOR A WARMING CLIMATE



IPCC AR5

Land-Surface Temperature Anomaly

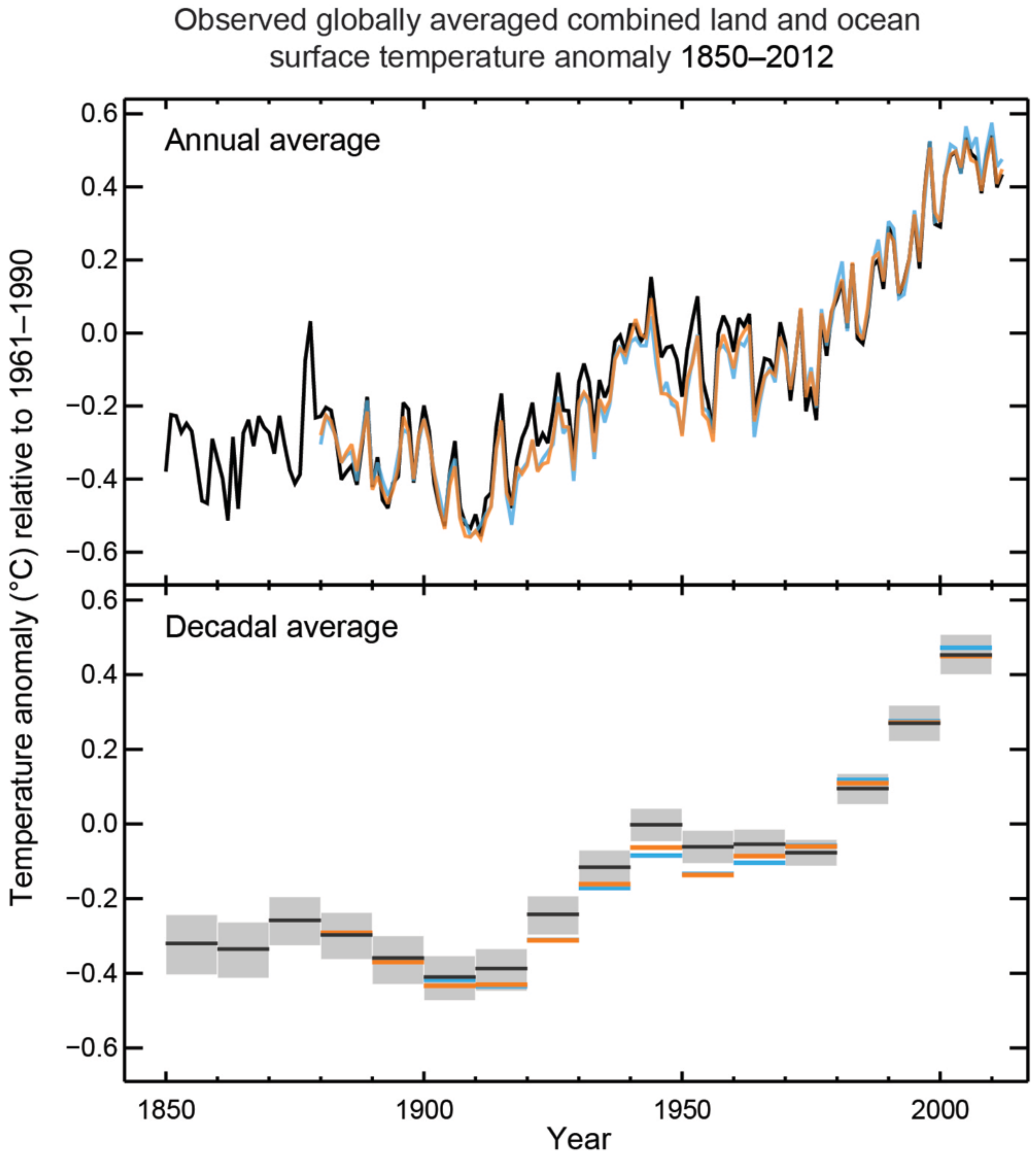


Data source: Berkeley Earth daily TAVG full dataset (experimental)
Global land-surface temperature anomaly
Base period: 1880-1920
https://berkeleyearth.org/

Antti Lipponen (@anttilip)

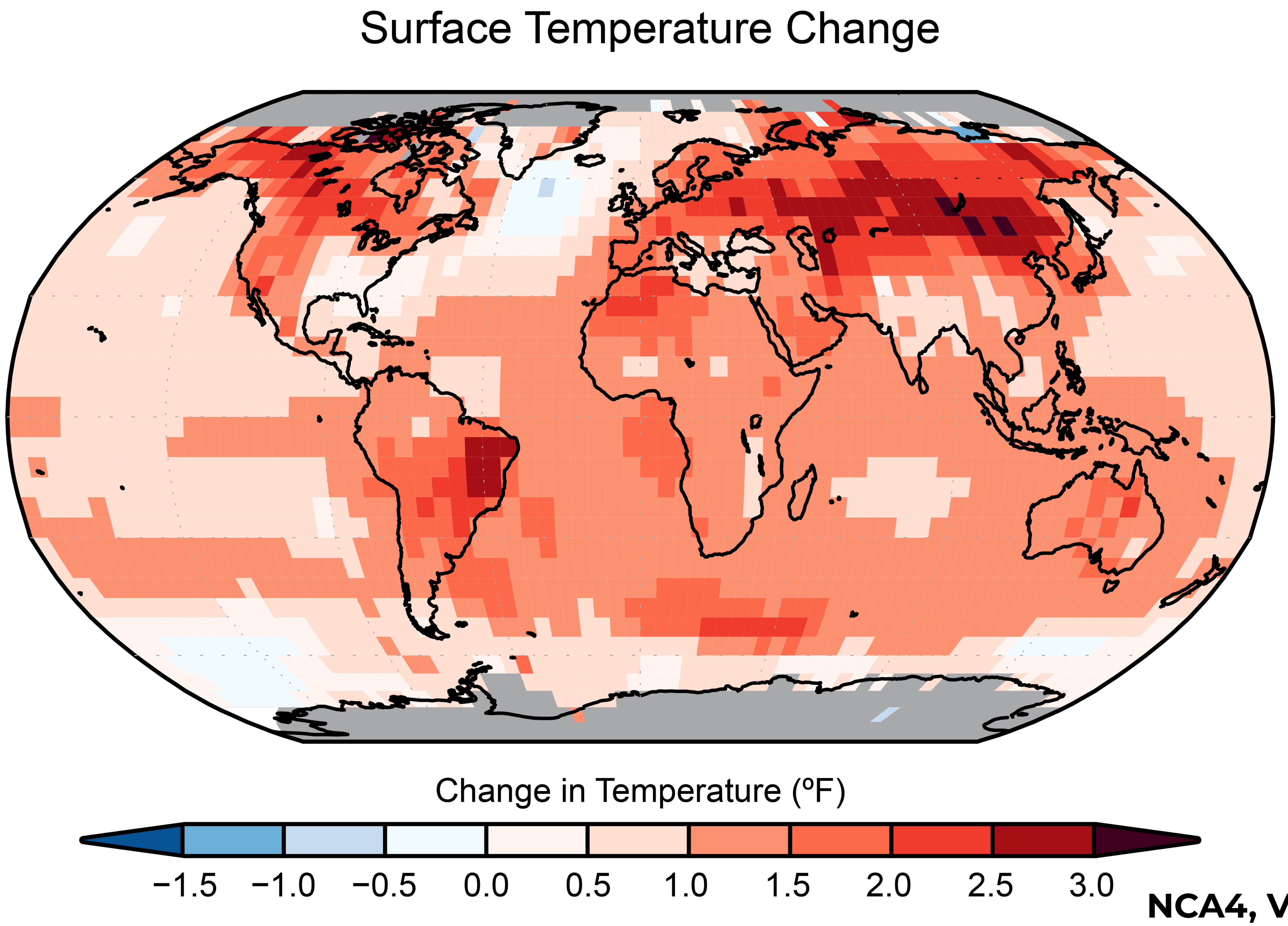
SURFACE AIR TEMPERATURE OBSERVATIONS

Globally, the past three decades have been successively warmer, on average, than the prior decades. Multi-decadal warming is superimposed on decadal and interannual variability from natural climate patterns.

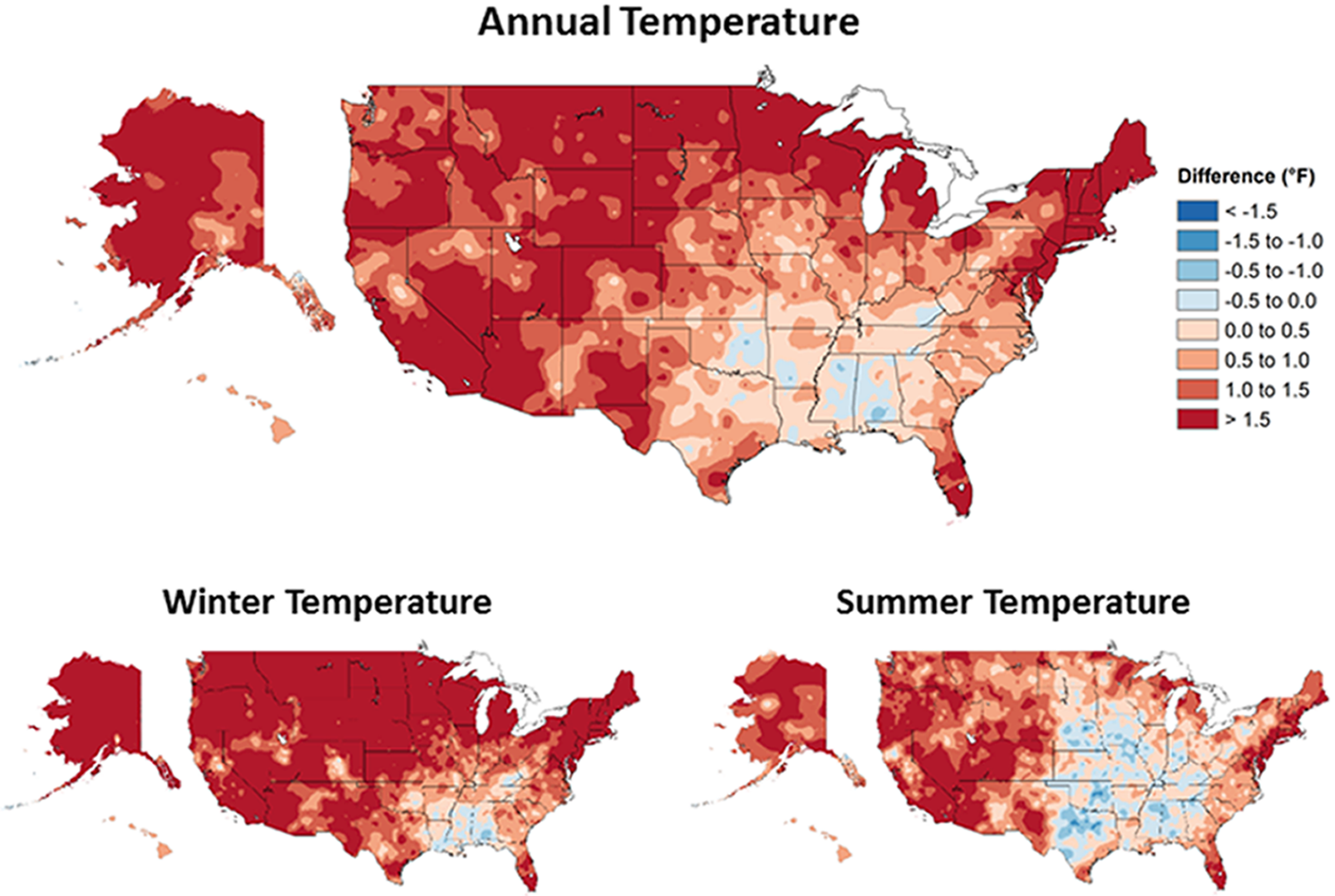


CLIMATE CHANGE IMPACTS ARE REGIONAL

For example, surface temperature changes are not uniform

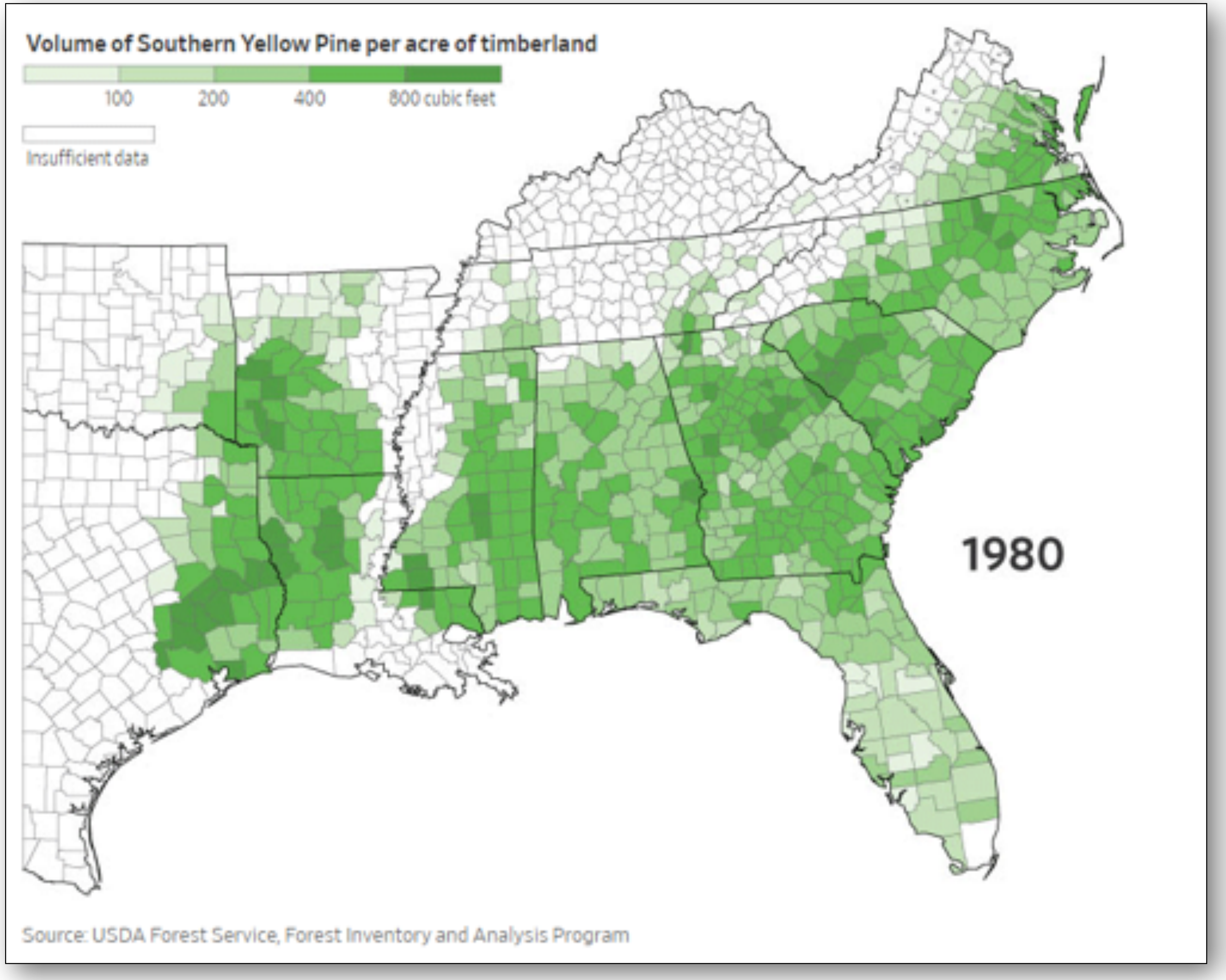


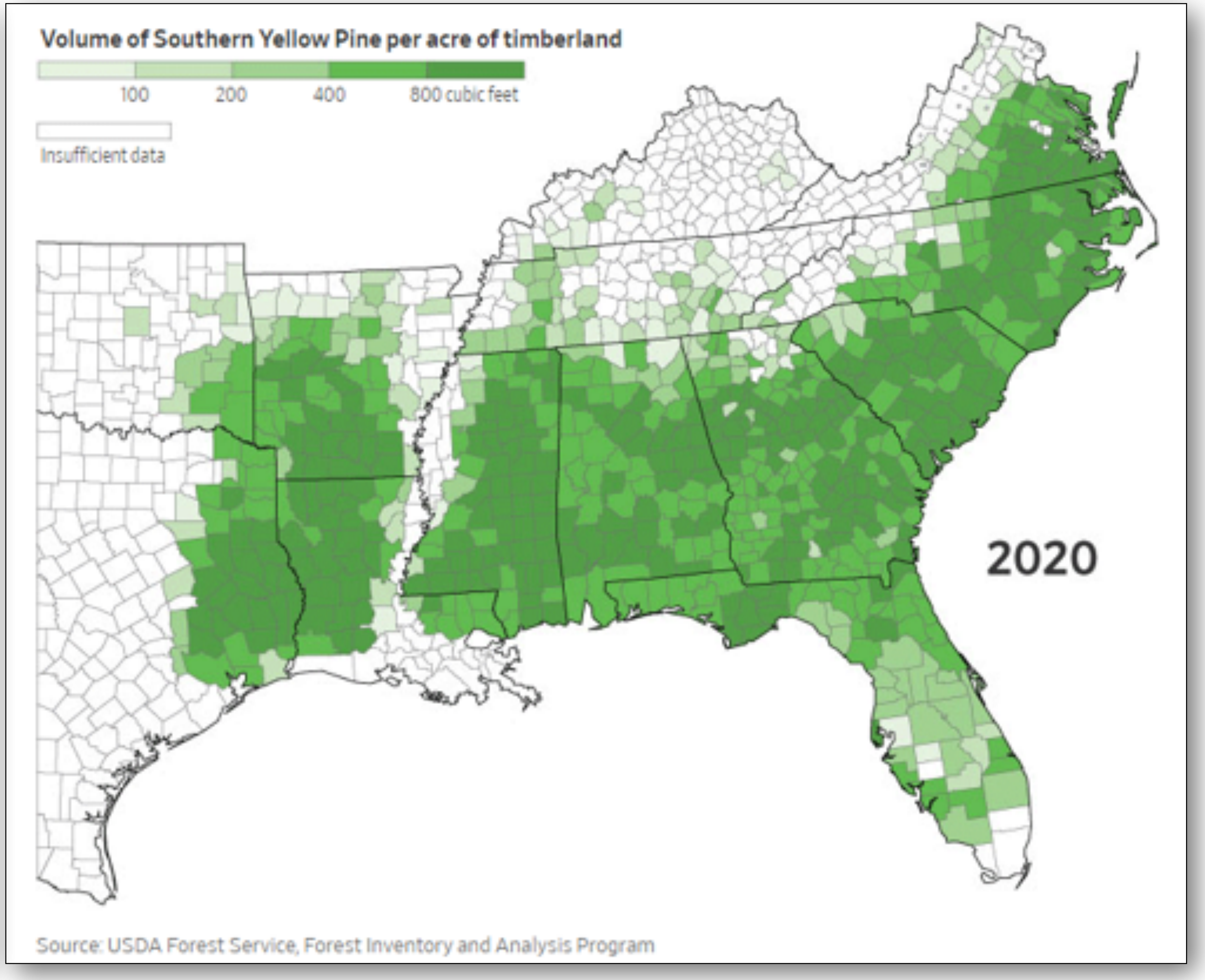
NCA4, Vol 1



NCA4, Vol 1

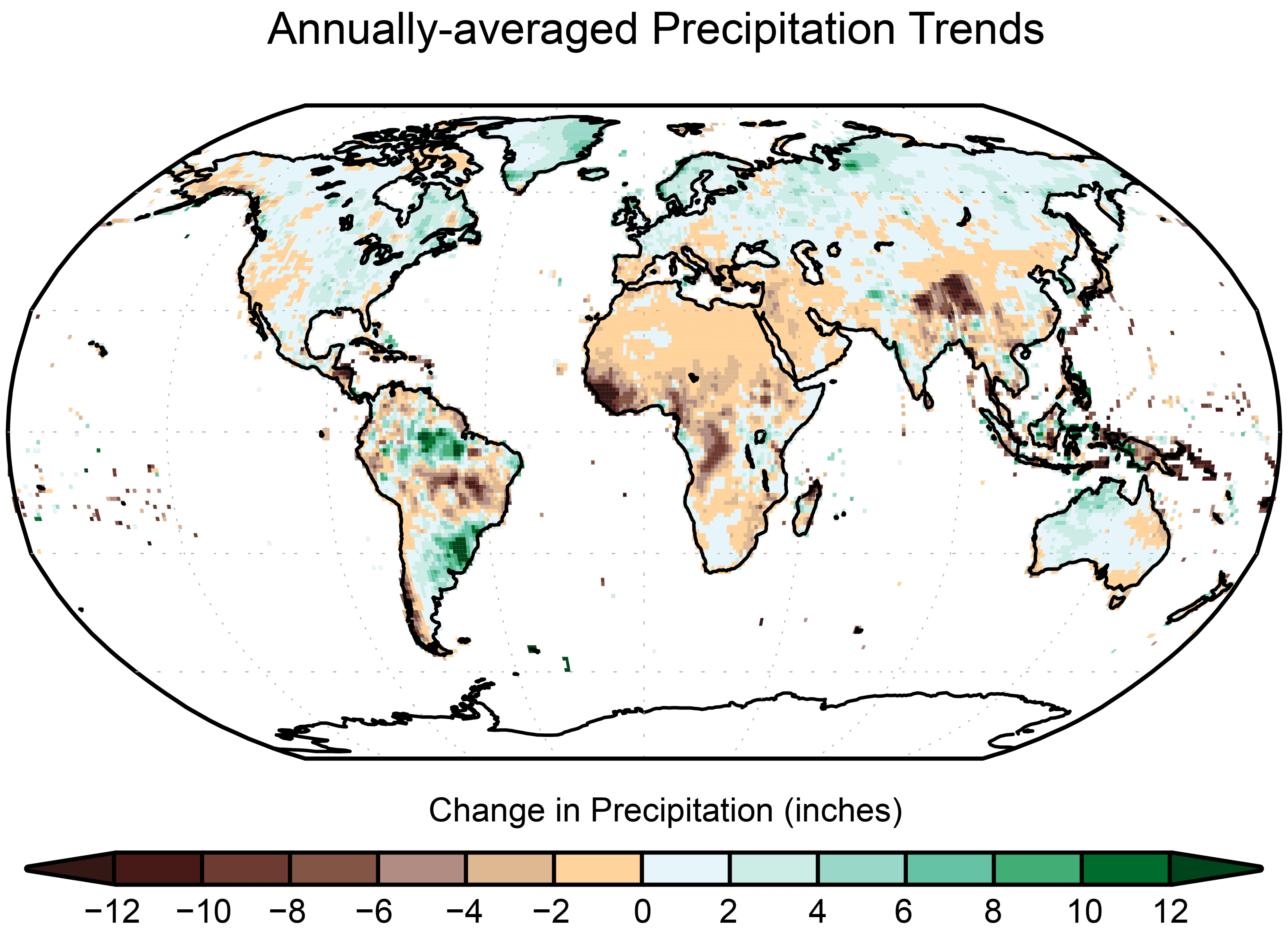
REGIONAL CHANGES HAVE CAUSES



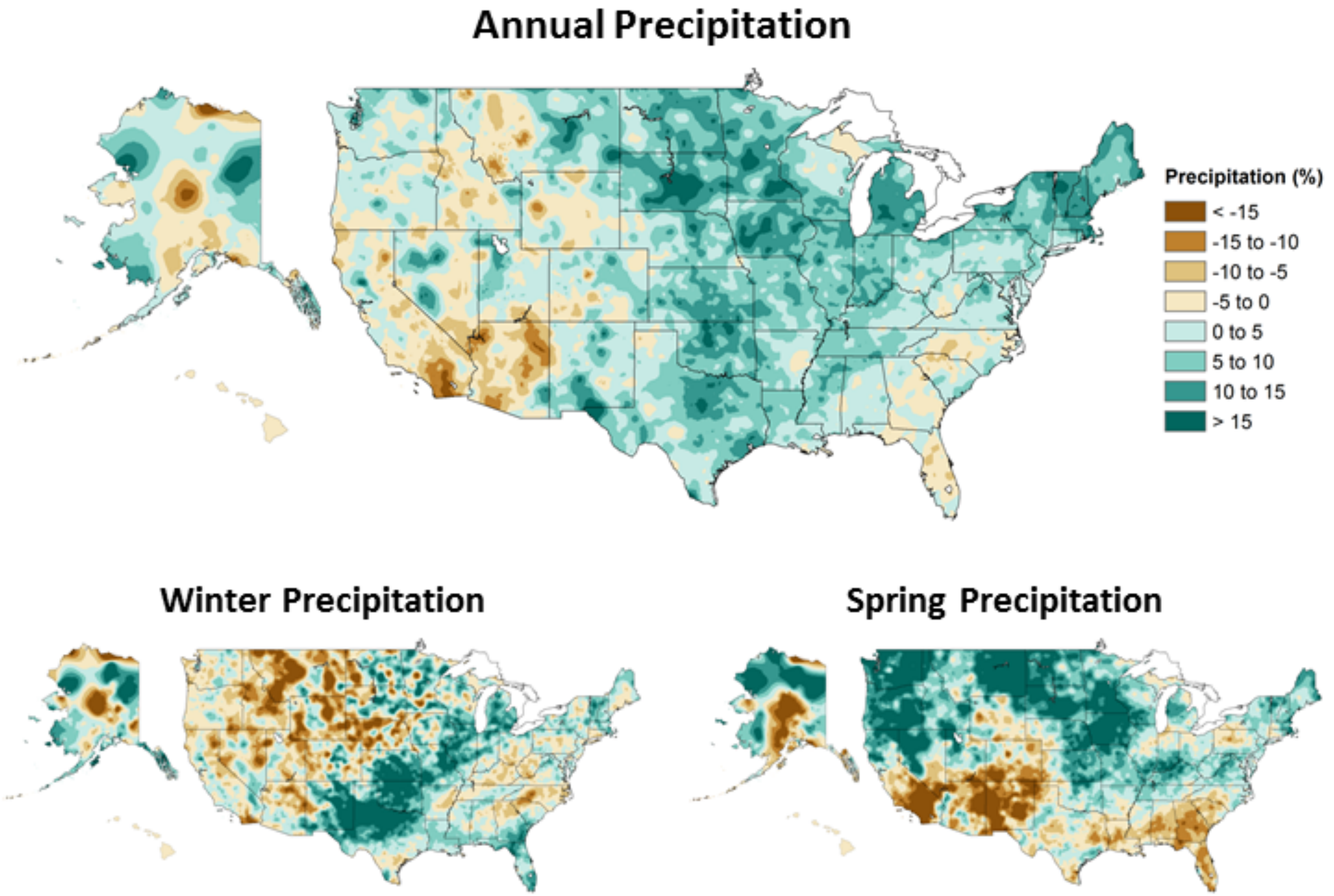


CLIMATE CHANGE IMPACTS ARE REGIONAL

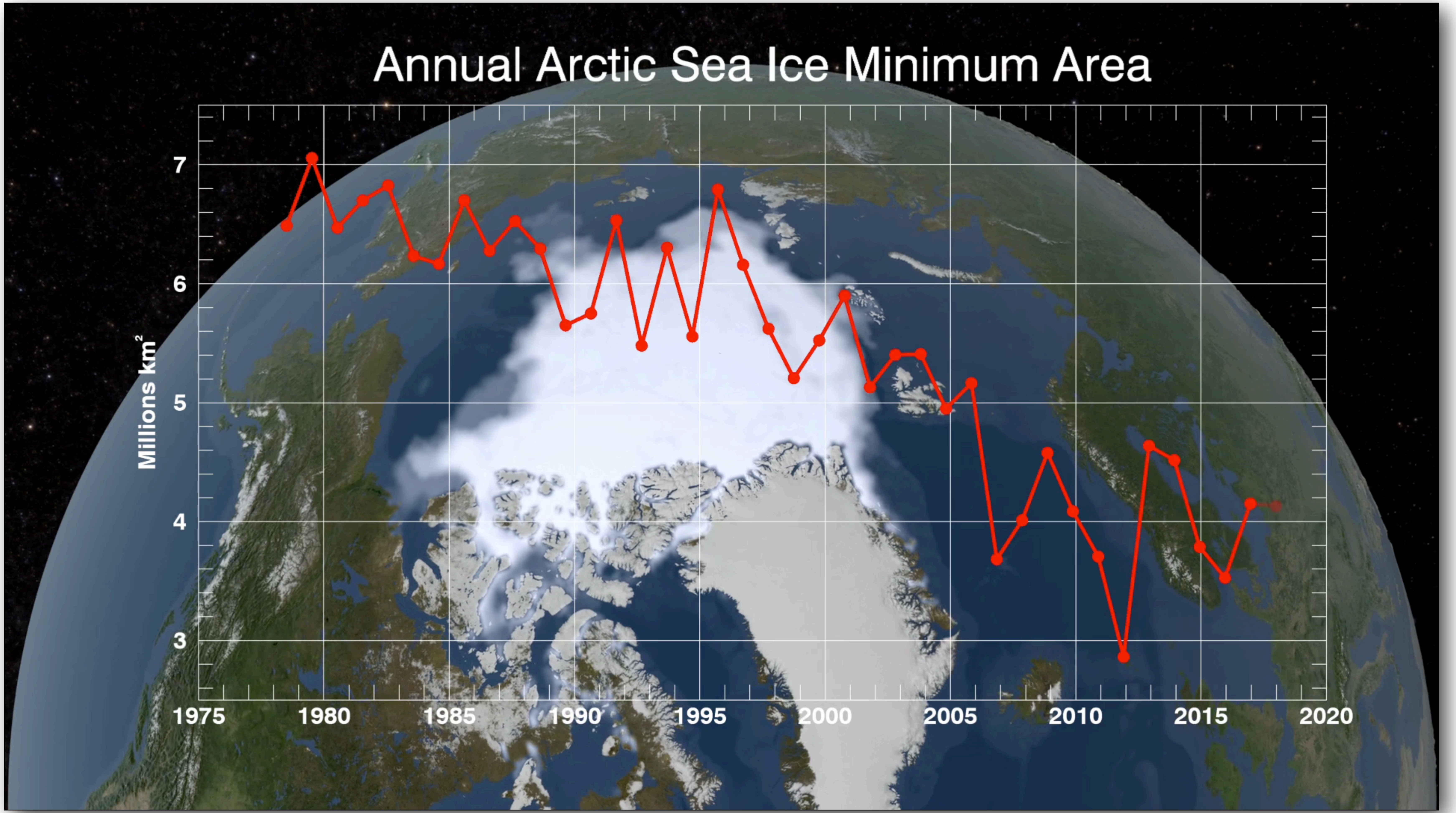
Precipitation changes are not uniform



NCA4, Vol 1



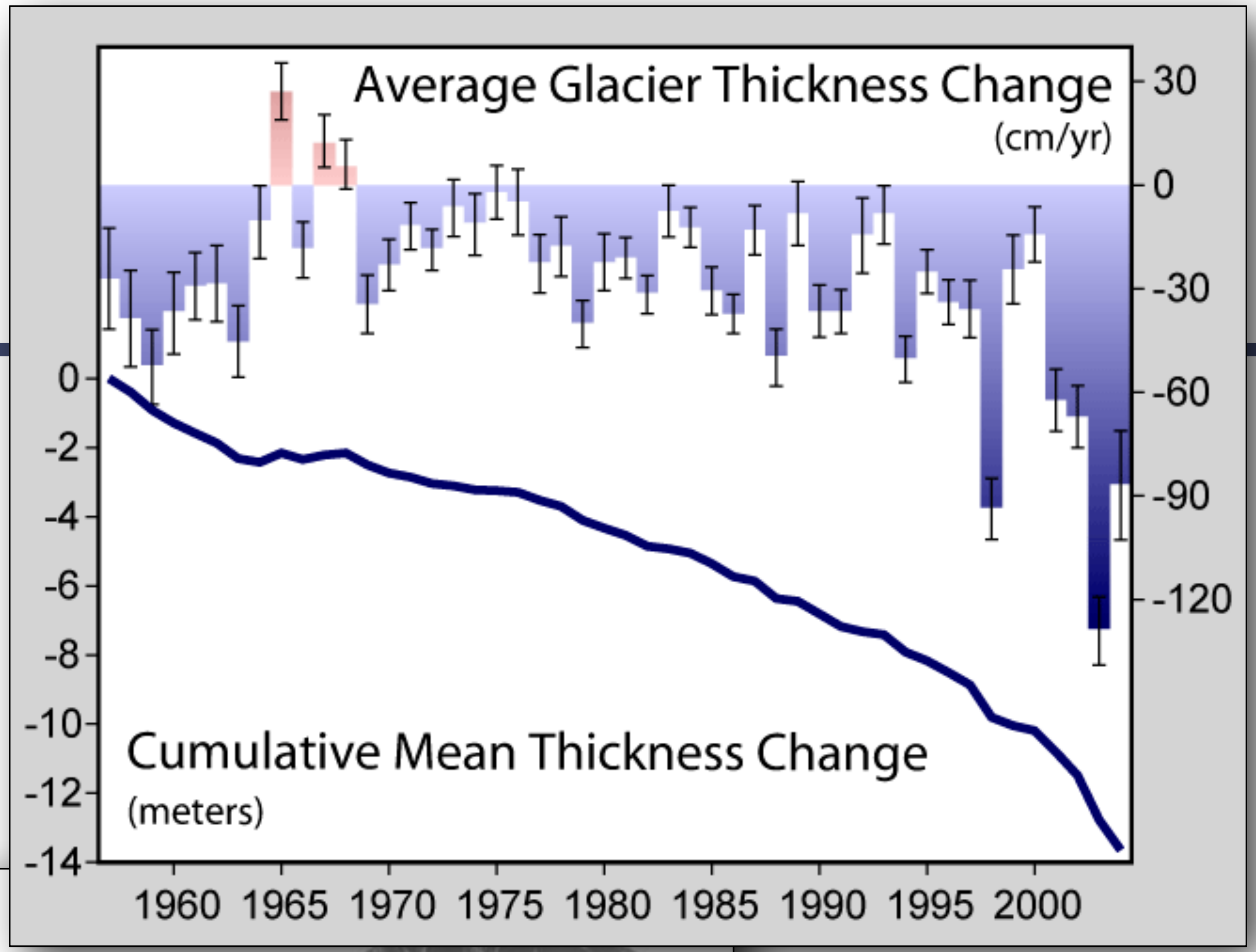
RAPID DECLINE OF ARCTIC SEA ICE



MOUNTAIN GLACIAL RETREAT

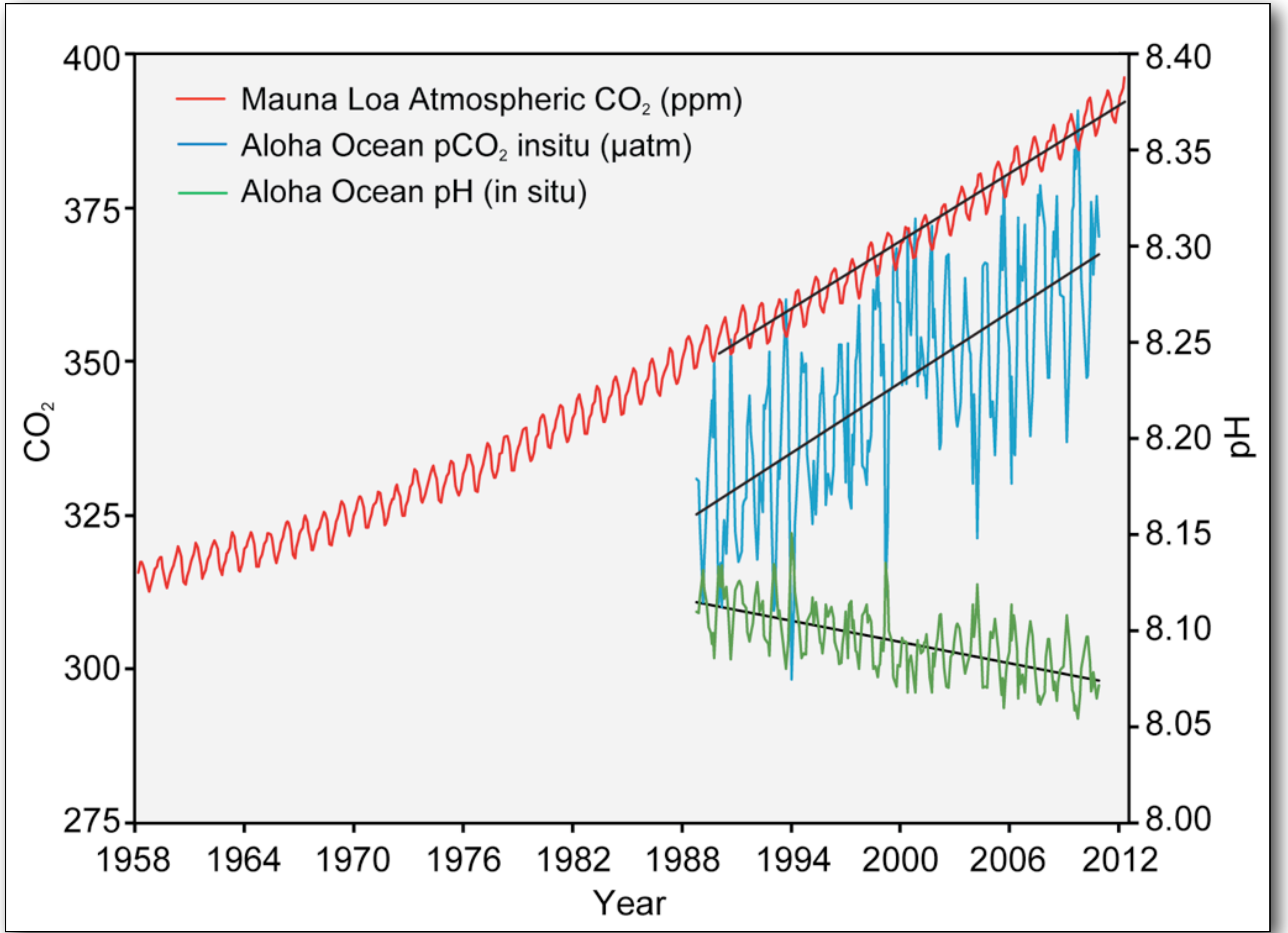
Okpilak Glacier 1907

Okpilak Glacier 2004

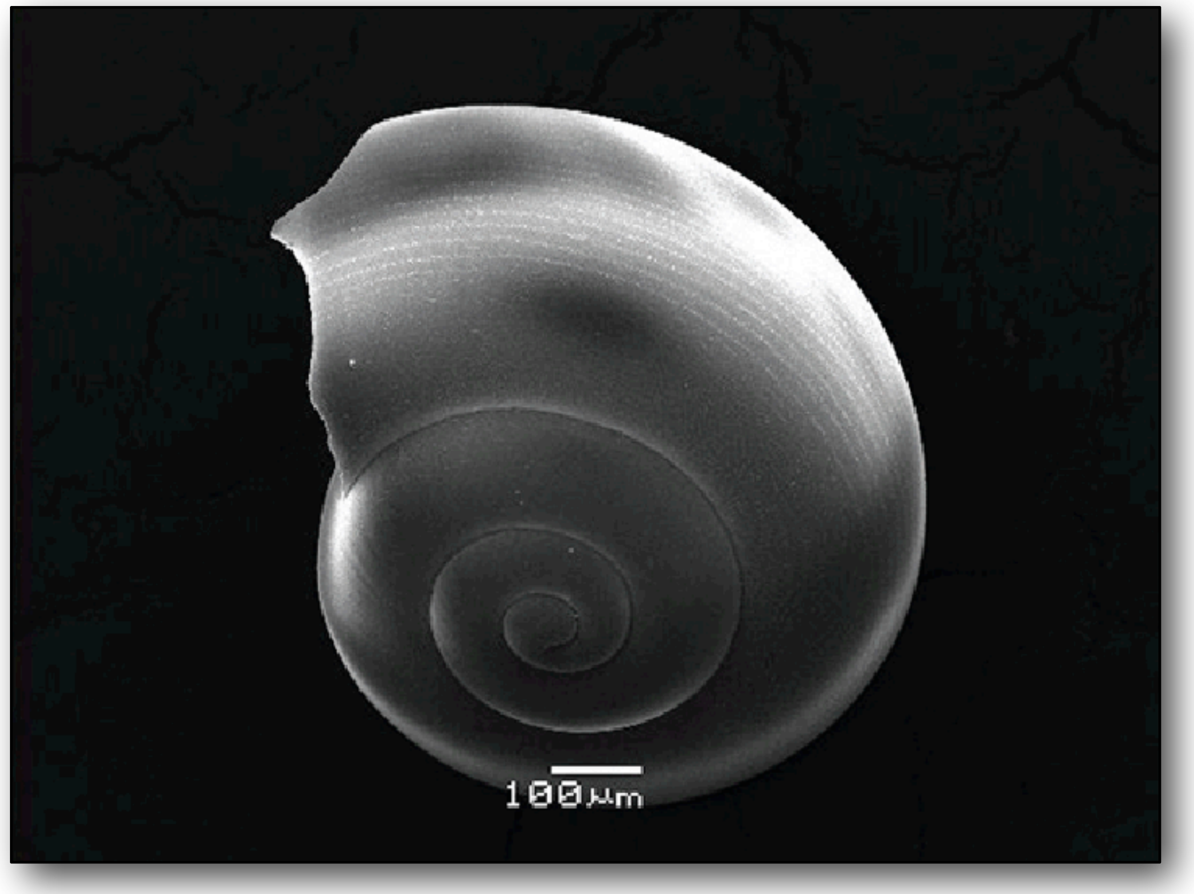


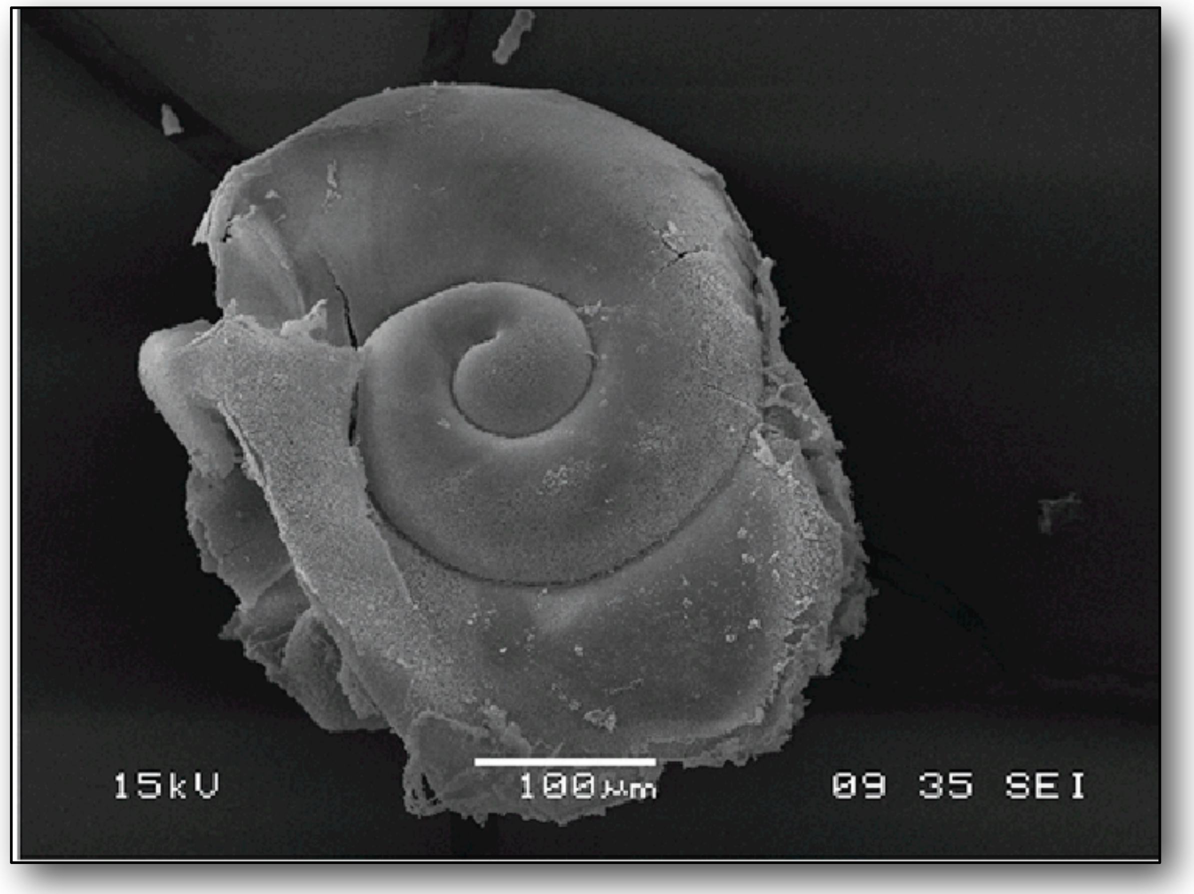
National Snow and Ice Data Center

AS OCEANS ABSORB CO_2, THEY BECOME MORE ACIDIC



NCA 2014; modified from Feely et al. 2009





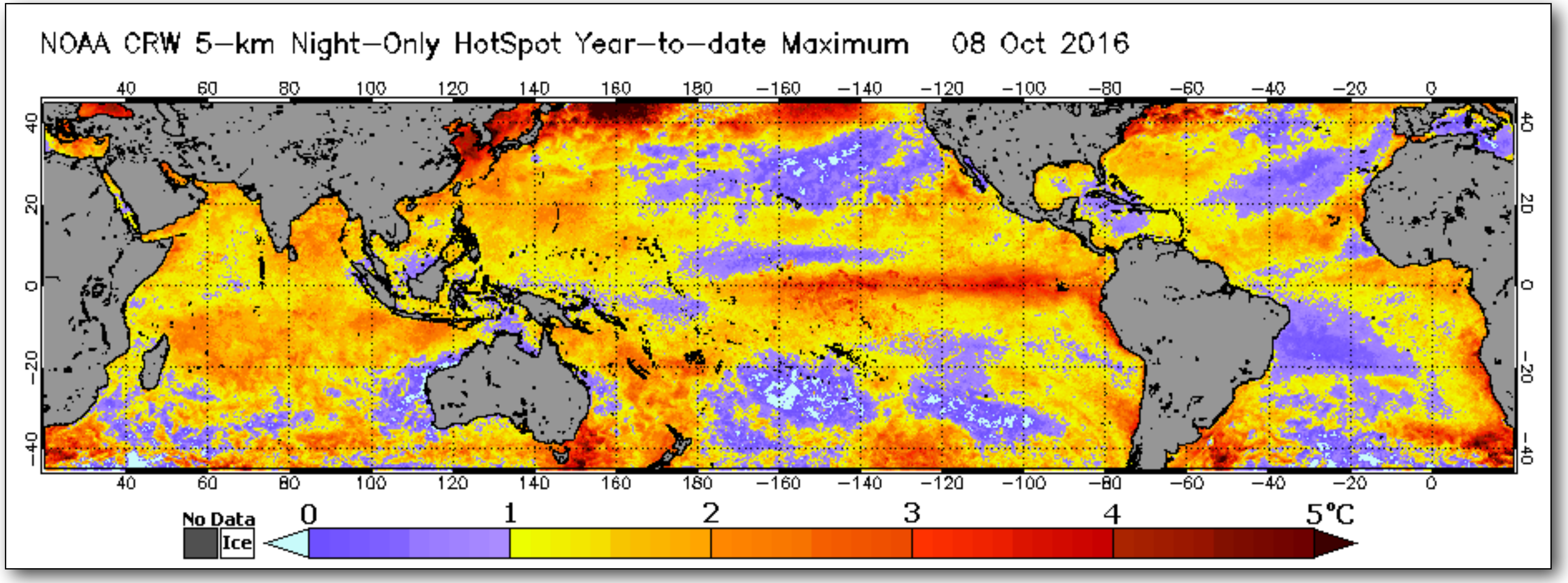
WARMING OCEANS BLEACH CORALS

NOAA

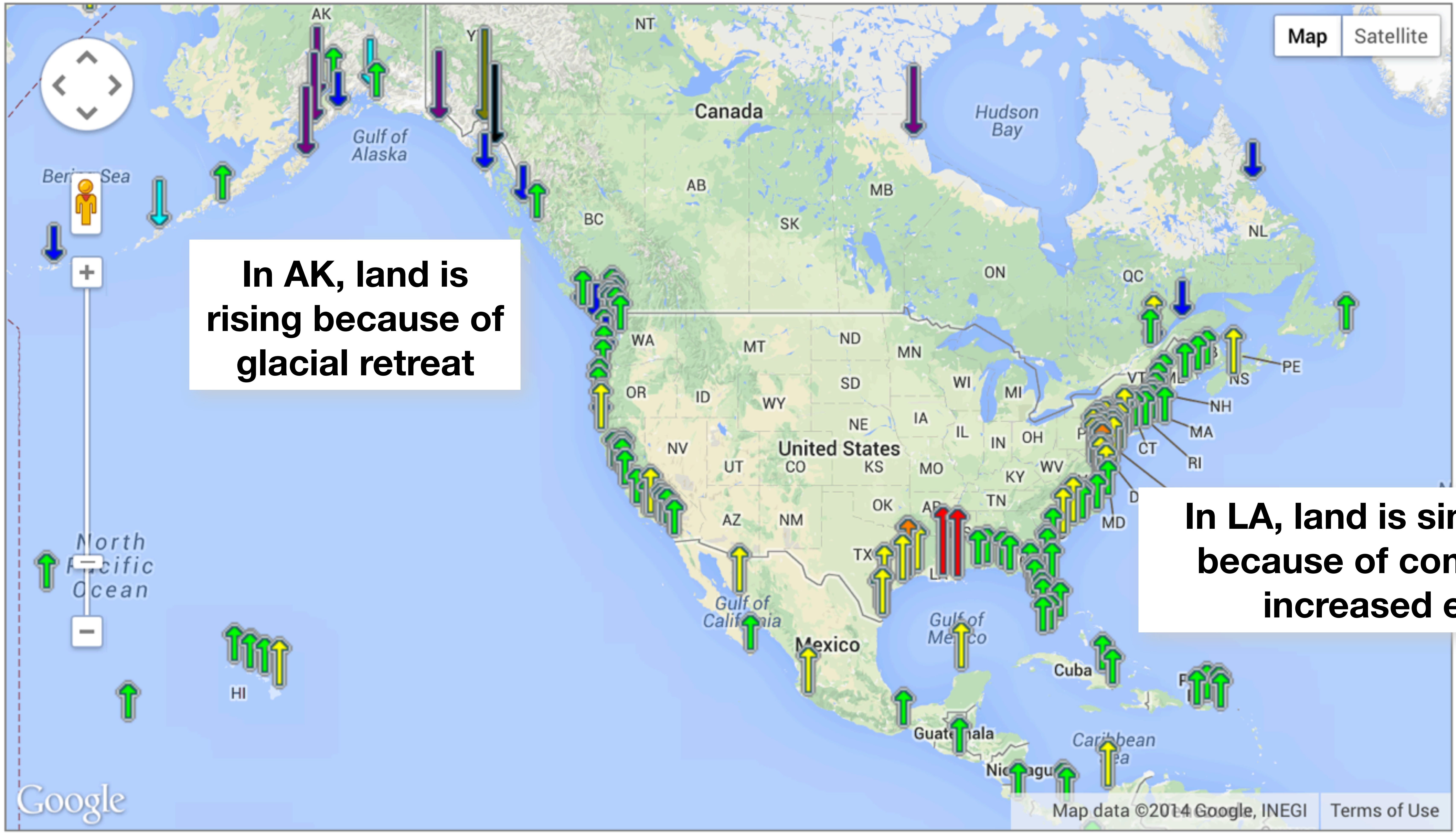
Coral reefs endangered by bleaching in global event, researchers say

By Adam Dunnakey, CNN

Updated 1:06 PM ET, Thu October 8, 2015



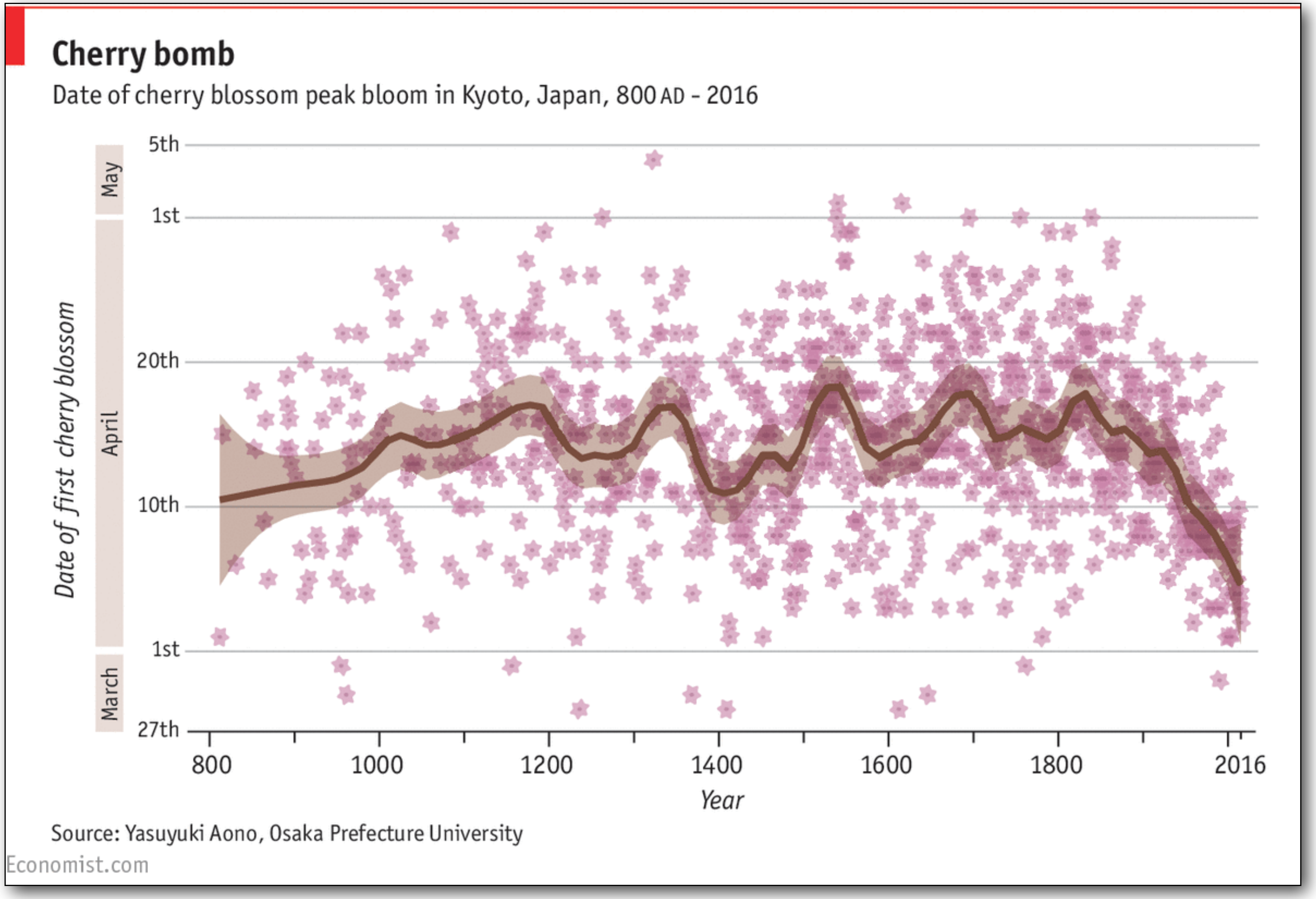
WARMER WATER + MELTING GLACIERS = SEA-LEVEL RISE



In AK, land is rising because of glacial retreat

In LA, land is sinking faster because of compaction & increased erosion

MANY OTHER CLIMATE CHANGE-RELATED CHANGES



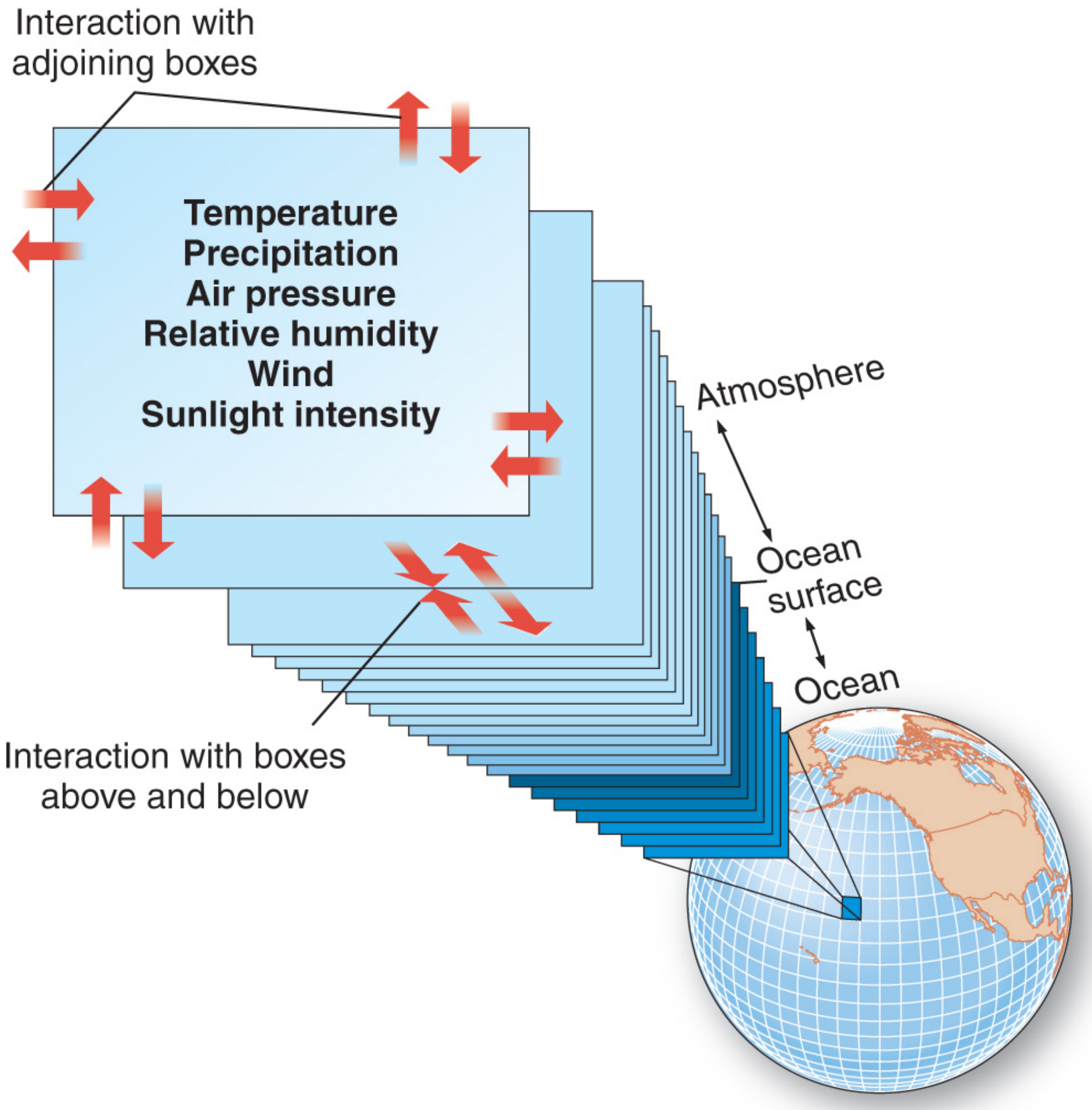
KEY POINTS

Historical observations demonstrate **rapid (decadal) climate changes** in surface temperature, sea ice, mountain glaciers, sea level, and other parts of our climate system.

These changes **<u>are all consistent</u> with a warming planet** resulting from increased greenhouse gases.

The changes **<u>are not consistent</u> with long-term natural variations** in our climate.

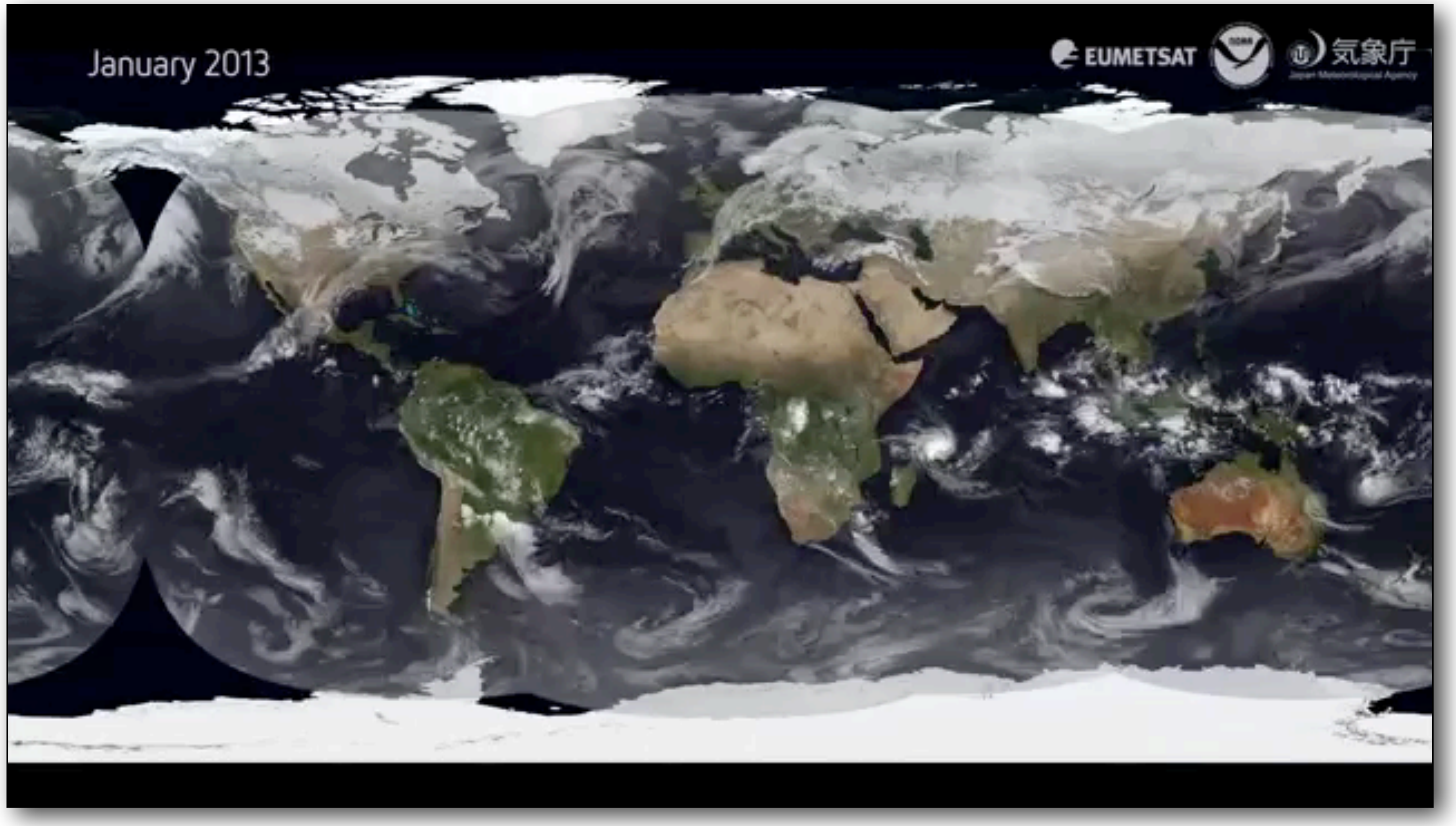
GLOBAL CLIMATE MODEL (GCM)



Models based on physical laws and statistical representations of observations

Provides reasonable description of physical changes, not detailed predictions

REAL VS. COMPUTED CLIMATE

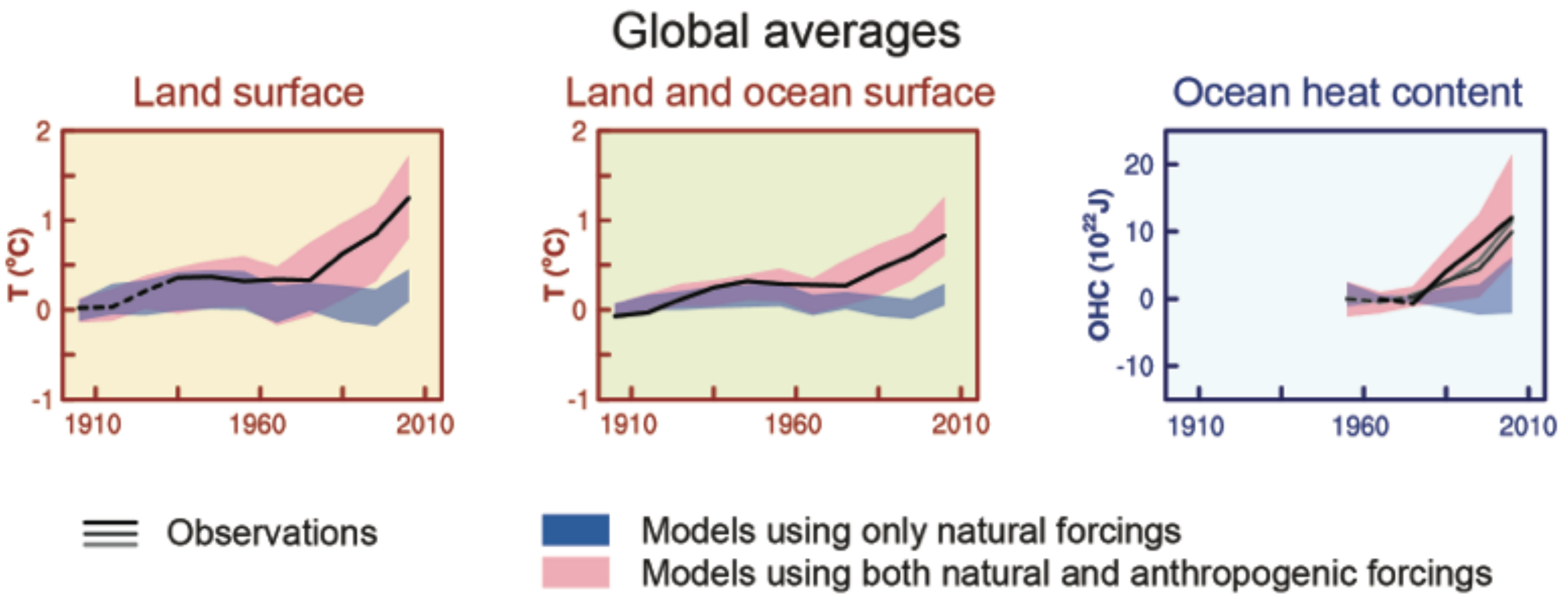


Multi-Satellite Image Animation

Global Climate Model Simulation

USING GLOBAL CLIMATE MODELS

Using computer models from 20 climate modeling groups worldwide, global climate models that include both natural forcing and forcing from human activities best relate to the actual observations



IPCC AR5

FUTURE SCENARIOS IN IPCC & NCA

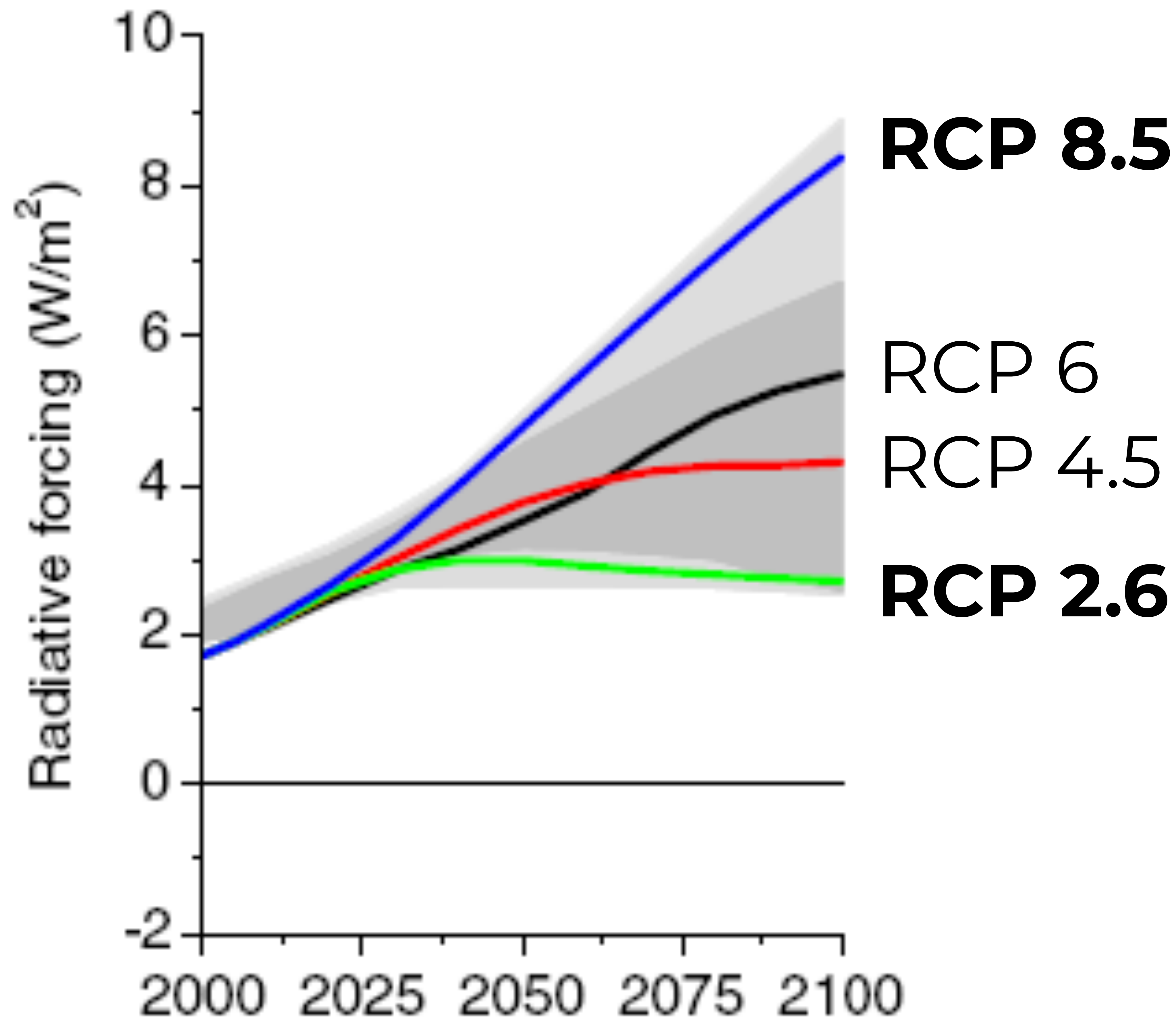
Several scenarios are used to depict how greenhouse gas (GHG) emissions may change in the future.

RCP 8.5 – GHG emissions continue to increase ("business as usual")

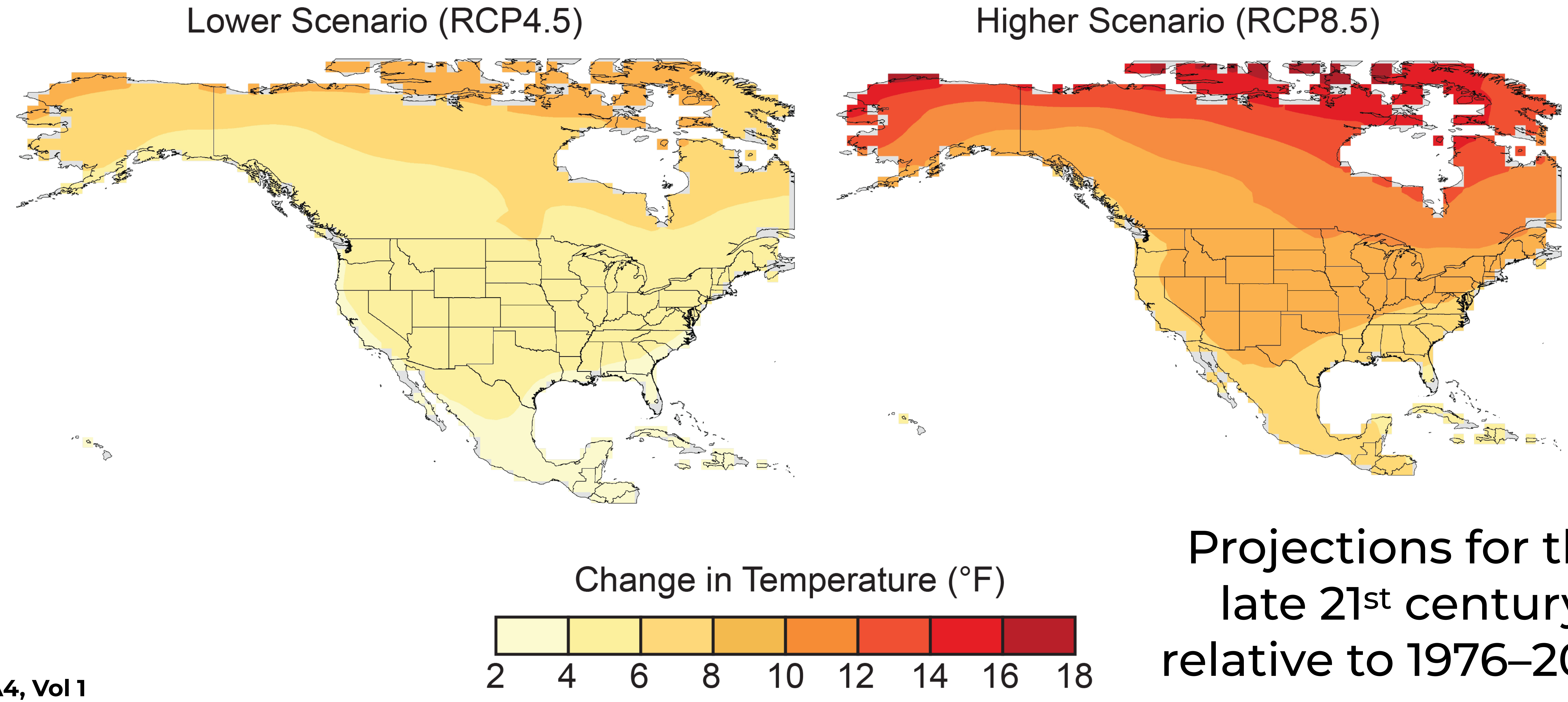
RCP 6 – GHG emissions stabilized around 2100 using various technologies & reduction strategies

RCP 4.5 – similar to RCP 6 but with a lower stabilization target

RCP 2.6 – a "peak-and-decline" scenario where GHG emissions are reduced significantly over time



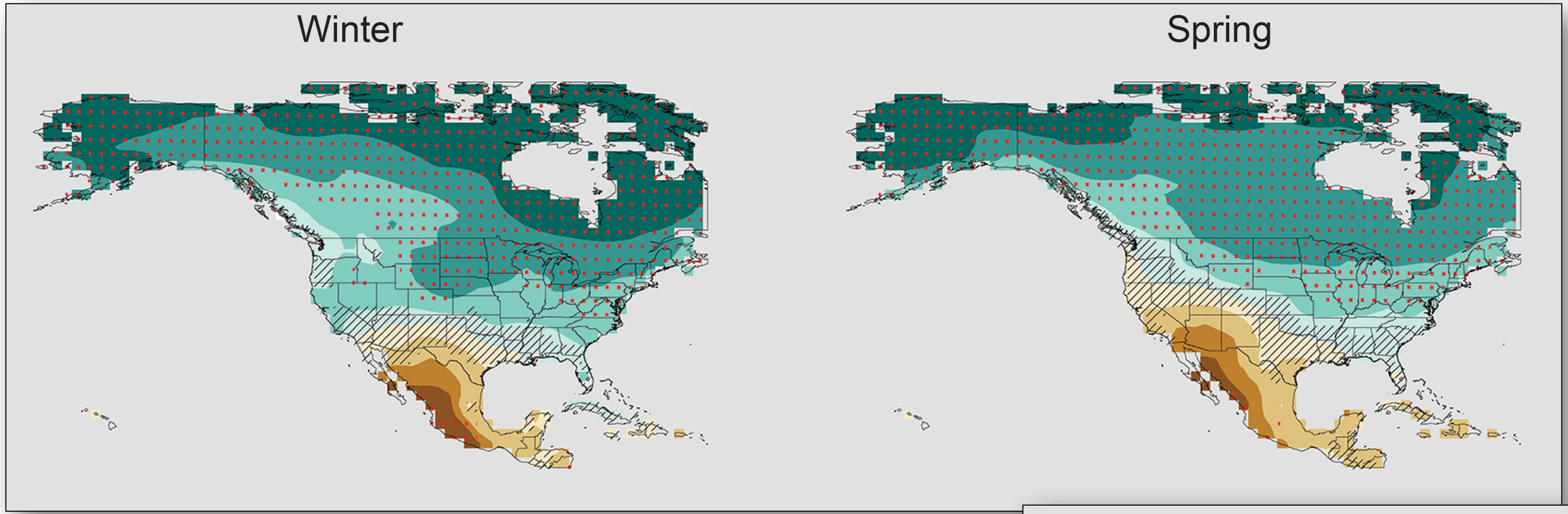
PROJECTED CHANGES IN AVERAGE ANNUAL TEMPERATURE

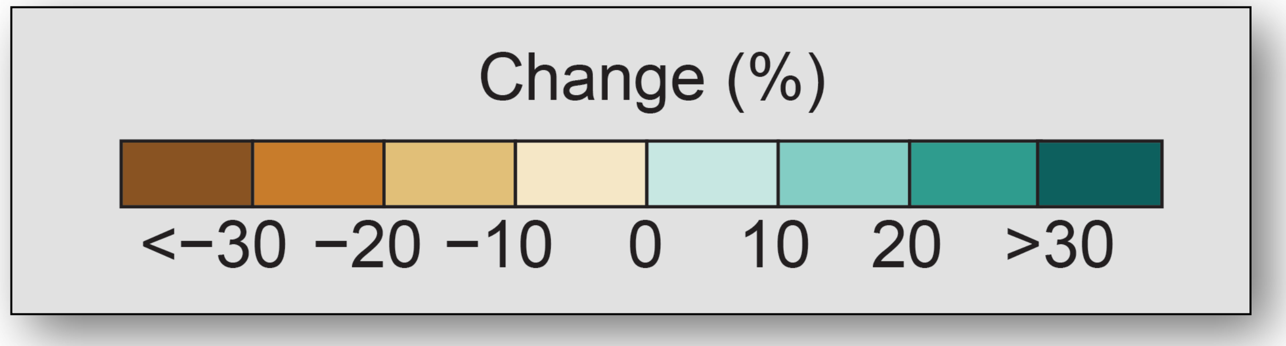


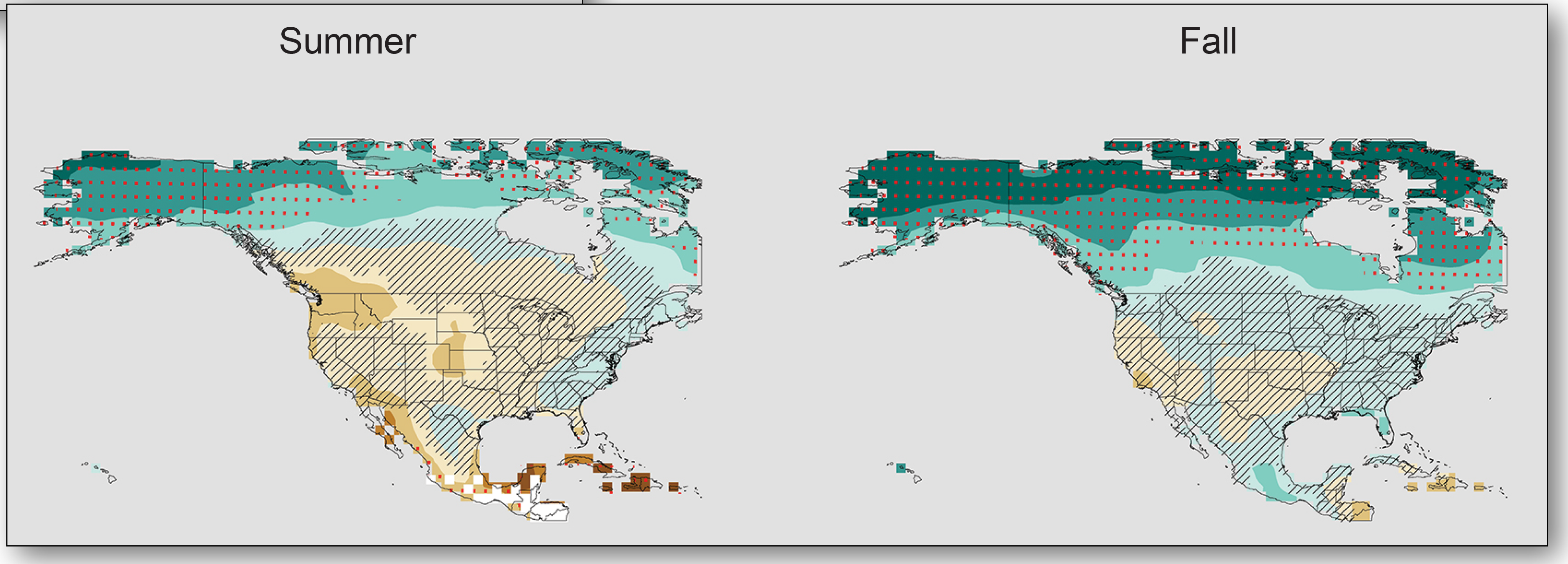
Projections for the late 21st century relative to 1976–2005

NCA4, Vol 1

PROJECTED CHANGES IN SEASONAL PRECIPITATION







Projections for the late 21st century relative to 1976–2005

NCA4, Vol 1

KEY POINTS

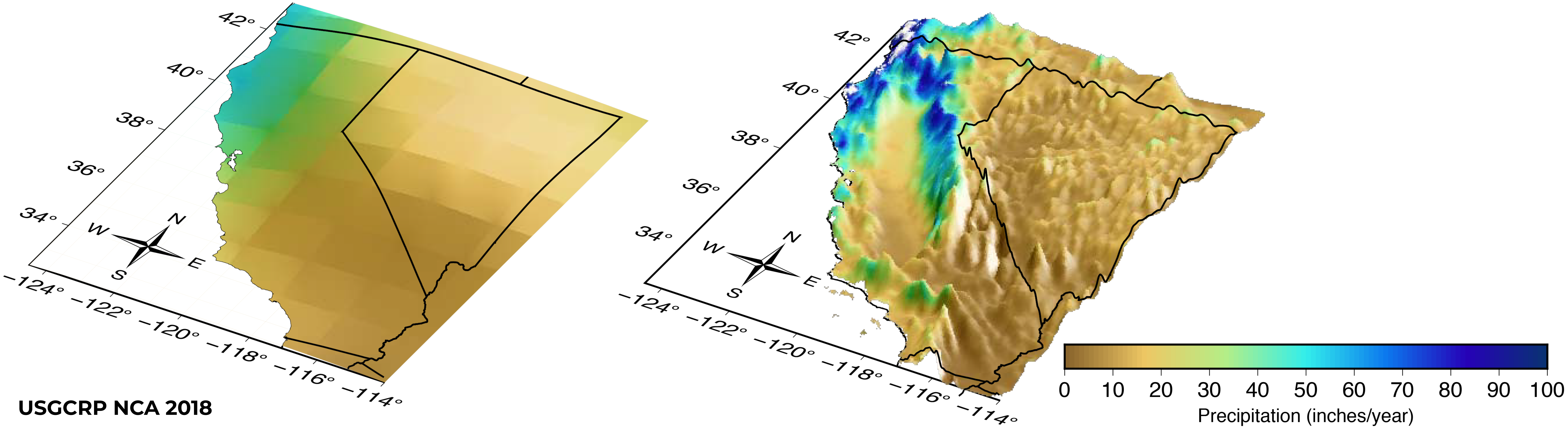
General trends over time and large-scale regional patterns **can be projected** using numerical climate models.

These **climate models have satisfactorily depicted changes** in the past.

Model results depicting future **changes in temperatures are more certain** than results depicting future changes in precipitation.

"DOWNSCALING" THE GCM OUTPUT

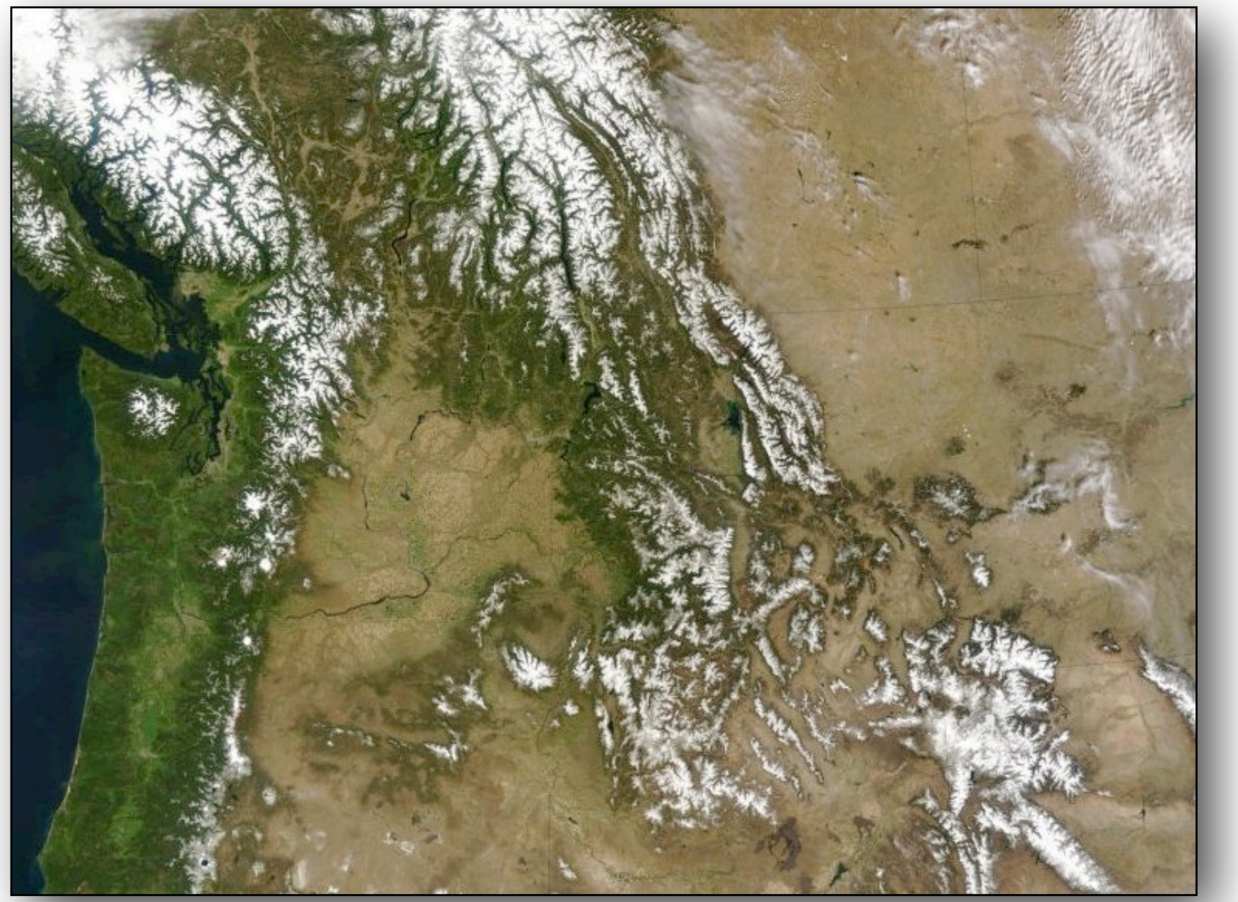
What is downscaling? – a method to use "low resolution" global climate model output (e.g., 100-500 km grid) & obtain "high resolution" (e.g., 10-50 km grid) climate projections



USGCRP NCA 2018

WHY DOWNSCALE?

Climate scientists downscale GCM data **to help answer stakeholders' questions** about how the climate will change in their location (i.e., impact assessments) & better represent local climates



Mountain climates

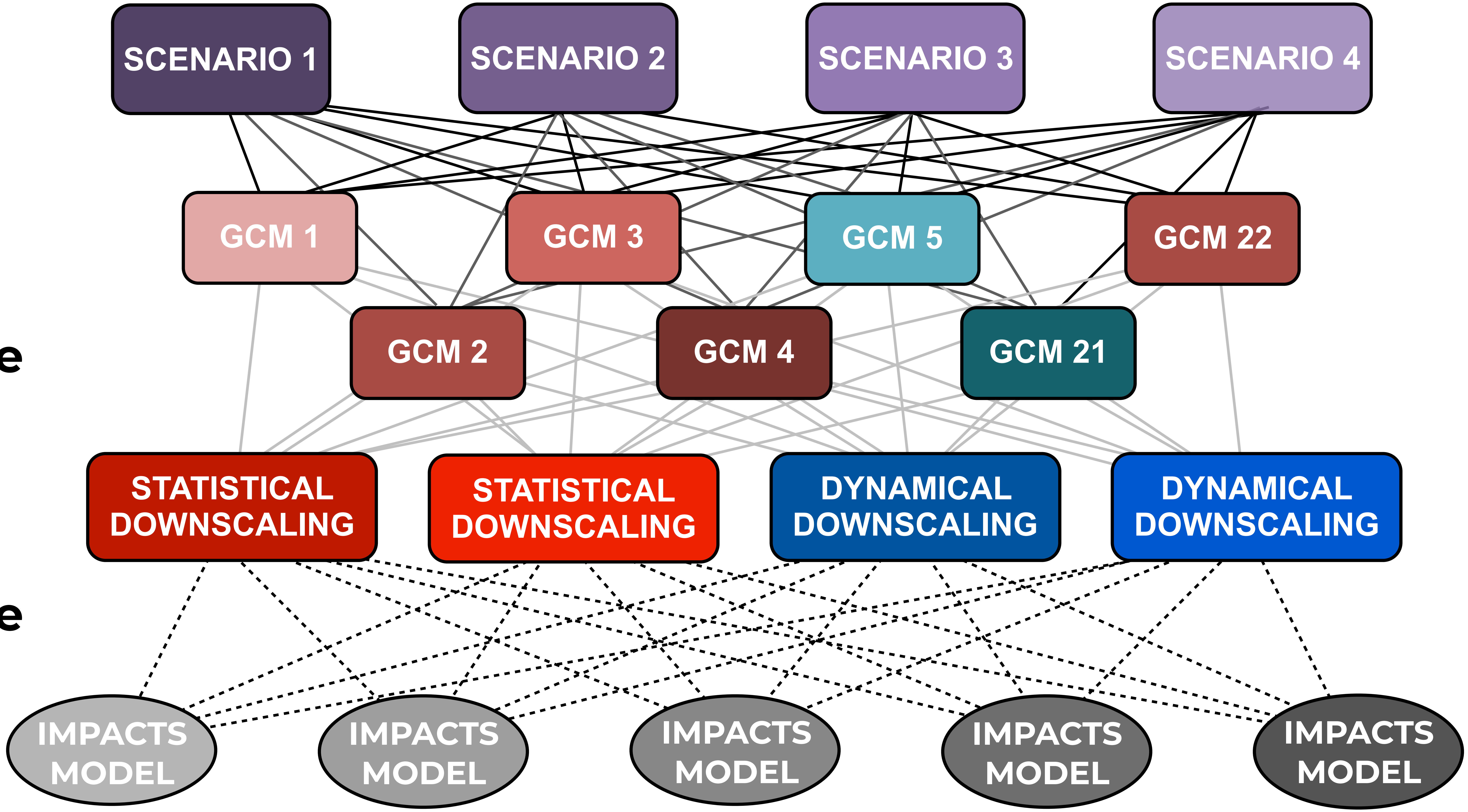
Coastal climates

Urban-rural climates

ENSEMBLE APPROACH TO DOWNSCALING

Each gray line represents multiple scenarios

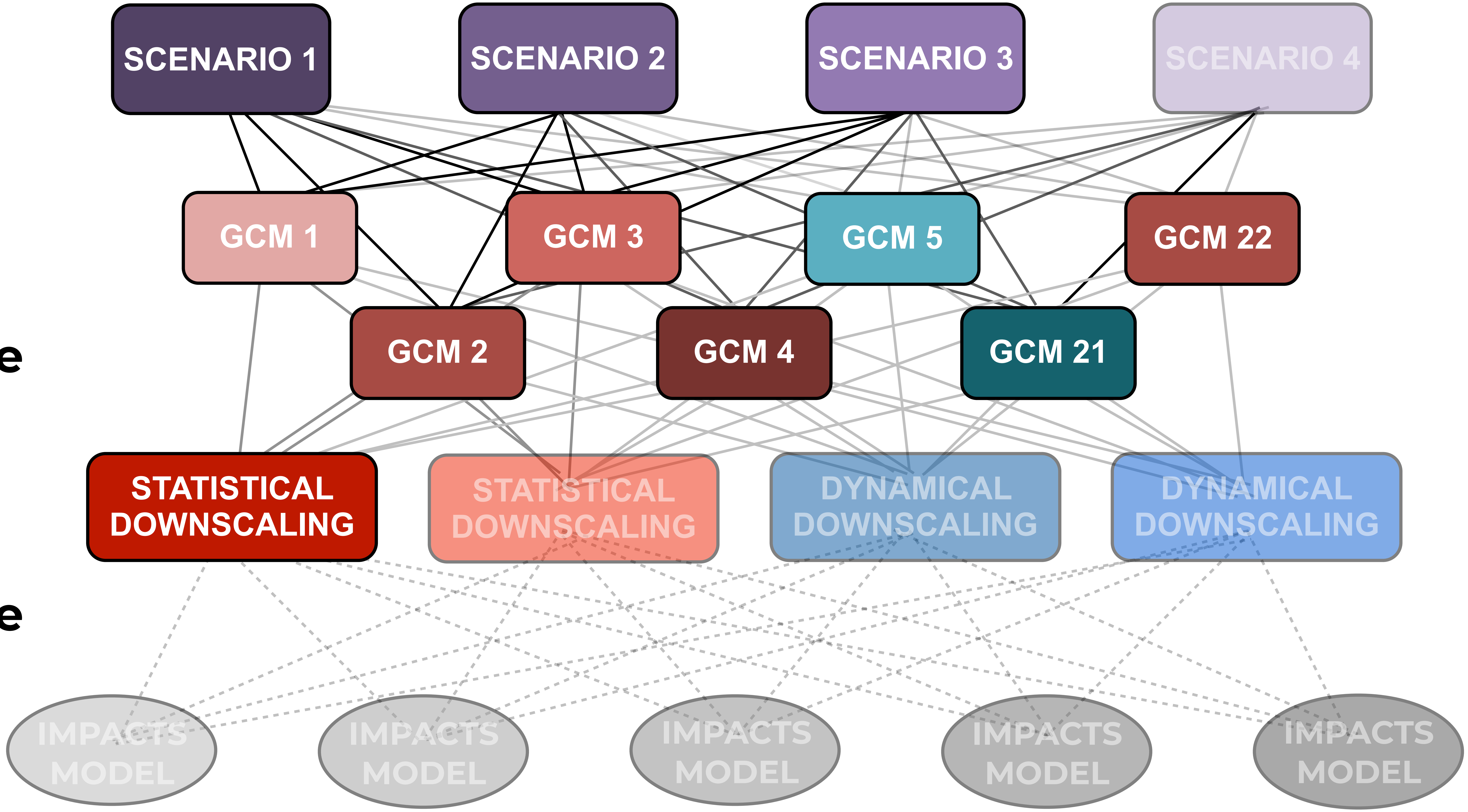
Each dotted line represents multiple GCMs & scenarios



ENSEMBLE APPROACH TO DOWNSCALING

Each gray line represents multiple scenarios

Each dotted line represents multiple GCMs & scenarios



KEY POINTS

Downscaled climate projections are helpful to decision makers because they **focus on specific locations or particular regions**.

As with any climate projection, **understanding how and when to use a chosen dataset is critical** for interpreting the information correctly. **Contact your colleagues at the DOI Climate Adaptation Science Centers** to discuss what you want to know and they will ensure you don't use a projection inappropriately.

Questions?