BASICS OF CLIMATE CHANGE & VARIABILITY

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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.”

Which of the following examples is NOT climate (but instead is weather)?

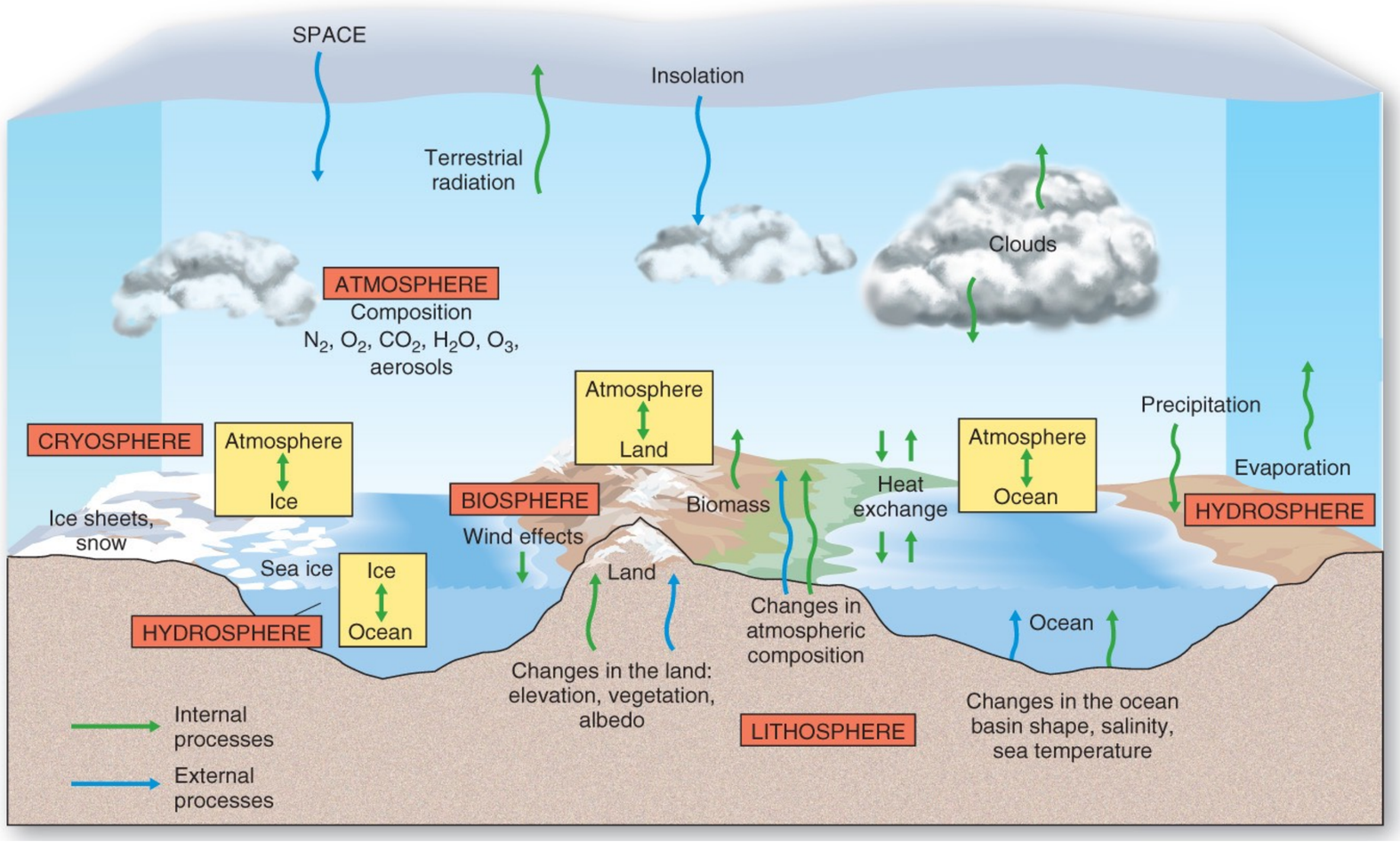
1. *average maximum temperature on July 22 in Oklahoma City, OK*
2. *heaviest rain rate measured in Dallas, TX*
3. *highest wind gust on July 22 in New Orleans, LA*
4. *mean annual snowfall amount in Albuquerque, NM*

?

WEATHER VS. CLIMATE

- **Weather**
  - What type of clothing should I wear today?
  - Should we open or close our windows today?
  - Is it dry enough to harvest my crop tomorrow?
- **Climate**
  - What clothing should I buy for my wardrobe?
  - What materials should I build my house from?
  - How much and what type of crops should I plant?

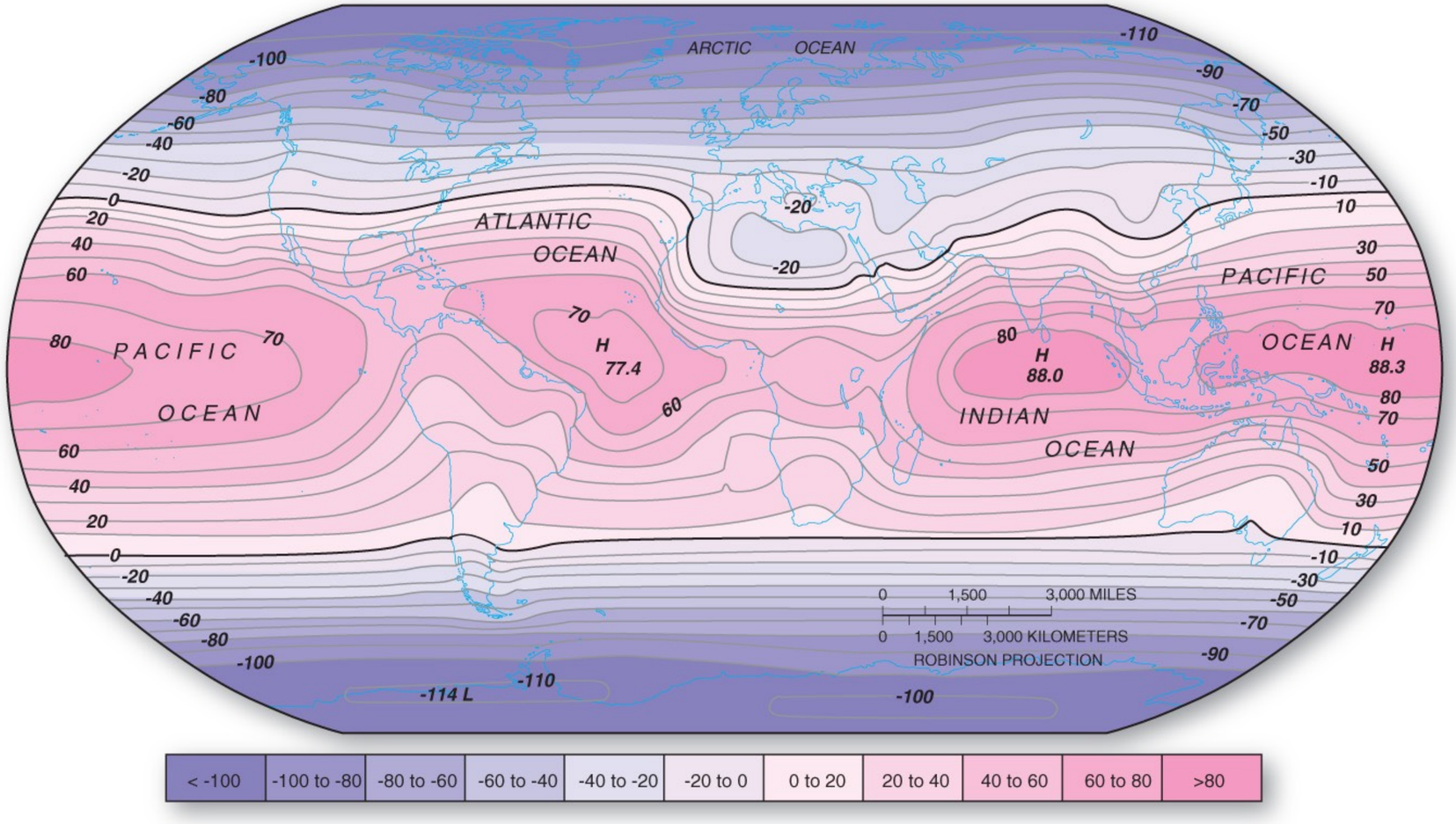
EARTH'S CLIMATE SYSTEM



EARTH'S CLIMATE SYSTEM COMPONENTS

- **Incoming & outgoing radiation** – energy input & output
- **Albedo** – percent of incoming sunlight reflected
- **Atmospheric composition** – absorption of energy at different wavelengths
- **Temperature** – driven by latitude, elevation, clouds, land-water differences
- **Pressure** – global highs & lows, prevailing winds
- **Ocean currents** – movement of cold vs. warm waters
- **Air masses** – movement of air with differing characteristics
- **Topography** – creates irregularities in other patterns
- **Precipitation** – driven by all of the above

AVERAGE NET RADIATION AT SURFACE

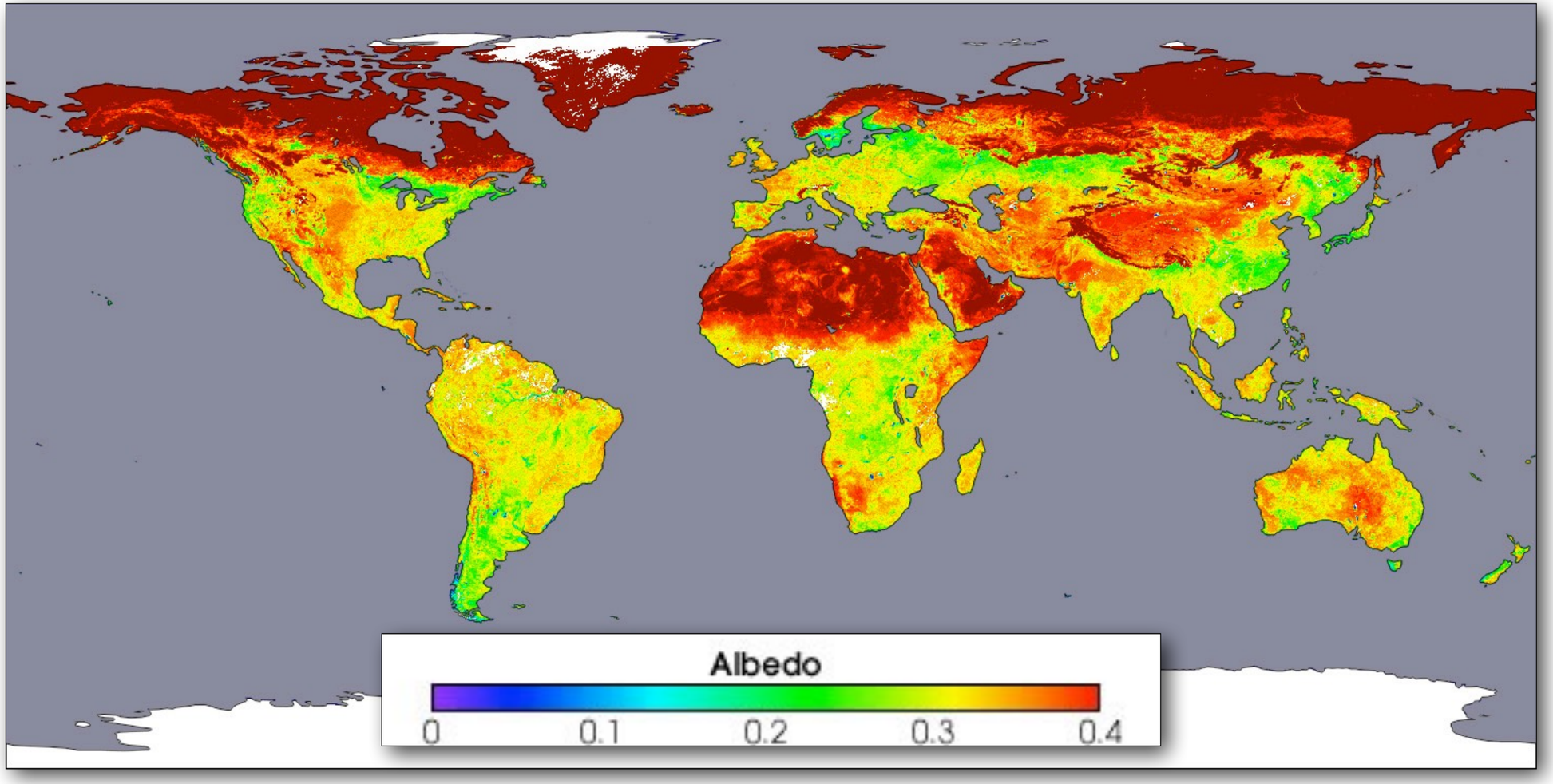


Deficit of radiation at the poles (purples)

Surplus of radiation near the equator (pinks)

Deficit of radiation at the poles (purples)

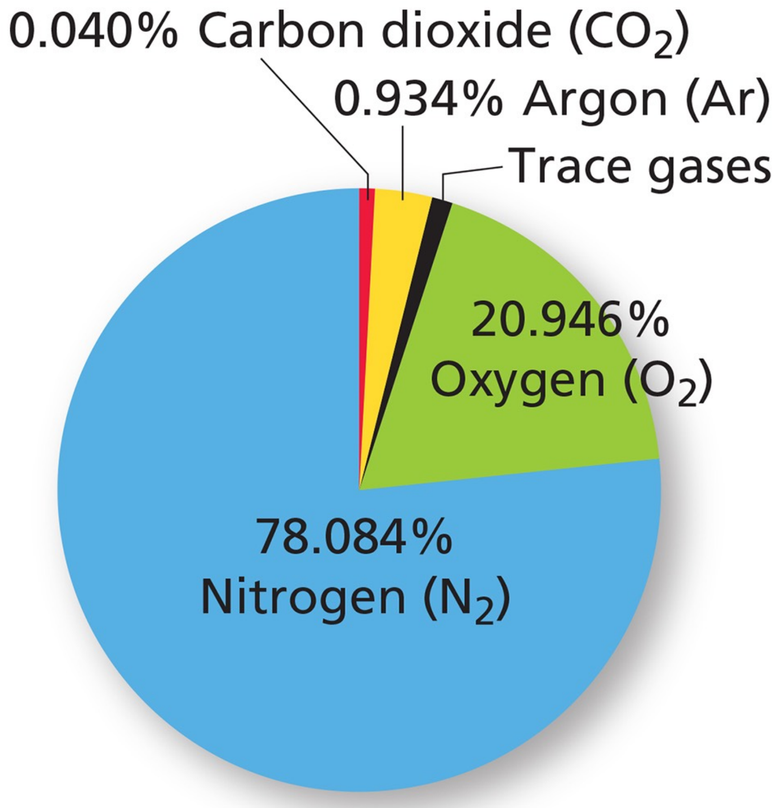
GLOBAL ALBEDO



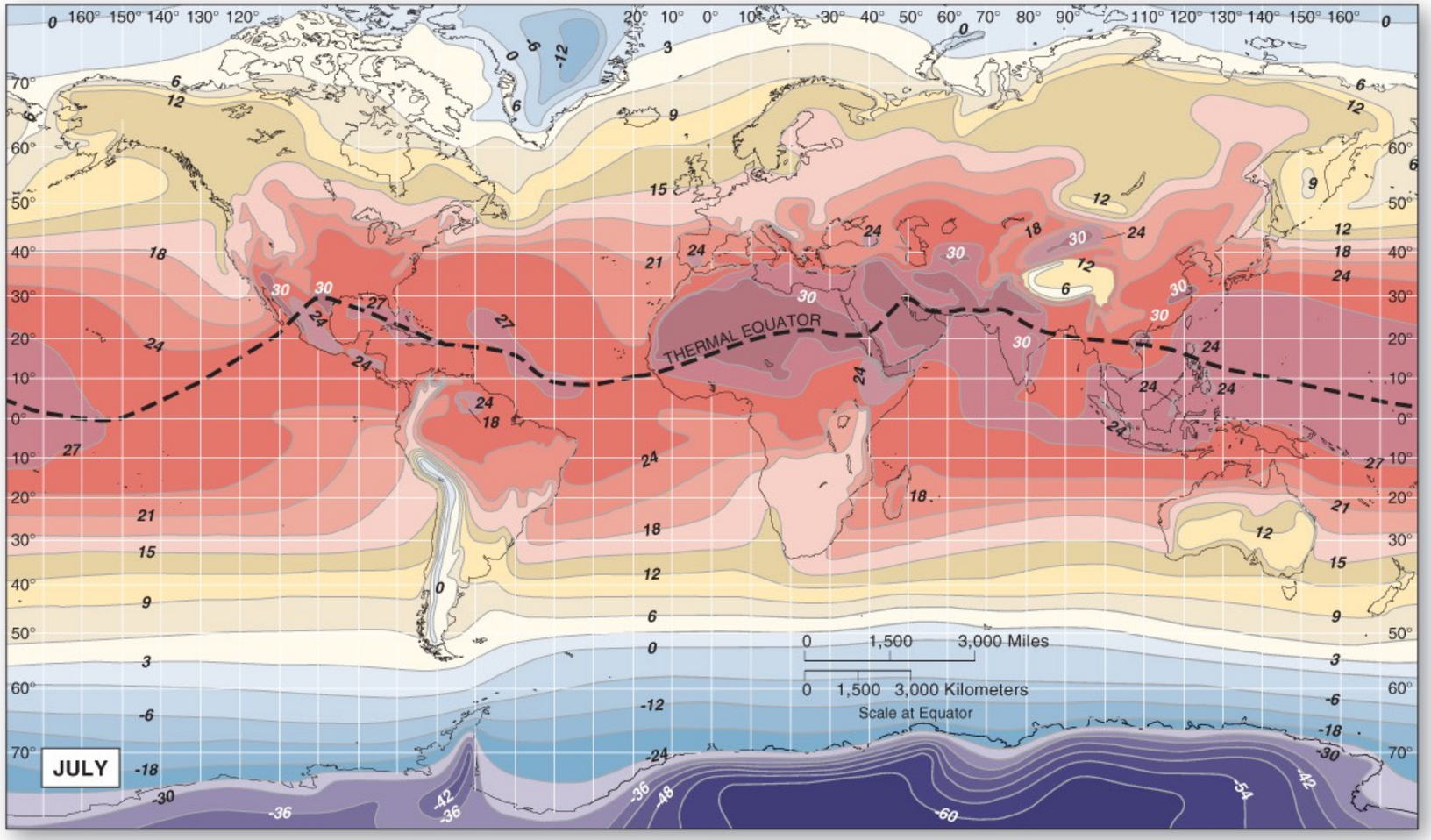
High albedos (reds) reflect lots of sunlight

ATMOSPHERIC COMPOSITION

Gas	Symbol	Content
Nitrogen	N_2	78.084%
Oxygen	O_2	20.947%
Water Vapor	H_2O	0–4%
Argon	Ar	0.934%
Carbon Dioxide	CO_2	0.0360%
Neon	Ne	0.0018%
Helium	He	0.0005%
Methane	CH_4	0.00017%
Hydrogen	H_2	0.00005%
Nitrous Oxide	N_2O	0.00003%
Ozone	O_3	0.000004%



GLOBAL AIR TEMPERATURES (JULY)



Cooler temperatures where there are deficits of radiation

Warmer temperatures where there is a surplus of radiation

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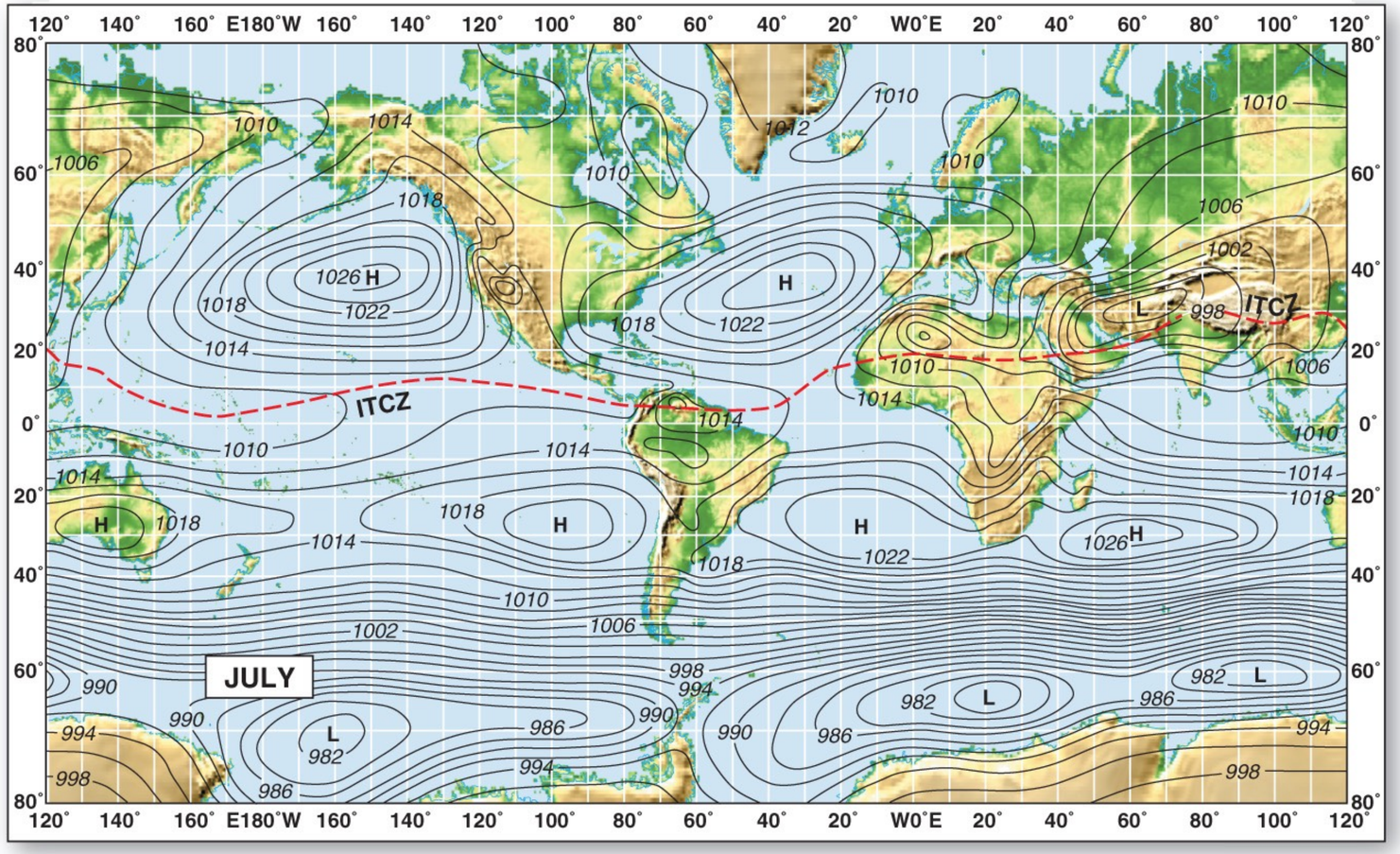
GLOBAL PRESSURE PATTERNS (JULY)

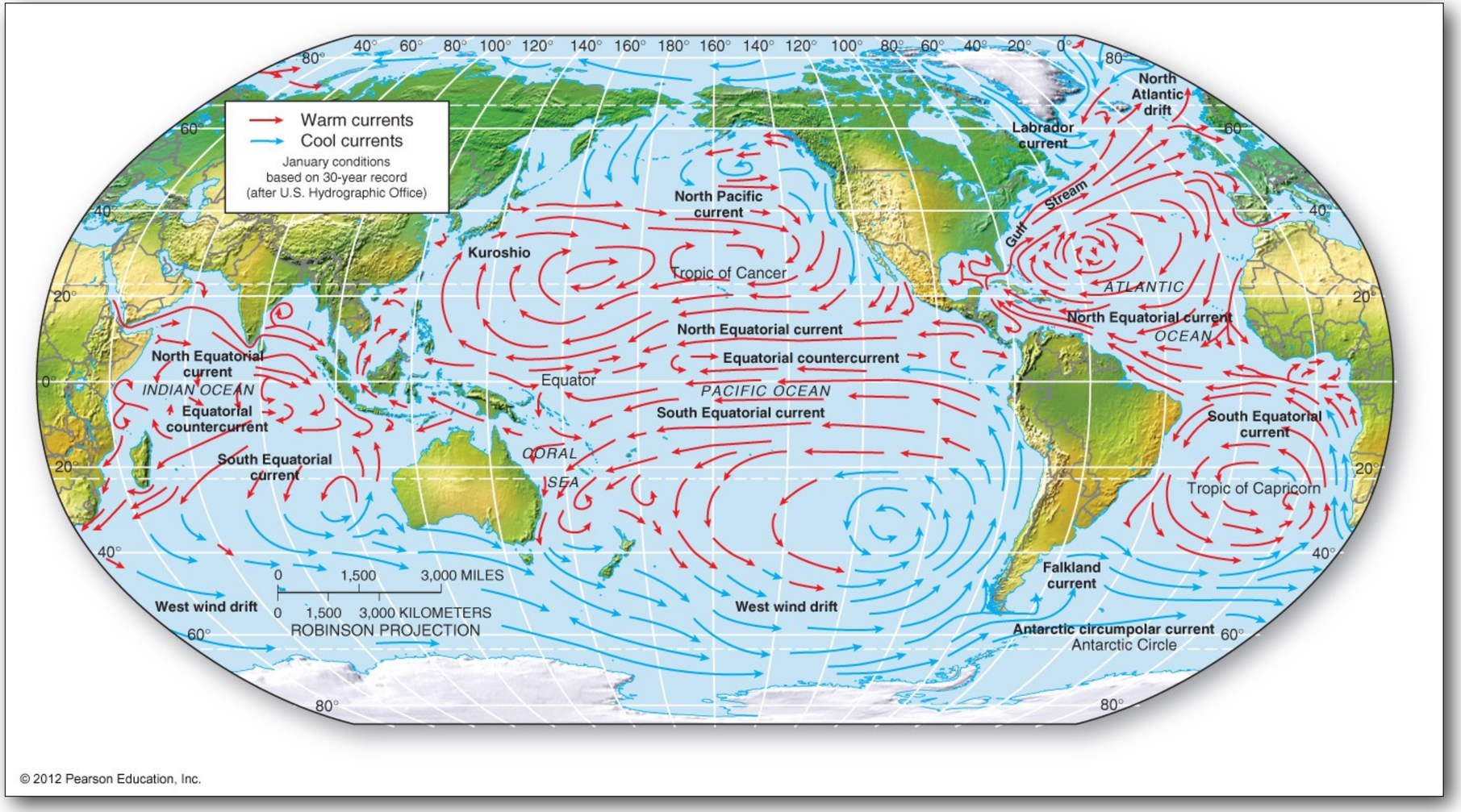


(b)

Winds blow clockwise around high pressure in Northern Hemisphere

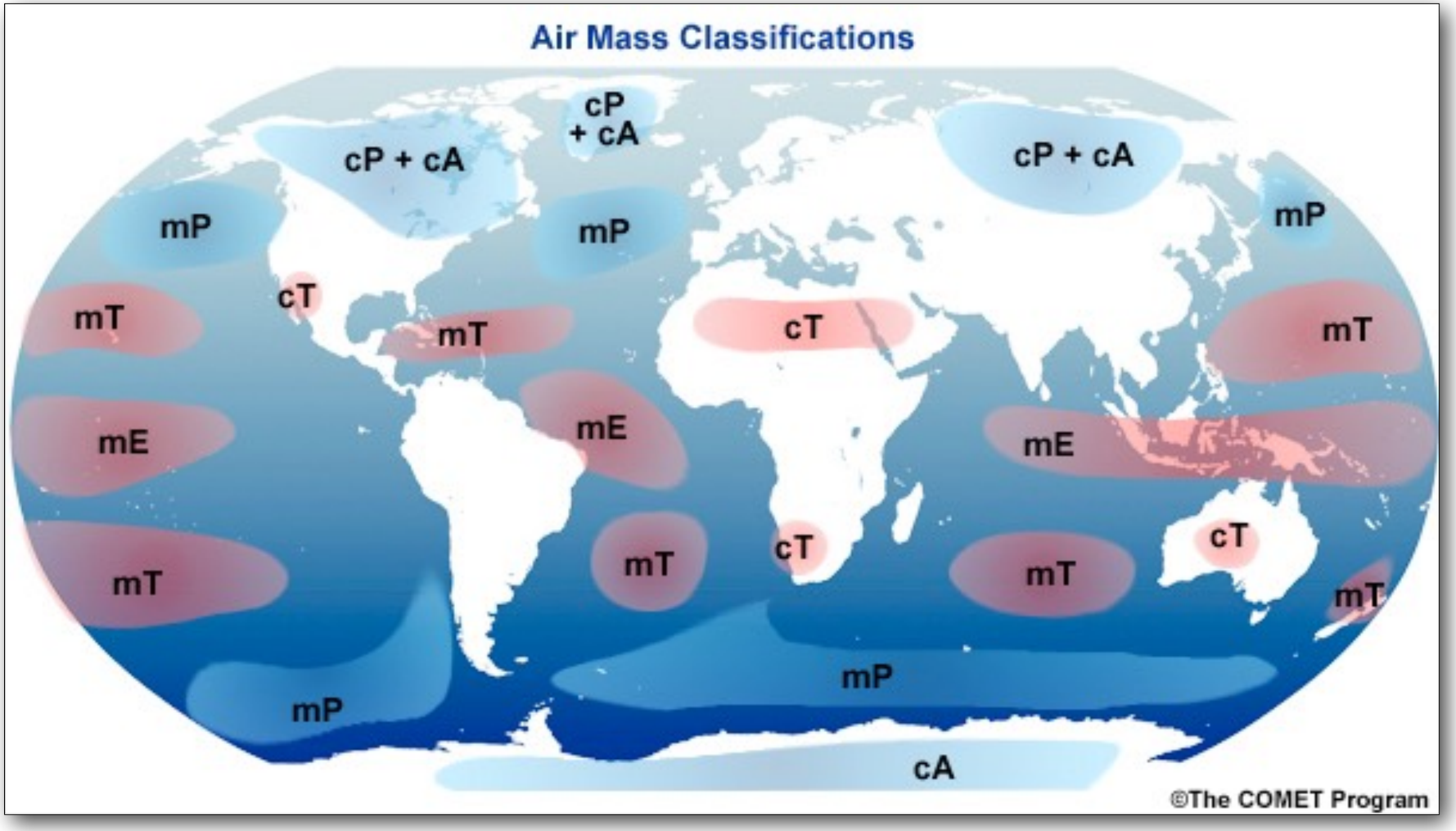
Winds blow counter-clockwise around high pressure in Southern Hemisphere

MAJOR OCEAN CURRENTS



Subtropical highs drag surface waters in same direction, causing ocean gyres

AIR MASSES (TEMPERATURE & MOISTURE)

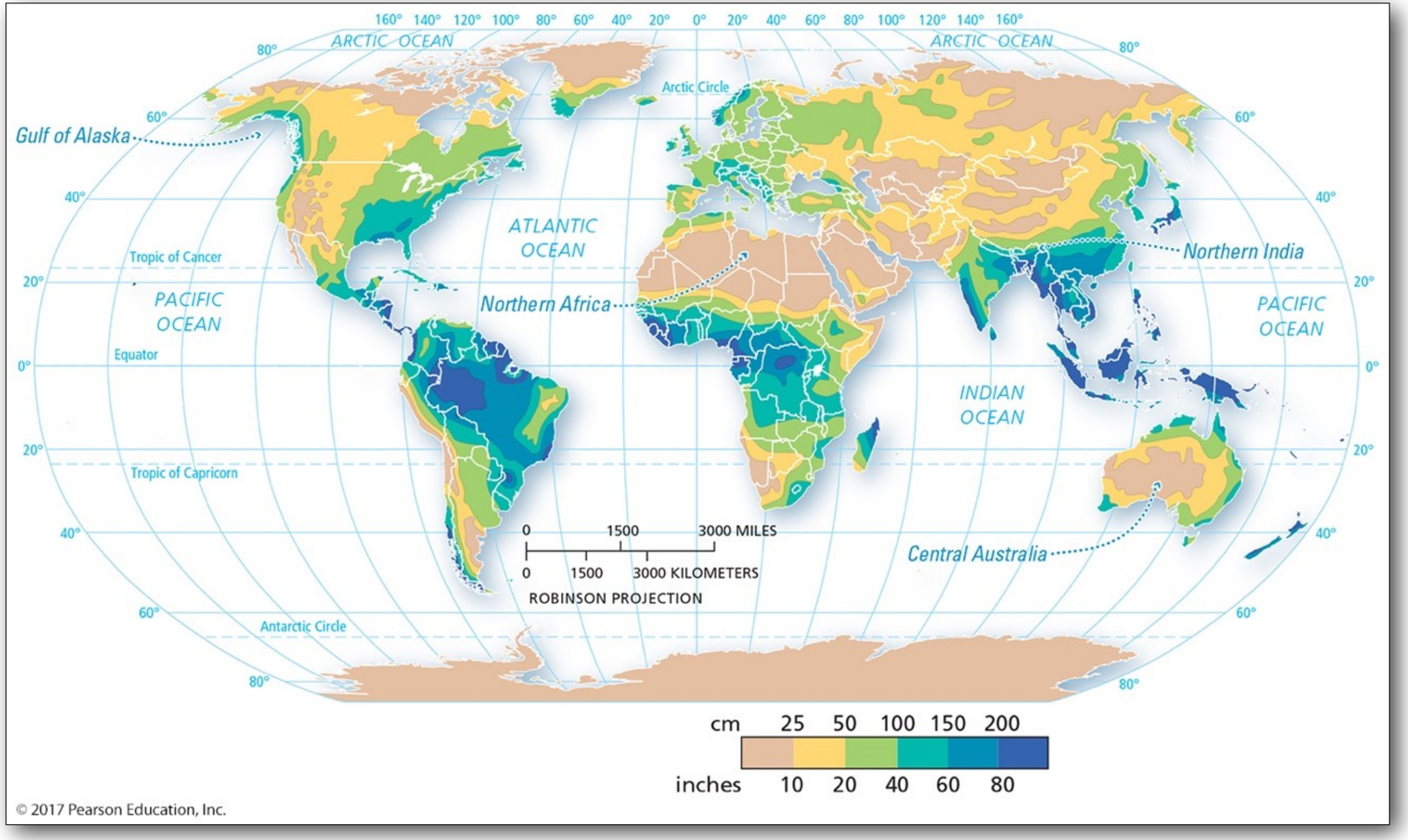


Air mass types result from their source regions:
polar = cold
tropical = warm
maritime = wet
continental = dry

TOPOGRAPHY

Mountains cause rising air = clouds & rain/snow

WORLDWIDE AVERAGE PRECIPITATION



Rain & snow occur only where there is rising motion

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Figure 6.1

Which of these climate system components causes major changes in the other variables? (choose the best answer)

1. *surface temperature*
2. *net radiation at the surface*
3. *global pressure patterns*
4. *topography*

?

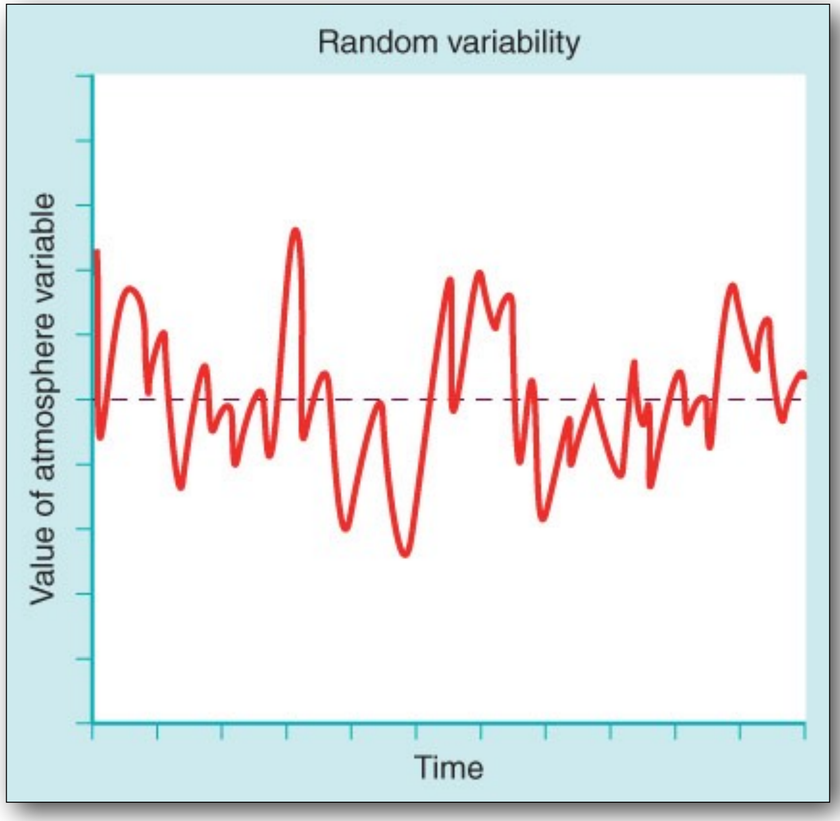
KEY POINTS

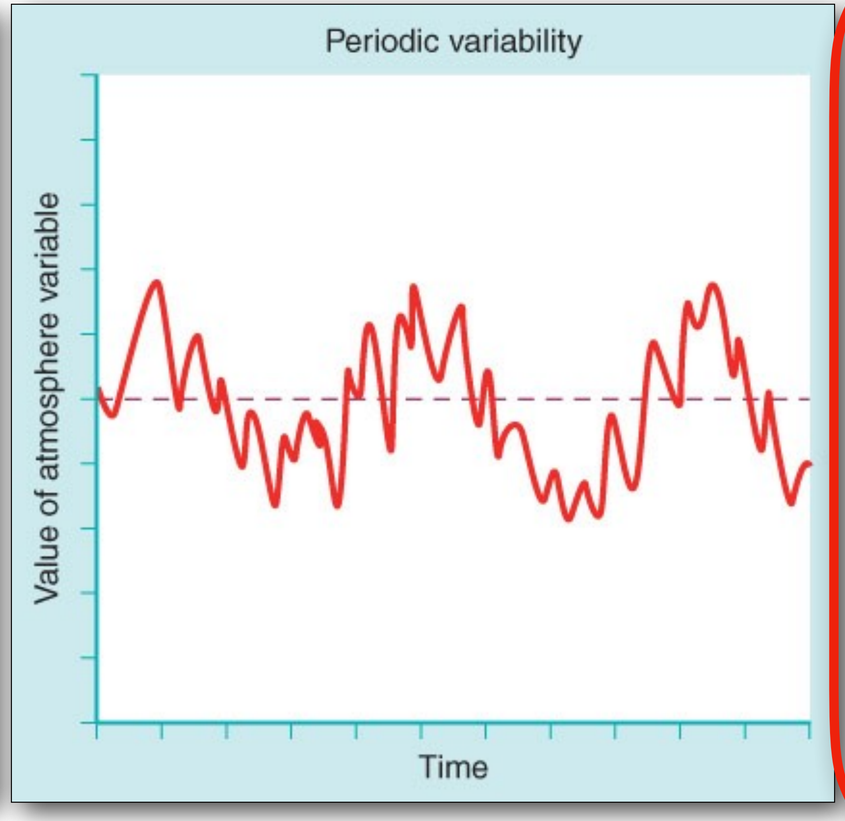
The **global climate system is complex and interconnected**. What happens in one part of the world eventually affects other areas.

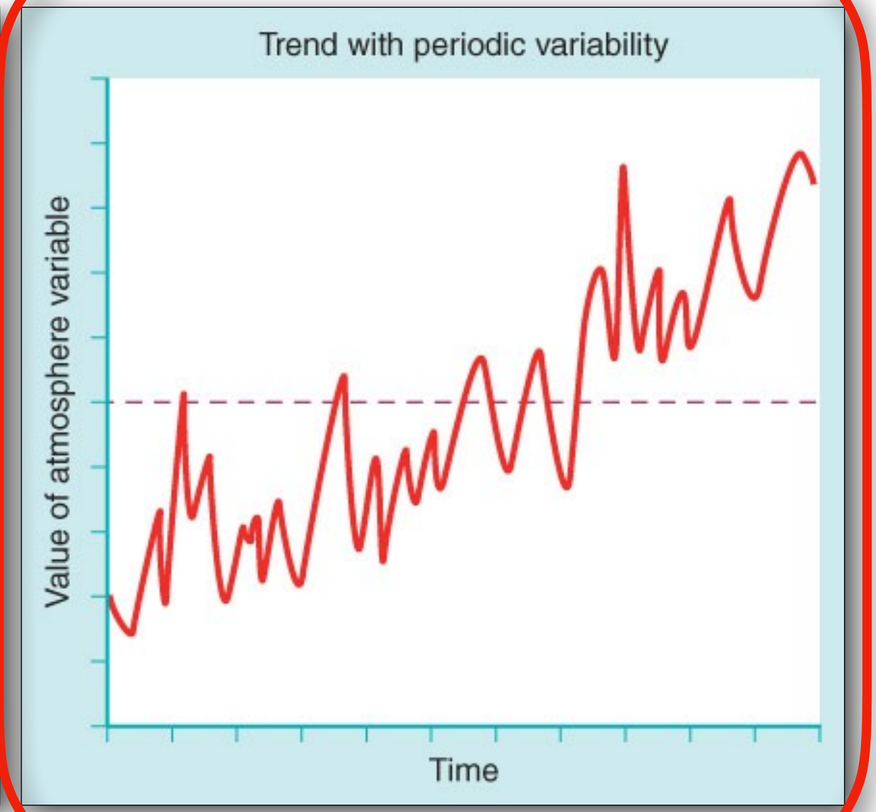
Although we must focus on our region for decision making, **it's a good practice to remember the bigger** picture from time to time, as changes elsewhere may ultimately have a great impact here.

The South Central CASC and your state climate office can help you access and interpret climate information

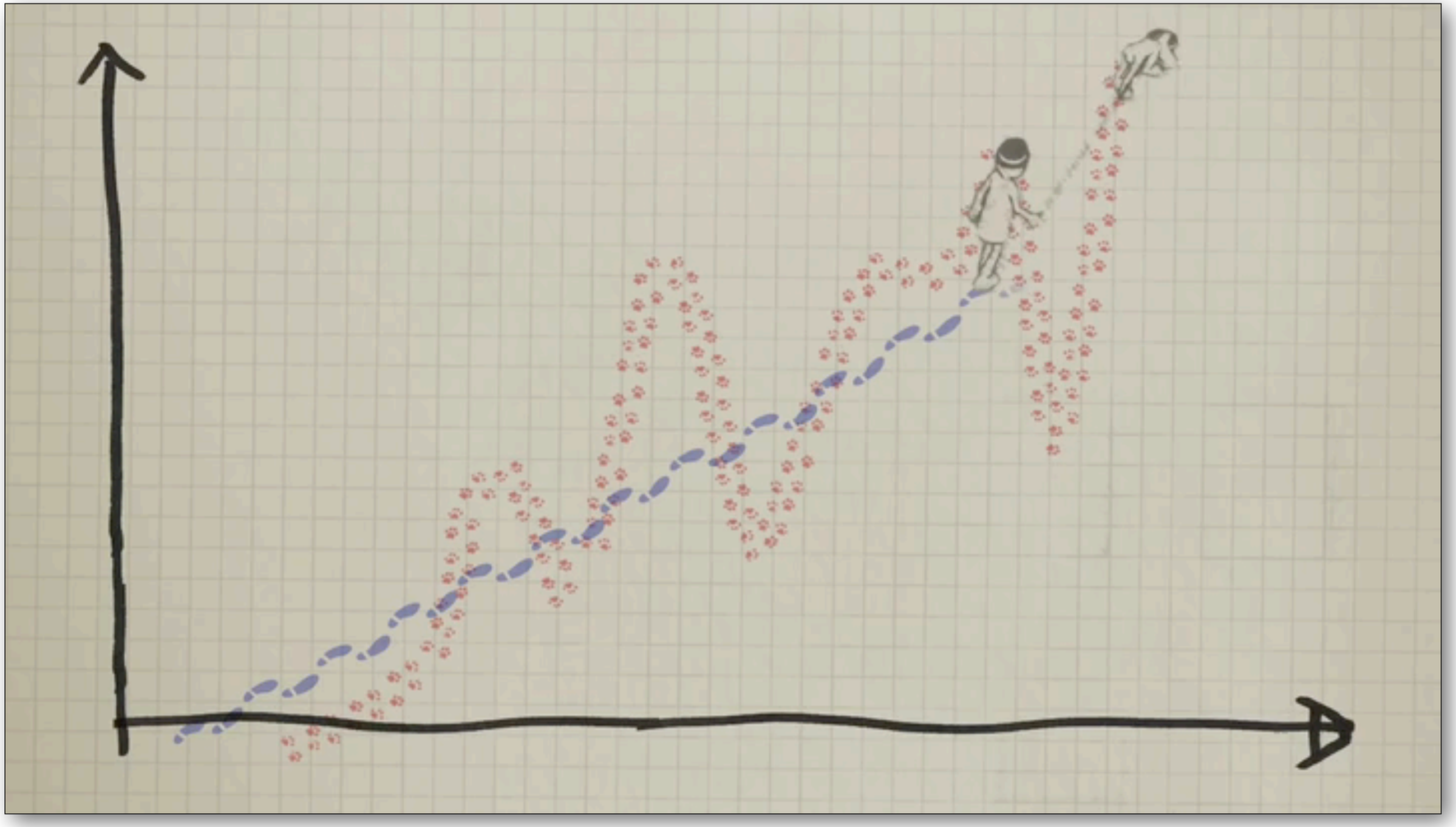
CLIMATE VARIABILITY VS. CHANGE





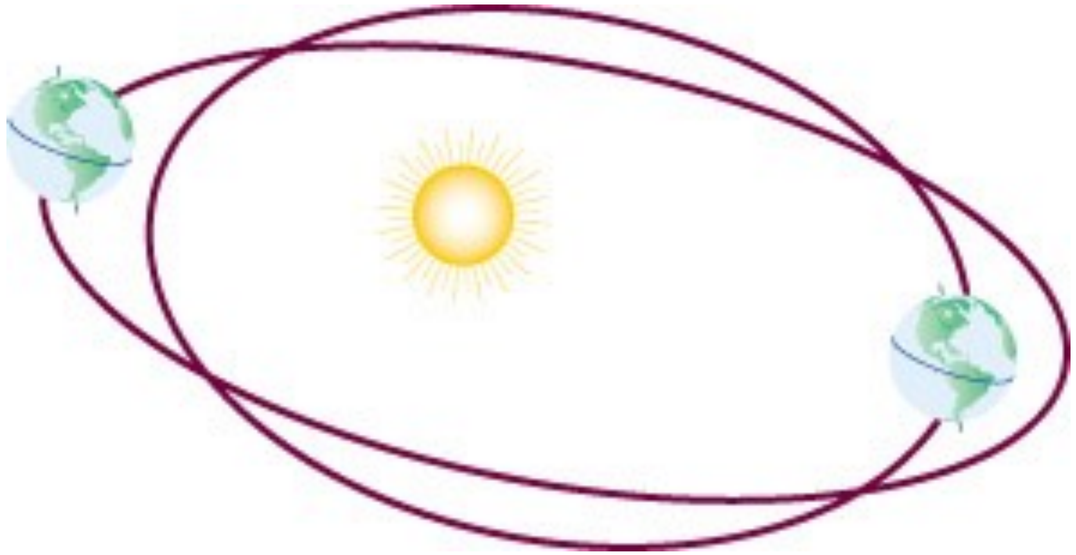


WEATHER VS. CLIMATE

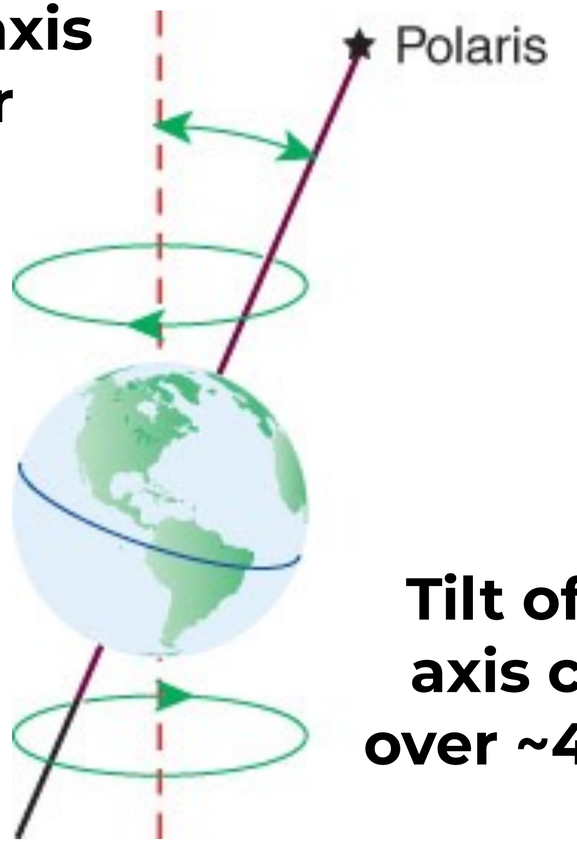


REALLY LONG-TERM CLIMATE CHANGE

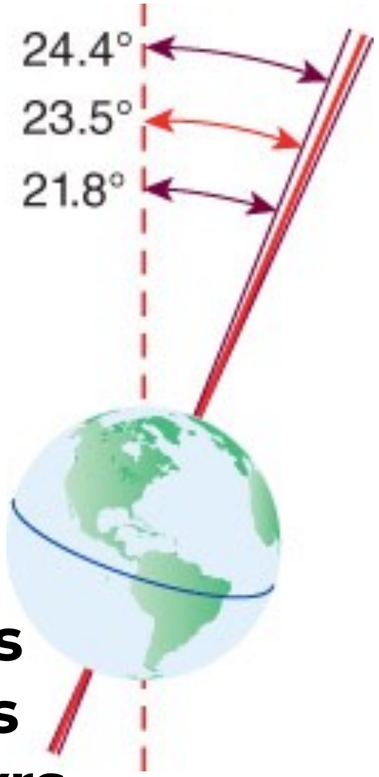
Shape of Earth's orbit changes over ~100,000 yrs



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

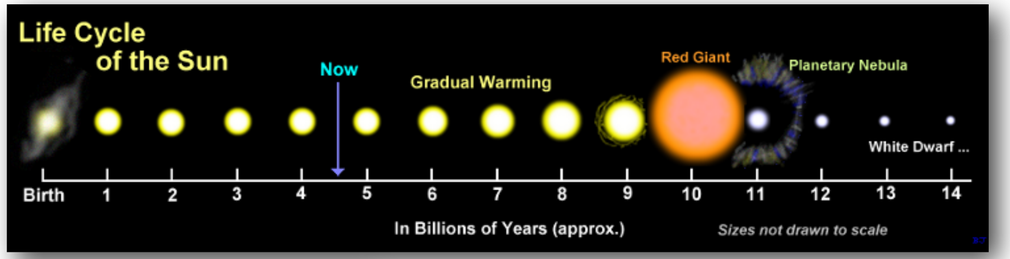


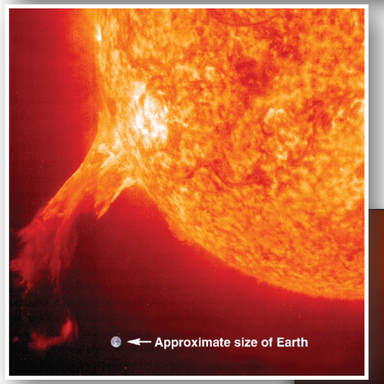
Tilt of Earth's axis changes over ~41,000 yrs



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**



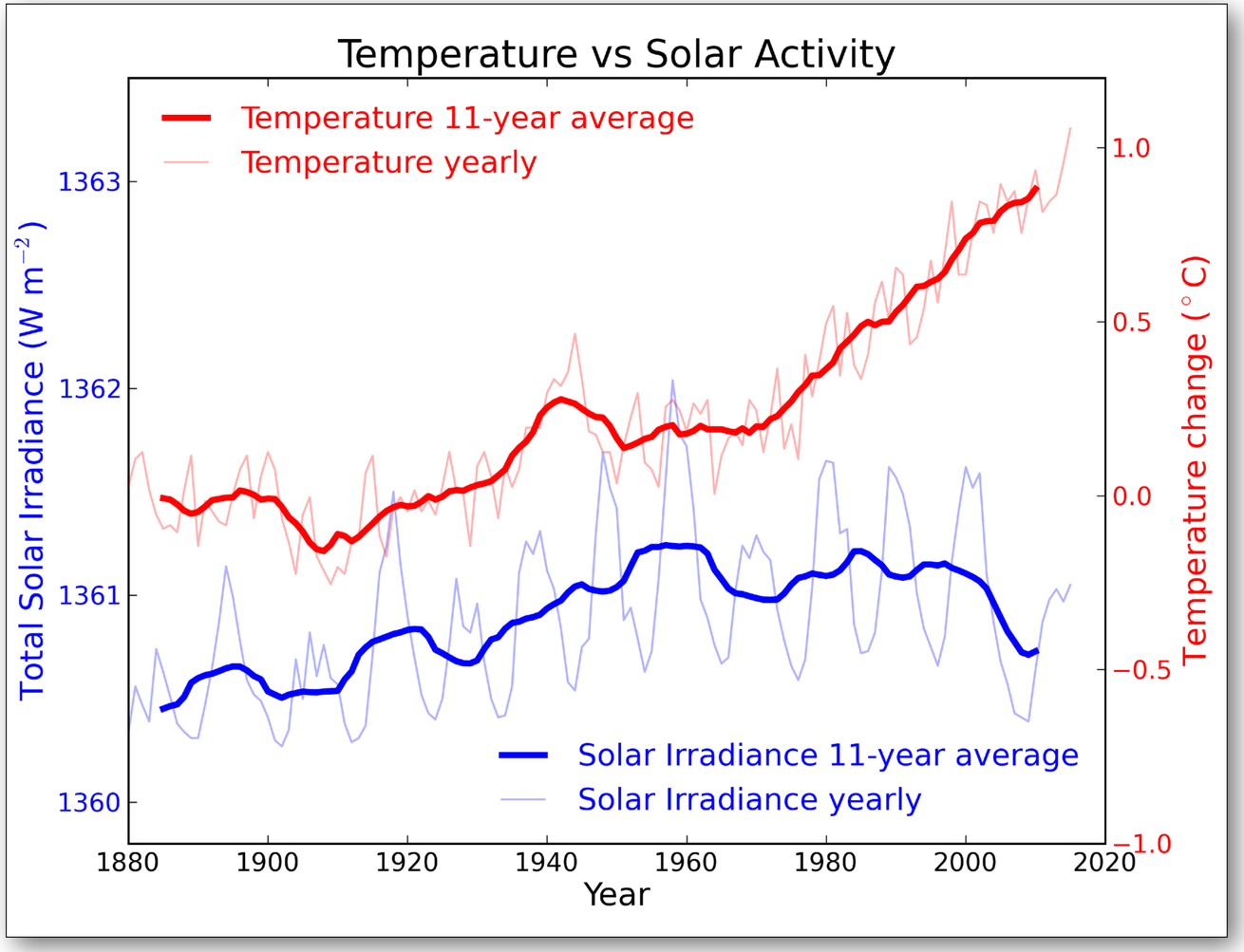


Internal factors: (1) **plate tectonics** (location of land, weathering), (2) **ocean** temperatures & currents, & (3) natural changes in **atmospheric composition**

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)



KEY POINTS

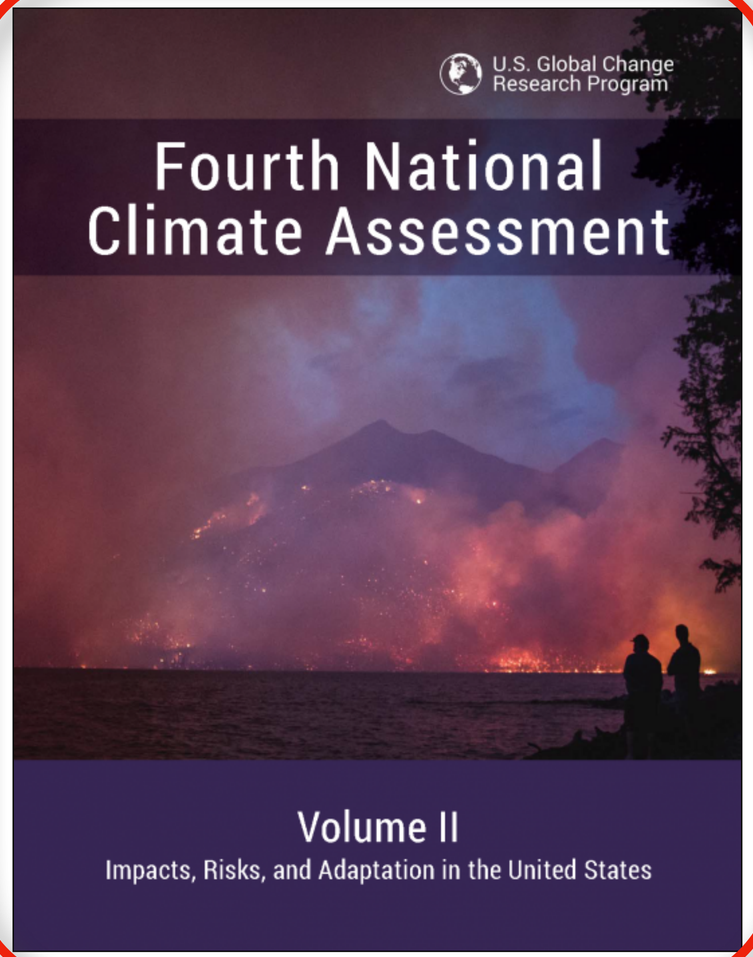
No single weather event (e.g., early autumn blizzard, December heat wave, landfalling hurricane) **is a sign of climate change**, but a **higher frequency** of certain events or **trend** toward **higher intensity events may be**.

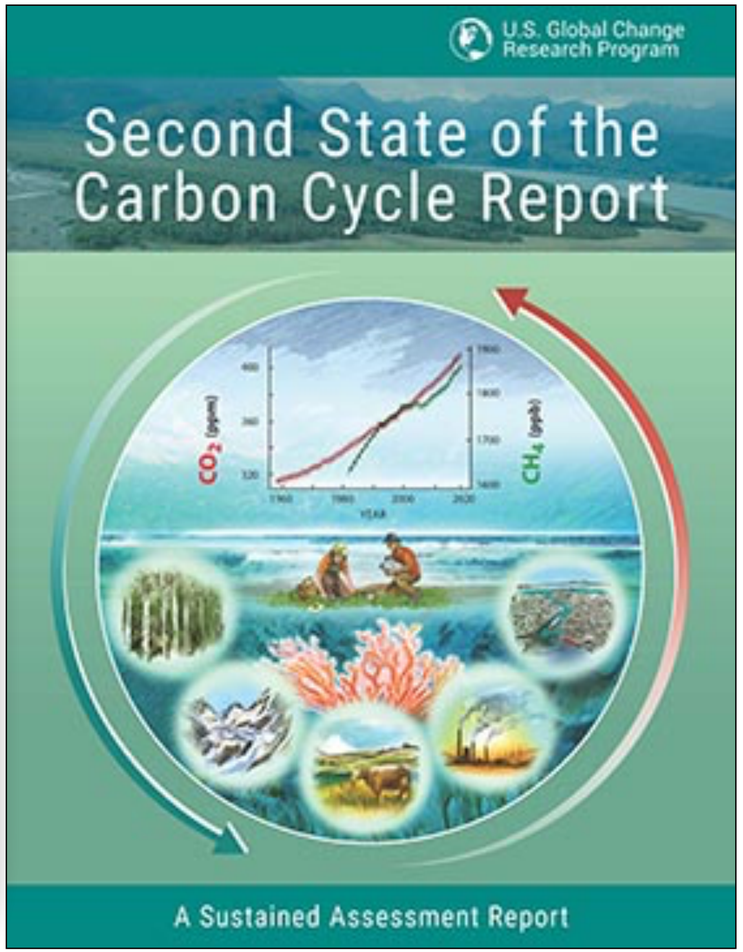
There are natural drivers to climate change, but they typically **occur over 1000s to 100,000s of years**. Faster changes, like those that occur with volcanic eruptions, usually last only a few years and are part of climate variability, not climate change.

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)





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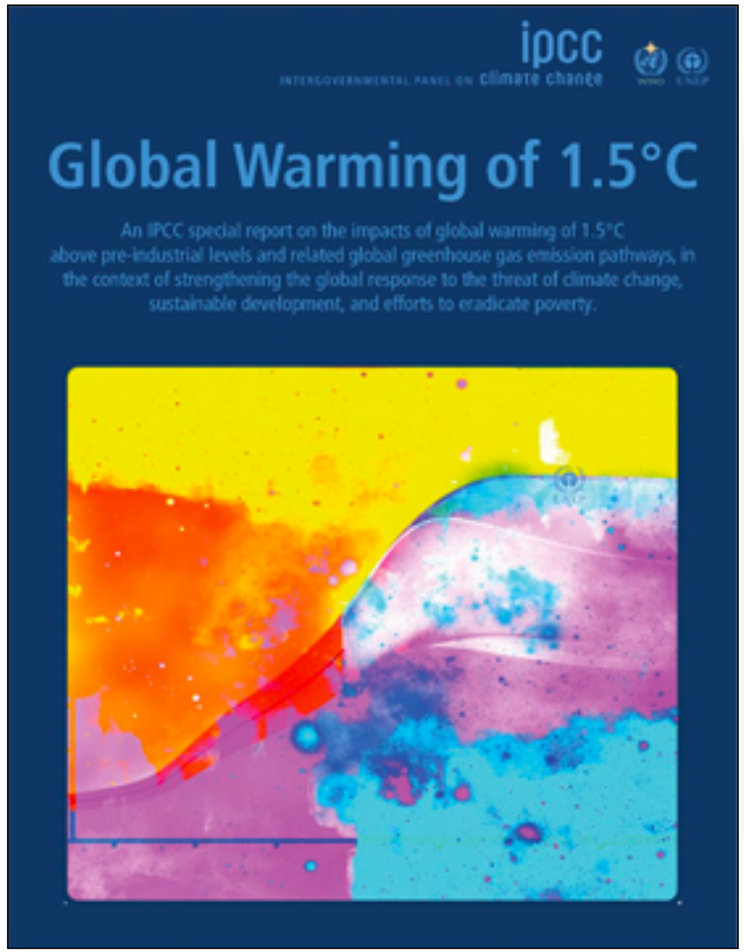
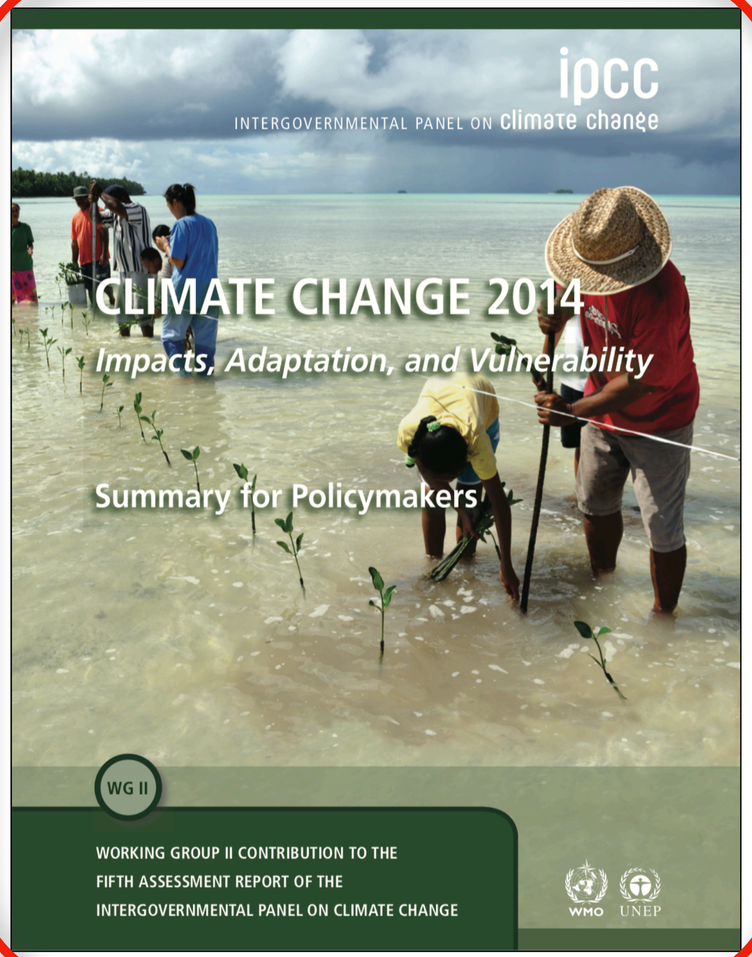
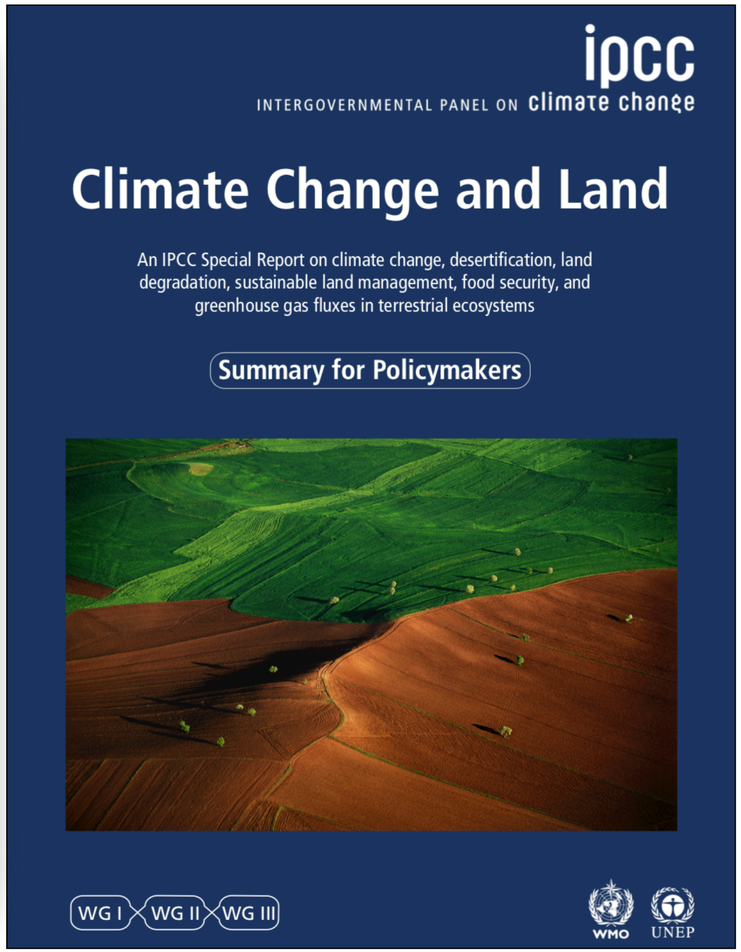
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)







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

When these reports talk about climate change, they are primarily referring to:

1. *changes in the climate system since the industrial revolution began, with changes accelerating in the past few decades*
2. *warming of the planet since the last glacial maximum, when much of the northern half of North America was covered by ice*
3. *increases in the incoming radiation from the sun that cause warming on a global scale in the last century*

?

IPCC REASONS FOR CONCERN

Aggregate impacts & damages

Risks of large-scale discontinuities & disruptions

Uneven distribution of climate change impacts

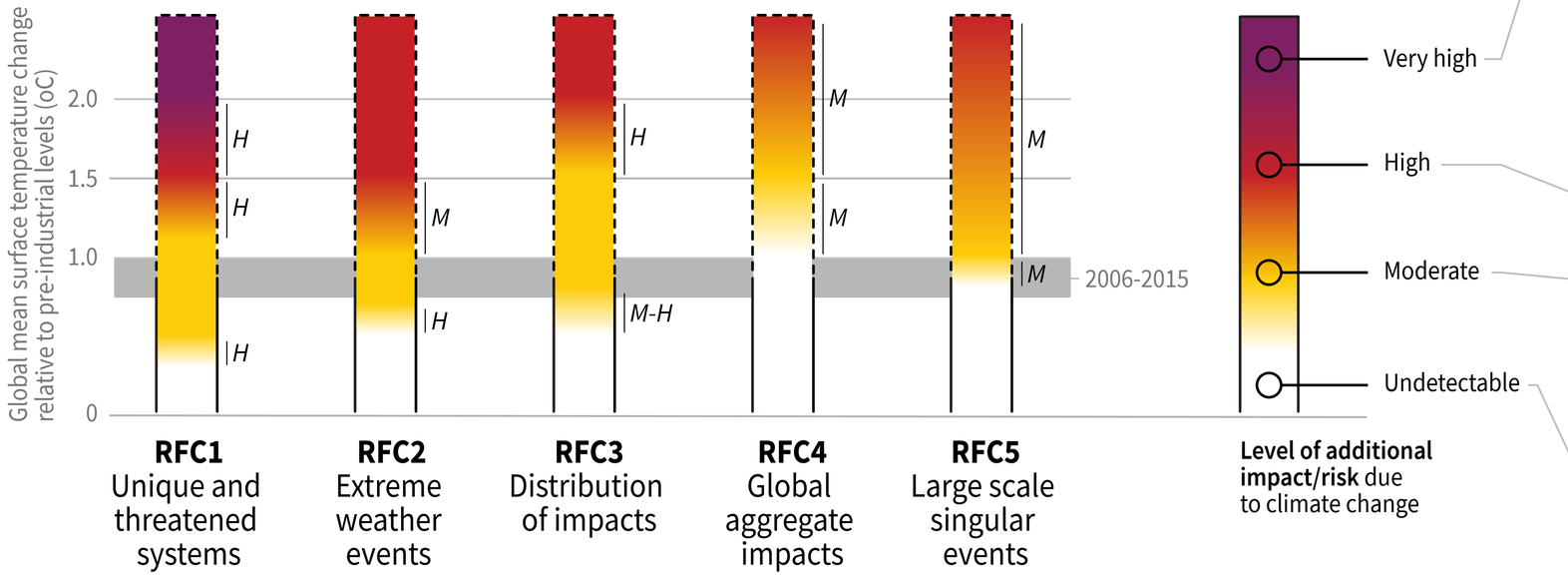
Risks of extreme weather events

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

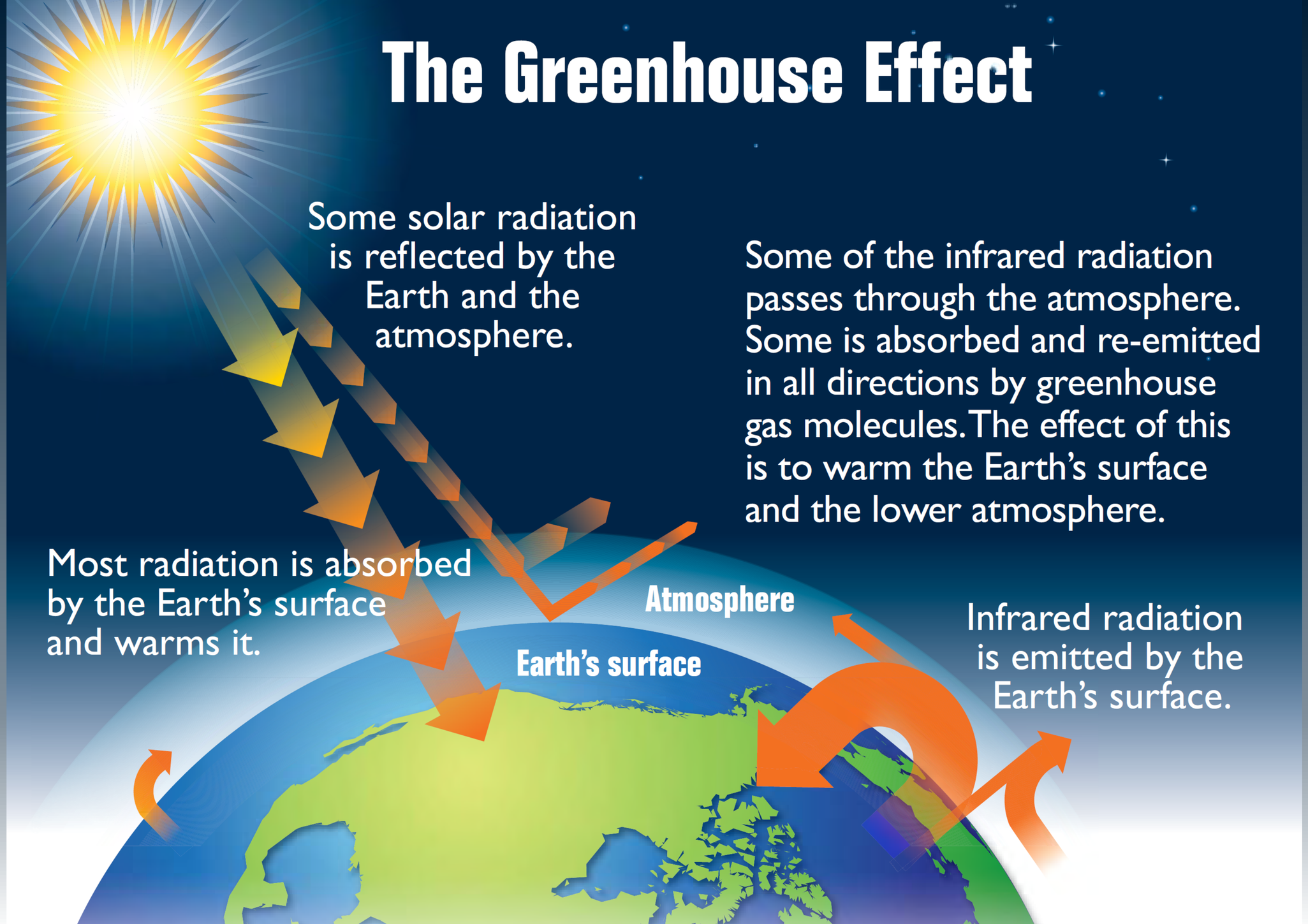
The **Intergovernmental Panel on Climate Change** (IPCC) reports and the **National Climate Assessment** (NCA) are the **two best sources** for expert assessments of climate change worldwide and across the United States.

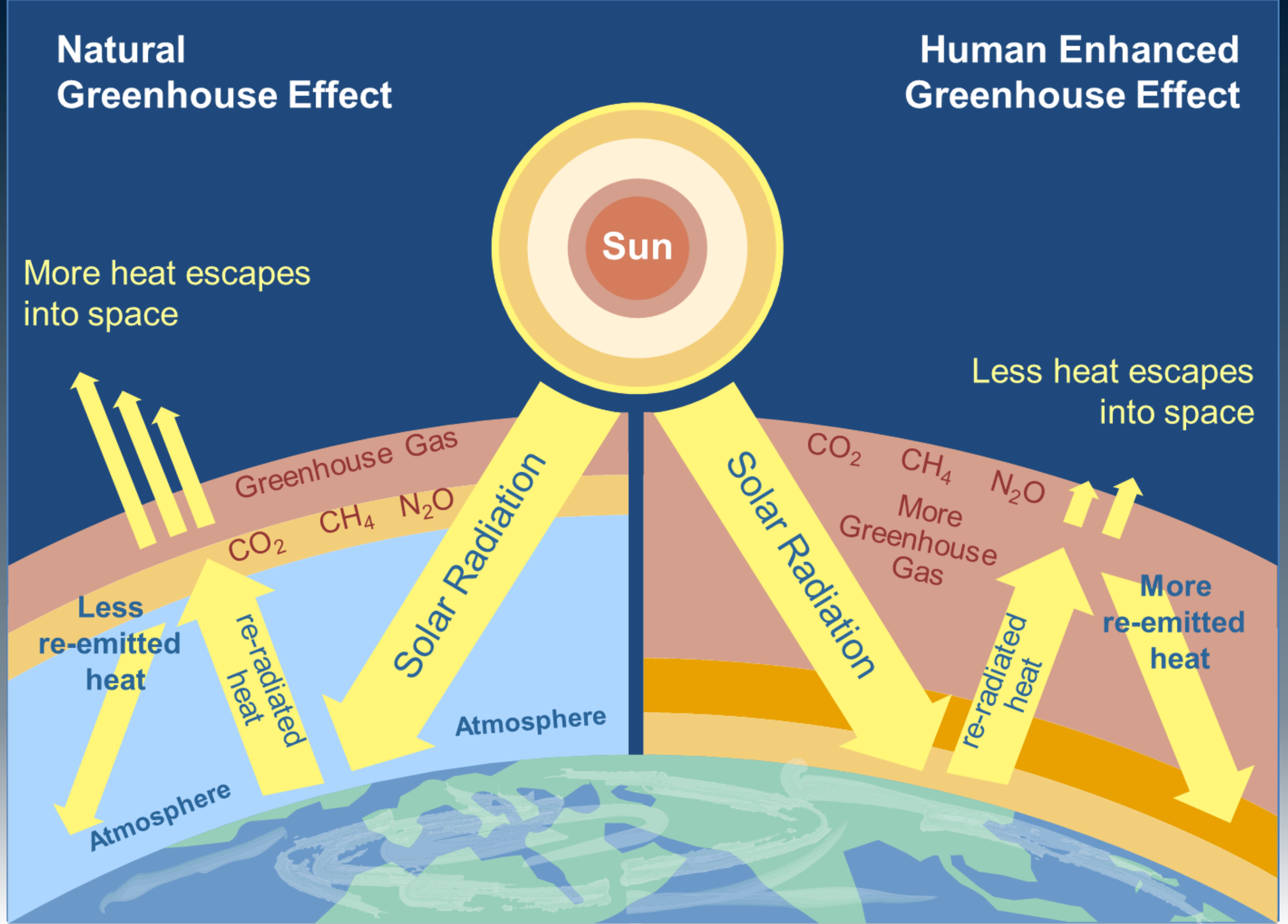
Available at:

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

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

The Greenhouse Effect




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

We've Known This Fact for More Than 150 Years

"… **an atmosphere of that gas would give to our earth a high temperature …**"
— Eunice Newton Foote, 1856

ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays;* by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

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

"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

Which of the following statements is true?

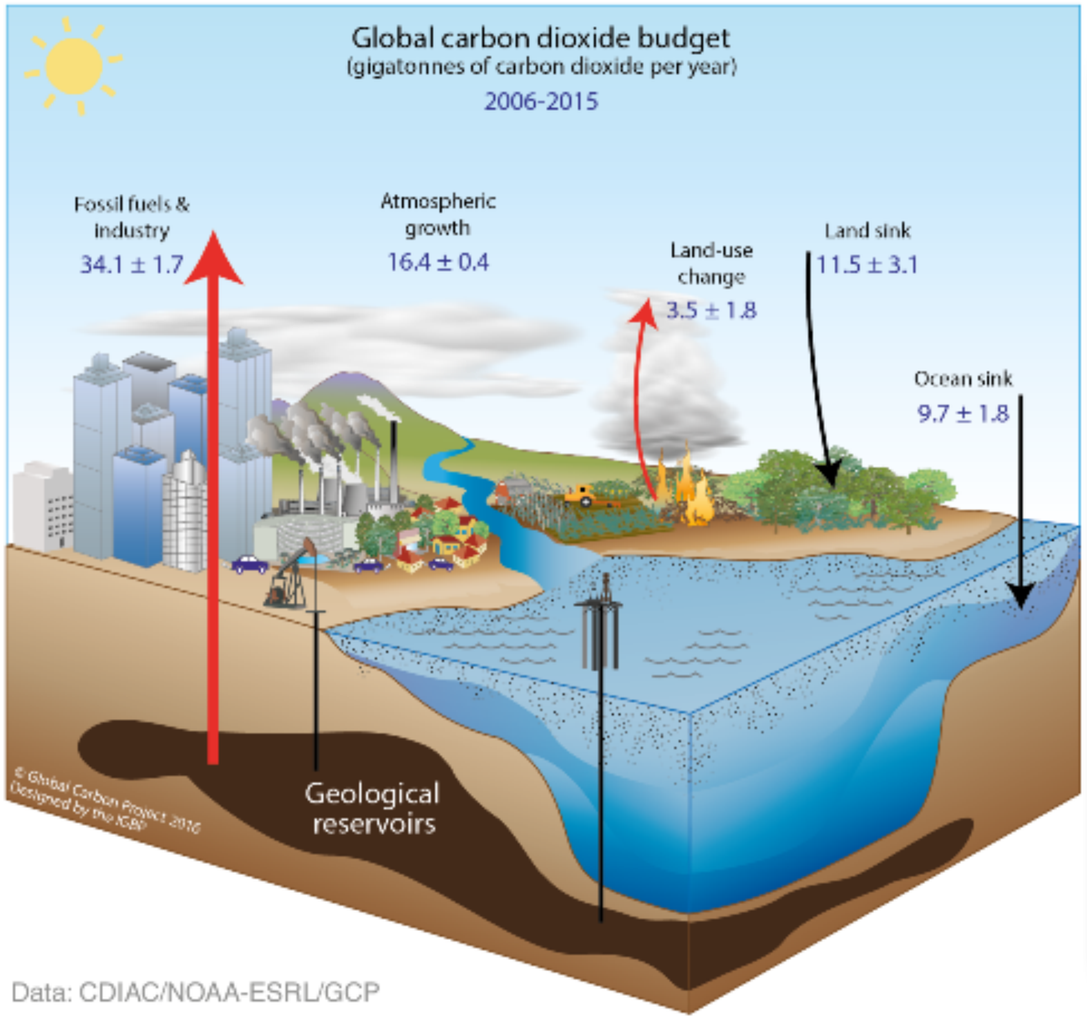
1. *globally averaged surface temperature can increase at the same time as the amount of incoming solar radiation is decreasing*
2. *IPCC assessment reports have more regional details for the south-central US than the National Climate Assessment*
3. *a male scientist is recognized as the first to state that more atmospheric greenhouse gases would lead to higher temperatures*

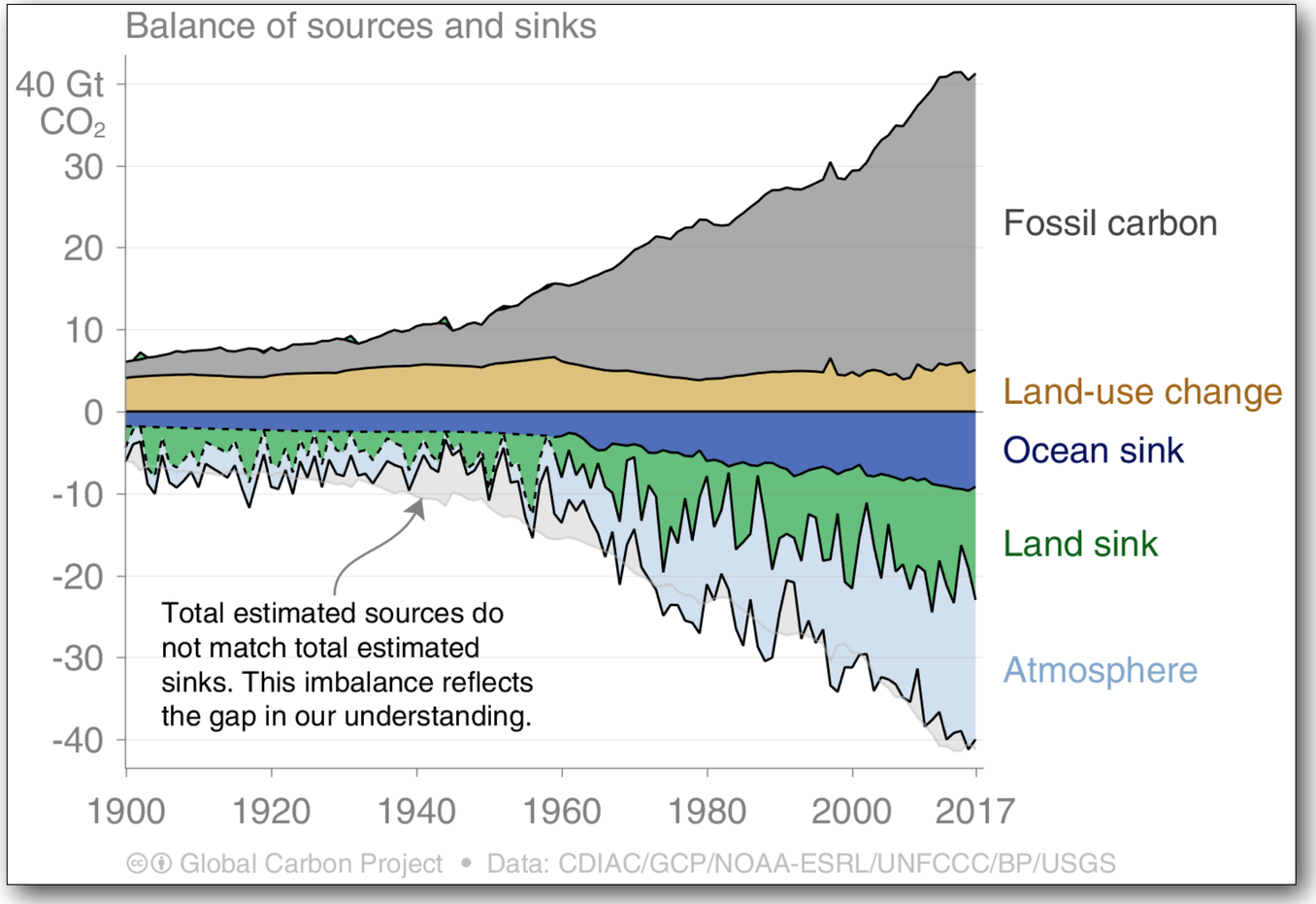
?

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.

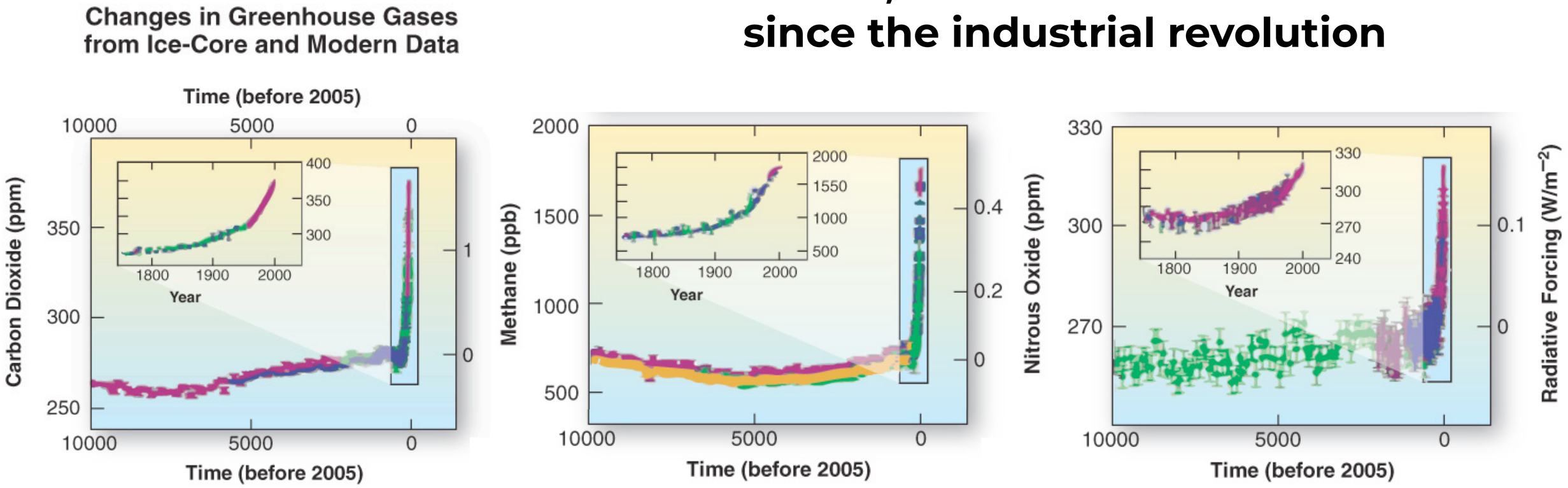
GLOBAL CARBON DIOXIDE BUDGET





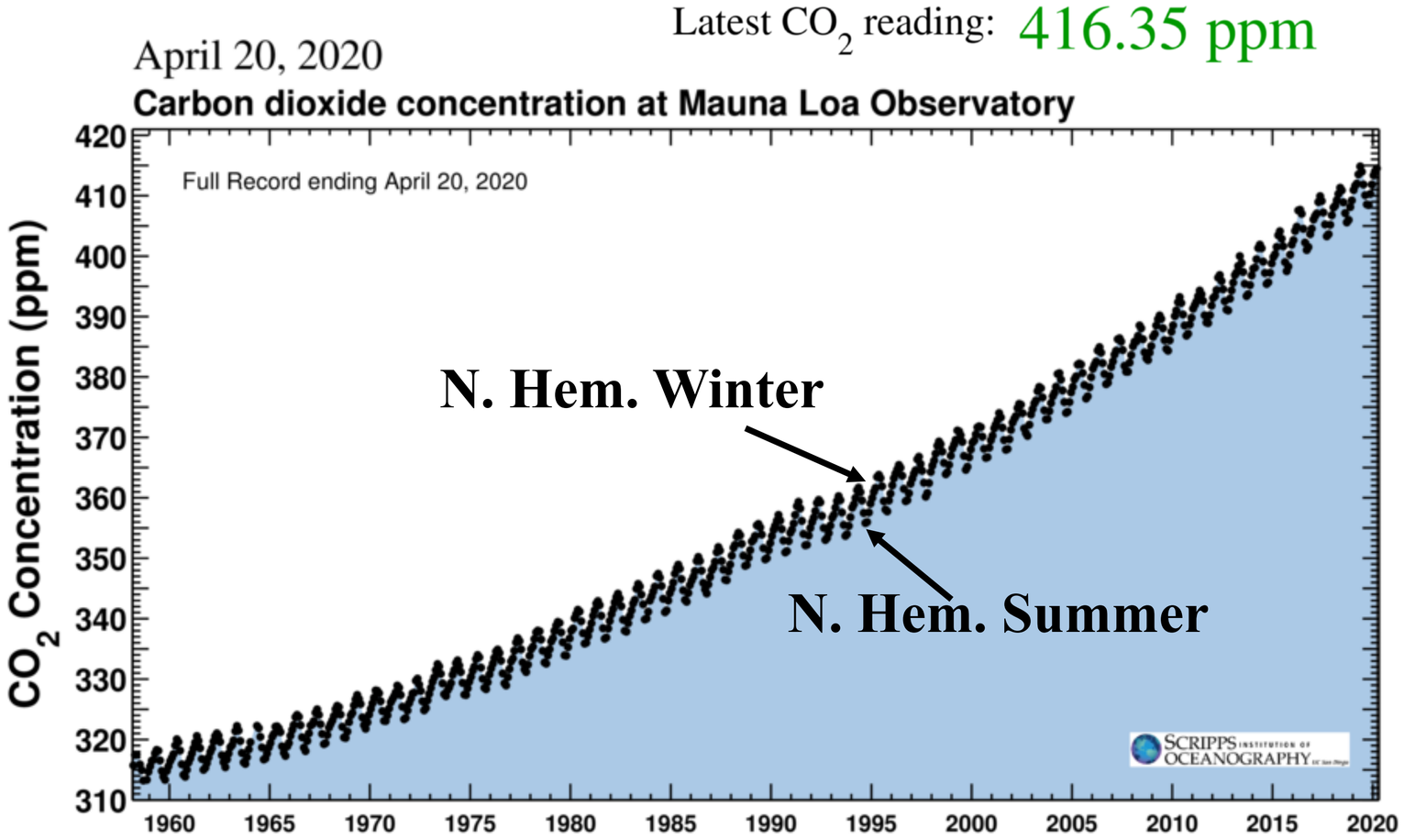
GREENHOUSE GASES INCREASING

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



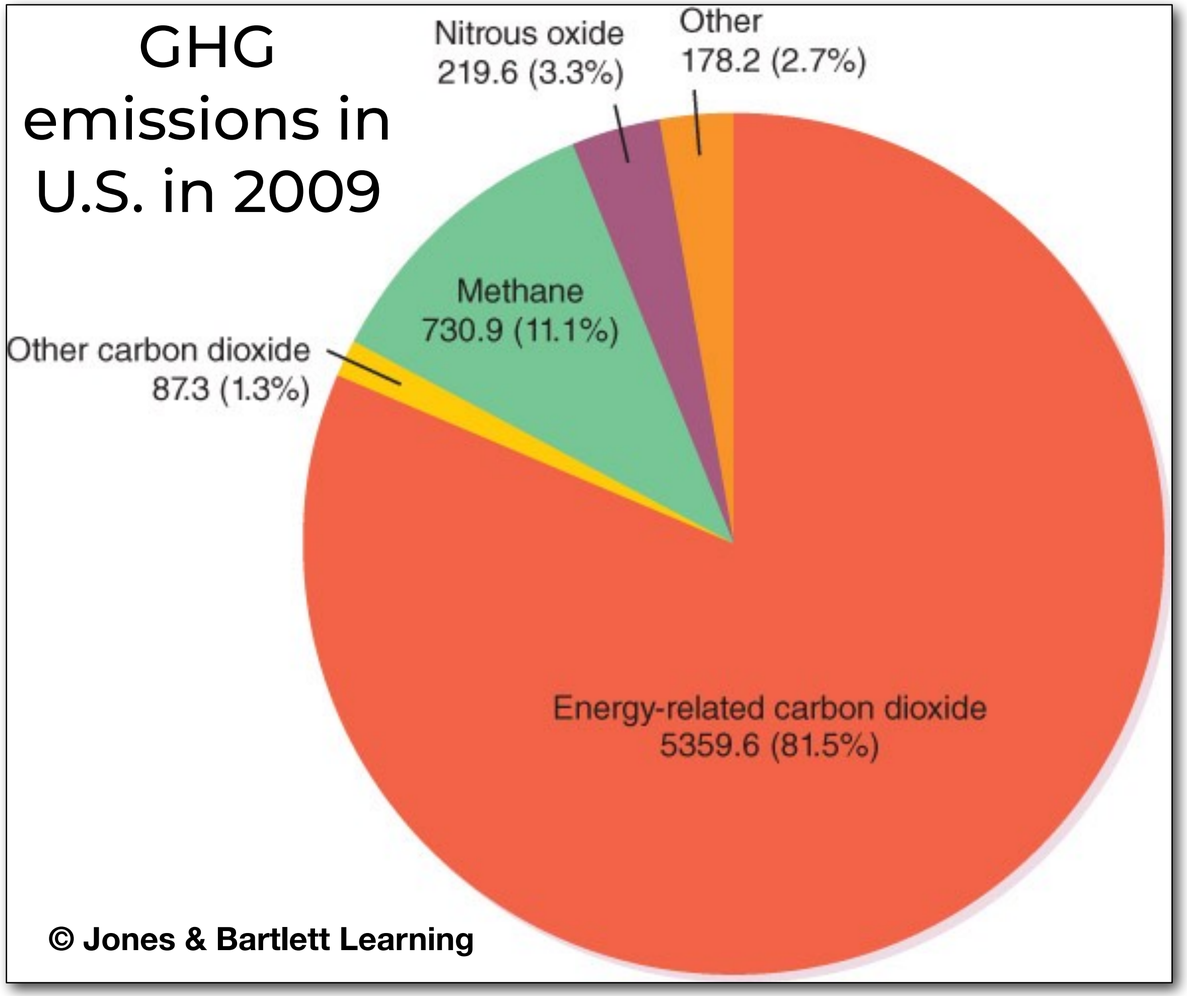
OBSERVATIONS OF CARBON DIOXIDE (CO_2)

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

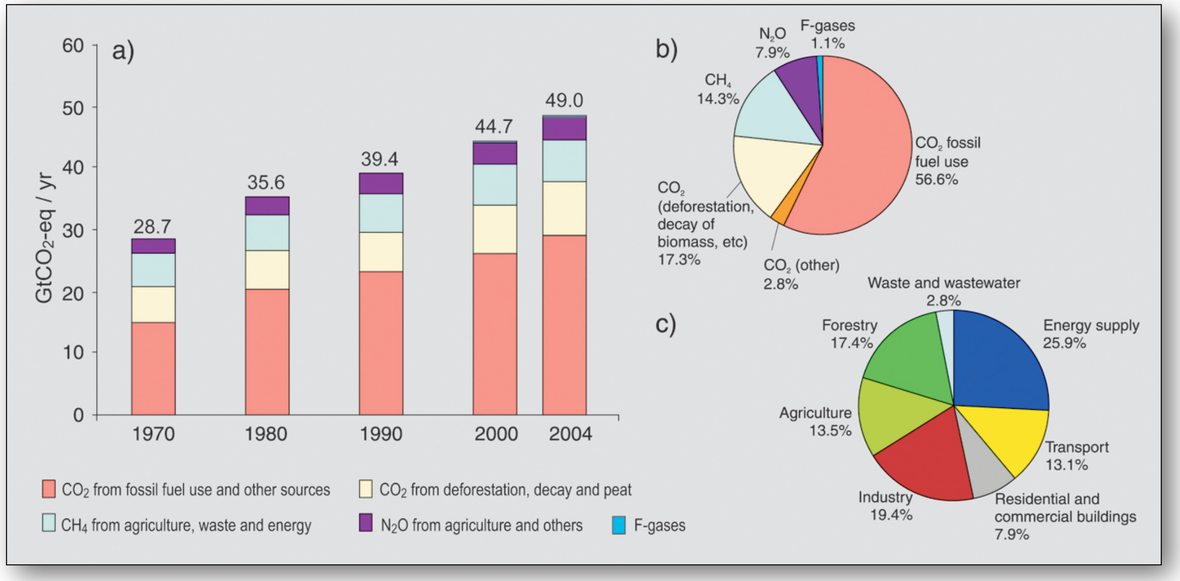


https://scripps.ucsd.edu/programs/keelingcurve/

GREENHOUSE GAS EMISSIONS BY GAS



Largest contributor is CO_2 from fossil fuel use



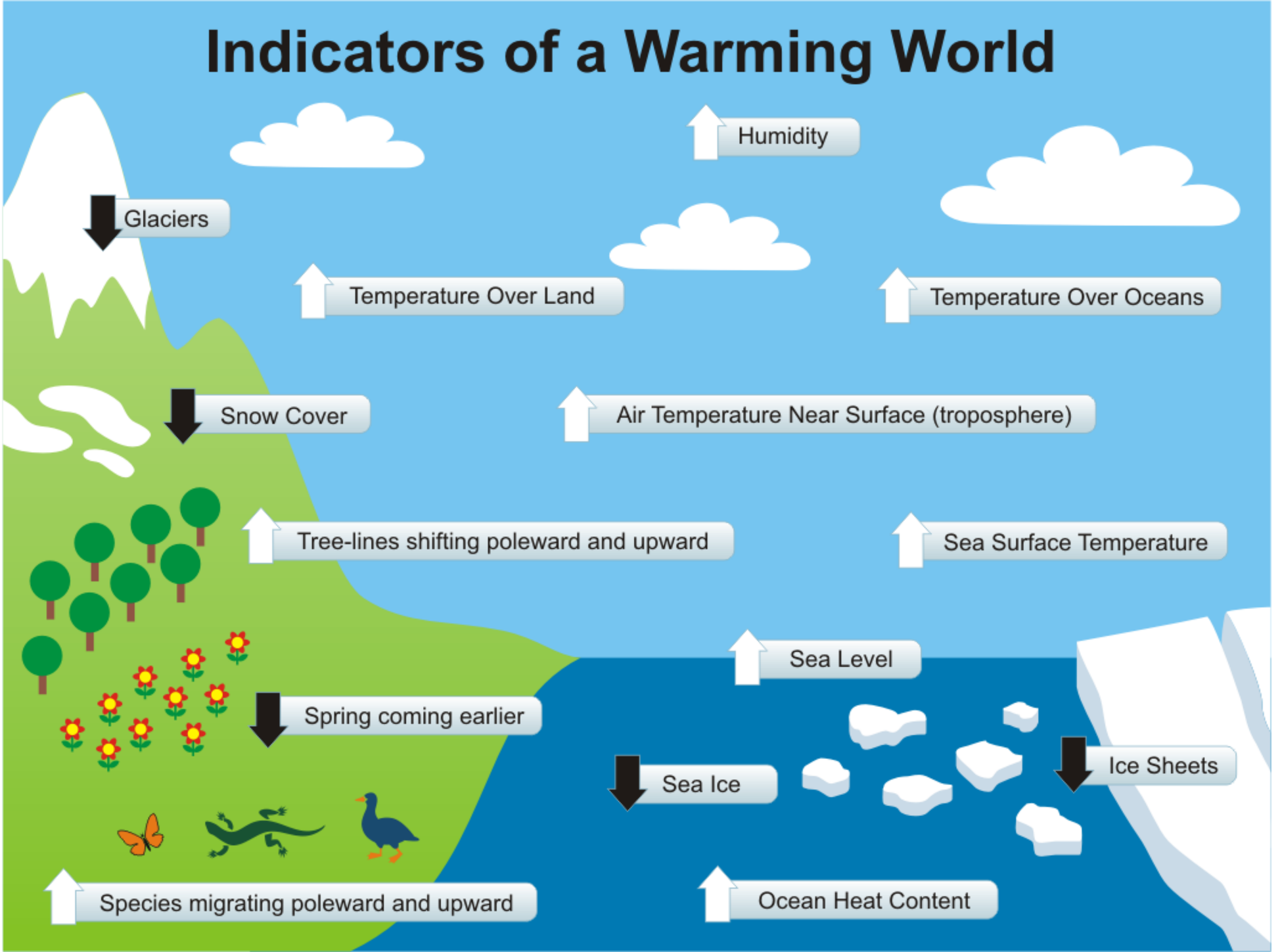
KEY POINT

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.

As greenhouse gases absorb more outgoing infrared radiation, what would expect to see occur?

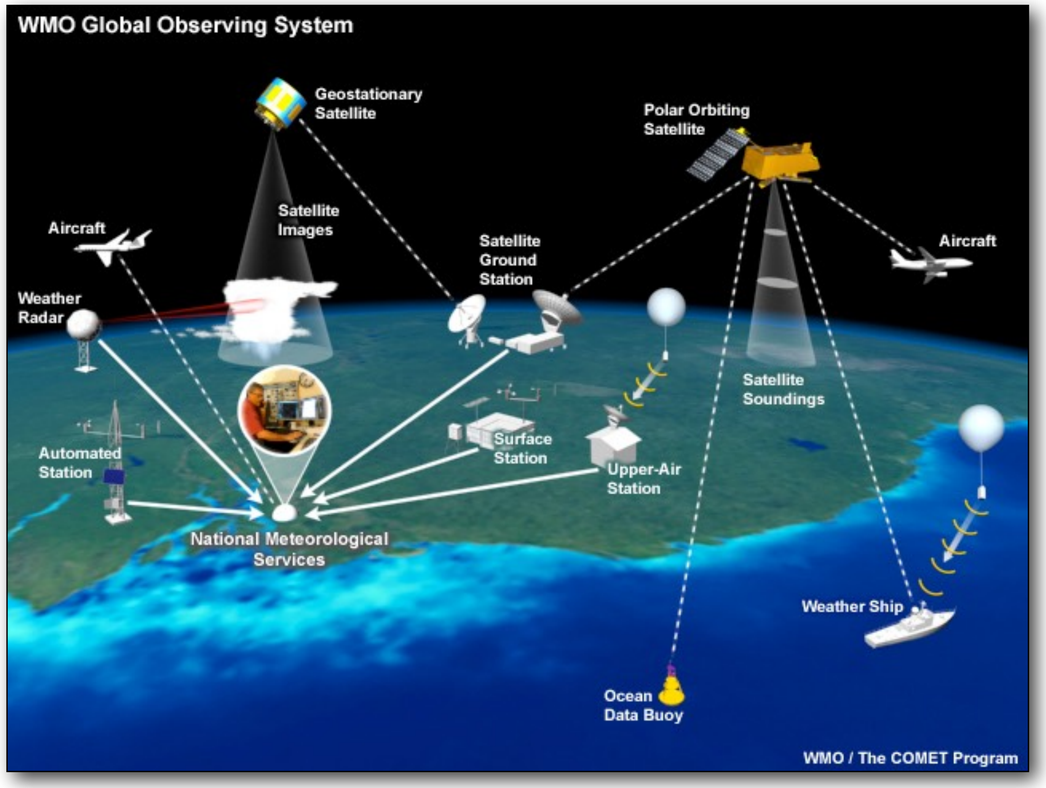
1. *temperatures of the ocean surface would warm*
2. *plants would bloom earlier, on average*
3. *more glaciers and sea ice would melt*
4. *none of the above*
5. *all of the above*

?

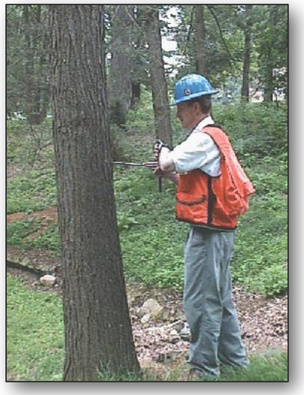


Skeptical Science

TECHNIQUES TO OBSERVE THE CLIMATE



Creative Commons



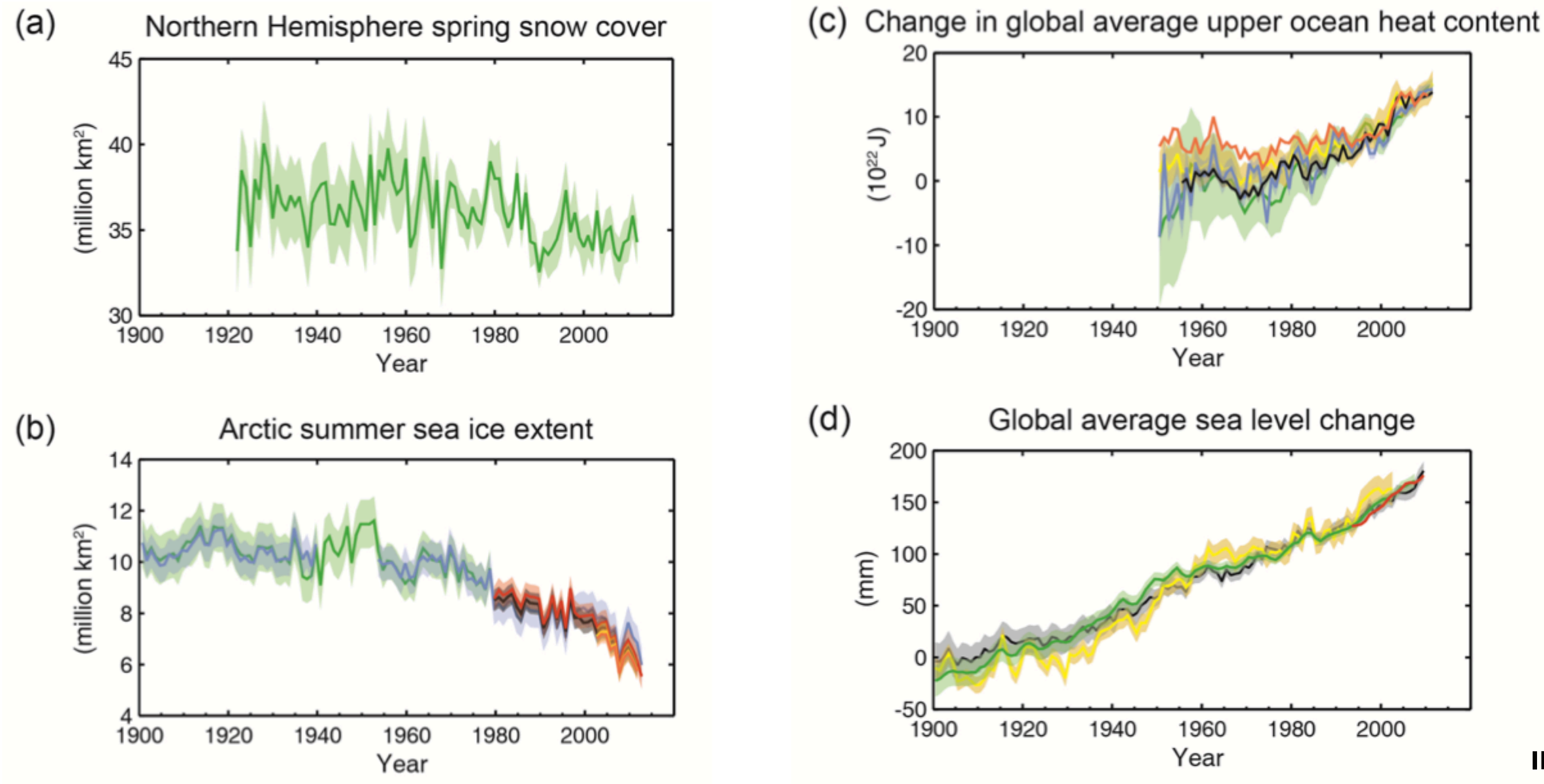
USGS

Kathy Krucker

Nat'l Park Service

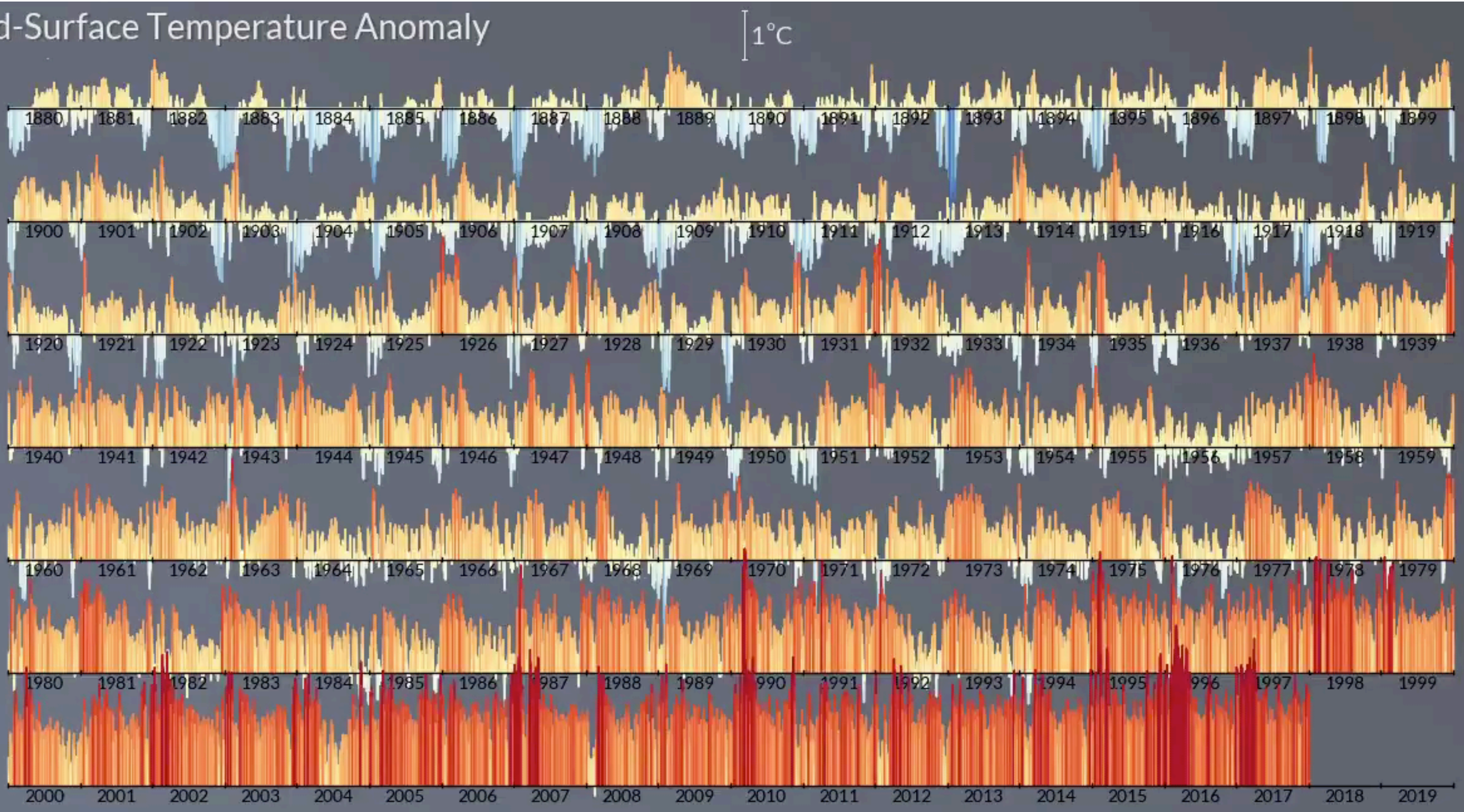
Carlye Calvin

OBSERVATIONAL EVIDENCE FOR A WARMING CLIMATE



IPCC AR5

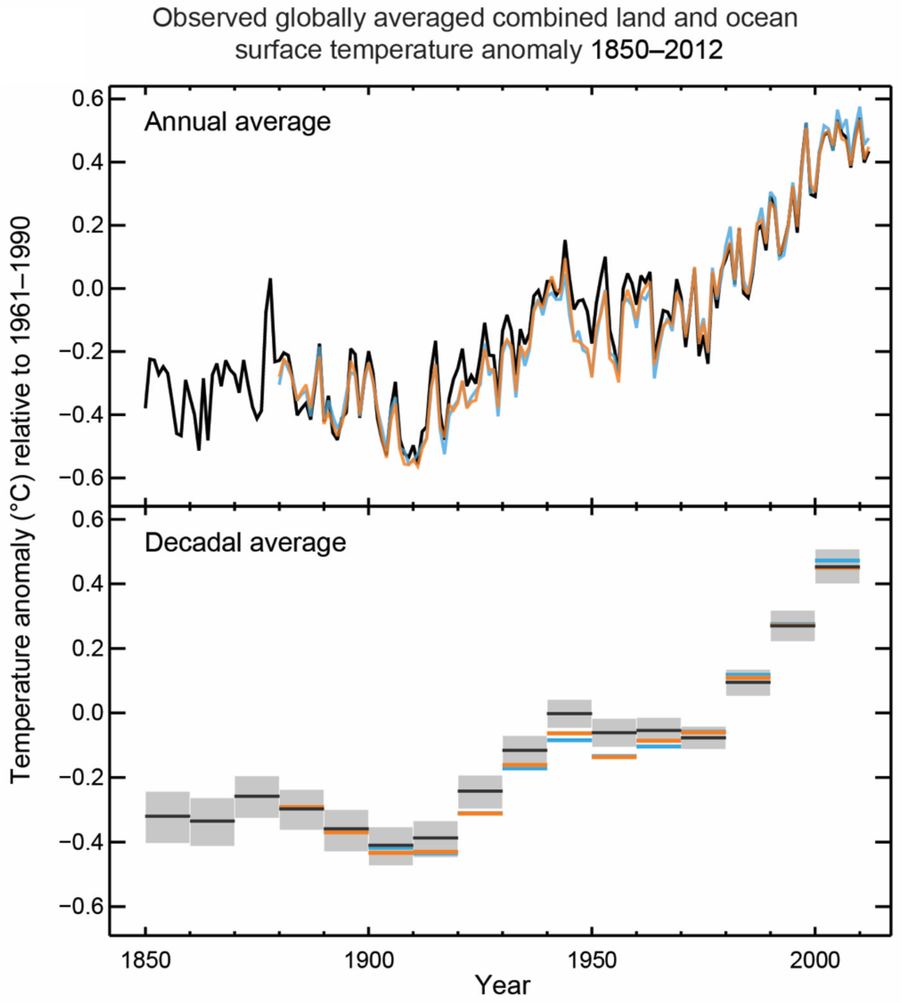
Land-Surface Temperature Anomaly



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

SURFACE AIR TEMPERATURE OBSERVATIONS

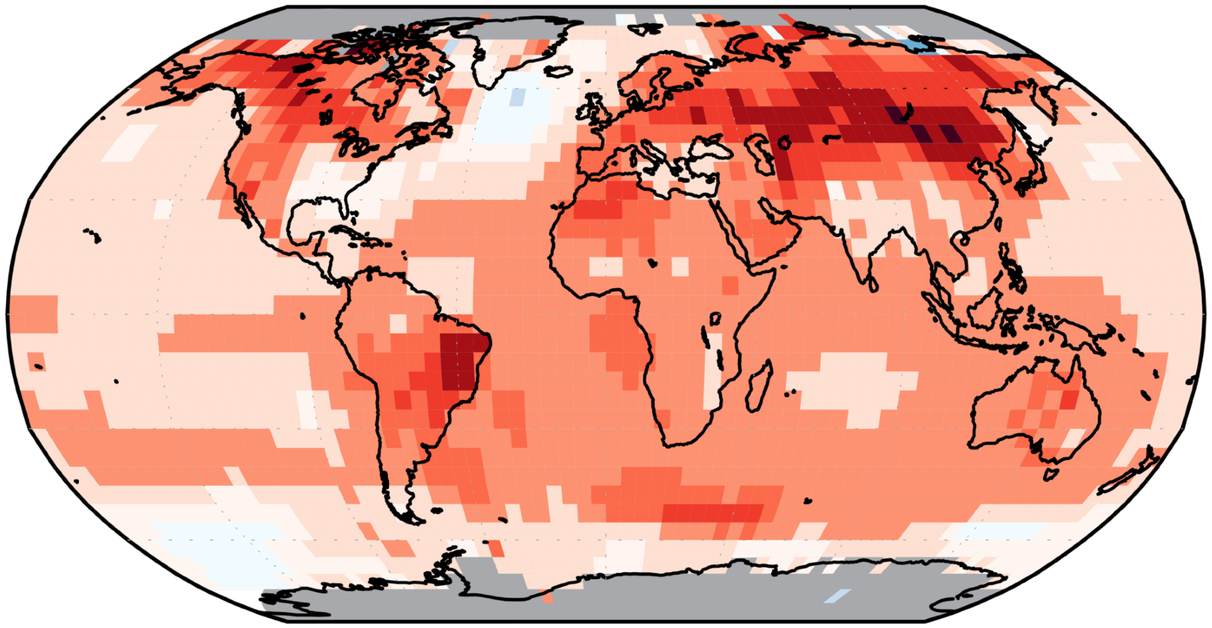
Globally, the **past three decades have been successively warmer**, on average, than the prior decades. Multi-decadal warming is superimposed on decadal and interannual variability from natural climate patterns.

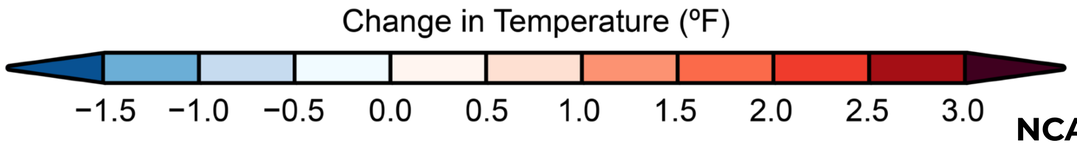


CLIMATE CHANGE IMPACTS ARE REGIONAL

For example, surface temperature changes are not uniform

Surface Temperature Change





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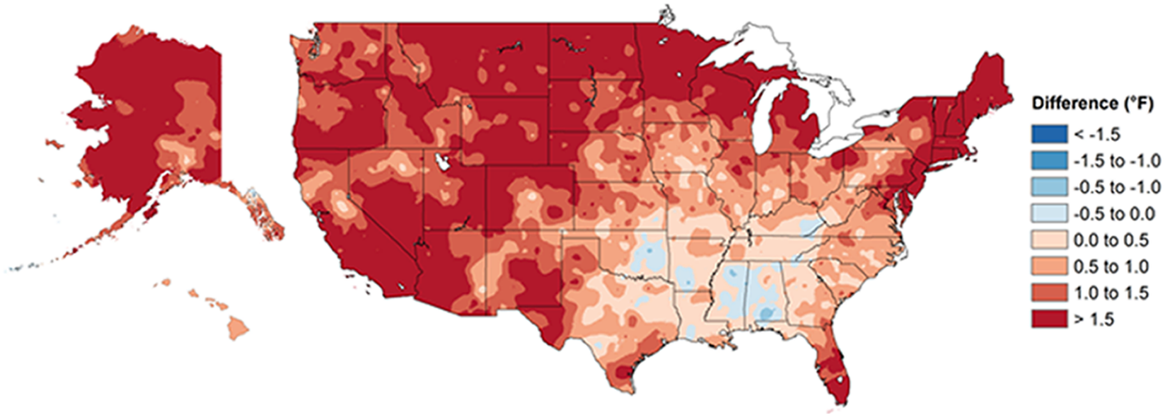
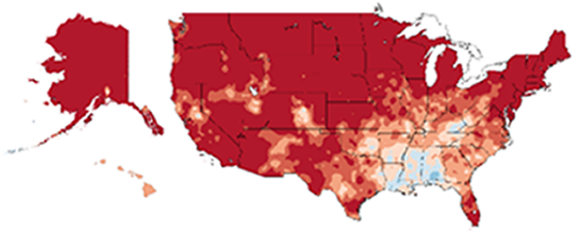
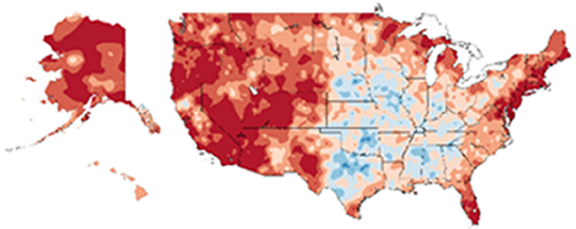
Annual Temperature



Winter Temperature

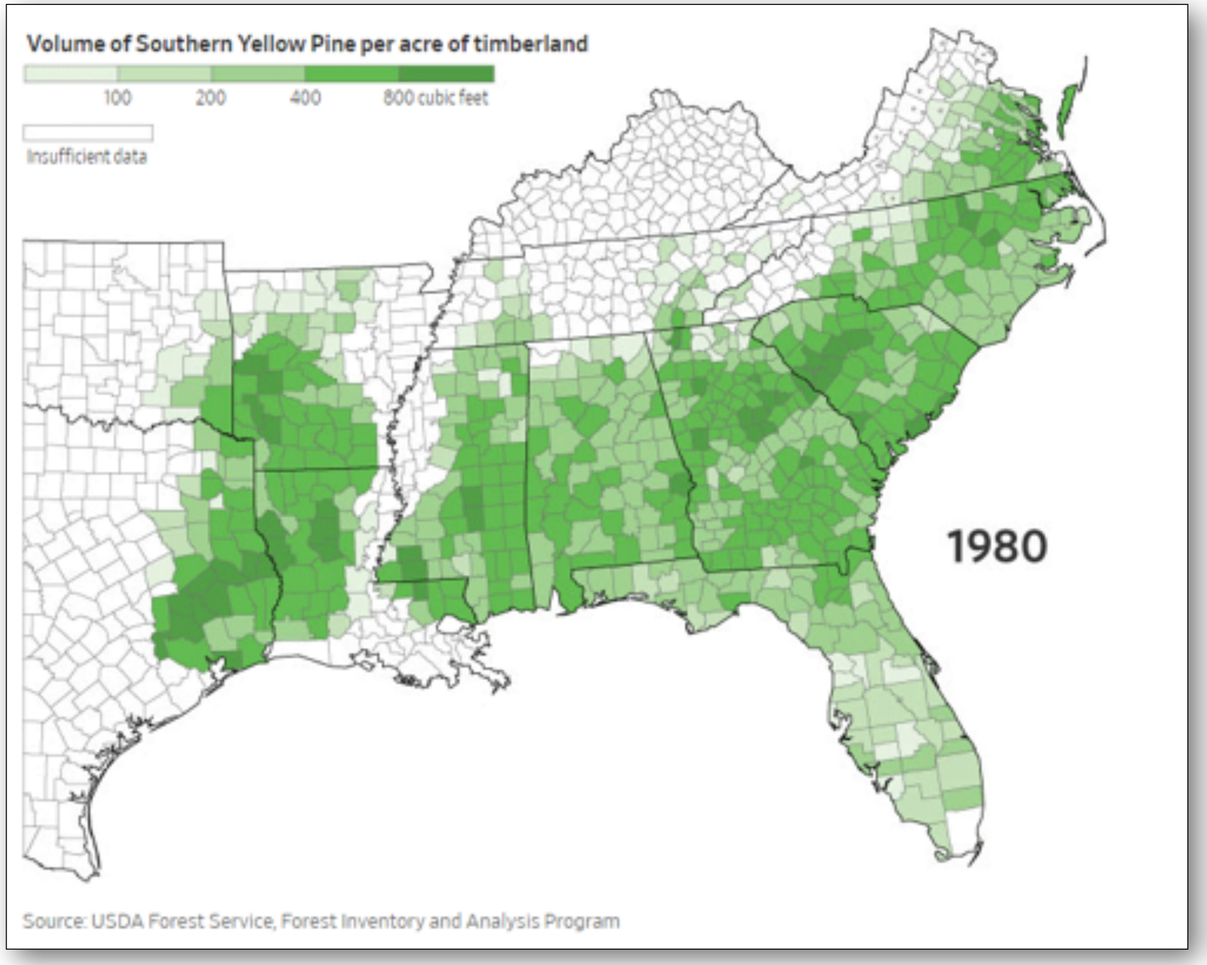


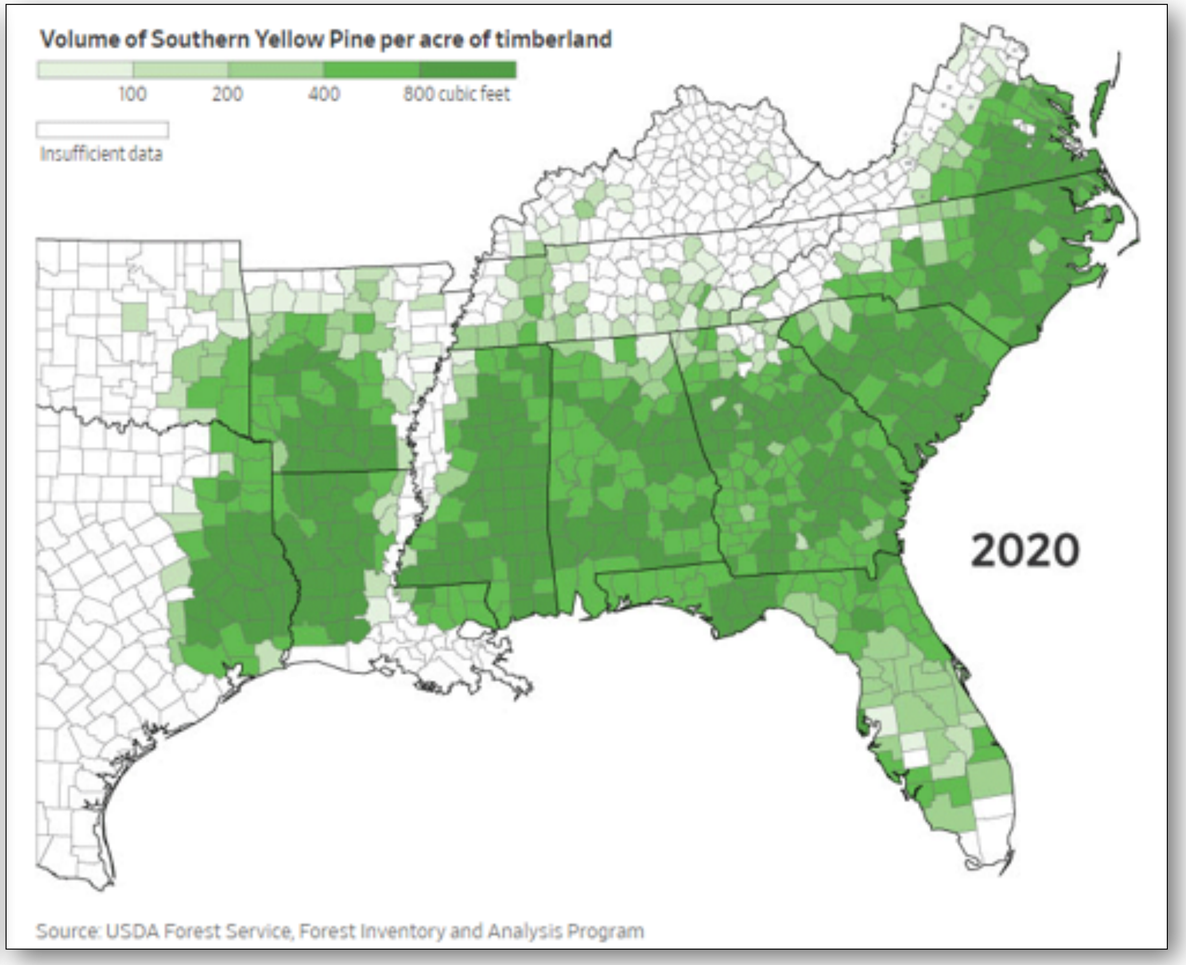
Summer Temperature



NCA4, Vol 1

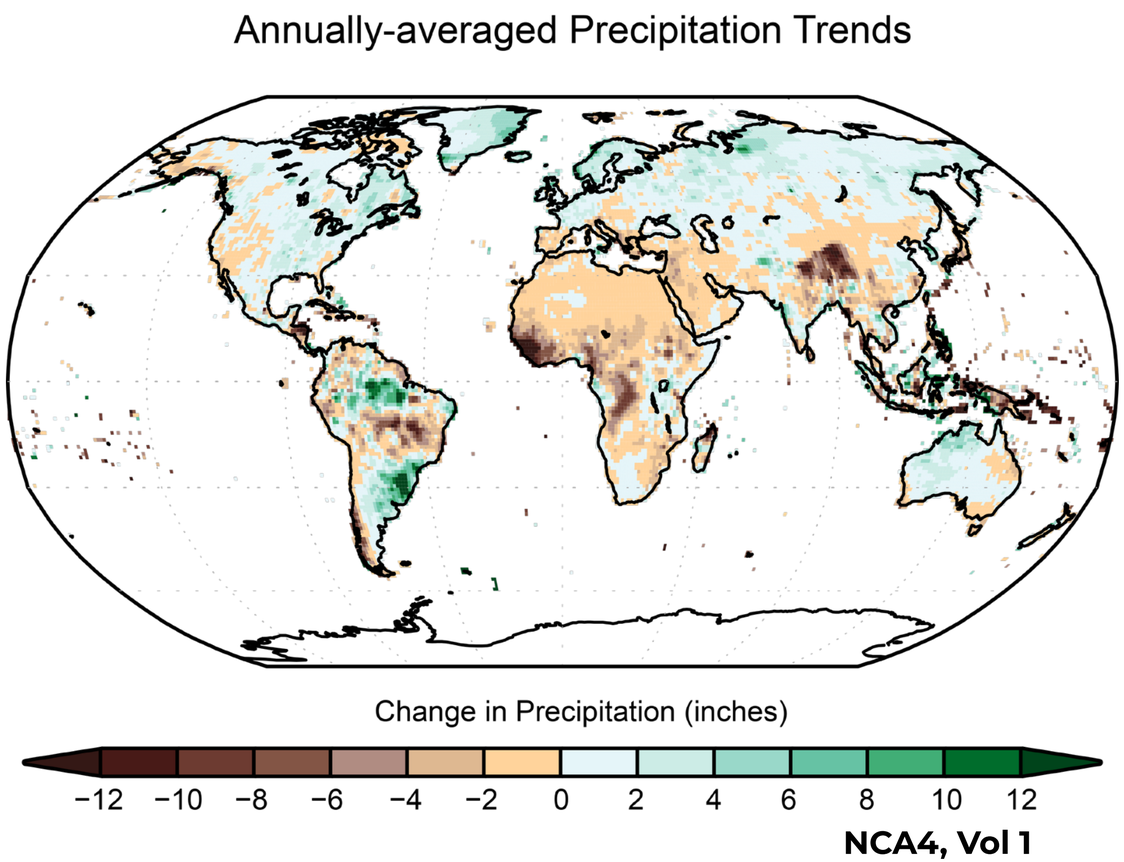
REGIONAL CHANGES HAVE CAUSES

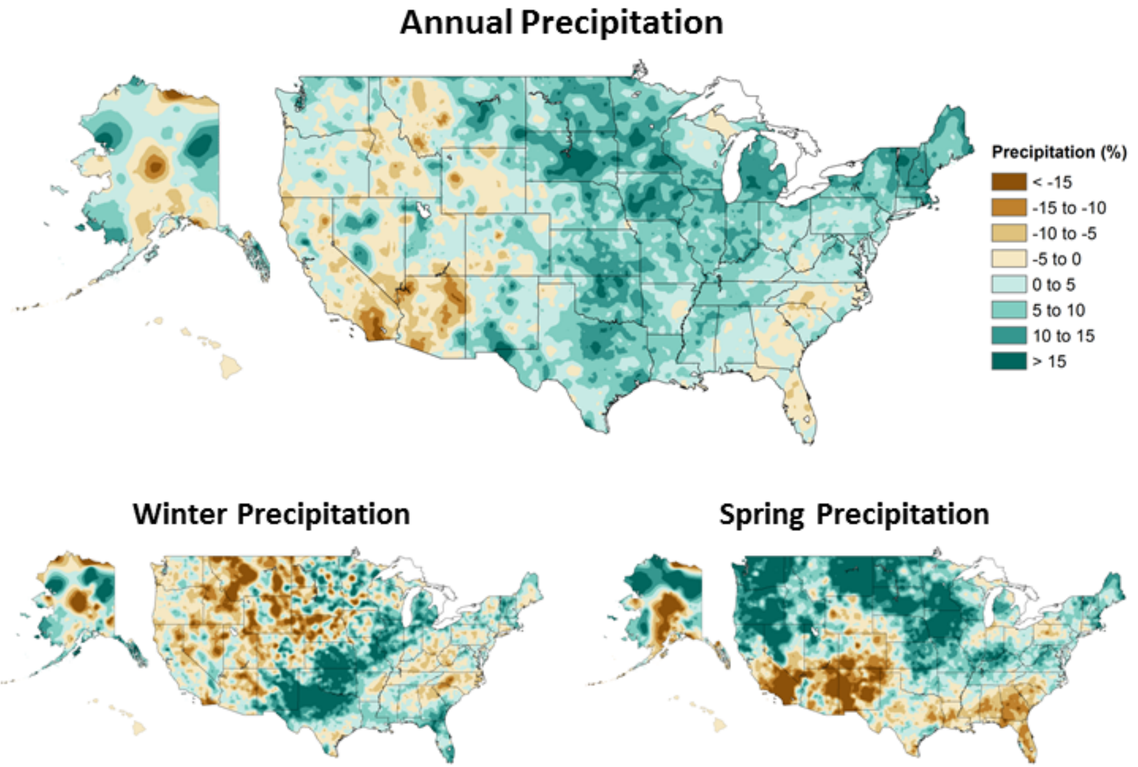




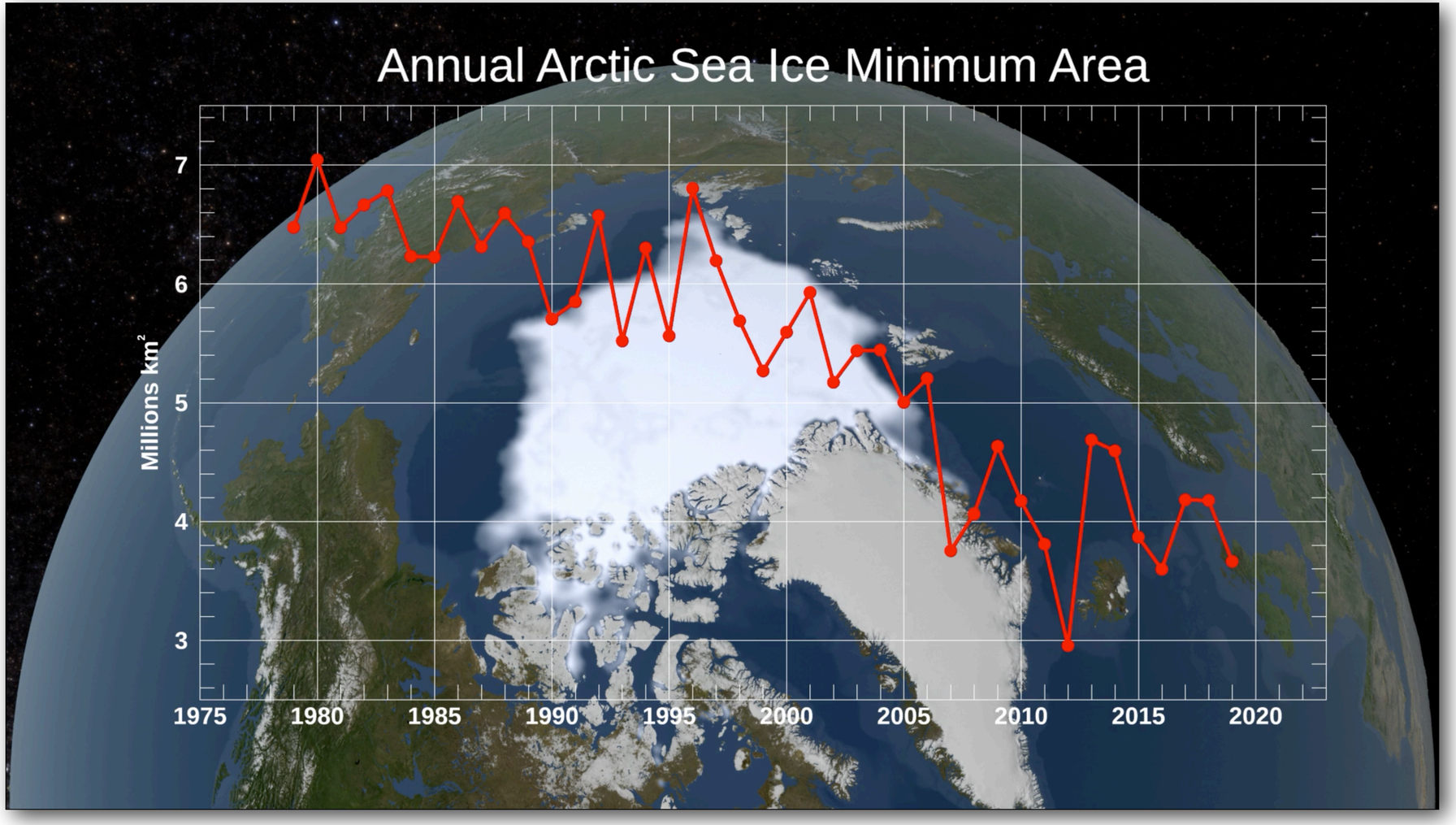
CLIMATE CHANGE IMPACTS ARE REGIONAL

Precipitation changes are not uniform



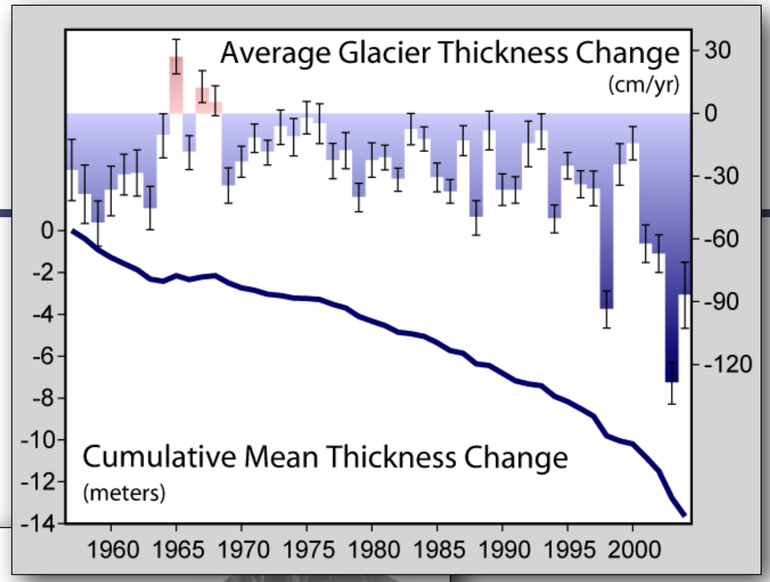


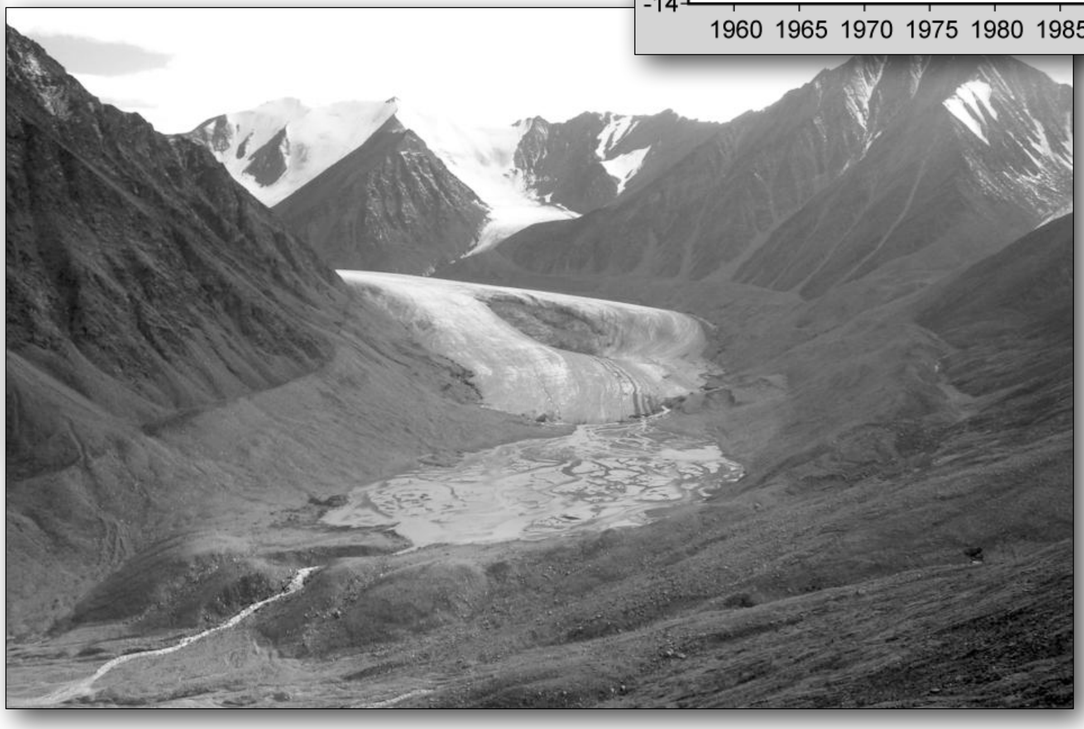
RAPID DECLINE OF ARCTIC SEA ICE



MOUNTAIN GLACIAL RETREAT

Okpilak Glacier 1907

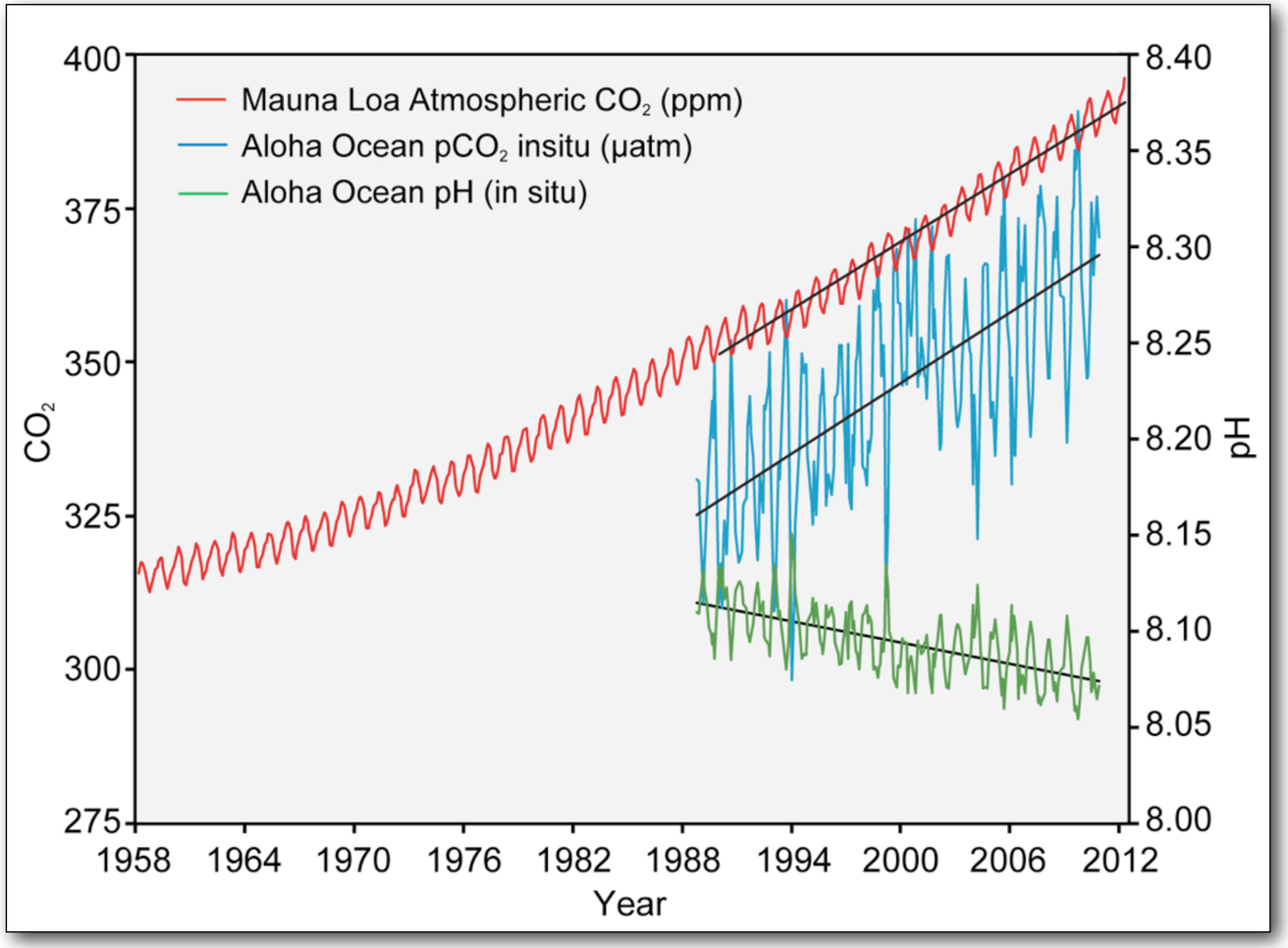




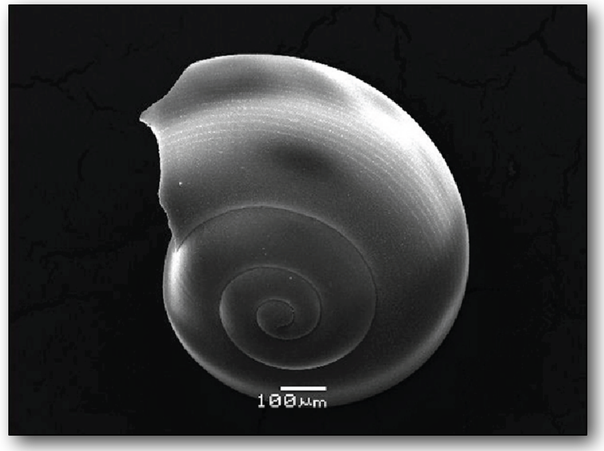
Okpilak Glacier 2004

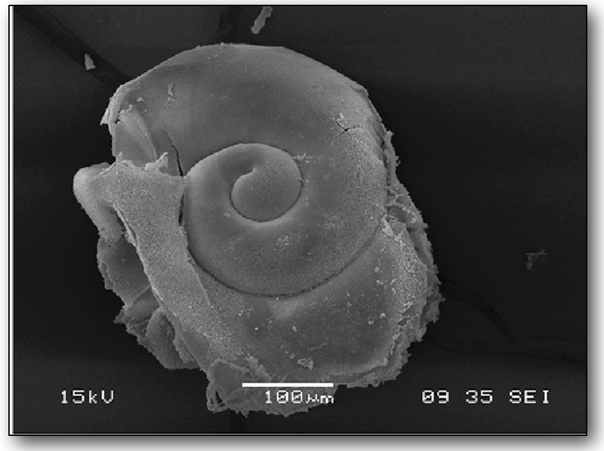
National Snow and Ice Data Center

AS OCEANS ABSORB CO_2, THEY BECOME MORE ACIDIC



NCA 2014; modified from Feely et al. 2009





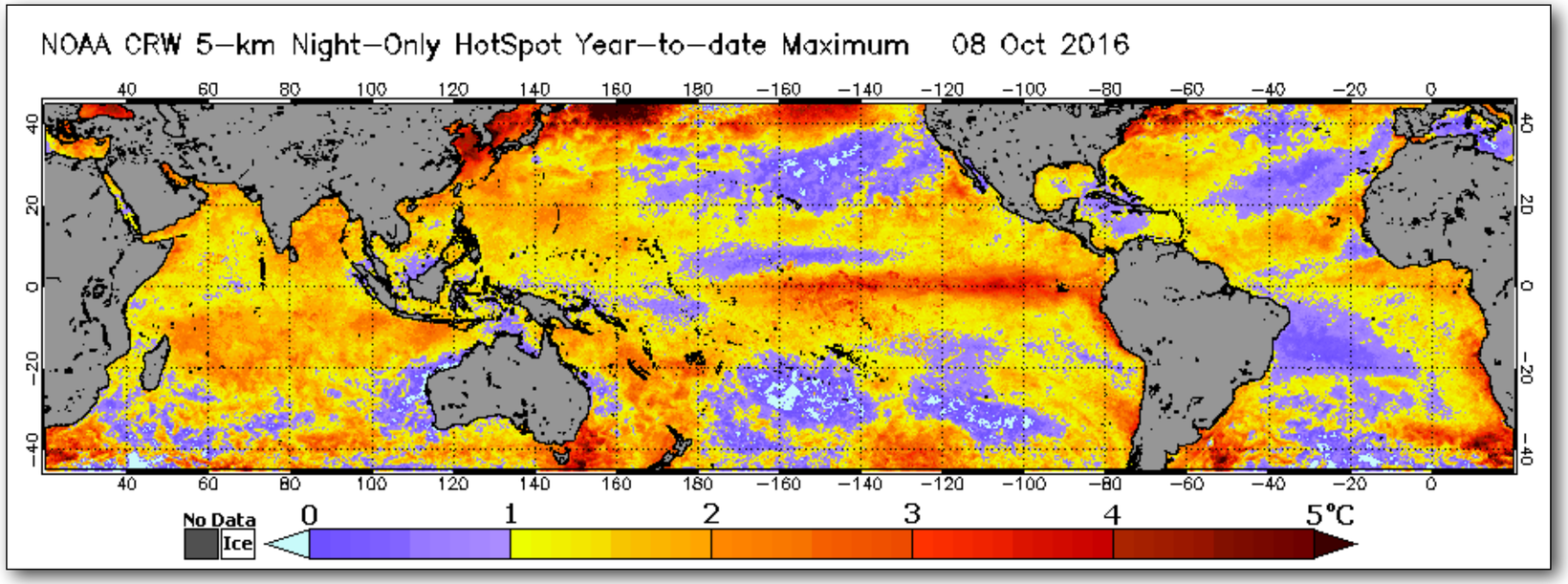
WARMING OCEANS BLEACH CORALS

NOAA

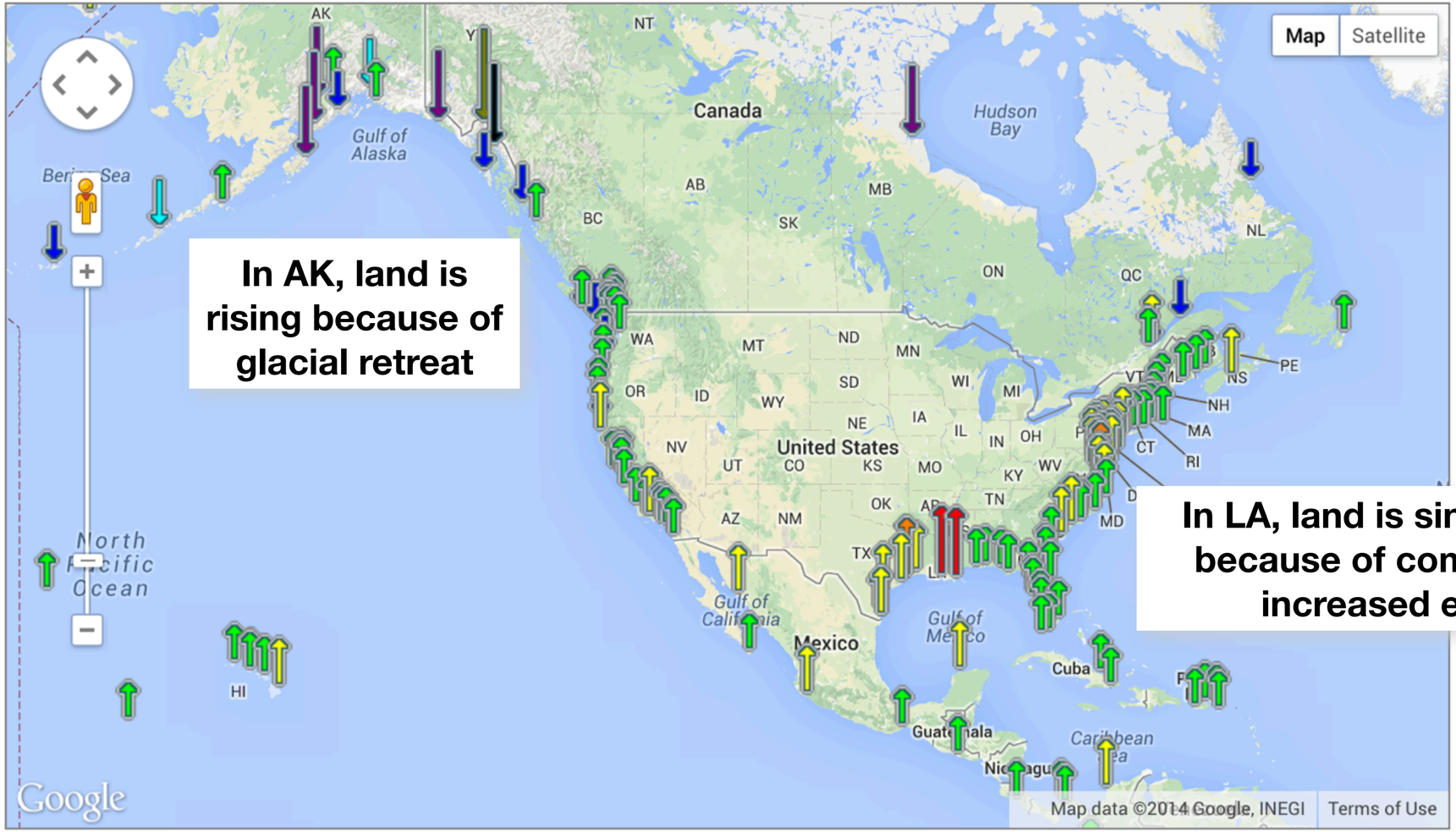
Coral reefs endangered by bleaching in global event, researchers say

By Adam Dunnakey, CNN

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

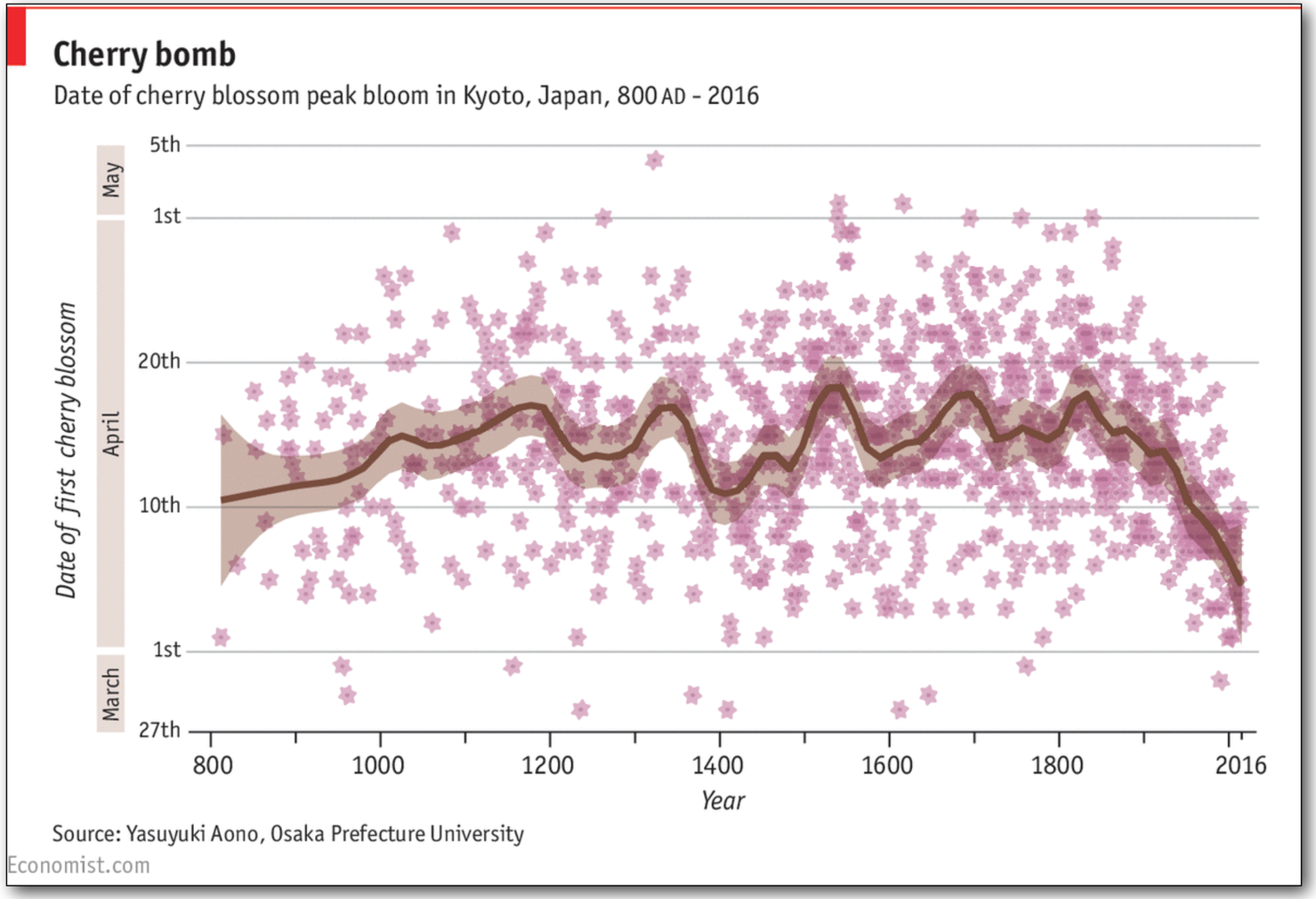


WARMER WATER + MELTING GLACIERS = SEA-LEVEL RISE



SOUTH CENTRAL
CLIMATE ADAPTATION SCIENCE CENTER

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 **are all consistent with a warming planet** resulting from increased greenhouse gases.

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

Which of the following statements is false?

1. *a fall in sea level at a specific location proves that global warming is not occurring*
2. *global warming can cause increases in precipitation in one place and decreases somewhere else*
3. *increases in temperatures on land can cause changes in pressure patterns and atmospheric circulations*

?

Questions & Discussion