

Changing Climates, the Black Sea, and the Rise of Civilizations



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Straits of Gibraltar

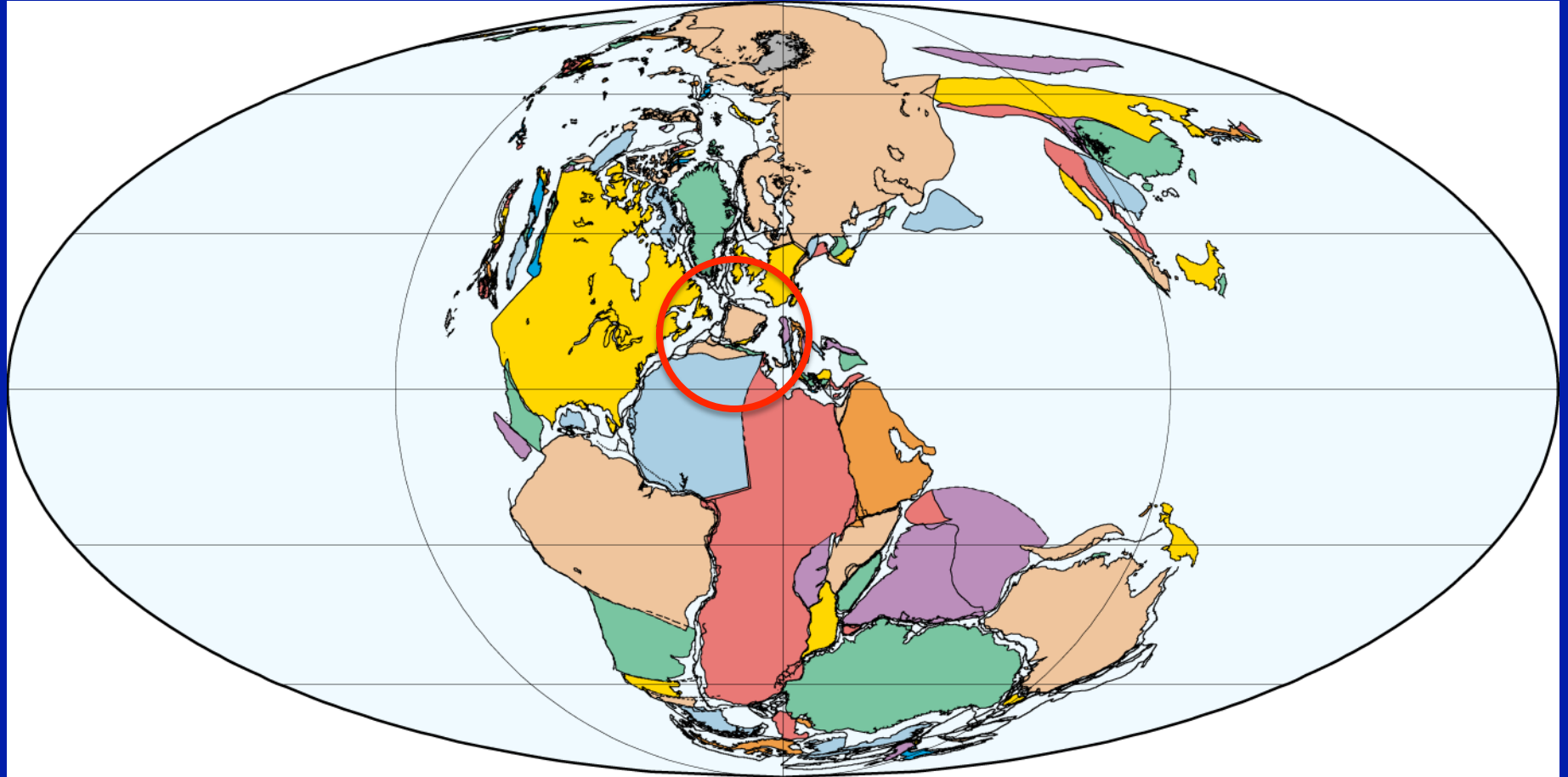


Pillars of Hercules: Jebel Musa (Morocco) and Jebel Tariq (Gibraltar)

Open or Close?



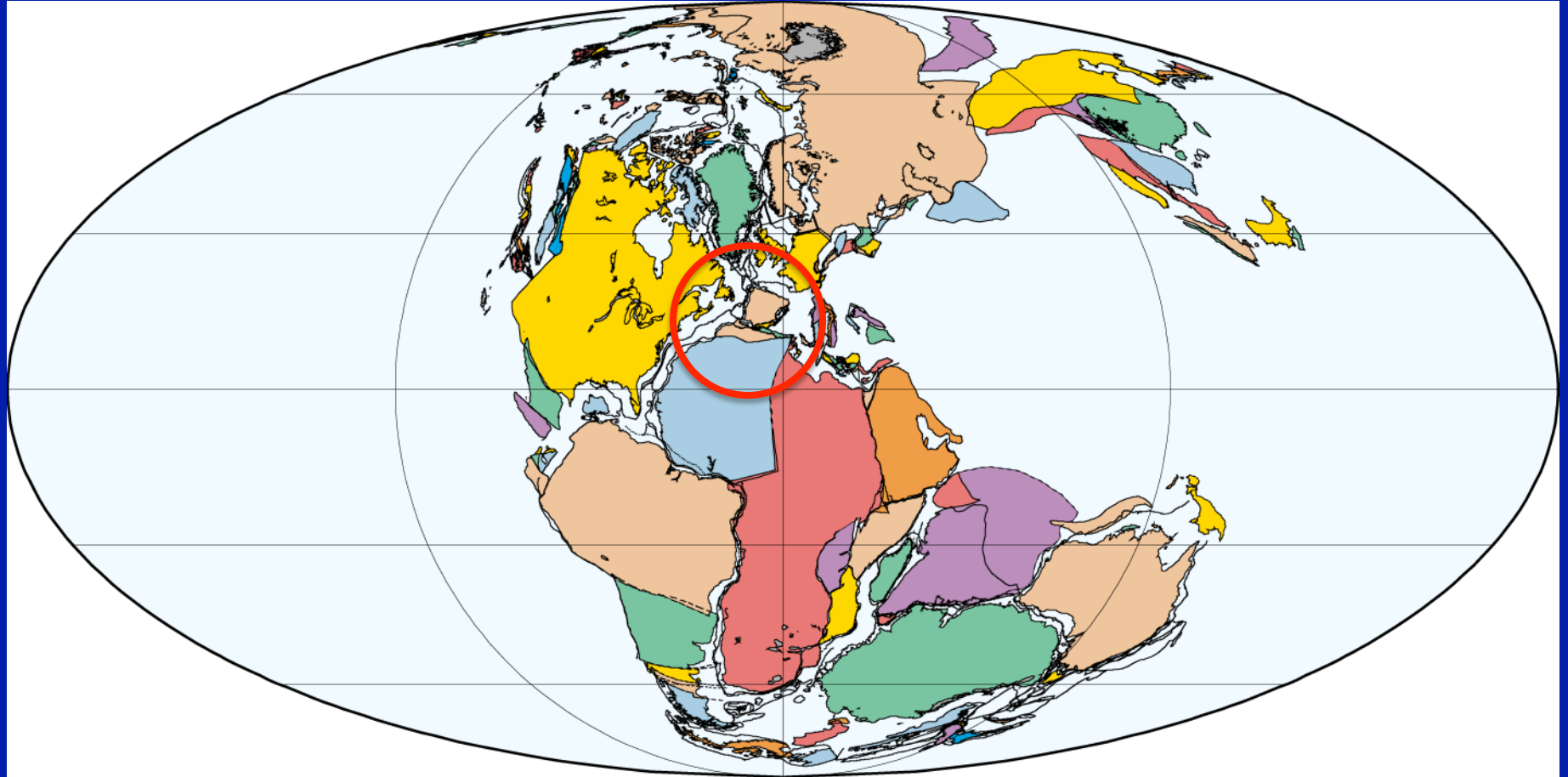
History of Gibraltar: 200 – 175 million years ago, rocks (limestone, dolomite, shale, sandstone) begin to form



200 Ma
Sinemurian (Early Jurassic)

PLATES/UTIG
August 2002

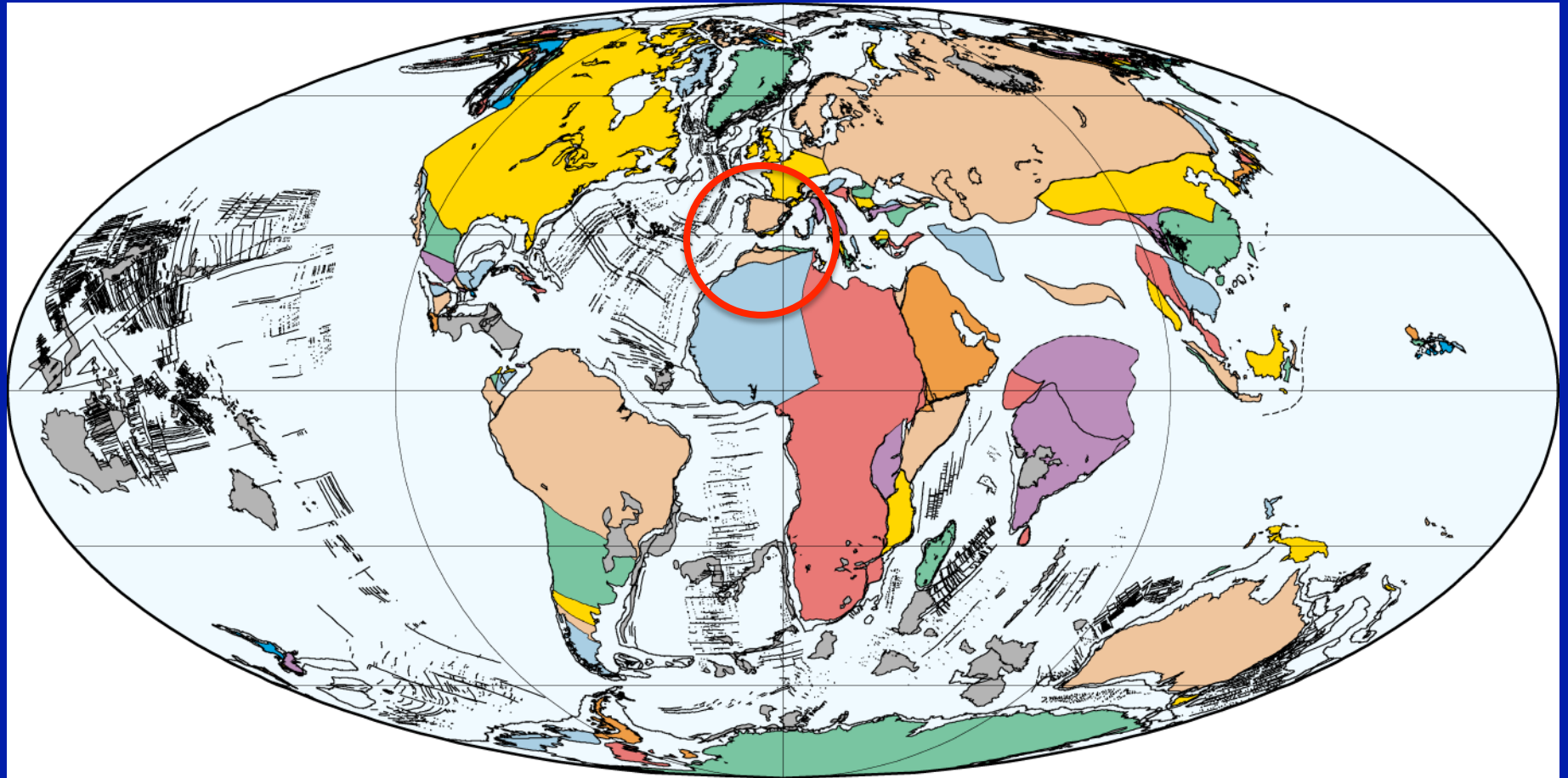
History of Gibraltar: 170 million years ago, Spain starts to break away from Africa



170 Ma
Bajocian (Middle Jurassic)

PLATES/UTIG
August 2002

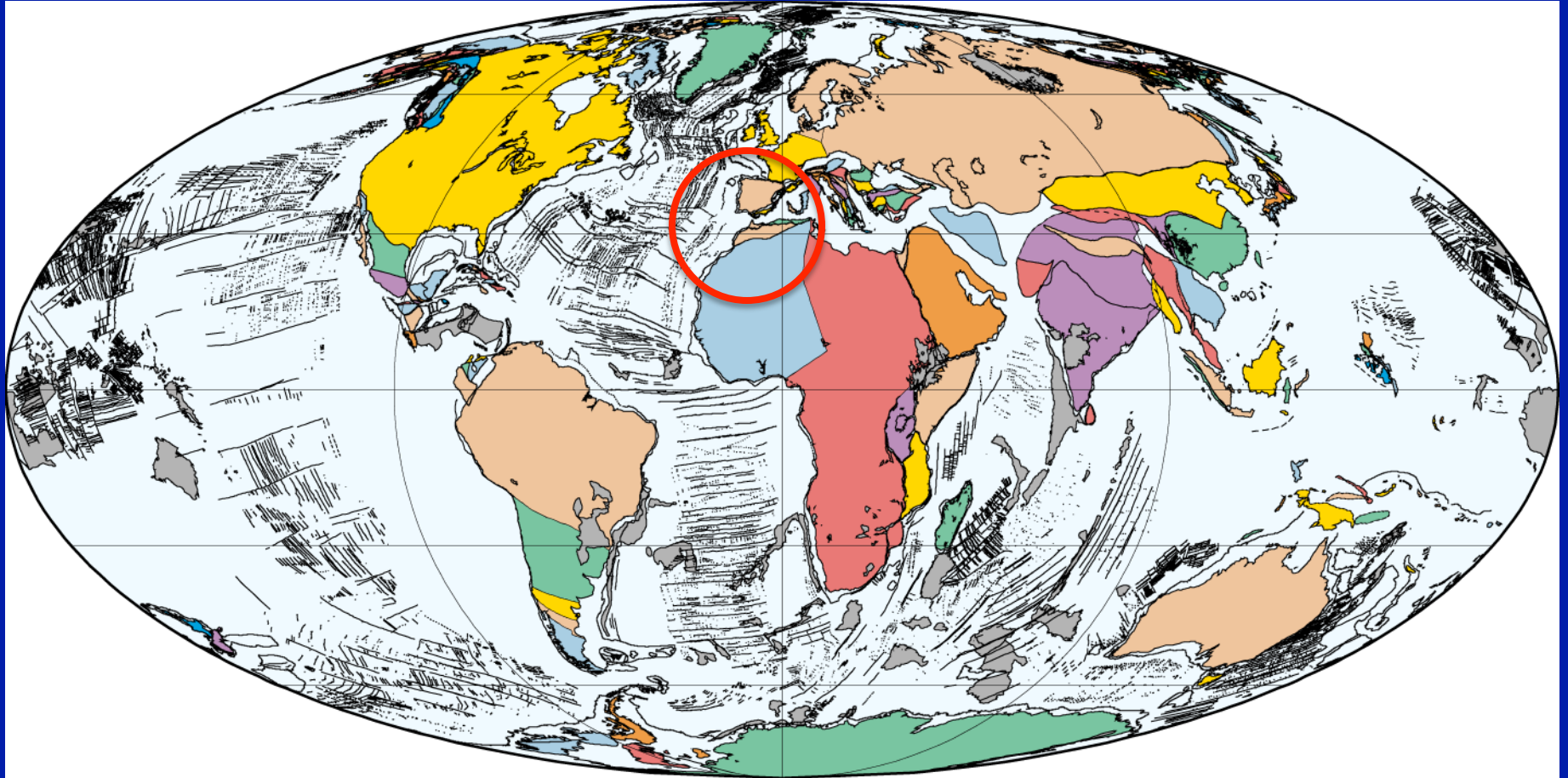
History of Gibraltar: 60 million years ago, Mediterranean starting to close



60 Ma
Late Paleocene

PLATES/UTIG
August 2002

History of Gibraltar: 30 million years ago, Mediterranean closed on the east end



30 Ma
Early Oligocene

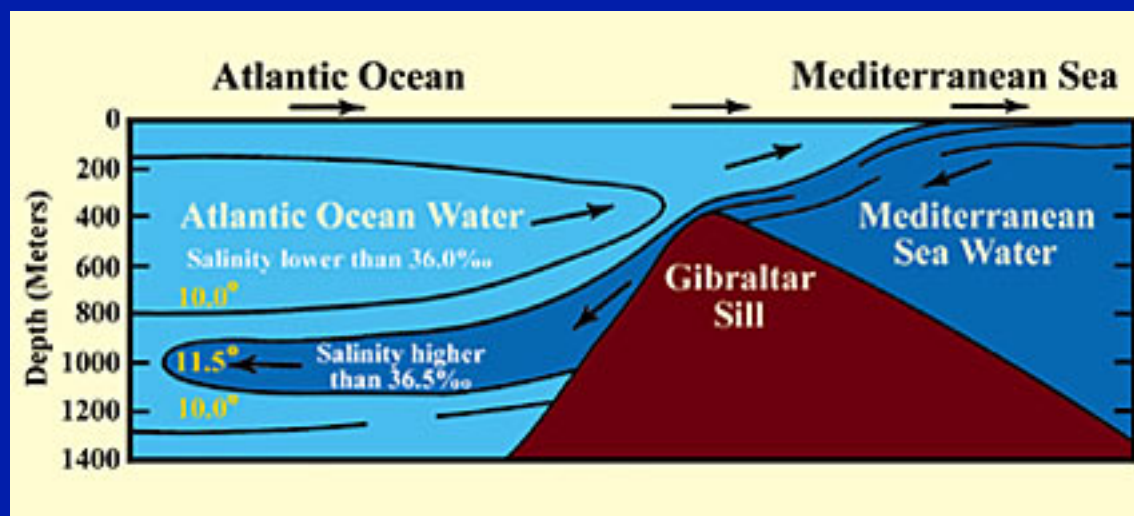
PLATES/UTIG
August 2002

If you visit Gibraltar, the current is always flowing eastward, into the Mediterranean.

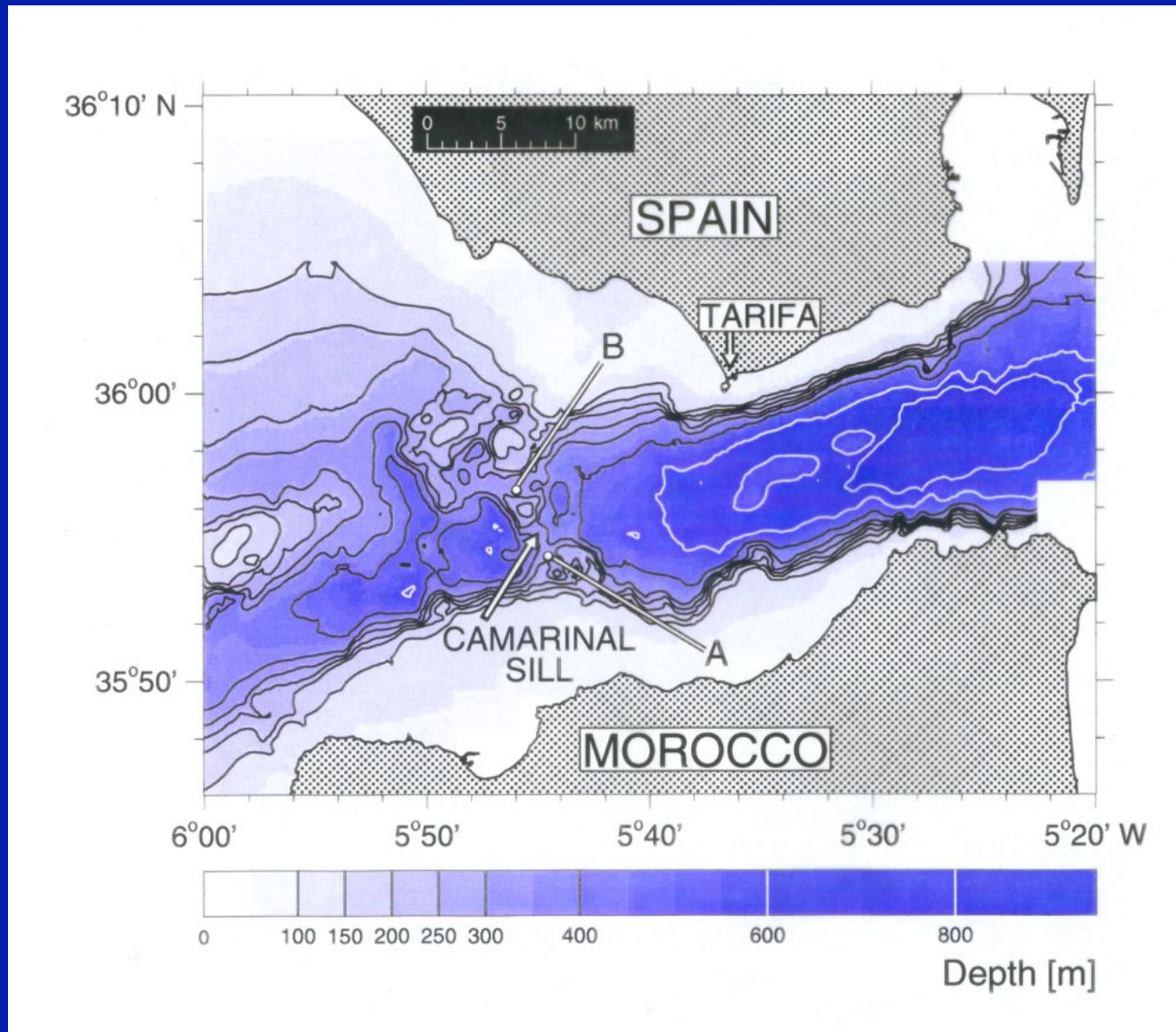
How is this possible?



Evaporation makes the Mediterranean water salty and dense, so it sinks.

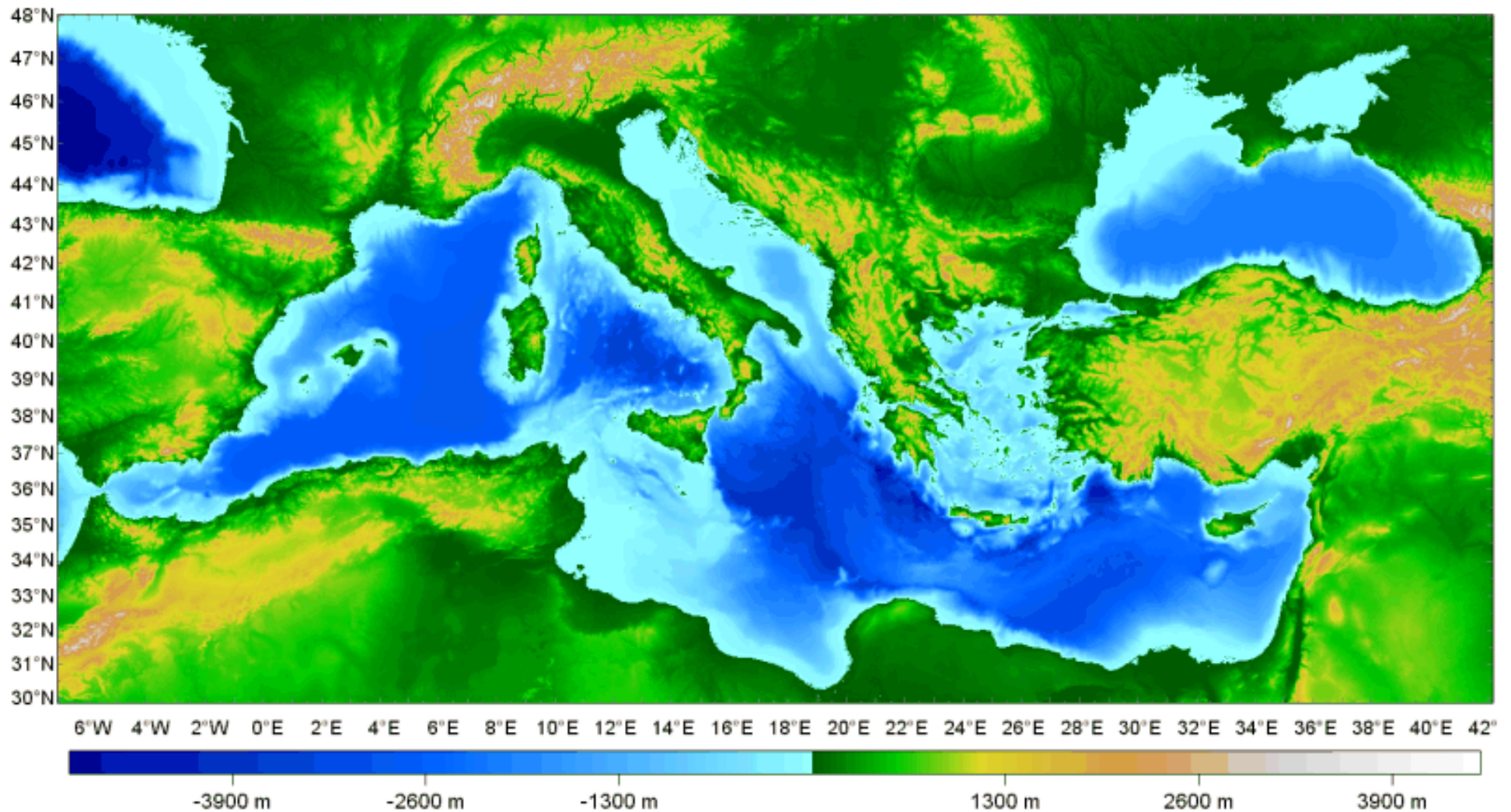


***Camarinal Sill* beneath the Straits of Gibraltar:
290 meters (950 feet) at its deepest**

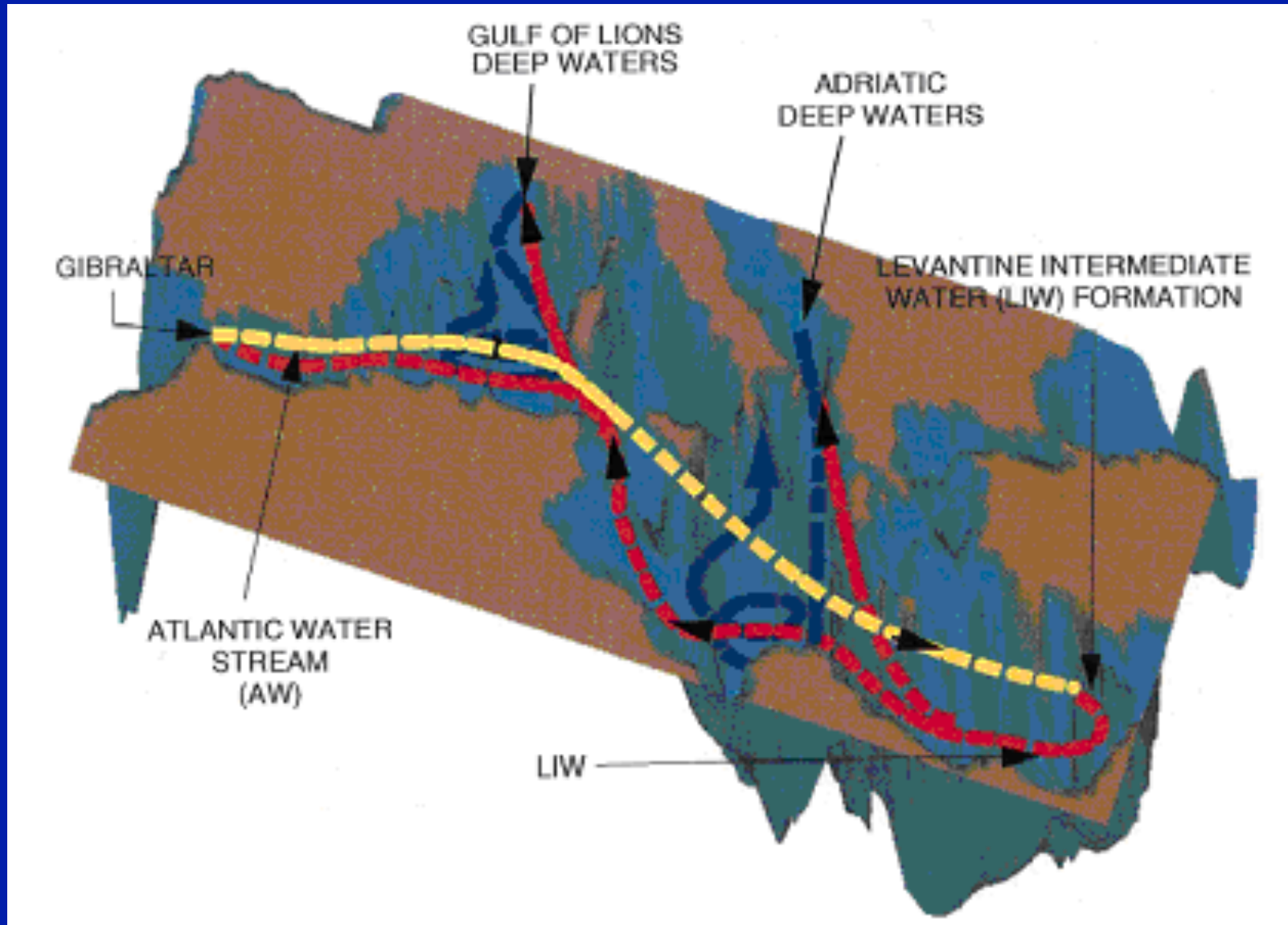


Mediterranean Bathymetry:

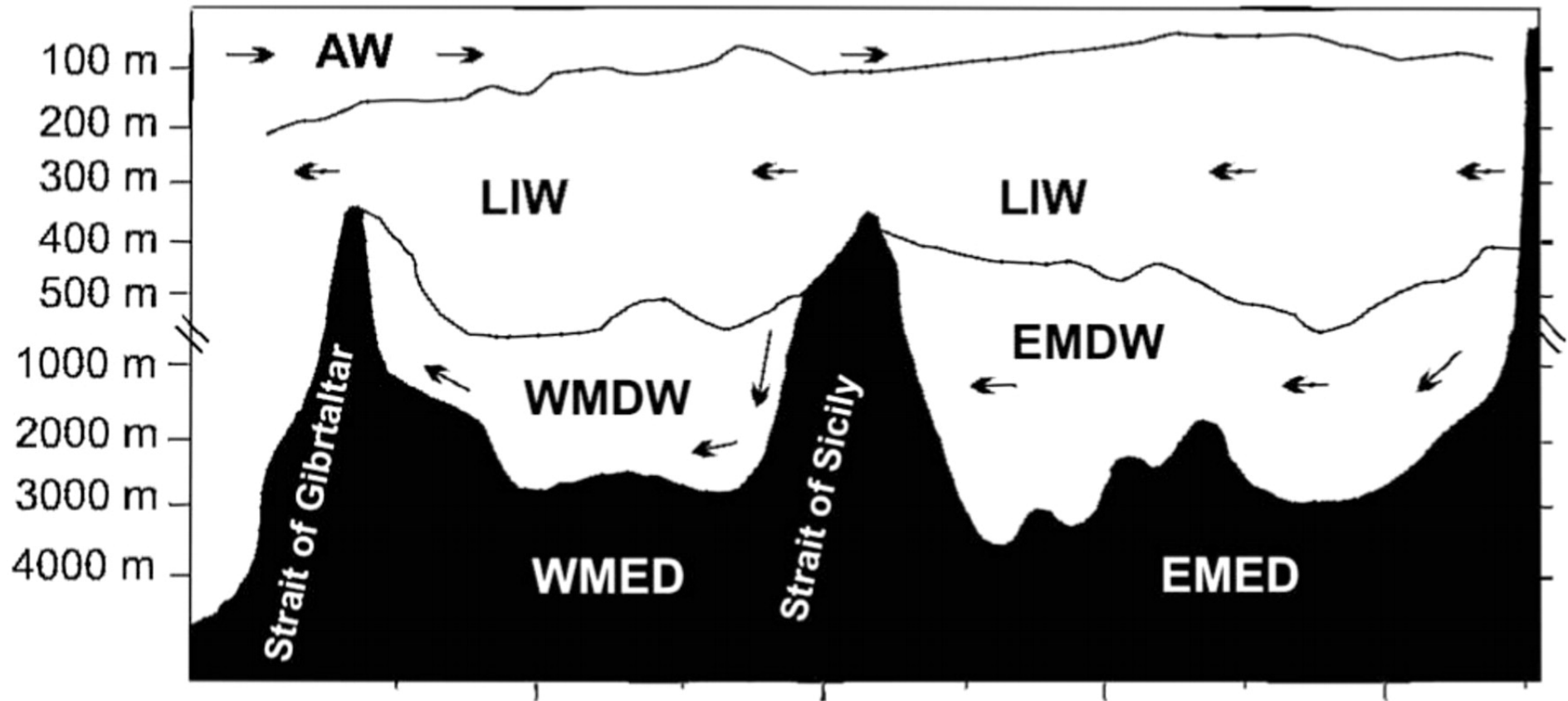
There are really two Mediterranean Seas!



Mediterranean Sea Water Circulation: 3 layers!



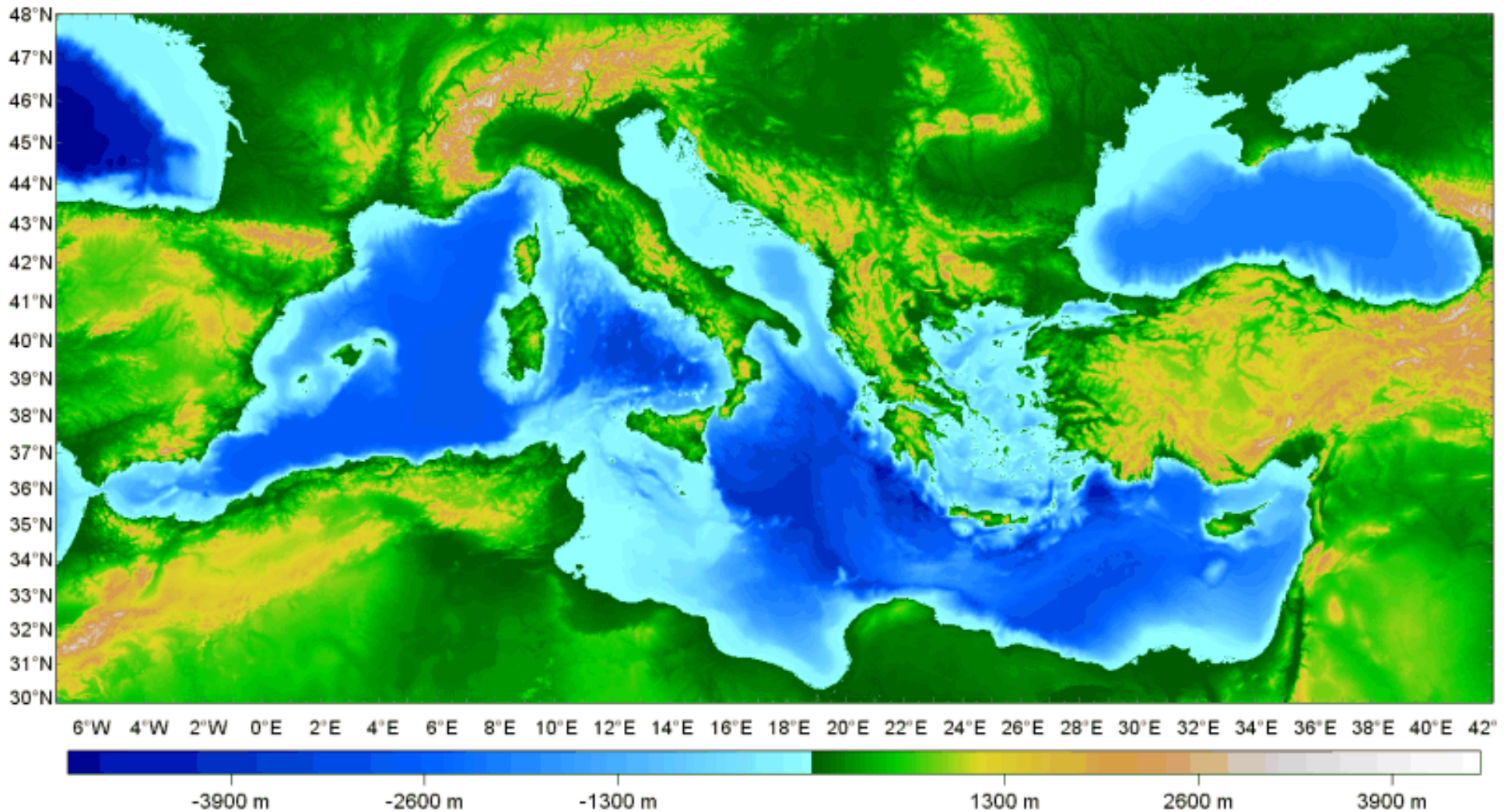
Mediterranean Sea Water Circulation: 3 layers!



**Mediterranean puzzle --- the sea floor is covered with 8 different layers of salt and gypsum. How?!?
(usually form as *evaporites*, like playas)**

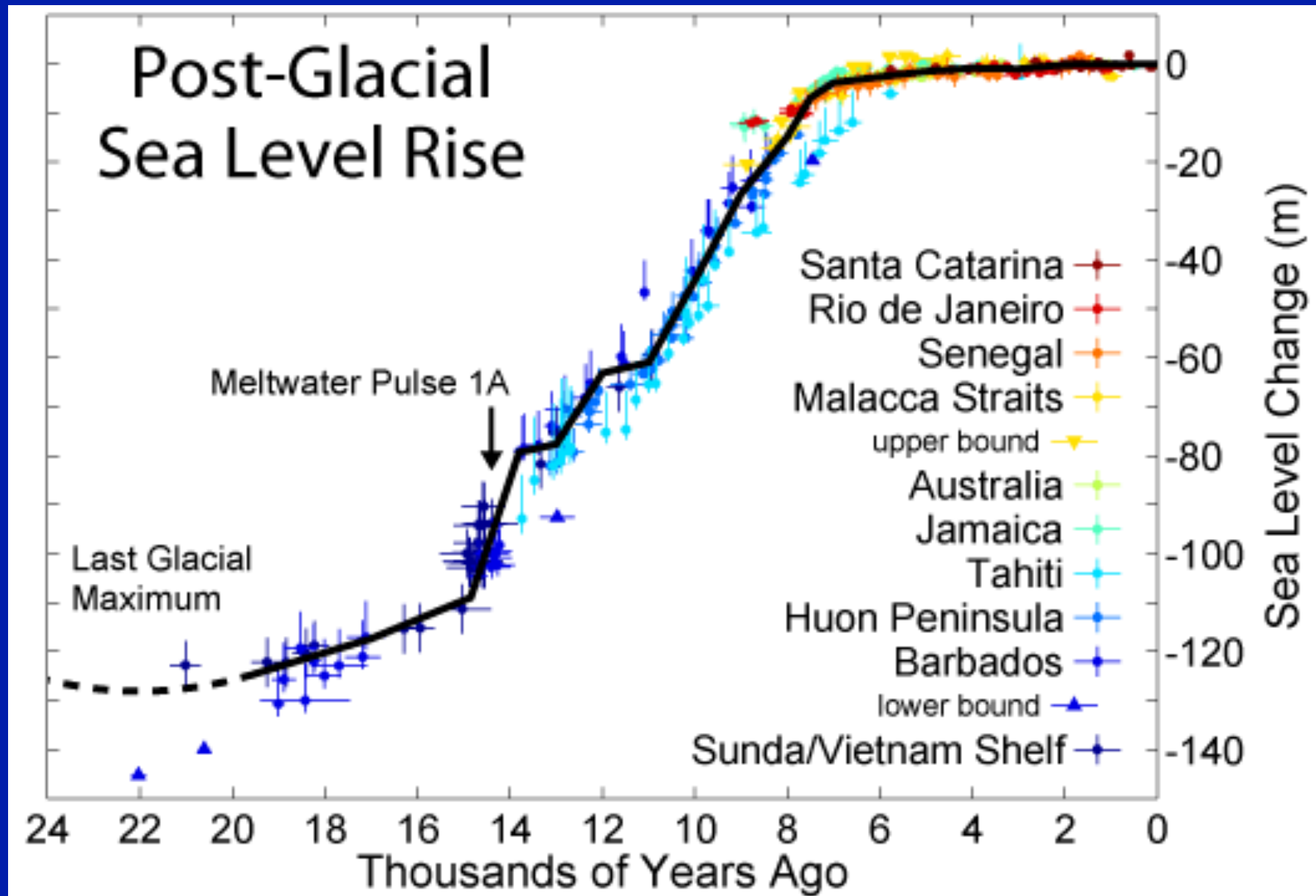


- *Strange conditions on the bottom of the sea floor!*
- *Carved a deep channel east of Gibraltar.
(Don't know how deep it was before)*



?? What does “*extreme cold*” have to do with this??

Change in Sea Level Since the End of the Last Ice Age:



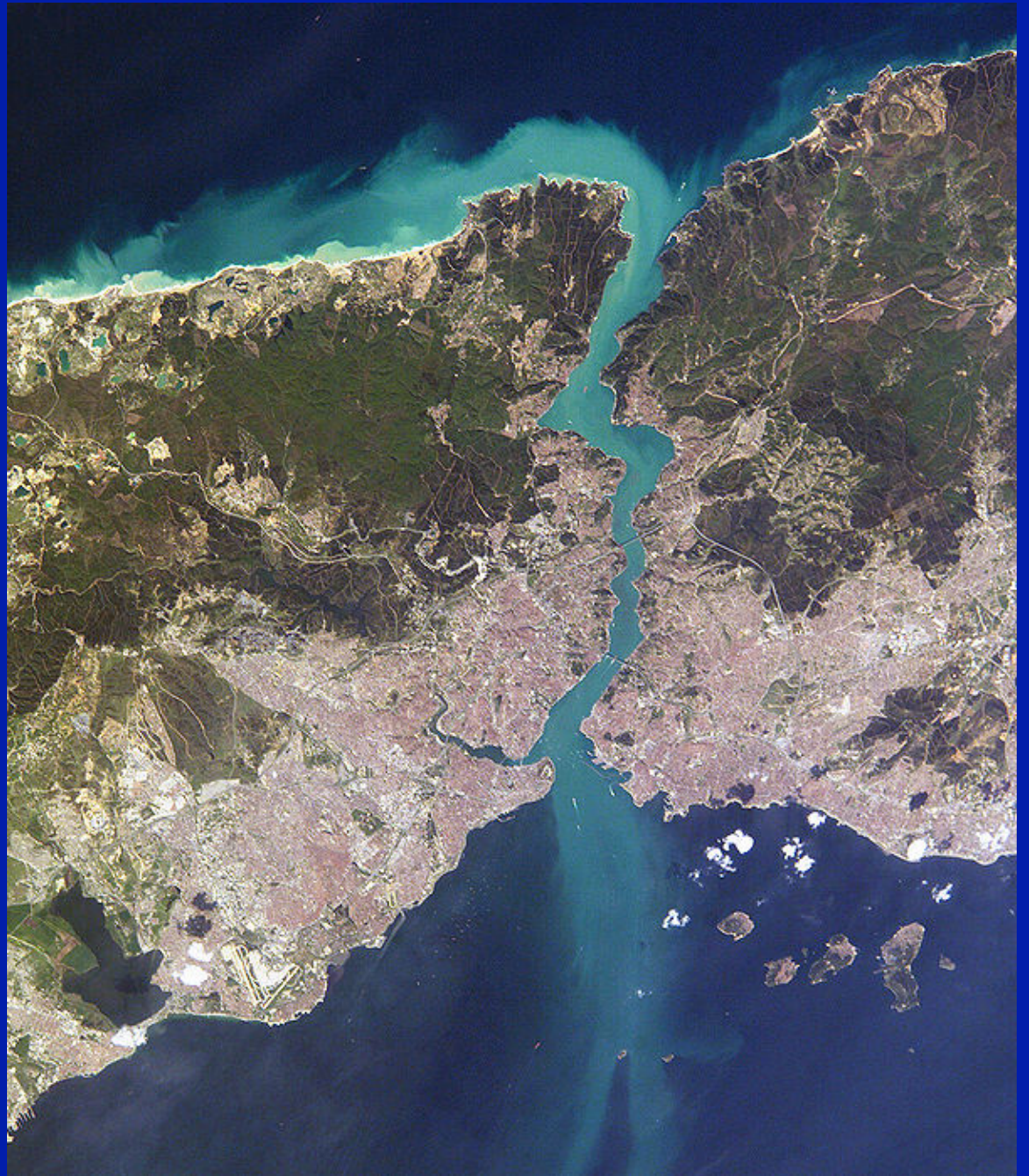
Bosphorus and Dardanelles







Bosphorus: Only 38 meters (118 feet) deep!!



Black Sea was a large fresh water lake after the melting of the Ice Age sheets (~15 thousand years ago)

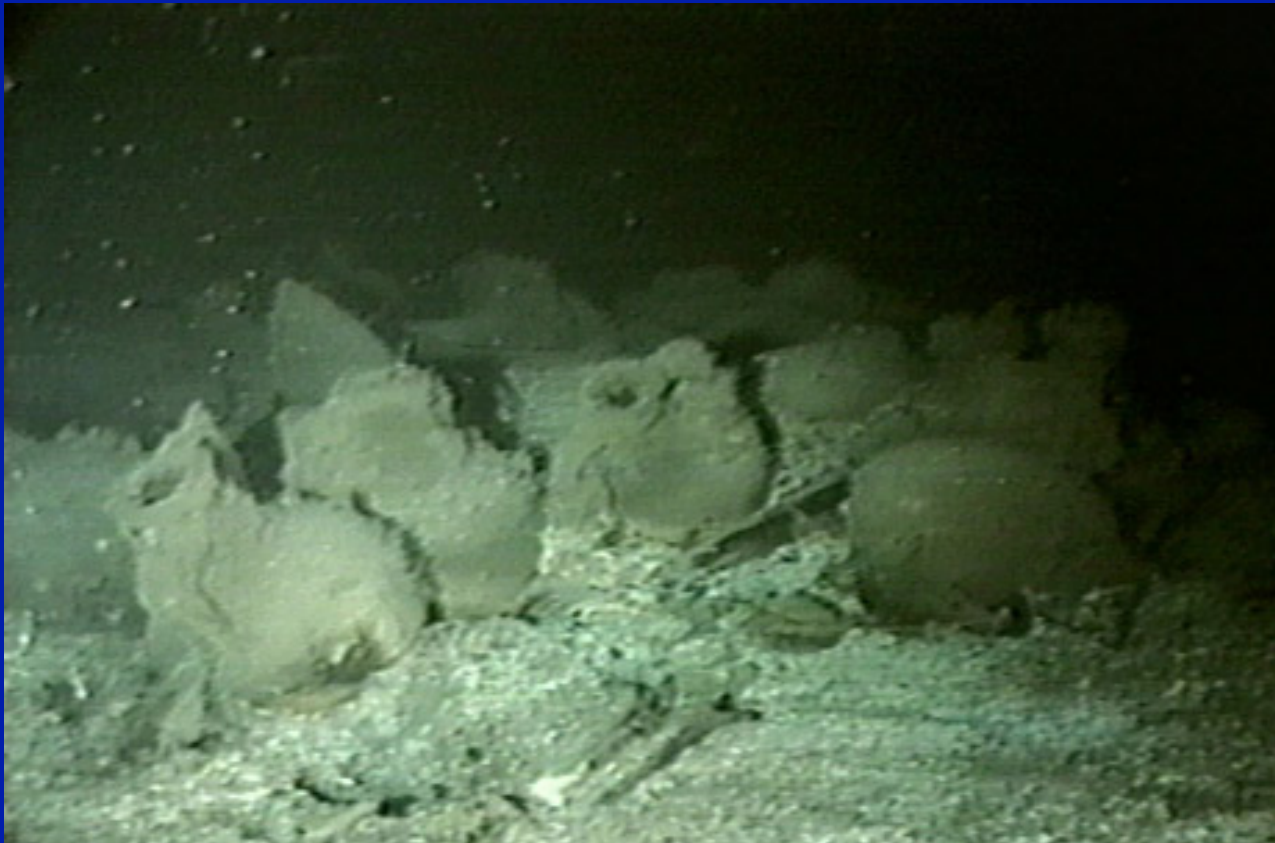


Significant debate about:

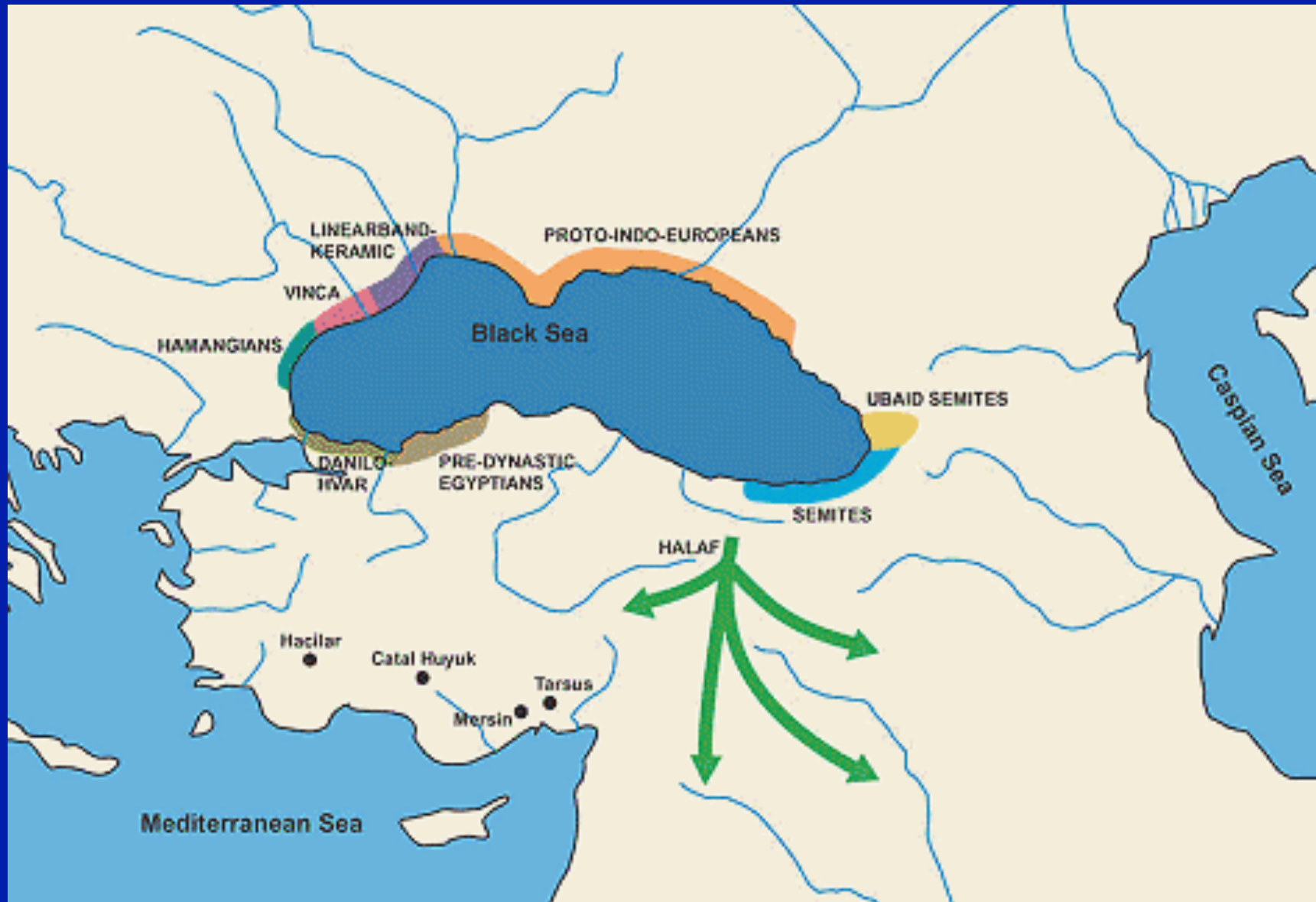
- Timing of flooding
- Catastrophic (William Ryan and Walter Pittman) vs. Gradual
- Which way water was flowing! (Both Mediterranean and Black Sea were simultaneously rising)

Most Convincing:

- **Bob Ballard discovered freshwater fossils (snail shells), drowned river valleys, tool-worked timbers, and man-made structures in ~100 meters (330 ft) of water dating to 7500 years ago!**



Tribes along the shores of the proto-Black Sea would have had to move.



Varna Necropolis: World's oldest worked gold

→ 6000 years ago

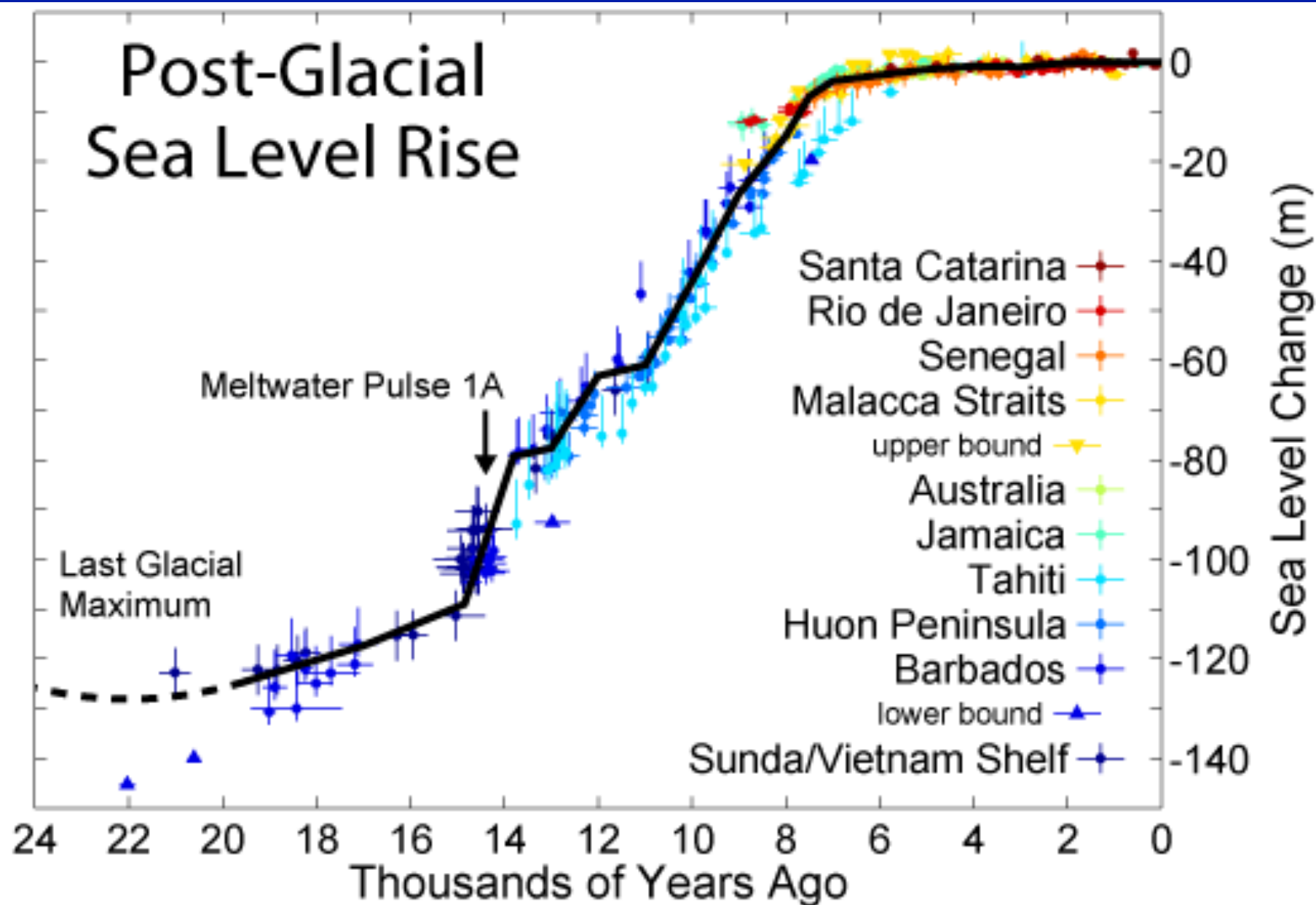


[Varna Archaeological Museum]



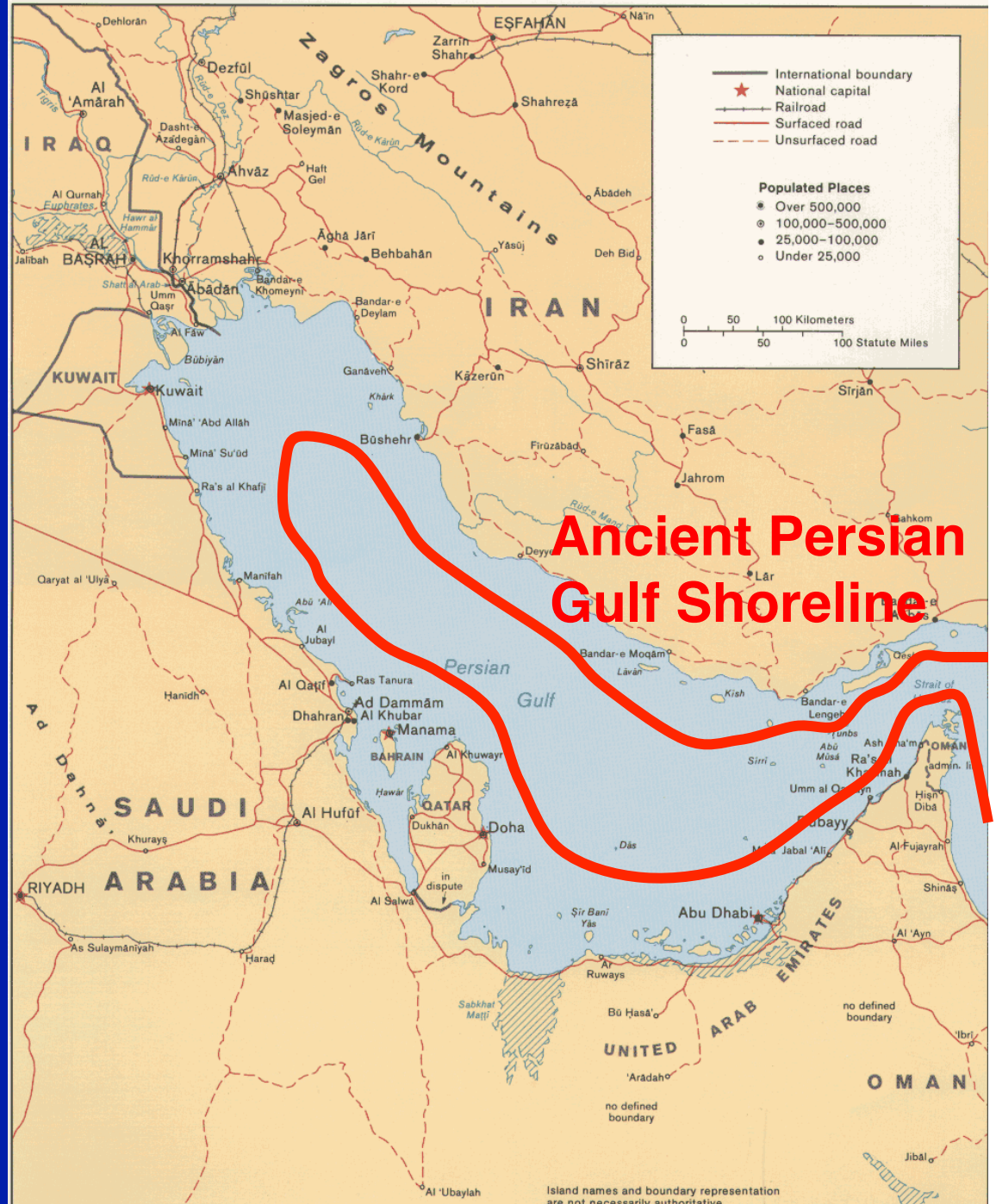
Many early cultures have a myth similar to the story of the expulsion from Eden. Why?

Post-Glacial Sea Level Rise



**Rising Sea Levels
After the End of the
Ice Age forced
many people from
their homelands!!**

Persian Gulf Region



**Ancient Persian
Gulf Shoreline**

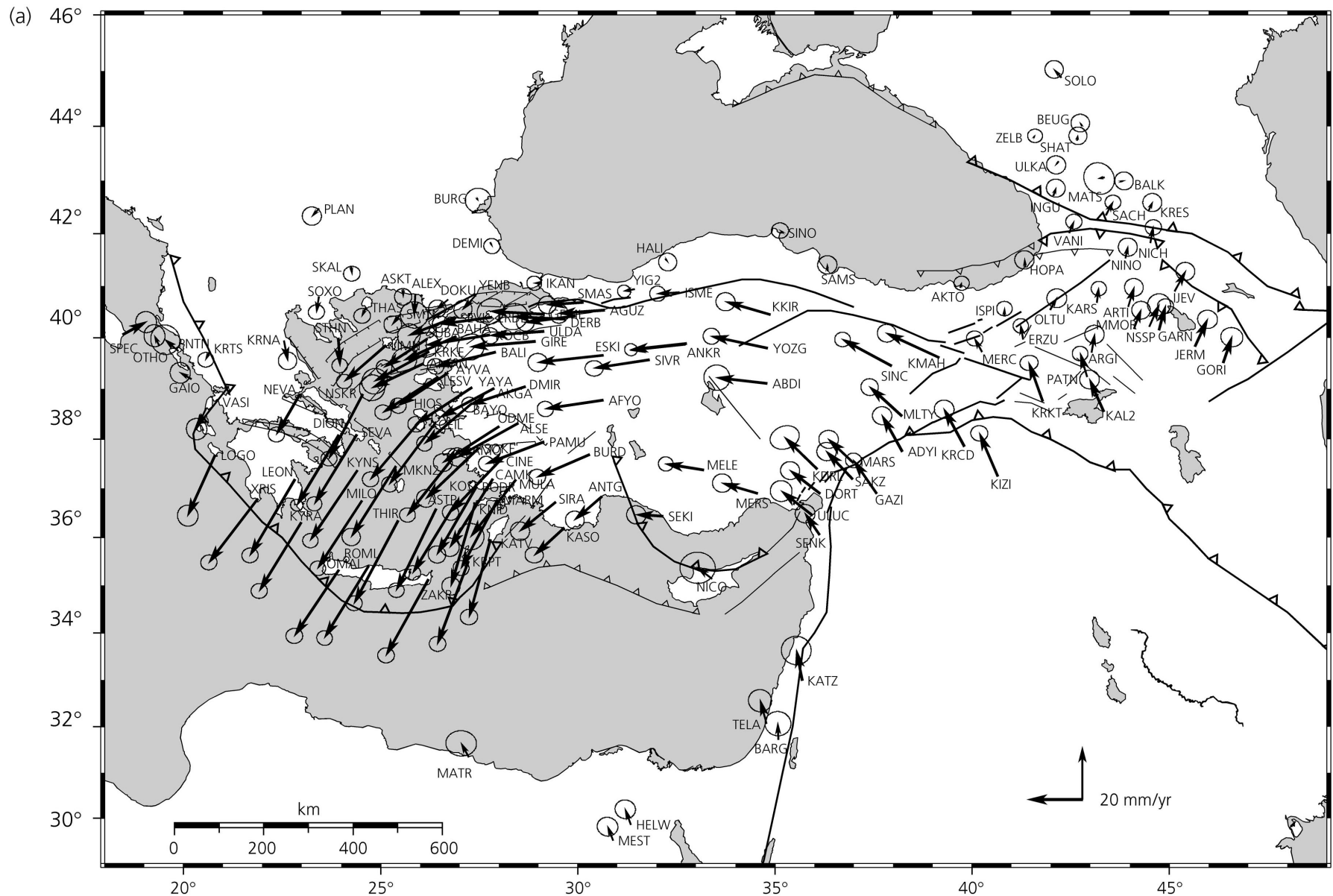
(Aside.....) Can you guess how Izmet Bay formed?



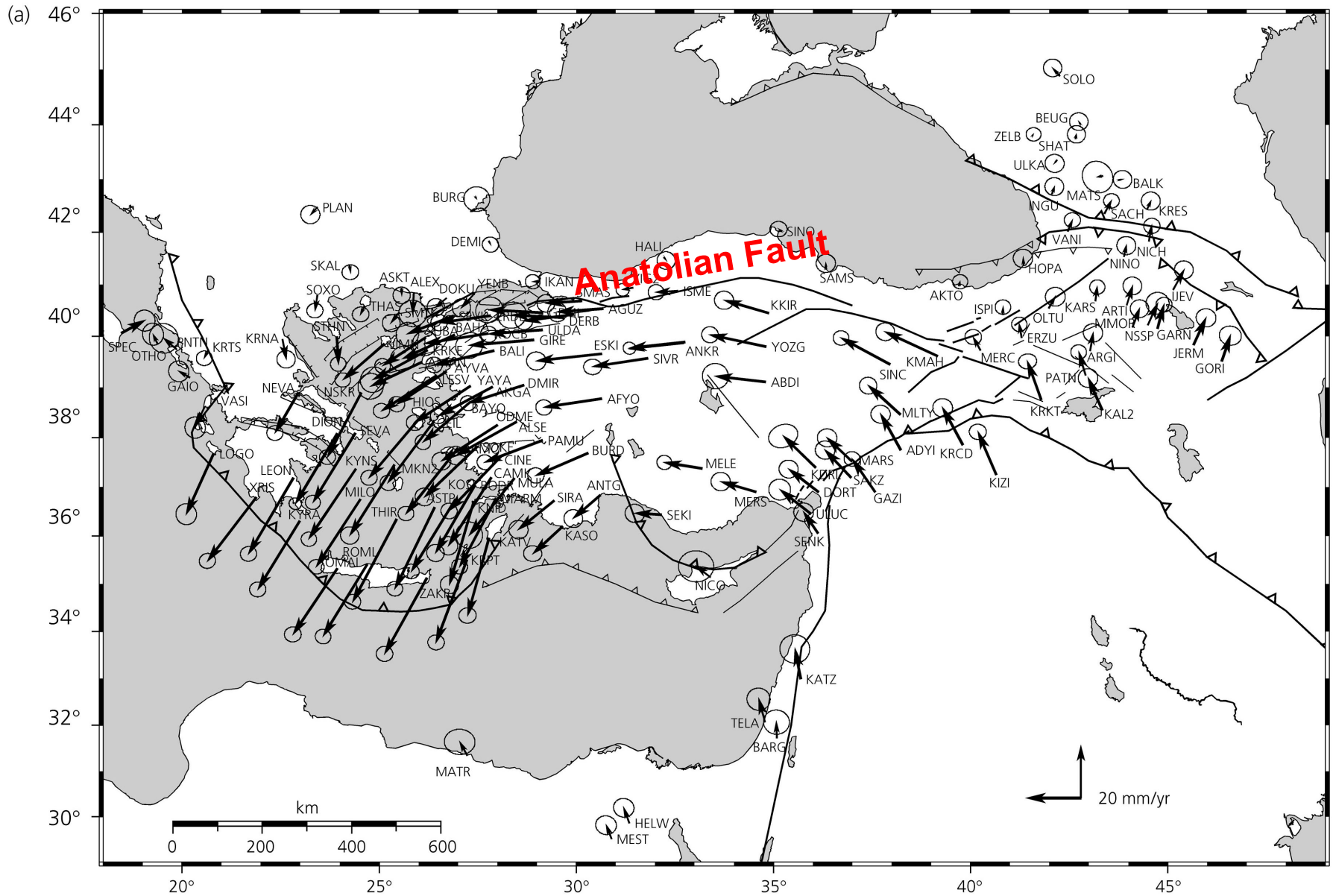
(Aside.....) Can you guess how Izmet Bay formed?



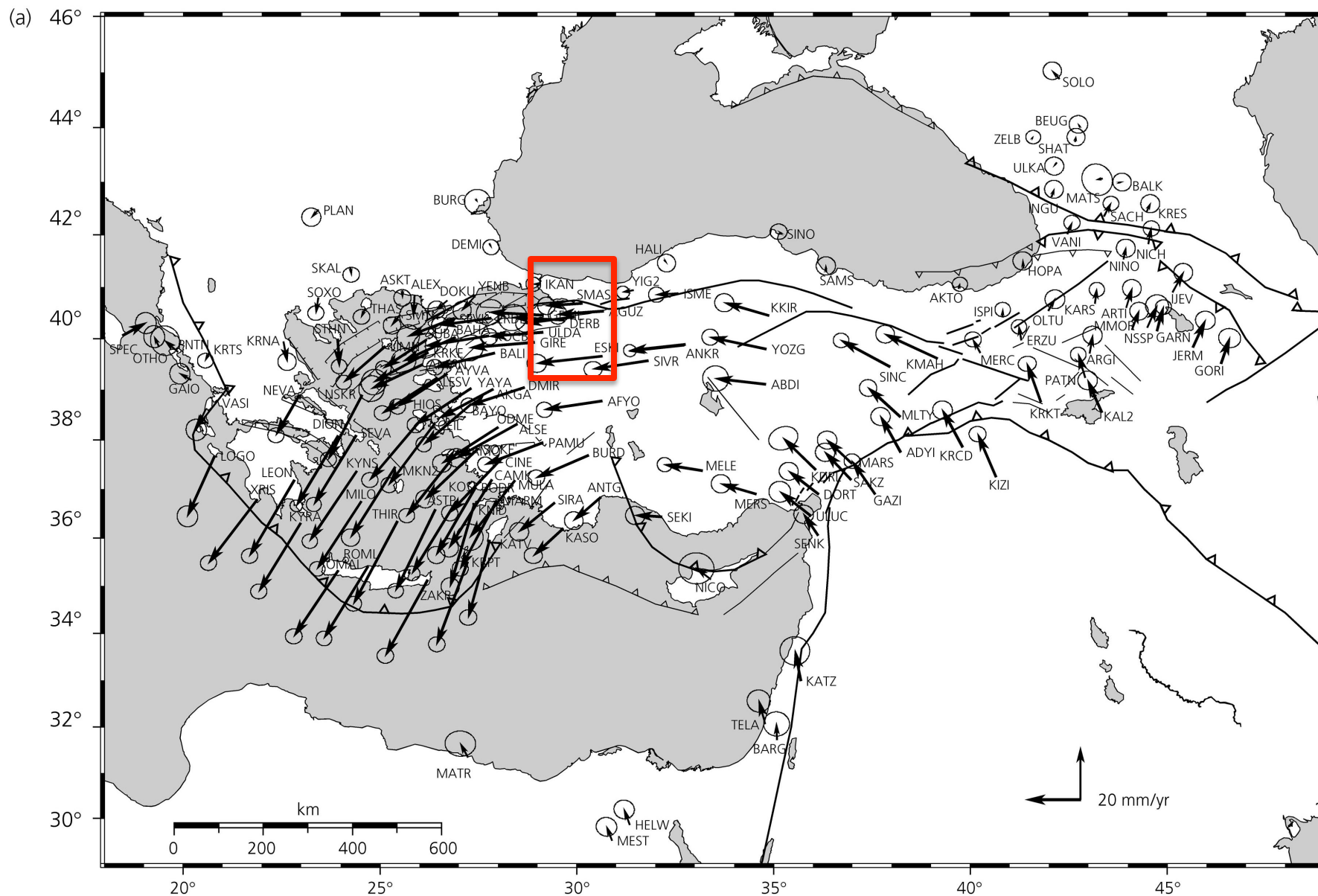
The westward motion of Turkey continues to close off the Black Sea



The westward motion of Turkey continues to close off the Black Sea

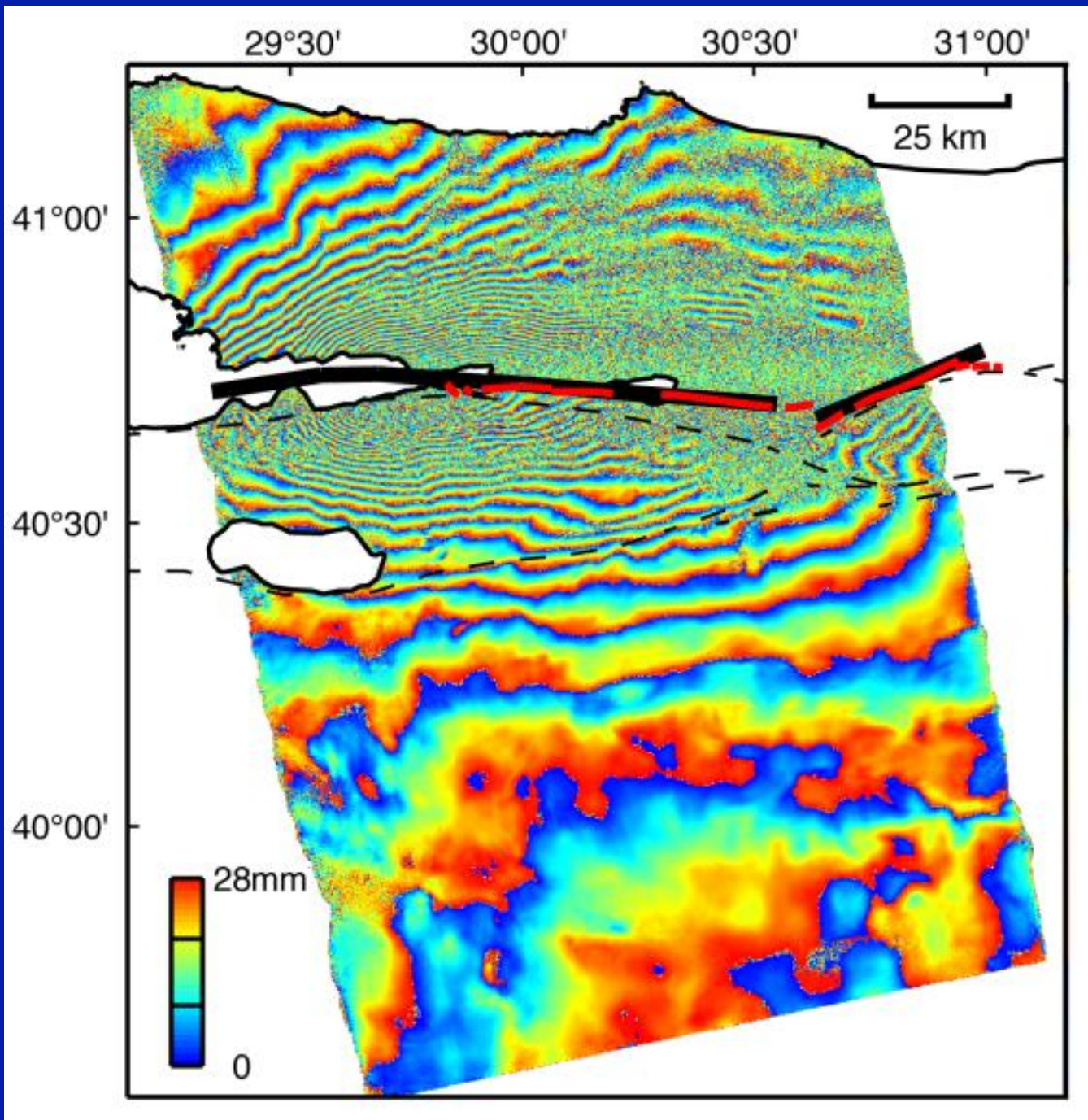


The westward motion of Turkey continues to close off the Black Sea

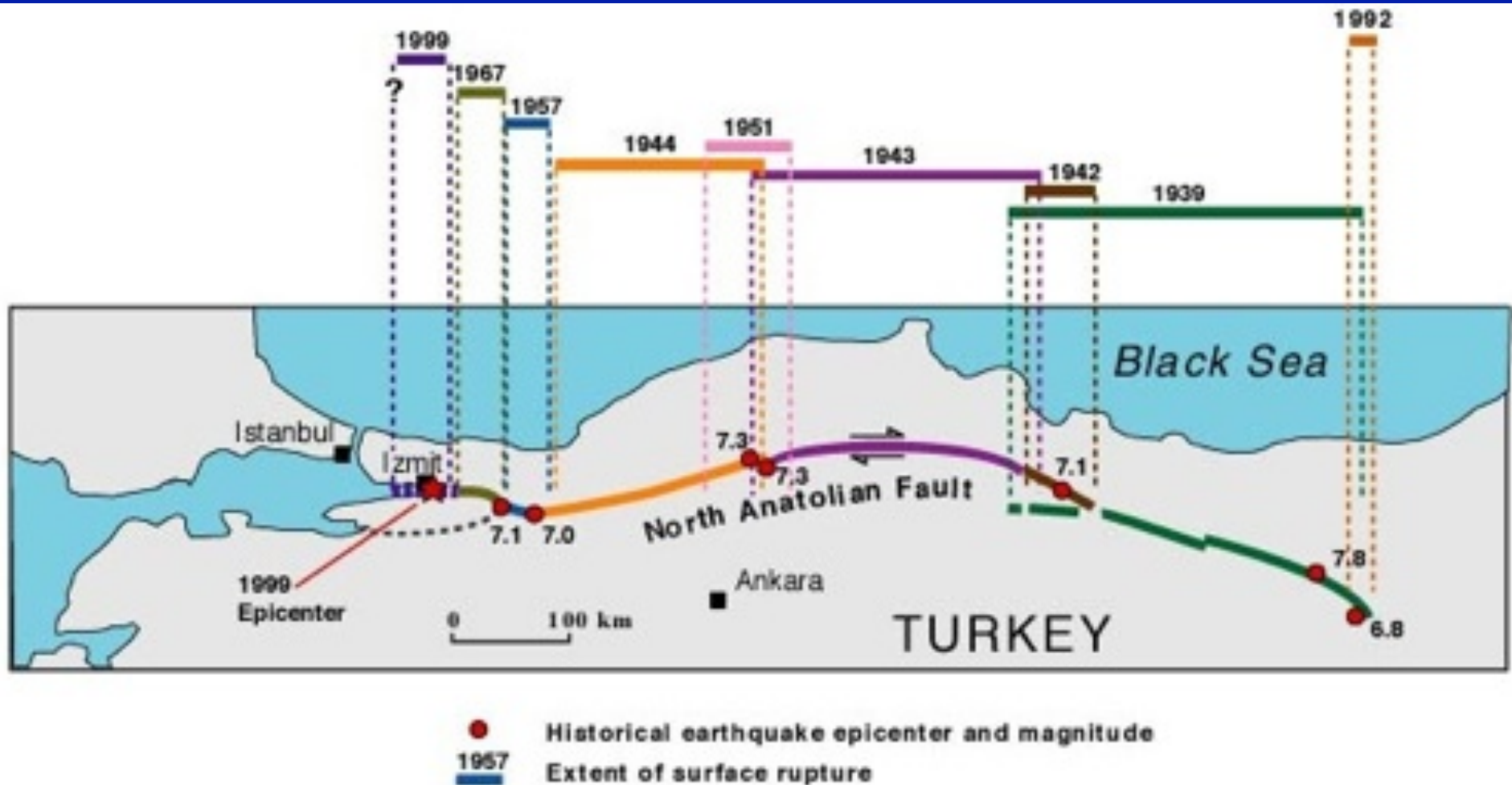


**Deformation
during the 1999
Izmit
Earthquake,
Turkey, along the
Anatolian Fault**

*Synthetic
Aperture Radar
(SAR)*



Propagating Earthquakes along the Anatolian Fault: *Frightening implications for Istanbul!!*



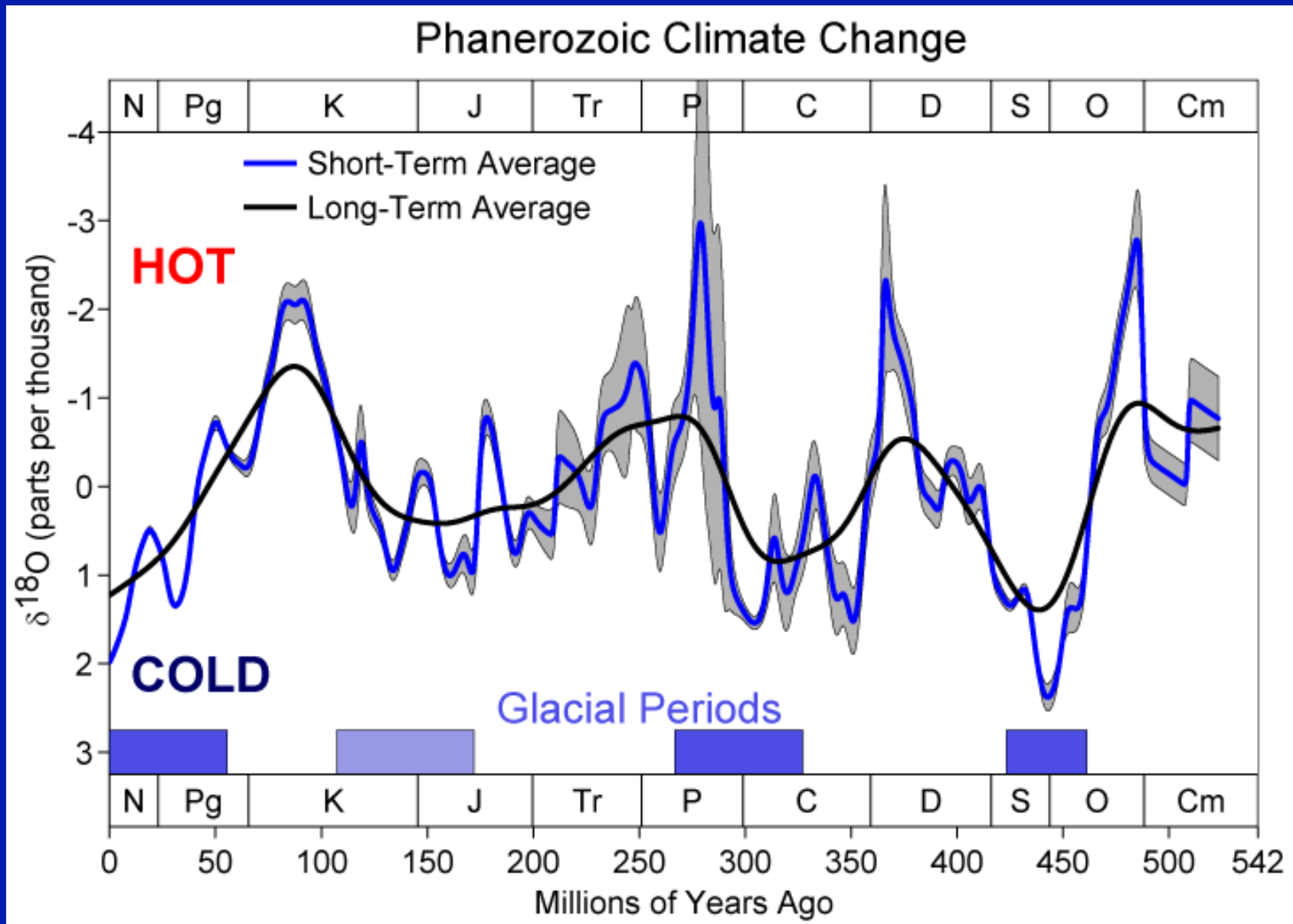
Human history has been strongly dependent on the history of climate change



→ Climate involves ALL of Earth's systems

→ Cycles within cycles within cycles

What drives the long-term temperature changes?

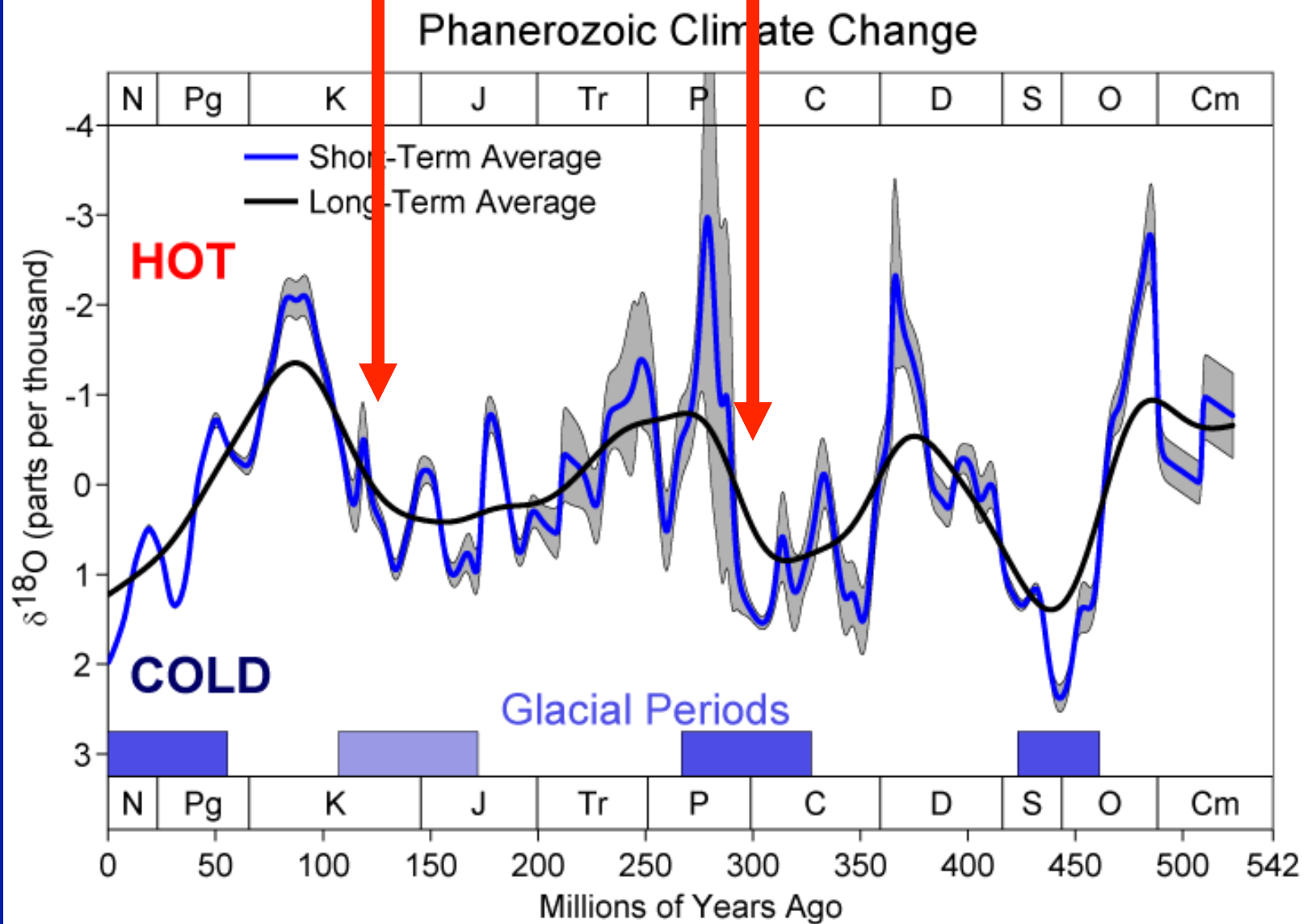




Volcanoes!!

- Eject Carbon Dioxide (CO₂) into the Atmosphere**
- Global Warming (on long term)**

Volcanic Flood Basalts





...and Mountains!!

→ Erosion (Carbonic Acid)

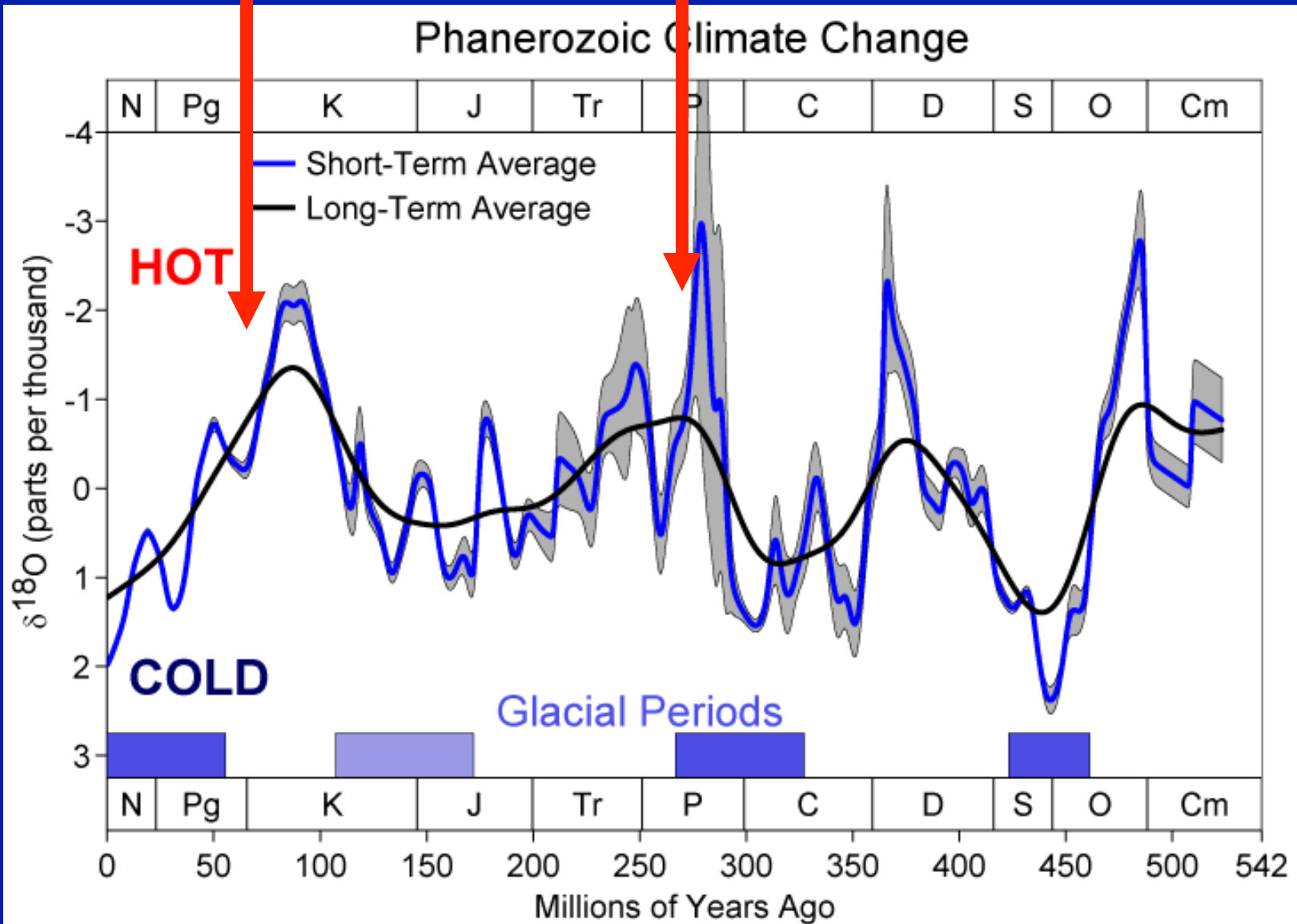
→ Deposition of Carbonates in the Oceans

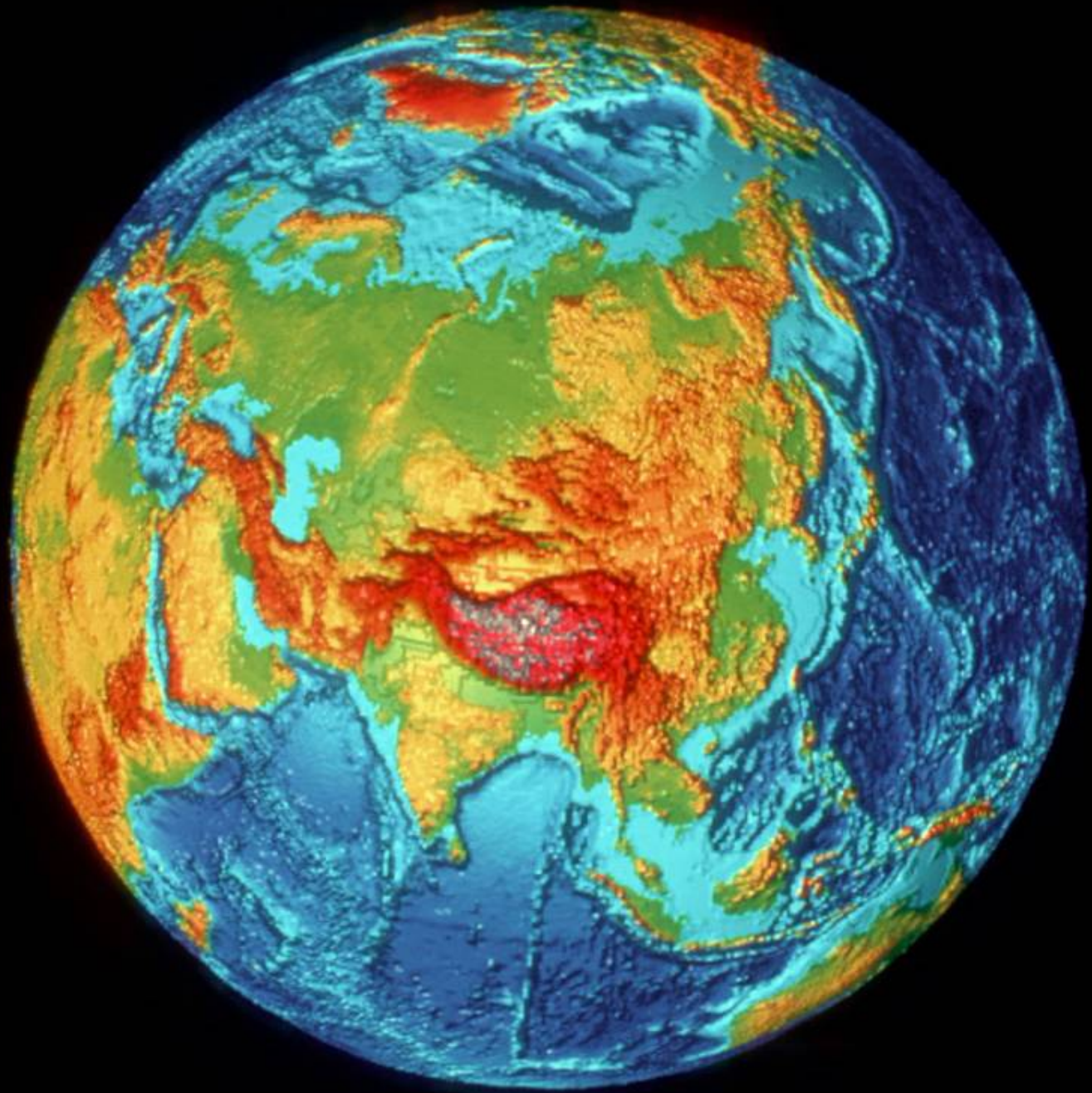
→ *Reduced* CO₂ in Atmosphere

→ Global Cooling

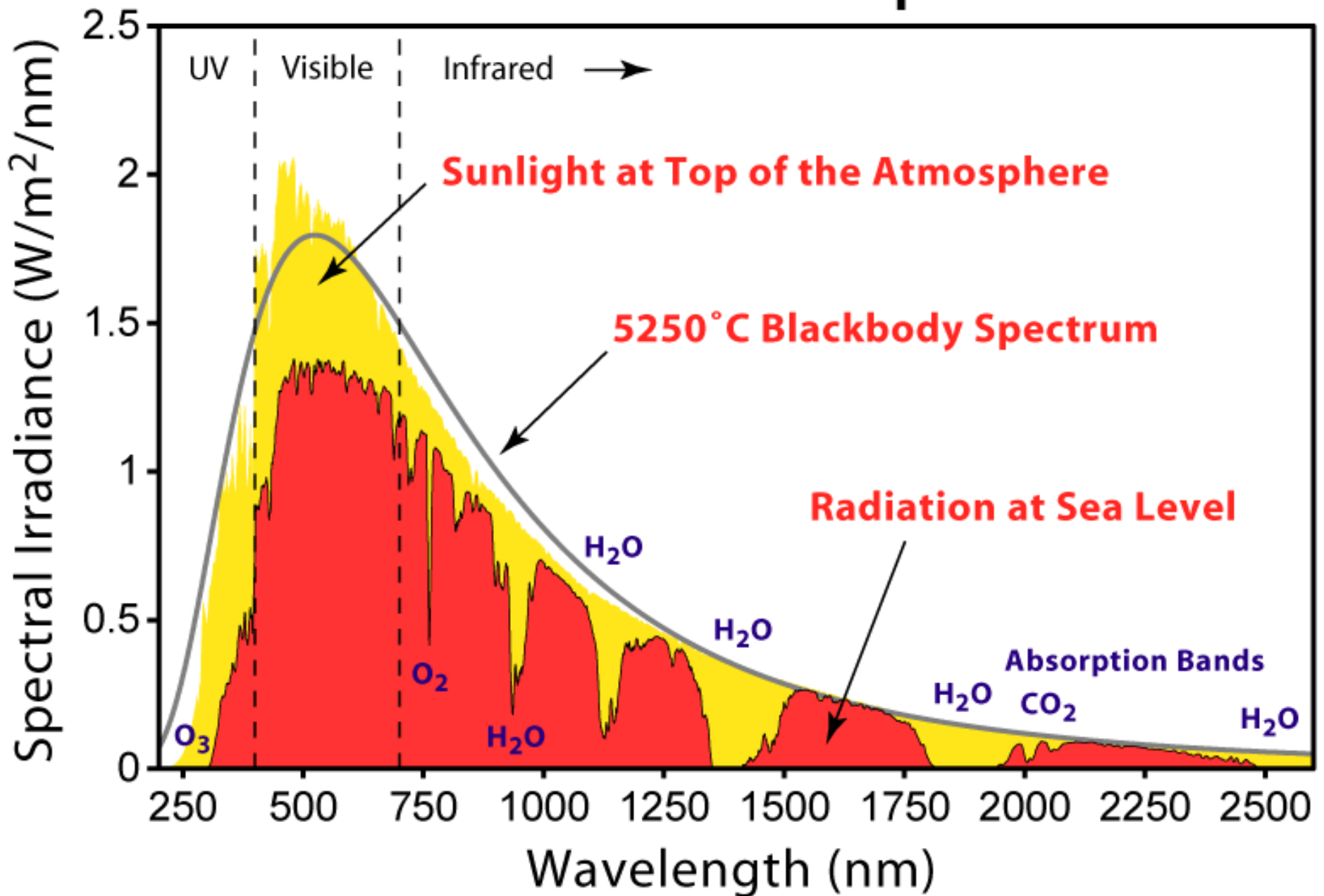
Himalayan Mtns

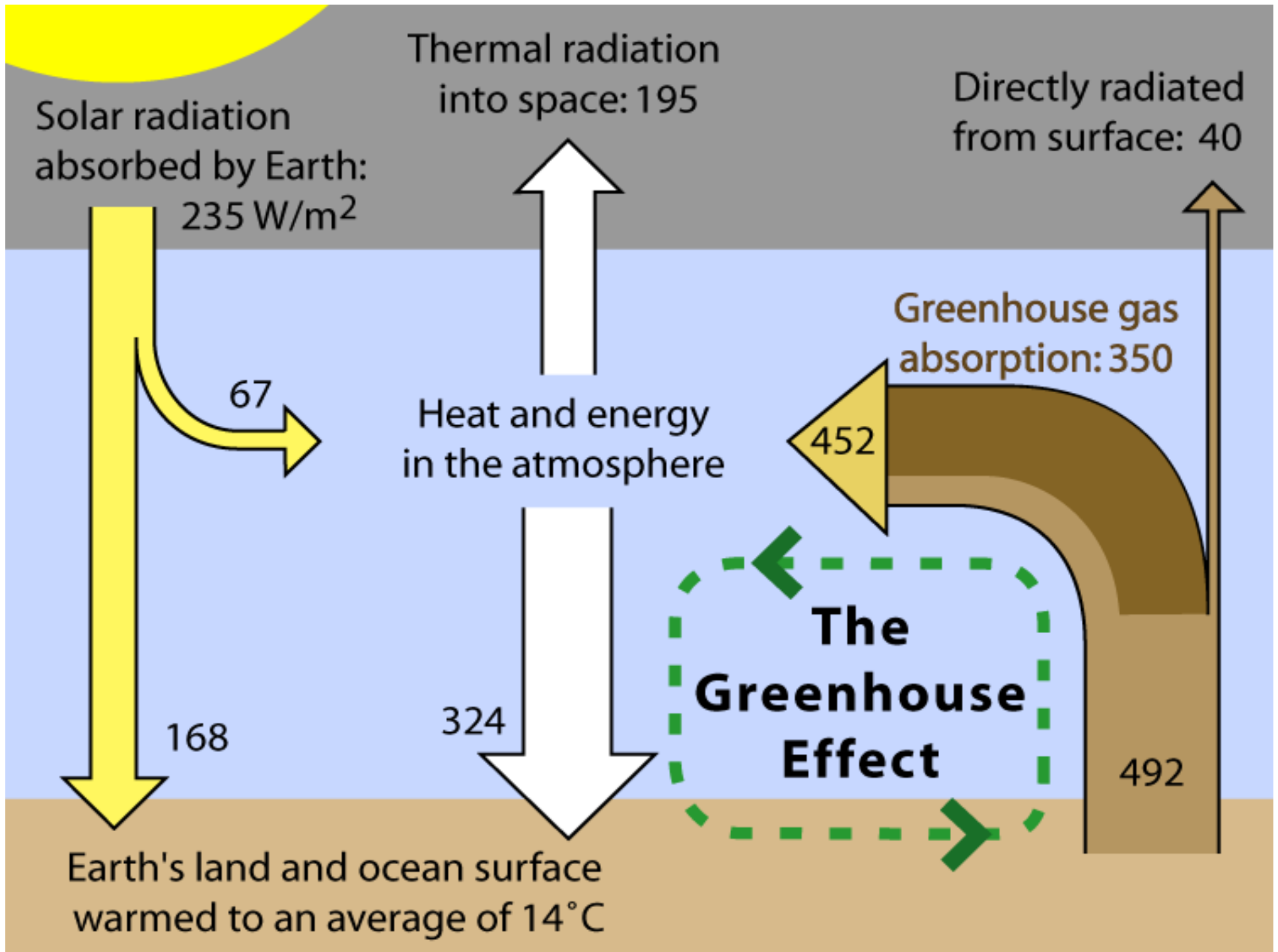
Close-up of Pangaea



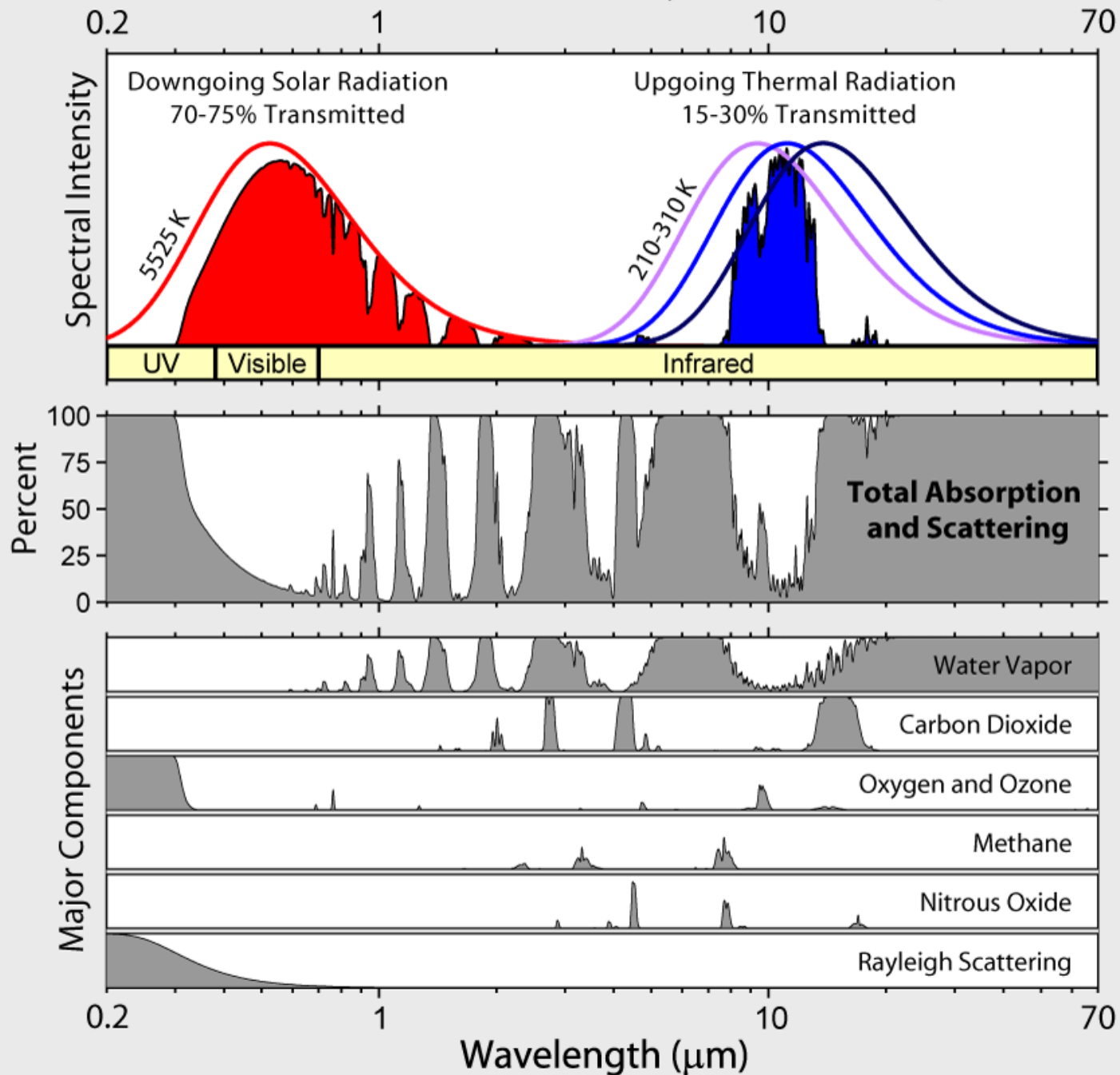


Solar Radiation Spectrum





Radiation Transmitted by the Atmosphere



Greenhouse Gases:

50% - Water Vapor

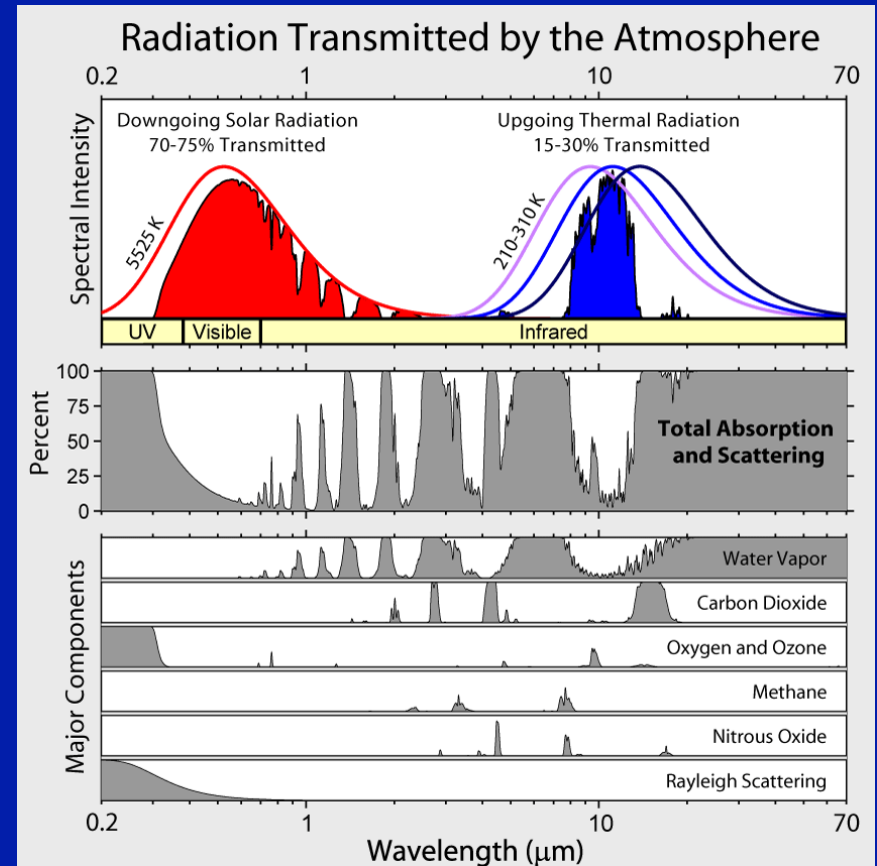
20% - Clouds

30% - CO₂ and everything else

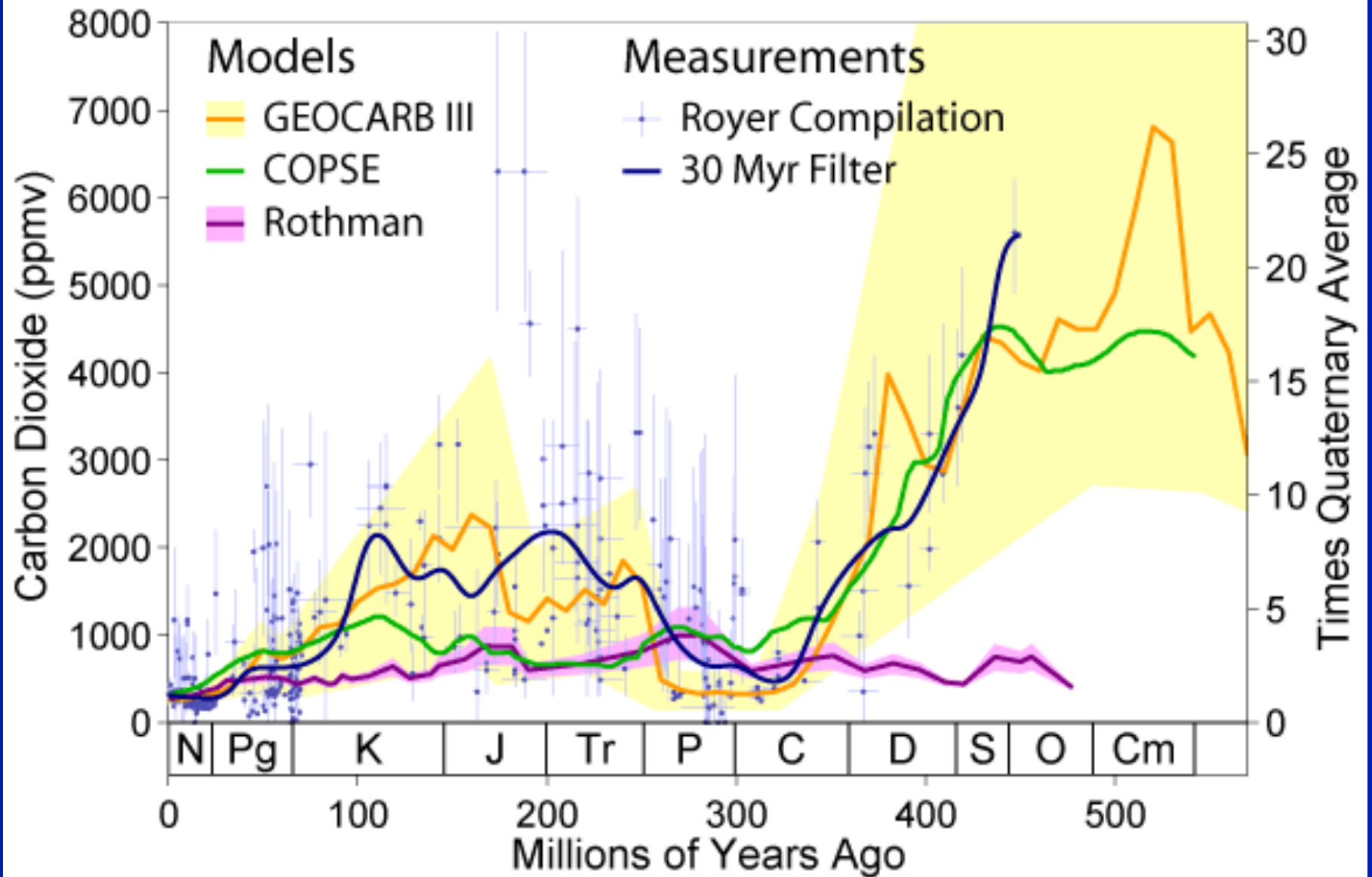
Why don't we hear more about water vapor?!?

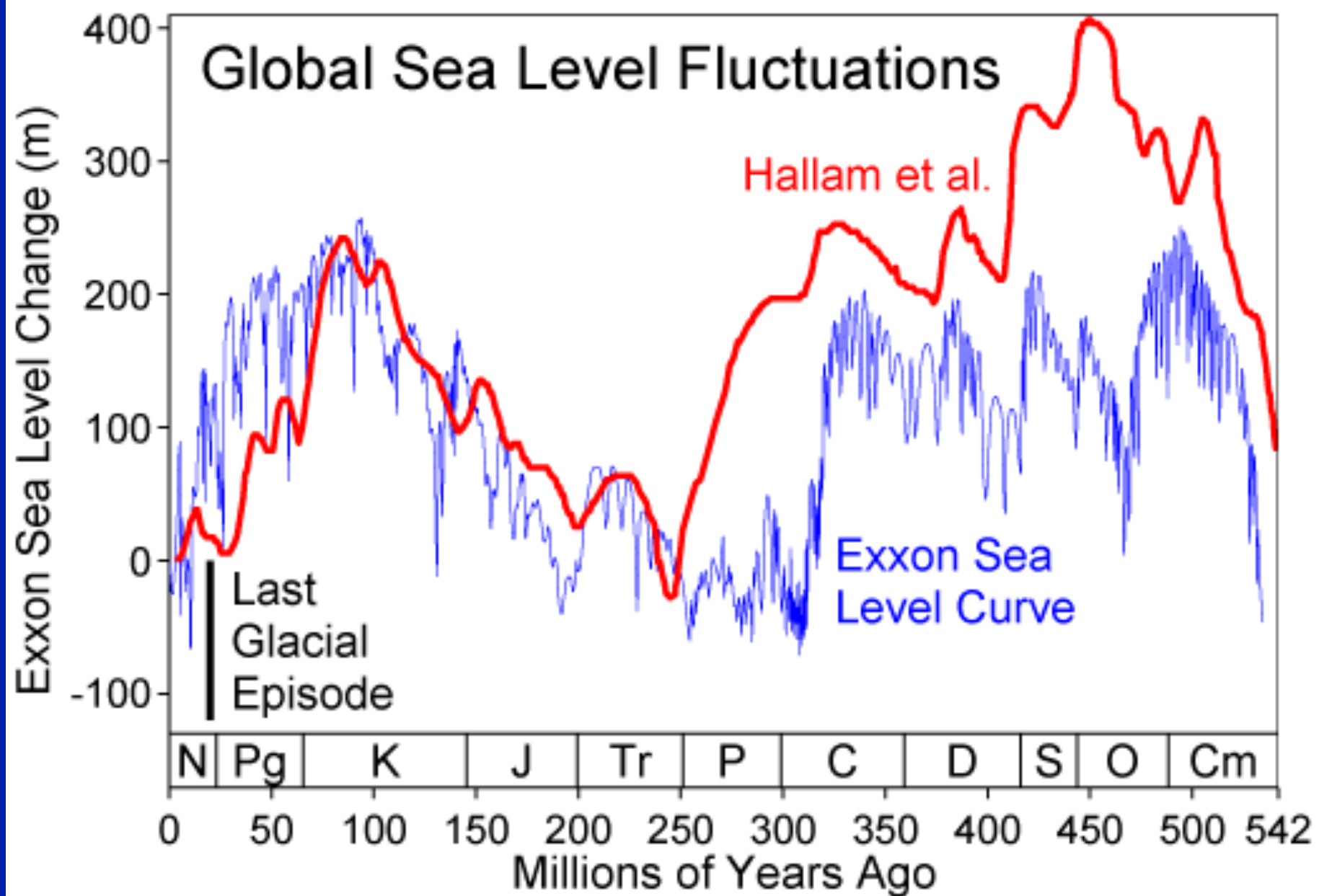
Human activities don't change water vapor content EXCEPT by increasing other greenhouse gases

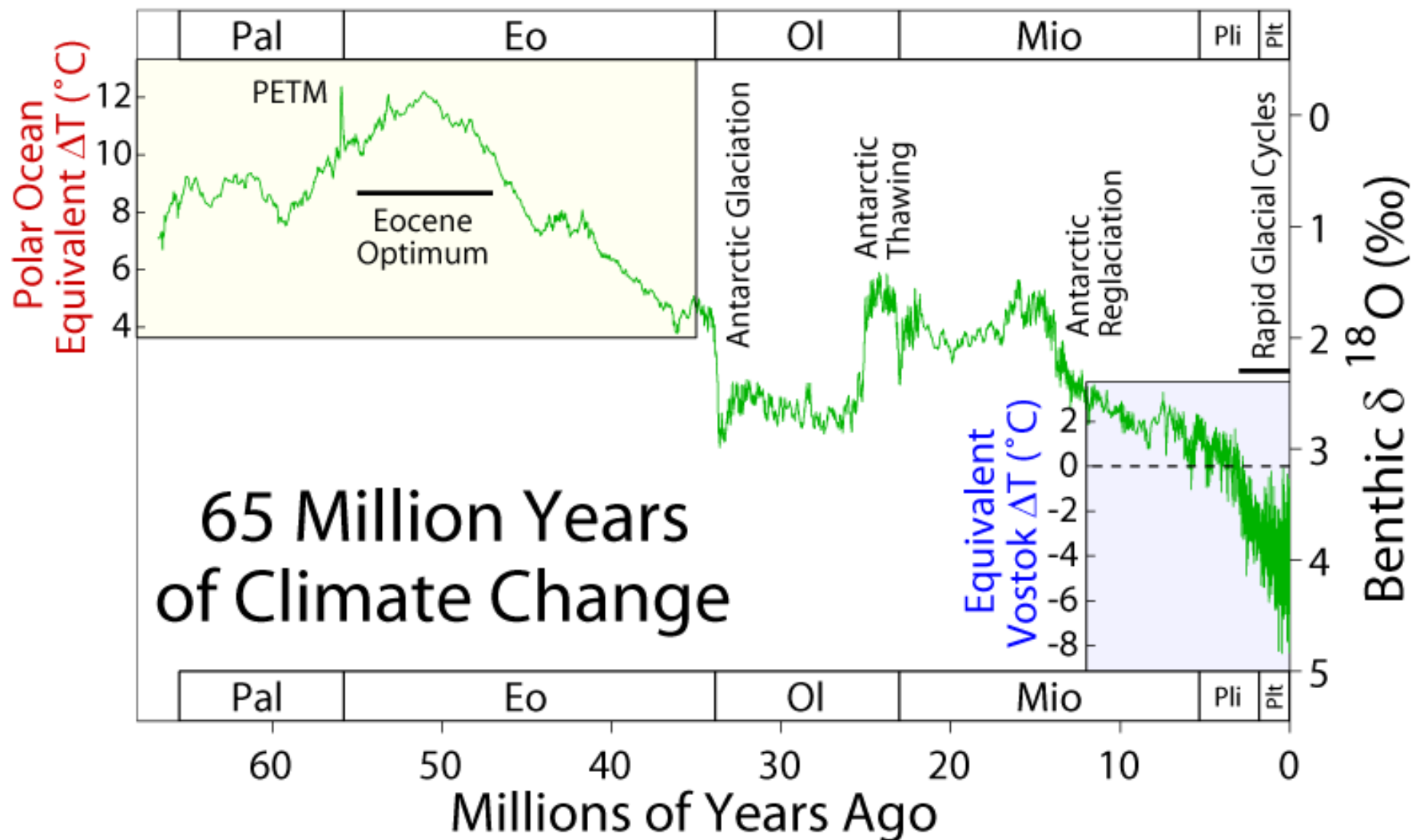
→ Positive Feedback!



Phanerozoic Carbon Dioxide

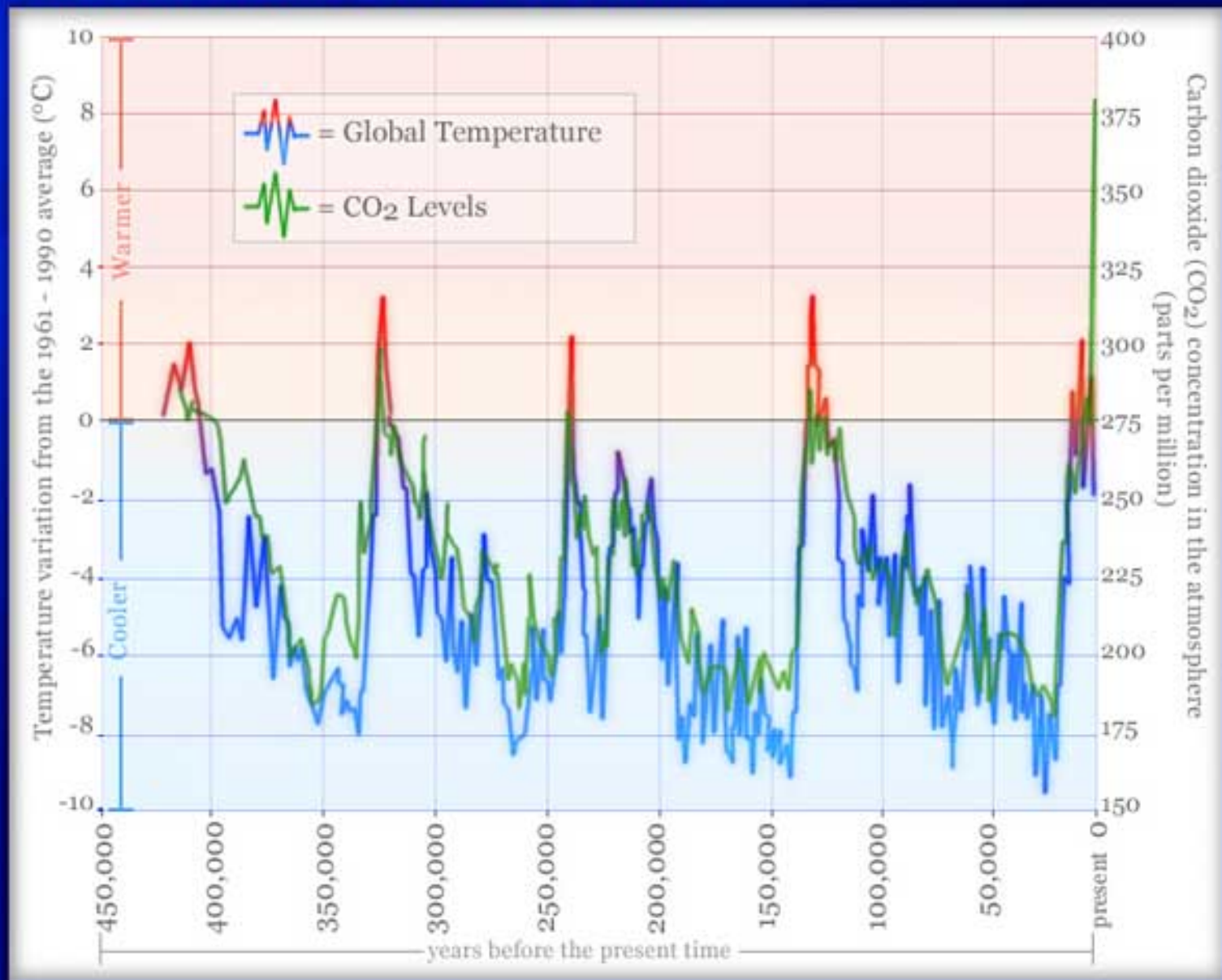




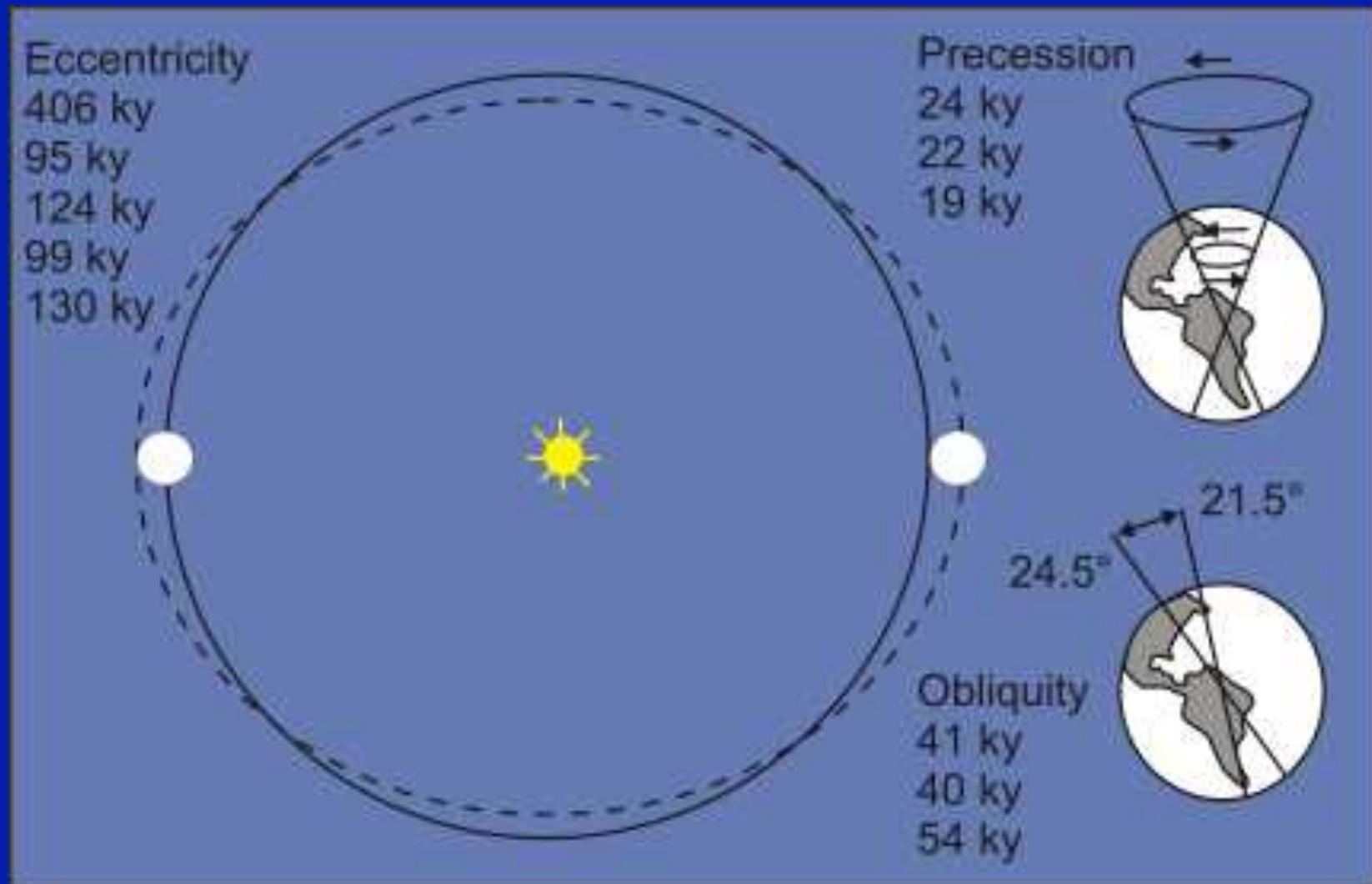


What drives the intermediate-term temperature changes?

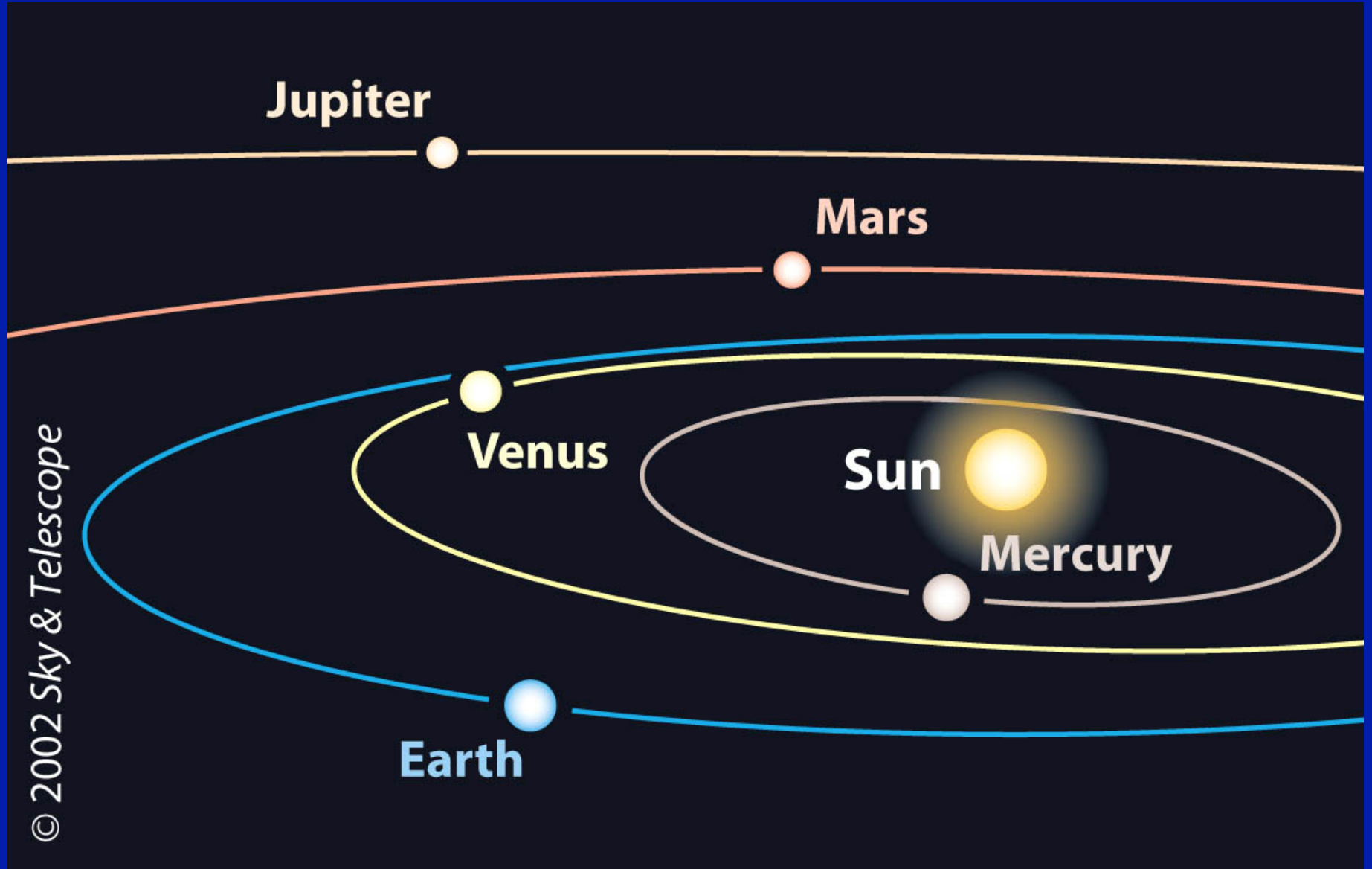
Carbon Dioxide Concentration

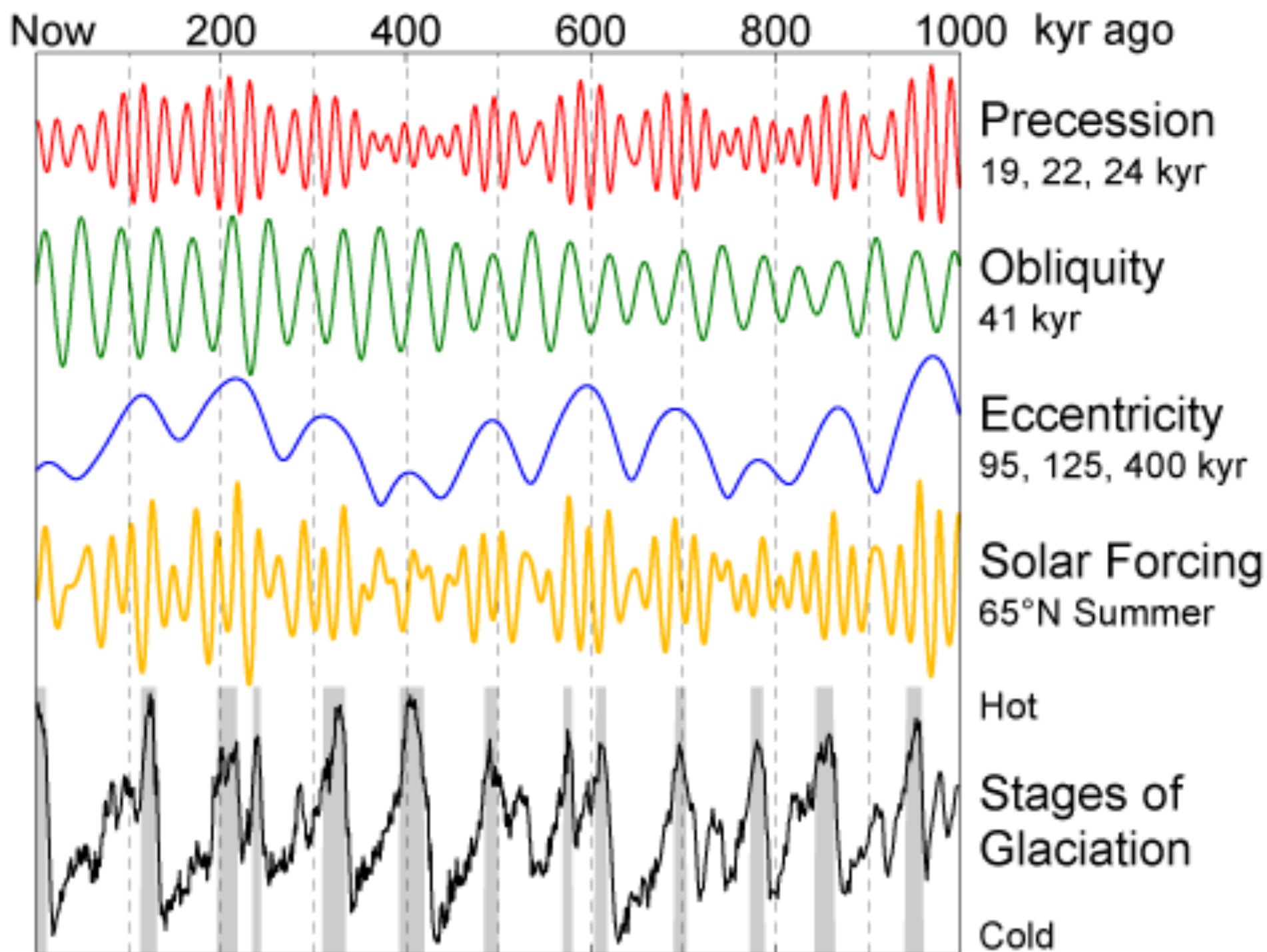


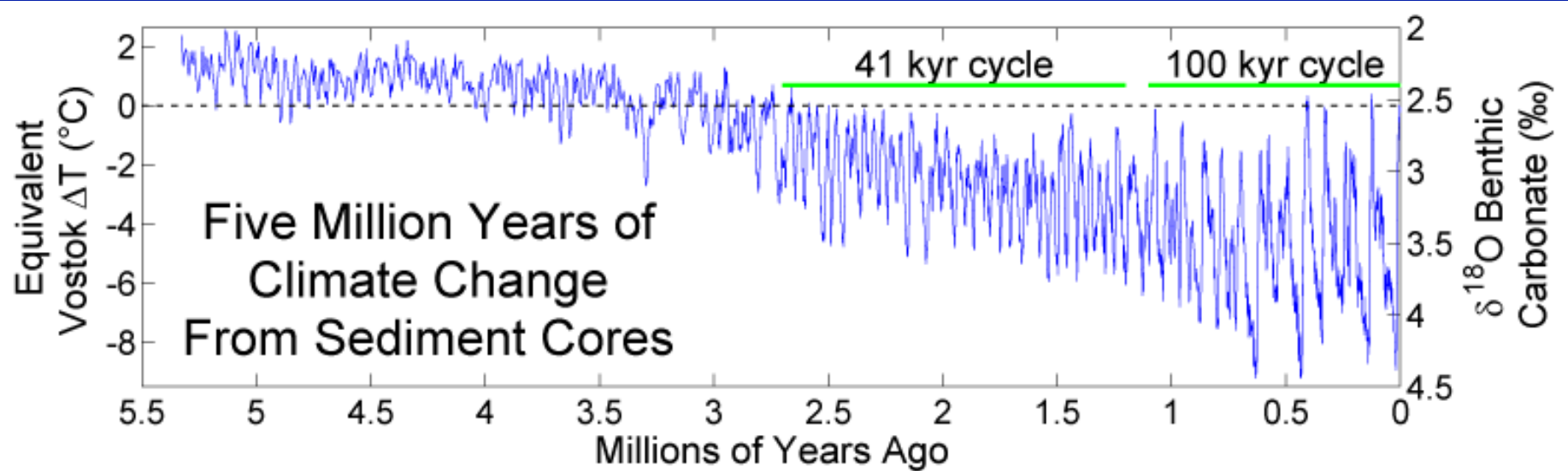
Fluctuations in Earth's Orbit (Milankovitch Cycles)



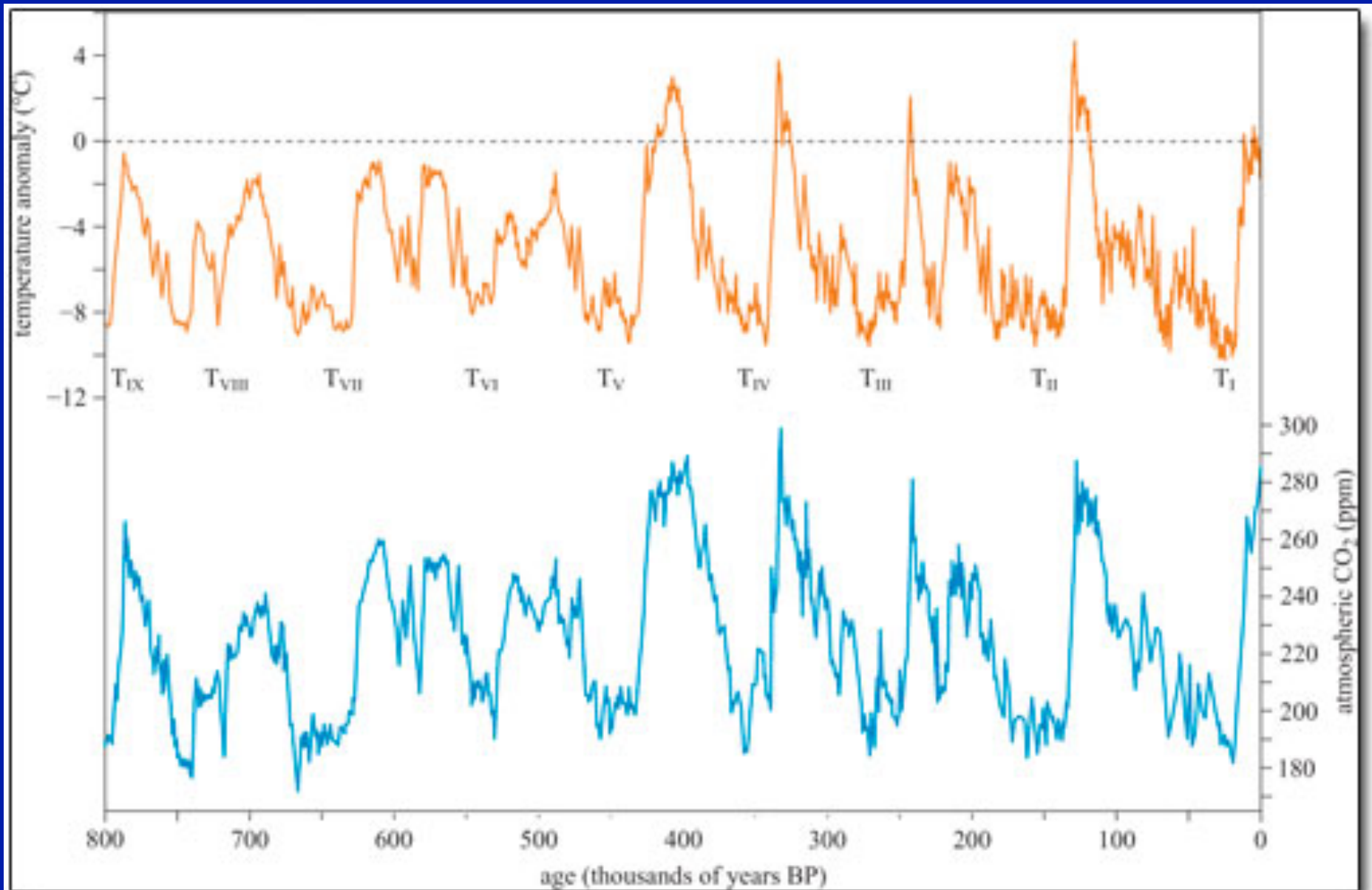
Ellipticity variations: Due to planetary orbits (gravity)







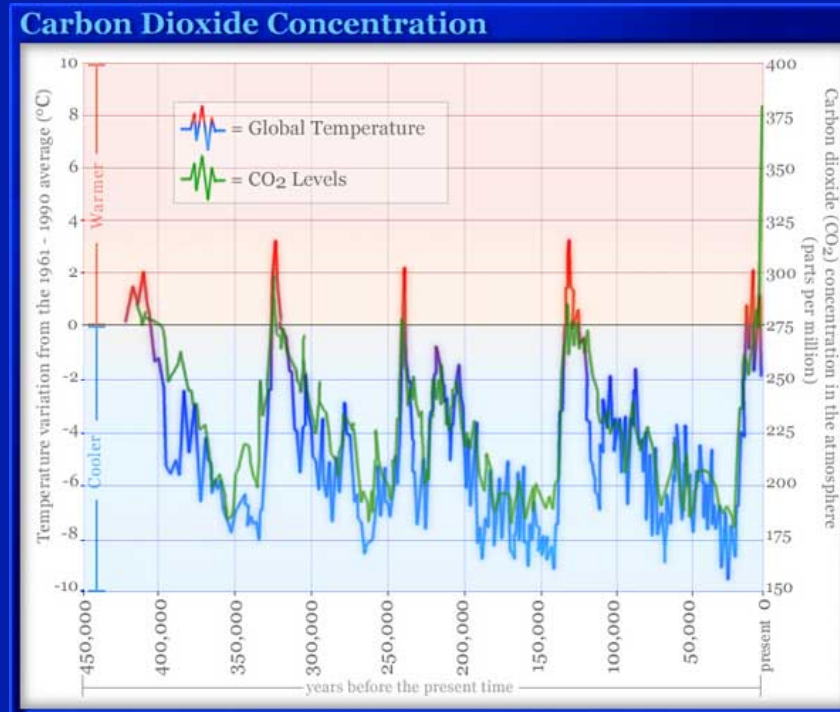
800,000-year record from EPICA Antarctica Ice Cores



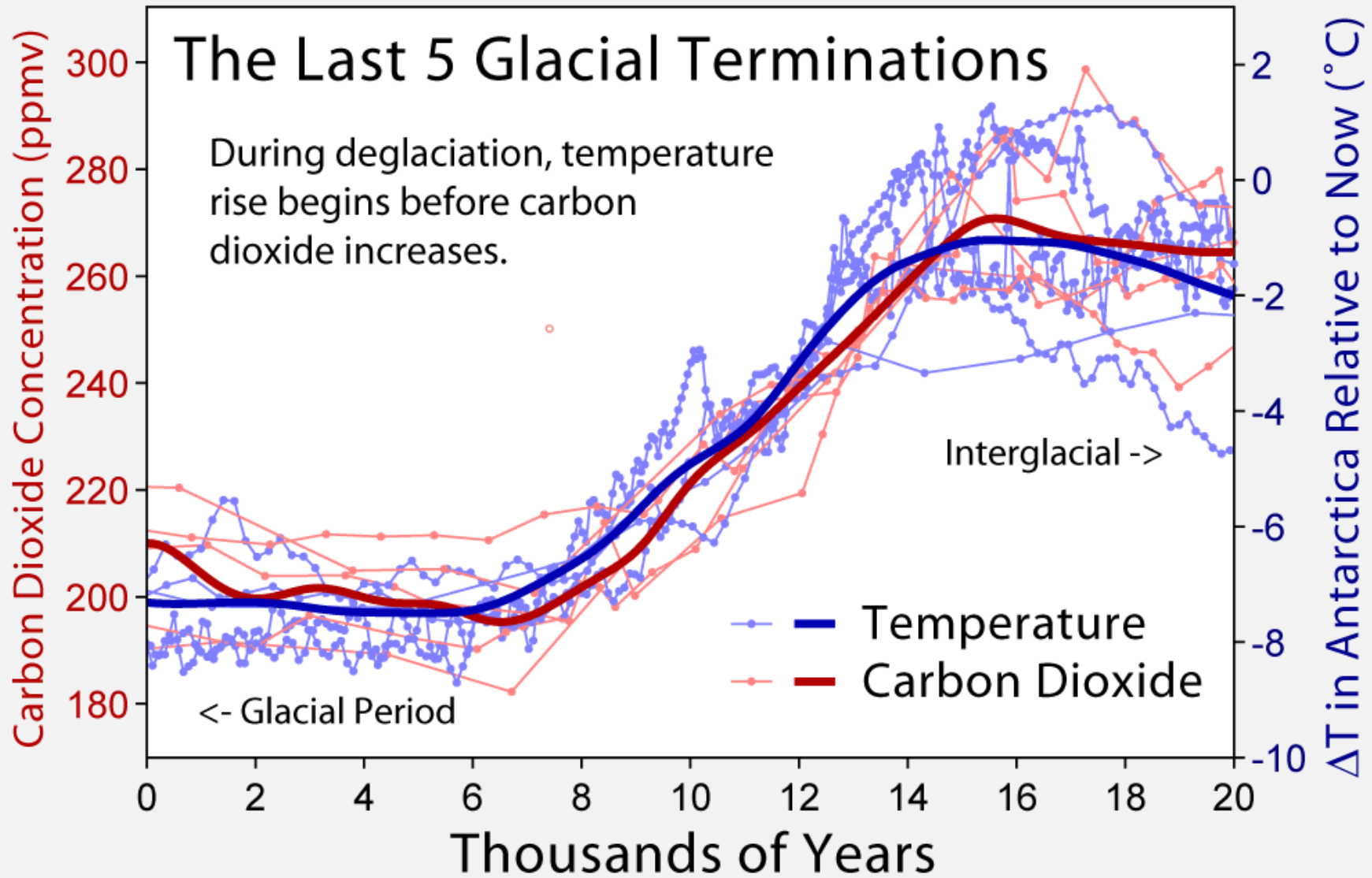
Carbon dioxide and temperature track each other:

→ *Increasing carbon dioxide increases temperature (Greenhouse effect)*

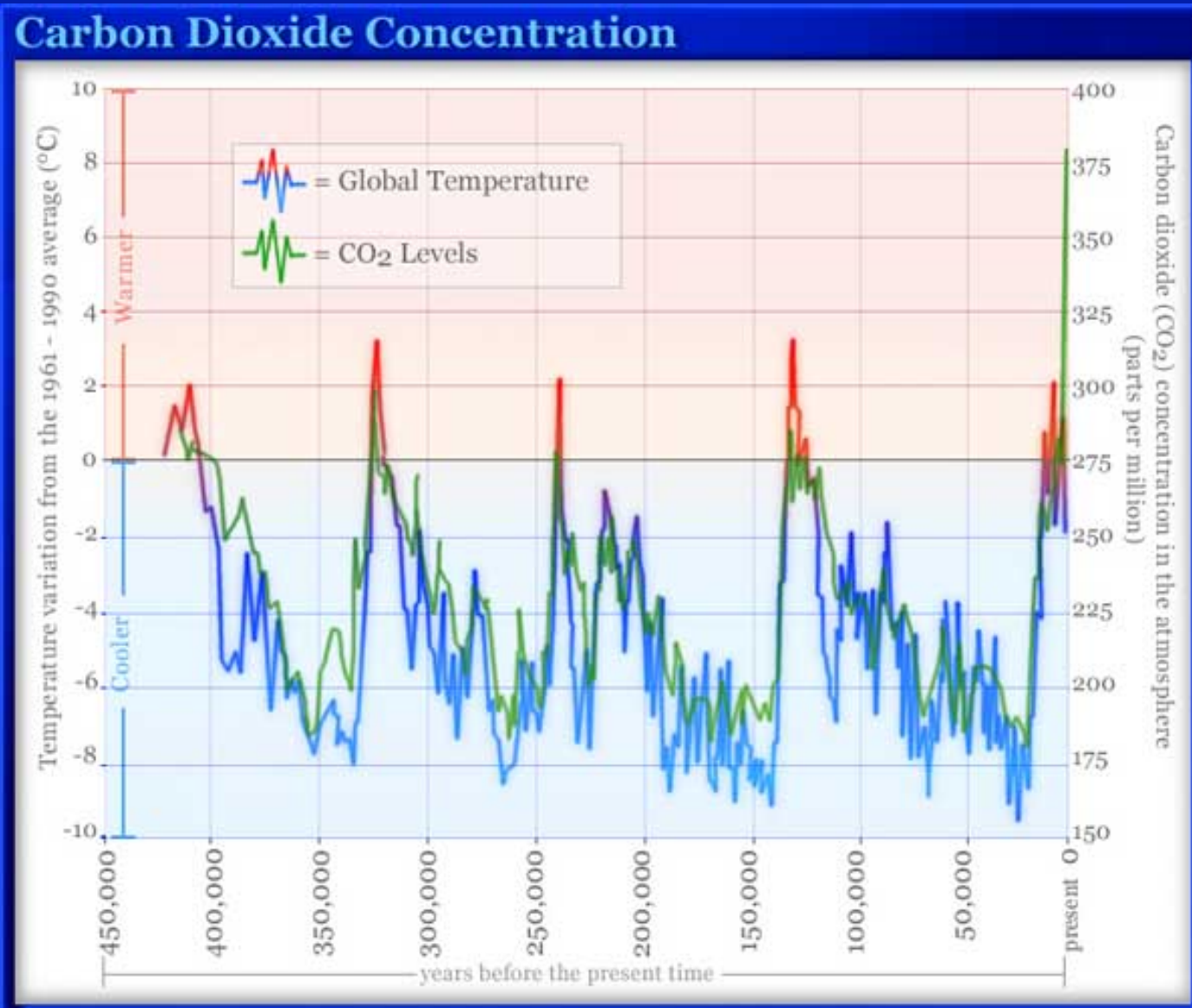
→ *Increasing temperature also increases carbon dioxide (During cold times, more carbon dioxide is stored in the ocean, due to changes in physical mixing, ocean chemistry, and biological activity)*

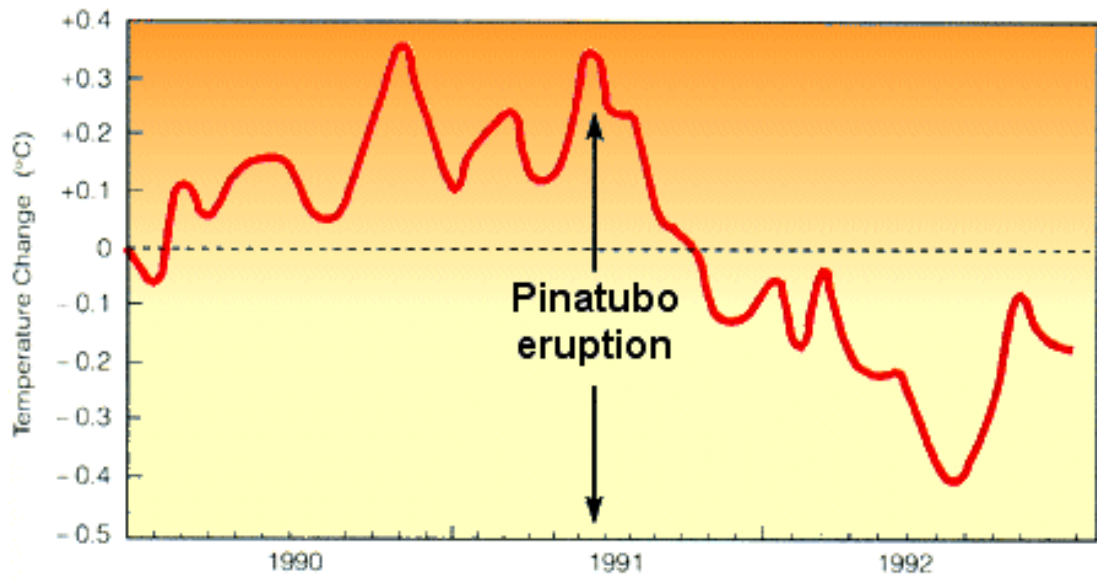


During Interglacial Starts, CO₂ lags Temperature by about 800 years due to Deep Ocean Circulation



What causes short-term climate variations? (*Lots of things!*)



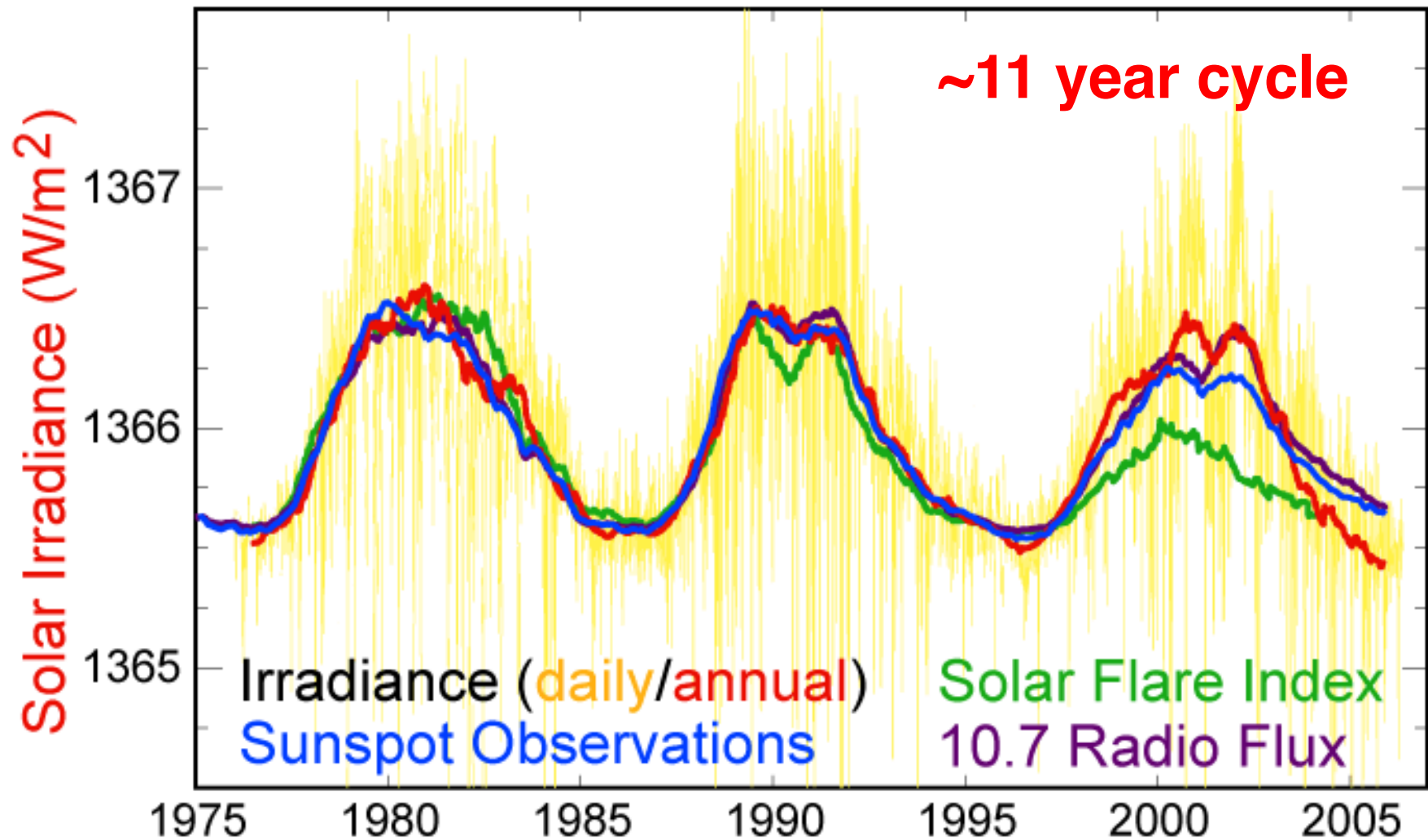


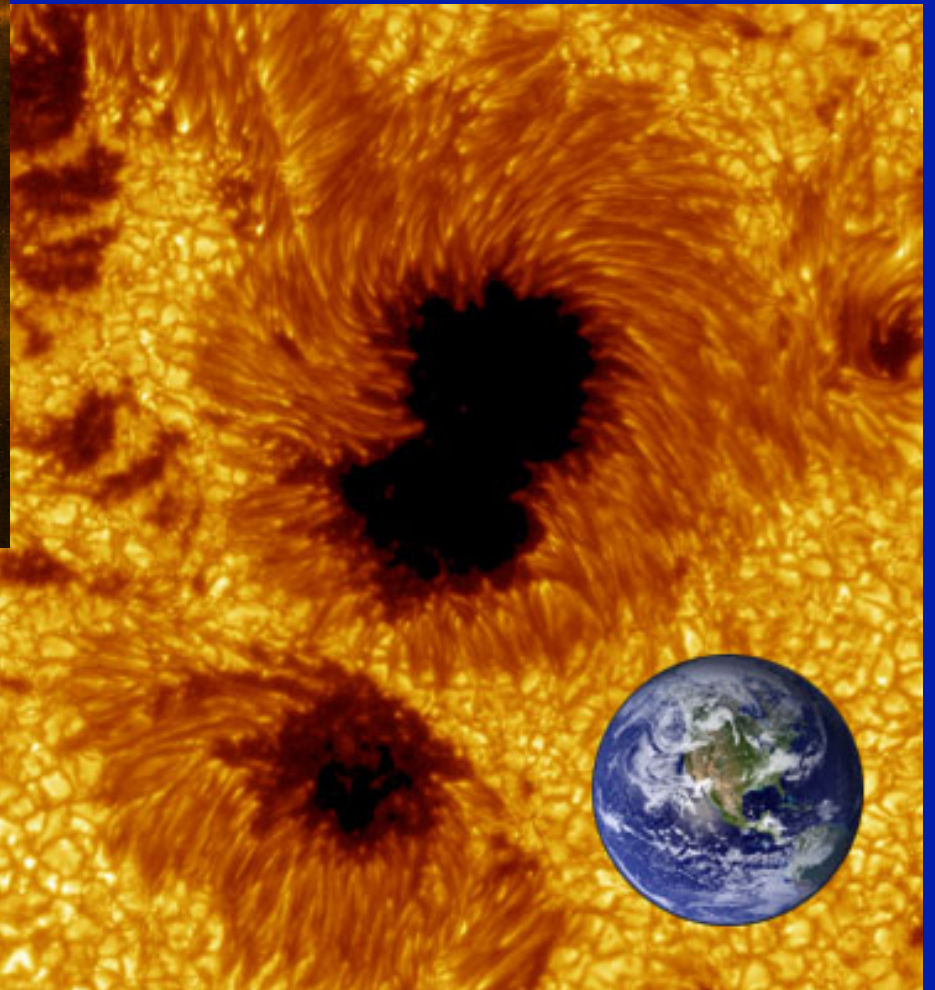
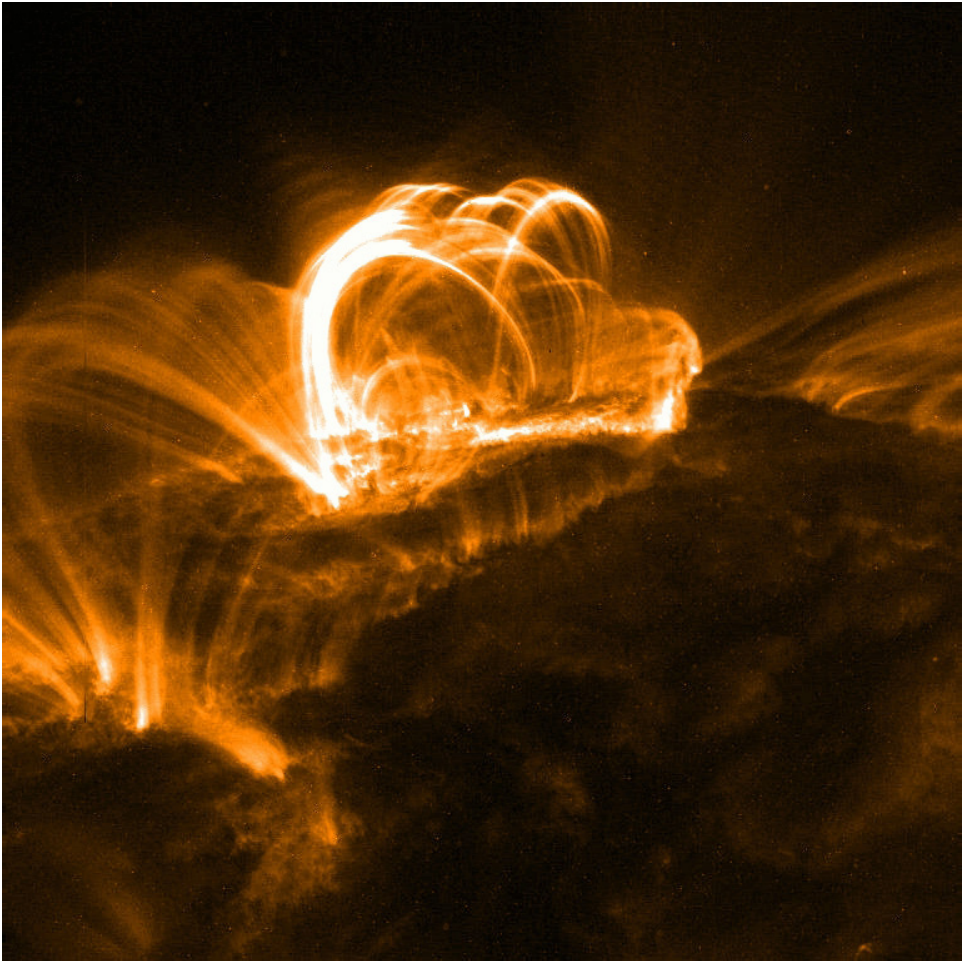
Volcanic Eruptions

Mt. Pinatubo, 1991:
So much ash & aerosols into the atmosphere that Earth's temperature dropped, and sunsets were redder.



Solar Cycle Variations



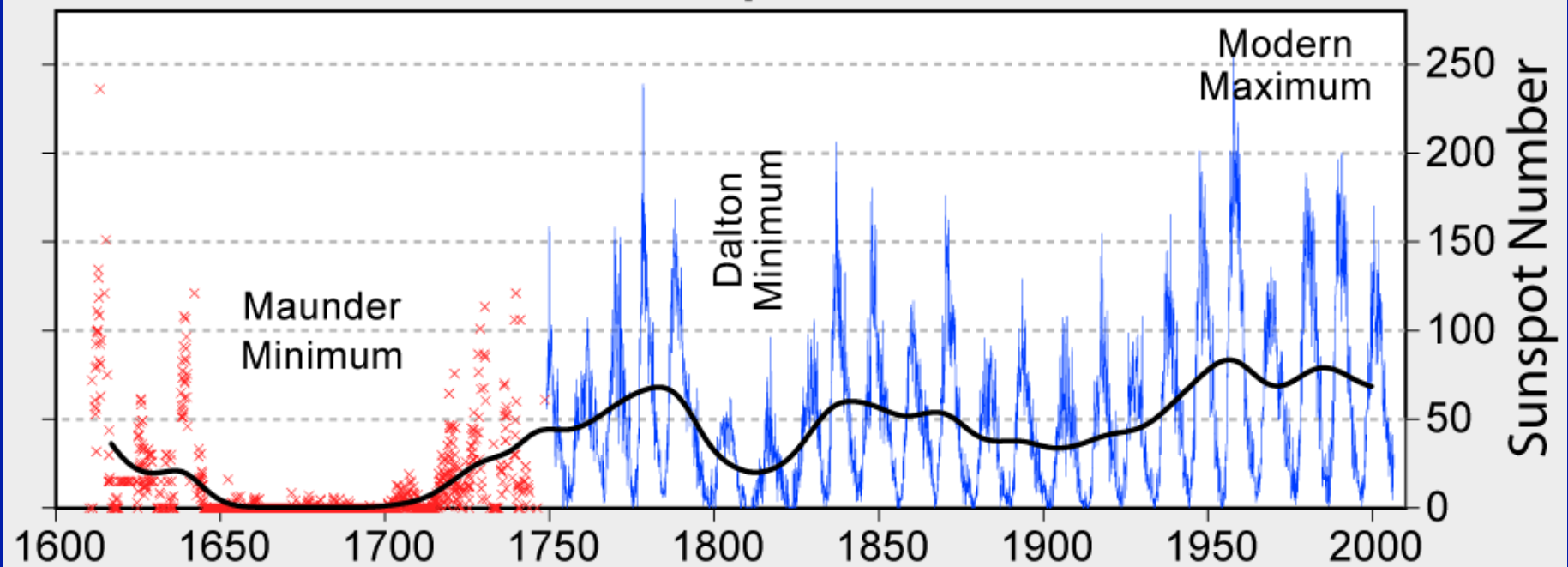


of Sunspots Correlates with Temperature:

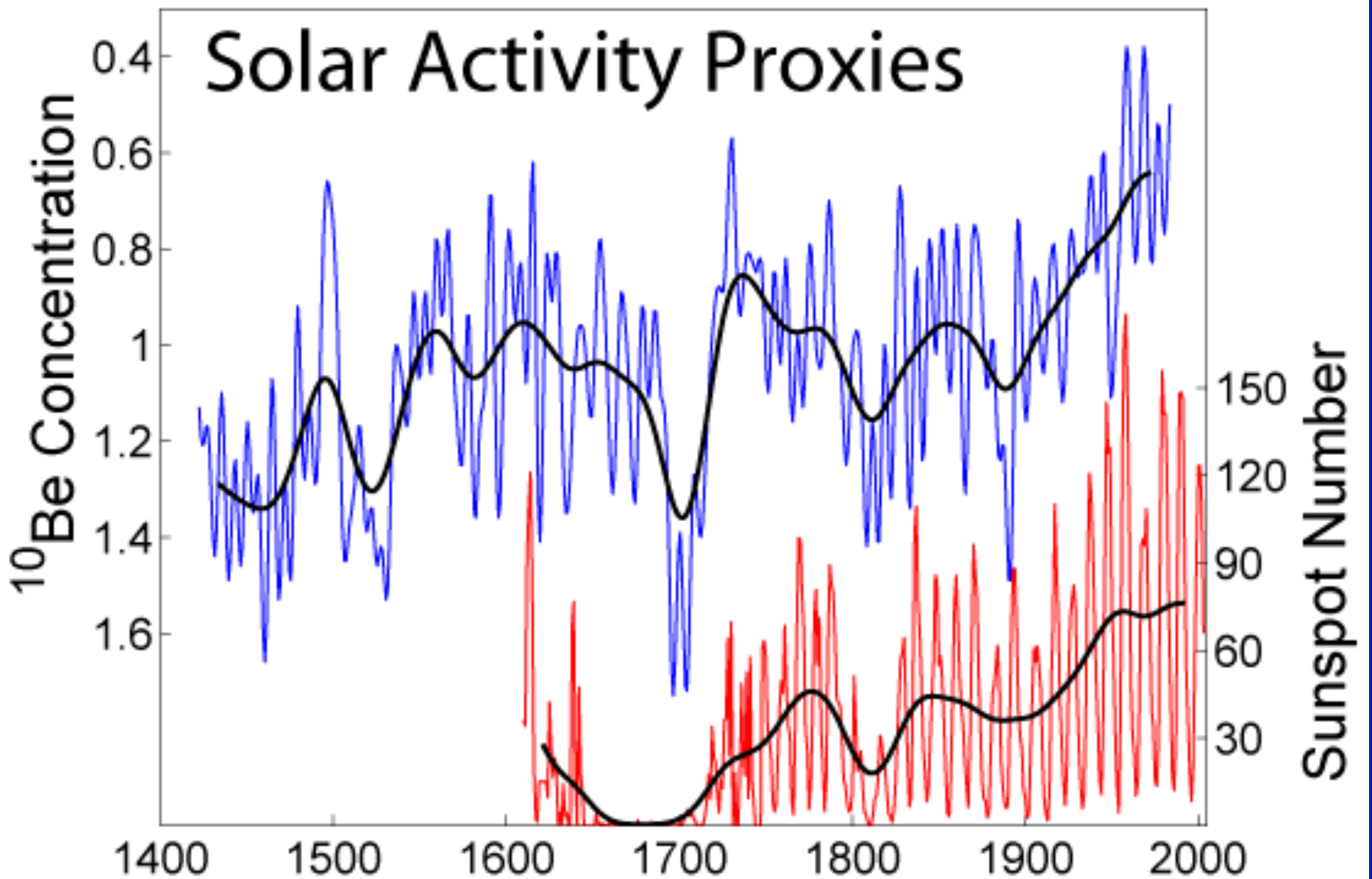
Many Sunspots = Warm

Few Sunspots = Cold

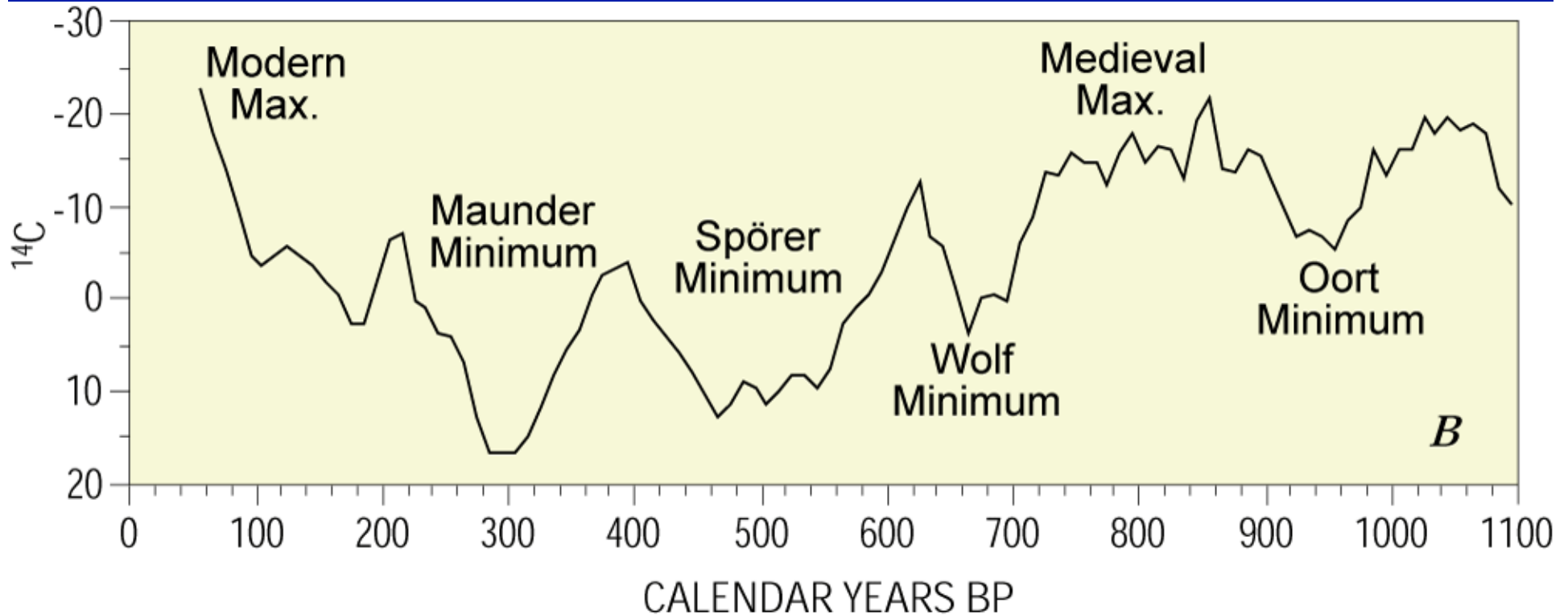
400 Years of Sunspot Observations



Solar Activity Proxies



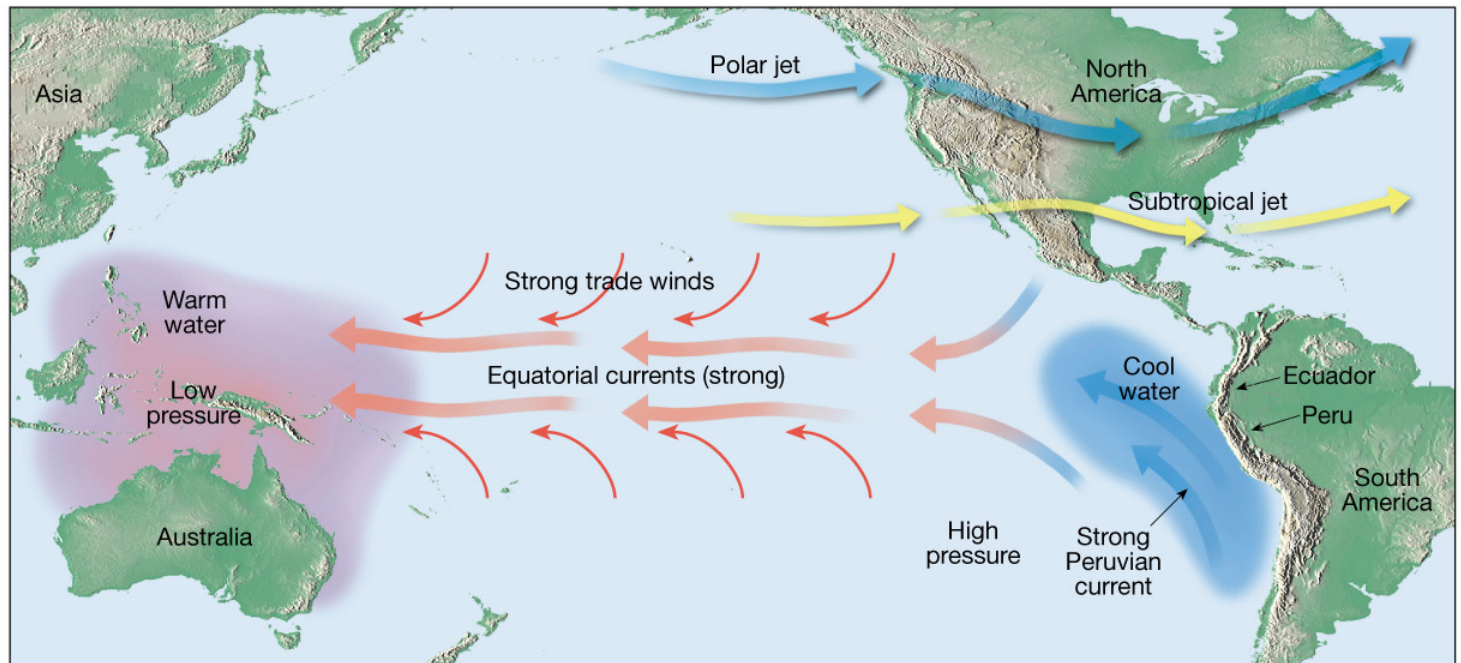
Past Solar Activity from Atmospheric C-14 Production



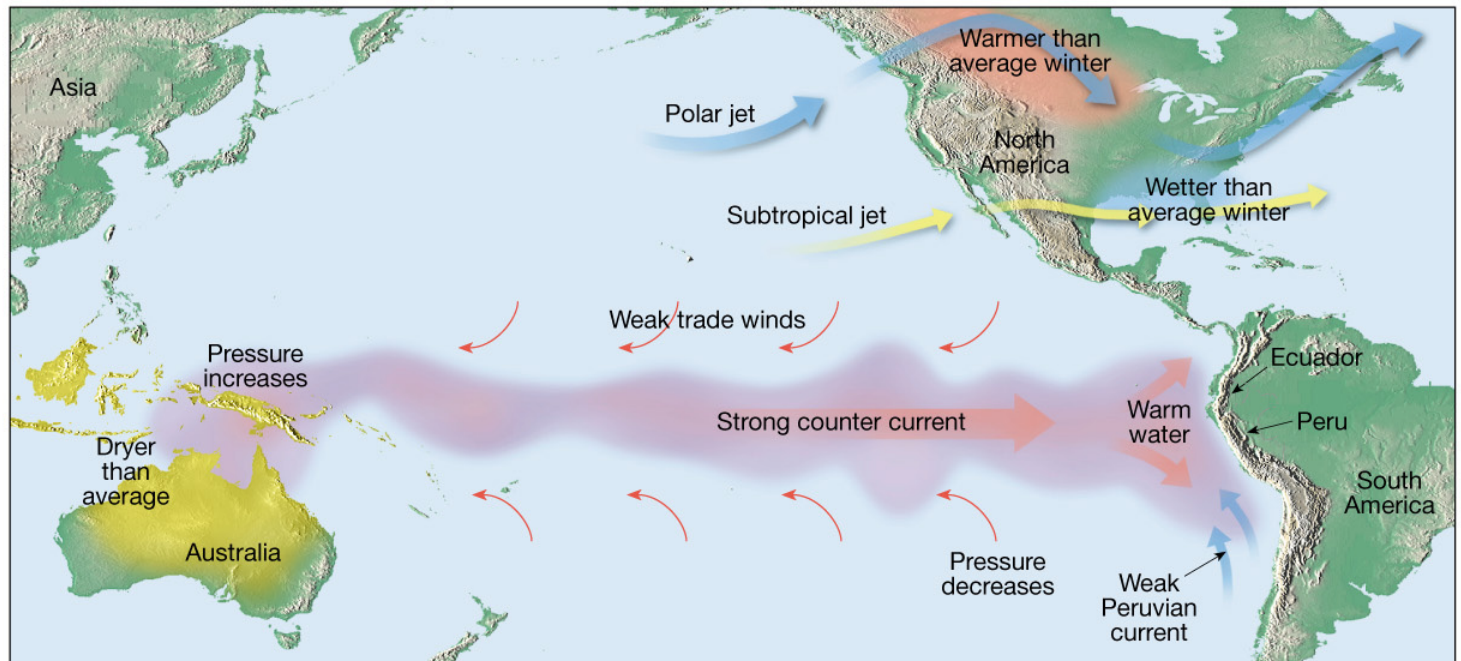
Temperature variations over centuries may be strongly driven by solar output.

Shorter Changes: Events like El Niño

*(affect
temperature
variations
over scales
of decades)*



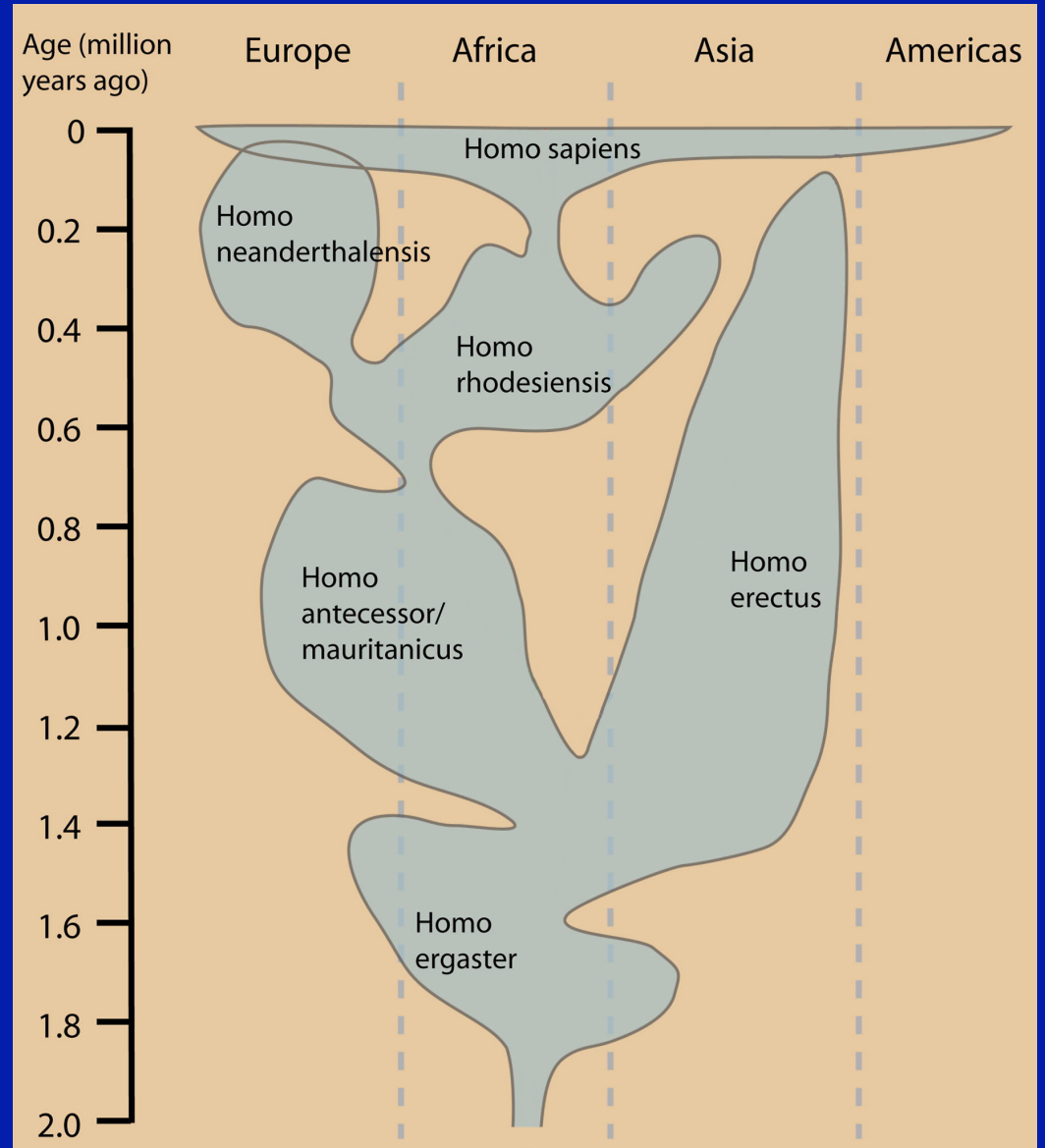
A. Normal conditions



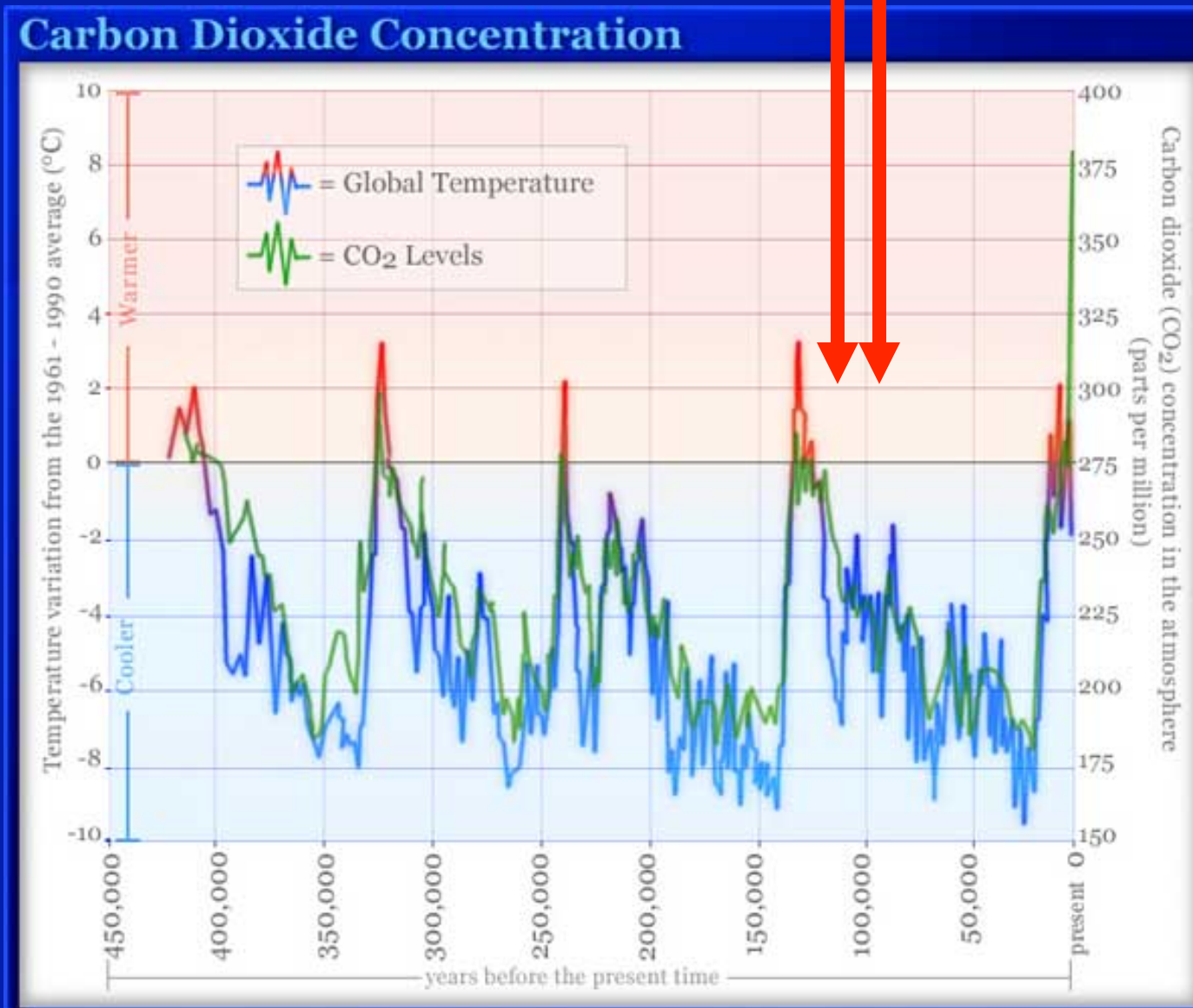
B. El Niño



By 100,000 years ago, Homo Sapiens was emerging as the dominant hominid. Why?



?? Selection for large brains during strong Ice Ages that occurred 120,000-90,000 years ago??



WARNING*

(* Correlation does not necessarily imply causation)



*50,000-40,000 years ago
there was a cultural
explosion in Europe.*

Why?

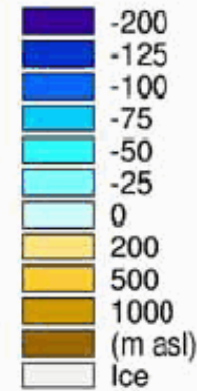
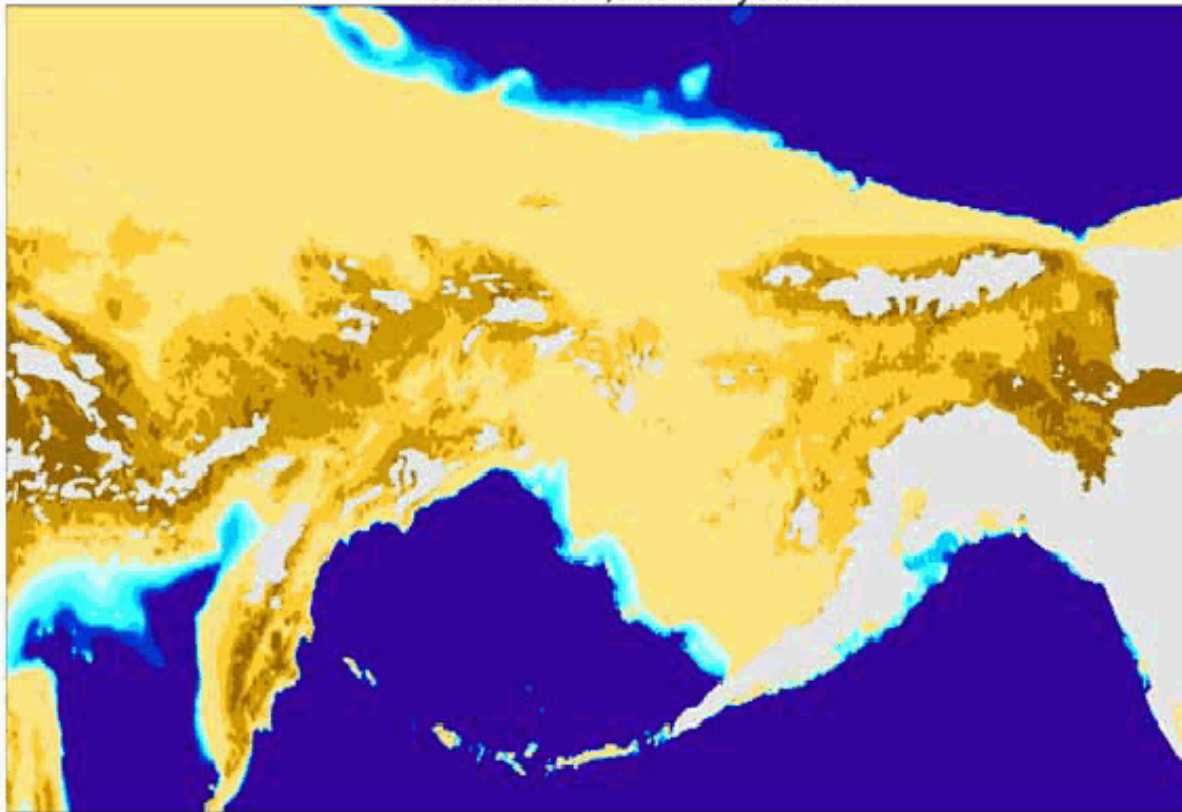
**Warming trend in Europe.
Life was easier?**



*North American Mammoths evolved in Asia.
How did they get here 20,000 years ago?*



Coastline 21,000 Cal years BP



→ 20,000 years ago was time of Ice Ages. Sea levels were low. Mammoths walked here.

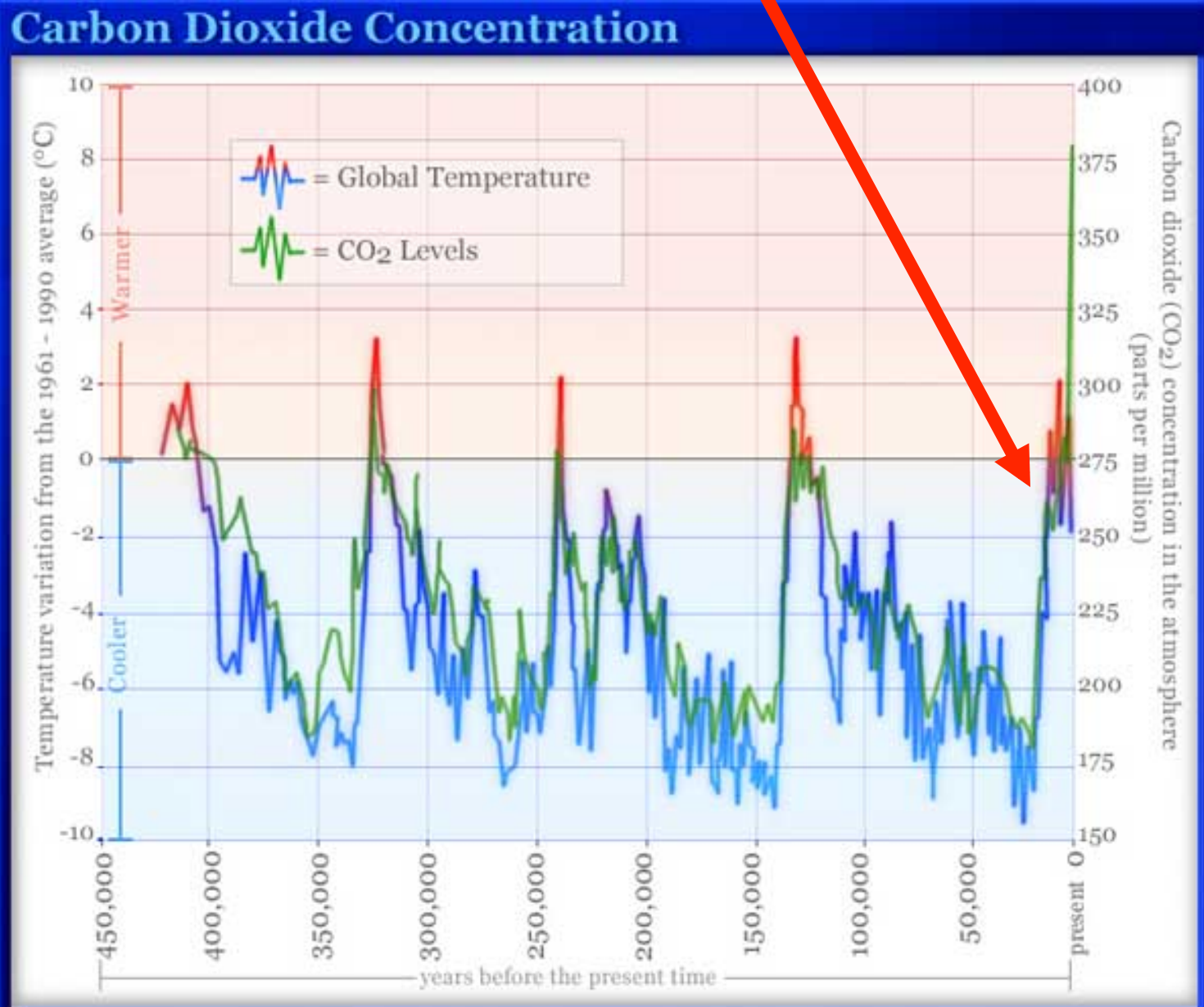
→ Native Americans followed 14,000 years ago (at least)!

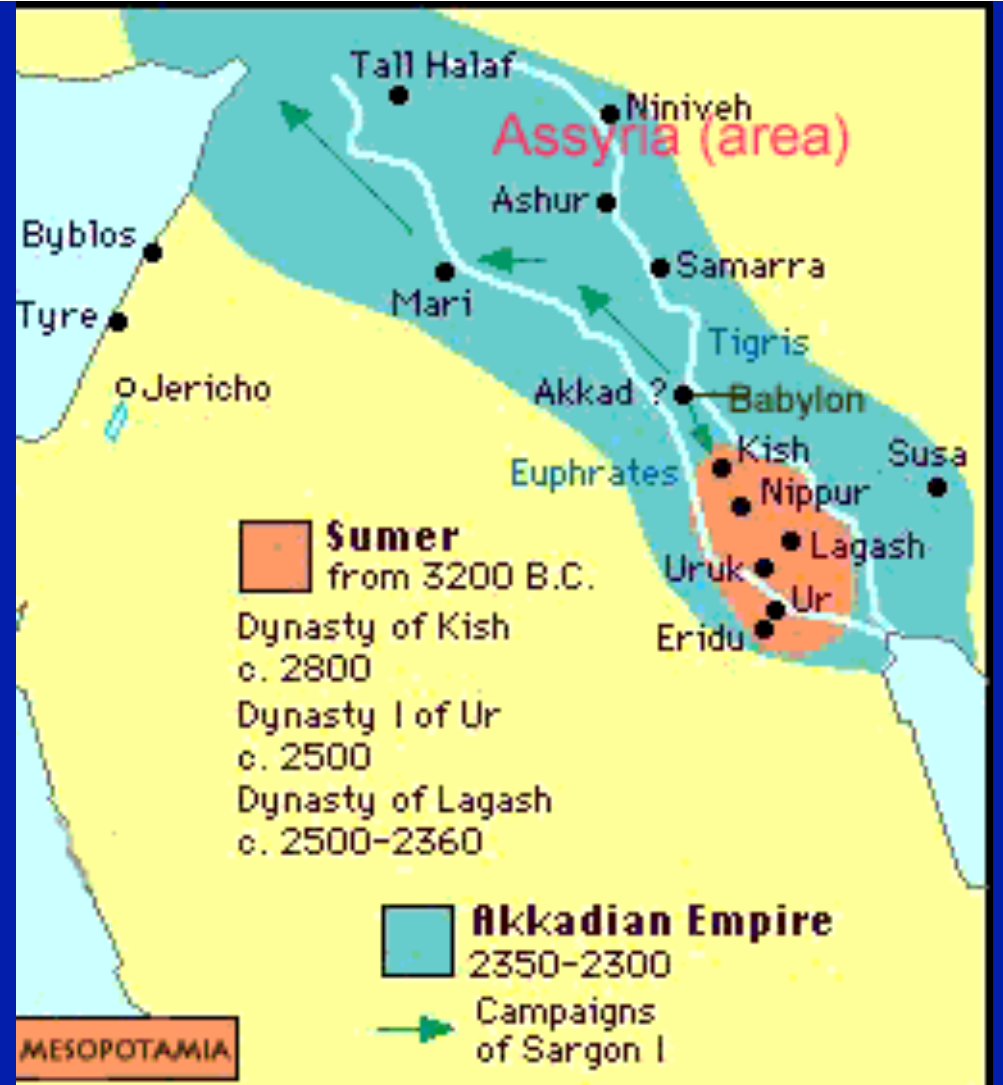
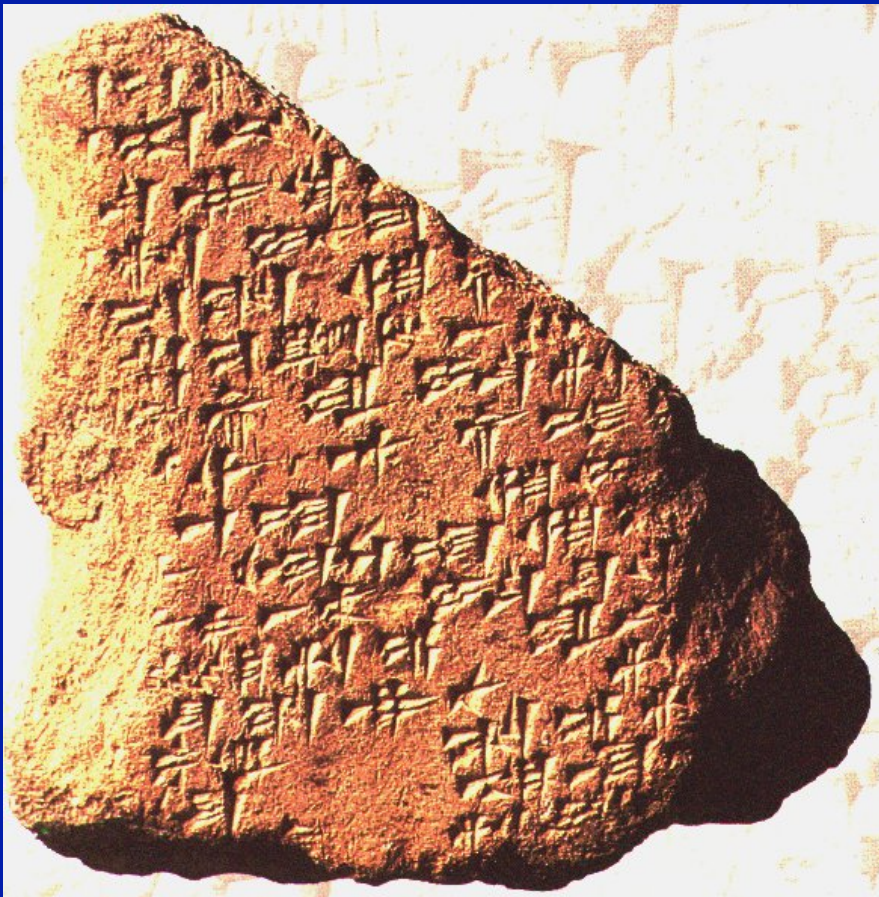


The beginnings of civilization didn't occur until 10,000 years ago. Why?



The start of a warm and relatively stable climate period!



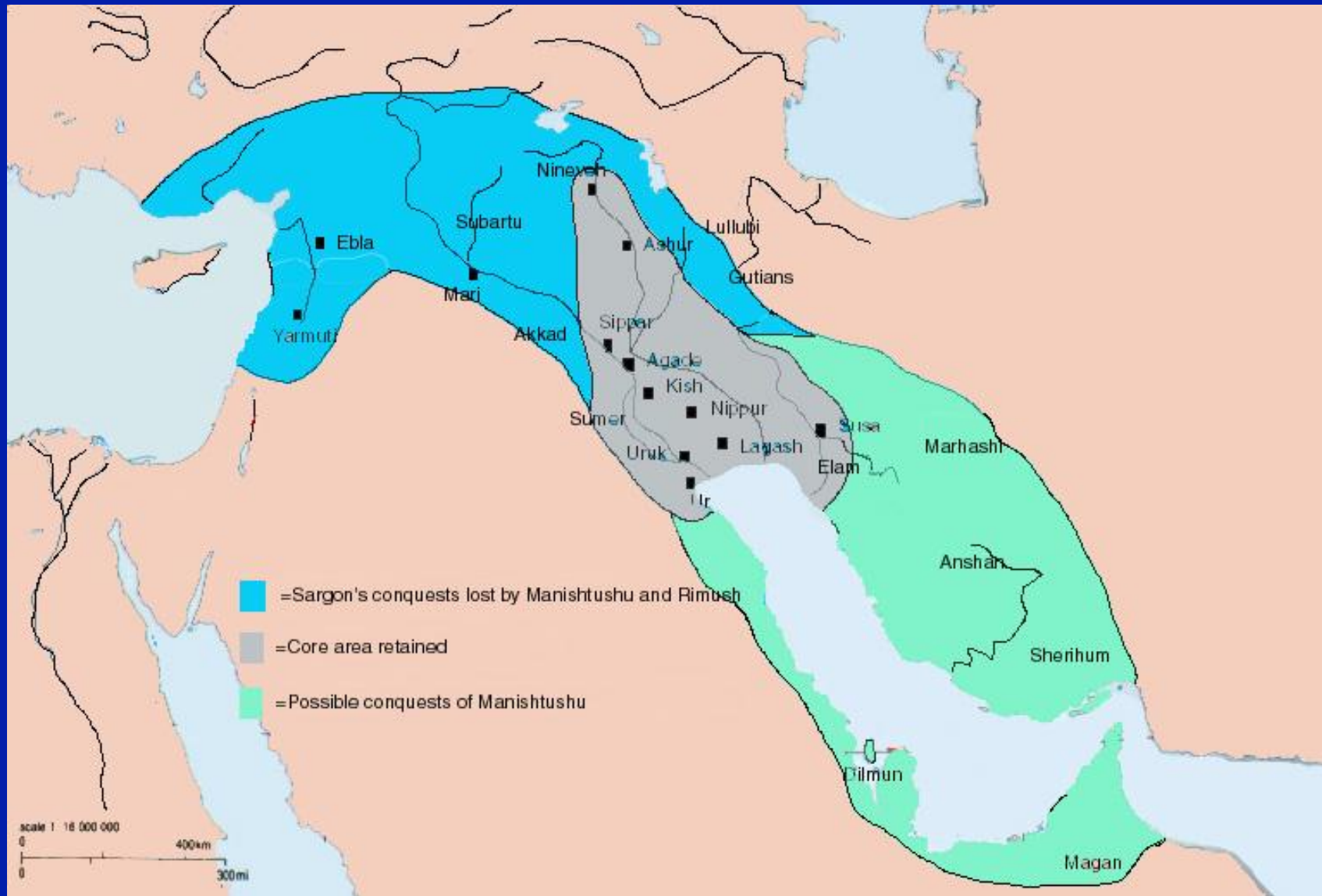


3000 BCE: Time of alternating droughts and flooding.

→ Complex societies like Akkadian Empire evolve in order to survive.



Story of Joseph warning the Egyptian Pharaoh to prepare for 7 lean years.

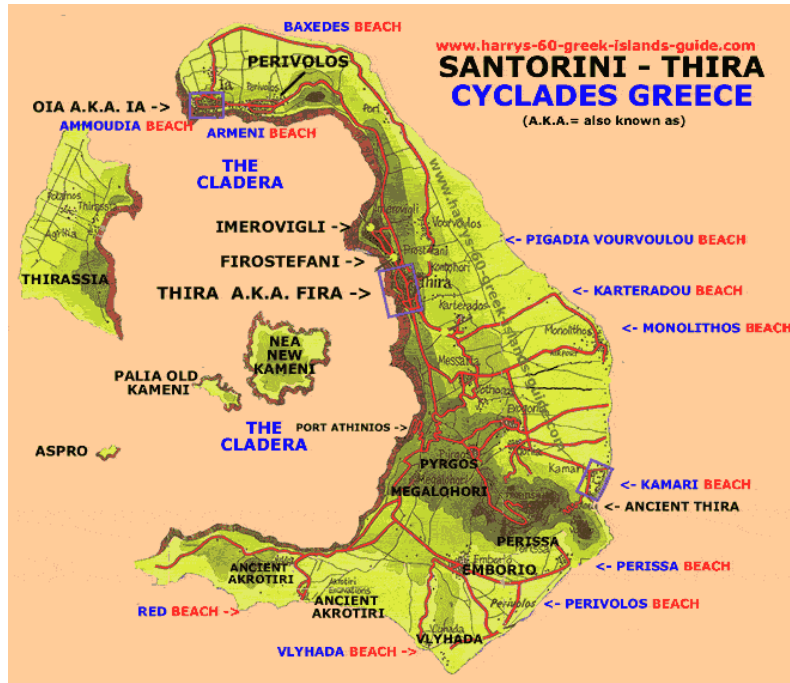


2200 BCE: Period of extended drought contributes to collapse of Akkadian Empire.



**1900 BCE: Cold and dry period.
→ Desertification contributes to
collapse of Indus Civilizations.**





www.harrys-60-greek-islands-guide.com
SANTORINI - THIRA
CYCLADES GREECE
 (A.K.A.= also known as)

1628 BCE: eruption of Mt. Thera

*** Minoan Culture ends 200 years later, overrun by Myceneans**

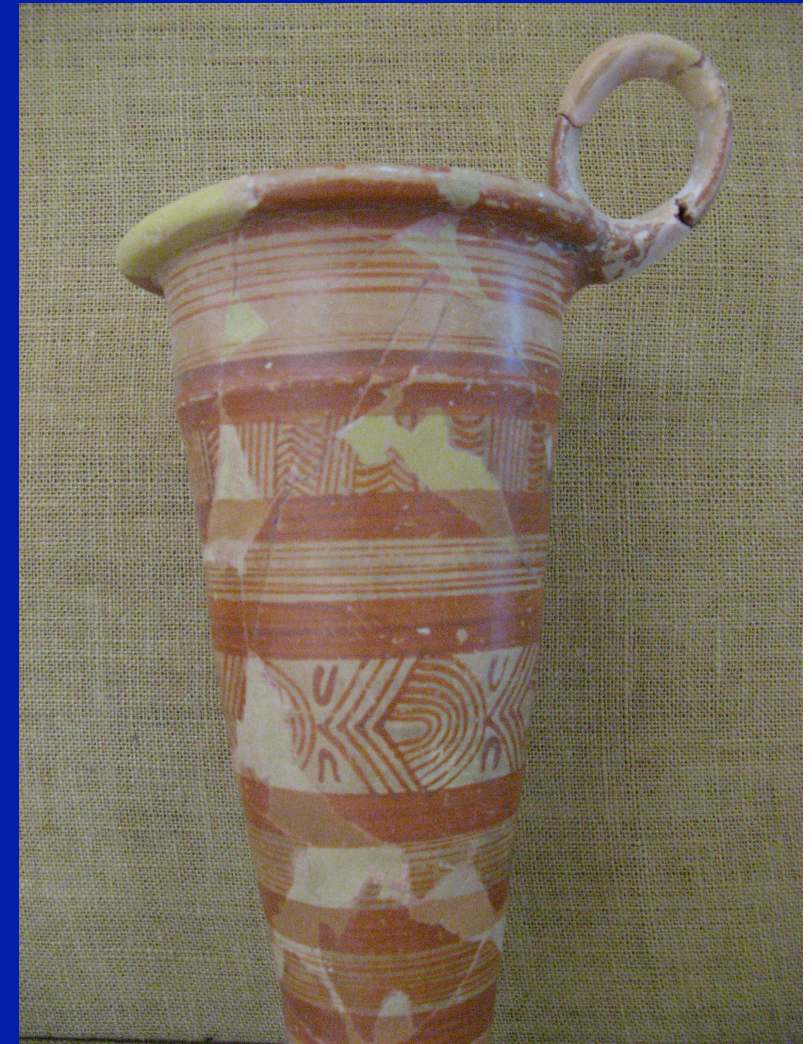




1200 BCE: Variable atmospheric circulation patterns hurt agriculture.

→ Mycenaean culture collapses.

→ Phoenicians resettle Santorini (“Callista”)





1200 BCE: Variable atmospheric circulation patterns hurt agriculture.

→ Also causes mass migrations of Phrygian and Hittite peoples.

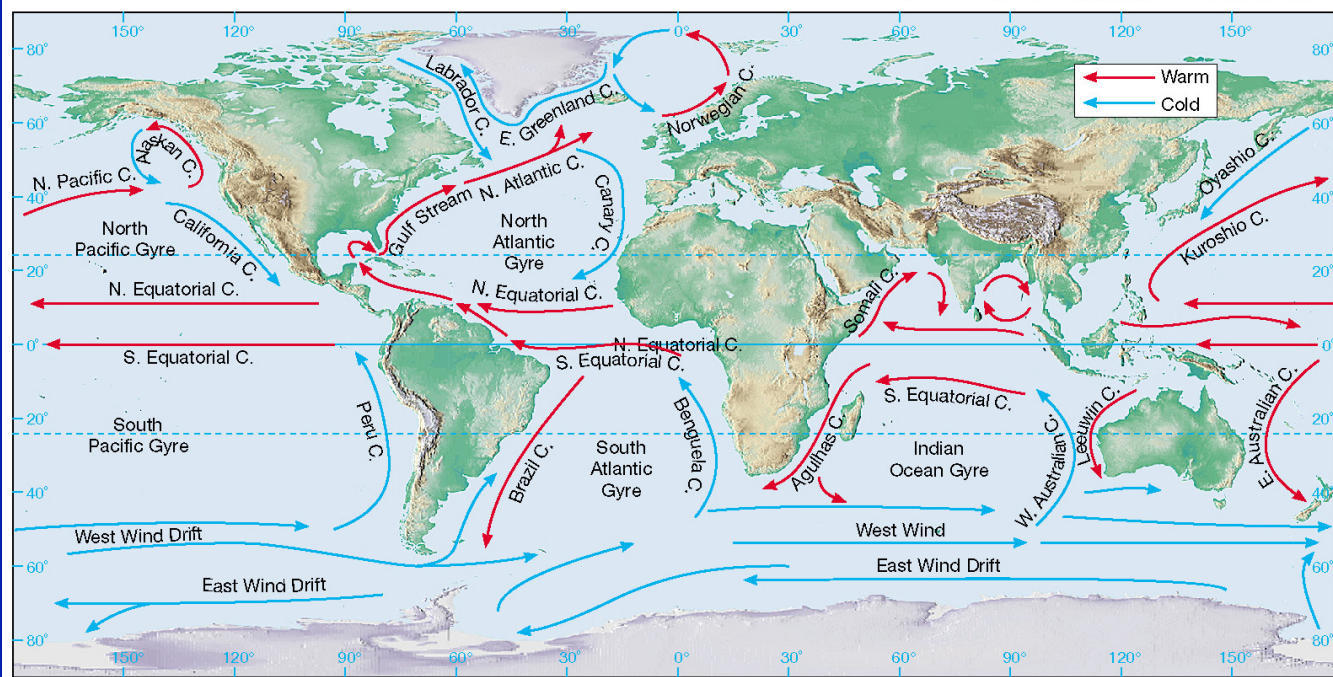
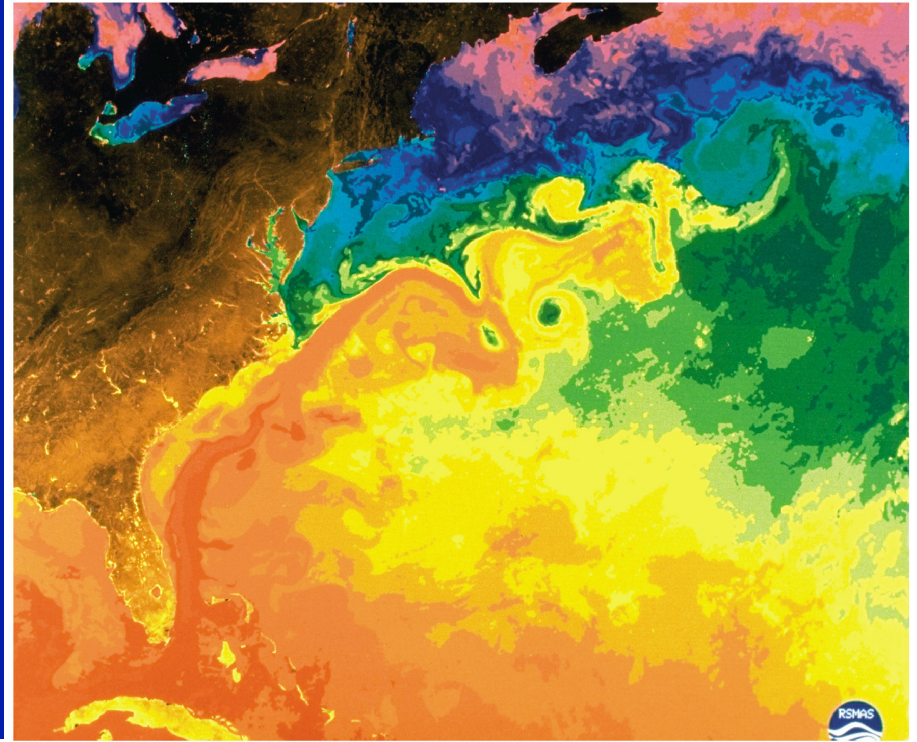


Alexander the Great

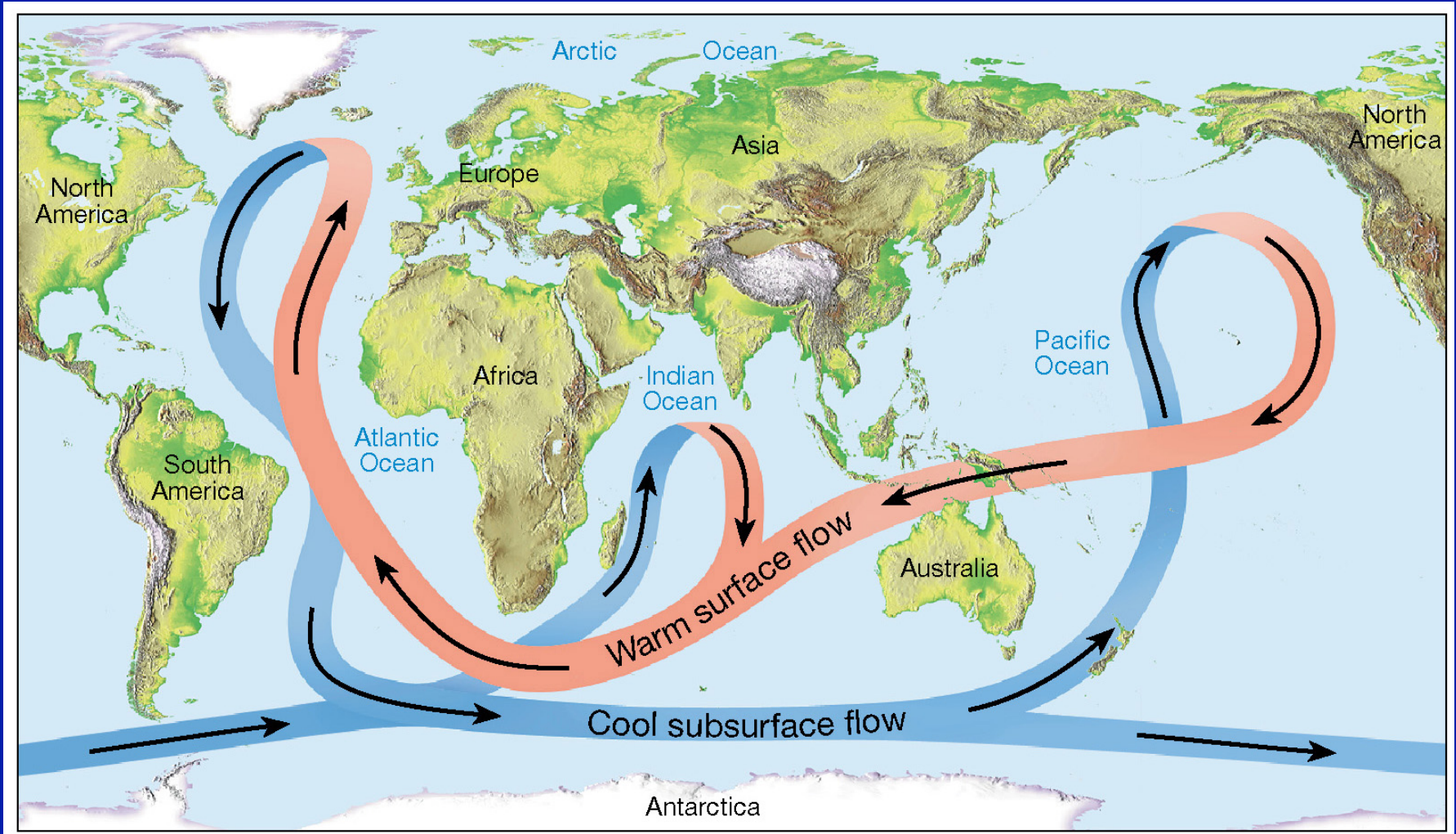


500-400 BCE: During a warm period, Europe freezes, setting the stage for the empire of Alexander the Great.

Europe is warmed by the *Gulf Stream*.



It is believed that an a period of global warming could freeze Europe.





Alexander the Great



500-400 BCE: North Atlantic thermohaline circulation shuts down.

→ Colder temperatures in Europe cause more southward migrations. Macedonians overrun Greece.



300 BCE: Warming period in Asia.

→ Opening of the “Silk Route.”

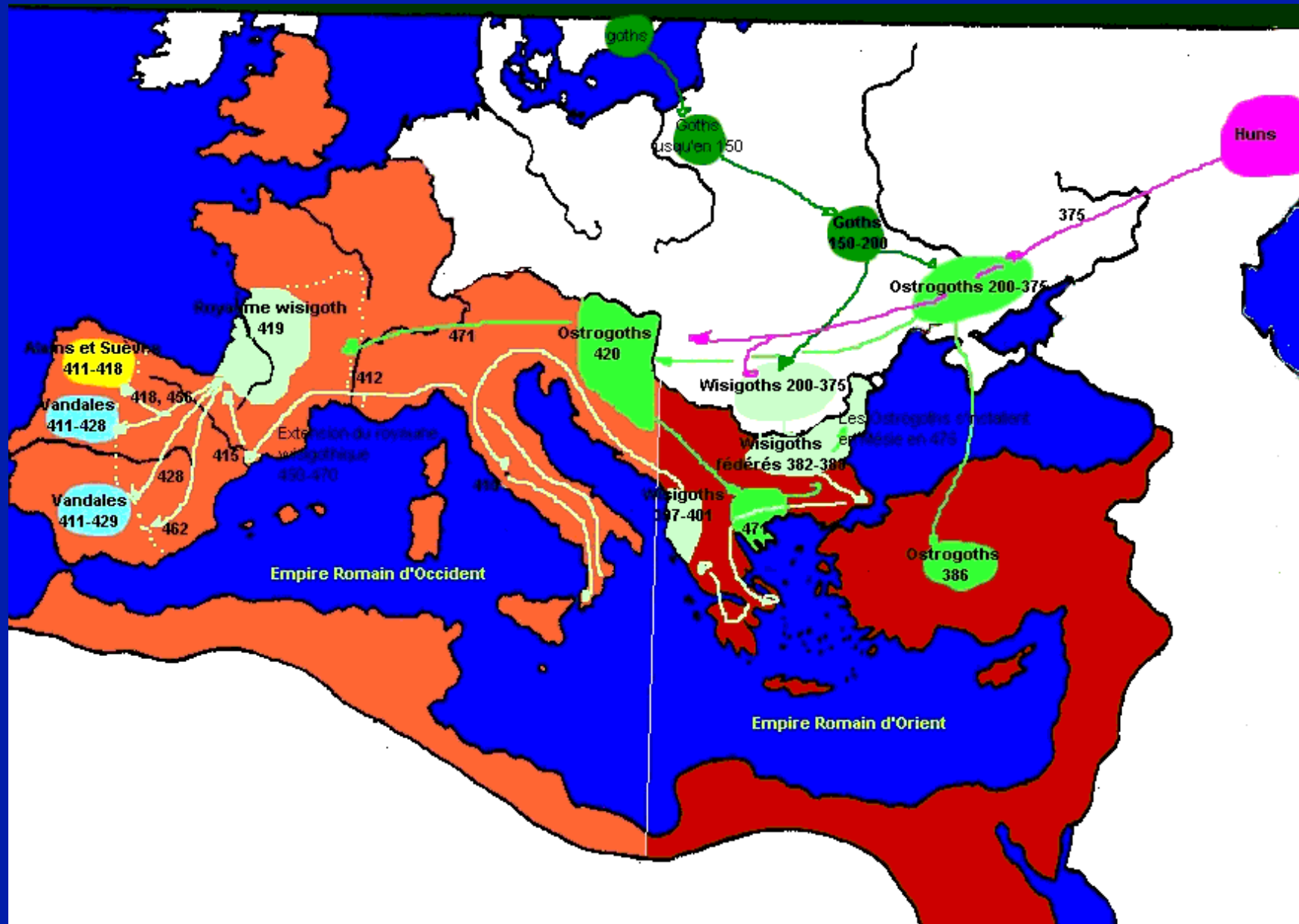
0 – 100 CE: Stable temperatures allow Roman Empire to thrive. Empire = >60 million people. Rome = >1 million.



So...why did the Roman/ Byzantine empire collapse?

400-500 CE: Cold spell; prolonged freezing.

→ Southward migration of Northern Europeans/Asians





Why is Leif Ericsson able to sail to America?



Why is Leif Ericsson able to sail to America?

950-1250 CE: Warm and dry period



**950-1250 CE: Warm and dry period
→ Mayan culture collapses**



950-1250 CE: Warm and dry period

→ American Southwest cultures like the one at Chaco Canyon collapse. Anasazi peoples disappear.

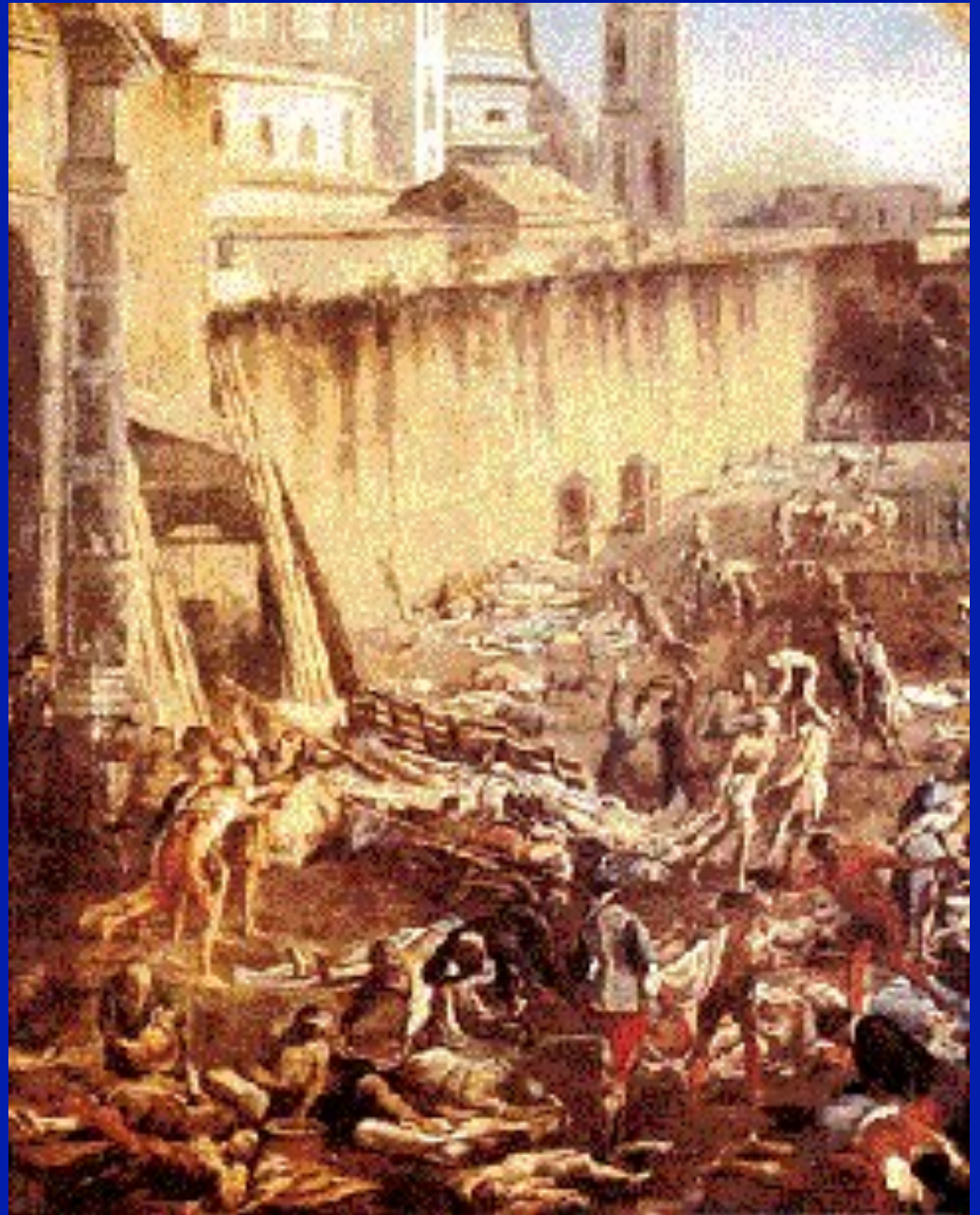
Why does the plague strike Europe in the 1300s?



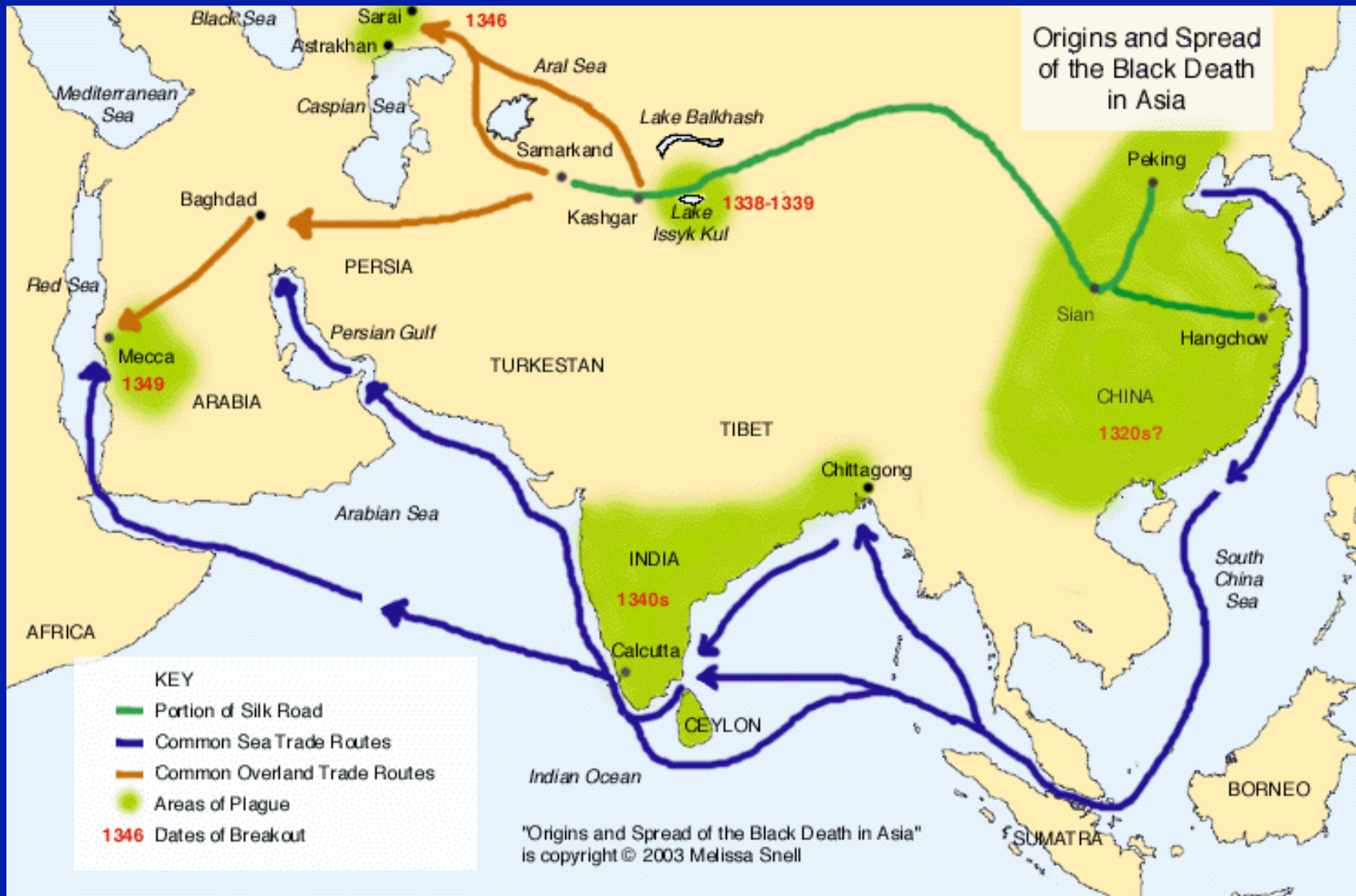
**~1250 CE Onward:
Increasing cold spell
possibly due to a
minimum in solar
activity**

**→Great famine of
1315-1317**

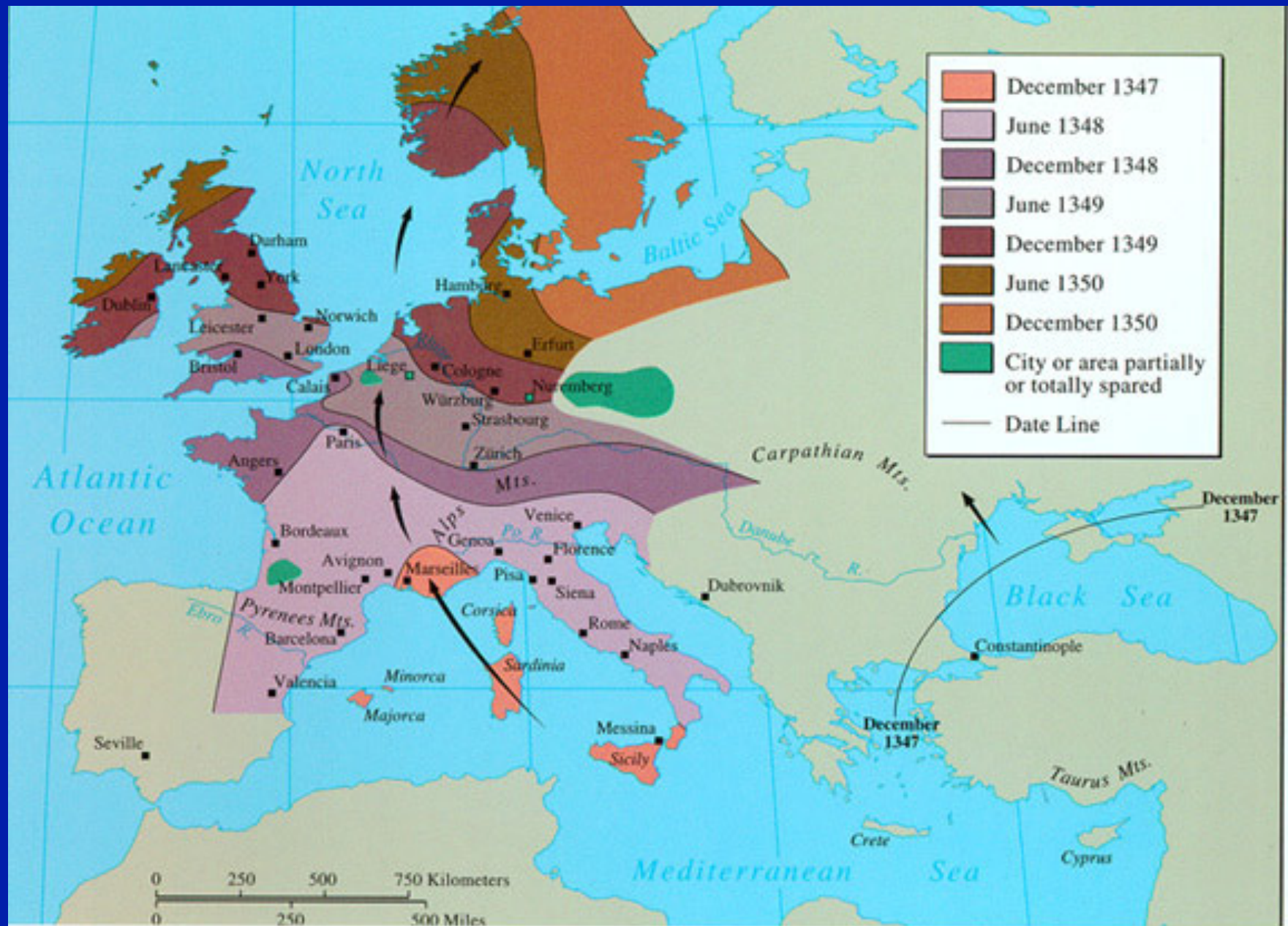
→Black Death, 1345

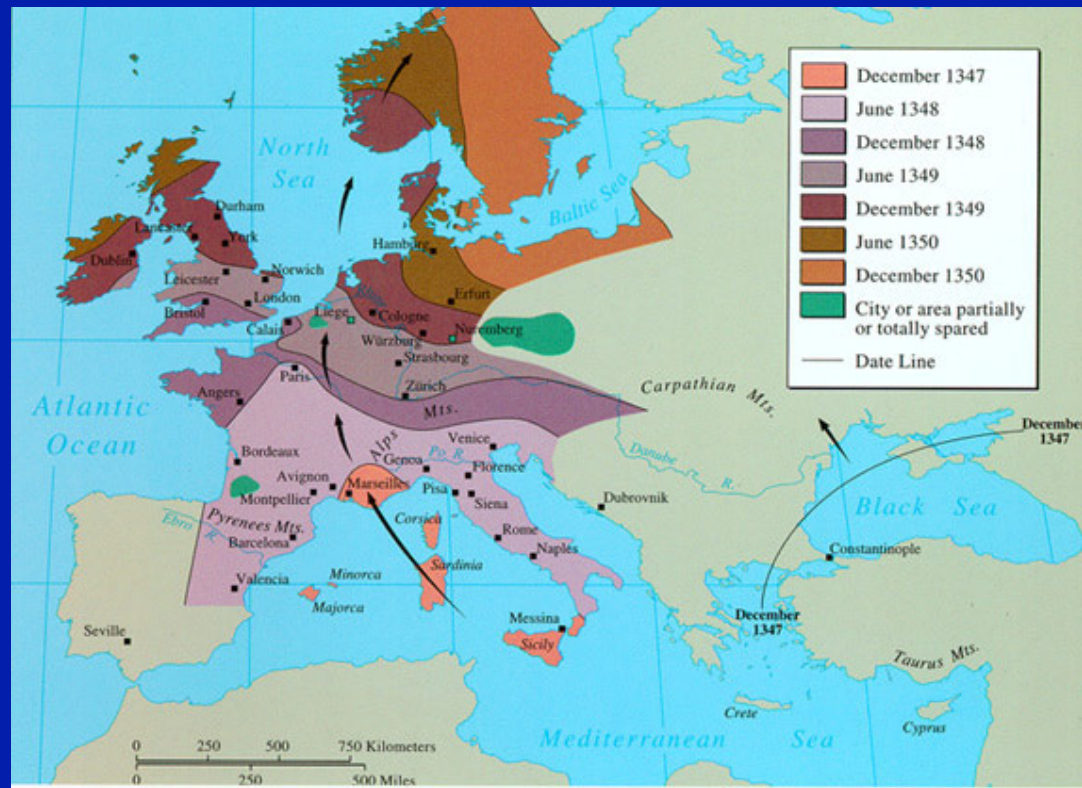


Begins with flooding in China. More than 7 million drown in Yellow River.



Spread of the plague through Europe





Plague returned in 1563, 1578, 1593, 1603, 1625, 1636, and 1665 (throughout Little Ice Age)

- * Social dynamics of Europe forever changed.**
- * Weakening of Catholic Church and Holy Roman Empire**
- * Pogroms destroy 210 Jewish communities in Western Europe by 1351. Jewish communities resettle in the east.**

Mongol Expansion in 13th Century:



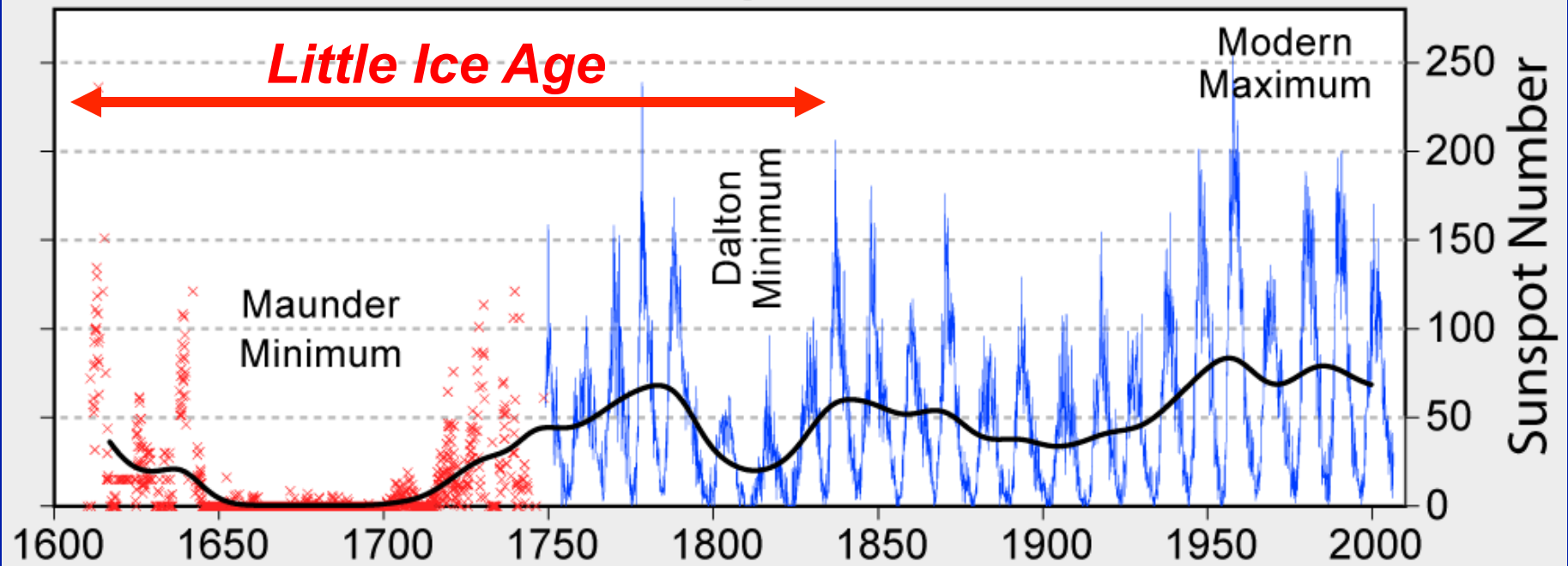
**Mongolian climate in the 13th century: Continual cooling;
severe droughts**

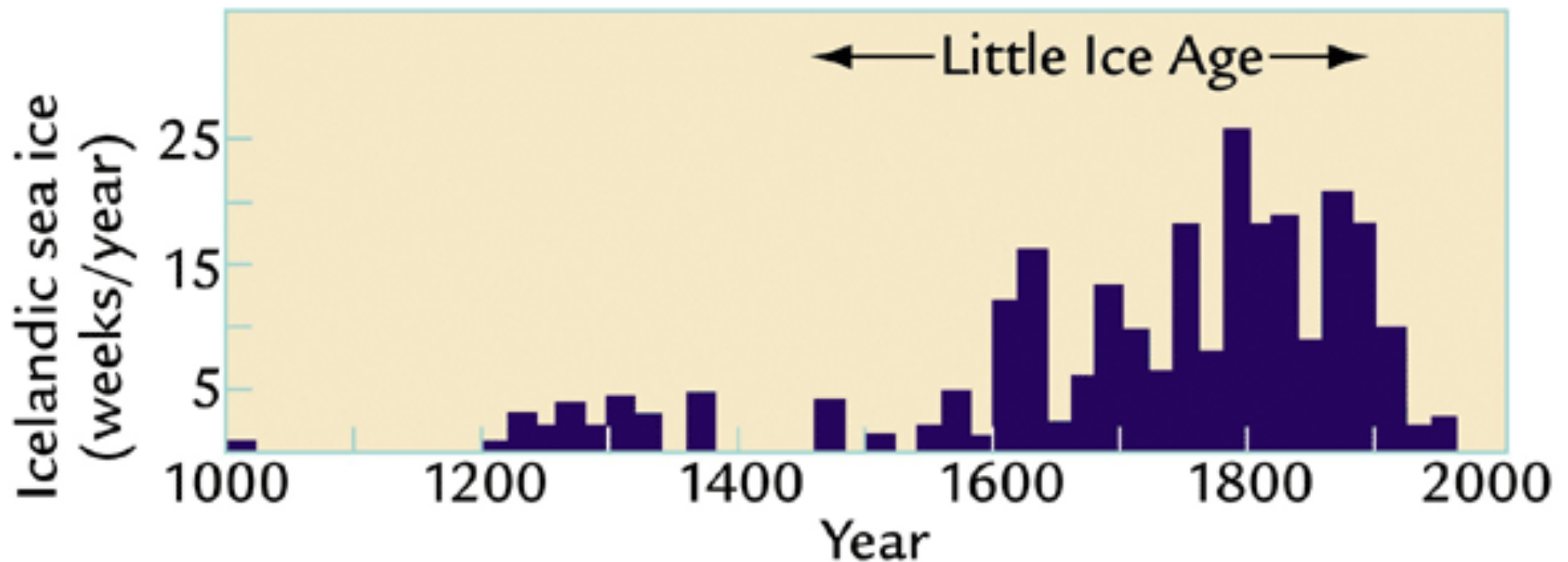


Late 1500's: Mega-droughts in North America

→ May have led to demise of Jamestown Colony, 1587-89.

400 Years of Sunspot Observations





1550-1850: Little Ice Age

→ Maunder minimum (1645-1715) – period of depressed solar activity

→ Eskimos land in Scotland (1690).

→ Scots emigrate to Ireland.

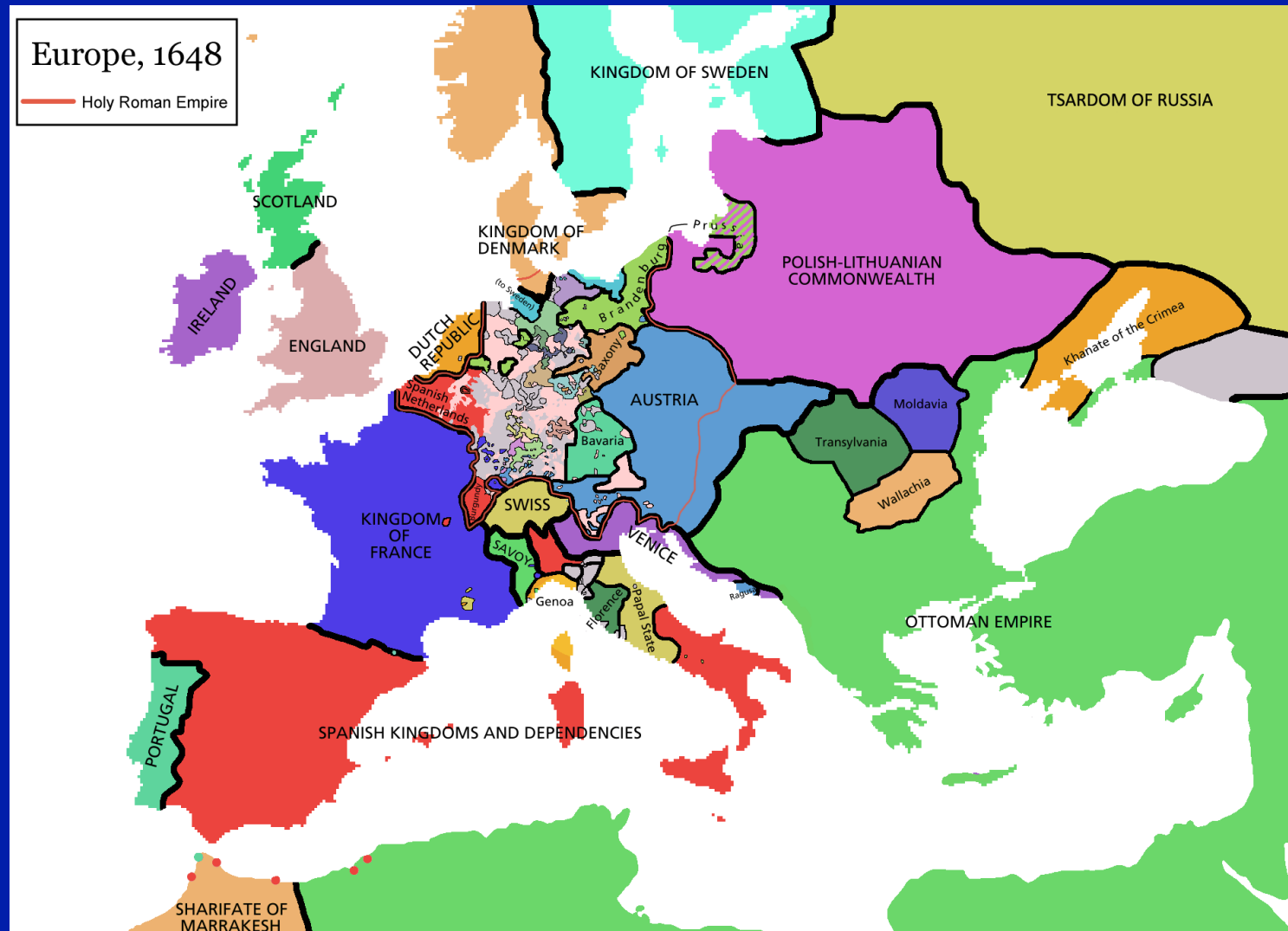


China 1620-1650: Extreme cold causes death of ~40% of population (≈70 million)

*** 1644: Manchu invasion ends Ming dynasty, starts Qing dynasty**



1618-1648: Thirty Years' War worst ever in European history in terms of percentage of population killed by warfare, starvation, and epidemics





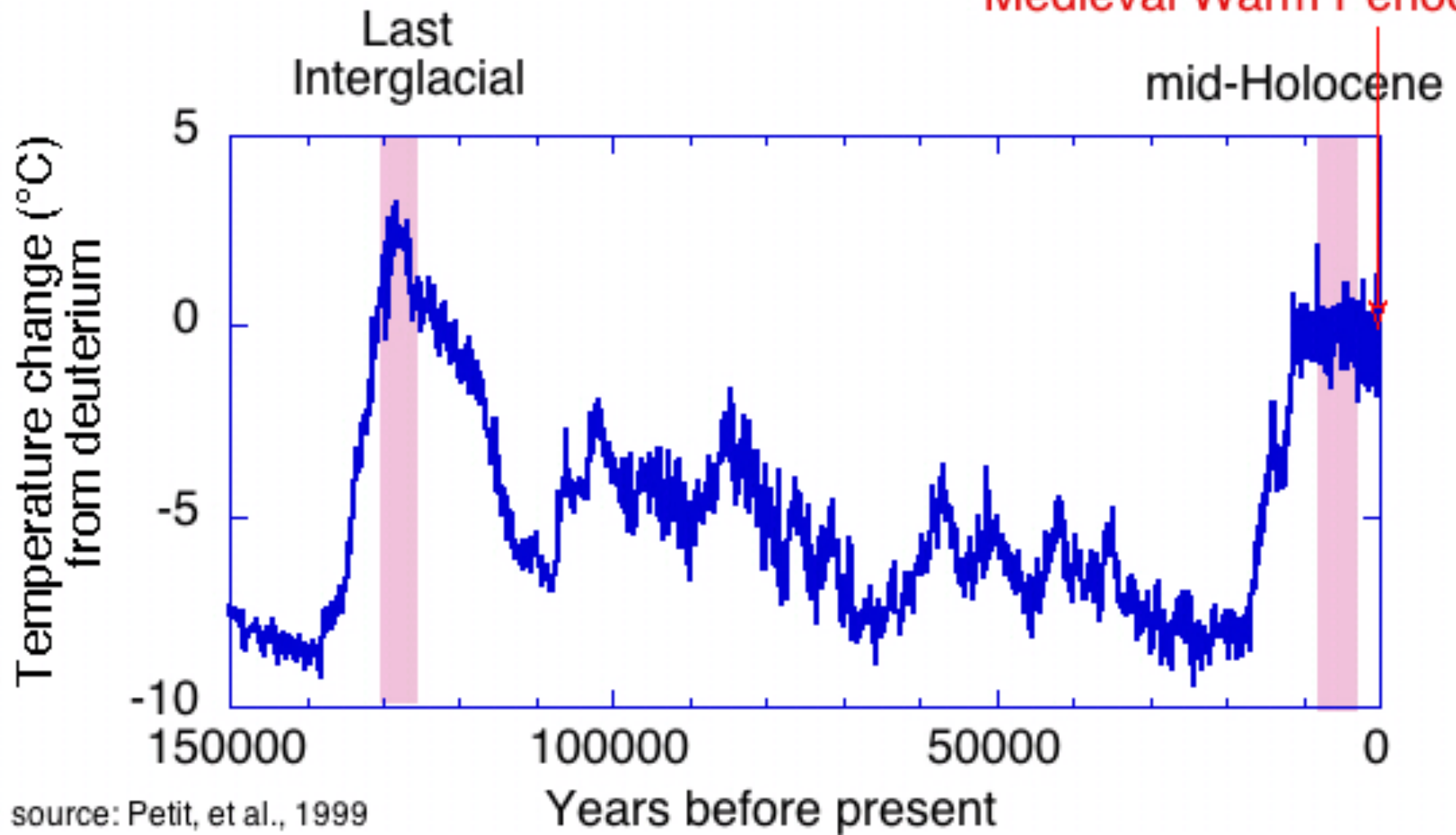
1840s: Increased warming and rains in Europe

→ Led to potato blight in Ireland. Huge migration to America.

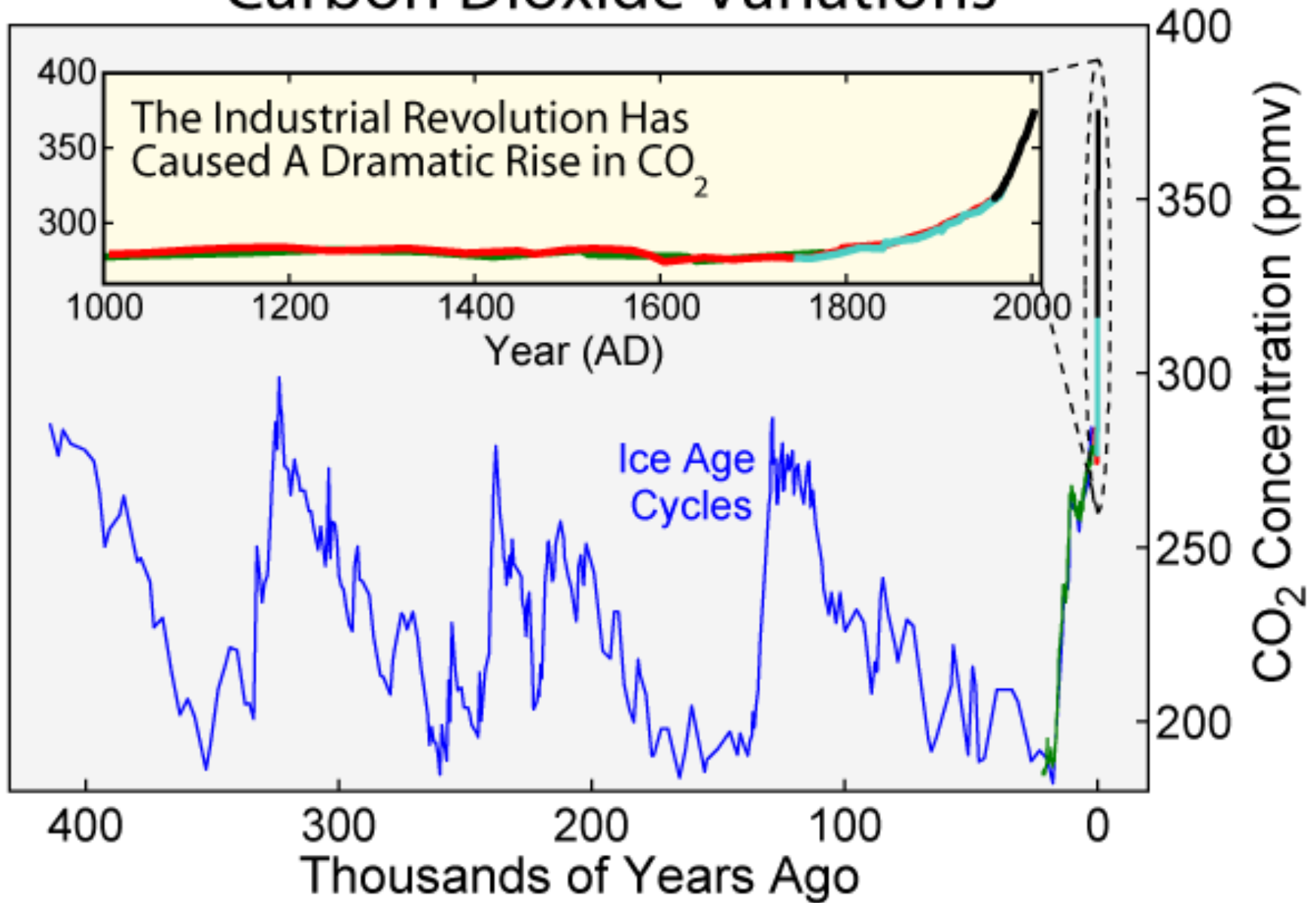


Last 10,000 years: VERY warm AND stable!!

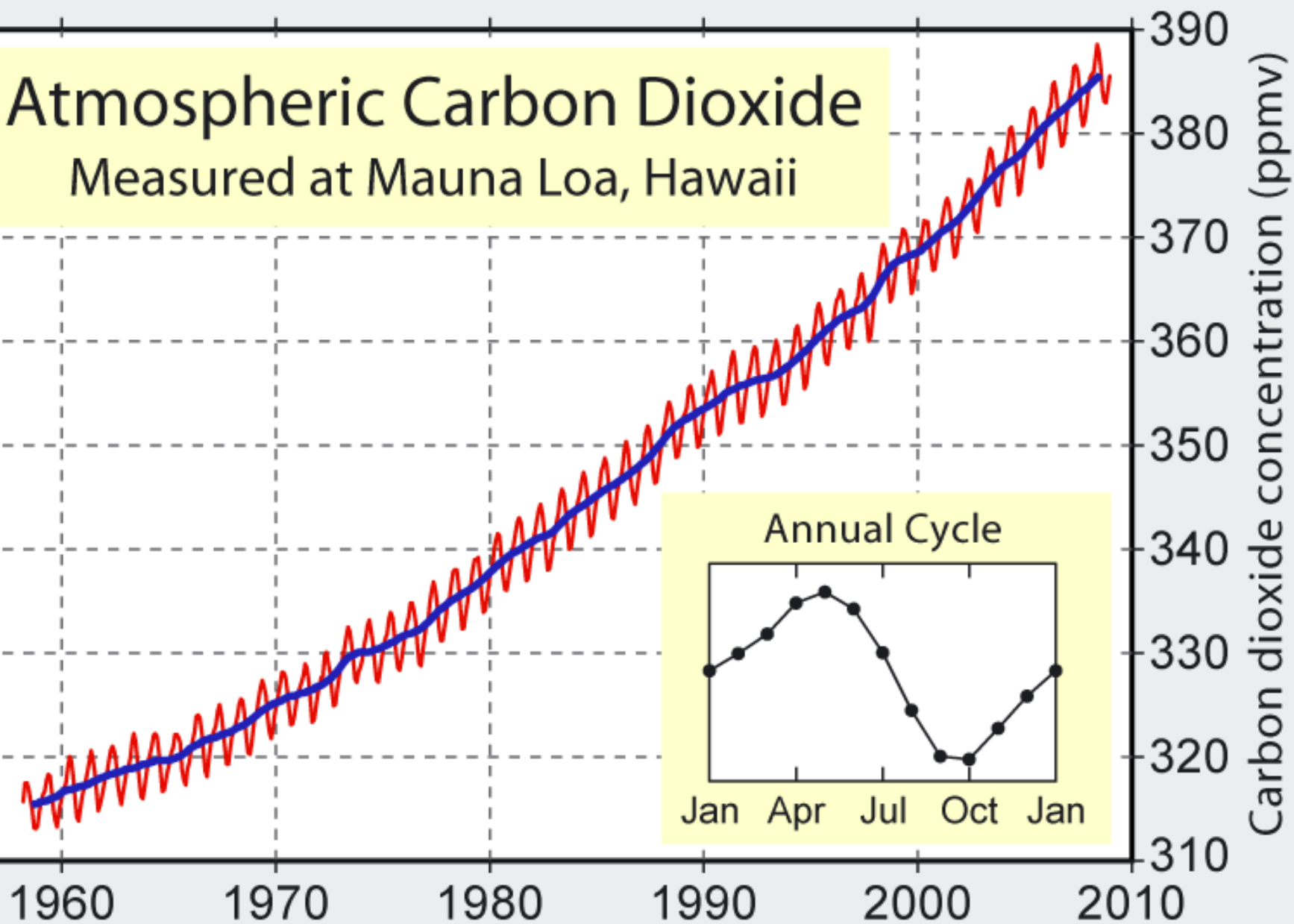
Medieval Warm Period



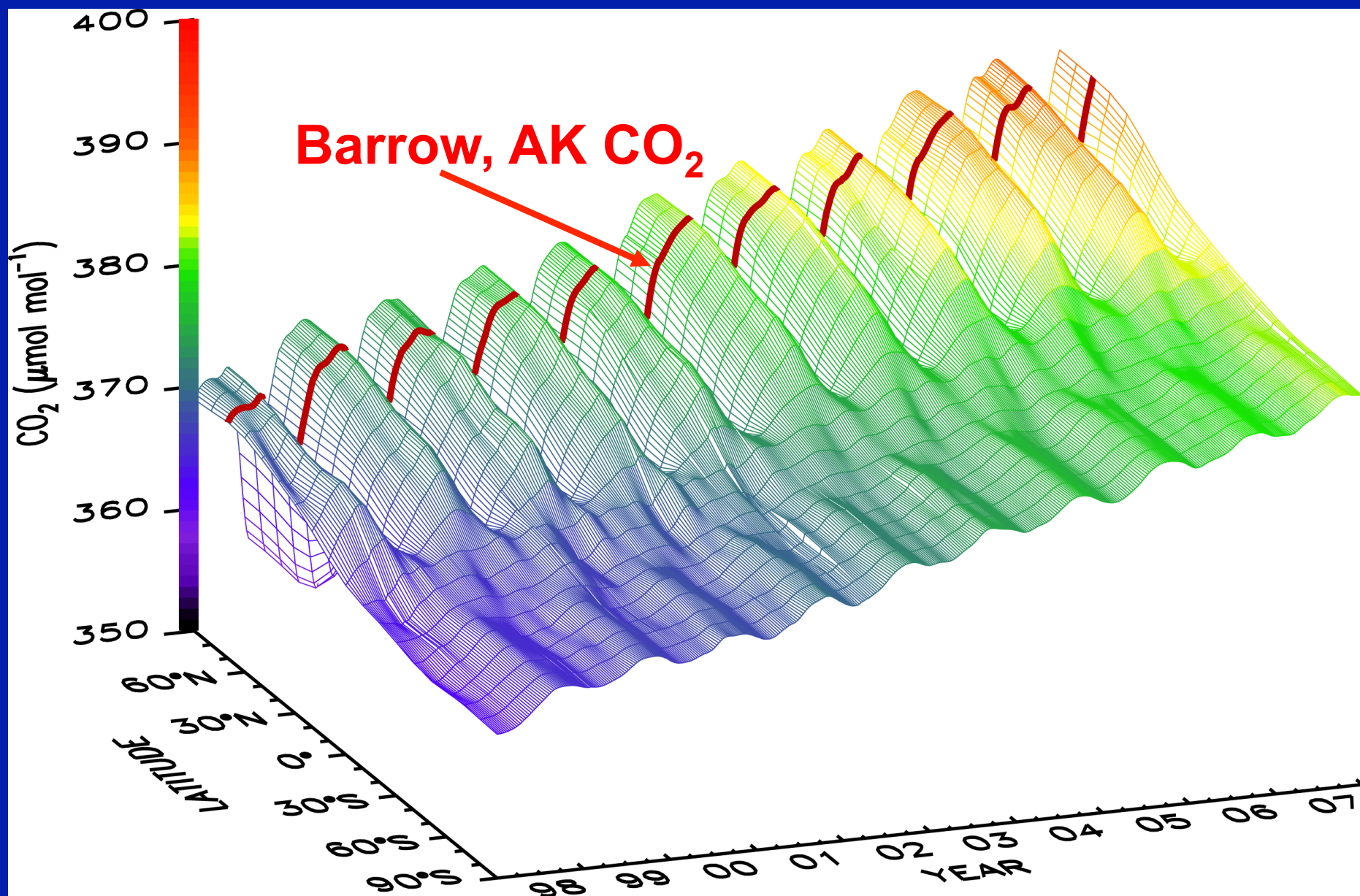
Carbon Dioxide Variations

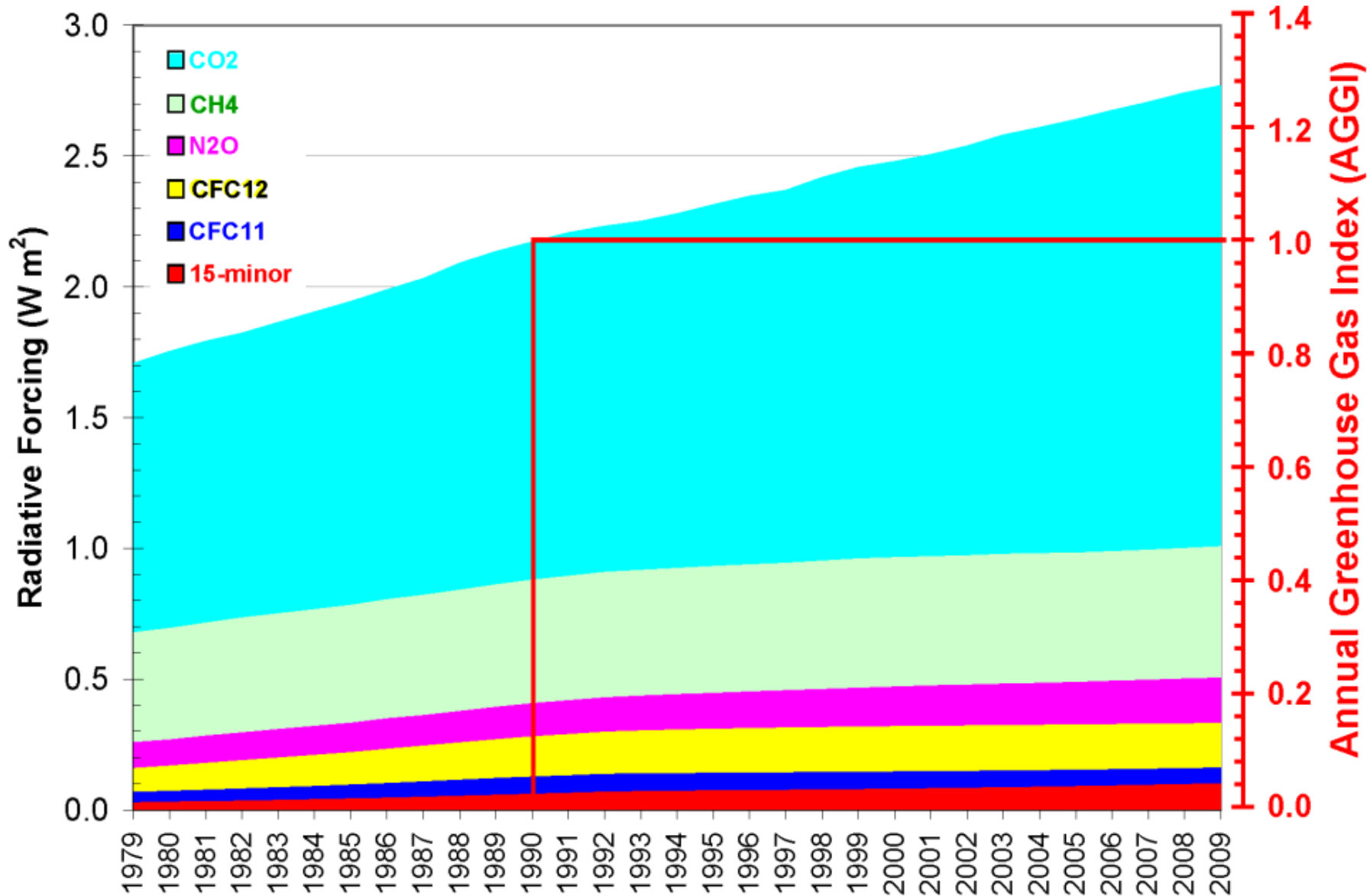


Atmospheric Carbon Dioxide Measured at Mauna Loa, Hawaii

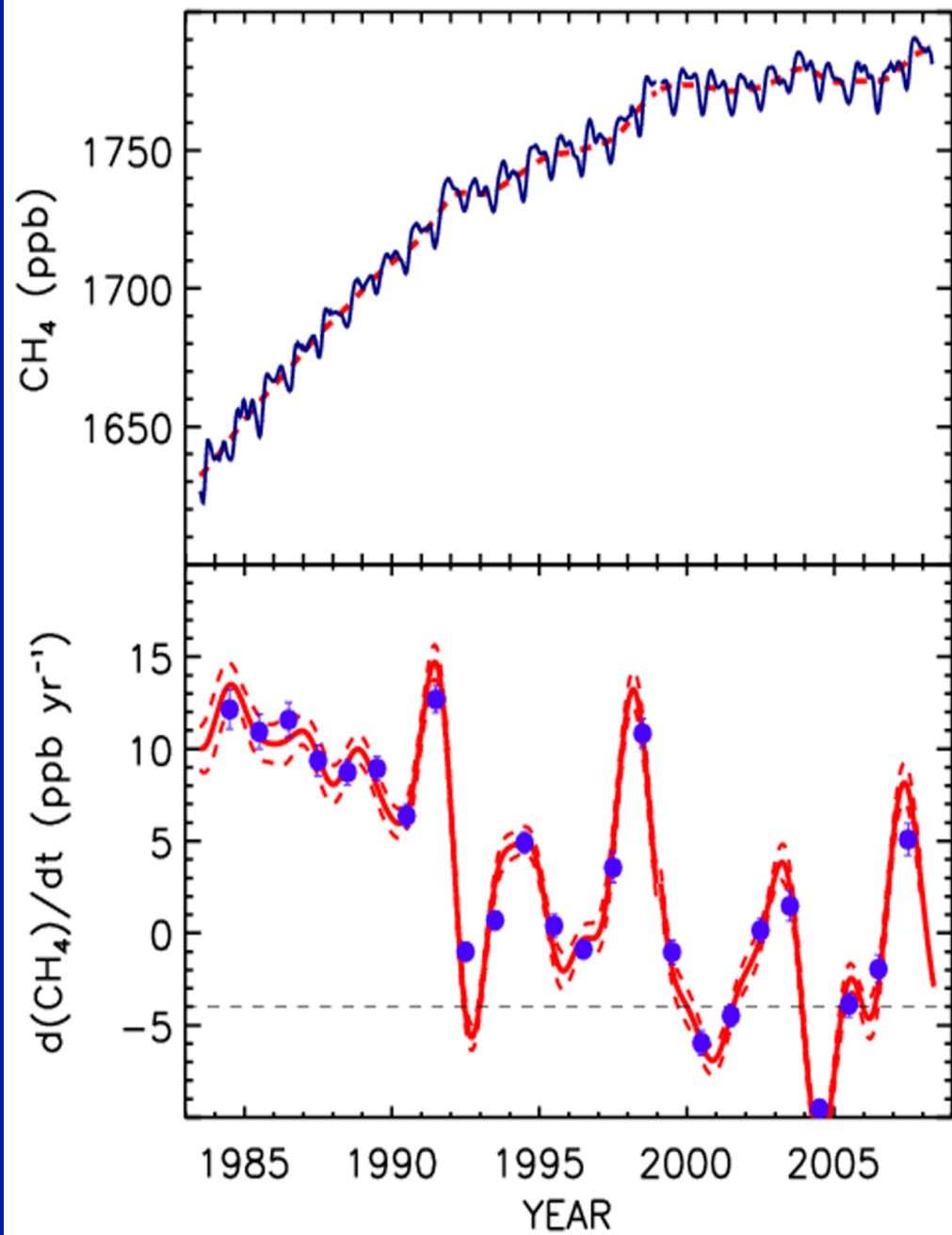


Global Carbon Dioxide Cycle

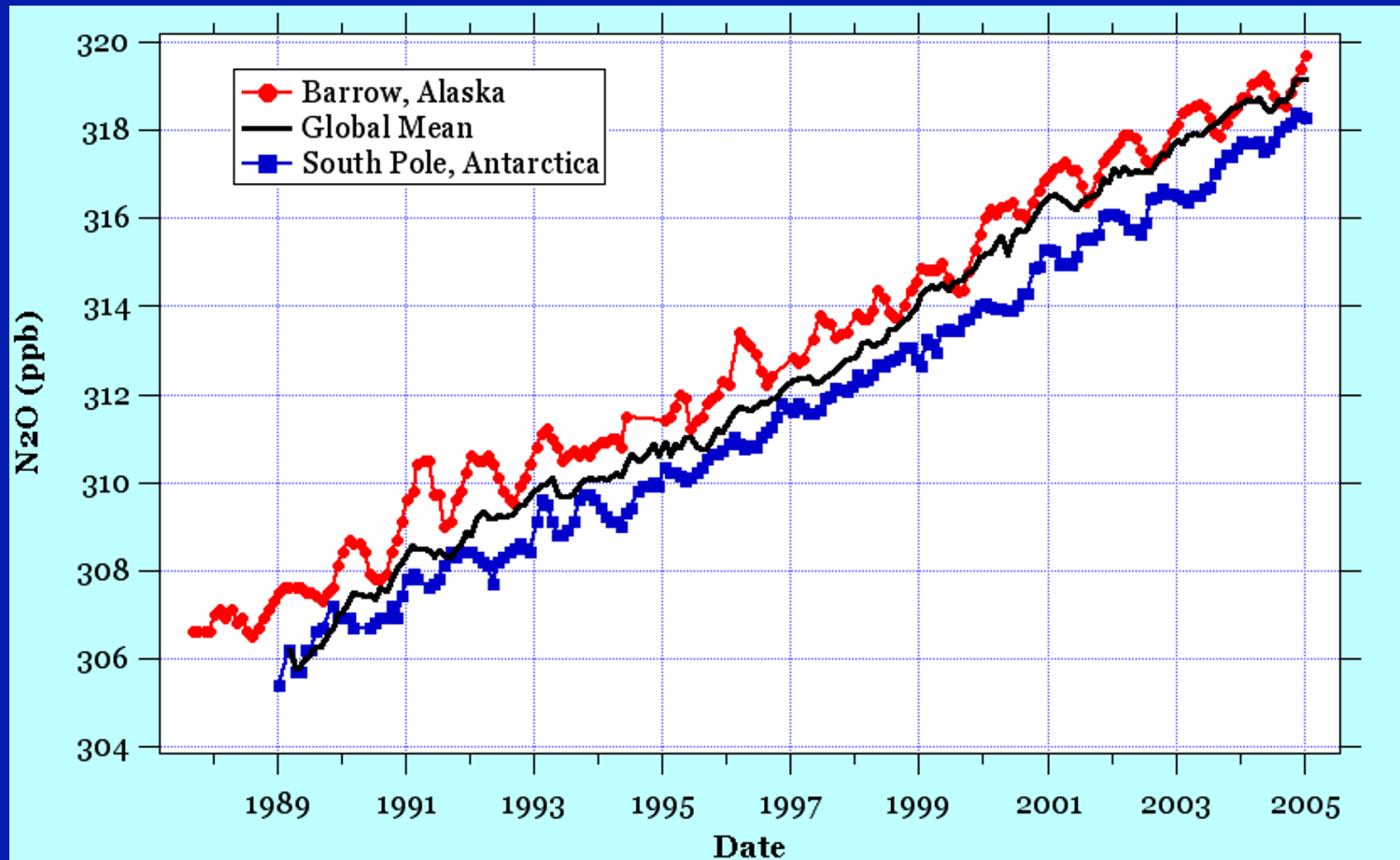




Global Methane

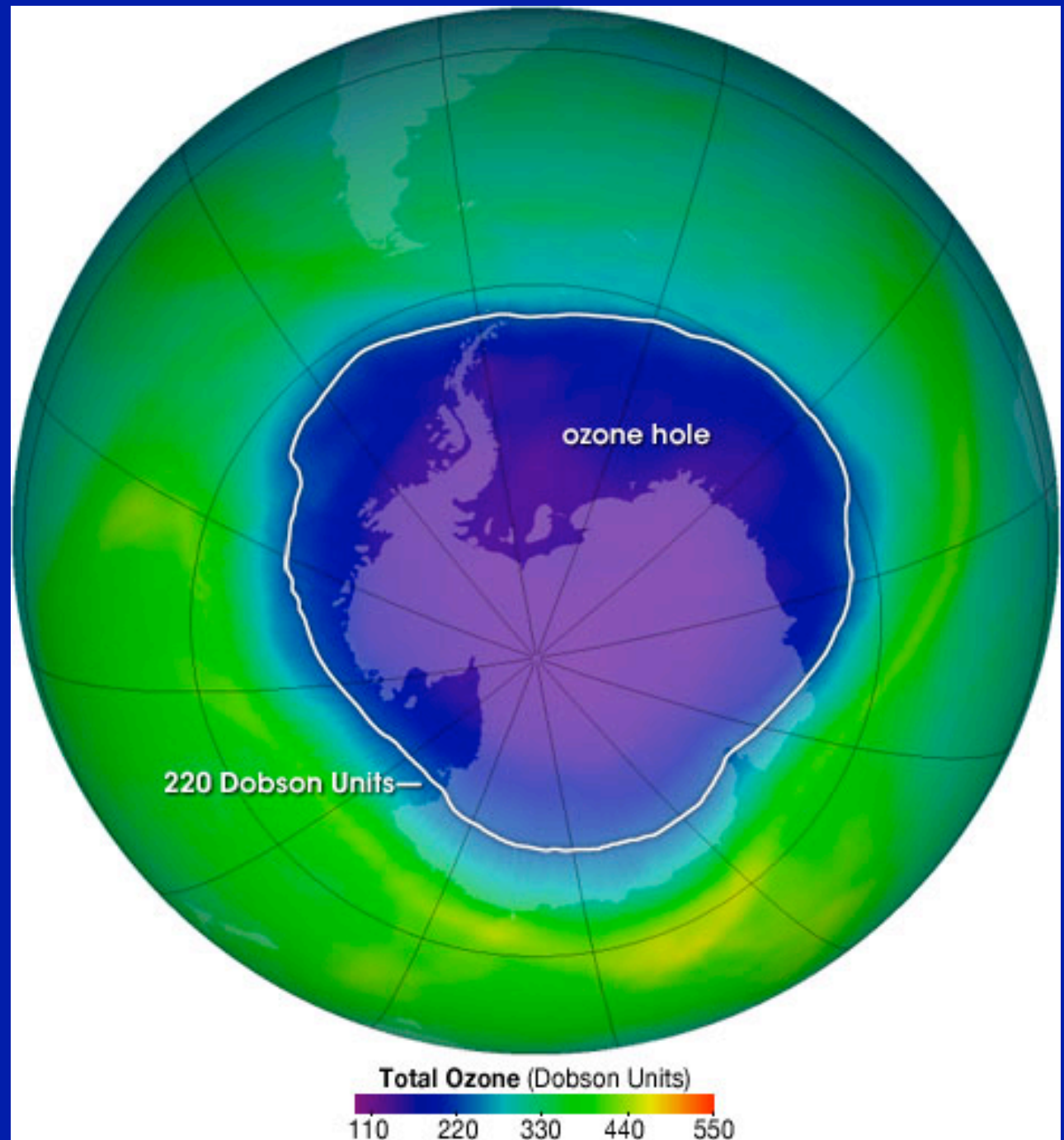


Nitrous Oxide (N_2O) is Produced by Combustion and Agricultural Practices



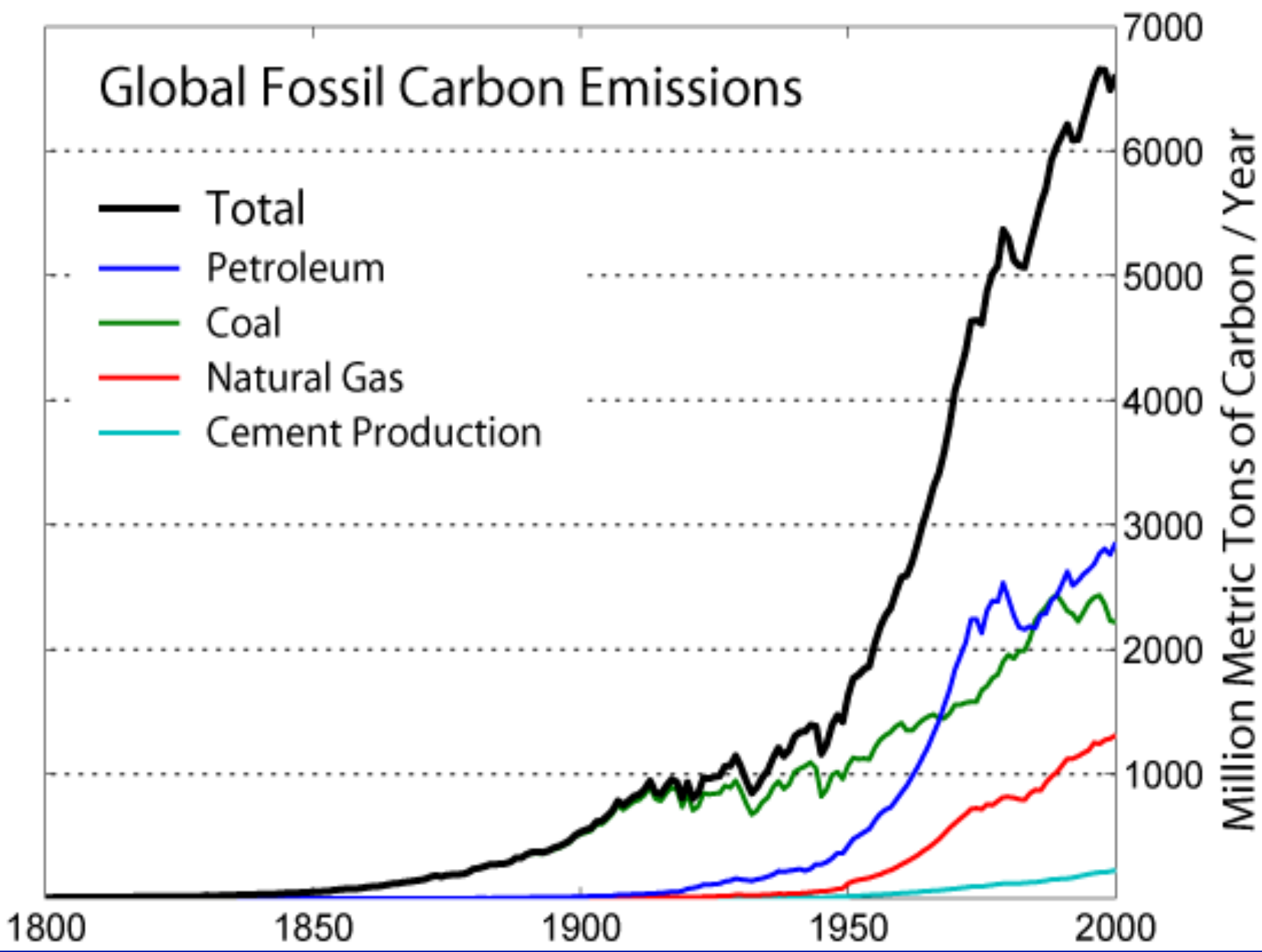
Nitrous oxide is the fourth strongest greenhouse gas. Nitrous oxide is also a major source of stratospheric nitric oxide, a compound that helps to catalytically destroy stratospheric ozone.

**Decrease of
South Polar
winter ozone
levels
(increase in
the southern
winter “ozone
hole”)
has a
net cooling
effect on
climate**

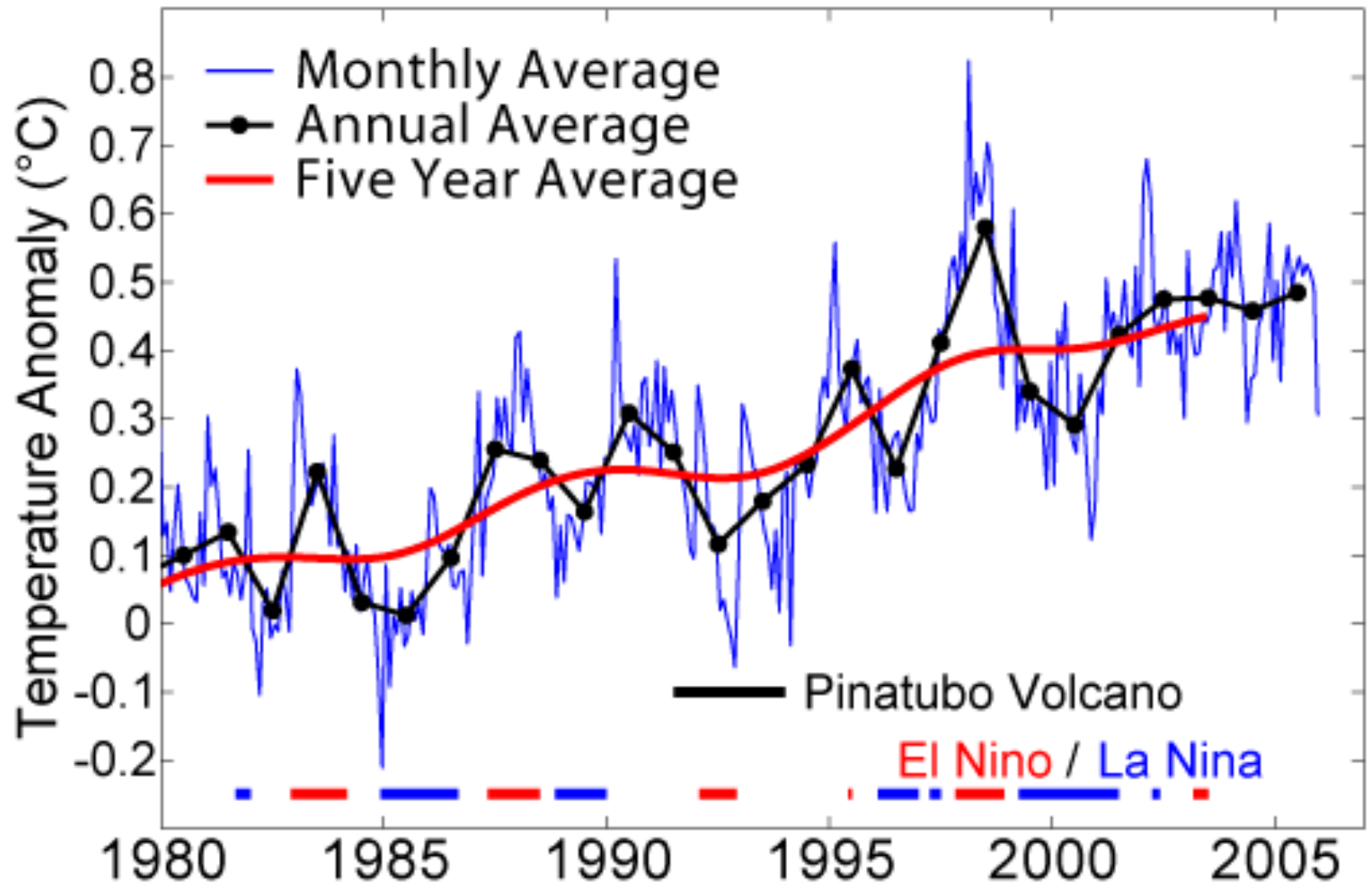


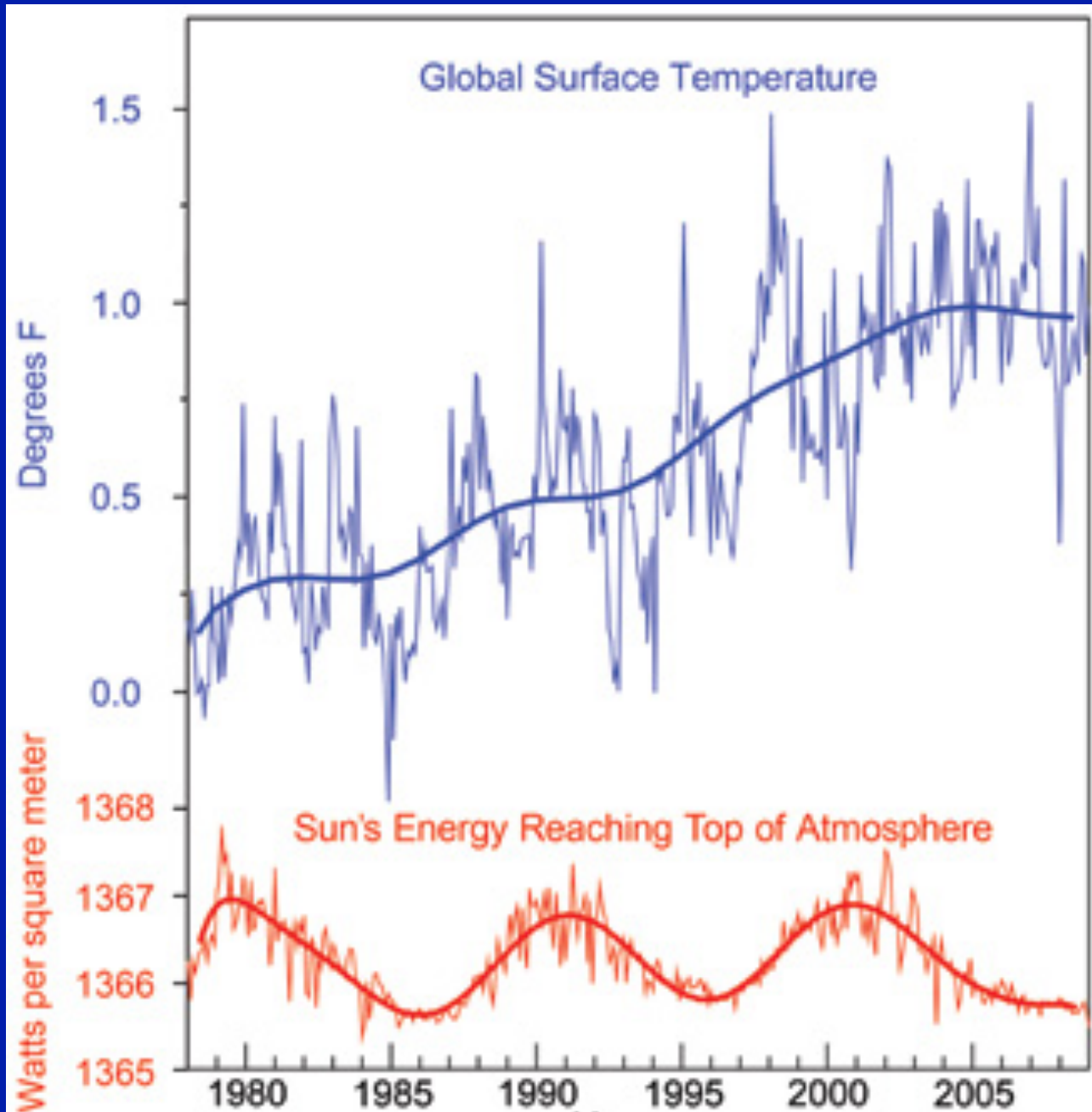
Global Fossil Carbon Emissions

- Total
- Petroleum
- Coal
- Natural Gas
- Cement Production

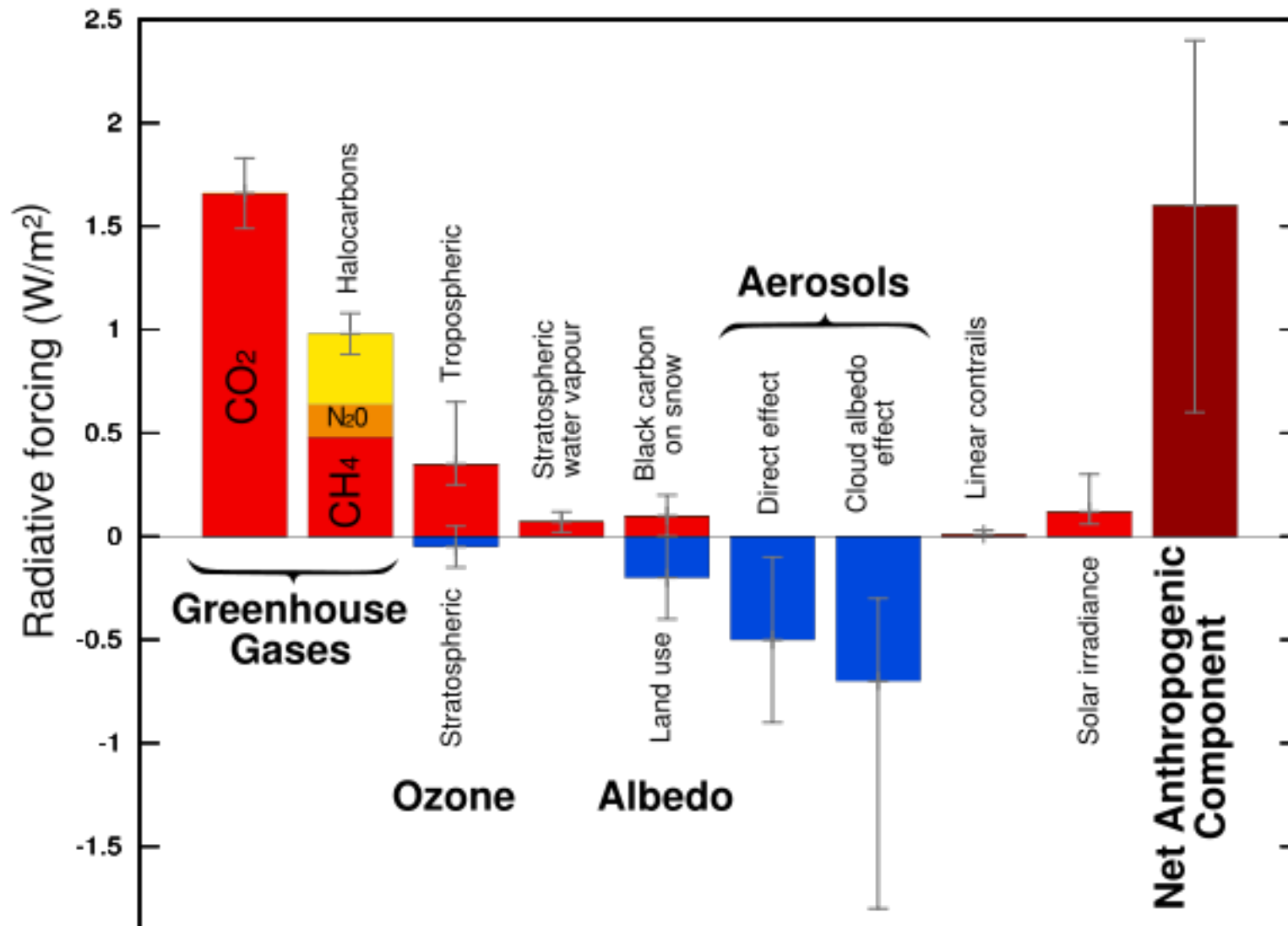


Surface Temperature Record

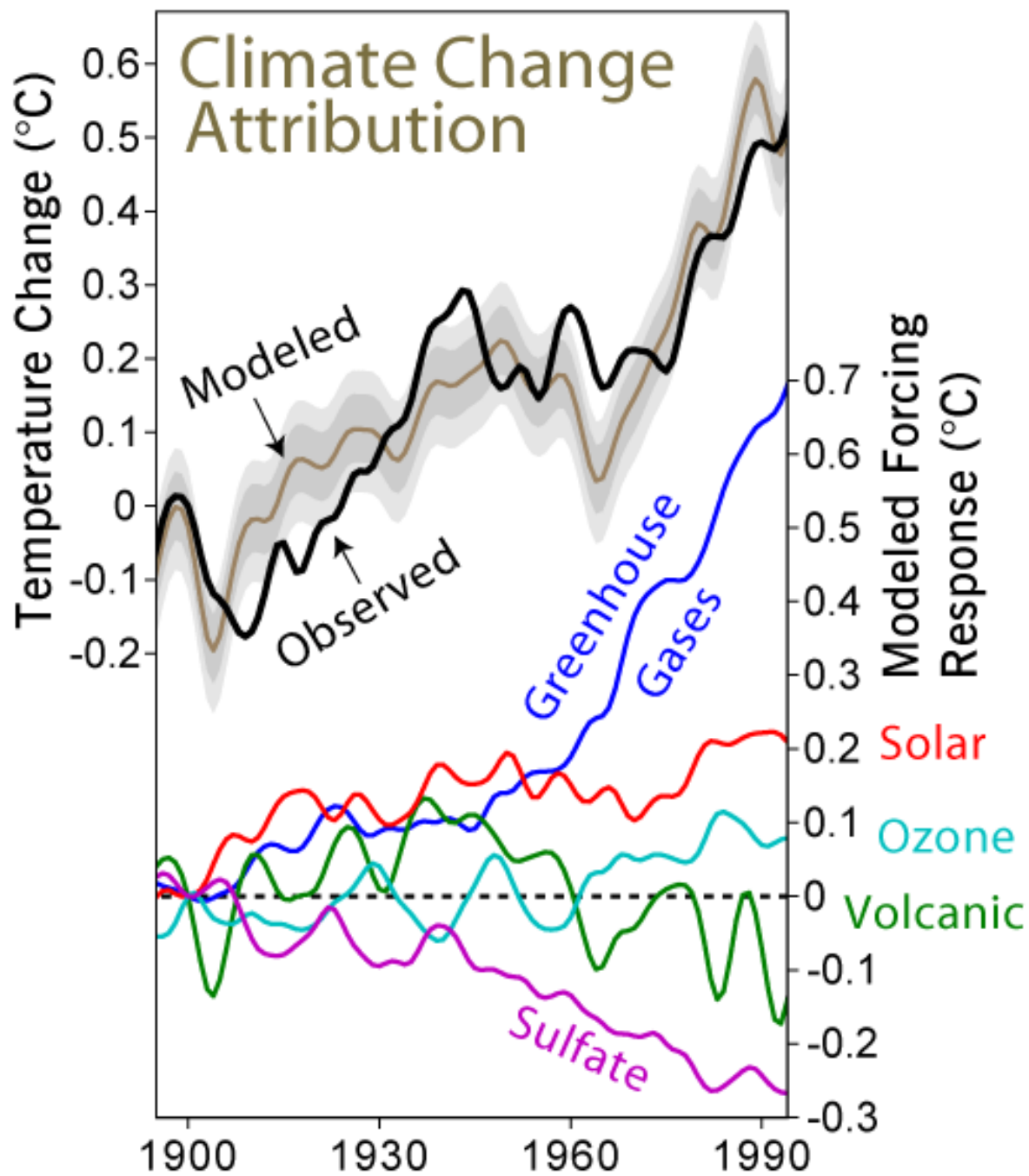




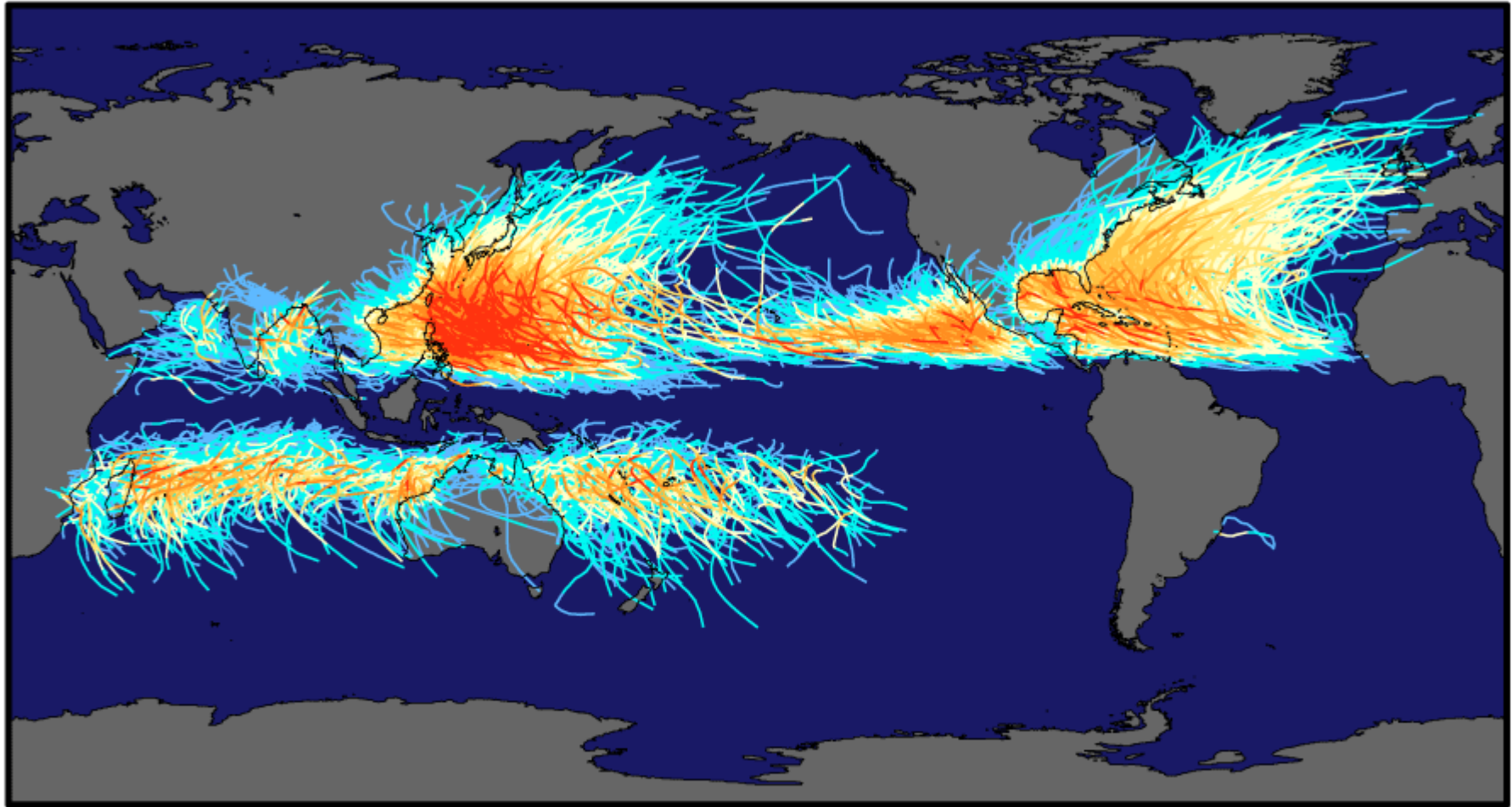
Radiative Forcing Components



IPCC Report



Tracks and Intensity of All Tropical Storms



TD

TS

1

2

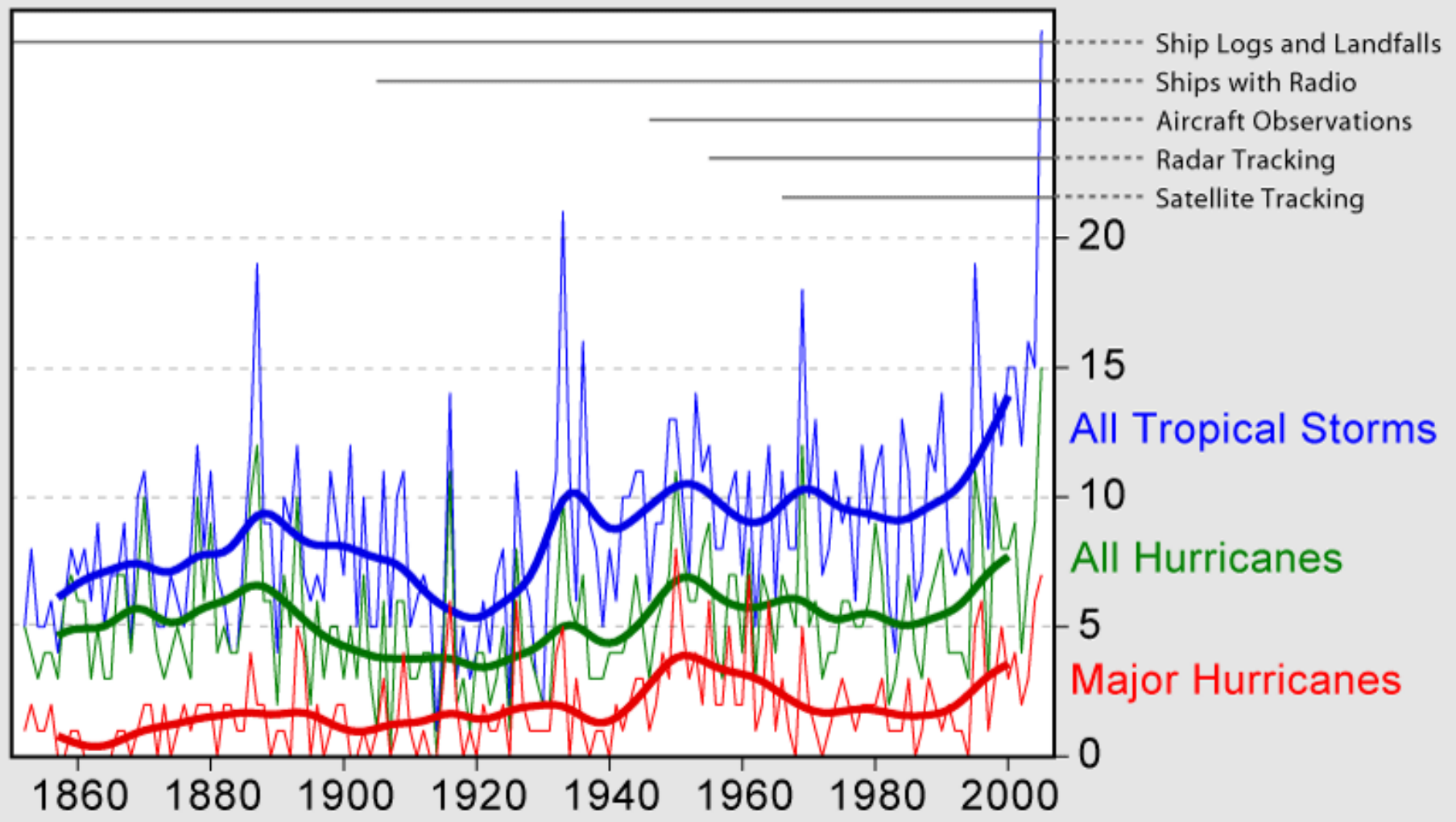
3

4

5

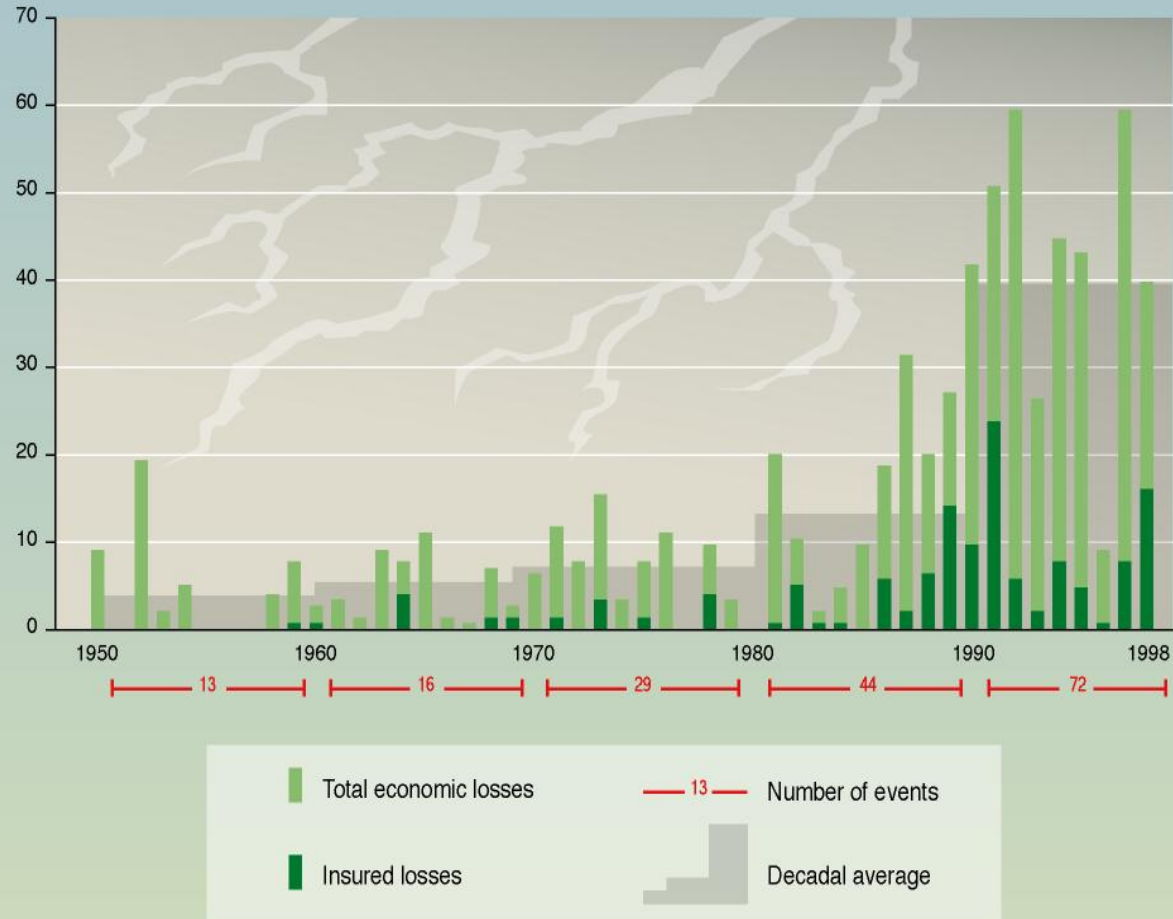
Saffir-Simpson Hurricane Intensity Scale

North Atlantic Tropical Storms and Observing Techniques



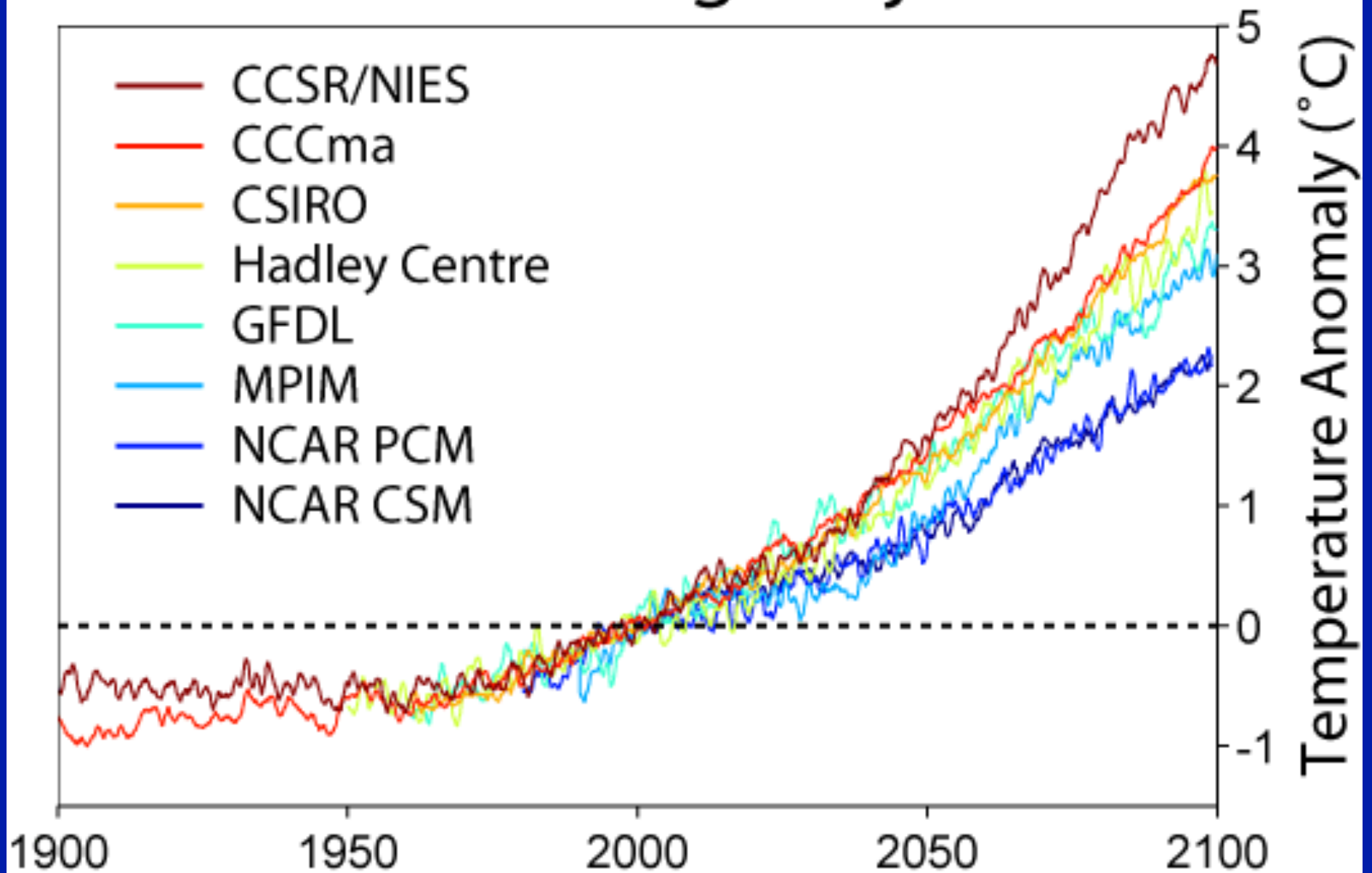
Global costs of extreme weather events (inflation-adjusted)

Annual losses, in thousand million U.S. dollars

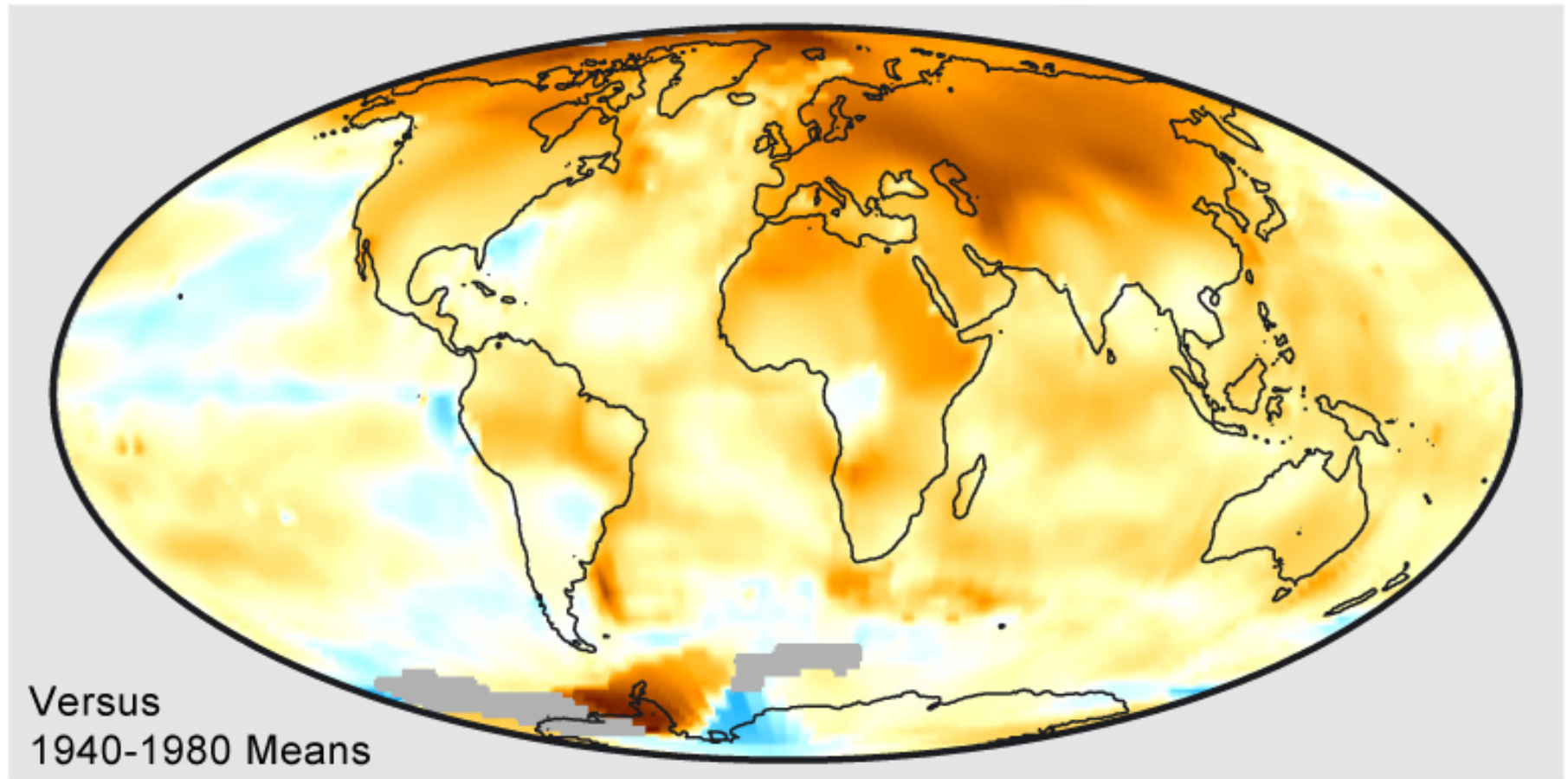


SYR - FIGURE 2-7

Global Warming Projections



1999-2008 Mean Temperatures

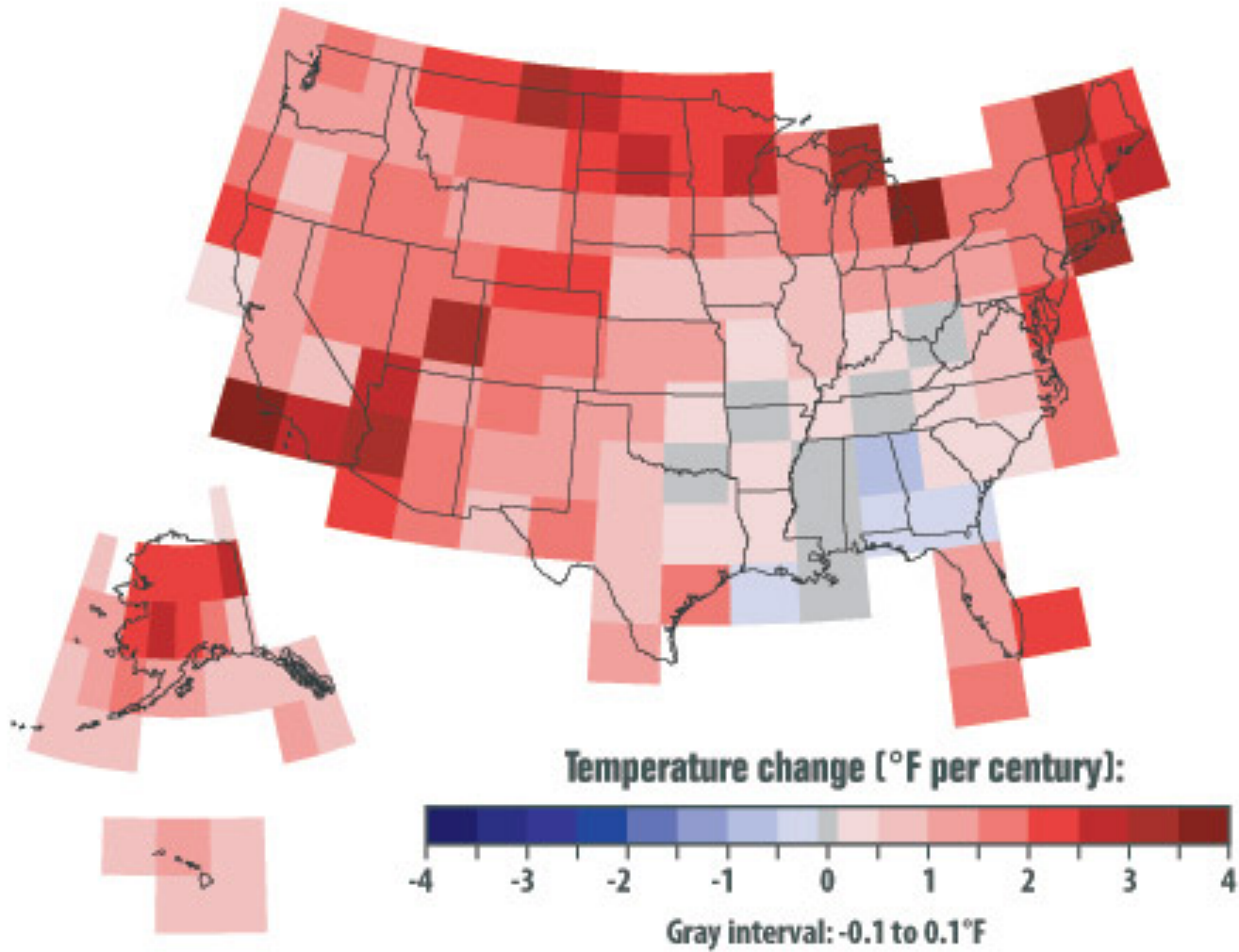


-2 -1.5 -1 -0.5 0 0.5 1 1.5 2

Temperature Anomaly ($^{\circ}\text{C}$)

United States:

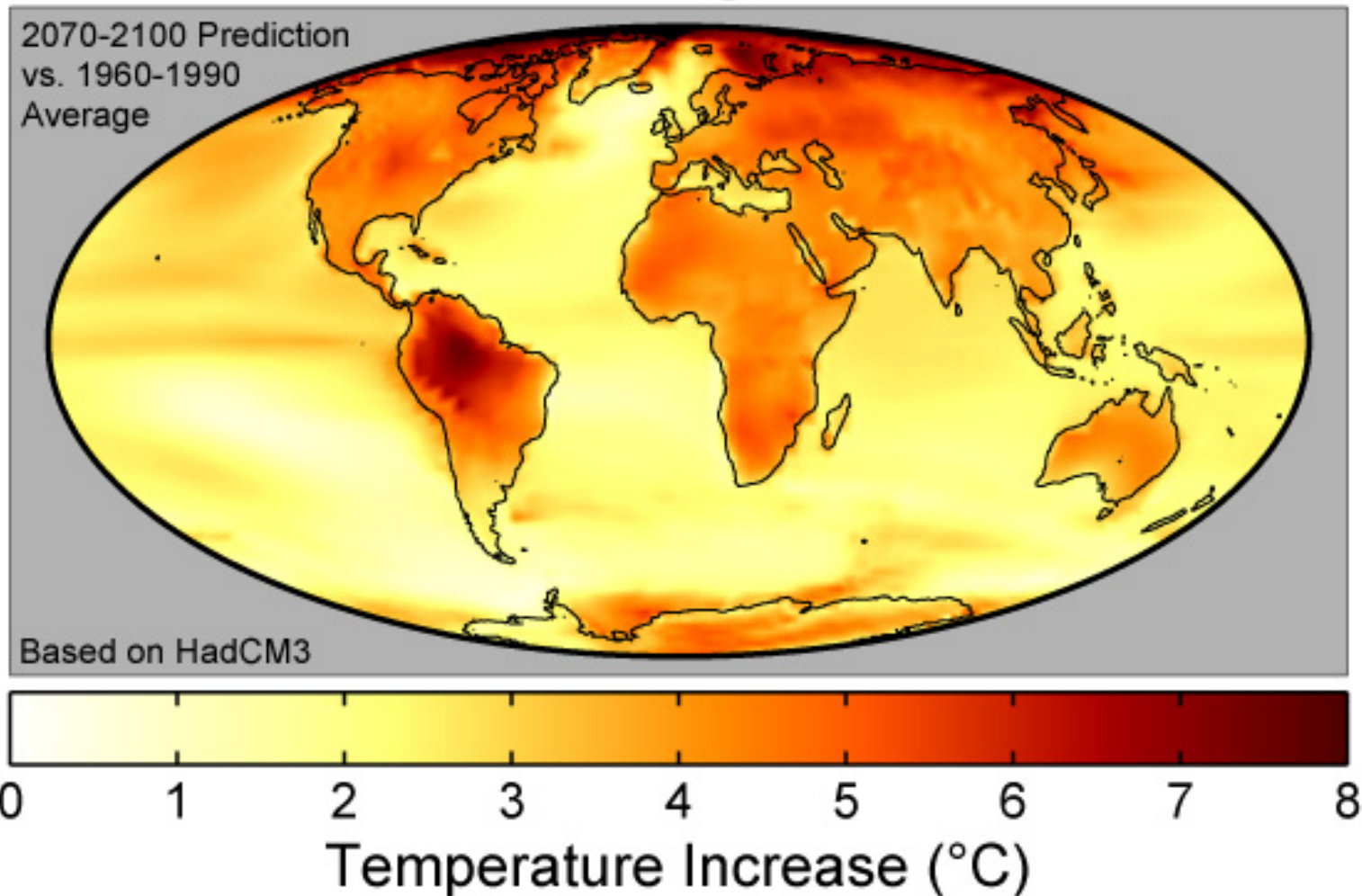
Rate of Temperature Change, 1901–2008



Projected Temperatures, 2070-2100

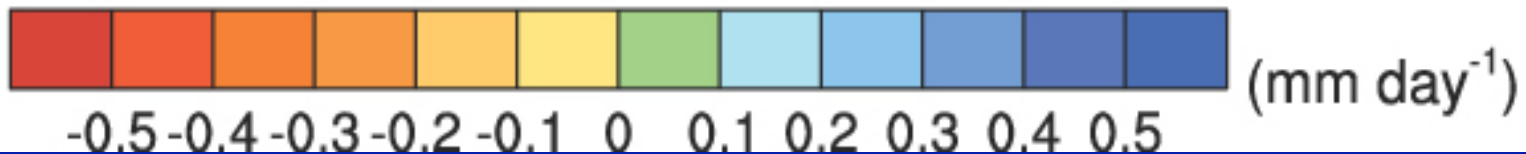
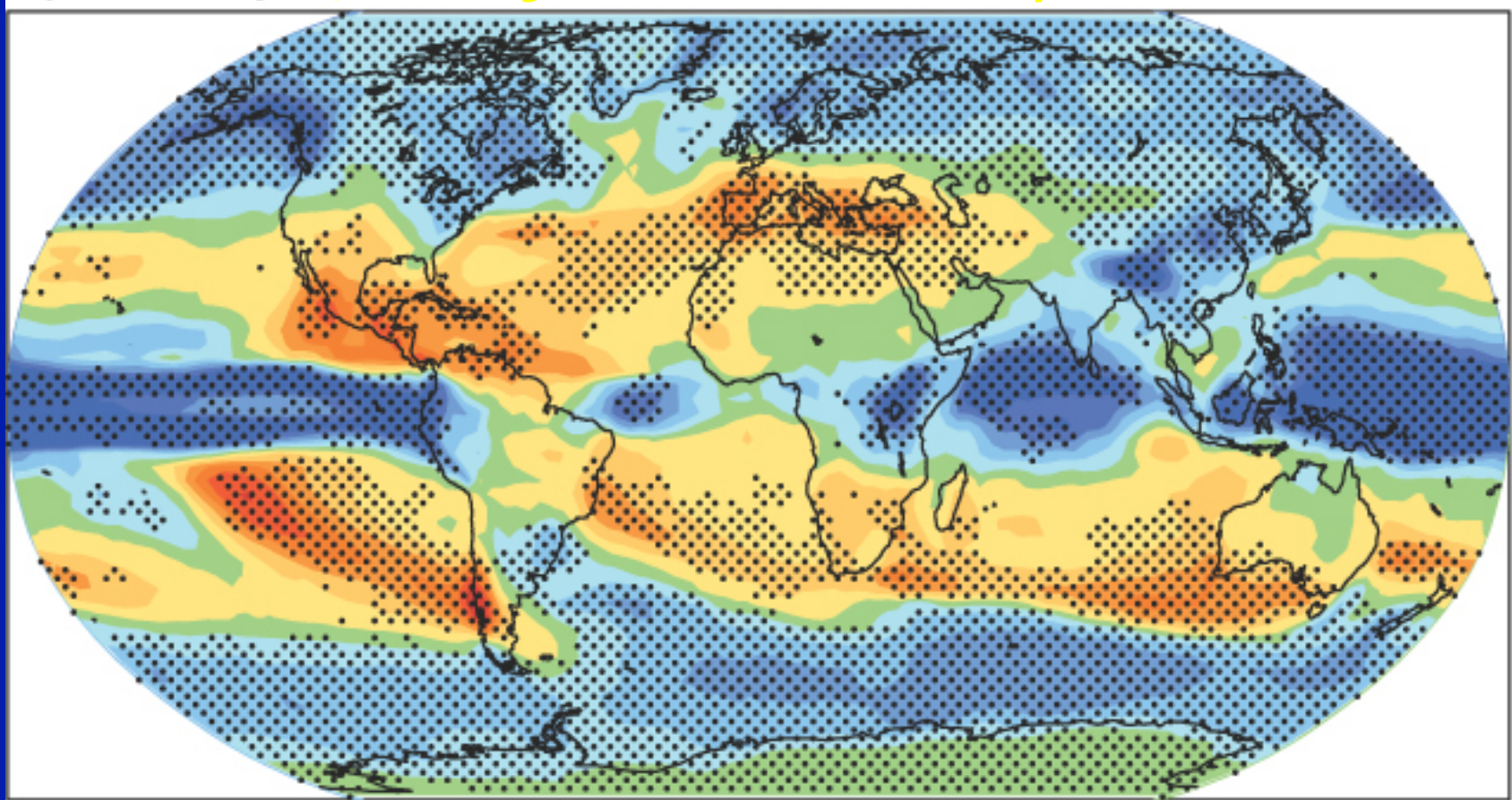
(Base years 1960-1990)

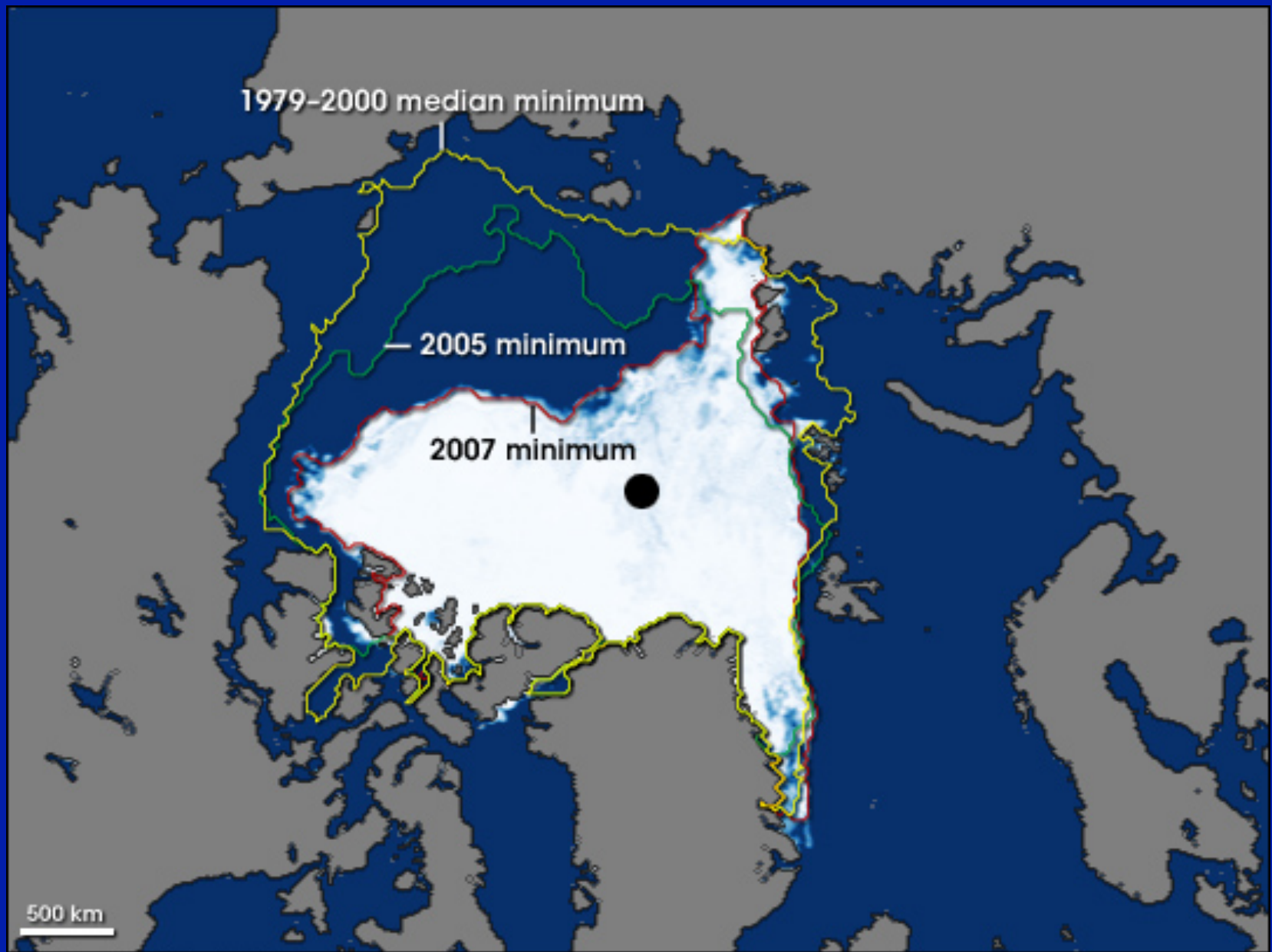
Global Warming Predictions



Projected Precipitation, 2080-2099

(Base years 1980-1990)



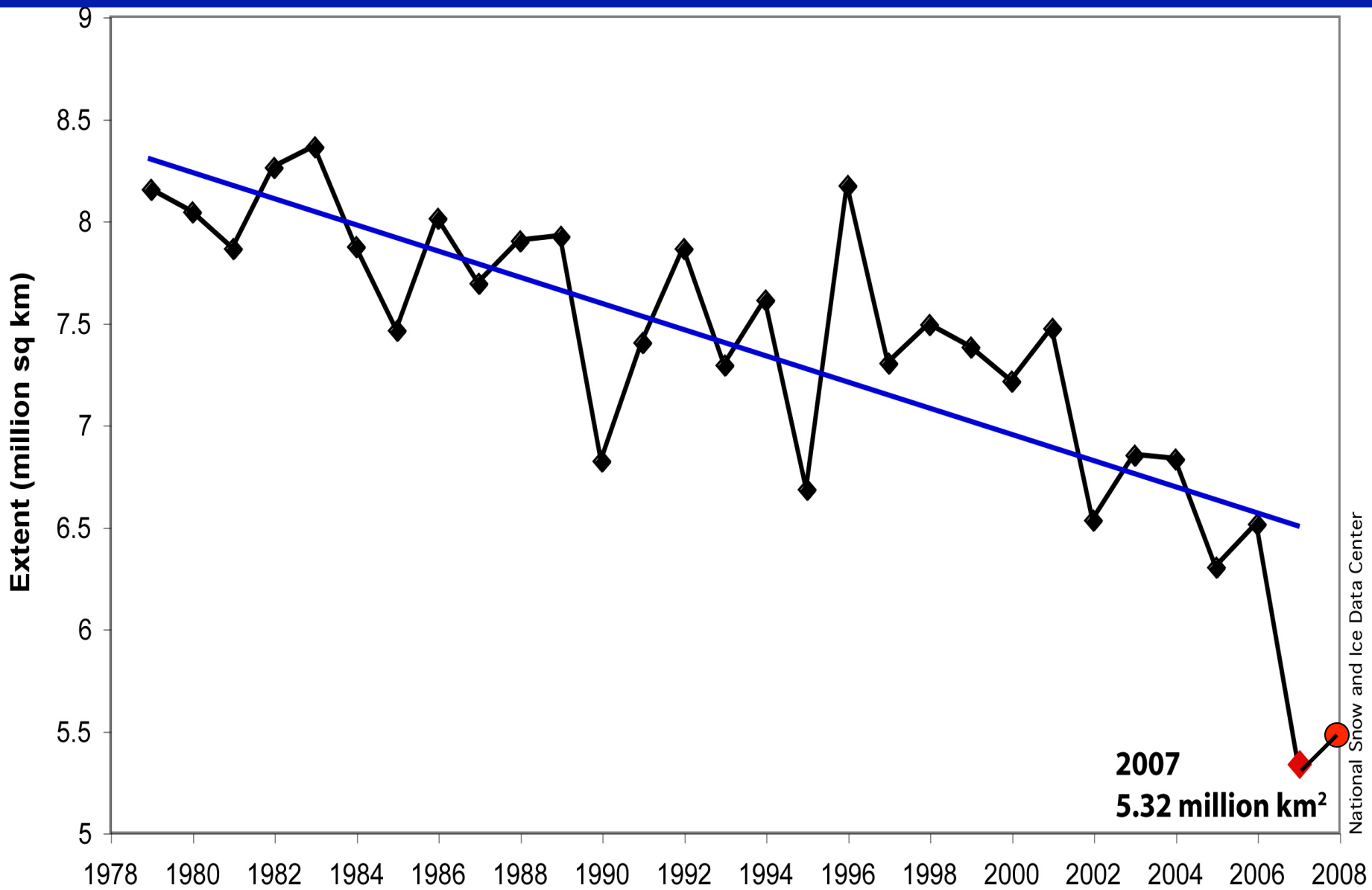


September 16, 2007

Sea Ice Concentration (percent)

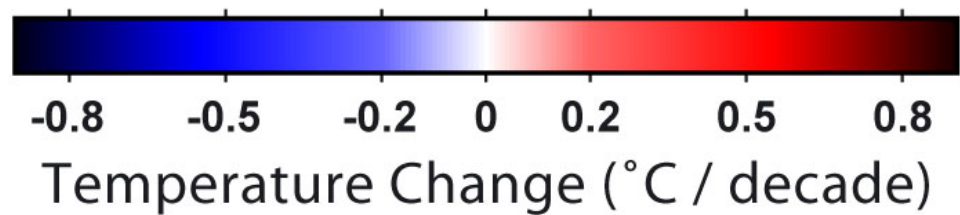
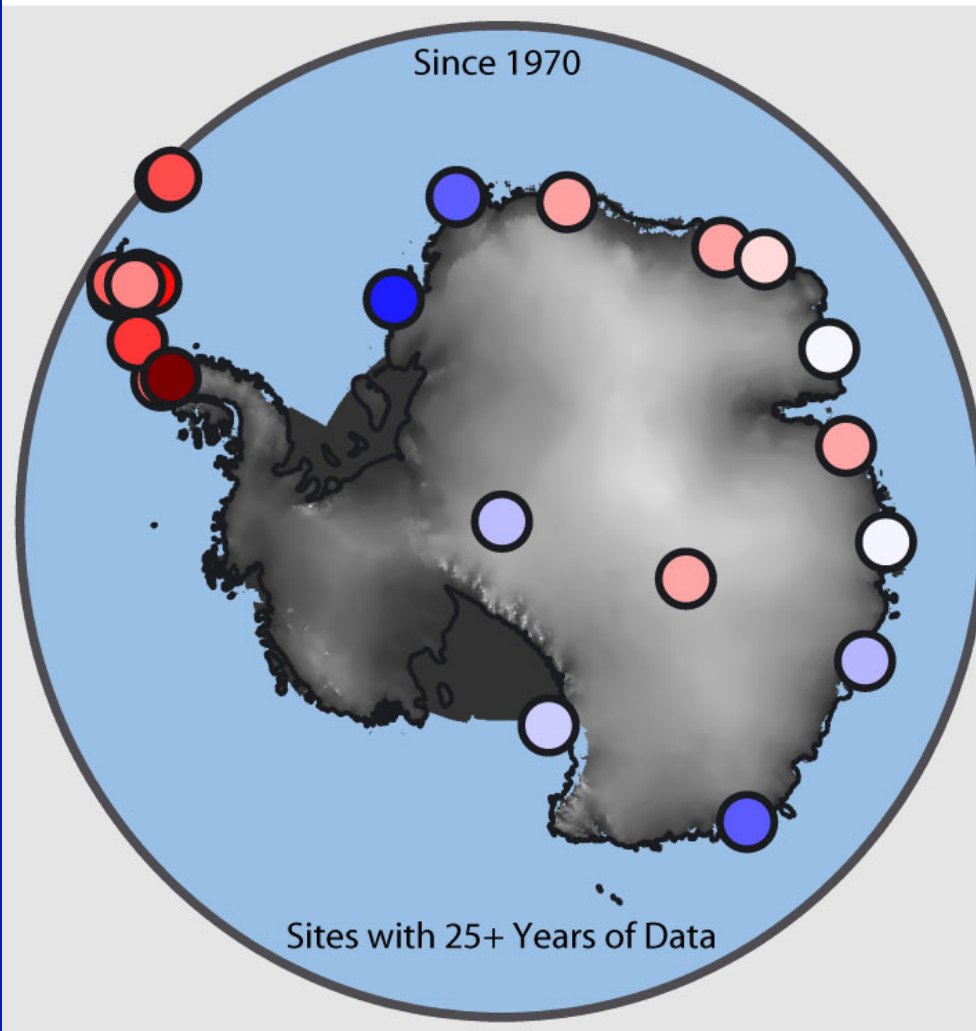


Areal Extent of Arctic Sea Ice



National Snow and Ice Data Center

Climate Change in Antarctica





Permafrost Melting, Tana Flats, Alaska

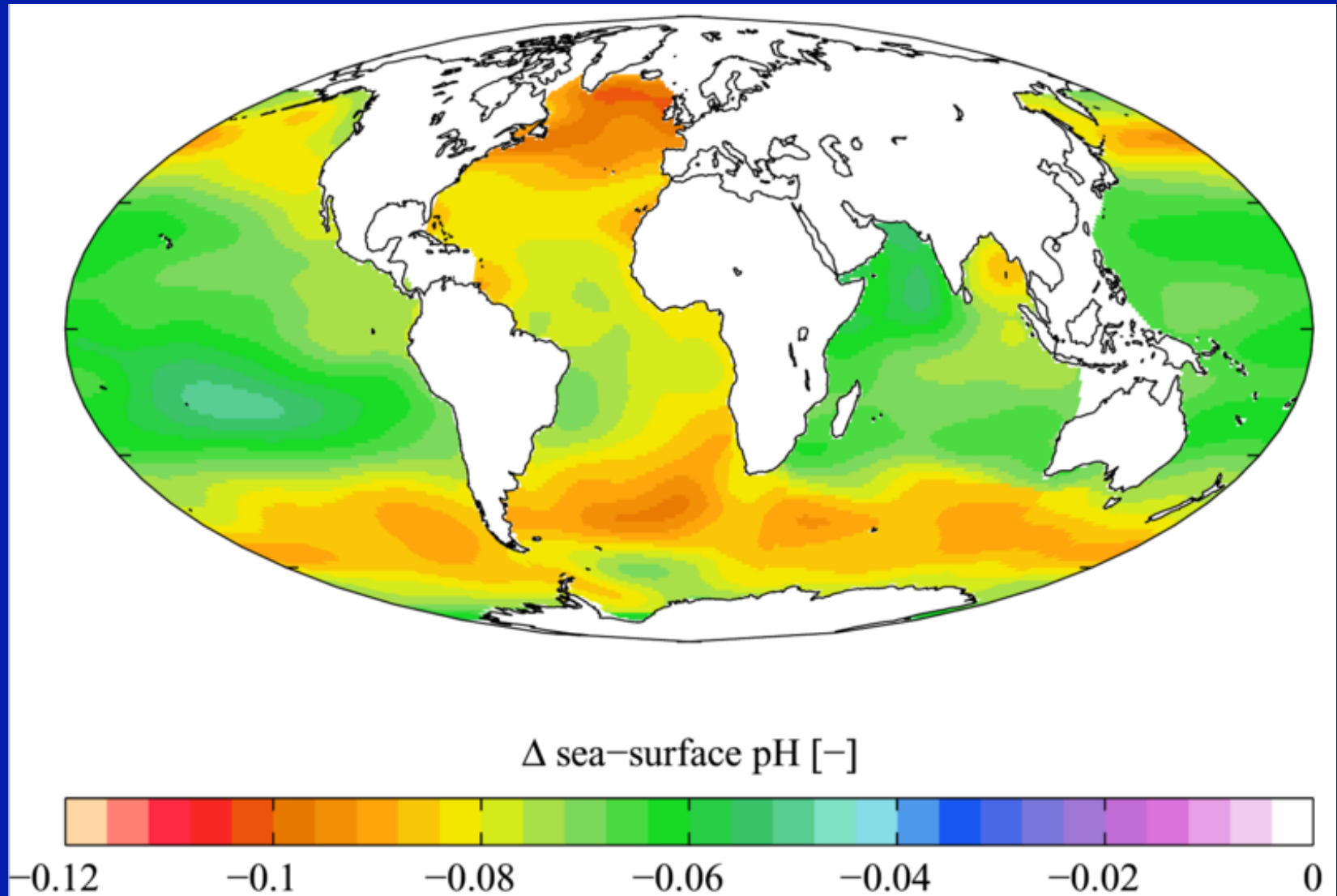
Tundra (1978)

to



Wetlands (1998)

Ocean Acidification has Increased by 30% since Industrialization



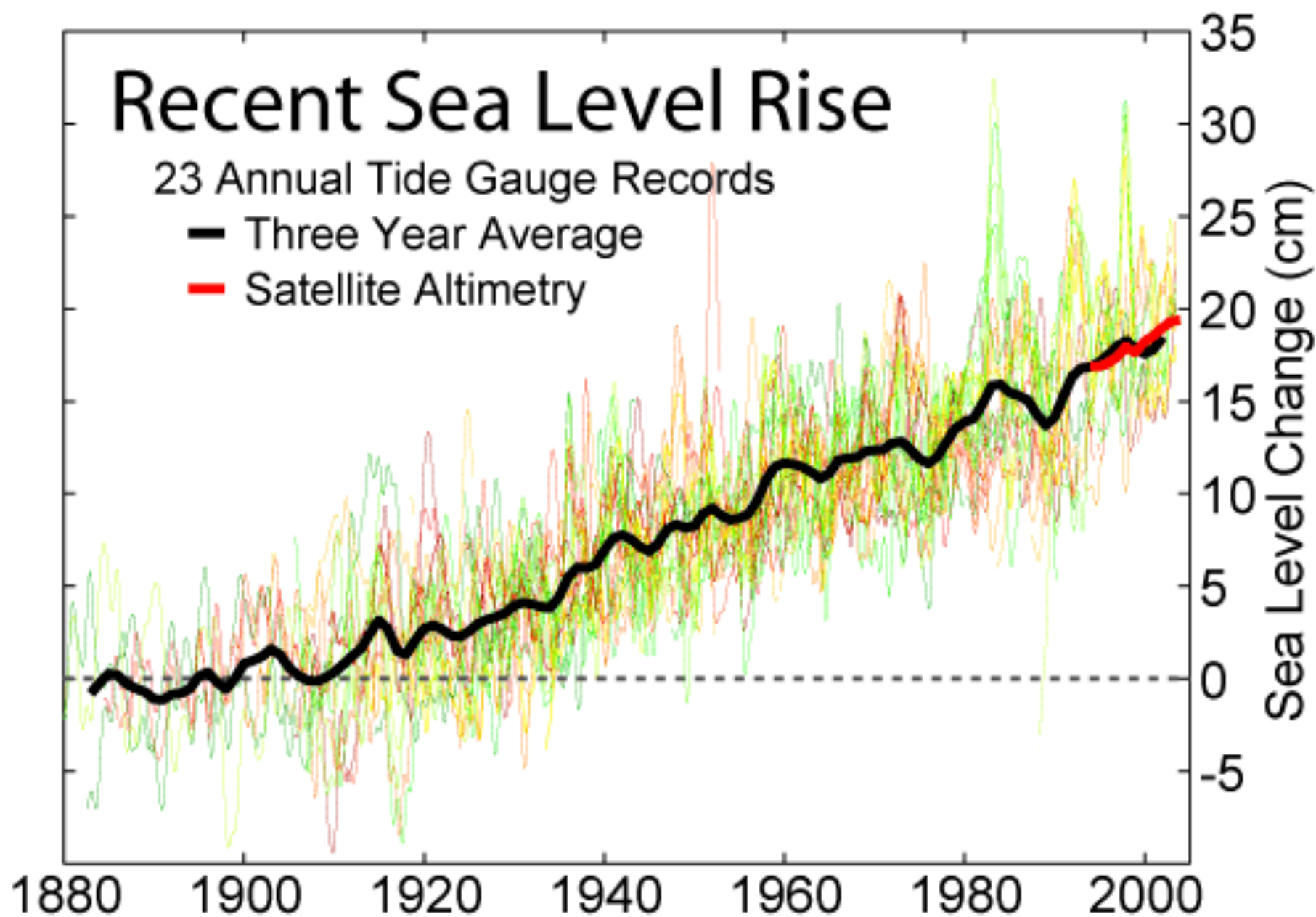
Change in ocean pH since 1700's

- ***Damaging to organisms that use calcium carbonate shells (corals, mollusks, foraminifera, etc.)***

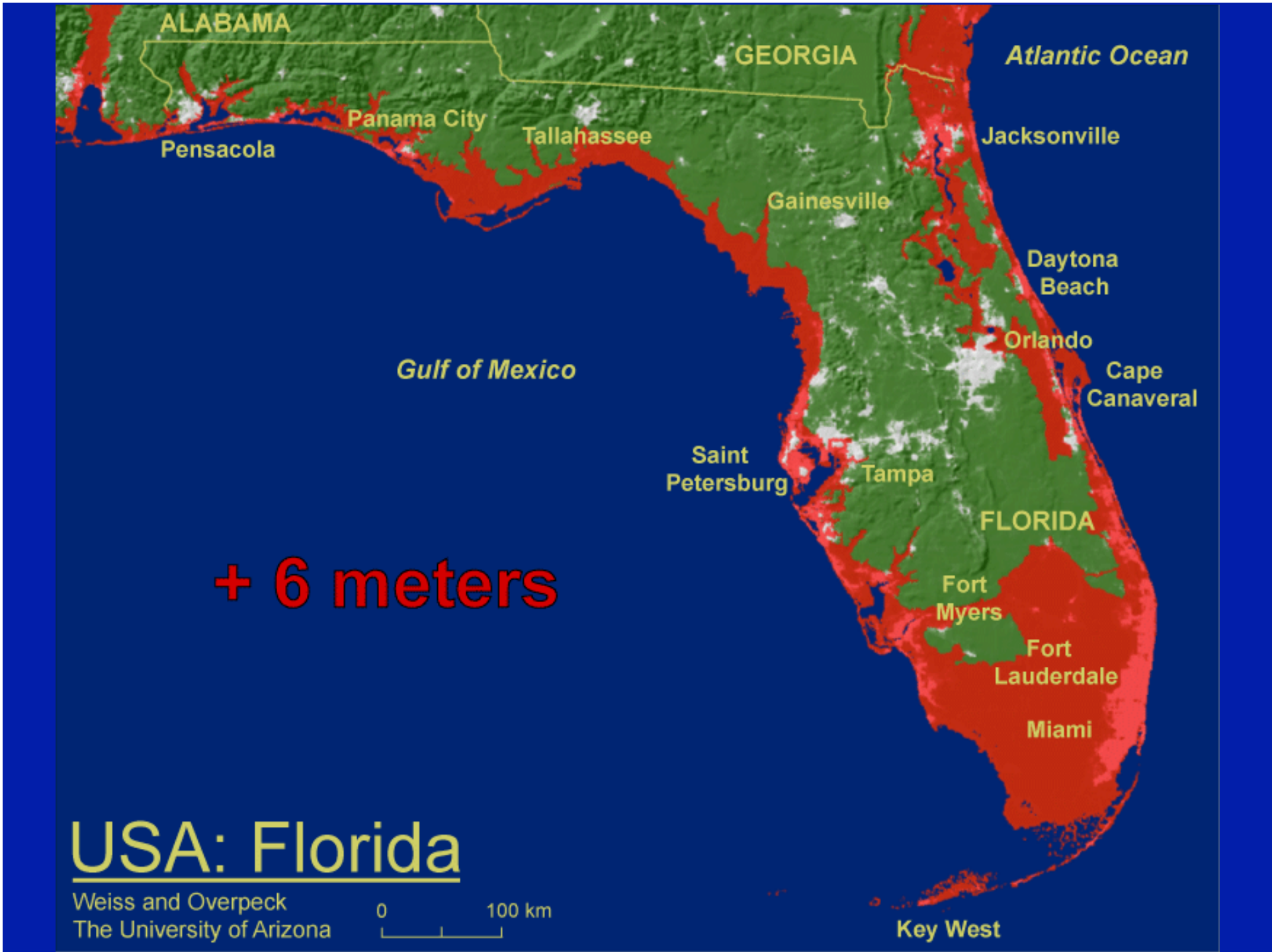
Recent Sea Level Rise

23 Annual Tide Gauge Records

- Three Year Average
- Satellite Altimetry







ALABAMA

GEORGIA

Atlantic Ocean

Pensacola

Panama City

Tallahassee

Jacksonville

Gainesville

Daytona Beach

Gulf of Mexico

Orlando

Cape Canaveral

Saint Petersburg

Tampa

FLORIDA

+ 6 meters

Fort Myers

Fort Lauderdale

Miami

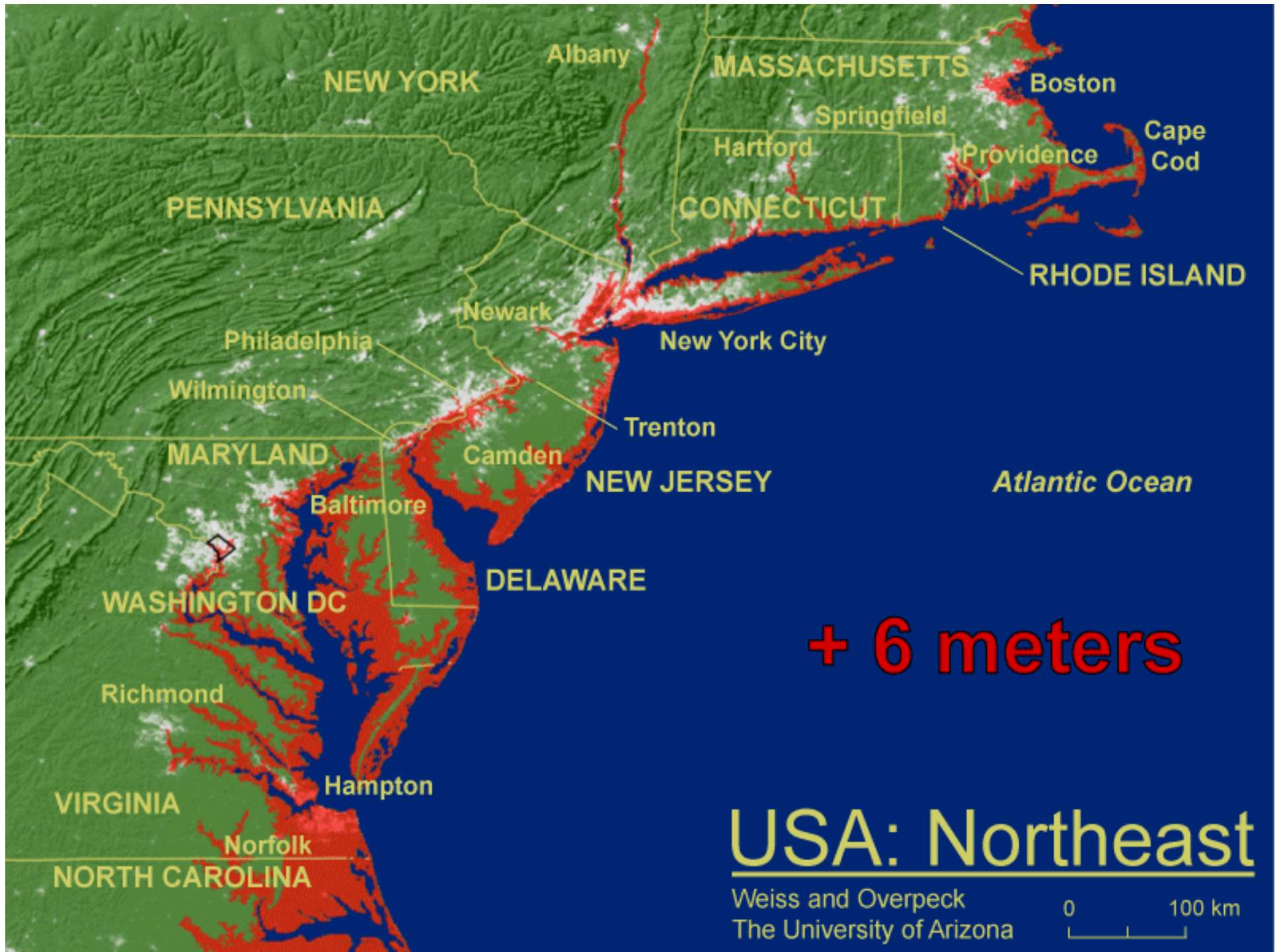
USA: Florida

Weiss and Overpeck
The University of Arizona

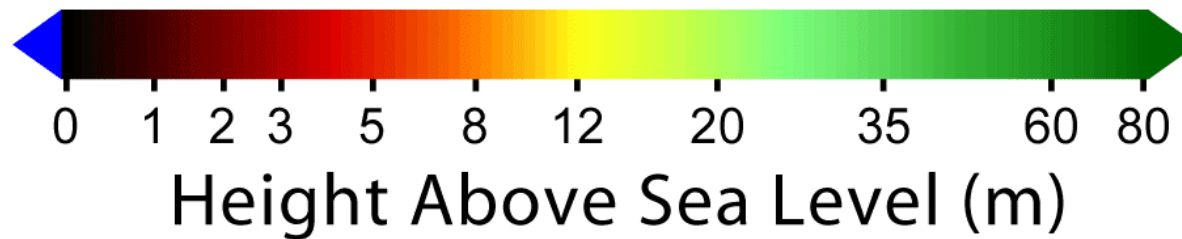
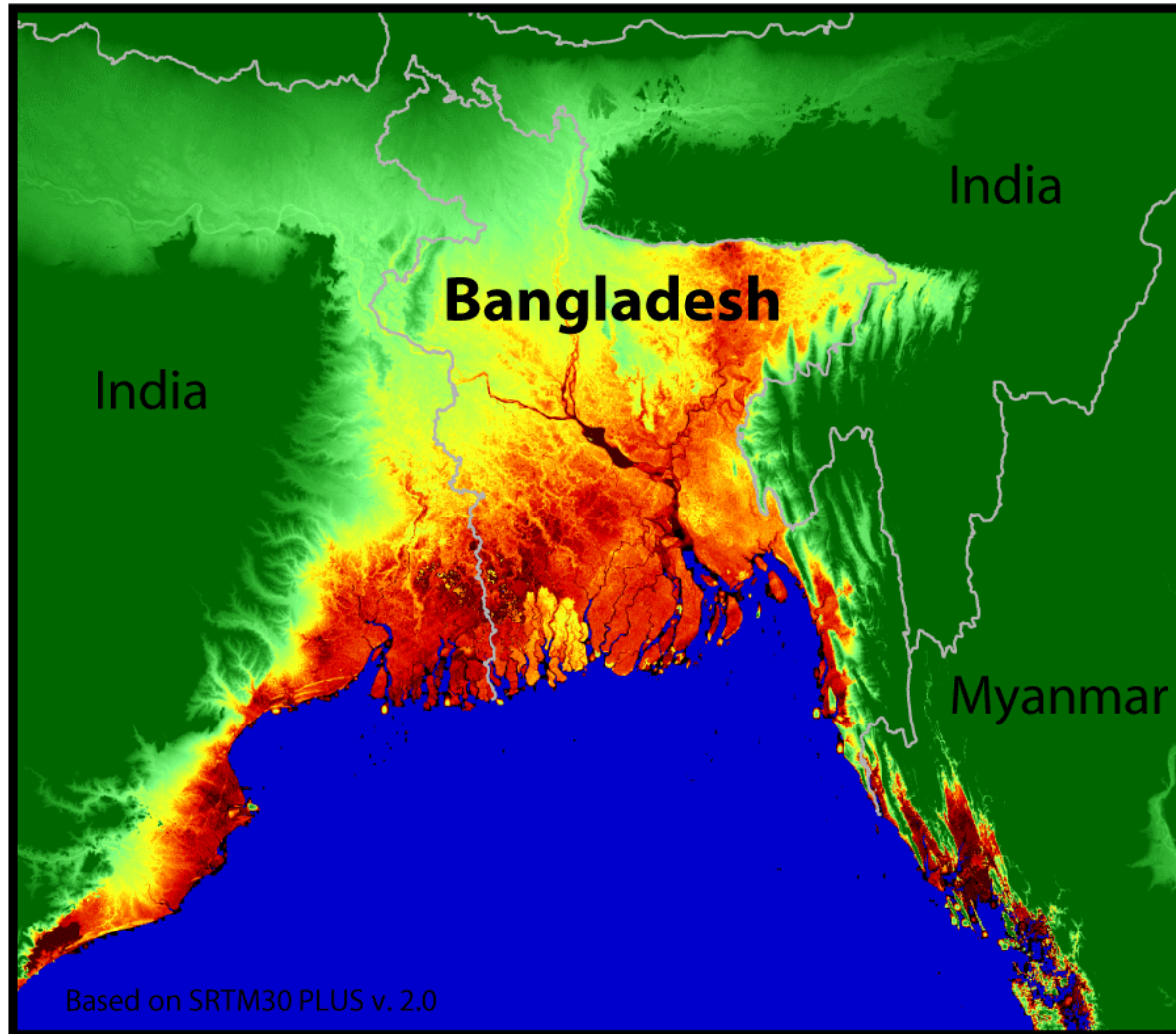


Key West





Sea Level Risks - Bangladesh



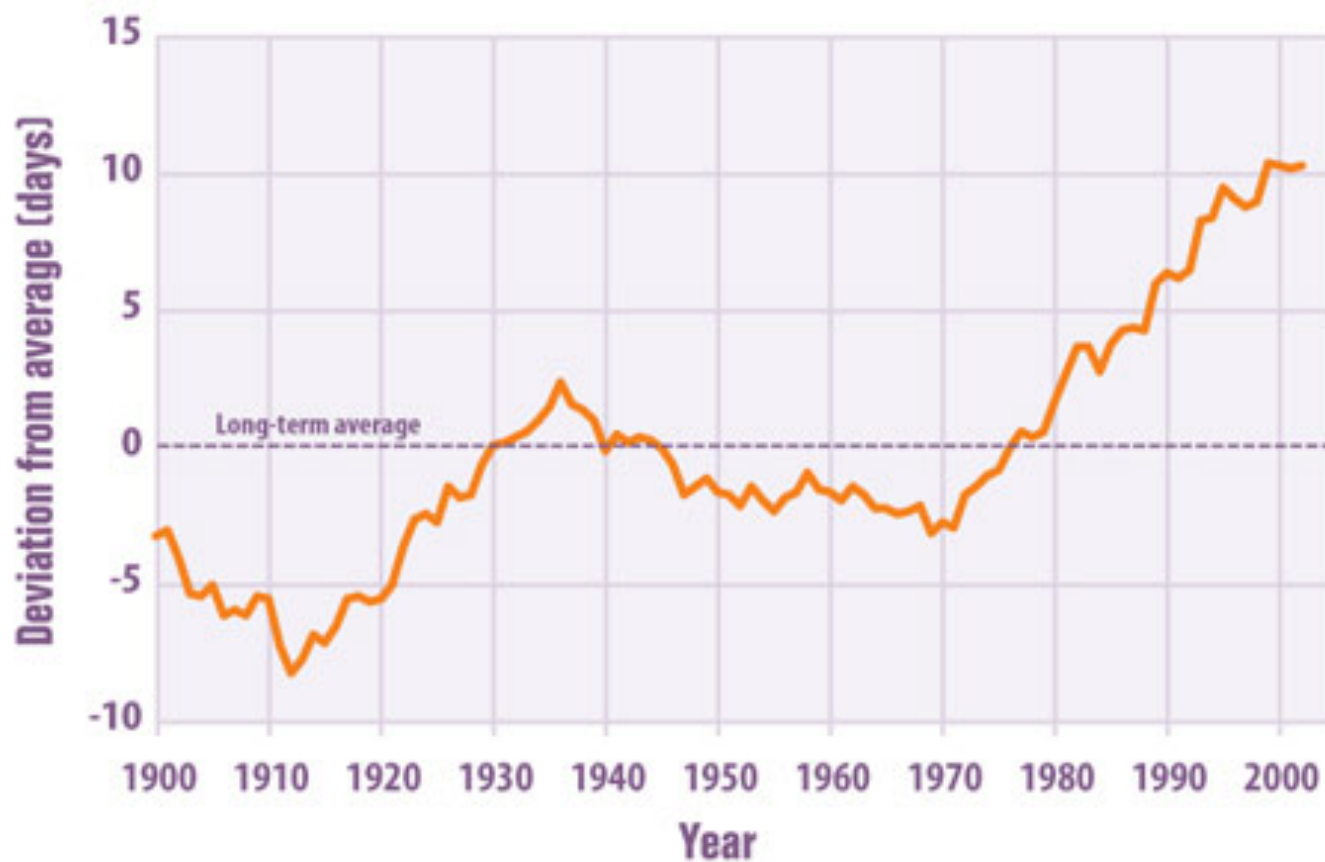
Coastlines if Greenland and Antarctica Melt



Lakes in the U.S. are staying frozen an average of 1 to 2 days less each decade.



Length of Growing Season in the Lower 48 States, 1900–2002



Last 10,000 years: VERY warm AND stable!!

Medieval Warm Period

