

Climate Change of the Past 2000 Years

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September 22, 2010



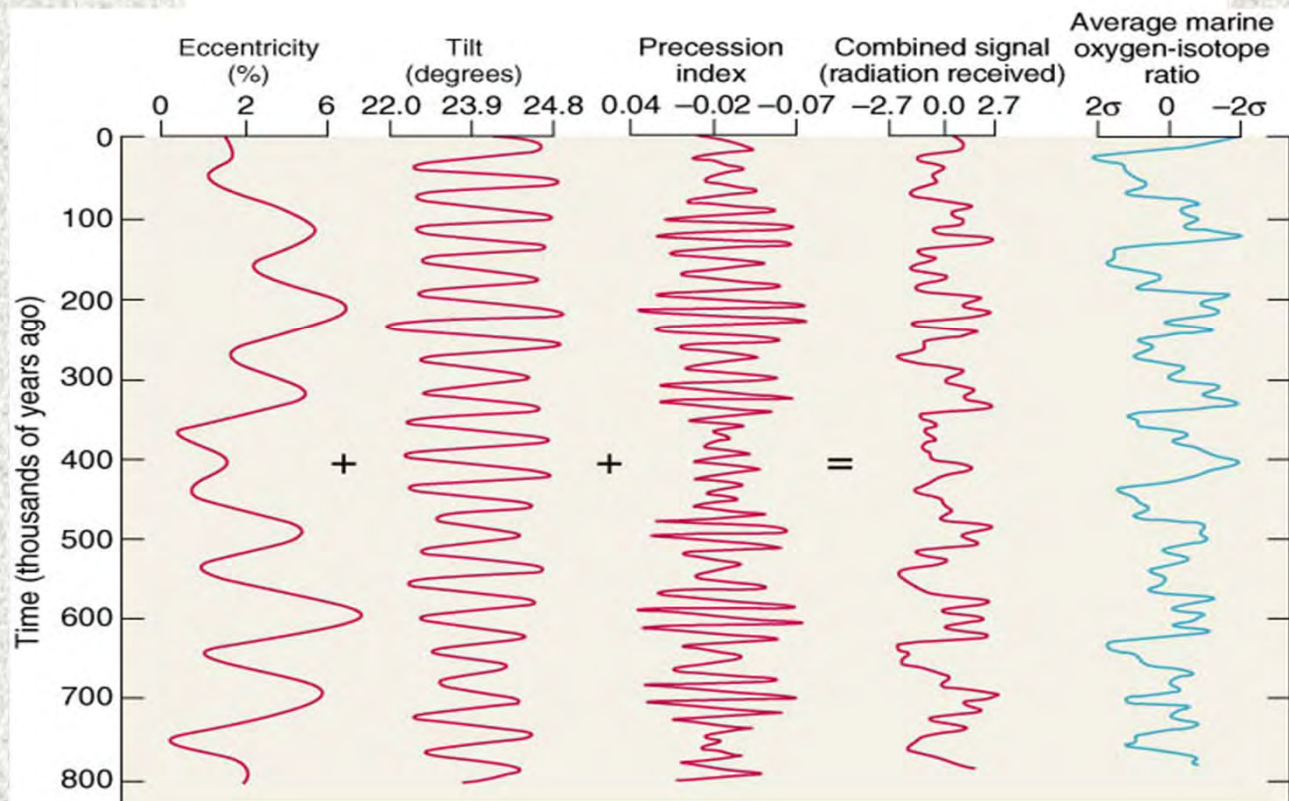
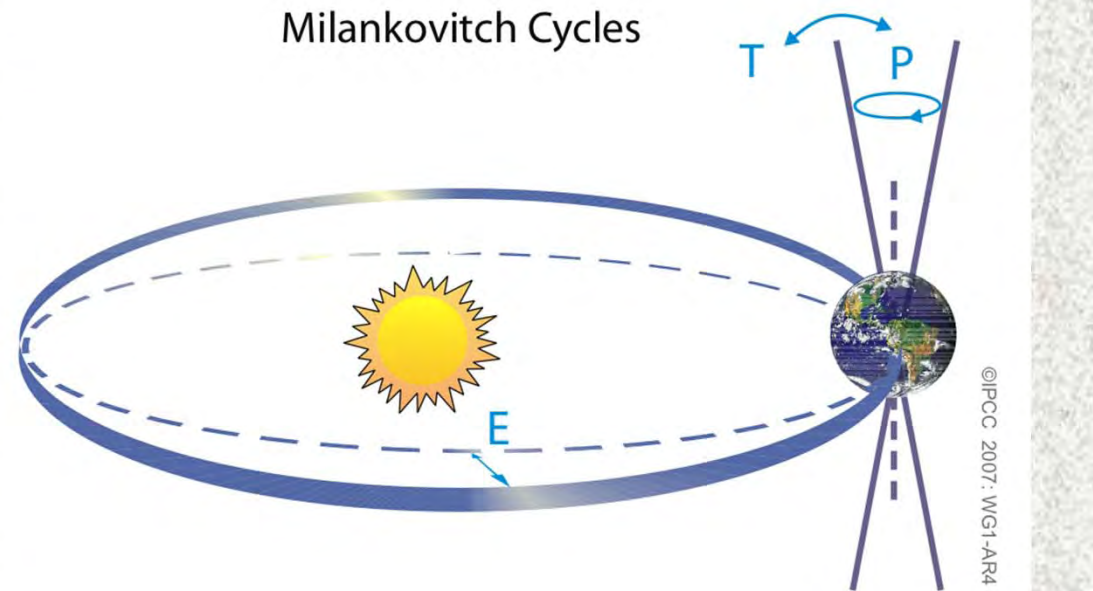
Image Credit: Saxon Holbrook

Paleoclimate: Milankovitch Cycles

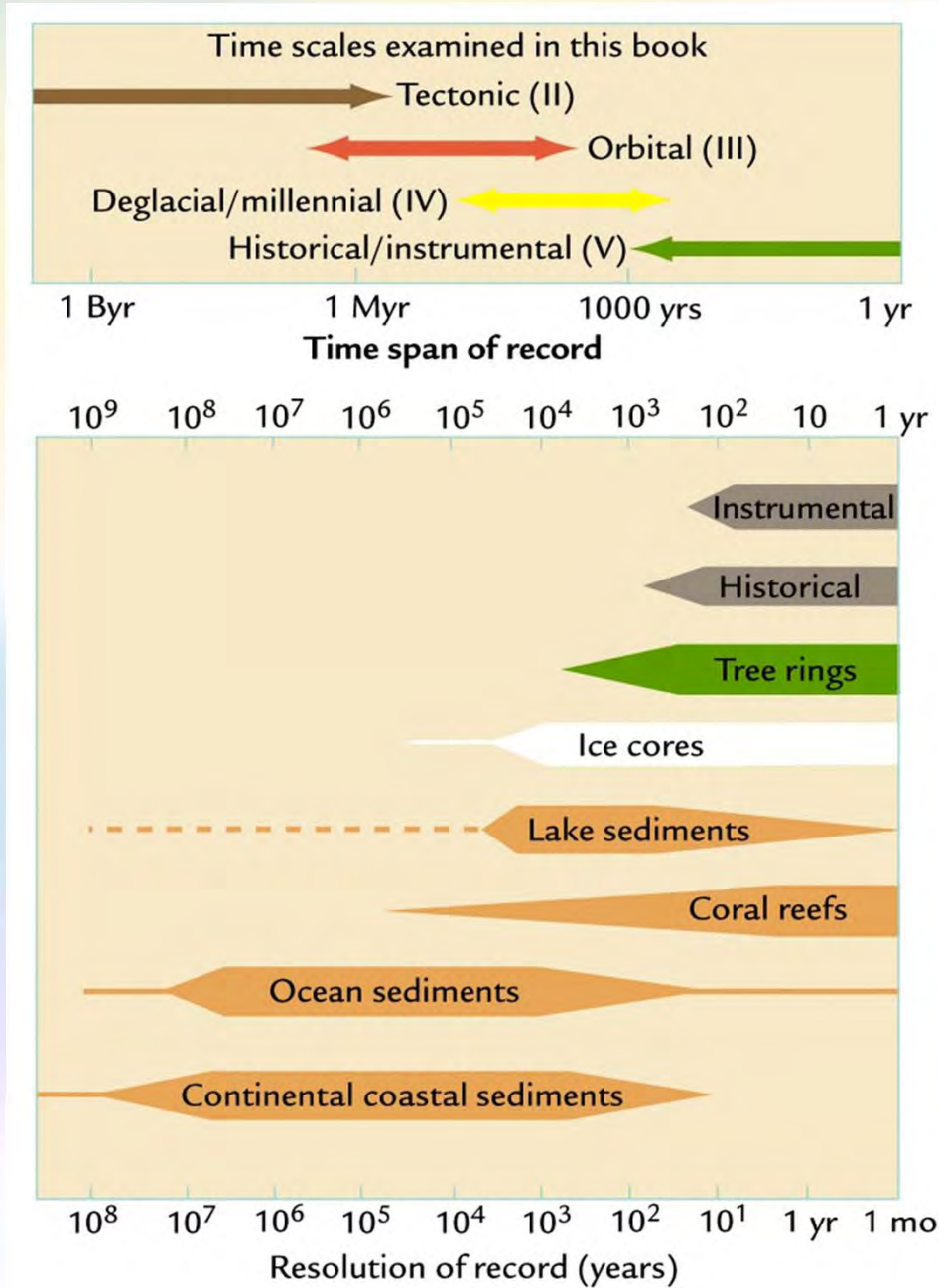
1911: Milutin
Milankovitch
proposes:

- ◆ All 3 cycles (23, 41, & 100 KYA) together control ice ages
- ◆ Summer insolation is driver

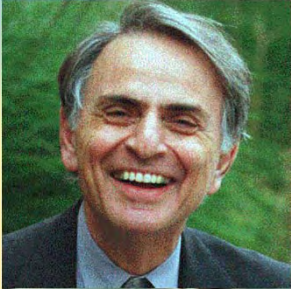
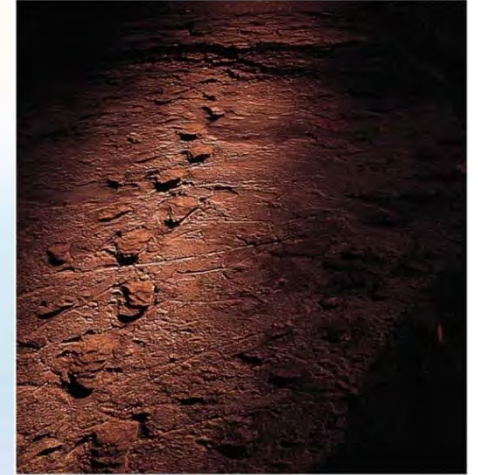
*Credit: Anna Klene,
U. of Montana*



Time scales for Proxy Data



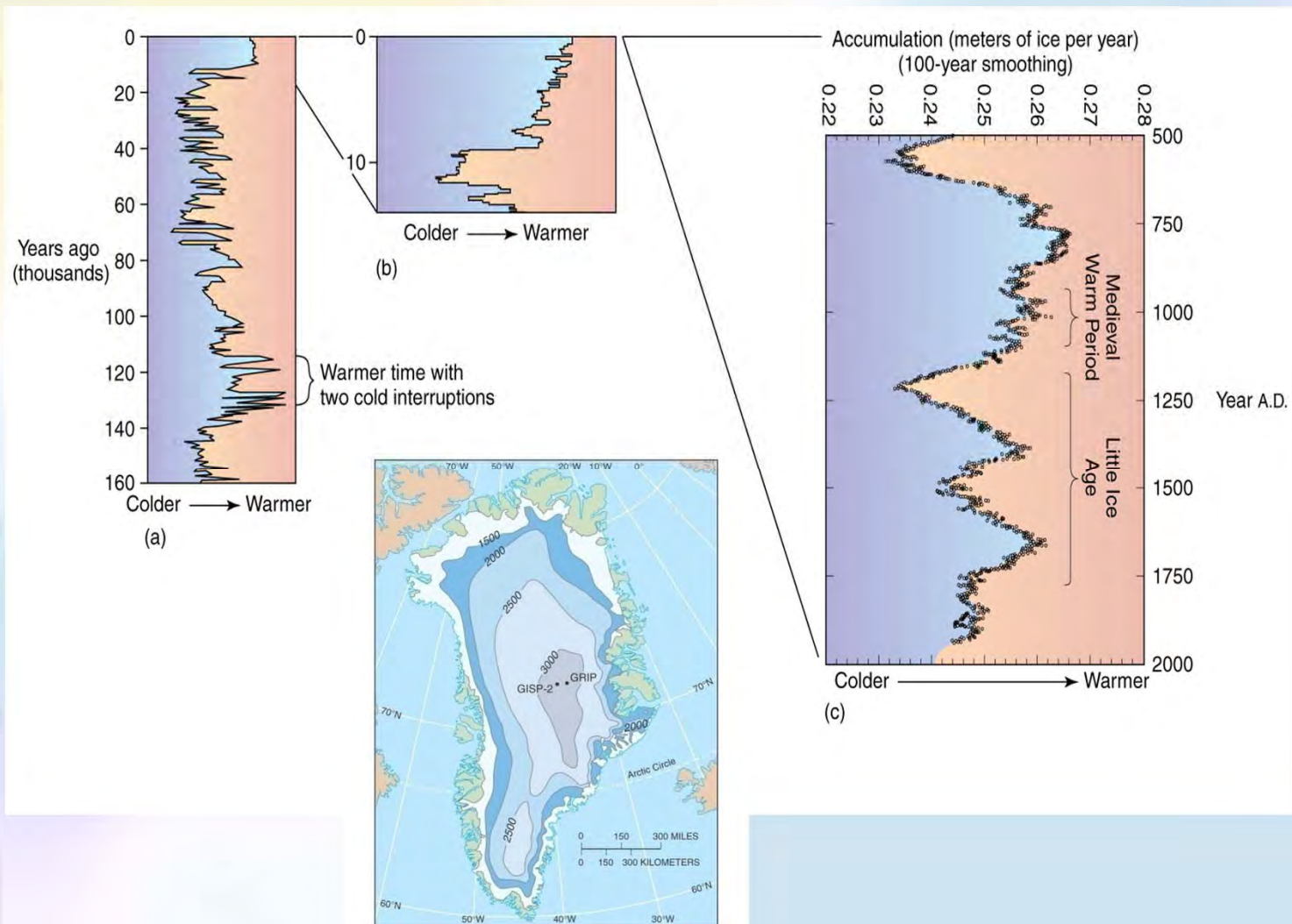
Anthropocene



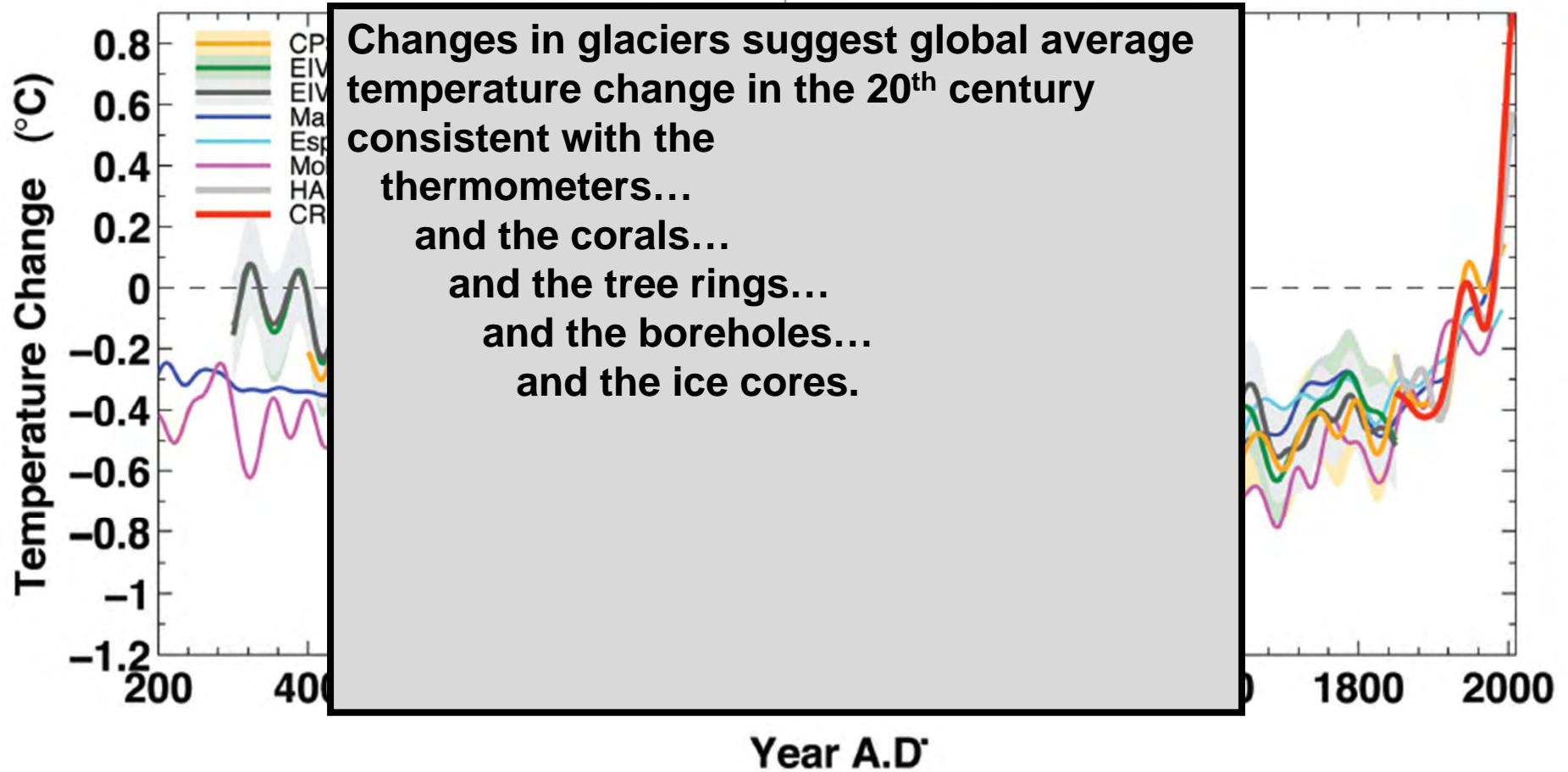
- Term used for climate where humans are the dominate controlling mechanism...
 - Concept first proposed in 1979 by Sagan
 - Phrase coined by Crutzen in 2000
 - Nobel prize winning chemist for his work on ozone depletion
 - No precise start date.
 - May be considered to start in late 18th century
 - "Start" of Industrial Revolution
 - Ruddiman proposes it started much earlier...8,000 years ago

Last 2000 years....

- Greenland Ice Cores:
 - High resolution record of temps near Europe...

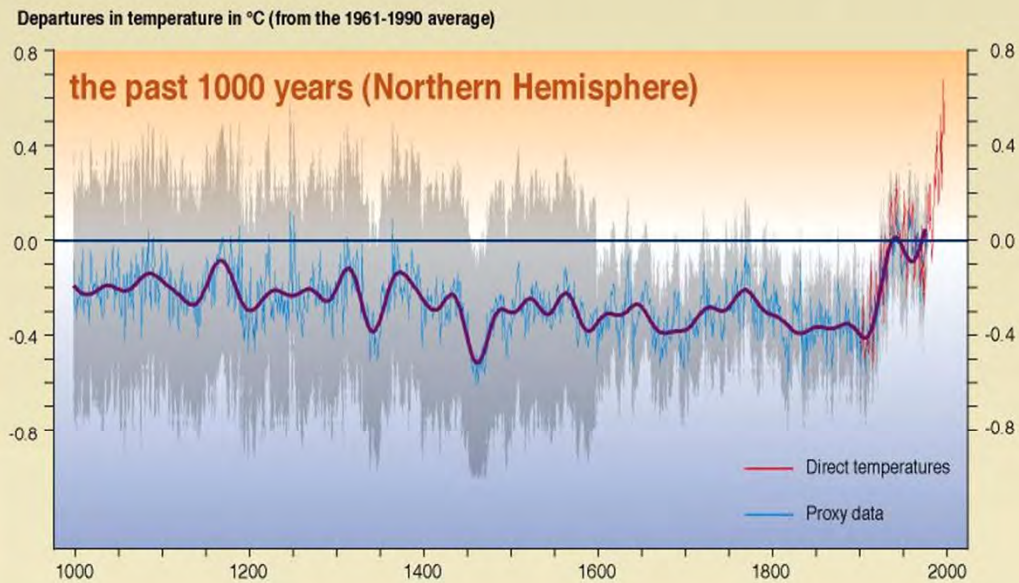
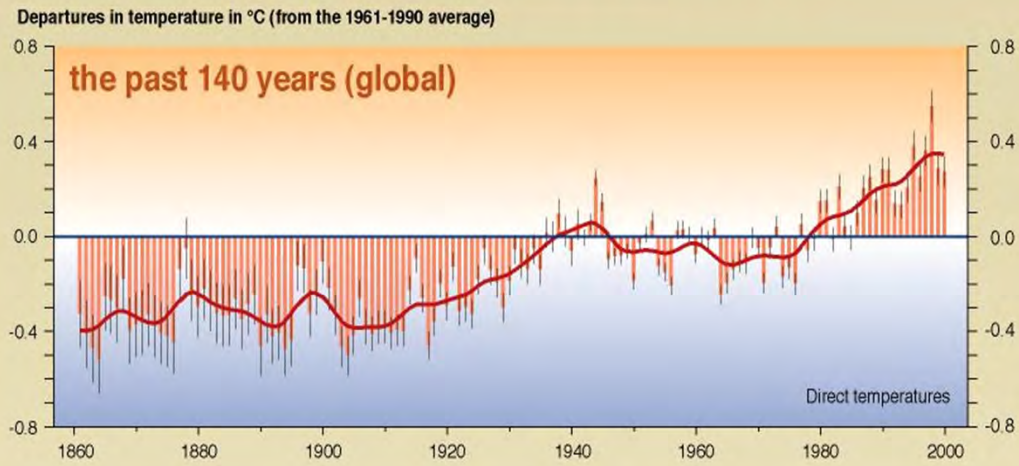


Comparison of Northern Hemisphere Temperature Reconstructions



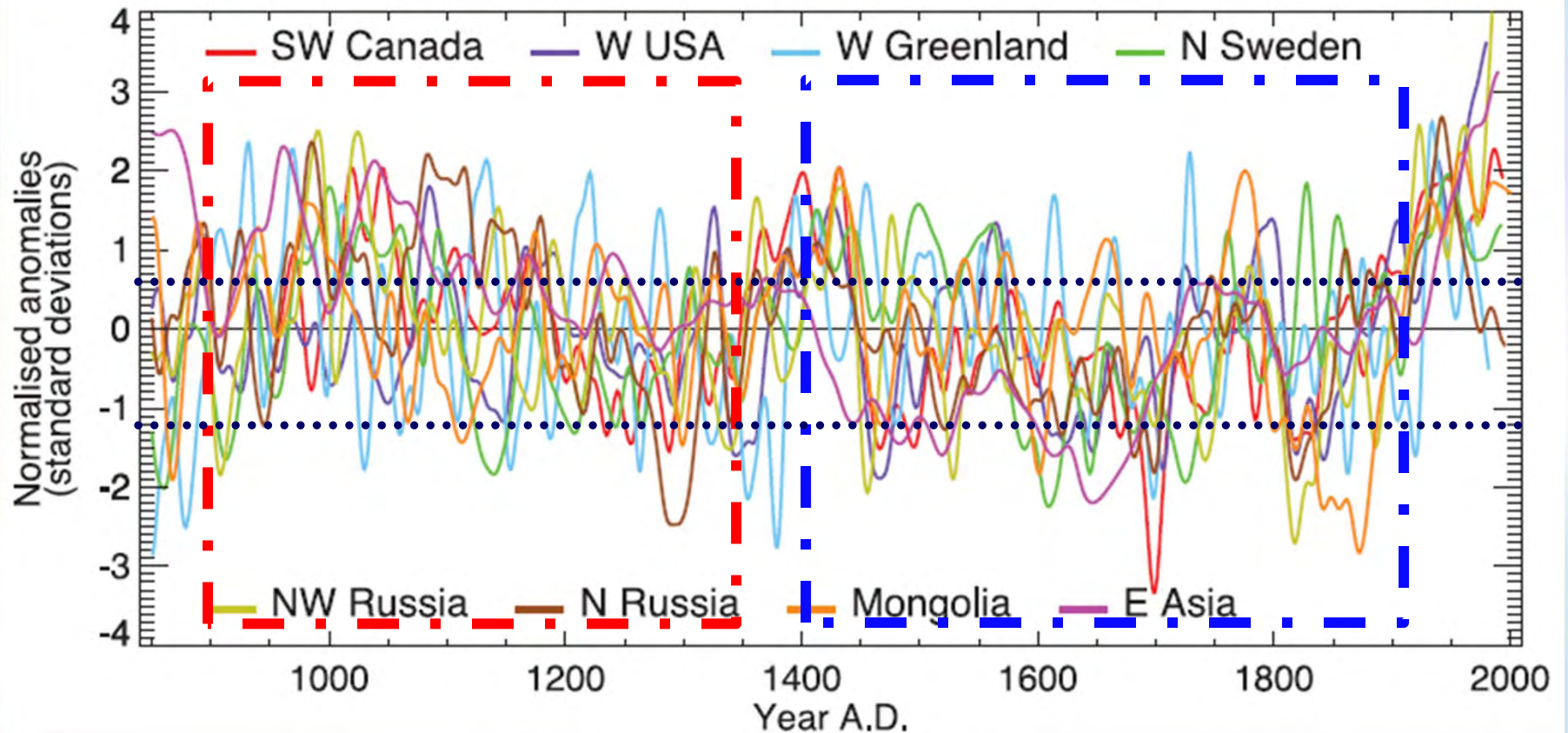
Mann et al. 2008

Variations of the Earth's surface temperature for...



SYR - FIGURE 2-3

Last 2000 years....



Last 2000 years....

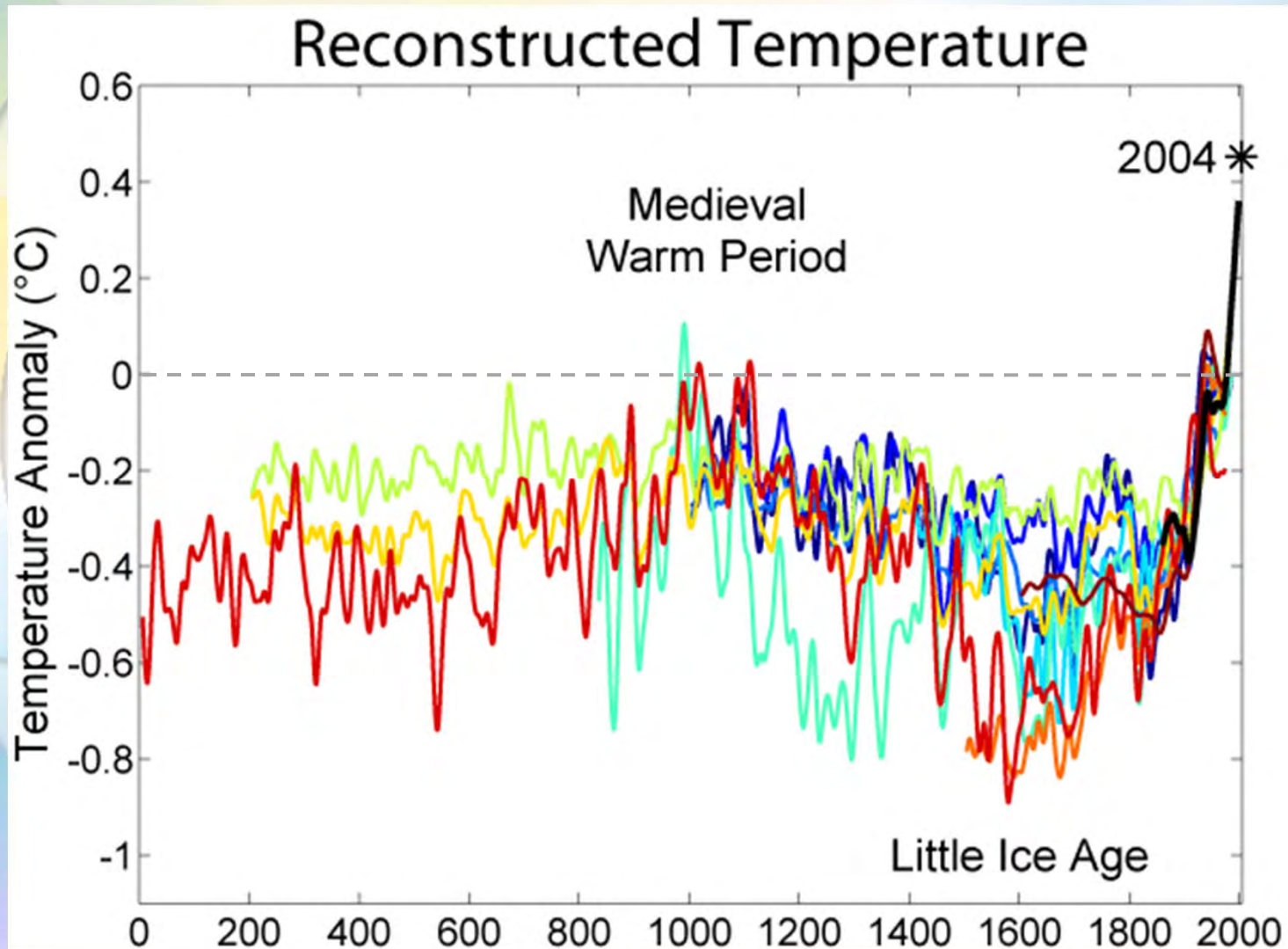


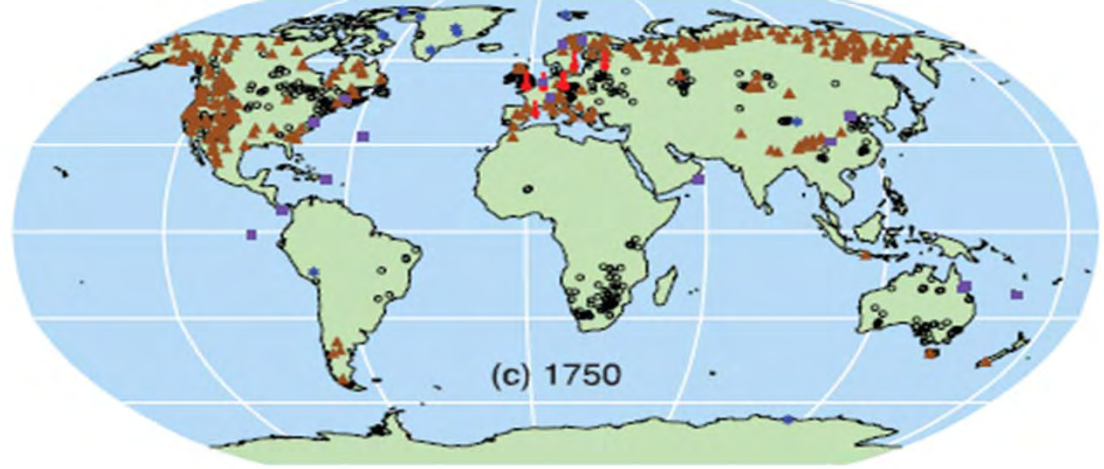
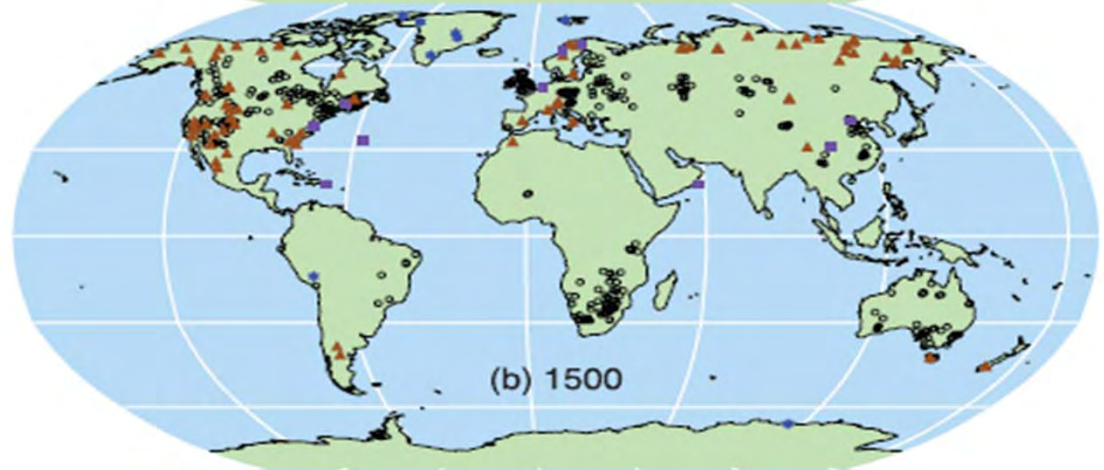
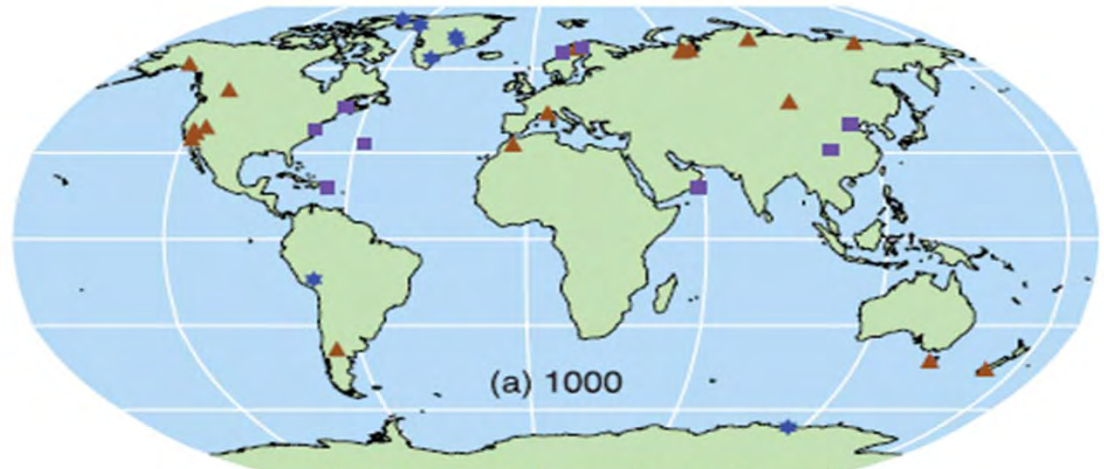
Image Credit: Robert A. Rohde,
Global Warming Art

Proxy Records

—

Where do they come from?

-  Instrumental record
-  Tree rings
-  Boreholes
-  Ice core/ice borehole
-  Other



Medieval Warm Period (~800-1300)

(a.k.a. Medieval Climate Optimum
a.k.a. Medieval Climatic Anomaly)



Medieval Warm Period (~800-1300)

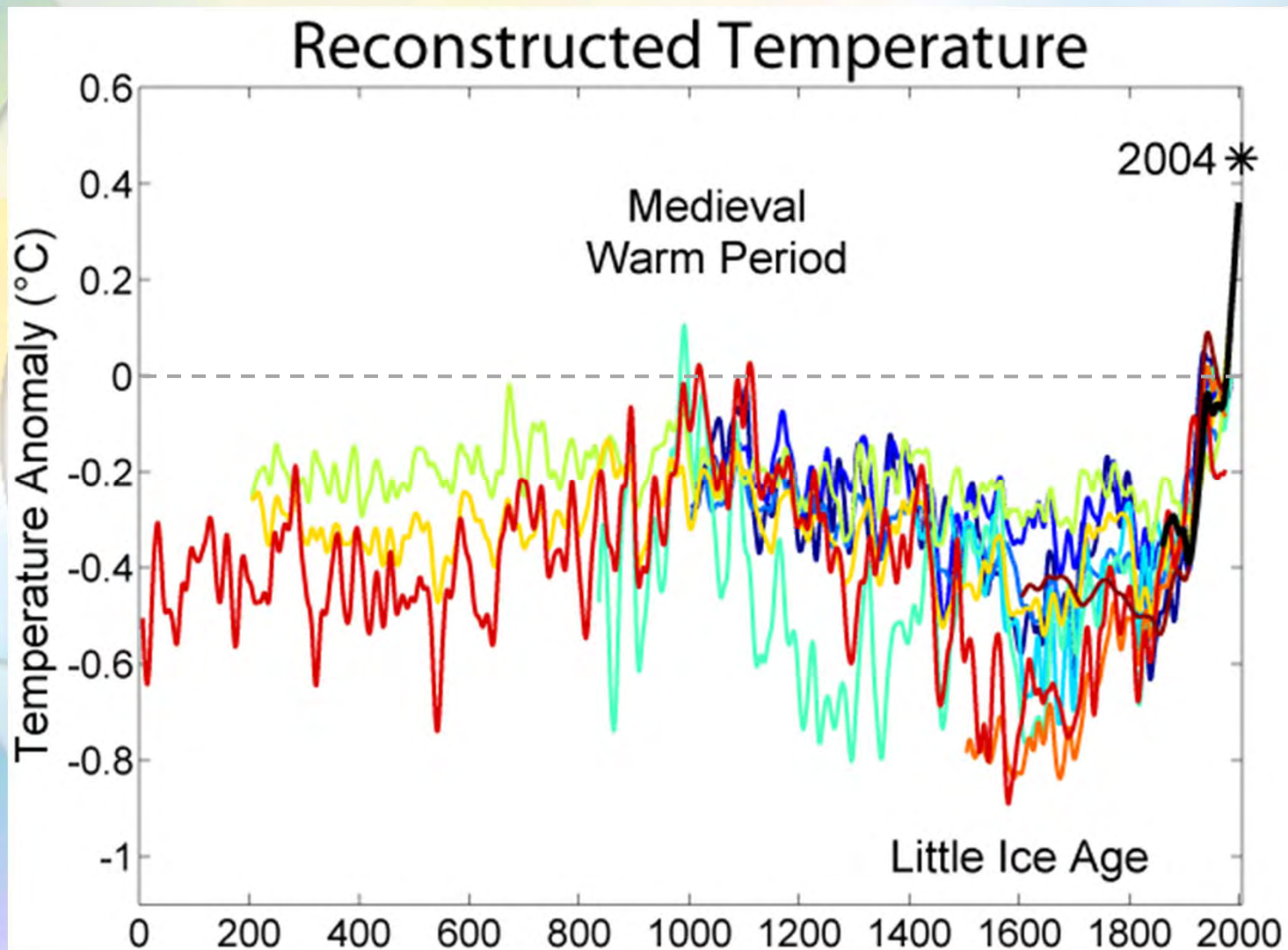
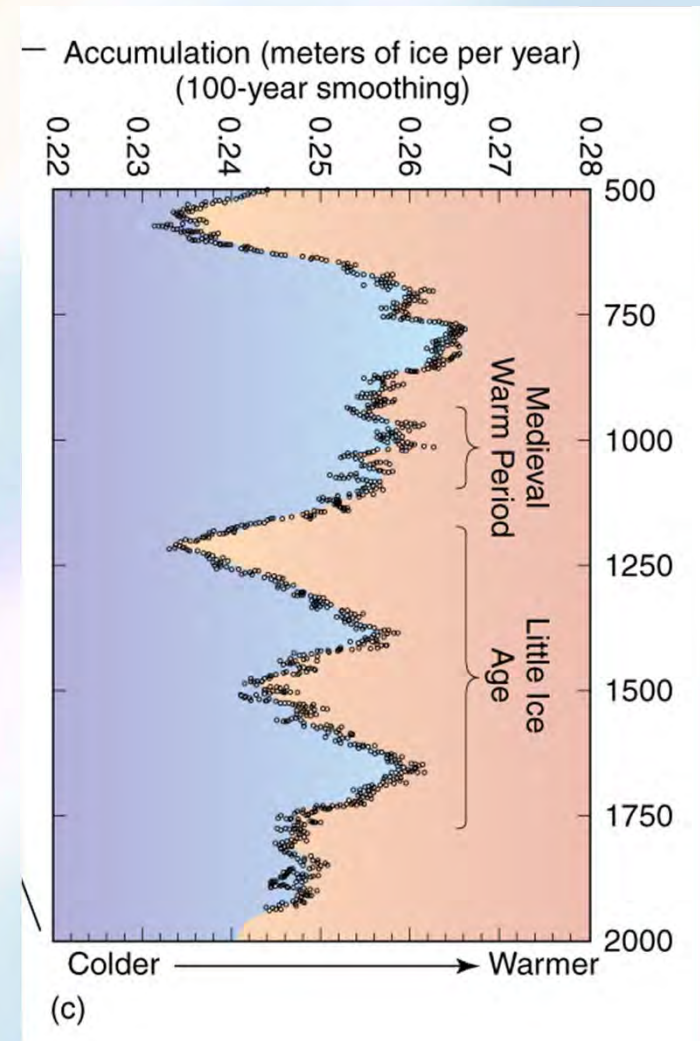


Image Credit: Robert A. Rohde,
Global Warming Art

Medieval Warm Period (~800-1300)

- Scattered evidence exists in Europe and the high latitudes surrounding the North Atlantic.
 - Cultivation of Greenland & Iceland
 - Grapes in England?
 - Medieval temperatures were probably 1-2°C above early 20th century levels at various European locations
 - Evidence in Japan, Alaska
 - Regional in nature
 - There were both warmer and colder areas
- Drought was evident in western U.S. (Anasazi), Central America (Mayan) & Africa

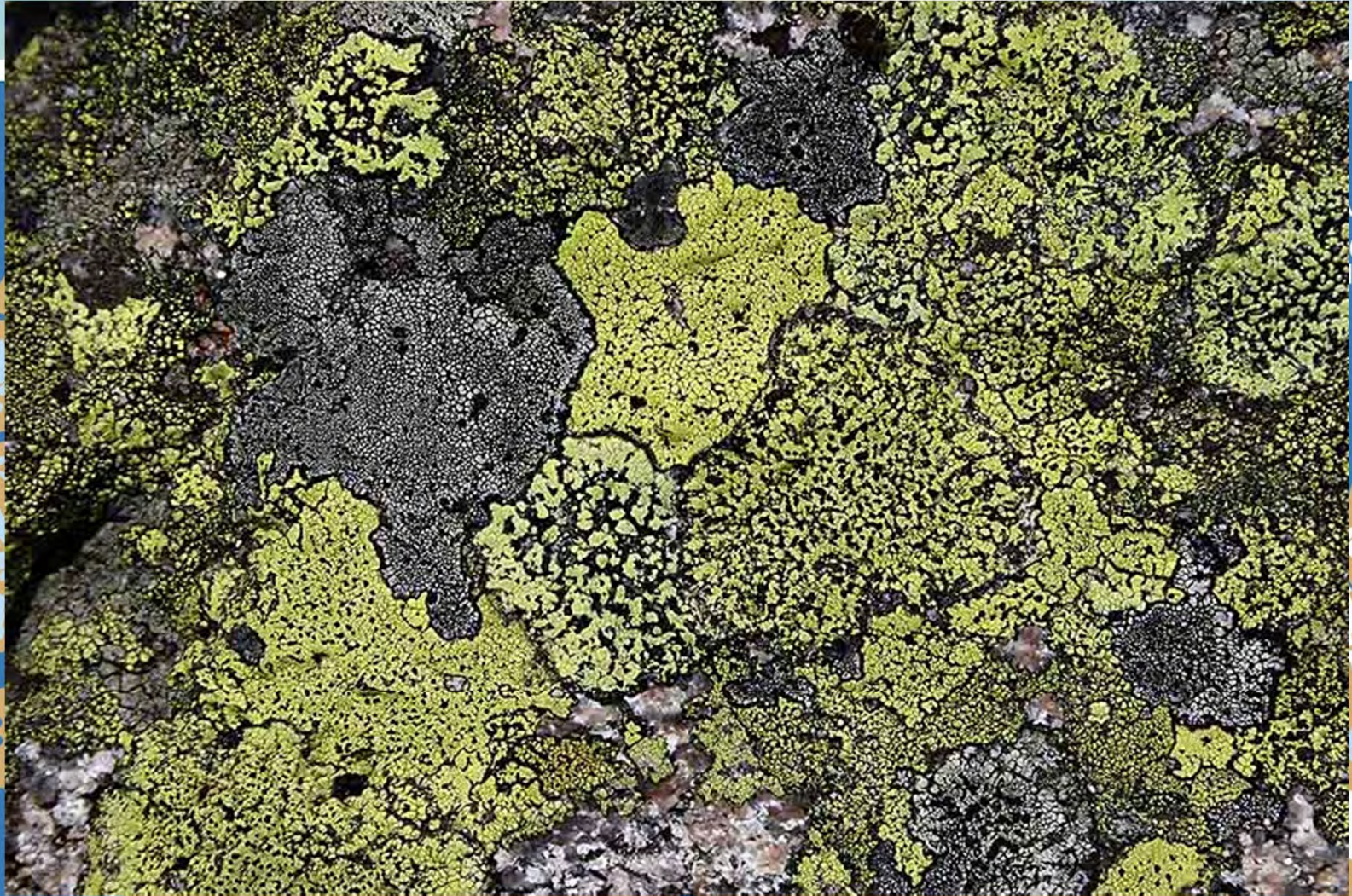


Medieval Warm Period (~800-1300)

“Evidence is not sufficient to support a conclusion that hemispheric mean temperatures were as warm, or the extent of warm regions as expansive, as those in the 20th century as a whole, during any period in medieval times.”
(IPCC 2007)



The Little Ice Age (1400-1900)



The Little Ice Age (1400-1900)

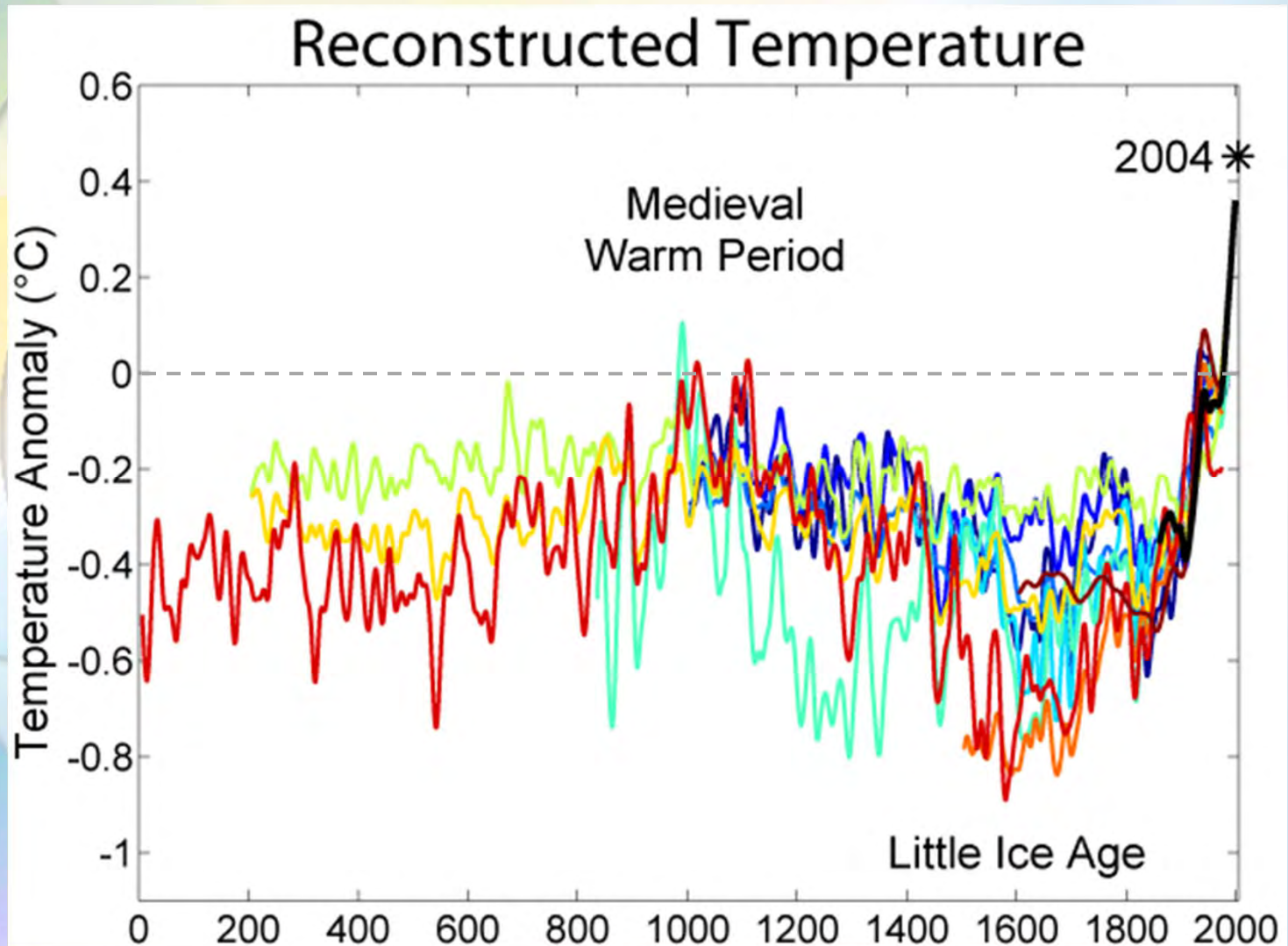
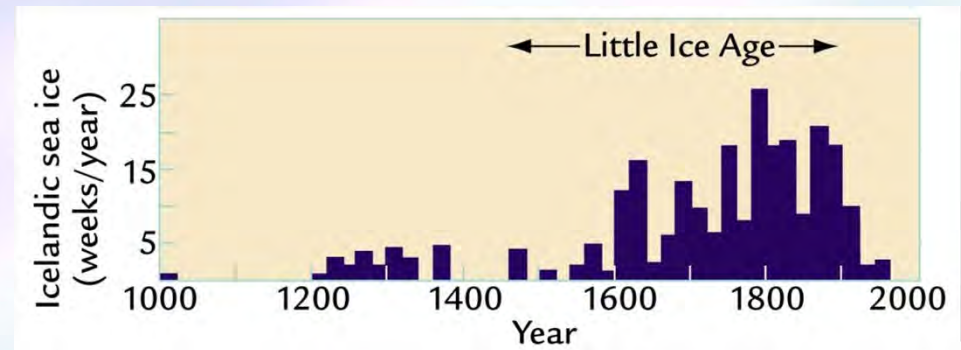


Image Credit: Robert A. Rohde,
Global Warming Art

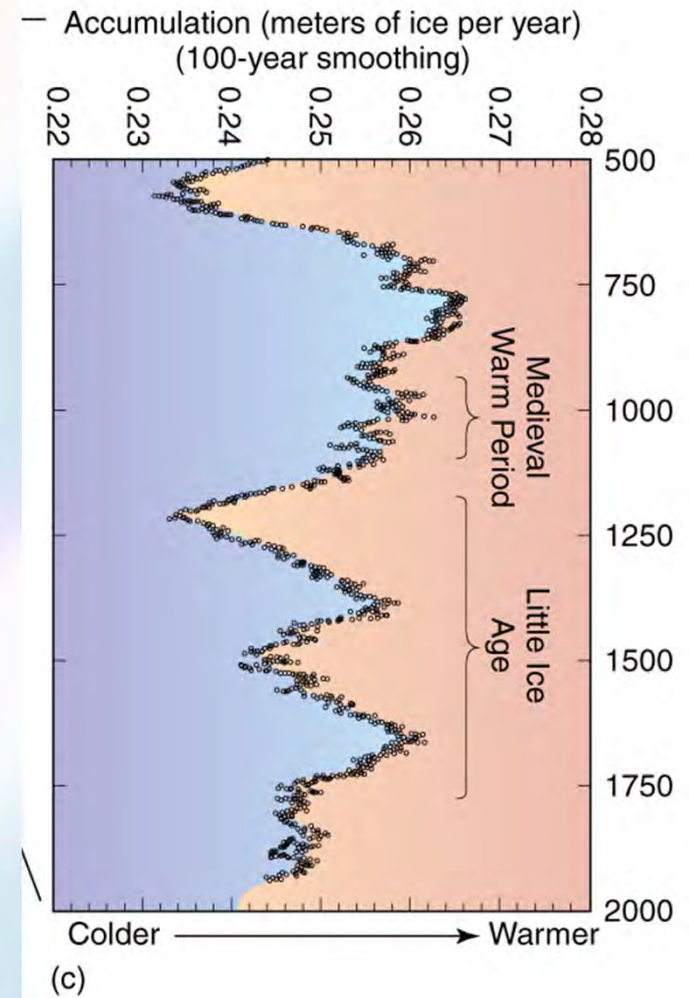
Little Ice Age (1400-1900)

- A modest cooling of the Northern Hemisphere of less than 1°C
 - Glaciers grew in Europe (1000 m lower than in 1850s)
 - Sea ice expansion
- Three minima, each separated by slight warming intervals beginning
 - About 1650
 - About 1770
 - About 1850
- Initially believed to be a global phenomenon; now less clear



Little Ice Age (1400-1900)

- Colder winters & shorter growing season meant crop failure and localized famine in northern regions of Europe
 - Great Famine of 1315-1317 (full recovery in 1322)
 - By the 1700s, cultivated land (MWP) in Iceland was covered by ice
- Settlements in Greenland were abandoned
 - Marginal climate?
 - Conflicts with native peoples?
- Large-scale advances of glaciers
- **Not a “true” ice age** since major ice sheets did not form



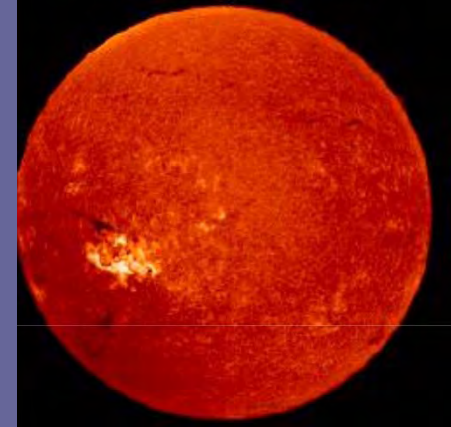
Transition from MWP to LIA OR Proposed causes of climate change from 1000-1850

- Orbital forcing
 - Decreasing summer insolation (tilt and precession cycles)
 - Only explains about half the amount observed in reconstruction for northern hemisphere (0.1°C)
- Millennial bipolar seesaw
 - Antarctica warm when Greenland is cold
 - Typical of large glacial-age oscillation
 - Insufficient proxy data in southern hemisphere to test

Proposed causes of climate change from 1000-1850

If the sun were the primary driver of climate change, we would expect to see (1) increasing daytime temperatures and (2) increasing summer temperatures. Instead, we are seeing just the opposite.

11 Aug 1983



Improved assessment:

a) no observed trend in solar irradiance since 1978 using high quality inter-calibrated data; b) spectral information c) solar magnetic flux model rather than proxy data; d) re-evaluation of variations in Sun-like stars.

Solar irradiance forcing much smaller than GHG.

Proposed causes of climate change from 1000-1850

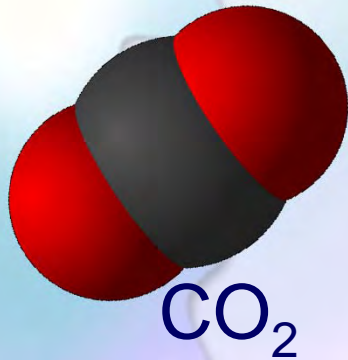
- Volcanic eruptions



- Sulfate aerosols
- The more frequent clusters of eruptions after 1300 could have contributed to the small cooling trend in the LIA

- Greenhouse-Gases

- Drop in CO₂ concentration by 7-8 ppm from 100-1200 to 1600-1800



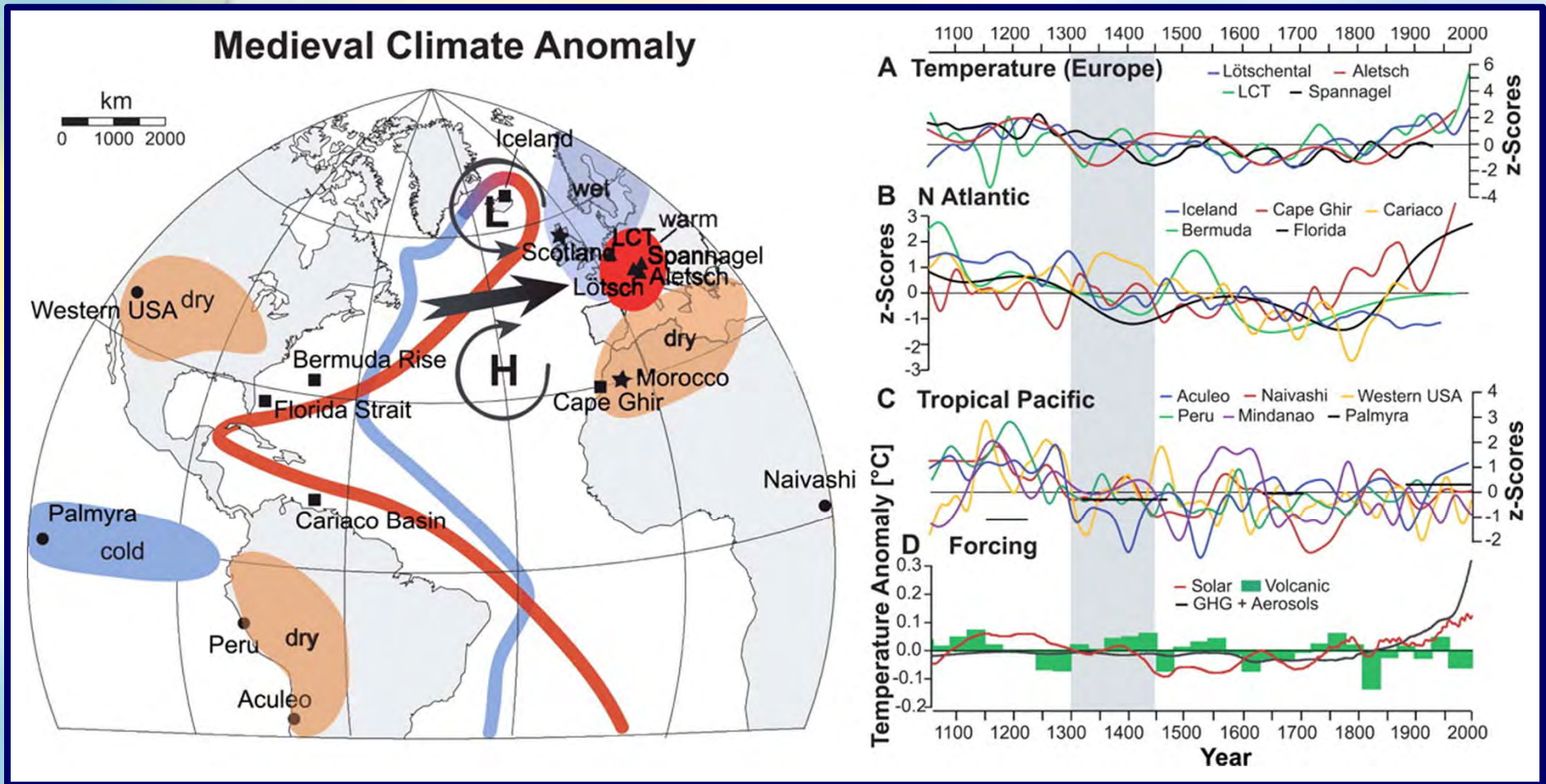
- Solar-volcanic changes
- Anthropogenic hypothesis
 - Reforestation of agricultural land
 - The "Black Death" (bubonic plague)
 - The American Pandemic (host of diseases)

Proposed causes of climate change from 1000-1850

- Recent research (Trouet et al. 2009) suggests
 - MWP is associated with persistent positive North Atlantic Oscillation
 - A clear shift to weaker NAO conditions into the LIA
 - This is one aspect of the MWP-LIA climate transition
- Stay tuned..... Few records exist to extend the NAO record into the MWP; new records might challenge this



Proposed causes of climate change from 1000-1850



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Proposed causes of climate change from 1000-1850

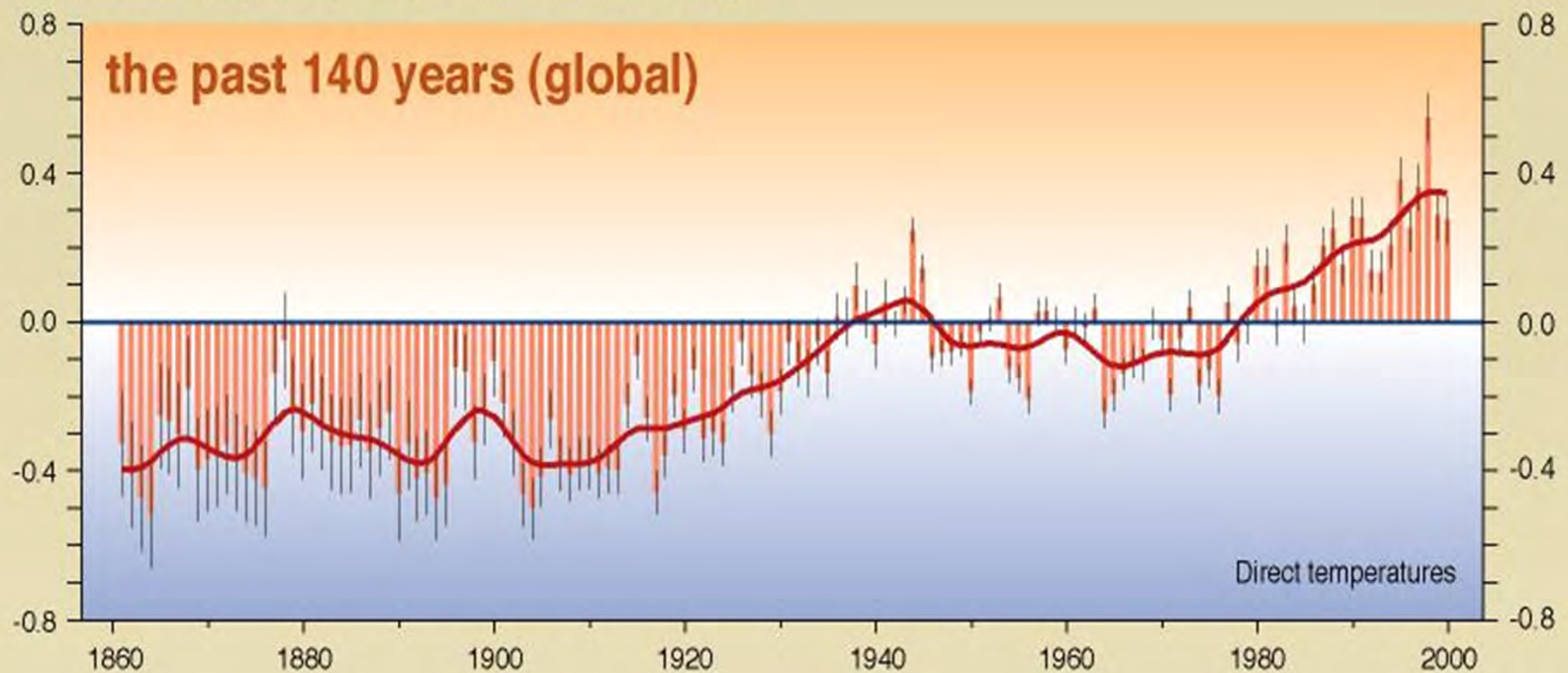
- Evidence for MWP is uncertain
 - Fewer records; larger uncertainties
- Estimated cooling from 1000 years ago into the LIA is small

Proposed causes of climate change from 1000-1850

- Any or all of several factors could have played a causal role
- Far greater geographic coverage is needed to define the *global* climatic response
 - Notion of MWA & LIA is valid for trends across eastern Canada, Greenland, Iceland, northern Europe – what about rest of earth's surface (90-95%)?
- No such ambiguity exists about the large, rapid and global warming since 1850

Variations of the Earth's surface temperature for...

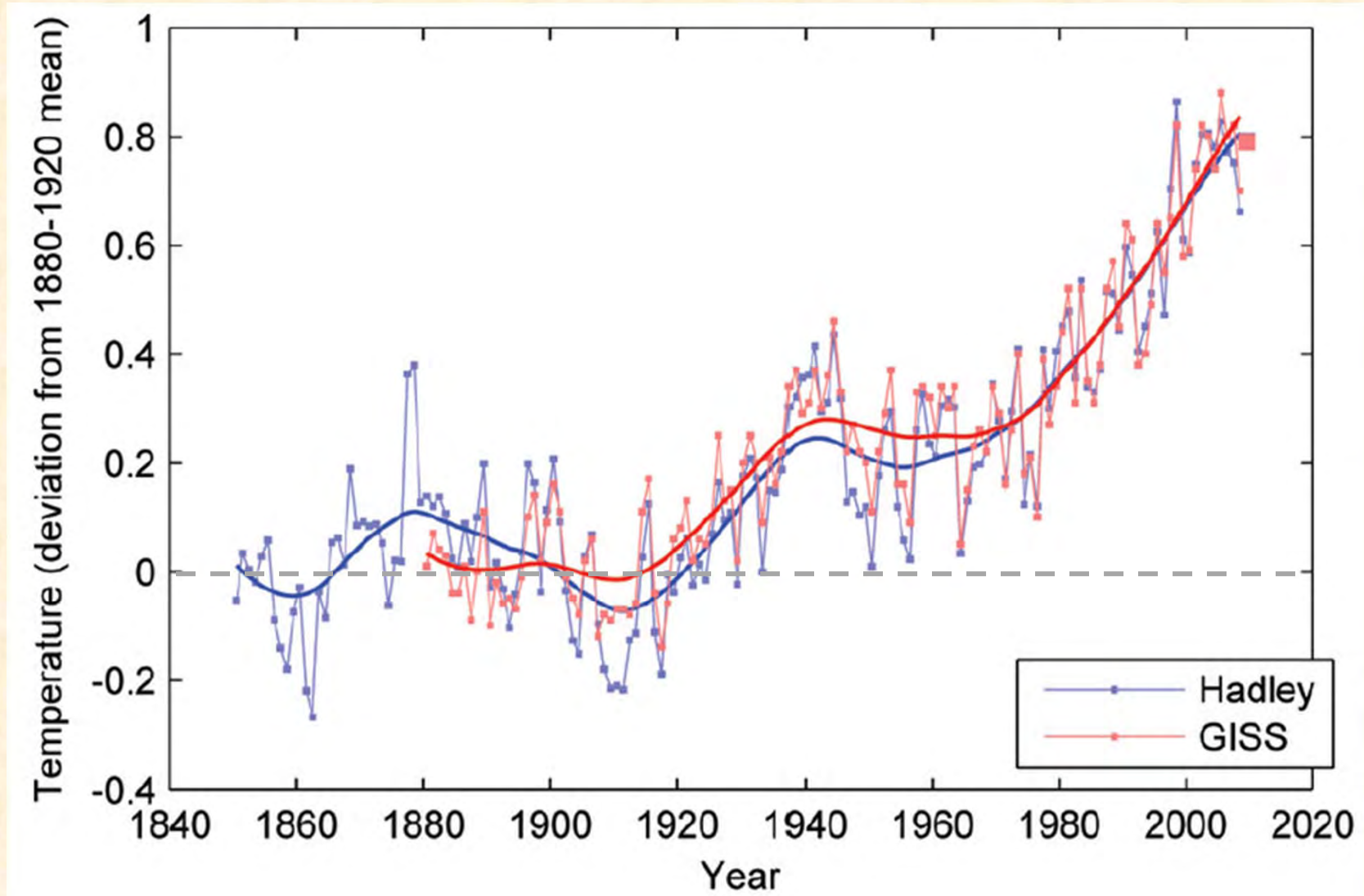
Departures in temperature in °C (from the 1961-1990 average)



SYR - FIGURE 2-3a

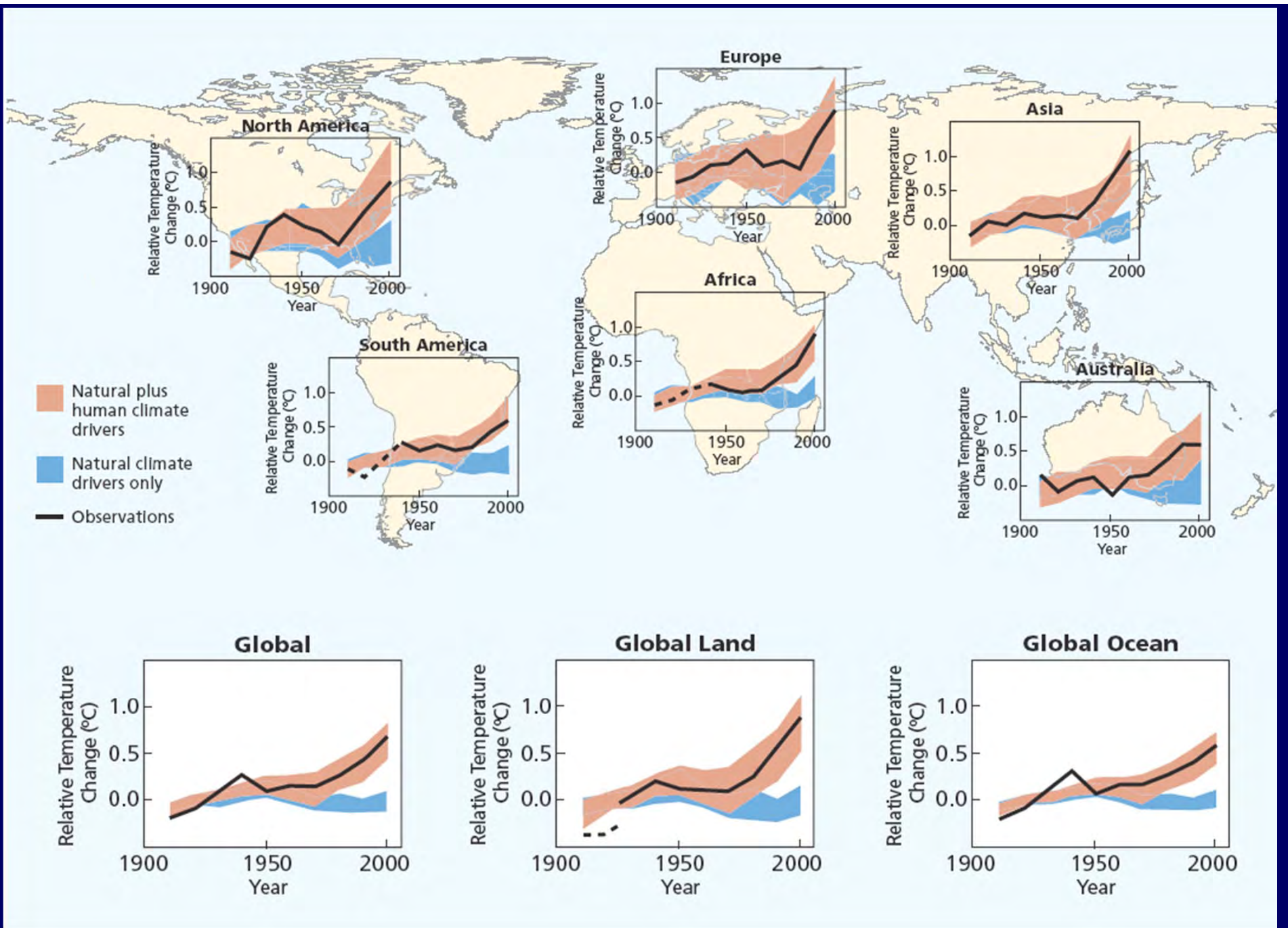
Global Average Temperature, 1850-2009

(relative to the baseline of 1880-1920)



■ Preliminary values for 2009 based on data up to and including August.

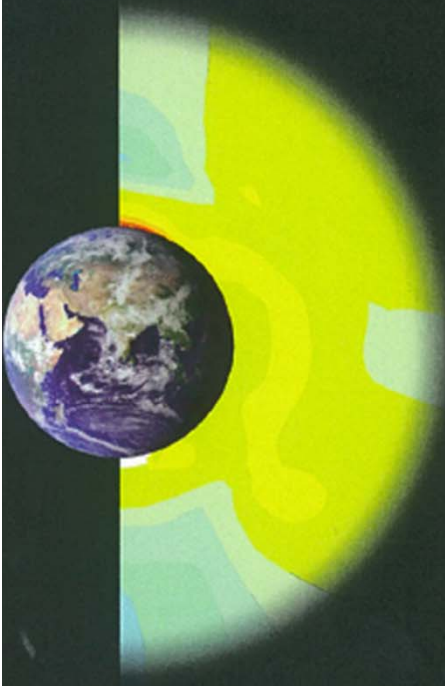
Source: *The Copenhagen Diagnosis, 2009*



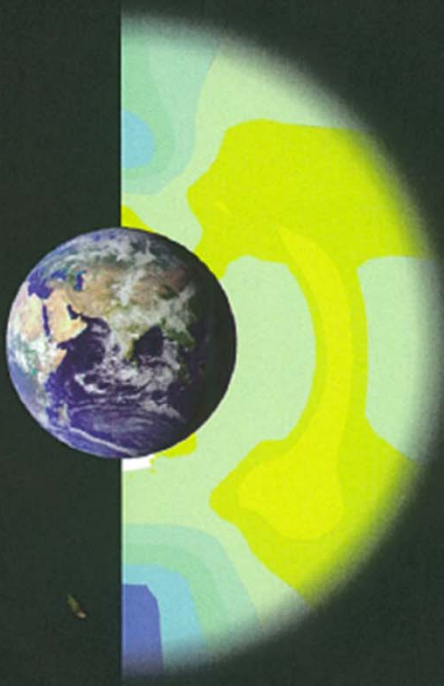
Source: IPCC *Climate Change 2007: The Physical Science Basis—Summary for Policymakers*.

Atmospheric Fingerprints 1890-1999

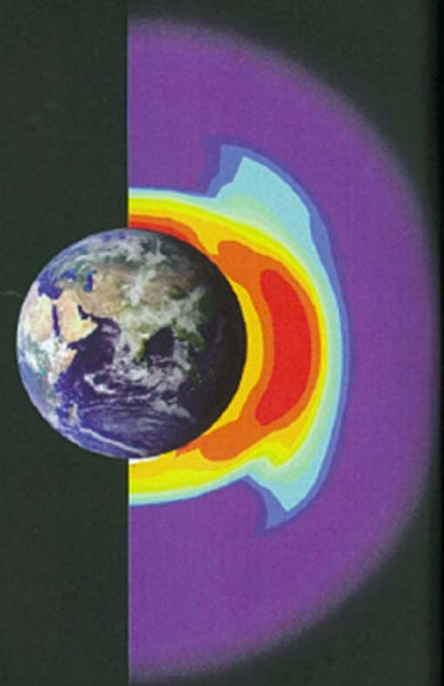
Solar effect on atmospheric temperature
1890-1999



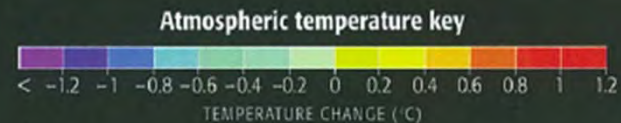
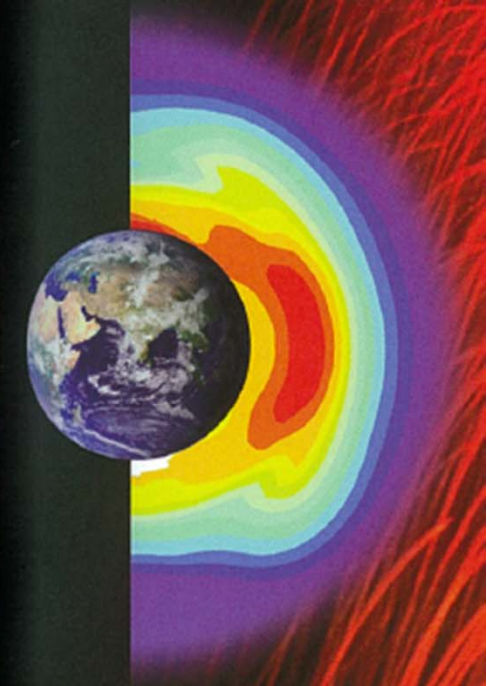
Volcanic effect on atmospheric temperature
1890-1999



Human-generated greenhouse gas effect on atmospheric temperature
1890-1999



Combined effect of human and natural forces on atmospheric temperature
1890-1999

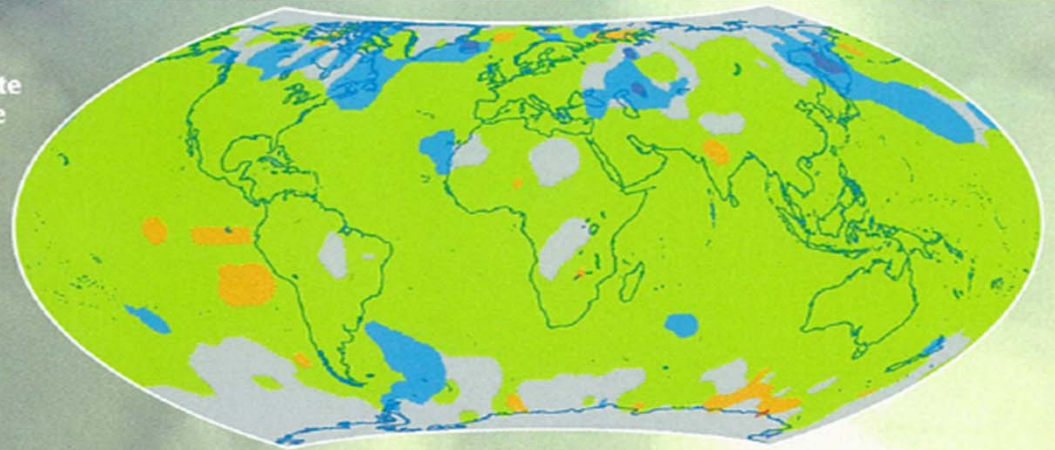


Atmospheric layers are not drawn to scale; height has been exaggerated in order to show color variations as clearly as possible.

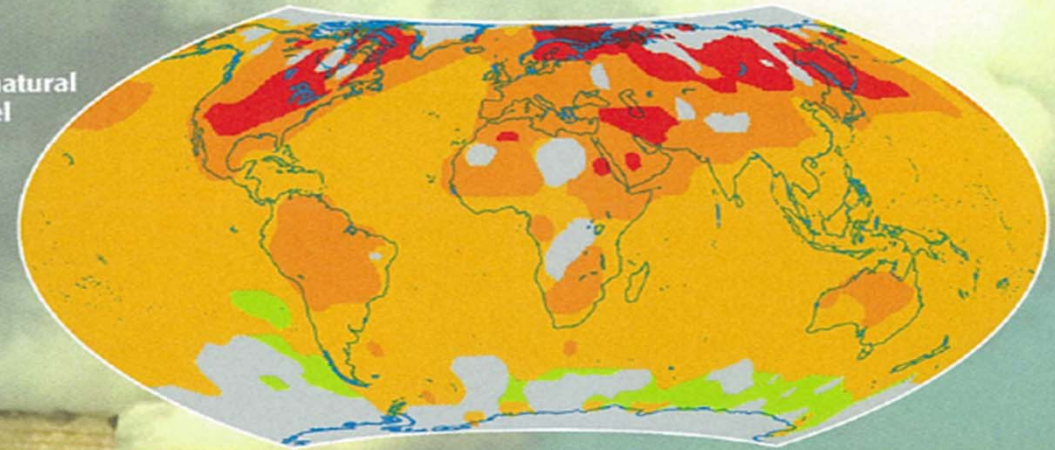
“Fingerprints”

Human and Natural Impacts on Climate, 1975-2005

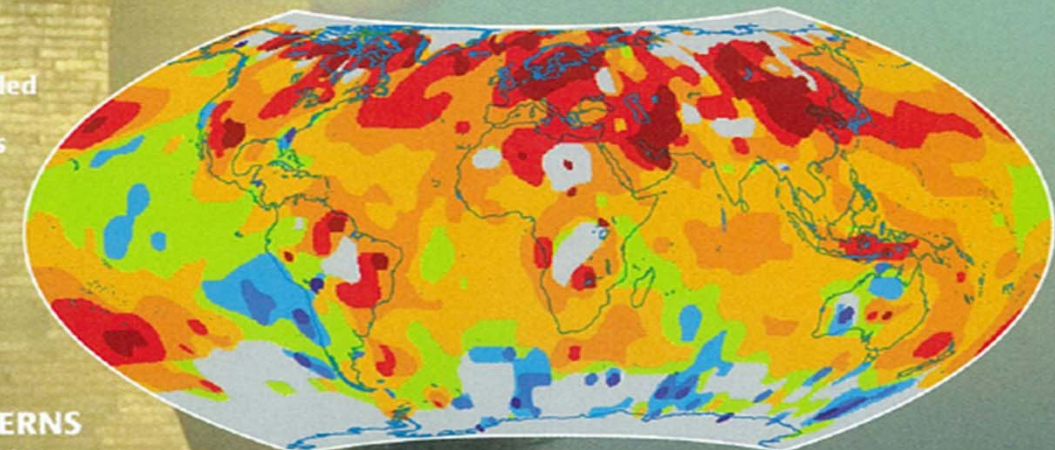
Natural climate model surface temperature calculation 1979-2005



Human and natural climate model surface temperature calculation 1979-2005



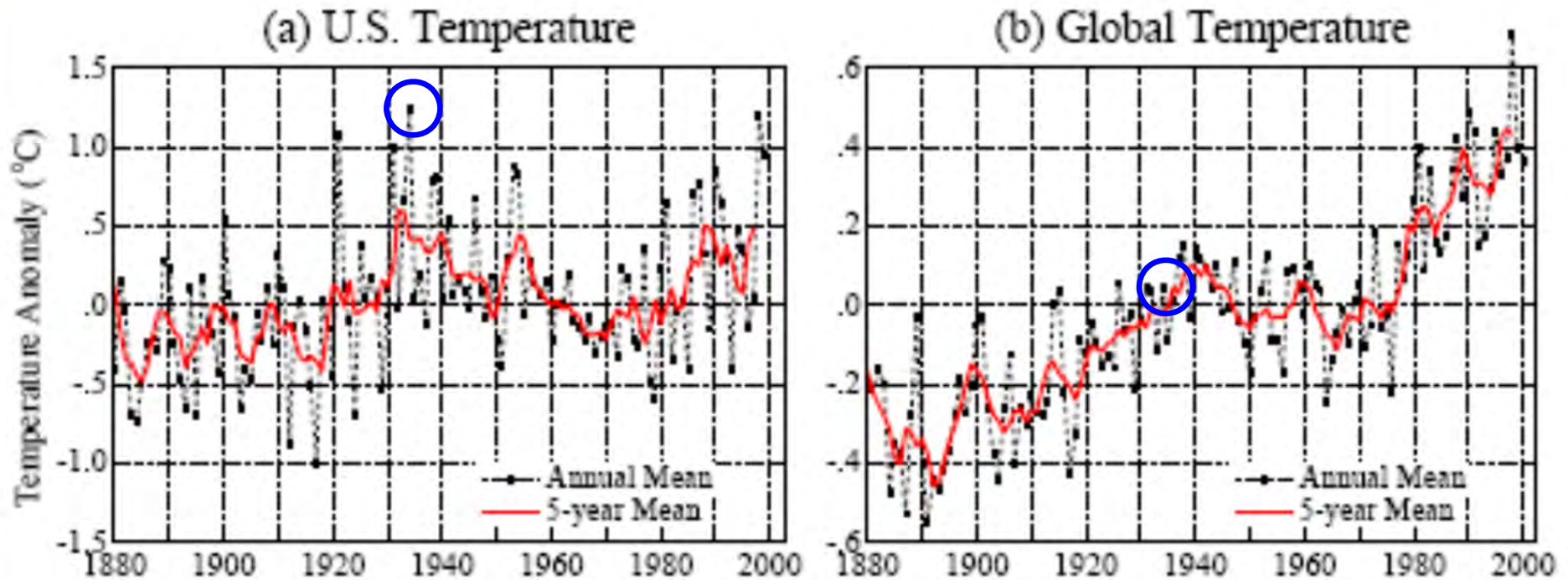
Actual recorded surface temperatures 1979-2005



Mann & Kump, 2008

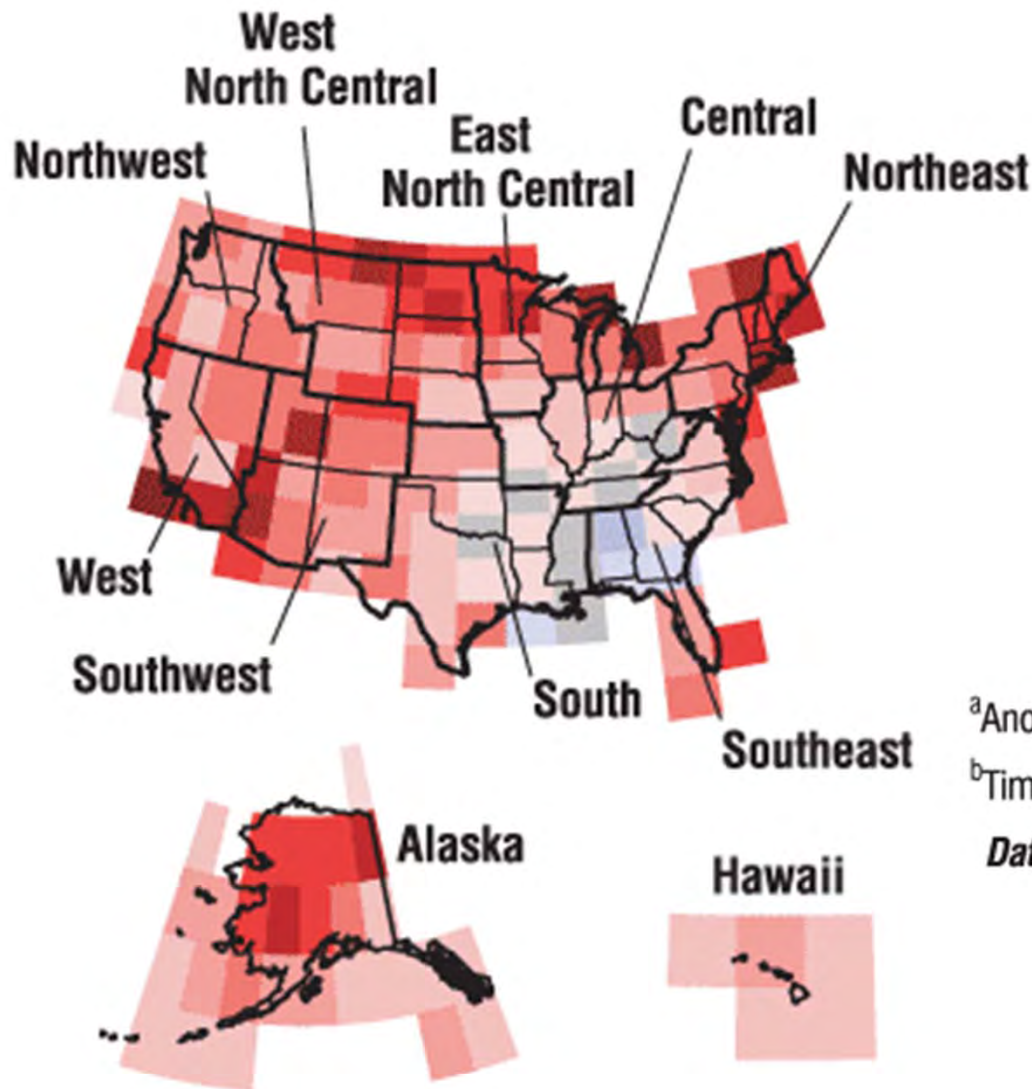
WARMING PATTERNS
a pattern of warming

Temperature Trends: 1880 to 2000



(Hansen et al., Journal of Geophysical Research, 2001)

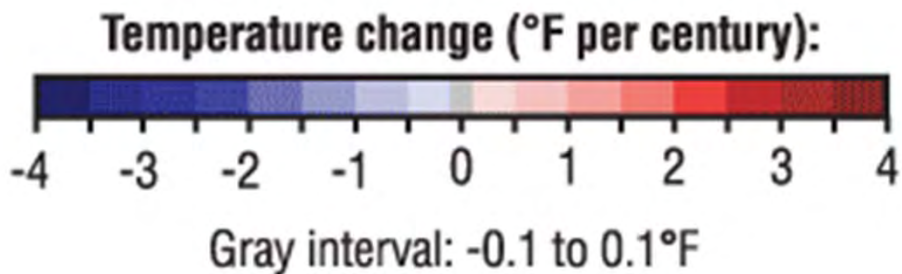
Annual Temperature Anomalies in the U.S., 1901-2008



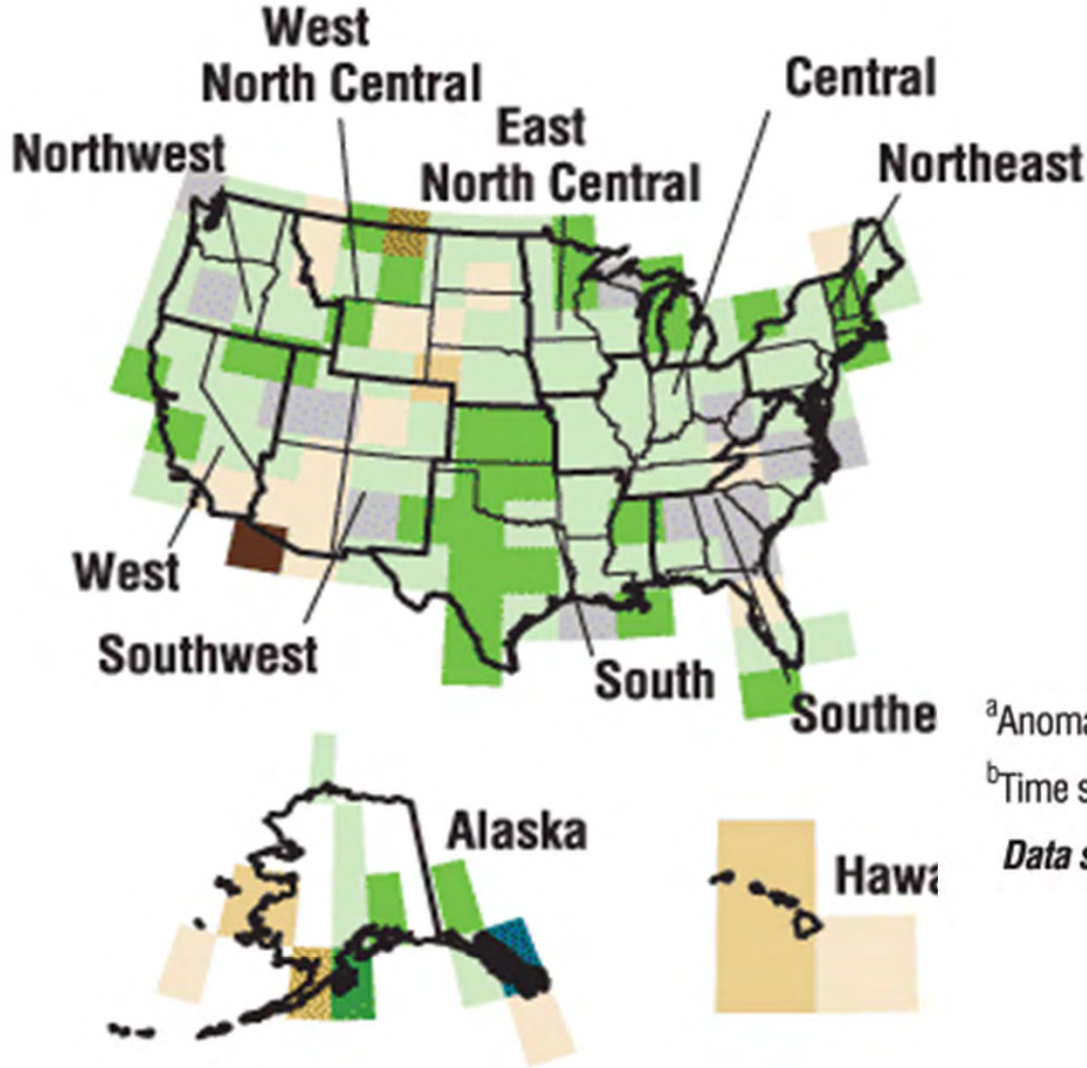
^aAnomalies are calculated with respect to the 1971-2000 mean.

^bTime series were smoothed using a nine-point binomial filter.

Data source: NOAA, 2009



Annual Precipitation Anomalies in the U.S., 1901-2008

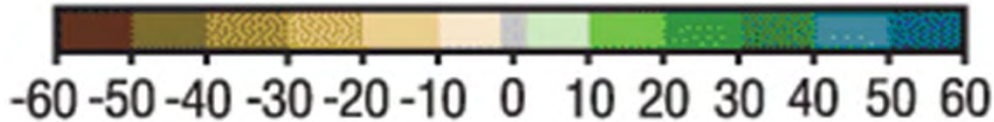


^aAnomalies are calculated with respect to the 1971-2000 mean.

^bTime series were smoothed using a nine-point binomial filter.

Data source: NOAA, 2009

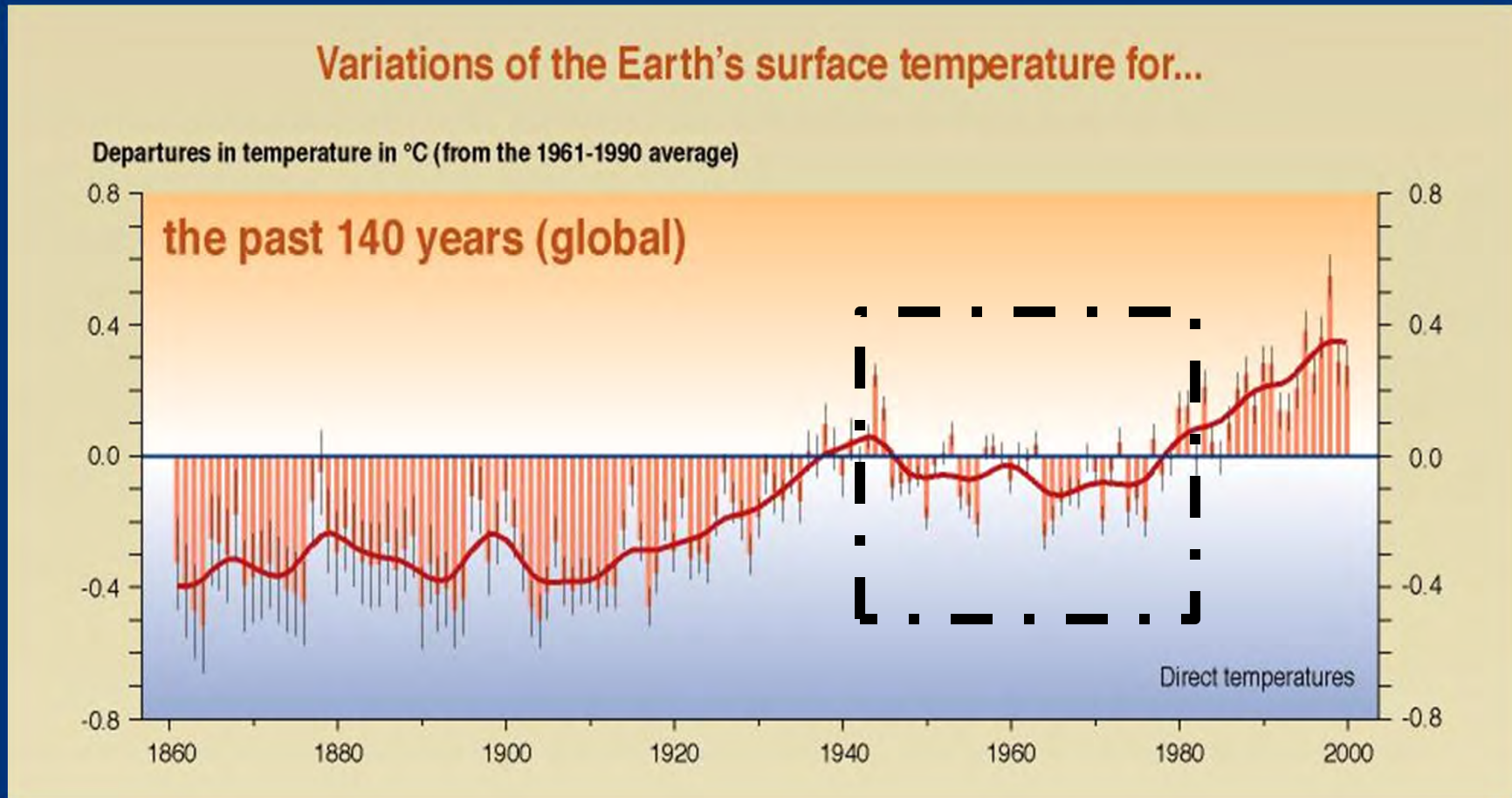
Change in precipitation (% per century):



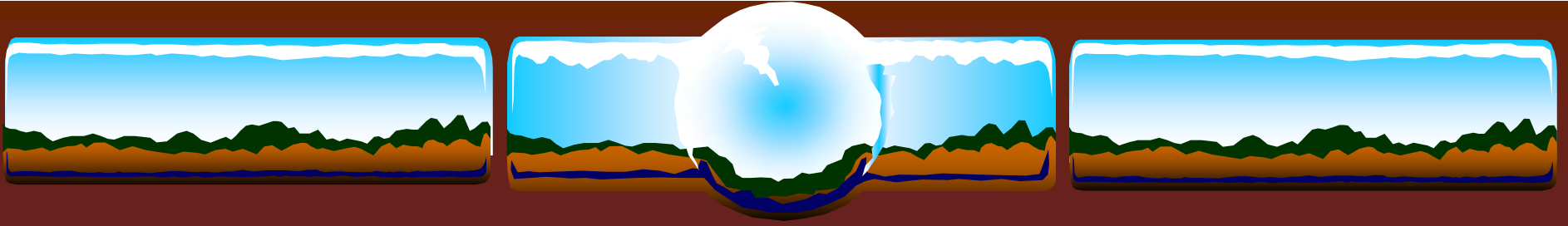
Gray interval: -2 to 2%



What about the cool temperatures from ~1945 to ~1980?

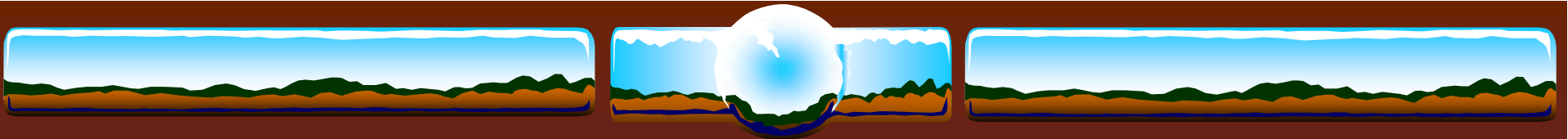


SYR - FIGURE 2-3a



Global Dimming or

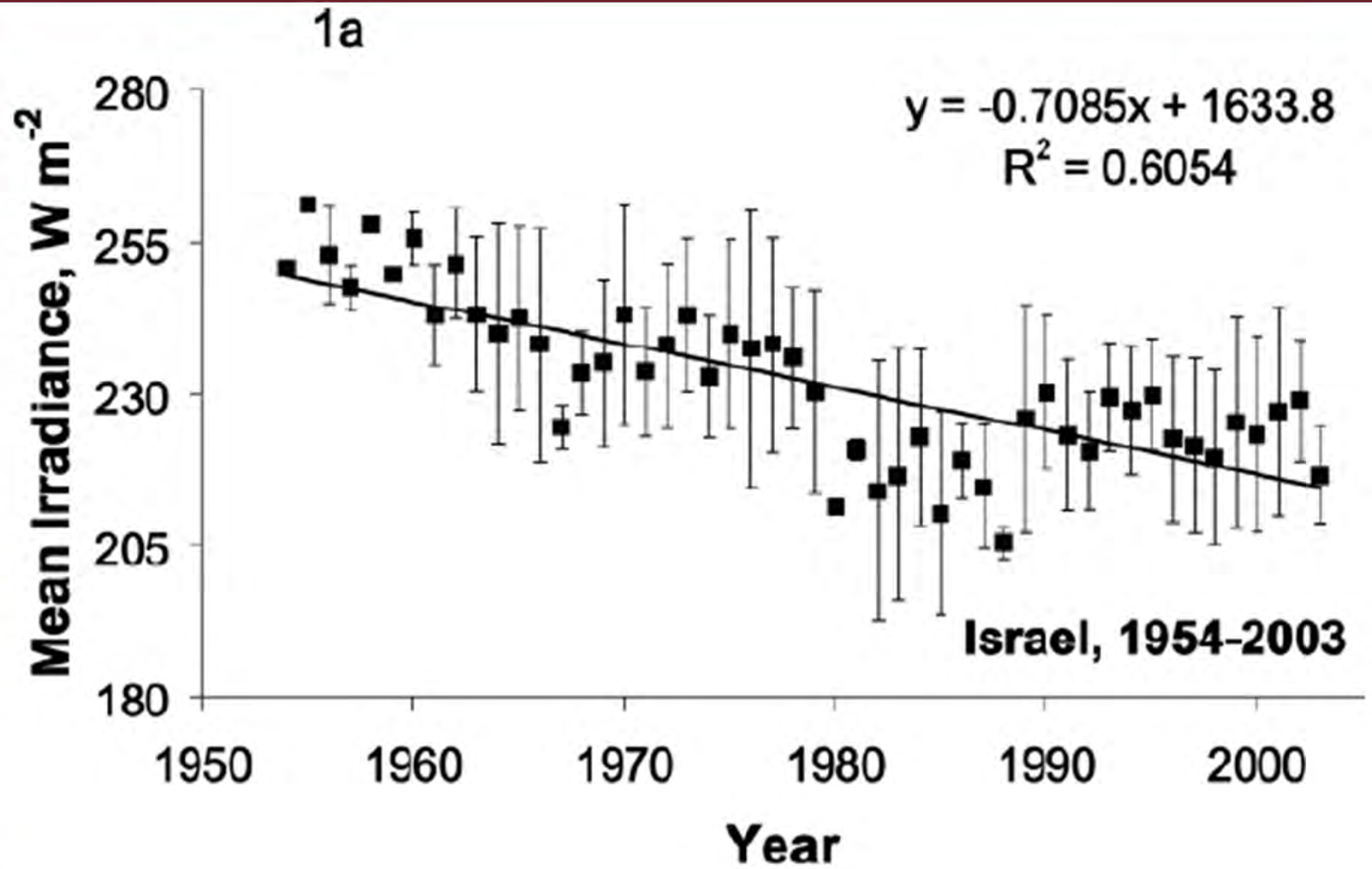
“Long Term Trends in Solar Radiation”



What is global dimming?

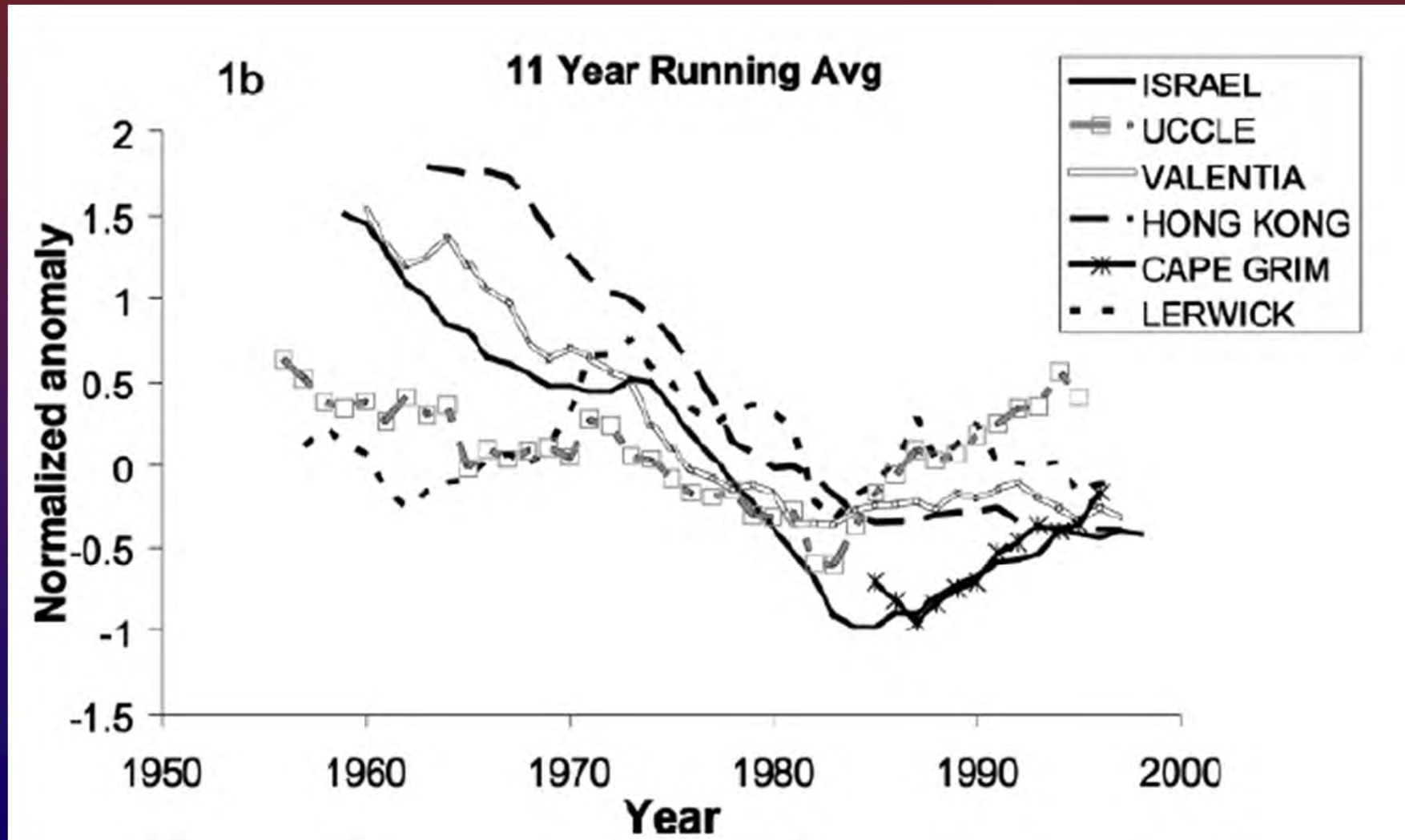
- **Global dimming** is the gradual reduction in the amount of global direct *irradiance* at the Earth's surface.
 - Measurements began in the 1950s.
 - Most data are from NH, and all taken on land
 - Data quality?
- Effect varies by location
 - Worldwide: ~4% reduction during 1960–1990

50 years of Radiation Data - Israel





Incoming Shortwave Radiation Anomalies in the annual mean

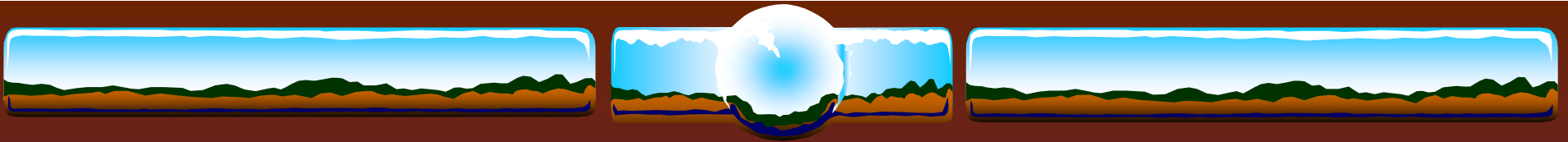




Supporting Evidence

- Worldwide decline in the “pan evaporation rate.”
 - Sunlight, humidity, and wind are dominant factors

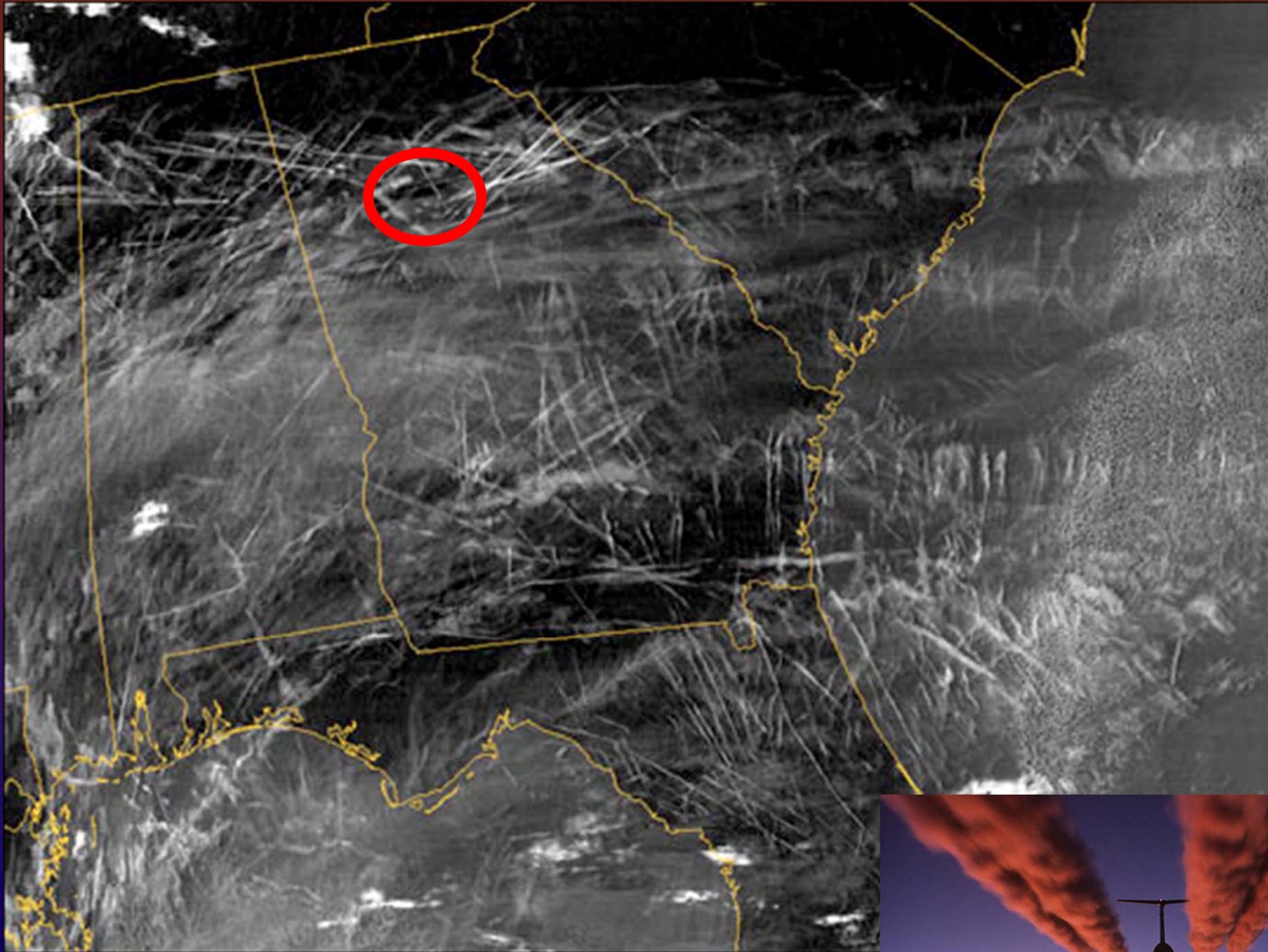




Where does it come from?

- Effect of global dimming is probably due *in part* to the increased presence of aerosol particles in the atmosphere.
 - Aerosol particles and other particulate pollutants absorb solar energy and reflect sunlight back into space.
 - Increased pollution, resulting in more particulates, creates clouds with a greater number of **smaller** droplets, making them more reflective.
- With global warming, there is a similar effect.
 - Water vapor and cloud feedback
 - Same effect as aerosols, but different cause

Aircraft Contrails, Jan 29 2004 MODIS



Aircraft Contrails over Europe

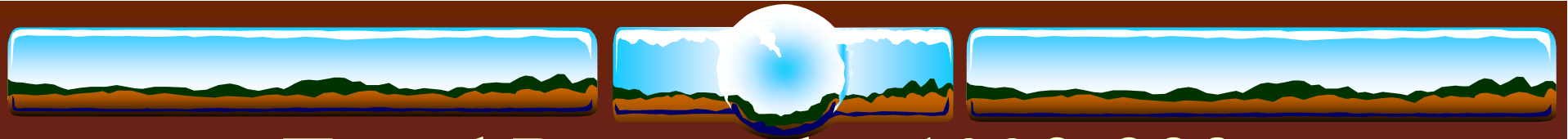




Effects are mostly regional

- Regions that are downwind from major sources of air pollution (specifically sulfur dioxide emissions) have generally cooled.
 - *may* help explain the cooling of the Eastern U.S. relative to the warming Western U.S.
 - examined effects in the Maldives
- *Extreme* regional effect
 - the Sahel



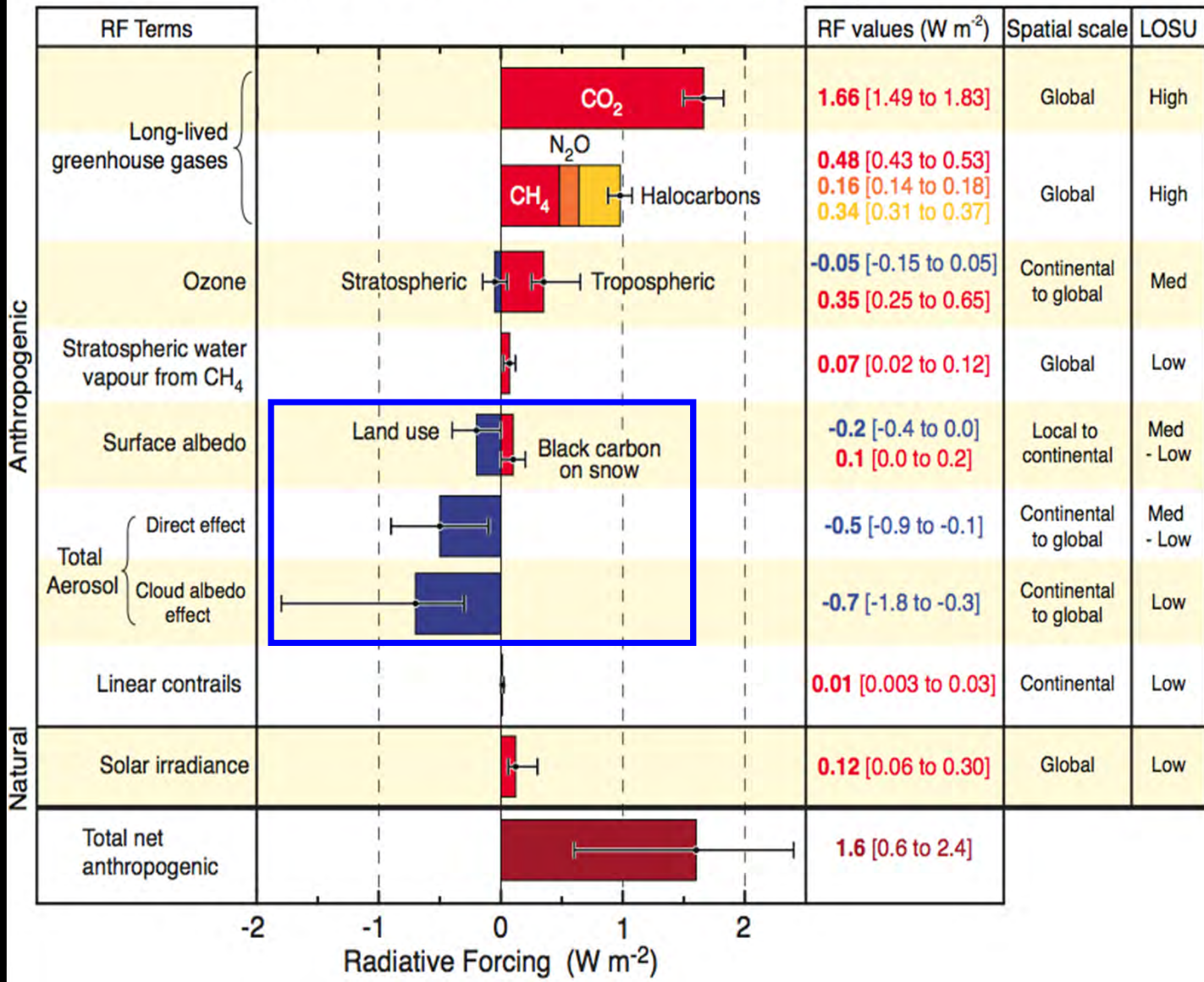


Trend Reversal – 1990-2006

- The “dimming” trend reversed
 - part of this change is due to decreases in pollution.
 - particularly over Europe
- Most developed nations have done more to reduce aerosols released into the atmosphere than to reduce CO₂ emissions.

Human and Natural Drivers of Climate Change

Radiative Forcing Components

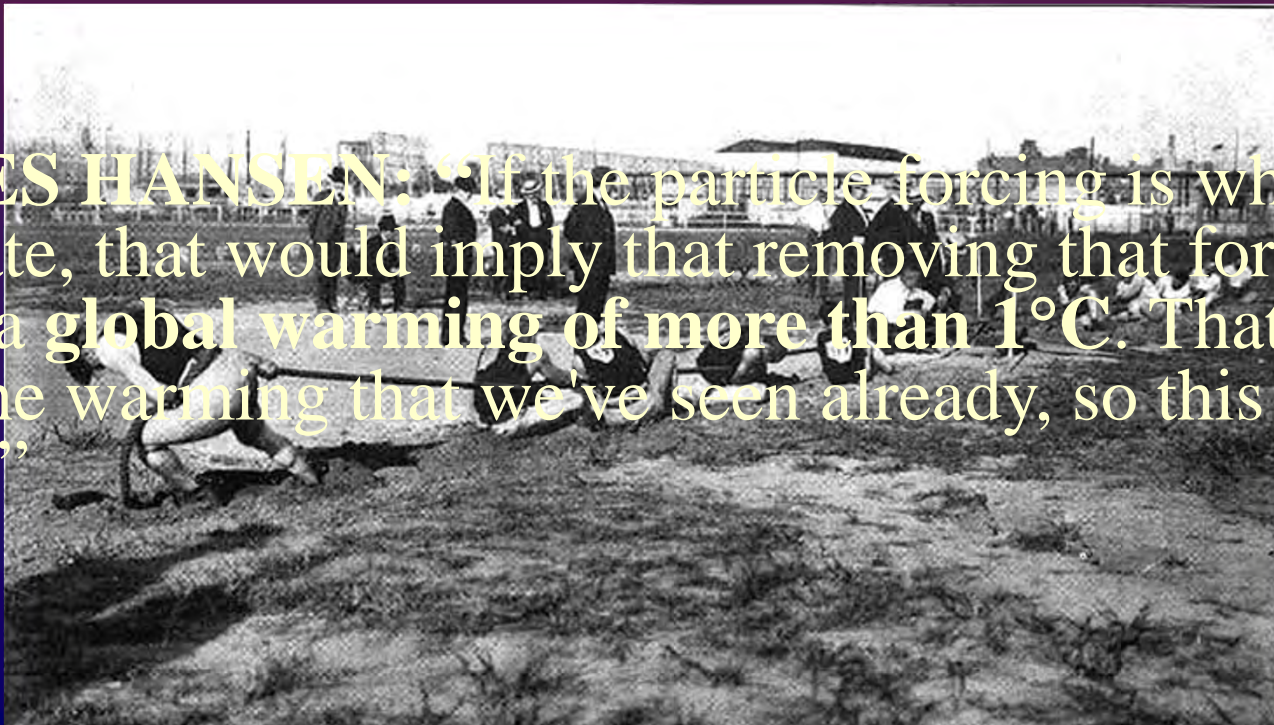


©IPCC 2007: WG1-AR4



Effects on Climate Systems

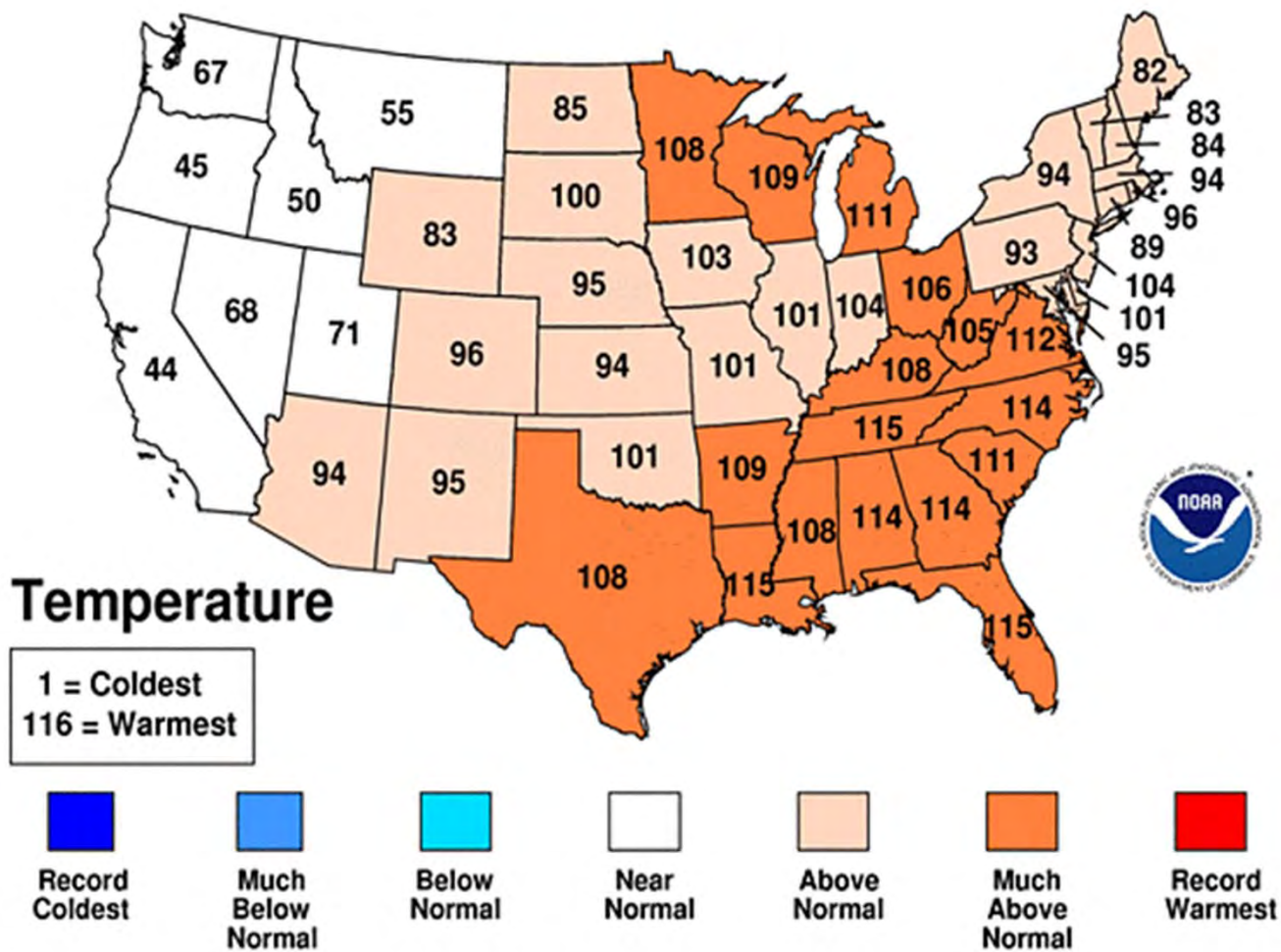
- Climate change, to the current date, appears to have been a tug of war, really, between two manmade pollutants.
 - greenhouse gases are pulling the system towards a warmer state (+2.6-3.0 W m⁻²)
 - particles from pollution that are cooling it down (-1.5 W m⁻²)
- **JAMES HANSEN:** “If the particle forcing is what we estimate, that would imply that removing that forcing would cause a **global warming of more than 1°C**. That's more than the warming that we've seen already, so this is a huge factor.”



Setting Records?

August 2010 Statewide Ranks

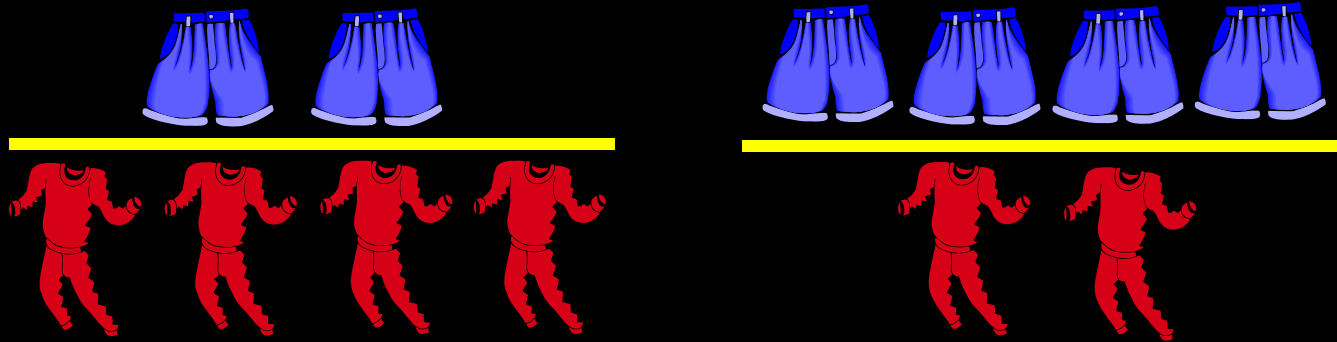
National Climatic Data Center/NESDIS/NOAA



Weather vs. Climate

“Choosing shorts or long underwear on a particular day is about weather; the ratio of shorts to long underwear in the drawer is about climate.”

Charles Wohlforth. *The Whale and the Supercomputer*



Setting Records?

Global Temperature Change Decade Averages

