Additional Courses Teaching Aspects of Paleoclimatology

- GEOS 108N – Climate Change: Past&Future
- GEOG 322N – Weather & Climate
- GEOS 382 – Global Change
- FOR 407 – Biogeochemistry
- GEOG 550 – Seminar in Paleoclimate & Global Change

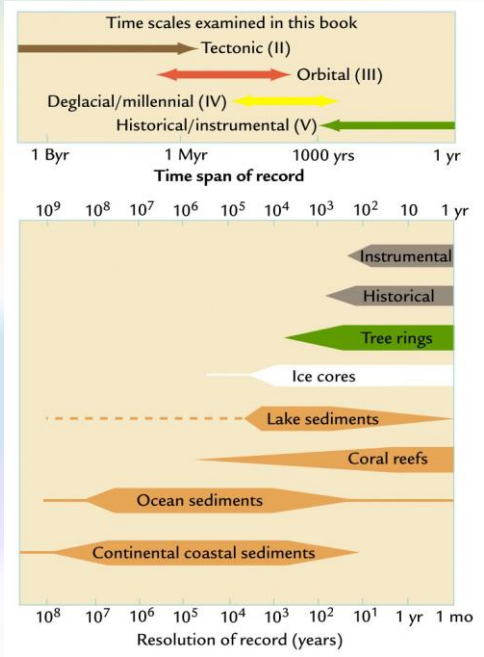
5 billion years of Earth's climate history – take home message

- What is the importance of proxy data?
- Why do scientists study paleoclimate?
- What can paleoclimates tell us about our current climate?
- Any questions on what was covered last time?

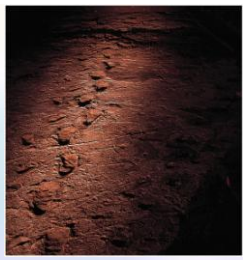
Climate Change of the Last 2000 Years

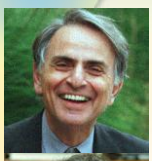
Dr. Faith Ann Heinsch
September 9, 2008

Time scales for Proxy Data



Anthropocene

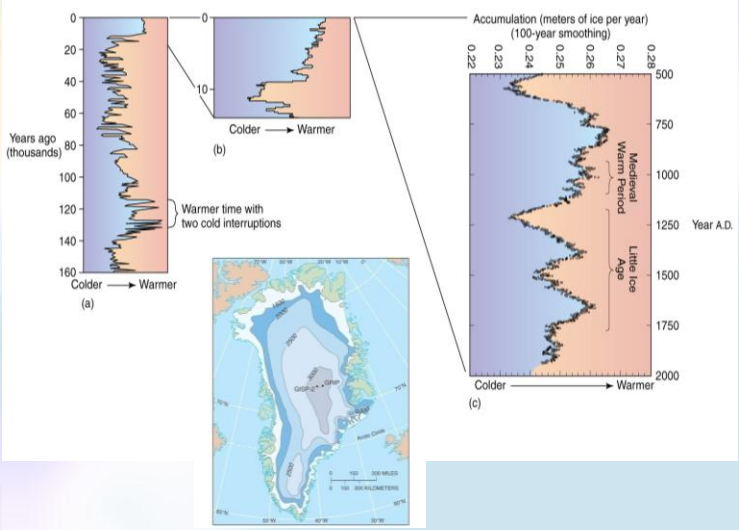


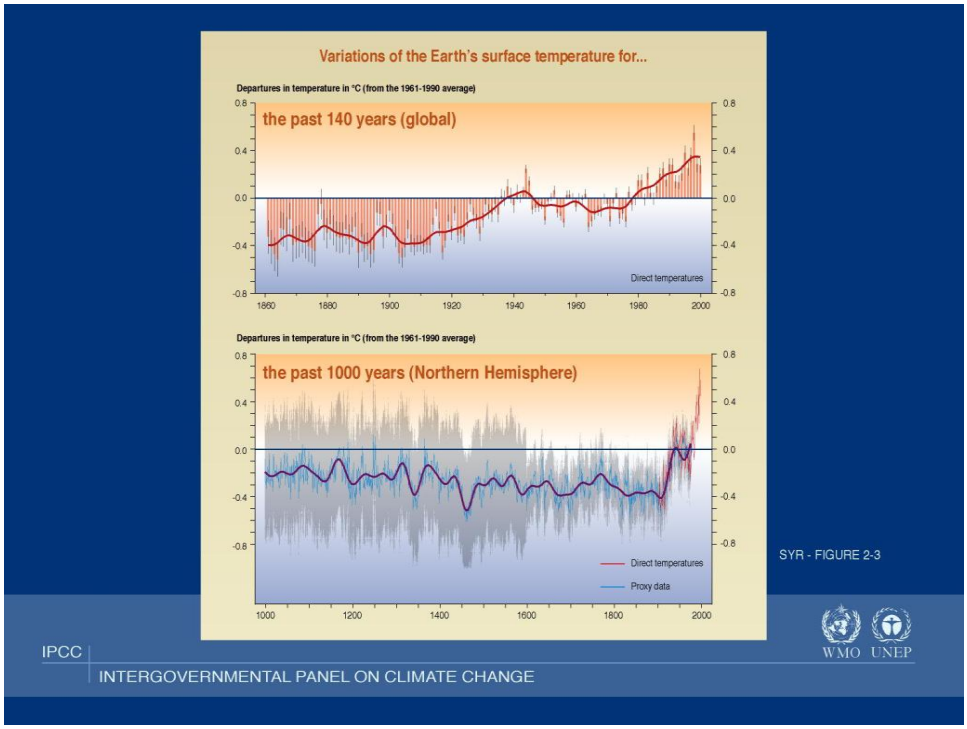


- Term used for climate where humans are the dominate controlling mechanism…
  - Concept first proposed in 1979 by Sagan
  - Phrase coined by Crutzen in 2000
    - Nobel prize winning chemist for his work on ozone depletion
  - No precise start date.
  - May be considered to start in late 18th century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

Last 2000 years….

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





Medieval Warm Period (~800-1300)

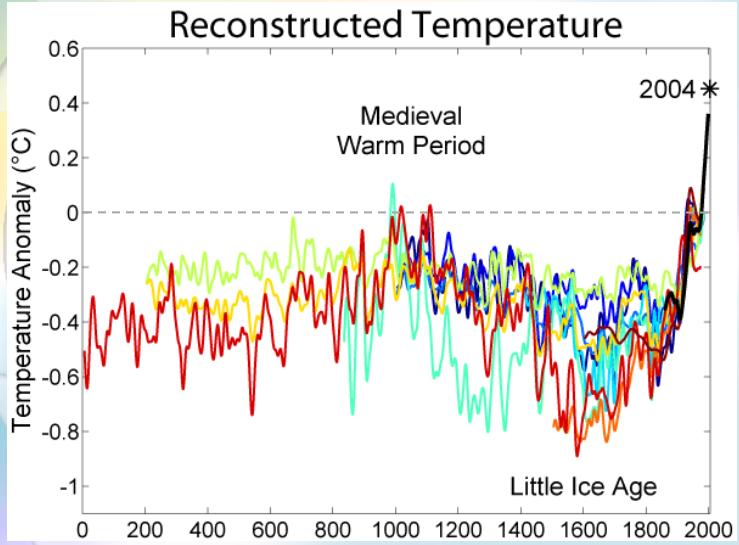
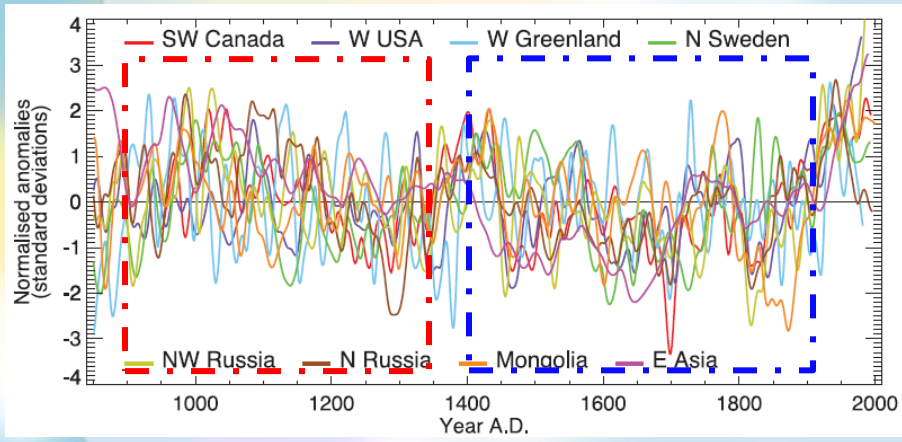


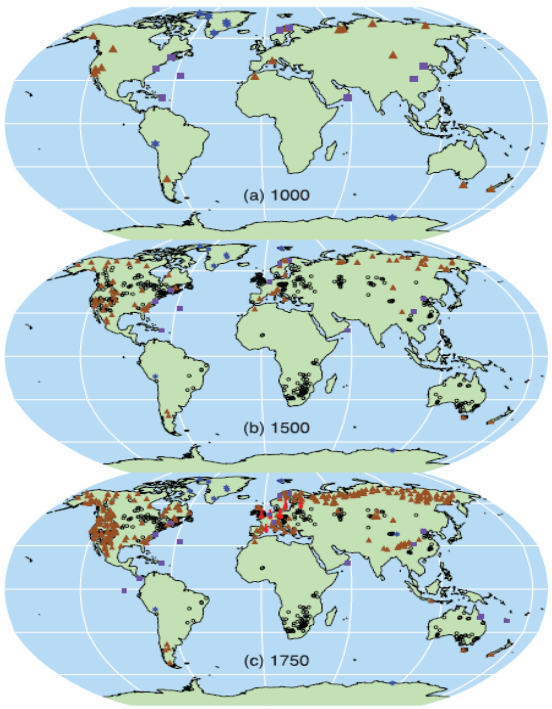
Image Credit: Robert A. Rohde, Global Warming Art

Medieval Warm Period (~800-1300)



IPCC 2007

Proxy Records – Where do they come from?



IPCC 2007

Medieval Warm Period (~800-1300)
(a.k.a. Medieval Climate Optimum)

Medieval Warm Period (~800-1300)

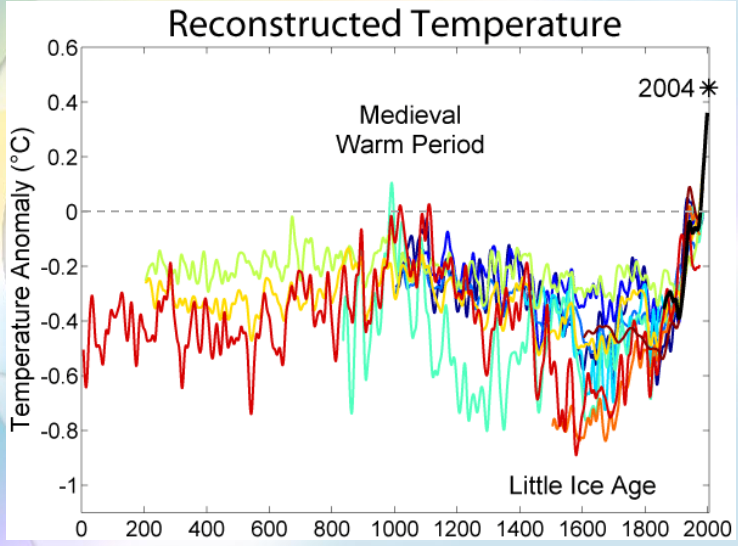
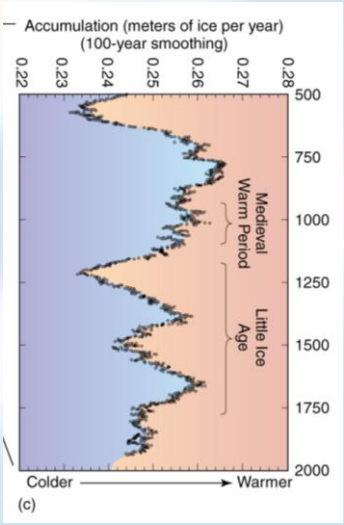


Image Credit: Robert A. Rohde, Global Warming Art

Medieval Warm Period (~800-1300)

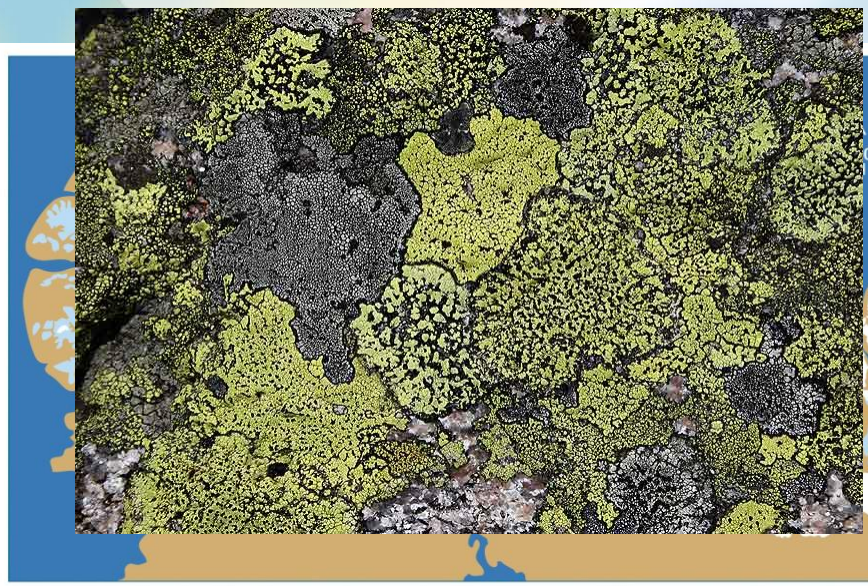
- Scattered evidence exists in Europe and the high latitudes surrounding the North Atlantic.
  - Cultivation of Greenland & Iceland
  - Grapes in England?
  - Medieval temperatures were probably 1-2°C above early 20th century levels at various European locations
  - Evidence in Japan, Alaska
  - Regional 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)



C

The Little Ice Age (1400-1900)

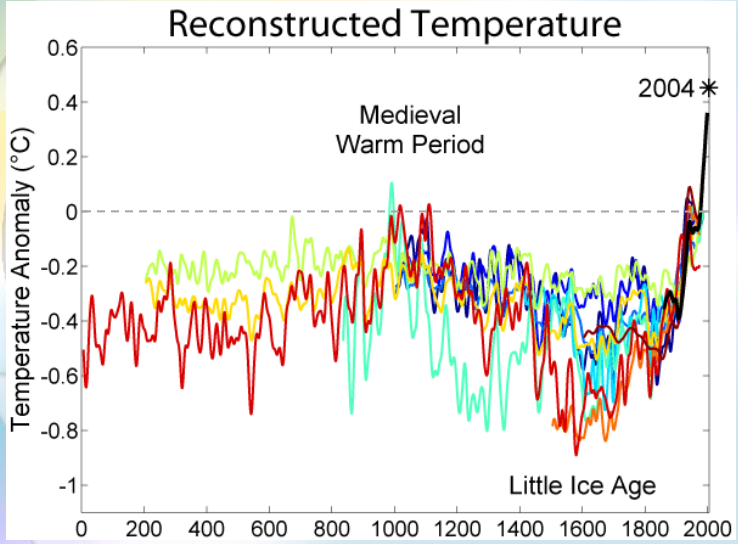
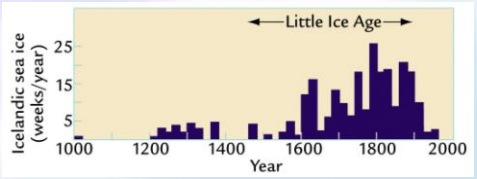


Image Credit: Robert A. Rohde, Global Warming Art

Little Ice Age (1400-1900)

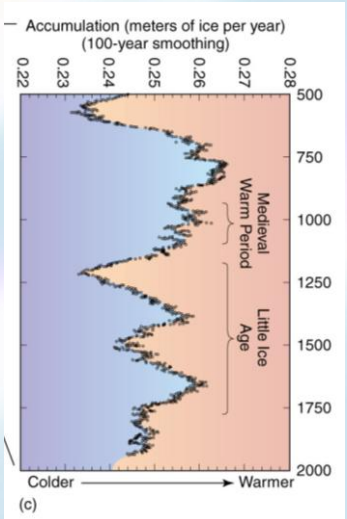
- A modest cooling of the Northern Hemisphere of less than 1°C
  - Glaciers grow in Europe (1000 m lower than in 1850s)
  - Sea ice expansion
- Three minima, each separated by slight warming intervals beginning
  - About 1650
  - About 1770
  - About 1850



- 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



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
  - Insufficient data to test
- Solar variability
  - Maunder Minimum
  - 11-year Sunspot cycle
  - Recent research minimizes this effect

The Little Ice Age (1400-1900)

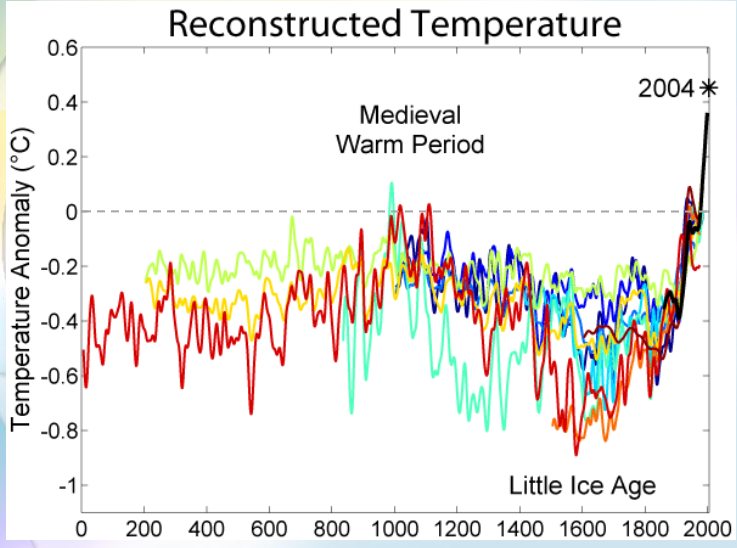


Image Credit: Robert A. Rohde, Global Warming Art

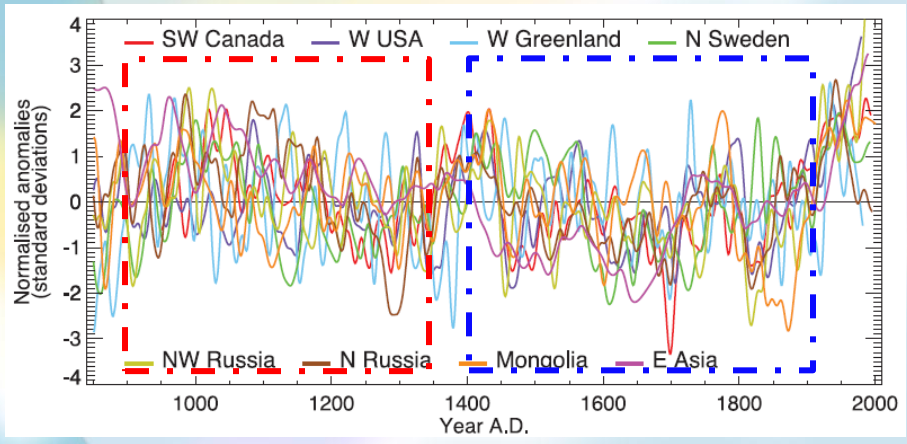
Proposed causes of climate change from 1000-1850

- Volcanic eruptions
  - Sulfate aerosols
  - The more frequent clusters of eruptions after 1300 could have constributed to the small cooling trend in the LIA
- Greenhouse-Gases
  - Drop in CO_2 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

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

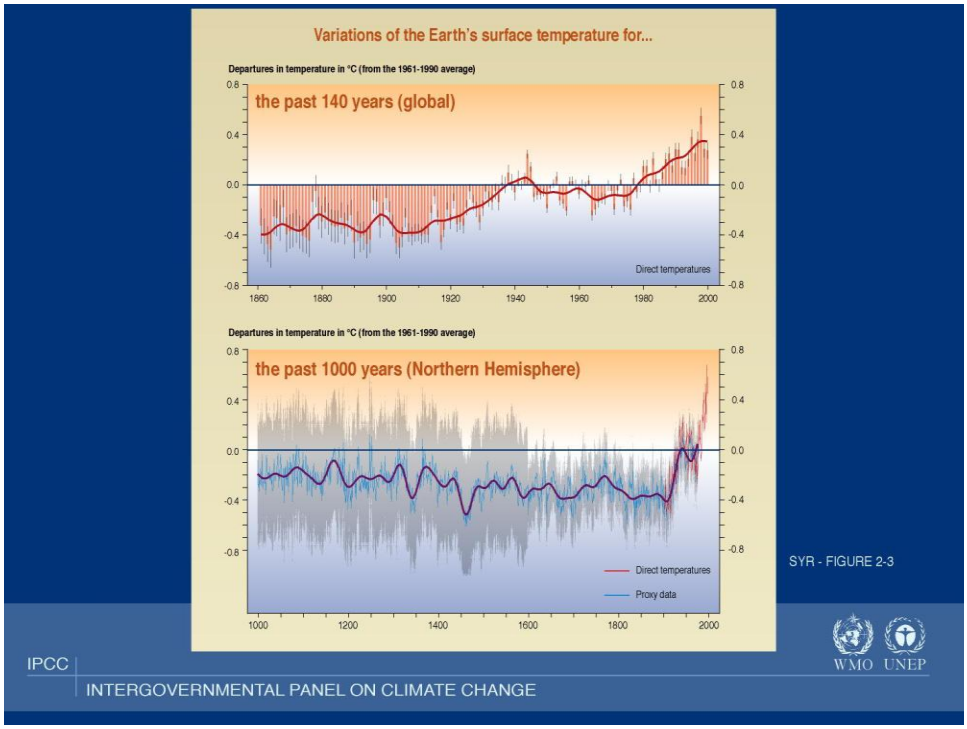
Medieval Warm Period (~800-1300)

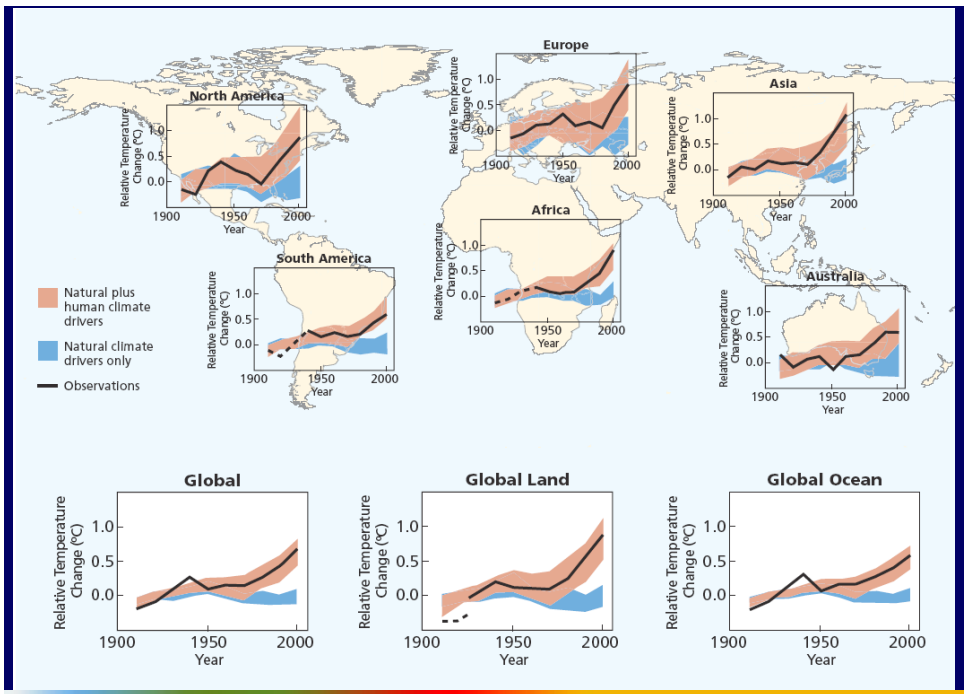


IPCC 2007

Proposed causes of climate change from 1000-1850

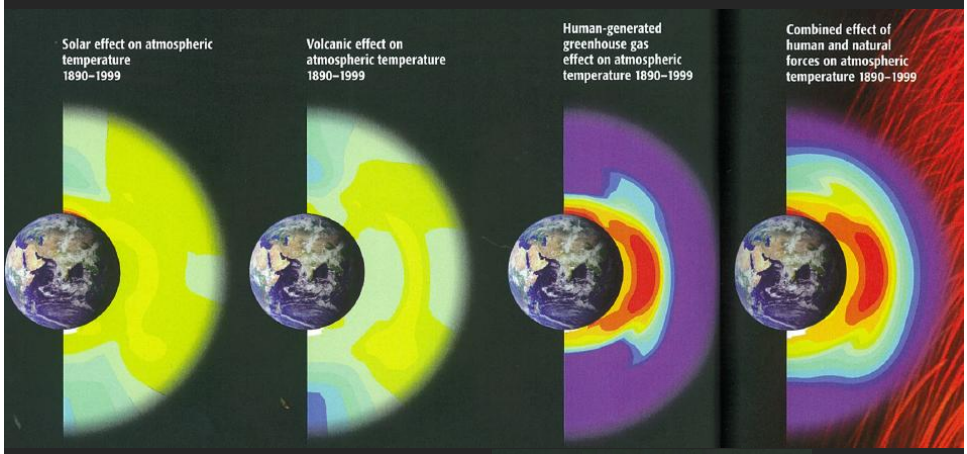
- Evidence for MWP is uncertain
  - Fewer records; larger uncertainties
- Estimated cooling from 1000 years ago into the LIA is small
- Any or all of several factors could have played a causal role
- Far greater geographic coverage is needed to define the *global* climatic response
  - Notion of MWA & 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





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

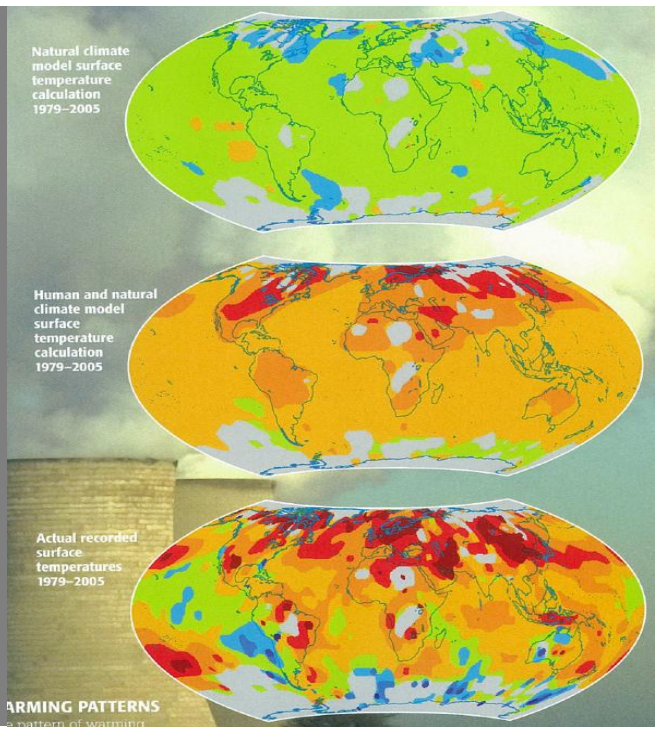
Atmospheric Fingerprints 1890-1999



Mann & Kump, 2008

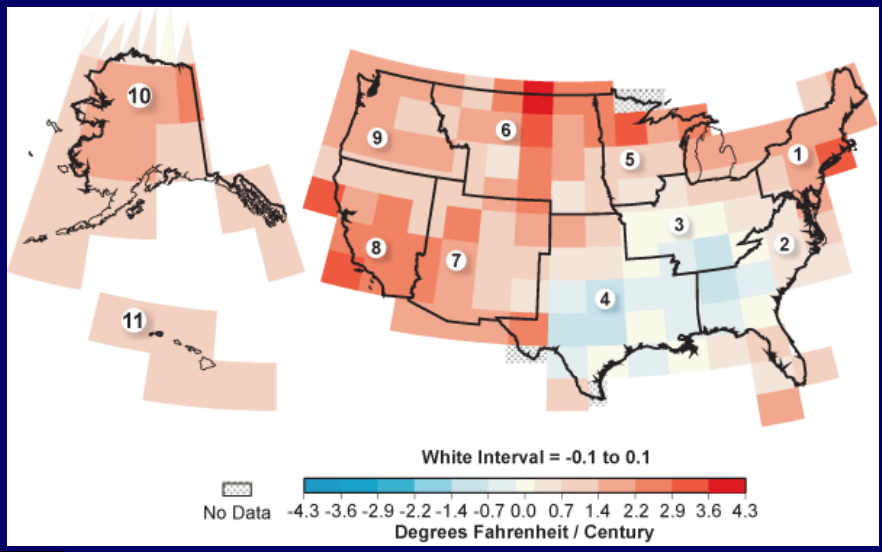
"Fingerprints"

Human and Natural Impacts on Climate, 1975-2005



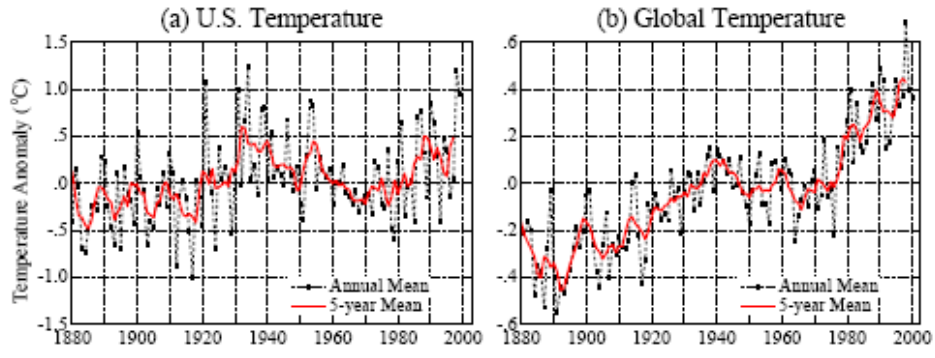
Mann & Kump, 2008

U.S. Mean Temperature Trends: 1901 - 2003



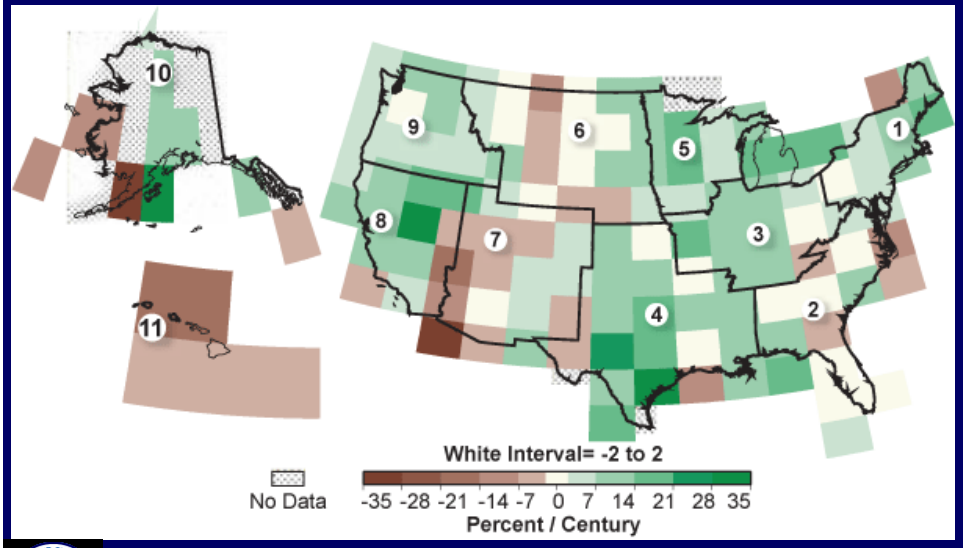
Data courtesy NOAA's National Climatic Data Center

Temperature Trends: 1880 to 2000



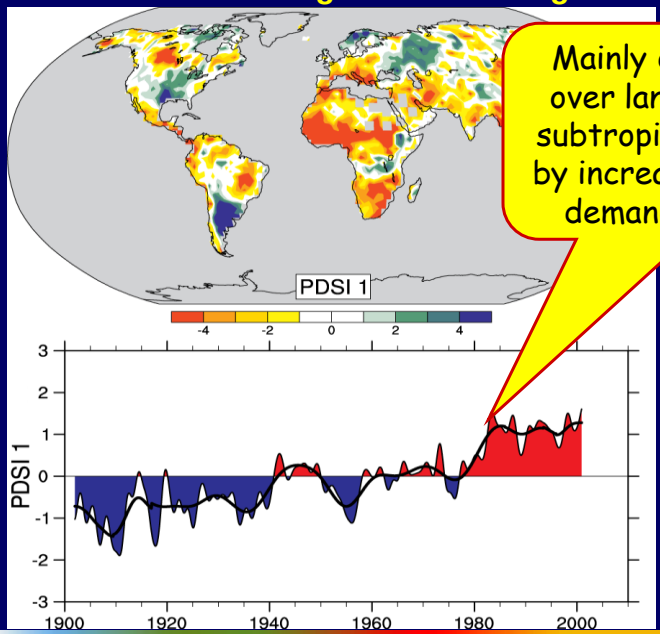
(Hansen et al., Journal of Geophysical Research, 2001)

U.S. Precipitation Trends: 1895 - 2003



Data courtesy NOAA's National Climatic Data Center

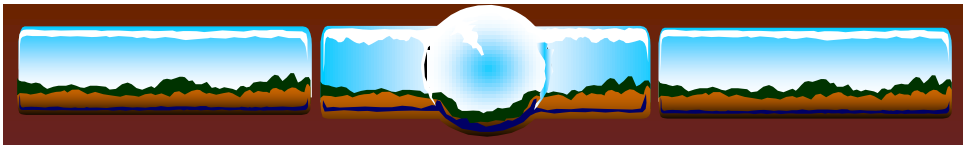
Drought is increasing most places



Mainly decrease in rain over land in tropics and subtropics, but enhanced by increased atmospheric demand with warming

Severity Index (PDSI) for 1900 to 2002.

The time series (below) accounts for most of the trend in PDSI



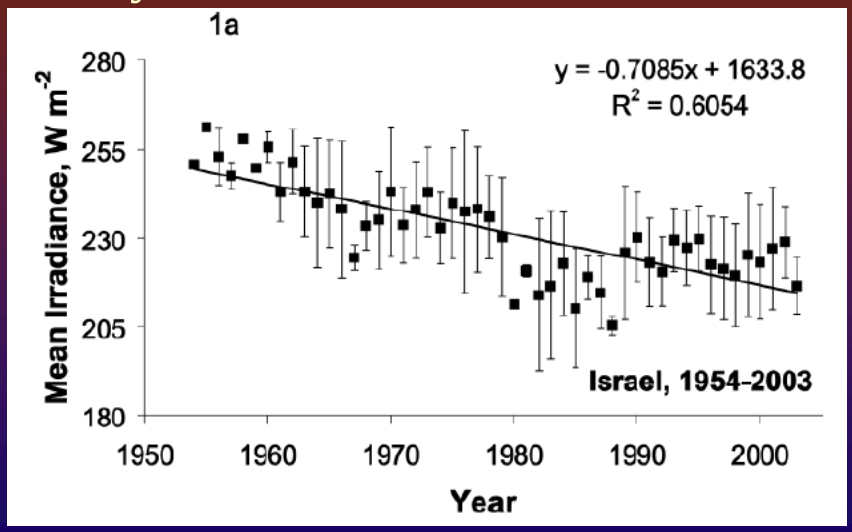
Global Dimming
or
"Long Term Trends in Solar Radiation"

Faith Ann Heinsch
NTSG, College of Forestry & Conservation
The University of Montana
February 28, 2006

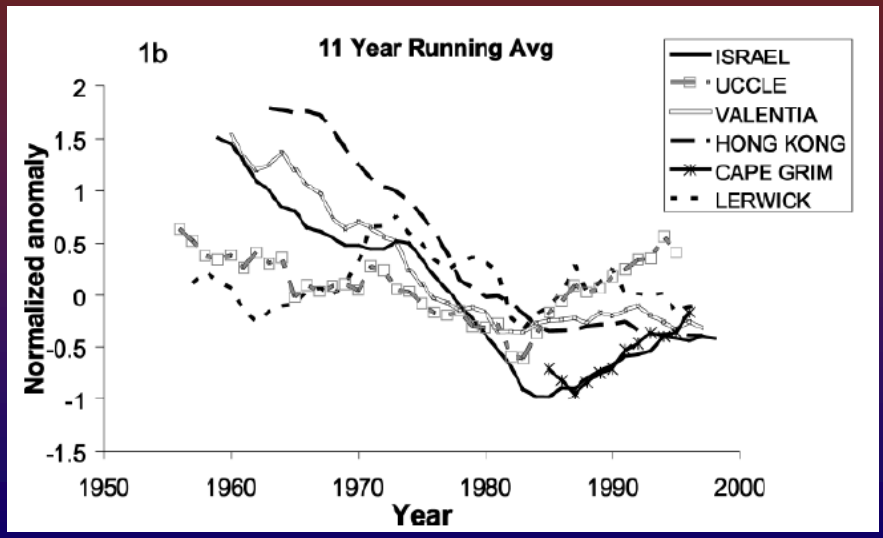
What is global dimming?

- **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



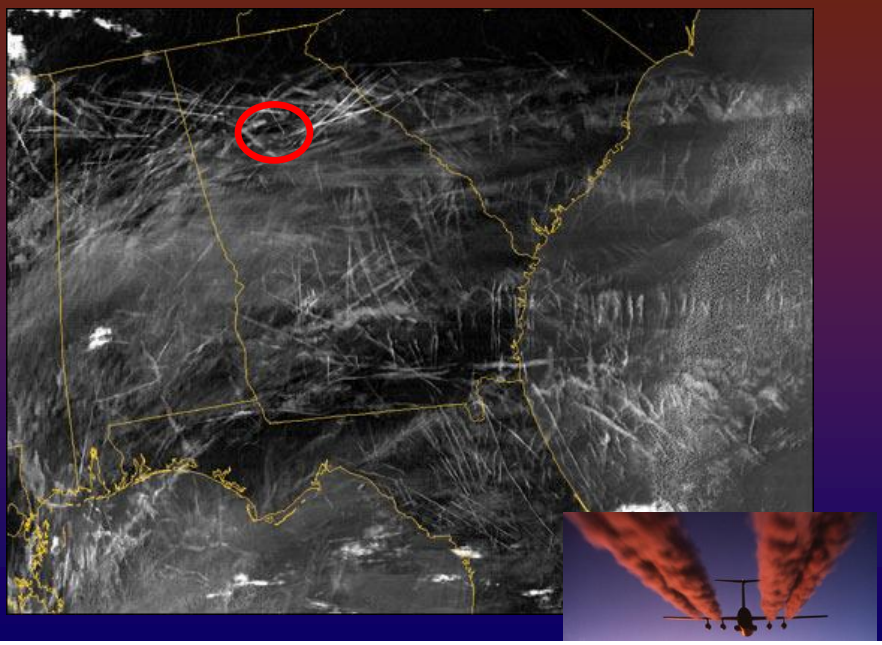
Supporting Evidence

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

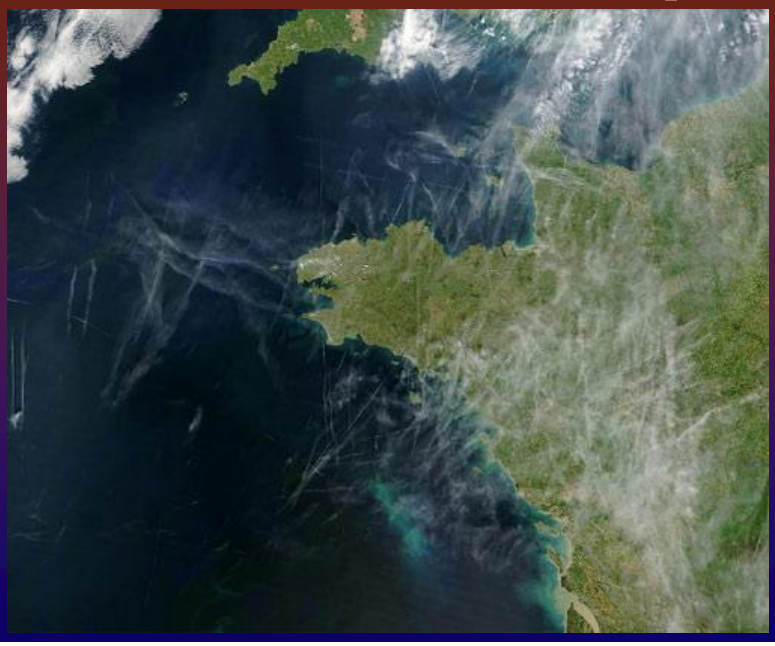
Where does it come from?

- 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.
- Global warming
  - Water vapor and cloud feedback
    - Same effect as aerosols, but different cause

Aircraft Contrails, Jan 29 2004 MODIS



Aircraft Contrails over Europe



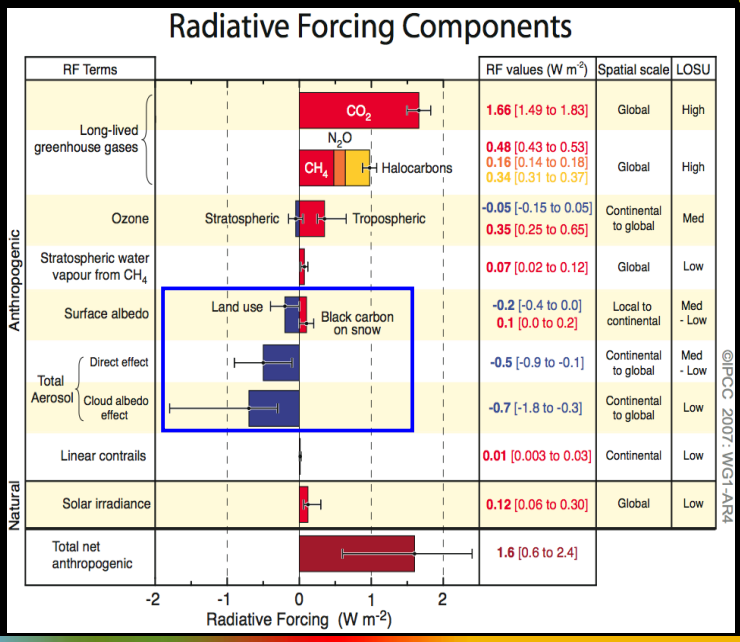
Effects are mostly regional

- 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.
- *Extreme* regional effect
  - the Sahel

Trend Reversal – 1990-2006

- The "dimming" trend had reversed
  - likely that part of this change, particularly over Europe, is due to decreases in pollution.
- Most developed nations have done more to reduce aerosols released into the atmosphere than to reduce CO_2 emissions.

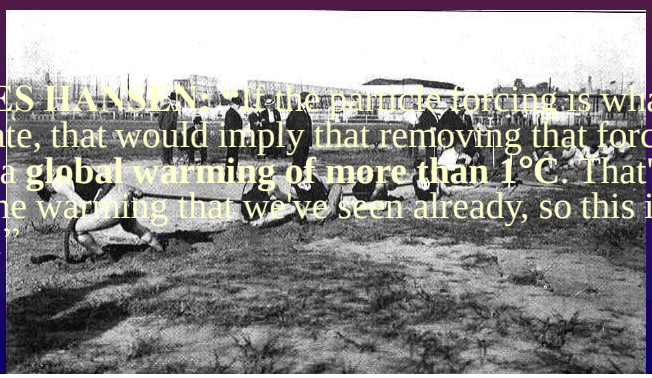
Human and Natural Drivers of Climate Change



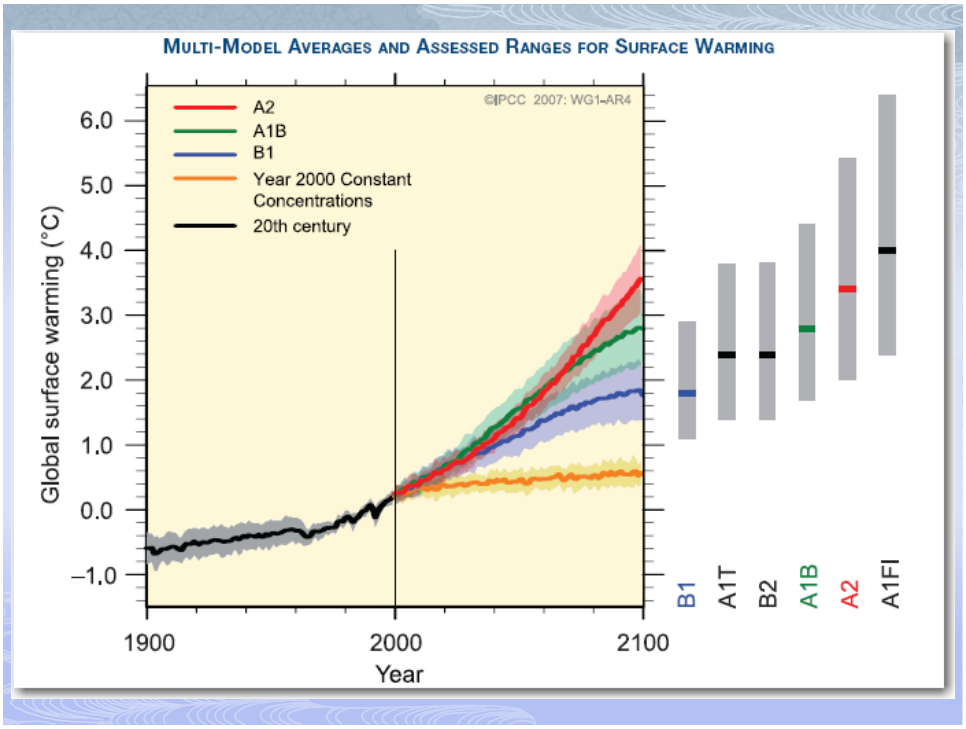
IPCC - WGI

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."


Multi-Model Averages and Assessed Ranges for Surface Warming
©IPCC 2007: WG1-AR4
A2
A1B
B1
Year 2000 Constant Concentrations
20th century
Global surface warming (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
1900
2000
2100
Year
B1
A1T
B2
A1B
A2
A1FI