Science of Global Warming and Climate Change

Part 2 – Science – History of Climate Change

by

Dr. David H. Manz, P. Eng.

University of Calgary
May 2018

Paleoclimatology or the History of Climate Change

Try to answer the questions:

1. **How has climate changed over the history of Earth's existence and how do the characteristics of present changes compare to past events?**
2. **Is there cause for alarm?**
3. **Is there reason to believe that human activity, anthropogenic forcing (GHG's), might be causing recent global warming and climate change?**

Earth Climate History

The climate of the earth has been estimated over the past 100's of millions of years with a reliability and significance that increases as the evaluations approach the past few 100's of years or even the last few decades.

Measurement of global temperature and precipitation – recent history.

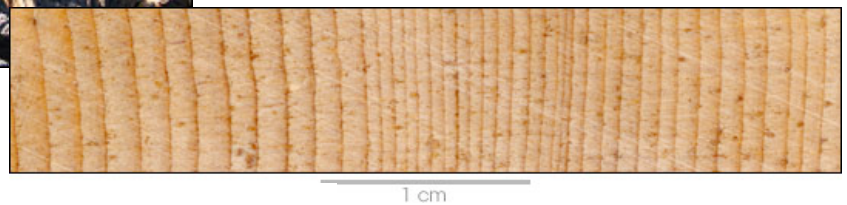
Temporal Scope & Potential Information from Paleoclimatic Proxies

Proxy Type	Sampling Interval (min.)	Temporal Scope (order: yr)	Temp.	Precip. or water balance	Chemical composition (air or water)	Biomass or vegetation	Volcanic eruptions	Sea Level	Solar Activity
Historical Records	day/hr	~10^3	X	X	X	X	X	X	X
Tree Rings	yr/season	~10^4	X	X	0	X	X	0	X
Lake Sediments	yr to 20 yr	~10^4~10^6	X	X	0	X	X	0	0
Corals	yr	~10^4	X	X	X	0	0	X	0
Ice Cores	yr	~5 X 10^5	X	X	X	X	X	0	X
Pollen	20 yr	~10^5	X	X	0	X	0	0	0
Speleothems	100yr	~5 X 10^5	X	X	X	0	0	0	0
Loess	100yr	~10^6	0	X	0	X	0	0	0
Geomorphic features	100 yr	~10^6	X	X	0	0	X	X	0
Marine sediments	500 yr	~10^7	X	X	X	X	X	X	0

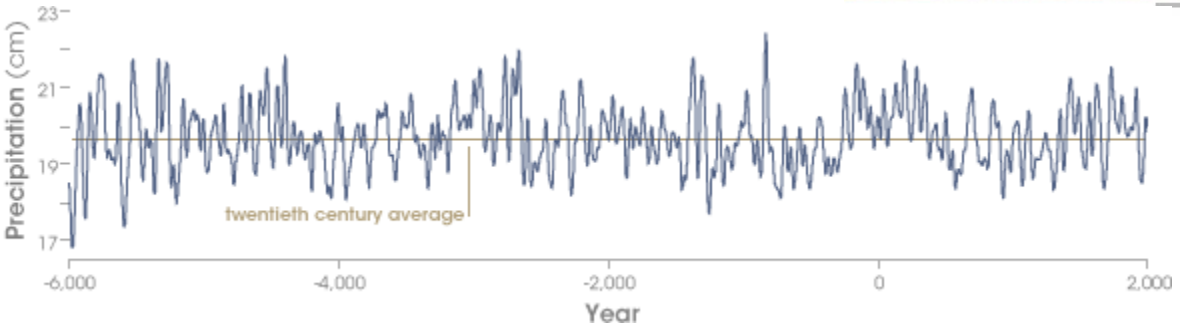
Other proxy techniques for estimating global and regional climate changes (recent history) are being discovered and evaluated – e.g. Recent discoveries of North Atlantic corals and stomata density on leaves. (NA corals look useful while stomata density do not.)

Tree Rings

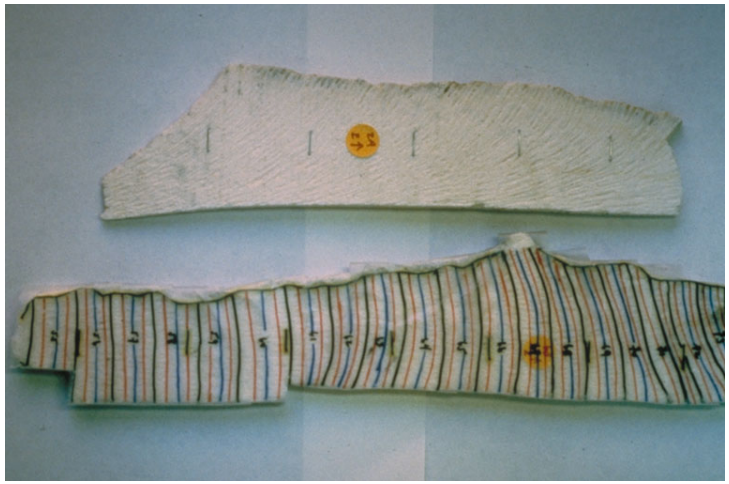
Pueblo Ruins



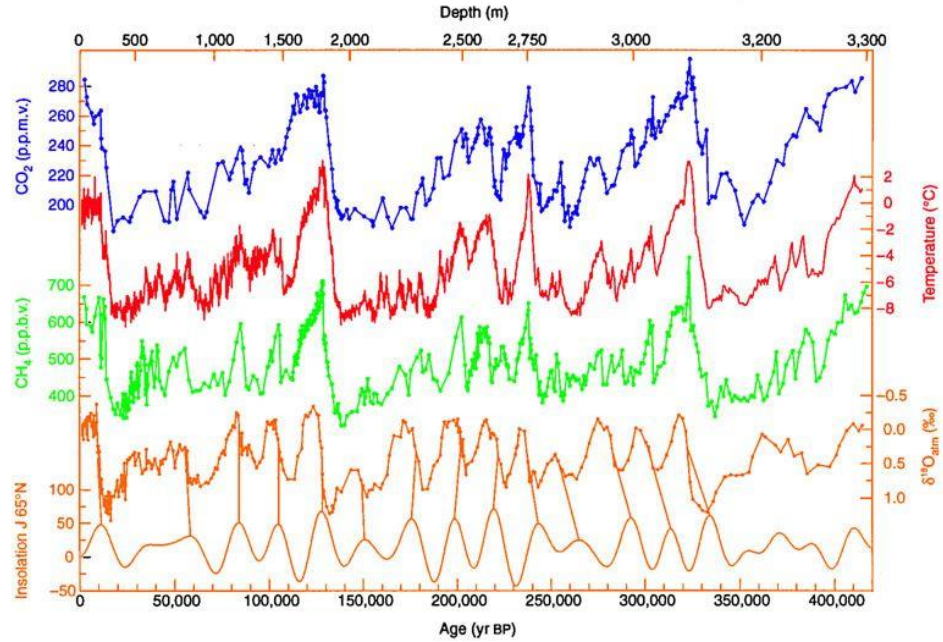
Bristlecone Pines

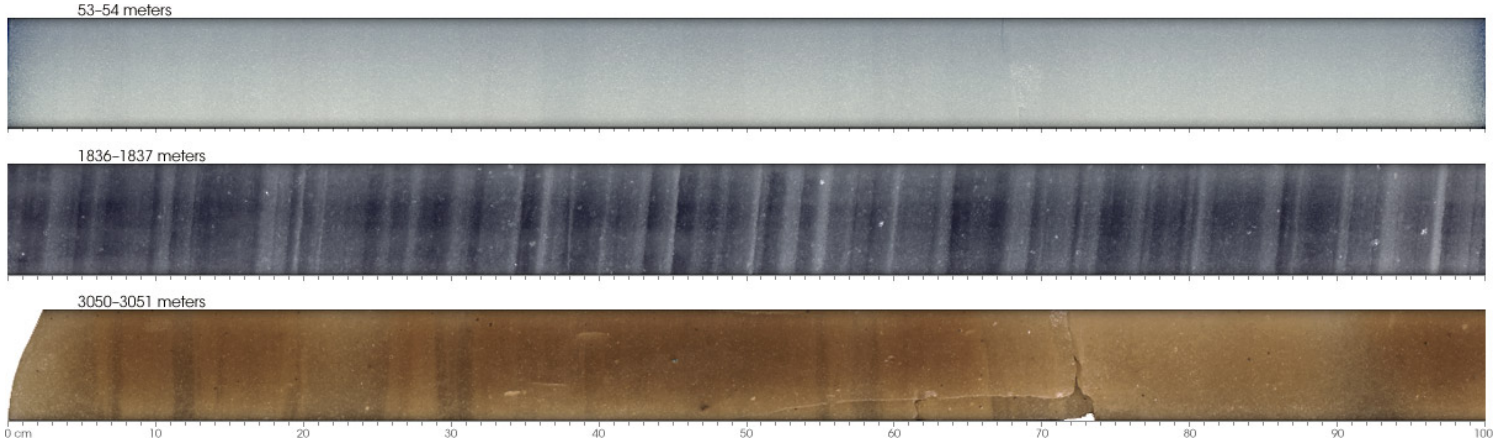


Corals



Ice Core

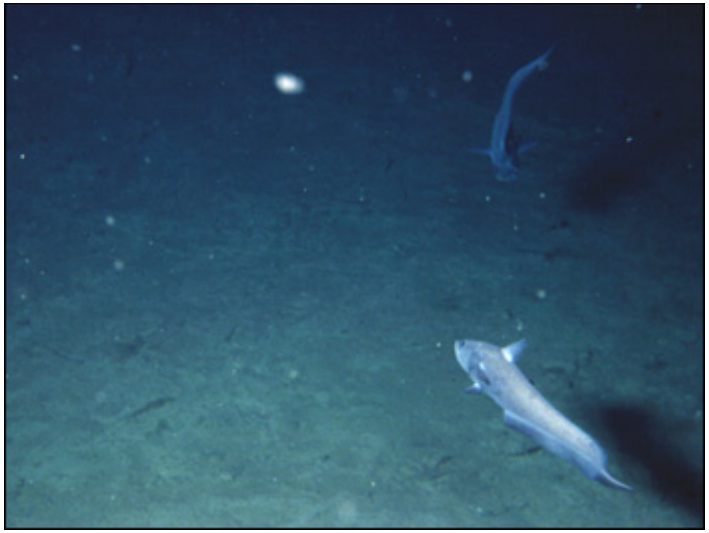

Depth (m)
0
500
1,000
1,500
2,000
2,500
2,750
3,000
3,200
3,300
CO_2 (p.p.m.v.)
280
260
240
220
200
Temperature (°C)
2
0
−2
−4
−6
−8
CH_4 (p.p.b.v.)
700
600
500
400
$\delta^{18}O_{atm}$ (‰)
−0.5
0.0
0.5
1.0
Insolation J 65°N
100
50
0
−50
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Age (yr BP)

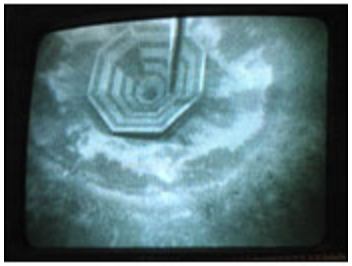

53–54 meters
1836–1837 meters
3050–3051 meters
0 cm
10
20
30
40
50
60
70
80
90
100

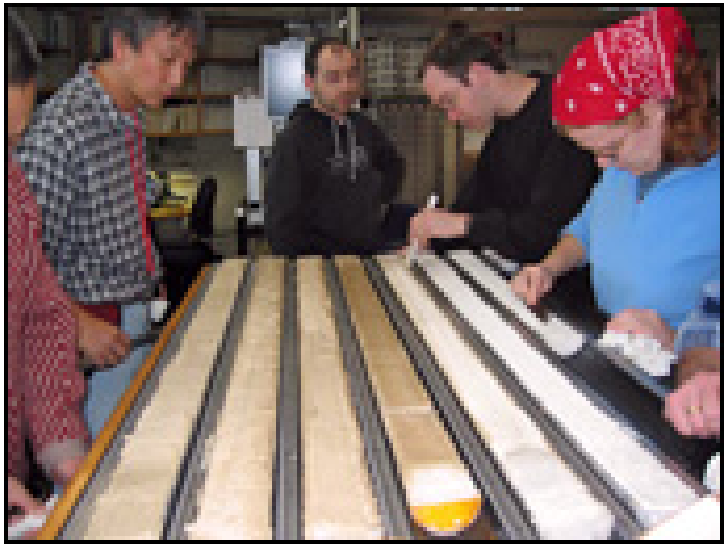
Speleothems

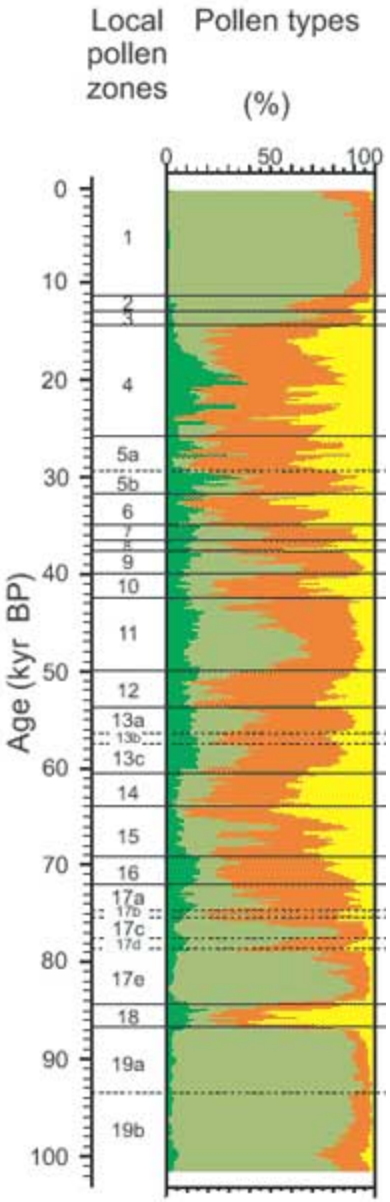
Loess

Marine Sediments









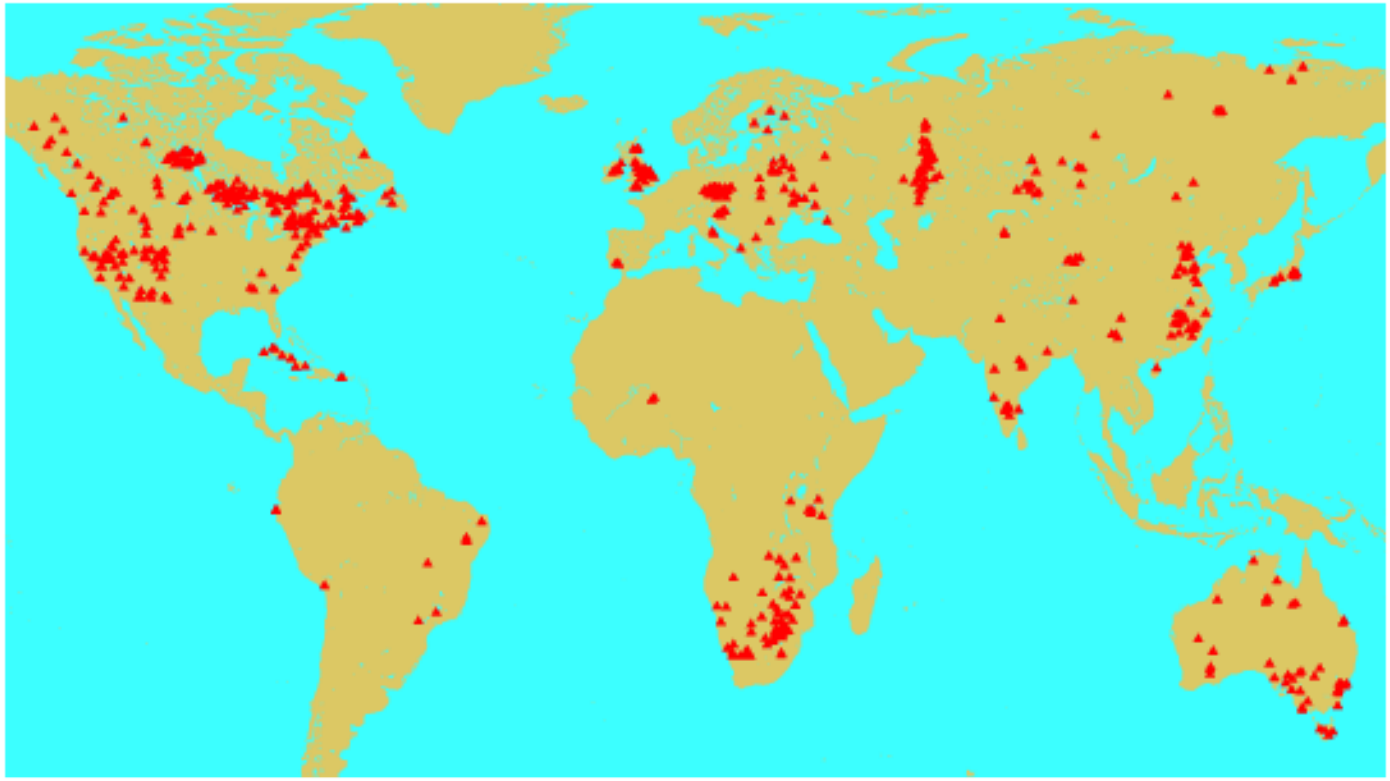
Pollen

Pollen will indicate the type of vegetation growing at a particular time. The type of vegetation is related to the climate at that time – average temperature and precipitation.

Stomata Density Index or SDI

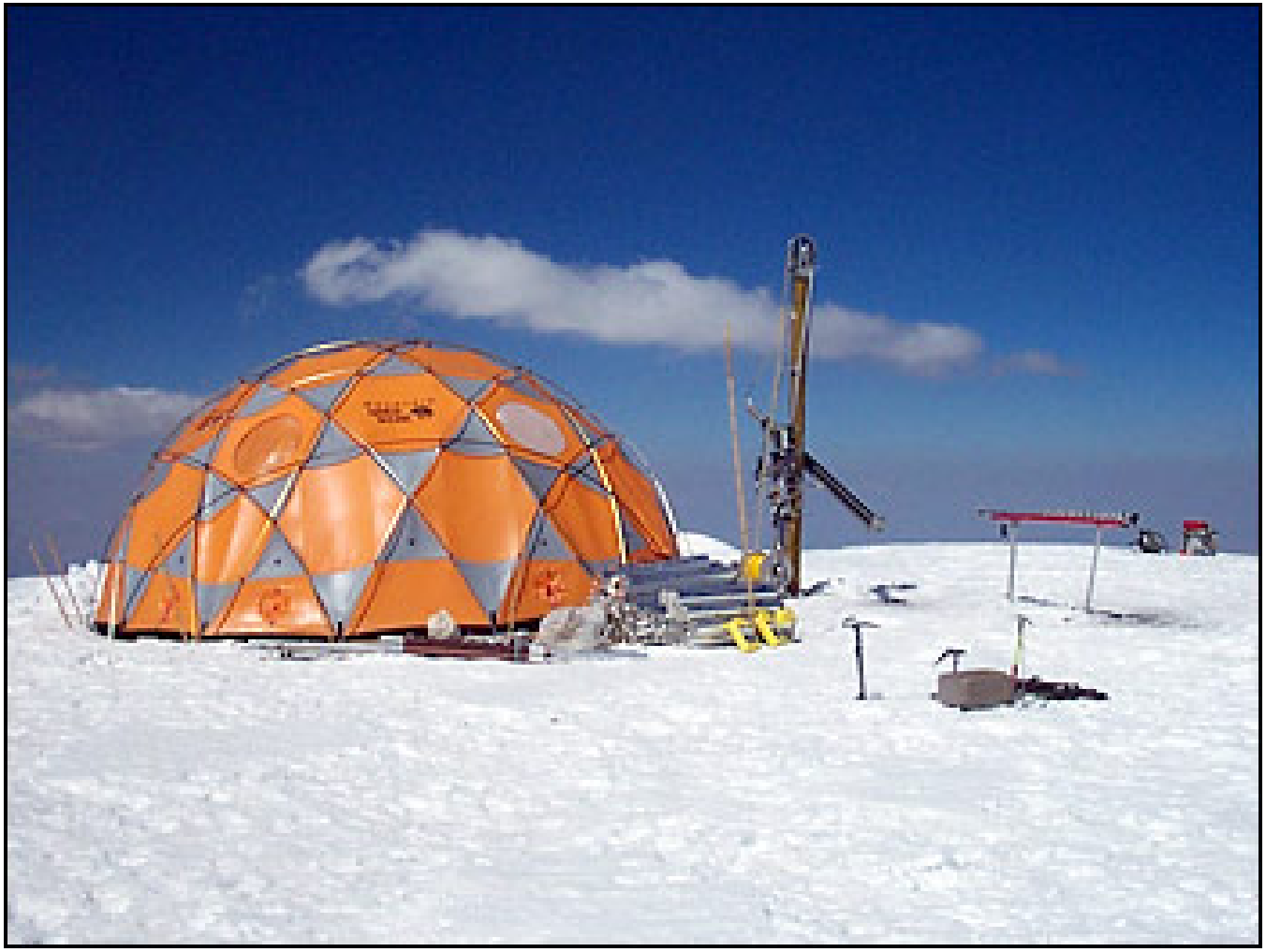
- SDI is the number of stomata on the surface of a leaf (typically the leaf).
- In a controlled environment (temperature, light type, duration and intensity, moisture conditions (soil and atmospheric), etc.) healthy plants will respond to increase in the concentration of CO_2 in the atmosphere by reducing the SDI on its leaves.
- The relationship between SDI and the concentration of CO_2 will vary with species of plant.
- The relationship between the concentration of CO_2 and SDI appears to be strong to some upper limit in the concentration of CO_2 . This varies with plant species.
- Well preserved accumulations of plant leaves have been found in bog environments in Europe and North America. The accumulations have occurred over several hundreds of years. The preservation of the leaves is sufficiently good that the SDI can be determined.
- The suggestion has been made the SDI of the leaves in layers which are able to be accurately dated, can be used to estimate the concentration of CO_2 in the atmosphere and even be used to correct the concentration of CO_2 in the atmosphere determined from ice core measurements.
- The scientific community is in general disagreement with the use of the SDI of leaves in the bog environments for estimation of atmospheric CO_2 because of the numerous other factors which also determine the SDI. SDI is not used as a proxy to estimate atmospheric CO_2 in paleo-climates.
- The estimates of the concentration of atmospheric CO_2 from ice core data is considered to be quite accurate and may be used to evaluate the SDI determinations.

Boreholes



Boreholes drilled around the world and used to determine characteristics of ancient climates.

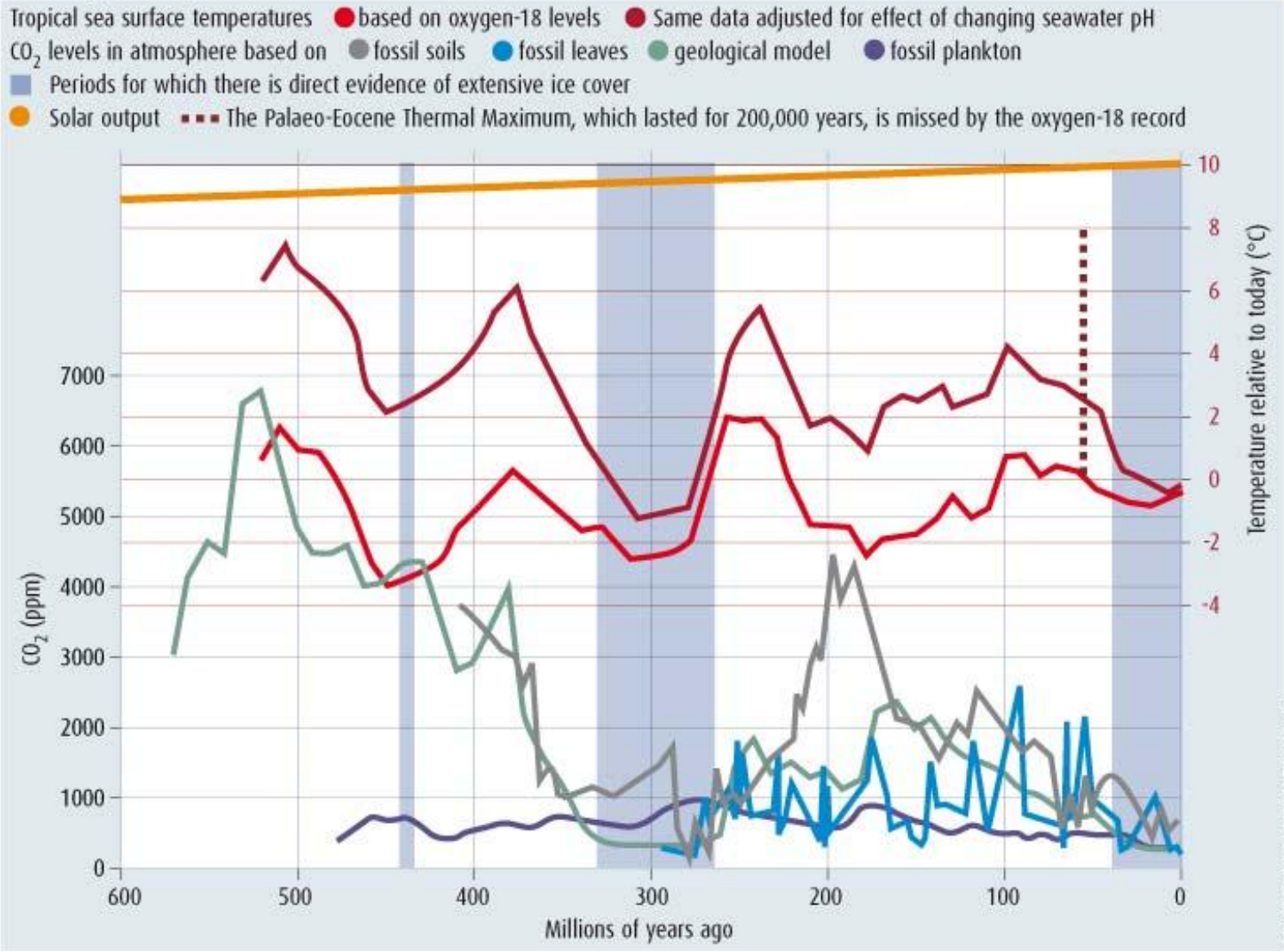
Glaciers



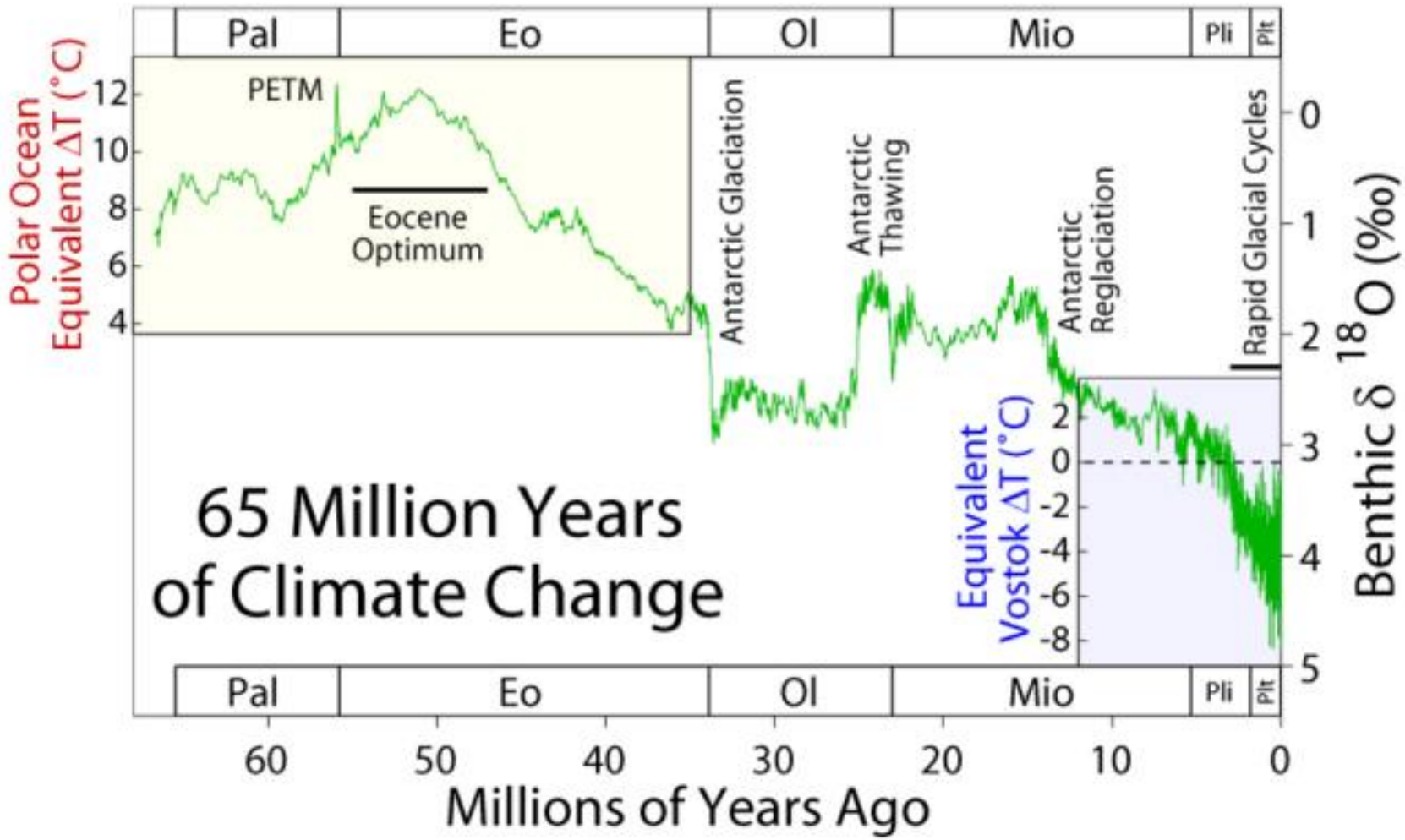
Canadian ice cores from glaciers will be stored in new facilities at the University of Alberta.

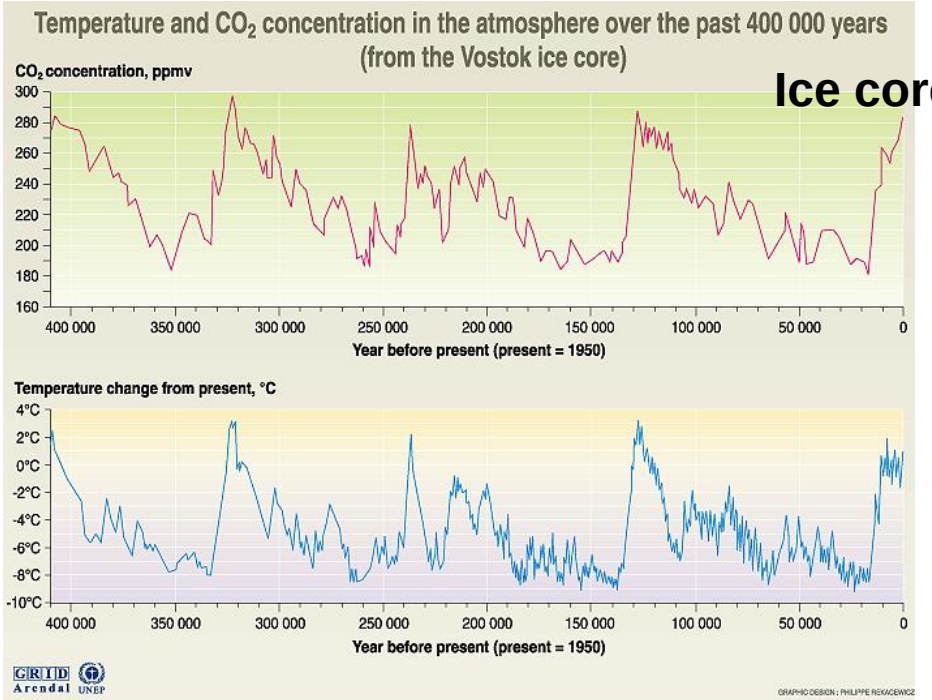
TEMPERATURE AND CO_2 OVER THE PAST 500 MILLION YEARS

Working out how carbon dioxide levels and temperature have varied in the very distant past is not easy. Estimates based on different methods produce quite different results



SOURCE: ROYER 2004, ROTHMAN 2002


Pal
Eo
Ol
Mio
Pli
Plt
Polar Ocean Equivalent ΔT (°C)
12
10
8
6
4
PETM
Eocene Optimum
Antarctic Glaciation
Antarctic Thawing
Antarctic Reglaciation
Rapid Glacial Cycles
Equivalent Vostok ΔT (°C)
2
0
-2
-4
-6
-8
65 Million Years of Climate Change
Benthic δ 18O (‰)
0
1
2
3
4
5
60
50
40
30
20
10
0
Millions of Years Ago

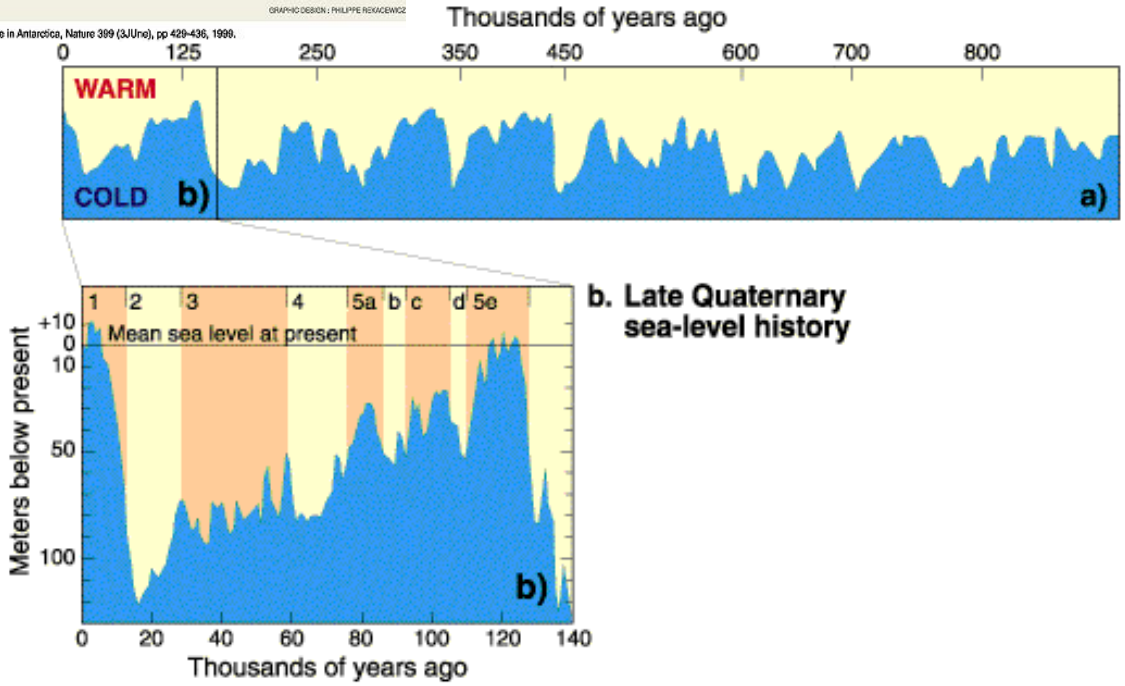


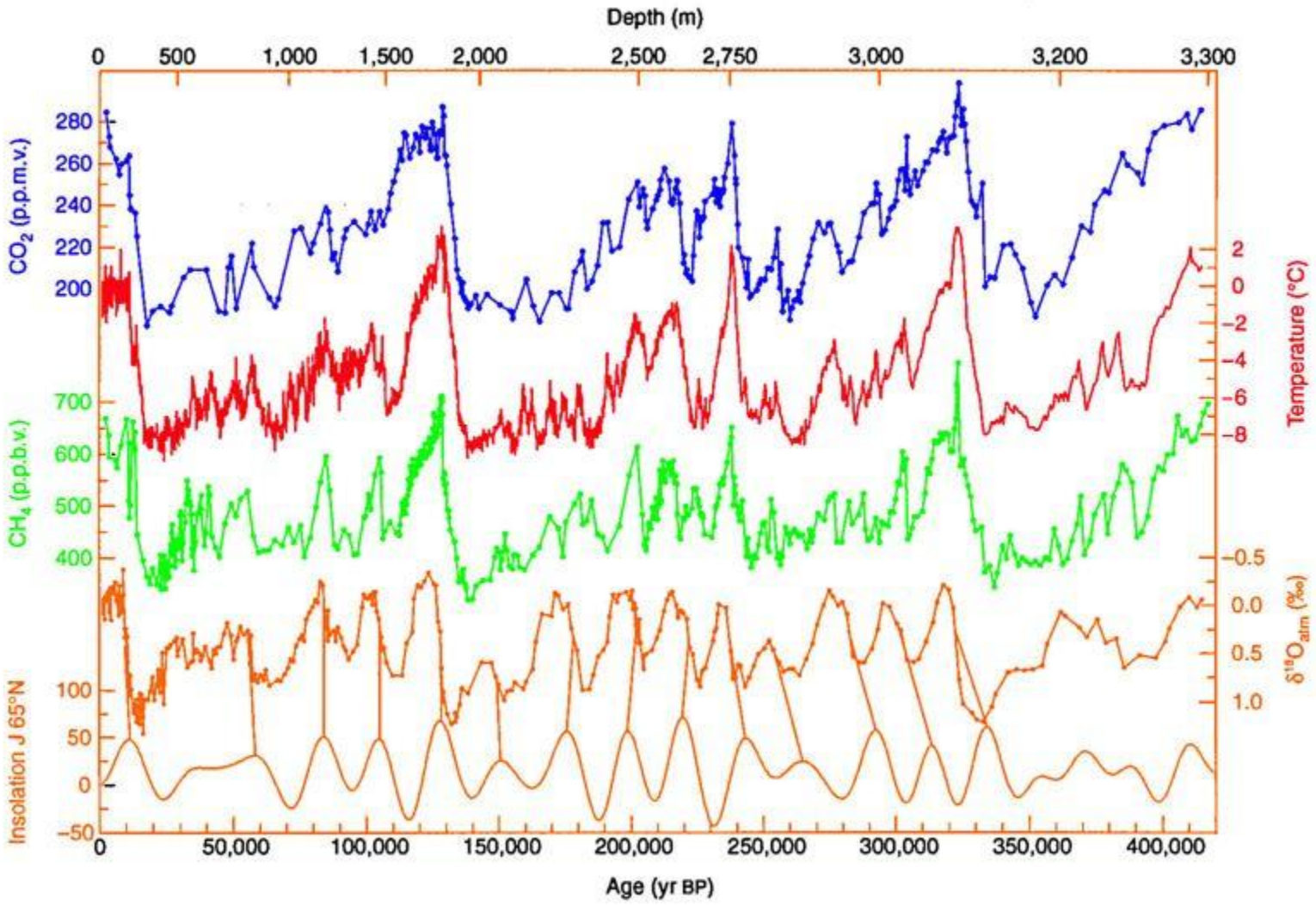
Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

Ice cores

Marine sediments, geomorphic features, loess, speleothems, ice core information and astronomical observations and calculations provide the means of reconstructing past climate variability at 100,000 year and longer time scales.

Sea Level

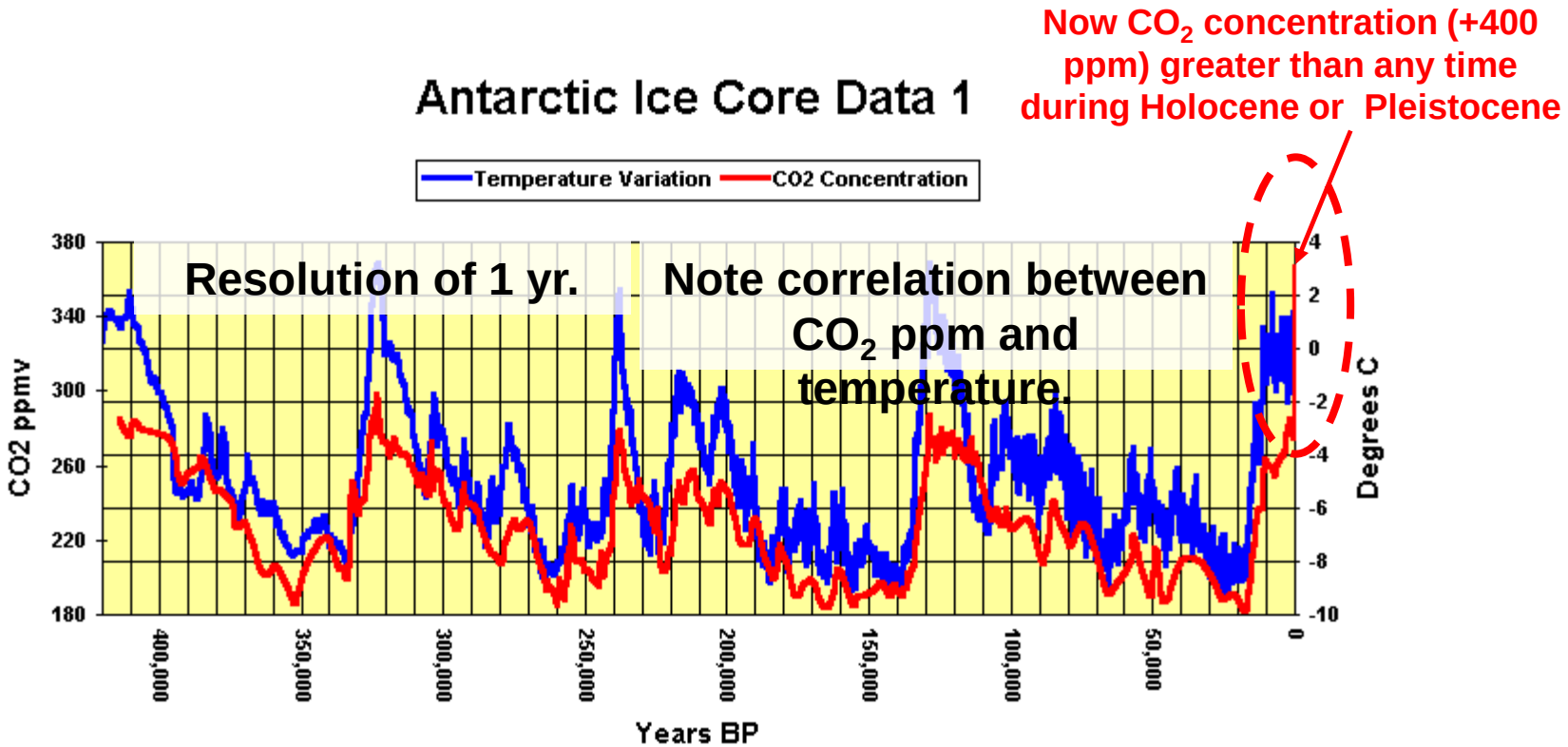




A great deal of information from ice cores.

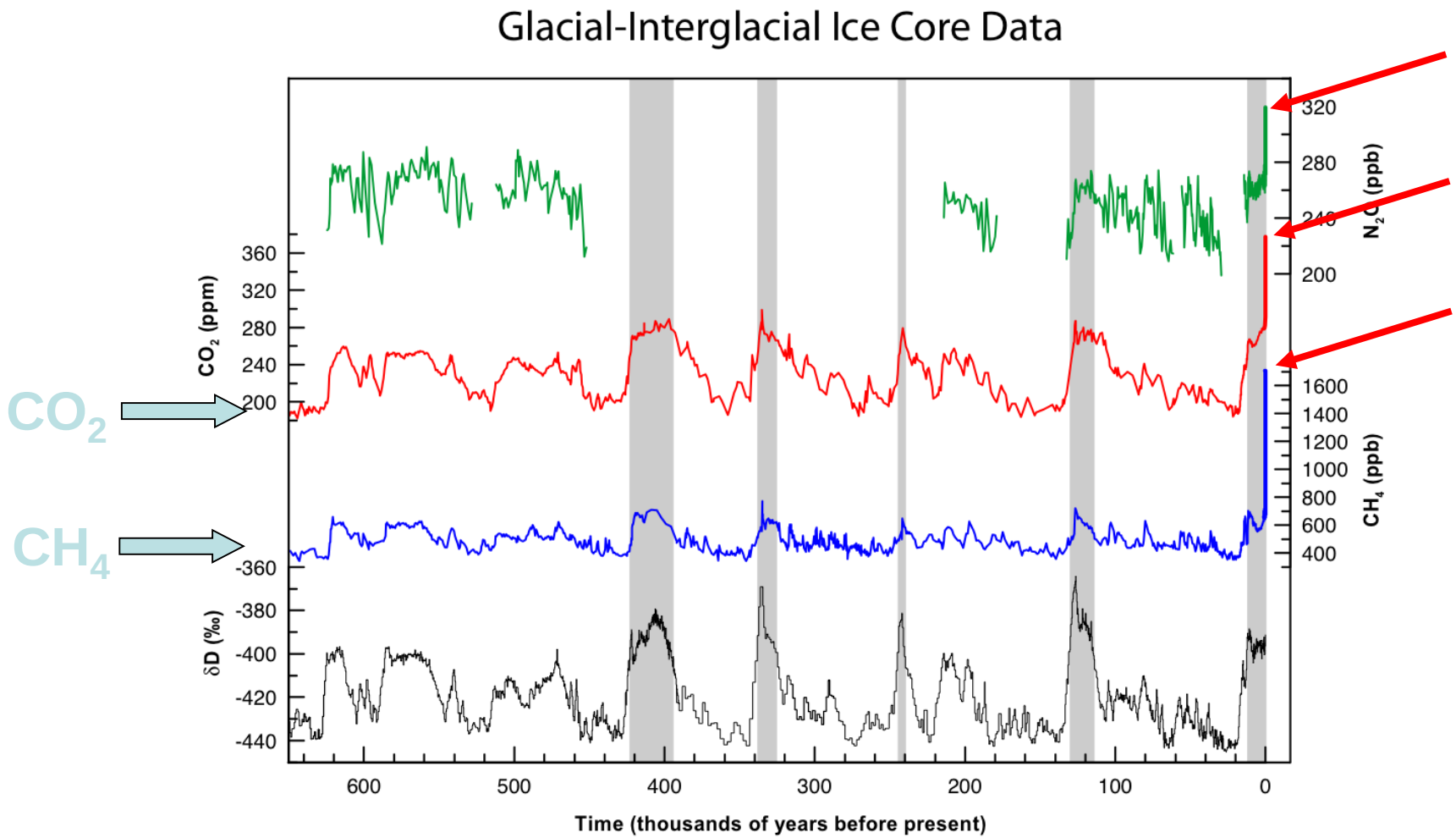
Last 500,000 years or so.

(Vlostok and Greenland ice cores.)



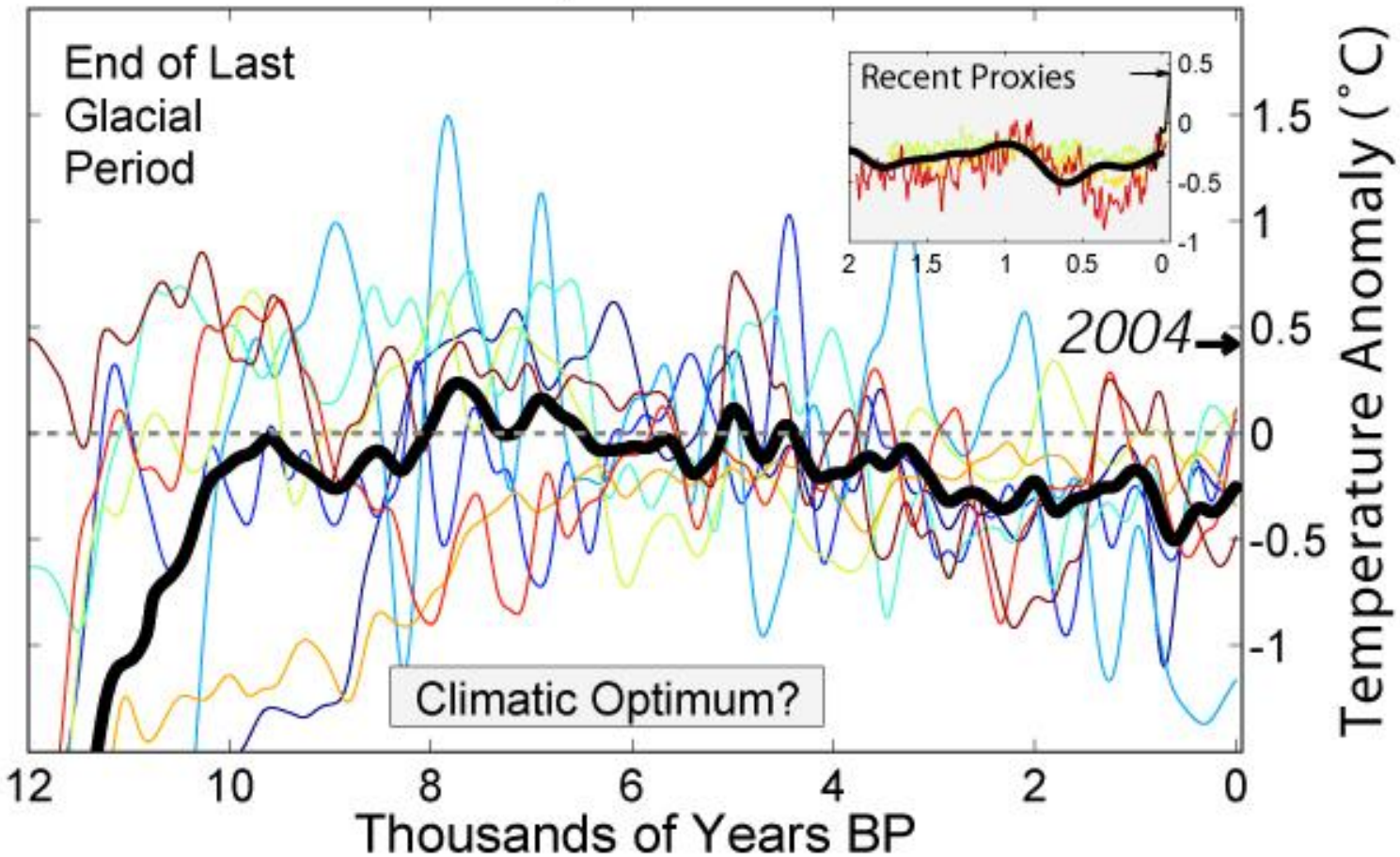
http://www.ncdc.noaa.gov/paleo/slides/slideset/

Pleistocene and until 100 years ago: increase in CO_2 temperature increase.
Last 100 years: Increase in CO_2 preceded temperature increase.

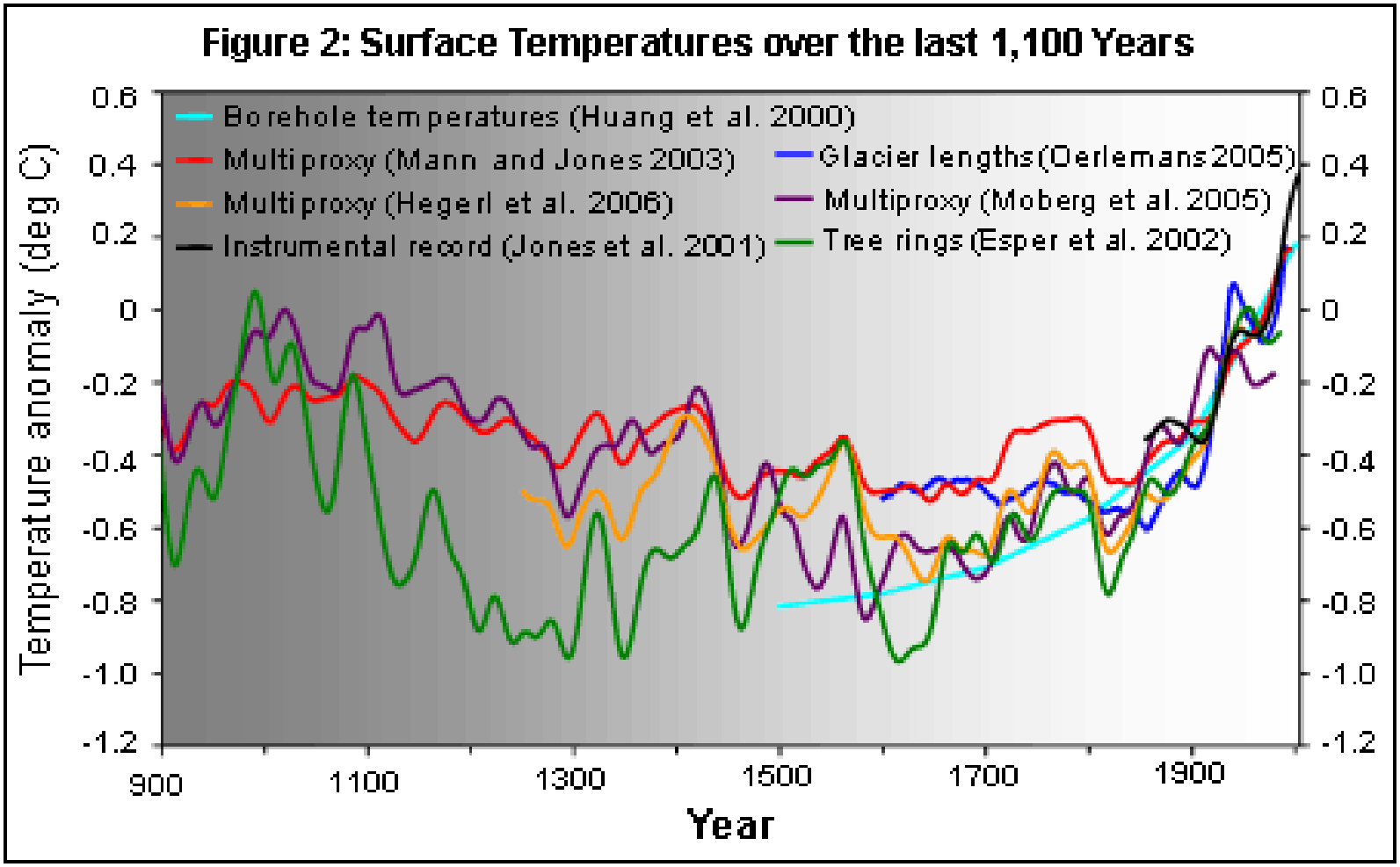


The atmospheric concentration of CO_2 and CH_4 in 2005 exceeds by far the natural range of the last 650,000 years

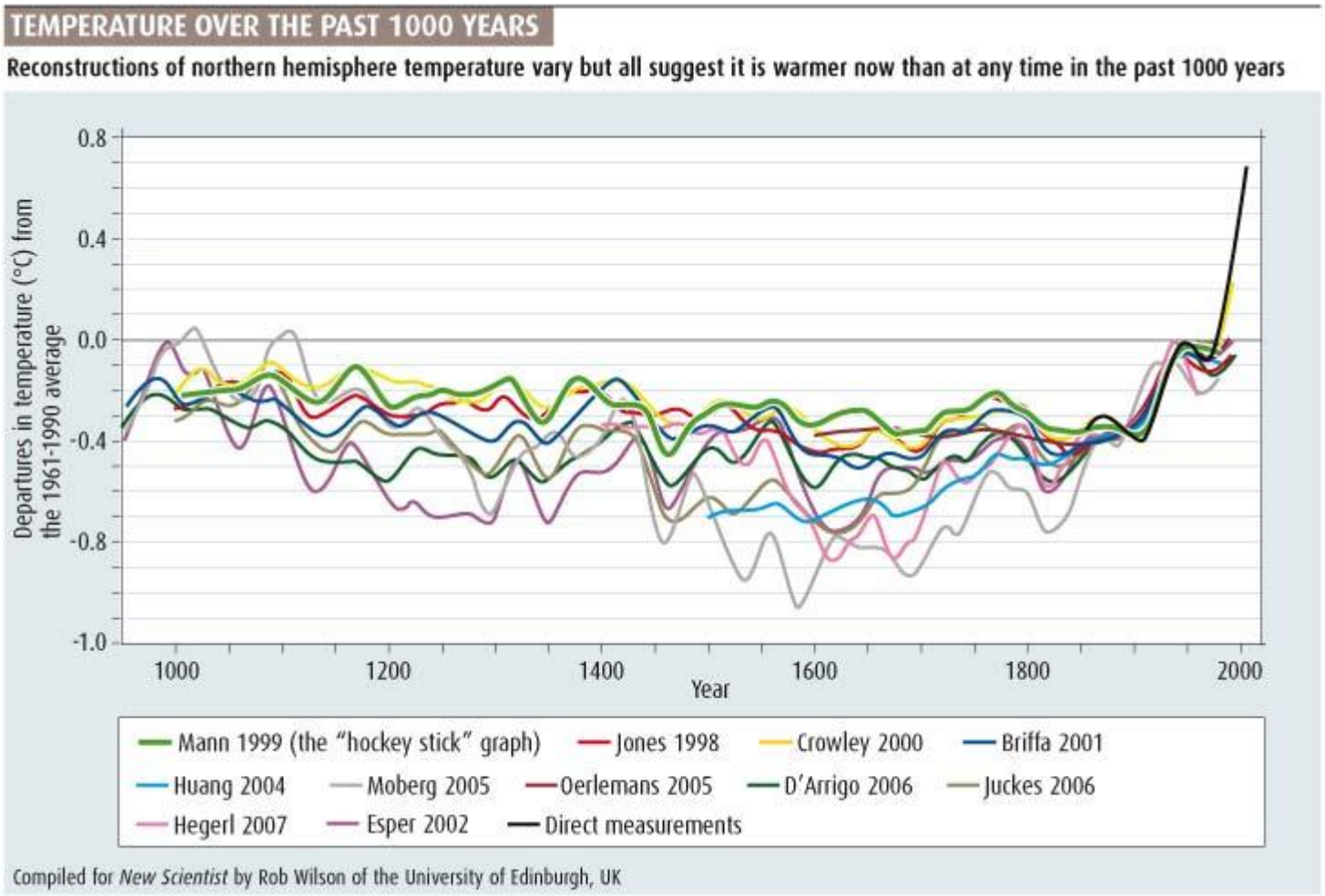
Holocene Temperature Variations



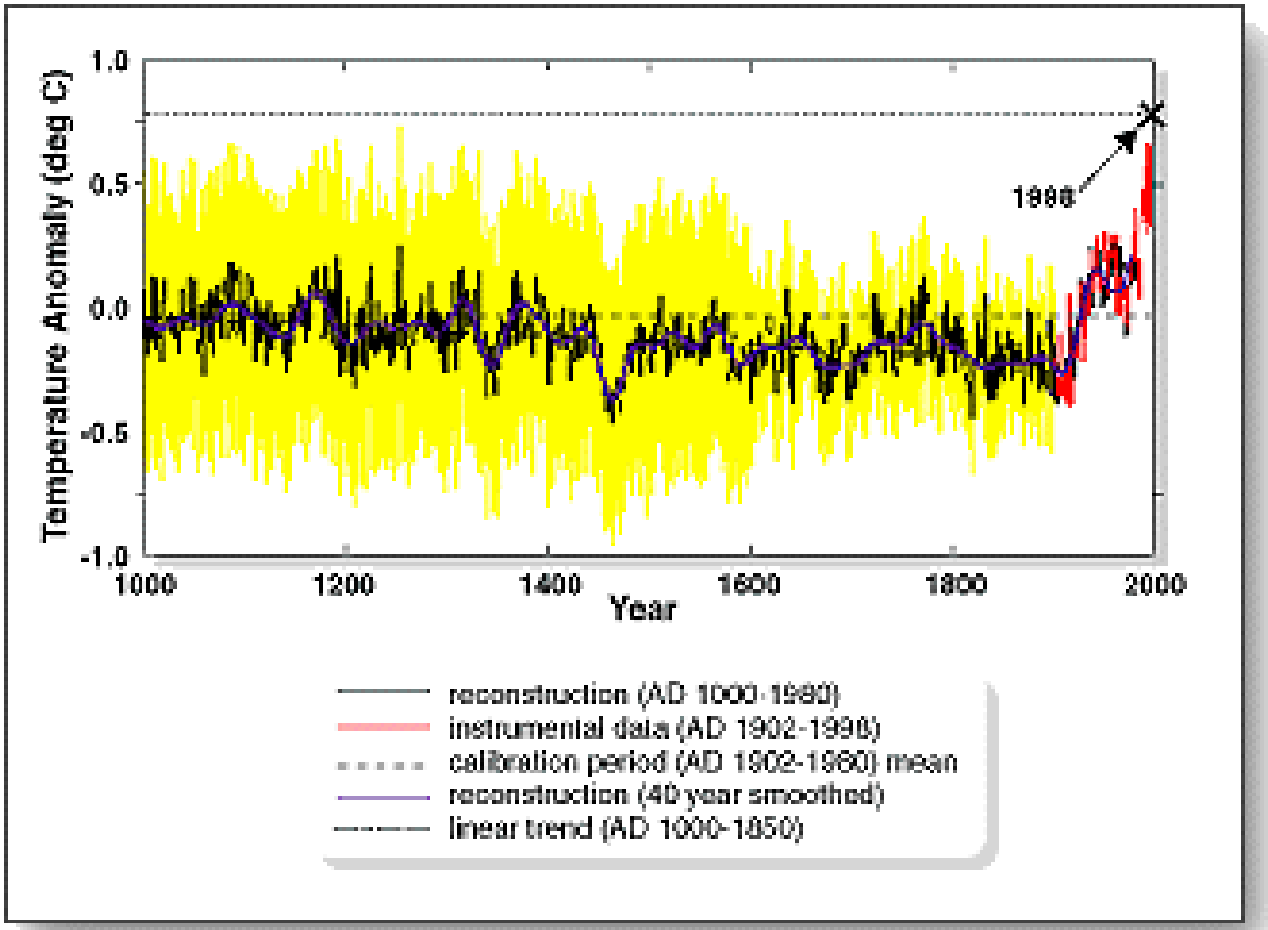
There are very good estimates of temperature over the past 12,000 years (and longer) using various proxy methods such as sea sediments and tree rings.



- **There are very good estimates of temperature over the past 12,000 years (and longer) using various proxy methods such as tree rings.**
- **It is only in the last 100 years or so that we have instrument recorded records (temperature and other climate data).**
- **It is only in the last 30 years or so that we have climate and GHG data that is needed in computer model studies (including satellite information).**

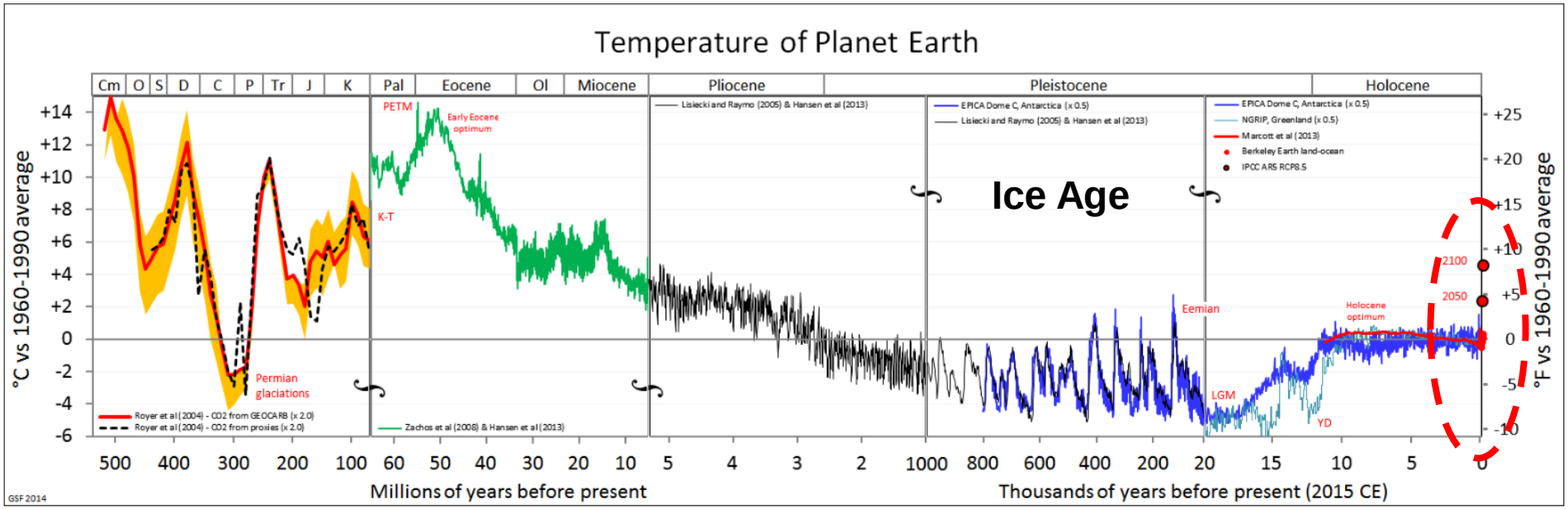

TEMPERATURE OVER THE PAST 1000 YEARS
Reconstructions of northern hemisphere temperature vary but all suggest it is warmer now than at any time in the past 1000 years
Departures in temperature (°C) from the 1961-1990 average
0.8
0.4
0.0
-0.4
-0.8
-1.0
1000
1200
1400
1600
1800
2000
Year
Mann 1999 (the "hockey stick" graph)
Jones 1998
Crowley 2000
Briffa 2001
Huang 2004
Moberg 2005
Oerlemans 2005
D'Arrigo 2006
Juckes 2006
Hegerl 2007
Esper 2002
Direct measurements
Compiled for New Scientist by Rob Wilson of the University of Edinburgh, UK

Emphasis


Temperature Anomaly (deg C)
1.0
0.5
0.0
-0.5
-1.0
1000
1200
1400
1600
1800
2000
Year
1998
reconstruction (AD 1000-1980)
instrumental data (AD 1902-1998)
calibration period (AD 1902-1980) mean
reconstruction (40 year smoothed)
linear trend (AD 1000-1850)

Emphasis

Variation of Earth's Temperature Over Last 500 Million Years



http://en.wikipedia.org/wiki/Paleoclimatology

There is considerable discussion that the climate has changed continuously over geologic time, for various reasons, and this is undeniably true.

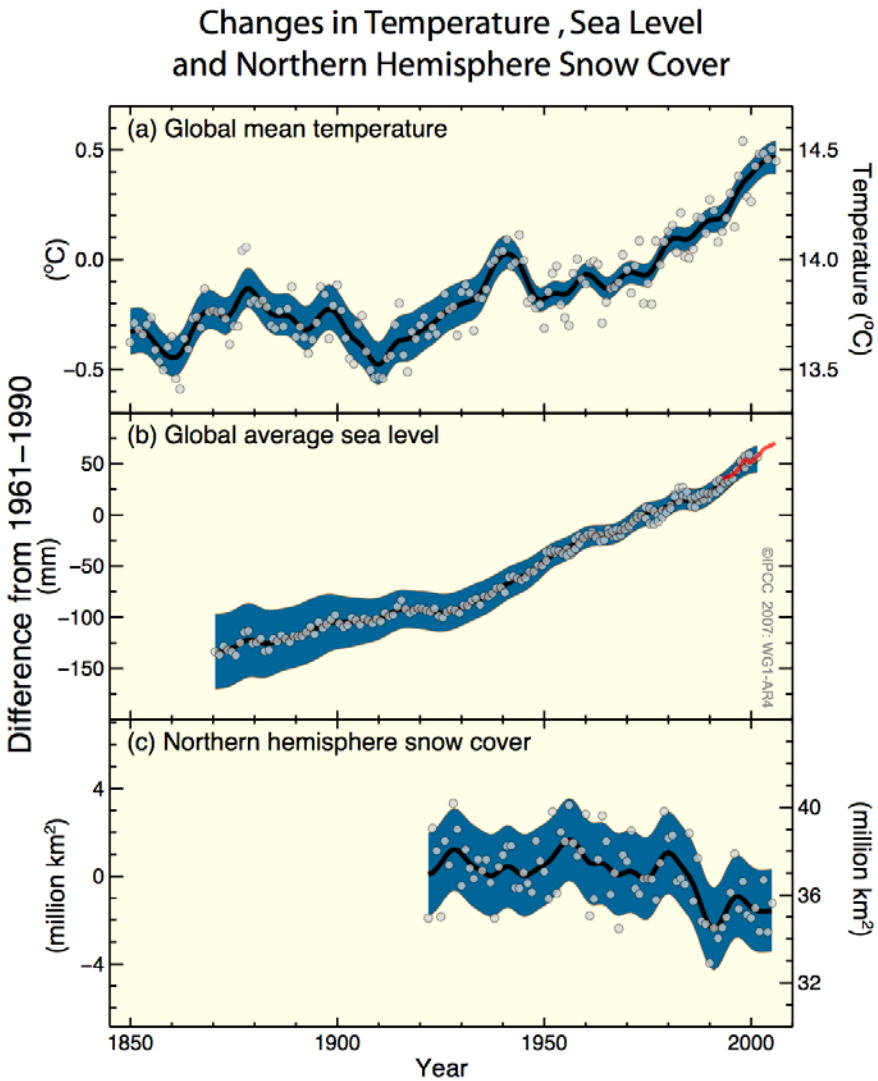
We are interested in knowing why the climate is changing now.

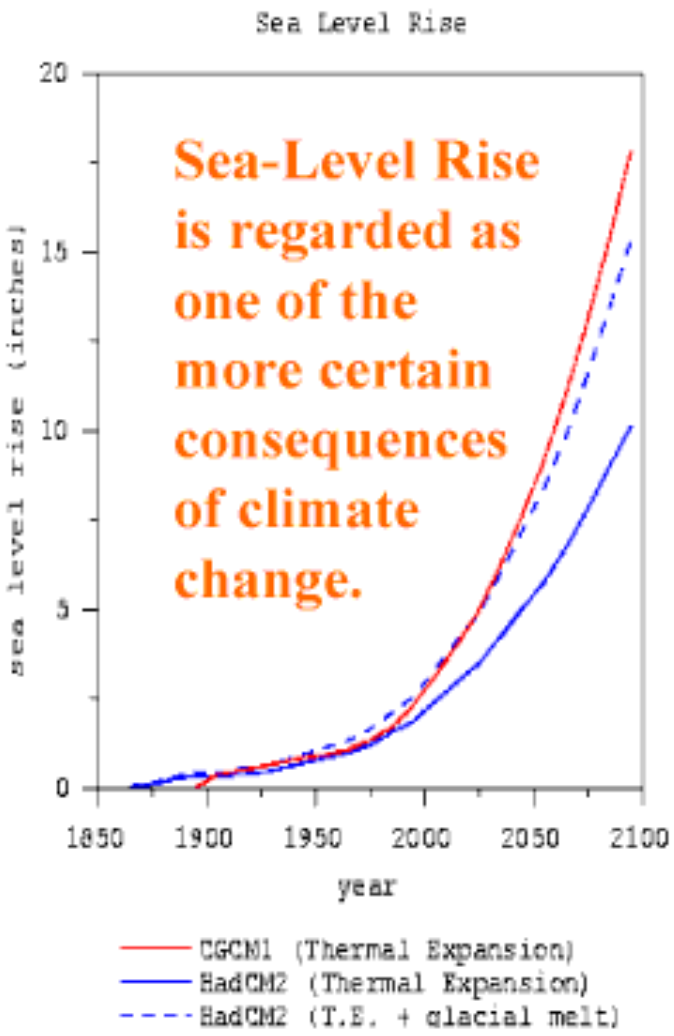
Direct Observations of Recent Climate Change

Global mean temperature

Global average sea level

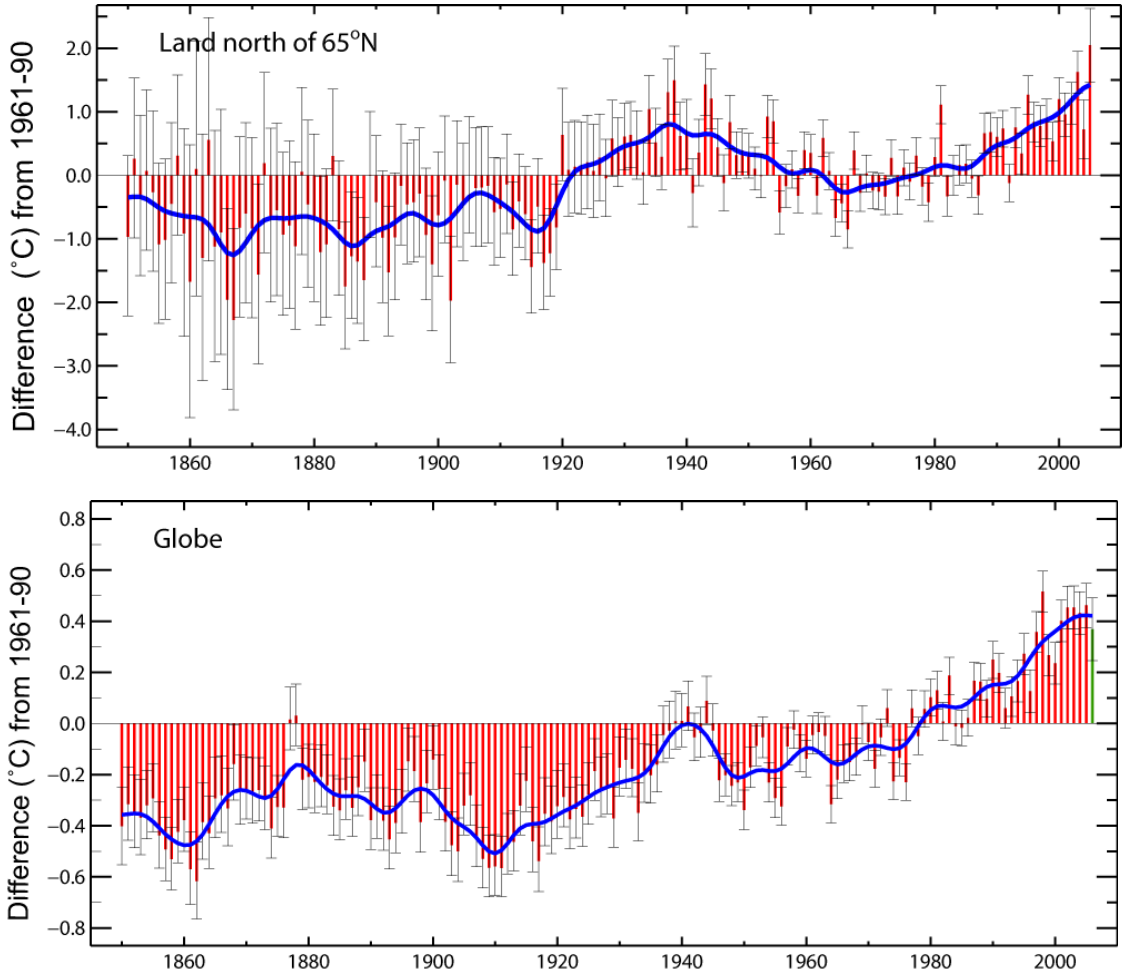
Northern hemisphere Snow cover





Note: First effect is thermal expansion. Second effect is increase as a result of glacial melt.

Arctic vs Global annual temperature anomalies (°C)

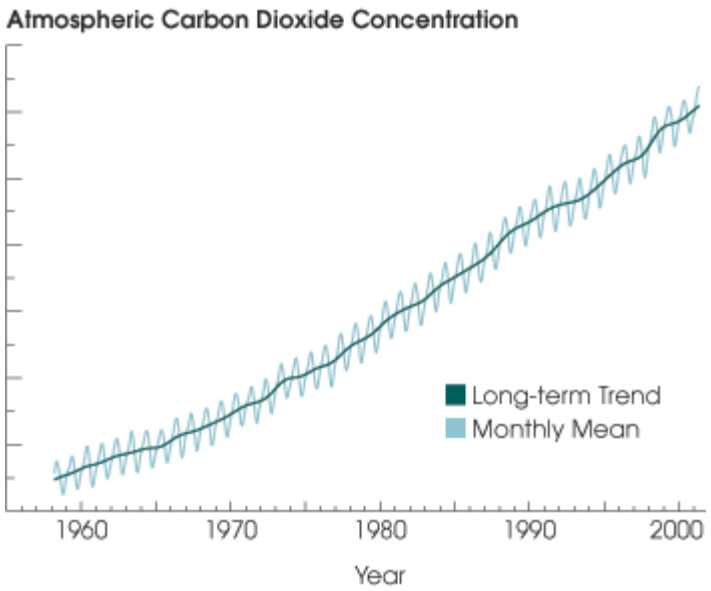


Warming in the Arctic is **double** that for the globe from 19th to 21st century and from late 1960s to present.

Warmth 1925 to 1950 in Arctic was not as widespread as recent global warmth.

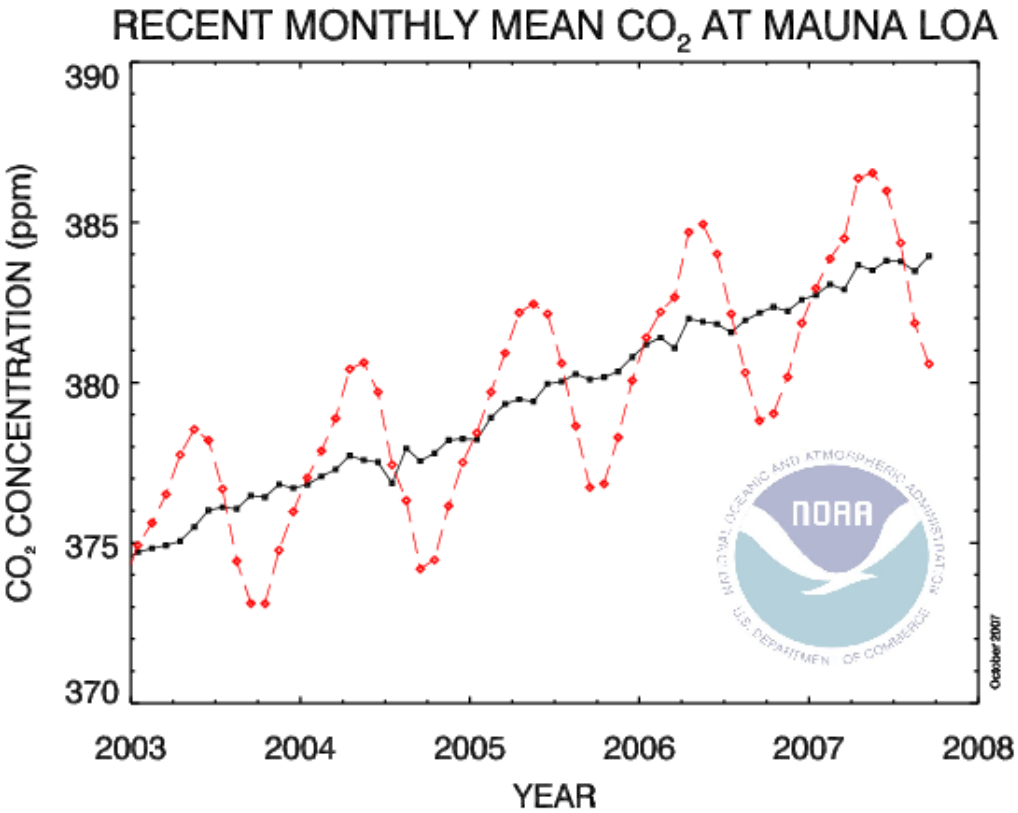
Note different scales

Atmospheric CO2 measurements on Mauna Loa, Hawaii



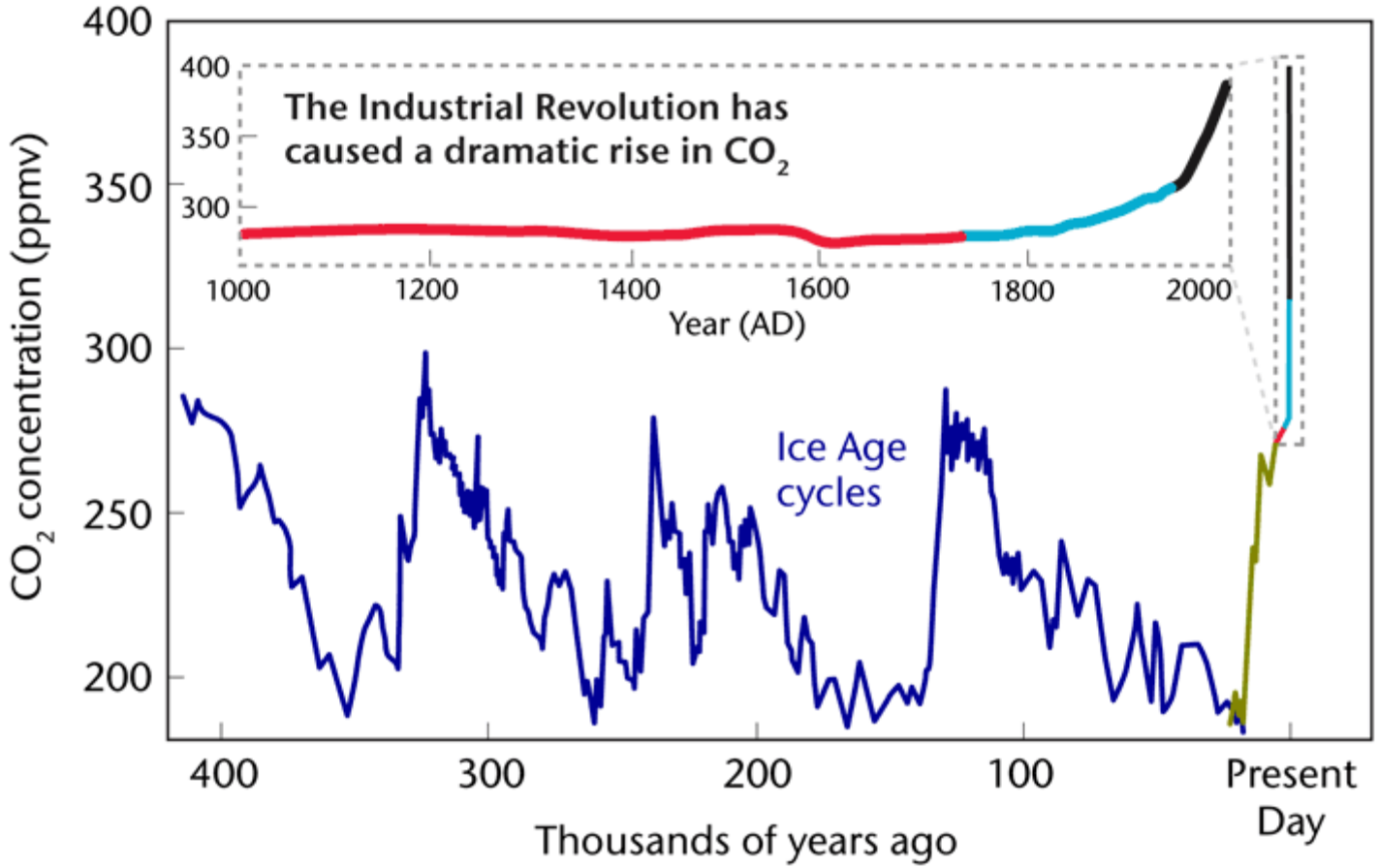
Recently passed 400 ppm - not observed for millions of years. Need to reduce to 350 ppm. (http://climate.nasa.gov/400ppmquotes/ and http://400.350.org/)

Observations of atmospheric CO2 Mauna Loa, Hawaii.



Met Office

Records of past variations in CO_2 concentrations from ice core records



Do we observe (measure) actual global warming?

Are we seeing the affects (impacts) of global warming?

Direct Observations of Recent Climate Change

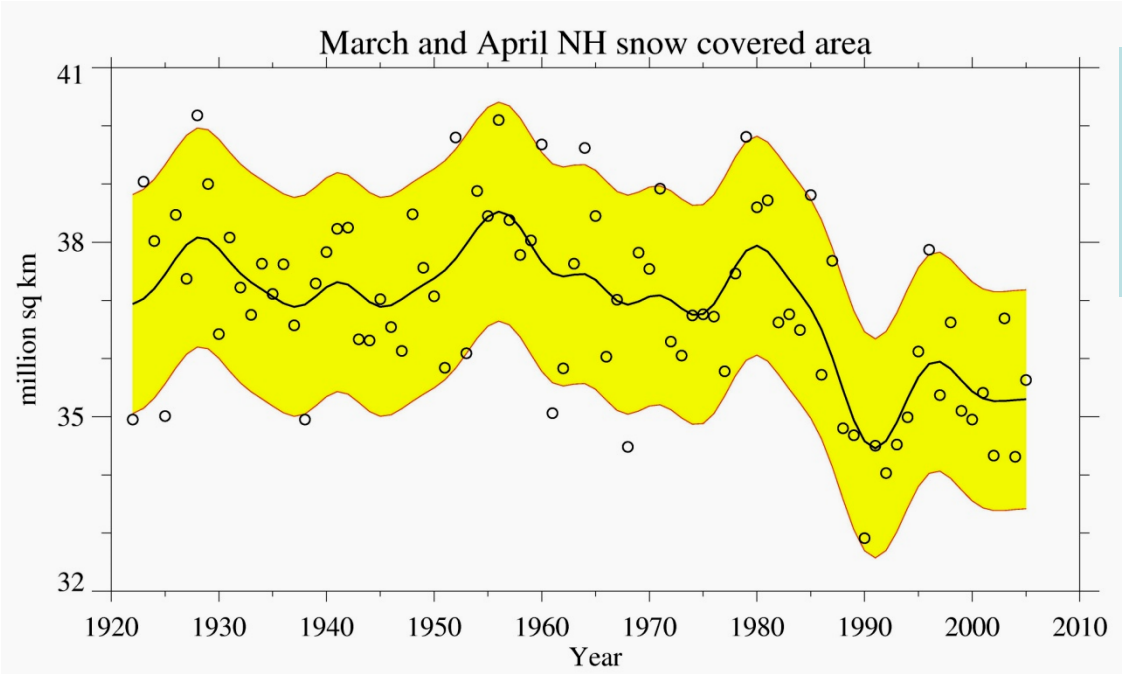
Global average air temperature

- Updated 100-year linear trend of 0.74 [0.56 to 0.92] ^{o}C for 1906-2005
- Larger than corresponding trend of 0.6 [0.4 to 0.8] ^{o}C for 1901-2000 given in TAR

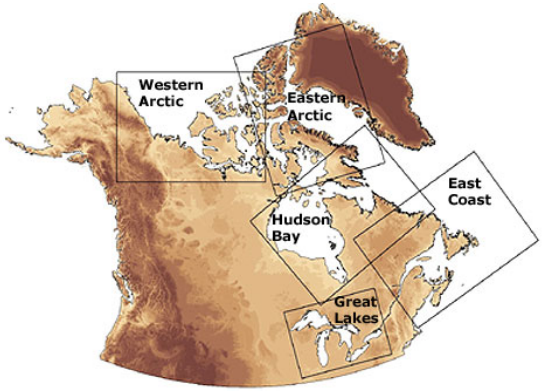
- Average ocean temperature increased to depths of at least 3000 m – ocean has absorbed 80% of heat added

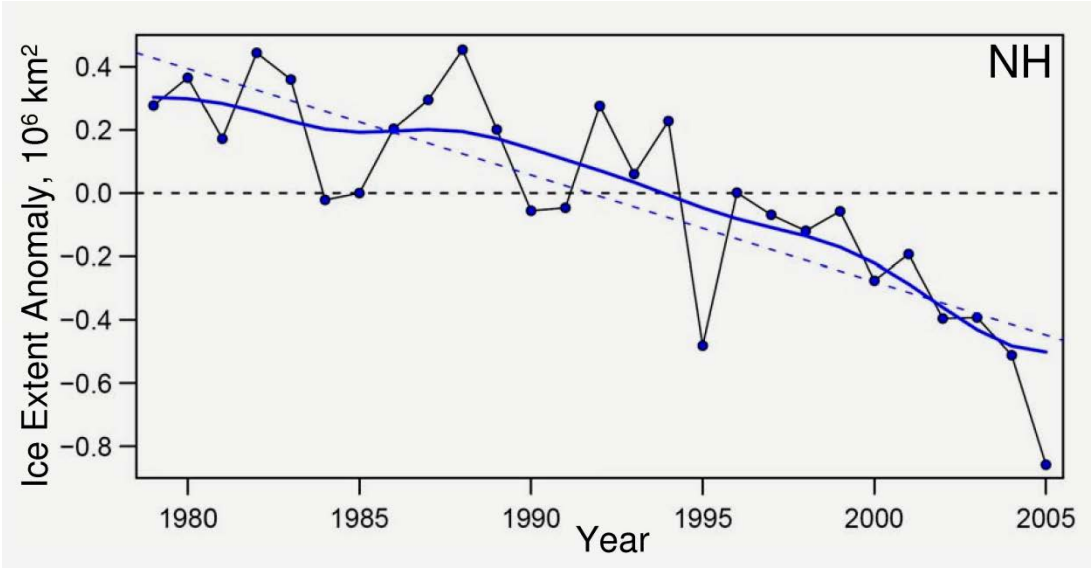
  > seawater expansion and SLR

Snow cover and Arctic sea ice are decreasing



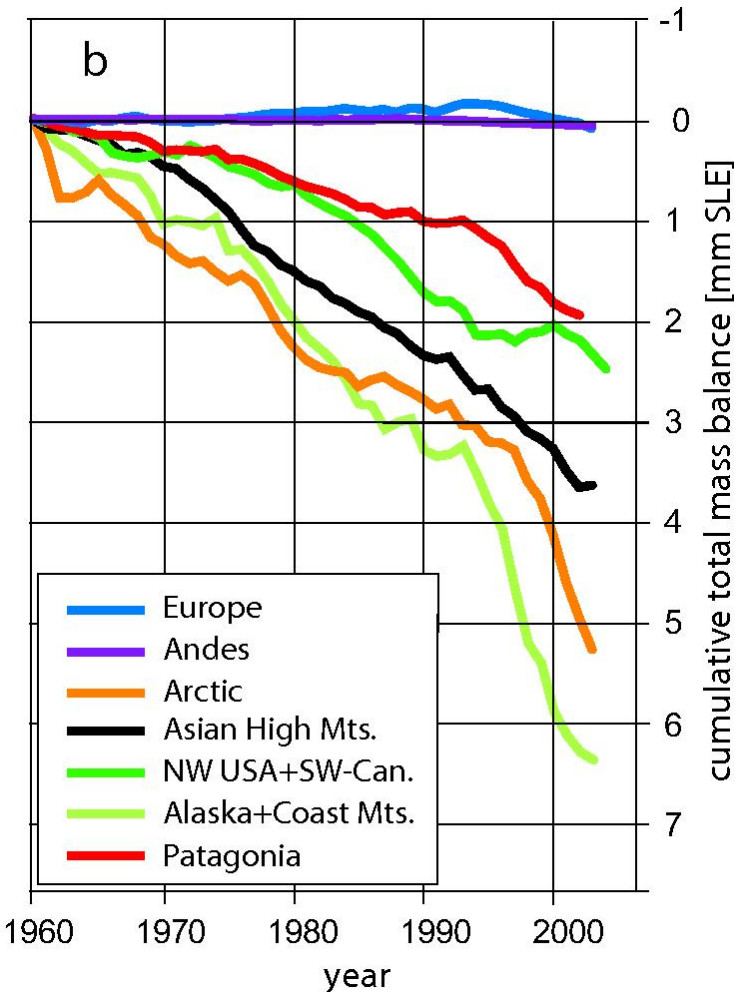
Spring snow cover shows 5% stepwise drop during 1980s

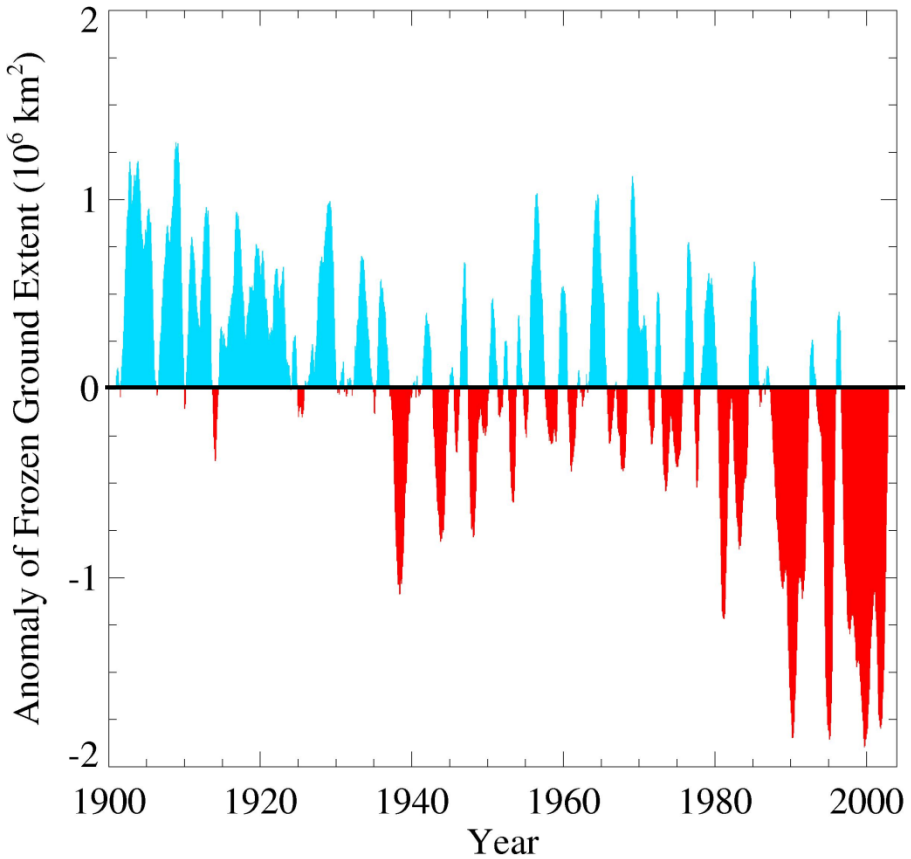




Arctic sea ice area decreased by 2.7% per decade (Summer: -7.4%/decade)

Glaciers and frozen ground are receding.





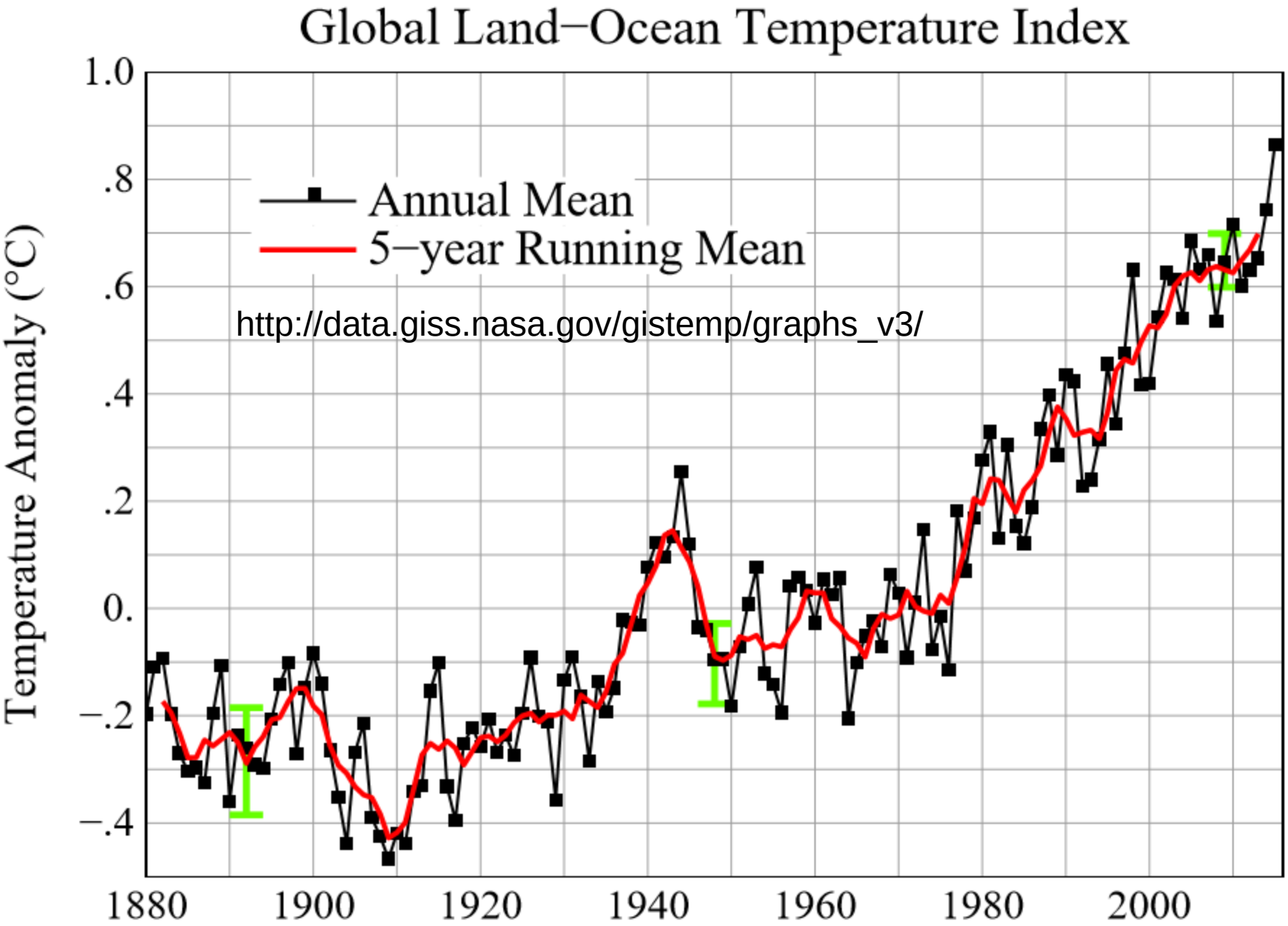
Increased Glacier retreat since the early 1990s

Area of seasonally frozen ground in NH has decreased by 7% from 1901 to 2002

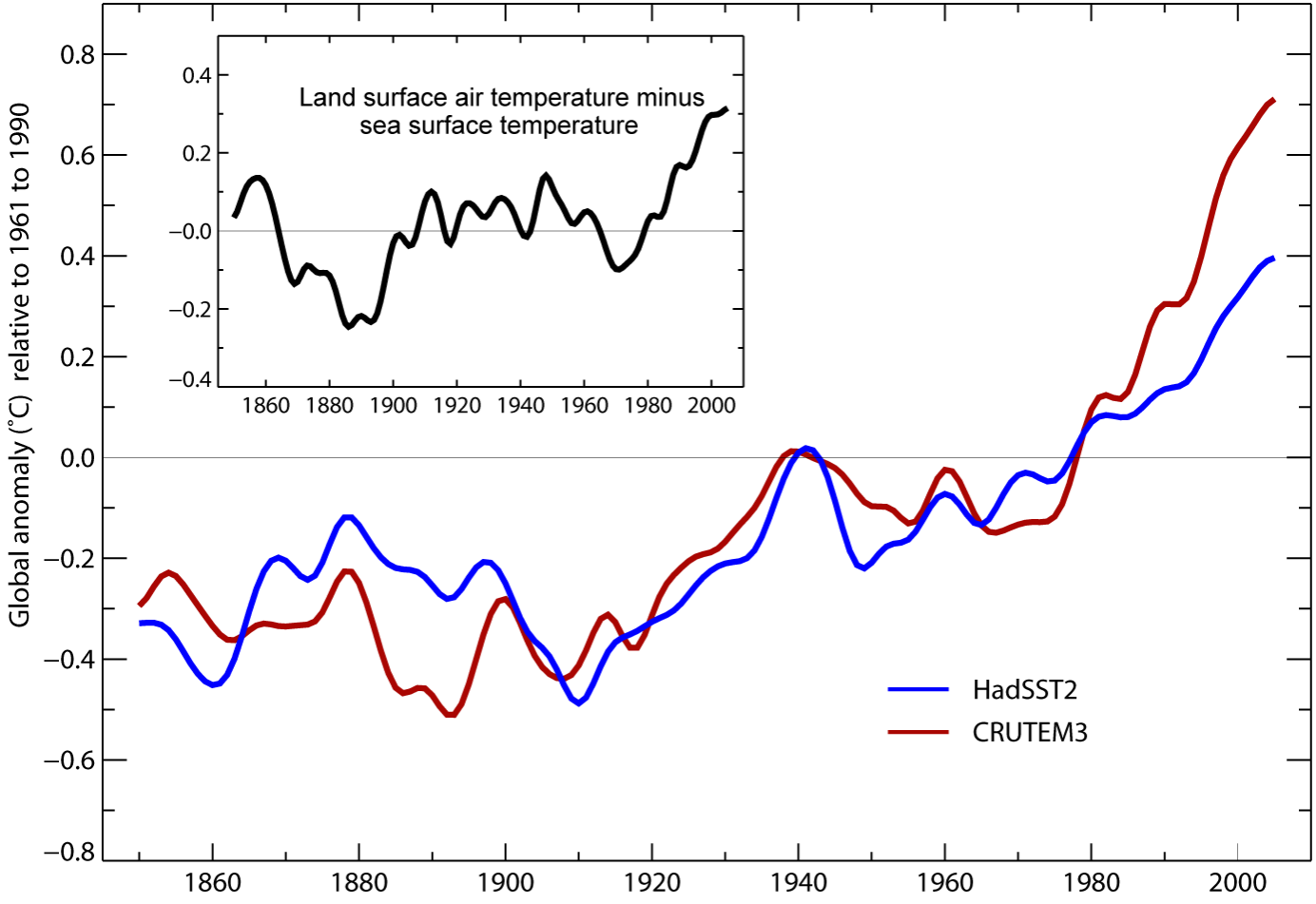
Further Changes in Artic and Frozen Ground

Annual average Arctic sea ice extent shrunk by 2.7 % per decade, decreases in summer 7.4 %

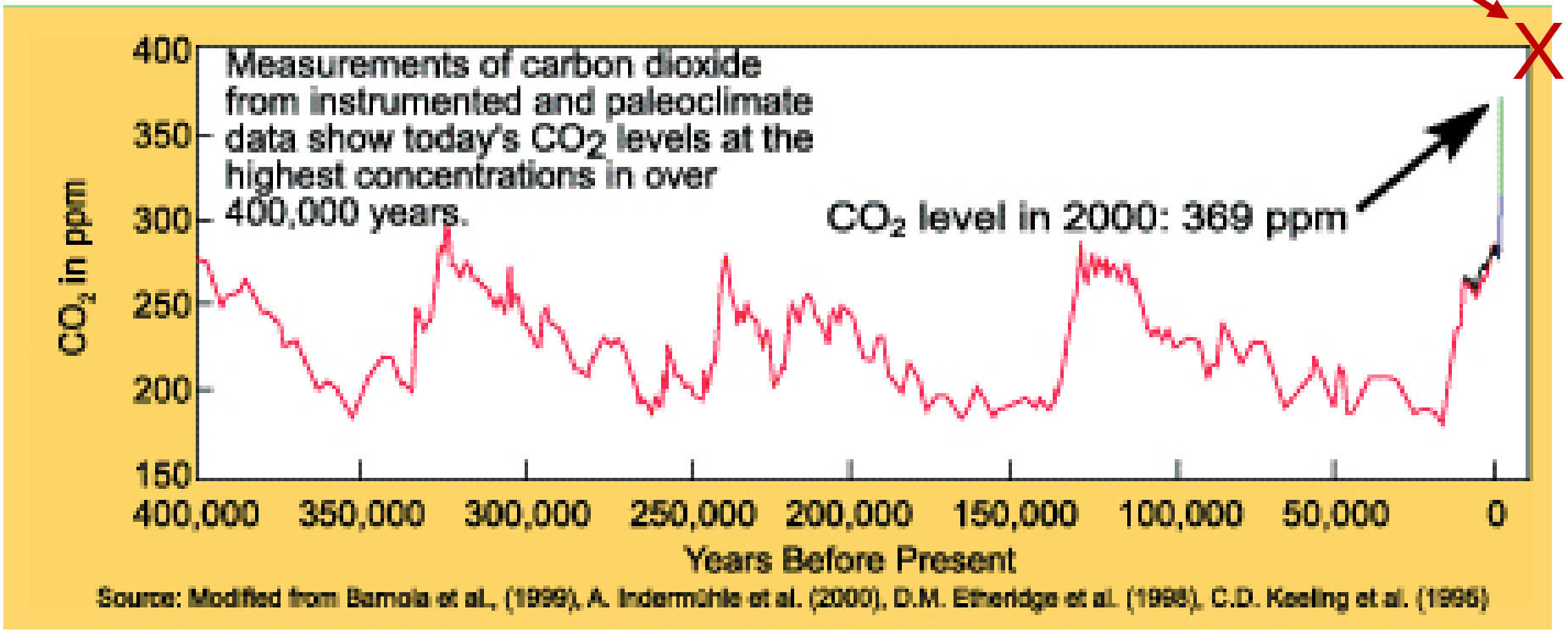
- Temperatures at the top of permafrost layer have generally increased since the 1980s by up to 3°C
- The maximum area covered by seasonally frozen ground has decreased by about 7% in Northern Hemisphere since 1900, in spring of up to 15%.


Global Land−Ocean Temperature Index
Annual Mean
5−year Running Mean
http://data.giss.nasa.gov/gistemp/graphs_v3/
Temperature Anomaly (°C)
1.0
.8
.6
.4
.2
0.
−.2
−.4
1880
1900
1920
1940
1960
1980
2000

Land surface temperatures are rising faster than sea surface tempertures.



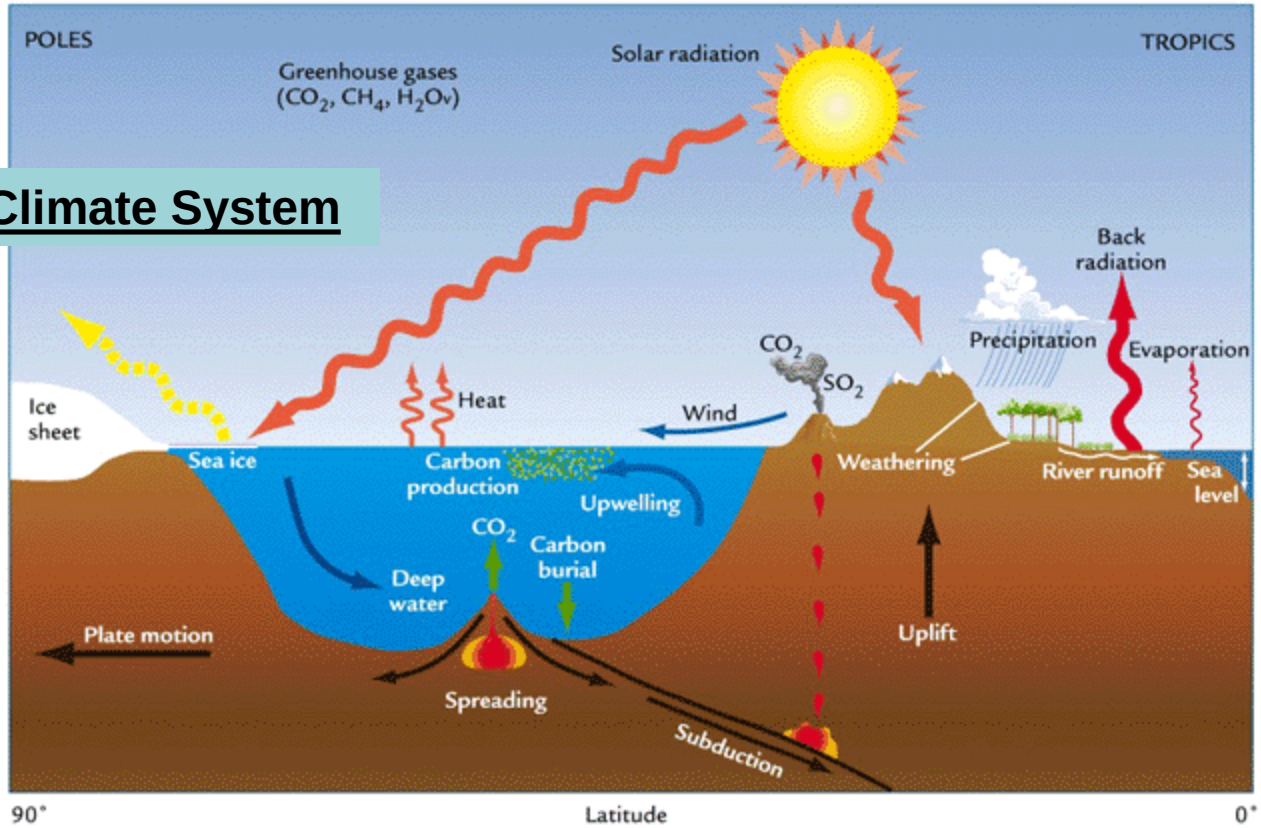
Today – over 400 ppm – highest concentration in millions of years.

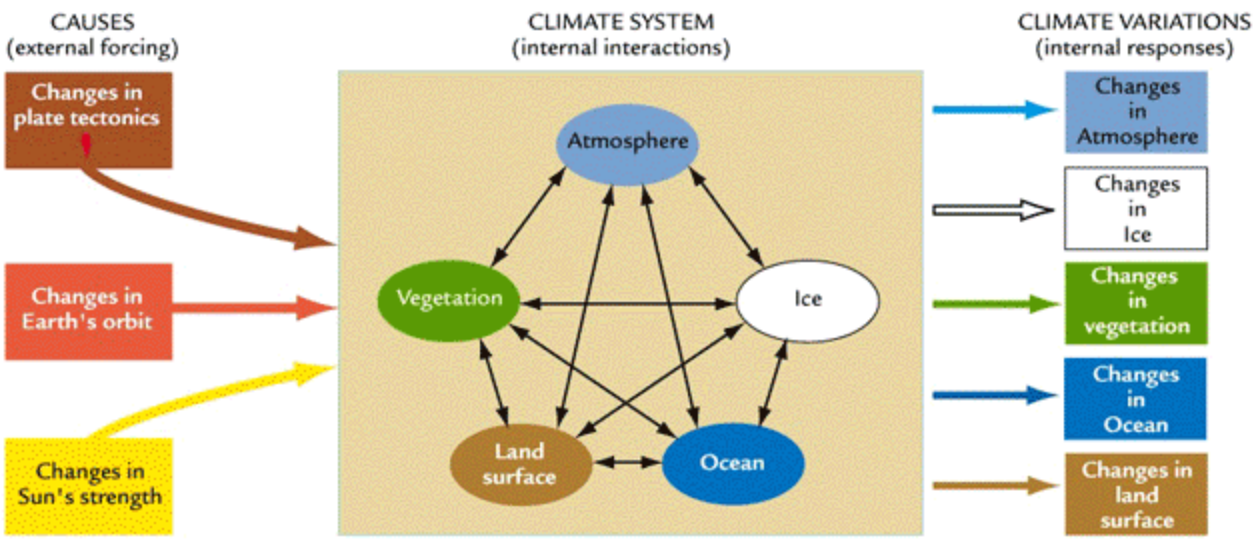


Conclusion:

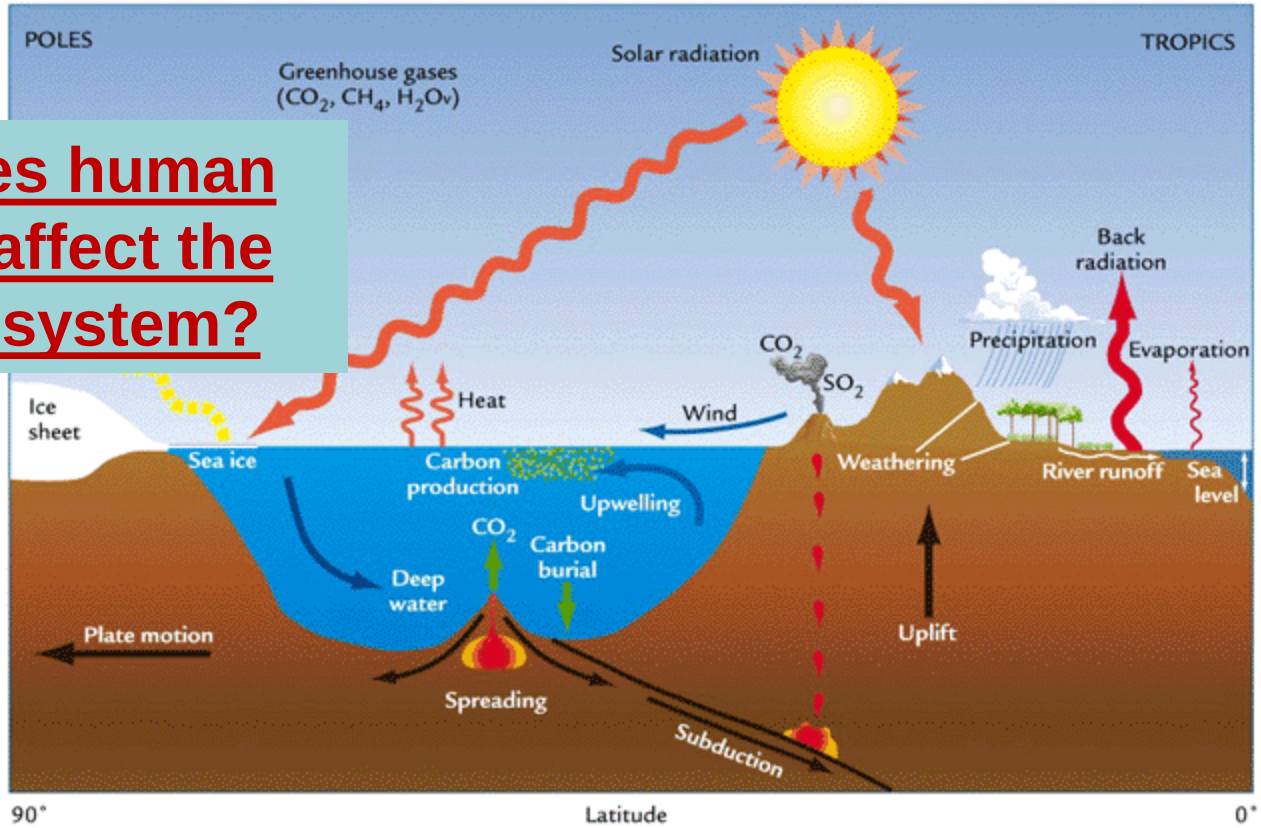
There is very strong evidence for significant global warming over the past 100 years or so and that the change is strongly correlated to increases in greenhouse gases over the same period.

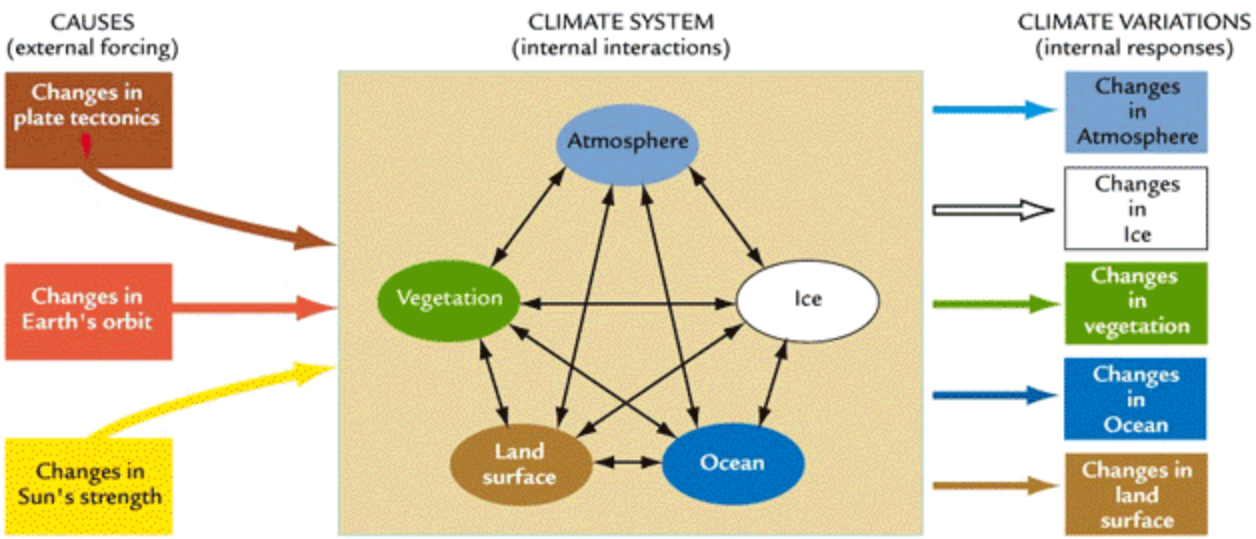
RECALL: Climate System





How does human activity affect the climate system?





There are compelling reasons to conclude that human activities are contributing to changes in climate.

How and by how much?

End Part 2