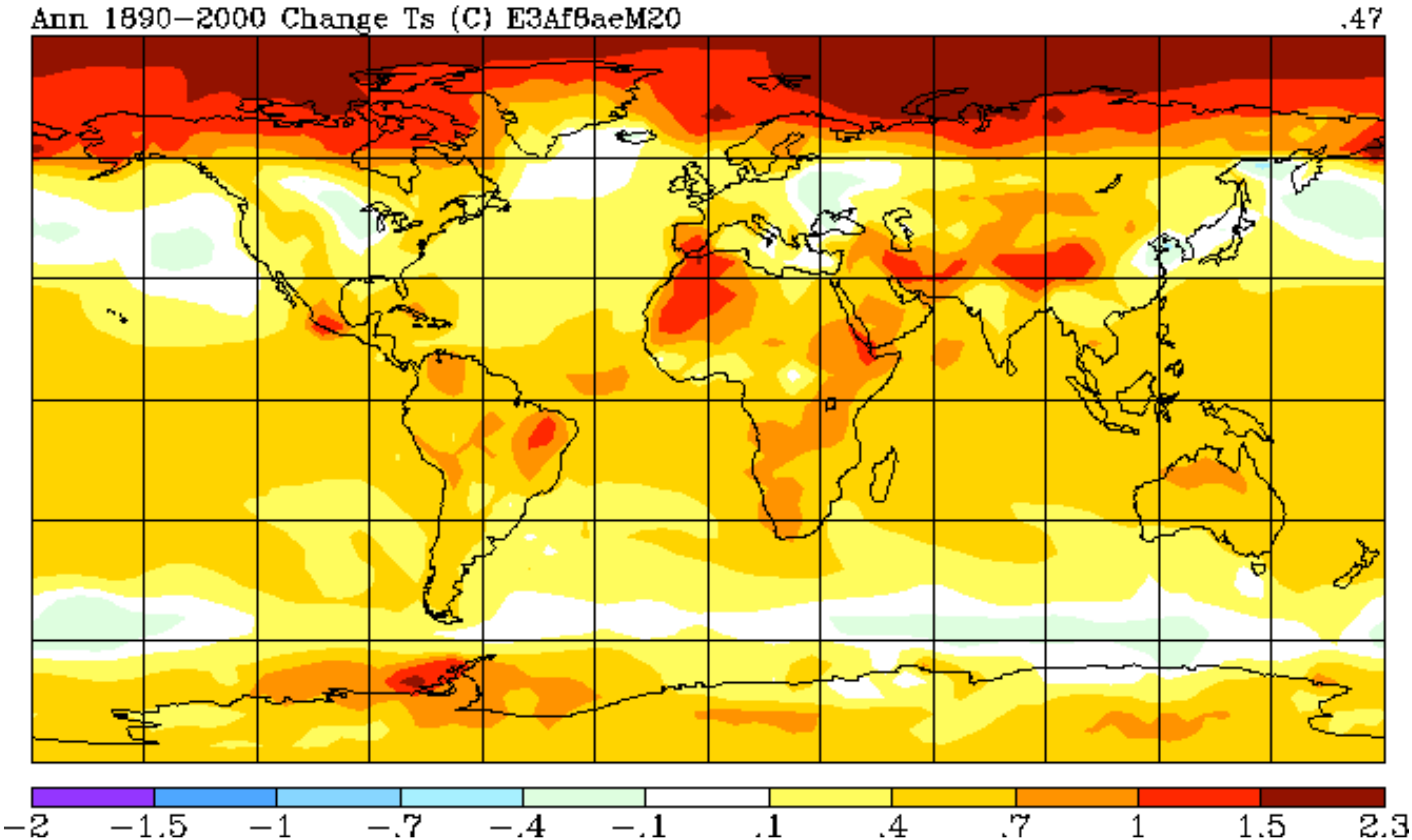
XIV. 20th Century warming



20th C temperature:

- thermometers...
- satellites...
- glacier lengths...
- bore holes...
- *all in the context of the last millennium*

clicker question

what is the difference between “global warming” and “greenhouse warming”?

a) nada, they are the same

b) “global warming” refers to an objective analysis of temperature change from thermometers and other measures of temperature

c) “greenhouse warming” refers to that part of global warming that can be attributed to the human enhancement of the greenhouse effect

d) <u>both b) and c)</u>

e) it depends on who you ask

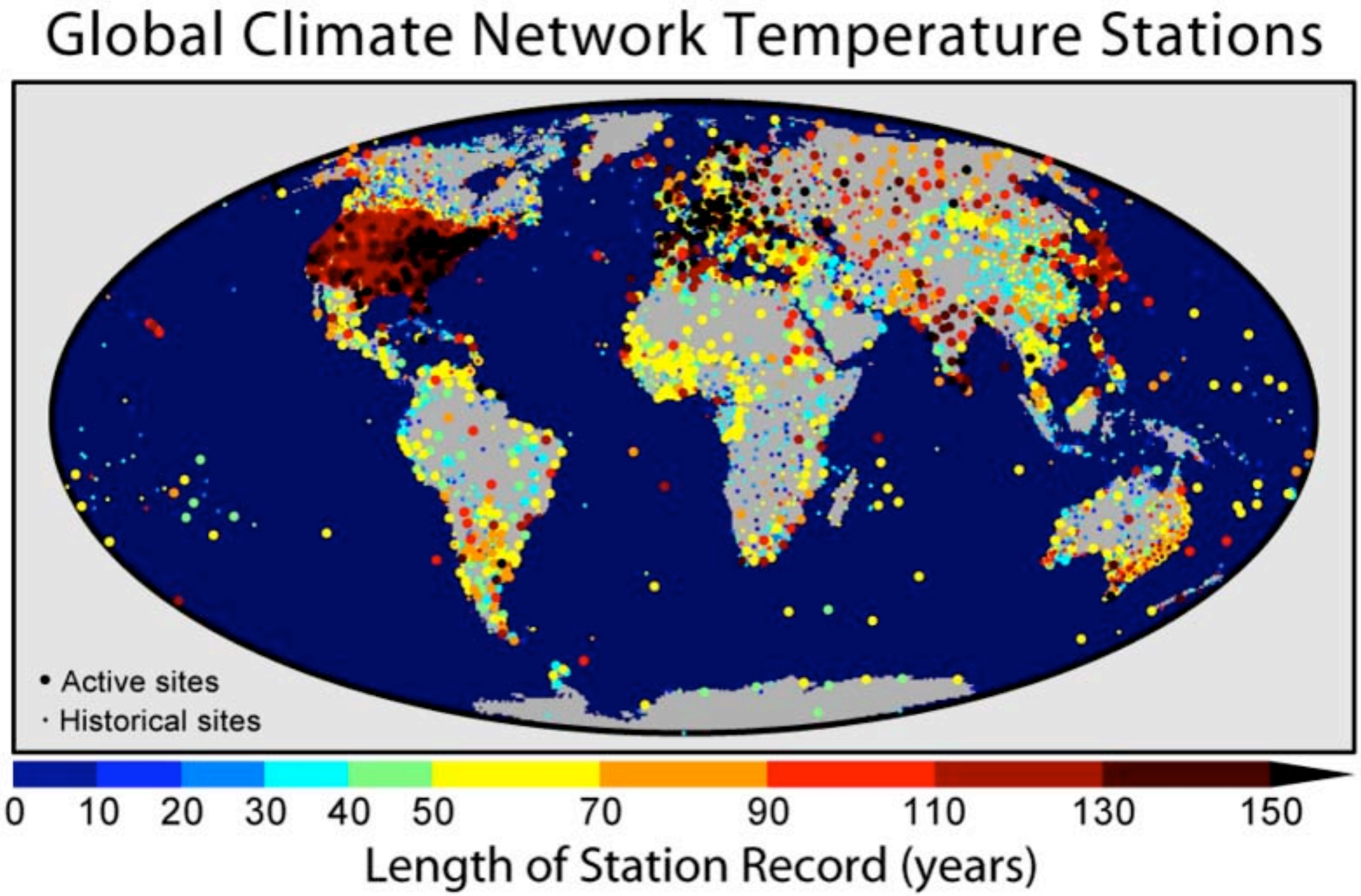
clicker question:

the difference between *climate* and *weather* is:

a) "*climate is what you expect and weather is what you get*"
b) climate describes a *long-term average* condition for a region, whereas weather describes relatively *short-term, local variations*
c) <u>both a) and b)</u>
d) nada, they are the same....
e) it depends on who you ask.....

climate

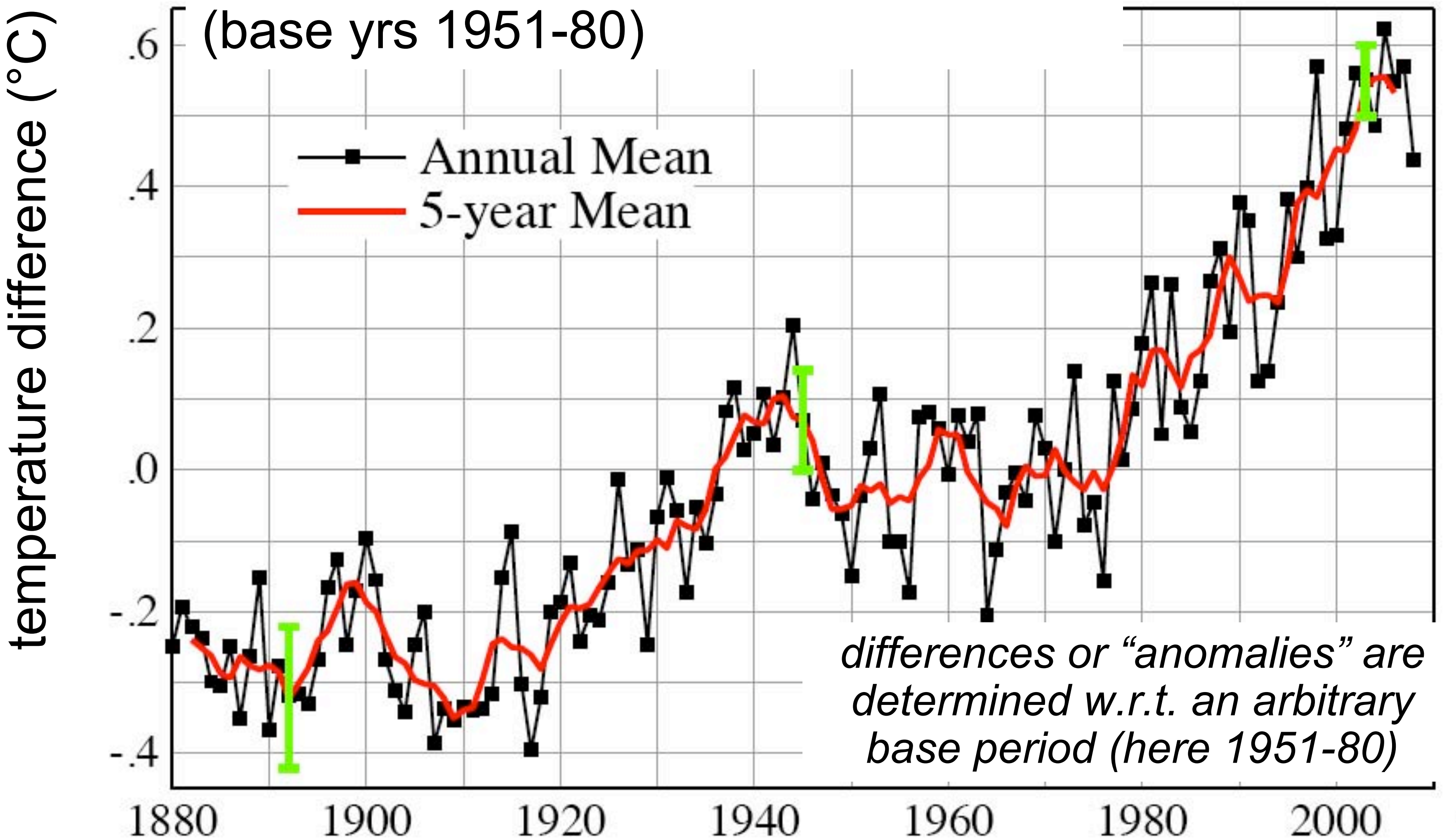
- climate is generally described as the long-term average condition (usually temperature and precipitation) for a region across which the condition is more or less the same
- we can also describe “climate” at larger scales by aggregating local or regional signals
- it is intrinsically more difficult to define “climate” when conditions are changing
- 30 year averages are often used to establish a baseline against which to evaluate change
- this permits us to define seasonal or annual differences from the long-term average or baseline (these are climate “anomalies”)



location and length of temperature (thermometer) records

thermometer record

NASA-GISS Global land-ocean index
(base yrs 1951-80)

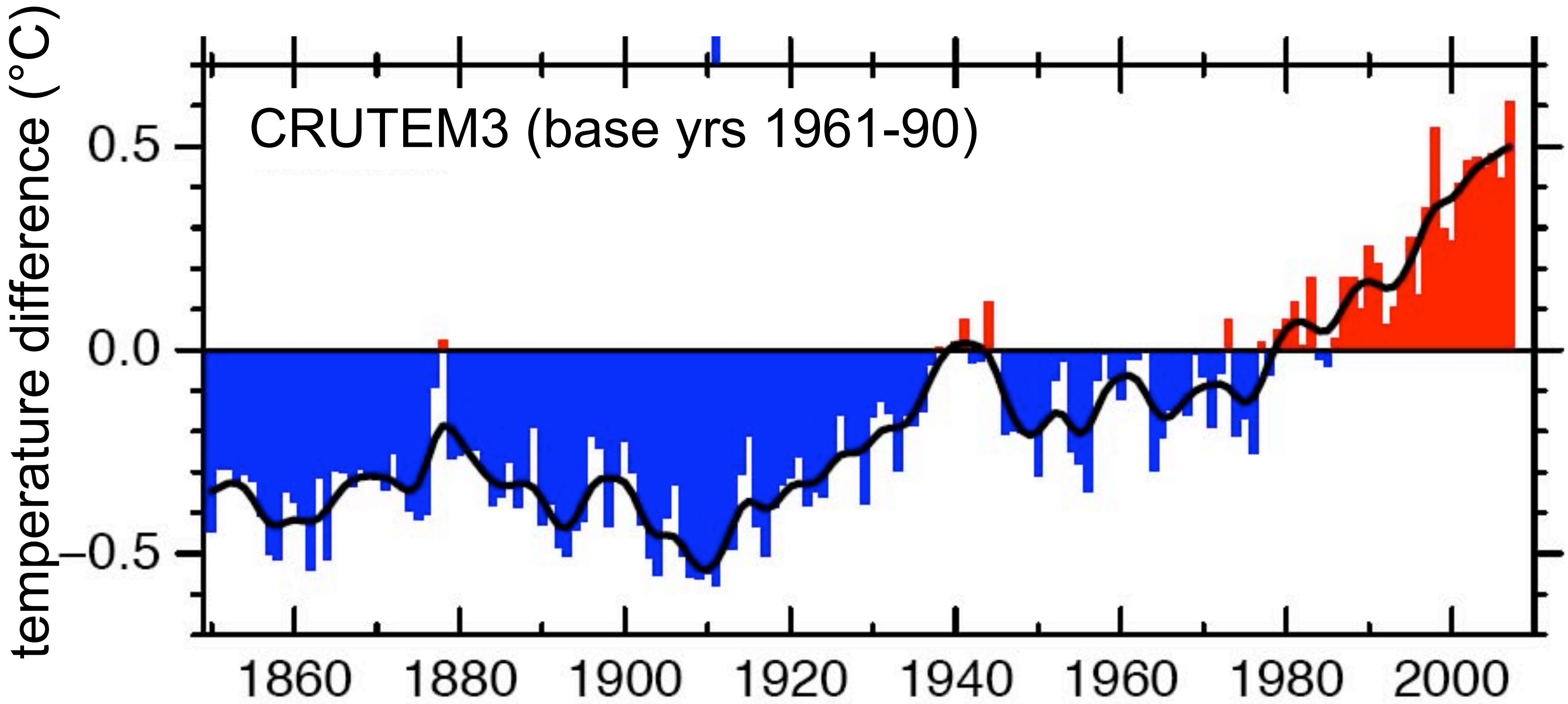


0.8 °C warming since inception, 10 of last 12 yrs warmest on record

what about other compilations?

http://data.giss.nasa.gov/gistemp/

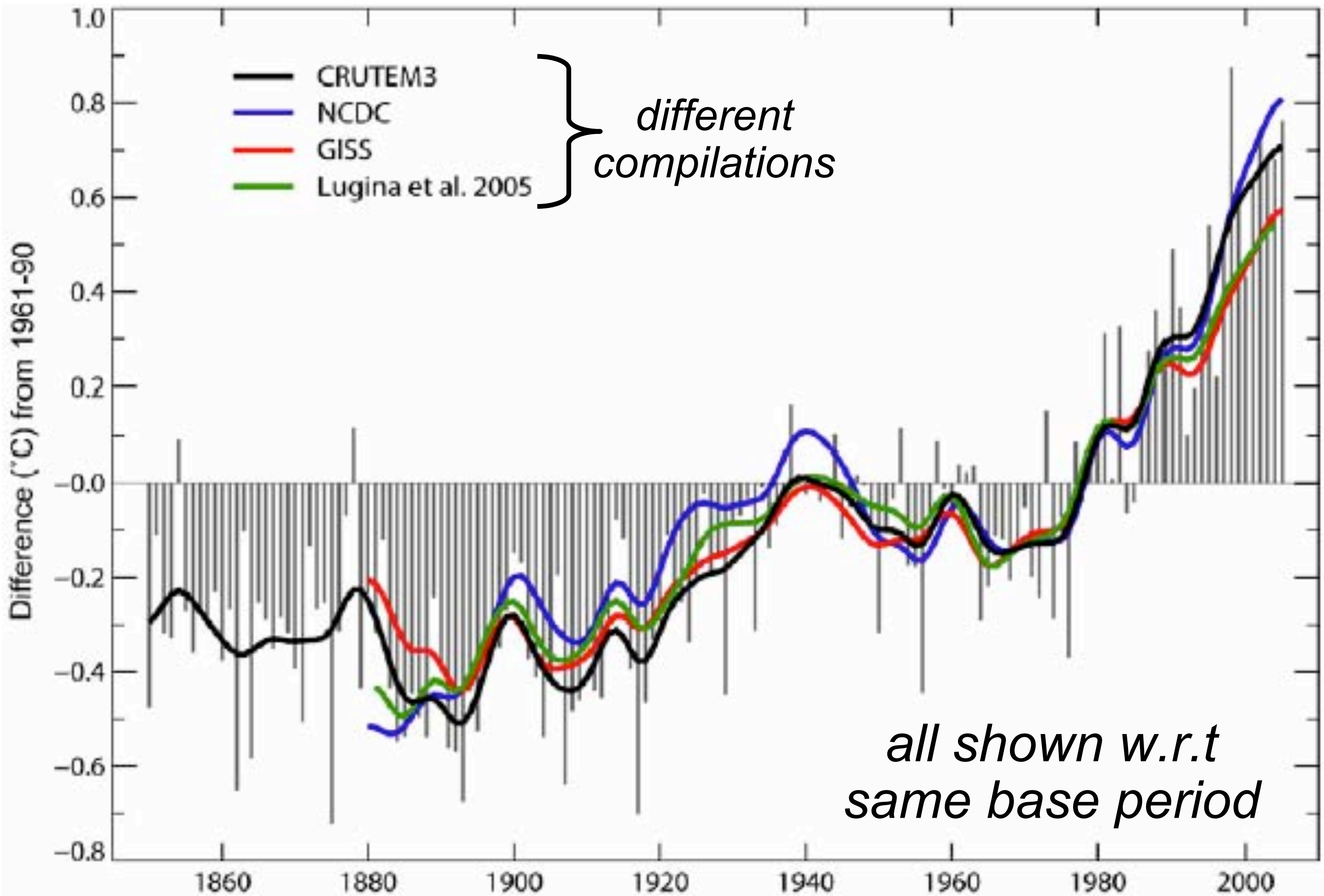
thermometer record



0.9 °C warming since inception, 11 of last 12 yrs warmest on record (as of 2007)

http://www.cru.uea.ac.uk/cru/data/temperature/

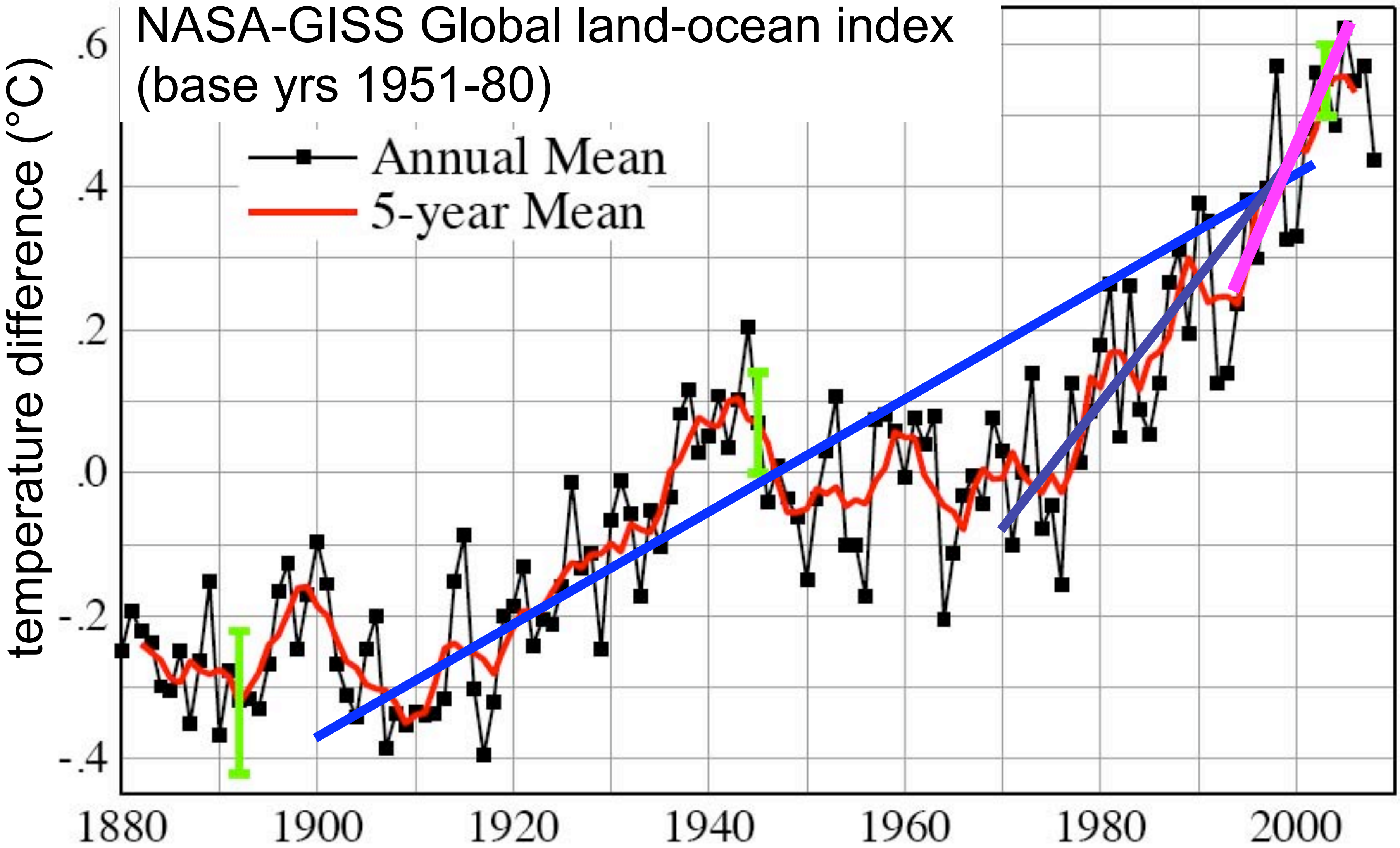
thermometer compilations compared



similar despite different methods of correction and averaging

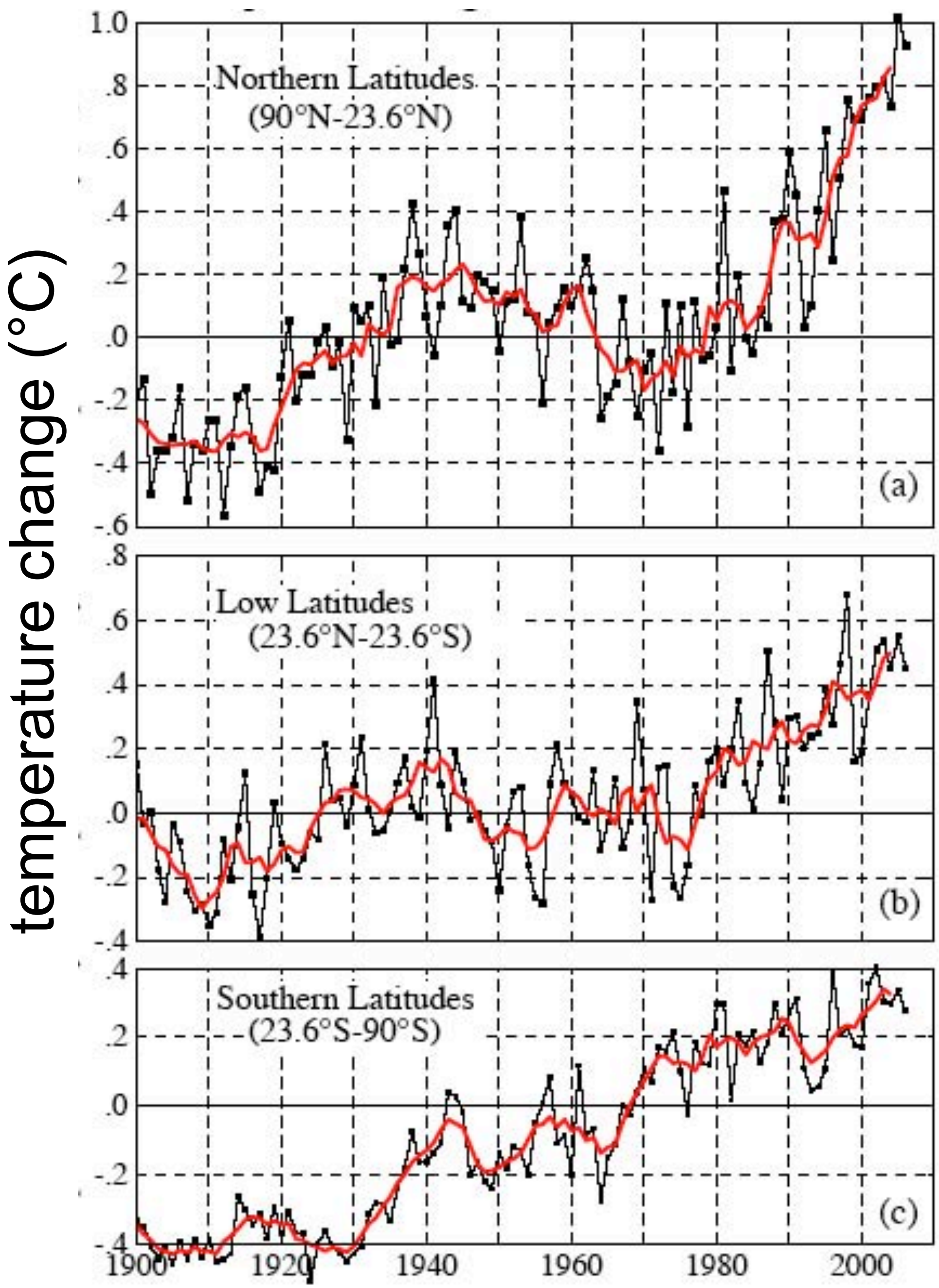
from IPCC AR4

thermometer record



the rate of warming is increasing

http://data.giss.nasa.gov/gistemp/



GISS temperature change for three latitude bands:

note high latitude amplification in NH

why might this be?

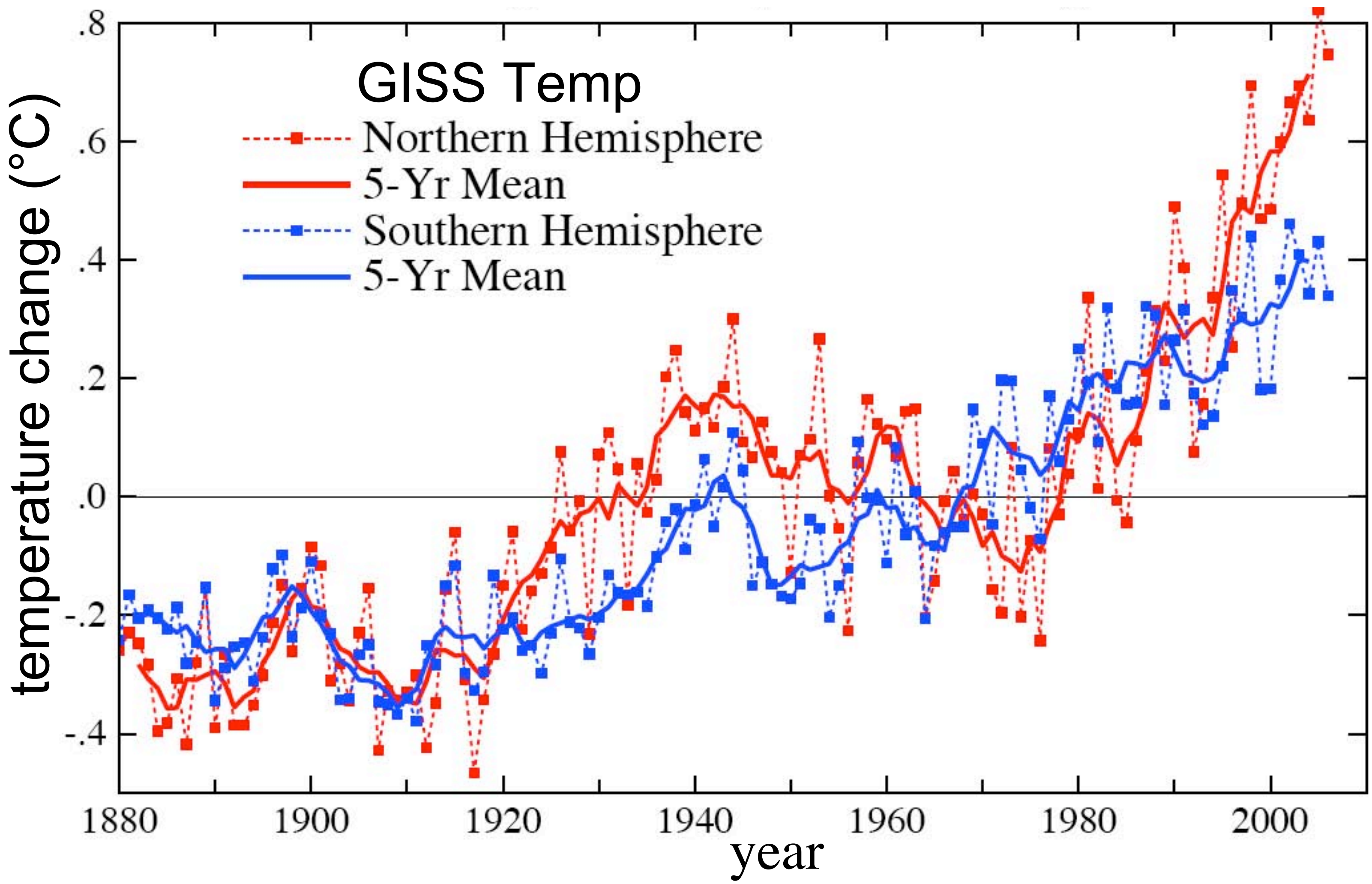
http://data.giss.nasa.gov/gistemp/

clicker question

Observations clearly indicate amplification of warming in the mid to high latitudes of the Northern Hemisphere which we might attribute to

a) more land in the NH
b) ice/snow - albedo feedback
c) sea ice - ocean heat flux feedback
d) <u>all of the above</u>
e) none of the above

hemispheric temperature change



more warming in the NH: more land (lower heat capacity) in the NH, data from Antarctica and Southern Ocean in SH more sparse

http://data.giss.nasa.gov/gistemp/

spatial patterns

view:

http://data.giss.nasa.gov/gistemp/animations/

note:

progressive warming and polar amplification

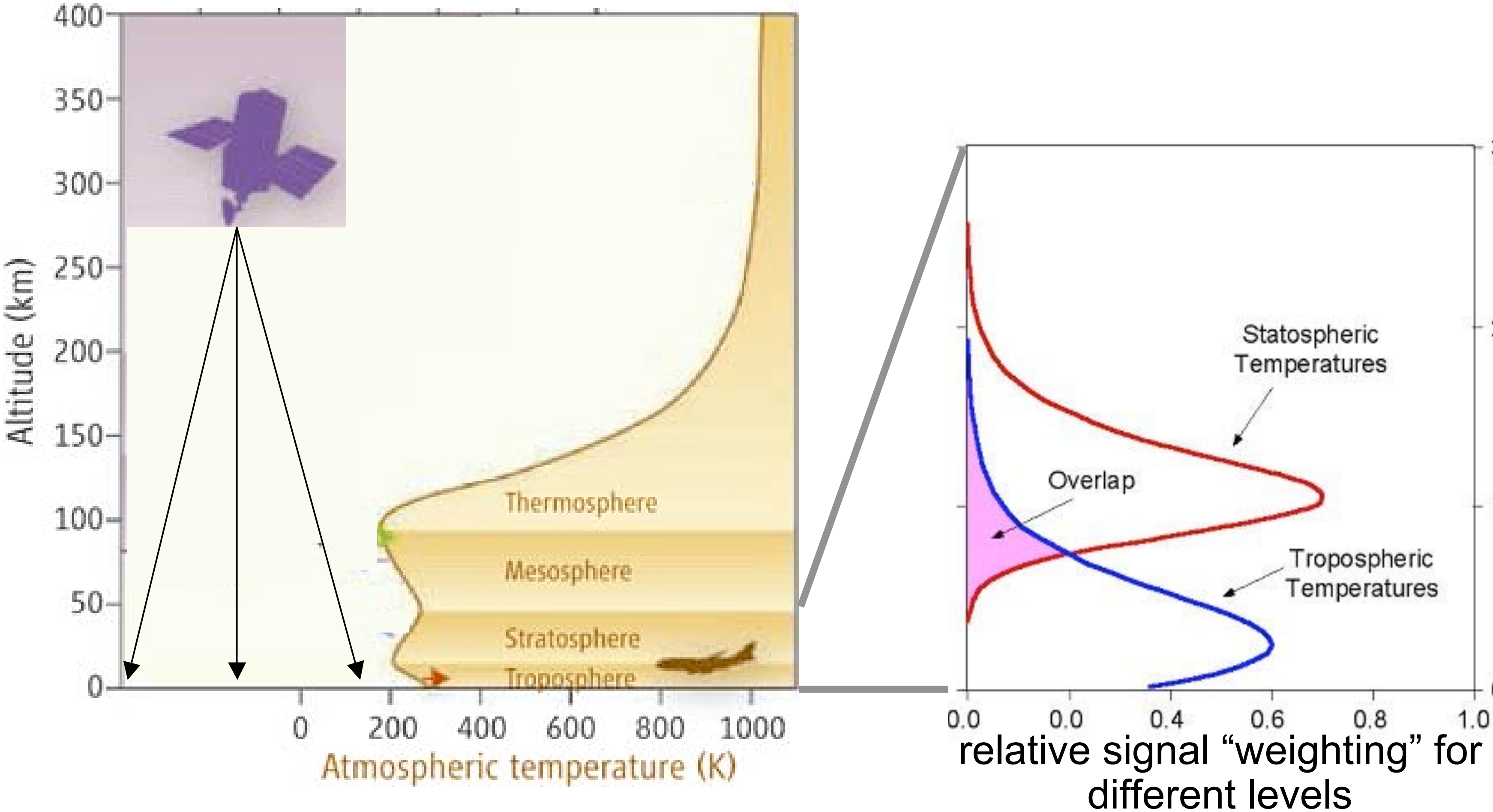
thermometer records

- fewer measurements in earlier years
- require spatial interpolation
- require corrections for changes in station location, urban heat island effects etc.
- *nevertheless*, different compilations using different methods of correction, averaging, and interpolation give very similar results
- largest temperature changes are at high latitude (and *not* in urban areas...)
- the thermometer record is clearly one of overall global warming (>0.8 °C since 1880)
- recent years and decades are warmest of record, and the *rate of warming* is increasing

temperature change from satellites

- satellites sense emissions of microwave energy from O_2 in the atmosphere
- O_2 absorbs and emits radiation in the microwave part of spectrum (so O_2 is *not* a greenhouse gas)
- microwave emissions increase with environmental temperature
- satellites “see” the whole atmosphere, so signals from L, M, & U troposphere and stratosphere must be separated

temperature change from satellites



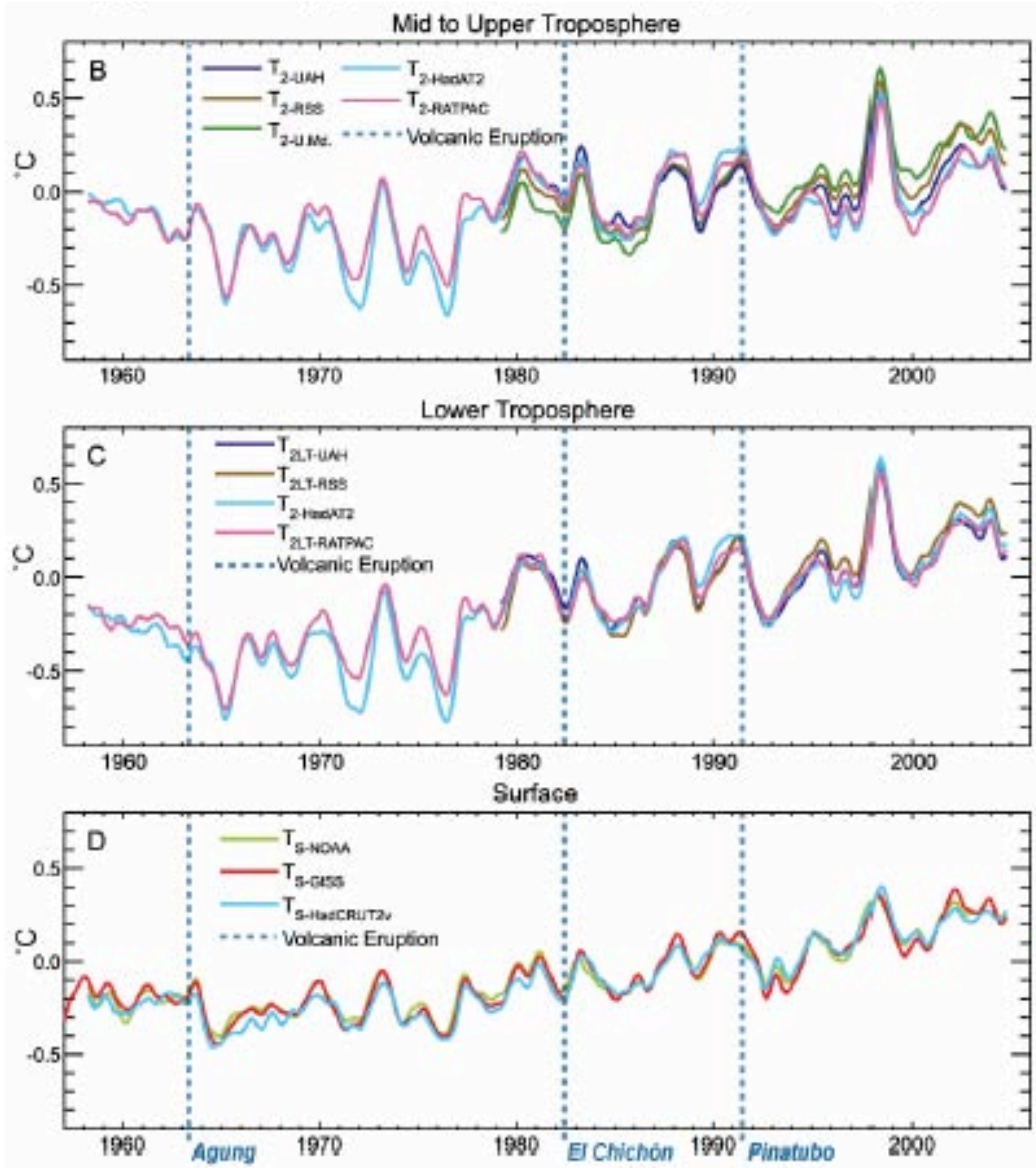
geometric and statistical trickery needed to isolate temperature signals for different levels in troposphere and stratosphere

temperature change from satellites

mid-upper troposphere

lower troposphere

surface



from satellites and balloons

from surface thermometers

troposphere and surface temperature records are (now) similar

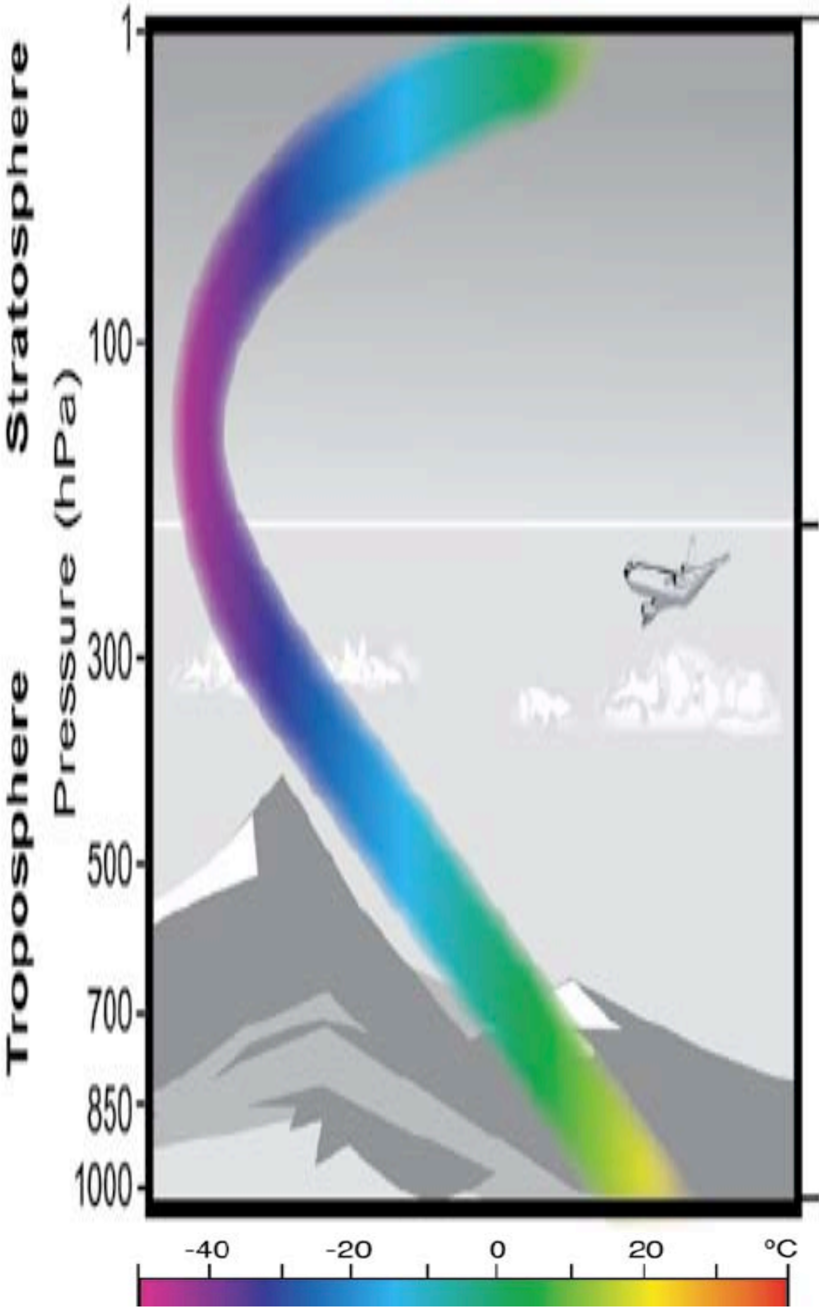
from Karl et al., USCCSP 2006

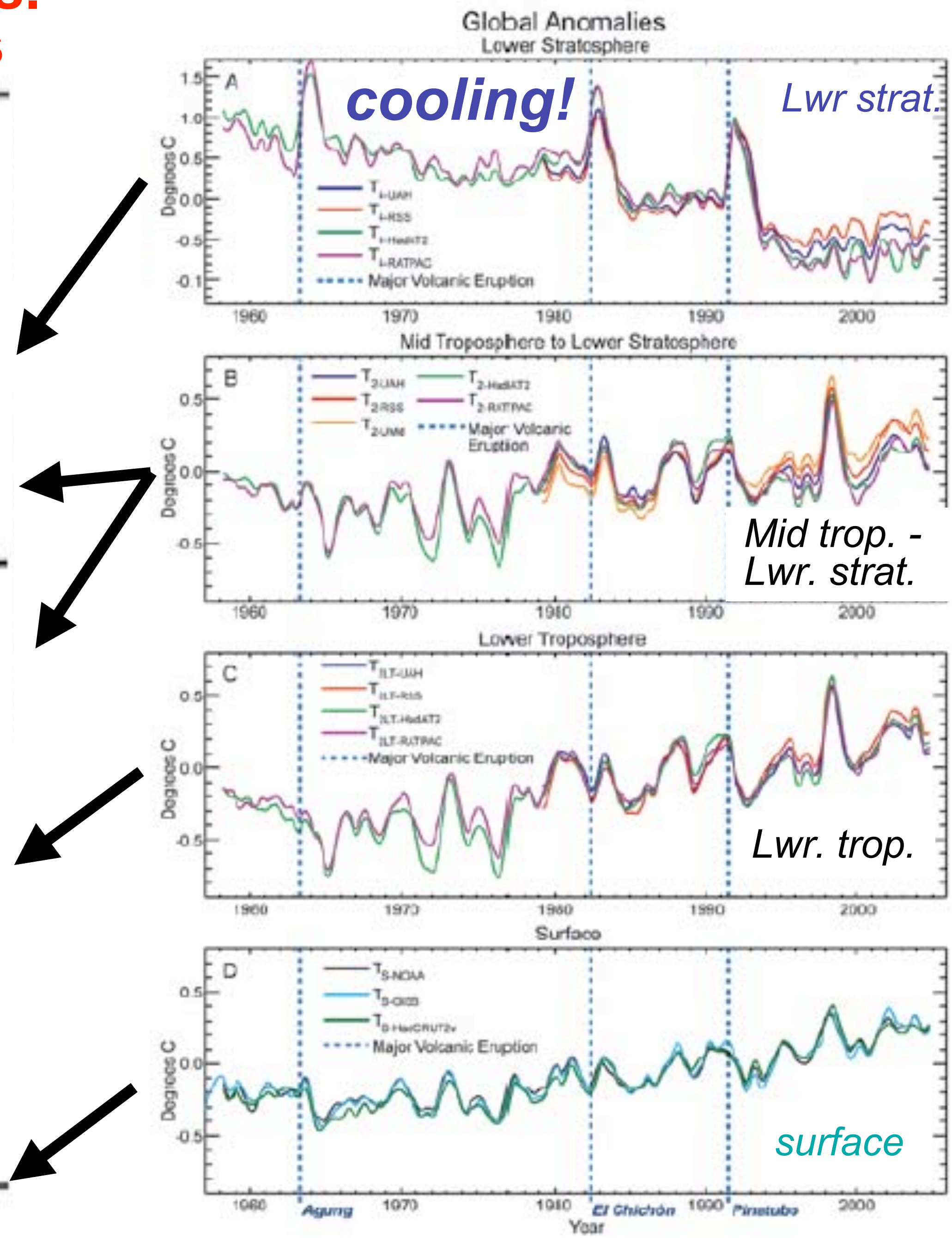
clicker question

Absorption of earth light (OLR) by GHGs reaches a maximum in the upper troposphere. In the stratosphere, this represents

a) a loss of energy, leading to warming
b) <u>a loss of energy, leading to cooling</u>
c) an increase in energy, leading to warming
d) an increase in energy, leading to cooling
e) it doesn’t matter, the stratosphere is heated by the Sun (via UV absorbing ozone)

satellite and balloon vs. surface observations

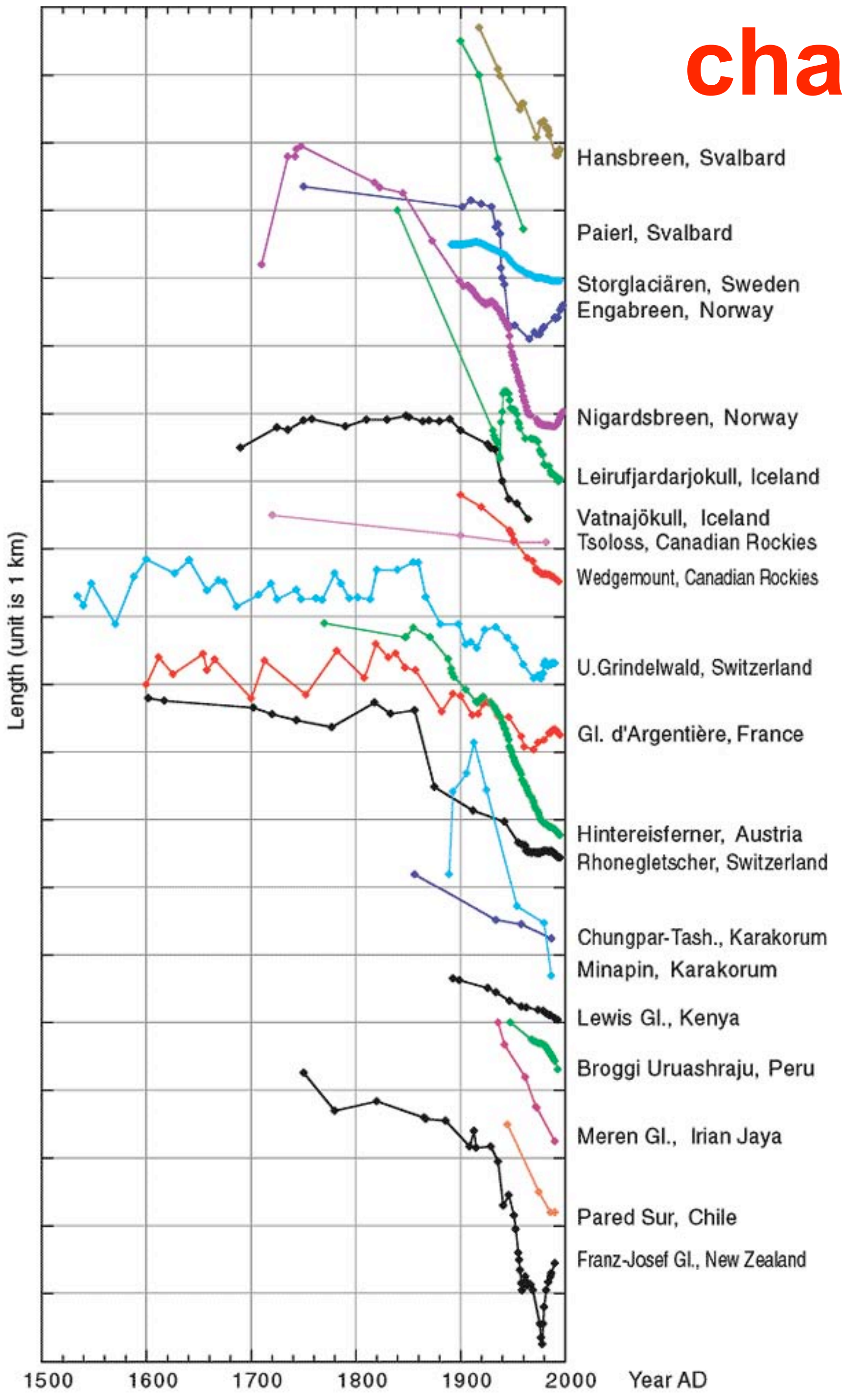




temperature change from satellites

- early reports of tropospheric temperatures determined from satellites *did not agree* with surface thermometer measurements
- the difference was due to improper correction of the satellite record for decay of satellite orbit, associated drift in observing times, and removal of the stratosphere signal
- following revised correction, there is *substantial agreement* between the records from surface thermometers and satellite sensors

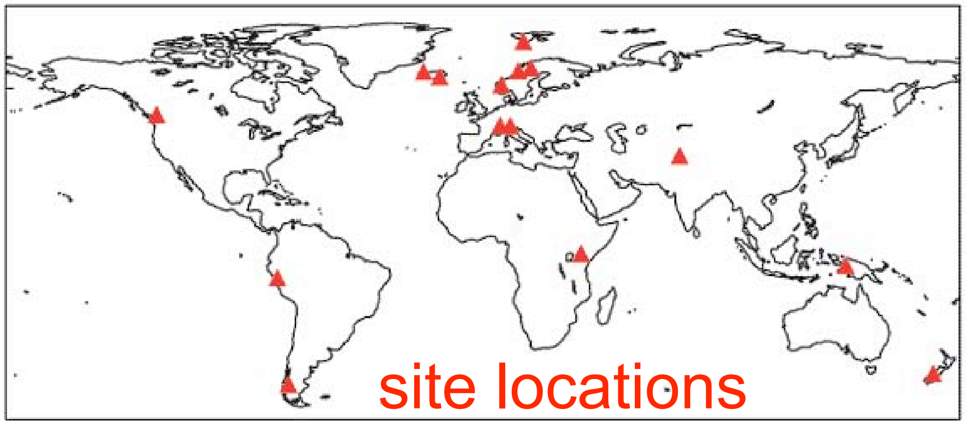
changing glacier length



glaciers around the world are getting shorter

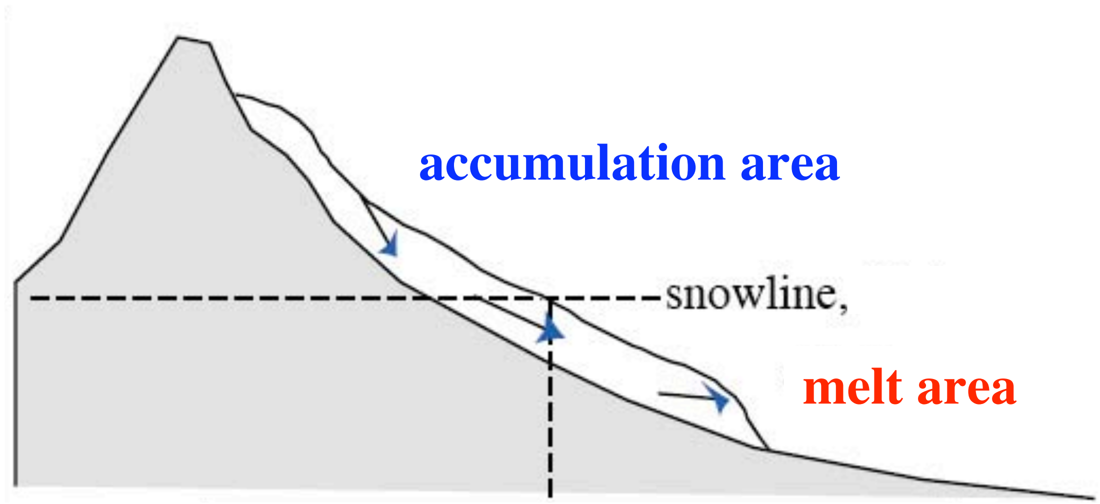
glaciers around the world are losing mass

mass loss is primarily a response to greater melting



from IPCC 2001

what controls glacier length



1) a glacier is a mass of ice that is thick enough to flow under its own weight

2) glacier growth (advance) and wasting (retreat) controlled by simple mass balance of annual snow accumulation and ice melting

melting is controlled by radiation and temperature

3) i.e. temperature melting dominates record of glacier retreat and glacier length

rule of thumb: a 25% increase in precip. required to offset melting from 1 °C temperature increase

glacier retreat

Grinnell Glacier,
Glacier National Park

Photo by Elrod, GNP Archives, ca 1910

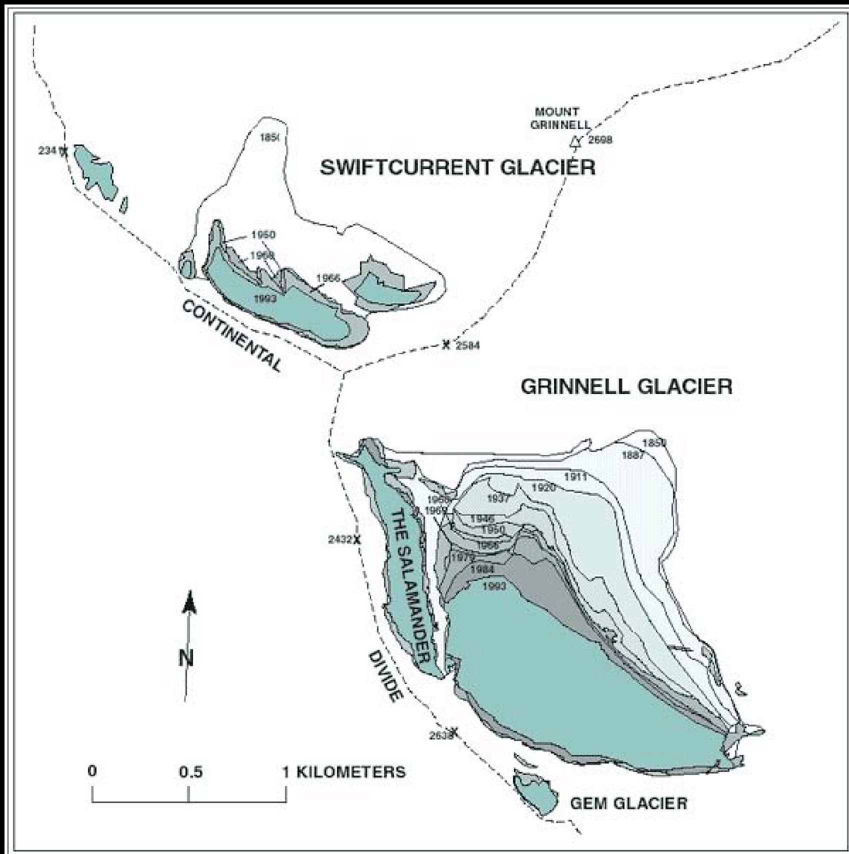
1910

Photo by Hileman, GNP Archives , 1931

1931

Photo by Fagre, 1997

1997



from USGS

glacier retreat

South Cascade Glacier, WA

1928

2000

from USGS

glacier retreat

Qori Kalis Glacier (Quelcaya Ice Cap), Peru

from L. Thompson, Byrd Polar Inst.

glacier retreat

Pasterze Glacier, Austria

from Gesellschaft fur Okologische Forschung

glacier retreat

Orubare Glacier, Uganda

from V. Sella and Patrick Glogg

glacier retreat

Imja Glacier, Khumbu Himal

from Erwin Schneider & Alton Byers (courtesy the Mountain Inst.)

glacier retreat

Blomstrandbreen, Svalbard

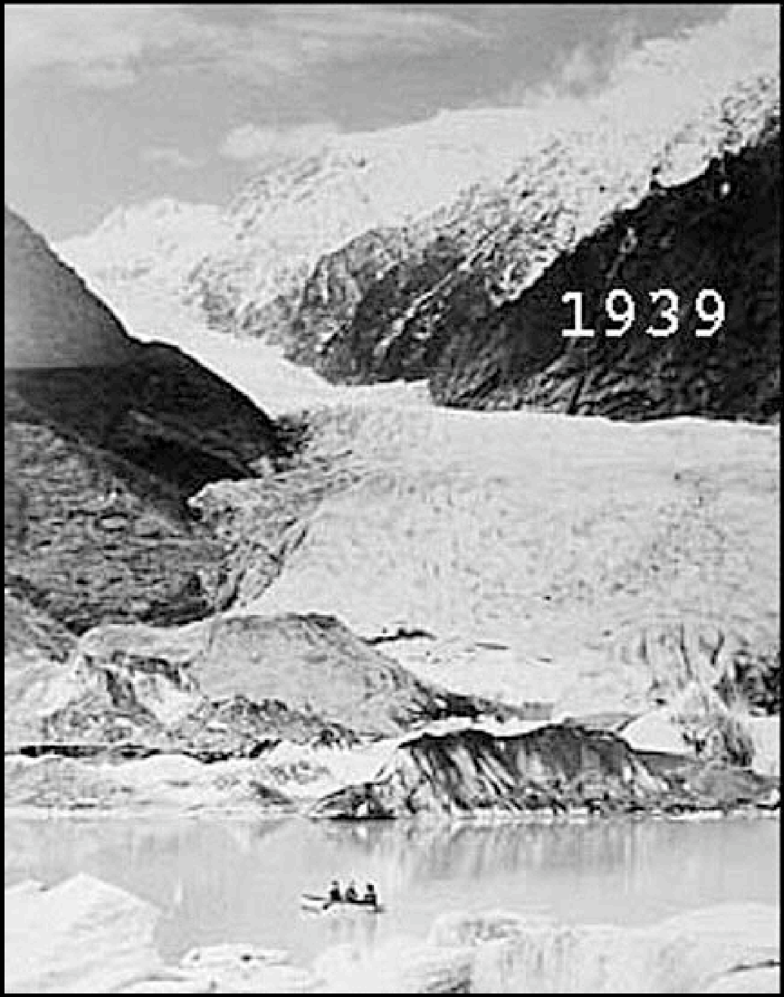
1922

2002

from Norsk Polar Institutt

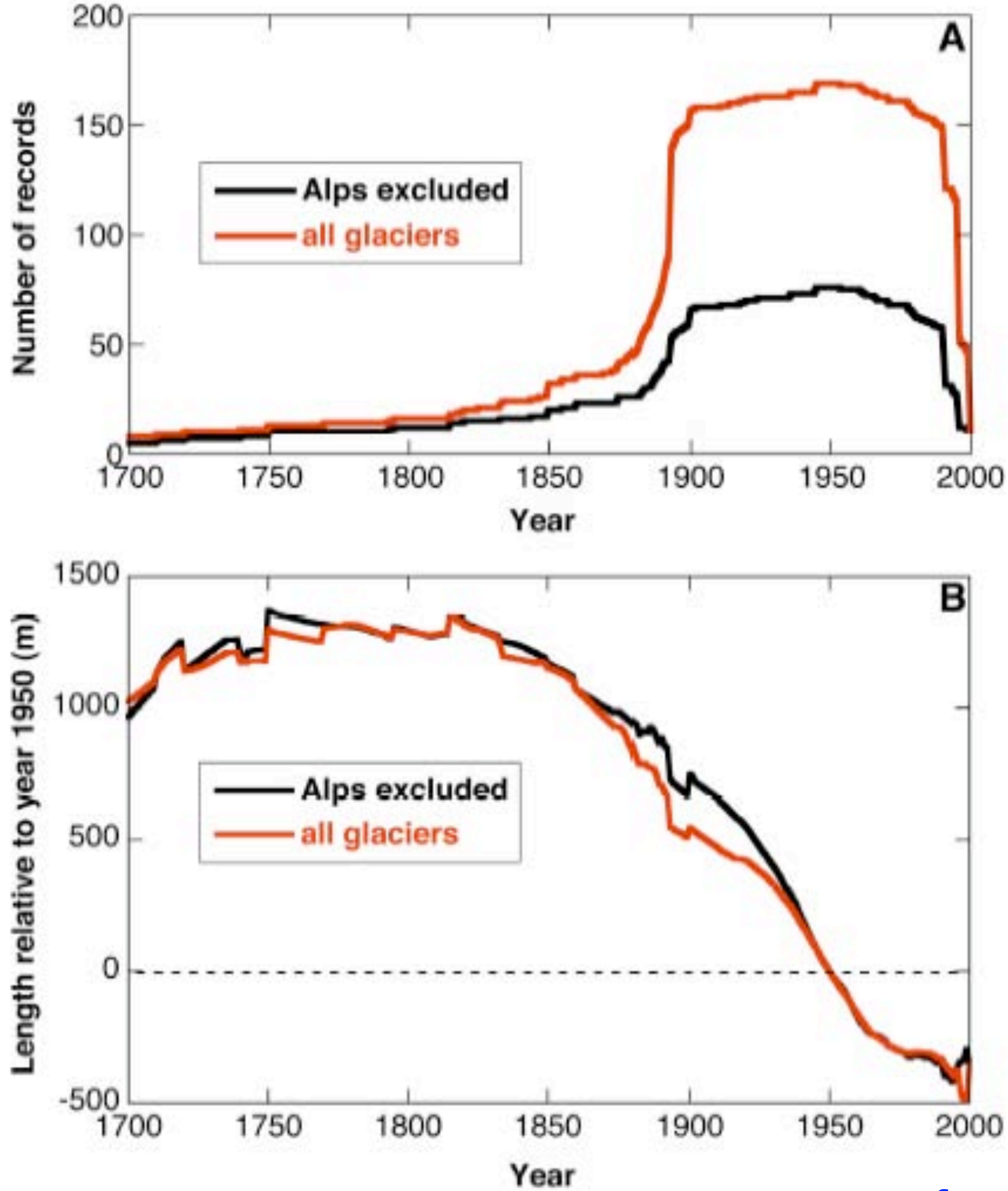
glacier retreat

Franz Josef Glacier, NZ



John Wattie, NZphoto

change in length of 169 glaciers



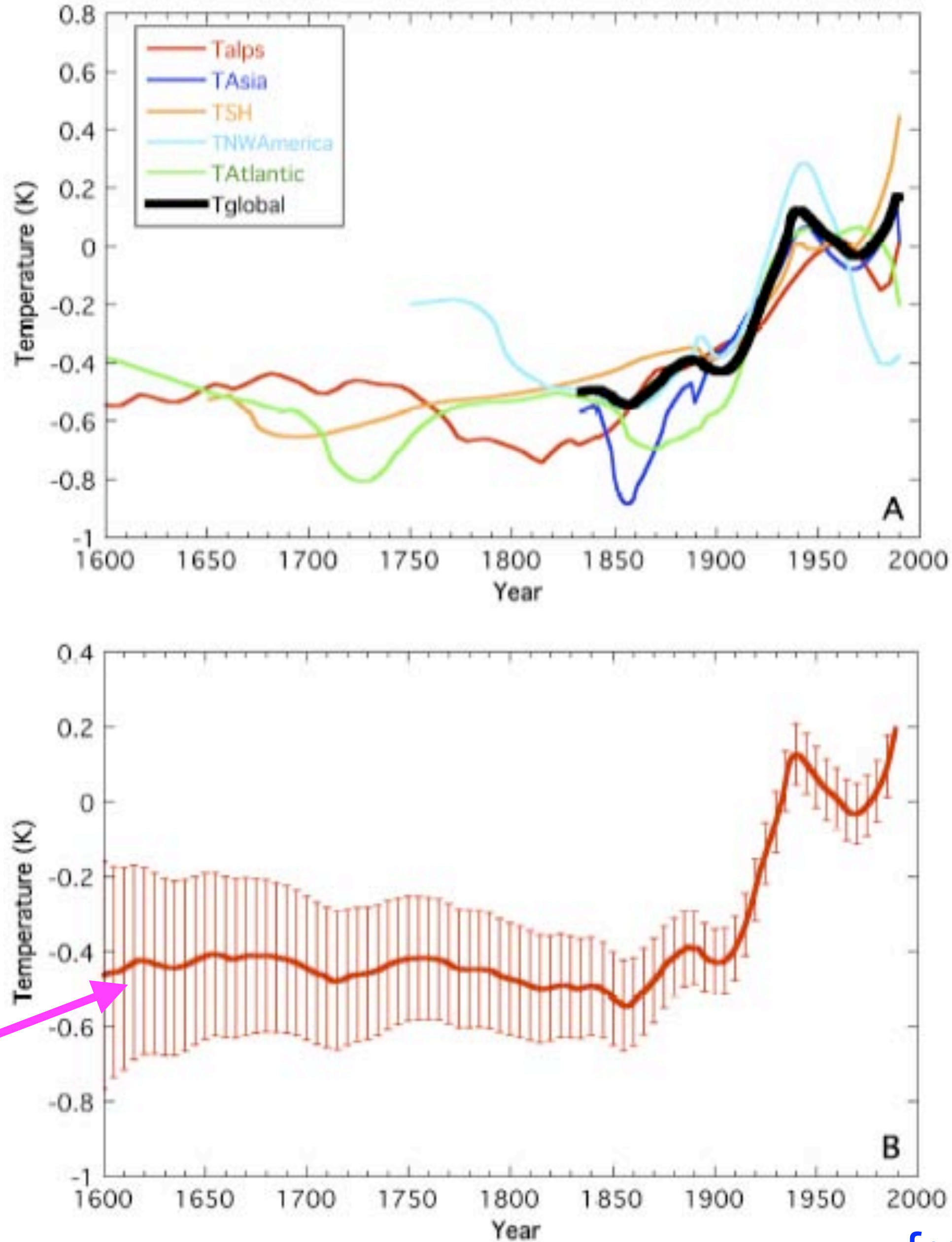
observations are globally distributed, but there are many more since 1900 and in the Alps

average of all records

from Oerlemans 2005

temperature change from 169 glaciers

from modeled temperature sensitivity of glacier length



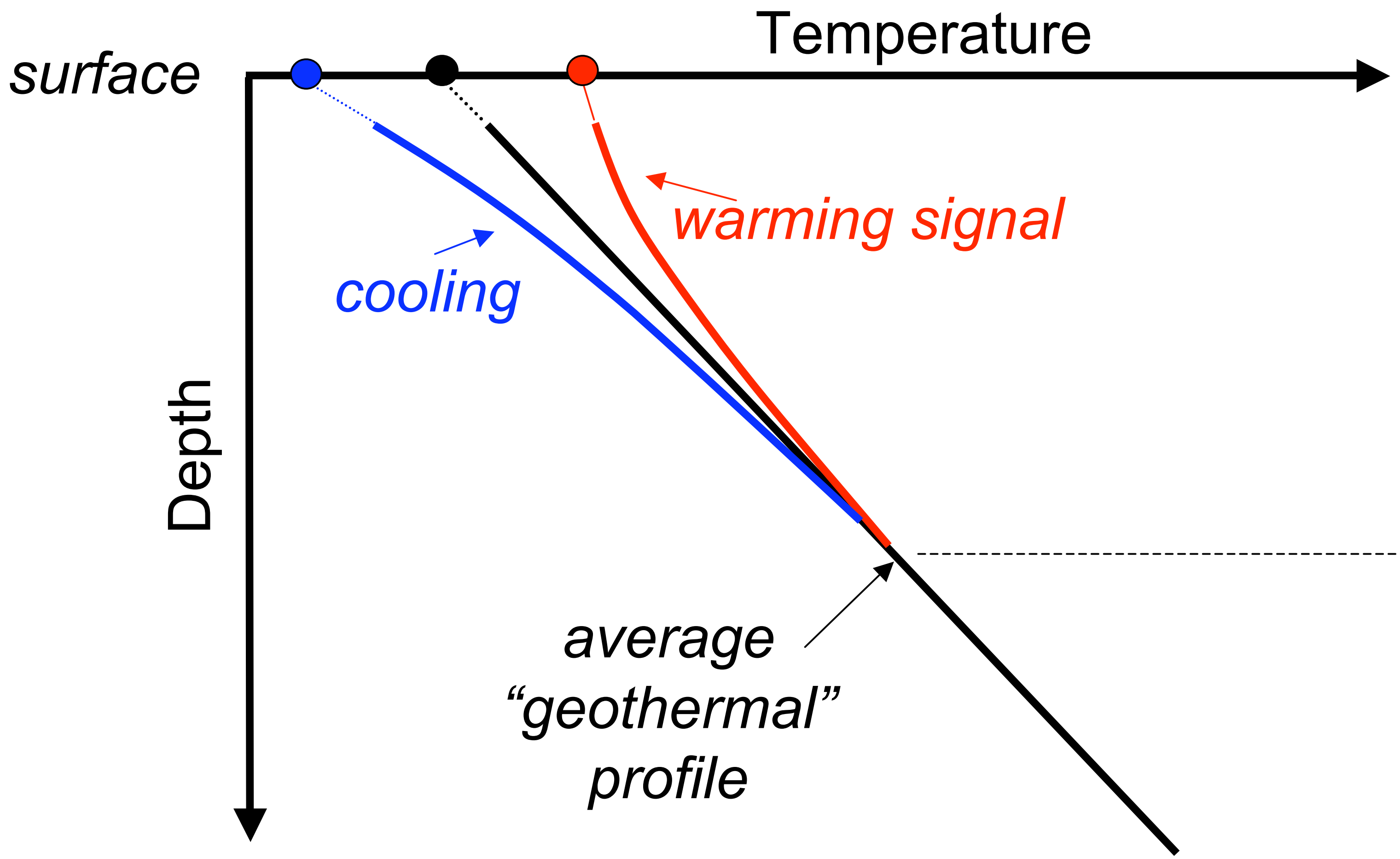
regional and global average estimates

global average w/ estimated error

20th C warming unique in last 400 yr

from Oerlemans 2005

temperature change from boreholes

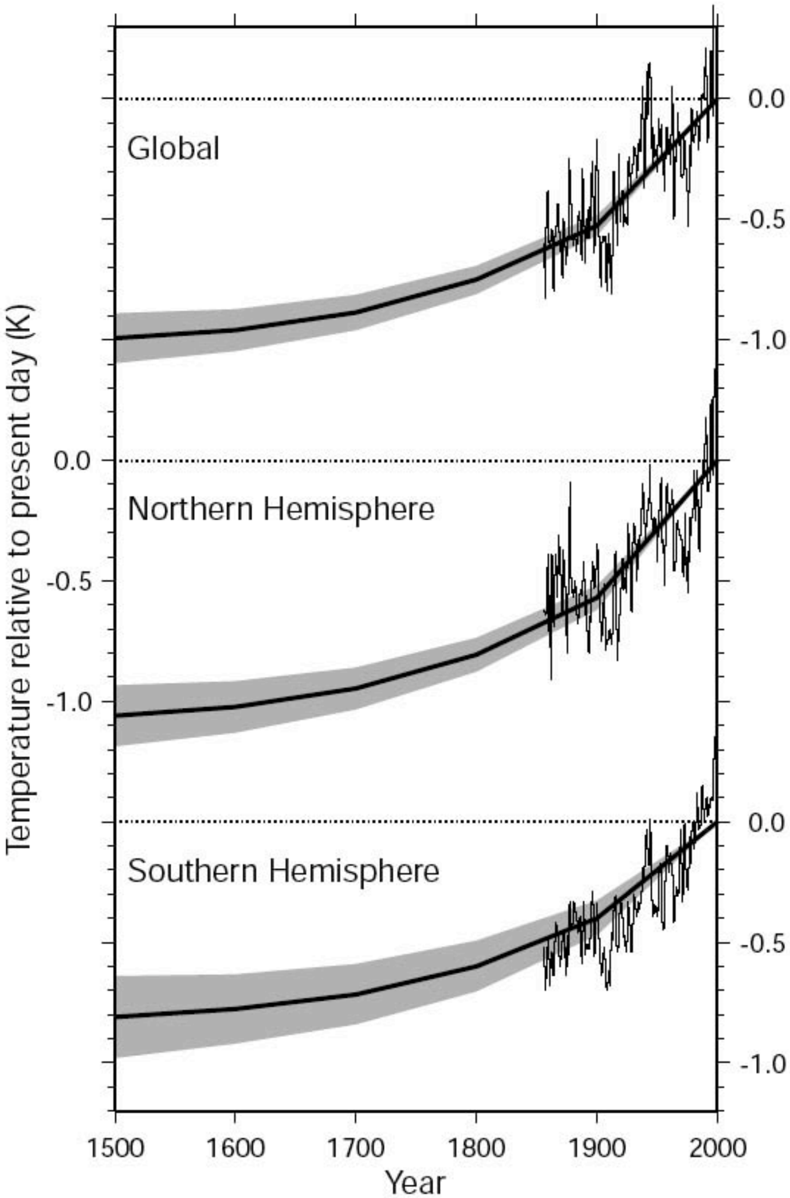


warming or cooling at the surface perturbs the average temperature profile above ~ 50 meters (daily, weekly and monthly changes are restricted to upper few meters)

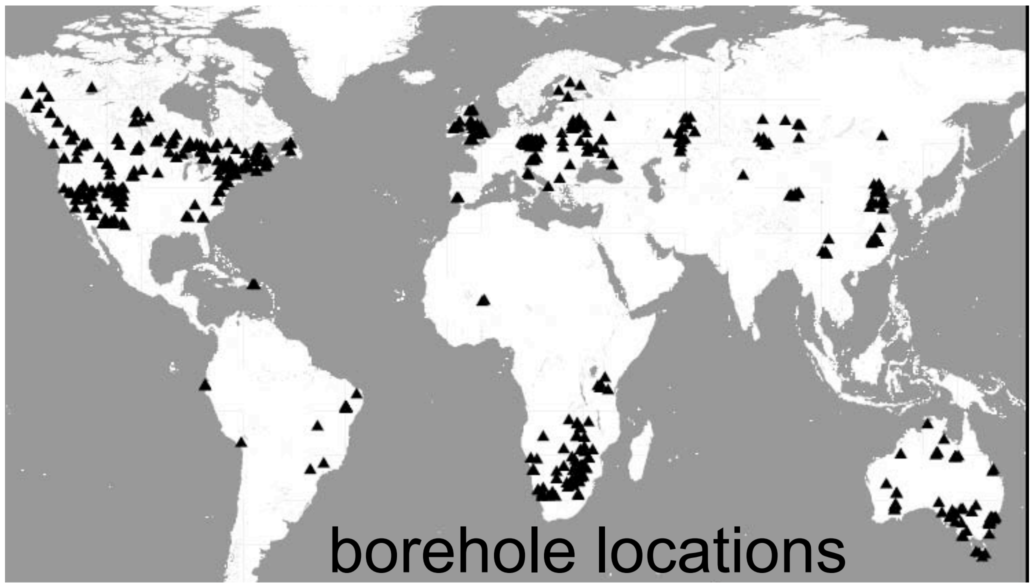
temperature change from boreholes

- the following three slides are courtesy of **Gary Clow, USGS**
- they provide an example of repeat borehole temperature measurements from Arctic Alaska
- temperatures in upper few meters are not shown as they vary daily to seasonally
- the lack of a warm “bulge” in the early observations tells us that the dramatic warming seen after the 1980’s is unique (“anomalous”) in the last century or more

temperature change from boreholes



borehole vs. respective instrumental record of temperature



borehole locations

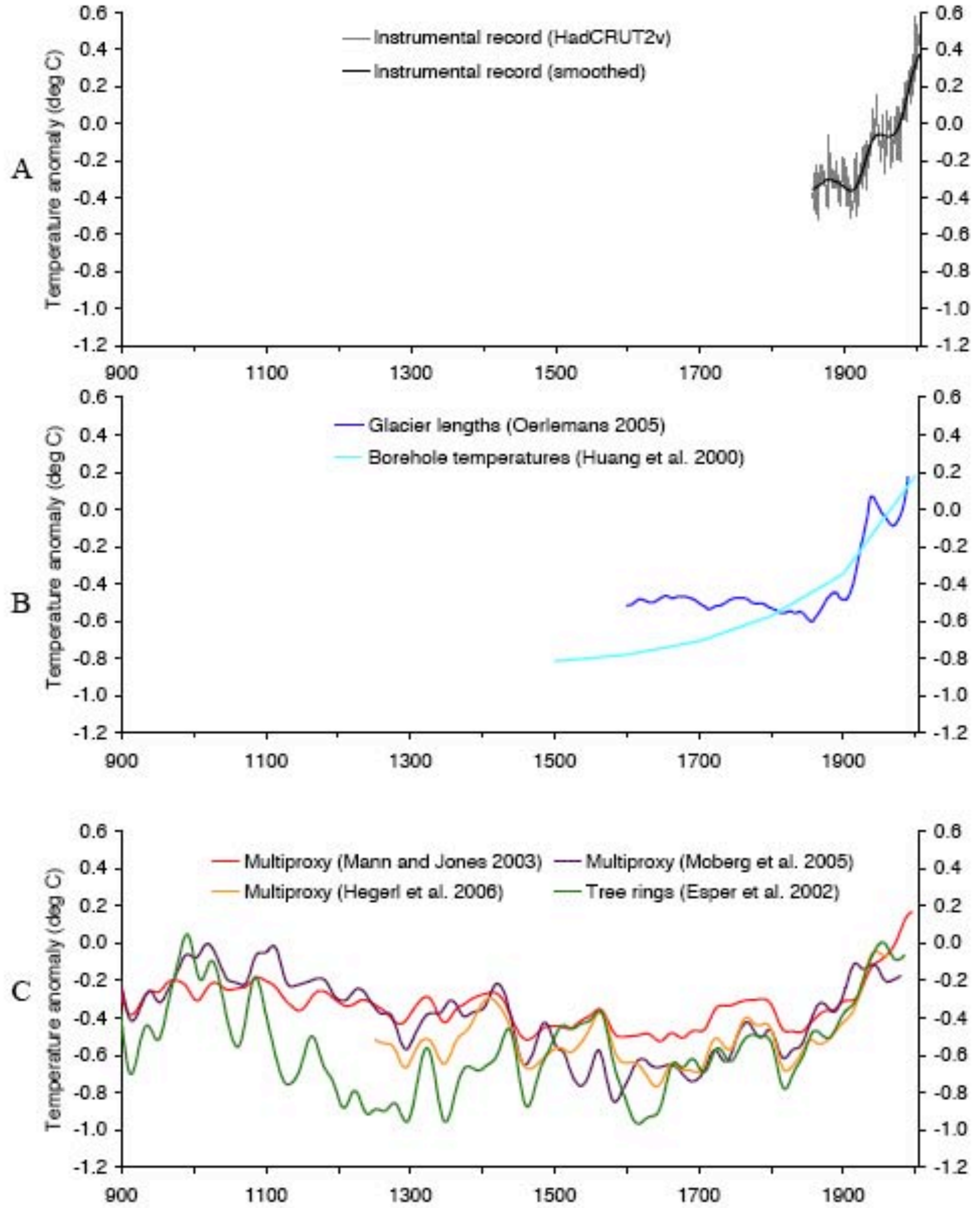
from Huang et al., 2000

temperature records compared

from thermo-meters

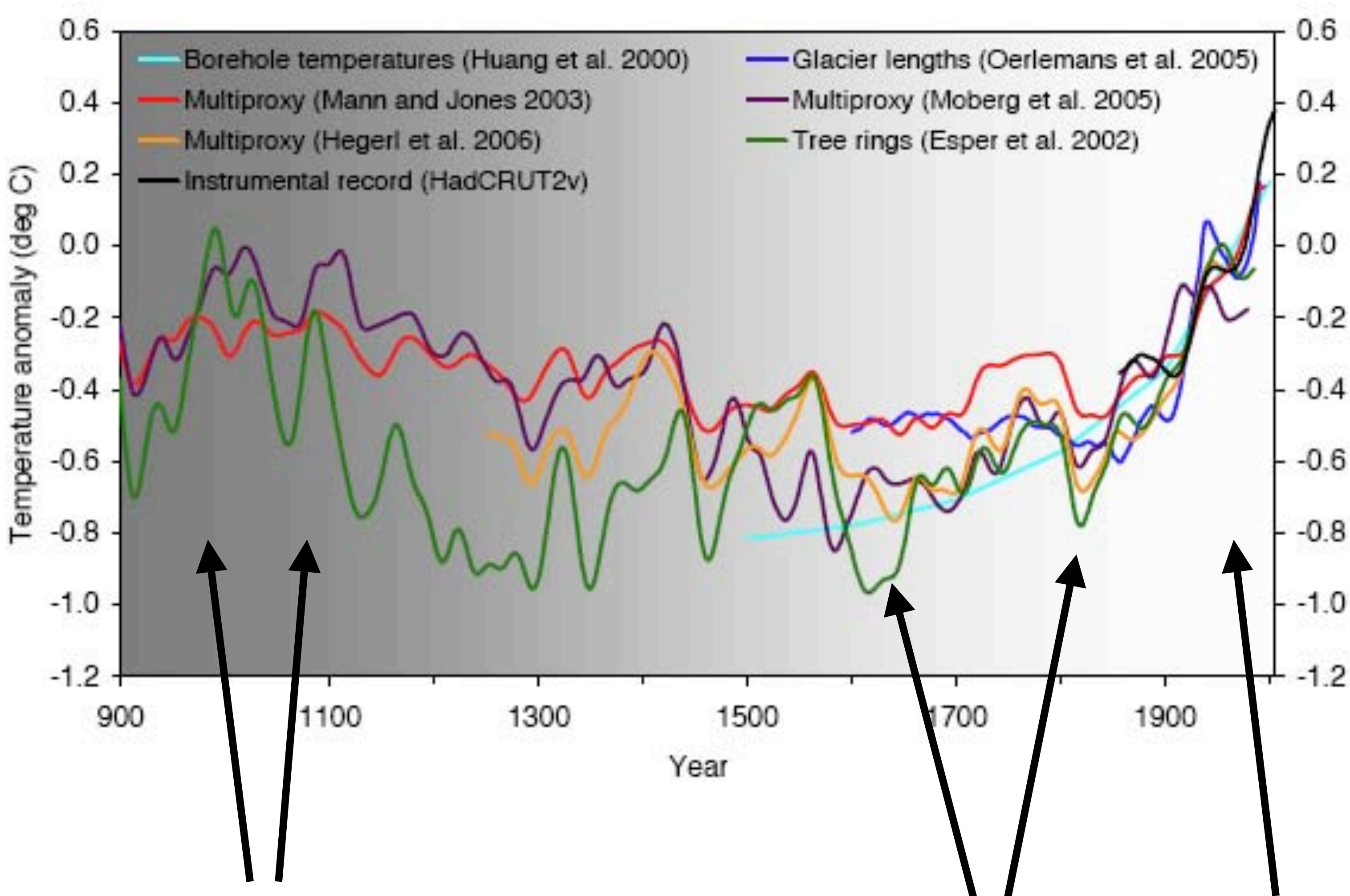
from bore-holes and glacier length

from tree-rings, lake sediments, ice cores



NRC, 2007

temperature records compared



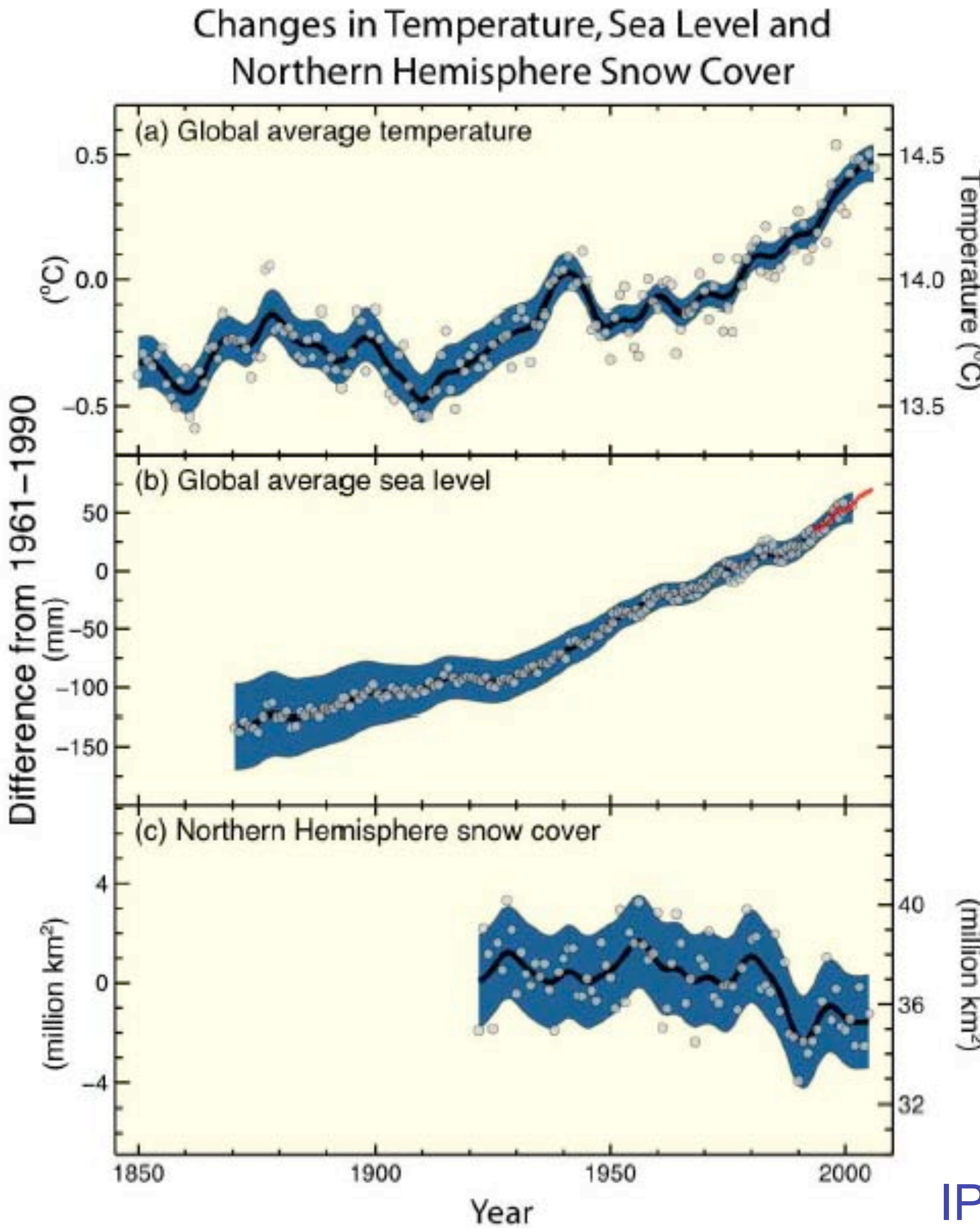
Medieval Warm Period

Little Ice Age

20th C.+ warming

NRC, in press

global ski report!



surfs up!

IPCC AR4, 2007

key points

- thermometers, satellites, boreholes and glaciers all show a pattern of 20th Century+ warming

- the longer records indicate that the 20th Century+ is unusually warm in the context of the last millennium

lecture 14 learning goals

- be able to describe climate or temperature changes with respect to some reference period (i.e. as “anomalies”)
- be able to broadly describe the global record of temperature from thermometers
- describe “polar amplification” and some of the factors and feedbacks that contribute to it
- be familiar with the relationship between the record of surface temperature from thermometers and tropospheric temperature from satellite sensors (similar? different?)
- describe the global trends in glacier length over the last few hundred years and their use in estimating past temperatures
- be able to compare the low resolution record of temperature from measurements in boreholes with that from thermometers

- *next class:*

  understanding the climate of the last millennium

- reading: Ch. 11