Welcome to ATMS 111 Global Warming

http://www.atmos.washington.edu/2010Q1/111

Sent to me from classmate Allison Swienty

On the homepage:
http://www.atmos.washington.edu/2010Q1/111

View your grades (Homework, Quizzes, and some clicker results so far) through GradeBook
If you have think you have a missing homework grade in error, go to the moodle homework site and check there. It is more up to date. If you still think there is an error, email your TA with the details.

If we have none of your clicks listed on GradeBook, FIRST check to see that you registered your name with your clicker ID by Feb 6 when we downloaded them.
NEXT check to see if we have your clicker ID on any of the tables of results. It is a complicated process for us to merge the databases of clicker IDs with the GradeBook, so it will not update just because you register now. We will do it again after Quiz 3. If you still think there is an error, email Tyler with your clicker ID and ask him to check.

Clicker points update

First ~4 weeks points for participation only

Now 3 points for participation + 1 for each correct answer up to 5 (which is about random luck)

Keeping Track RG p 171-192

measuring the global warm up

two case studies

heat at a height

distinguishing between human influences and natural variability

trends in other variables

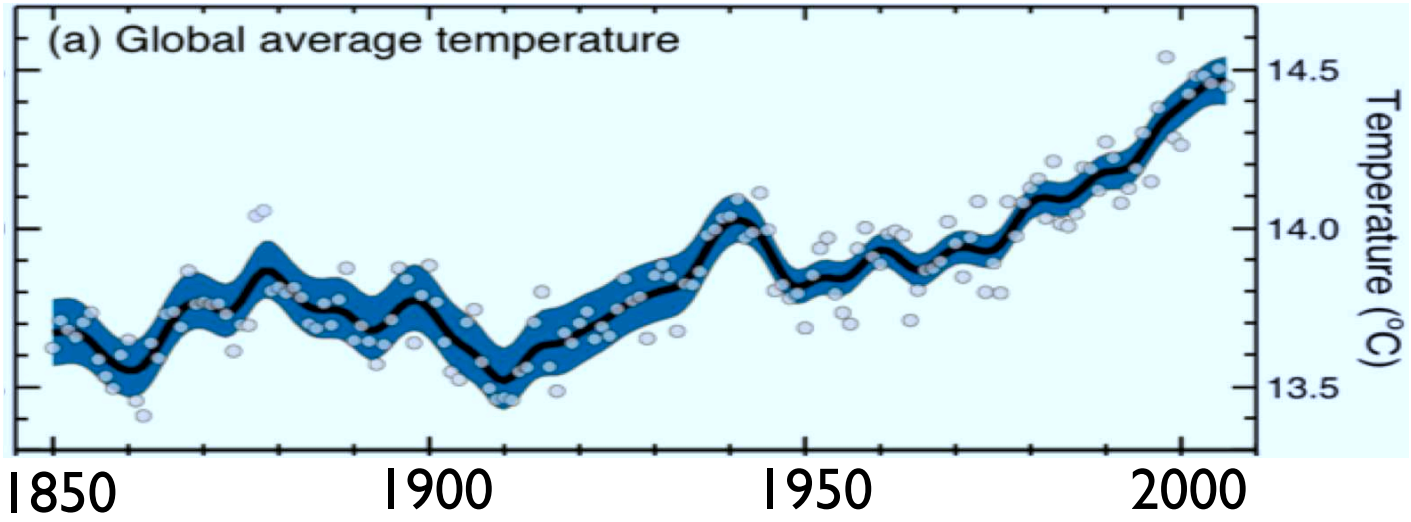
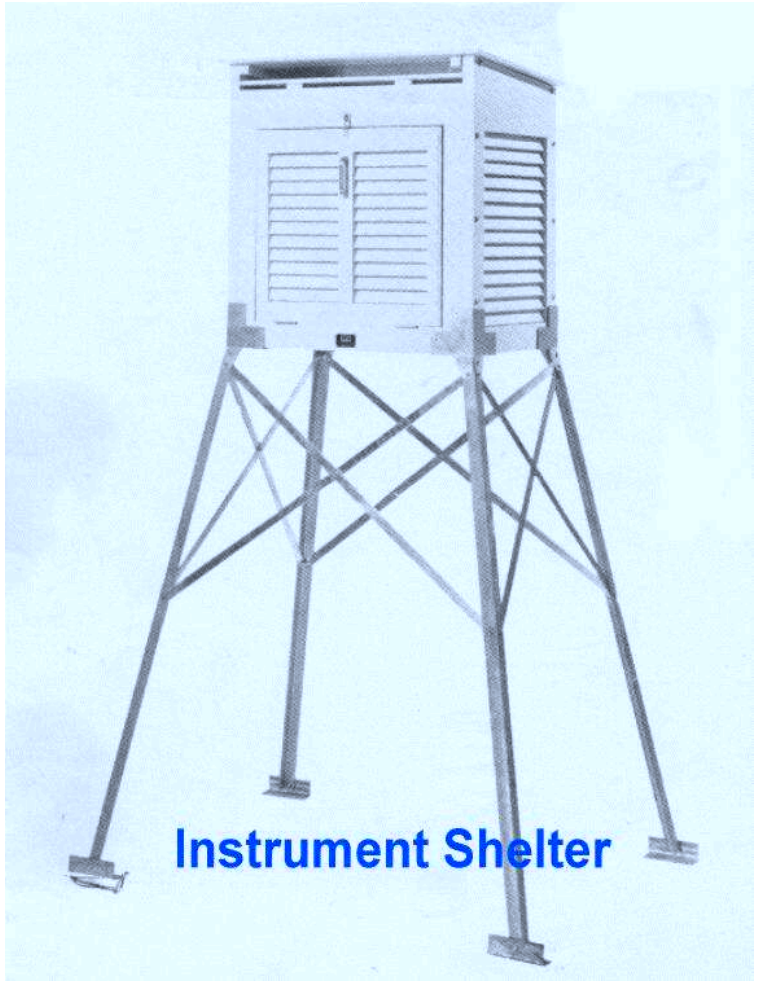
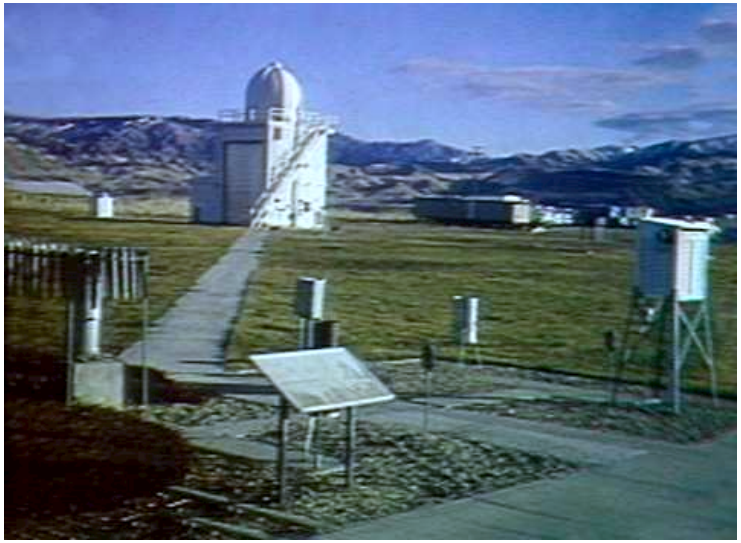
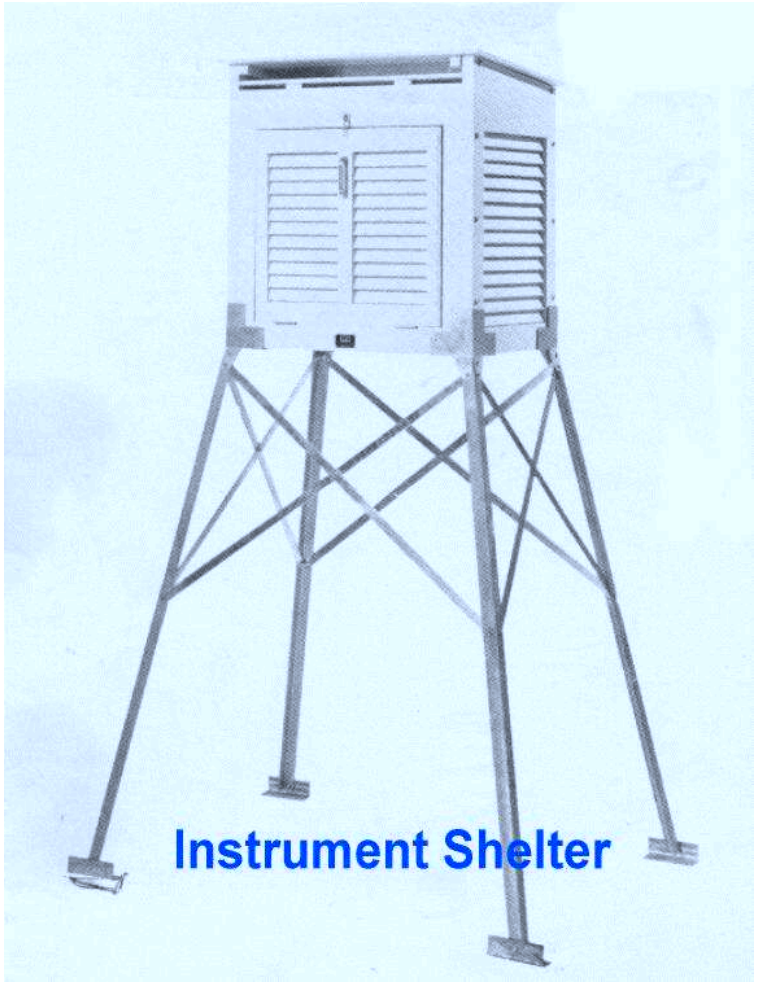


Figure from 2007 IPCC Summary for Policy Makers (SMP)

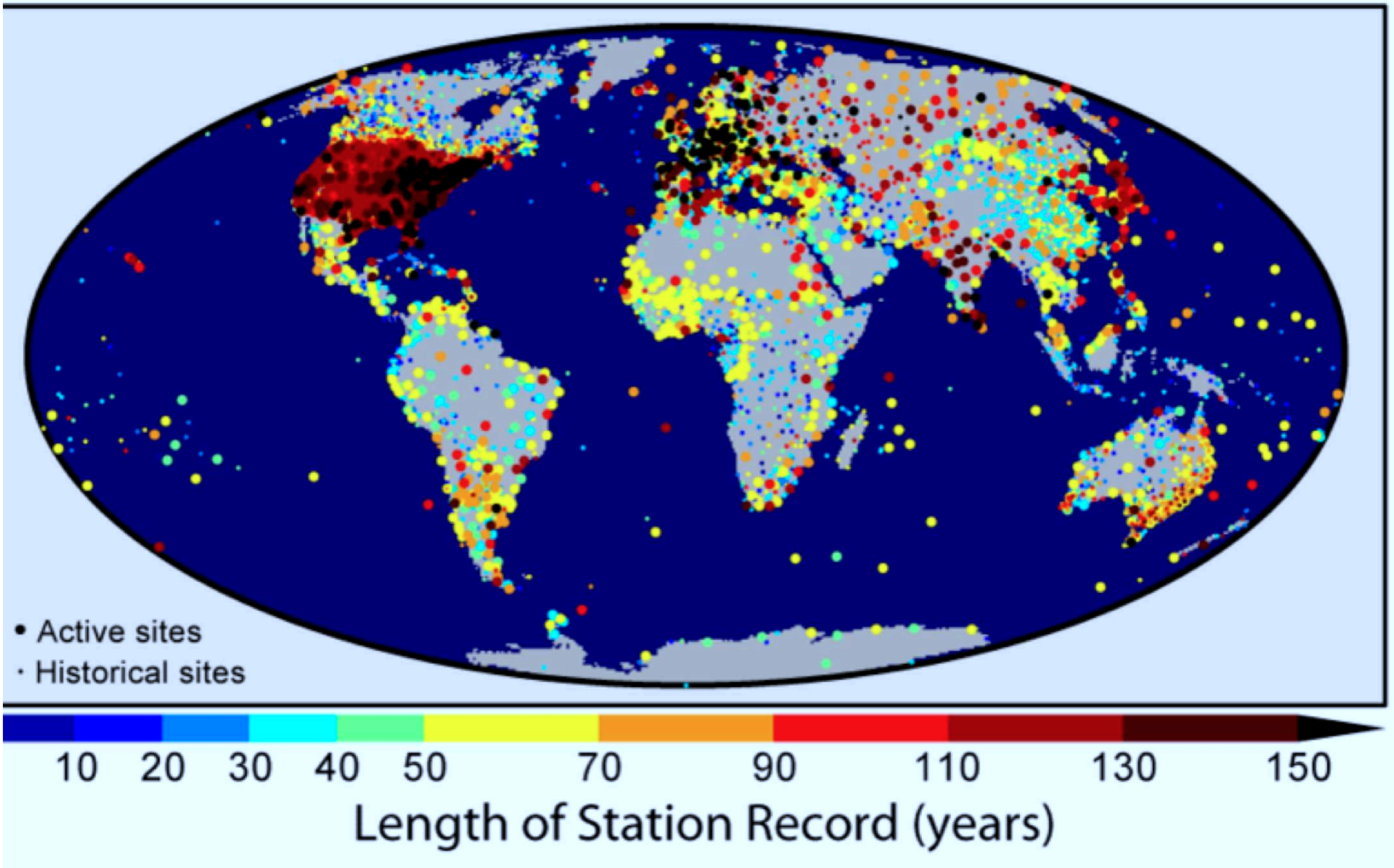
surface air temperature over land



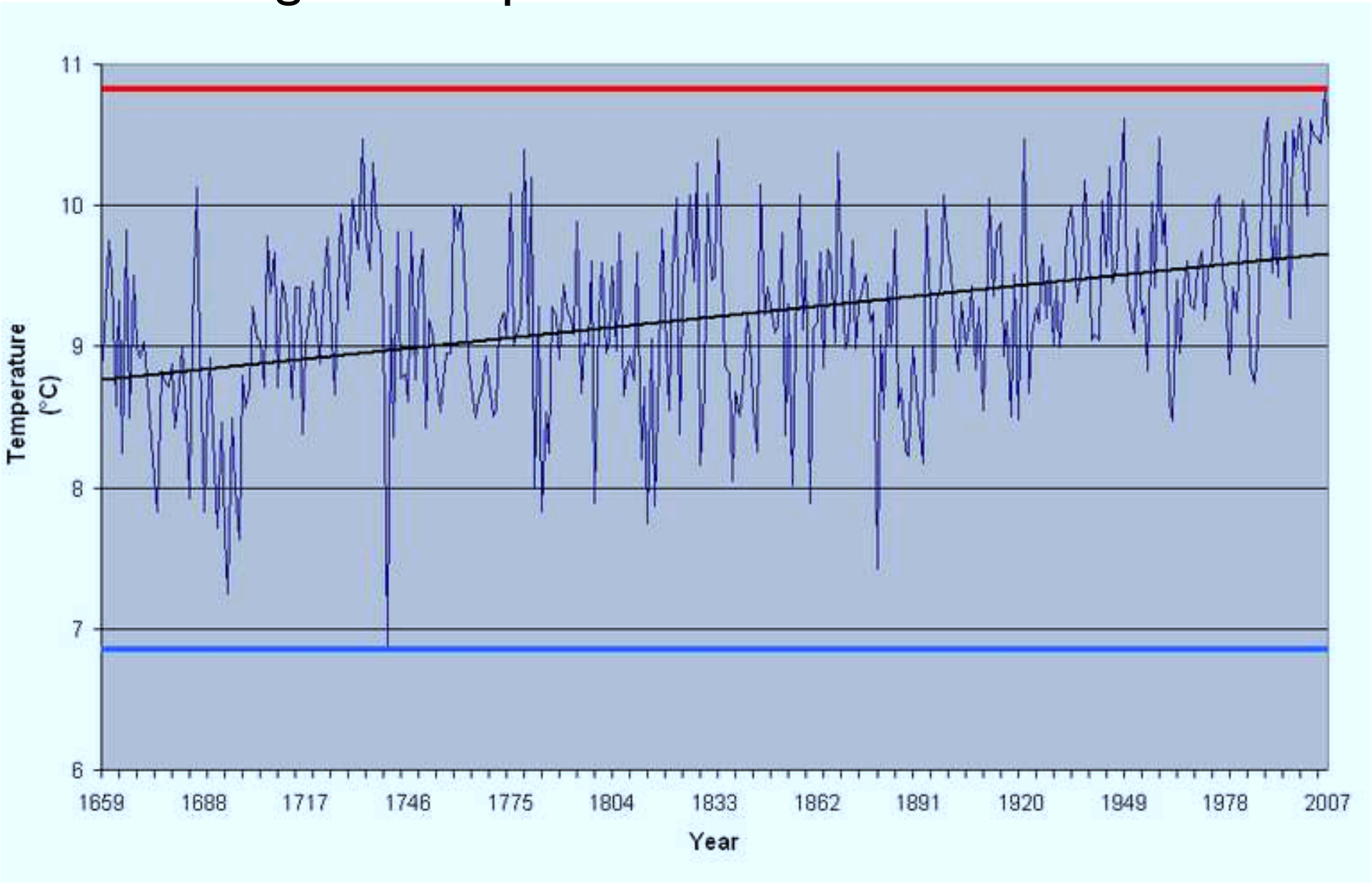



Instrument Shelter

Global Climate Network Temperature Stations



Central England temperature record



Sea surface temperature

Standard bucket ~1891

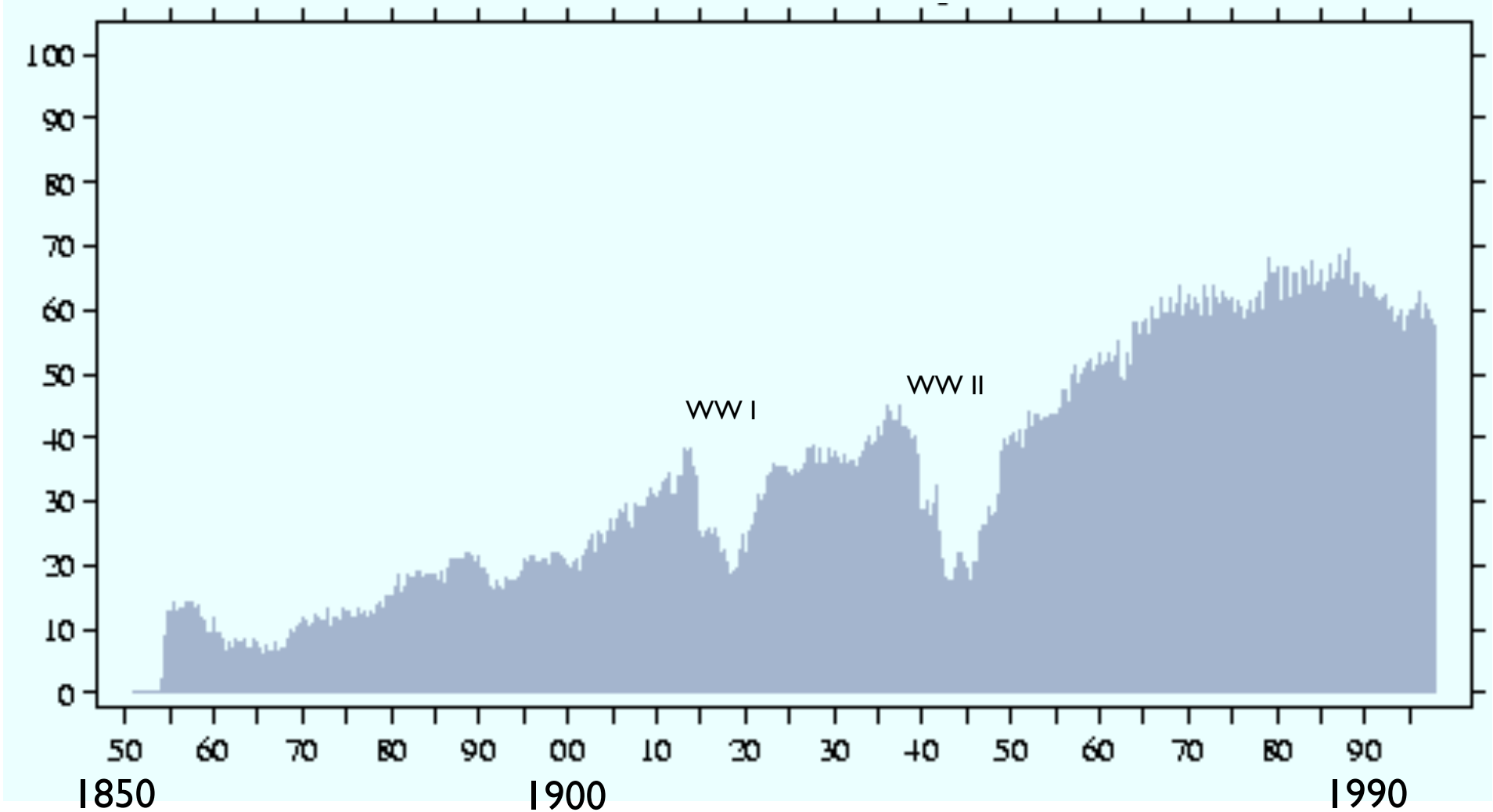
Canvas bucket pre WWII

Insulated bucket now

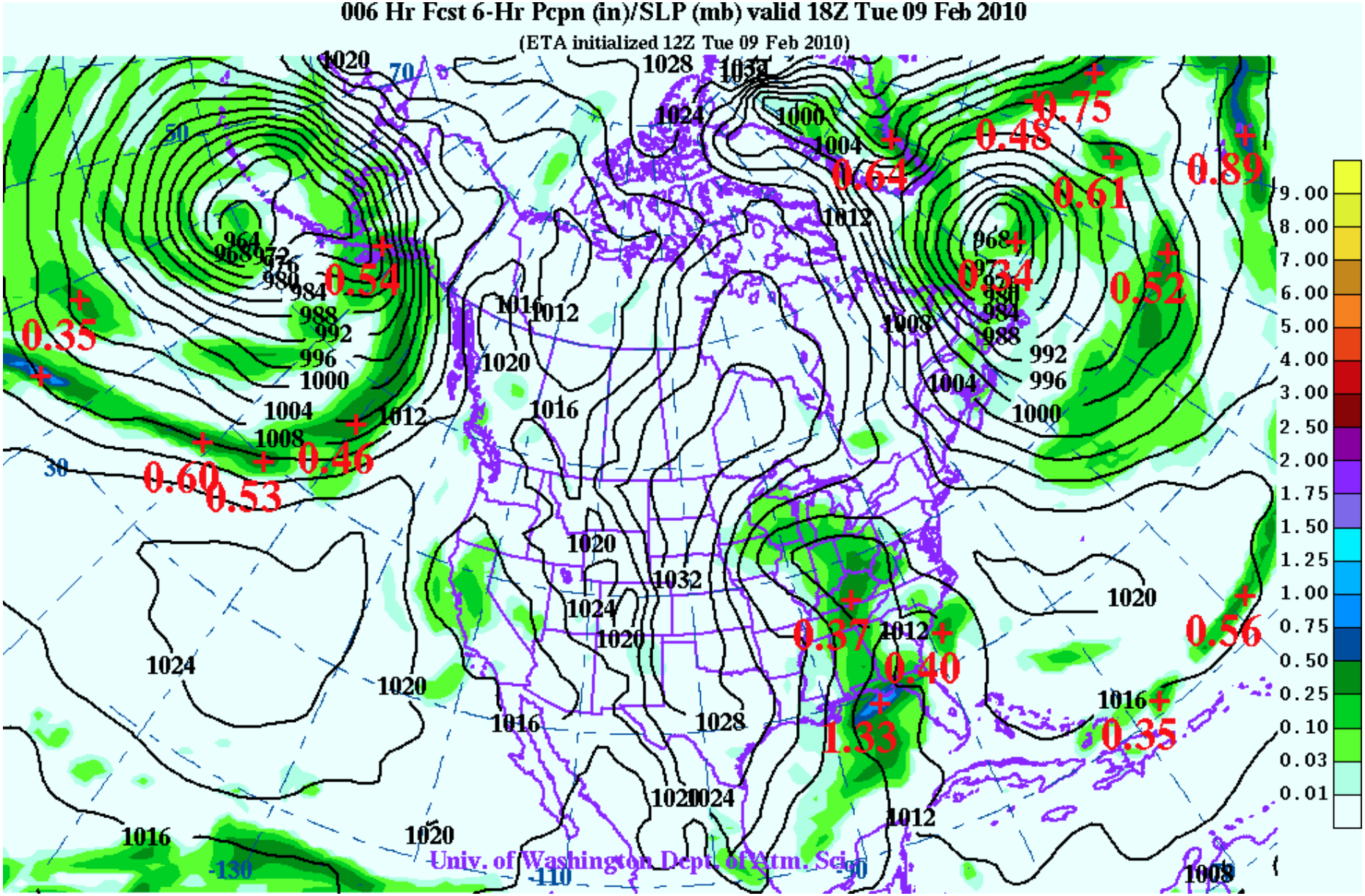
"bucket" temperature older style subject to evaporative cooling

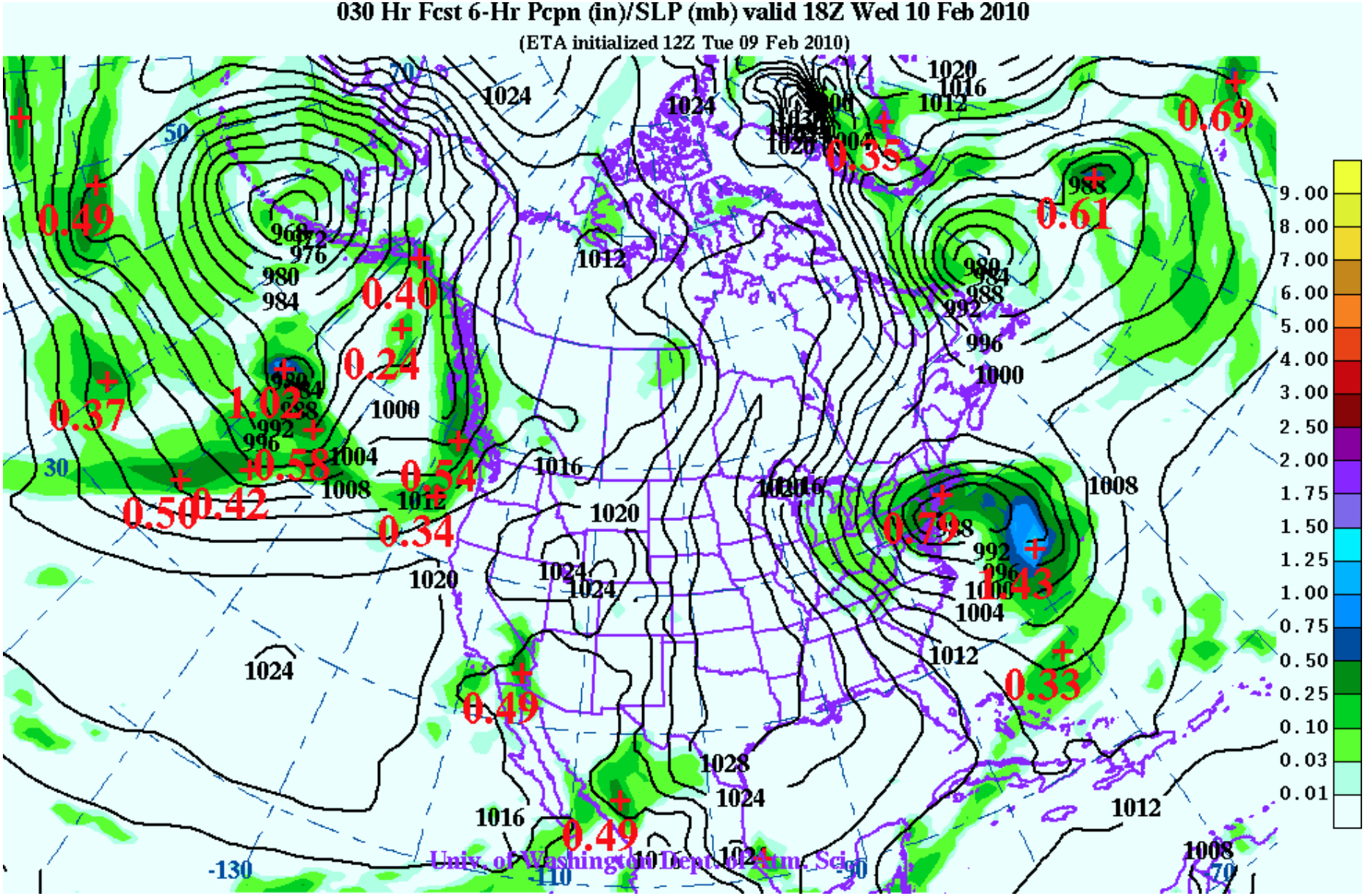
Roughly at the time of WWII, it became common to measure temperature of water in condenser intake pipe. Typically 0.5C warmer than old style buckets

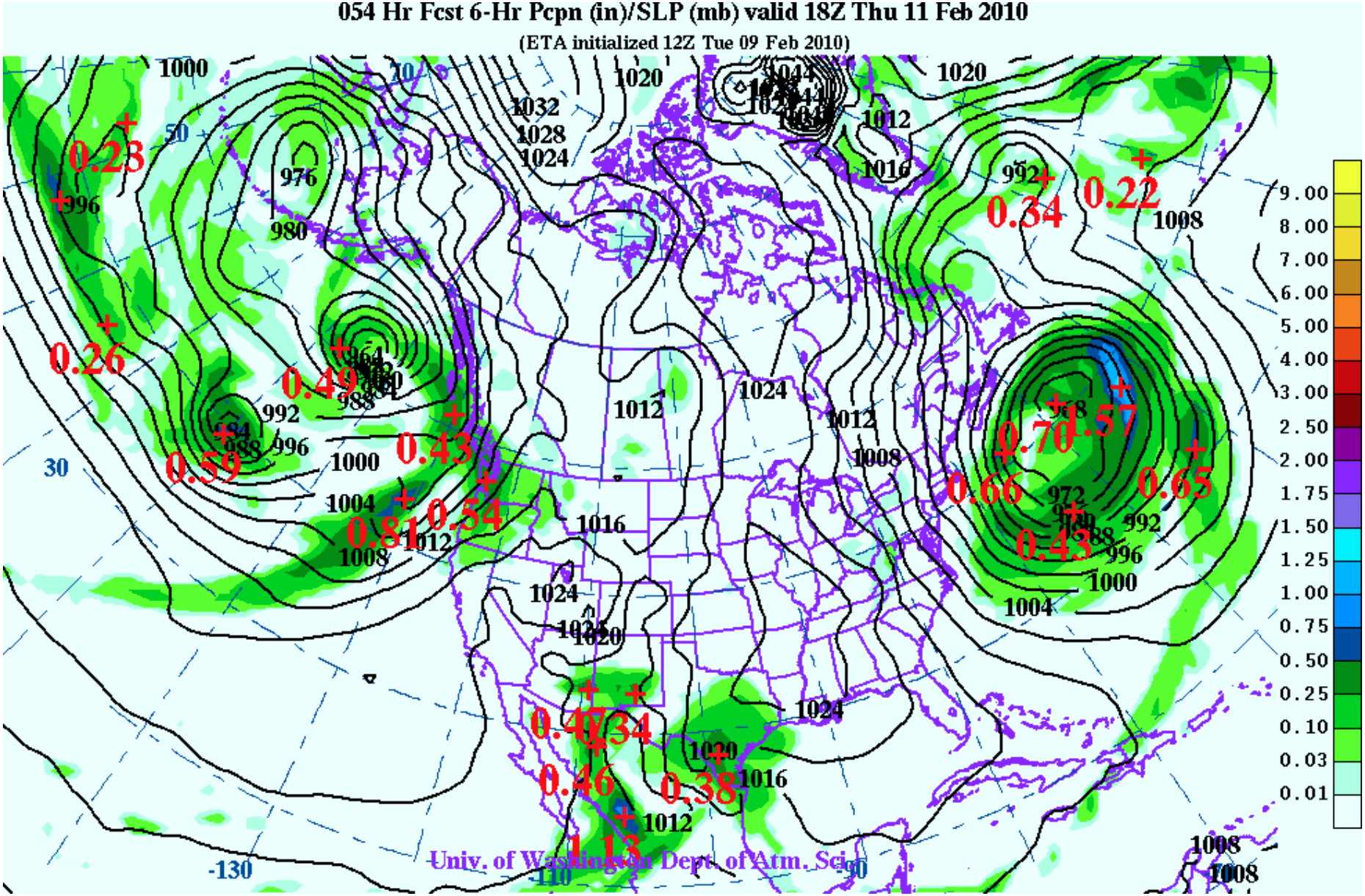
SST Percent coverage of total ocean by year



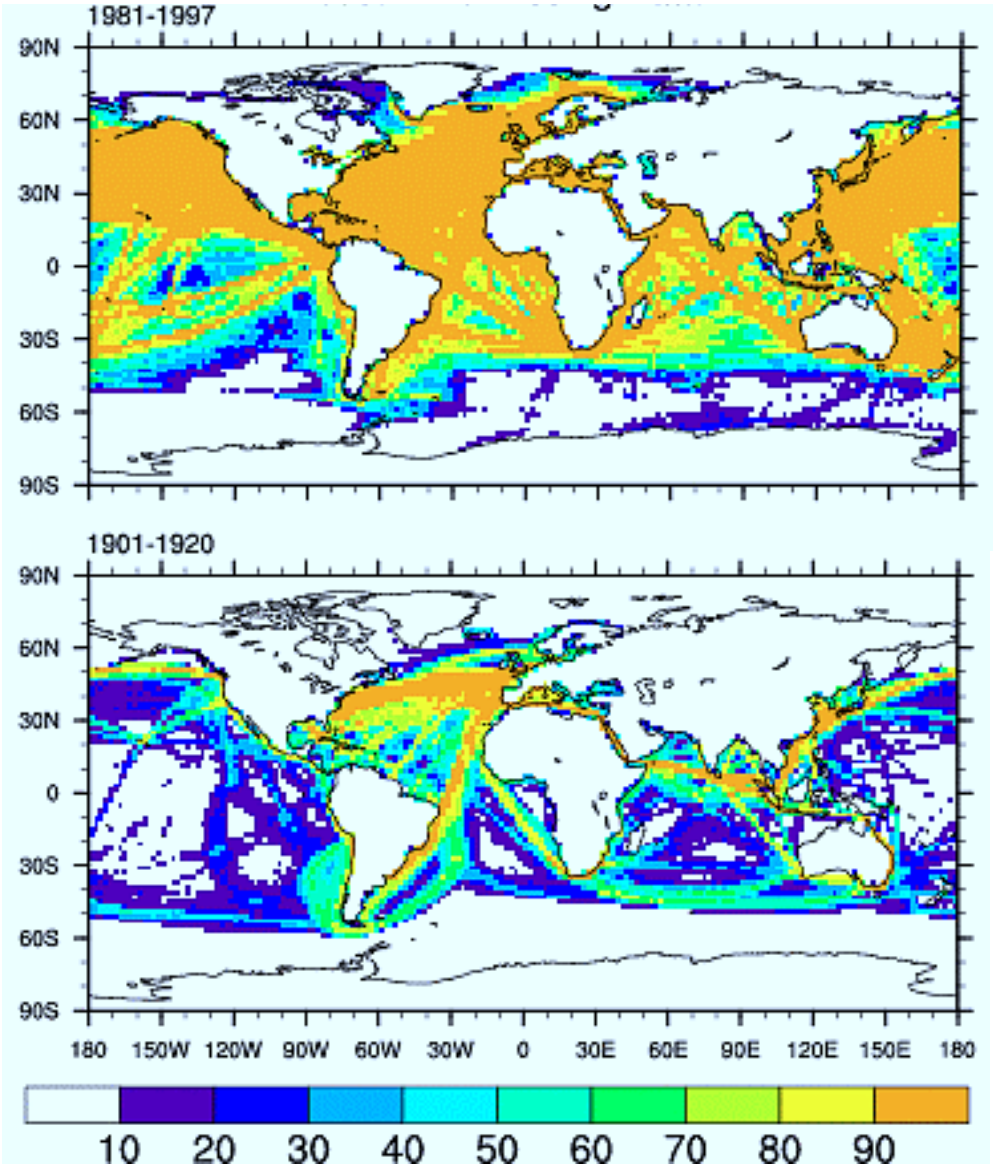
This observing network was designed for Numerical Weather Prediction (NWP)


006 Hr Fcst 6-Hr Pcpn (in)/SLP (mb) valid 18Z Tue 09 Feb 2010
(ETA initialized 12Z Tue 09 Feb 2010)
0.35
0.60
0.53
0.46
0.54
0.64
0.48
0.75
0.61
0.89
0.34
0.52
0.37
0.40
1.33
0.56
0.35
Univ. of Washington Dept. of Atm. Sci.
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.03
0.01


030 Hr Fcst 6-Hr Pcpn (in)/SLP (mb) valid 18Z Wed 10 Feb 2010
(ETA initialized 12Z Tue 09 Feb 2010)
0.49
0.37
1.02
0.58
0.50
0.42
0.40
0.24
0.54
0.34
0.35
0.61
0.69
0.79
1.43
0.33
0.49
0.49
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.03
0.01
Univ. of Washington Dept. of Atm. Sci.


054 Hr Fcst 6-Hr Pcpn (in)/SLP (mb) valid 18Z Thu 11 Feb 2010
(ETA initialized 12Z Tue 09 Feb 2010)
0.23
0.26
0.49
0.59
0.43
0.54
0.81
0.34
0.22
0.70
0.57
0.66
0.65
0.43
0.47
0.34
0.46
0.38
0.13
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.03
0.01
Univ. of Washington Dept. of Atm. Sci.

SST Percent coverage

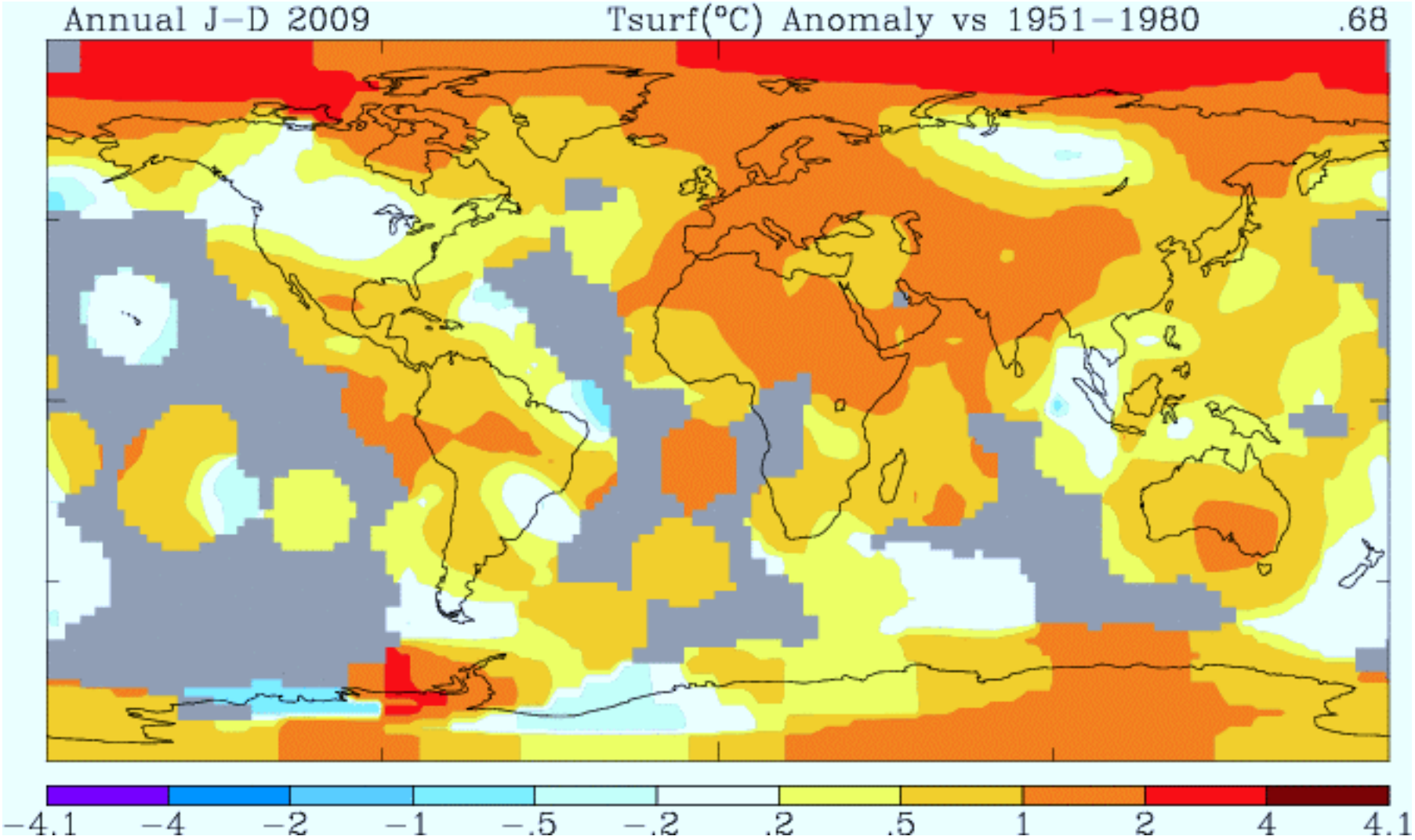


10% = 1 in 10 months had a ship measurement

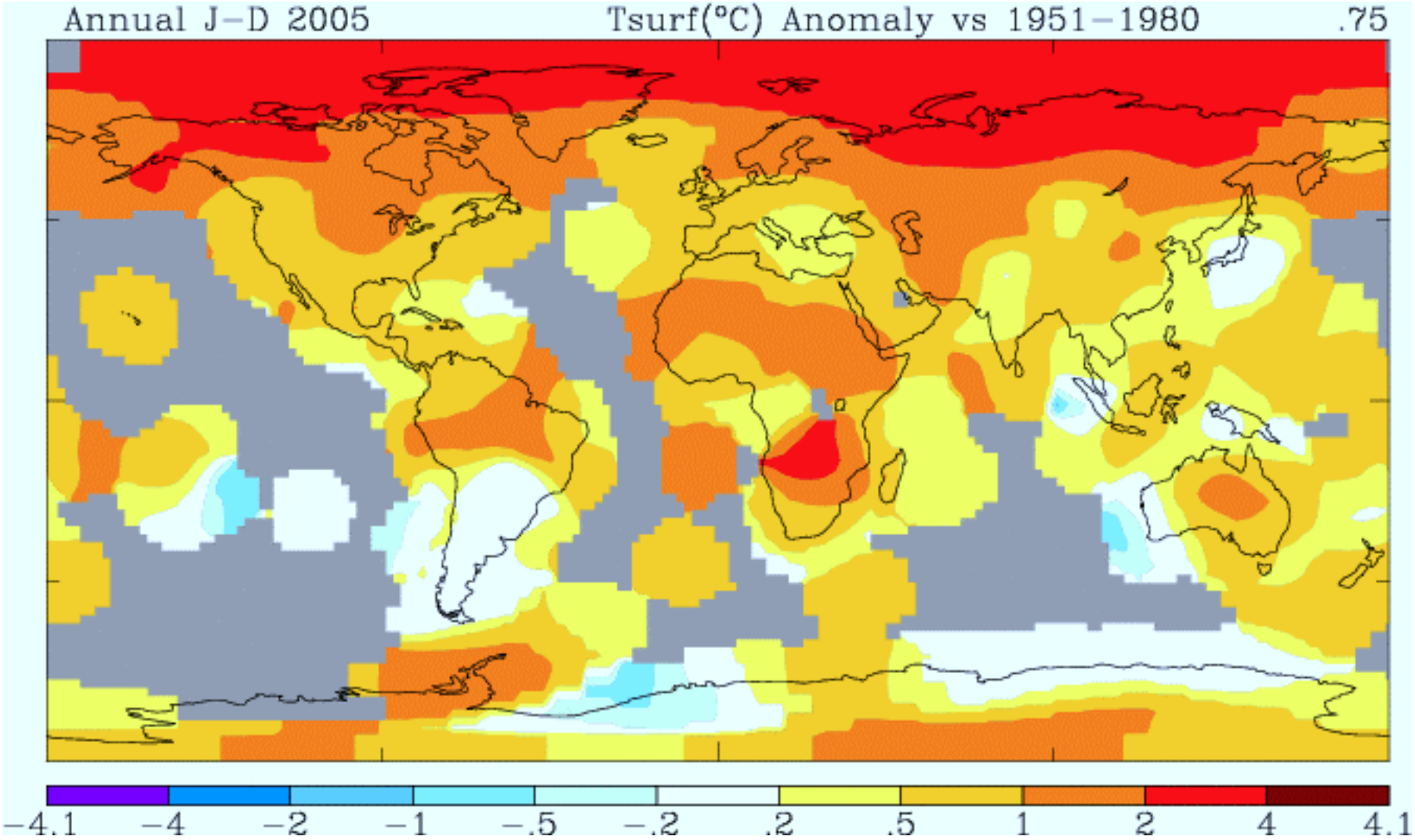
1981-1997

1901-1920

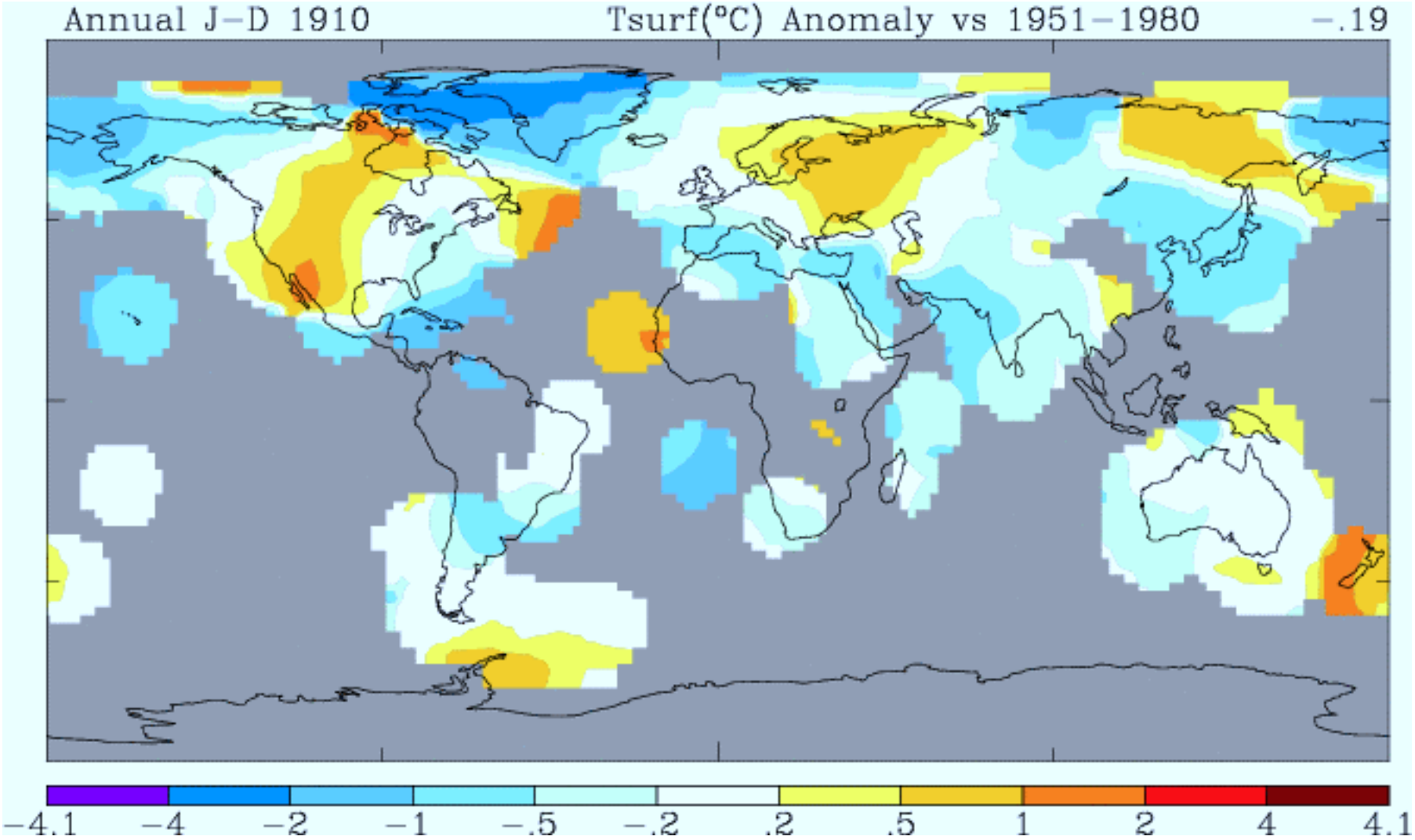
2009 Surface Temperature Anomaly NASA (departure from 1951-1980 mean)



2005 Surface Temperature Anomaly NASA (departure from 1951-1980 mean)

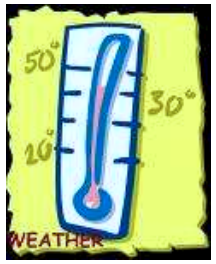


1910 Surface Temperature Anomaly NASA (departure from 1951-1980 mean)



Where are these data sets assembled?

And what do groups like NASA or UEA do to the raw data?



Raw Weather Station Data

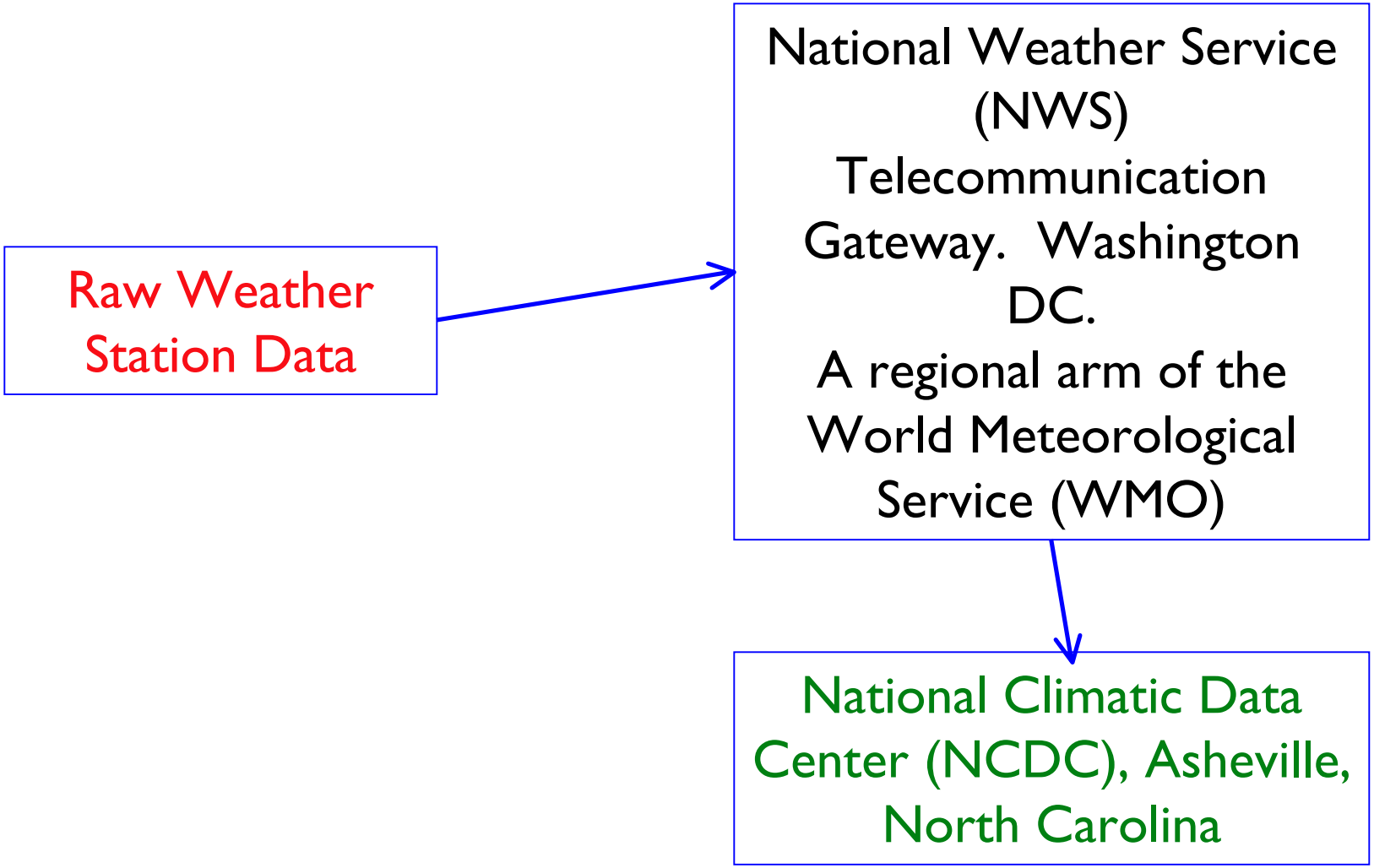
```
#
#       This data is from: ATG rooftop, U. of Wash. (stn. code uwa)
#
#
```

Atmospheric Sciences Rooftop Site and Instrument specifications

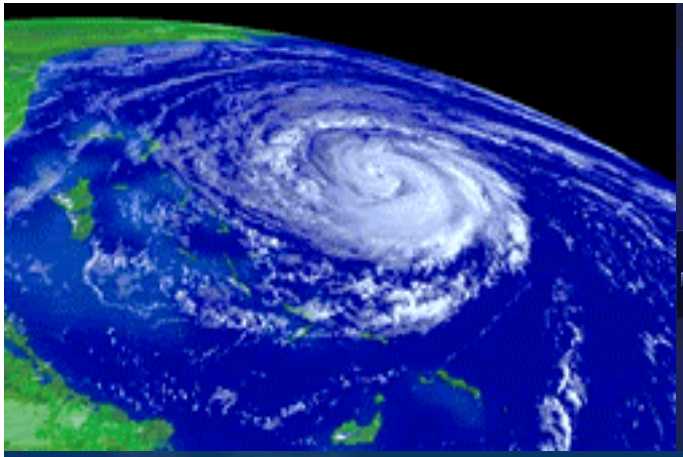
University of Washington
Seattle, WA

Established: July 1999

```
#  Rain Gauge (inches) ------------------------------------------------------------------*
#  Relative humidity (%) ---------------------------------------------------------------*     |
#  Solar irradiance (W/m^2) ------------------------------------------------------*     |     |
#  Visibility (miles) ---------------------------------------------------------*     |     |     |
#  Cloud height (100's of feet) ---------------------------------------*     |     |     |     |
#  Cloud cover (1/8ths of sky) ----------------------------------*     |     |     |     |     |
#  Wind peak (nautical miles per hour) ----------------------*     |     |     |     |     |     |
#  Wind speed (nautical miles per hour) -----------------*     |     |     |     |     |     |     |
#  Wind direction (clockwise degrees from North) --*     |     |     |     |     |     |     |     |
#  Dewpoint temperature (F) -------------------*     |     |     |     |     |     |     |     |     |
#  Air temperature (F) -------------------*     |     |     |     |     |     |     |     |     |     |
#  Pressure (millibars) -----------*     |     |     |     |     |     |     |     |     |     |     |
#                                  |     |     |     |     |     |     |     |     |     |     |     |
#                                  |     |     |     |     |     |     |     |     |     |     |     |
#    Date(GMT)      Julian date    Pres  Tair Tdew Dir Spd  Peak  Cc Cht Vis  Radn   RelH Rain
# -------------- -------------- ------ ---- ---- --- ---- ---- --- --- --- ------ ----- ----
#
2010-02-07 04:34 2455235.1902778 1010.8 49.7 38.7 132  6.6  8.7   X  M   M     0.0  65.8 0.00
2010-02-07 04:35 2455235.1909722 1010.8 49.7 39.0 125  6.0  7.1   X  M   M     0.0  66.4 0.00
2010-02-07 04:36 2455235.1916667 1010.5 49.8 38.9 136  6.8  7.6   X  M   M     0.0  66.1 0.00
2010-02-07 04:37 2455235.1923611 1010.7 49.7 38.9 137  6.5  7.6   X  M   M     0.0  66.2 0.00
2010-02-07 04:38 2455235.1930556 1010.7 49.7 39.0 128  6.5  8.7   X  M   M     0.0  66.4 0.00
2010-02-07 04:39 2455235.1937500 1010.8 49.6 38.9 143  6.4  7.5   X  M   M     0.0  66.3 0.00
2010-02-07 04:40 2455235.1944444 1010.6 49.6 39.0 131  6.9  7.5   X  M   M     0.0  66.6 0.00
2010-02-07 04:41 2455235.1951389 1010.7 49.6 39.0 134  6.1  7.5   X  M   M     0.0  66.7 0.00
2010-02-07 04:42 2455235.1958333 1010.7 49.6 38.9 131  6.7  8.8   X  M   M     0.0  66.7 0.00
```



My primitive slide, then I found….



NOAA's
NWS Telecommunication Gateway
RTH Washington

Fred Branski, Team Leader for Data Management

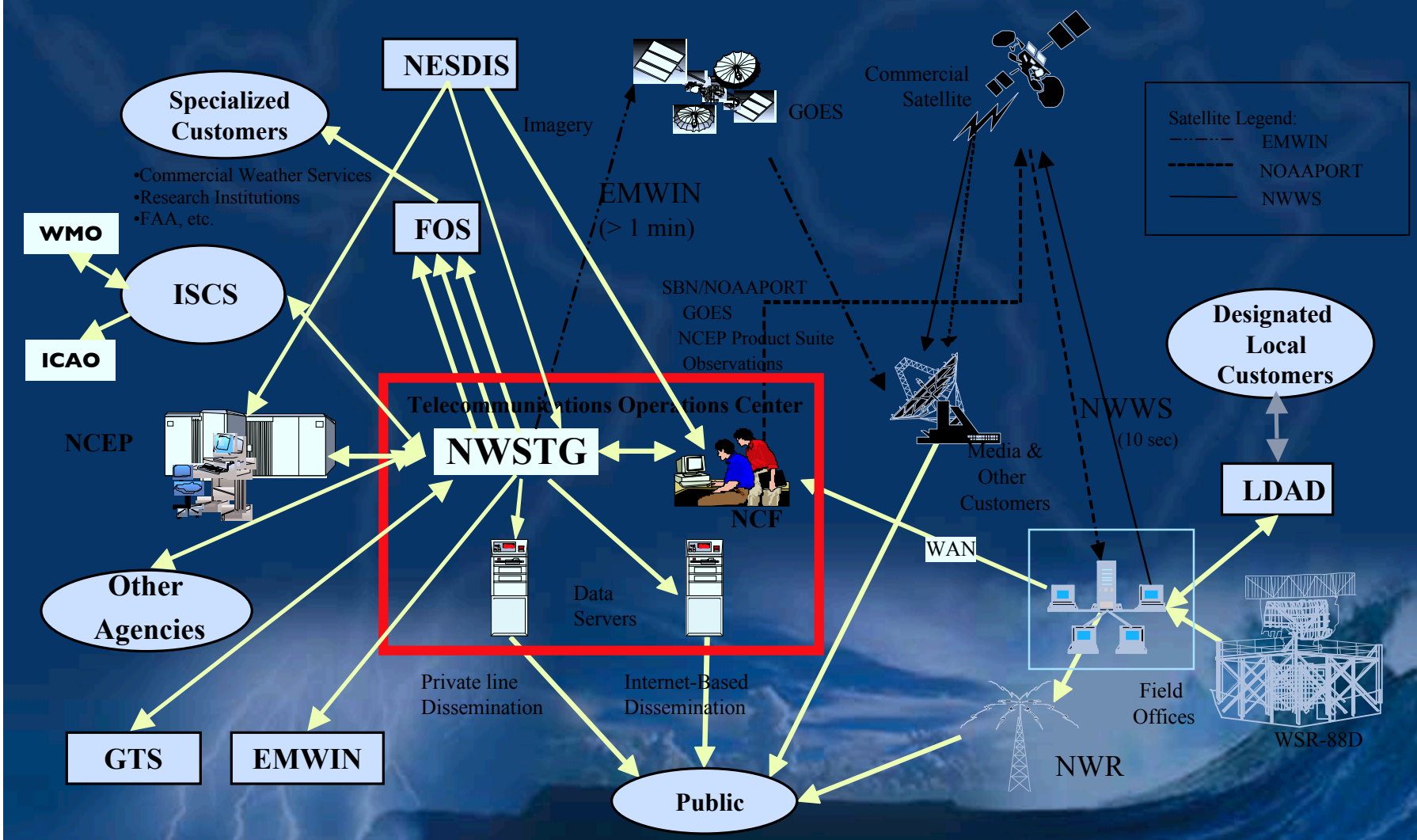
Office of the Chief Information Officer

NOAA's National Weather Service

ICT-MTN / ET-OI Meeting

May 16-19, 2006

Dissemination and Distribution



"Taking the pulse of the planet"

*You can download **raw** weather station data from the "World Monthly Surface Station Climatology"*
http://dss.ucar.edu/datasets/ds570

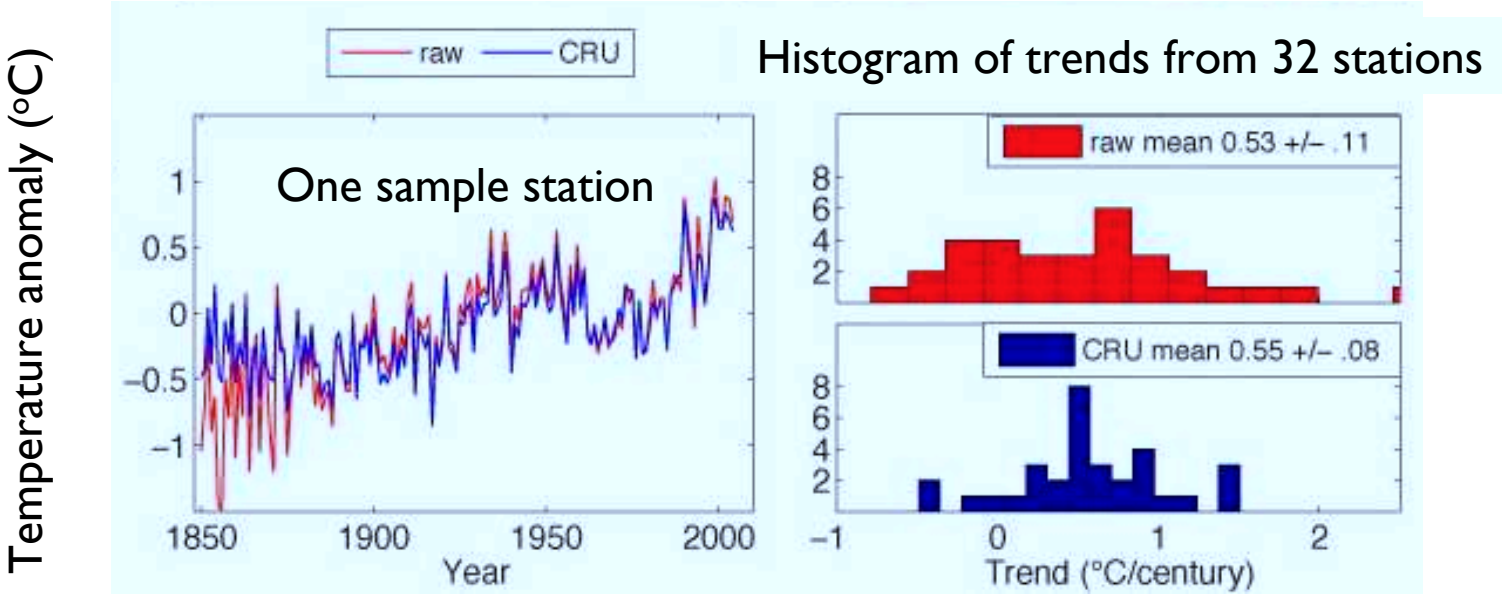
Publications from this data go back as early as a Smithsonian Institution report in 1927

Groups like NASA, NOAA, UEA/CRU have two steps:

1) They try to remove discontinuities or inhomogeneities in individual stations due to changes in observing practices, station environment, or other non-meteorological factors.

2) They also have procedures for combining fragmented record. Well documented. More about this in a minute…

Step 1

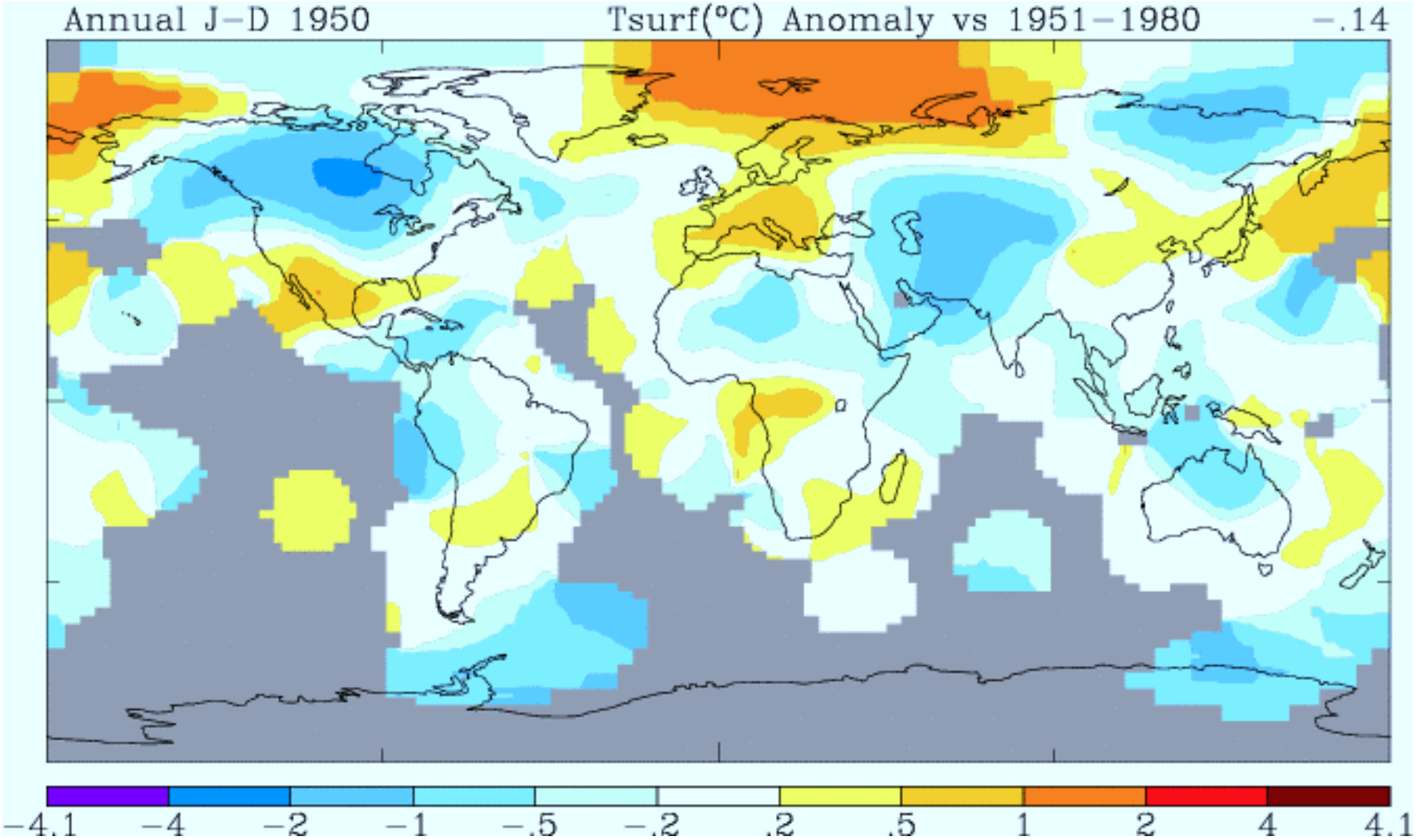


UW graduate student Kevin Wood took a random set of 32 stations and compared the raw data to the UEA (or CRU) analysis.

As expected UEA/CRU weeded out some extremes but didn't change the mean much at all

Step 2

How is this averaged to give a “global mean”?



Global Mean Surface temperature

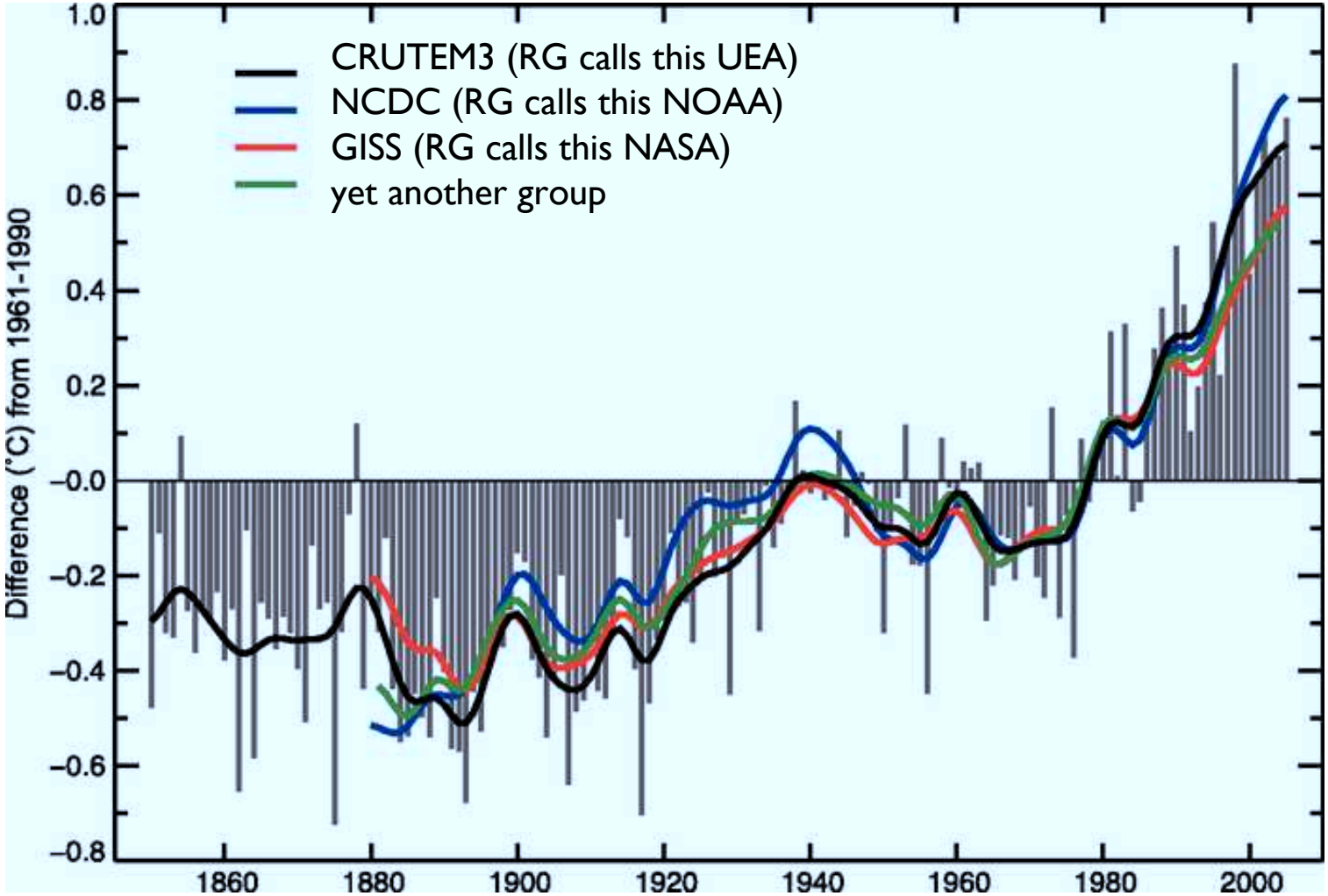
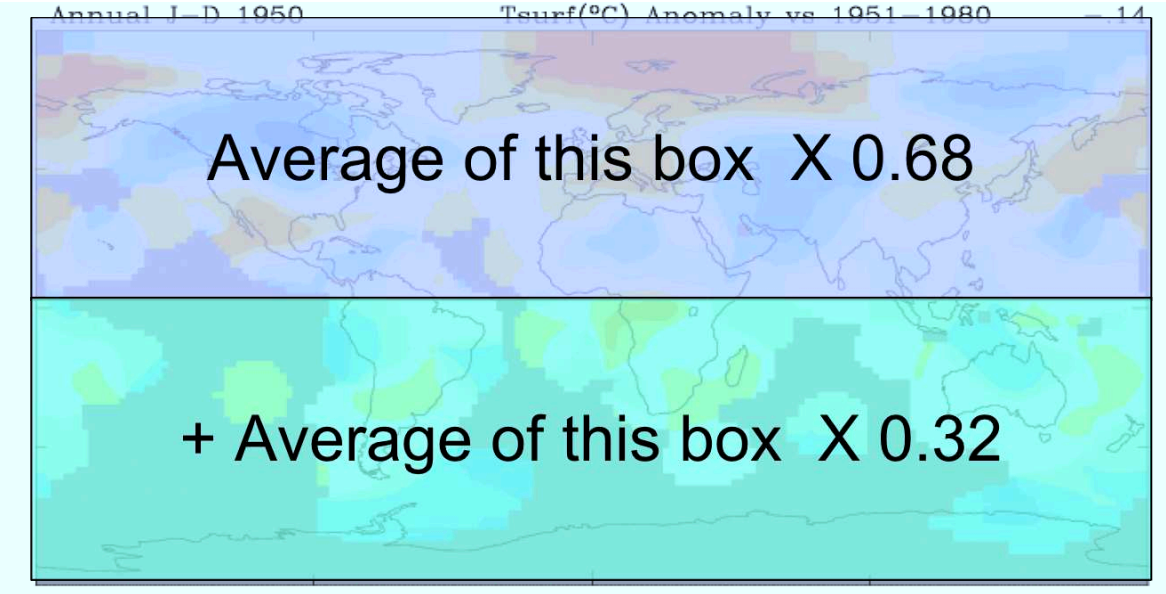
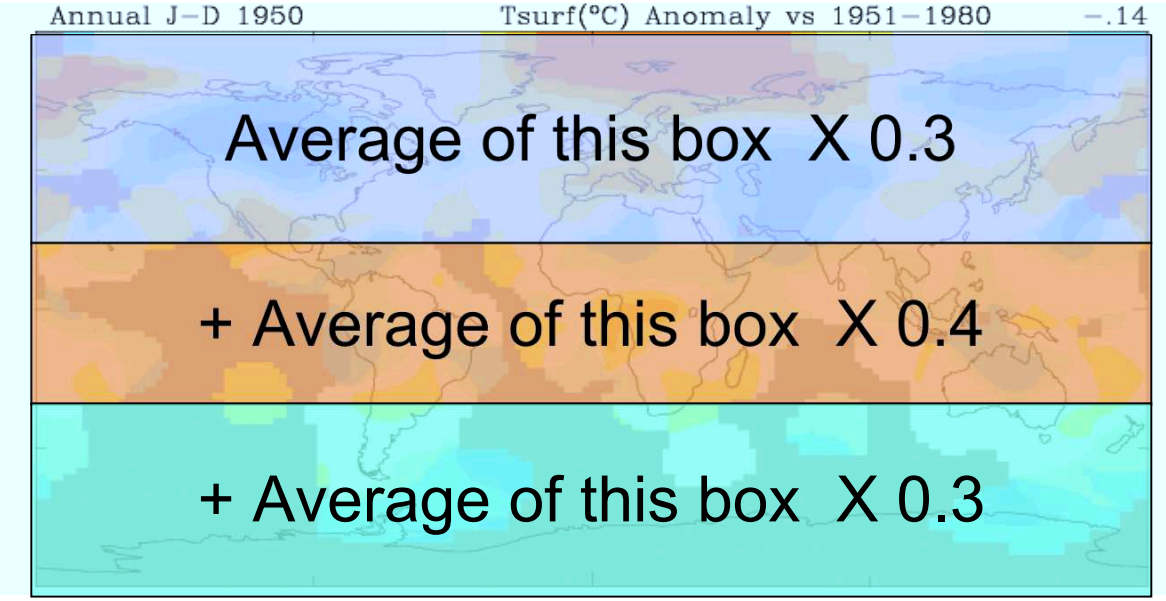


Figure 3.1 from 2007 IPCC

This record since 1850 is ONLY THERMOMETER DATA

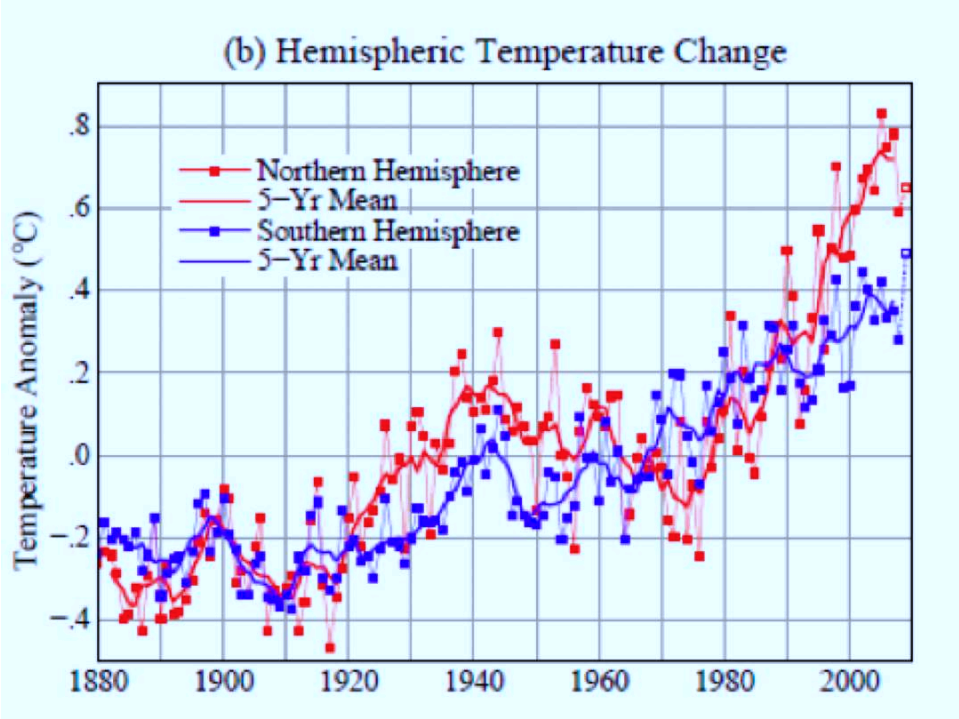


= "global mean" in UEA/CRU record

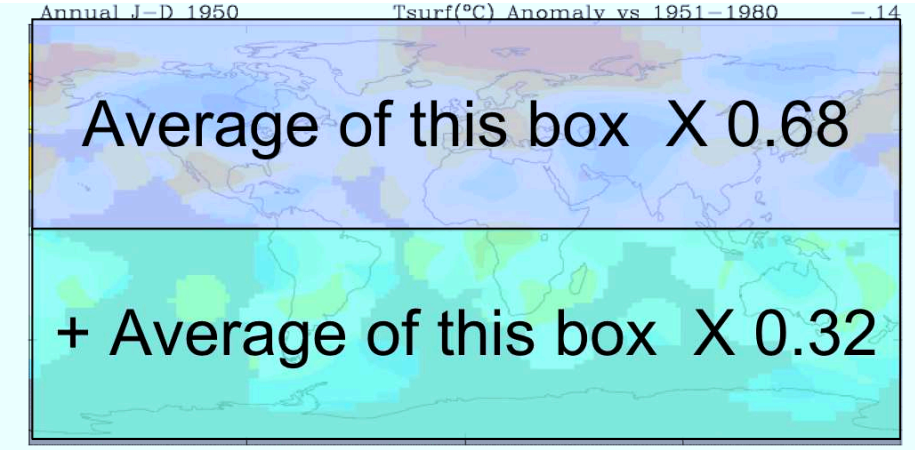


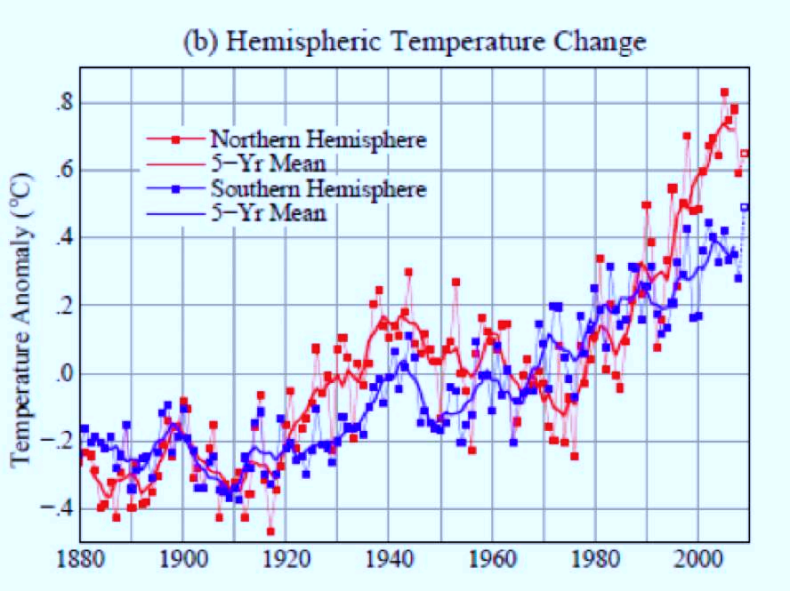
= "global mean" in NASA record

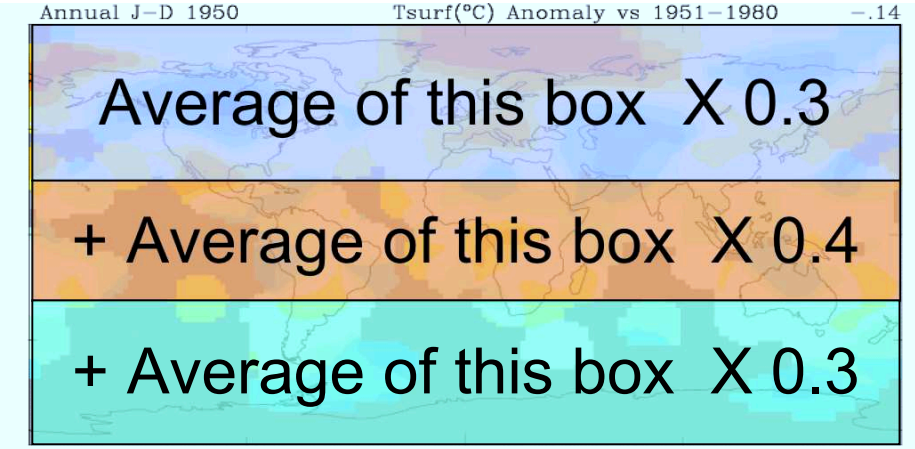
The NH has warmed more than the SH



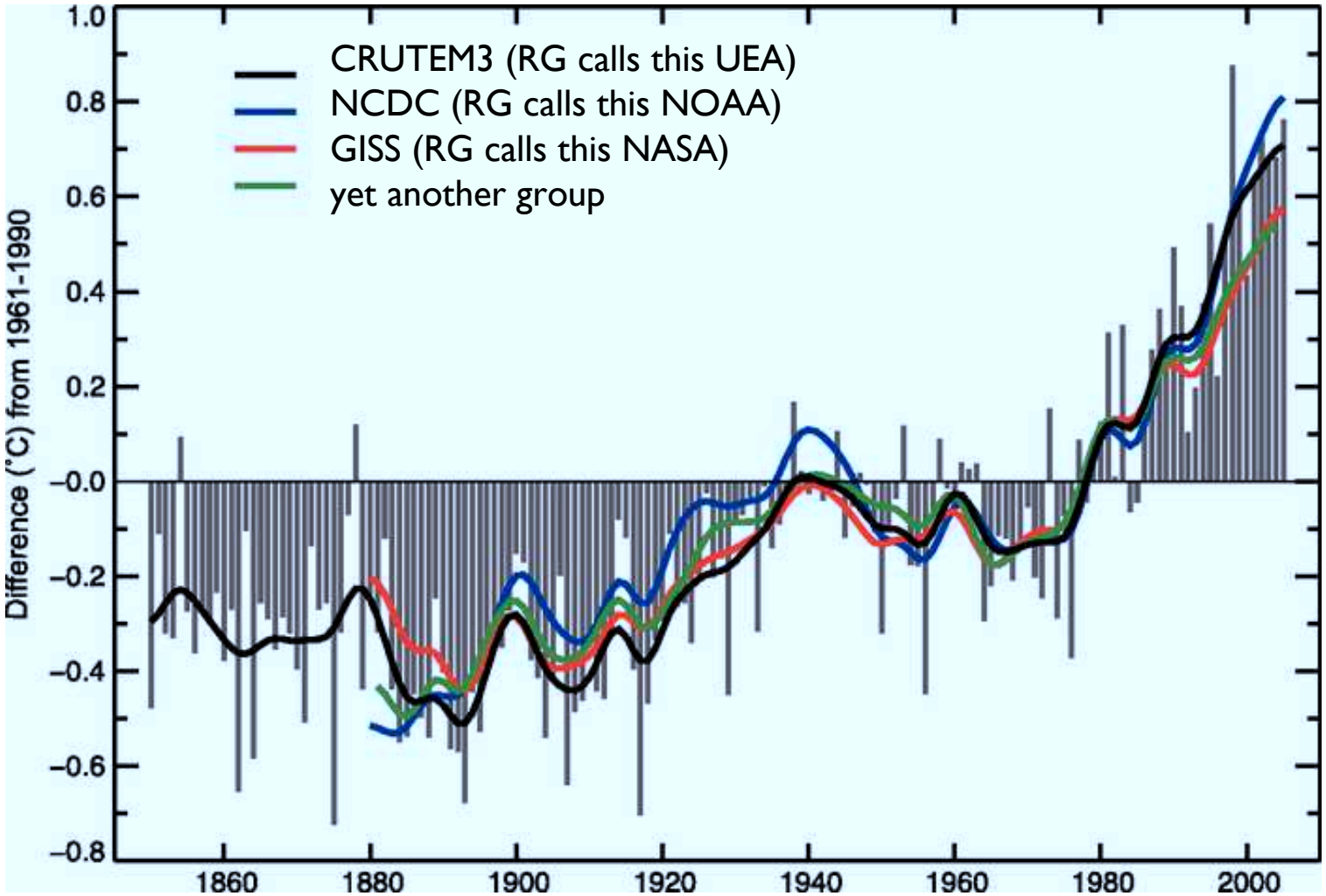
Which method should produce the greater warming?







Which method should produce the greater "global" warming?


CRUTEM3 (RG calls this UEA)
NCDC (RG calls this NOAA)
GISS (RG calls this NASA)
yet another group
Difference (°C) from 1961-1990
1.0
0.8
0.6
0.4
0.2
−0.0
−0.2
−0.4
−0.6
−0.8
1860
1880
1900
1920
1940
1960
1980
2000

Pitfalls of temperature measurements

incomplete spatial sampling

short and “gappy” records

instrument changes

changes in station site, sometimes undocumented

changes in exposure of station site

changes in observing protocol

transcription errors

invalid data (faulty instruments, unreliable observers)

“urban heat island” effect

Virtue of the temperature measurements:

redundancy

many different stations

three different data sets (land, ocean, upper air)

multiple analytic methods by different groups

Random errors tend to average out

Systematic errors can be removed by calibration

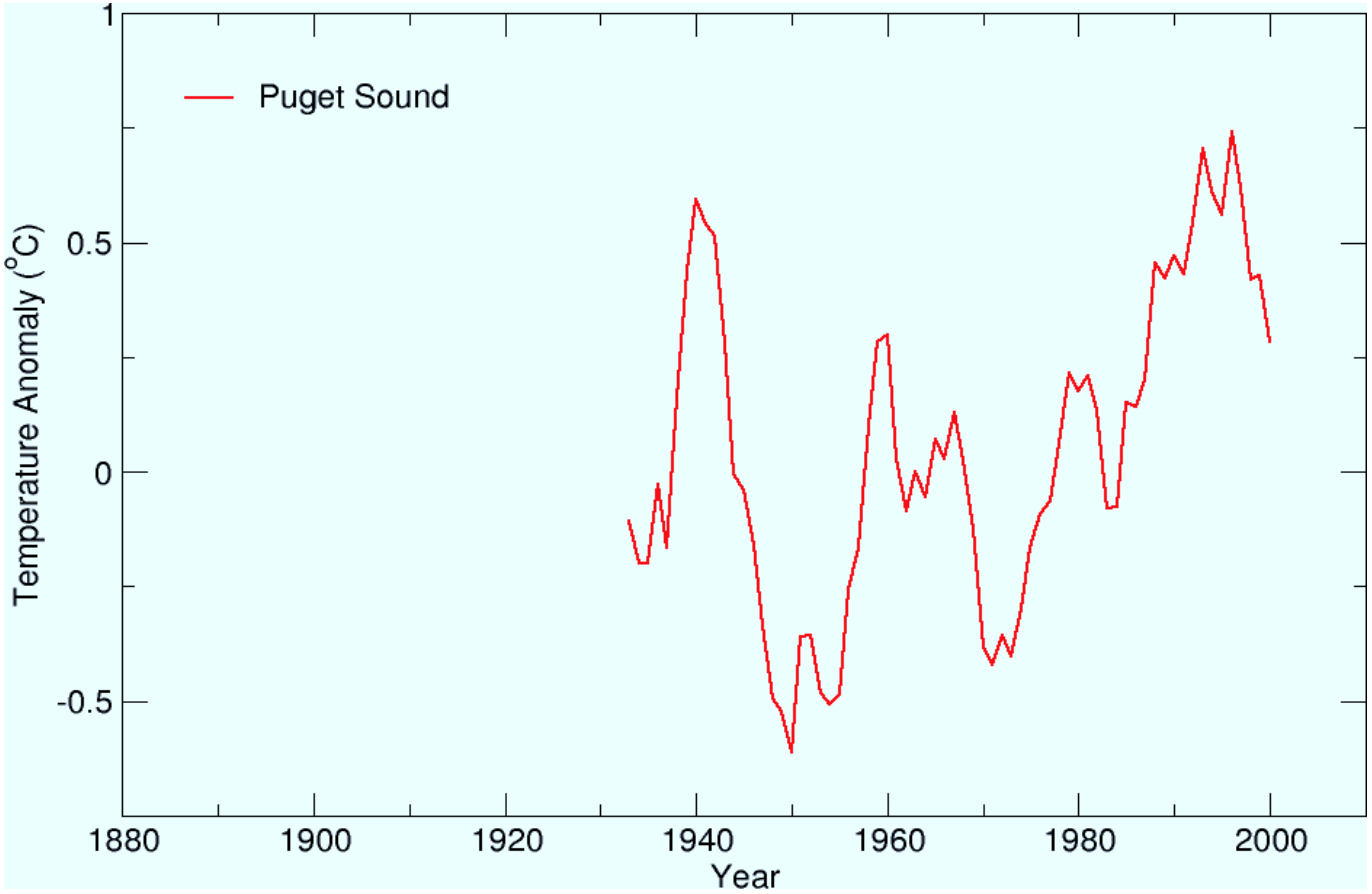
The benefits of evaluating global mean temperature is that it is global

Changes in instruments site exposure, etc. can be ignored so long as they are randomly distributed in time because we are averaging over many stations and random variations tend to average out.

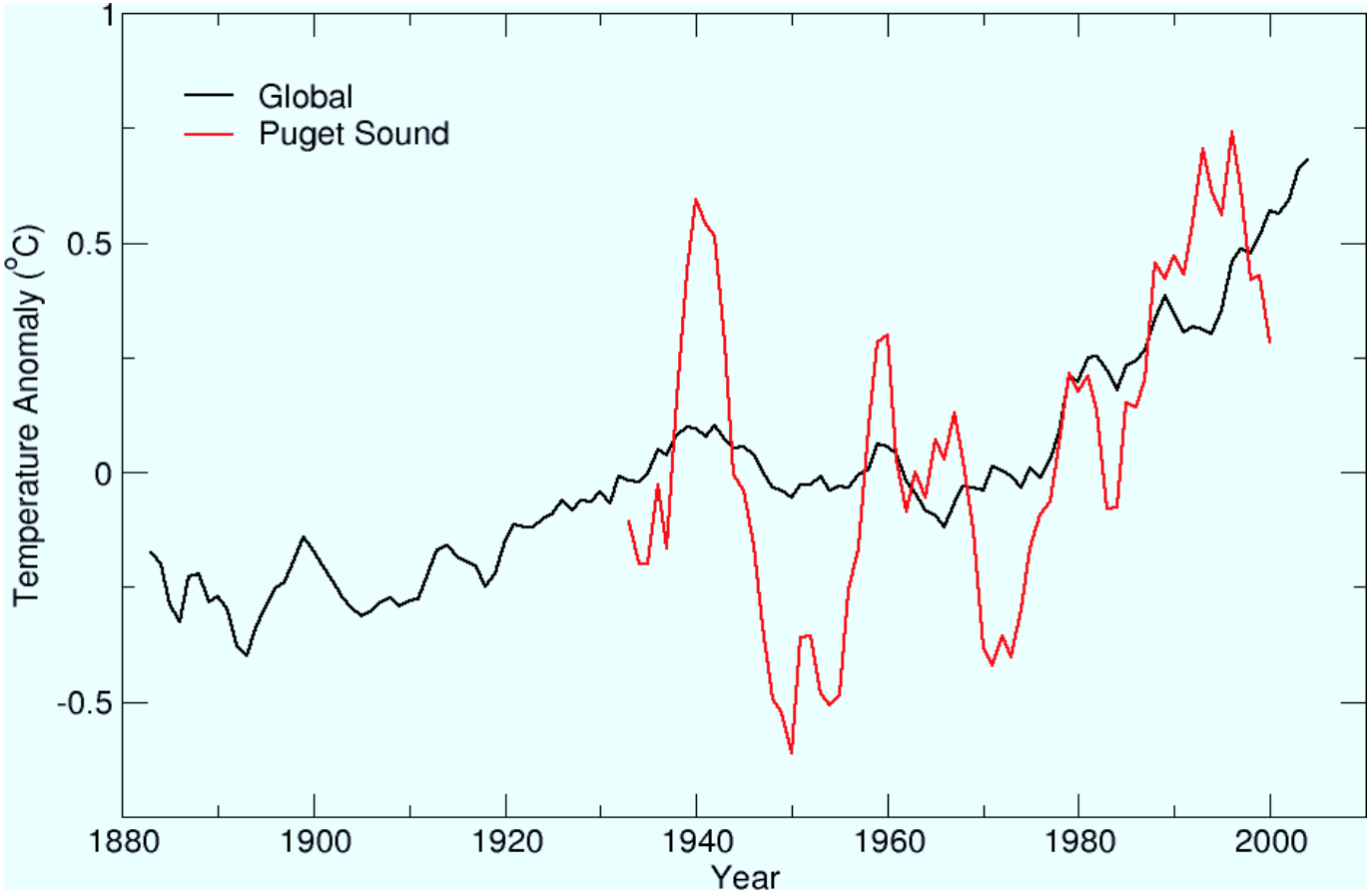
Similar long term temperature trends are seen in a subset of rural stations. Hence, urban sprawl evidently hasn't raised the global average temperature as much as one might think.

But adjustments are required if many stations experienced changes in instrumentation all around the same time.

Puget Sound compared to Global Mean



Puget Sound compared to Global Mean

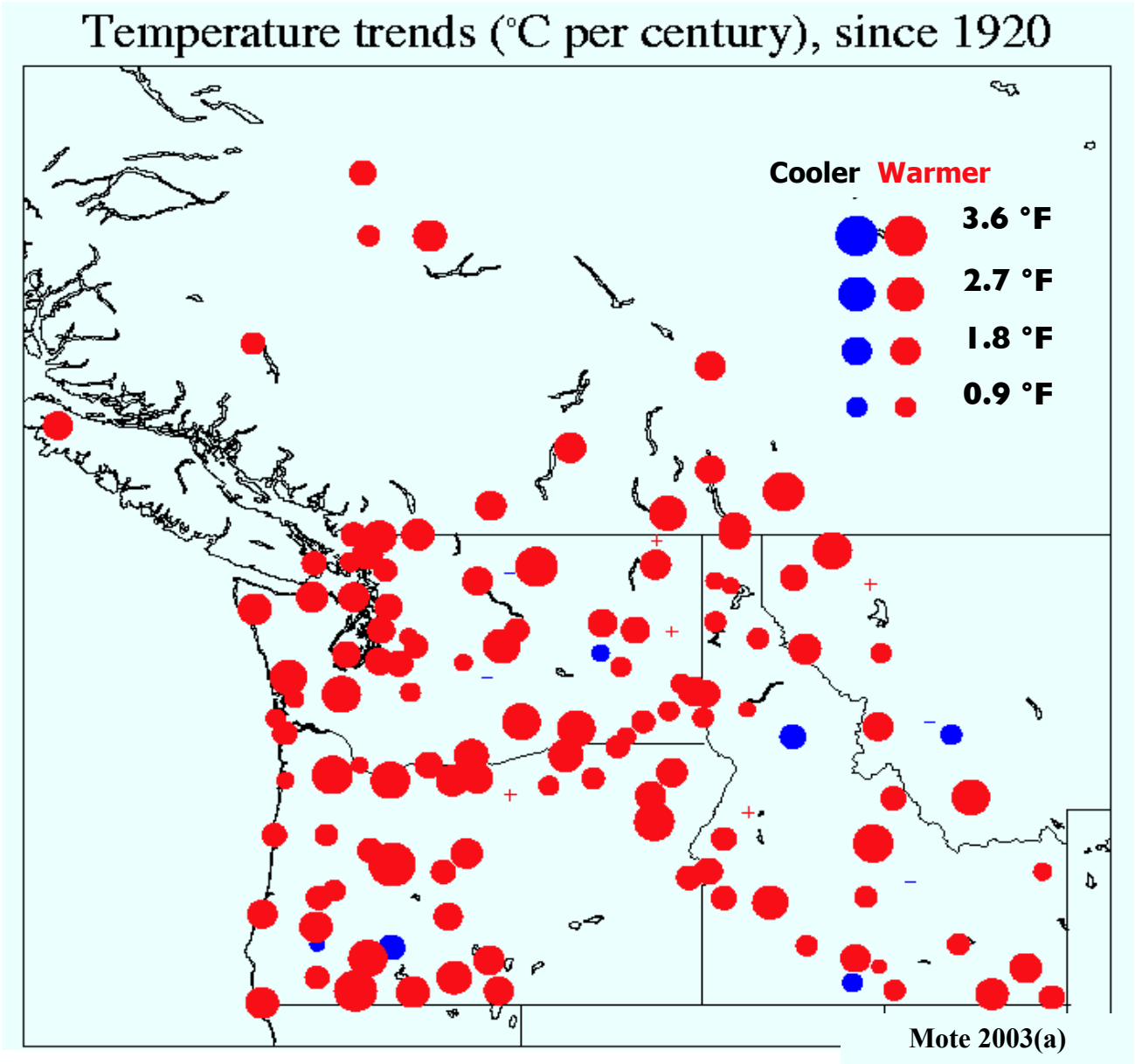


Temperature Trends by Station

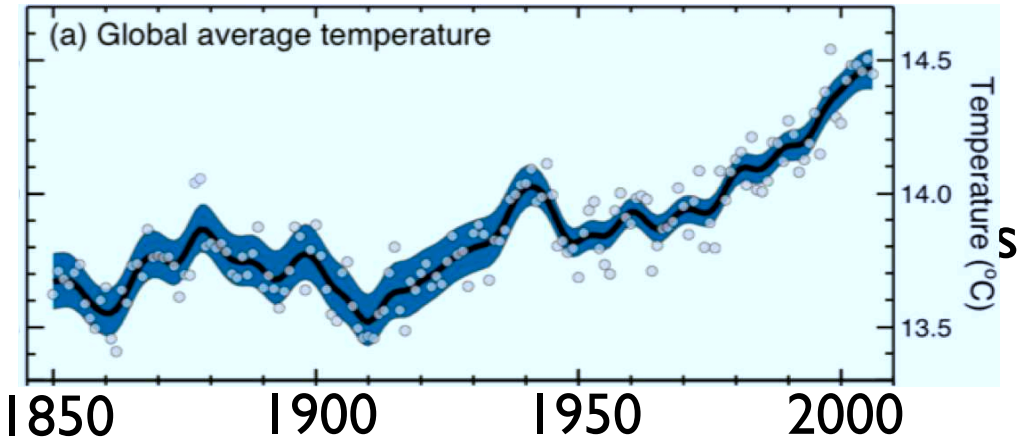
154 stations with long records

Almost every station shows **warming**

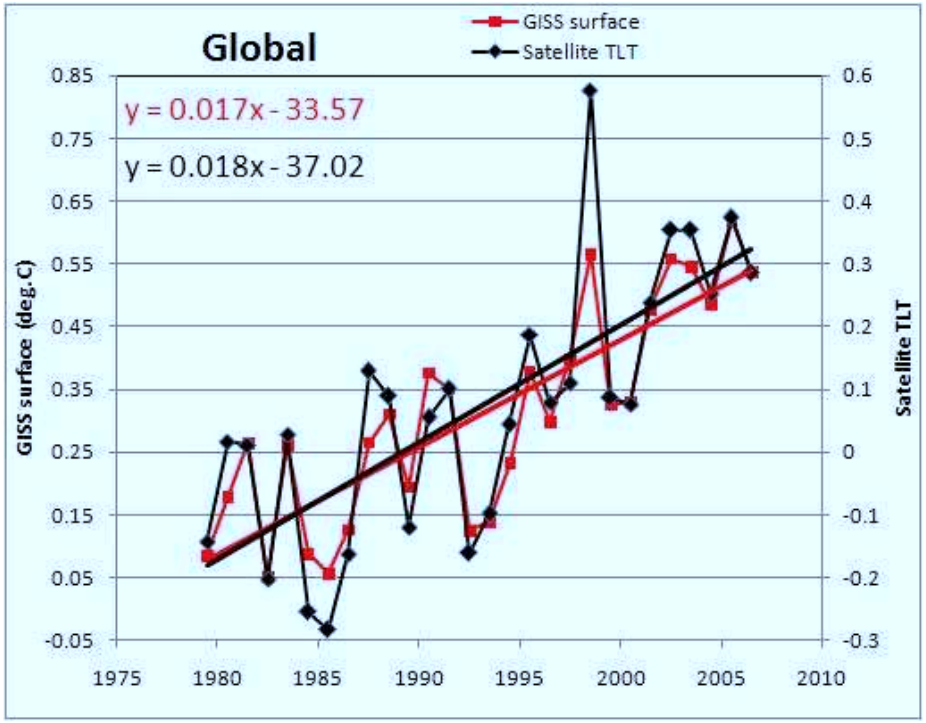
Urbanization **not** a major source of warming



Monitoring global temperatures
Two case studies

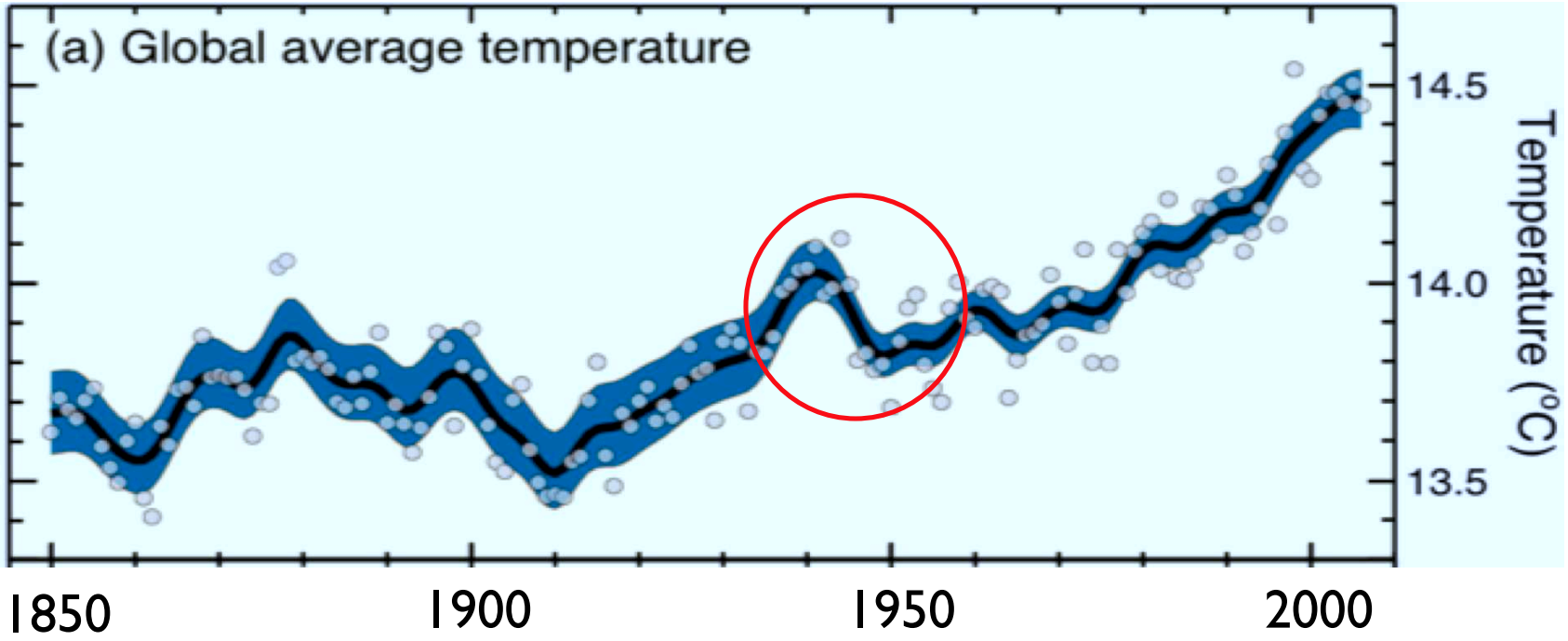


sea surface temperature



upper air temperature

Case study 1



Is this feature real?

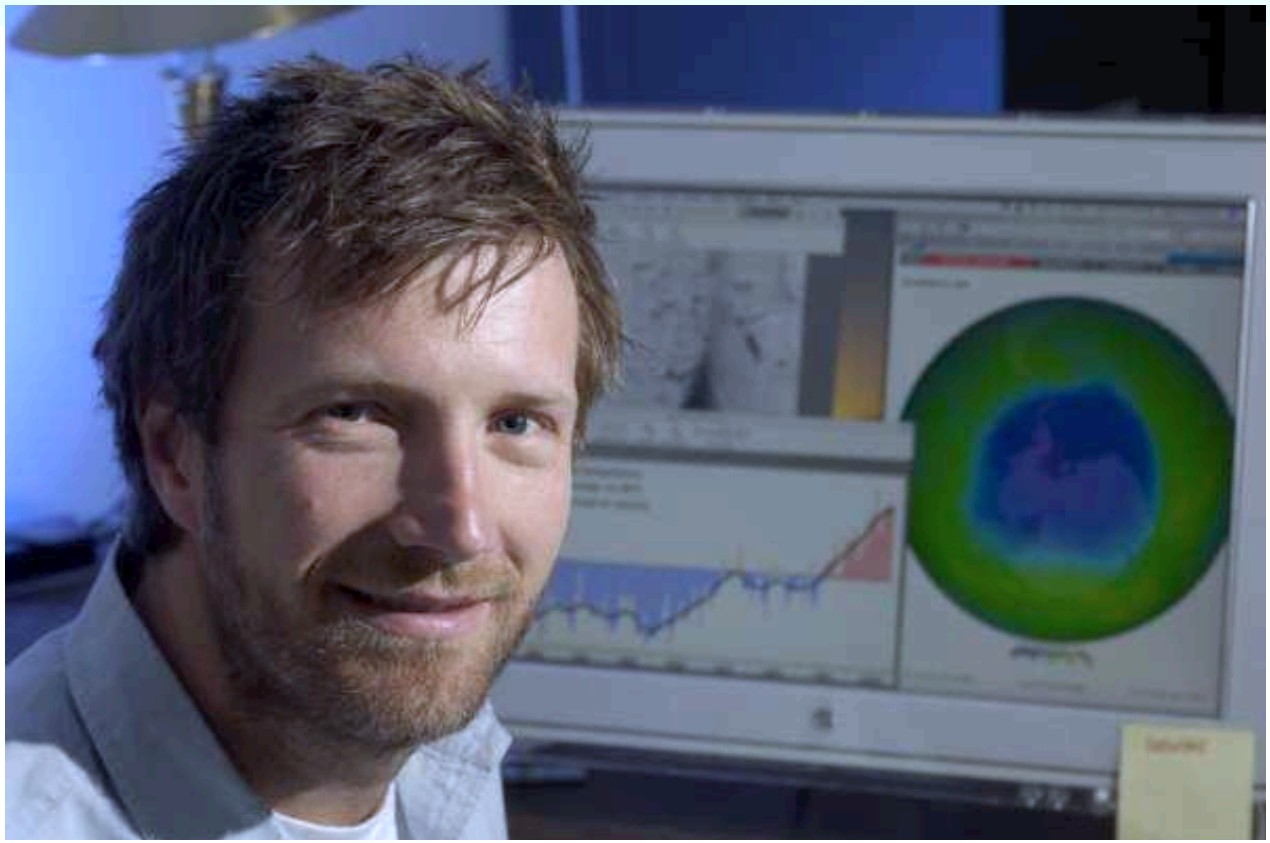
The accidental discovery that it isn't?

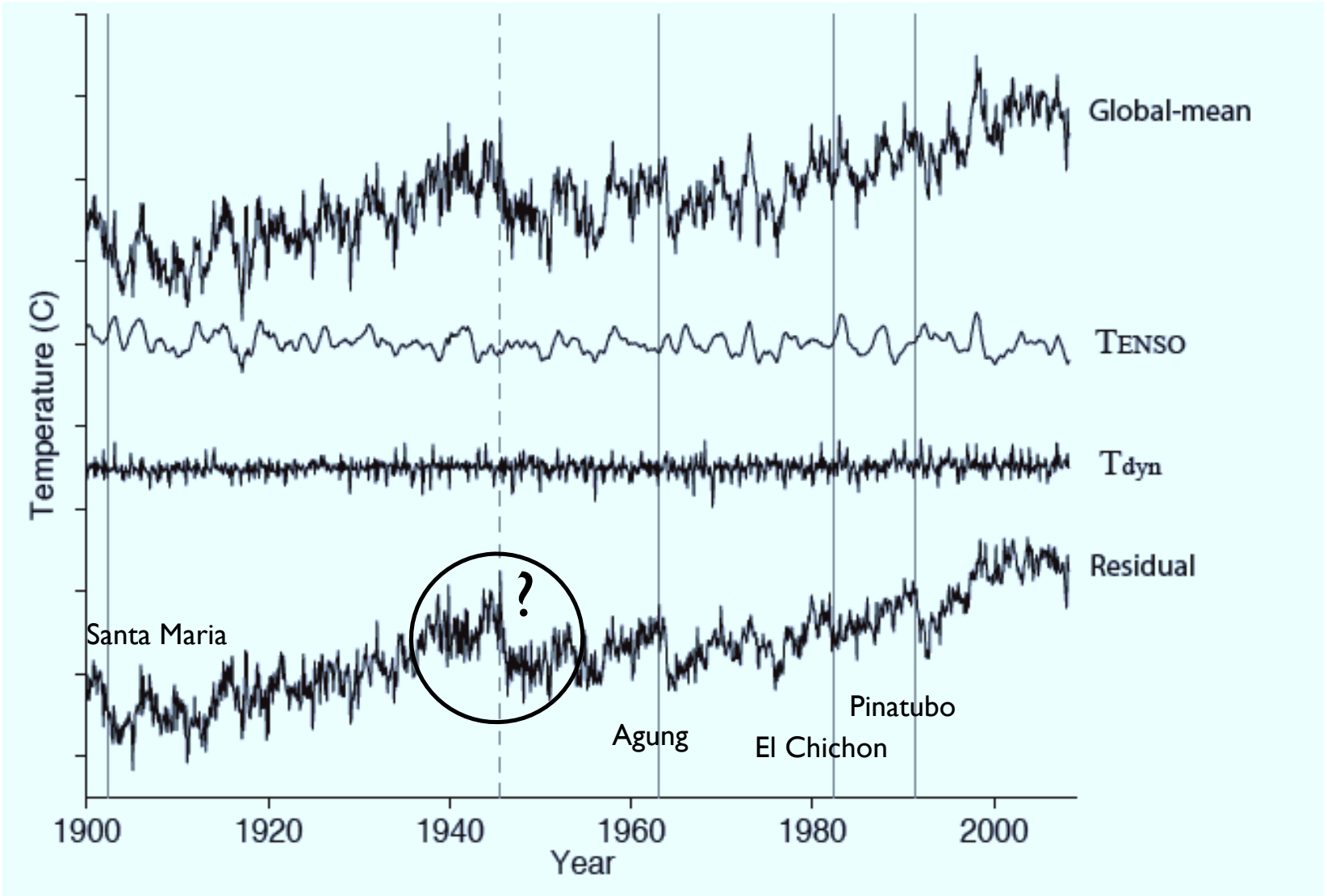
nature Vol 453|29 May 2008|doi:10.1038/nature06982

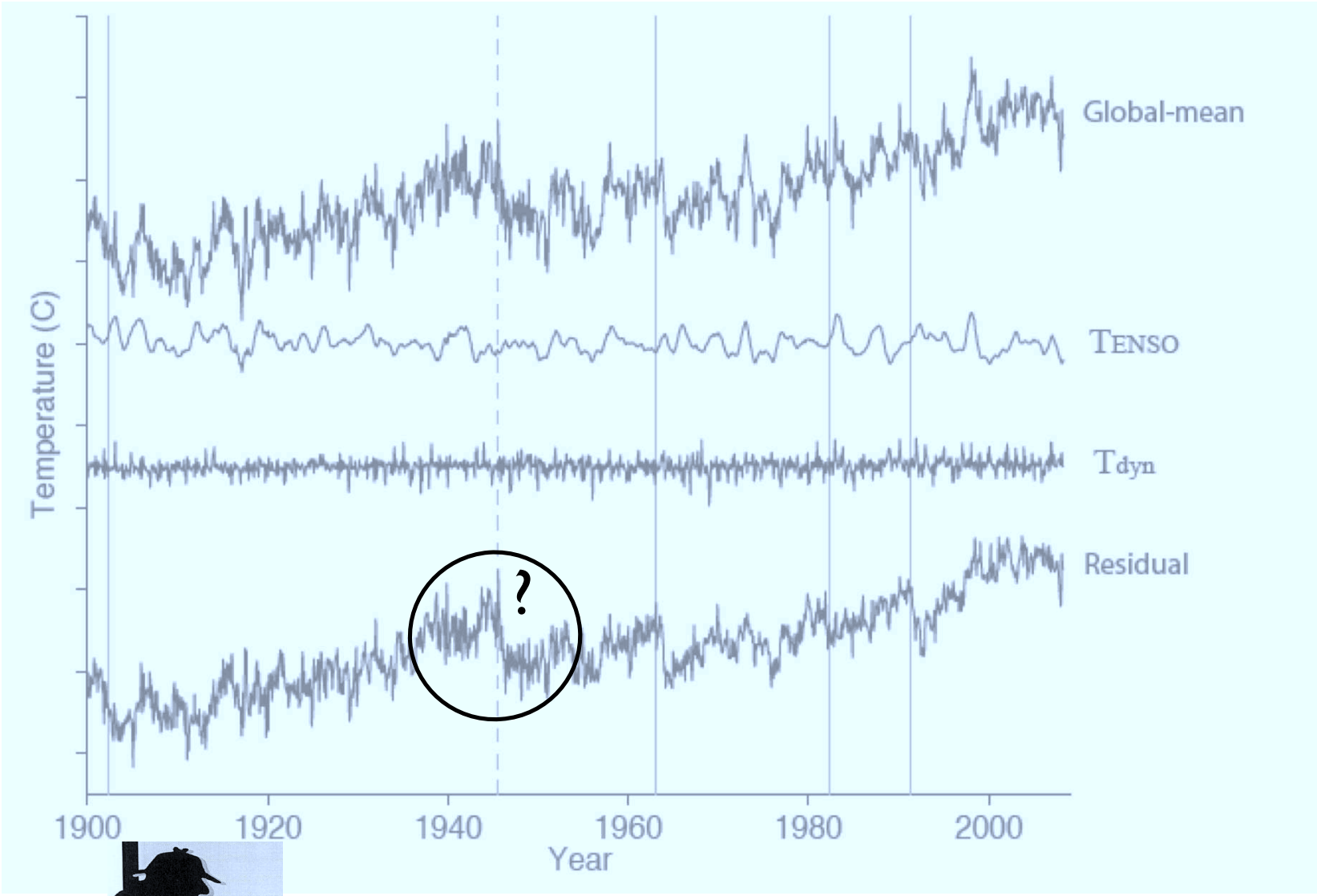
LETTERS

A large discontinuity in the mid-twentieth century in observed global-mean surface temperature

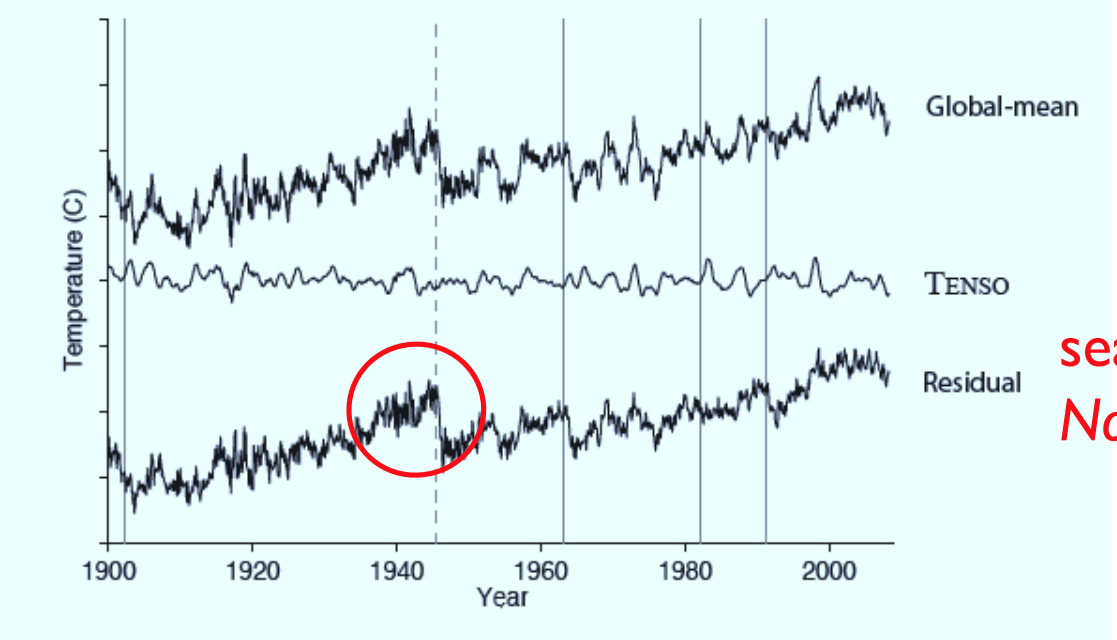
David W. J. Thompson[1], John J. Kennedy[2], John M. Wallace[3] & Phil D. Jones[4]




Temperature (C)
Global-mean
TENSO
Tdyn
Residual
?
Santa Maria
Agung
El Chichon
Pinatubo
1900
1920
1940
1960
1980
2000
Year

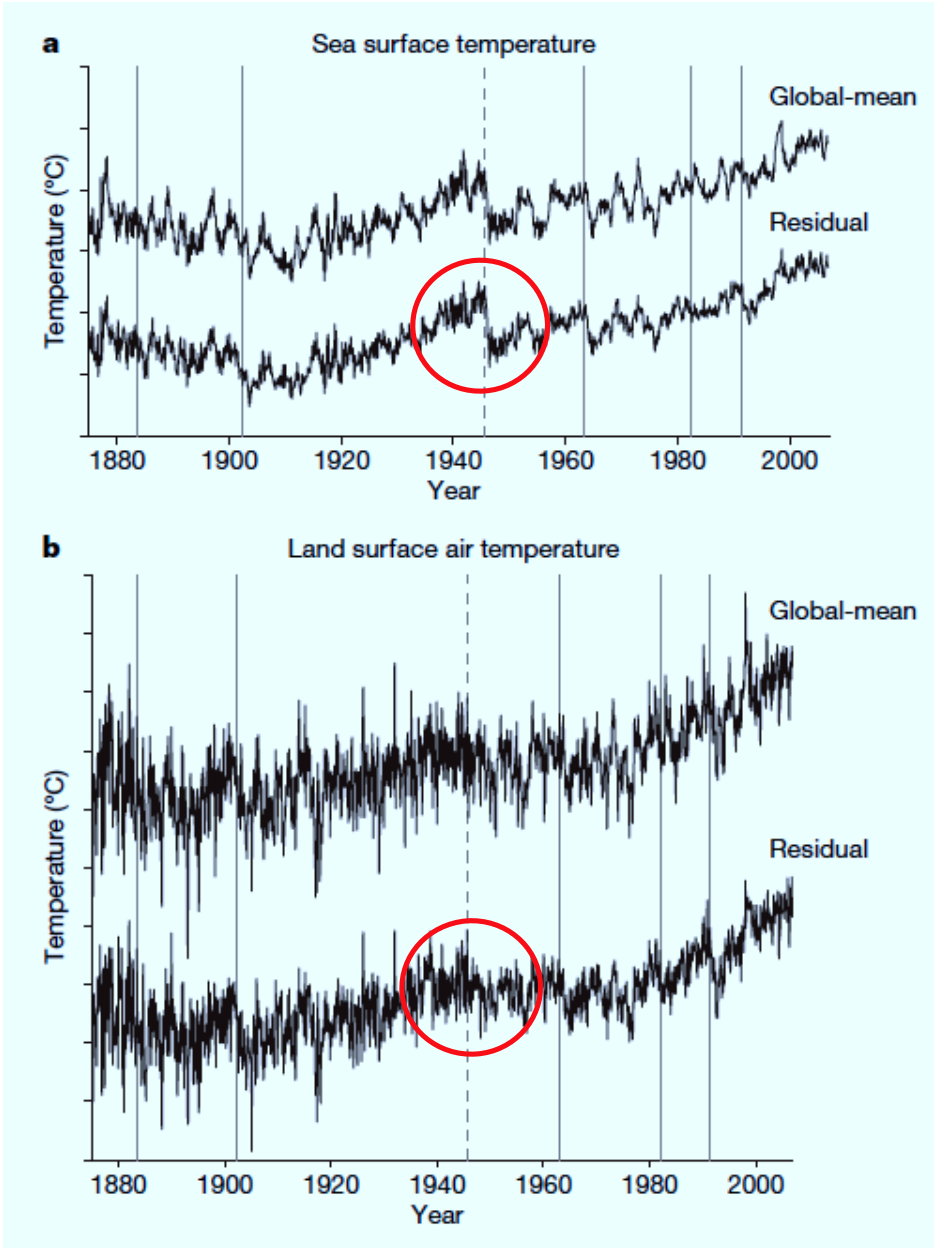


1945: Could it be the effect of the atomic bombs?



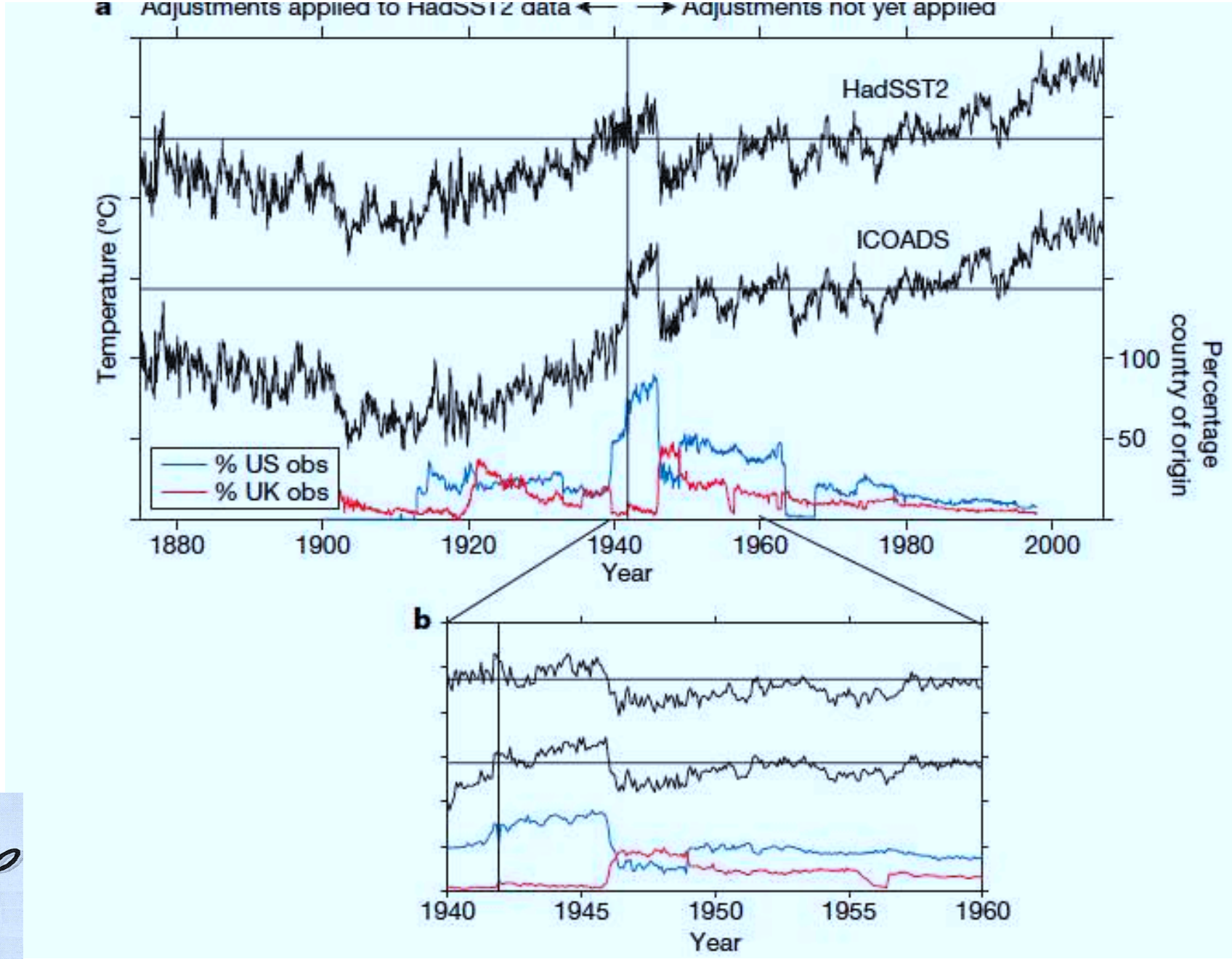
sea surface temperature:

Now you see it!

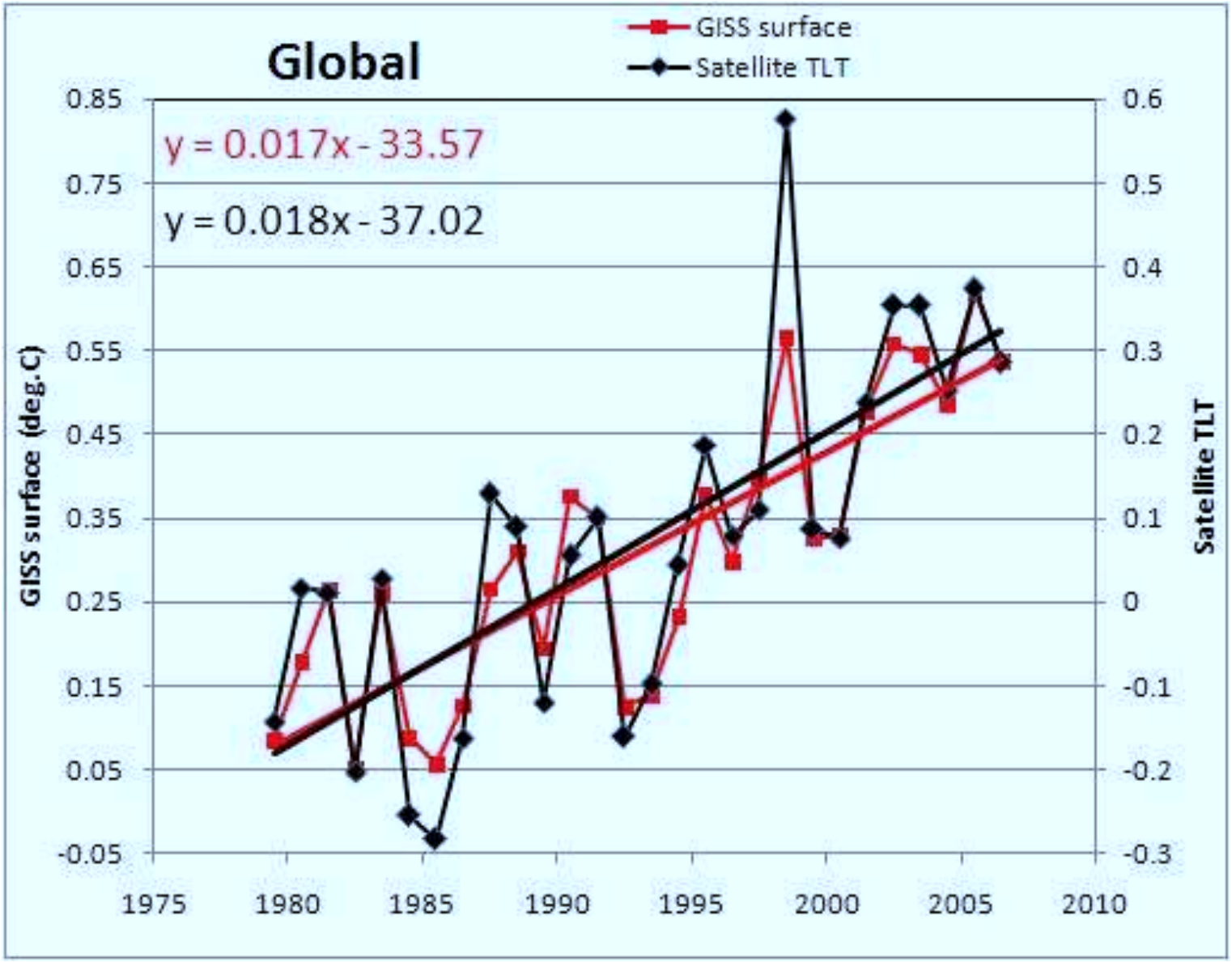


sea surface temperature:
Now you see it!

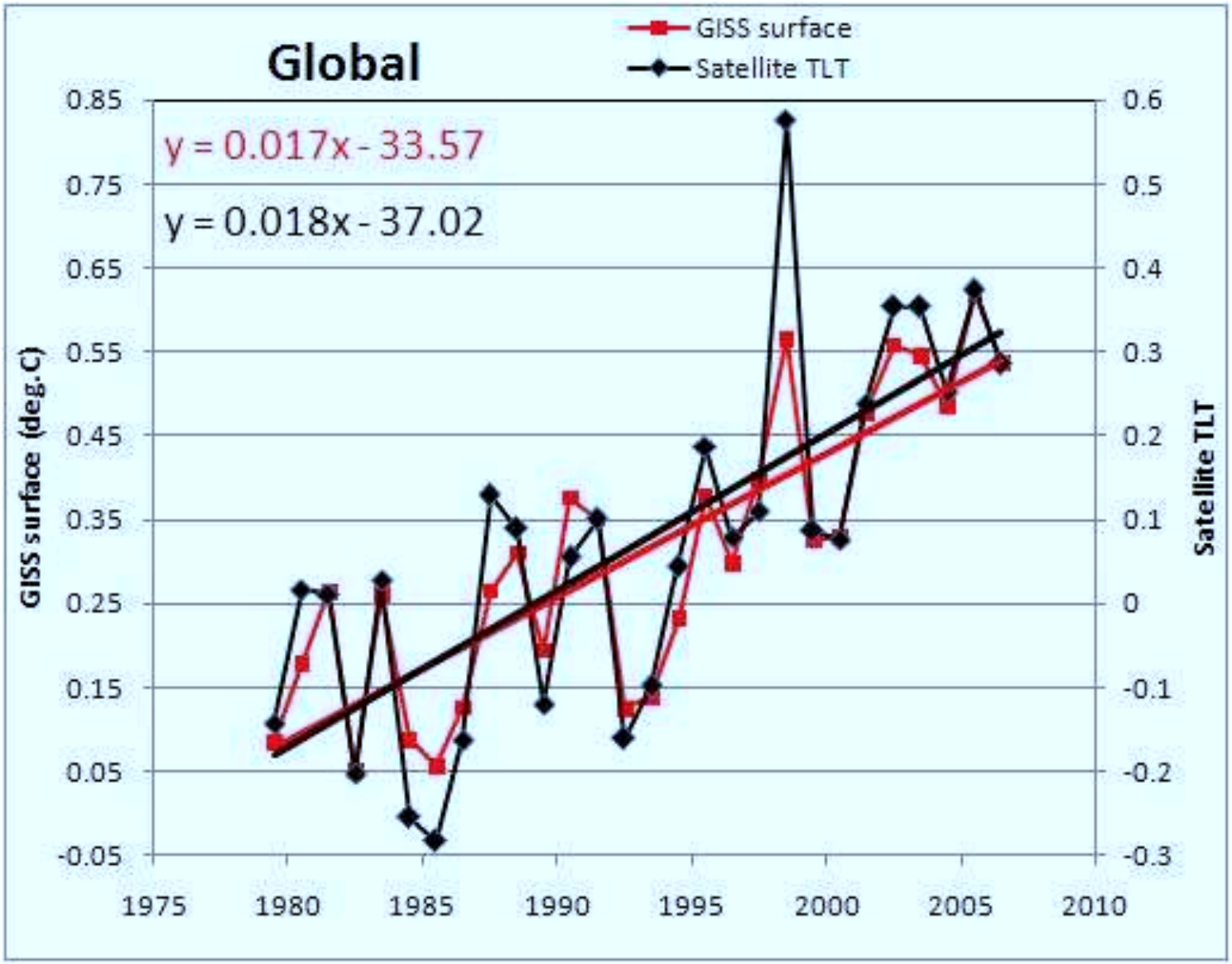
land surface air temperature:
Now you don't!


a
Adjustments applied to HadSST2 data
Adjustments not yet applied
HadSST2
ICOADS
Temperature (°C)
% US obs
% UK obs
Percentage country of origin
100
50
1880
1900
1920
1940
1960
1980
2000
Year
b
1940
1945
1950
1955
1960
Year

Case study 2: Heat at a Height



Lower troposphere from MSU vs. GISS surface based measurements



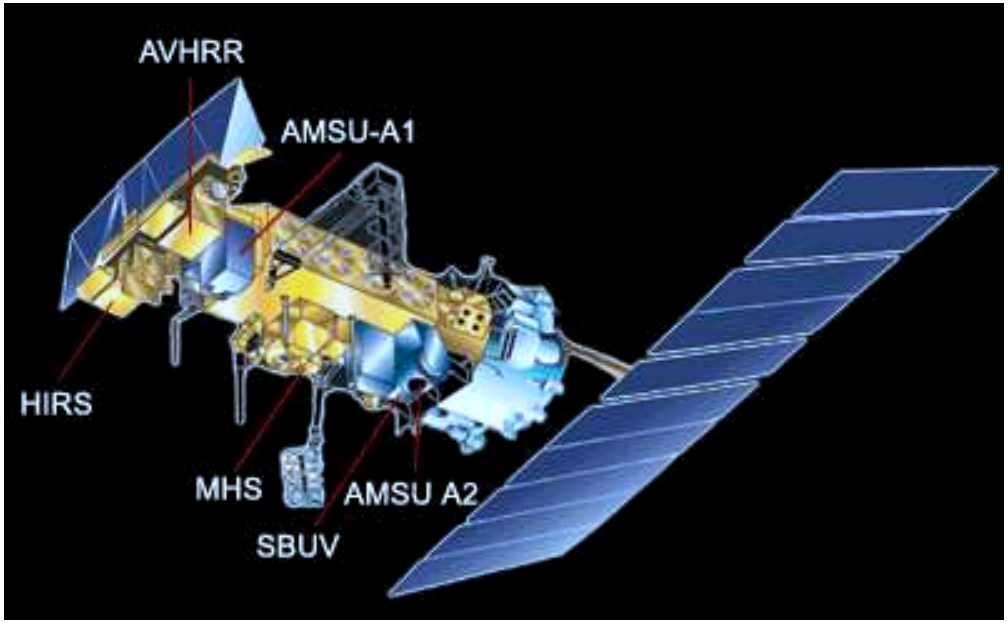
Remote temperature sensing

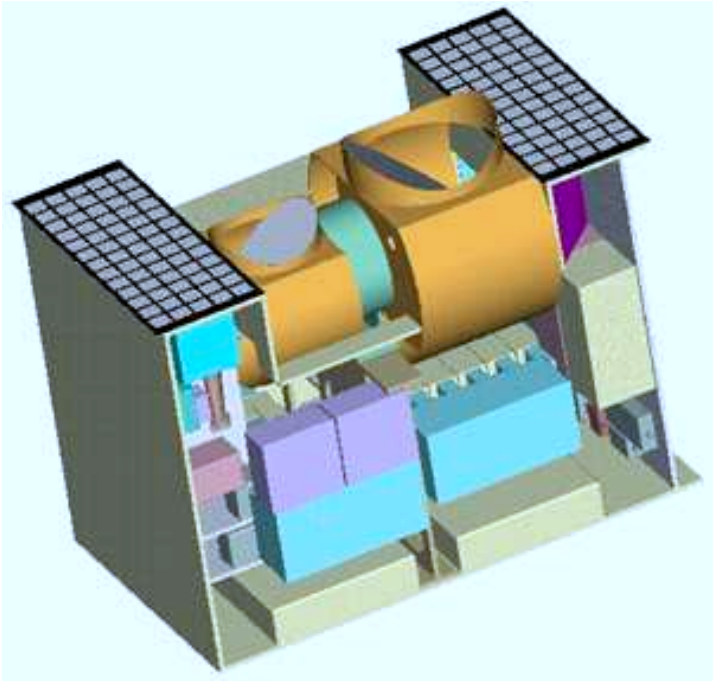
the microwave sounding unit (MSU): since 1979

works like infrared thermometer

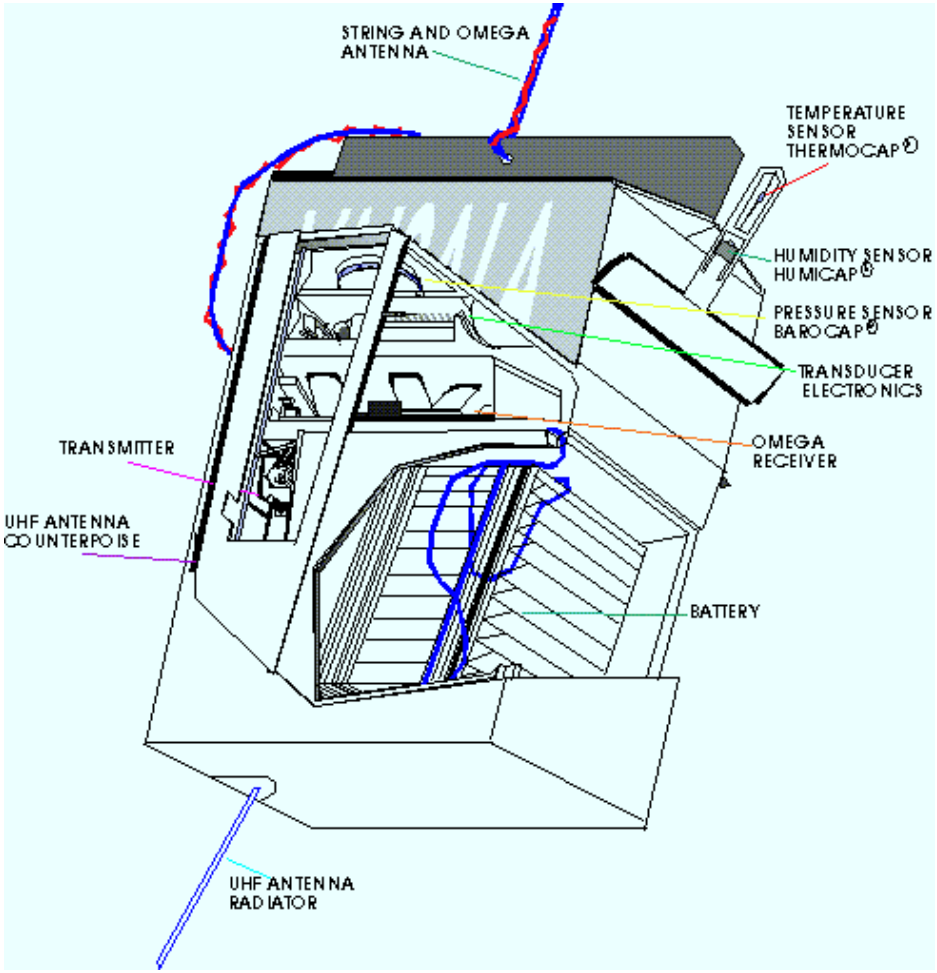
multiple wavelength channels give temperature readings at multiple levels

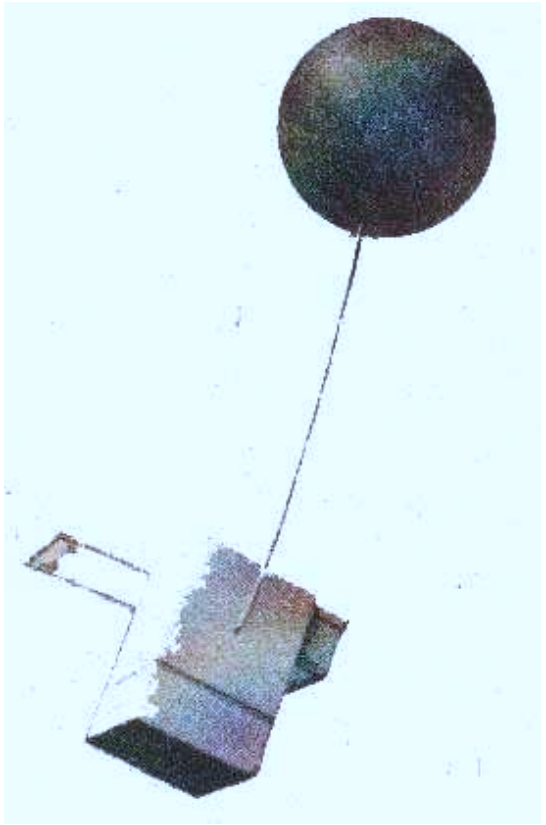
global coverage twice daily



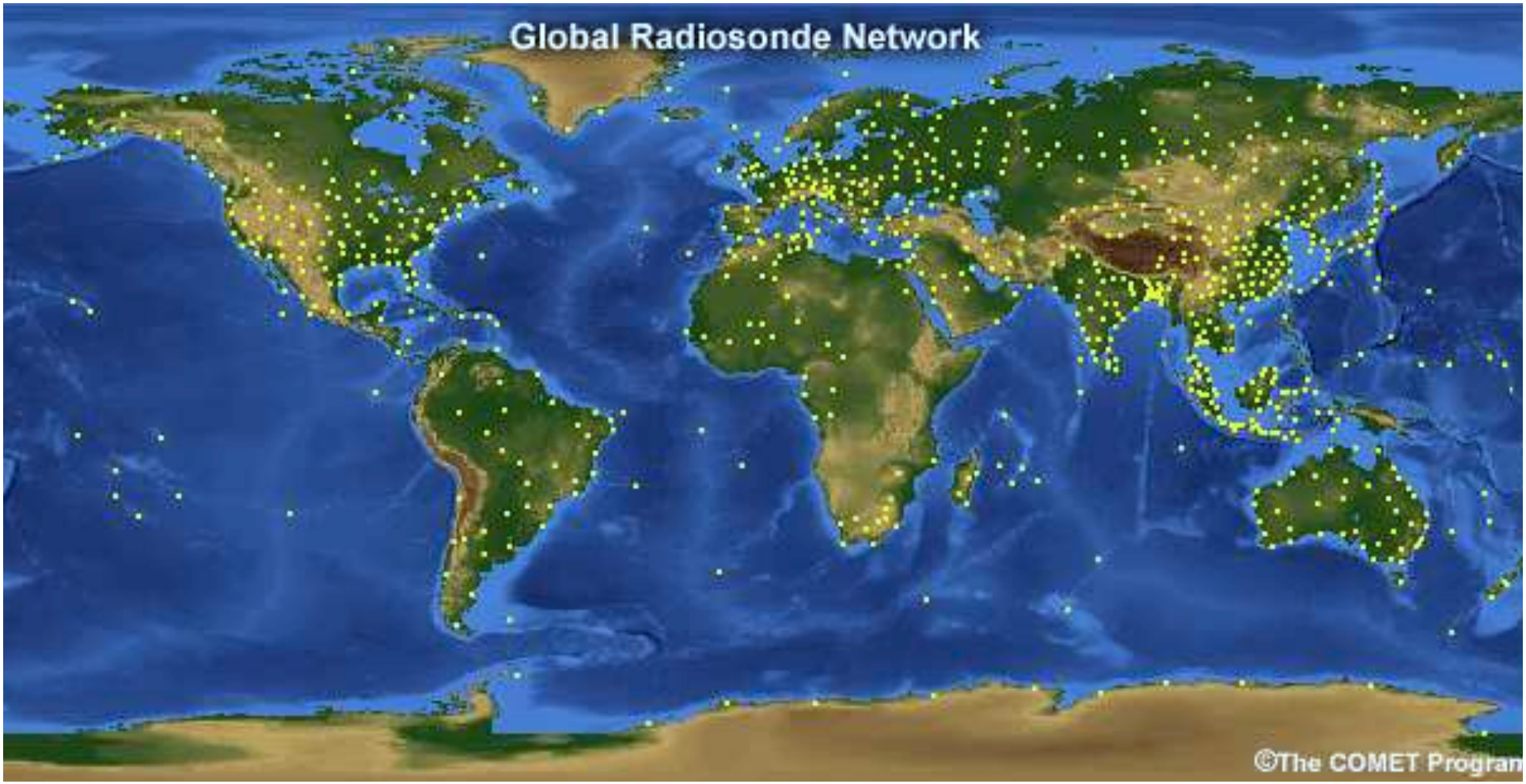


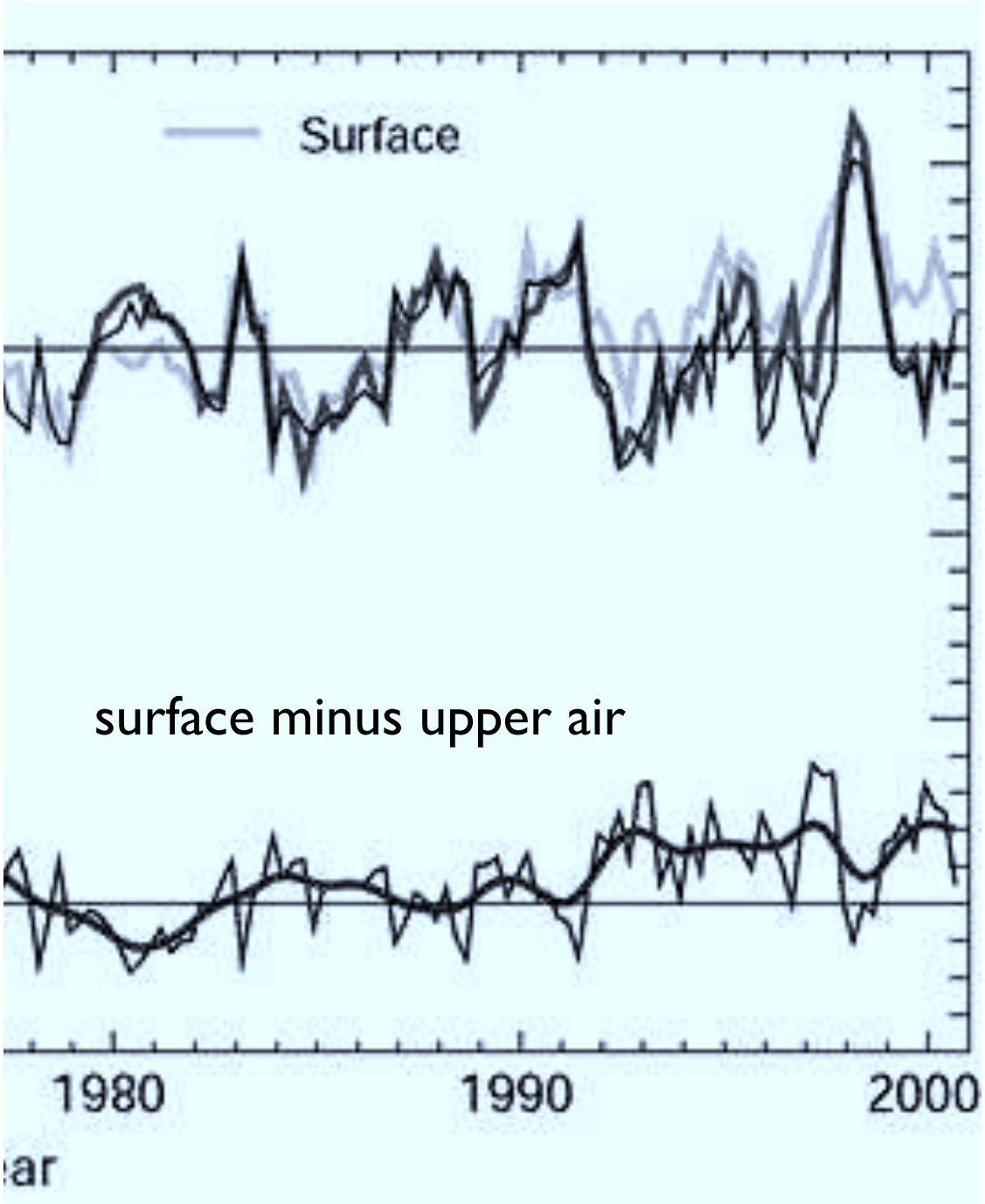
Upper air observations





Radiosondes: since 1946


Global Radiosonde Network
©The COMET Program

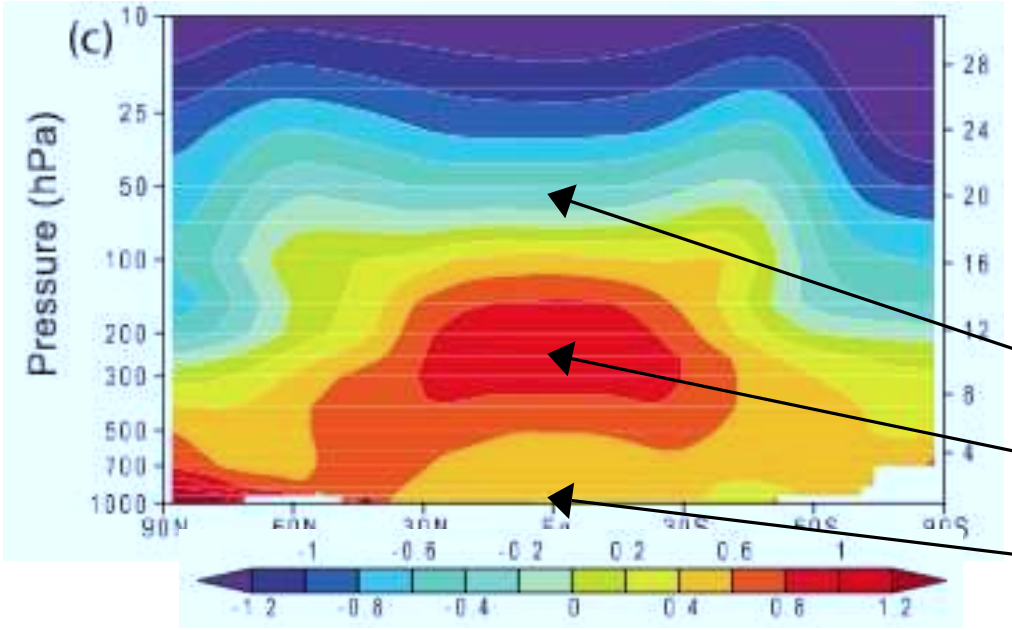


2001 IPCC Report

Noted: Surface warmed much faster than upper atmosphere (black lines are balloons and MSU)

Yet: Both are supposed to heat up together.

Figure used to discuss Lapse Rate Feedback
Higher tropospheric warming is seen in climate models and expected for a moist atmosphere

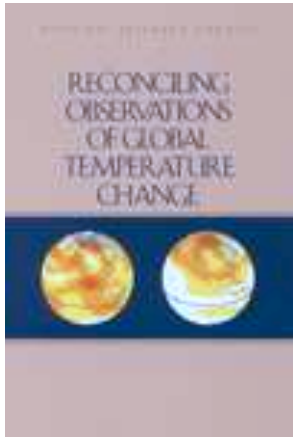


In degree C per century

Simulated zonal temperature change (1890-1999) in one climate model

- -0.5C strato
- +1C tropo
- +0.5C surface

Stratospheric cooling is expected from higher outgoing LW radiation



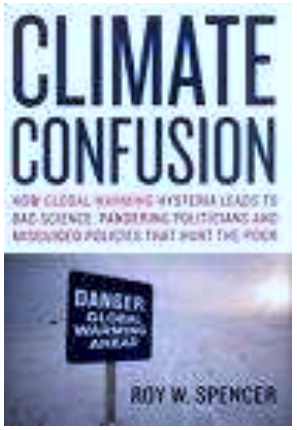
In 2000 a panel convened by the National Academy of Sciences said:

"Major advances in the ability to interpret and model the subtle variations in the vertical temperature profile of the lower atmosphere" are needed… In other words, in 2000 we needed to figure out how the earth's surface can be heating up while the middle layers of the atmosphere are not.

Skeptics said: The satellite data are more comprehensive and more accurate than the surface data. Those who claim that the earth is overheating are just blowing hot air. If the global warming modelers admitted that, their gravy train would derail.

paraphrased from panel chair J. M. Wallace

Prior to 2001, global warming skeptics Spencer and Christy and the UAH team were the sole producers of the MSU satellite estimates



Roy Spencer, NASA

John Christy, UAH

Contribution of stratospheric cooling to satellite-inferred tropospheric temperature trends

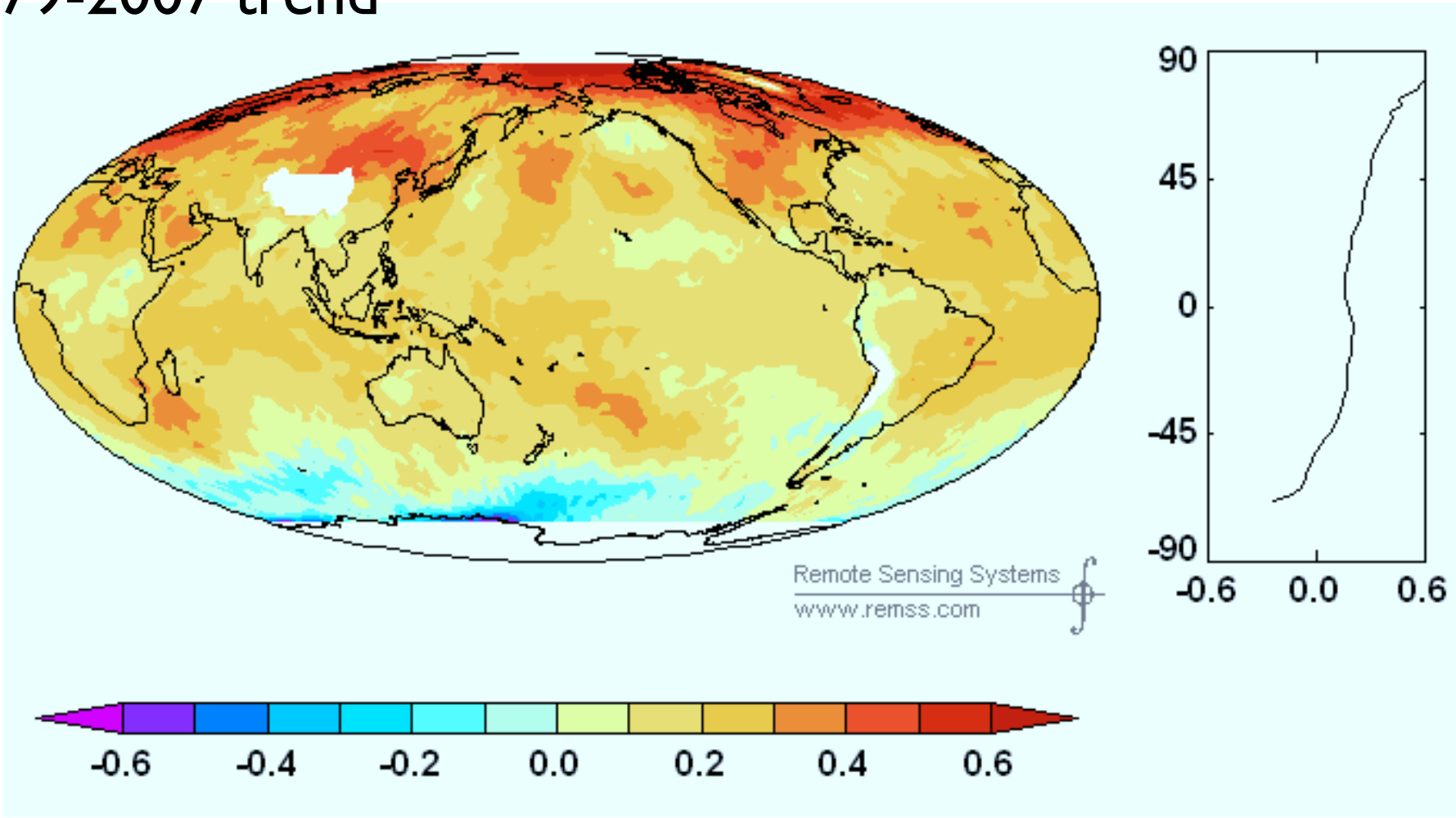
Qiang Fu[1], Celeste M. Johanson[1], Stephen G. Warren[1] & Dian J. Seidel[2]

[1]*Department of Atmospheric Sciences, University of Washington, Seattle, Washington 98195, USA*
[2]*NOAA Air Resources Laboratory, Silver Spring, Maryland 20910, USA*

The RSS team now offers an independent estimates of trends and shows much more significant warming. The group identified an error in the algorithm used by Spencer and Christy. Spencer and Christy have acknowledged the error in their algorithm,

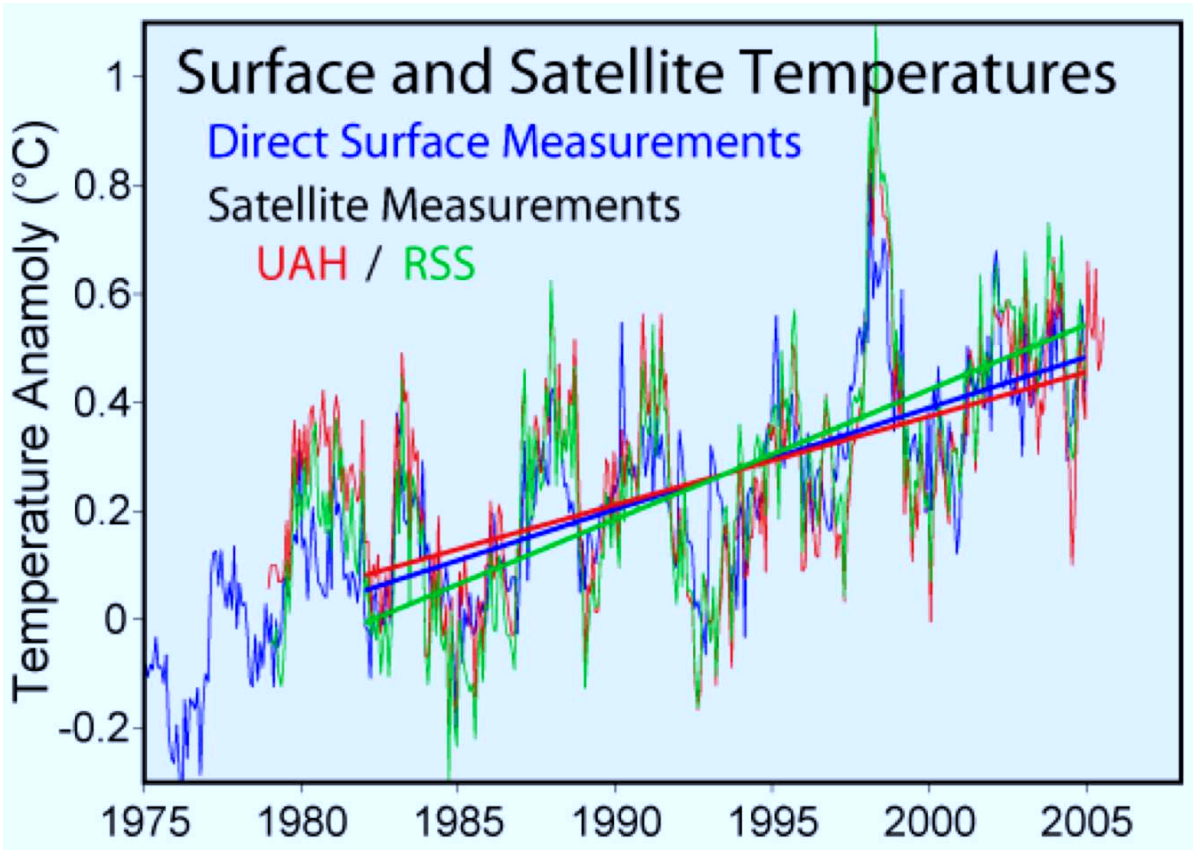
The RSS team in fact show substantial upper air warming

1979-2007 trend



deg C in 29 years

The surface and (satellite derived) atmospheric temperature trends are not inconsistent with what is expected with human forced global warming



The apparent difference between the surface and (satellite derived) atmospheric temperature trends has been resolved

Take home messages from the two case studies

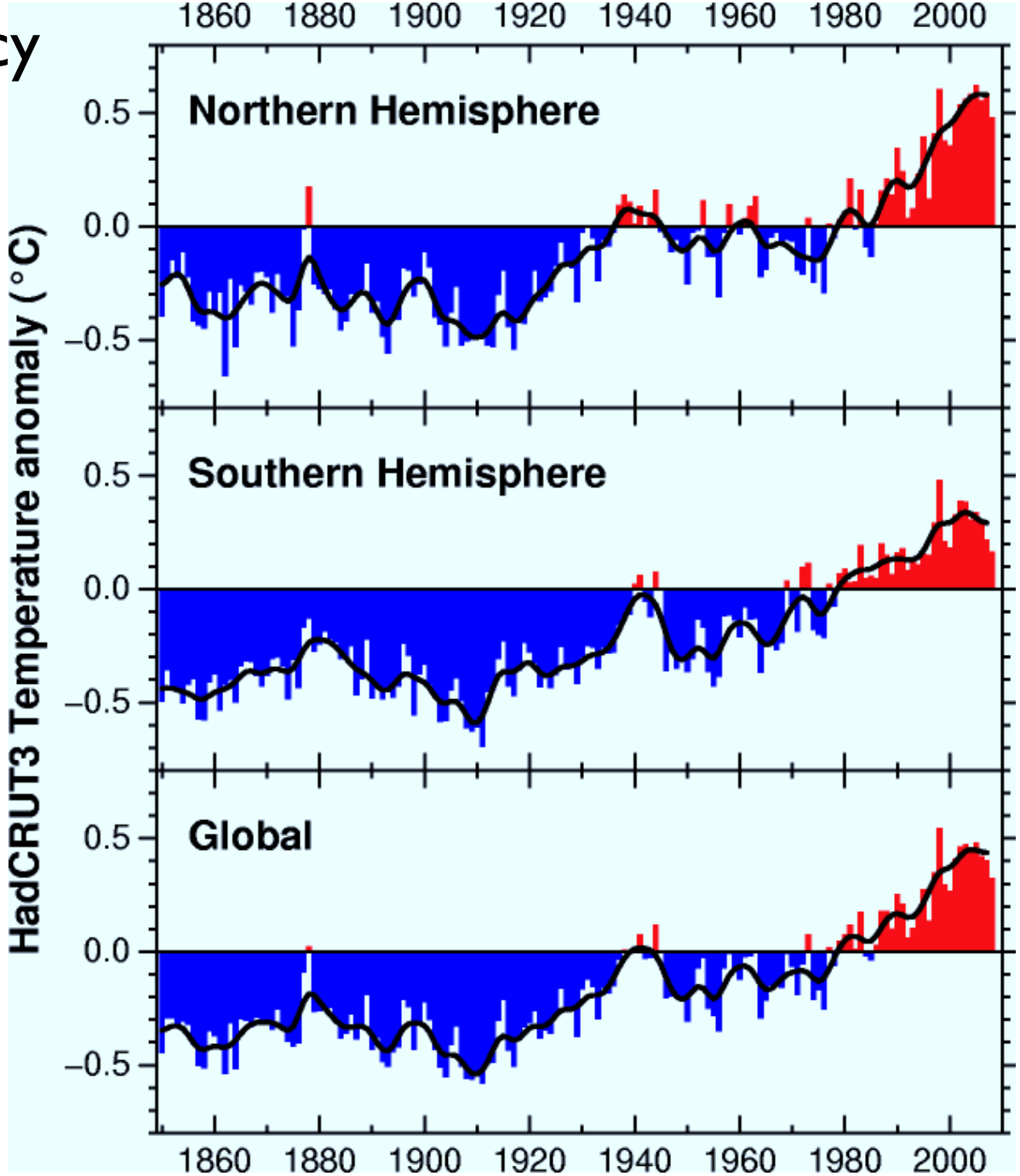
- value of curiosity-driven research
- value of cross-checking results, redundancy

Evidence of 20th-century warming is compelling

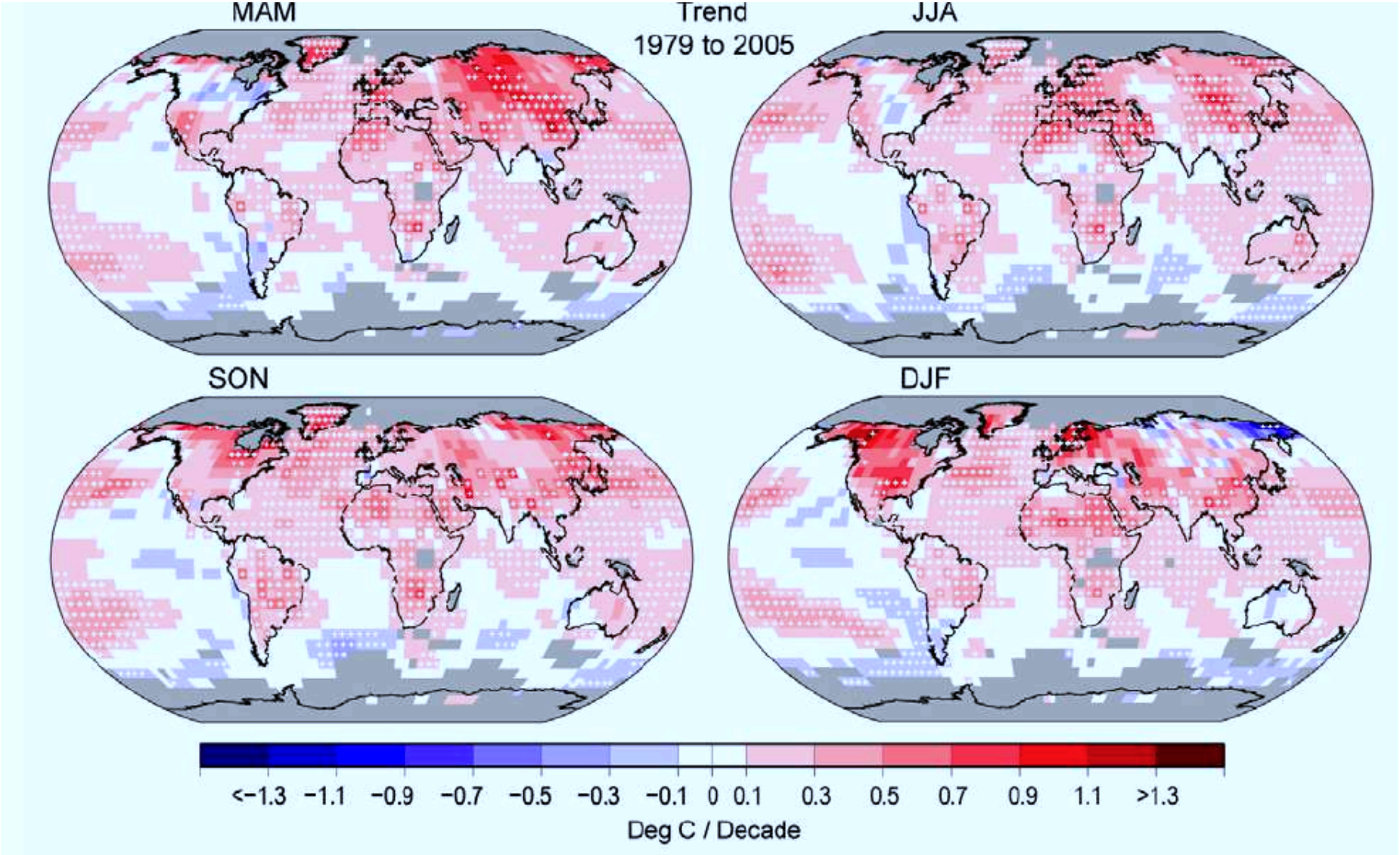
Snowmageddon

Evidence of consistency

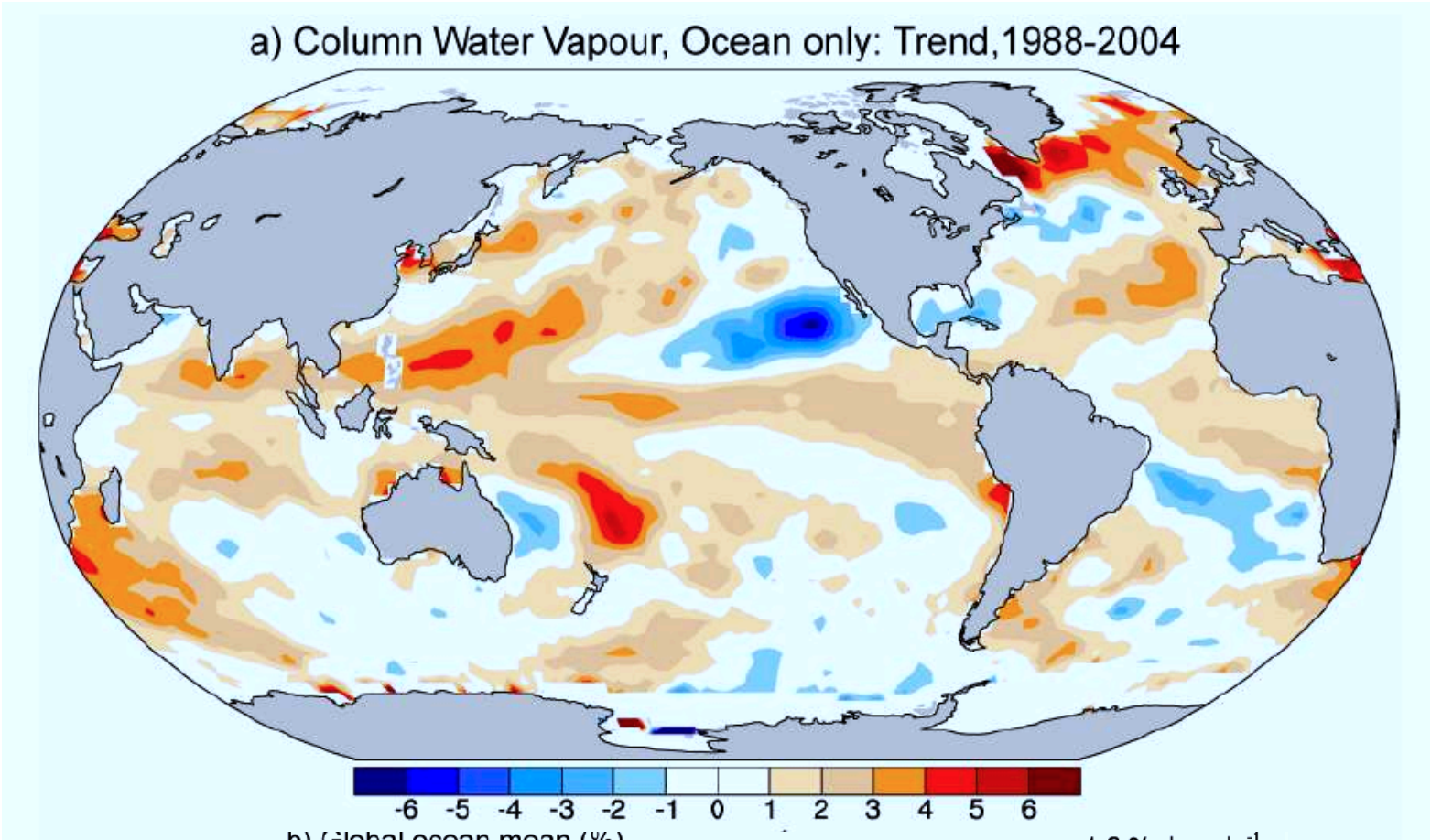
Northern vs. Southern Hemispheres



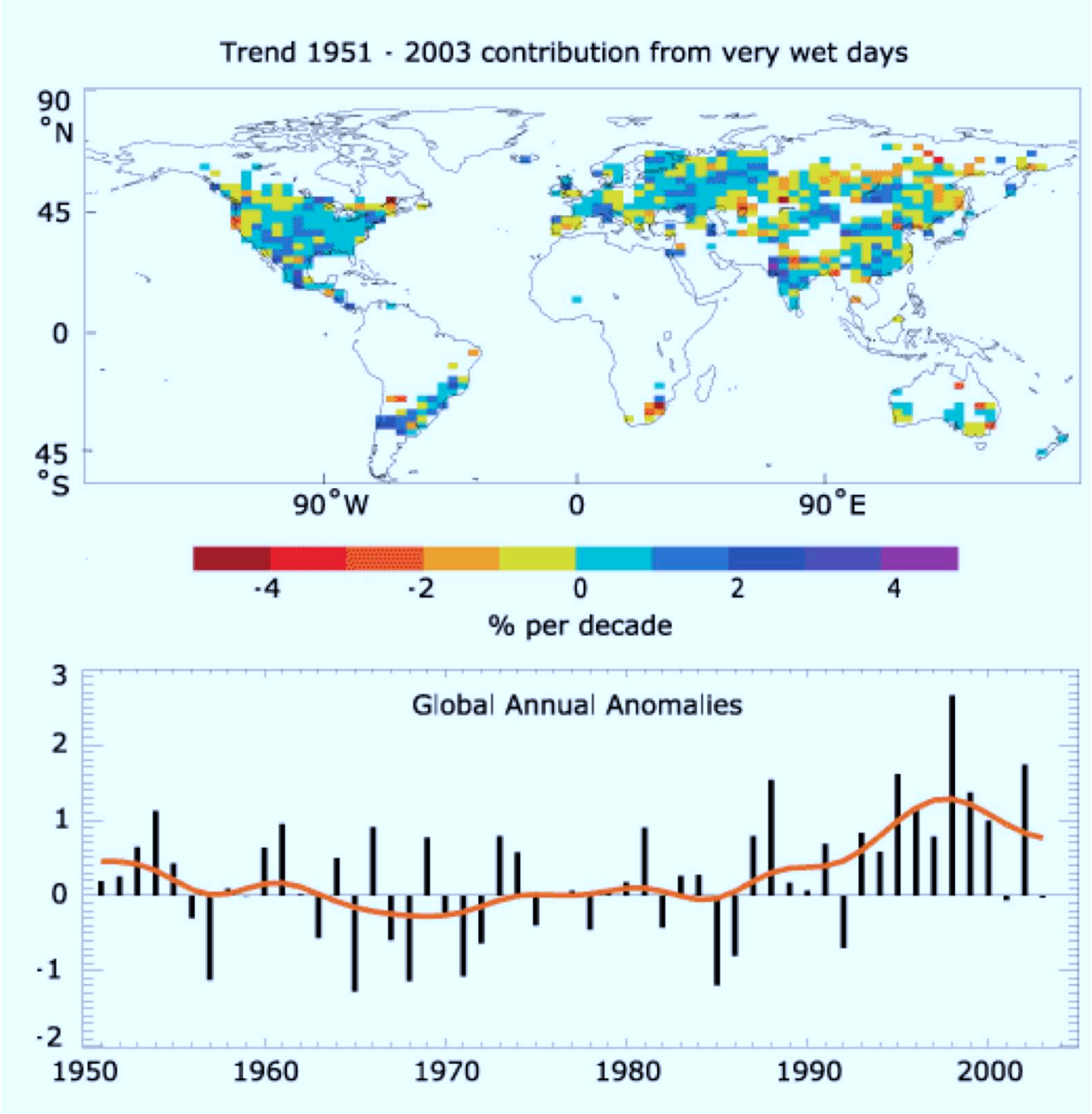
Consistency with season



Water vapor concentration is increasing



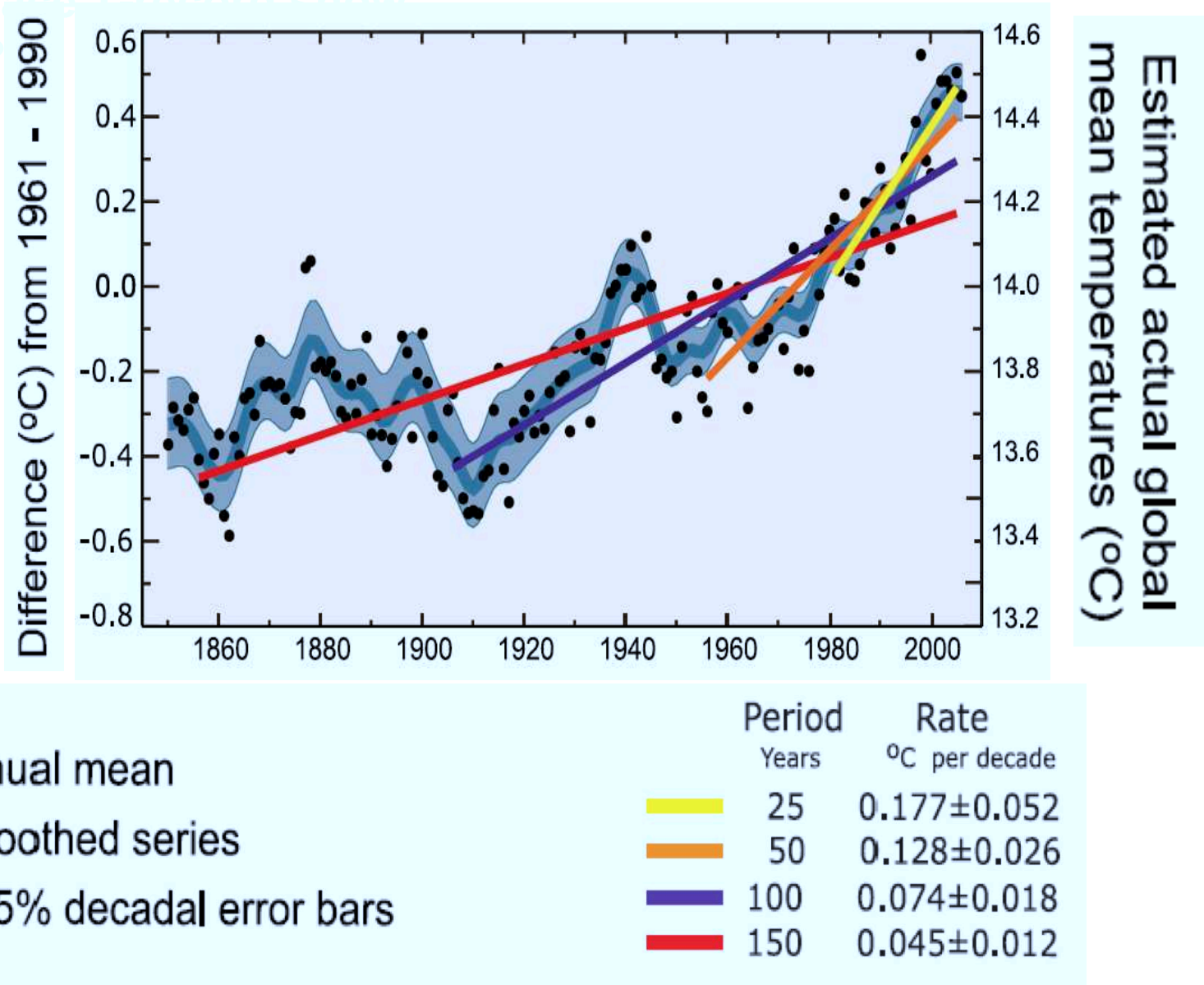
A larger % of the annual rainfall is falling on the wettest days



Does the surface temperature record show warming?

Yes: trend analysis reveals <u>accelerated</u> warming

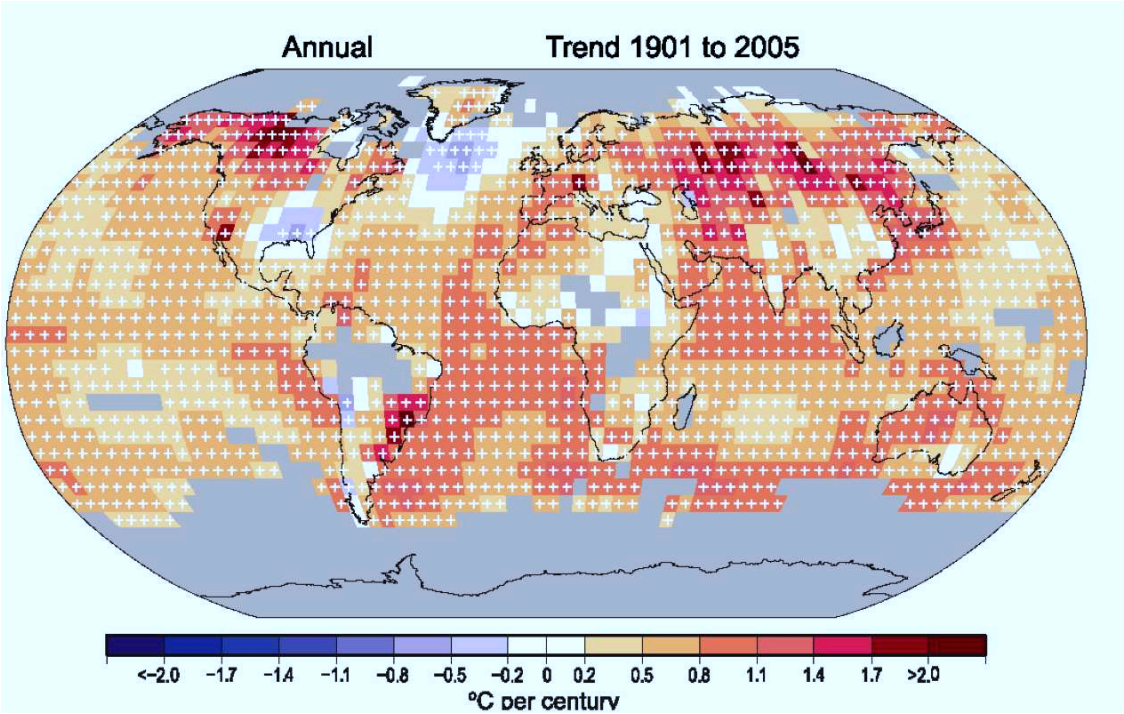
IPCC, 2007
WG I
Fig TS.6



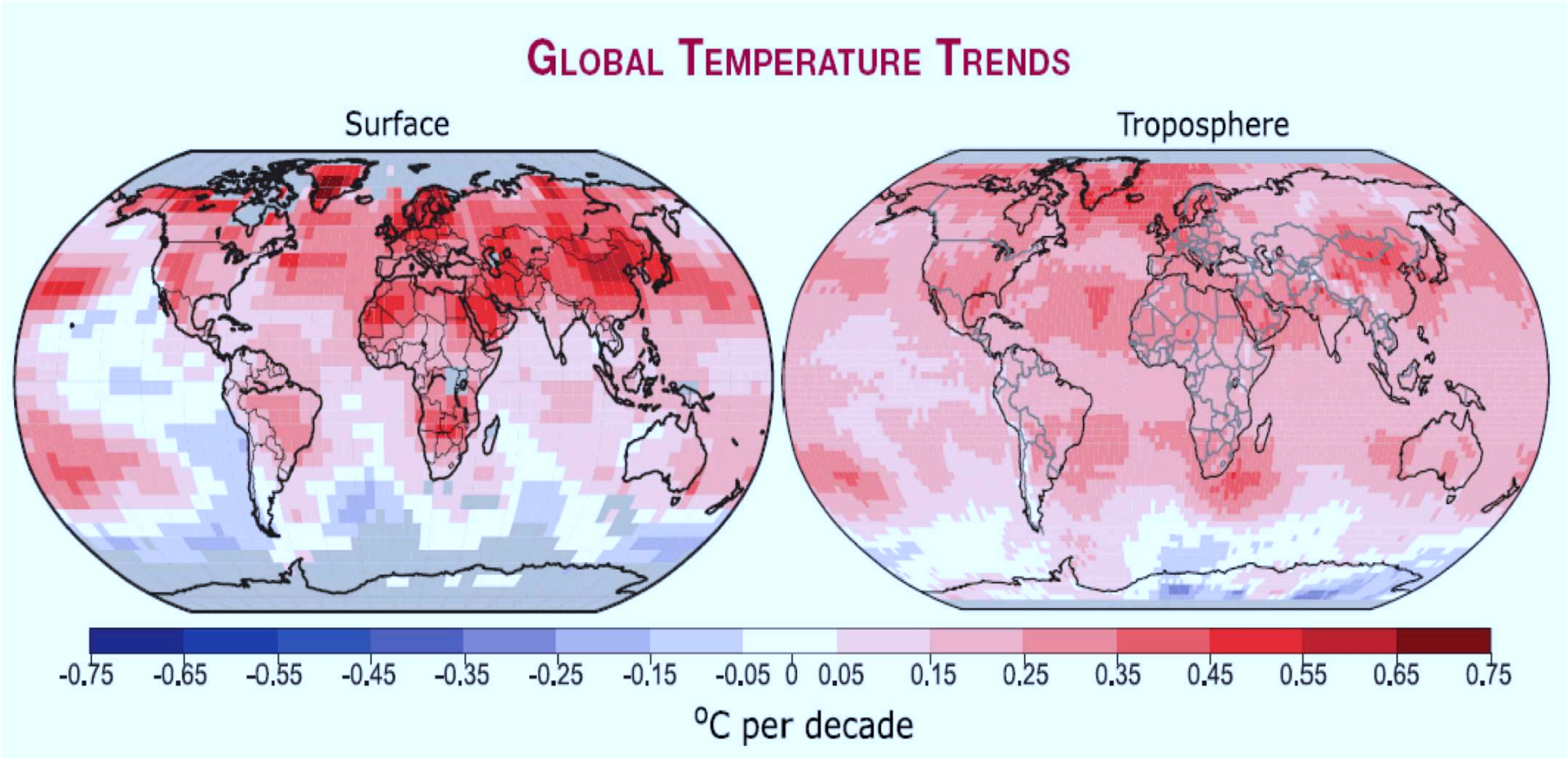
Is the warming "Global"?

Is the warming global?

Yes, although enhanced over land at poles (as expected)

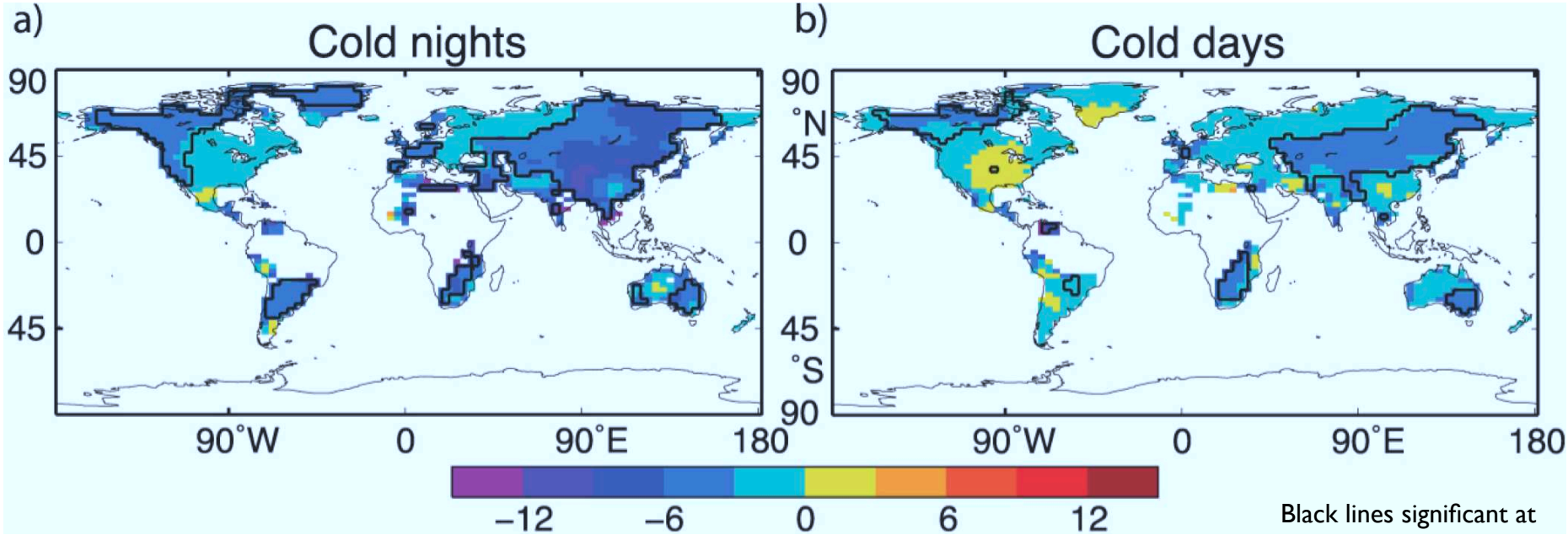


Warming extends above the surface



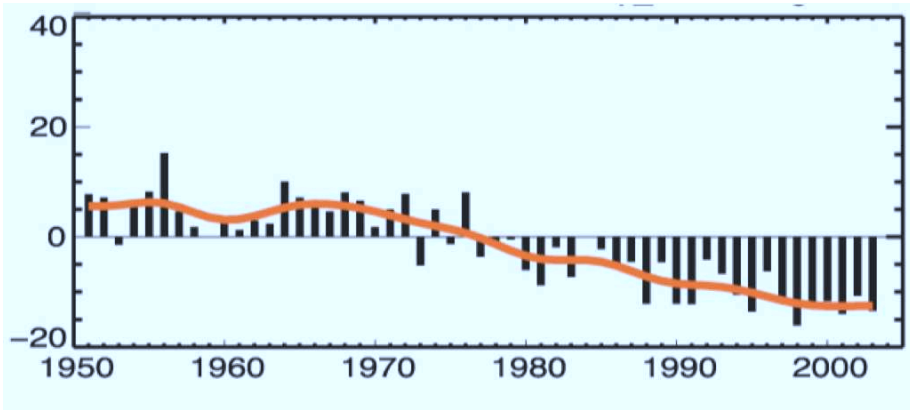
IPCC, 2007, WG I, Fig TS.6: Patterns of linear warming trends over the period 1979-2005 for the surface (right, from thermometers) and lower atmosphere (left, from satellite).

Decreasing Cold Nights

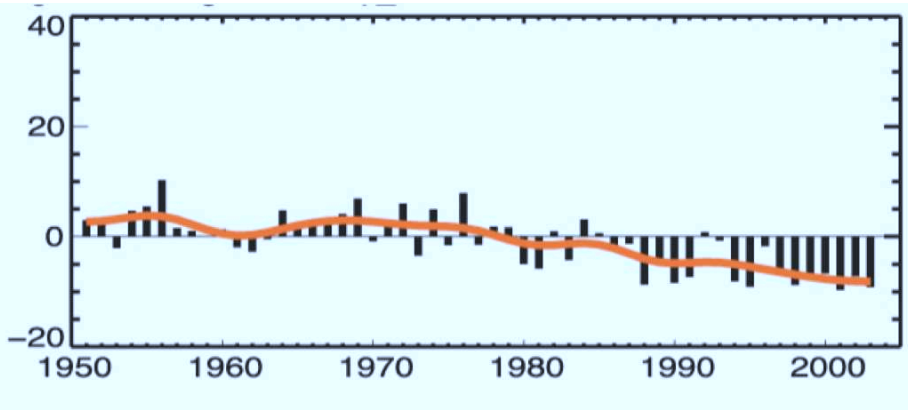


Trends (days per decade)

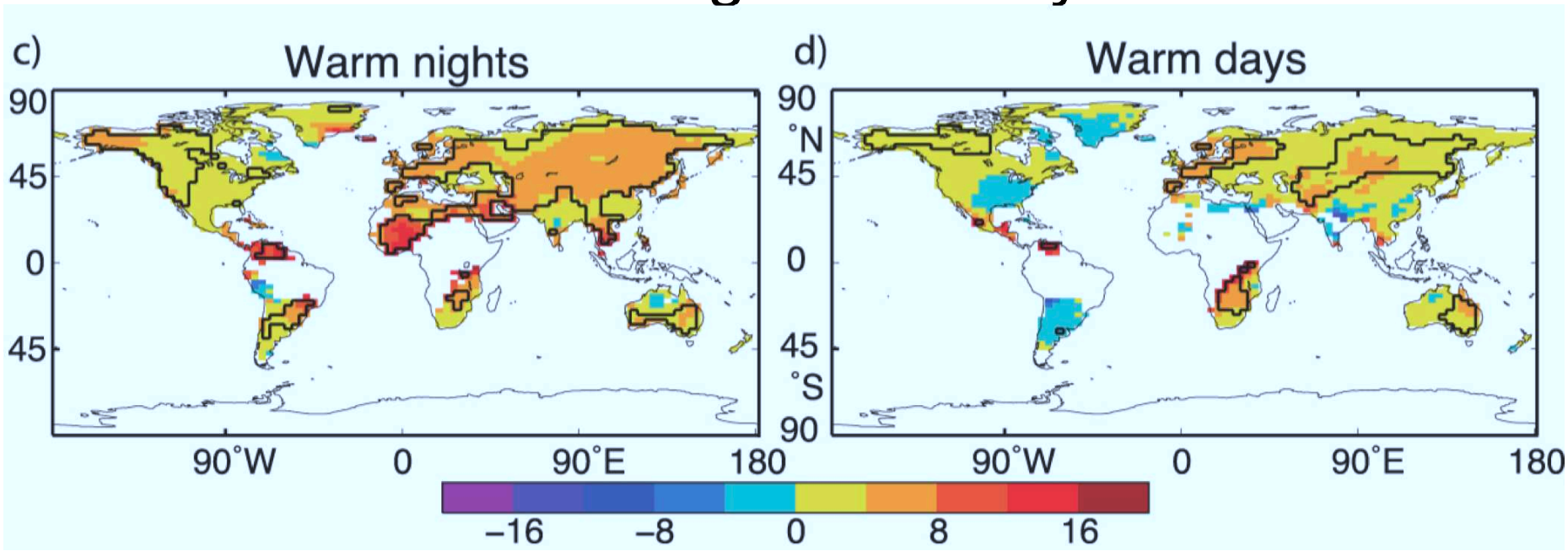
Global Annual Cold Nights



Global Annual Cold Days

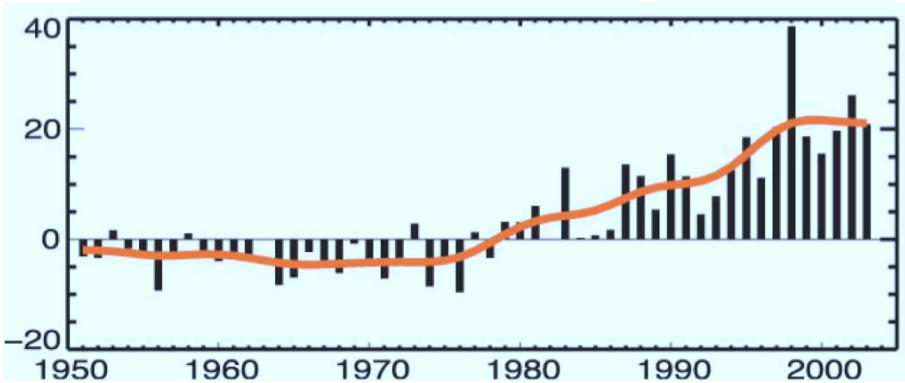


Increasing Warm Days

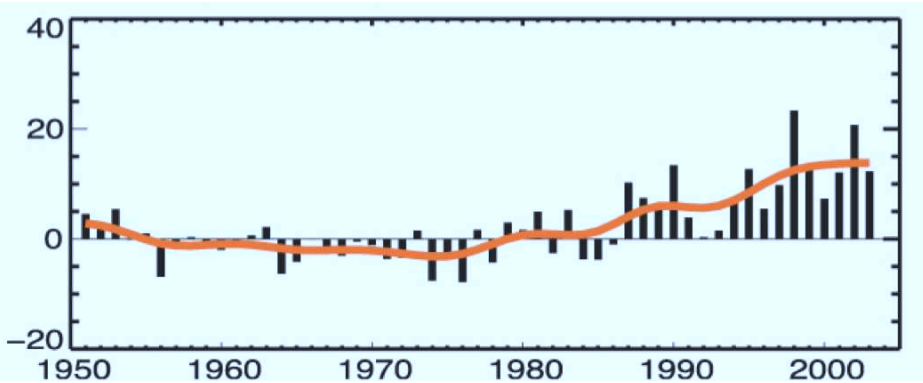


Trends (days per decade)

Global Annual Warm Nights

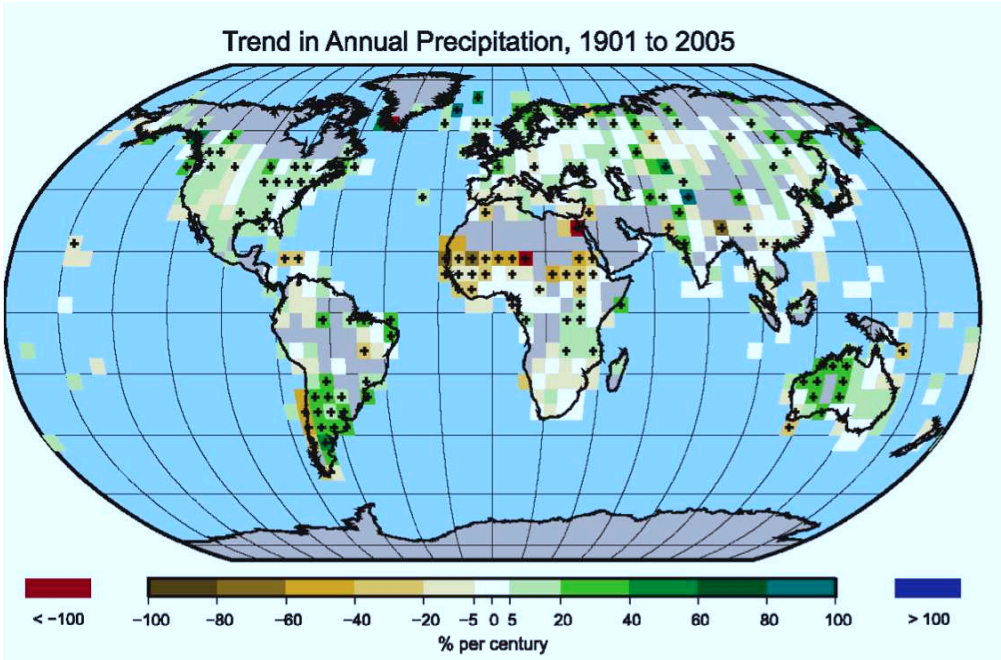


Global Annual Warm Days

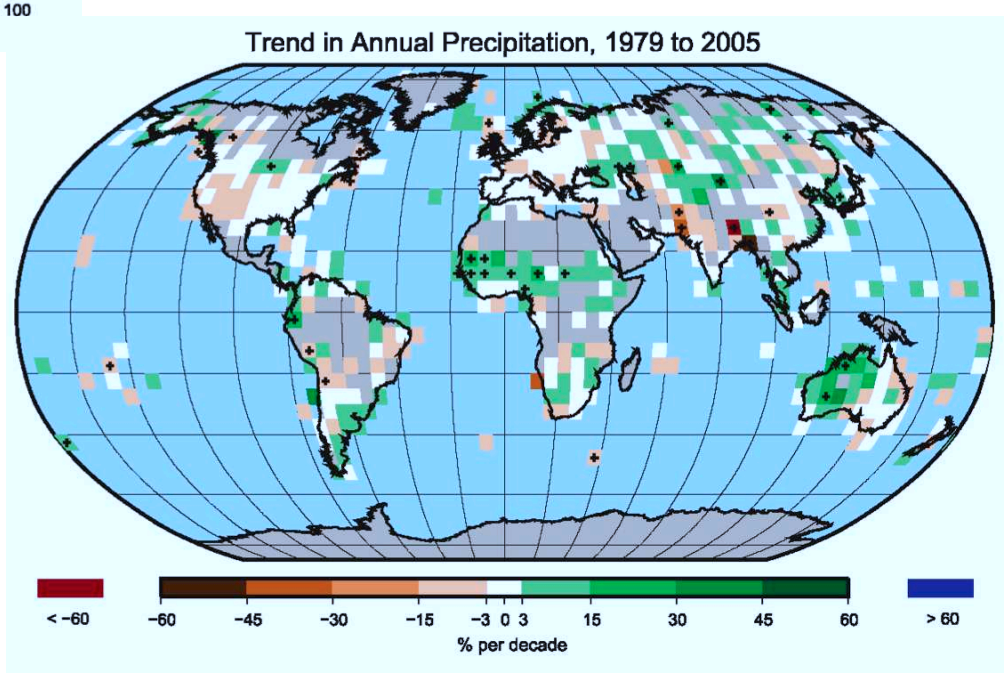


IPCC WG1 2009; FAQ 3.3, Figure 1.

Trends in Annual Land Precipitation



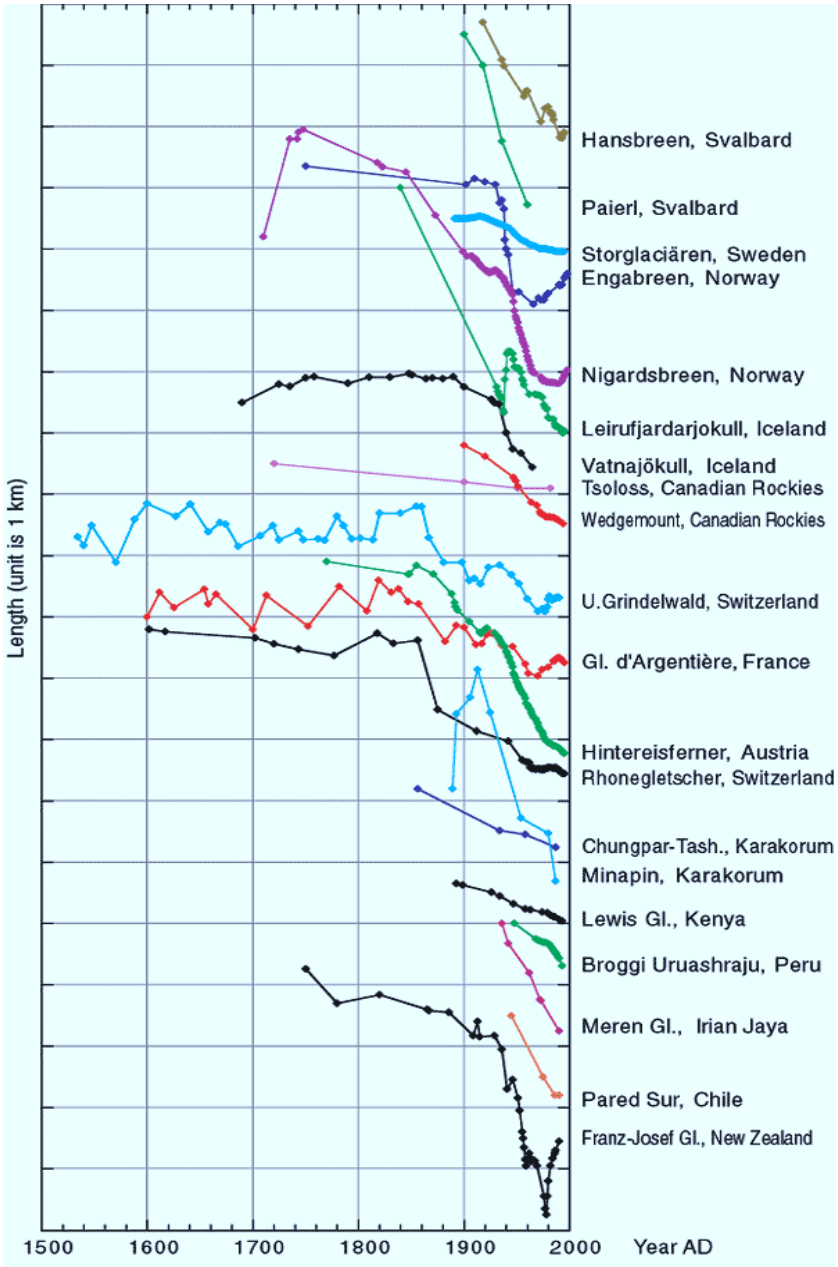
Trend for 1901 to 2005 (left, % per century) and 1979 to 2005 (bottom, % per decade). The percentage is based on the means for the 1961 to 1990 period.

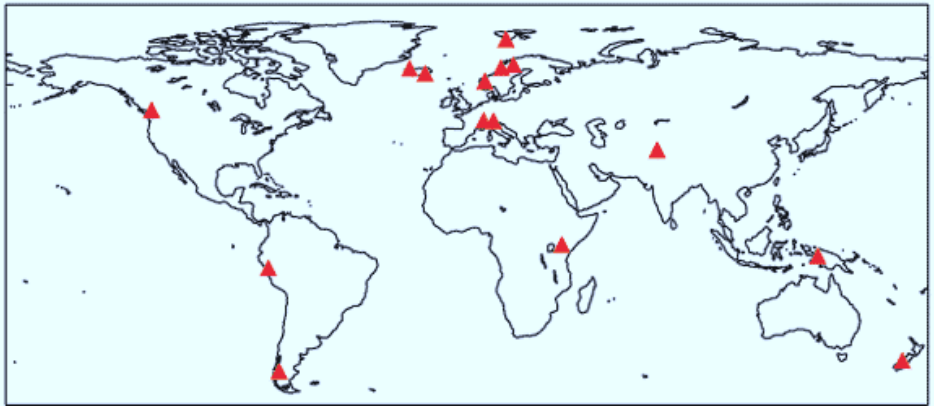


Areas in grey have insufficient data to produce reliable trends. Trends significant at the 5% level are indicated by black + marks.

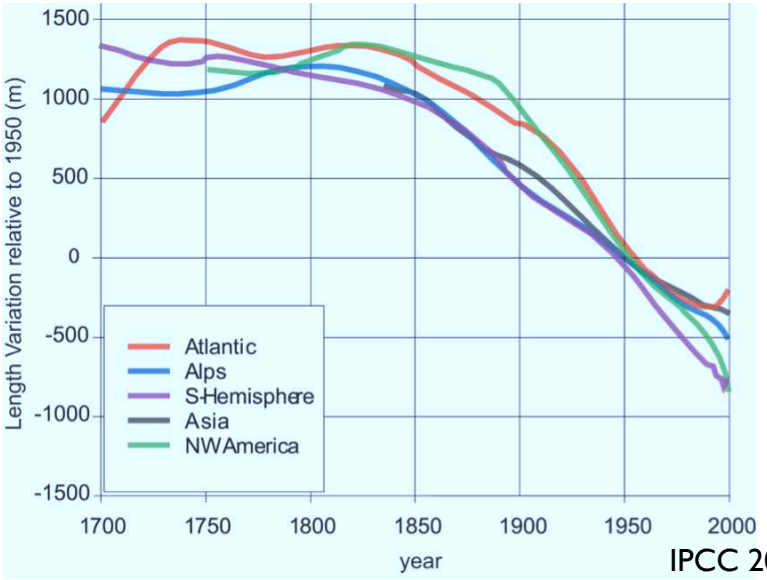
IPCC WG1 2007 Figure 3.13.

Changes in Glacier Length 1500-2000





Most glaciers around the world are



IPCC 2007 Fig4.13

Other signs of (global) warming

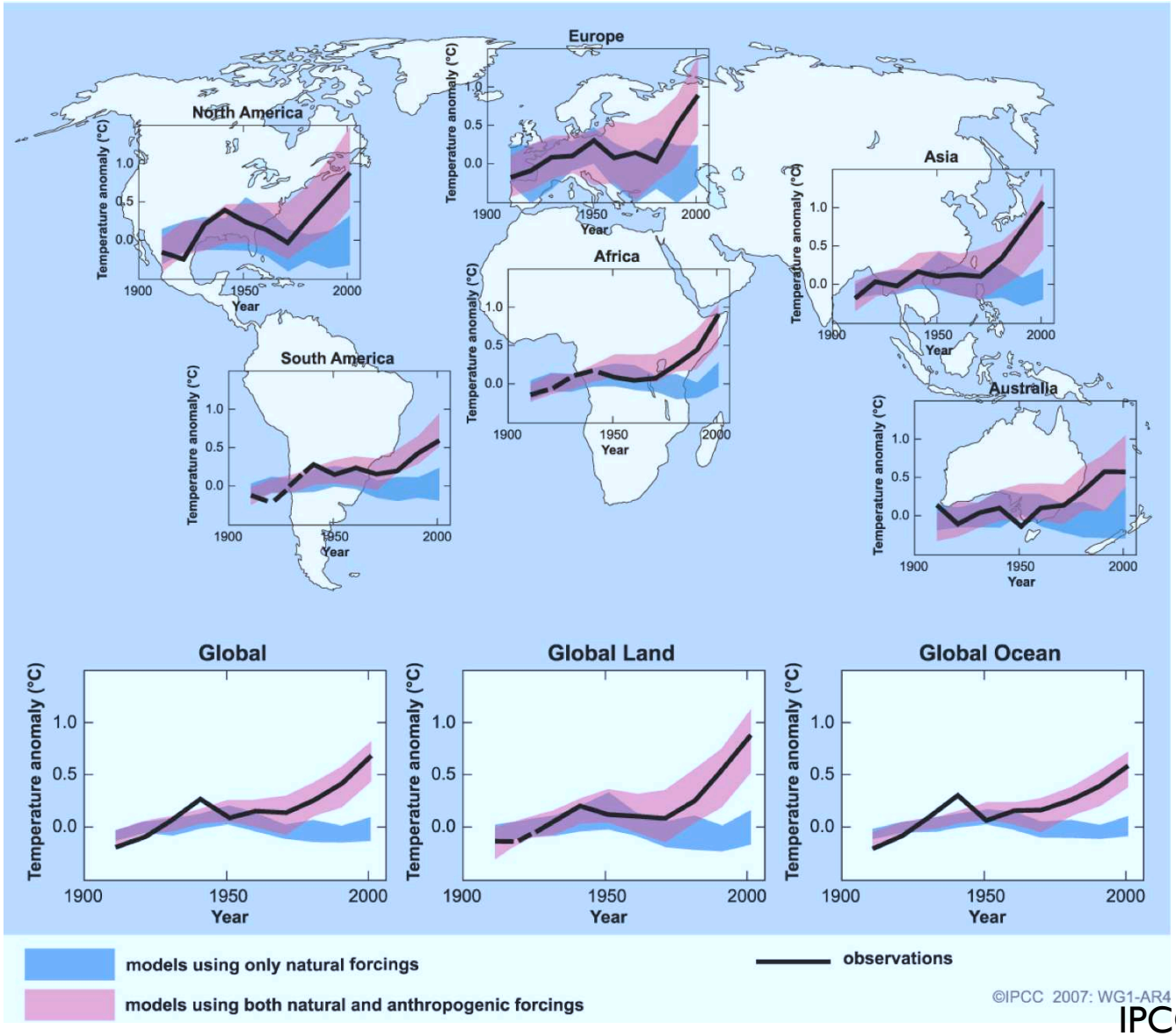
- melting mountain glaciers
- decrease in winter snow cover
- increasing atmospheric water vapor
- warming of global oceans
- rising sea level (due to warming and ice-melt)
- timing of seasonal events
  e.g. earlier thaws, later frosts
- thinning and disappearing Arctic sea ice
- species range shifts (poleward and upward)

Every one of these data sets can be questioned.
Taken together, the totality of evidence of global warming is quite convincing.

Detection and Attribution

1) Determine the change is above the natural variability
2) Determine the cause of the change

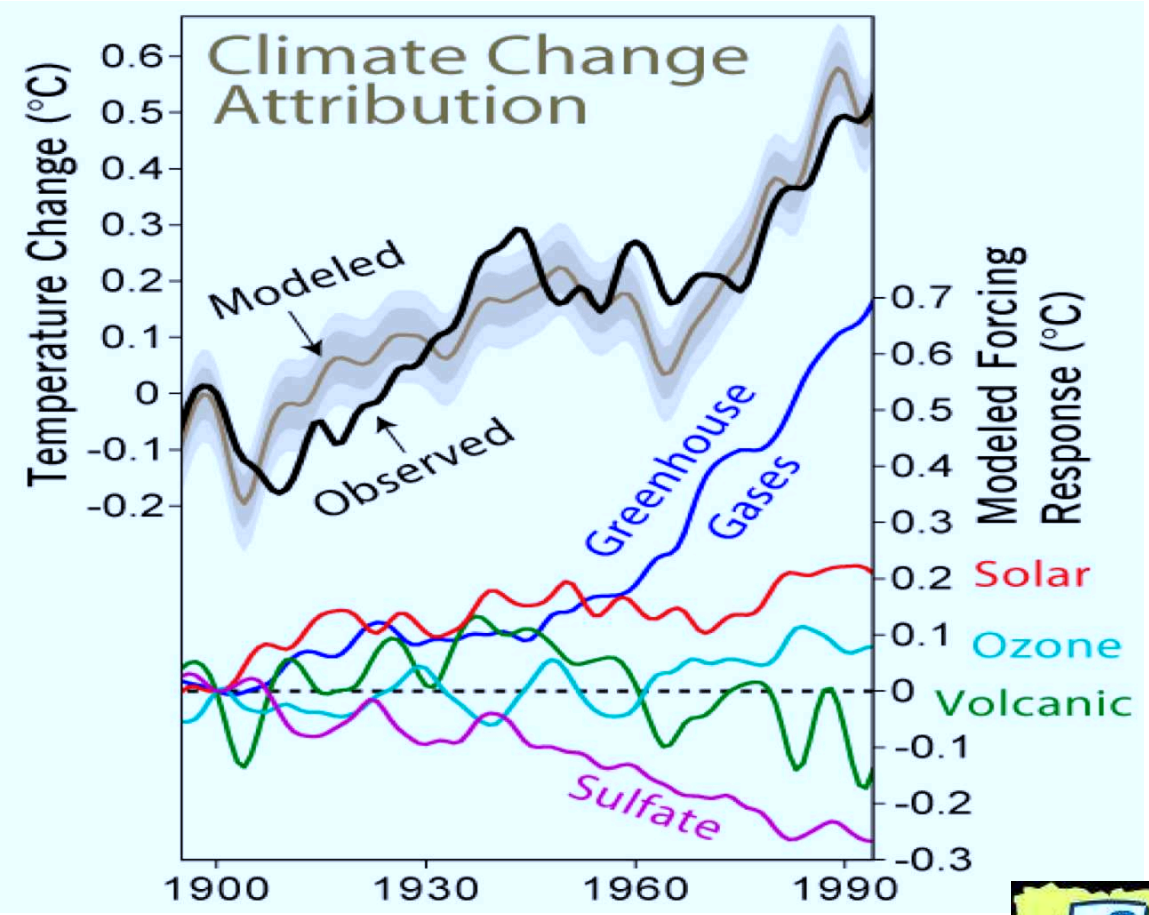
- Warming seen over all land and ocean regions
  - More in higher latitudes than in tropics; more over land than water



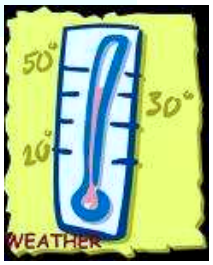
IPCC Fig SPM4

Attribution of the 20th Century Temperature Trends

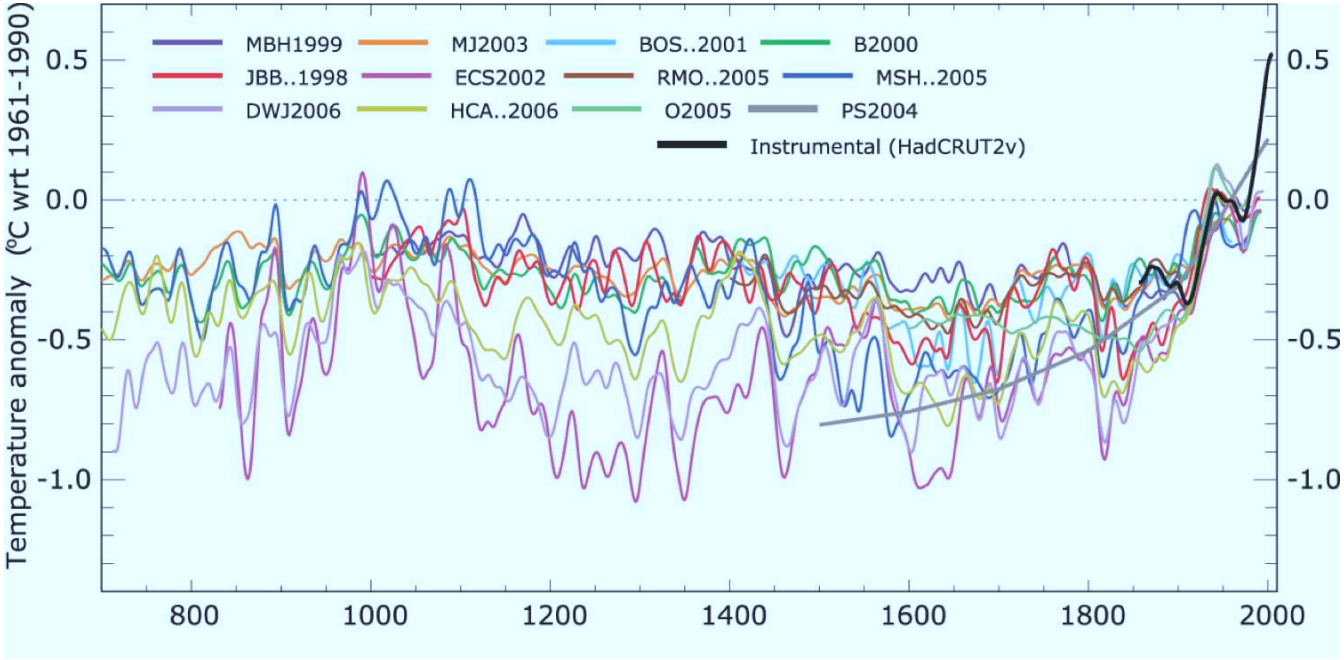
The pause in warming from ~1950-1980 is consistent with the natural (volcanoes and solar) and human (sulfate) forcing.

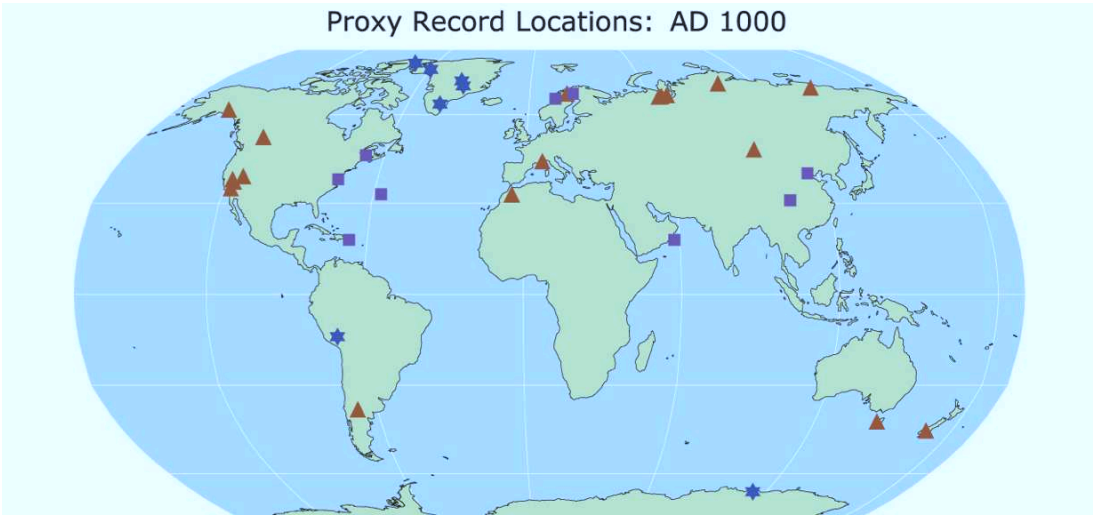


The warming trend can only be explained (and is consistent with) human induced increases in greenhouse gases.



Northern Hemisphere average surface temperature from "Proxies"





▲ Tree rings ● Boreholes

★ Ice cores ■ Other

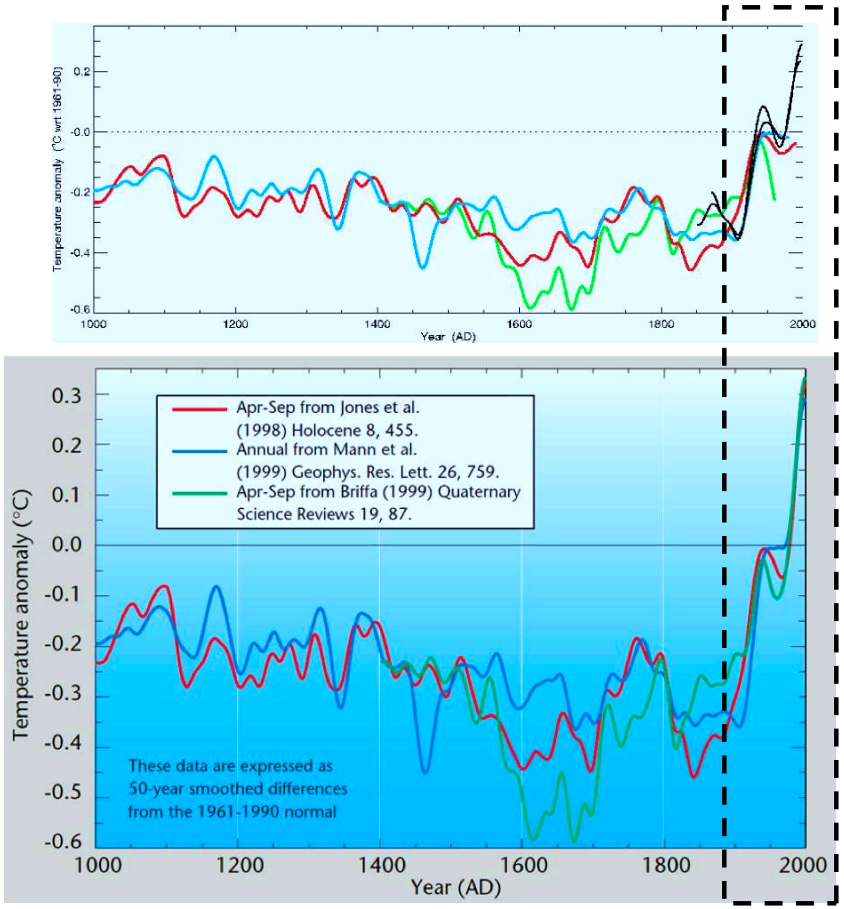
IPCC 2007 TS.20

From: Phil Jones. To: Many. Nov 16, 1999

"I've just completed Mike's Nature [the science journal] trick of adding in the real temps to each series for the last 20 years (ie, from 1981 onwards) and from 1961 for Keith's to hide the decline."

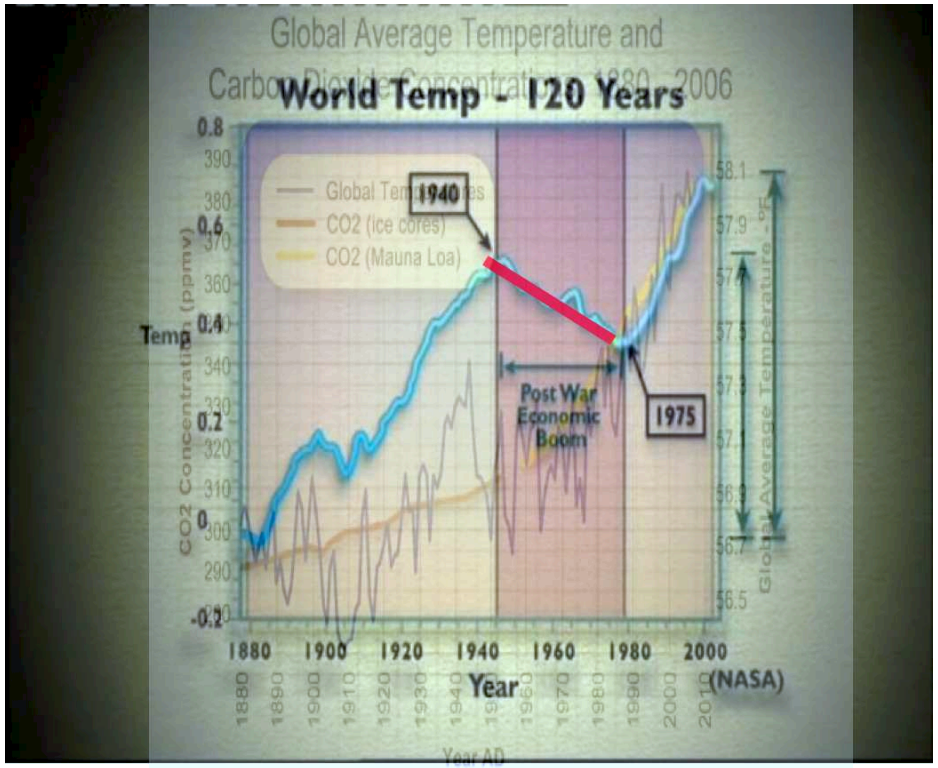
Damning Excerpt (?) from the Stolen Emails

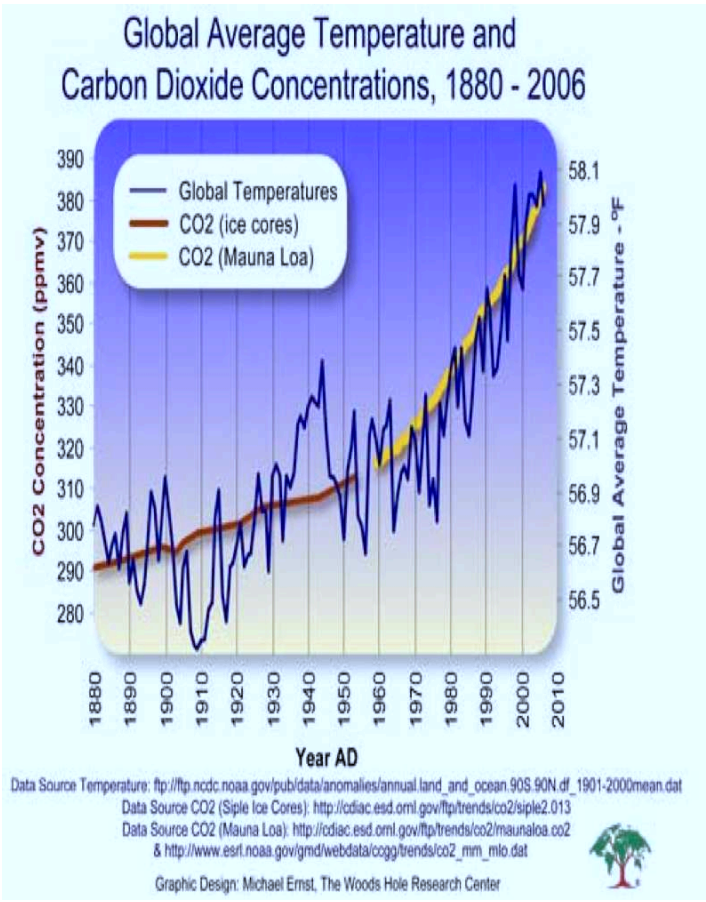
Skeptics cite this email as evidence that data was manipulated to mask the fact that global temperatures are falling.



Blending the instrumental temperature data to extend the tree ring reconstruction to 1999 is "the trick" that *doesn't* "hide the decline" in temperature from 1950-75.

A movie called the “Global Warming Swindle”: Claims that global temperature dropped between 1940-75, just when CO2 was increasing fastest





Note: the temperature data (above in blue) shown in this movie are not consistent with any published data