
U3AC SCE 05

Climate change: is it as bad as we thought?

Session 2 Temperature

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Why look at temperature?

The climate debate is fundamentally about “global warming”

Temperature can be ‘easily’ measured and we are all familiar with temperature from day to day experience

Climate studies look at:

- Present and past temperatures

- Projections of future temperatures

Climate debate is usually about ‘global’ temperatures

Some questions

What is 'temperature'?

Where are measurements being made?

What is being measured?

Who makes the measurements and holds the data?

Past, present and future

Present temperatures:

From thermometer measurements being made today
(The 'instrumental' record)

Past temperatures:

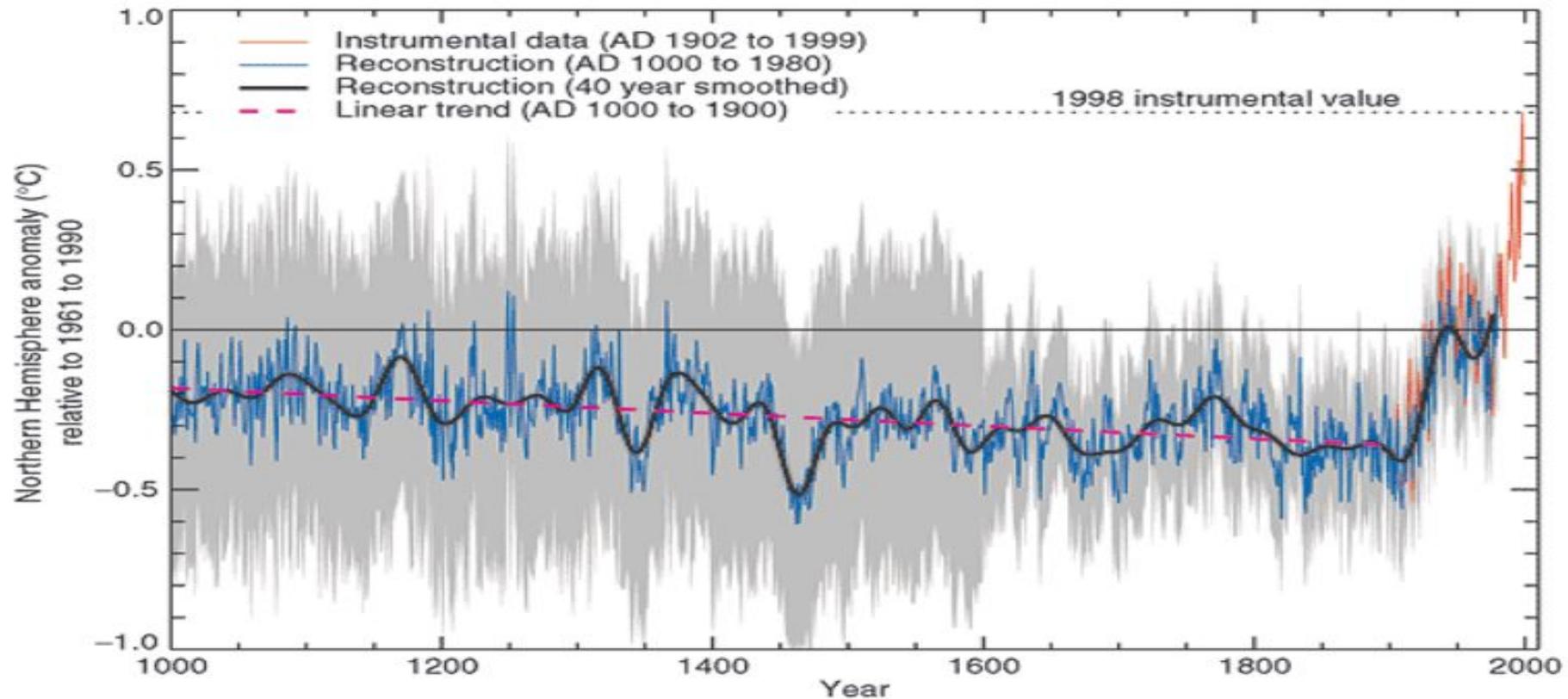
From historical thermometer measurements which can go back about 150 years, and 'proxy' measurements that aim to go back much further

Records over long periods of time need to use combinations of different source data- 'reconstructions'

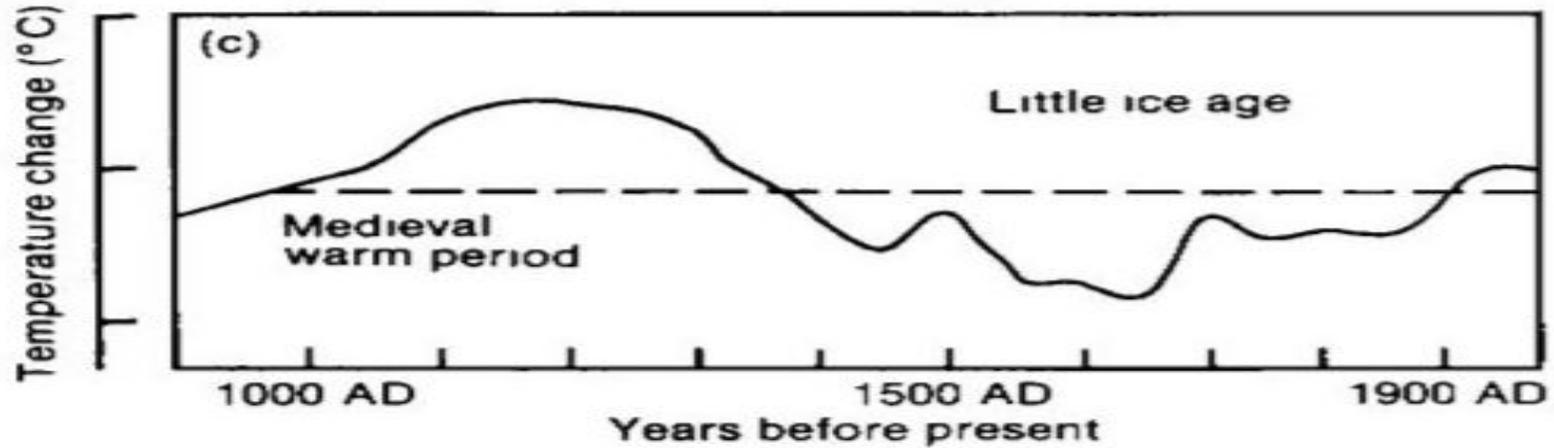
Future temperatures:

From simple extrapolation of trends from recent measurements
From projections produced by climate models

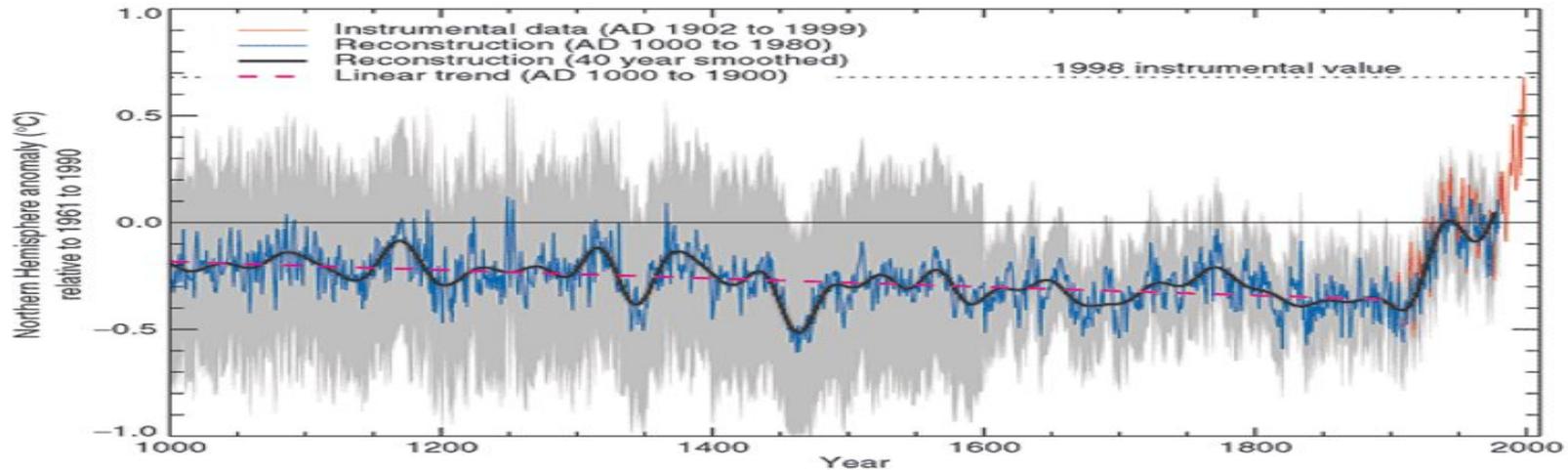
An example of a temperature reconstruction: from IPCC AR3 (2001)



An earlier example reconstruction: IPCC AR1 (1990)



Compare: what features do we notice?



Plot is of 'temperature anomaly', NH
+/- 1 deg C range
Grey error estimate significant
Smooth line is 40 year filter
No Little Ice Age (LIA)
No Medieval Warm Period (MWP)
Steep rise in anomaly in last 150 years
Slow decreasing trend prior to that

The graph that started it all: "hockey stick"
Created by Michael Mann [MBR99]
Front cover of AR3 reports
Al Gore video
Circulated to schools in UK, Australia, Germany...
Discredited by subsequent statistical analysis
No longer used by later IPCC reports

The hockey stick analysis

Mann's graph (MBR99) is constructed from many different temperature records and proxies

Different proxies, different time spans: stitched together using Principal Component (PC) analysis

One of the proxies was tree core samples: bristlecone pines

Samples were used from only a small number of trees (NH only)

This proxy was given undue weight: 300 times more than standard PC analysis would do

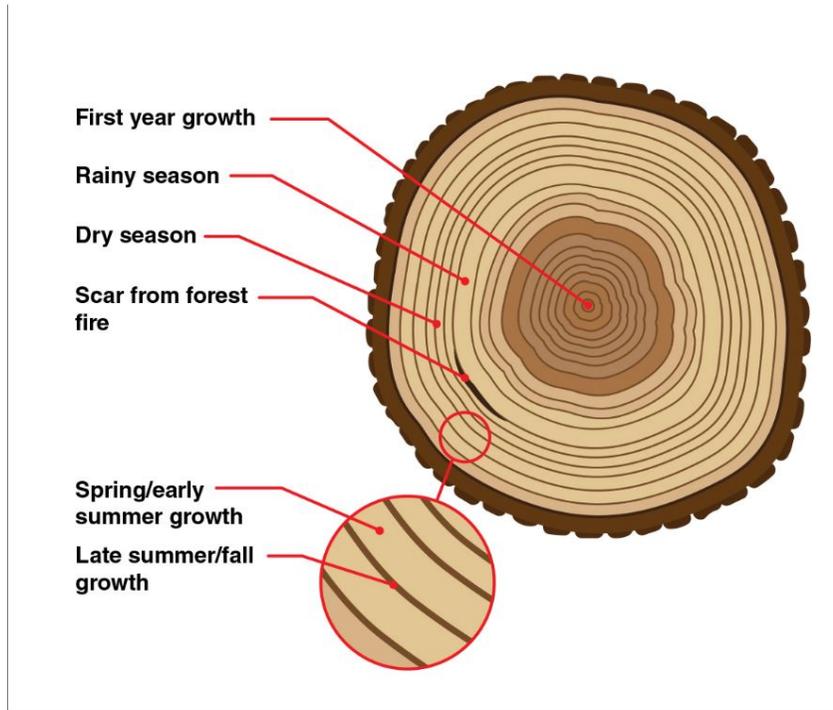
This had the effect of removing the MWP and the LIA from the record and emphasising the recent warming, even though the LIA and MWP were well documented from other sources

Tree core samples

Number of rings indicate age

Size of ring determined by temperature and rainfall at time of growth

Source: Nasa



This is said to be the Methuselah Tree, one of the oldest living trees in the world. Methuselah, a bristlecone pine tree in White Mountain, California is thought to be almost 5,000 years old. Credit: Oke/Wikimedia Commons.

Why still look at the hockey stick?

Climate studies want to estimate past temperatures to put current temperatures in a historical context

There are few long term proxies available. The problem with proxies is calibration and the fact that several parameters can have on the measured variable (ring width)

Despite the hockey stick graph having prominence in 2001 there are **STILL** arguments about the use of tree ring proxies

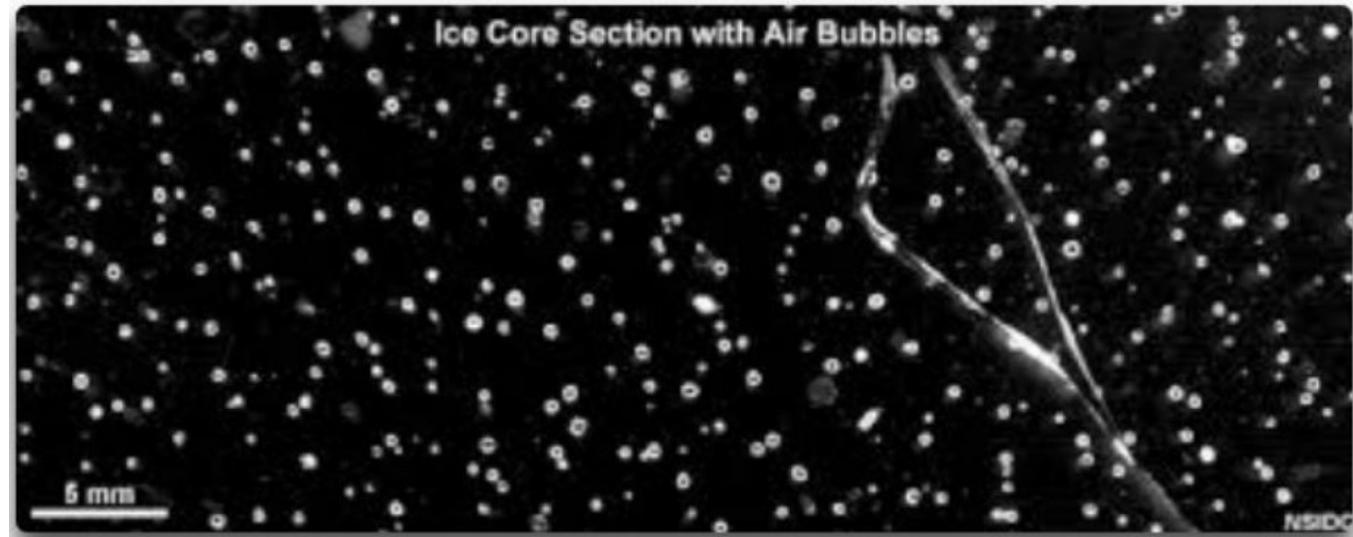
Databases of tree ring proxies are available at <https://www.nature.com/articles/sdata201788>

See also Steve MacIntyre and Ross McKittrick <https://climateaudit.org/>

Ice cores: another proxy

Bubbles are trapped in ice. Analysis of gas in bubbles give estimate of composition at time of deposit

Ratio of O₂(16) to O₂(18) indicates temperature
Depth in ice core indicates age



Many assumptions and some uncertainties in results

Where temperatures are measured: land surface and oceans

Land surface measurements are basis of earliest records

Usually from accessible areas and initially where there was a need for temperature data (eg airfields)

Stations are defined with tight parameters on shading, location and thermometer height (Stevenson Screen)

Height of thermometer specified as 2m above ground surface



Ocean temperature measurements

The earth surface area is 510 million square kilometres

The sea area is 71% of this.

Water has an enormous heat capacity compared to air and the volume of the oceans is huge.

Temperature changes in the oceans are much smaller than air temperature changes (for the same energy input) and so more difficult to measure

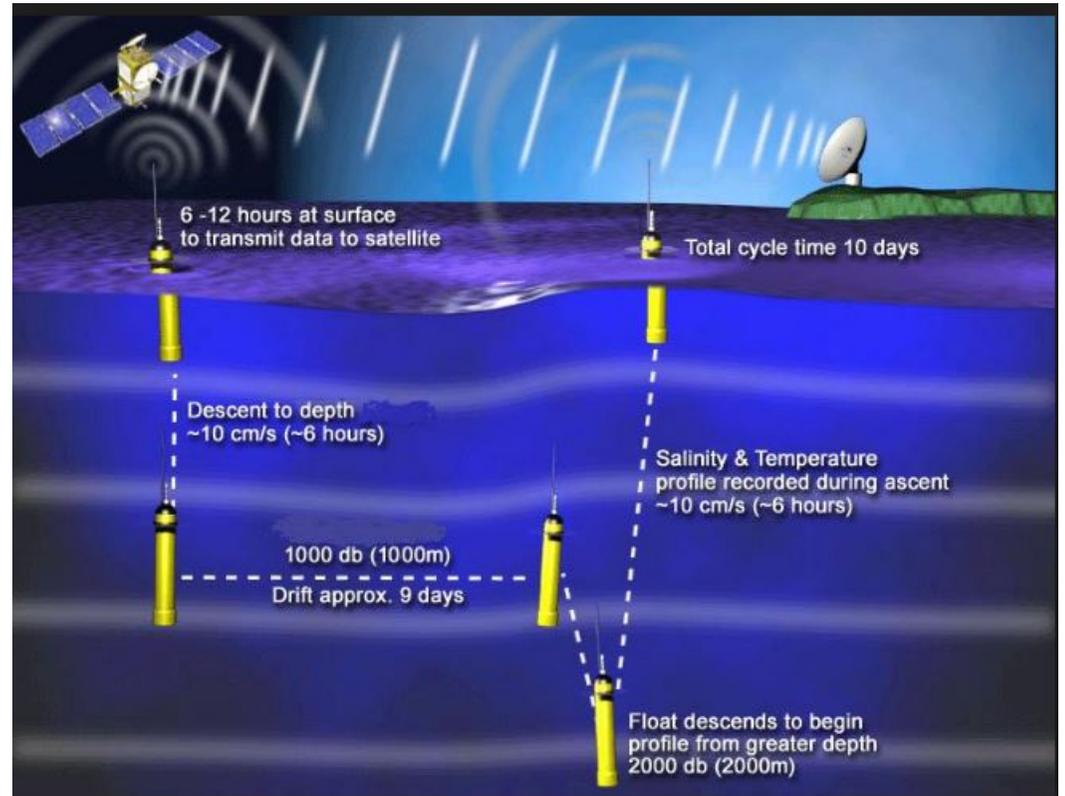
Oceans' surface and subsurface are inaccessible and only recently providing measurements with some reliable data from Argo buoys and tethered buoys

Previously shipping provided temperature data by taking water samples from the surface

Ocean temperature measurements by argo



About 4000 Argo buoys are currently in world's oceans
Deployment started in 1972



Sources of temperature data

Three main sources of measurement data, all data available on the web

NASA's GISTEMP (Goddard Institute of Space Studies)

CRUTEM (East Anglia Climate Research Unit and UK Met Office)

NOAA's NCDC (National Climatic Data Centre)

Also

CET (Central England Temperature) Local region in UK Midlands
Longest (near) continuous temperature record in the world

BEST (Berkely Earth Surface Temperature)

Satellite measurements (from 1970s): near Global continuous coverage

UAH

University of Alabama at Huntsville

RSS

Remote Sensing Systems

What is recorded ?

Stations record 'absolute' or 'raw' temperatures
Most data sets report 'anomalies'

Temperature anomalies are how much the recorded absolute temperature differs from a baseline. A baseline might be the mean temperature between 1960 and 1980 (for example). Arguments often rage over which baseline should be used and different reports adopt different baselines. Different baselines will affect the resulting report (small, but anomalies are also small)

Anomalies are used to try to remove the differences measured by stations in the same region but at different altitudes. **Anomaly does not mean 'unusual'.**

Historically stations recorded max and min within 24 hour period.
Average was the mean of max and min, not the true average.
Modern stations record continuously and can give max, min and true average.

There is huge controversy over station siting and later adjustment of recorded data

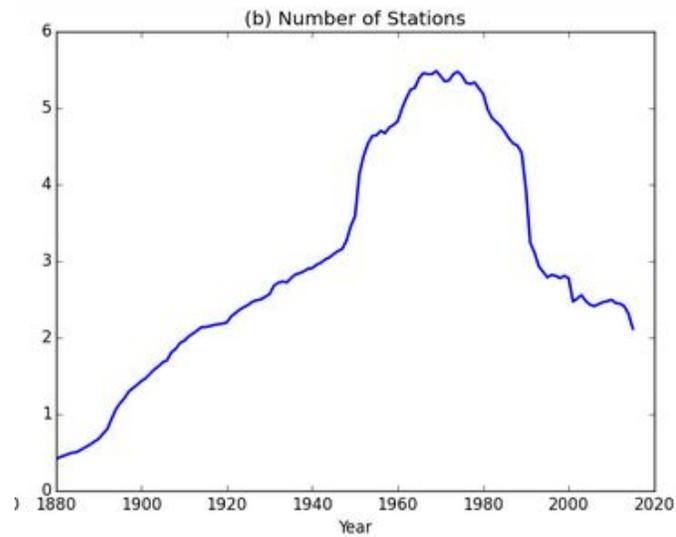
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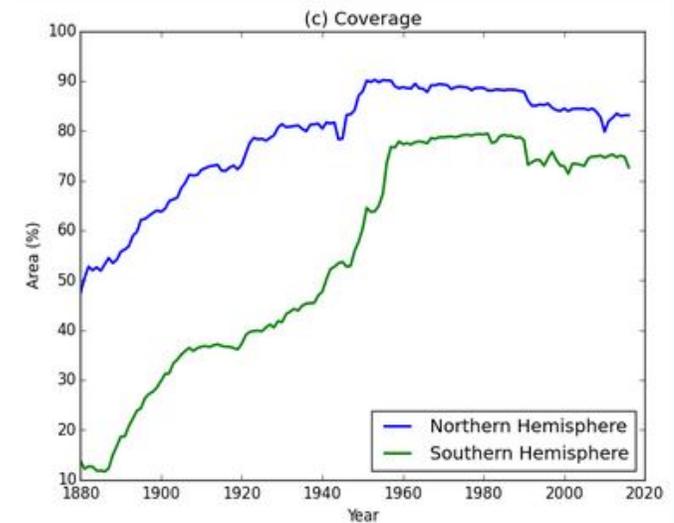
Modern stations record continuously and can give max, min and true average.

There is huge controversy over:
Changes in station siting
Adjustments of recorded data
Urban heat island effects

Coverage and quantity of data: GISS



About 2000 stations
Down from about 5500 stations in 1980

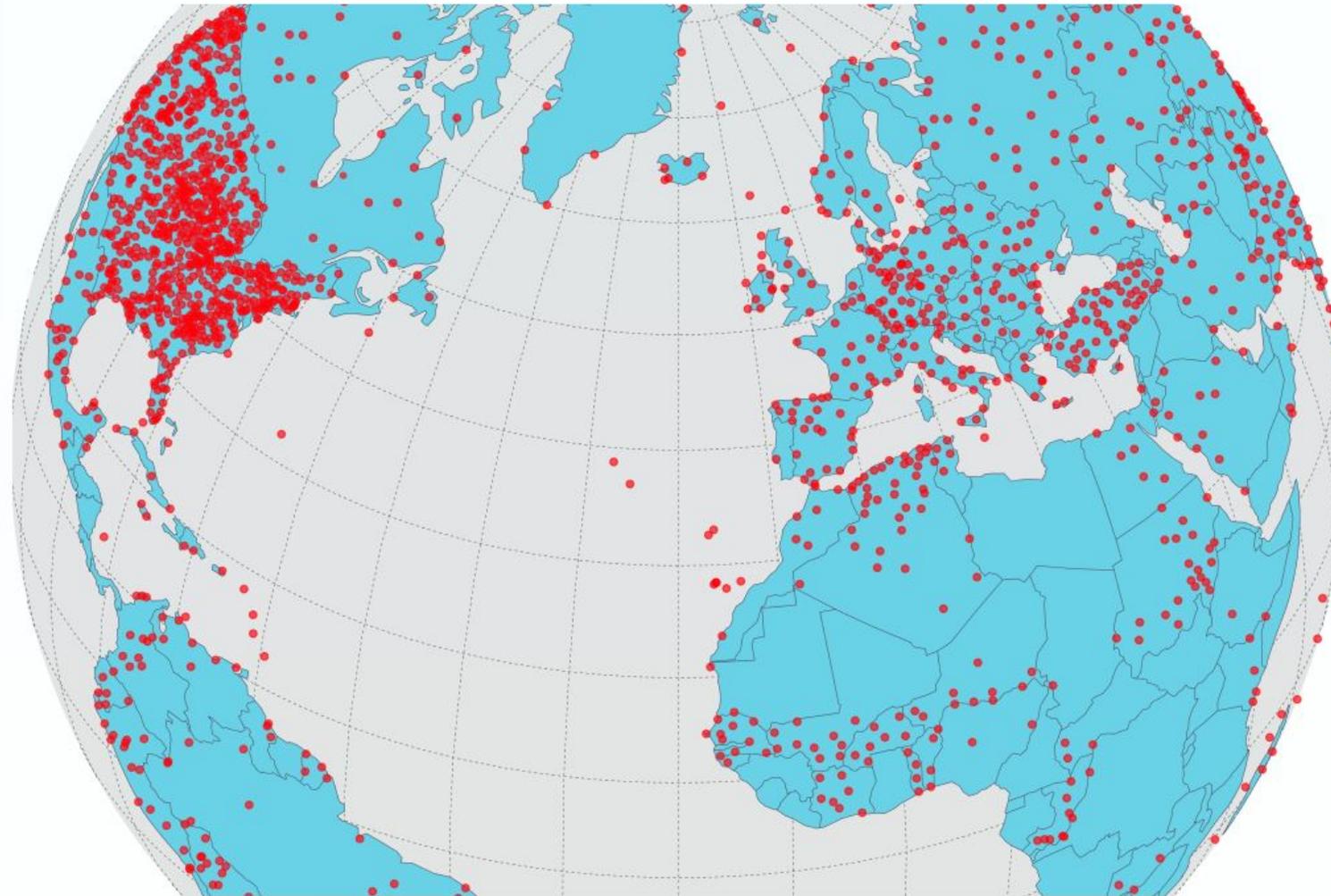


Includes land area within 1200km of station

Raw station locations: GISS

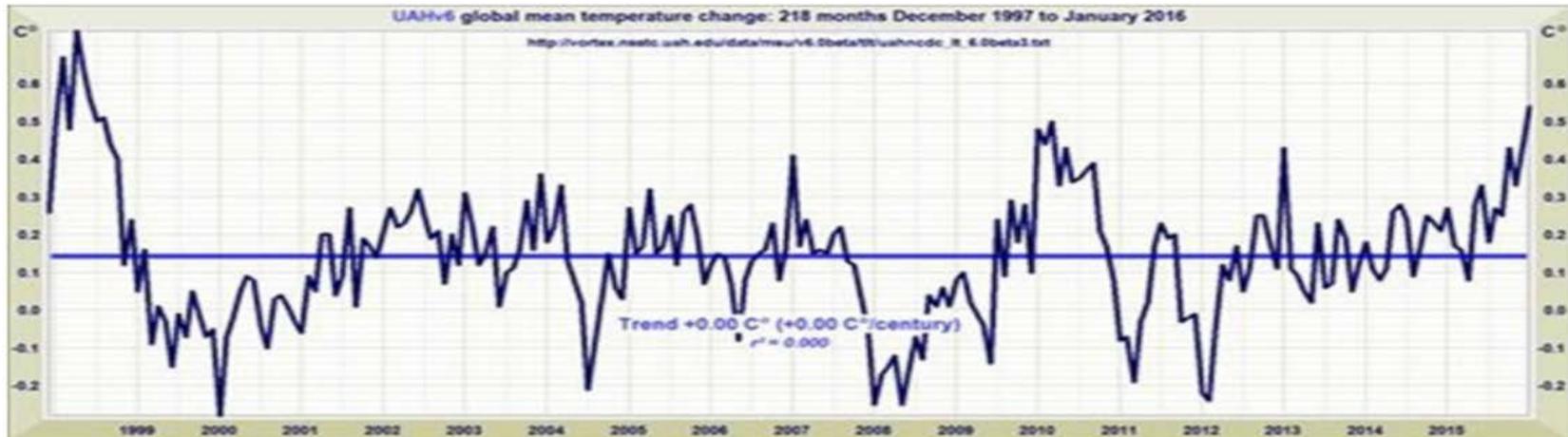
<https://data.giss.nasa.gov/gistemp/stdata/>

From: To: Dataset: Stations: 2171



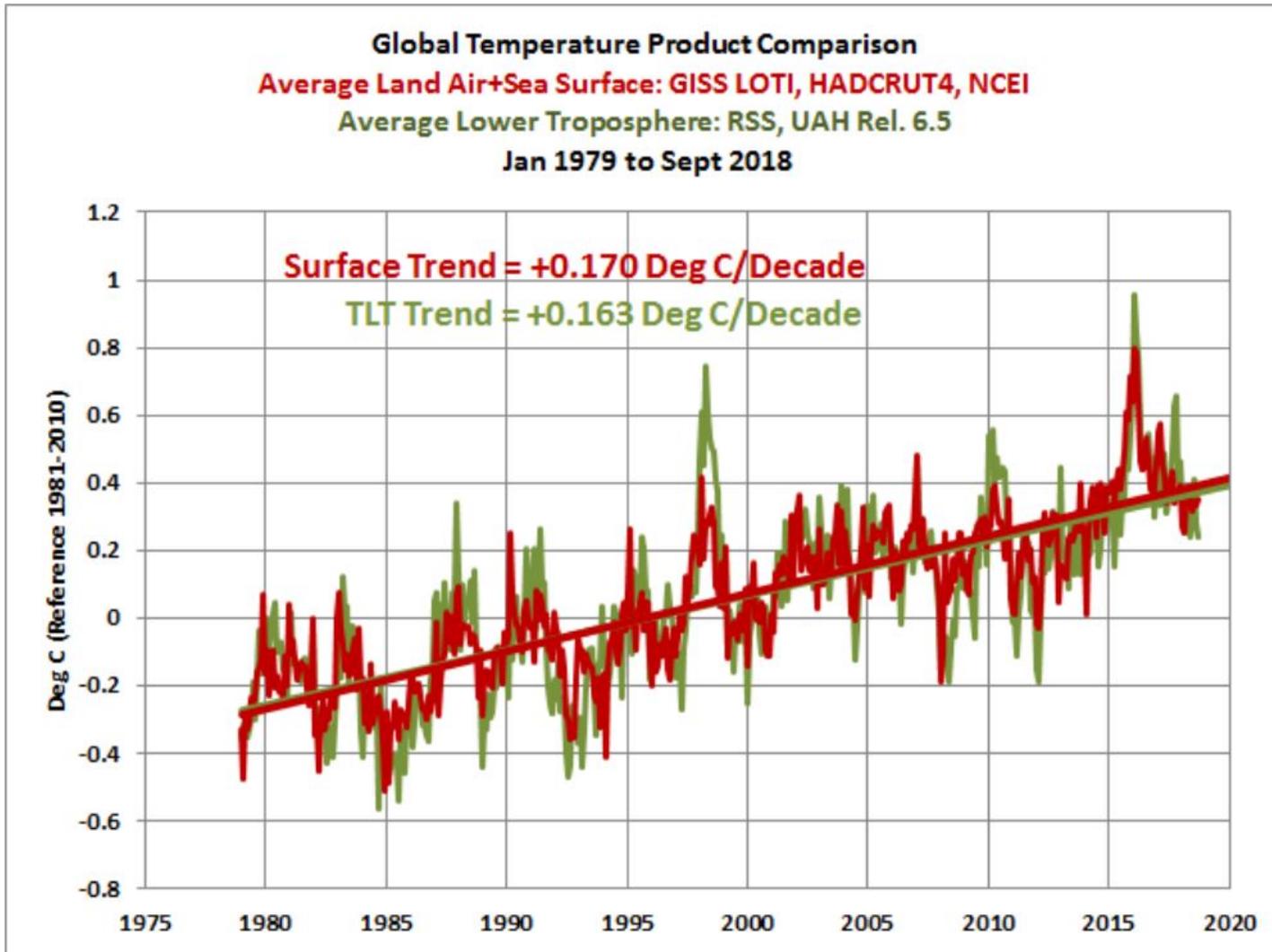
UAH temperature estimate (satellite)"

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This example shows the so-called 'pause' where there was zero temperature trend for over 18 years from 1998

Global temperature measurements to Sep 2018



Factors affecting temperatures and measurement

Thermometer calibration and accuracy

Different measures: old style max and min, modern true average, observer error

Spatial coverage for global estimates

Adjustments made to the records for numerous reasons, eg Time of Observation

Station siting: urban/rural

Station siting: local heat sources

Global effects such as El Nino, volcanoes, variations in sun activity

Calibration of proxies

Some conclusions

We believe that the climate IS changing and the temperature records show that there has been a temperature increase in recent decades, and historically over a long period

Measuring global average temperature is quite difficult and has limited physical meaning. Measurement sites are unevenly distributed: oceans and vast continental areas are sparse, and few at poles. Measurements of sea surface temperatures show tiny changes

Historical temperature records are unreliable: failure of the hockey stick prediction. It is difficult to calibrate proxies

The surface temperature records are not only measurements: they contain many adjustments, corrections and interpolations

Natural variations are significant: El Niño–Southern Oscillation (ENSO), volcanoes

However, satellite measurements have shown no global warming for periods that last 18 years even though CO2 measurements show consistently increasing levels in the same period