Société de Calcul Mathématique SA
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Global Temperatures

Available data and

critical analysis

Extract of the white paper drawn up by the SCM
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Before looking at modern temperature recordings and their limitations, we shall begin with a brief history of the subject.

I. History of measurement technologies

A. The historical development of measurement technologies

The history of meteorology, and particularly of the measurement of atmospheric temperatures, begins in ancient times, with the publication of Aristotle's *Meteorology* (in the fourth century BC). However, advances in scientific method and in the understanding of the physical variables associated with meteorology date from the seventeenth century, with the invention of the mercury thermometer and the barometer [see Civiate and Mandel].

The first really usable measurements in Europe date from the 1850s [see Info-Climat], with a hundred measurement sites spread throughout the continent, while the US has been relatively well provided with sensors since 1880. This information will be important later.

The technology for measuring temperature at ground level is fairly basic: the thermometers used more than a hundred years ago can be considered reliable.

Land-based measurement stations (also known as weather instrument shelters) comprise an array of sensors measuring various physical variables (including temperature, pressure and rainfall). These stations comply with the standards set by the World Meteorological Organization (thermometer between 1.25 and 2 meters above the ground, box painted white to reflect the sun, and so on).

Vertical exploration of the atmosphere was developed using hot-air balloons. On the first hot-air-balloon flight for scientific purposes, organized by the Académie des Sciences (French Academy of Science) in 1804, Jean-Baptiste Biot and Louis Gay-Lussac measured atmospheric pressure and temperature up to an altitude of 4,000 meters.
In 1892, Gustave Hermite invented the sounding balloon, which carries recording instruments that are recovered when they fall to the ground.

In the second half of the twentieth century, the use of satellites made it possible to establish a global database, particularly of atmospheric temperatures (at altitude). Since 1978, the data gathered by infrared sensors on National Oceanic and Atmospheric Administration (NOAA) satellites have been measuring both surface temperatures (using advanced high-resolution radiometers) and atmospheric temperatures at various altitudes (upper-air soundings). There are two types of weather satellite: geostationary satellites and polar-orbiting satellites.

Geostationary satellites always cover the same area (rotating at the same speed as the Earth). They locate cloud masses and identify the main clouds, operating at an altitude of approximately 36,000 km. The area covered by these satellites (orbiting at the level of the Equator) is adequate, except at the level of the Poles.

Polar-orbiting satellites have an almost circular orbit around the Earth, at much lower altitudes than geostationary satellites (about 850 km), and they pass close to the Poles. Unlike geostationary satellites, they do not allow for the monitoring of a specific area over time, but they do make it possible to monitor cloud masses at the Poles.

Temperature cannot be measured directly by satellite. In the case of a geostationary satellite, and in clear weather, temperature is obtained by applying Planck's law, which links the radiation emitted by a black body (on the surface – land and oceans) to temperature.

To determine the temperature at altitude, polar-orbiting satellites (orbiting at a lower level) use the absorption band of carbon dioxide, or of oxygen in cloudy weather. In both cases, the measurements are indirect.

Satellite measurements are inaccurate: parameters such as atmospheric pressure or wind speed are difficult to estimate by satellite, and the interaction of clouds with radiation is even less well understood. Infrared radars detect the highest clouds, but not those below them. Microwave sensors can see through cloud, but are poor at estimating distances.

This means that satellite measurements are reliable only in clear weather, and estimated temperatures must take into account the uncertainties associated with other parameters, which can be only poorly estimated.

The technologies used to measure temperature at sea are the same as those used on land, with weather buoys constantly measuring the temperature at sea level, as well as atmospheric pressure, wind speed and direction, and so on.
The most commonly used buoys are called drifting buoys, which can operate independently for a year, and are very light and easy to put in place. They have been used since the 1970s and transmit measurements by radio. They follow ocean currents and therefore never measure the temperature twice at the same point.

The other type of weather buoy is the moored buoy, which is very heavy and held in place by an anchor on the seabed. The advantage of moored buoys is their fixed position, which makes it possible to confirm and calibrate satellite data. However, they are extremely expensive and difficult to put in place, and there is not at the moment a global network of moored buoys.

As on land, weather satellite radiometers make it possible to measure the temperature at the surface, but they are dependent on local conditions.

To measure the temperature at sea, use is also made of research vessels, though they have an error margin of about 0.6°C (because the ship's sensor is close to the engine room).

B. Development of measurement station networks

At the end of the eighteenth century, the Société Royale de Médecine (French Royal Society of Medicine) was the first body to develop a network of observers to measure the temperature at various places in France (including Haguenau in Alsace, Dijon and La Rochelle). The monthly averages were published in the journal, *Histoire et mémoires de la Société Royale de Médecine* (History and Memoirs of the French Royal Society of Medicine) [see CNRS].

In 1849, the Smithsonian Institute, under the leadership of the physicist Joseph Henry, began to set up a network of weather observation stations in the US. The observations were quickly broadcast, thanks to Samuel Morse's invention of the telegraph in 1837.

Following the storm of 14 November 1854 that destroyed the French, British and Turkish fleets in the Black Sea, the director of the Paris Observatory created a measurement network to warn sailors of imminent storms. This meteorological service was gradually extended to Europe, with 59 measurement stations across the continent by 1865. The French service was named the Bureau Central Météorologique de France (French Central Meteorological Office) in 1878.

In 1873, the International Meteorological Organization (IMO) was founded in Vienna by countries with a meteorological service.

According to the Global Historical Climatology Network (a database managed by the National Climatic Data Center), 226 stations have been recording data for more than 150 years, mostly in Europe, and 1,656 stations have been in use for more than 100 years.

The map below shows the distribution and age of temperature stations. Europe has been well provided with sensors for more than 150 years, and the distribution of stations in the US has been satisfactory for more than 110 years.

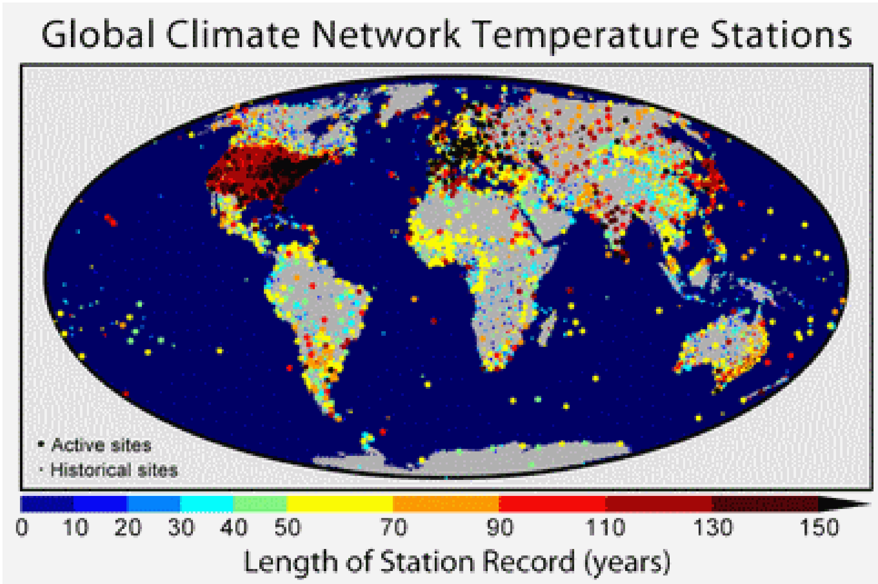


Figure 1. Distribution and age of temperature stations

II. Distribution of measurement stations

A. Distribution of measurement stations in France

The Météo-France network of professional weather stations, which is known as the Radome network, comprises 554 stations in mainland France (one every 30 km) and 67 in the overseas territories. These stations automatically measure basic parameters (temperature and humidity under shelter), precipitations and wind (speed and direction) at a height of 10 meters.

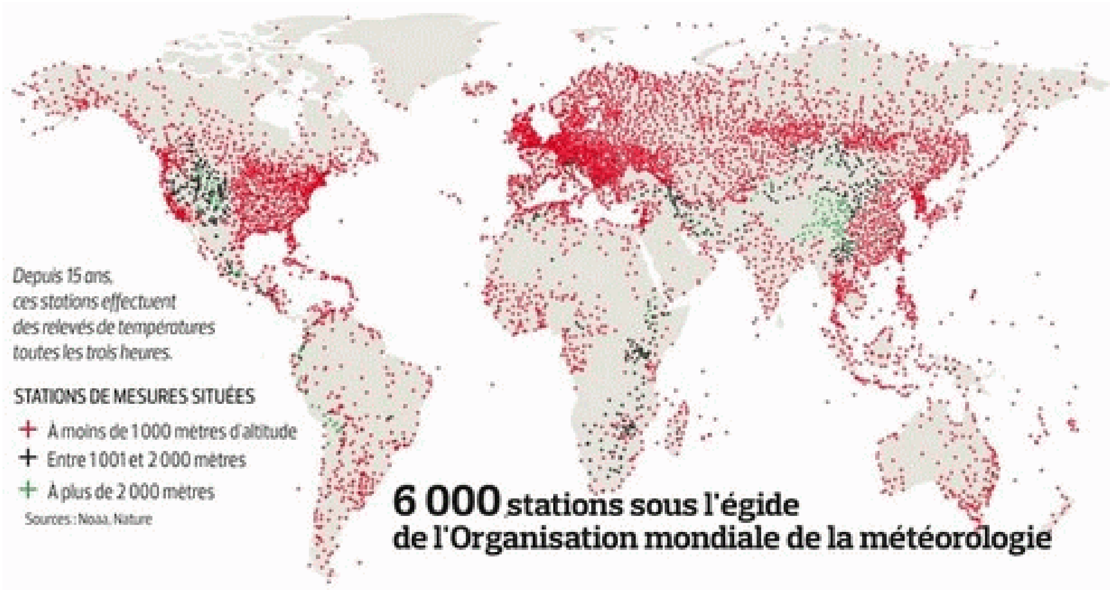
About fifty stations are part of the World Meteorological Organization's (WMO) World Weather Watch (WWW), with their data being fed into databases of model inputs for all countries.

Figure 2. Map of measurement stations in France

The map above shows the current distribution of measurement stations in France [see Météo France]. In our opinion, the stations used by Météo France (all points) are quite well distributed, while those used by the WMO (in blue) are poorly distributed.

It is not reasonable, today, to be using just 50 stations to cover a country as large and readily accessible as France. Why not use all existing stations? There is a strange story here, which we shall come back to later.

B. Globally (land-based)



Key

For the past 15 years, these stations have been taking temperature readings every three hours.

LOCATION OF MEASUREMENT STATIONS
+ At an altitude of less than 1,000 meters
+ At between 1,001 and 2,000 meters
+ At more than 2,000 meters
Source: NOAA Nature

6,000 stations under the aegis
of the World Meteorological Organization

Figure 3. Global distribution of ground-based measurement stations in 2010

The map in Figure 3 shows the distribution of the 6,000 measurement stations used by the WMO [see NOAA and Nature]. Europe (excluding France, Spain and Norway), the US and eastern China are well supplied with sensors, but this is by no means the case for the majority of land masses [see Surface Stations]. There are very few sensors in areas such as Greenland, northern Canada, central Africa and Australia. Globally, areas that are difficult to access, such as high mountain areas, deserts and forests, have few land-based measurement stations.

As we have seen, satellites measuring temperature using infrared make it possible to estimate surface temperature, but this technology is hugely dependent on local conditions (clear weather at the time of reading, absence of trees, etc.).

But remember: the NOAA says it is currently using just 1,500 of the 6,000 stations on the map, which is only a quarter. The NOAA explains this as follows: 'the number of land-based stations being used has fallen because of improvements in technology and the fact that data from old stations are no longer accessible in real time'. Which makes the inadequate sampling even more shocking.

The NOAA's argument that 'data are not accessible in real time' is not justifiable. A study of global warming does not require data in real time. It is enough for stations to submit their data once a year.

C. Globally (at sea)

As explained earlier, weather buoys are the most commonly used method of measuring temperature at sea.

According to the NOAA, there are currently 1,285 buoys operating in the world's oceans. The map in Figure 4 shows their distribution.

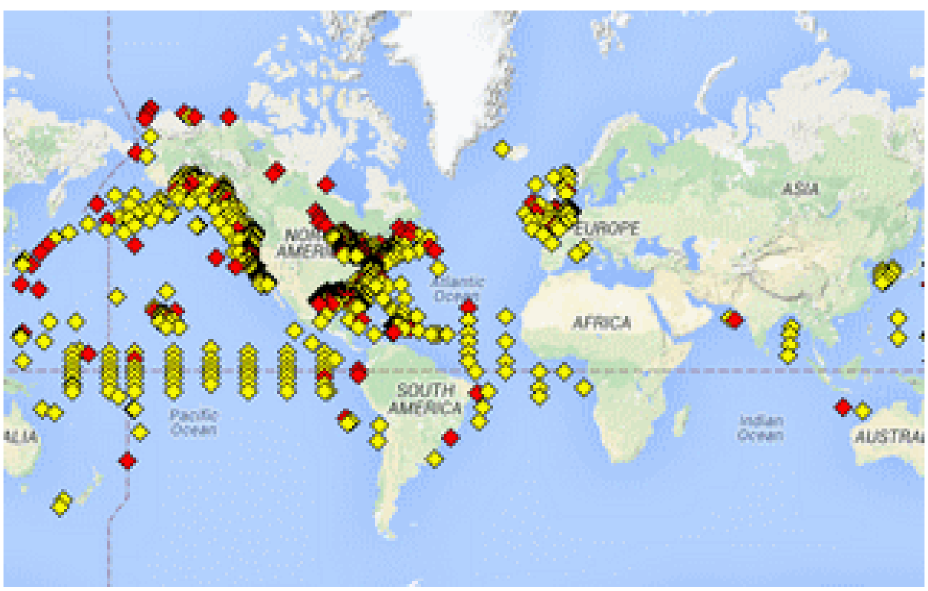


Figure 4. Distribution of weather buoys

The Gulf of Mexico and the west coast of the US are well provided with sensors. The distribution of stations in the Pacific Ocean is uneven, and is very inadequate in the

Atlantic and Indian Oceans and at the Poles.

D. Critical analysis

Measurement instruments are not evenly distributed throughout the world. There are areas that are very well provided with both land-based and marine measurement stations, such as the UK and the US. Other areas are well supplied with land-based stations but have no readings at sea (East Asia and the Mediterranean coast). Alaska is well provided with marine sensors but has very few land-based sensors. Lastly, huge areas (the Indian Ocean, Australia, the North Pole, the North Atlantic and Canada) have very few sensors, on land or at sea.

Furthermore, the NOAA is using fewer and fewer stations to establish a global temperature profile, justifying this by technological advances and the difficulty of accessing data from old stations.

Let us make a rough analysis of how well stations are distributed. Let us say that the information provided by a sensor is representative of weather conditions in the surrounding 100 km^2.

The Earth has a total surface area of approximately 500 million km^2; this means that a reliable global analysis would require at least five million sensors, which is 1,600 times more than the 3,000 stations being used at the moment. And that is simply for the calculation of surface temperatures. This distribution would have to be repeated at every layer of the atmosphere and every depth of the seas.

This simple calculation clearly demonstrates that there are not enough stations to model the surface temperature of the globe, and satellites cannot replace surface stations. The reduction in the number of sensors being used is fundamentally unsound: temperature varies from one place to another, from one hour to the next, and this natural variability can be tracked only by a very dense network of sensors.

III. Recent temperature trends

A. Data sources

Average annual temperatures are given on the NOAA site, in climate information sheets on the 'Climate Monitoring' page.

The annual figures published by the NOAA are mostly data in the form of 'temperature anomalies' (this is explained later, in section D,'Methodology: thinking in terms of temperature anomalies'). A temperature anomaly is the difference between the average temperature for the year in question and a long-term average (from 1880 to 2000), which serves as the baseline. According to NASA and the NOAA, these data are more appropriate for calculating averages over space and time because they are representative over much larger areas and longer periods than absolute temperatures (the explanation provided by the NOAA is given later).

However, these data are not very clear for the reader because these annual anomalies are calculated in relation to a 'sliding' baseline which changes every year. For example, the anomaly given for 2005 is in relation to the average between 1880 and 2004, the anomaly for 2006 is in relation to the average between 1880 and 2005, and so on. Worse still, data are sometimes referenced in relation to the period 1961-1990. Although using a baseline to establish long-term comparisons might initially seem to be a good idea, it loses all meaning if the baseline itself is variable.

It is fascinating to see that, on such a heavily debated subject, nowhere on the American Government site is there any mention of a simple, global figure: for year N, the averagetemperature is so much. This in itself is enough to set off alarm bells for any mildly curious scientist.

The data on global annual averages are very difficult to obtain, even for recent periods, because of the varied formats of NOAA information sheets.

B. Recent temperatures

The format of the NOAA's information sheets varies from one period to another, and it is difficult to find equivalent information. In fact, the absolute average temperature is almost never given explicitly, and all the values are anomalies in relation to the 'sliding' baseline we mentioned earlier.

We did manage to find, on the CRU website (the Climatic Research Unit, which is part of the University of East Anglia), an information sheet giving annual average temperatures since 1850. The temperatures are given in the form of anomalies in relation to the reference period 1961-1990. On the WMO website, we find that this reference average is 14°C.

Below is the histogram of annual average temperatures for the past 20 years.

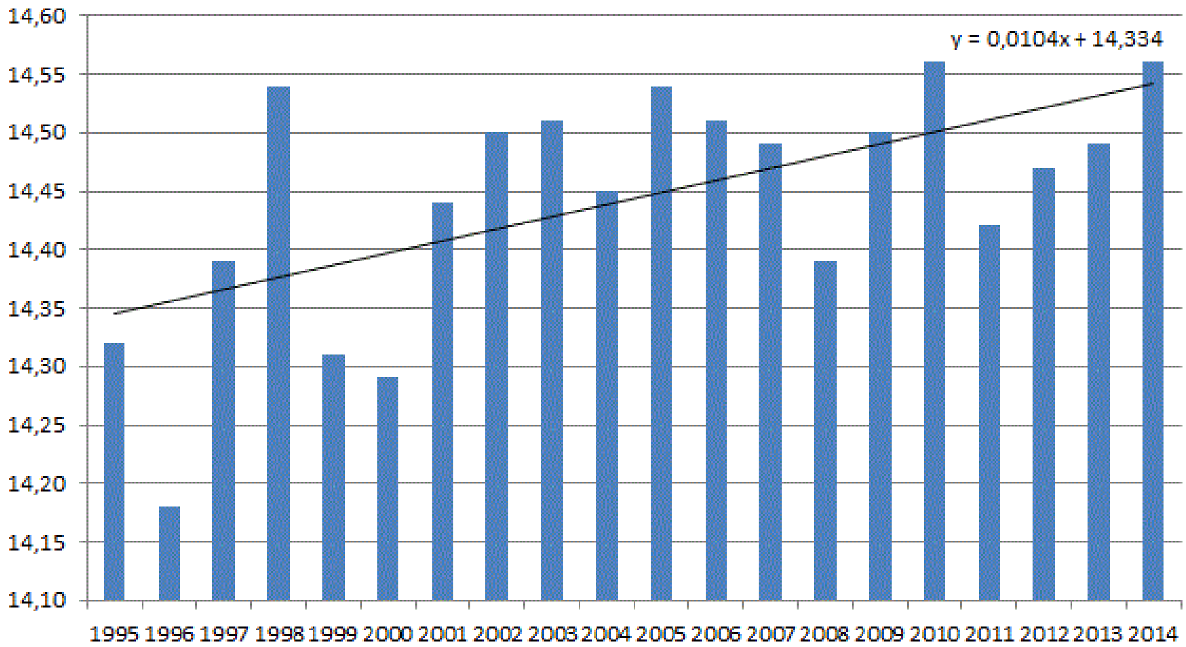


Figure 5. Histogram of annual mean temperatures for the past 20 years (source: CRU)

A linear regression gives us a slope of 0.0104°C per year, which is a rise of 1.04°C over 100 years.

There is something in this graph that is really interesting for scientists: you can see that, from one year to another, the calculated average temperatures are different. Now, the action of the Sun and geothermal energy are fairly constant. These inequalities are to do with the fact that sensors are unevenly distributed and that, from one year to another, it is hotter in one place or another. What we have here then is evidence that the number of sensors is inadequate. So, in these conditions, one cannot come to any conclusion about climate change in any sense. All that we are recording (today and even more so in the past) are variations that derive simply from inadequate observations.

This simple observation – the average temperatures recorded vary from year to year. Why? – is never analyzed by the scientists responsible for these matters.

IV. Thinking in terms of temperature anomalies

A. Introduction

Most websites on global warming provide data on temperatures. However, the parameter considered is not the temperature itself but an 'anomaly', that is to say a discrepancy in

relation to an average temperature.
This average is for a so-called reference period, which serves as a basis for temperature comparisons. This reference period is 1951-1980 for NASA, and 1961-1990 for the NOAA.

The temperature anomaly is therefore the difference between the temperature recorded and theaverage temperature over the reference period.

B. Why think in terms of anomalies?

Here is the NOAA's explanation for its decision to use temperature anomalies rather than absolute readings [NCDC]:

'Absolute temperatures are difficult to use for several reasons. Some areas have only a few measurement stations, and interpolations have to be made over vast expanses. In mountainous areas, most observations come from inhabited valleys, so altitude has to be taken into account in average temperatures for a region. For example, a summer month might be colder than usual, both at the top of a mountain and in a nearby valley, but the absolute temperatures will be very different on the mountaintop and in the valley. The use of anomalies in such a case will show that temperatures are below average in both places.

So large areas are analyzed using anomalies rather than absolute temperatures. Anomalies give a more accurate picture of climate variability over a large area than absolute temperatures would, and make it possible to compare areas more easily.'

The word 'anomaly' is loaded in itself and not very scientific; it gives the reader the idea that there is going to be something abnormal, whereas it simply concerns the difference in relation to a reference period.

C. Flaws in the thinking

The NOAA explains that thinking in terms of anomalies makes it possible to 'smooth out' temperature discrepancies from one place to another. This implies having measurement stations in both places – in this case, to use our earlier example, at the top of the mountain and in the valley. So why not use absolute temperatures? Thinking in terms of anomalies is simply a method of processing raw data and, if there is an error in a temperature value, then this will necessarily affect the anomaly.

Also, a temperature anomaly in relation to a reference period implies careful consideration of the choice of reference period. NASA and the NOAA use averages over 30 years (1951-1980 for NASA, and 1961-1990 for the NOAA).

NASA's data cover only the US, giving temperature anomalies between 1880 and 2010 in relation to the 1951-1980 average. But we have already seen that there have been a large number of evenly distributed measurement stations in the US since 1880.

A question immediately comes to mind: if there has been a reasonable amount of good-quality data since 1880, why use the reference period 1951-1980 instead of the period 1880-2010? It seems logical to choose the longest possible reference period, and the quality of the American system means this can go back as far as 1880.

We find a similar situation in Europe, which has access to good-quality data dating back to 1850, yet the NOAA chooses to use the reference period 1961-1990.

There is a contradiction on the NOAA website, in the 'Warming Climate' section of the 'Global Climate Change Indicators' page. In this section, temperatures are now given as absolute temperatures rather than in terms of anomalies.

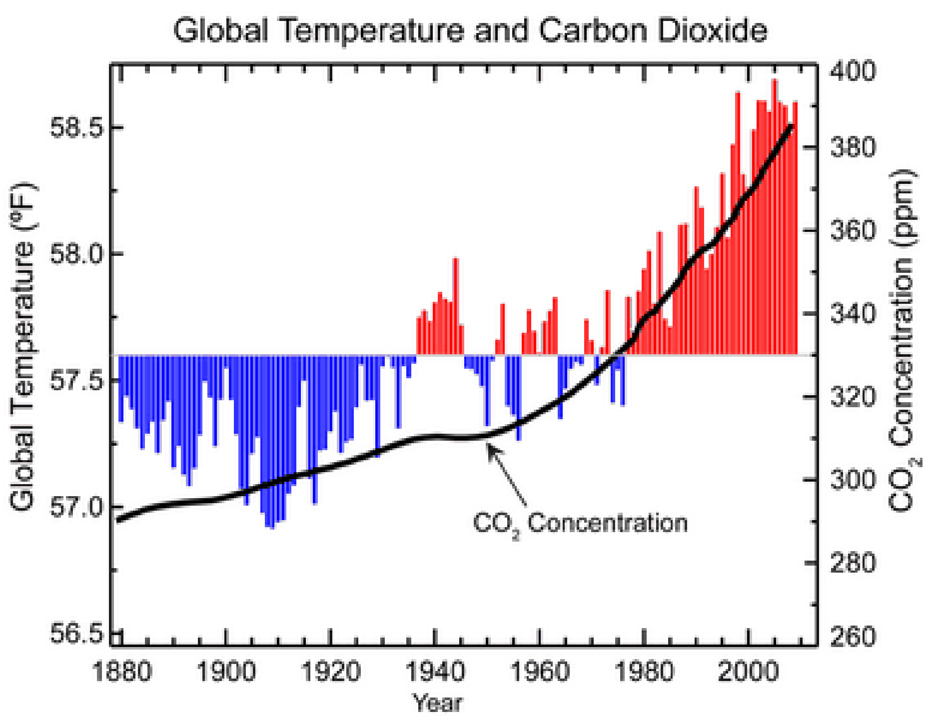


Figure 6. Graph of temperatures between 1880 and 2010 (in °F)

Here too, a reference period is used as a standard, but using an arithmetic mean for the period 1901-2000. This reference temperature is 57.6°F, or 14.2°C. There is reason to question the choice of this reference temperature, which involves using a color code to interpret the graph, when a comparison with 0°C would have been more logical.

So the format of this graph (color-coded 'reverse histogram') encourages the reader to interpret it as showing a recent rise in temperatures. The graph also shows the CO_2 profile, and the graph's format might lead to a misreading: the reader will be tempted to see a correlation between temperature and CO_2, when in fact the two profiles are different between 1880 and 1980, and a simple change in the scaling of the axes would alter the shape of the CO_2 curve, destroying the visual link the reader has been tempted to make.

As we said earlier, thinking in terms of anomalies makes no sense if the reference period varies from one organization to another (and even within an organization, as in the case here of the NOAA).

Let us state this clearly: there is absolutely no scientific justification for presenting data in terms of anomalies. It is tendentious and encourages conclusions concerning global warming. One has every right to expect to be given a simple, global figure, which would simply be the average of values recorded locally. This figure would not have any particular practical value (since, as we have seen, there are not enough sensors in some areas), but one could at least compare values from one year to another.

However, on a totally different note, we shall see that the very definition of a global temperature for the Earth poses some serious problems.

How do you define an 'average temperature'? There are, of course, several types: arithmetic mean (sum of values divided by number of readings), geometric mean (less sensitive to extreme values), and thermodynamic mean (more complex, based on thermodynamic equations). We are going to look at the various possibilities. The astonishing thing is that none of the organizations with any kind of responsibility for global warming has ever asked this question!

D. How do you define and calculate an average temperature?

The competent organizations use an arithmetic mean, adding up all the temperature readings available and dividing the total by the number of sensors. But this poses some serious problems, as we shall now see.

First of all, let us imagine a simple situation: two sensors, each monitoring an area of 1 km^2. The first gives a reading of 10°C, while the second gives a reading of 12°C. One is tempted to say that the overall average (covering 2 km^2) is 11°C. We shall see later that this simple reasoning is not correct.

Now let us imagine that one of the sensors covers 1 km^2, while the other covers 5 km^2. The sensors are still giving readings of 10°C and 12°C. How are we going to calculate the average temperature? Nobody knows!

Now let us imagine a more difficult situation, which is what happens in reality: one of the sensors is monitoring 1 km^3 of the atmosphere, while the other is monitoring 3 km^2at the surface. How do you calculate the average temperature of this surface-atmosphere combination?

Nobody can answer these questions, and nobody even dares to ask them. Let us go back to the basics of physics, to try to understand what a temperature is.

1. Definition

A system comprises particles (atoms, molecules and ions) which are in perpetual motion (chaotic motion in the case of fluids and gases; oscillations around a point of equilibrium in the case of a crystal lattice).

Temperature is a macroscopic measurement of the molecular agitation of the system. It represents the average energy of a molecule. The higher the temperature, the greater an atom's oscillations around its average position. But this definition is not quantitative.

The basic unit of the international system is the Kelvin (K). Zero Kelvin (absolute zero) is the temperature that corresponds to the weakest molecular agitation.

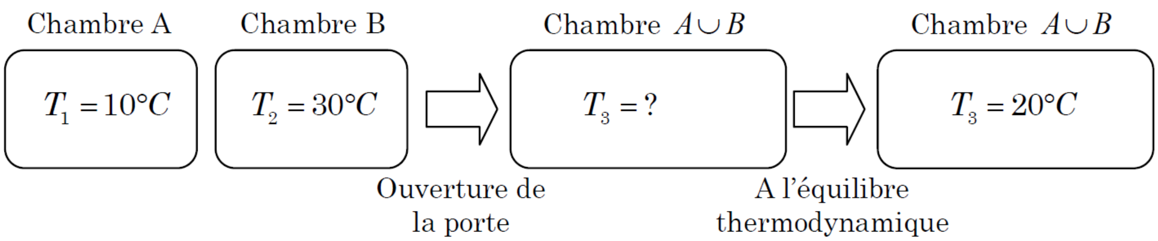
Temperature is an intensive variable: it does not depend on the quantity of material present and it is the same throughout the system. Let us take the example of two rooms, A and B, separated by a door, in which the temperature is respectively 10ºC and 30ºC. When you open the door, the temperature in the $A \cup B$ system is not 40ºC, but an intermediate temperature throughout the space.

By contrast, volume is an extensive variable, dependent on the quantity of materialpresent. Let us take rooms A and B again and suppose that their volumes are respectively 10 m^3 and 20 m^3. The volume of the whole space, the $A \cup B$ system, is 30 m^3.

2. Pertinence of an average temperature

As explained earlier, temperature is an intensive variable. Therefore, if we once again use the example given above, it is impossible to add together the temperatures of the two rooms.

Let us imagine that, before we open the door, rooms A and B are adiabatic systems (no heat source, no heat sink, and no heat exchange with the outside) in thermodynamic equilibrium: this means that in room A (and respectively room B), the temperature is the same throughout and is 10°C (or respectively 30°C). When the door is opened, heat exchanges take place until equilibrium is reached. Once thermodynamic equilibrium has been reached, the temperature is the same throughout the two rooms, and the 'average' temperature can be measured (there are variations, but only at the microscopic level).

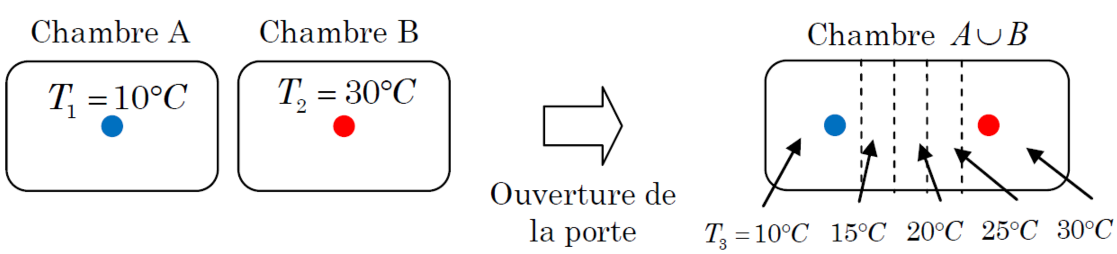


Key: Chambre = Room; Ouverture de la porte = Door opens; A l'équilibre thermodynamique = Dynamic equilibrium reached

The Earth is not an adiabatic system: it has heat sources and heat sinks. Thermodynamic equilibrium is never reached. Let us return to the two rooms:

- room A contains an air-conditioning unit cooling the room to 10°C;
- room B contains a radiator heating the room to 30°C.

Heat exchanges occur when the door is opened, with the system stabilizing itself by forming a temperature gradient between the cold source and the heat source. If we calculate the average temperature of the $A \cup B$ system, we get 20°C. But this average temperature is not representative of the temperature everywhere in the room.



Key: Chambre = Room; Ouverture de la porte = Door opens

Determining an average temperature for a system as complex as the Earth has no physical meaning. Unfortunately, this question, fundamental though it is, has never been tackled by organizations involved in meteorology. For them, the answer is simple: you take all the sensors and calculate the average!

Quite apart from the question of the significance and pertinence of global temperature, it is also reasonable to question whether this variable can actually be calculated with any reliability.

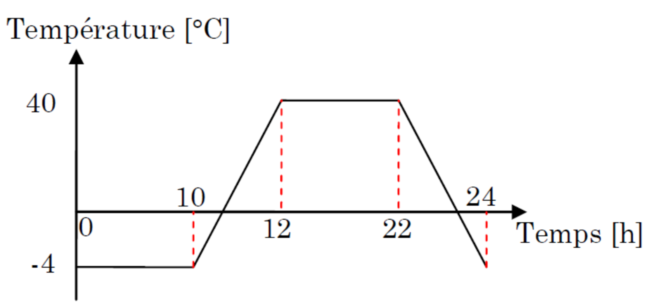
To explain more clearly the error in calculating an average for an intensive variable, let us take the example of speed. When a hare moves at a speed of 9 km/hr and a tortoise moves at a speed of 1 km/hr, the average is as follows:

- arithmetic mean: $\frac{(9+1)}{2}$ =5 km/hr for the hare-tortoise system;
- harmonic mean: when they travel a distance of 1 km, the hare will take about 6 minutes and 40 seconds, and the tortoise will take an hour. This means that the hare-tortoise system takes 1 hour 6 minutes and 40 seconds to cover a distance of 2 km. Their average speed is 1.8 km/hr.

The method used to calculate the average affects the result.

Now let us take the example of a room with a temperature that fluctuates over time as follows:

- -4°C from 0.00 hrs to 10.00 hrs;
- a temperature rise from -4°C to +40°C between 10.00 hrs and 12.00 hrs;
- 40°C from 12.00 hrs to 22.00 hrs;
- a temperature drop from 40°C to -4°C between 22.00 hrs and 24.00 hrs.



Key: Température = Temperature; Temps (h) = Time (hr)
Arithmetic mean: $T_{average} = \sum T/n$; or 13.6°C
Integral: $T_{average} = \frac{1}{24} \cdot \int_0^{24} T(t) \cdot dt$; or 18°C

We can see again from this example that the method used to calculate the average has an influence on the result. According to the integration method, the average is 18°C, which is a comfortable temperature for people. However, this average temperature of 18°C occurs during a short period (twice a day) and the periods of high and low temperatures would prevent any normal life in this environment. So the average temperature is of no practical significance.

None of the methods enable us to represent the actual temperature of the room over a day.

The term 'average temperature' isa scientific aberration, and all the more so when this variable is being calculated for a system with enormous disparities over time and space. The average temperature does not correspond to any immediate, local, perceptible reality. There are two factors to be taken into account: time and space.

3. Calculation of average temperature

Several methods have been suggested for determining the Earth's temperature. We are going to present two of them here, and comment on them.

- **Thermal mean**

All bodies, whatever their state (solid, liquid or gas) emit electromagnetic radiation, which travels in a straight line at the speed of light and is made up of rays.

The Stefan-Boltzmann law enables us to link the luminosity emitted by a black body with a surface area of A [m^2] with temperature and the constant $\sigma = 5.67 \cdot 10^{-8}$ [$W.m^{-2}.K^{-4}$], according to the equation:

$$\Phi = A\sigma T^4$$

By definition, a black body absorbs all the radiation it receives. However, the Earth is not a black body, because some of the Sun's rays are reflected by the oceans and ice sheets, and also by land masses. It is impossible to use this method to determine global temperature.

- **Thermodynamic mean**

As we explained earlier, temperature is a representation of the oscillation of molecules. It is possible to use statistical models to find a correlation between temperature and energy. The difference between the two is that temperature is an intensive variable, while energy is an extensive variable. This means it is possible to add the energies together and obtain an average. The difficulty is in taking account of the many relations that make it possible to link temperature and energy, which vary depending on the system being studied (solid, liquid or gas).

For example, the internal energy, U, of a system is:

- for a monatomic ideal gas: $U = \frac{3}{2} nRT$
- for a polyatomic ideal gas: $U = nC_{Vm}T$
- for a condensed phase: $U = nC_{Vm}T + Ep_{\text{int}}$ or $dU = nC_{Vm}dT$

The different variables are defined in the following table:

T	temperature [K]
U	internal energy [J] or [kg.m^2.s^{-2}]
n	molar quantity of atom [mol]
$R = 8.314$	constant of ideal gases [J.K^{-1}.mol^{-1}]
C_{Vm}	molar heat capacity at constant volume [J.K^{-1}.mol^{-1}]
Ep_{int}	constant energy because volume is constant [J]

Although it is possible to make an energy assessment of the planet and determine an average energy, it is, by contrast, impossible to reach a temperature value without making an aberrant hypothesis: 'Earth is an ideal gas'.

4. The averages currently being used

With regard to these explanations, we have looked into what is being done in practice. International bodies all seem to be using the arithmetic mean to establish the average for the reference period. In Canada, for example, the average is, 'an arithmetic mean over the period in question'. According to the British Met Office, 'The global average temperature is the arithmetic mean of the northern hemisphere average and the southern hemisphere average.'

This type of reasoning is being used by all the international bodies, and one might legitimately question its validity. The thermodynamic mean, for its part, is too complicated to apply and requires the use of models (with all their limitations and uncertainties).

We might, however, wonder why the arithmetic mean is also being used in areas that are less well provided with sensors or have very high or very low temperatures. If we content ourselves with an unweighted arithmetic mean, then areas with the highest density of sensors are going to be over-represented!

Our conclusion here is very clear:

- to calculate the arithmetic mean for the entire planet makes no sense and can only lead to errors;
- you can calculate the arithmetic mean for areas well provided with sensors (Europe and the US), and compare the values from one year to another. This might provide information on local climate variation.

V. Disinformation

A. Study of NASA data

A publication by Hansen et al, 1999 [Hansen 1], which is available on the NASA website, analyzes temperature changes on the Earth's surface for the period 1880-1999. This analysis is based on measurements recorded by weather stations.

We are interested in a graph (Figure 6, page 37 of the publication), which shows temperature anomalies in the US between 1880 and 2000, in relation to the reference period 1951-1980.

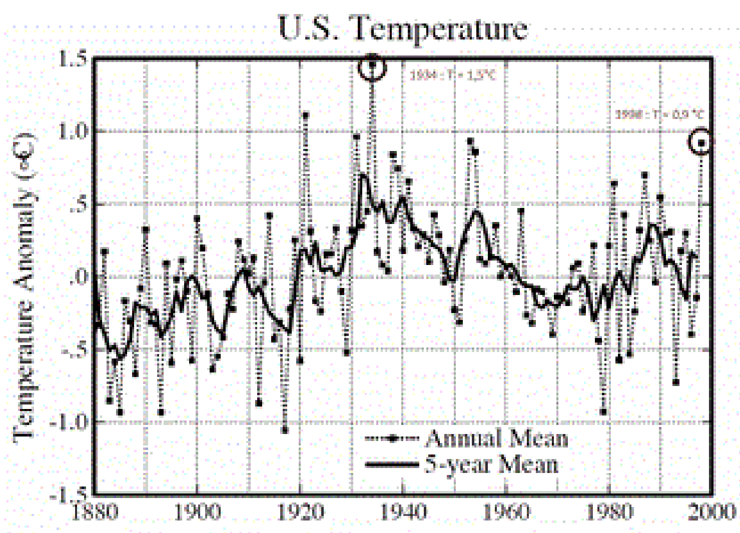


Figure 7. Annual mean and five-year mean temperature anomalies for 48 US states, in relation to the reference period 1951-1980 (1999 version)

Between 1880 and 1930, temperatures rise by 0.8°C, with a peak of 1.5°C in 1934. Between 1930 and 1970, temperatures fall by 0.7°C. Lastly, from 1970 to 1990, temperatures rise by 0.3°C, with a peak of 0.9°C in 1998.

The 1999 data were later corrected by NASA in 2001 because, at the time, they had failed to take account of the movement of weather stations (we have no idea what 'movement' they are talking about!) and changes in observation periods (idem). After correcting the databases, NASA obtained the following graph [Hansen 2]:

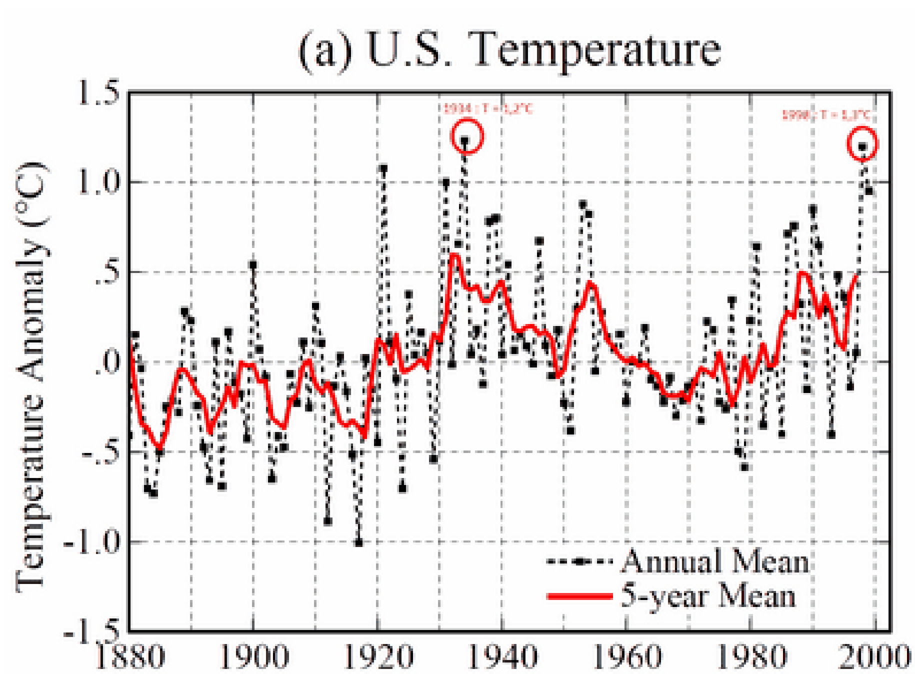


Figure 8. Annual mean and five-year mean temperature anomalies for 48 US states, in relation to the reference period 1951-1980 (after corrective updating in 2001)

Temperatures rise gradually from the 1880s to the 2000s. The corrections mean that the peak anomaly of 1934 is reduced from 1.5°C to 1.2°C, whereas the 1998 temperature peak rises from 0.9°C to 1.3°C after the adjustments.

B. Study of corrections made by NASA

The new publication by Hansen et al, 2001 [Hansen 2], which is also available on the NASA website, uses changes in the analyses of the Goddard Institute for Space Studies (GISS) and the United States Historical Climatology Network (USHCN) to explain the corrections made to the 1999 data.

The adjustments made by the USHCN are shown in Figure 9.

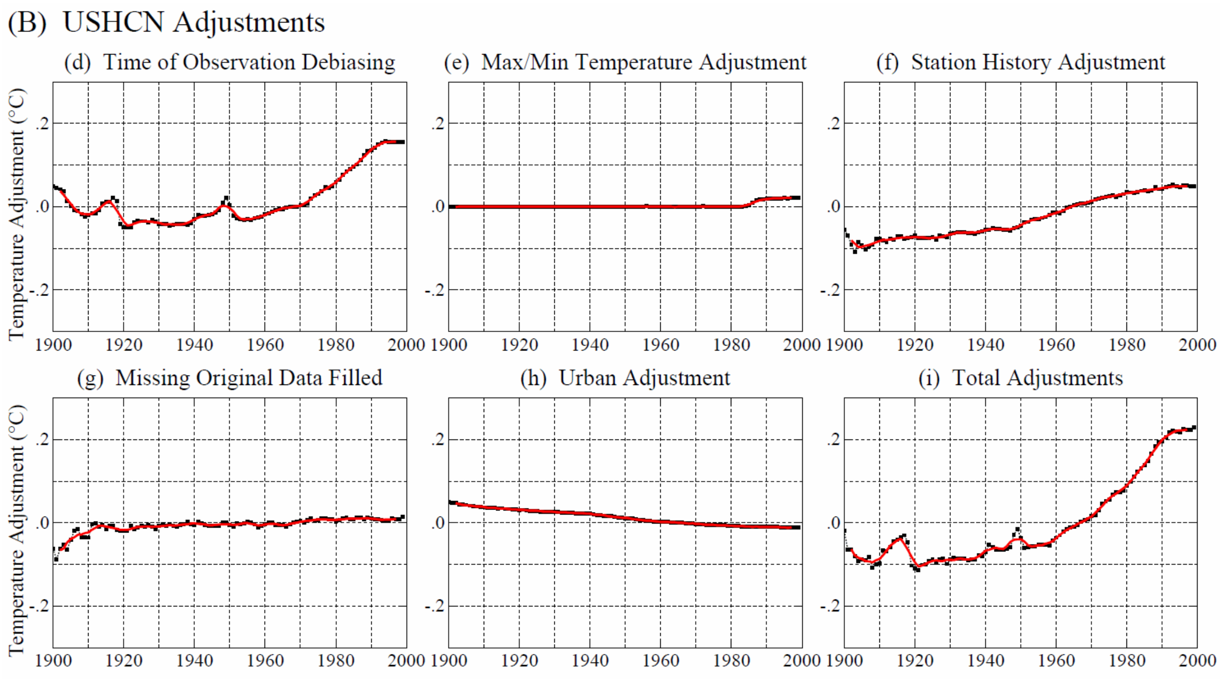


Figure 9. USHCN corrections (2001)

The adjustments made by the GISS are shown in Figure 10.

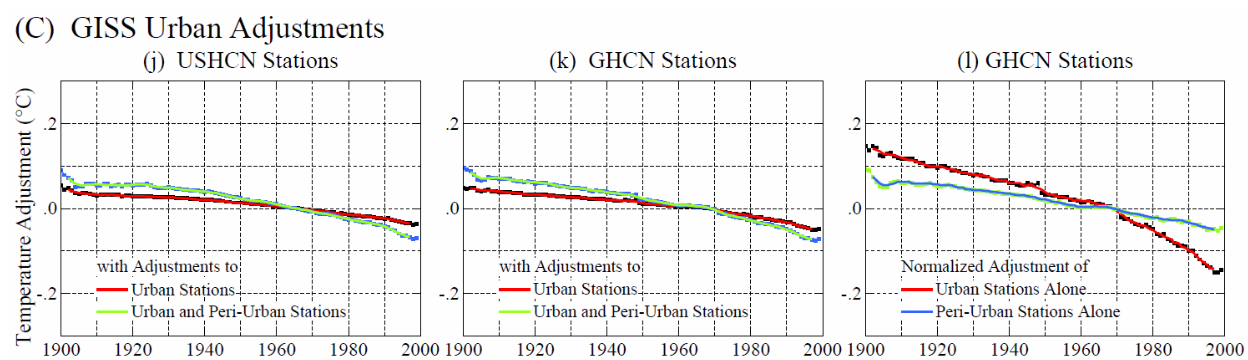


Figure 10. GISS corrections

Lastly, using raw data, Figure 11 gives the picture following the various corrections:

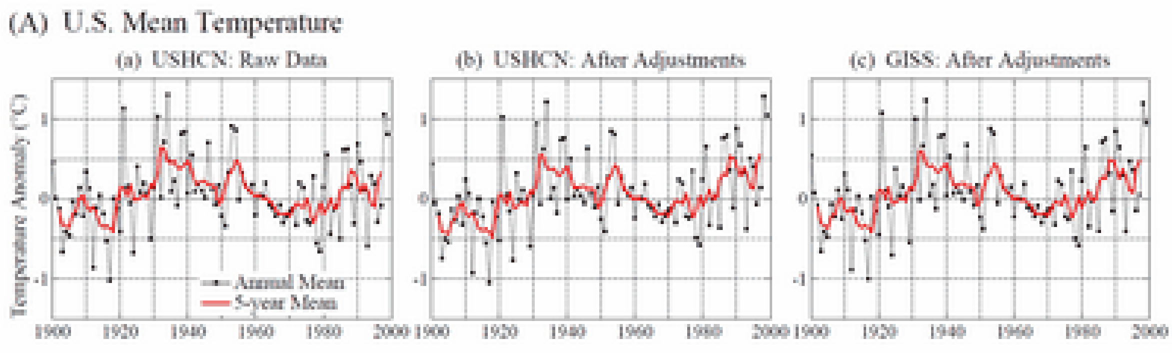


Figure 11. Summary of USHCN and GISS corrections

After the corrections, the general trend of the curve peaks is less severe between 1900 and 1970. The peaks for 1920 and 1934 are smaller. By contrast, the general trend of peaks after 1970 is accentuated, with steeper peaks for 1990 and 1998 in particular.

As we have said before, it is legitimate to correct a set of data only if the corrections are applied to all the data; if you make corrections only from a certain date onwards, then you falsify comparisons.

C. Study of EPA data

The United States Environmental Protection Agency (EPA) recorded annual heat waves (Heat Wave Index) in the US between 1895 and 2013 [see EPA].

A heat wave is a prolonged period during which it is abnormally hot. According to the EPA, there is no universal definition of a heat wave. The EPA defines a heat wave as a period lasting at least four days with an average temperature that would only be expected to occur once every ten years (based on the historical record).

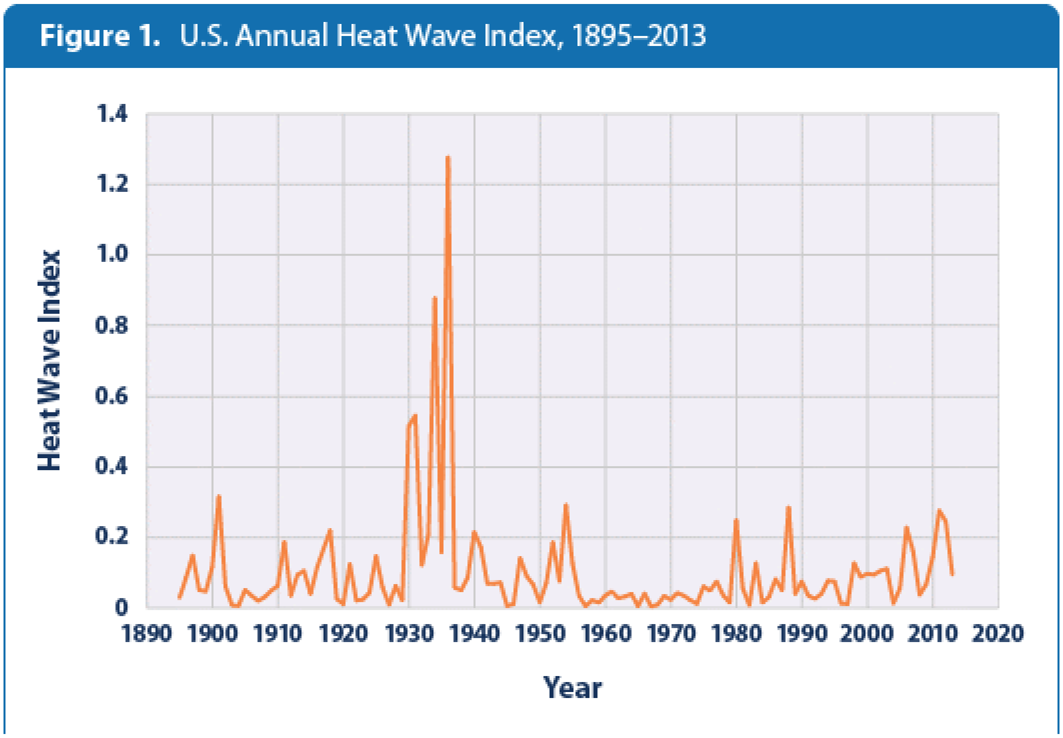


Figure 12. US Heat Wave Index, 1895-2013

The biggest heat wave occurred between 1930 and 1940 (with an index variation of 0.6 to 1.3). There is almost no variation in the index between 1940 and 2013 (it fluctuates between 0 and 0.3).

D. Inter-organization comparison

We might question the corrections made by NASA, particularly when these data are compared with the EPA's data.

Figure 13 provides three graphs of temperature anomalies in the US, drawn up in 1999, 2001 and 2014 respectively [see NASA].

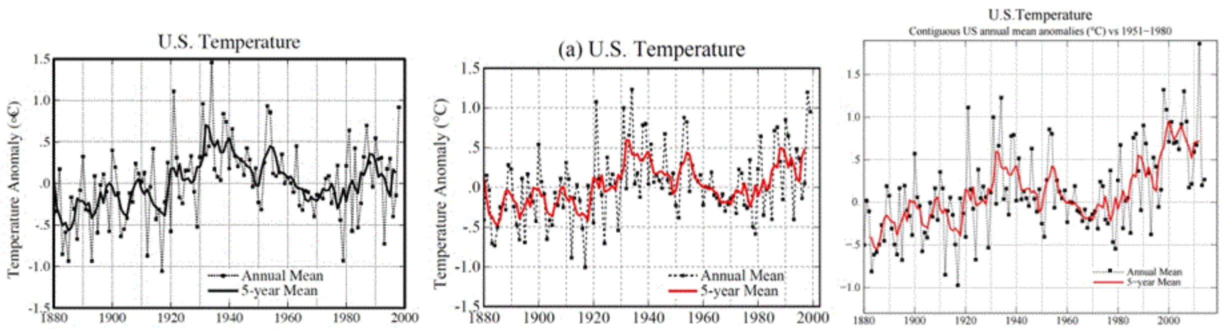


Figure 13. Temperature anomalies in the US – 1999 version (left), 2001 version (center) and 2014 version (right)

The general trend of the five-year mean curves changes from 1999 to 2014:

- in 1999, we have an increase in the five-year mean curve, with a peak of 1.5°C in 1934, followed by a drop in anomalies through to 1980. There is a slight increase from 1980 to 2000, with a peak of 0.9°C in 1998;
- in 2001, the corrections have reduced the 1934 peak to 1.2°C, and increased the 1998 peak to 1.3°C. This means the general trend of the five-year mean curve is that of an upward curve;
- in 2014, the corrections accentuate the upward trend even further. Indeed, between 2001 and 2014, the shape of the curve has changed for the period 1880-1900, with the upward trend being clearly accentuated in the 2014 version of the graph. At 2°C, the 2012 peak accentuates the effect of a constantly rising curve for five-year temperature anomalies.

If we make a comparison with the heat waves observed by the EPA, we find that NASA's data corrections (showing significant peaks in 1998, 2006 and 2012, and a smaller peak in 1930) no longer agree with the EPA's data (showing a heat wave in the US between 1930 and 1940, and relative stability during the periods 1895-1930 and 1940-2013). The 1999 version of NASA's graph (peak in 1930, followed by smaller anomalies) is much closer to the observations made by the EPA.

E. Critical analysis

None of the information on global temperatures is of any scientific value, and it should not be used as a basis for any policy decisions. It is perfectly clear that:

- there are far too few temperature sensors to give us a picture of the planet's temperature;

- we do not know what such a temperature might mean because nobody has given it any specific physical significance;

- the data have been subject to much dissimulation and manipulation. There is a clear will not to mention anything that might be reassuring, and to highlight things that are presented as worrying;

- despite all this, direct use of the available figures does not indicate any genuine trend towards global warming!