Climate Story Telling: Temperature

Version 1.1. August 8, 2019.

Yes, this is a story about temperature, but temperature is the result of many phenomena, of which the development of vegetation that involves the interaction of oxygen, water, carbon dioxide, and solar irradiation. No direct historic temperature measurement is existing, but only evaluations from so-called proxy parameters can be made, such as $\delta^{18}O$, the isotopic ratio of ^{18}O to ^{16}O that can be measured in ice cores, or tree rings when available.
The long-term picture looks like this:

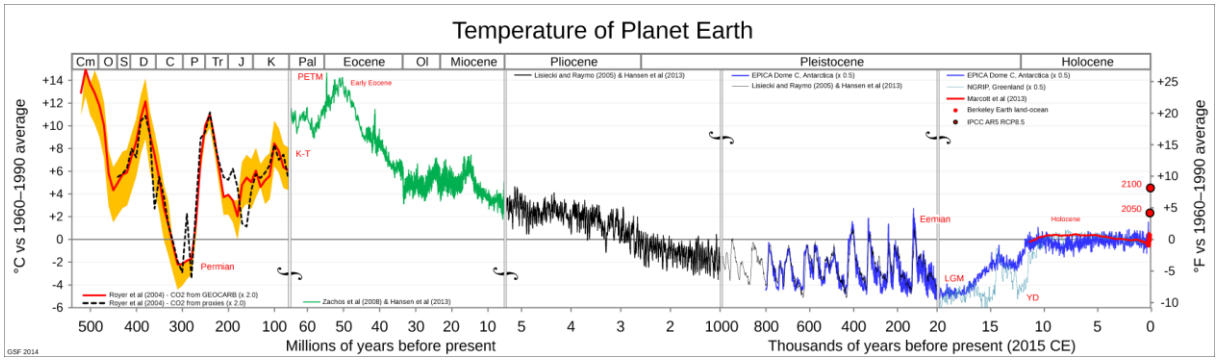

Figure 1 Temperature anomalies of the atmosphere over the past 500 years (logarithmic time scale).
The last two points at the right of the diagram are suggestive wild guesses.
Source: Wikipedia, Glen Fergus. Data: http://gergs.net/wp-content/uploads/2015/06/All_palaeotemps.xlsx

The diagram on Figure 1 does not show temperatures in absolute terms but so-called temperature anomalies, that express the temperature difference at a given point of time as compared to the mean temperature measured at that same place over a reference period, in this case the average over 1960 to 1990.

500 million years ago, the global temperature was 14 °C warmer and the CO_2 concentration ~20 times higher than nowadays. Between 240 and 60 million years before our era, dinosaurs lived on a land covered with abundant vegetation at much higher temperatures than today, apparently well until something special happened, provoking their sudden eradication.

A succession of glaciations and interglacial periods took place over the Pleistocene, from 11 700 years ago back to 2.58 million years.

The Eemian, 130 000 year ago, is the last interglacial before the one in which we now live; it went through a maximal temperature anomaly 2-4 °C higher than today, and a corresponding higher global sea level, by 6-9 meters, due to thinner ice sheets over Greenland and Antarctica, and thermal expansion of the ocean water. *Homo sapiens* was already a living species during this time, albeit without having migrated farther than North-eastern Africa.

Over the Holocene, our current stratigraphic era, a so-called climatic optimum took place between 9 000 and 5 000 years before present (BP), with a maximum temperature around 8 000 BP that was 1 to 3 °C higher than present. The melting of the Alpine glaciers reveals pieces of wood from trees that grew at much higher altitudes, with the tree line several hundred metres above current levels.

Temperature reconstruction over the past two millennia is controversial. It has been obfuscated be the famous and ominous hockey stick diagram published by M. Mann in 1998:

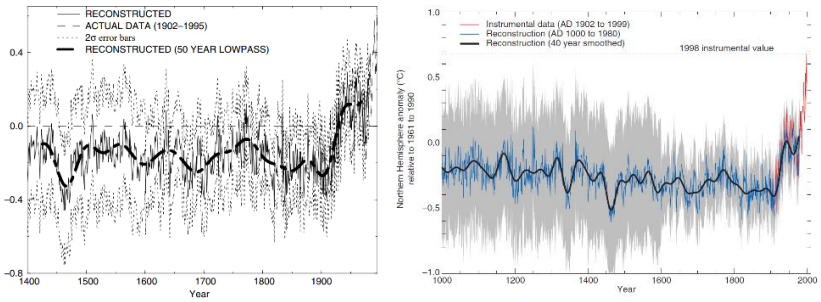

Figure 2 Mann's hockey stick diagram
On the left: original paper (Mann, Bradley, & Hughes, 1998)
On the right: as published by the IPCC in 2001.

Temperature

is an intensive physical quantity. This means that it does not depend from the amount of material or from the system size, but from its thermal state.

It makes no physical sense to calculate an average of the temperatures of different bodies at different places or points of time.

Take two buckets, one filled with ice cold water, the other one with boiling water. An average temperature of approx. 50 °C would have no physical meaning. To obtain an actual average it is necessary to mix these two water volumes; However, this makes it impossible to return back to the original state of two buckets at two different temperatures.

Put one hand in ice cold water and the other in warm water, it is impossible to distinguish any tepid sensation.

Therefore, affirming that temperature of the atmosphere at the Earth surface is on average 14-15 °C is a misrepresentation.

Temperature anomalies are used to compare the temperature evolution at distinct locations. They are historic series, each concerning one given place at different points of time expressed as the departure from the average measurements made at that place over a reference period, usually 1961 -1990. They can be statistically massaged to express average regional or global patterns, regardless of the altitude or the prevailing climatic conditions at the measuring station. In Switzerland for example, the rate of warming since 1864 (°C/decade) is similar for measuring stations situated at low or high altitude.

However, in its 5th assessment report of 2013, the IPCC published a less dramatic and assertive view, this time over 2 000 years, albeit not anymore shown in the Summary for Policy Makers:

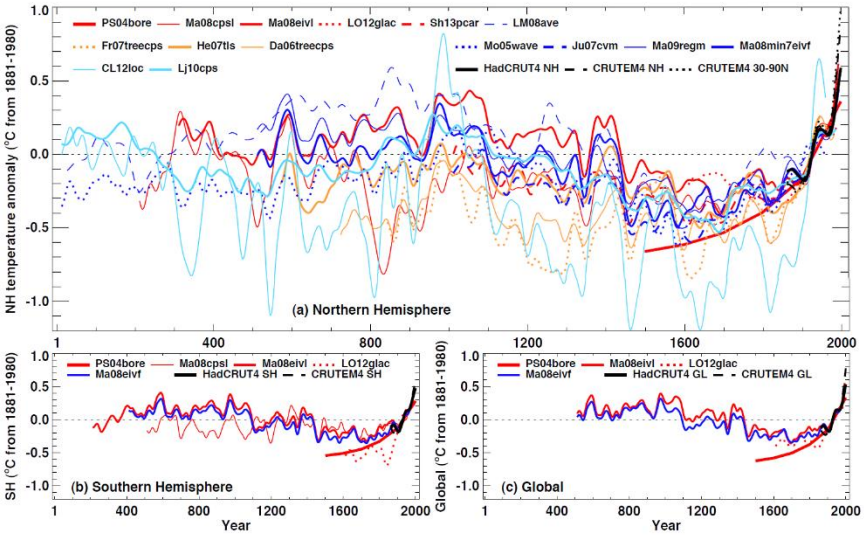

Figure 5.7 | Reconstructed (a) Northern Hemisphere and (b) Southern Hemisphere, and (c) global annual temperatures during the last 2000 years. Individual reconstructions (see Appendix 5.A.1 for further information about each one) are shown as indicated in the legends, grouped by colour according to their spatial representation (red: land-only all latitudes; orange: land-only extratropical latitudes; light blue: land and sea extra-tropical latitudes; dark blue: land and sea all latitudes) and instrumental temperatures shown in black (Hadley Centre/ Climatic Research Unit (CRU) gridded surface temperature-4 data set (HadCRUT4) land and sea, and CRU Gridded Dataset of Global Historical Near-Surface Air TEMperature Anomalies Over Land version 4 (CRUTEM4) land-only; Morice et al., 2012). All series represent anomalies (°C) from the 1881–1980 mean (horizontal dashed line) and have been smoothed with a filter that reduces variations on time scales less than about 50 years.

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Figure 3 Temperature reconstruction over the past 2000 years
Source IPCC AR5 WG1 Report.

More specific for the Northern Hemisphere at latitudes higher than the tropics, another view has been assembled by Ljungqvist in which warm and cold periods coincide with the known history of abundances, famines and diseases.

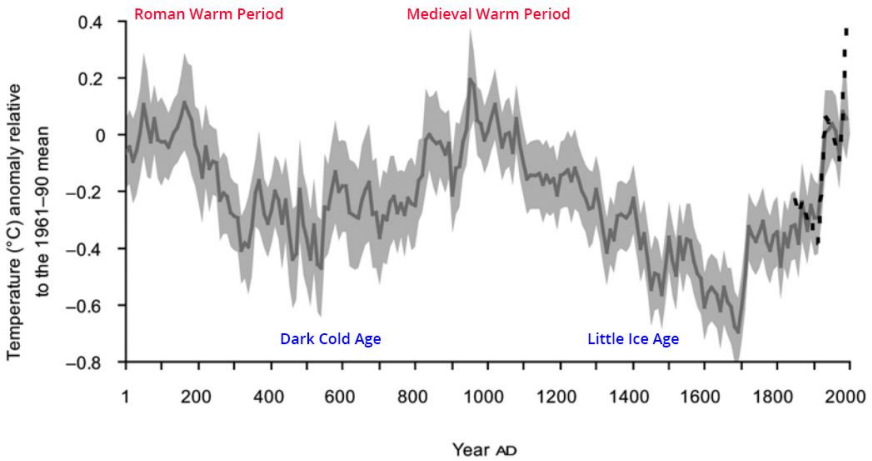

Fig. 3. Estimations of extra-tropical Northern Hemisphere (90–30°N) decadal mean temperature variations (dark grey line) AD 1–1999 relative to the 1961–1990 mean instrumental temperature from the variance adjusted CRUTEM3+HadSST2 90–30°N record (black dotted line showing decadal mean values AD 1850–1999) with 2 standard deviation error bars (light grey shading).

Figure 4 Decadal mean temperature variations in the Northern Hemisphere over the past two millennia.
Source: (Ljungqvist, 2010)

Actual instrumental temperature measurements are only available since the midst of the 19th century. Reconstructions needing a lot of interpolating massaging have been made to obtain monthly temperature series covering the whole globe, even though all places were not the object of regular readings. Various institutions have made such work, with only slight differences, with exception of the NASA Goddard Institute for

Space Studies (GISS) who abruptly, sometime between 2010 and 2015, inflated the warming since 1880 by approx. 0.4 °C from 0.8 to 1.2 °C.

The series HADCRUT4 published by the UK Met Office serve as general reference.

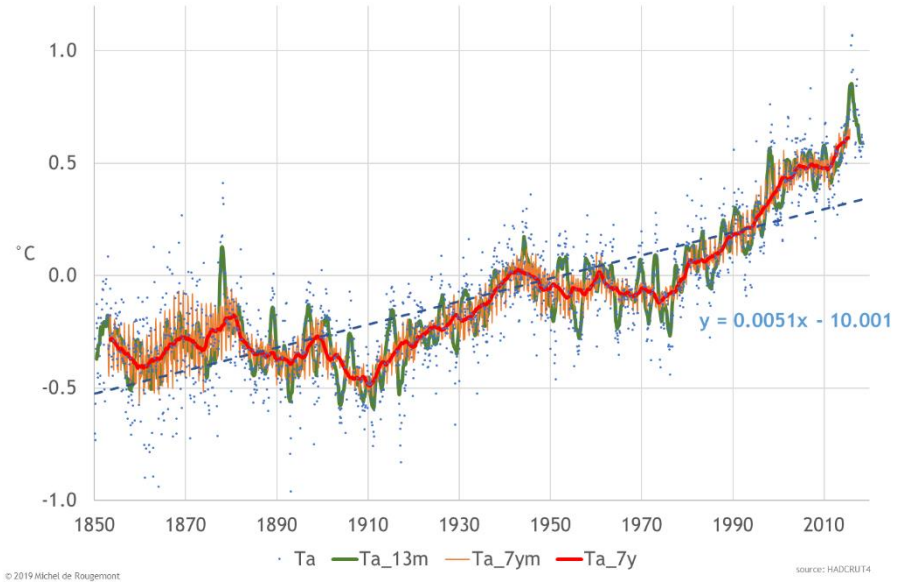

Figure 5 Global temperature anomalies since 1855. Monthly series, relative to 1961-1990.
Blue points: monthly values.
Blue dotted line: linear regression, average warming rate 0.51 °C per century
Green: centred running average over 13 months.
Yellow: centred running average of month of years values over 7 years.
Red: centred running average over 7 years.
Source: HADCRUT4, North and South hemispheres.

Two periods of fast warming took place, the first at the beginning of the 20th century, and the second from 1975 to 1995. The marked peak in 1998 and 2016 are associated with the El Niño phenomenon in the Pacific Ocean.

Data from other series can be visualized on-line at:

http://www.woodfortrees.org/graph/hadcrut4gl/from:1855/offset:-0.26/plot/gistemp/from:1855/offset:-0.35/plot/uah6/from:1979/plot/rss/from:1979/offset:-0.10

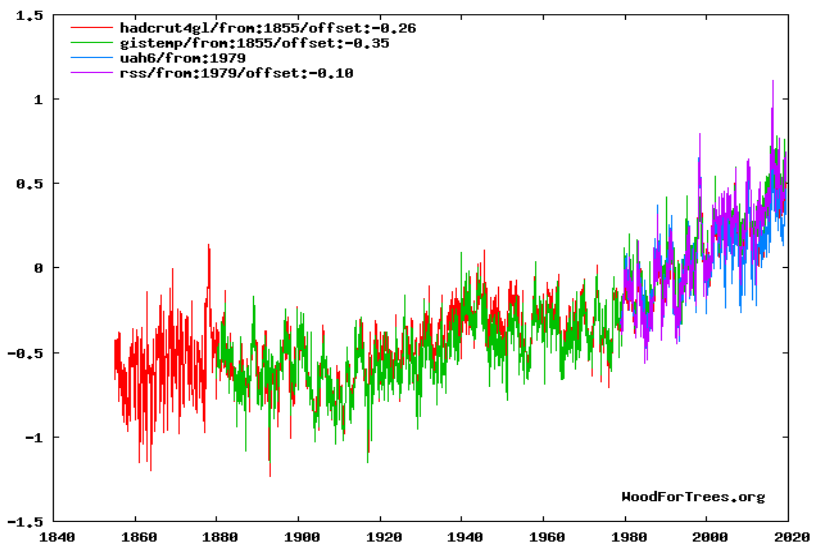

Figure 6 Temperature series comparison
Source : Wood for Trees

While differences can be noticed, they all use the same original data but apply different strategies to interpolate them for the whole globe surface.

Since 1979, satellite observations are made by microwave sounding for various layers of the atmosphere by the University of Alabama at Huntsville in collaboration with NASA.

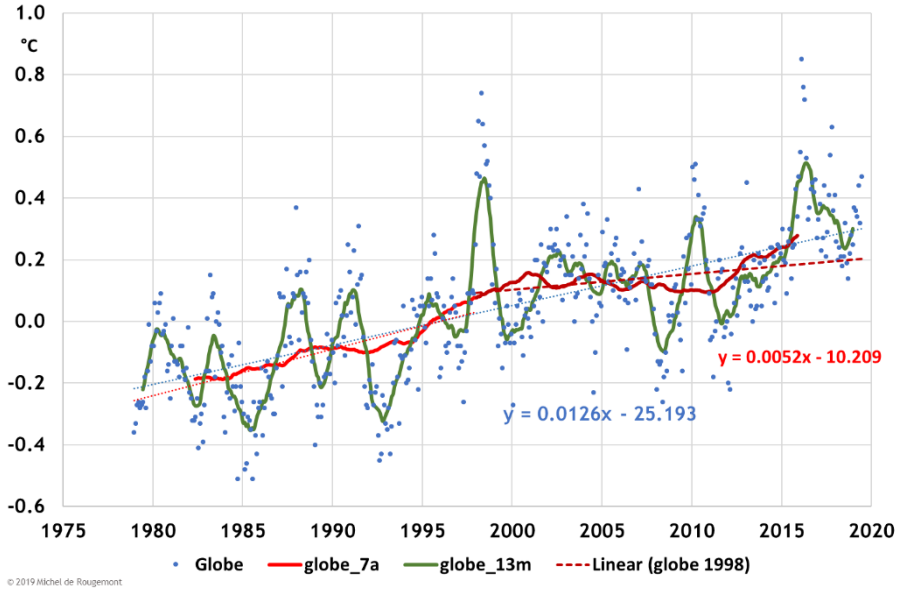

Figure 7 Temperature anomalies (in °C relative to 1981-2010) of the lower troposphere (0-7000m).
Blue dots: monthly values.
Blue dotted line: linear regression over whole period, average warming rate 1.26 °C per century.
Green: centred running average over 13 months.
Red: centred running average over 7 years.
Red dotted line: linear regression since 1998, average warming rate 0.52 °C per century

While the warming rate over the whole period is 1.26 °C/100yr, a slowdown is noticeable since 1998, being now 0.52 °C/100yr.

The higher the latitude the more pronounced is the warming.

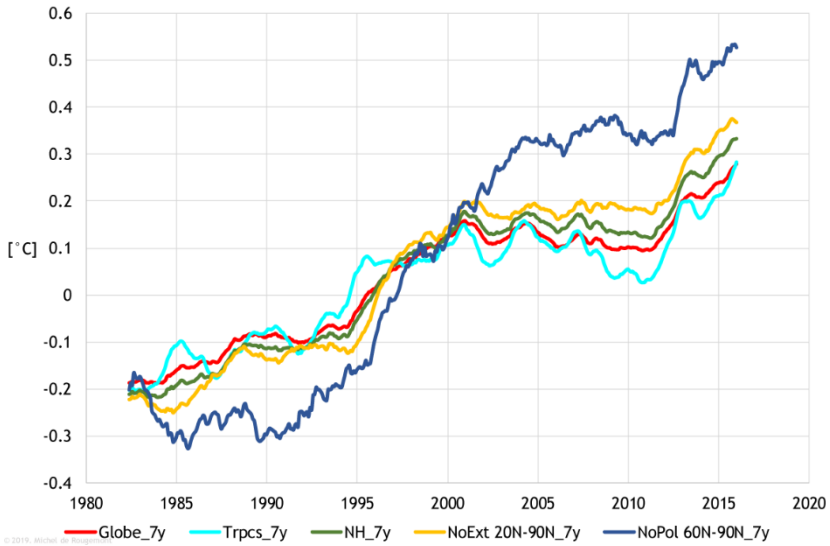

Figure 8 Temperature anomalies of the lower troposphere according to latitudes (7-yr running averages)
Source: UAH, Global, Tropics, Northern Hemisphere, North extended, North Pole

The rate of warming over the period 1979-2019 was:

- Globally: 1.24 °C per century
- Under the tropics (20S – 20N): 1.08
- Whole Northern Hemisphere: 1.51
- North extended part (20N – 90N): 1.78
- North Pole: 2.80

It is often said that the current rate of warming is unprecedented. However, this affirmation cannot be sustained, although the current rates of warming are steep.

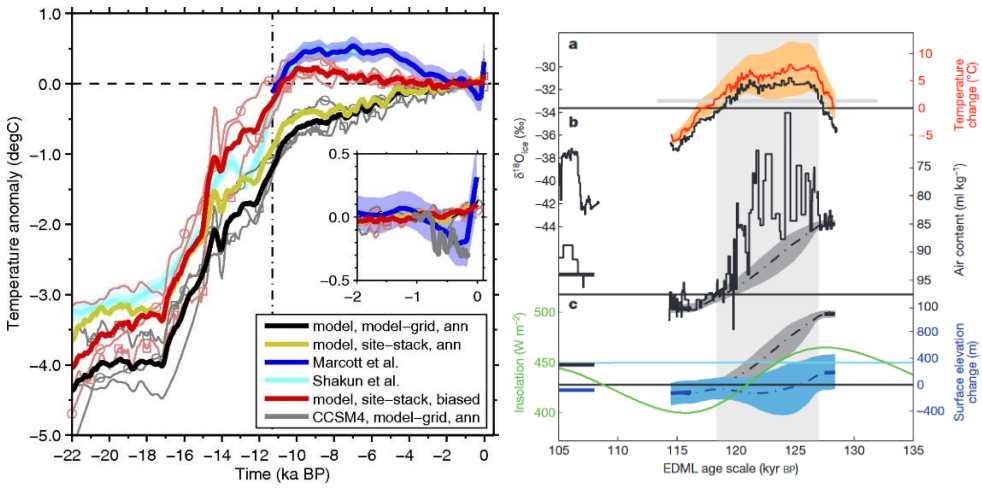

Figure 9 Temperature evolution at the beginning of the Holocene and during the Eemian, with similarly high rates of warming as the current trend.

In lieu of cutting time periods to evaluate distinct linear warming velocities, a running average of the rates of warming cab be derived from the monthly data series HADCRUT4.

Thus, the first derivative of the temperature anomalies over time – dTa/dt – is evaluated over different time filters. To do this, it suffices to apply the Excel function SLOPE over a centred running 7-yr or 31-yr time period.

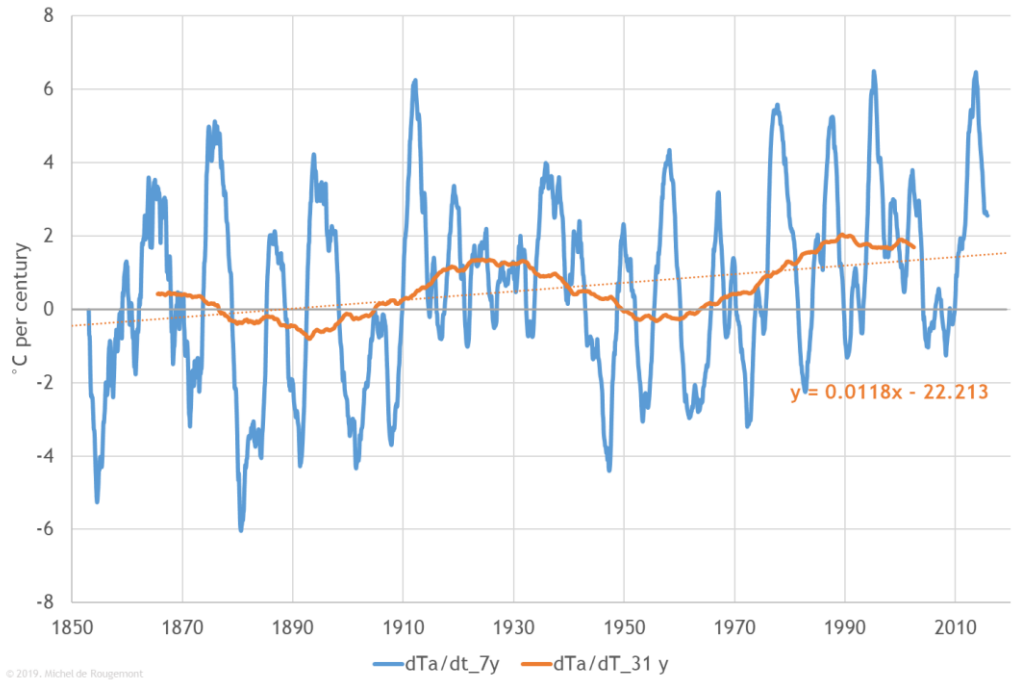

Figure 10 Rate of warming, in °C/100a (per century).
Blue line: centred running average over 7 years
Orange line: centred running average over 31 years
Orange dotted line: linear regression, slope 0.0118 K·century^{-1}·a^{-1}
Source: HADCRUT4 global monthly values.

This graph is quite original, and, probably, the most interesting of all those shown in this story.

- The blue line (7-yr filter) shows a succession of widely changing warming and cooling velocities, with an inconstant period of 9 years on average.
- Both lines ride on a linear and steady accelerating trend since the beginning of the measurements: the warming gets stronger by 1.2 °C/century every century.
- With the 31-yr filter (orange line) another cyclical pattern is revealed, with a 66-68-yr period. Currently, a maximum appears to be reached.

From this it can be discussed, if not concluded, that:

- It is necessary to contemplate climate variations on a long-term basis. No story should be construed about trends over a time span shorter than 30 years. Categorical comments made about differences between single years or about any spell of cold or warm are plainly dishonest. To announce catastrophic boiling when it warms at +6 °C /100a makes no more sense than to try to ridicule warming if it cools for a while at –4 °C/100a.
- It can be understood why, in the 60s, some concern had been expressed over a future global climate cooling. It was wrong, but it takes decades to appreciate this.
- an underlying warming is on-going since measurements were done.
  It is very likely that it has no or little dependence on anthropogenic emissions of greenhouse gases that barely took place during the second half of the

19th century. It must have begun as a global climate turnaround with the exit from the little ice age. According to the Ljundqvist diagram (Figure 4) successions of warm and cold ages take places every 500-800 years. Therefore, this current accelerated warming trend will probably remain short lived; and if this is wrong, then we are going to boil anyway.

- The 66-68 years cycle may or may not be a repetitive pattern. One and a half observation cycle is too few to conclude to an on-going oscillation. If it is the case, then the current warming velocity should slow down over the next 20-30 years. This does not exclude further short record phases.
- The maxima exemplified with the 7-yr. filter may announce El Niño events in the Pacific 2-3 -years ahead of time (a weak hypothesis).

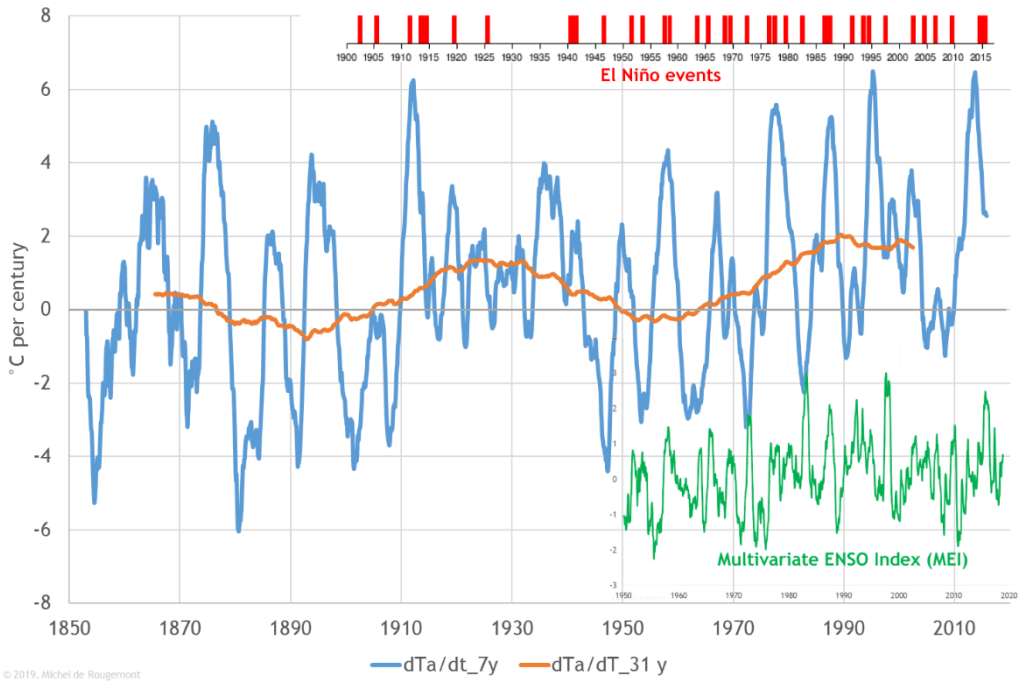

Figure 11 Maxima of the warming velocities, chronology of El-Niño events (red bars, from Wikipedia), and Multivariate El Niño/Southern Oscillation (ENSO) Index.

Correlation with carbon dioxide emissions

The "scientific consensus" among climatologists is that warming is real and that its cause is overwhelmingly of anthropogenic (human made) nature, the major culprit being carbon dioxide, a so-called greenhouse gas (GHG). While the first statement is correct, the second one should remain open for a severe dispute:

See more information on carbon dioxide in Climate Story Telling: Carbon Fate.

The CO_2 emitted from fossil fuels and cement production from 1955 to 1990 amounts to 147 Gt C (Gigatons of elemental carbon), 194,1 Gt C when adding changes of land use to these emissions. Between 1890 and 1925 these were 25, respectively 65 Gt C. These two very different historic emissions cannot be the cause of temperature changes that are almost exactly the same. If it would be so, an acceptable phenomenological explanation should be provided for this sudden multiplication of the climate sensitivity to radiative forcing by a factor 3 to 6. Neither is it acceptable to explain the second phase (late 20th century) almost exclusively by GHG emissions, and to attribute the first to something else that, so far, climatologists did not explain.

To push further the controversy, a diagram relating the warming rates as presented in Figure 10 to the atmospheric CO_2 concentration should reveal an obvious correlation, but this is not the case:

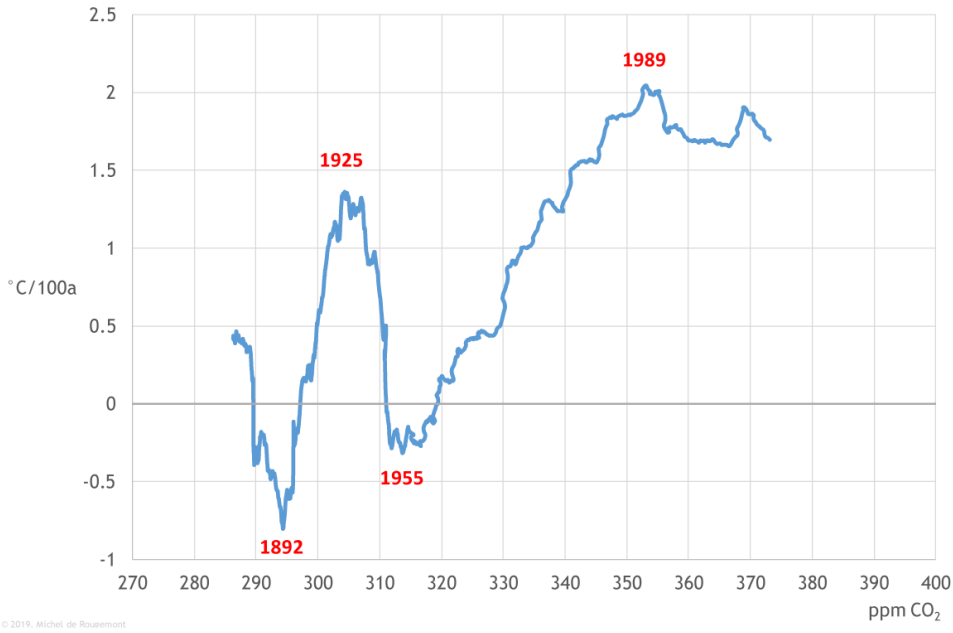

Figure 12 Warming rate (in °C/100a) in function of the measured atmospheric CO_2 concentration
Temperature: HADCRUT4 with a centred 31-yr. filter.
CO_2 concentration (CDIAC and Mauna Loa since 1959): trend filtered over 13 months .
Important note: Because of the 31-yr. filter and because the time average is centred, the diagram ends at 364 ppm. However, the last data point includes the latest reading (April 2019) in its average calculation. Patience is of the order.

No correlation can reasonably be established between these two variables. While the concentrations are at their maximum, the warming rate is even slightly decreasing.

It seems obvious that the science of the climate is far from being settled, before all in its fundamental anthropogenic mantra. If, as it is physically plausible, CO_2 and other GHGs play a role in climate change, then the climate sensitivity to their atmospheric concentration should be revisited. Climatologists should explain why their hypothesis are still valid despite of getting easily falsified with such elementary considerations. The self-appointed experts dare no more take refuge behind a so-called consensus and their pretentious authority.

Temperature of the seas.

The seas occupy 70.8% of the surface of the globe. Not only heat exchange takes place at their surface, but also mass transfers in the form of water vapour that evaporates or gets condensed and of CO_2 that gets absorbed and desorbed.

As measured by buoys and, in earlier times, by sampling water buckets, the sea surface temperature (SST) represents roughly the thermal state of an upper 1 metre layer.

Water, in its liquid state, has a much higher thermal capacity than air. As much energy is required to warm by 1 °C the 0-12'000 meters high atmosphere as to warm the first 3.4 m below the sea surface.

The most recent SST data series hast just be published by the Hadley Centre of the UK Met Office in June 2019. As can be expected, the global monthly series HADSST4 has a similar look as atmospheric temperature (Figure 5), albeit with different magnitude.

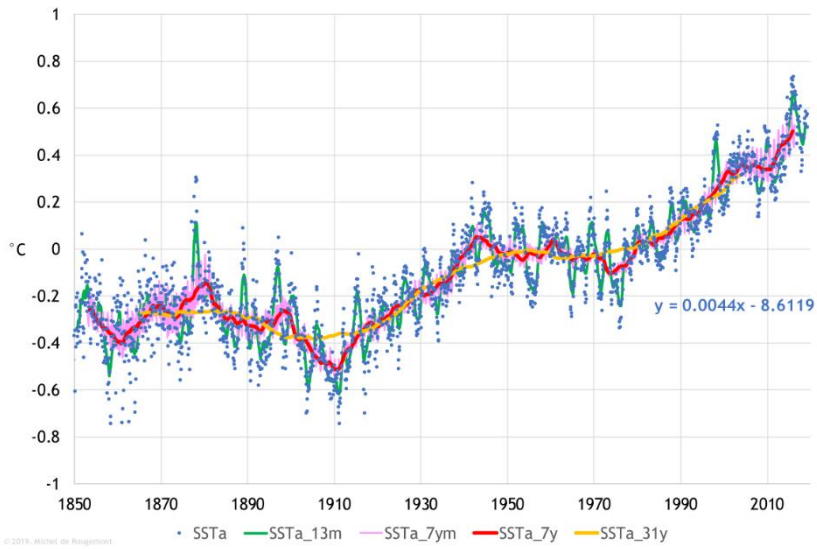

Figure 13 Sea Surface Temperature monthly anomalies (°C relative to 1961-1990).
Blue points: monthly values.
Blue dotted line: linear regression, average warming rate 0.44 °C per century
Green: centred running average over 13 months.
Pink: centred running average of month of years values over 7 years.
Red: centred running average over 7 years.
Yellow: centred running average over 31 years.
Source: HADSST4.

The rate of warming analysis shows also a similar (Figure 11) pattern:

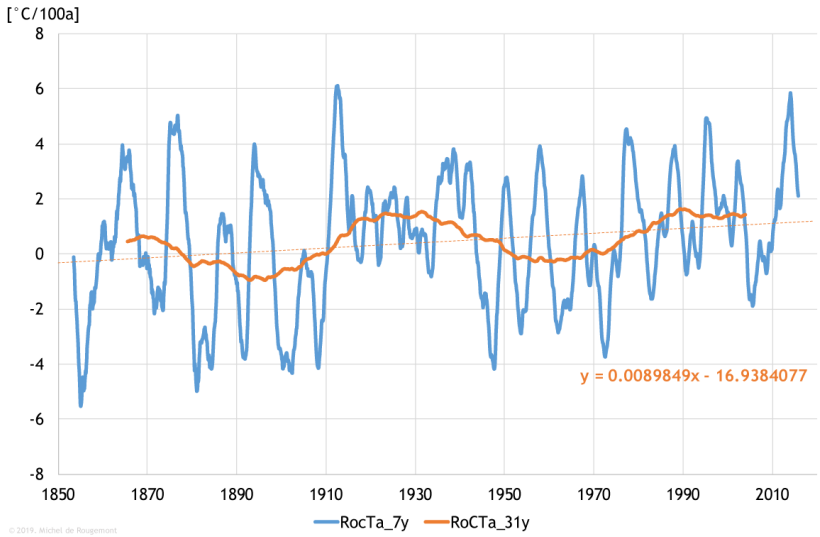

Figure 14 Rate of change of the Sea Surface Temperature, in °C per century [°C/100a].
Blue: centred and filtered over 7 years
Orange: centred and filtered over 31 years. The oscillation has a period of 61 years.
The orange dotted linear regression line indicates an underlying acceleration
by 0.9 °C/100a every century [0.009 °C·a^{-2}].

At further depths, the thermal state of the oceans is no more expressed as temperature but calculated as accumulated heat in a defined layer.

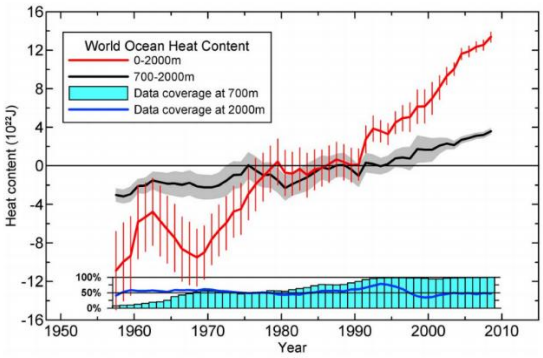

Figure 1. Time series for the World Ocean of ocean heat content (10^{22} J) for the 0–2000 m (red) and 700–2000 m (black) layers based on running pentadal (five-year) analyses. Reference period is 1955–2006. Each pentadal estimate is plotted at the midpoint of the 5-year period. The vertical bars represent +/−2.*S.E. about the pentadal estimate for the 0–2000 m estimates and the grey-shaded area represent +/−2.*S.E. about the pentadal estimate for the 0–700 m estimates. The blue bar chart at the bottom represents the percentage of one-degree squares (globally) that have at least four pentadal one-degree square anomaly values used in their computation at 700 m depth. Blue line is the same as for the bar chart but for 2000 m depth.

Figure 15 World Ocean Heat Content differences relative to 1955-2006 (Levitus et al., 2012).
Red : 0-2000 m, total increase: 24.0 ± 1.9·10^{22} J, corresponding to a calculated 0.09 °C temperature rise, annual uptake: 0.43·10^{22} J·a^{-1}.
Black: 0–700 m, total increase 16.7 ± 1.6·10^{22} J, representing a rate of 0.27 W·m^{-2} per unit area of the World Ocean (0.19 W·m^{-2} per unit area of the whole globe).
As comparison: The World production of primary energy is only 5.80·10^{20} J·a^{-1}.
The mean solar irradiation is 341.5 W·m^{-2}.
On average, the Earth's geothermal heat flow is 0.04-0.09 W·m^{2}.
The primary radiative forcing attributable to greenhouse gases is 3.06 W·m^{-2} (as of 2017).

According to this diagram and to the underlying hypothesis, the oceans are currently accumulating 0.08% of the energy that had been received by the sun. At a later time and to satisfy a required null balance, it will have to be emitted back to the outer

space. All these considerations are about small differences between large unprecise numbers, thus entailing much uncertainties. No data are available over a longer term. The past 60 years are too short for climatic considerations. To make extrapolations and model predictions on such basis would be quite risky.

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Michel de Rougemont, chemical engineer, Dr sc tech, is an independent consultant.
In his activities in fine chemicals and agriculture, he is confronted, without fearing them, to various environmental and safety challenges.

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He has no conflict of interest in relation with the subject of this paper.