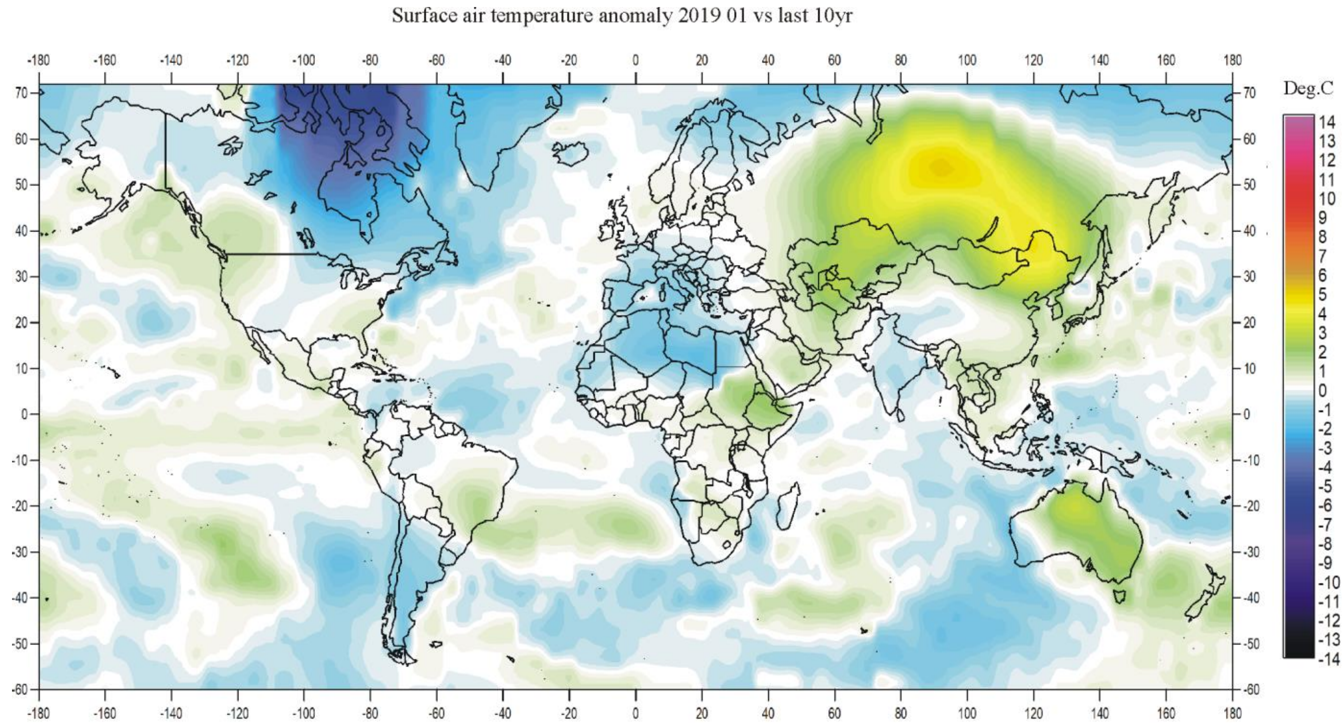
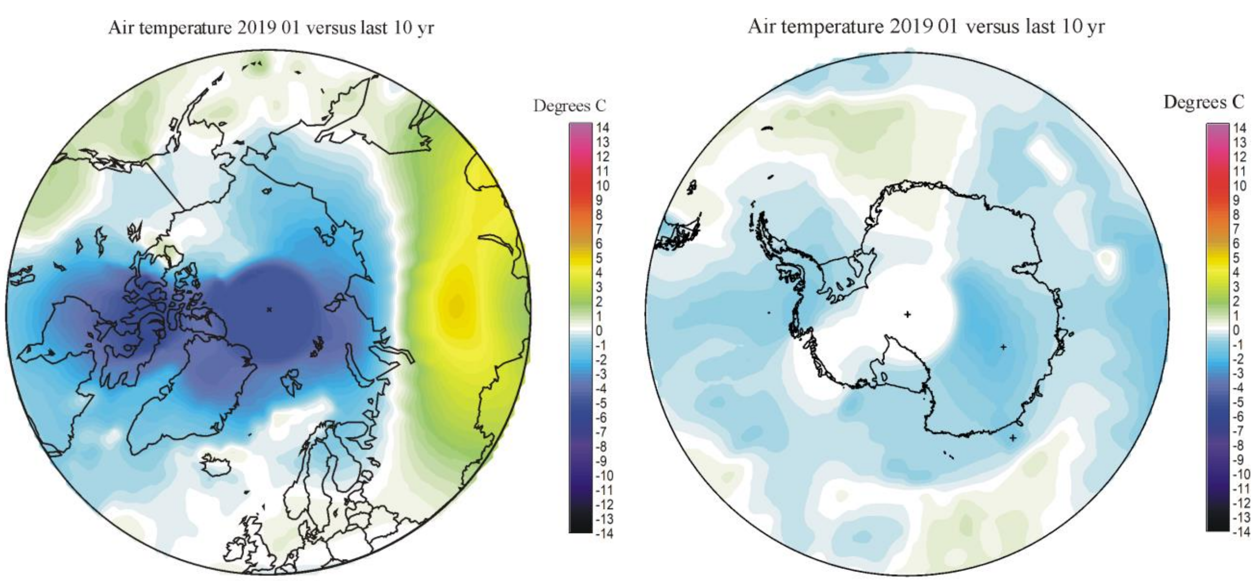
Climate4you update January 2019

Contents:

January 2019 global surface air temperature overview





January 2019 surface air temperature compared to the average of the last 10 years. Green-yellow-red colours indicate areas with higher temperature than the 10-year average, while blue colours indicate lower than average temperatures. Data source: Goddard Institute for Space Studies (GISS) using Hadl_Reyn_v2 ocean surface temperatures.

Comments to the January 2019 global surface air temperature overview

General: This newsletter contains graphs showing a selection of key meteorological variables for the past month. *All temperatures are given in degrees Celsius*.

In the above maps showing the geographical pattern of surface air temperatures, *the last previous 10 years are used as reference period*.

The rationale for comparing with this recent period instead of the official WMO 'normal' period 1961-1990, is that the latter period is affected by the cold period 1945-1980. Most comparisons with this time period will automatically appear as warm, and it will be difficult to decide if modern surface air temperatures are increasing or decreasing. Comparing instead with the last previous 10 years overcomes this problem and displays the modern dynamics of ongoing change. This decadal approach also corresponds well to the typical memory horizon for many people.

In addition, the GISS temperature data used for preparing the above diagrams display distinct temporal instability for data before the turn of the century (see p. 7). Any comparison with the WMO 'normal' period 1961-1990 is therefore influenced by ongoing monthly mainly administrative changes. An unstable value is clearly not suited as reference value. Simply comparing with the last previous 10 years makes more sense and is more useful. See also the additional reflections on page 46.

The different air temperature records have been divided into three quality classes, QC1, QC2 and QC3, respectively, as described on page 7.

In many diagrams shown in this newsletter the thin line represents the monthly global average value, and the thick line indicate a simple running average, in most cases a simple moving 37-month average, nearly corresponding to a three-year average. The 37-month average is calculated from values covering a range from 18 months before to 18 months after, with equal weight given to all individual months.

The year 1979 has been chosen as starting point in many diagrams, as this roughly corresponds to both the beginning of satellite observations and the onset of the late 20th century warming period. However, several of the data series have a much longer record length, which may be inspected in greater detail on www.climate4you.com.

January 2019 global surface air temperatures

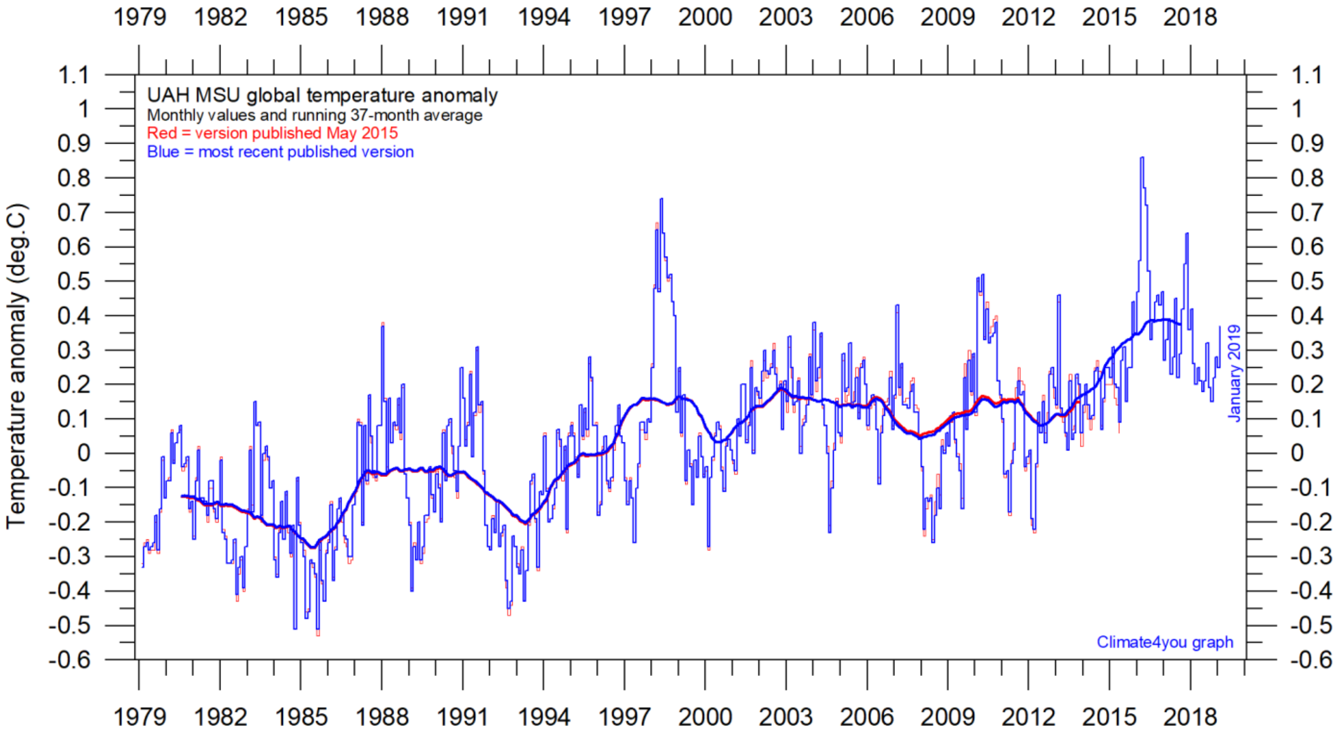
General: For January 2019 GISS supplied 15956 interpolated surface air data points; all values are used to produce the diagrams shown on page 2. According to the GISS data, the average global January temperature anomaly was nearly at the same level as in the previous month. However, the overall decrease of global surface air temperatures since the 2016-17 El Niño global temperature peak persists, as illustrated by the diagrams on p. 4-6.

The Northern Hemisphere anomality pattern was characterised by large regional contrasts. Most of North America were cold compared to the previous 10 years, especially northern Canada. Also, southern Europe and northern Africa was relatively cold. In contrast, much of Russia, including Siberia, was relatively warm. Most of Arctic was cold. The GISS surface air temperatures north of 80° N still appears to have an issue with interpolation, resulting in an unrealistic circular anomaly pattern.

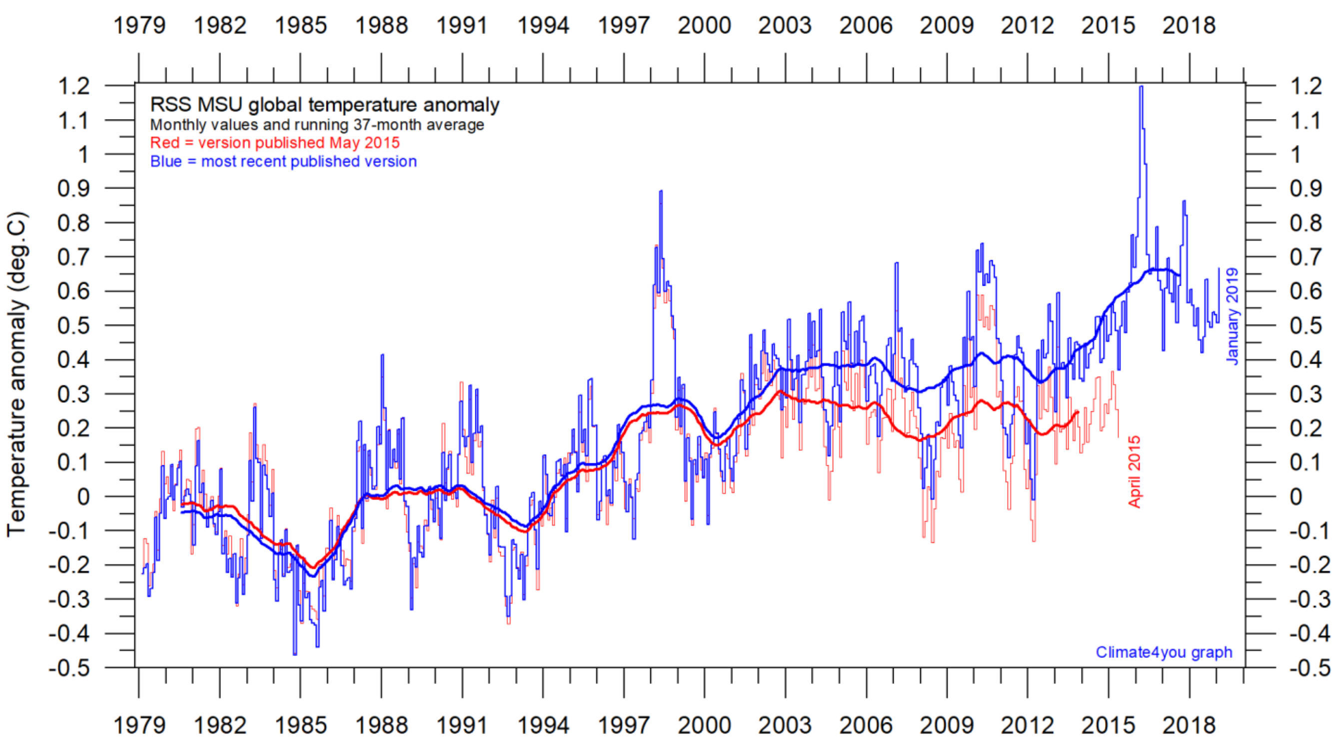
Near the Equator temperatures were mainly near or below the 10-year average. In the Pacific, however, temperatures were somewhat above average.

The Southern Hemisphere temperatures were near or below the average for the previous 10 years. However, Australia and New Zealand had air temperatures above average. In contrast, much of South America was below the 10-yr temperature average. In the Antarctica, much of the continent was relatively cold or near the average. South of 80°S the GISS anomaly pattern is influenced by an interpolation artefact.

Temperature quality class 1: Lower troposphere temperature from satellites, updated to January 2019

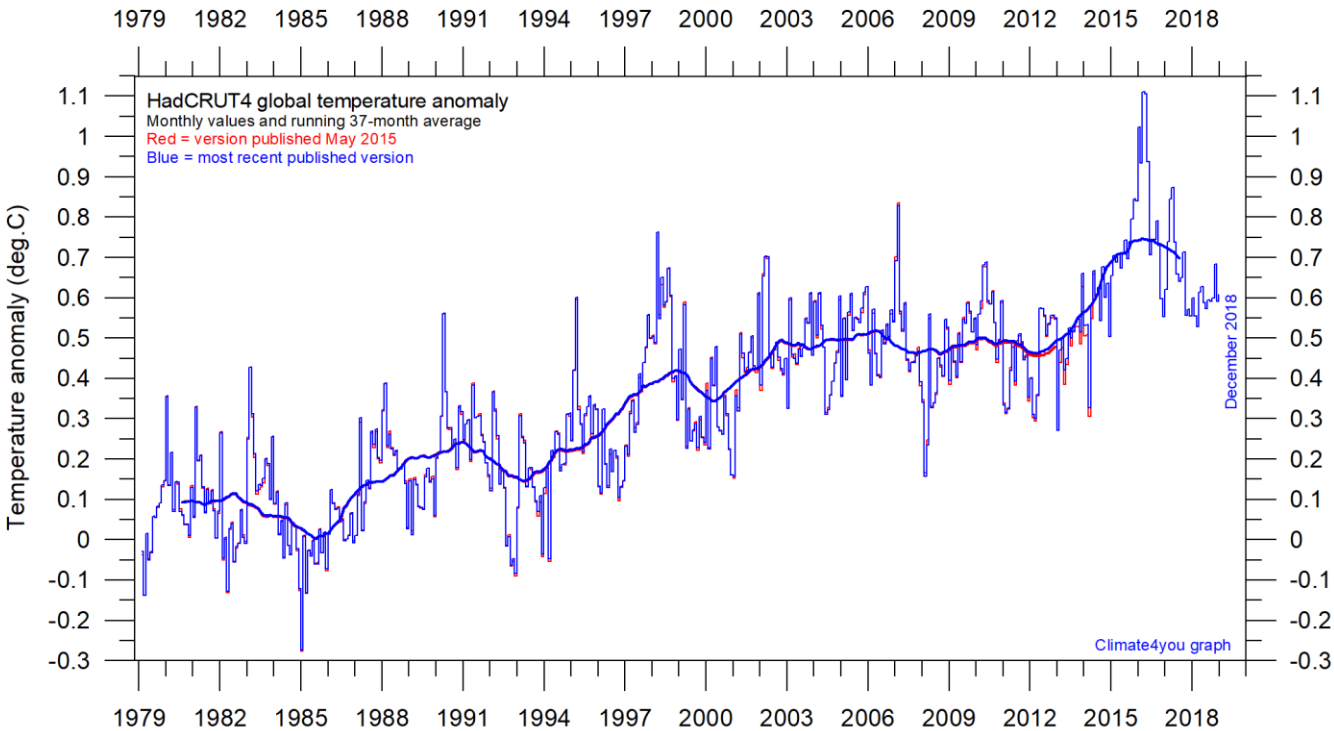


Global monthly average lower troposphere temperature (thin line) since 1979 according to University of Alabama at Huntsville, USA. The thick line is the simple running 37-month average.



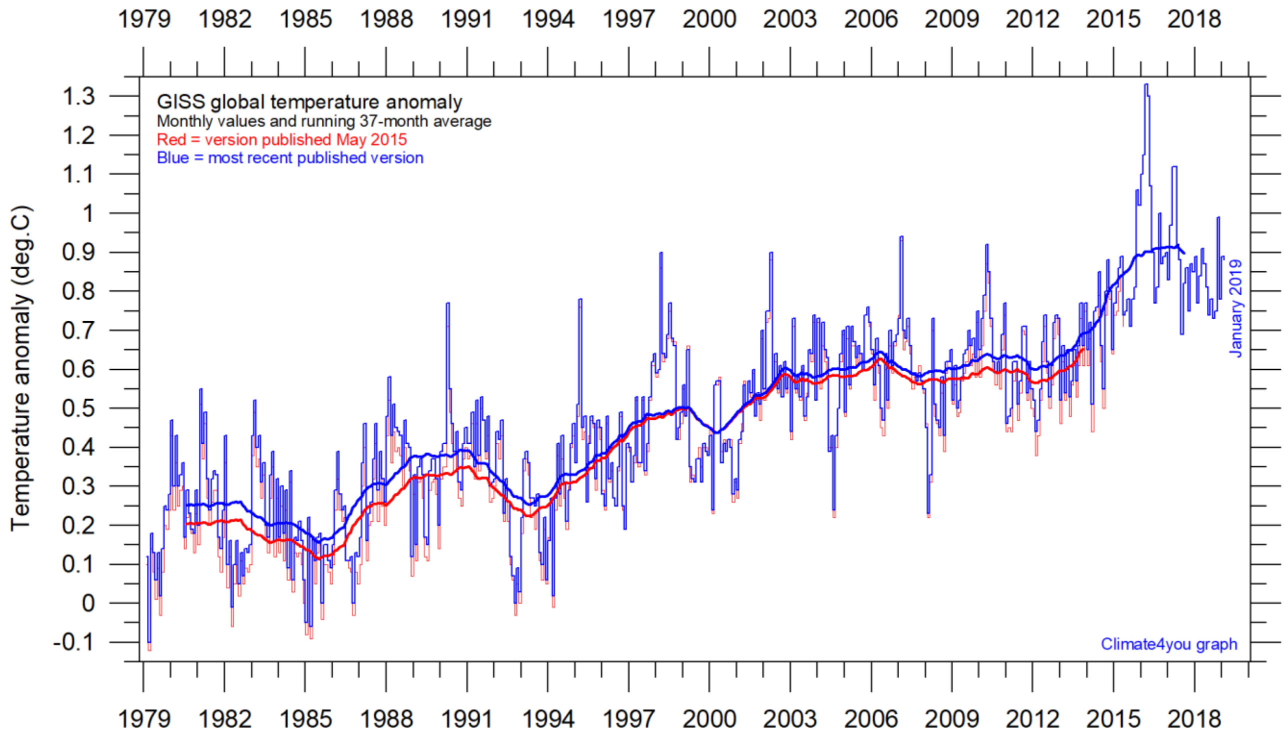
Global monthly average lower troposphere temperature (thin line) since 1979 according to according to Remote Sensing Systems (RSS), USA. The thick line is the simple running 37-month average.

Temperature quality class 2: HadCRUT global surface air temperature, updated to December 2018

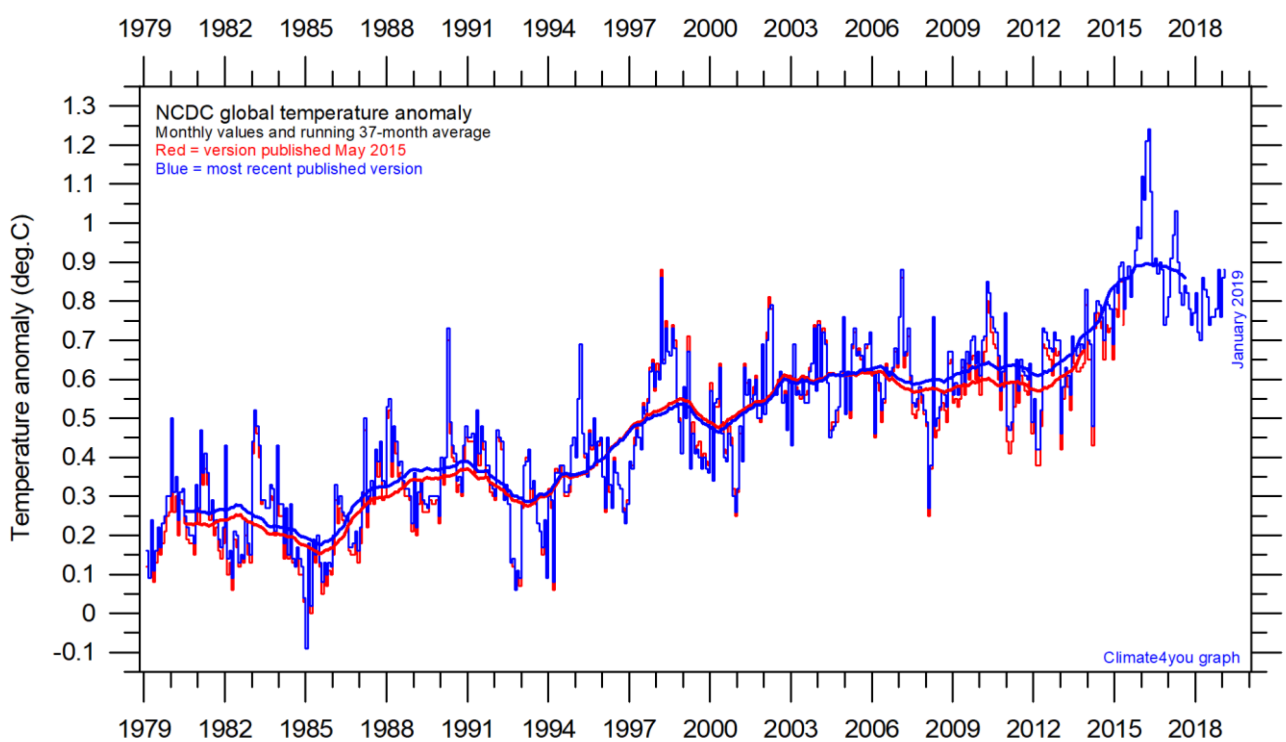


Global monthly average surface air temperature (thin line) since 1979 according to according to the Hadley Centre for Climate Prediction and Research and the University of East Anglia's [Climatic Research Unit](#) ([CRU](#)), UK. The thick line is the simple running 37-month average.

Temperature quality class 3: GISS and NCDC global surface air temperature, updated to January 2019



Global monthly average surface air temperature (thin line) since 1979 according to according to the Goddard Institute for Space Studies (GISS), at Columbia University, New York City, USA, using ERSST_v4 ocean surface temperatures. The thick line is the simple running 37-month average.



Global monthly average surface air temperature since 1979 according to according to the National Climatic Data Center (NCDC), USA. The thick line is the simple running 37-month average.

A note on data record stability and -quality:

The temperature diagrams shown above all have 1979 as starting year. This roughly marks the beginning of the recent episode of global warming, after termination of the previous episode of global cooling from about 1940. In addition, the year 1979 also represents the starting date for the satellite-based global temperature estimates (UAH and RSS). For the three surface air temperature records (HadCRUT, NCDC and GISS), they begin much earlier (in 1850 and 1880, respectively), as can be inspected on www.climate4you.com.

For all three surface air temperature records, but especially NCDC and GISS, administrative changes to anomaly values are quite often introduced, even for observations many years back in time. Some changes may be due to the delayed addition of new station data or change of station location, while others probably have their origin in changes of the technique adopted to calculate average values. It is clearly impossible to evaluate the validity of such administrative changes for the outside user of these records; it is only possible to note that such changes appear very often (se example diagram next page).

In addition, the three surface records represent a blend of sea surface data collected by moving ships or by other means, plus data from land stations of partly unknown quality and unknown degree of representativeness for their region. Many of the land stations also has been moved geographically during their period of operation, their instrumentation have been changed, and they are influenced by changes in their near surroundings (vegetation, buildings, etc.).

The satellite temperature records also have their problems, but these are generally of a more technical nature and therefore correctable. In addition, the temperature sampling by satellites is more regular and complete on a global basis than that represented by the surface records. It is also important that the sensors on satellites measure temperature directly by emitted radiation, while most surface temperature measurements are indirect, using electronic resistance.

Everybody interested in climate science should gratefully acknowledge the efforts put into maintaining the different temperature databases referred to in the present newsletter. At the same time, however, it is also important to realise that all temperature records cannot be of equal scientific quality. The simple fact that they to some degree differ shows that they cannot all be correct.

On this background, and for practical reasons, Climate4you operates with three quality classes (1-3) for global temperature records, with 1 representing the highest quality level:

Quality class 1: The satellite records (UAH and RSS).

Quality class 2: The HadCRUT surface record.

Quality class 3: The NCDC and GISS surface records.

The main reason for discriminating between the three surface records is the following:

While both NCDC and GISS often experience quite large administrative changes (see example on p.8), and therefore essentially are unstable temperature records, the changes introduced to HadCRUT are fewer and smaller. For obvious reasons, as the past does not change, any record undergoing continuing changes cannot describe the past correctly all the time. Frequent and large corrections in a database also signal a fundamental doubt about what is likely to represent the correct values.

You can find more on the issue of lack of temporal stability on www.climate4you.com (go to: *Global Temperature*, followed by *Temporal Stability*).

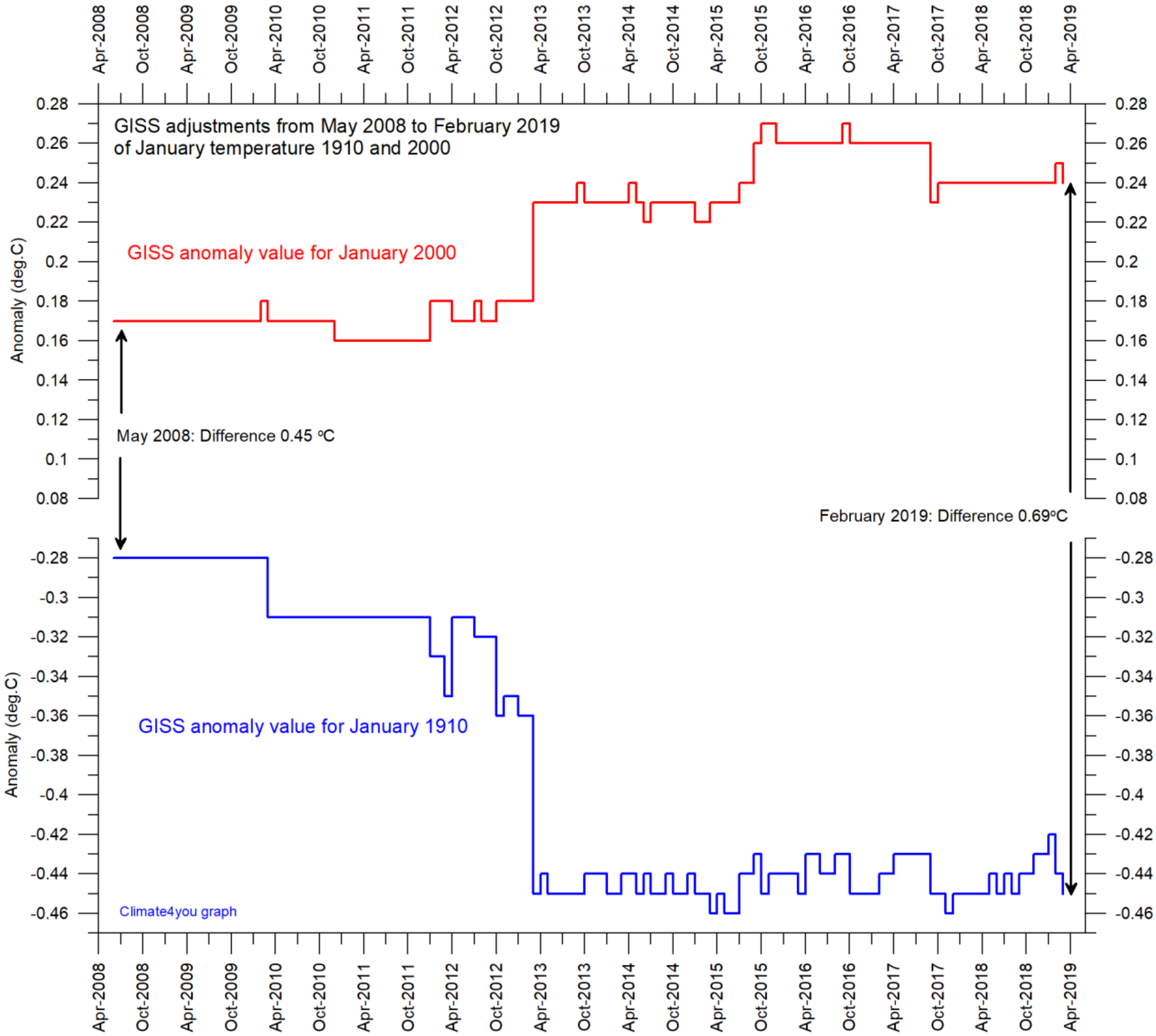
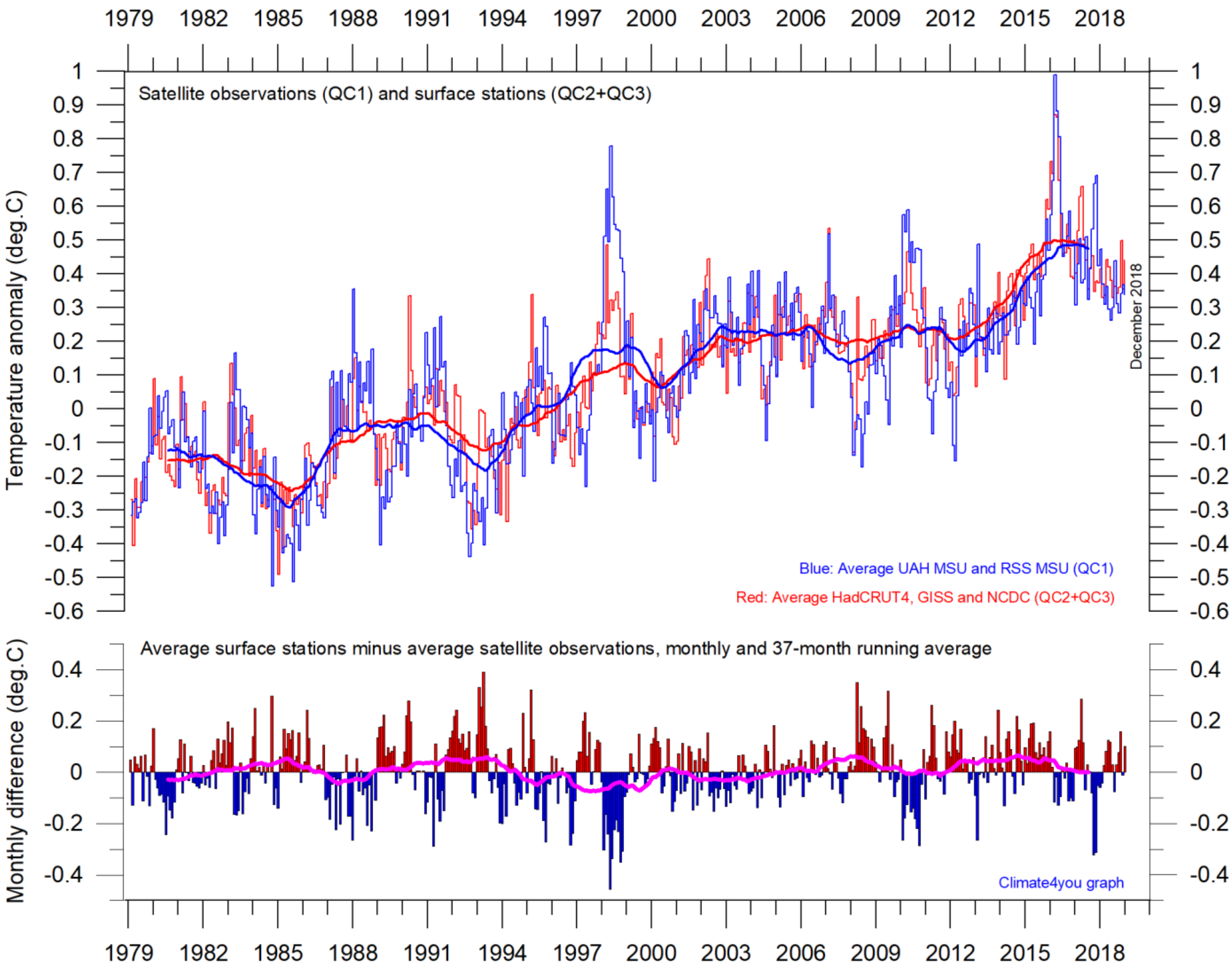


Diagram showing the adjustments made since May 2008 by the Goddard Institute for Space Studies (GISS), USA, in published anomaly values for the months January 1910 and January 2000.

Note: The administrative upsurge of the temperature increase from January 1915 to January 2000 has grown from 0.45 (reported May 2008) to 0.69°C (reported February 2019). This represents an about 53% administrative temperature increase over this period, meaning that more than half of the apparent global temperature increase from January 1910 to January 2000 (as reported by GISS) is due to administrative changes of the original data since May 2008.

Comparing global surface air temperature and lower troposphere satellite temperatures; updated to December 2018



Plot showing the average of monthly global surface air temperature estimates (HadCRUT4, GISS and NCDC) and satellite-based temperature estimates (RSS MSU and UAH MSU). The thin lines indicate the monthly value, while the thick lines represent the simple running 37-month average, nearly corresponding to a running 3-yr average. The lower panel shows the monthly difference between average surface air temperature and satellite temperatures. As the base period differs for the different temperature estimates, they have all been normalised by comparing to the average value of 30 years from January 1979 to December 2008.

NOTE: Since about 2003, the average global surface air temperature has slowly been drifting away in positive direction from the average satellite temperature, meaning that the surface records show warming in relation to the troposphere records. The reason(s) for this is not entirely clear but can presumably at least partly be explained by the recurrent administrative adjustments made to the surface records (see p. 7-8).

Global air temperature linear trends updated to December 2018

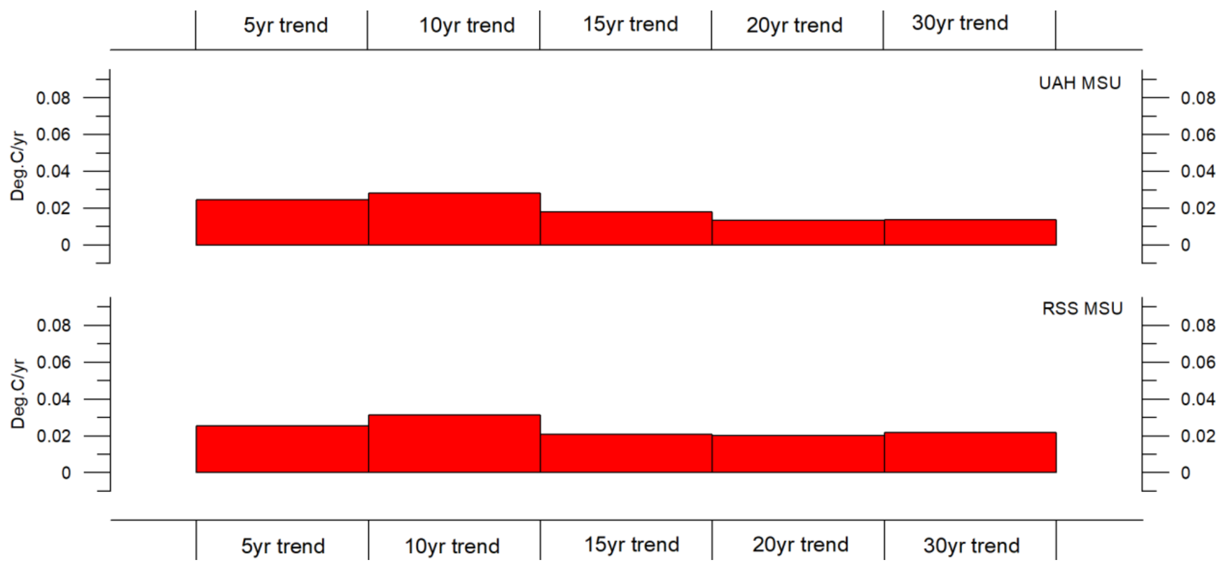


Diagram showing the latest 5, 10, 20 and 30-yr linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for two satellite-based temperature estimates (UAH MSU and RSS MSU).

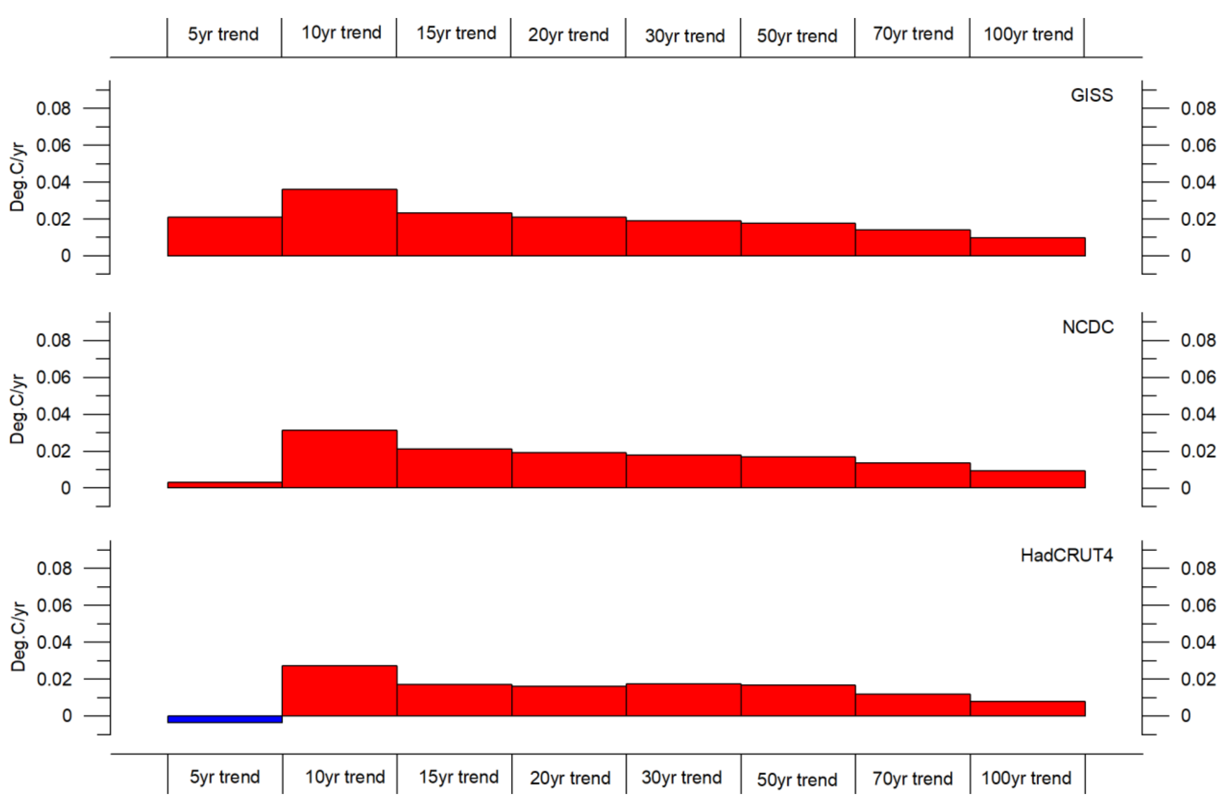
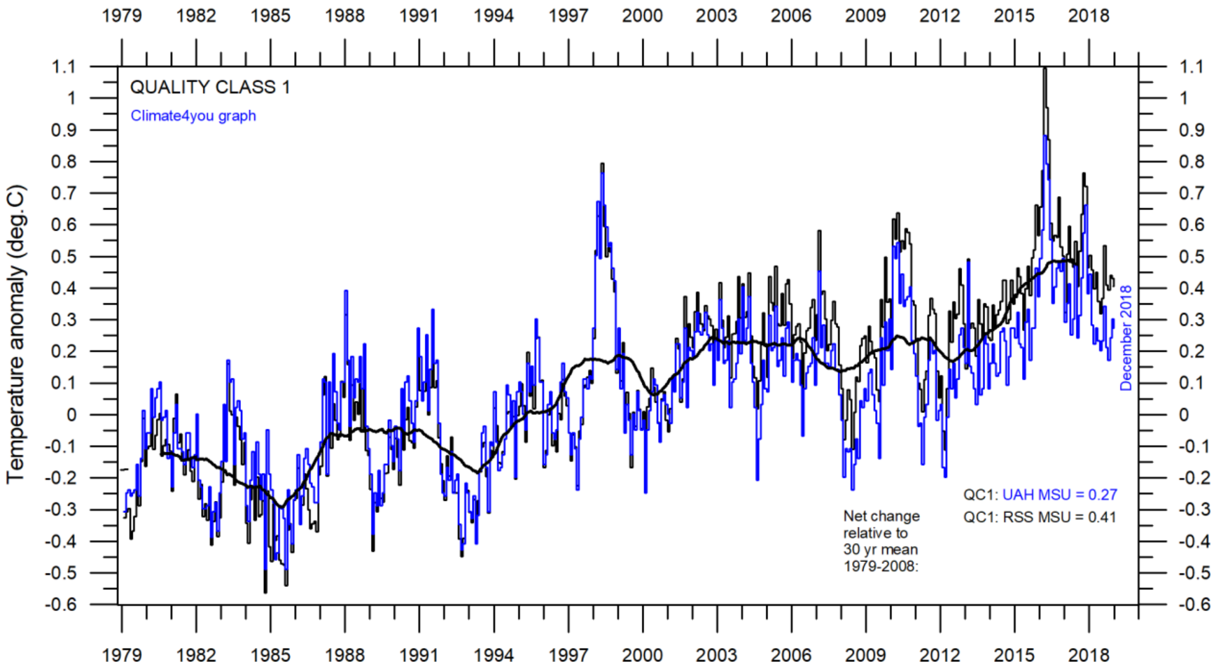
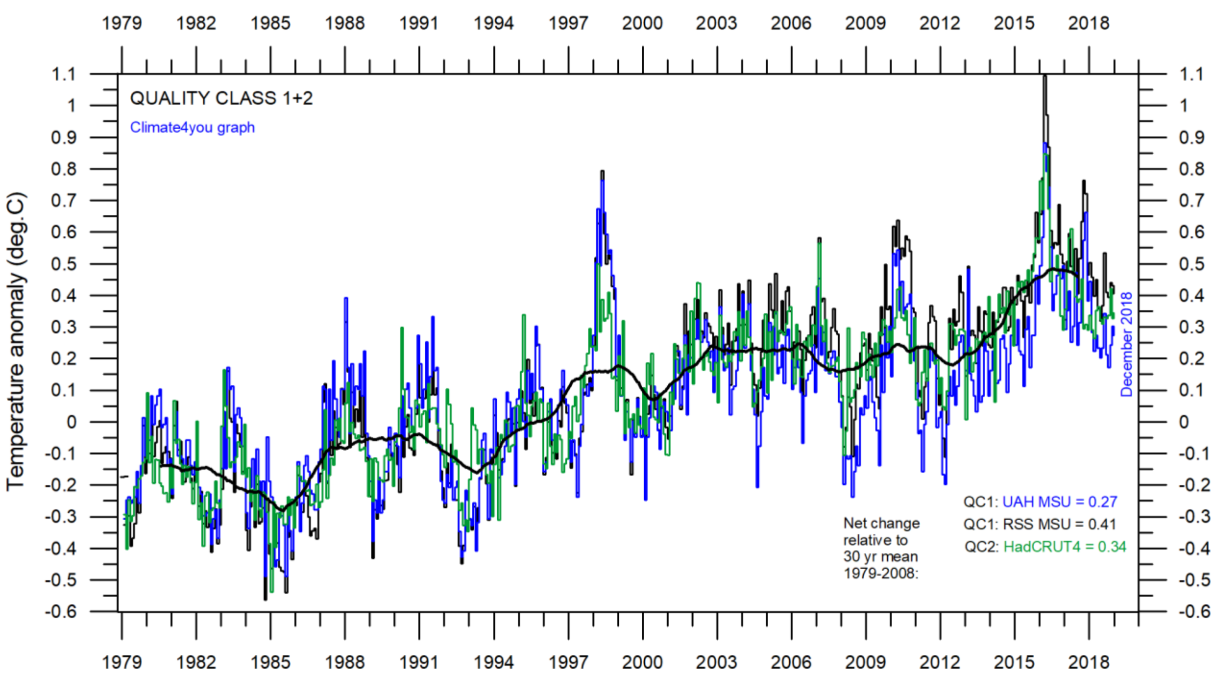


Diagram showing the latest 5, 10, 20, 30, 50, 70 and 100-year linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for three surface-based temperature estimates (GISS, NCDC and HadCRUT4).

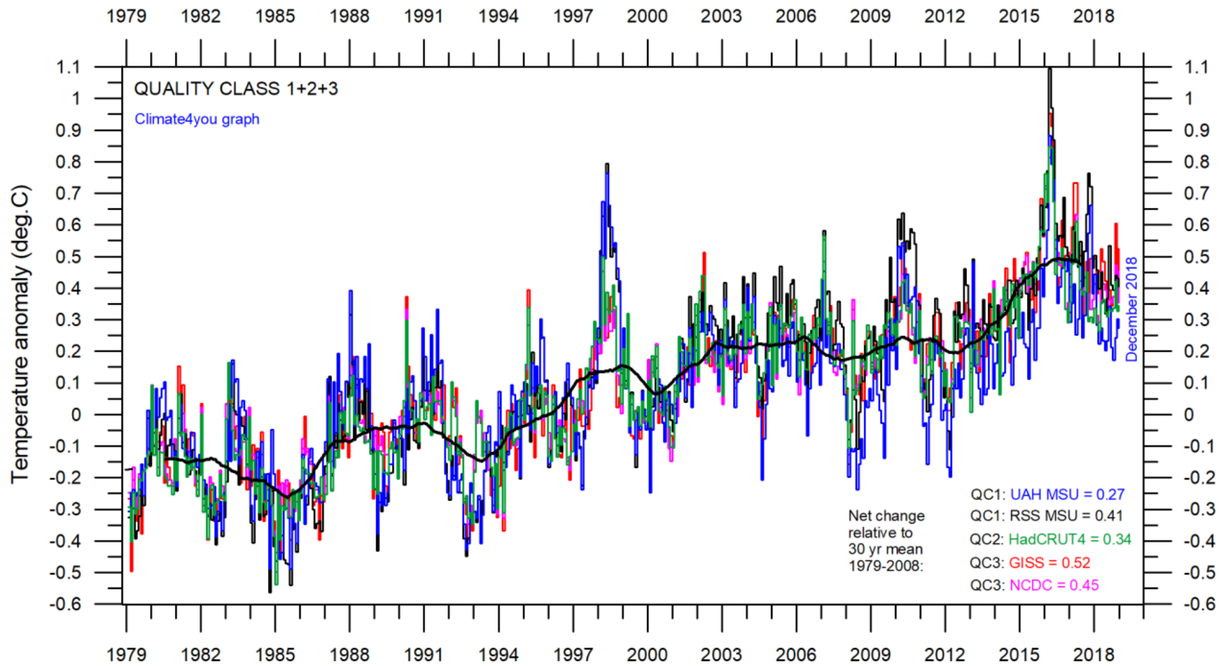
All in one, Quality Class 1, 2 and 3; updated to December 2018



Superimposed plot of Quality Class 1 (UAH and RSS) global monthly temperature estimates. As the base period differs for the individual temperature estimates, they have all been normalised by comparing with the average value of the initial 120 months (30 years) from January 1979 to December 2008. The heavy black line represents the simple running 37 month (c. 3 year) mean of the average of both temperature records. The numbers shown in the lower right corner represent the temperature anomaly relative to the individual 1979-2008 averages.



Superimposed plot of Quality Class 1 and 2 (UAH, RSS and HadCRUT4) global monthly temperature estimates. As the base period differs for the individual temperature estimates, they have all been normalised by comparing with the average value of the initial 120 months (30 years) from January 1979 to December 2008. The heavy black line represents the simple running 37 month (c. 3 year) mean of the average of all three temperature records. The numbers shown in the lower right corner represent the temperature anomaly relative to the individual 1979-2008 averages.



Superimposed plot of Quality Class 1, 2 and 3 global monthly temperature estimates (UAH, RSS, HadCRUT4, GISS and NCDC). As the base period differs for the individual temperature estimates, they have all been normalised by comparing with the average value of the initial 120 months (30 years) from January 1979 to December 2008. The heavy black line represents the simple running 37 month (c. 3 year) mean of the average of all five temperature records. The numbers shown in the lower right corner represent the temperature anomaly relative to the individual 1979-2008 averages.

Please see notes on page 7 relating to the above three quality classes.

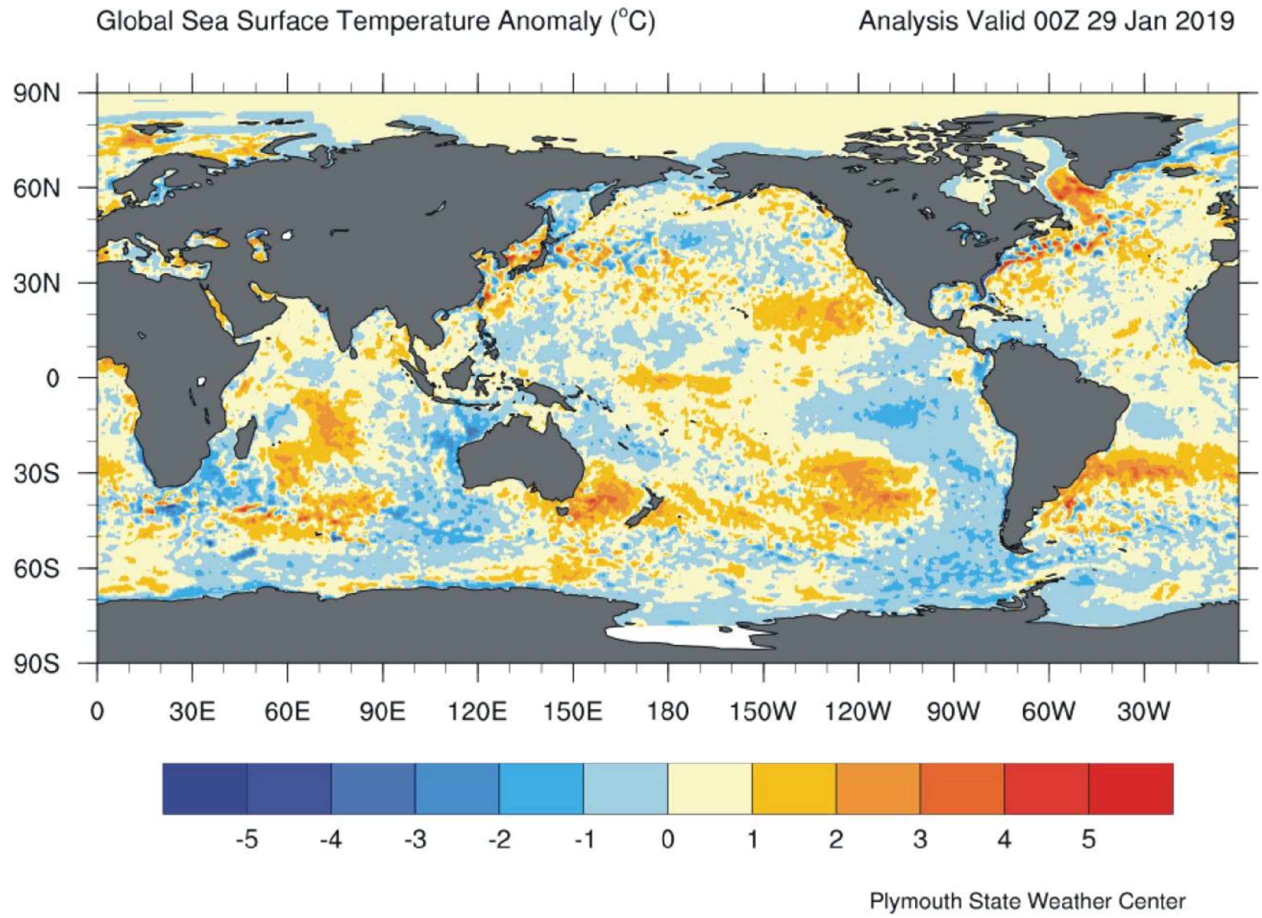
It should be kept in mind that satellite- and surface-based temperature estimates are derived from different types of measurements, and that comparing them directly as done in the diagram above therefore may be somewhat problematical.

However, as both types of estimate often are discussed together, the above diagram may nevertheless be of some interest. In fact, the different types of temperature estimates appear to agree as to the overall temperature variations on a 2-3-year scale, although on a shorter time scale there are often considerable differences between the individual records. However, since about 2003 the surface records are slowly drifting towards higher temperatures than the combined satellite record (see p. 9).

The average of all five global temperature estimates presently shows an overall stagnation, at least since 2002-2003. There has been no significant increase in global air temperature since 1998, which however was affected by the oceanographic El Niño event. Also, the recent (2015-16) El Niño event probably represents a relatively short-lived spike on a longer development. The coming years will show if this is the case or not. Neither has there been a temperature decrease since about 2002-2003.

The present temperature stagnation does not exclude the possibility that global temperatures will begin to increase significantly again later. On the other hand, it also remains a possibility that Earth just now is passing an overall temperature peak, and that global temperatures will begin to decrease during the coming years. Again, time will show which of these possibilities is correct.

Global sea surface temperature, updated to January 2019



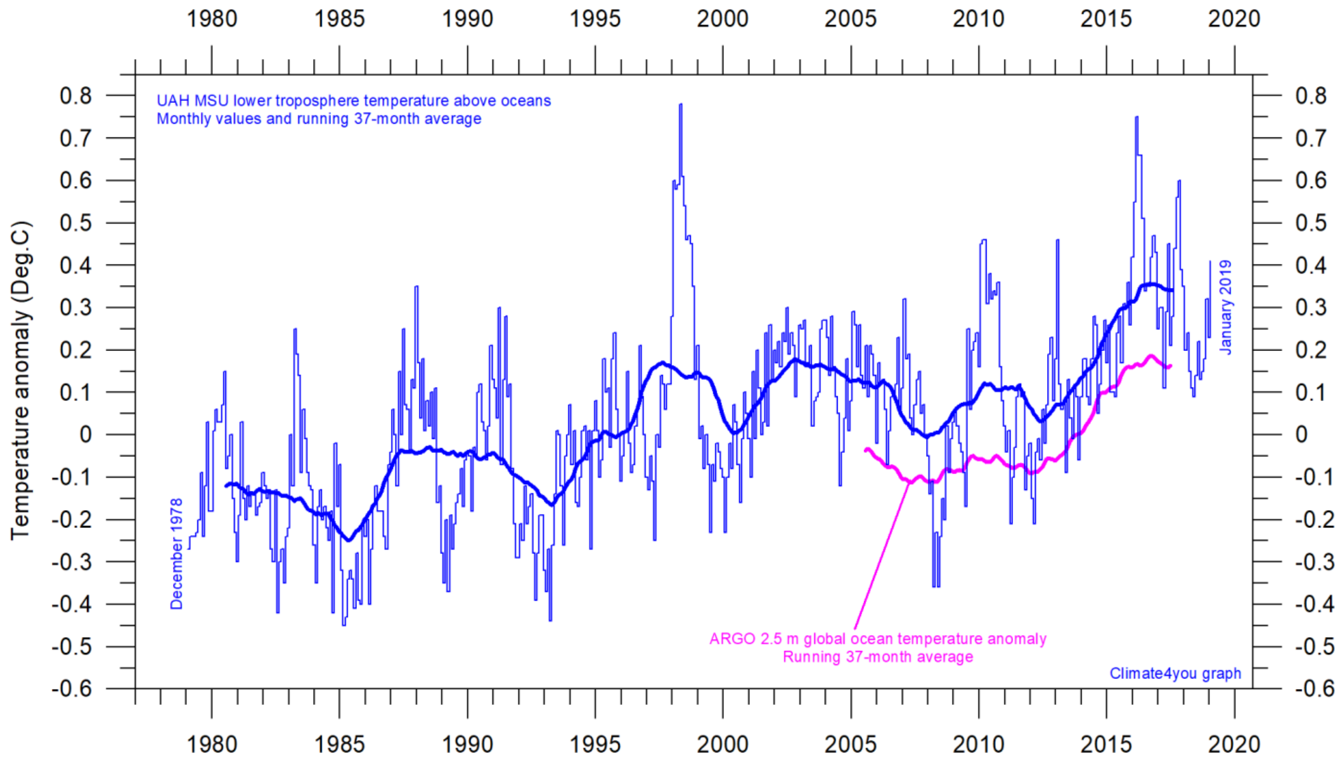
Sea surface temperature anomaly on 29 January 2019. Map source: Plymouth State Weather Center. Reference period: 1977-1991.

Because of the large surface areas near Equator, the temperature of the surface water in these regions is especially important for the global atmospheric temperature (p. 4-6). No less than 50% of planet Earth's surface area is located within 30^{o}N and 30^{o}S.

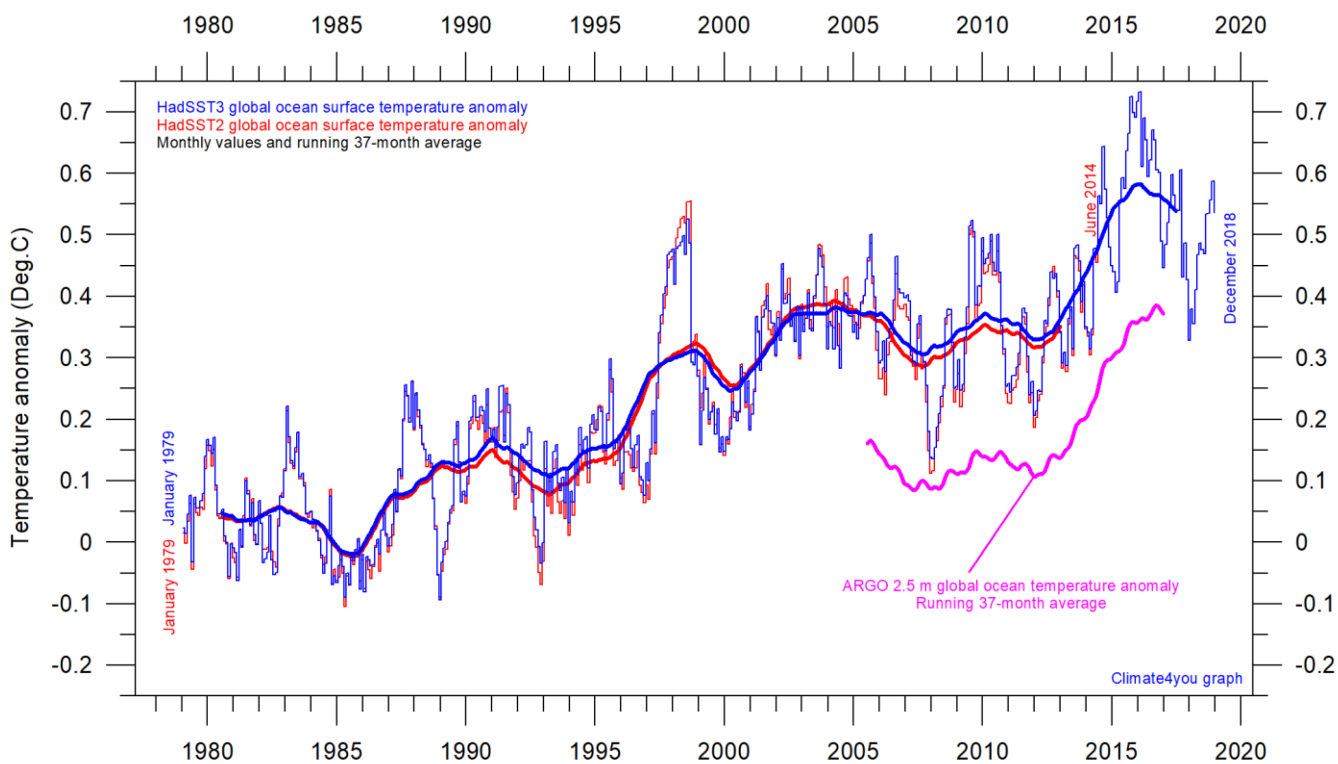
A mixture of relatively warm and cold water in August 2018 dominates much of the oceans near the Equator. In addition, parts of the North Atlantic are cooling. Presumably, all this will be influencing global air temperatures in the months to come.

However, the significance of any short-term cooling or warming reflected in air temperatures should not be overstated. Whenever Earth experiences cold La Niña or warm El Niño episodes (Pacific Ocean) major heat exchanges takes place between the Pacific Ocean and the atmosphere above, eventually showing up in estimates of the global air temperature.

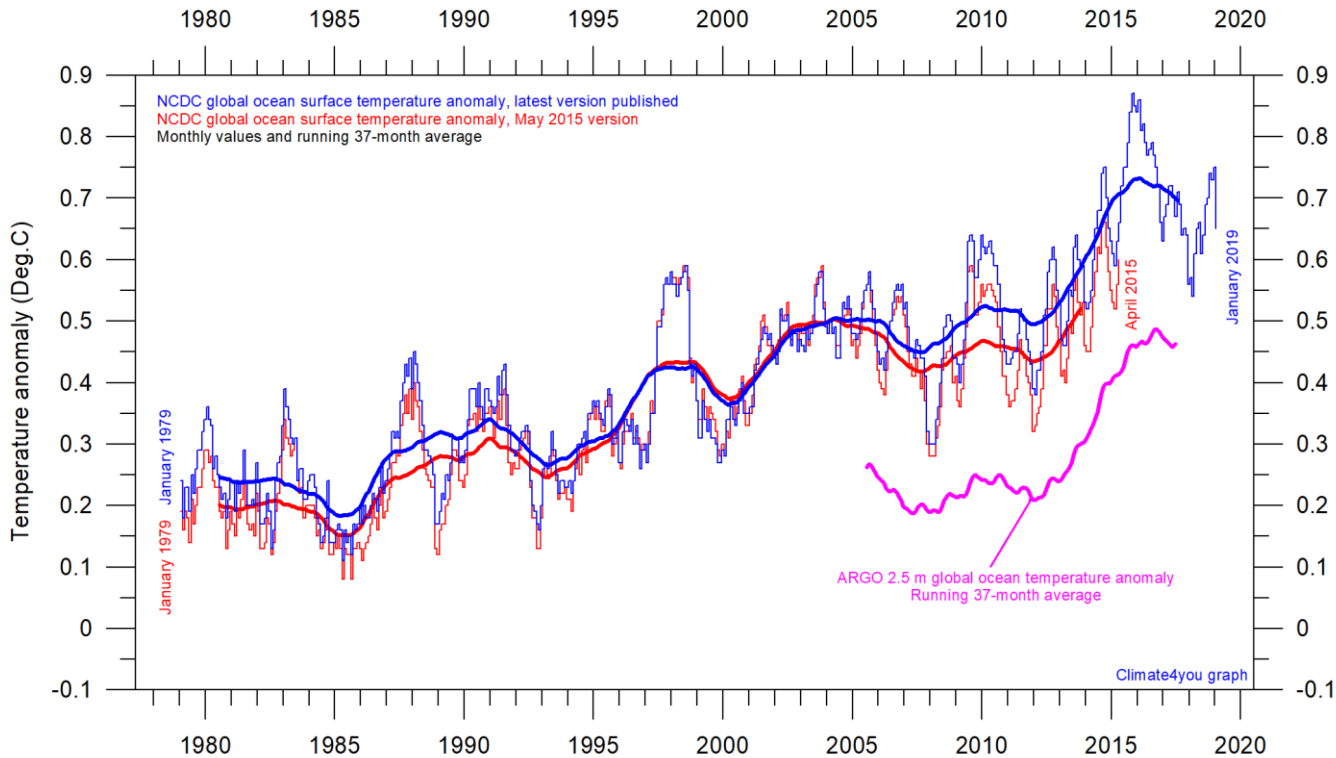
However, this does not reflect similar changes in the total heat content of the atmosphere-ocean system. In fact, global net changes can be small and such heat exchanges may mainly reflect redistribution of energy between ocean and atmosphere. What matters is the overall temperature development when seen over several years.



Global monthly average lower troposphere temperature over oceans (thin line) since 1979 according to [University of Alabama]() at Huntsville, USA. The thick line is the simple running 37-month average. Insert: Argo global ocean temperature anomaly from floats.



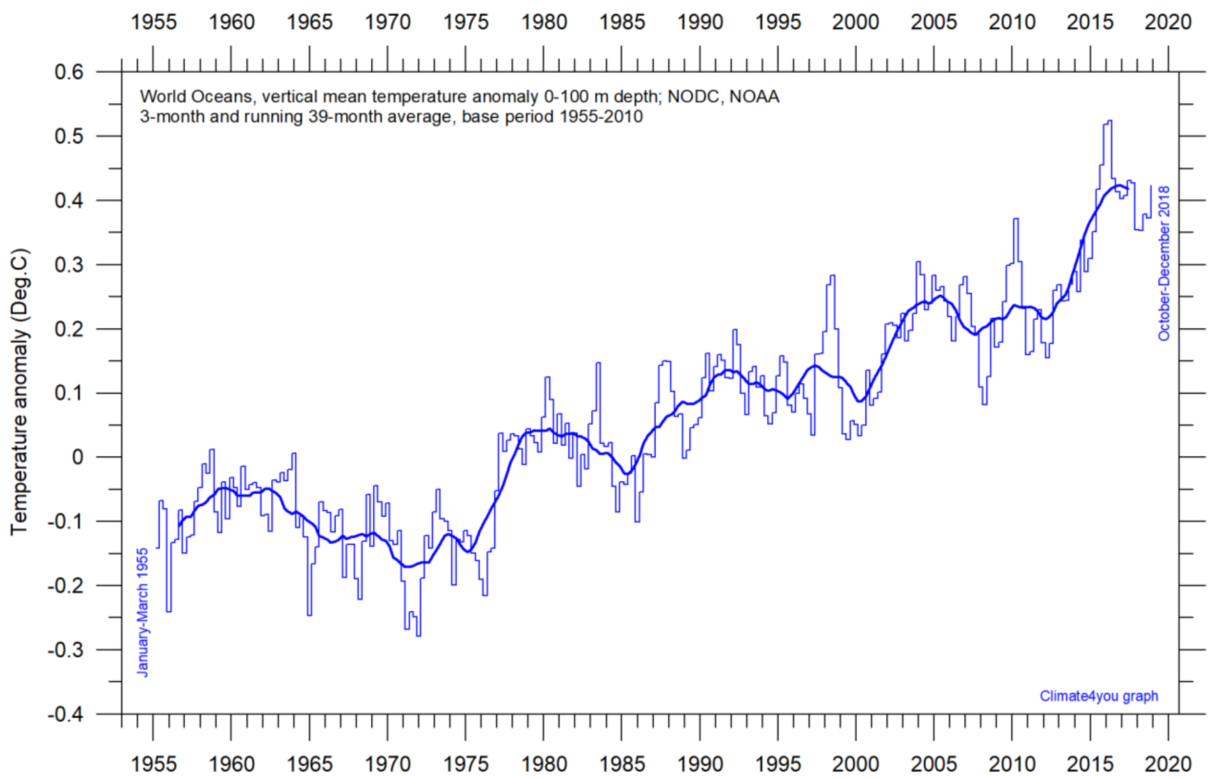
Global monthly average sea surface temperature since 1979 according to University of East Anglia's [Climatic Research Unit]() ([CRU]()), UK. Base period: 1961-1990. The thick line is the simple running 37-month average. Insert: Argo global ocean temperature anomaly from floats.



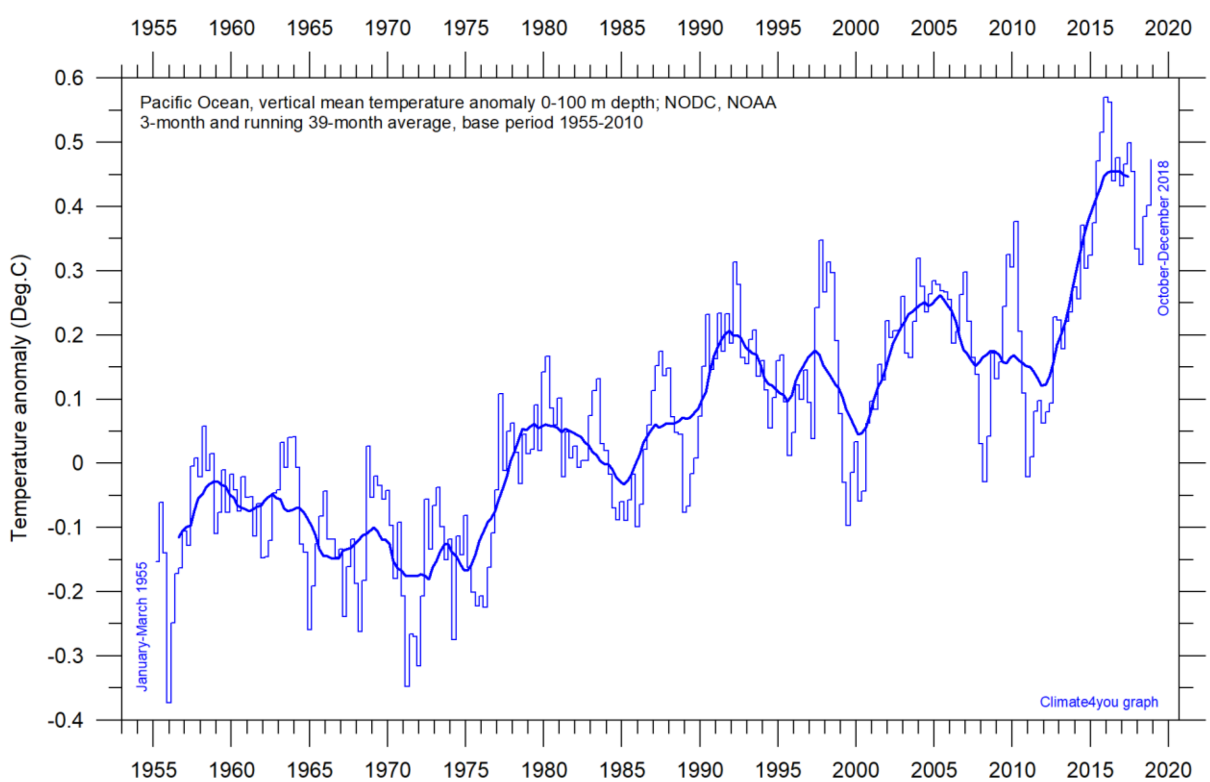
Global monthly average sea surface temperature since 1979 according to the National Climatic Data Center (NCDC), USA. Base period: 1901-2000. The thick line is the simple running 37-month average. Insert: Argo global ocean temperature anomaly from floats.

June 18, 2015: *NCDC has introduced several rather large administrative changes to their sea surface temperature record. The overall result is to produce a record giving the impression of a continuous temperature increase, also in the 21st century. As the oceans cover about 71% of the entire surface of planet Earth, the effect of this administrative change is clearly seen in the NCDC record for global surface air temperature (p. 6).*

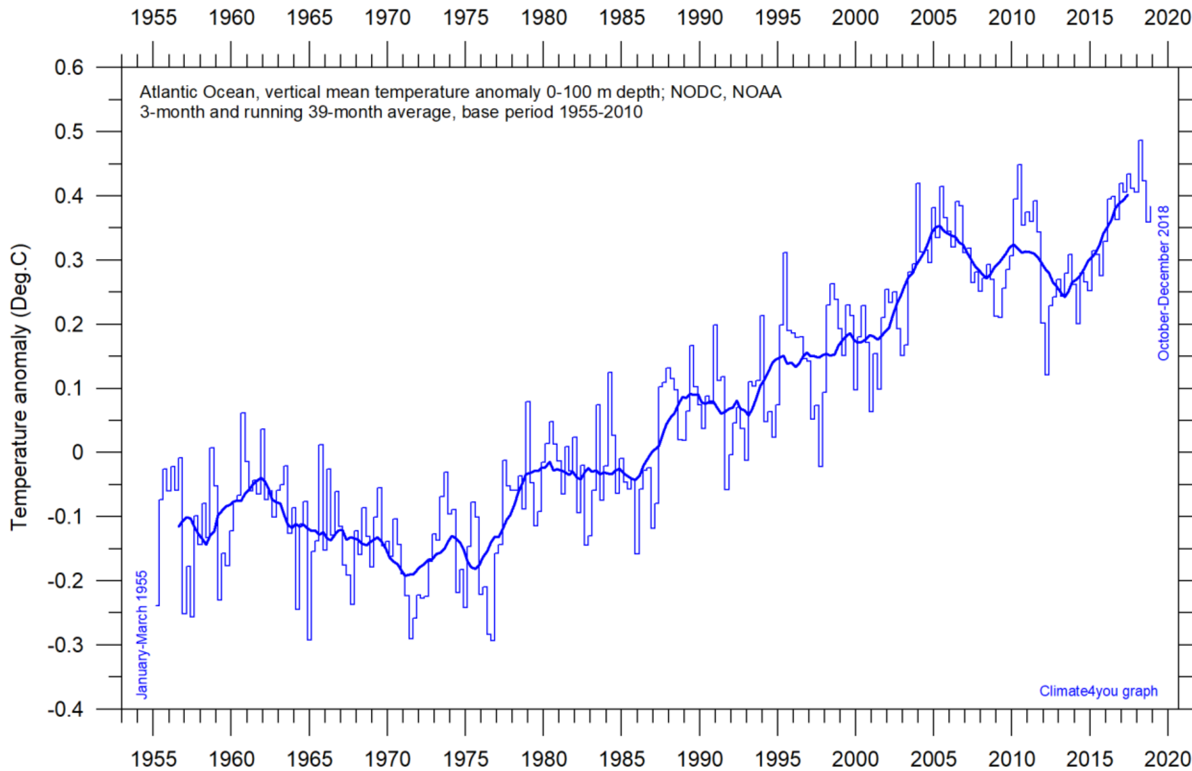
Ocean temperature in uppermost 100 m, updated to December 2018



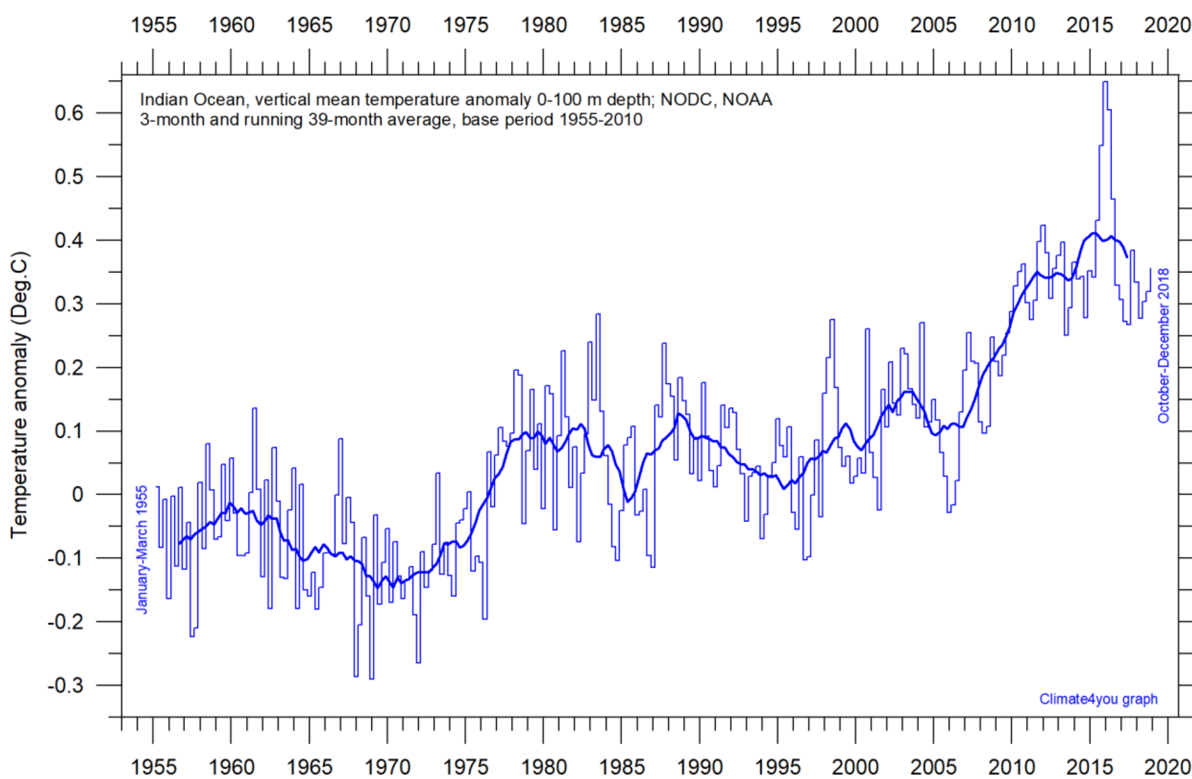
World Oceans vertical average temperature 0-100 m depth since 1955. The thin line indicates 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: [NOAA National Oceanographic Data Center](#) (NODC). Base period 1955-2010.



Pacific Ocean vertical average temperature 0-100 m depth since 1955. The thin line indicate 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: [NOAA National Oceanographic Data Center](#) (NODC). Base period 1955-2010.

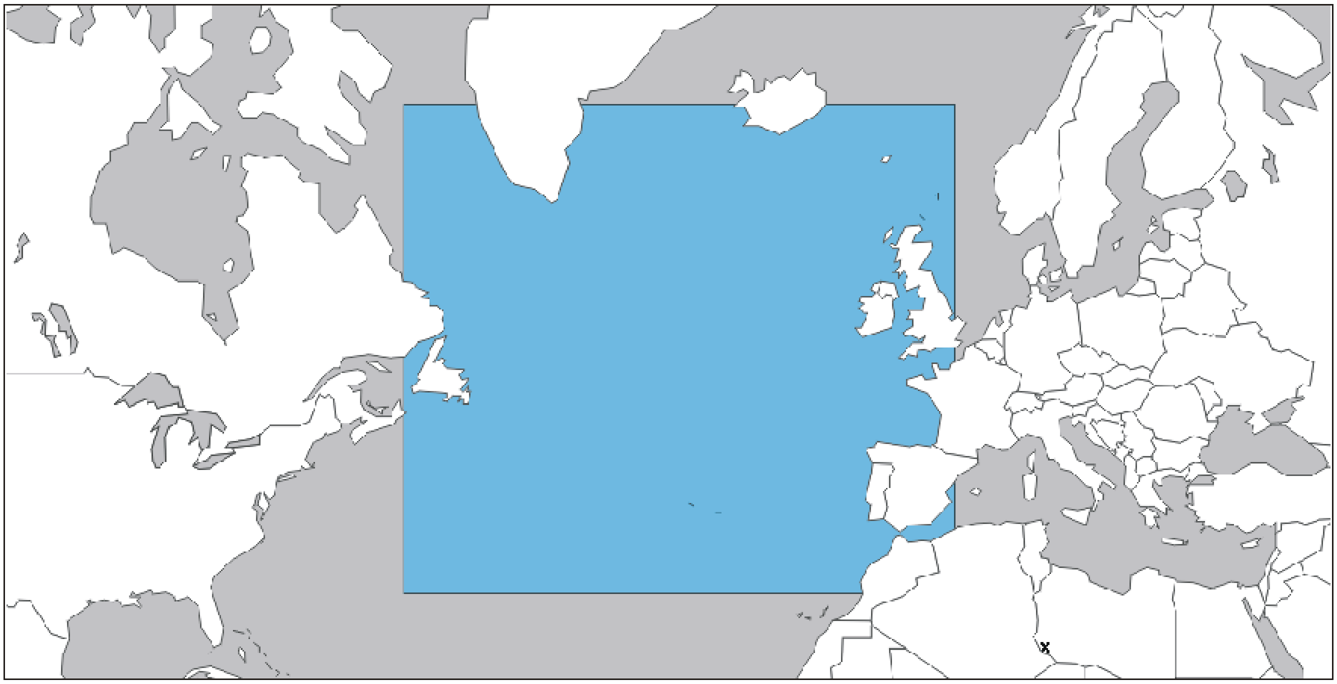


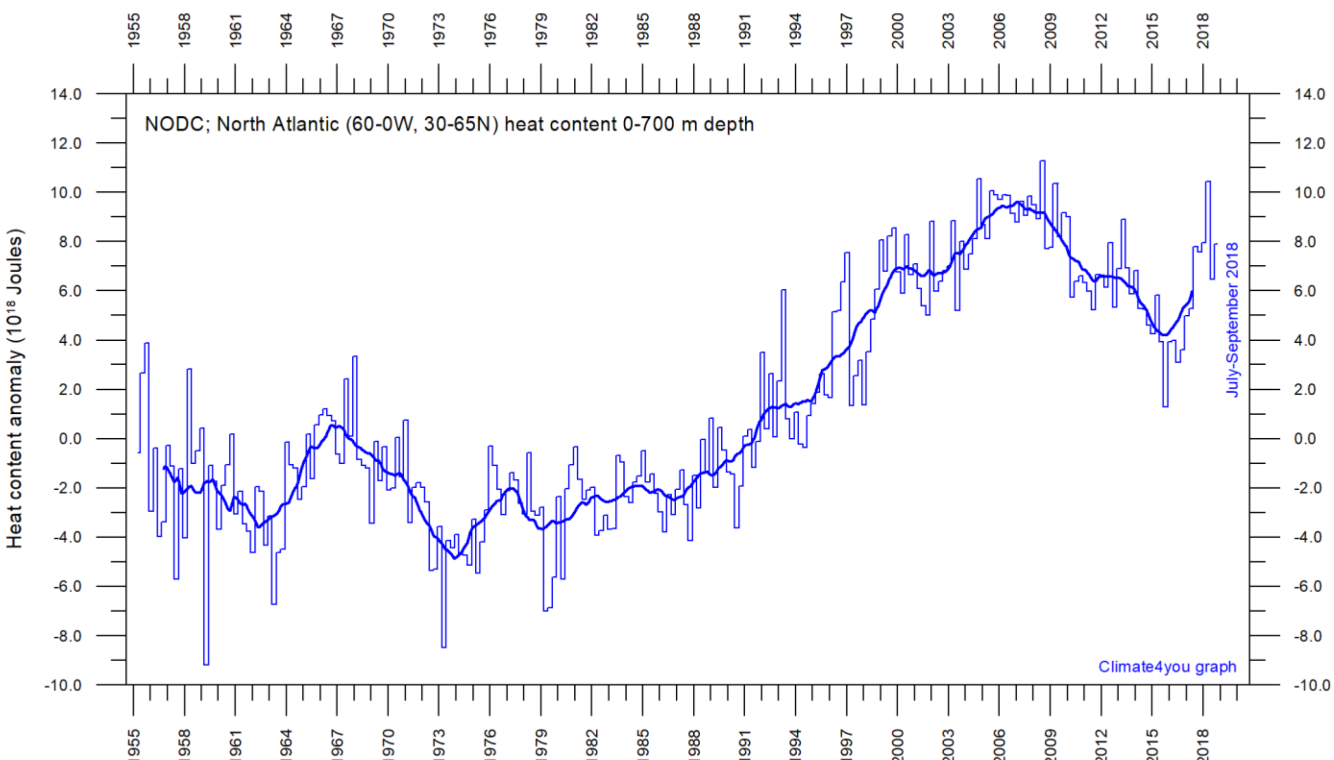
Atlantic Ocean vertical average temperature 0-100 m depth since 1955. The thin line indicate 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: NOAA National Oceanographic Data Center (NODC). Base period 1955-2010.



Indian Ocean vertical average temperature 0-100 m depth since 1955. The thin line indicate 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: NOAA National Oceanographic Data Center (NODC). Base period 1955-2010.

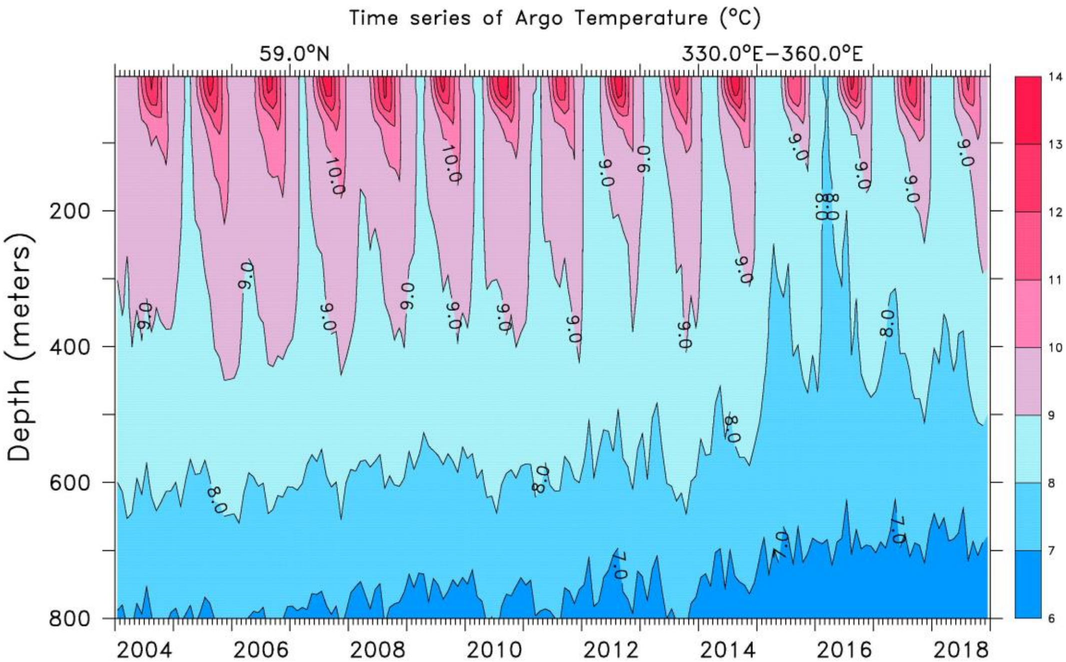
North Atlantic heat content uppermost 700 m, updated to September 2018



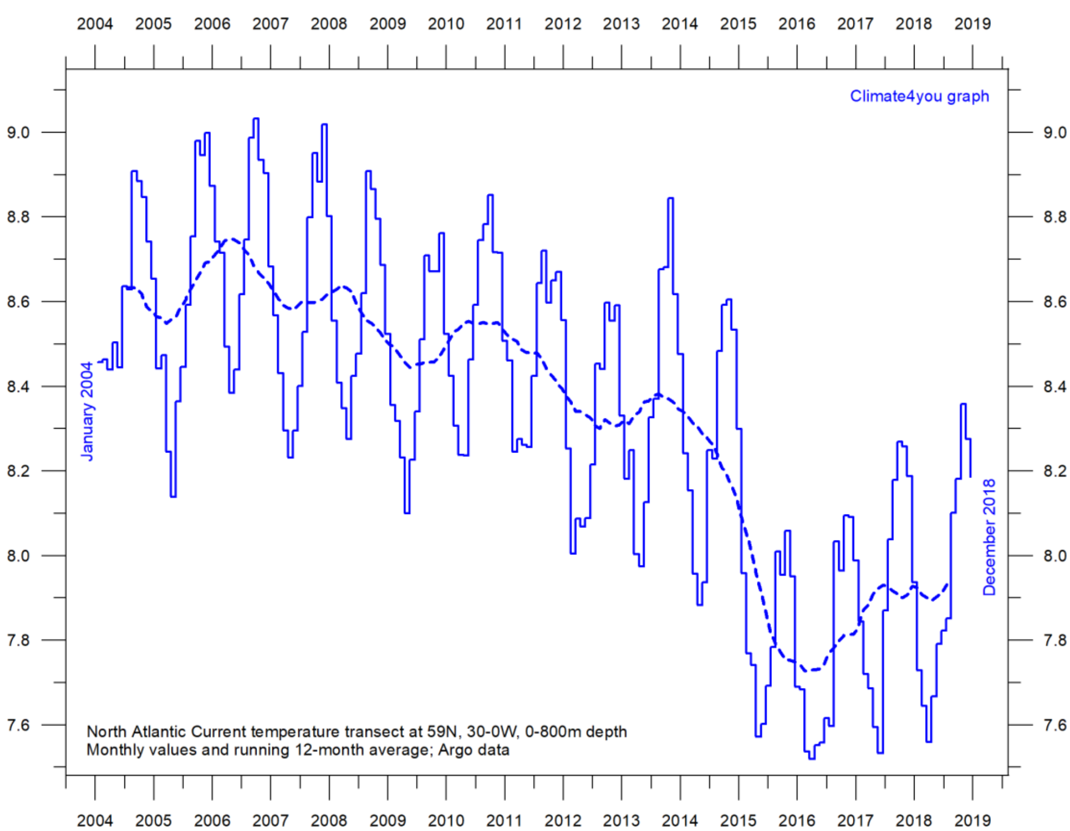


Global monthly heat content anomaly (10^{18} Joules) in the uppermost 700 m of the North Atlantic (60-0W, 30-65N; see map above) *ocean since January 1955. The thin line indicates monthly values, and the thick line represents the simple running 37-month (c. 3 year) average. Data source: National Oceanographic Data Center (NODC).*

North Atlantic temperatures 0-800 m depth along 59ºN, 30-0W, updated to December 2018

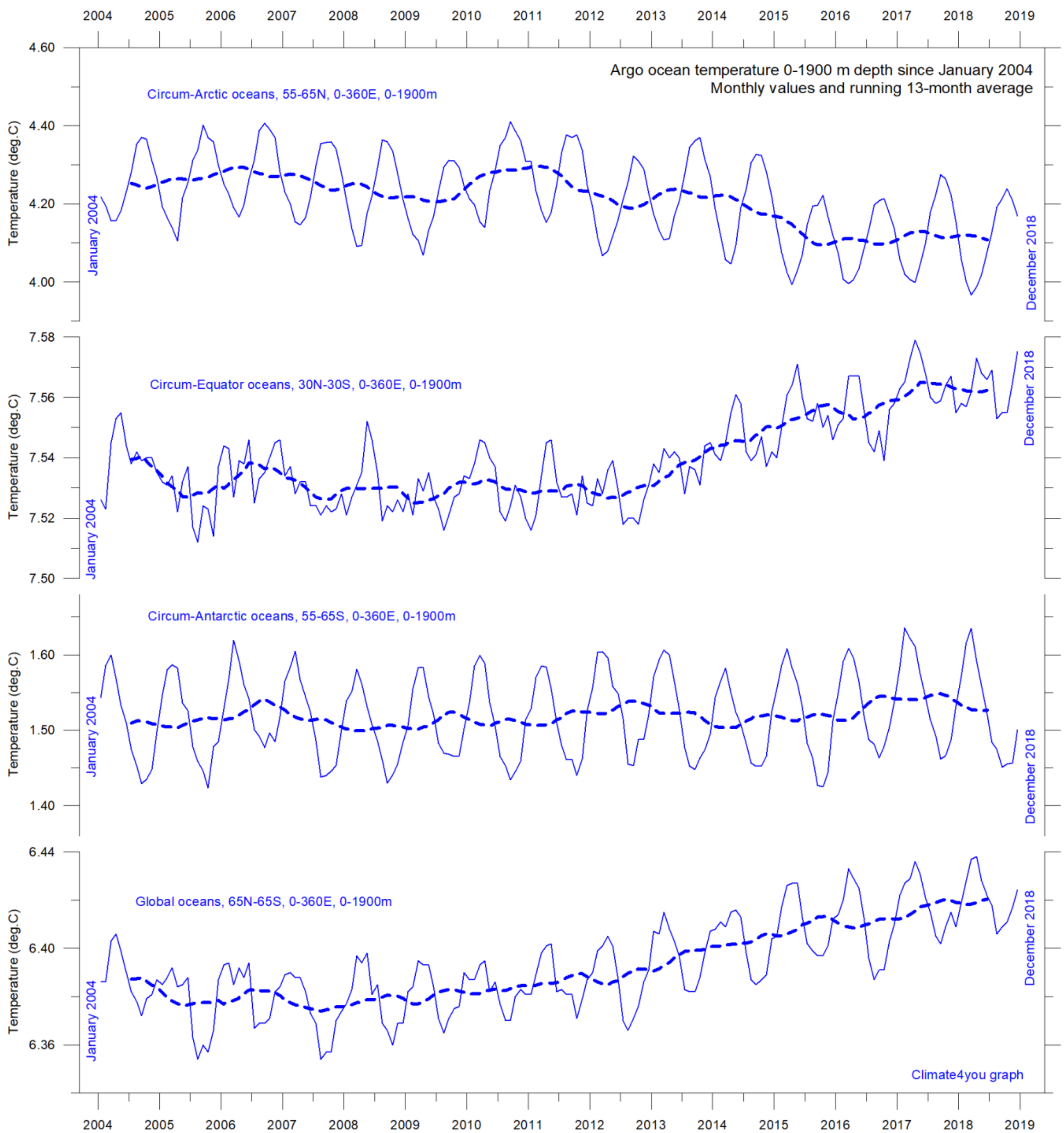


Time series depth-temperature diagram along 59 N across the North Atlantic Current from 30ºW to 0ºW, from surface to 800 m depth. Source: Global Marine Argo Atlas. See also the diagram below.



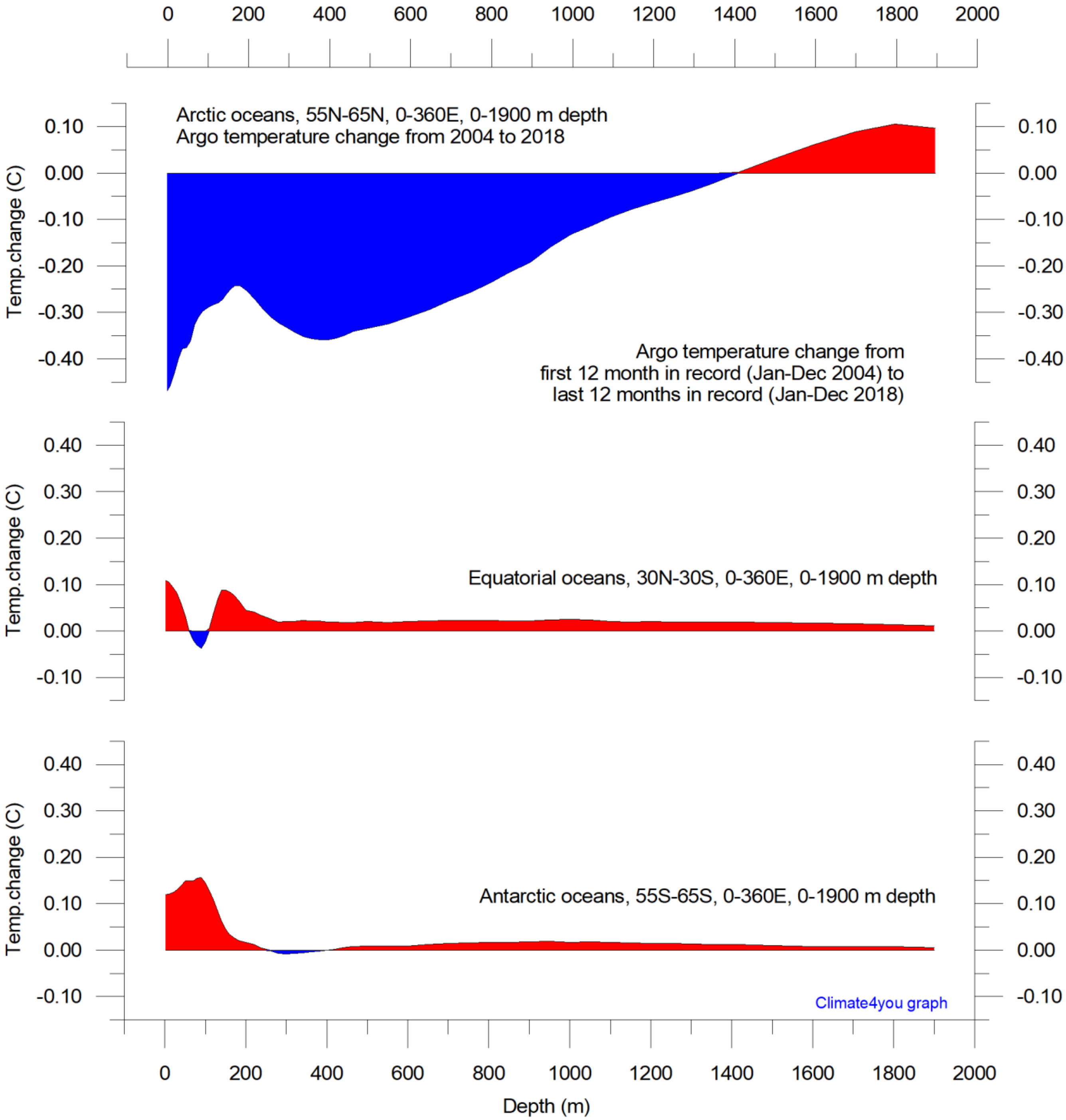
Average temperature along 59 N, 30-0W, 0-800m depth, corresponding to the main part of the North Atlantic Current, using Argo-data. Source: Global Marine Argo Atlas. Additional information can be found in: Roemmich, D. and J. Gilson, 2009. The 2004-2008 mean and annual cycle of temperature, salinity, and steric height in the global ocean from the Argo Program. Progress in Oceanography, 82, 81-100.

Global ocean temperature 0-1900 m depth summary, updated to December 2018



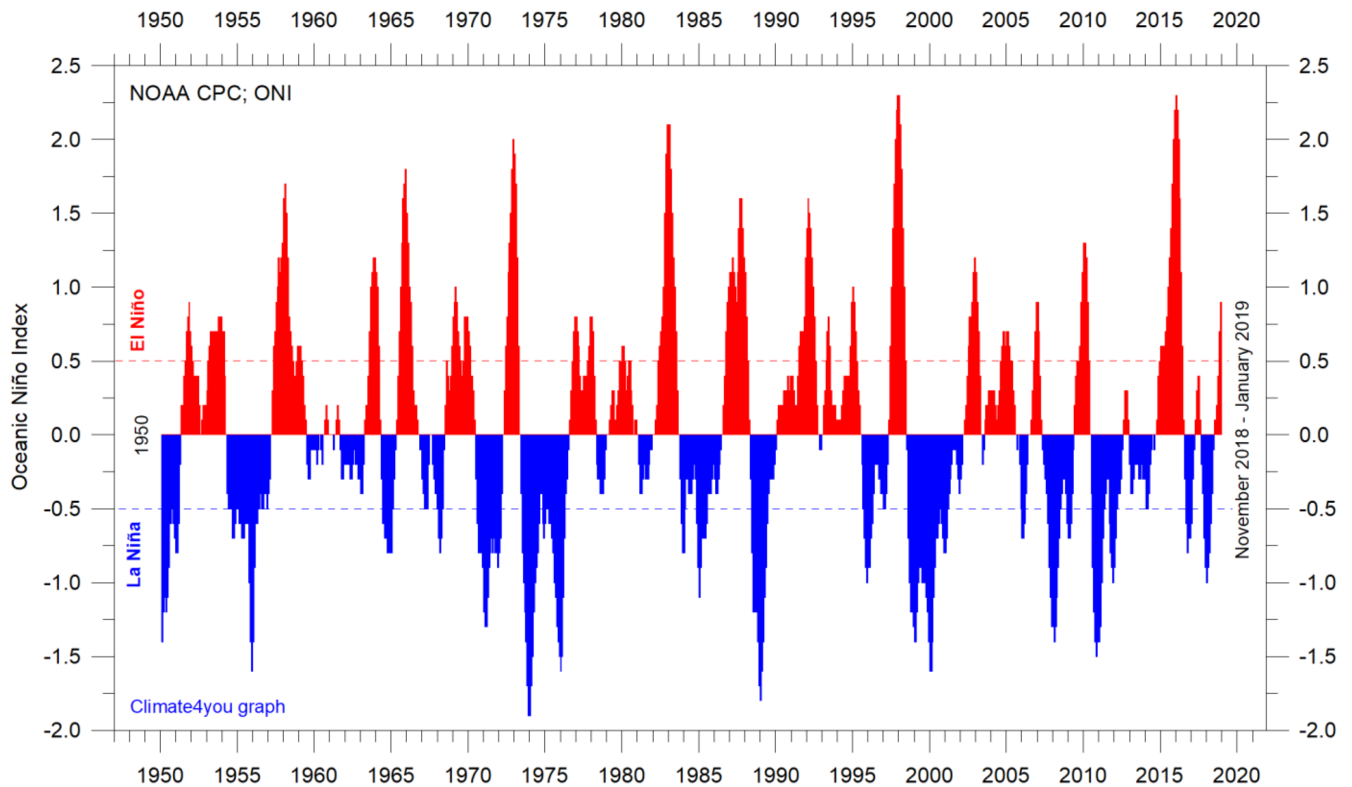
Summary of average temperature in uppermost 1900 m in different parts of the global oceans, using Argo-data. Source: Global Marine Argo Atlas. Additional information can be found in: Roemmich, D. and J. Gilson, 2009. The 2004-2008 mean and annual cycle of temperature, salinity, and steric height in the global ocean from the Argo Program. Progress in Oceanography, 82, 81-100.

Global ocean net temperature change since 2004 at different depths, updated to December 2018



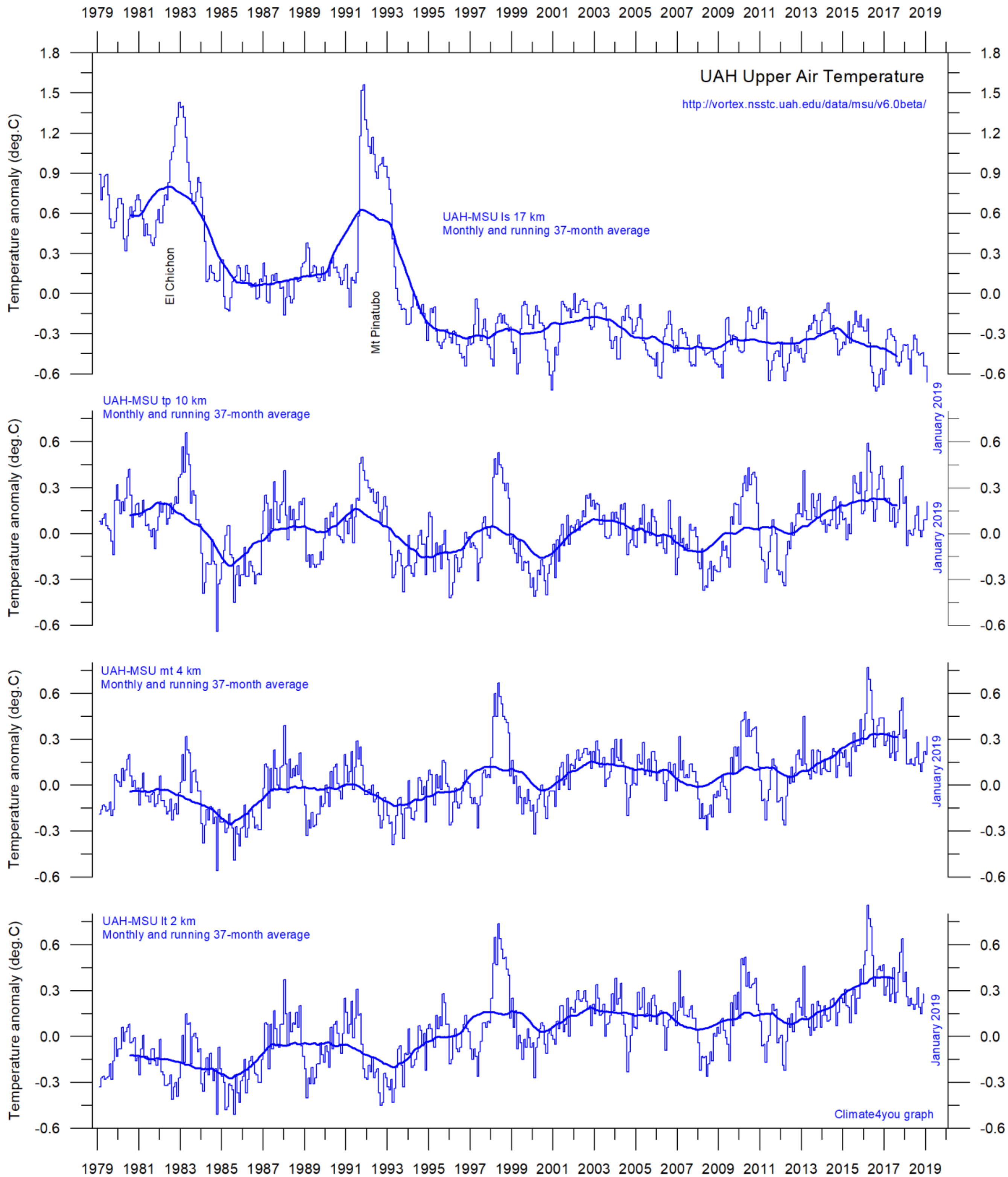
Net temperature change since 2004 from surface to 1900 m depth in different parts of the global oceans, using [Argo](#)-data. Source: [Global Marine Argo Atlas](#). Additional information can be found in: Roemmich, D. and J. Gilson, 2009. The 2004-2008 mean and annual cycle of temperature, salinity, and steric height in the global ocean from the Argo Program. [Progress in Oceanography](#), 82, 81-100. Please note that due to the spherical form of Earth, northern and southern latitudes represent only small ocean volumes, compared to latitudes near the Equator.

La Niña and El Niño episodes, updated to January 2019



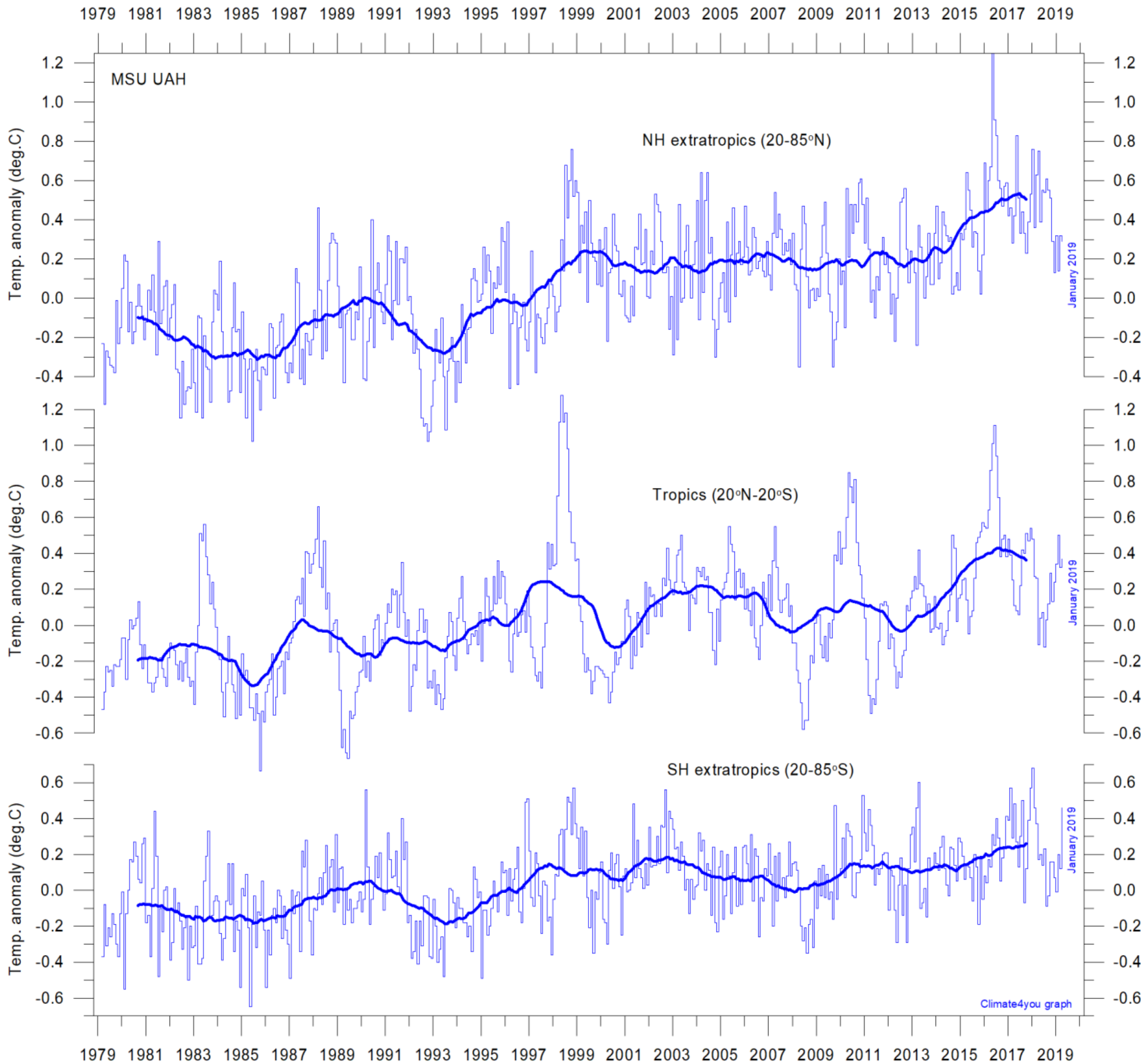
Warm (>+0.5°C) and cold (<0.5°C) episodes for the Oceanic Niño Index (ONI), defined as 3 month running mean of ERSSTv4 SST anomalies in the Niño 3.4 region (5°N-5°S, 120°-170°W)]. For historical purposes cold and warm episodes are defined when the threshold is met for a minimum of 5 consecutive over-lapping seasons. Anomalies are centred on 30-yr base periods updated every 5 years.

Troposphere and stratosphere temperatures from satellites, updated to January 2019



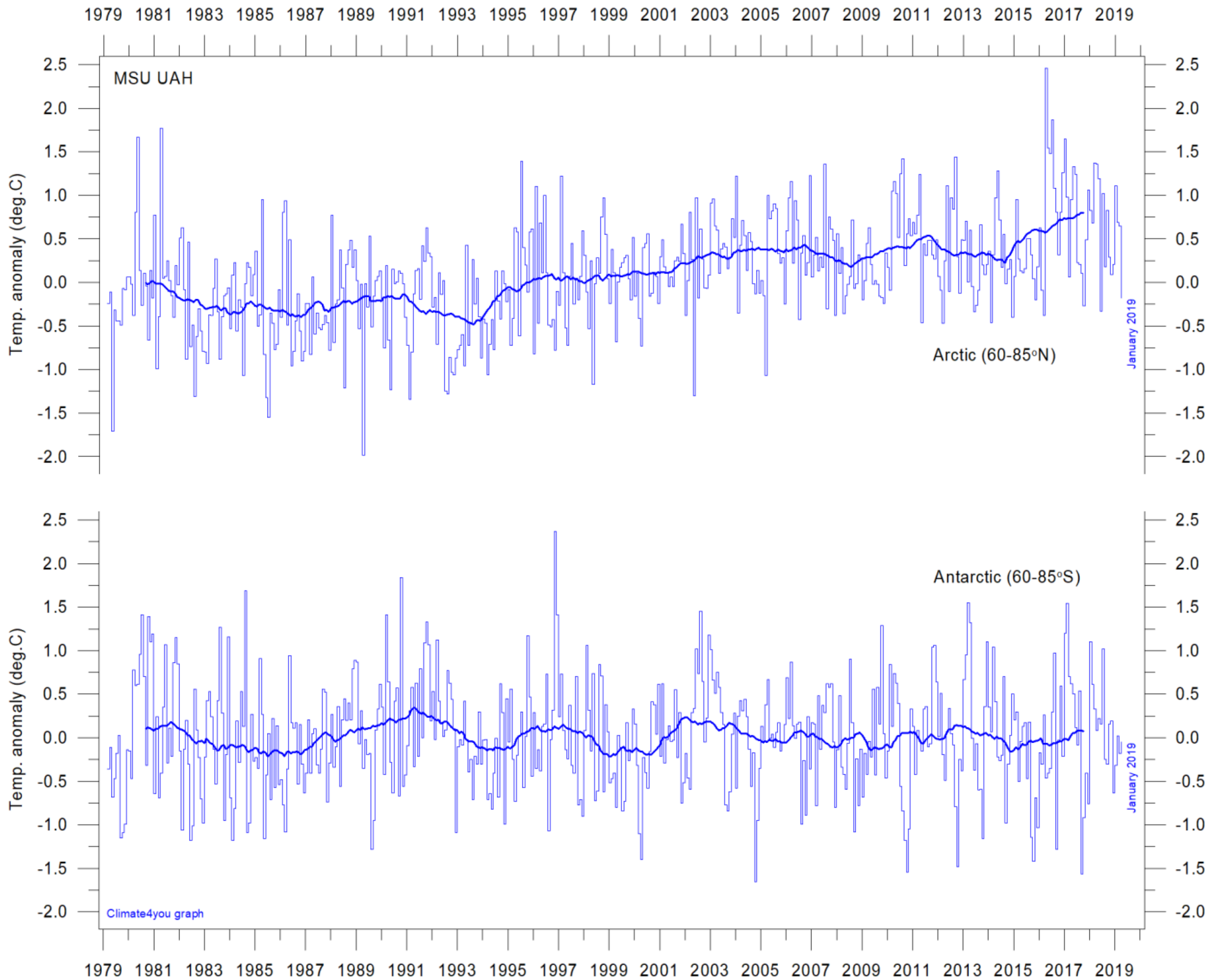
Global monthly average temperature in different according to University of Alabama at Huntsville, USA. The thin lines represent the monthly average, and the thick line the simple running 37-month average, nearly corresponding to a running 3-year average.

Zonal lower troposphere temperatures from satellites, updated to January 2019



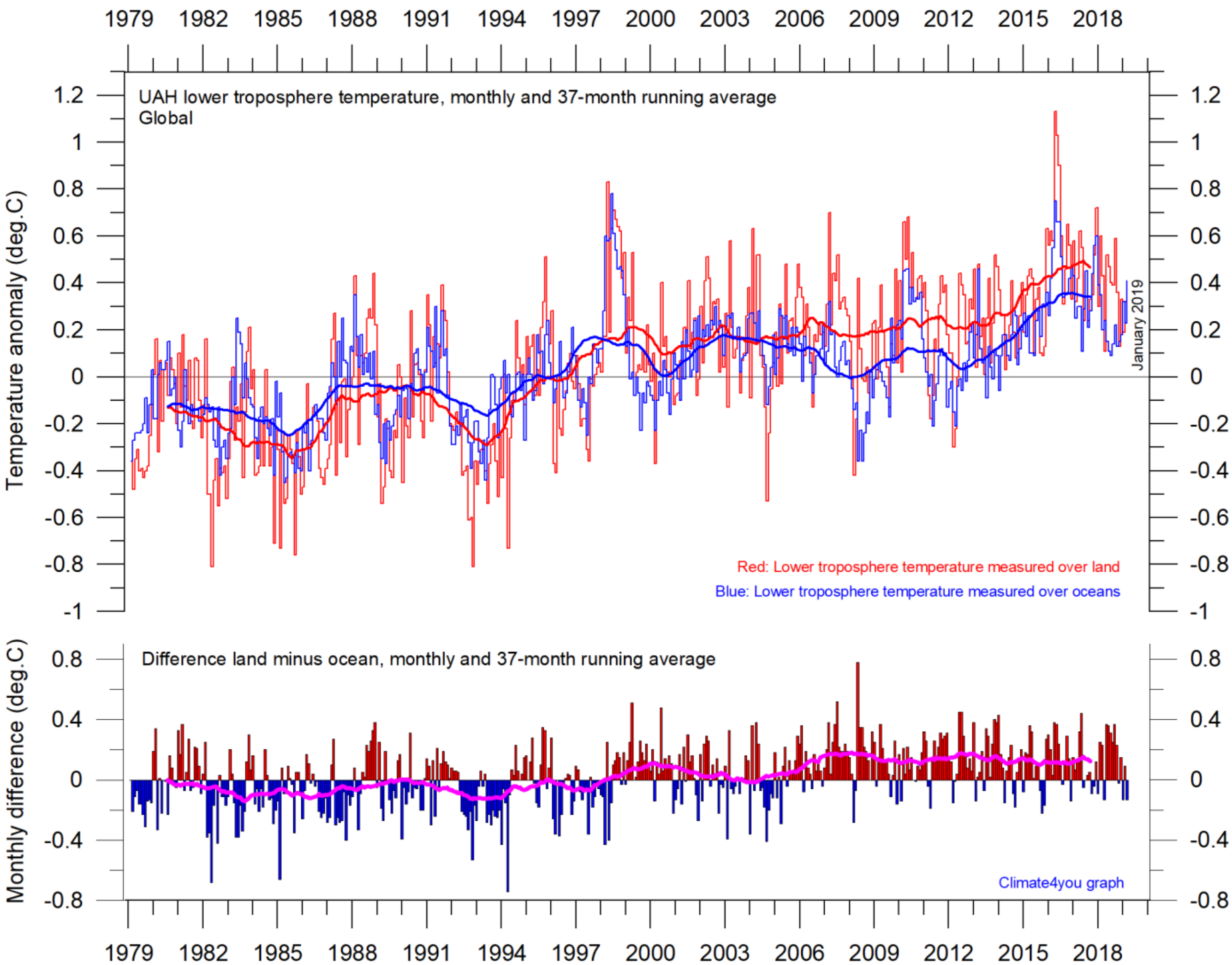
Global monthly average lower troposphere temperature since 1979 for the tropics and the northern and southern extratropics, according to University of Alabama at Huntsville, USA. Thin lines show the monthly temperature. Thick lines represent the simple running 37-month average, nearly corresponding to a running 3-year average. Reference period 1981-2010.

Arctic and Antarctic lower troposphere temperature, updated to January 2019



Global monthly average lower troposphere temperature since 1979 for the North Pole and South Pole regions, based on satellite observations (University of Alabama at Huntsville, USA). Thin lines show the monthly temperature. The thick line is the simple running 37-month average, nearly corresponding to a running 3-year average. Reference period 1981-2010.

<u>Temperature over land versus over oceans, updated to January 2019</u>



Global monthly average lower troposphere temperature since 1979 measured over land and oceans, respectively, according to University of Alabama at Huntsville, USA. Thick lines are the simple running 37-month average, nearly corresponding to a running 3-year average. Reference period 1981-2010.

Arctic and Antarctic surface air temperature, updated to December 2018

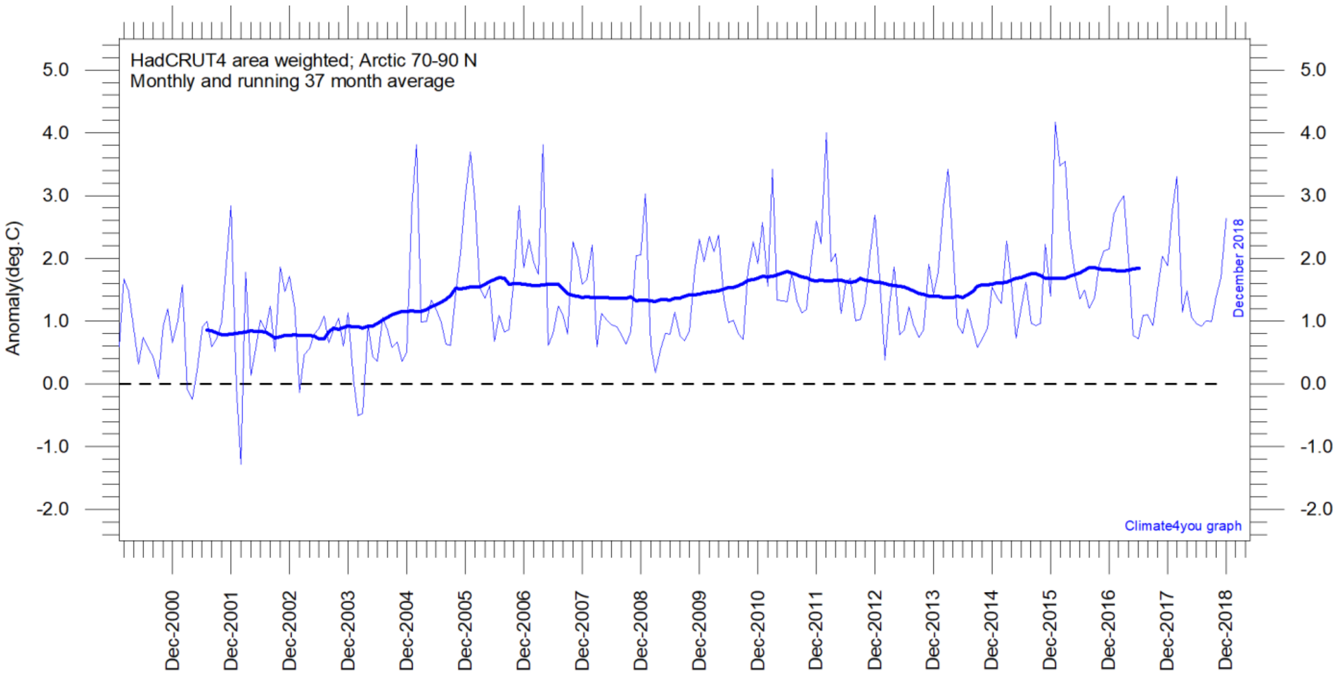


Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4]) since January 2000, in relation to the WMO [normal period] 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37-month (c. 3 year) average.

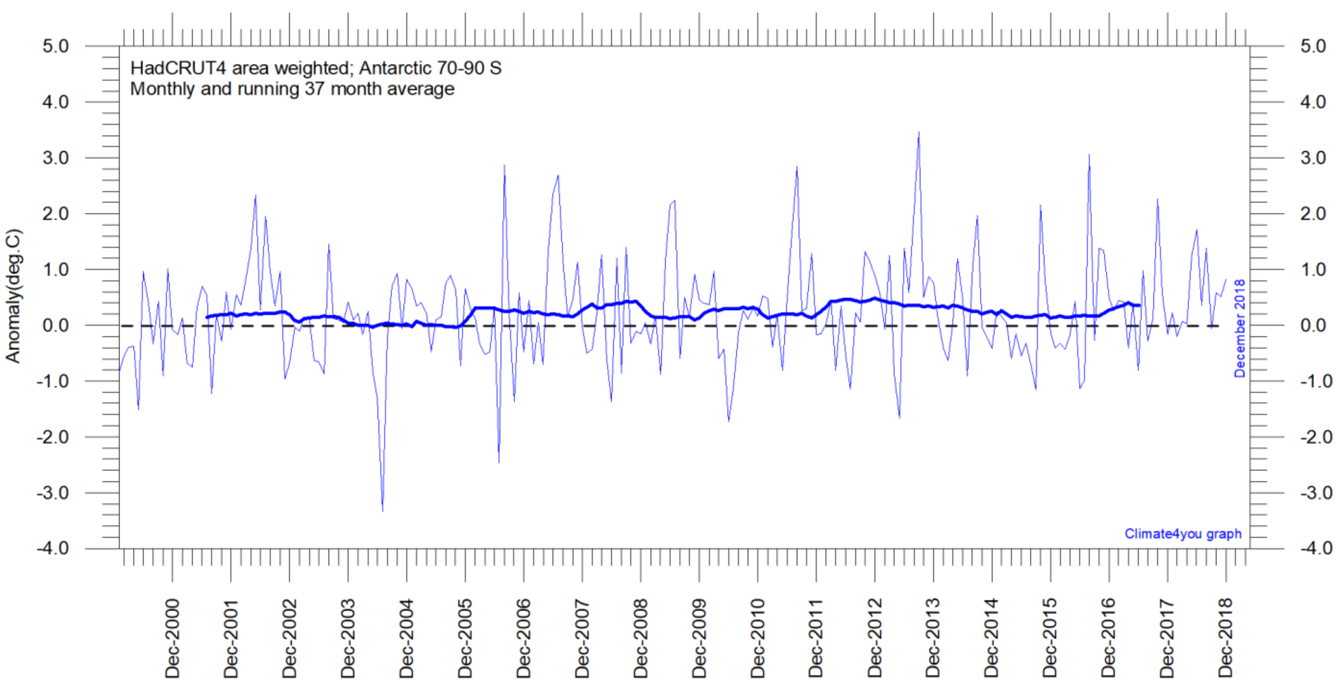


Diagram showing area weighted Antarctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4]) since January 2000, in relation to the WMO [normal period] 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37-month (c. 3 year) average.

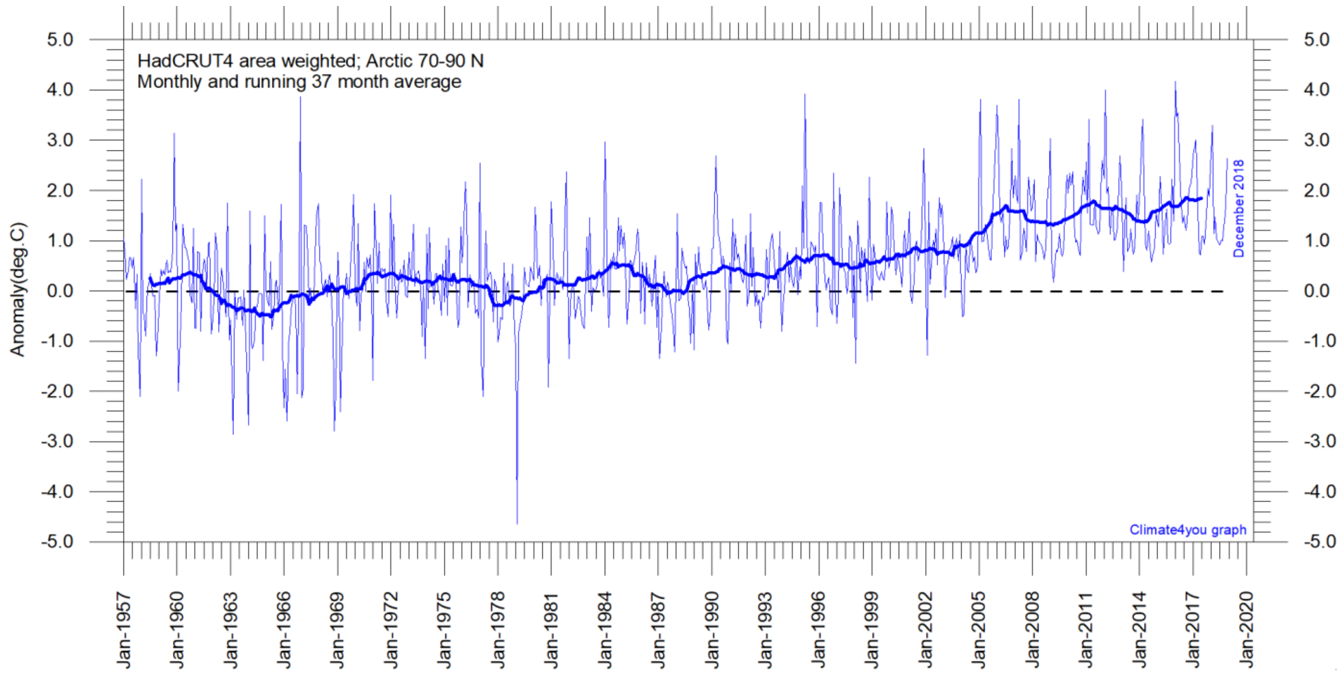


Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies (HadCRUT4) since January 1957, in relation to the WMO normal period 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37-month (c. 3 year) average.

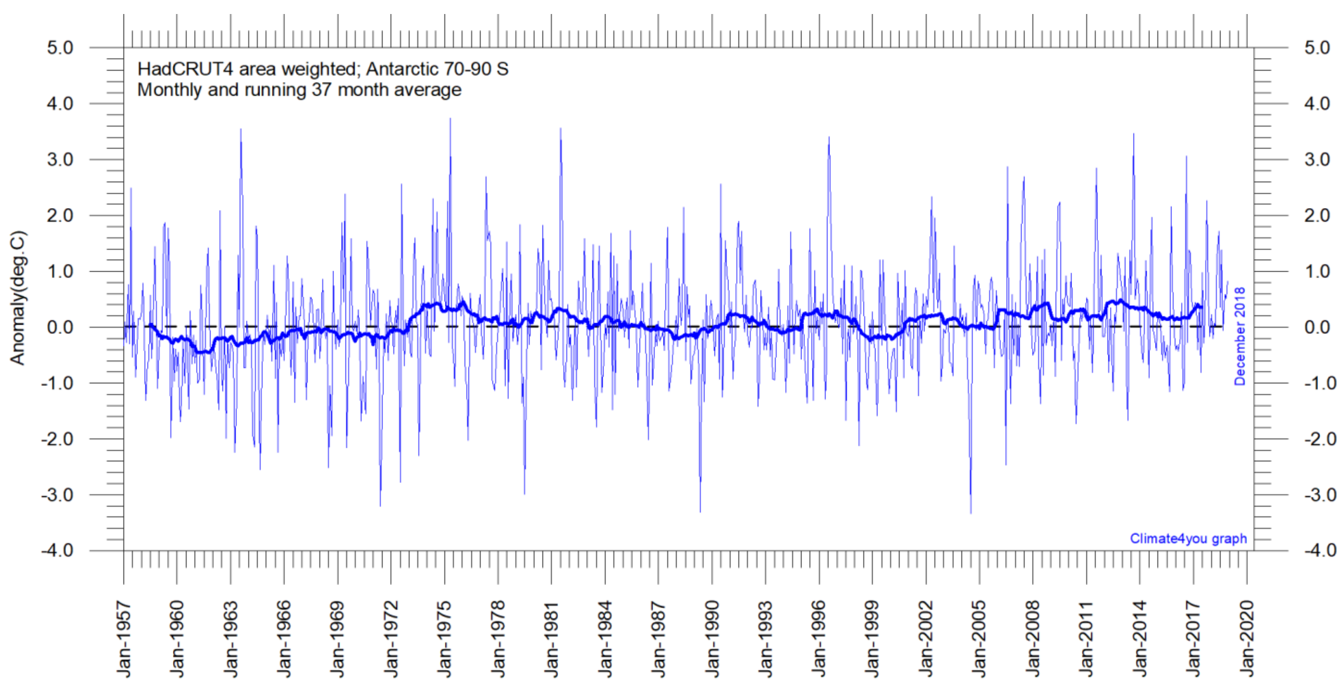


Diagram showing area weighted Antarctic (70-90°N) monthly surface air temperature anomalies (HadCRUT4) since January 1957, in relation to the WMO normal period 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37-month (c. 3 year) average.

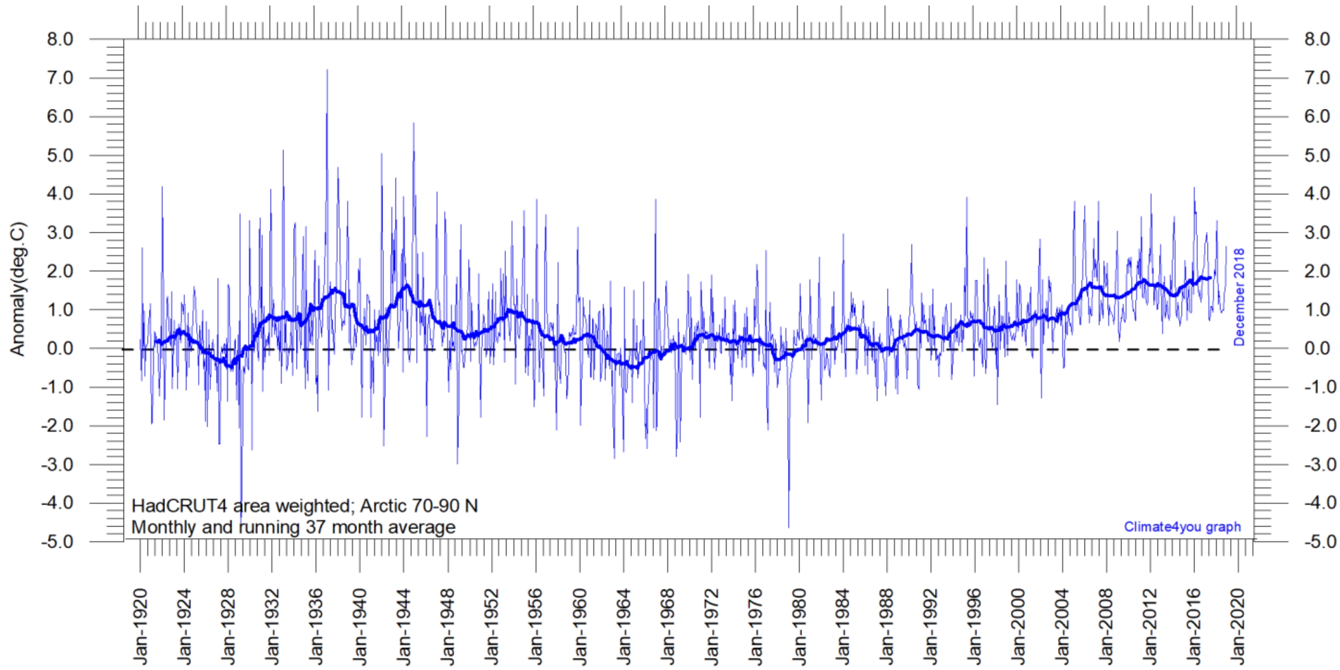


Diagram showing area-weighted Arctic (70-90ºN) monthly surface air temperature anomalies (HadCRUT4) since January 1920, in relation to the WMO normal period 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37-month (c. 3 year) average.

Because of the relatively small number of Arctic stations before 1930, month-to-month variations in the early part of the Arctic temperature record 1920-2018 are larger than later (diagram above).

The period from about 1930 saw the establishment of many new Arctic meteorological stations, first in Russia and Siberia, and following the 2nd World War, also in North America. The period since 2005 is warm, about as warm as the period 1930-1940.

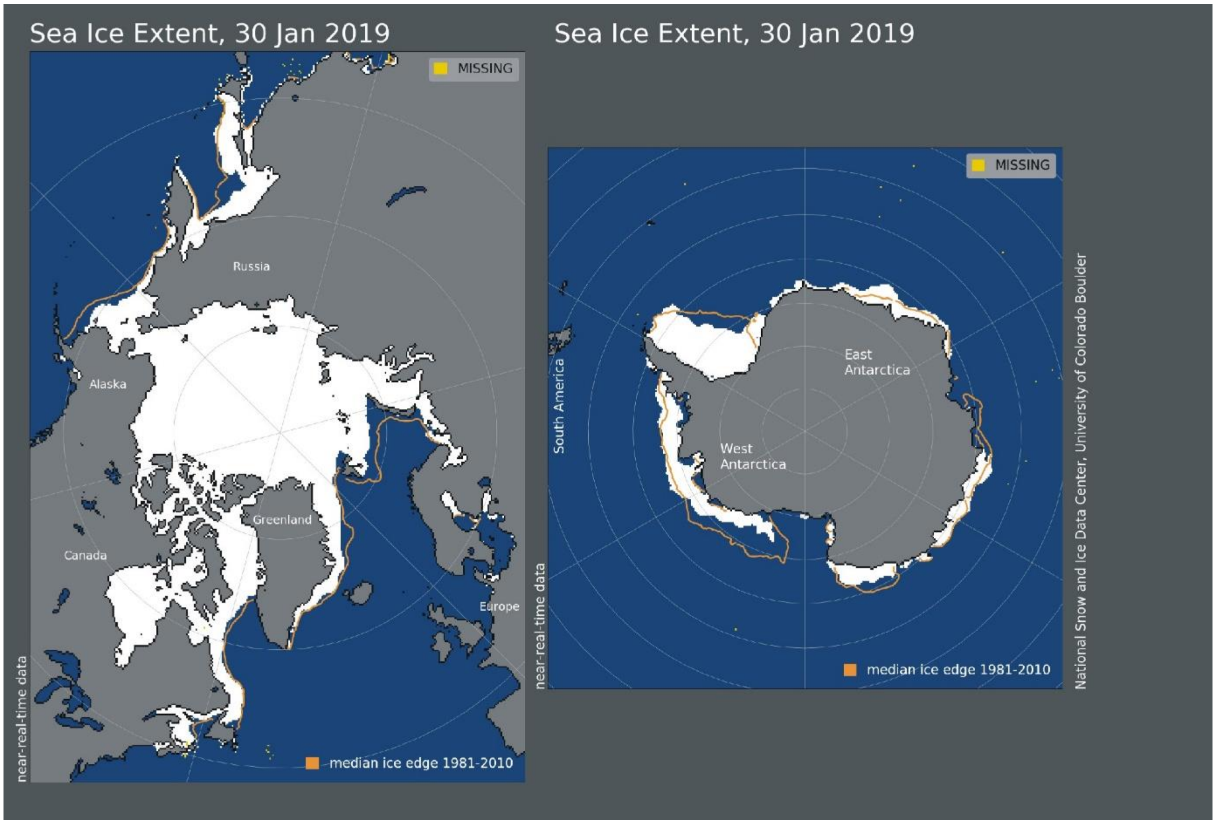
As the HadCRUT4 data series has improved high latitude coverage data coverage (compared to the HadCRUT3 series), the individual 5ºx5º grid cells has been weighted according to their surface area. This area correction is especially important for polar regions.

This approach contrasts with that adopted by Gillet et al. 2008, which calculated a simple average, with no correction for the significant surface area effect of latitude in polar regions.

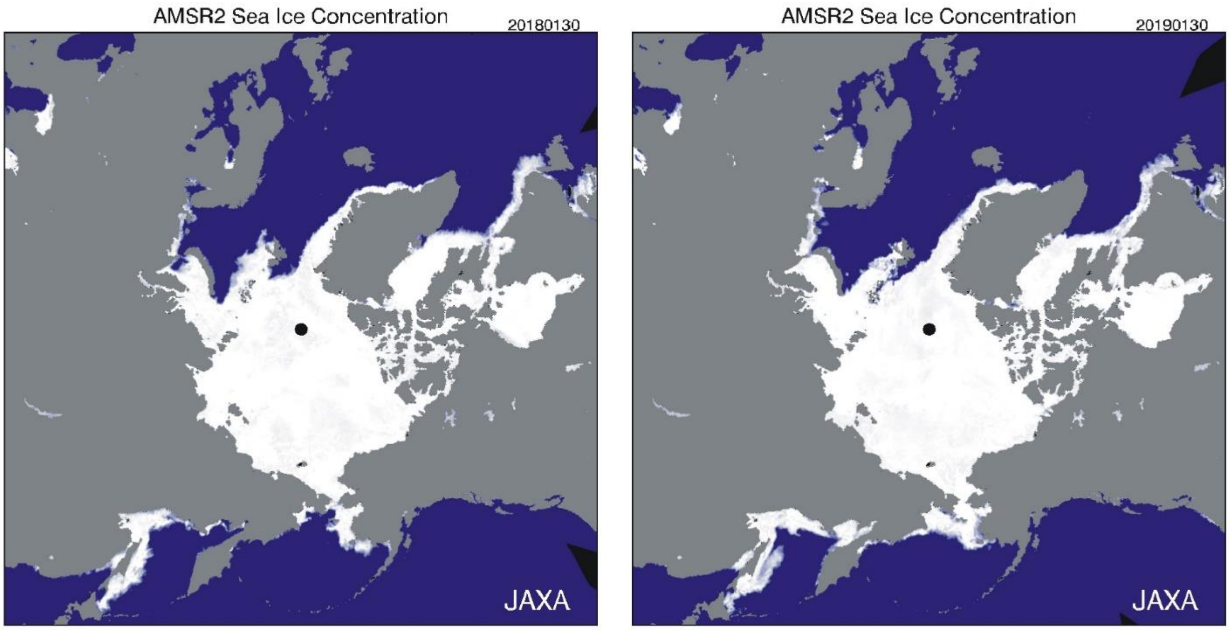
Literature:

Gillett, N.P., Stone, D.A., Stott, P.A., Nozawa, T., Karpechko, A.Y.U., Hegerl, G.C., Wehner, M.F. and Jones, P.D. 2008. Attribution of polar warming to human influence. *Nature Geoscience* 1, 750-754.

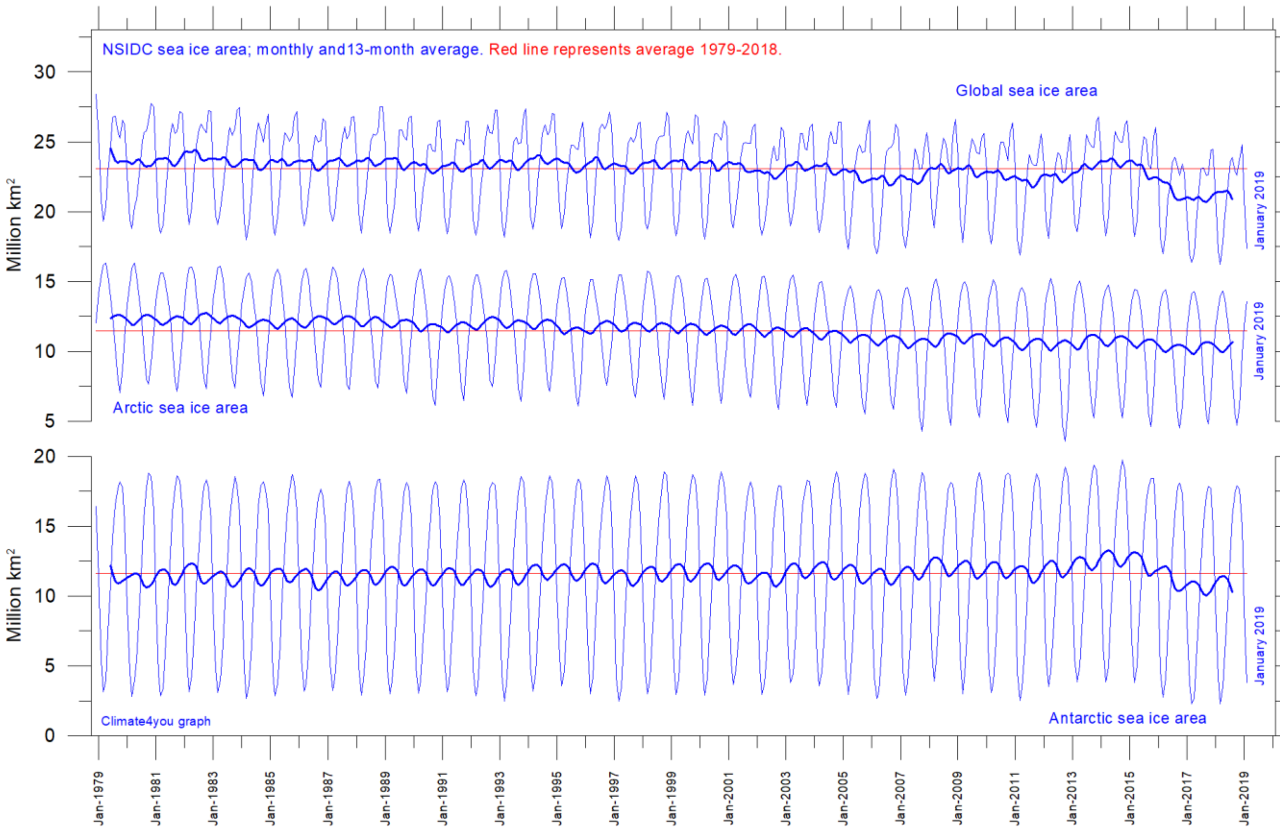
Arctic and Antarctic sea ice, updated to January 2019



Sea ice extent 30 January 2019. The median limit of sea ice (orange line) is defined as 15% sea ice cover, according to the average of satellite observations 1981-2010 (both years included). Sea ice may therefore well be encountered outside and open water areas inside the limit shown in the diagrams above. Map source: National Snow and Ice Data Center (NSIDC).



Diagrams showing Arctic sea ice extent and concentration 30 January 2018 (left) and 2019 (right), according to the Japan Aerospace Exploration Agency (JAXA).



Graphs showing monthly Antarctic, Arctic and global sea ice extent since November 1978, according to the [National Snow and Ice data Center](#) (NSIDC).

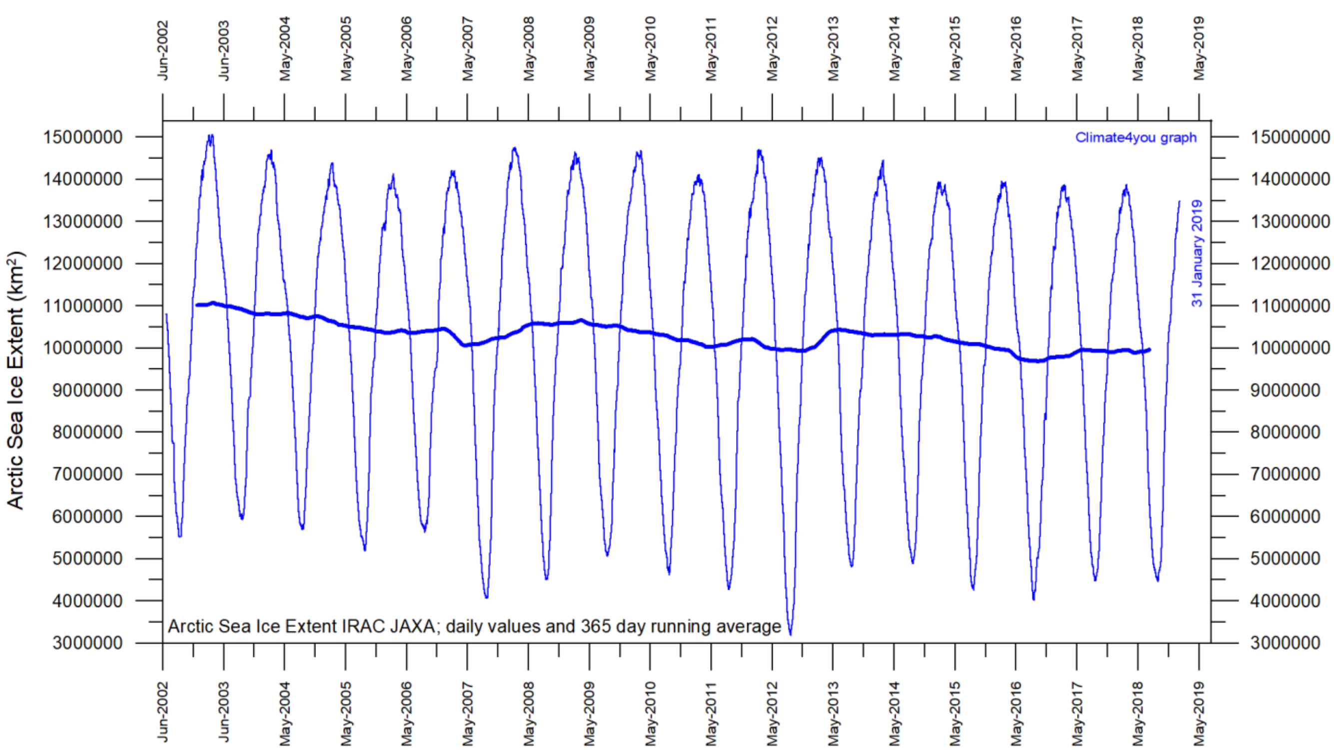
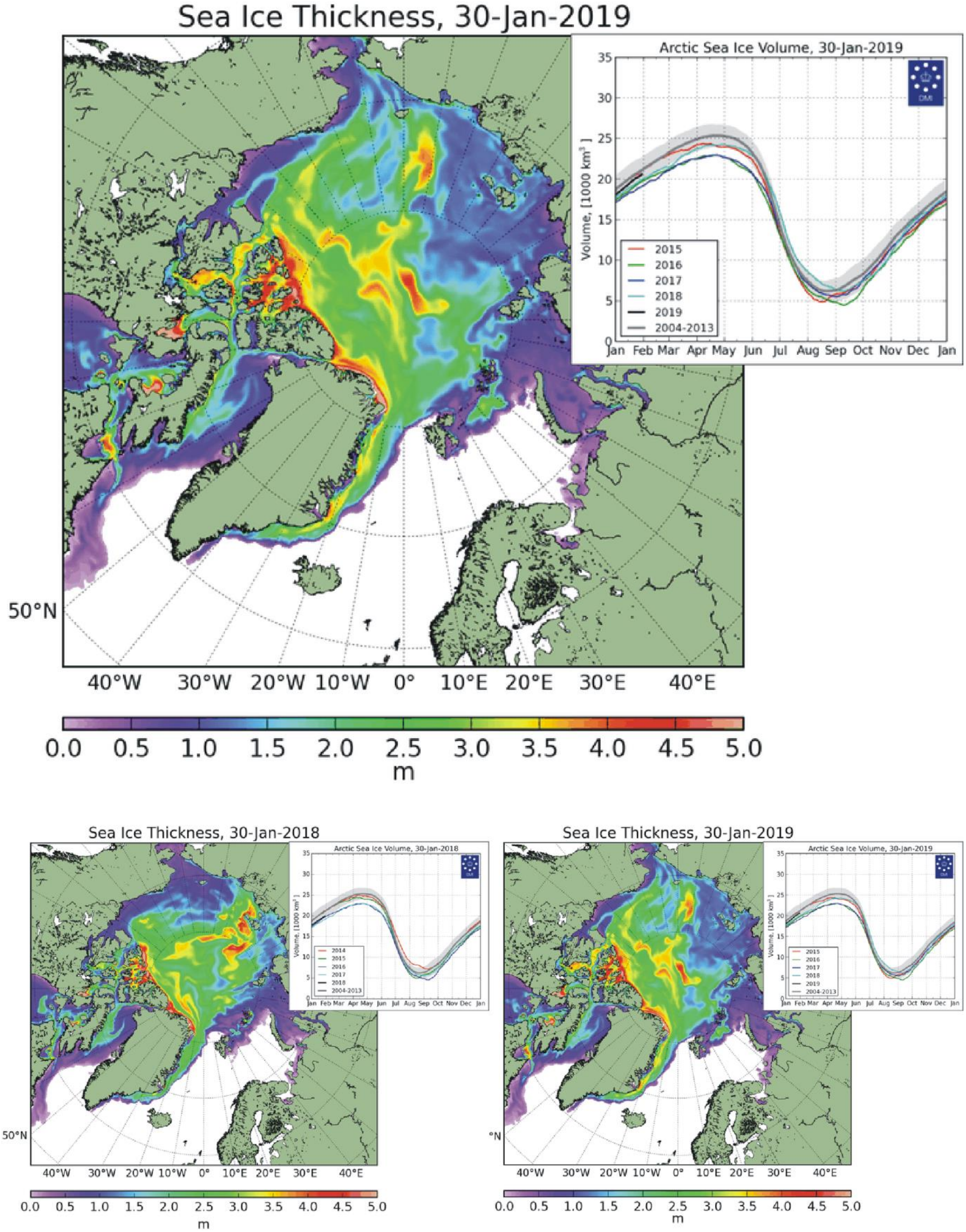
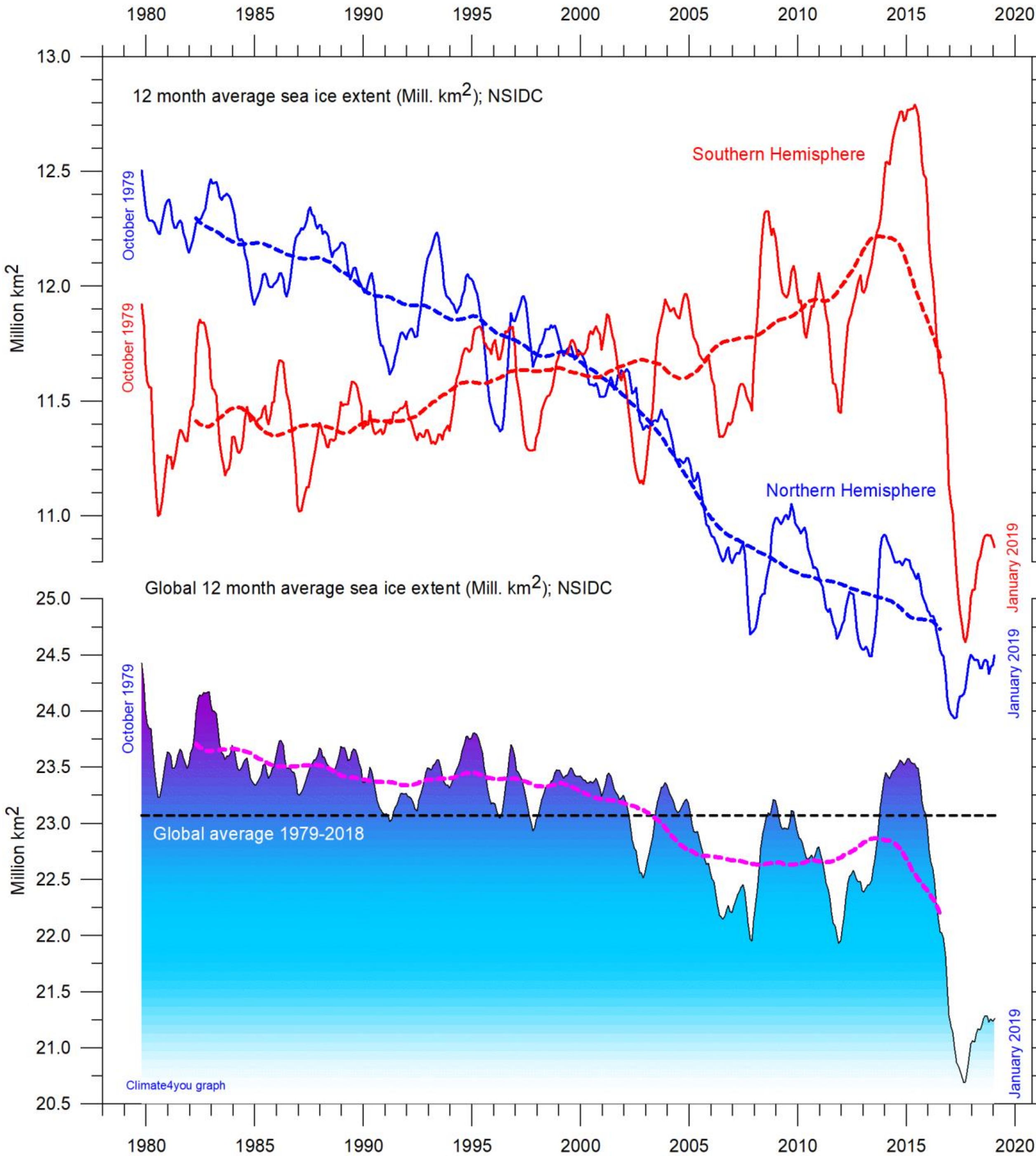


Diagram showing daily Arctic sea ice extent since June 2002, to 31 January 2019, by courtesy of [Japan Aerospace Exploration Agency](#) (JAXA).



Diagrams showing Arctic sea ice extent and thickness 30 January 2018 (left) and 2019 (right and above) and the seasonal cycles of the calculated total arctic sea ice volume, according to [The Danish Meteorological Institute (DMI)](). The mean sea ice volume and standard deviation for the period 2004-2013 are shown by grey shading.



12 month running average sea ice extension, global and in both hemispheres since 1979, the satellite-era. The October 1979 value represents the monthly 12-month average of November 1978 - October 1979, the November 1979 value represents the average of December 1978 - November 1979, etc. The stippled lines represent a 61-month (ca. 5 years) average. Data source: National Snow and Ice Data Center (NSIDC).

Sea level in general

Global (or eustatic) sea-level change is measured relative to an idealised reference level, the geoid, which is a mathematical model of planet Earth's surface (Carter et al. 2014). Global sea-level is a function of the volume of the ocean basins and the volume of water they contain. Changes in global sea-level are caused by – but not limited to - four main mechanisms:

1. Changes in local and regional air pressure and wind, and tidal changes introduced by the Moon.
2. Changes in ocean basin volume by tectonic (geological) forces.
3. Changes in ocean water density caused by variations in currents, water temperature and salinity.
4. Changes in the volume of water caused by changes in the mass balance of terrestrial glaciers.

In addition to these there are other mechanisms influencing sea-level; such as storage of ground water, storage in lakes and rivers, evaporation, etc.

Mechanism 1 is controlling sea-level at many sites on a time scale from months to several years. As an example, many coastal stations show a pronounced annual variation reflecting seasonal changes in air pressures and wind speed. Longer-term climatic changes playing out over decades or centuries will also affect measurements of sea-level changes. Hansen et al. (2011, 2015) provide excellent analyses of sea-level changes caused by recurrent changes of the orbit of the Moon and other phenomena.

Mechanism 2 – with the important exception of earthquakes and tsunamis - typically operates over long (geological) time scales and is not significant on human time scales. It may relate to variations in the sea-floor spreading rate, causing volume changes in mid-ocean mountain ridges, and to the slowly changing configuration of land and oceans. Another effect may be the slow rise of basins due to isostatic offloading by deglaciation after an ice age. The floor of the Baltic Sea and the Hudson Bay are presently rising, causing a slow net transfer of water from these basins into the adjoining oceans. Slow changes of very big glaciers (ice sheets) and movements in the mantle will affect the gravity field and thereby the vertical position of the ocean surface. Any increase of the total water mass as well as sediment deposition into oceans increase the load on their bottom, generating sinking by viscoelastic flow in the mantle below. The mantle flow is directed towards the surrounding land areas, which will rise, thereby partly compensating for the initial sea level increase induced by the increased water mass in the ocean.

Mechanism 3 (temperature-driven expansion) only affects the uppermost part of the oceans on human time scales. Usually, temperature-driven changes in density are more important than salinity-driven changes. Seawater is characterised by a relatively small coefficient of expansion, but the effect should however not be overlooked, especially when interpreting satellite altimetry data. Temperature-driven expansion of a column of seawater will not affect the total mass of water within the column considered and will therefore not affect the potential at the top of the water column. Temperature-driven ocean water expansion will therefore not in itself lead to any lateral displacement of water, but only locally lift the ocean surface. Near the coast, where people are living, the depth of water approaches zero, so no temperature-driven expansion will take place here (Mörner 2015). Mechanism 3 is for that reason not important for coastal regions.

Mechanism 4 (changes in glacier mass balance) is an important driver for global sea-level changes along coasts, for human time scales. Volume changes of floating glaciers – ice shelves – has no influence on the global sea-level, just like volume changes of floating sea ice has no influence. Only the mass-balance of grounded or land-based glaciers is important for the global sea-level along coasts.

Summing up: Mechanism 1 and 4 are the most important for understanding sea-level changes along coasts.

References:

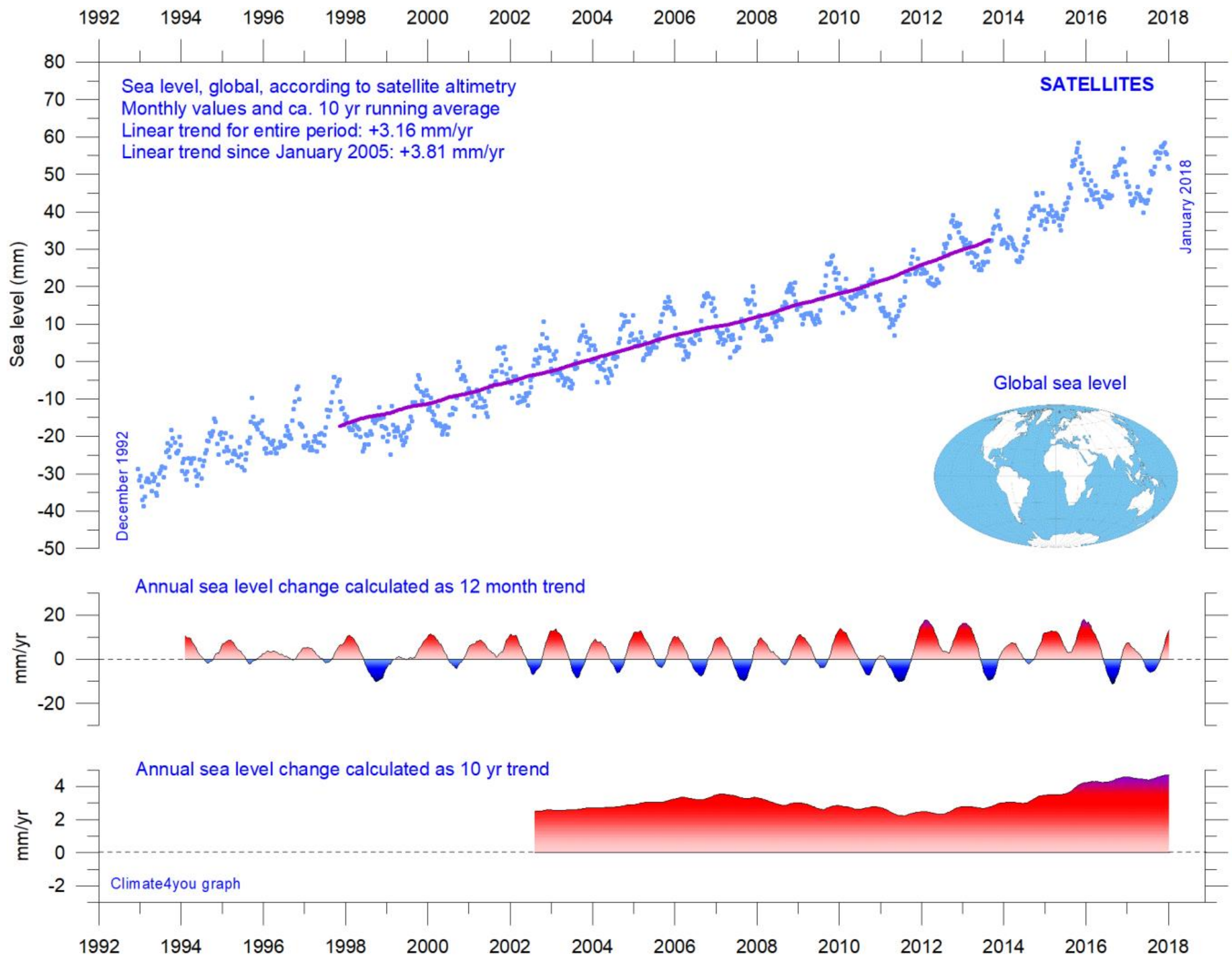
Carter R.M., de Lange W., Hansen, J.M., Humlum O., Idso C., Kear, D., Legates, D., Mörner, N.A., Ollier C., Singer F. & Soon W. 2014. Commentary and Analysis on the Whitehead& Associates 2014 NSW Sea-Level Report. Policy Brief, NIPCC, 24. September 2014, 44 pp. http://climatechangereconsidered.org/wp-content/uploads/2014/09/NIPCC-Report-on-NSW-Coastal-SL-9z-corrected.pdf

Hansen, J.-M., Aagaard, T. and Binderup, M. 2011. Absolute sea levels and isostatic changes of the eastern North Sea to central Baltic region during the last 900 years. Boreas, 10.1111/j.1502-3885.2011.00229.x. ISSN 0300–9483.

Hansen, J.-M., Aagaard, T. and Huijpers, A. 2015. Sea-Level Forcing by Synchronization of 56- and 74-YearOscillations with the Moon's Nodal Tide on the Northwest European Shelf (Eastern North Sea to Central Baltic Sea). Journ. Coastal Research, 16 pp.

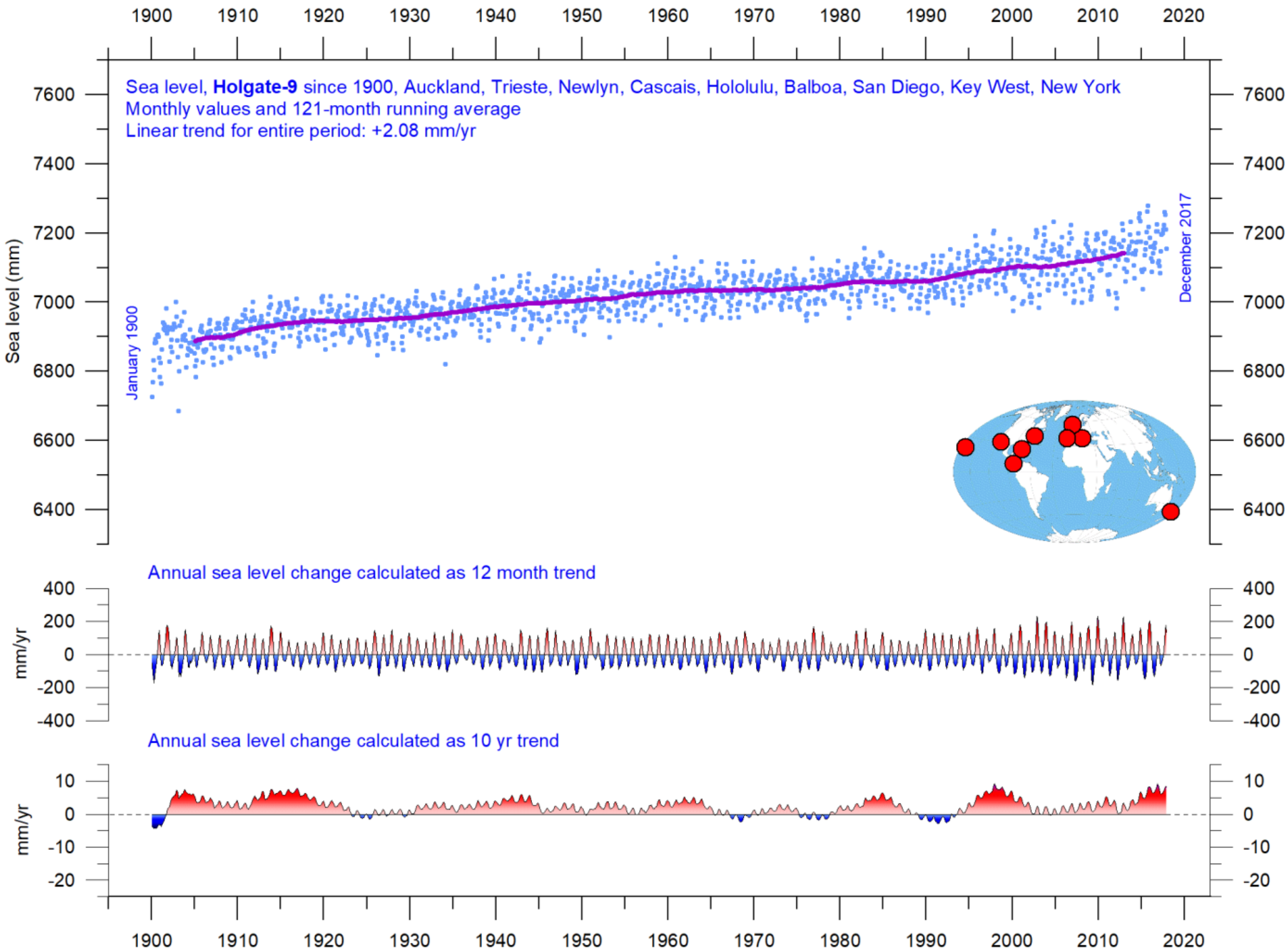
Mörner, Nils-Axel 2015. Sea Level Changes as recorded in nature itself. Journal of Engineering Research and Applications, Vol.5, 1, 124-129.

Global sea level from satellite altimetry, updated to January 2018



Global sea level since December 1992 according to the Colorado Center for Astrodynamics Research at University of Colorado at Boulder. The blue dots are the individual observations, and the purple line represents the running 121-month (ca. 10 year) average. The two lower panels show the annual sea level change, calculated for 1 and 10-year time windows, respectively. These values are plotted at the end of the interval considered. Data from the TOPEX/Poseidon mission have been used before 2002, and data from the Jason-1 mission (satellite launched December 2001) after 2002.

Global sea level from tide-gauges, updated to December 2017

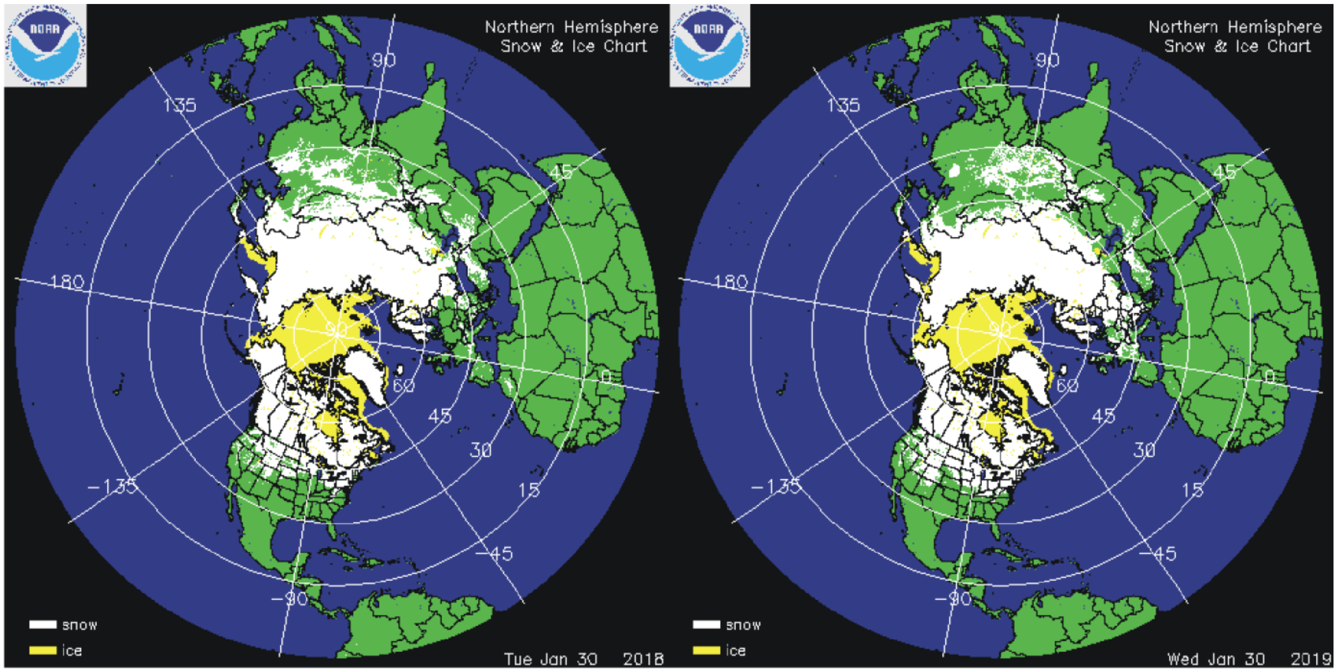


Holgate-9 monthly tide gauge data from PSMSL Data Explorer. Holgate (2007) suggested the nine stations listed in the diagram to capture the variability found in a larger number of stations over the last half century studied previously. For that reason, average values of the Holgate-9 group of tide gauge stations are interesting to follow. The blue dots are the individual average monthly observations, and the purple line represents the running 121-month (ca. 10 year) average. The two lower panels show the annual sea level change, calculated for 1 and 10-year windows, respectively. These values are plotted at the end of the interval considered.

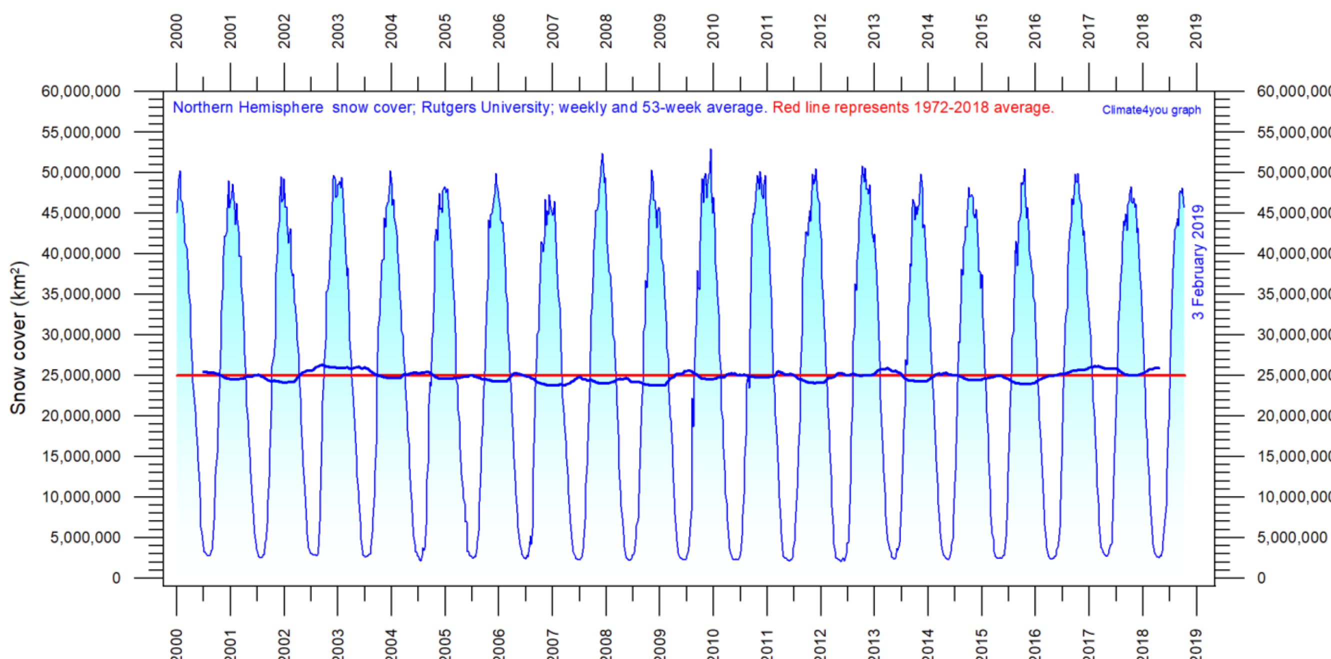
Reference:

Holgate, S.J. 2007. On the decadal rates of sea level change during the twentieth century. Geophys. Res. Letters, 34, L01602, doi:10.1029/2006GL028492

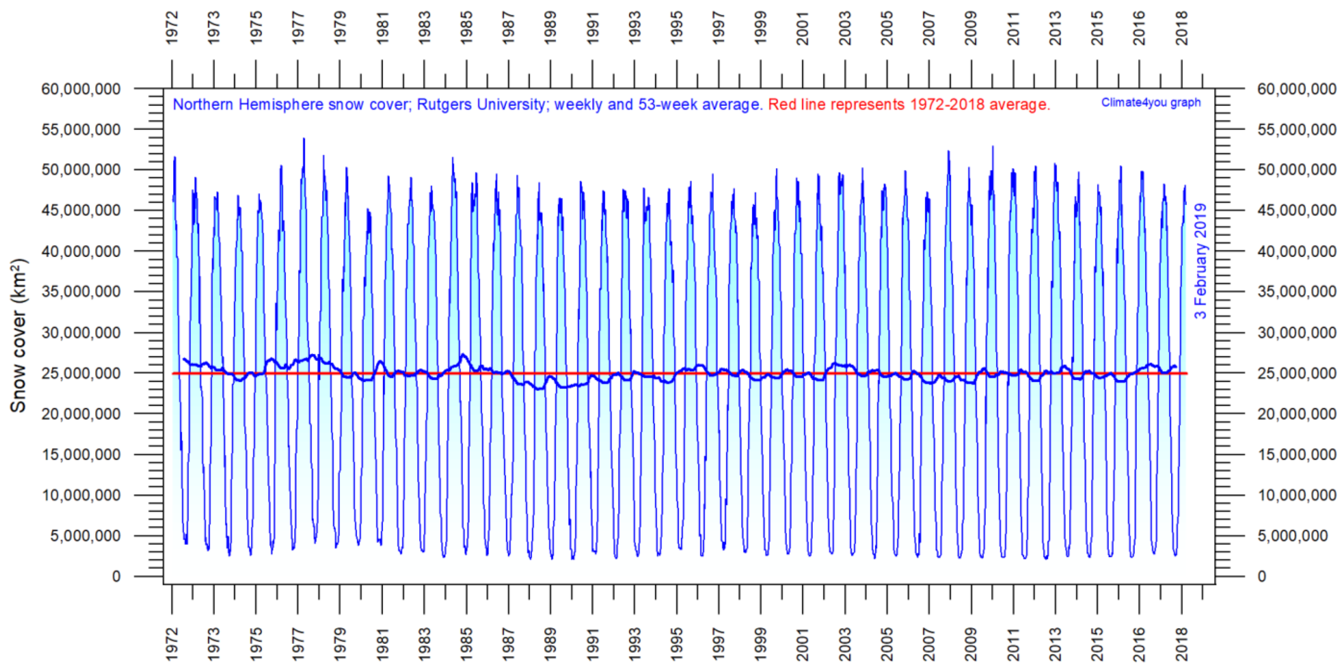
Northern Hemisphere weekly and seasonal snow cover, updated to January 2019



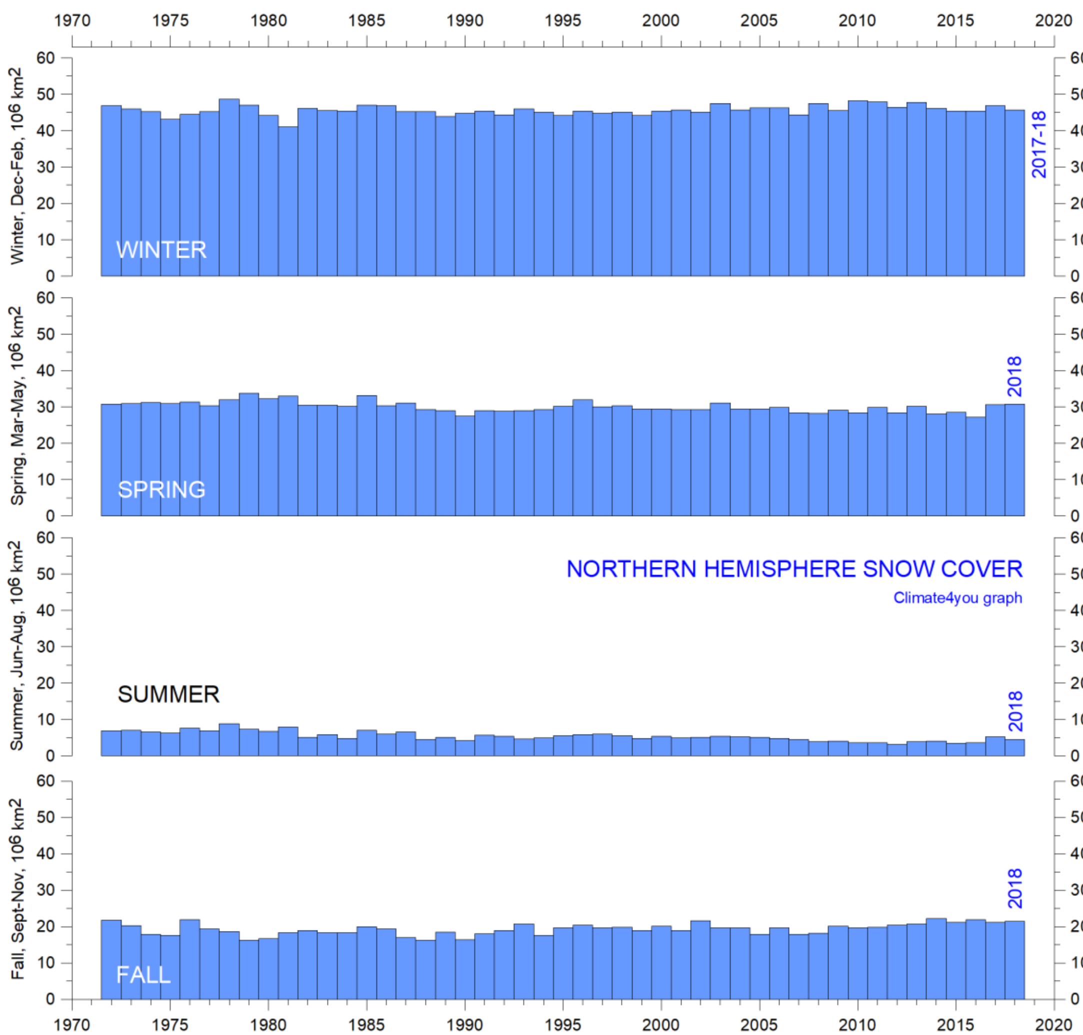
Northern hemisphere snow cover (white) and sea ice (yellow) 30 January 2018 (left) and 2019 (right). Map source: National Ice Center (NIC).



Northern hemisphere weekly snow cover since January 2000 according to Rutgers University Global Snow Laboratory. The thin blue line is the weekly data, and the thick blue line is the running 53-week average (approximately 1 year). The horizontal red line is the 1972-2018 average.

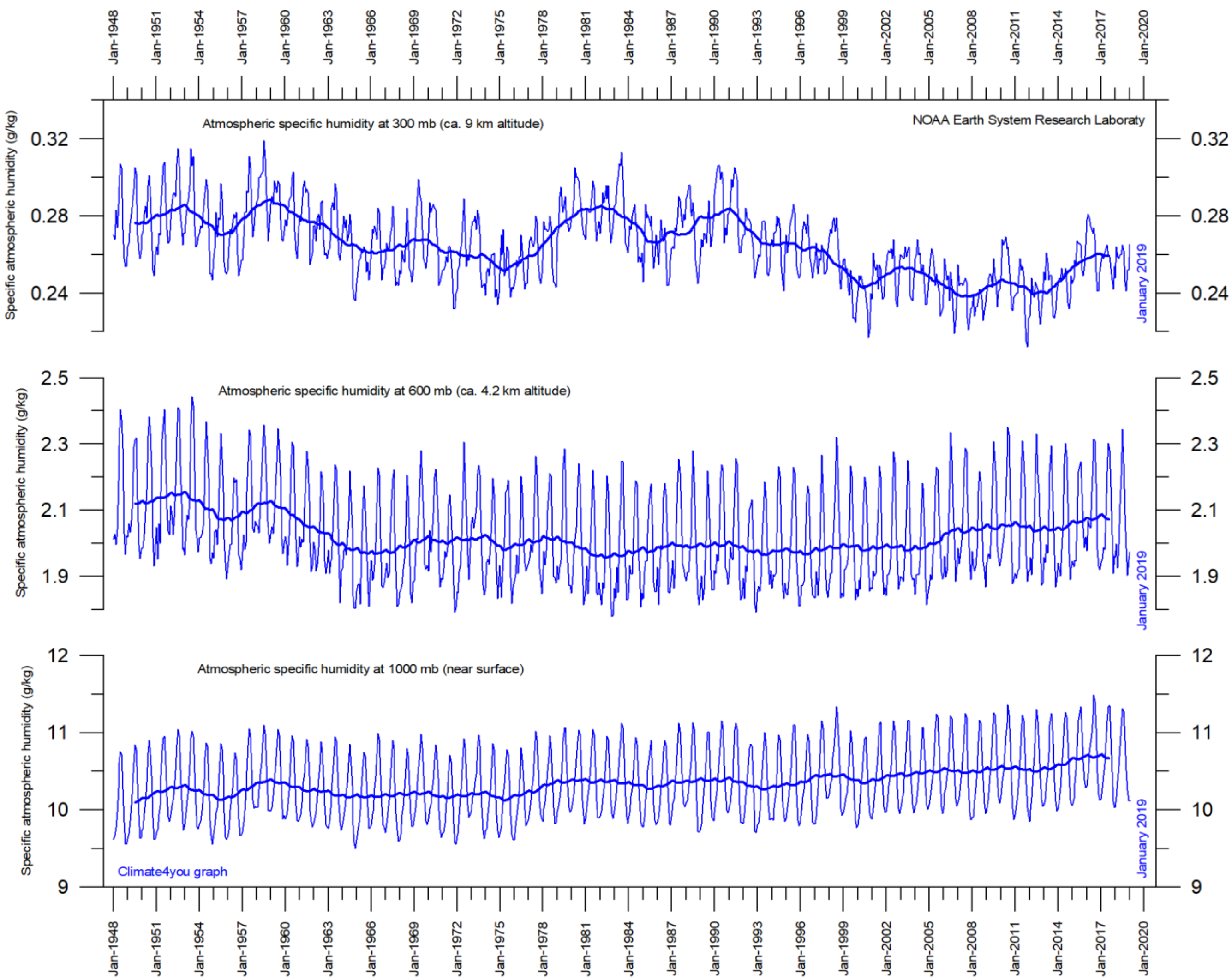


Northern hemisphere weekly snow cover since January 1972 according to Rutgers University Global Snow Laboratory. The thin blue line is the weekly data, and the thick blue line is the running 53-week average (approximately 1 year). The horizontal red line is the 1972-2018 average.



Northern hemisphere seasonal snow cover since January 1972 according to Rutgers University Global Snow Laboratory.

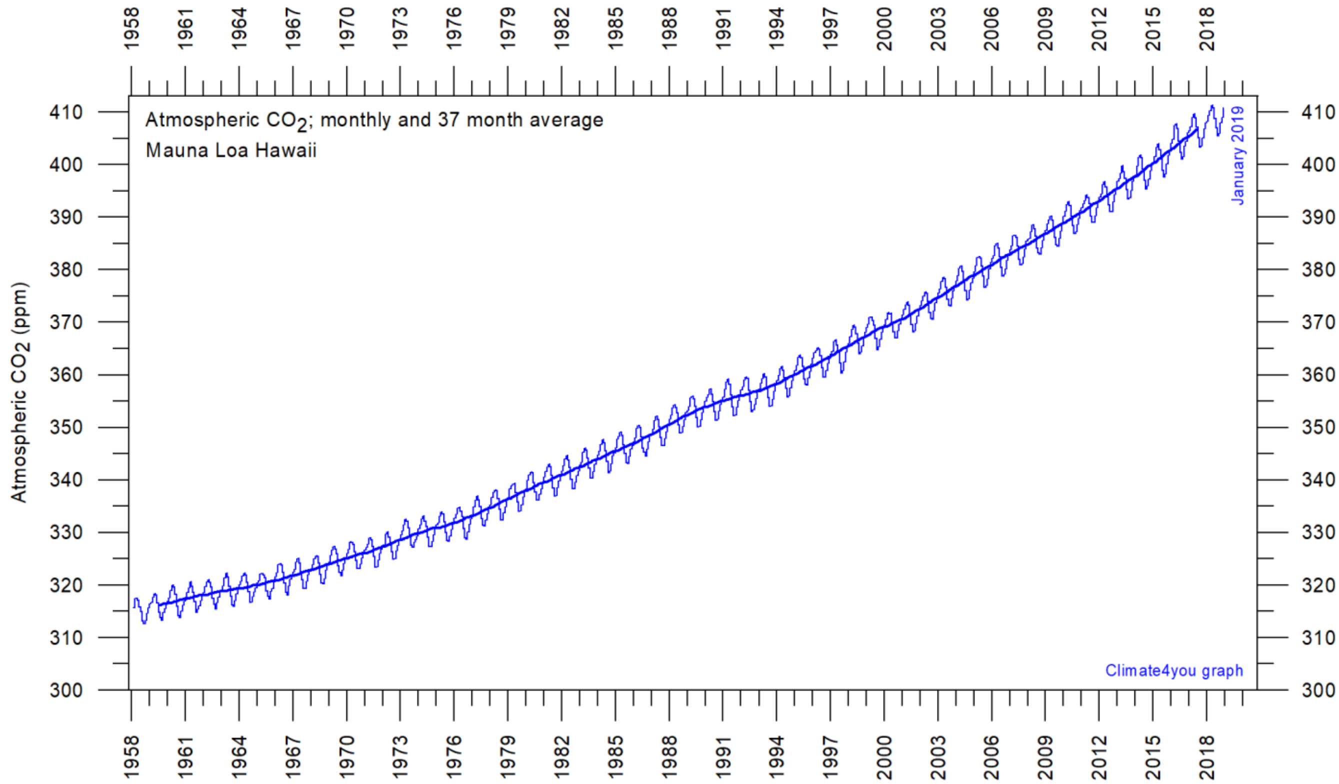
Atmospheric specific humidity, updated to January 2019

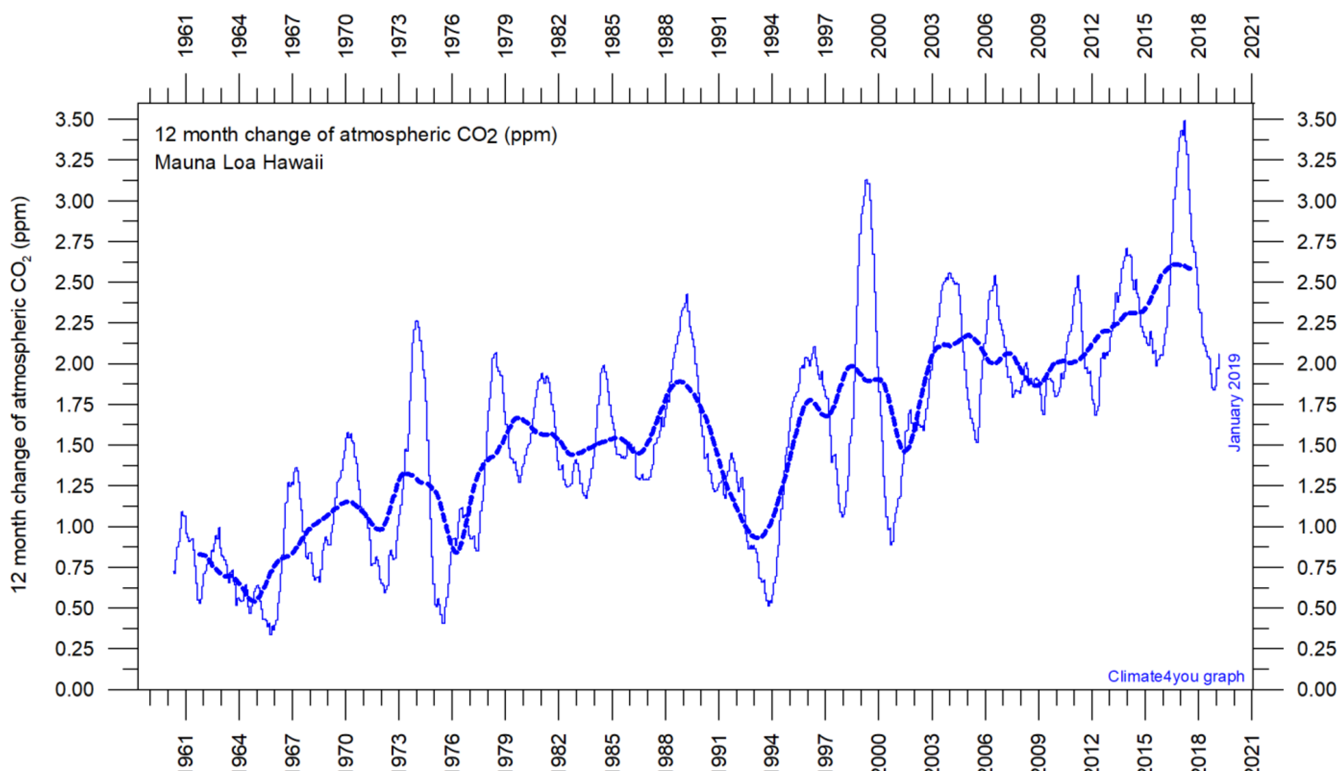


Specific atmospheric humidity (g/kg) at three different altitudes in the lower part of the atmosphere (the Troposphere) since January 1948 (Kalnay et al. 1996). The thin blue lines show monthly values, while the thick blue lines show the running 37-month average (about 3 years). Data source: Earth System Research Laboratory (NOAA).

Note: Water vapour is the most important greenhouse gas in Earth's atmosphere, much more important than CO_2.

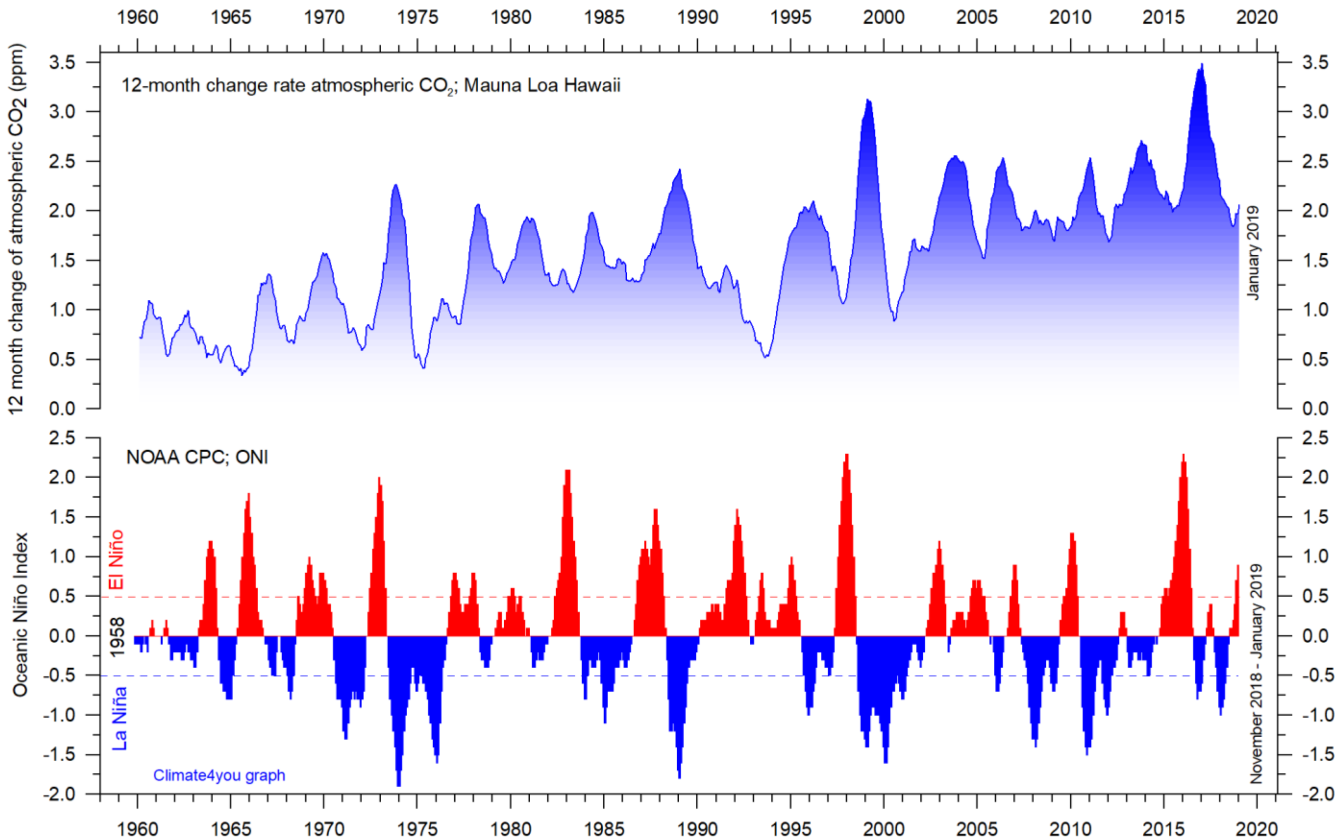
Atmospheric CO_2, updated to January 2019





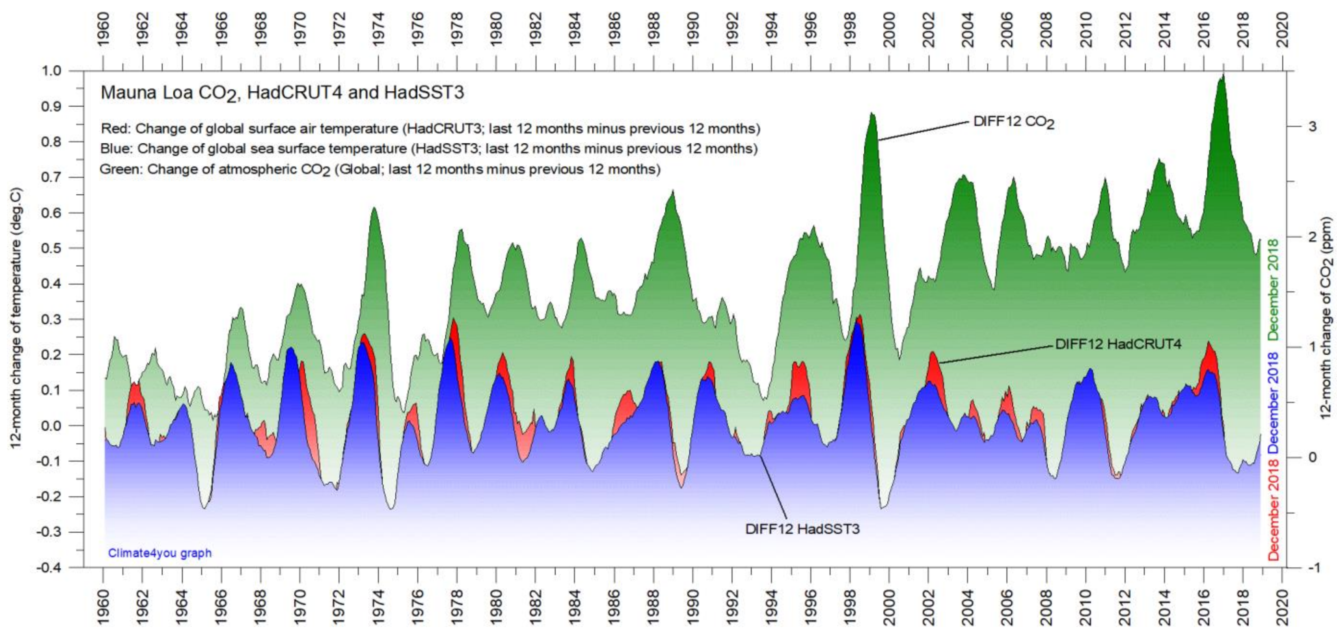
Monthly amount of atmospheric CO_2 (upper diagram) and annual growth rate (lower diagram); average last 12 months minus average preceding 12 months, thin line) of atmospheric CO_2 since 1959, according to data provided by the Mauna Loa Observatory, Hawaii, USA. The thick, stippled line is the simple running 37-observation average, nearly corresponding to a running 3-year average.

The relation between annual change of atmospheric CO_2 and La Niña and El Niño episodes, updated to January 2019



Visual association between annual growth rate of atmospheric CO_2 (upper panel) and Oceanic Niño Index (lower panel). See also diagrams on page 40 and 22, respectively.

The phase relation between atmospheric CO_2 and global temperature, updated to December 2018



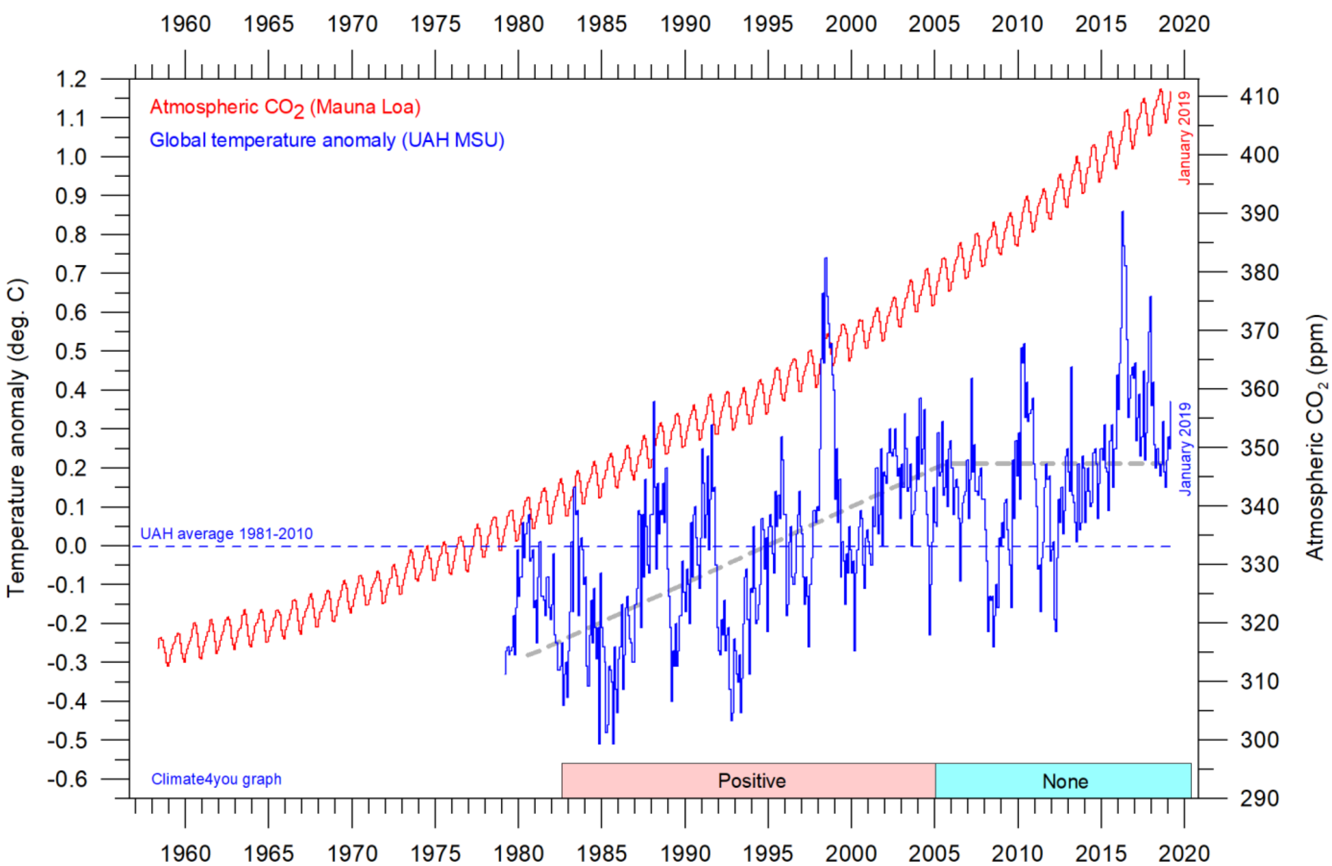
12-month change of global atmospheric CO_2 concentration (Mauna Loa; green), global sea surface temperature (HadSST3; blue) and global surface air temperature (HadCRUT4; red dotted). All graphs are showing monthly values of DIFF12, the difference between the average of the last 12 month and the average for the previous 12 months for each data series.

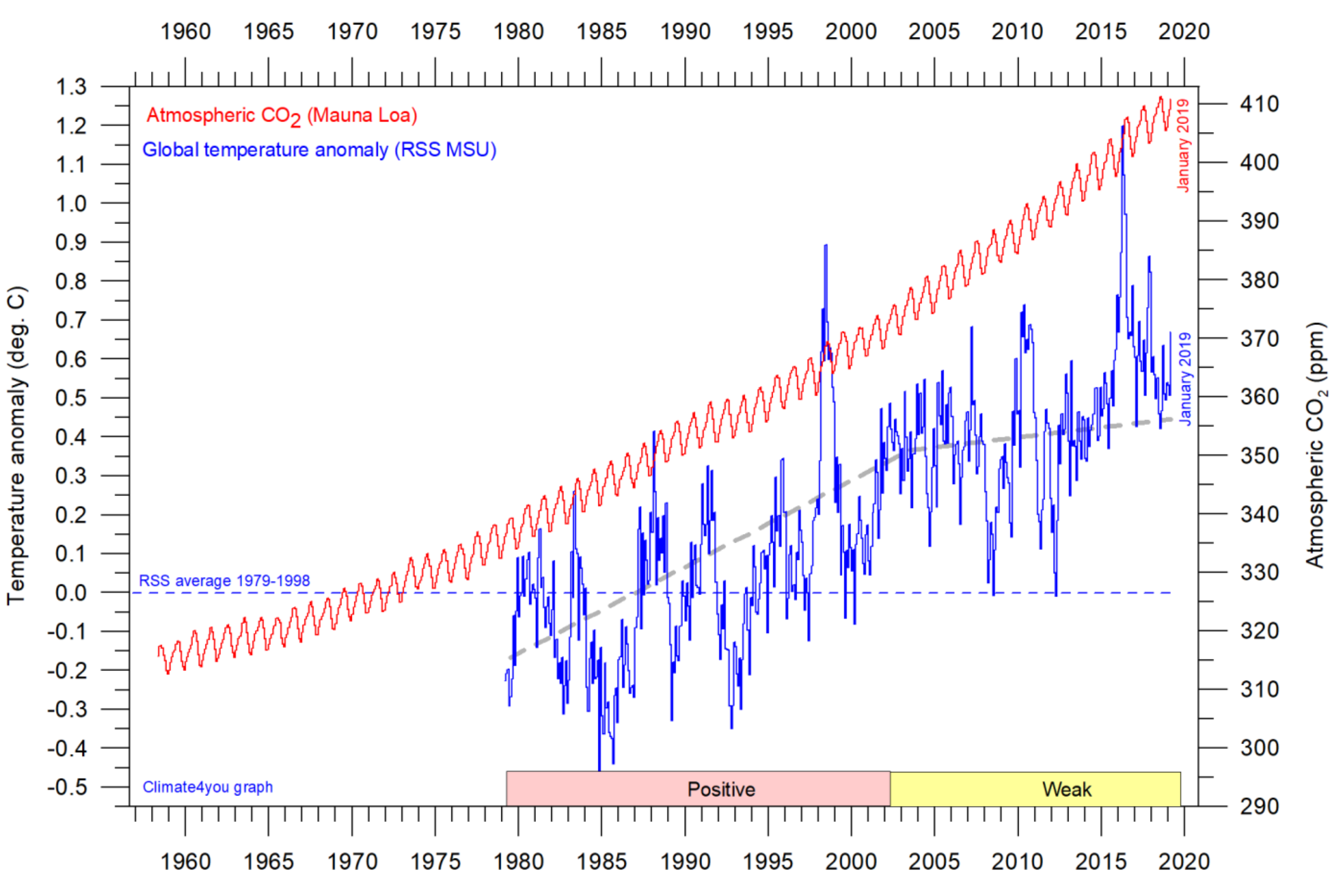
Note: The typical sequence of events is seen to be that changes in the global atmospheric CO_2 follows changes in global surface air temperature, which again follows changes in global ocean surface temperatures. Thus, changes in global atmospheric CO_2 are lagging 9.5–10 months behind changes in global air surface temperature, and no less than 11–12 months behind changes in global sea surface temperature.

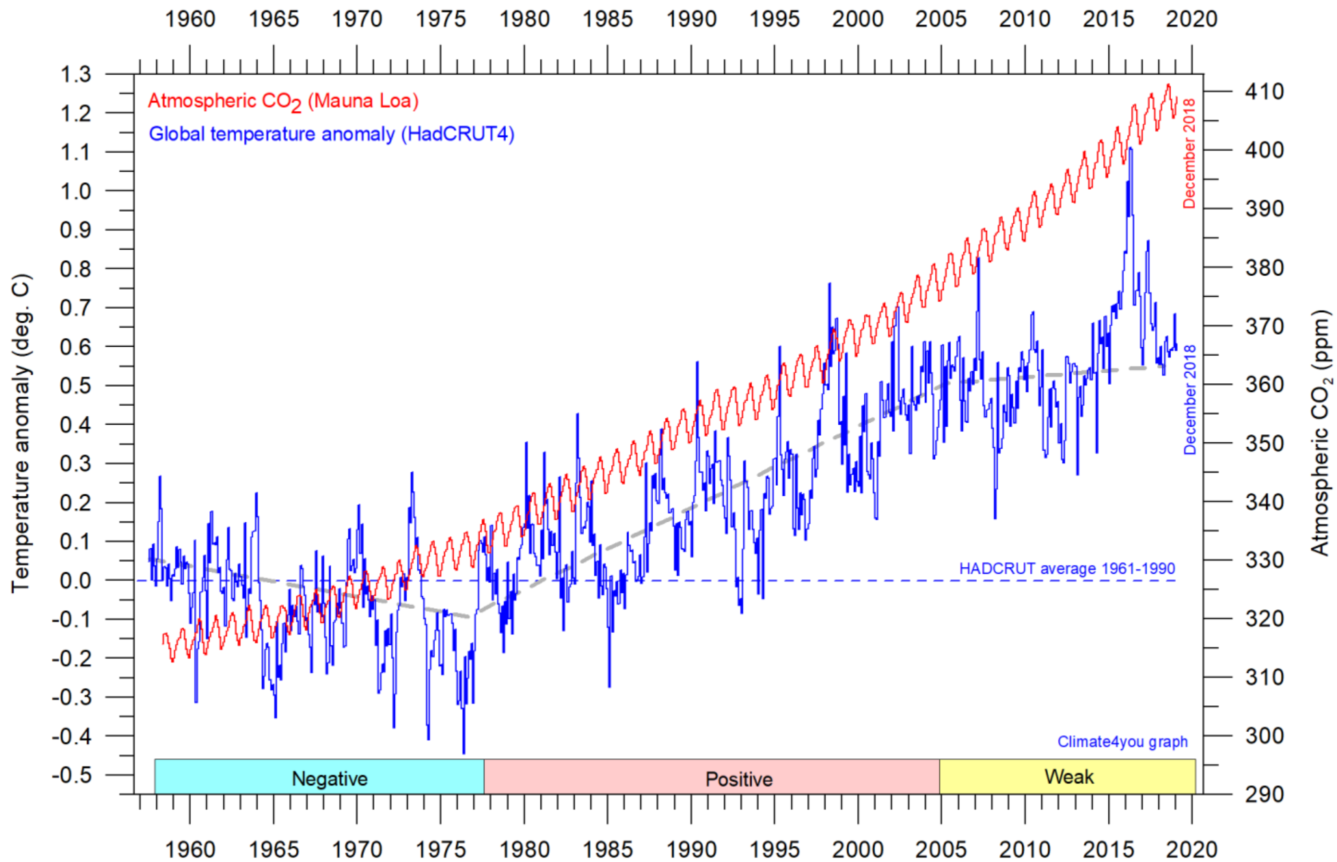
References:

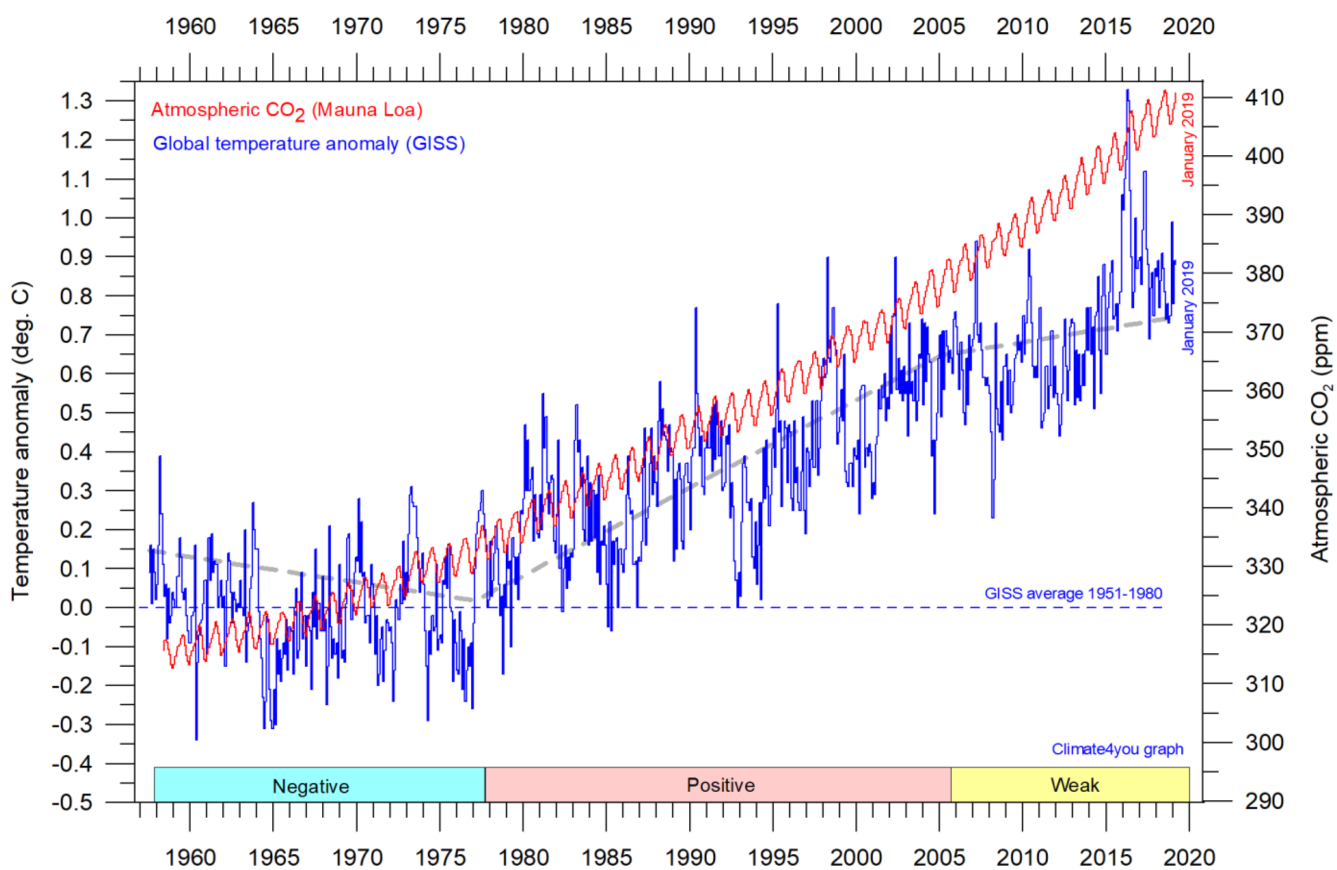
Humlum, O., Stordahl, K. and Solheim, J-E. 2012. The phase relation between atmospheric carbon dioxide and global temperature. Global and Planetary Change, August 30, 2012. http://www.sciencedirect.com/science/article/pii/S0921818112001658?v=s5

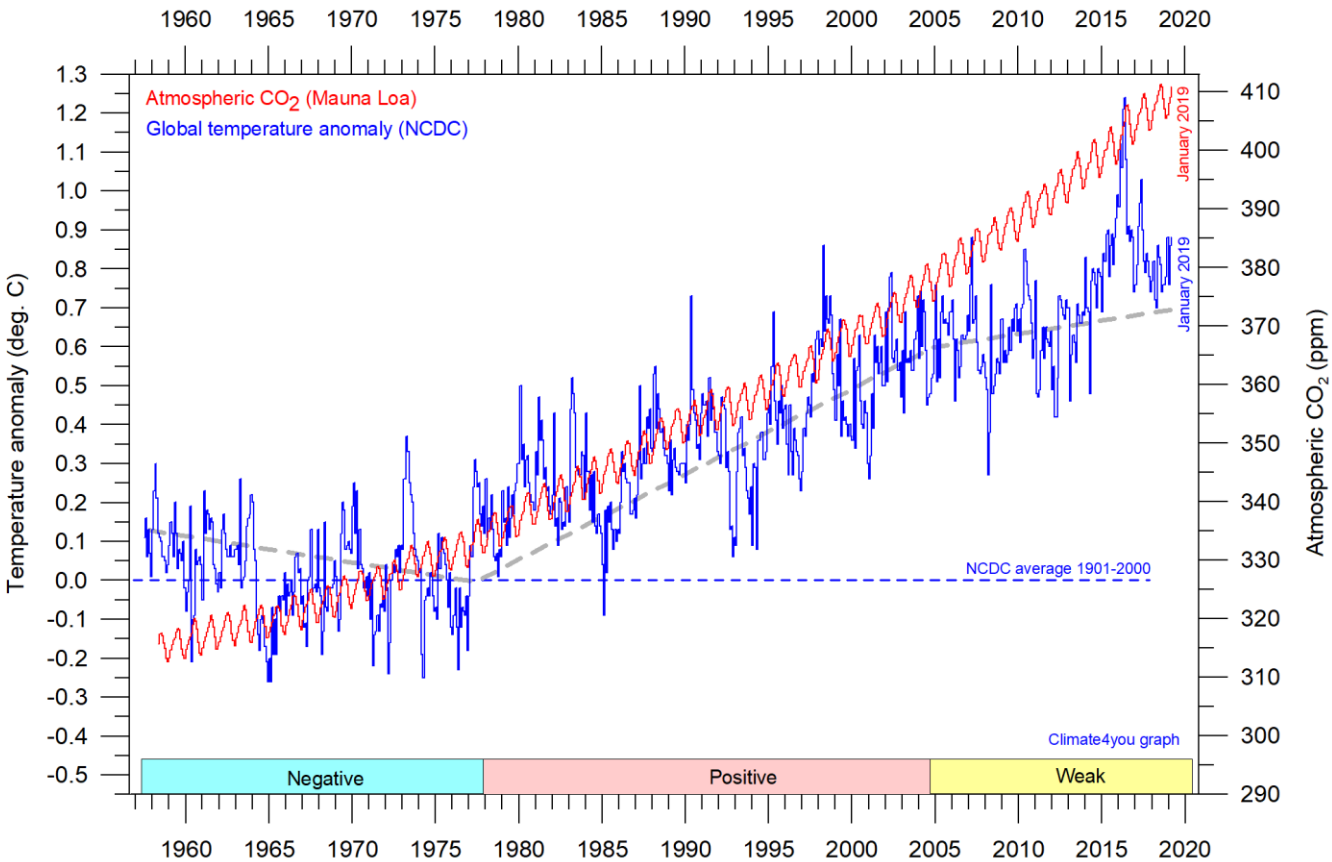
Global air temperature and atmospheric CO_2, updated to January 2019






Atmospheric CO_2 (Mauna Loa)
Global temperature anomaly (HadCRUT4)
Temperature anomaly (deg. C)
Atmospheric CO_2 (ppm)
December 2018
December 2018
HADCRUT average 1961-1990
Climate4you graph
Negative
Positive
Weak


Atmospheric CO_2 (Mauna Loa)
Global temperature anomaly (GISS)
Temperature anomaly (deg. C)
Atmospheric CO_2 (ppm)
January 2019
January 2019
GISS average 1951-1980
Climate4you graph
Negative
Positive
Weak



Diagrams showing UAH, RSS, HadCRUT4, GISS, and NCDC monthly global air temperature estimates (blue) and the monthly atmospheric CO_2 content (red) according to the Mauna Loa Observatory, Hawaii. The Mauna Loa data series begins in March 1958, and 1958 was therefore chosen as starting year for the all diagrams above. Reconstructions of past atmospheric CO_2 concentrations (before 1958) are not incorporated in this diagram, as such past CO_2 values are derived by other means (ice cores, stomata, or older measurements using different methodology), and therefore are not directly comparable with direct atmospheric measurements. The dotted grey line indicates the approximate linear temperature trend, and the boxes in the lower part of the diagram indicate the relation between atmospheric CO_2 and global surface air temperature, negative or positive.

Most climate models are programmed to give the greenhouse gas carbon dioxide CO_2 important influence on global temperature. It is therefore relevant to compare different temperature records with measurements of atmospheric CO_2, as shown in the diagrams above.

Any comparison, however, should not be made on a monthly or annual basis, but for a longer time, as other effects (oceanographic, cloud cover, etc.) may well override the potential influence of CO_2 on short time scales such as just a few years.

It is of cause equally inappropriate to present new meteorological record values, whether daily, monthly or annual, as support for the hypothesis ascribing high importance of atmospheric CO_2 for global temperatures. Any such meteorological record value may well be the result of other phenomena. Unfortunately, many news media repeatedly fall into this trap.

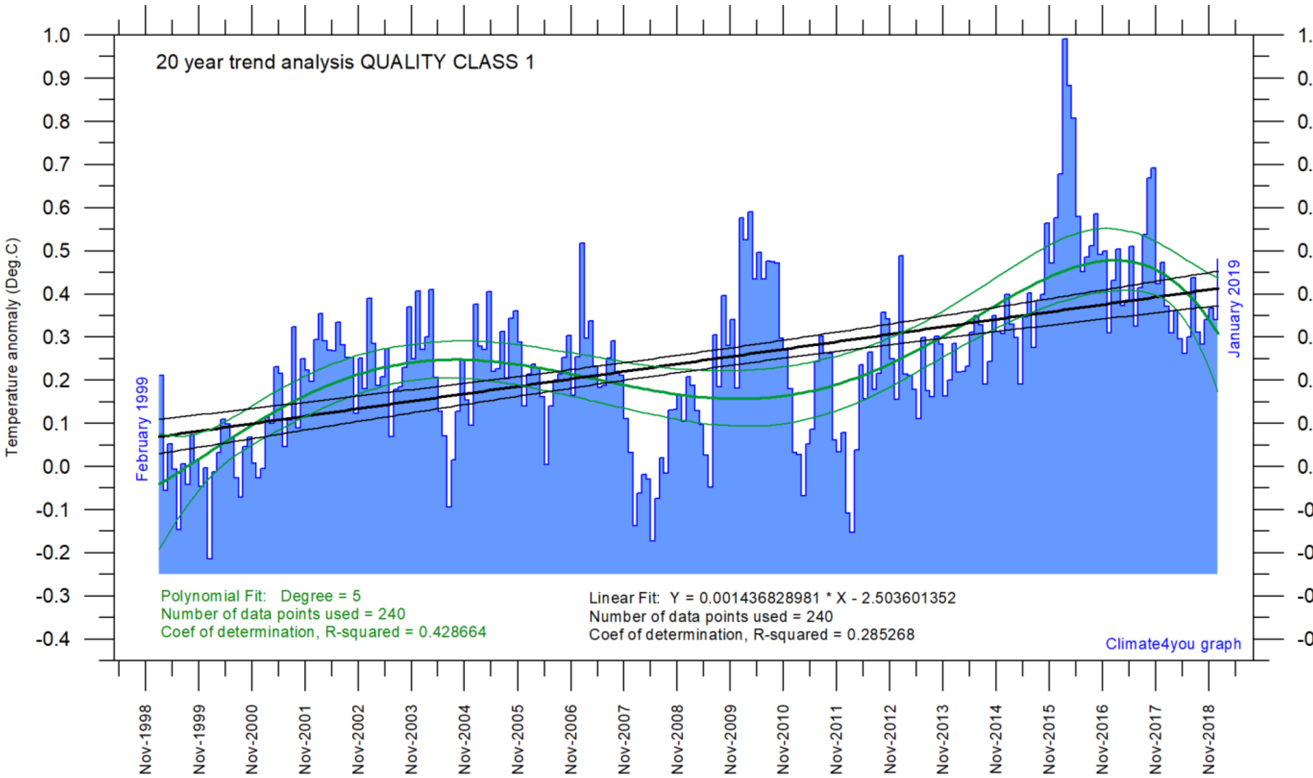
What exactly defines the critical length of a relevant period length to consider for evaluating the alleged importance of CO_2 remains elusive and represents a theme for discussion. However, the length of the critical period must be inversely proportional to the temperature sensitivity of CO_2, including feedback effects. Thus, if the net temperature effect of atmospheric CO_2 is strong, the critical period will be short, and vice versa.

However, past climate research history provides some clues as to what has traditionally been considered the relevant length of period over which to compare temperature and atmospheric CO_2. After about 10 years of concurrent global temperature- and CO_2-increase, IPCC was established in 1988. For obtaining public and political support for the CO_2-hyphotesis the 10-year warming period leading up to 1988 most likely was considered important. Had the global temperature instead been decreasing, politic support for the hypothesis would have been difficult to obtain in 1988.

Based on the previous 10 years of concurrent temperature- and CO_2-increase, many climate scientists in 1988 presumably felt that their understanding of climate dynamics was enough to conclude about the importance of CO_2 for global temperature changes. From this it may safely be concluded that 10 years was considered a period long enough to demonstrate the effect of increasing atmospheric CO_2 on global temperatures. The 10-year period is also basis for the anomality diagrams shown on page 2.

Adopting this approach as to critical time length (at least 10 years), the varying relation (positive or negative) between global temperature and atmospheric CO_2 has been indicated in the lower panels of the diagrams above.

Latest 20-year QC1 global monthly air temperature changes, updated to January 2019



Last 20 years' global monthly average air temperature according to Quality Class 1 (UAH and RSS; see p.10) global monthly temperature estimates. The thin blue line represents the monthly values. The thick black line is the linear fit, with 95% confidence intervals indicated by the two thin black lines. The thick green line represents a 5-degree polynomial fit, with 95% confidence intervals indicated by the two thin green lines. A few key statistics are given in the lower part of the diagram (please note that the linear trend is the monthly trend).

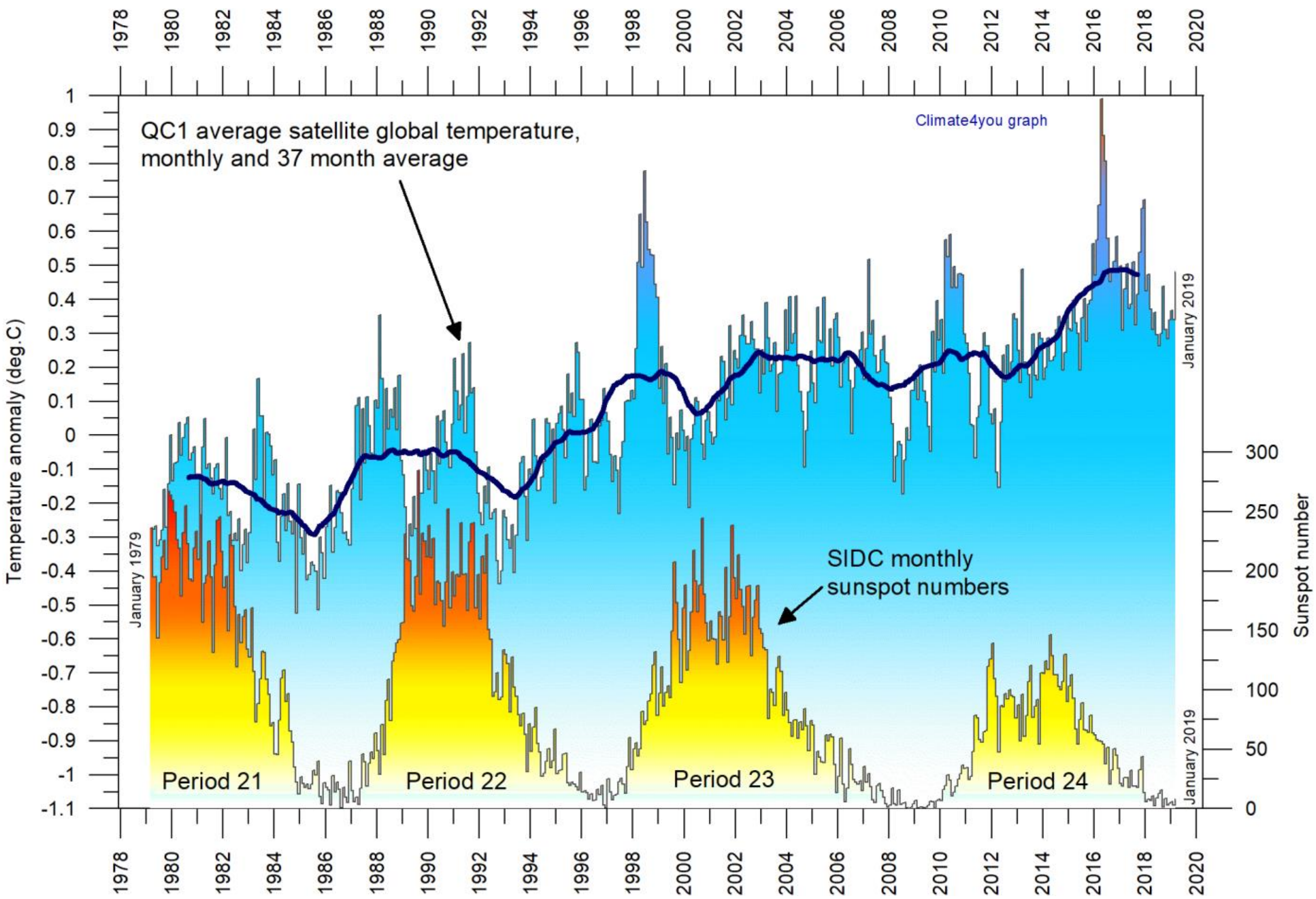
In the still ongoing climate debate the following about the global surface air temperature is often put forward: Is the surface air temperature still increasing or has it basically remained without significant changes during the last about 15 years?

The diagram above may be useful in this context and demonstrates the differences between two often used statistical approaches to determine recent temperature trends. Please also note that such fits only attempt to describe the past, and usually have small, if any, predictive power. In addition, before using any linear trend (or other) analysis of time series a proper statistical model should be chosen, based on statistical justification.

For temperature time series, there is no *a priori* physical reason why the long-term trend should be linear in time. In fact, climatic time series often have trends for which a straight line is not a good approximation, as can clearly be seen from several of the diagrams in the present report.

For an excellent description of problems often encountered by analyses of temperature time series analyses, please see Keenan, D.J. 2014: Statistical Analyses of Surface Temperatures in the IPCC Fifth Assessment Report.

Sunspot activity and QC1 average satellite global air temperature, updated to January 2019



Variation of global monthly air temperature according to Quality Class 1 (UAH and RSS; see p.4) and observed sunspot number as provided by the Solar Influences Data Analysis Center (SIDC), since 1979. The thin lines represent the monthly values, while the thick line is the simple running 37-month average, nearly corresponding to a running 3-year average. The asymmetrical temperature 'bump' around 1998 is influenced by the oceanographic El Niño phenomenon in 1998, as is the case also for 2015-16.

1838: Charles Darwin visits the Parallel Roads of Glen Roy

View of the Parallel Roads of Glen Roy, western Scotland (drawing published in Darwin 1839a; left). Compare with Glen Roy scenery June 2006. The young Charles Darwin shortly after returning from the Beagle expedition, about the time when he visited Glen Roy (right).

The parallel roads of the valley Glen Roy in the western highlands of Scotland have fascinated local people and travellers for many hundreds of years. It was once thought they were constructed by *Fingal the Giant* as hunting roads, or that they were the work of fairies.

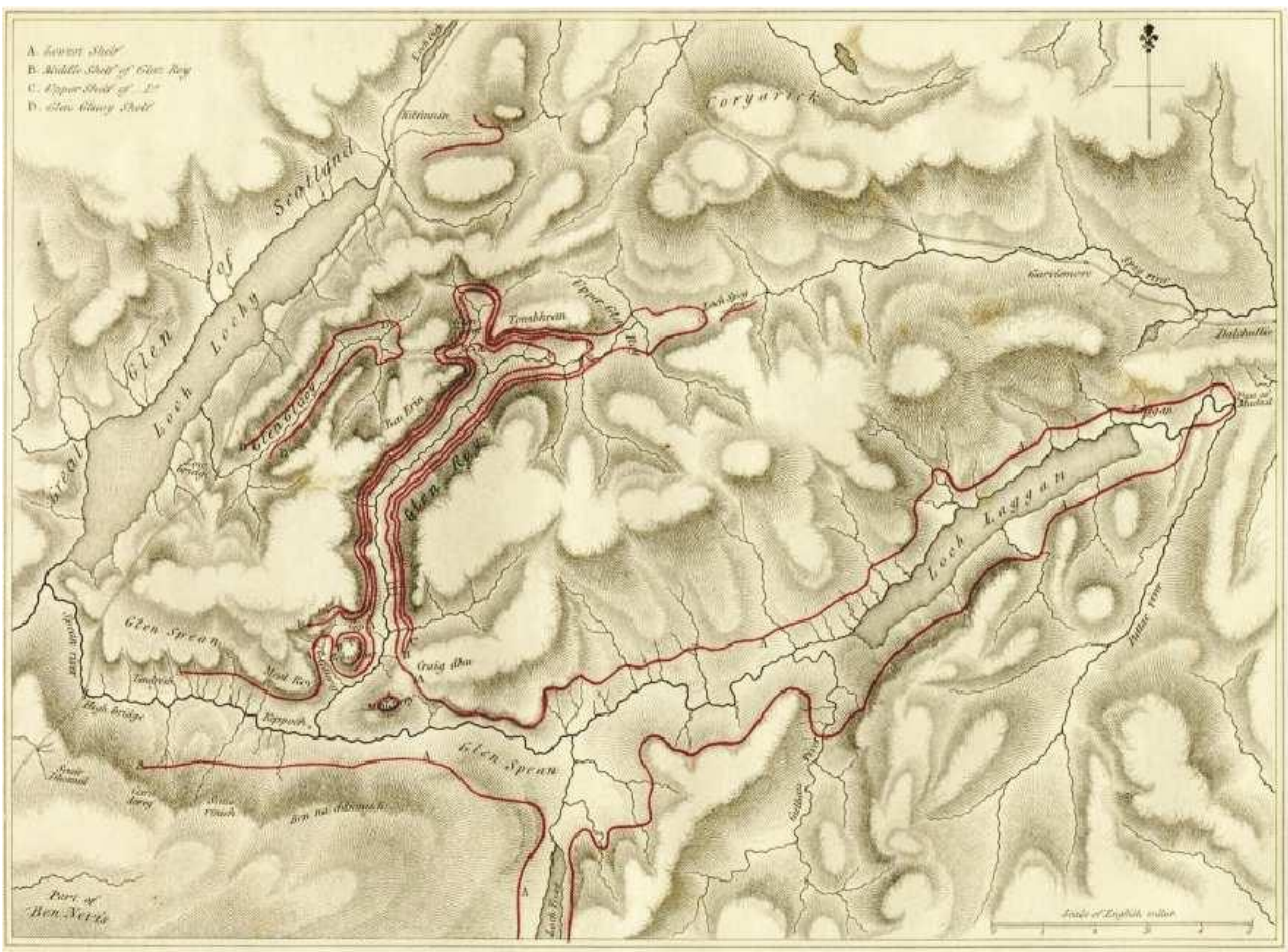
In the 19th century, the Parallel Roads attracted the attention of many early geologists, including the Reverend William Buckland, James Geikie, Charles Lyell and Joseph Prestwich. This ensured that the Parallel Roads featured prominently in the rapid development of geological science and understanding of landforms.

Charles Darwin back from his famous Beagle expedition (Darwin 1839b) had great geological interest and therefore visited Glen Roy in June 1838. Next year he published his findings in the Philosophical Transactions of the Royal Society (Darwin 1839a), a publication which later was known as Darwin's "Gigantic Blunder" and which was bitterly regretted by himself.

Drawing on his recent findings in South America during the Beagle expedition Darwin argued in detail that the Parallel Roads of Glen Roy were old shorelines of marine origin. This was later contradicted by Louis Agassiz's Glacial theory of 1840 which instead suggested that the Parallel Roads were shorelines which had been cut by freeze-thaw processes along the shore of a glacier-dammed lake ice during the last ice age.

Darwin's 'Gigantic Blunder' is interesting to consider, because it illustrates how even the most sophisticated scientific analysis may lead to a completely wrong result, if the contemporary understanding of all relevant processes is not yet fully developed. As such, Darwin's blunder represents a general warning to all engaged in science. Darwin later recognized his error, made while he still was a relatively young scientist, and his 'blunder' therefore in no way today discredits his otherwise exceptional fine scientific standing.

Glen Roy had the attention of geologists of that time. Two geologists, Sir Thomas Lauder Dick and Dr. MacCullock, had shortly before in separate talks before the *Edinburgh Royal Society* and the *Geological Society of London* suggested that the so-called Parallel Roads of Glen Roy were old shorelines, created by a lake dammed by some unknown object at the lower end of the valley. This was simply what their observations and plain common sense told them, but given accepted geological knowledge at that time, they were unable to explain the physical character of the alleged damming object.



Map showing with red lines the inferred ocean shorelines proposed by Charles Darwin (Darwin 1839a). Glen Roy is the valley in the left centre part of the map. The map covers an area about 35 km from east to west.

The young Charles Darwin, fresh from his voyage to South America, had been deeply impressed by the uplift of the Chilean coastline by recent earthquakes (McKirdy et al. 2007). On this background it is interesting to read and follow Darwin's line of argumentation on the origin of the Parallel Roads of Glen Roy. His line of argumentation demonstrates substantial self-confidence and attempts of ridiculing scientists holding another opinion than himself. Here are a few examples:

Page 47: *…. it is here, where the slope of the turf-covered hills is unbroken, where there is not a remnant of any projecting mass, that we are compelled by the theory (Dick and MacCullock) to believe that the two enormous barriers stood, which formed Glen Roy into the imaginary Loch Roy.*

Page 48: *…. In conclusion, therefore, I do not hesitate to affirm, that more convincing proofs of the non-existence of the imaginary Loch Roy could scarcely have been invented, with full play given to the imagination, than those which are marked in legible characters on the face of these hills.*

Page 49: *…. It may be safely asserted that more improbable situations could hardly be imagined in the whole of Scotland . It is perhaps useless to ask, were the barriers composed of rock or alluvium? if of the former, they were transverse to every line of hill in this part of the country; if of alluvium, we must assume an unexampled case; for where in the whole world shall we find even one barrier a mile and upward in length, and 1200 feet high, composed of loose waterworn materials? Secondly, the theory of one large lake does not explain in a satisfactory manner the remarkable coincidence between the shelves and the watersheds. Thirdly, when by the bursting of any one of the barriers, the level of the lake had fallen from one shelf to another, the hypothesis requires (as with Loch Roy) that the three other barriers, now high and dry, and distant many leagues from each other, should have been swept away by some unknown power, acting by some unknown and scarcely conceivable means, from the smooth sides of the mountains, without a remnant of them having been left; so that MACCULLOCH even frankly confesses one part is almost as probable (I would say improbable) as another for the position of the barriers. And it should be borne in mind, that these extraordinary forces are supposed to have acted on the outskirts of that large area, throughout which we have proofs, most wonderful and unequivocal, of the entire preservation of the surface of the land, as it was left at a period long anterior to the removal (if such removal ever did take place) of the barriers of the lower lakes. I do not hesitate to assert that this one difficulty, even by itself, would be sufficient to refute the theory of one great lake: Sir LAUDER'S theory has been shown to be equally untenable….. Finally, then, in giving up both, the conclusion is inevitable, that no hypothesis founded on the supposed existence of a sheet of water confined by barriers, that is, a lake, can be admitted as solving the problematical origin of the "parallel roads of Lochaber."*

Page 55: *…. It is a startling assumption to close up the mouth of even one valley by an enormous imaginary barrier; to do this with all would be monstrous. Of such barriers in the district we are considering I need not say there does not exist any trace, nor need I repeat what I have already said against so vain a supposition as that they could have been swept away by any great debacle from the sides of those hills, of which the whole alluvial covering has been preserved since the period when the upper shelves formed beaches, without even a remnant of them being left.*

Editor's note: The hypothesis on the former existence of an unknown damming body at the lower end of the valley Glen Roy clearly did not appeal to Charles Darwin, which several times is seen falling into the self-made trap of ridiculing his opponents' point of view. Instead, he argued that the Parallel Roads were formed as marine shorelines at a time when the ocean partly covered Scotland, and that subsequent tectonic uplift explained why these marine shorelines today were found high above the modern sea level. Based on the contemporary geological accepted knowledge this was a quite understandable conclusion to reach. But is gave no reason whatsoever to ridicule alternative points of view, just because they appeared unreasonable, given his understanding of what might be physical possible.

<u>Page 58:</u> *…. From these facts it is certain that there has been a change of level affecting within recent times the whole central part of Scotland, and of a kind very similar to that which has been the subject of so much attention in Sweden, where, according to Mr. Lyell, remains of existing marine animals have been raised to the height of between 500 and 600 feet above the sea. The change of level in the case of Sweden is as certainly known to be due to a slow movement of the land, and not of the water, as it is on the coast of Chile, where a small tract is violently upraised during an earthquake, the distant parts of the same coast being unmoved. It would, however, be quite superfluous here to enter into this question at length, as it has almost ceased to be debateable ground. It may then be concluded that the supposed great change of level in Scotland, deduced from the foregoing arguments, as well as that smaller fraction of it attested by marine remains and ancient sea-beaches, is due to the rising of the land, and not to the sinking of the waters….*

<u>Page 79-80:</u> *….Considering these latter facts, together with the inferences deduced from the phenomena observed in South America , it may be granted as not improbable in any high degree, that this part of Scotland when it was upraised rested on matter possessed of considerable fluidity, which underwent a slow change of form.*

Glen Roy with its Parallel Roads on June 2, 2008, looking north. The horizontal terraces indicate variations in the surface level of a former ice-dammed lake filling the valley and are arguably the most famous landforms in Great Britain. Three systems of terraces are found, at 350 m, 325 and 260 m above sea level. These different terraces were caused by thickness variations in the glacier blocking the lower part of the valley, controlling the damming ability of the glacier. Glen Roy after 1840 became a key locality for the acceptance of the glacial hypothesis in the 19th century. Compare with drawing above (p.50), published in Darwin 1839a.

A few years later, new geological knowledge on the action of glaciers was introduced when Louis Agassiz visited Scotland. Of cause Agassiz had to visit the already at that time famous Glen Roy valley, and drawing upon his knowledge on glaciers from the Alps, he immediately suggested that the 'unknown damming body' suggested by Dick and MacCullock and ridiculed by Darwin simply had been a glacier, which later had melted away. New knowledge was put forward, and previously ridiculed observational-based conclusions suddenly appeared very reasonable.

As mentioned above, Darwin later admitted his error. In 1838, he had been deeply impressed by the uplift of the Chilean coastline by recent earthquakes, and presumably was inclined to see this as a likely explanation of similar landforms found elsewhere in the world. This was a very understandable human error, and in addition, geology at that time still was a relatively young science. The effects of large natural climatic variations on landscapes were far from fully understood at that time, neither was the extent of natural climatic changes.

Actually, Darwin's so-called 'Gigantic Blunder' was not the fact that he made a flawed interpretation of his observations and arrived at a wrong geological explanation, being carried away as he was by a new and important idea about tectonic uplift. This happens all the time when new interpretations are put forward, and should simply be considered an integral part of scientific progress. His really 'Gigantic Blunder' was the sad fact that he in the process allowed himself to ridicule other fellow scientists, just because he believed (wrongly) himself to be driven by a superior hypothesis and have enough physical understanding of all relevant processes in nature.

Today the Parallel Roads of Glen Roy is seen as a textbook example of shorelines created along an ice-dammed lake filling the valley, when it about 12.000 years ago became blocked at the lower end by an advancing glacier. This glacier advance was caused by a sudden period of climatic cooling at the end of the last ice age. This climatic reversal is today known as the Younger Dryas or the Greenland Stadial 1. In Scotland it is locally better known as the Loch Lomond Readvance.

REFERENCES:

Darwin, C.R. 1839a. Observations on the parallel roads of Glen Roy, and of other parts of Lochaber in Scotland, with an attempt to prove that they are of marine origin. *Philosophical Transactions of the Royal Society* 129, 39-81. Read before the Society 7 February 1839. http://darwin-online.org.uk/content/frameset?itemID=F1653&viewtype=text&pageseq=1

Darwin, C.R. 1839b. *Narrative of the surveying voyages of His Majesty's Ships Adventure and Beagle between the years 1826 and 1836, describing their examination of the southern shores of South America, and the Beagle's circumnavigation of the globe.* Volume III. Journal and remarks, 1832-1836, 629 pp, London, Colburn.

McKirdy, A., Gordon, J. and Crofts, R. 2007. *Land of mountain and flood. The geology and landforms of Scotland*. Birlinn Limited, Edinburgh, Scotland, 324 pp.

*****

All diagrams in this report, along with any supplementary information, including links to data sources and previous issues of this newsletter, are freely available for download on www.climate4you.com

Yours sincerely,

Ole Humlum (Ole.Humlum@gmail.com)

Arctic Historical Evaluation and Research Organisation, Longyearbyen, Svalbard

February 22, 2019.