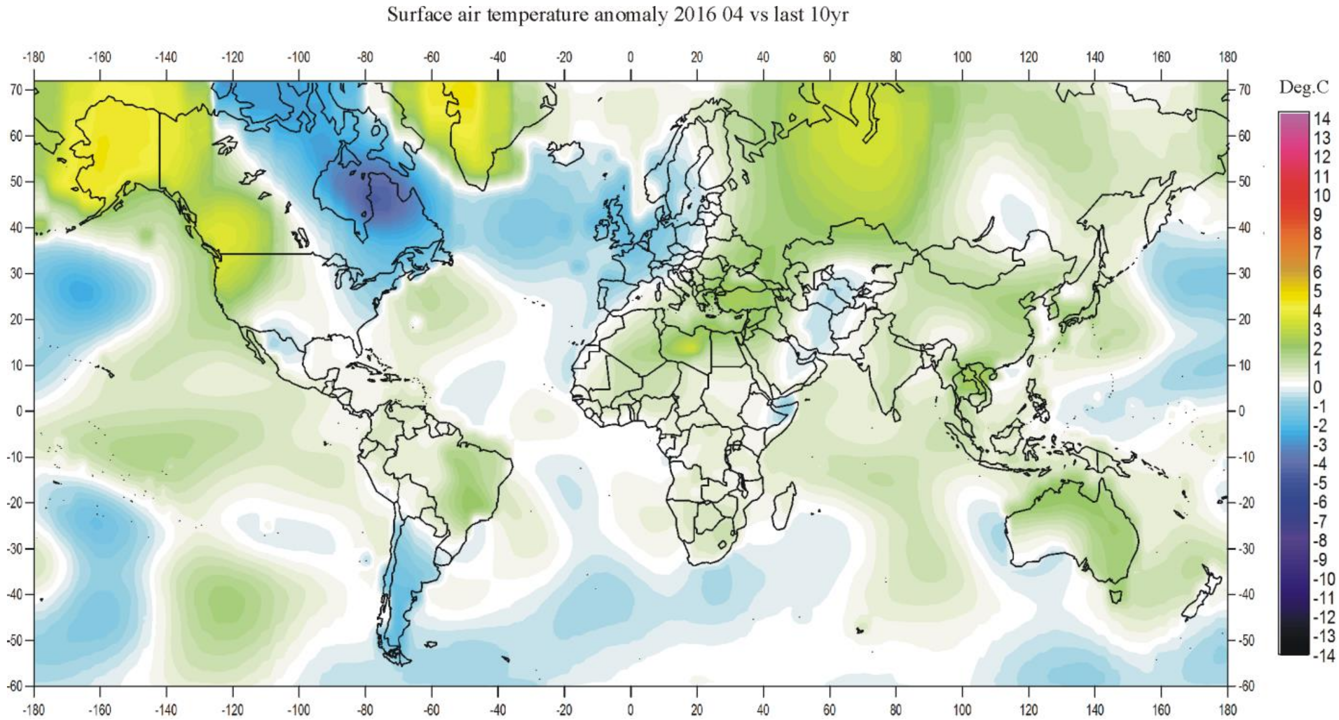
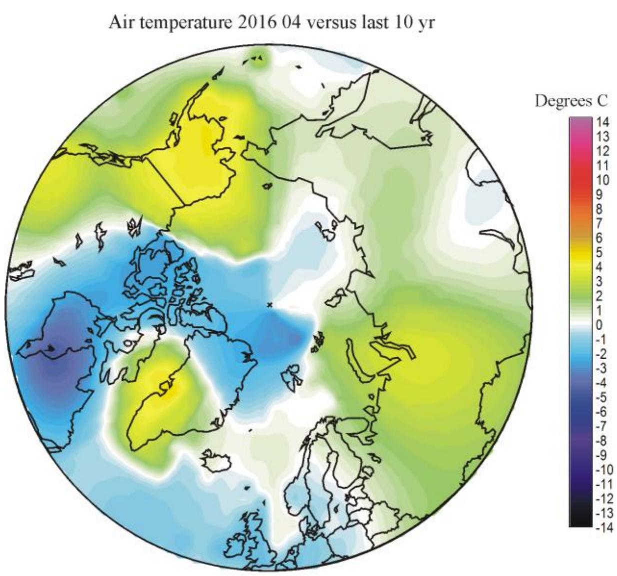
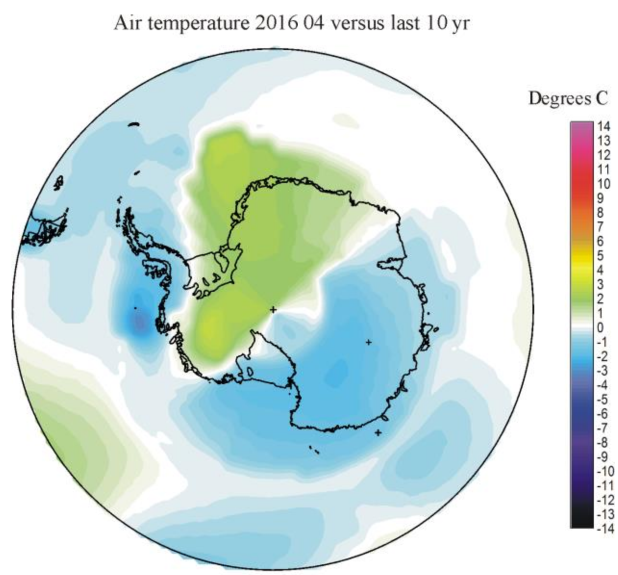
Climate4you update April 2016

Contents:

April 2016 global surface air temperature overview







April 2016 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 ERSST_v4 ocean surface temperatures.

Comments to the April 2016 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 reason for comparing with this recent period instead of the official WMO 'normal' period 1961-1990, is that the latter period is profoundly 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 dynamics of ongoing modern change.

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 changes of the so-called 'normal' period, and is not suited as reference. Comparing with the last previous 10 years is more useful.

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 month before to 18 months after, with equal weight for every month.

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.

April 2016 global surface air temperatures

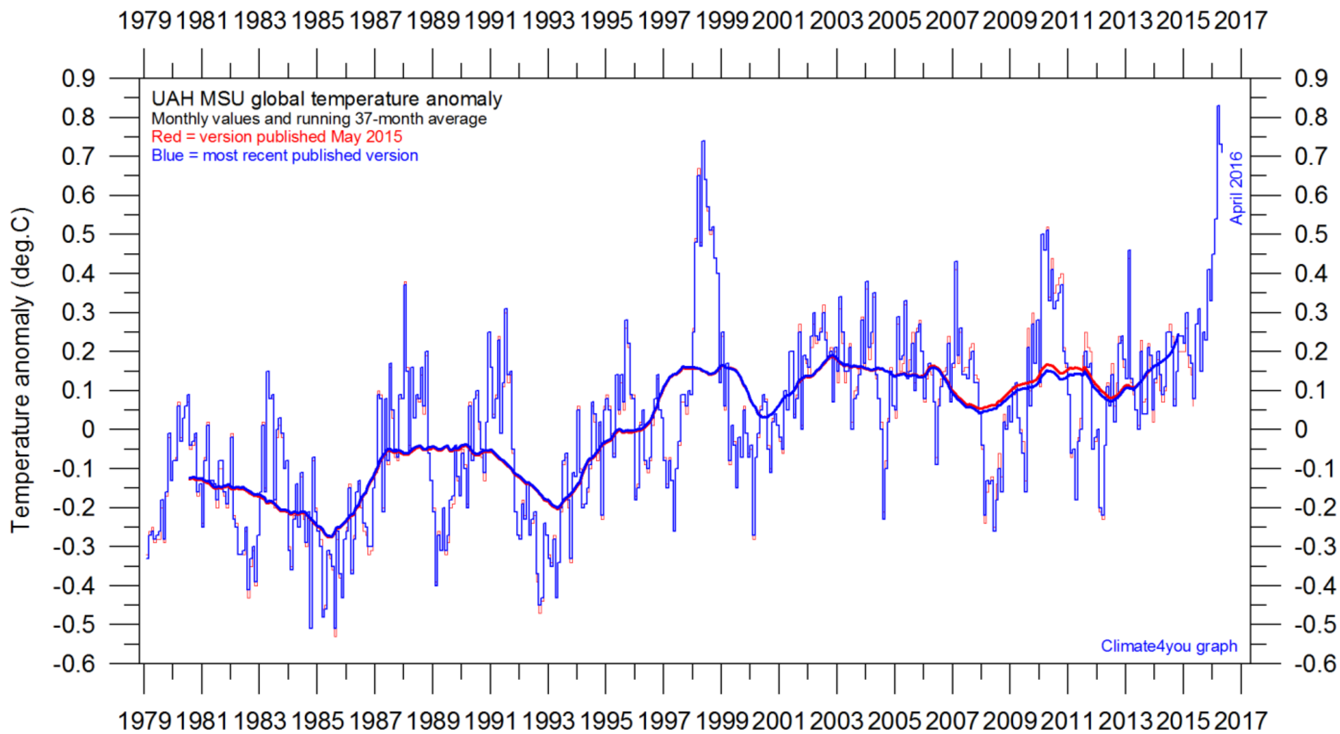
General: The average global air temperature was above the average for the last ten years. One reason for this is the present El Niño episode in the Pacific Ocean (see p.12), affecting the global air temperature because of the large surface areas represented by this Near-Equator phenomenon. Another reason is marked warm regions in parts of Alaska and Russia.

The Northern Hemisphere was generally relatively warm, but especially in Asia and Alaska. In contrast, parts of NE Canada, the North Atlantic, Europe, and parts of northern Pacific were relatively cold.

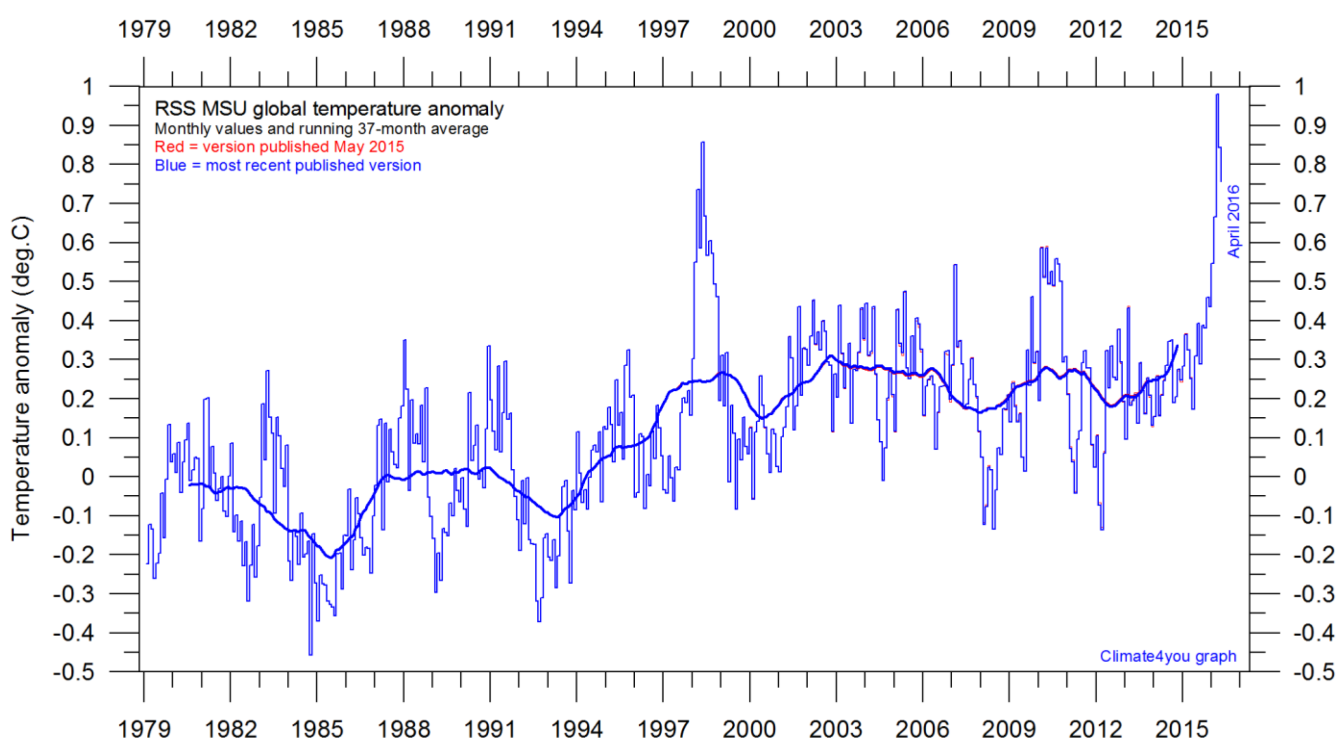
Near the Equator temperatures were above average in most of the central and eastern Pacific Ocean, reflecting the ongoing El Niño episode. Also significant parts of Africa and the Indian Ocean were relatively warm, compared to the average for the last 10 years. Only parts of western Pacific were relatively cold.

The Southern Hemisphere temperatures were generally near the previous 10-year average. However, temperatures were above the average in Australia. The Antarctic continent was divided into two regions, with above and below average temperature, respectively.

Temperature quality class 1: Lower troposphere temperature from satellites, updated to April 2016

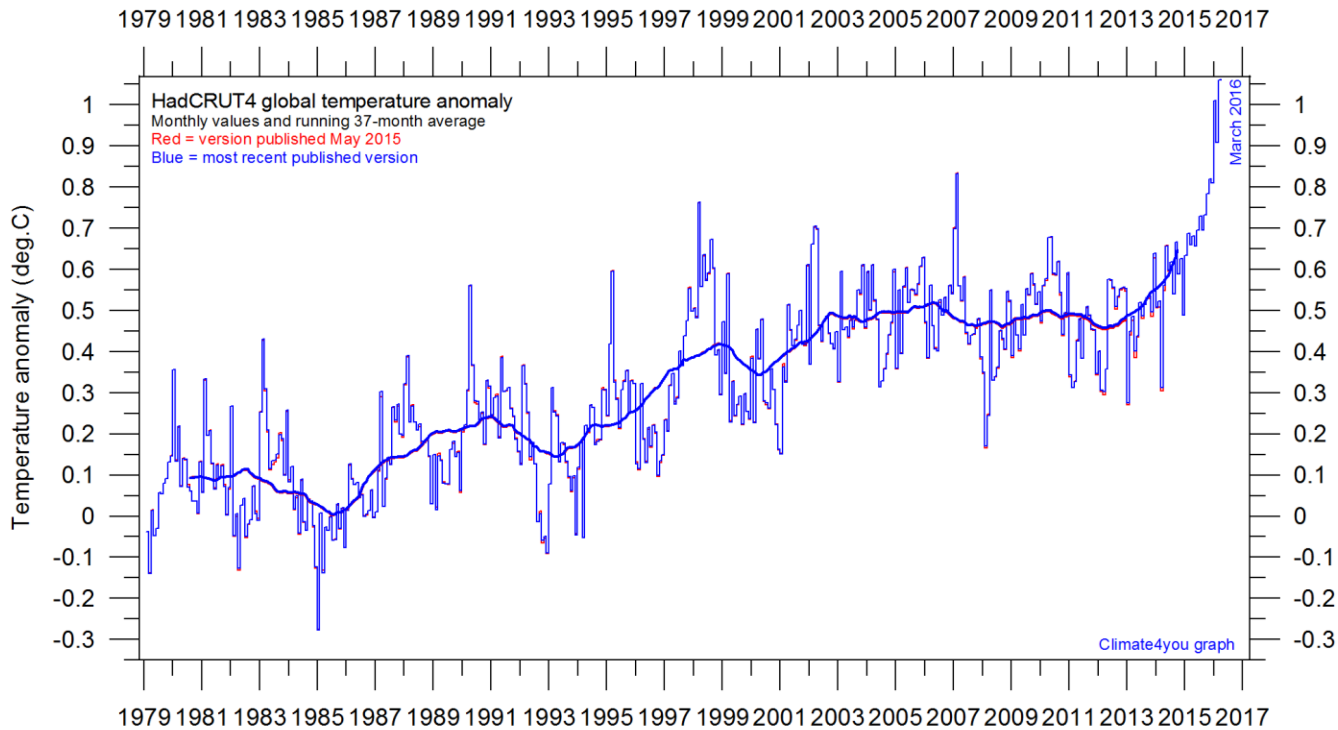


Global monthly average lower troposphere temperature (thin line) since 1979 according to University of Alabama at Huntsville, USA. The thick line is the simple running 37-month average.



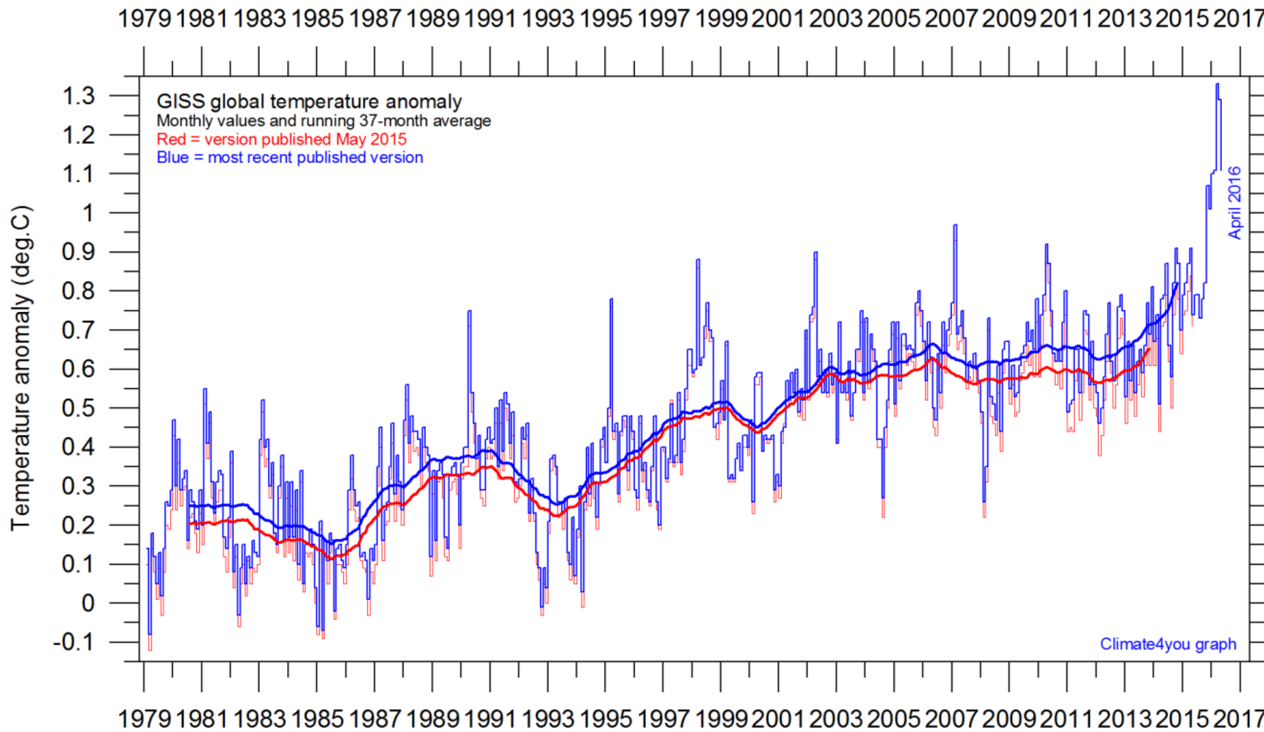
Global monthly average lower troposphere temperature (thin line) since 1979 according to according to Remote Sensing Systems (RSS), USA. The thick line is the simple running 37-month average.

Temperature quality class 2: HadCRUT global surface air temperature, updated to March 2016

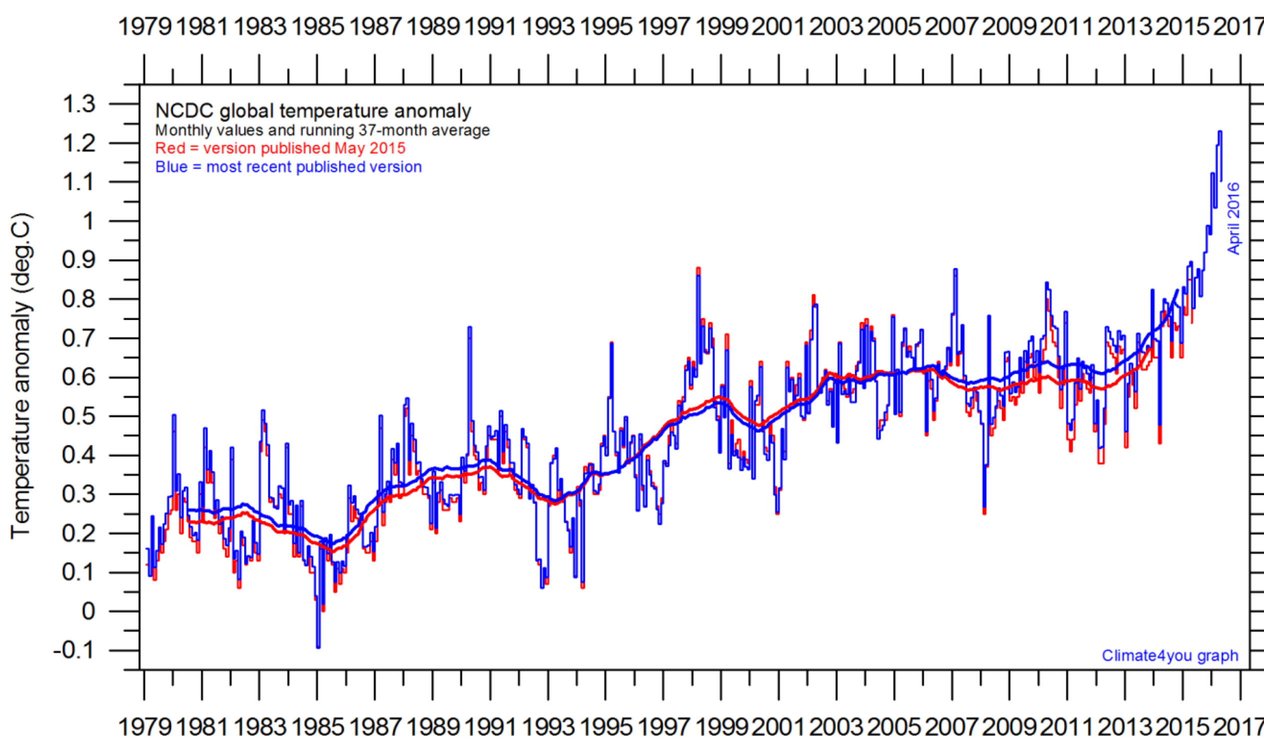


Global monthly average surface air temperature (thin line) since 1979 according to according to the Hadley Centre for Climate Prediction and Research and the University of East Anglia's Climatic Research Unit (CRU), UK. The thick line is the simple running 37-month average. Please note that this diagram is not yet updated beyond March 2016.

Temperature quality class 3: GISS and NCDC global surface air temperature, updated to April 2016



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:

All temperature diagrams shown above have 1979 as starting year. This roughly marks the beginning of the recent period of global warming, after termination of the previous period 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 start much earlier (in 1850 and 1880), 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, while others probably have their origin in a change of technique 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 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 have also moved geographically during their existence, and their instrumentation changed, and they are influenced by changes in their 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. Also important is that the sensors on satellites measure temperature directly by emitted radiation, while most surface temperature measurements are indirect, using electronic resistance.

All interested in climate science should gratefully acknowledge the efforts put into maintaining all 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 signals that they cannot all be correct.

On this background, and for practical reasons, Climate4you has decided to operate 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 (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.

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

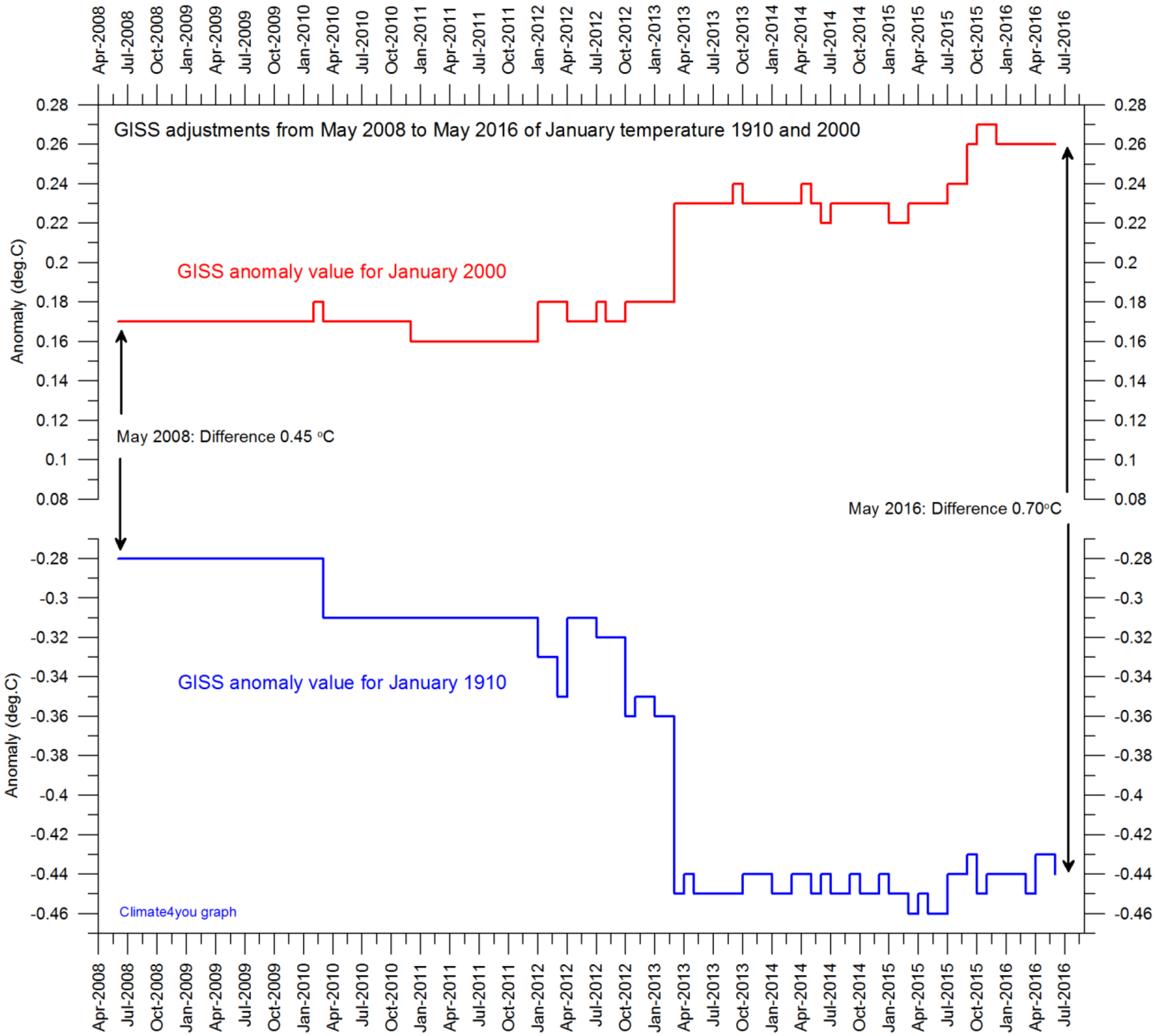
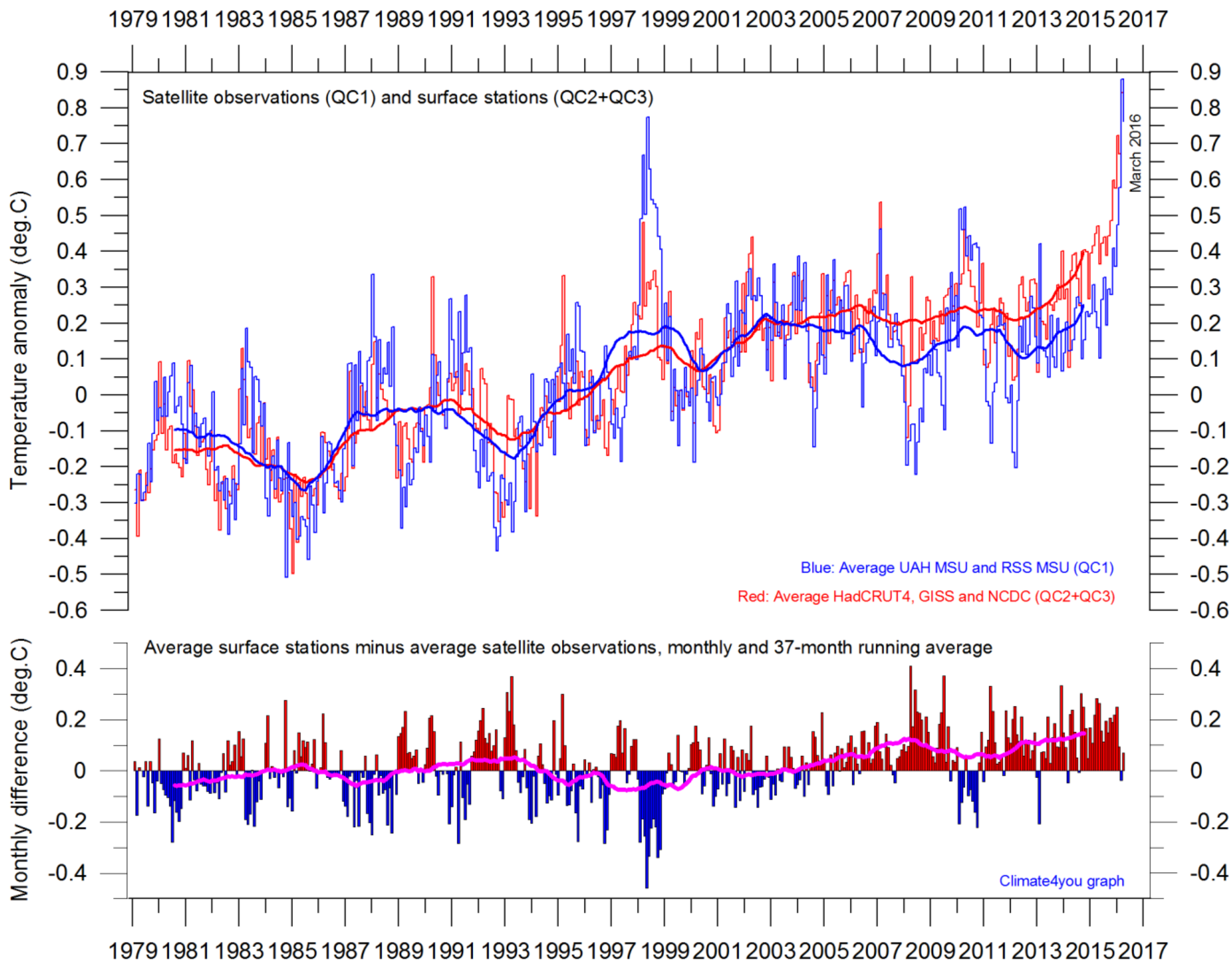


Diagram showing the adjustment made since May 2008 by the Goddard Institute for Space Studies (GISS), USA, in anomaly values for the months January 1910 and January 2000.

Note: The administrative upsurge of the temperature increase between January 1915 and January 2000 has grown from 0.45 (reported May 2008) to 0.70°C (reported May 2016), representing an about 56% administrative temperature increase over this period, meaning that more than half of the reported (by GISS) temperature increase from January 1910 to January 2000 is due to administrative changes of the original data since May 2008.

Comparing global surface air temperature and lower troposphere satellite temperatures; updated to March 2016



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 is steadily 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 March 2016

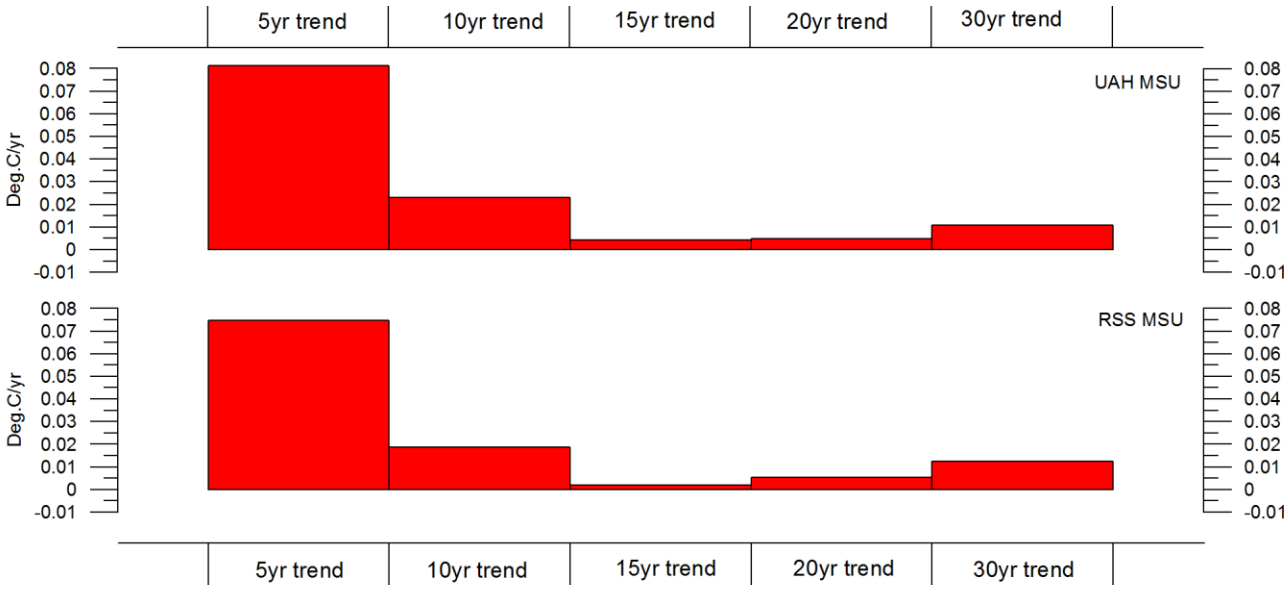


Diagram showing the latest 5, 10, 20 and 30 yr linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for two satellite-based temperature estimates (UAH MSU and RSS MSU).

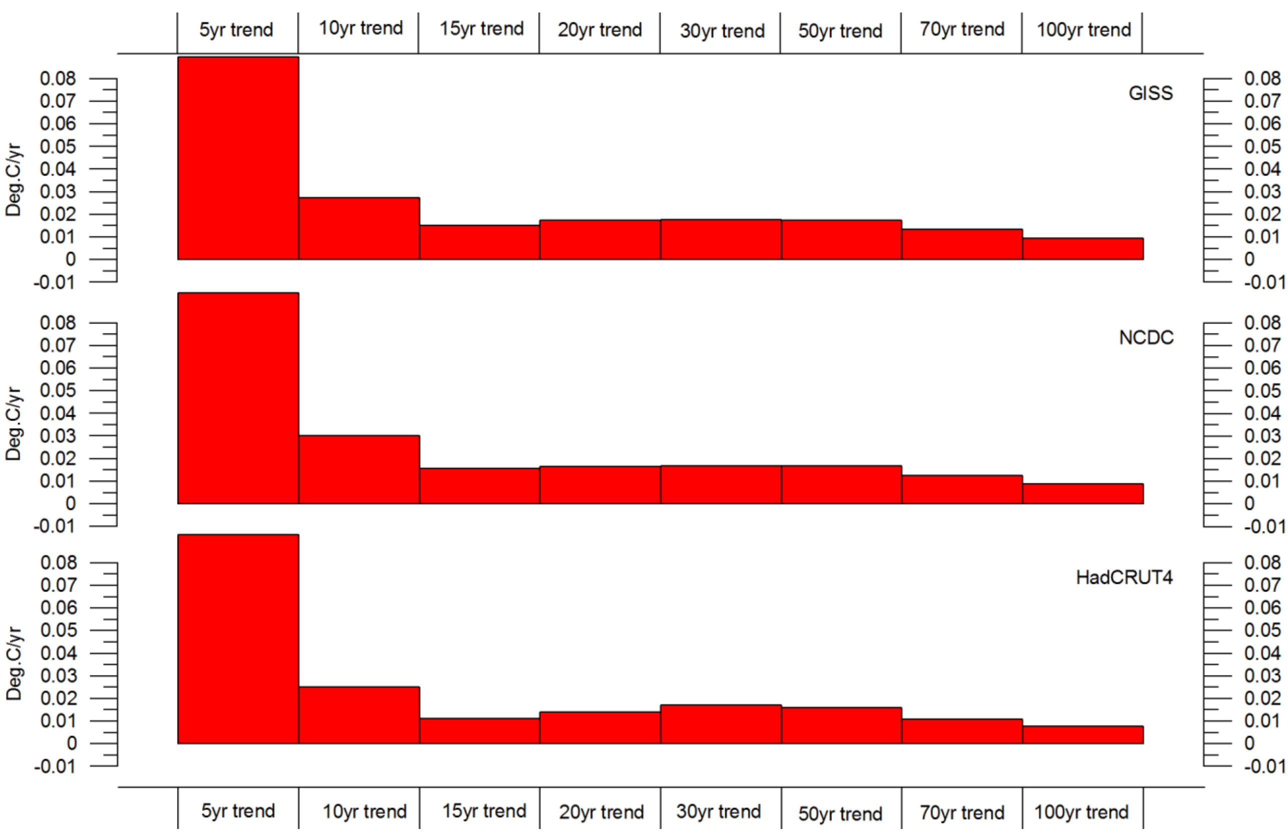
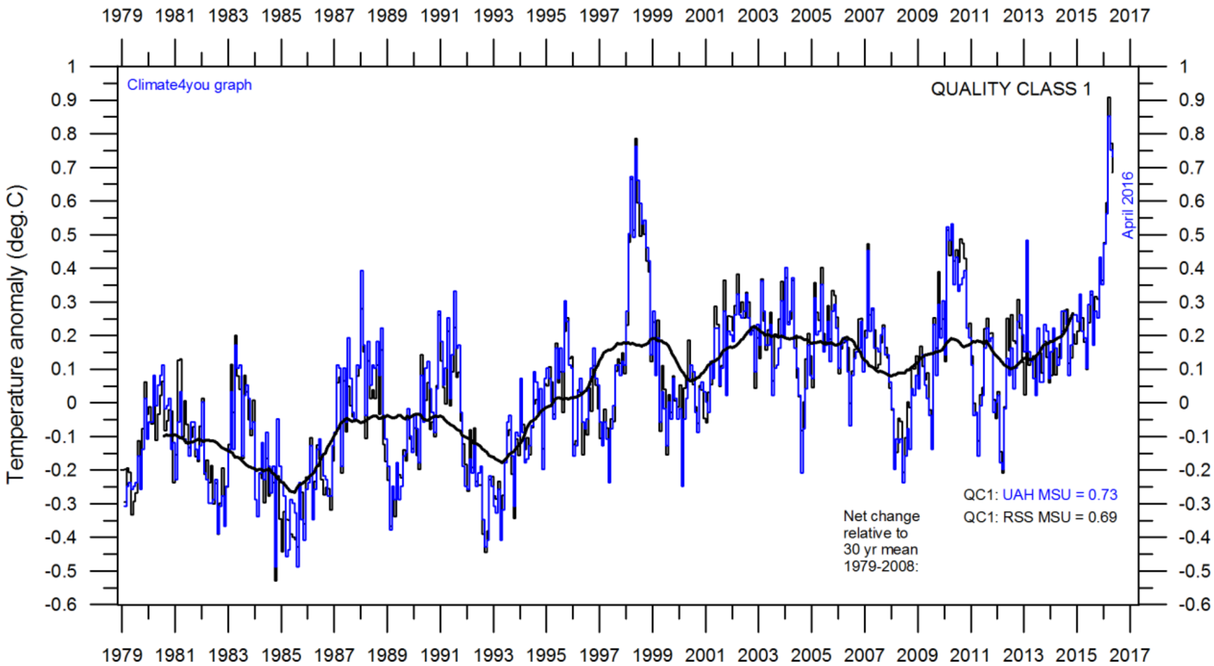
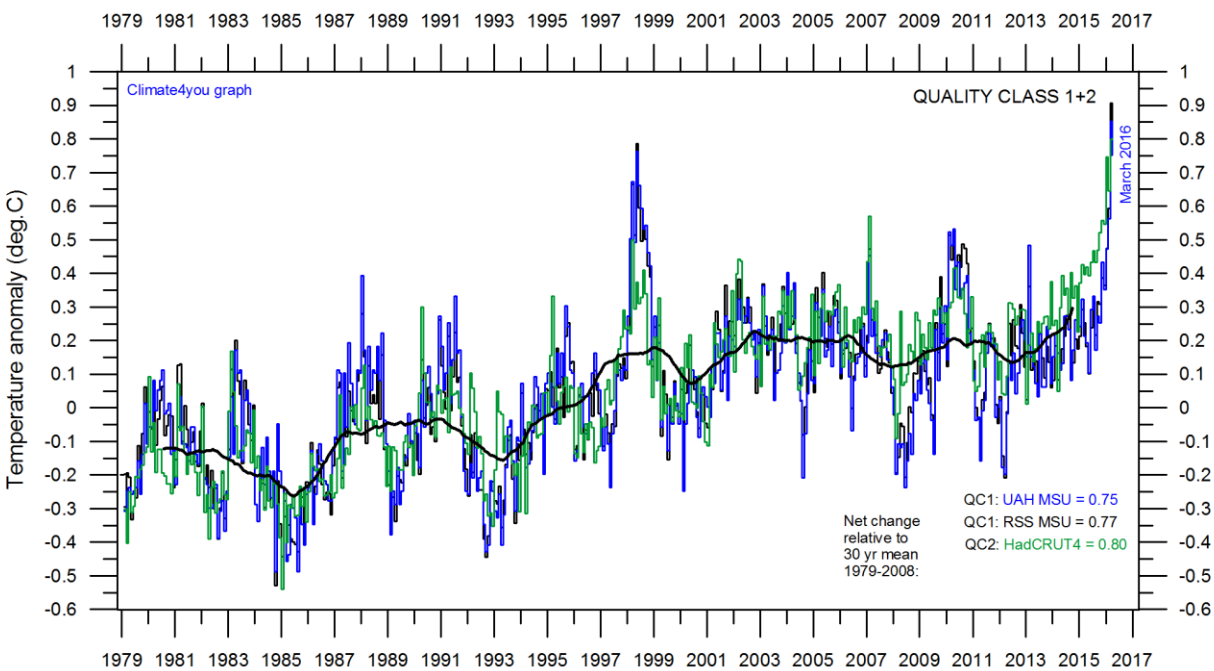


Diagram showing the latest 5, 10, 20, 30, 50, 70 and 100 year linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for three surface-based temperature estimates (GISS, NCDC and HadCRUT4).

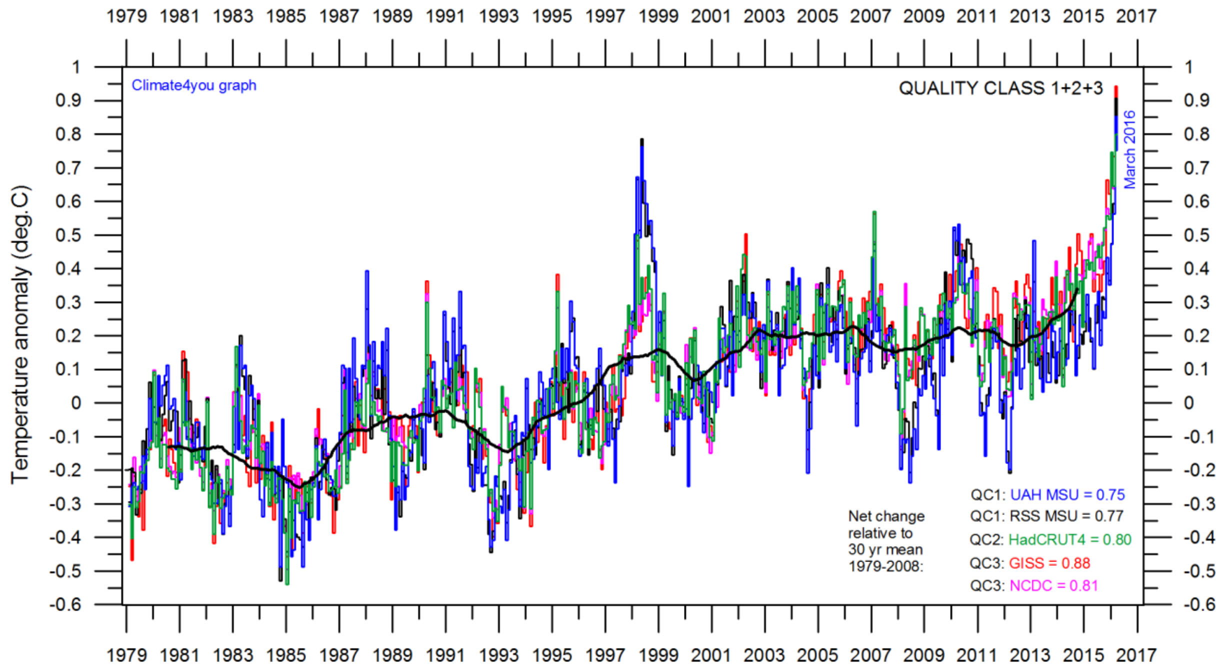
All in one, Quality Class 1, 2 and 3; updated to April and March 2016



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 all five temperature records. The numbers shown in the lower right corner represent the temperature anomaly relative to the individual 1979-1988 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 five temperature records. The numbers shown in the lower right corner represent the temperature anomaly relative to the individual 1979-1988 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 1979-1988 averages.

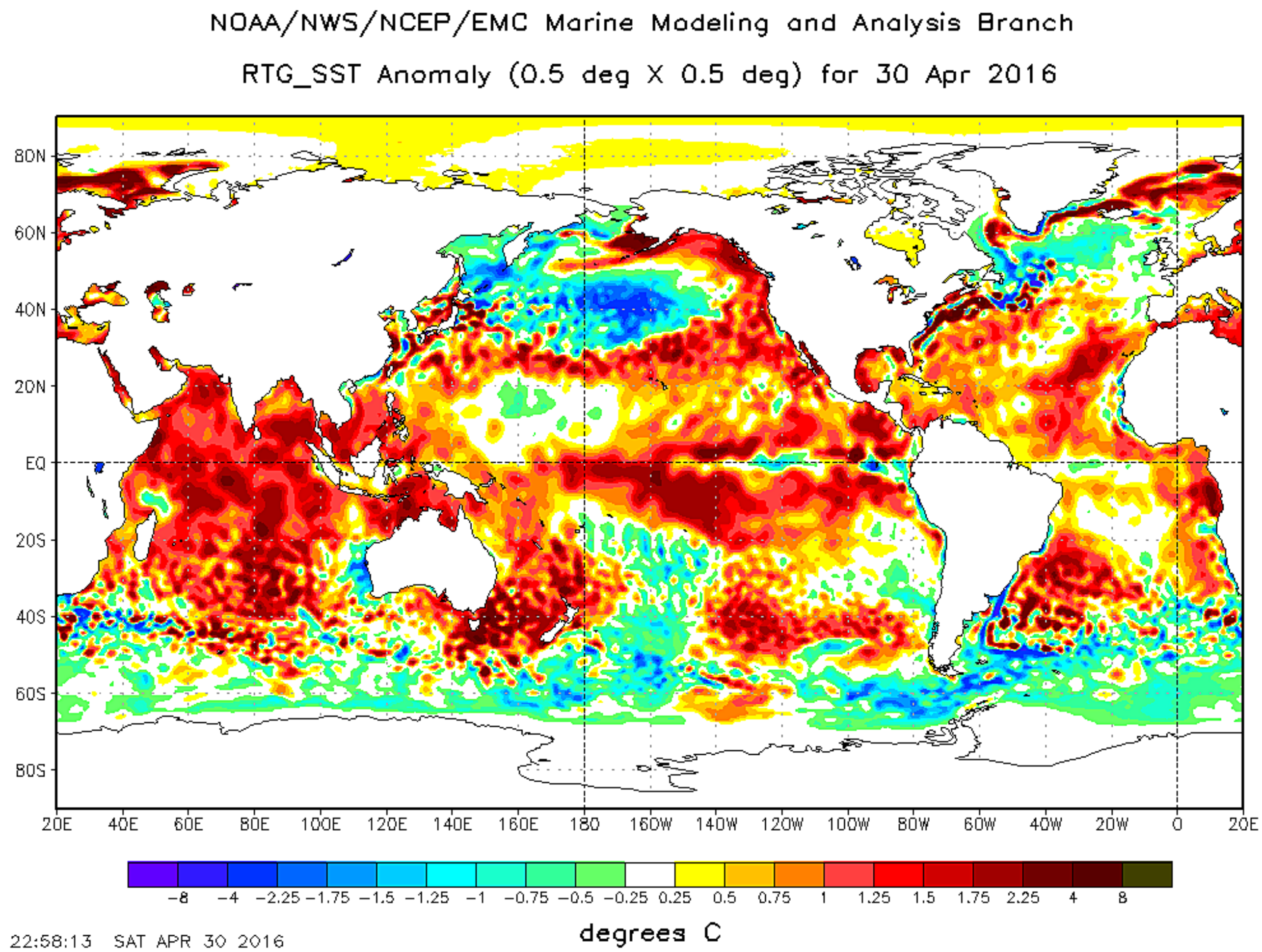
Please see notes on page 7 relating to the above three quality classes.

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 seem to be drifting towards higher temperatures than the satellite records in a consistent way (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 real increase in global air temperature since 1998, which however was affected by the oceanographic El Niño event. Neither has there been a temperature decrease during this time interval.

This temperature stagnation does not exclude the possibility that global temperatures will begin to increase again later. On the other hand, it also remain a possibility that Earth just now is passing a temperature peak, and that global temperatures will begin to decrease during the coming years. Time will show which of these two possibilities is correct.

Global sea surface temperature, updated to April 2016



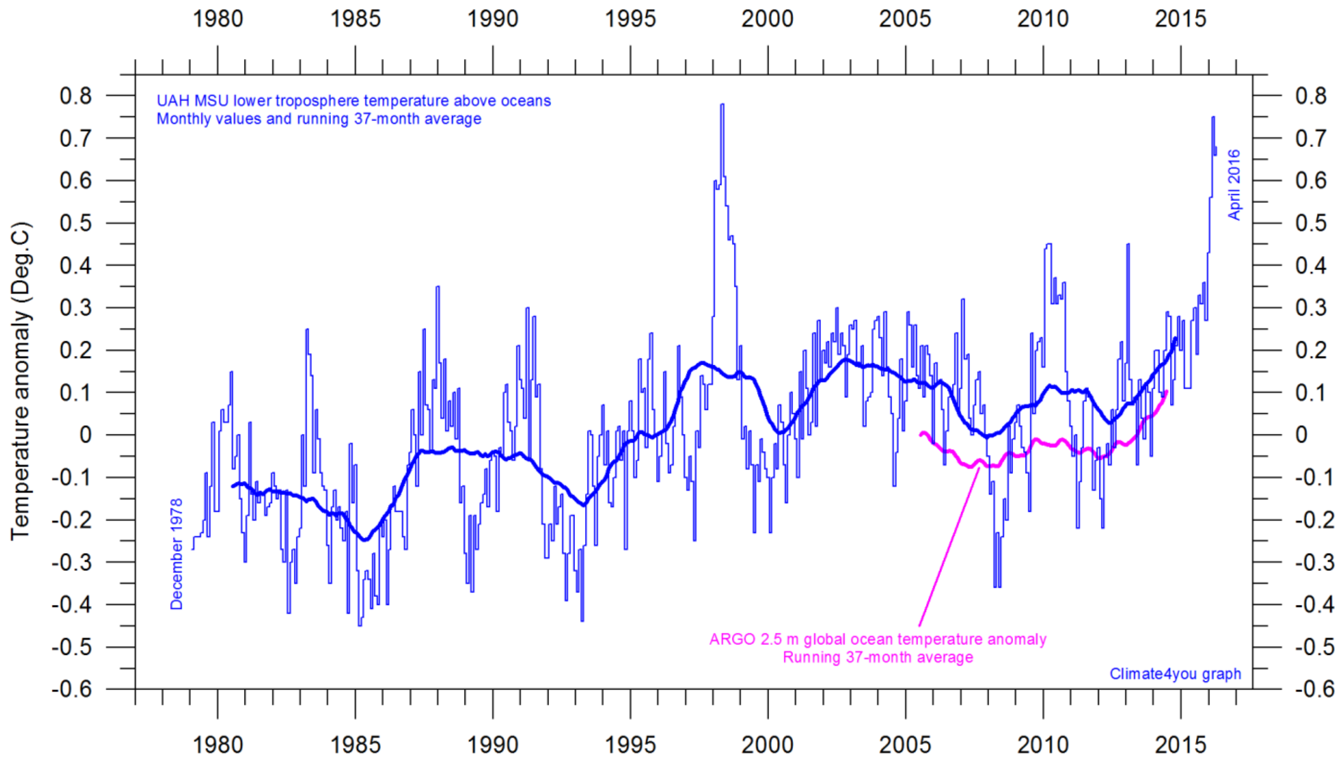
Sea surface temperature anomaly on 30 April 2016. Map source: National Centers for Environmental Prediction (NOAA).

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).

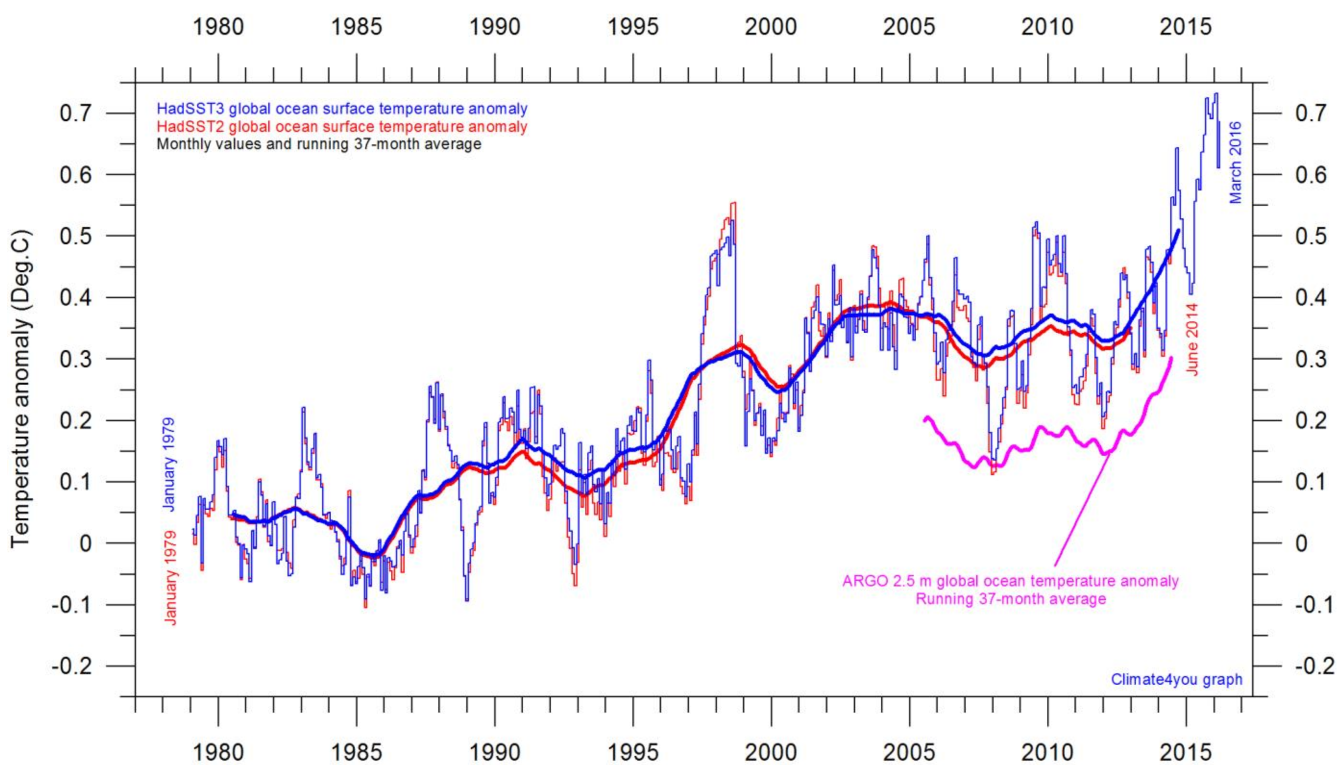
Relatively warm water is dominating the oceans near the Equator, and is influencing global air temperatures now and in the months to come.

The significance of any such short-term cooling or warming reflected in air temperatures should not be over stated. 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.

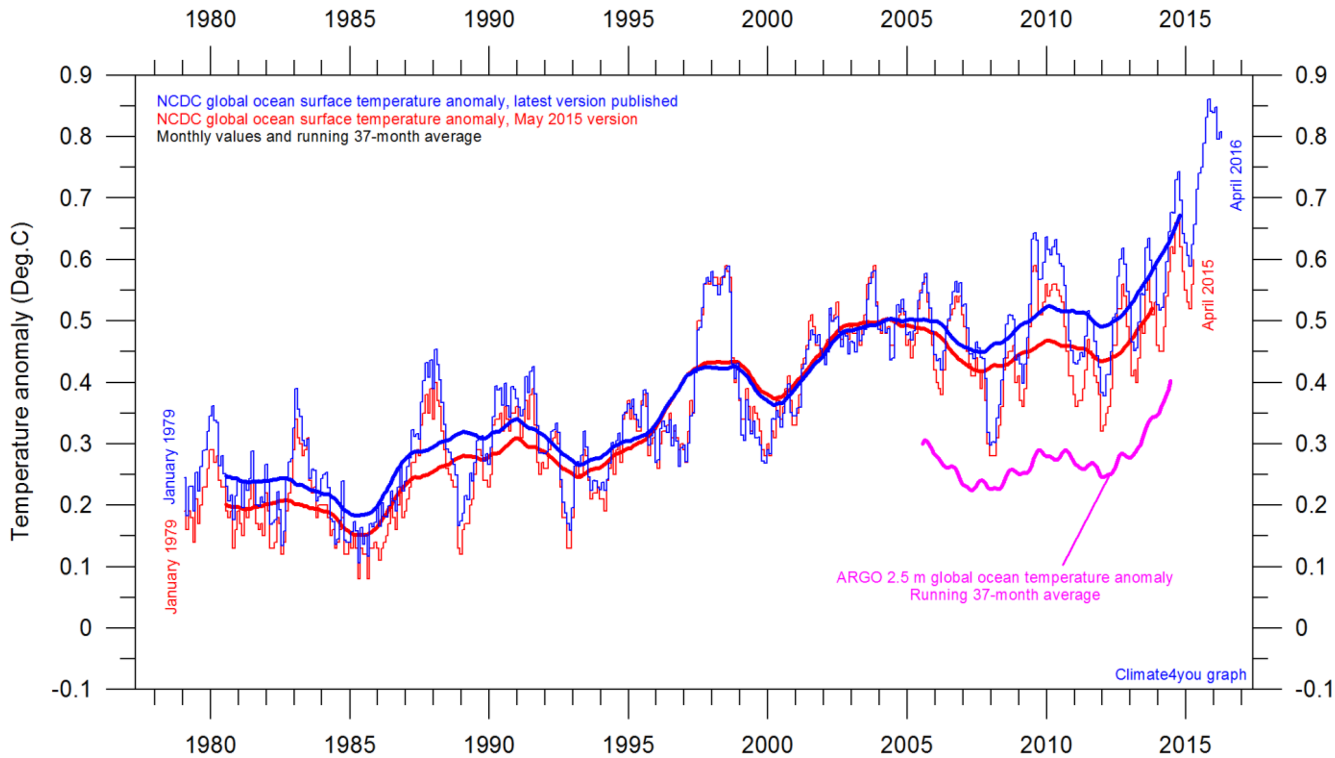
However, this does not reflect similar changes in the total heat content of the atmosphere-ocean system. In fact, global net changes can be small and such heat exchanges may mainly reflect redistribution of energy between ocean and atmosphere. What matters is the overall temperature development when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



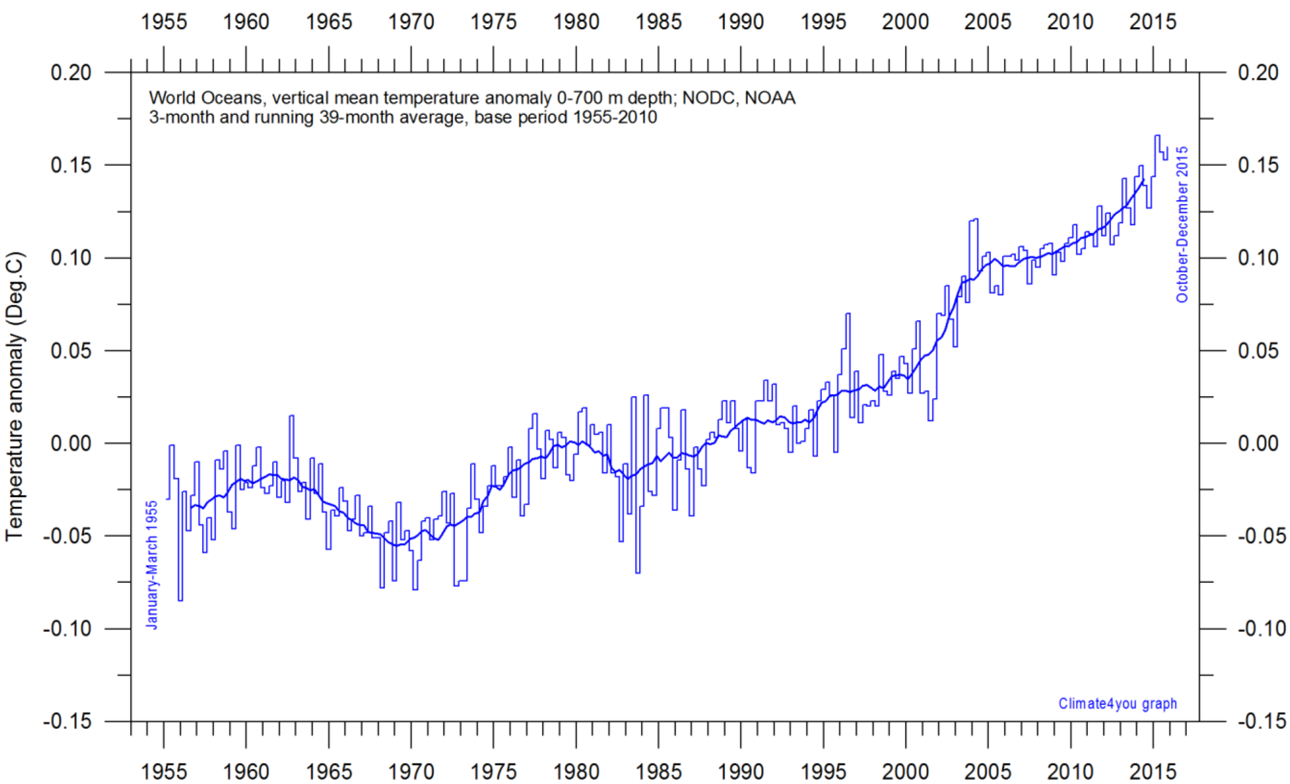
Global monthly average sea surface temperature since 1979 according to University of East Anglia's [Climatic Research Unit](#) ([CRU](#)), UK. Base period: 1961-1990. The thick line is the simple running 37-month average. Insert: Argo global ocean temperature anomaly from floats. Please note that this diagram is not yet updated beyond March 2016.



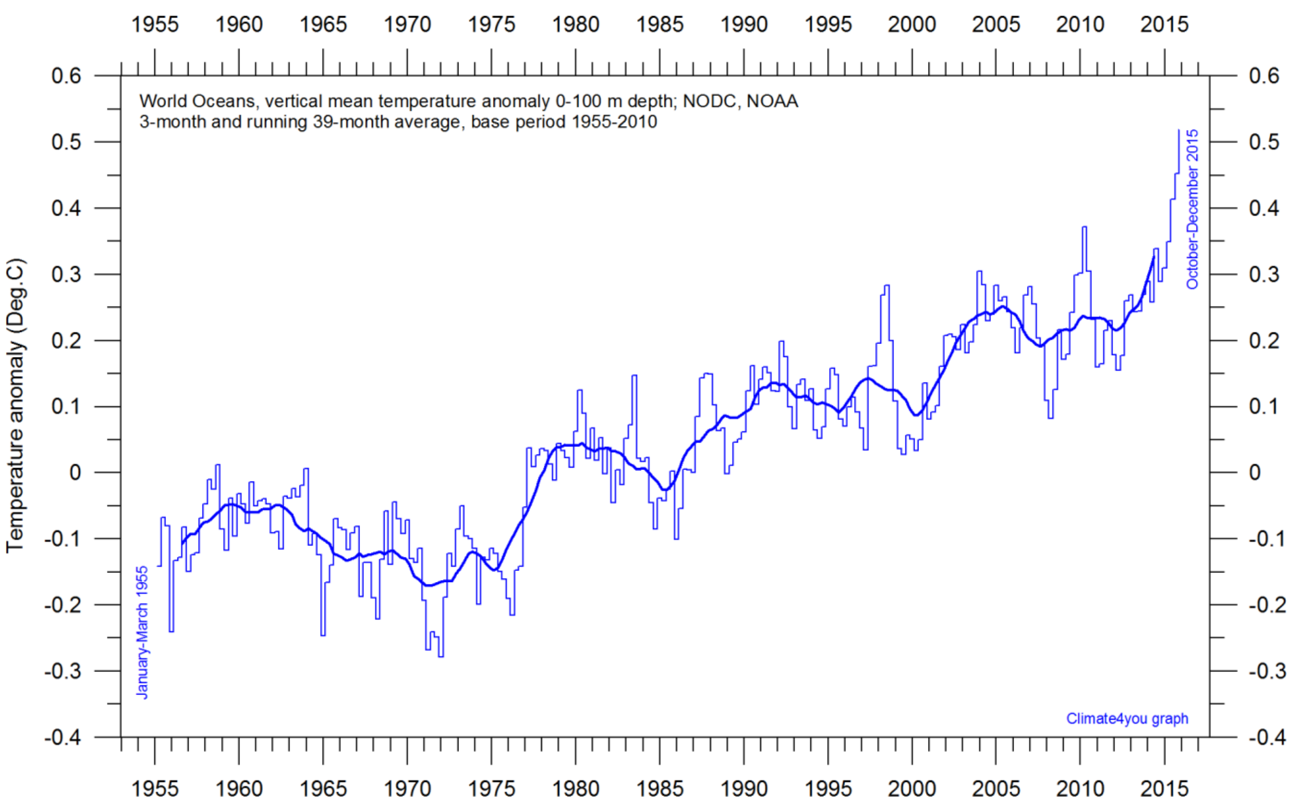
Global monthly average sea surface temperature since 1979 according to the National Climatic Data Center (NCDC), USA. Base period: 1901-2000. The thick line is the simple running 37-month average. Insert: Argo global ocean temperature anomaly from floats.

June 18, 2015: *NCDC has introduced a number of 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).*

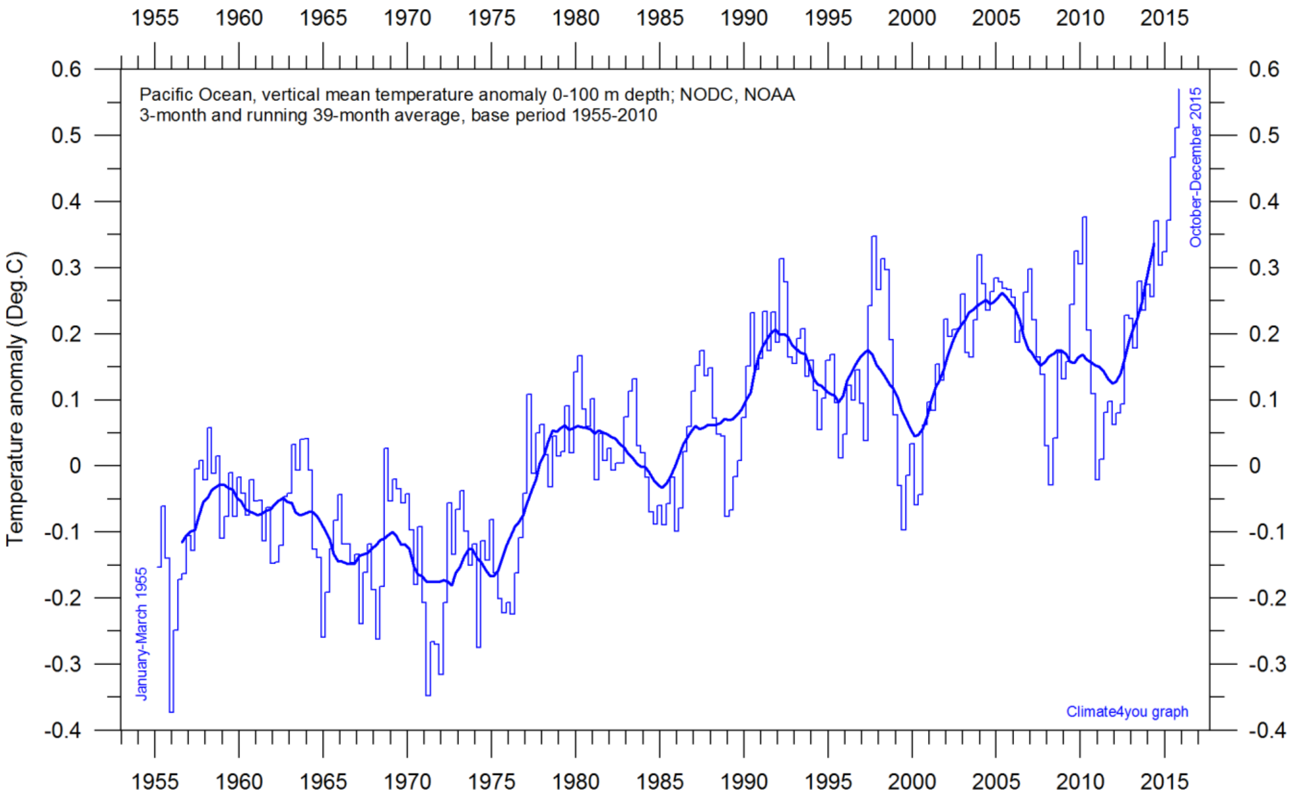
Ocean temperature in uppermost 100 and 700 m, updated to December 2015



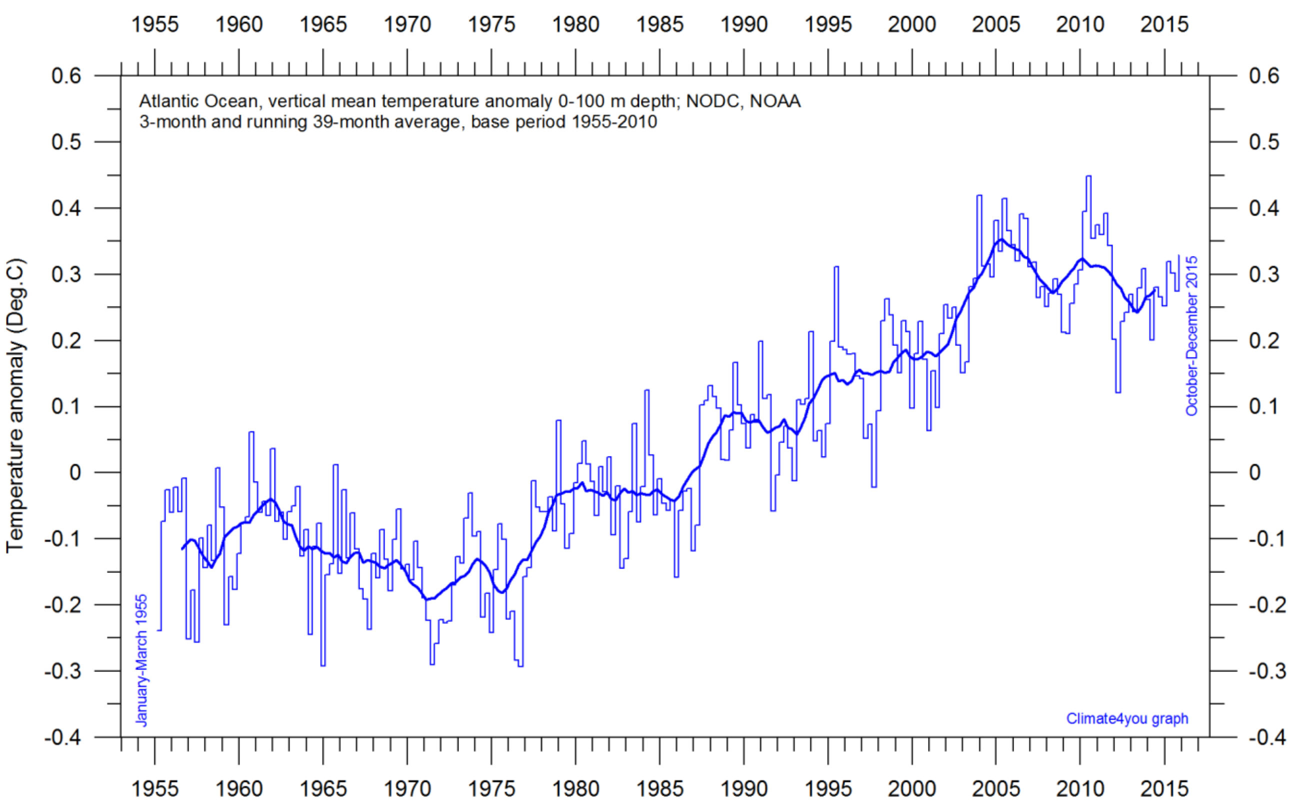
World Oceans vertical average temperature 0-700 m depth since 1955. The thin line indicates 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: NOAA National Oceanographic Data Center (NODC). Base period 1955-2010.



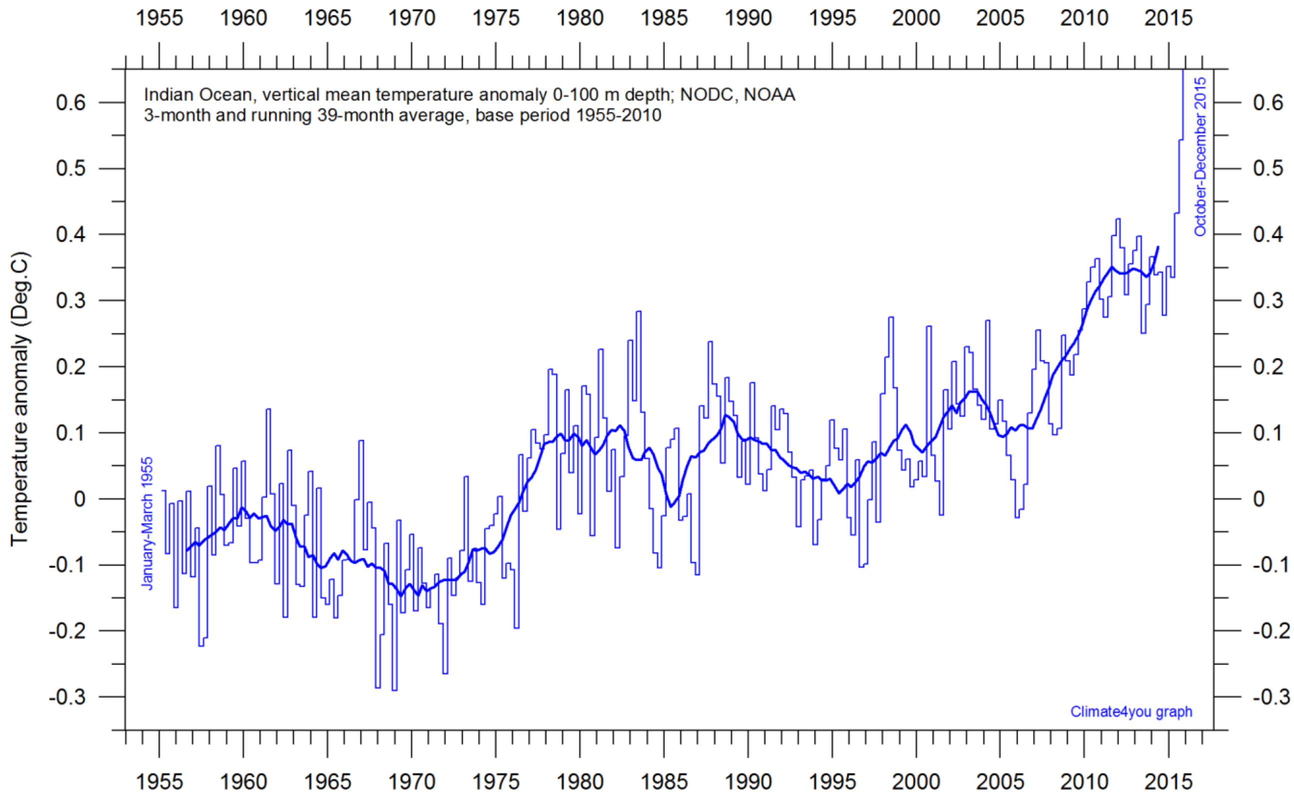
World Oceans vertical average temperature 0-100 m depth since 1955. The thin line indicates 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: NOAA National Oceanographic Data Center (NODC). Base period 1955-2010.



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.

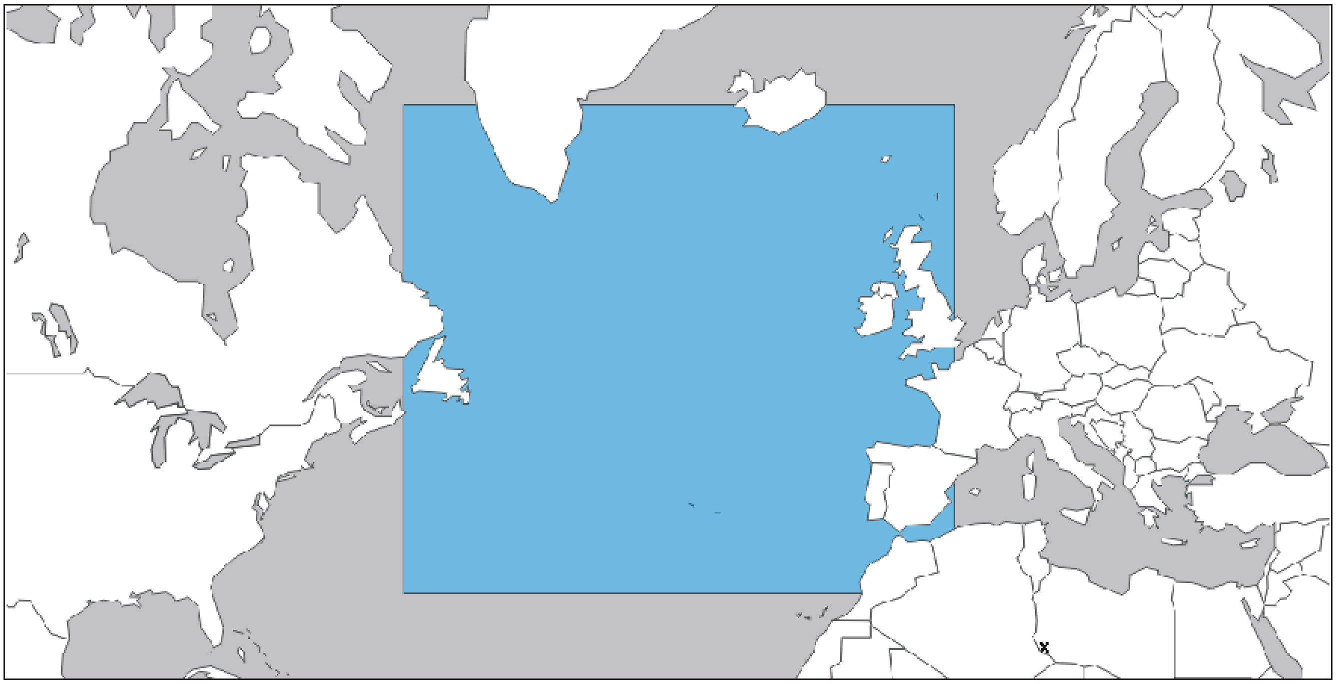


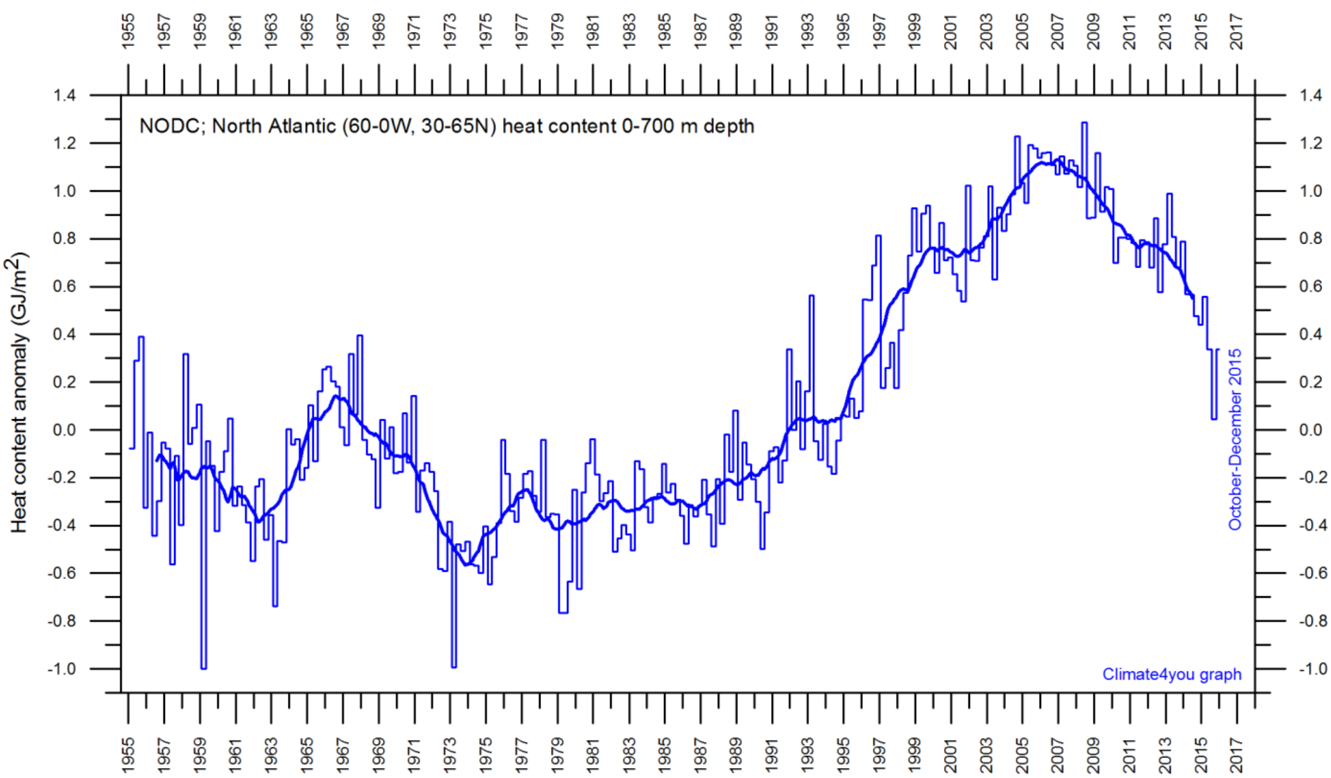
Atlantic Ocean vertical average temperature 0-100 m depth since 1955. The thin line indicate 3-month values, and the thick line represents the simple running 39-month (c. 3 year) average. Data source: [NOAA National Oceanographic Data Center](#) (NODC). Base period 1955-2010.



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.

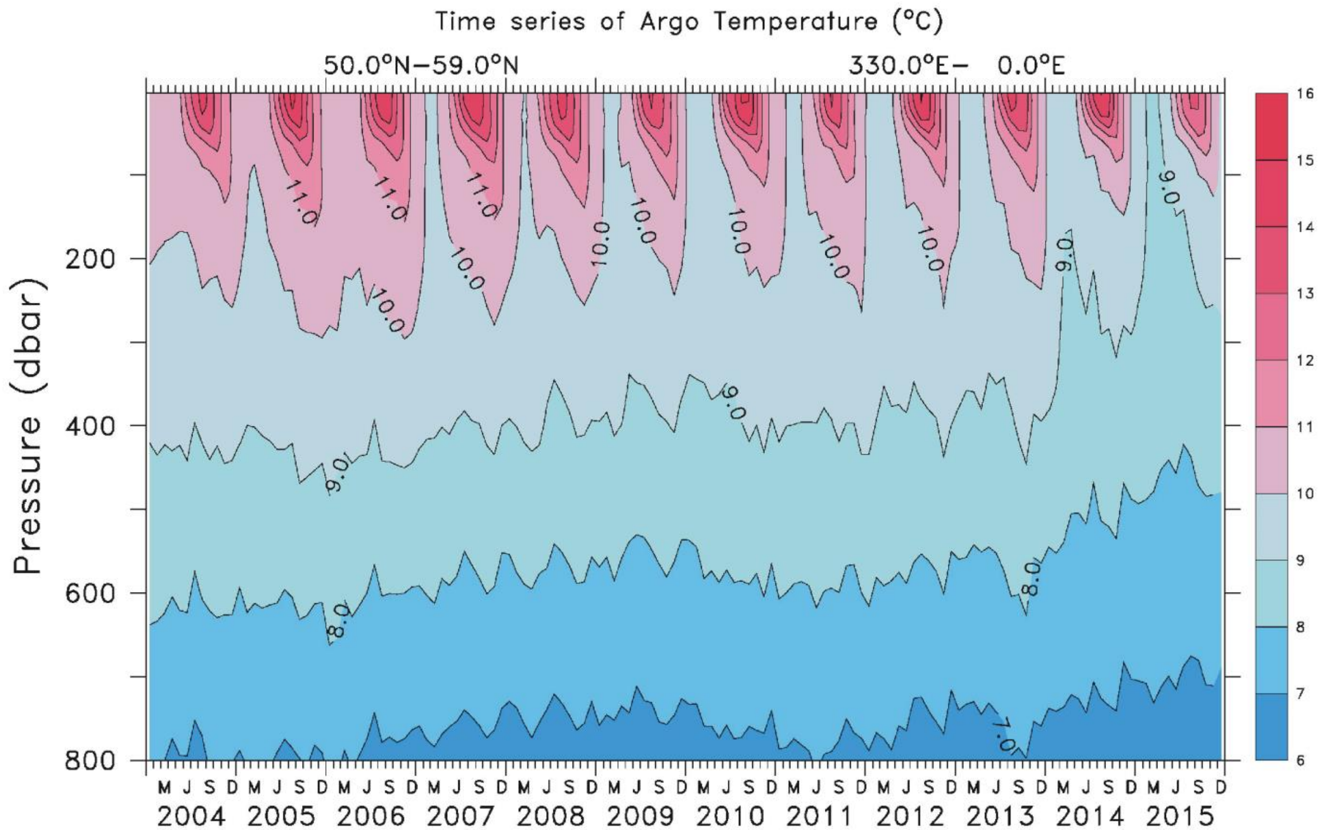
[North Atlantic heat content uppermost 700 m, updated to December 2015]()





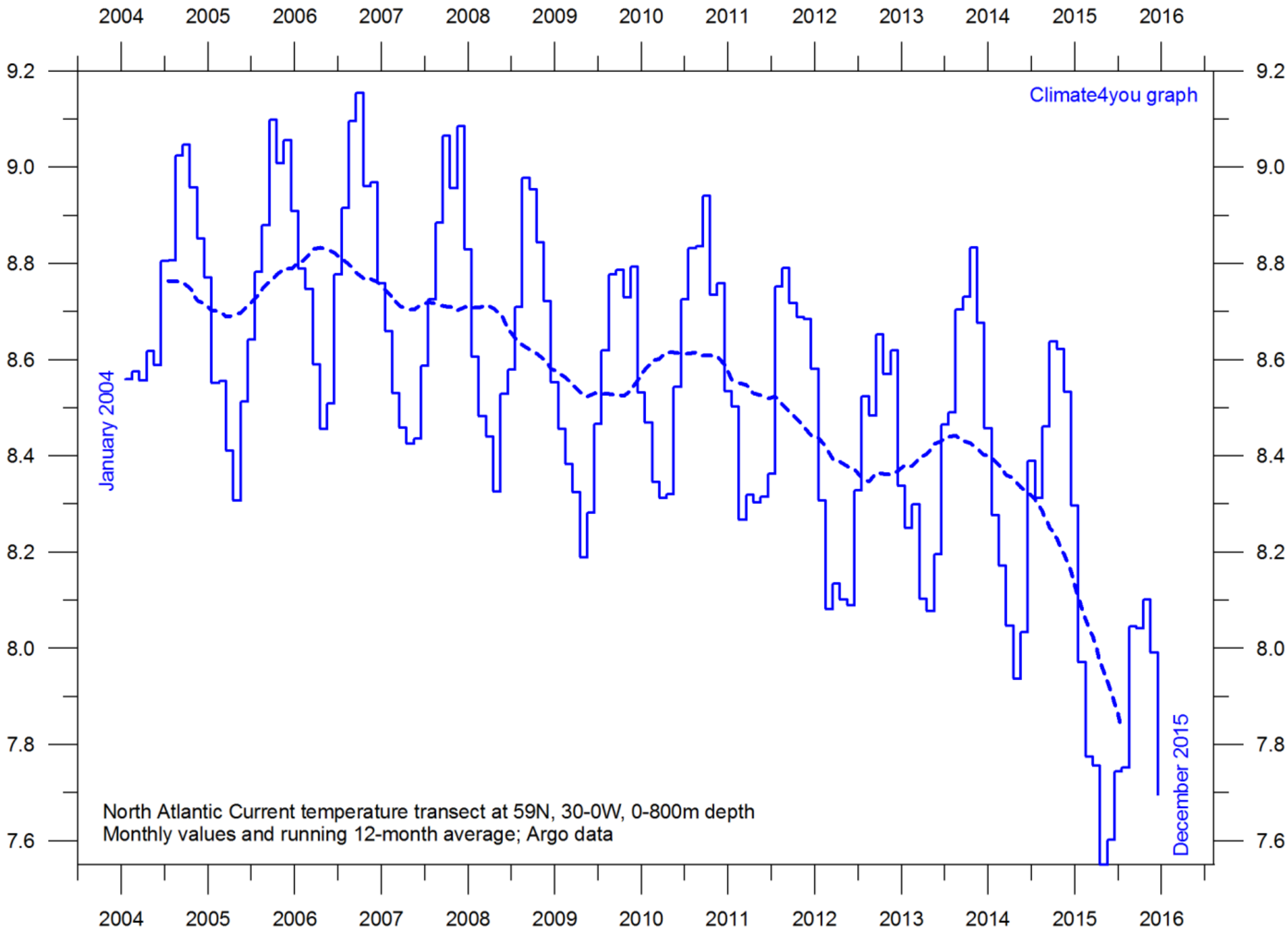
Global monthly heat content anomaly (GJ/m2) in the uppermost 700 m of the North Atlantic (60-0W, 30-65N; see map above) *ocean since January 1955. The thin line indicates monthly values, and the thick line represents the simple running 37 month (c. 3 year) average. Data source: [National Oceanographic Data Center]() (NODC).*

North Atlantic sea temperatures along 59^{o}N, updated to December 2015



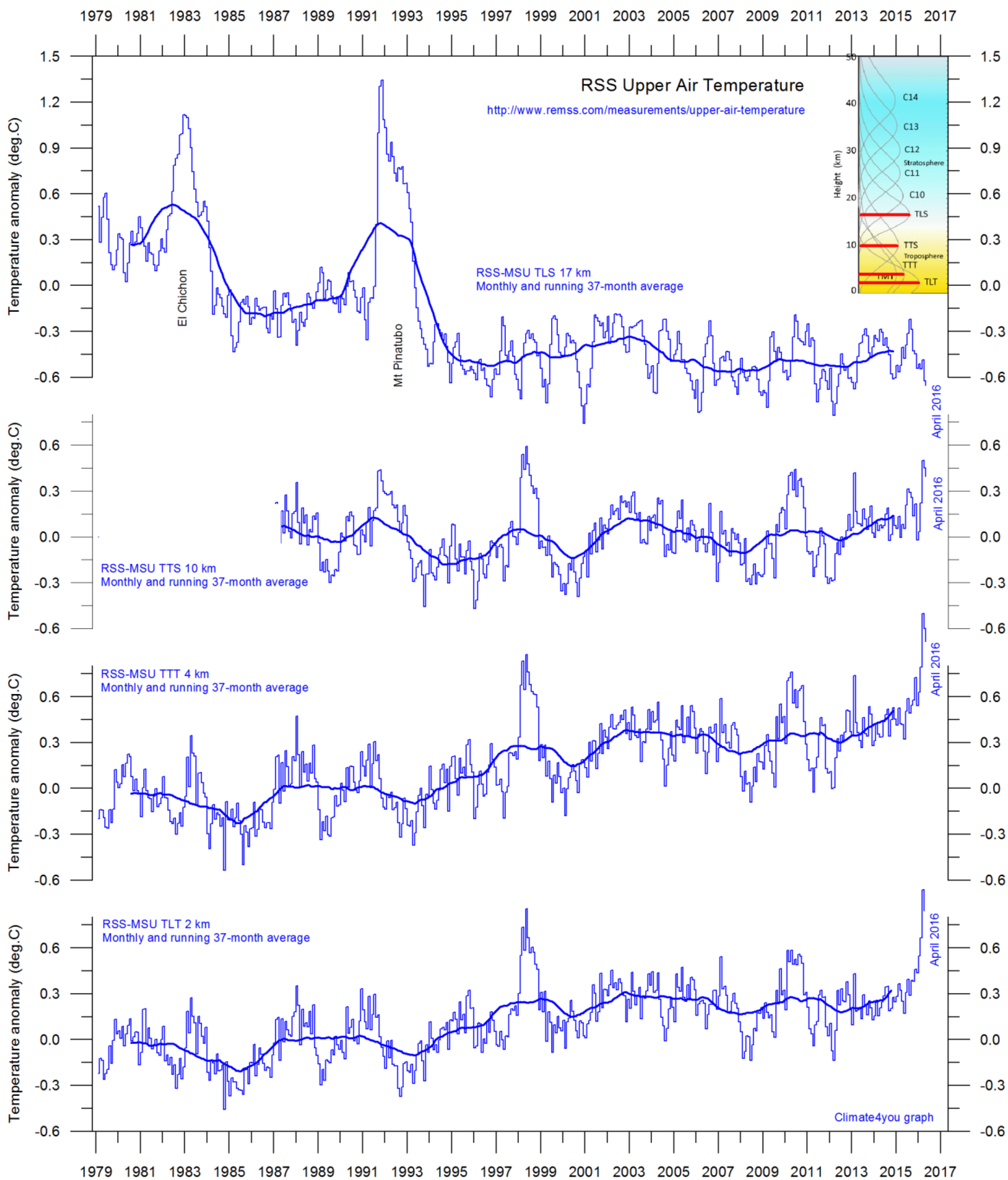
Time series depth-temperature diagram along 59 N across the North Atlantic Current from 30^{o}W to 0^{o}W, from surface to 800 m depth. Source: Global Marine Argo Atlas. See also diagram next page.

North Atlantic sea temperatures 30-0W at 59°N, updated to December 2015



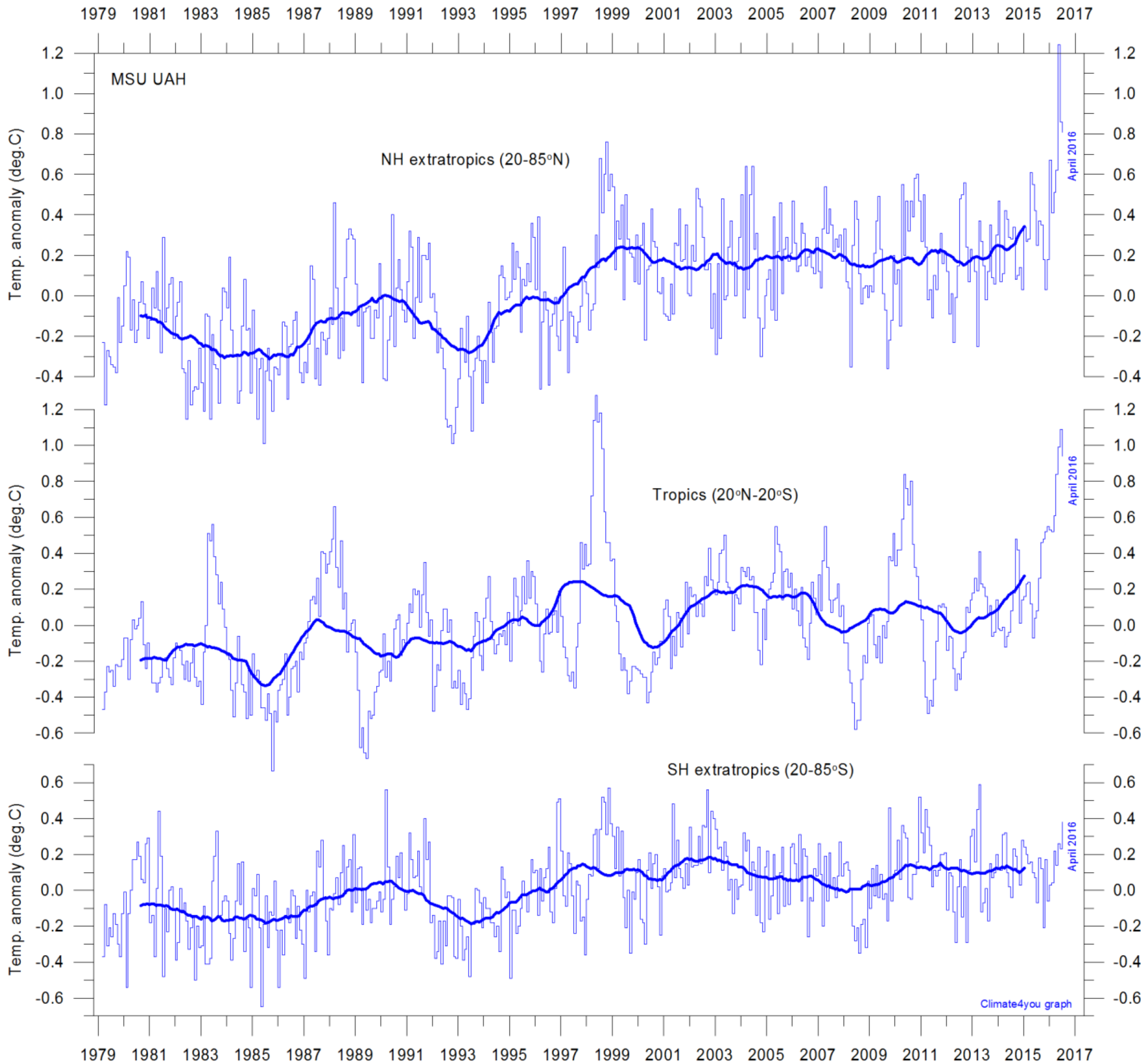
Average temperature along 59 N, 30-0W, 0-800m depth, corresponding to the main part of the North Atlantic Current, using Argo-data. Source: Global Marine Argo Atlas. Additional information can be found in: Roemmich, D. and J. Gilson, 2009. The 2004-2008 mean and annual cycle of temperature, salinity,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

Troposphere and stratosphere temperatures from satellites, updated to April 2016



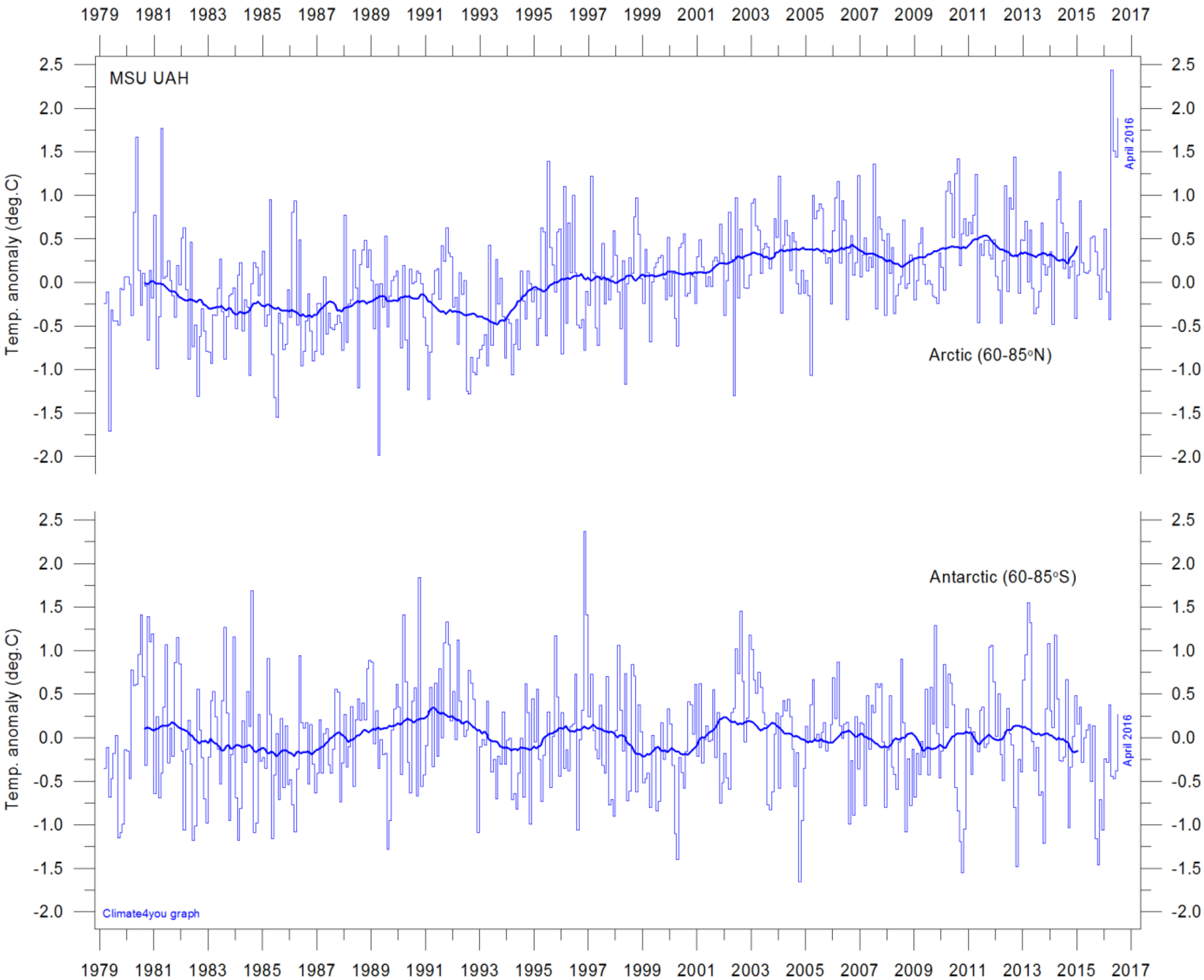
Global monthly average temperature in different altitudes according to [Remote Sensing Systems](http://www.remss.com/) (RSS). The thin lines represent the monthly average, and the thick line the simple running 37 month average, nearly corresponding to a running 3 year average.

Zonal lower troposphere temperatures from satellites, updated to April 2016



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 April 2016



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.

Arctic and Antarctic surface air temperature, updated to February 2016

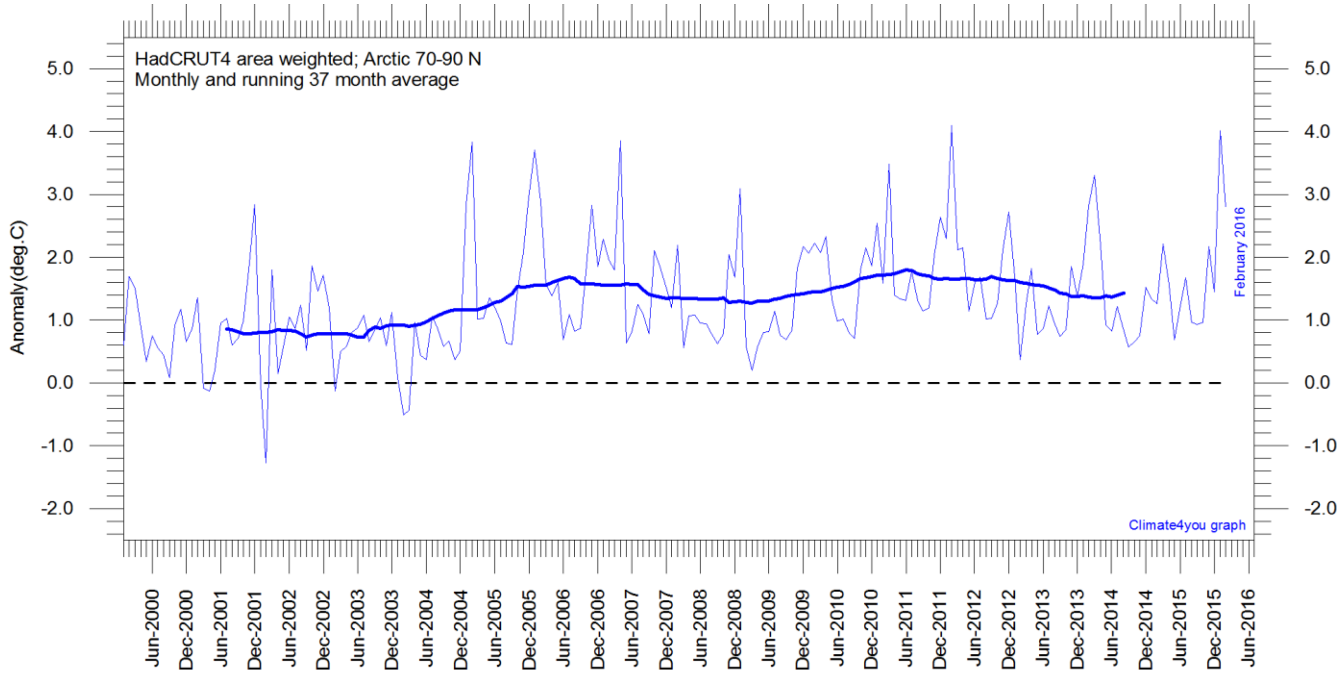


Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies (HadCRUT4) since January 2000, in relation to the WMO normal period 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37 month (c. 3 year) average.

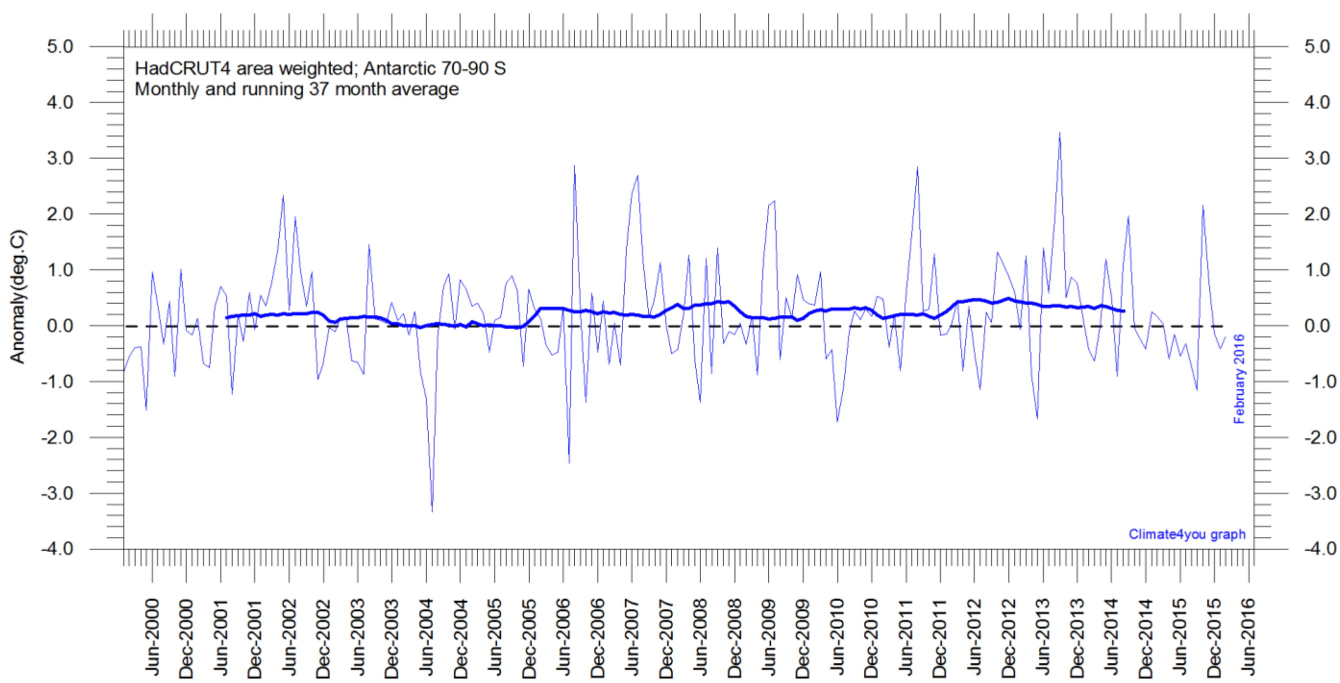


Diagram showing area weighted Antarctic (70-90°N) monthly surface air temperature anomalies (HadCRUT4) since January 2000, in relation to the WMO normal period 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37 month (c. 3 year) average.

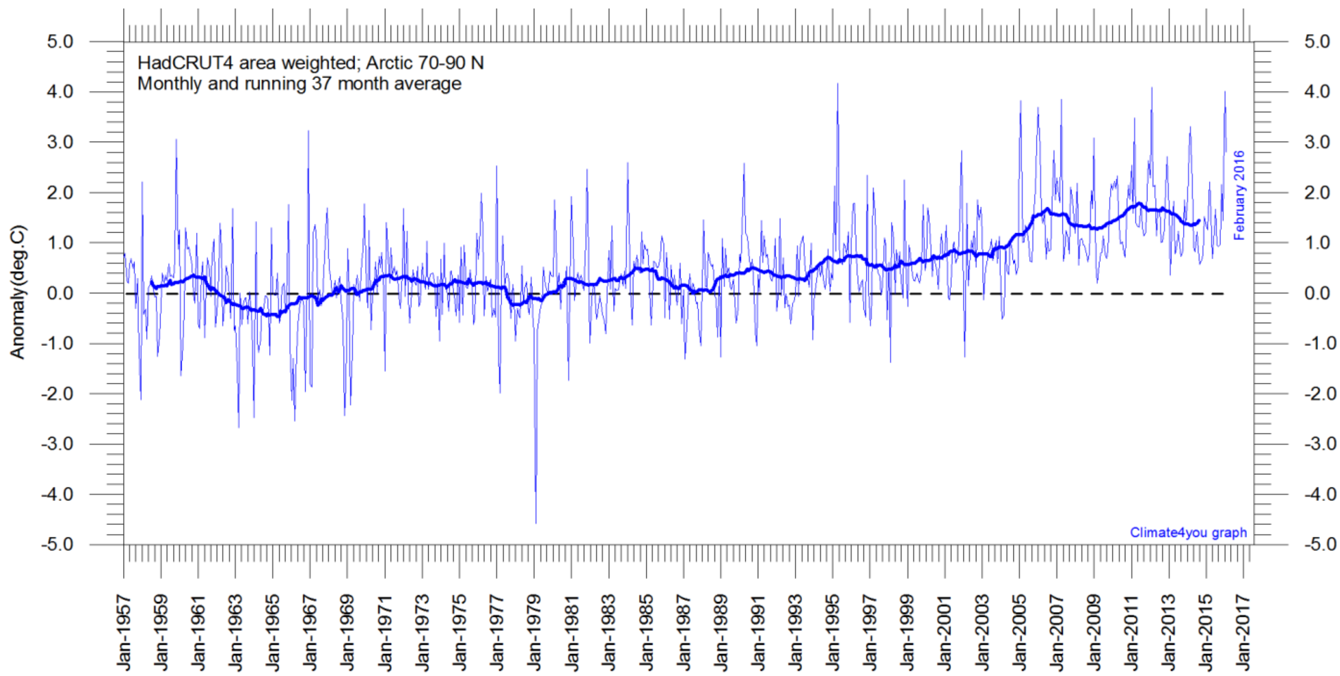


Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4]) since January 1957, in relation to the WMO [normal period] 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37 month (c. 3 year) average.

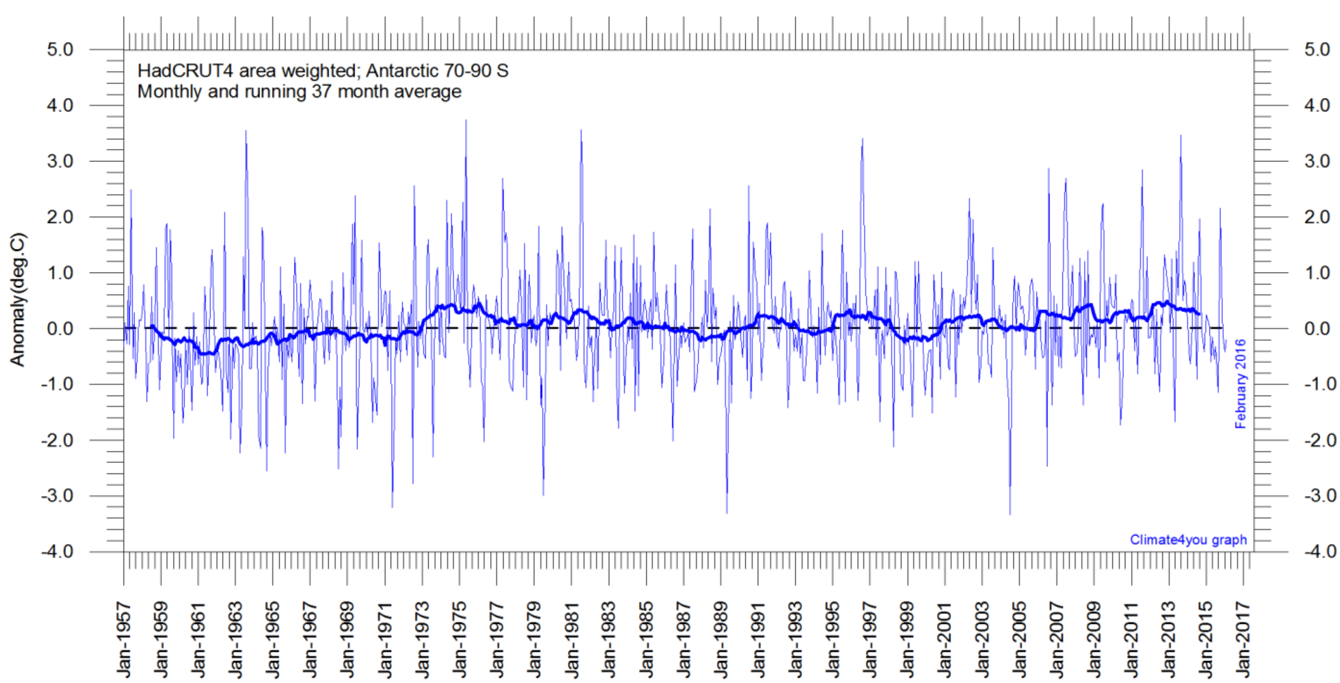


Diagram showing area weighted Antarctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4]) since January 1957, in relation to the WMO [normal period] 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37 month (c. 3 year) average.

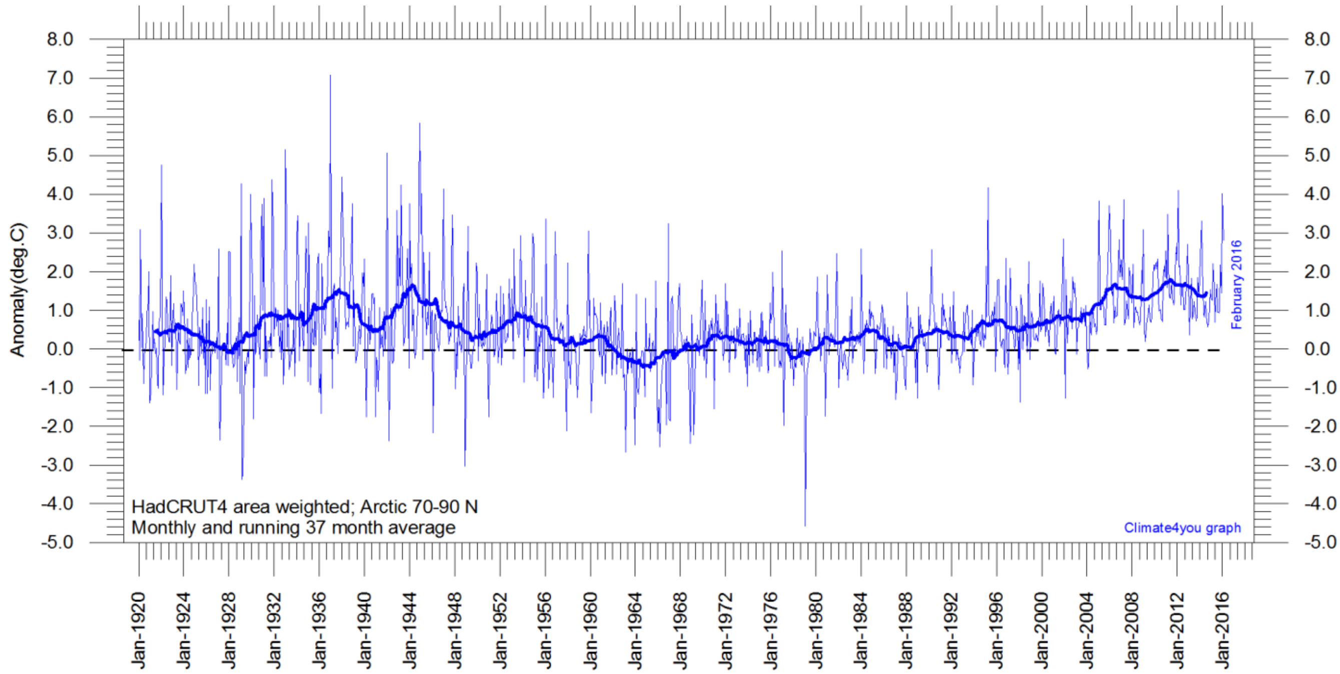


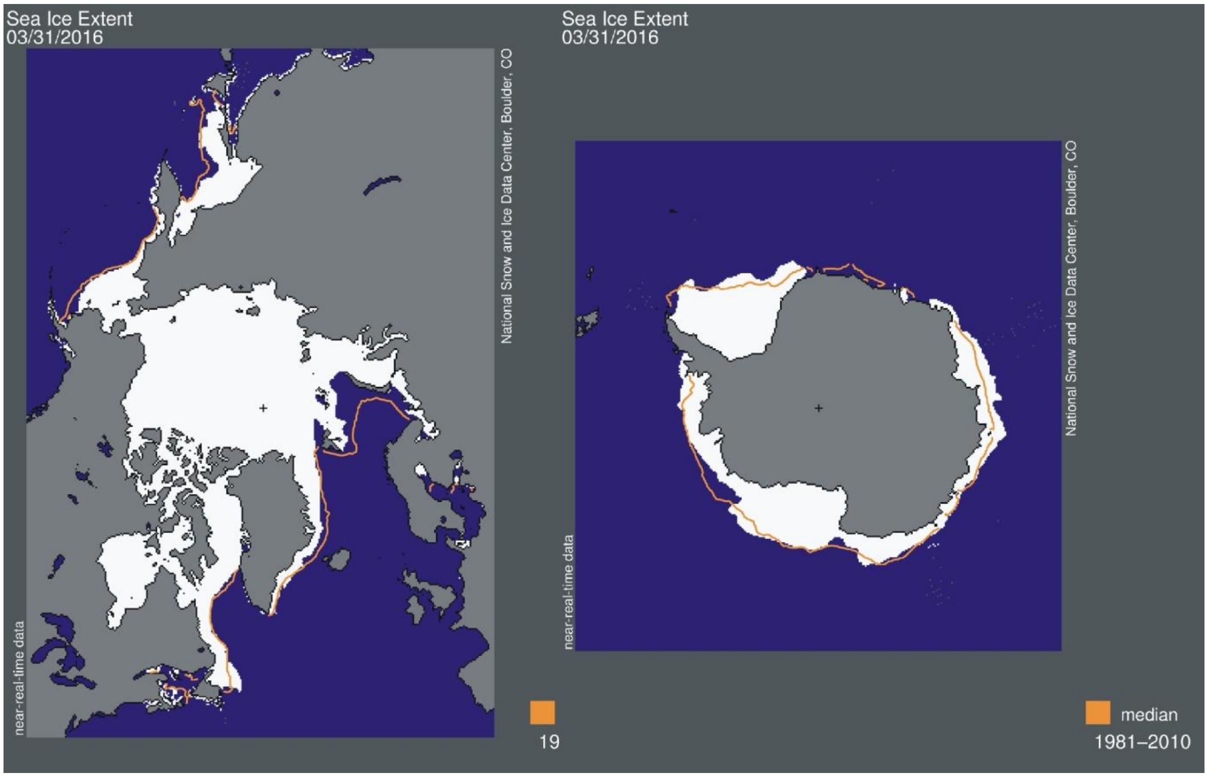
Diagram showing area-weighted Arctic (70-90°N) monthly surface air temperature anomalies (HadCRUT4) since January 1920, in relation to the WMO normal period 1961-1990. The thin line shows the monthly temperature anomaly, while the thicker line shows the running 37 month (c. 3 year) average. Because of the relatively small number of Arctic stations before 1930, month-to-month variations in the early part of the temperature record are larger than later. 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 2000 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 5°x5° grid cells has been weighted according to their surface area. This is in contrast to Gillet et al. 2008 which calculated a simple average, with no consideration to the surface area represented by the individual 5°x5° grid cells.

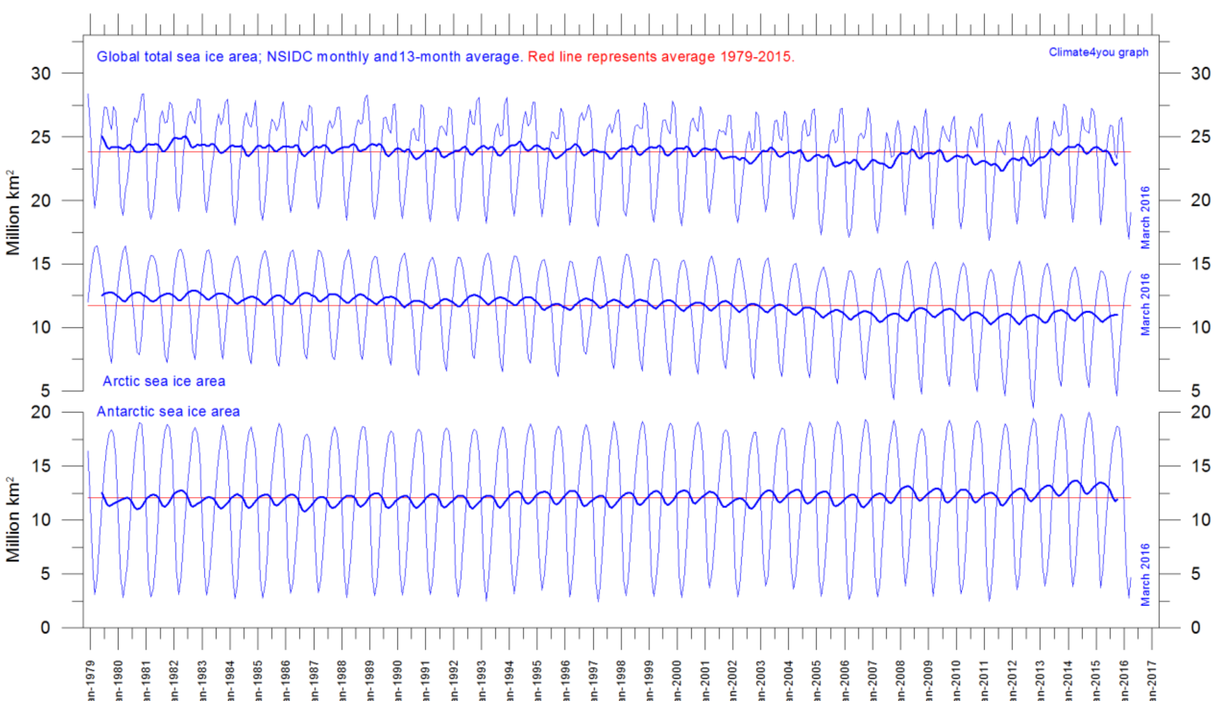
Literature:

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 March and April 2016



Sea ice extent 31 March 2016. The 'normal' or average limit of sea ice (orange line) is defined as 15% sea ice cover, according to the average of satellite observations 1981-2010 (both years inclusive). 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).



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

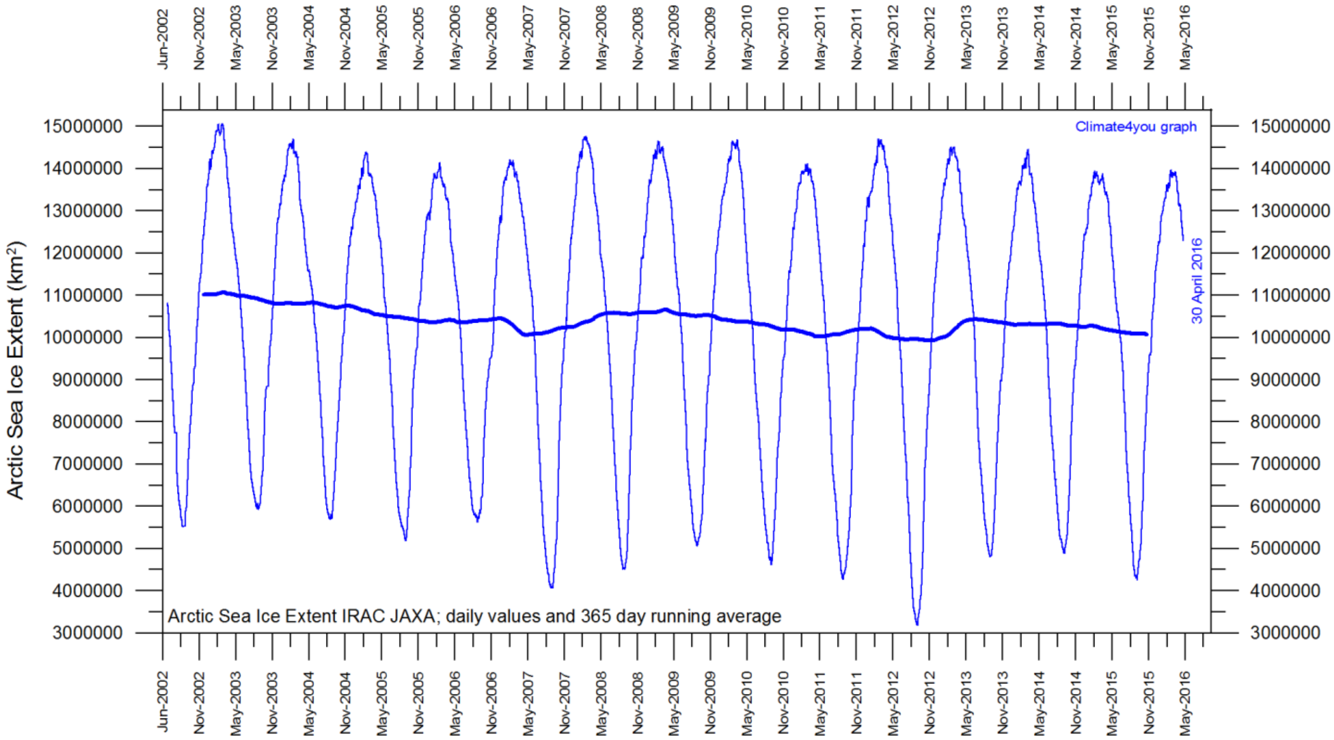
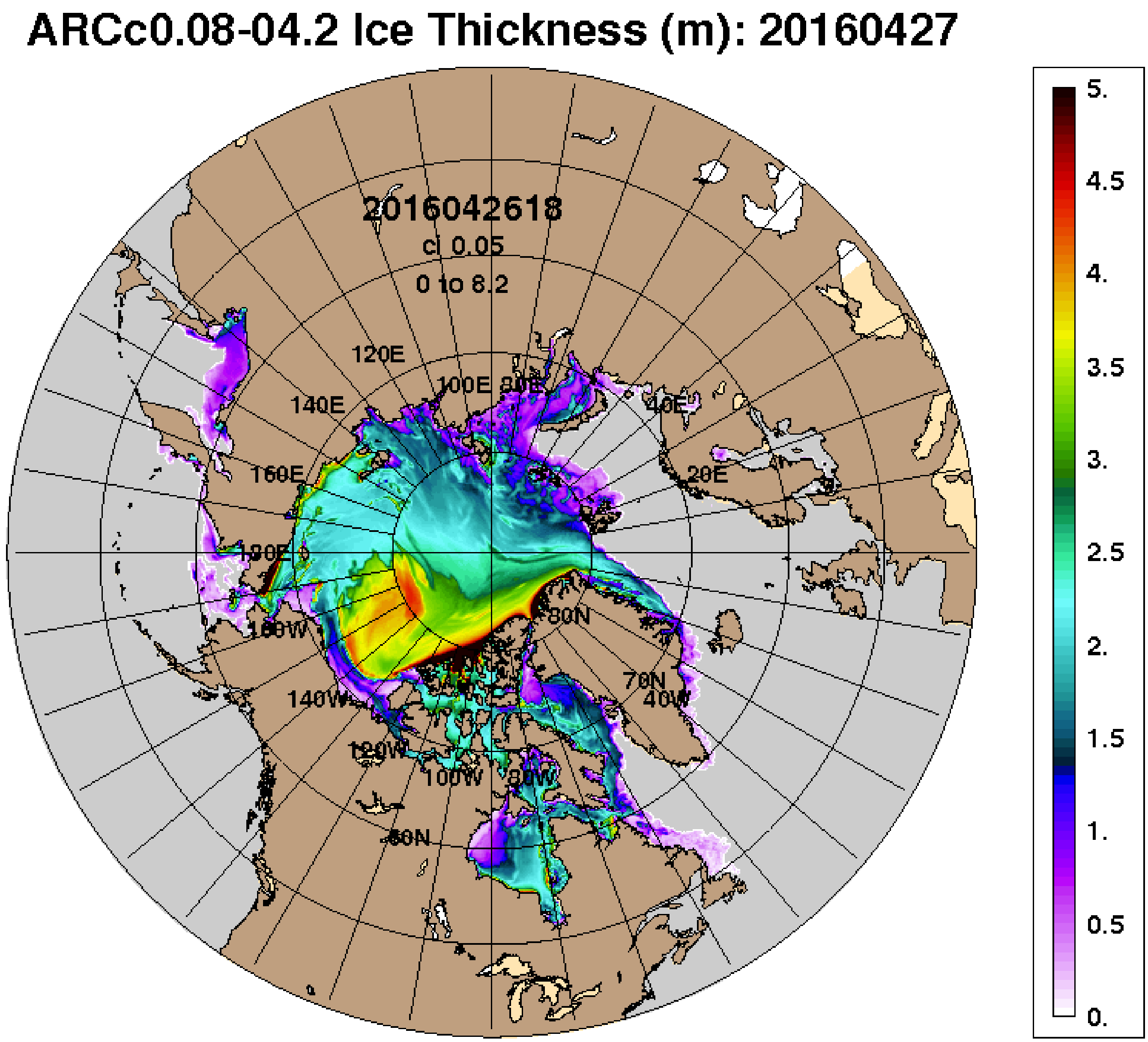
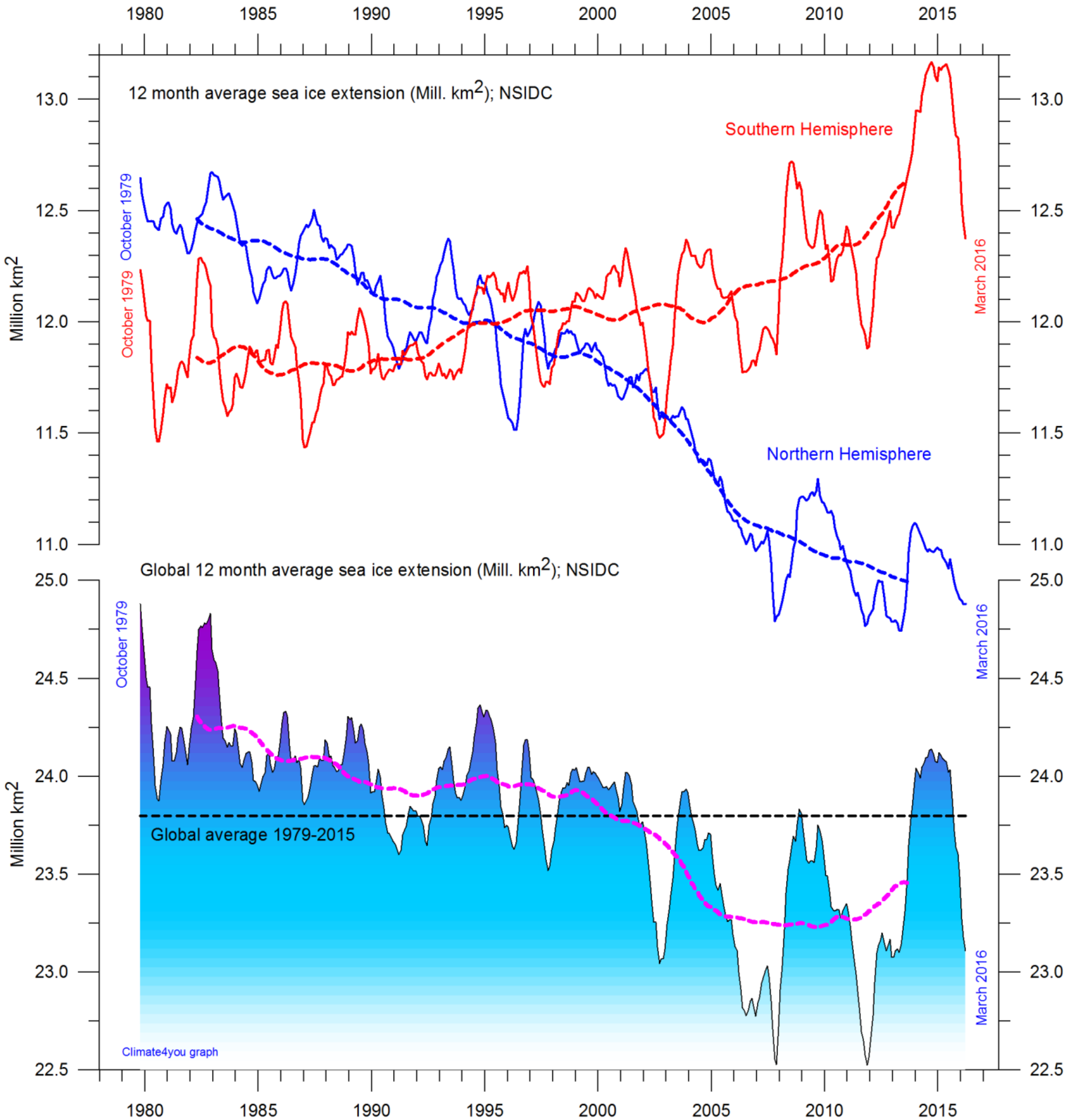


Diagram showing daily Arctic sea ice extent since June 2002, to 30 April 2016, by courtesy of [Japan Aerospace Exploration Agency](#) (JAXA).



Northern hemisphere sea ice extension and thickness on 27 April 2016 according to the Arctic Cap Nowcast/Forecast System (ACNFS), US Naval Research Laboratory. Thickness scale (m) to the right.



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 lateral displacement of water, but only lift the ocean surface locally. 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.

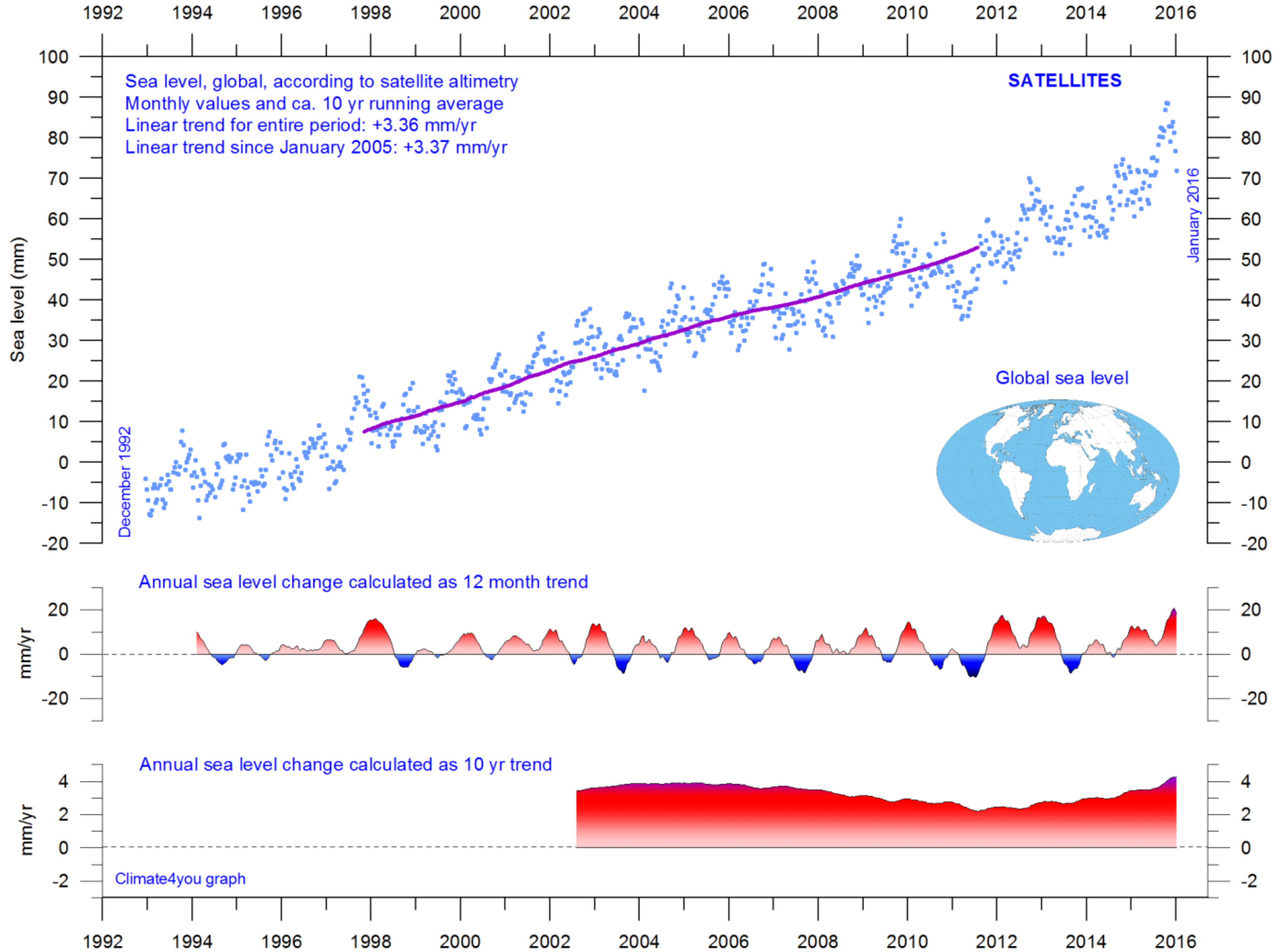
References:

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.pdfHansen, 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.

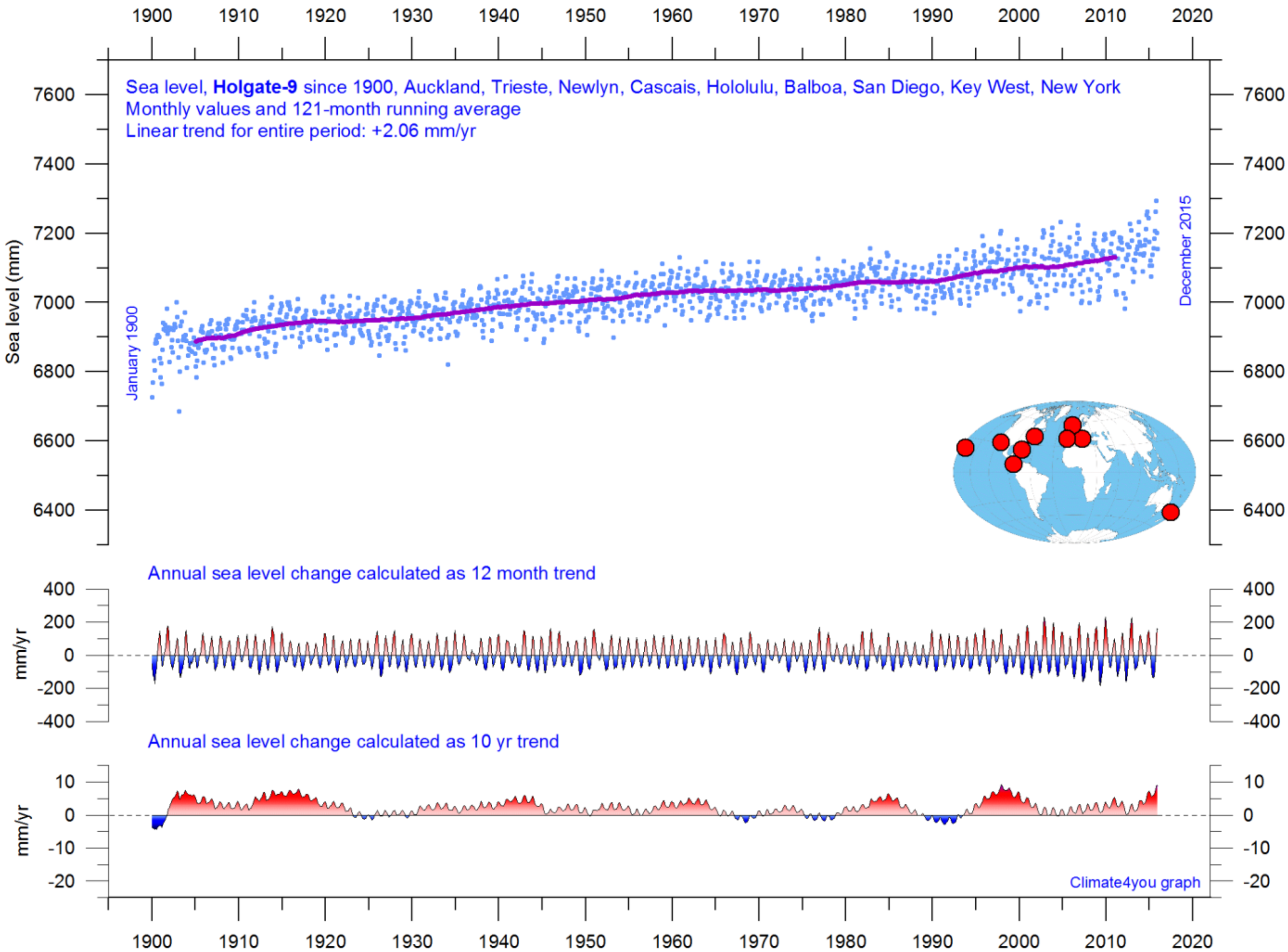
Mörner, Nils-Axel 2015. Sea Level Changes as recorded in nature itself. Journal of Engineering Research and Applications, Vol.5, 1, 124-129.

Global sea level from satellite altimetry, updated to January 2016



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 2015

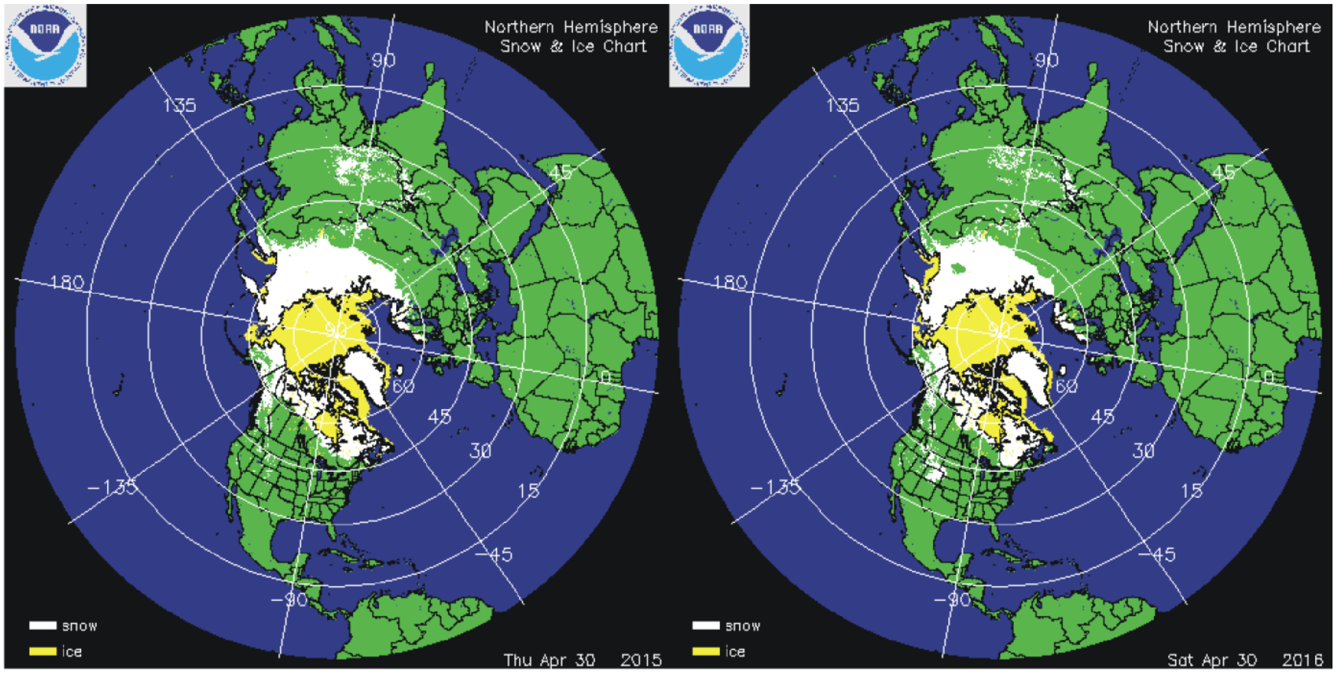


Holgate-9 monthly tide gauge data from PSMSL Data Explorer. Holgate (2007) suggested the nine stations listed in the diagram to capture the variability found in a larger number of stations over the last half century studied previously. For that reason average values of the Holgate-9 group of tide gauge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

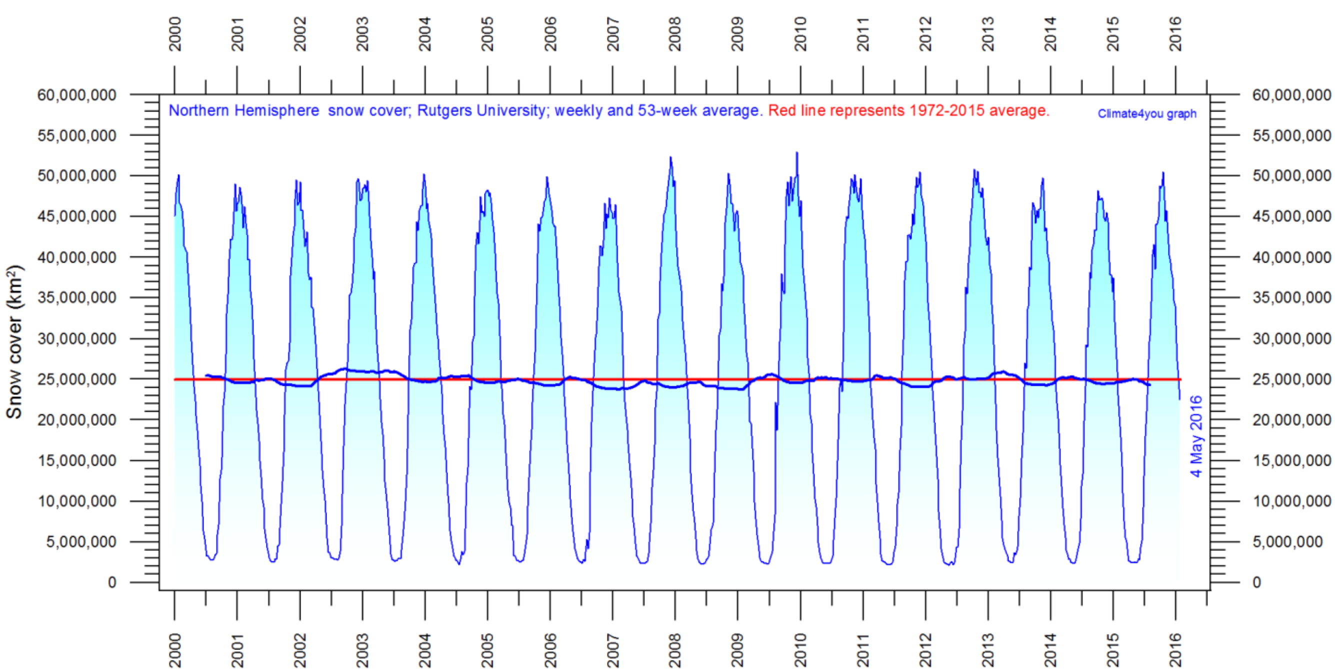
Reference:

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

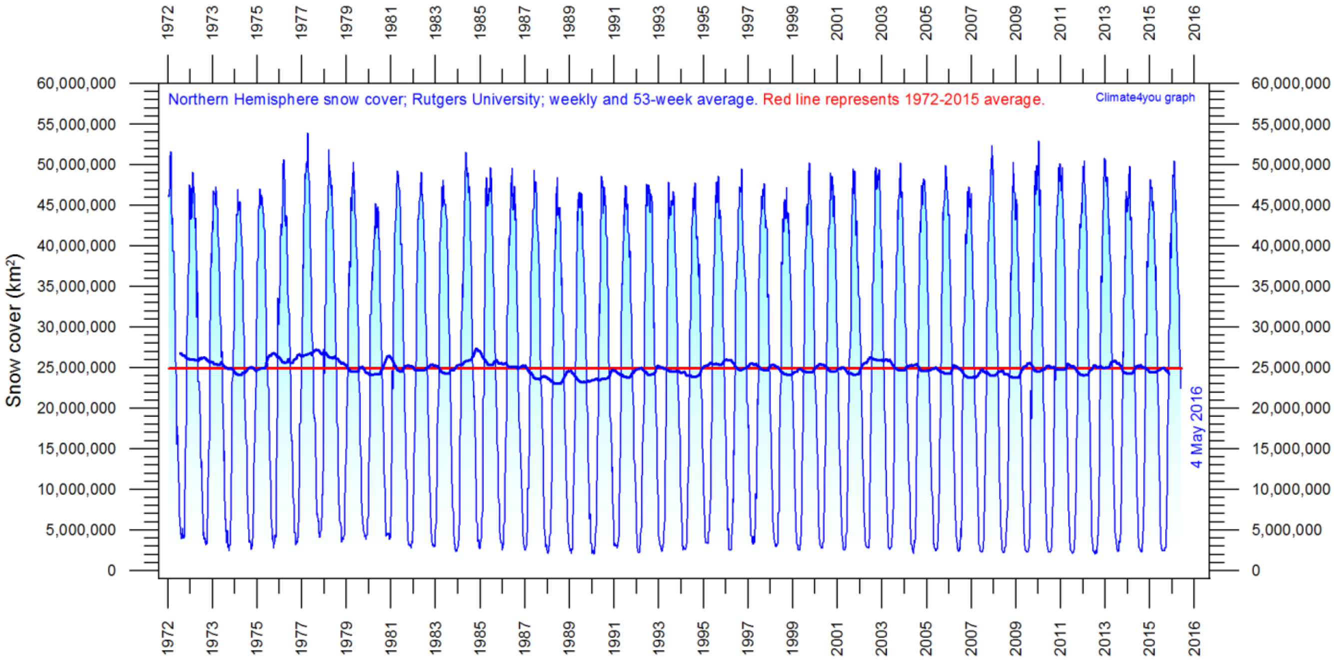
Northern Hemisphere weekly snow cover, updated to April 2016



Northern hemisphere snow cover (white) and sea ice (yellow) 30 April 2015 (left) and 2016 (right). Map source: National Ice Center (NIC).

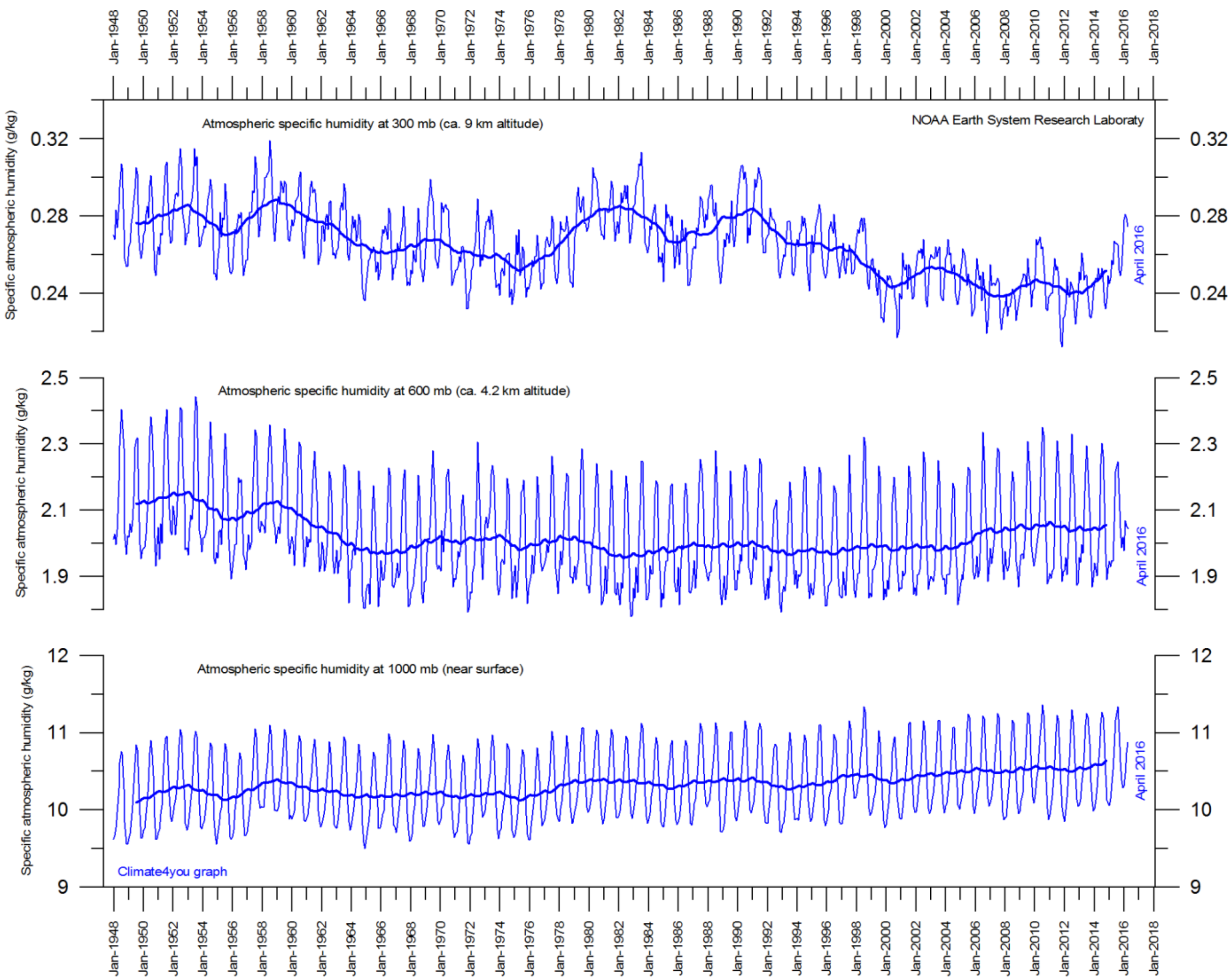


Northern hemisphere weekly snow cover since January 2000 according to Rutgers University Global Snow Laboratory. The thin blue line is the weekly data, and the thick blue line is the running 53-week average (approximately 1 year). The horizontal red line is the 1972-2015 average.



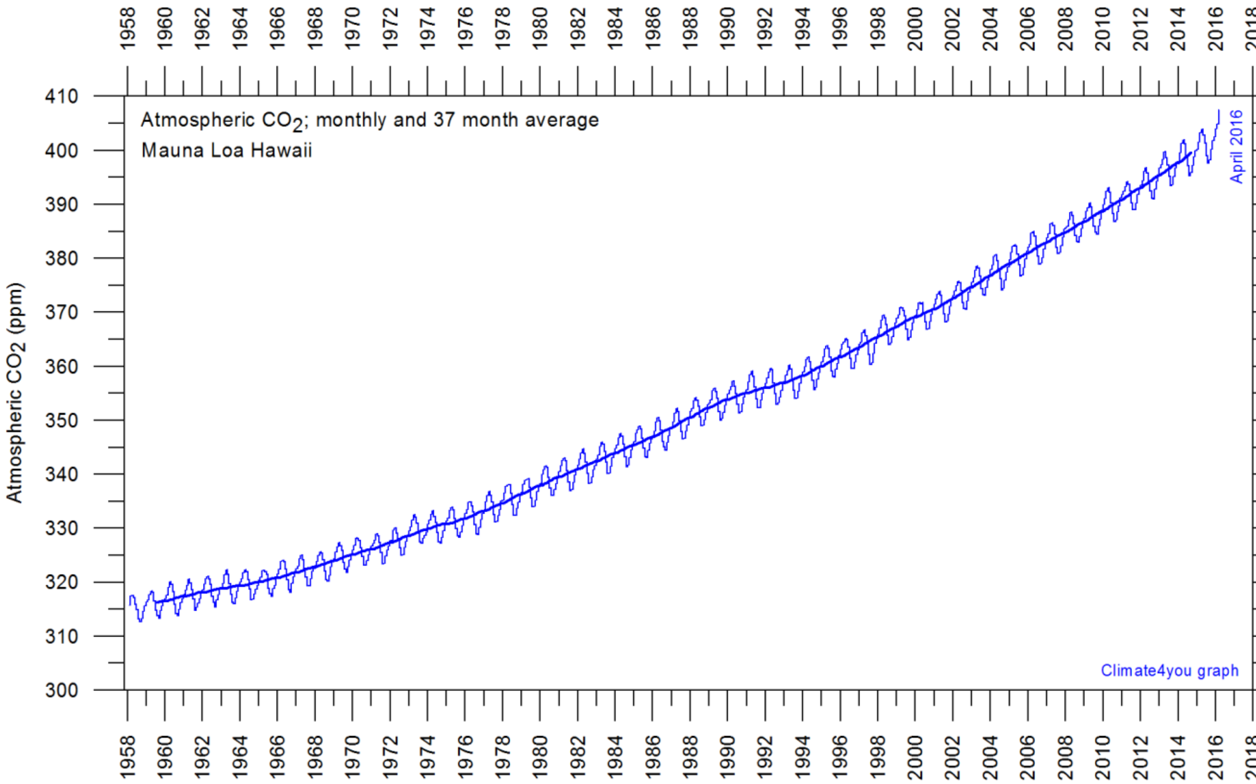
Northern hemisphere weekly snow cover since January 1972 according to Rutgers University Global Snow Laboratory. The thin blue line is the weekly data, and the thick blue line is the running 53-week average (approximately 1 year). The horizontal red line is the 1972-2015 average.

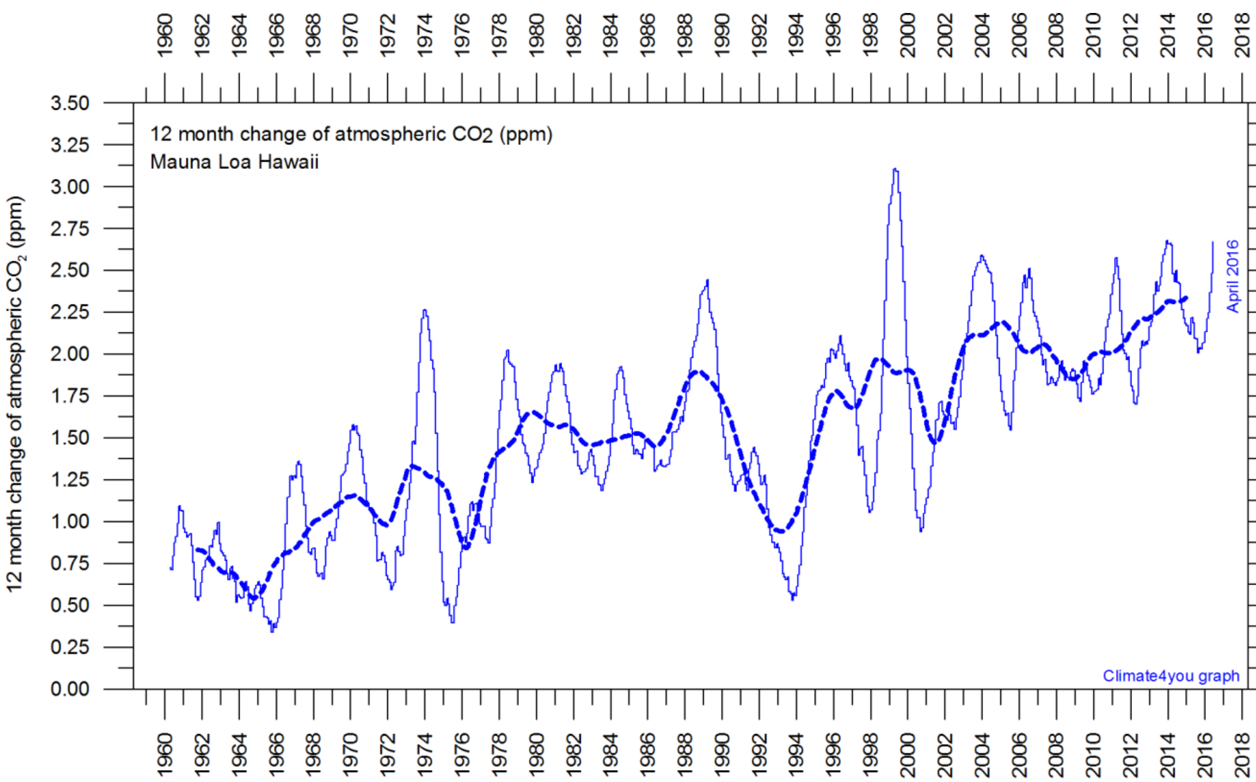
Atmospheric specific humidity, updated to April 2016



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 shows monthly values, while the thick blue lines show the running 37-month average (about 3 years). Data source: Earth System Research Laboratory (NOAA).

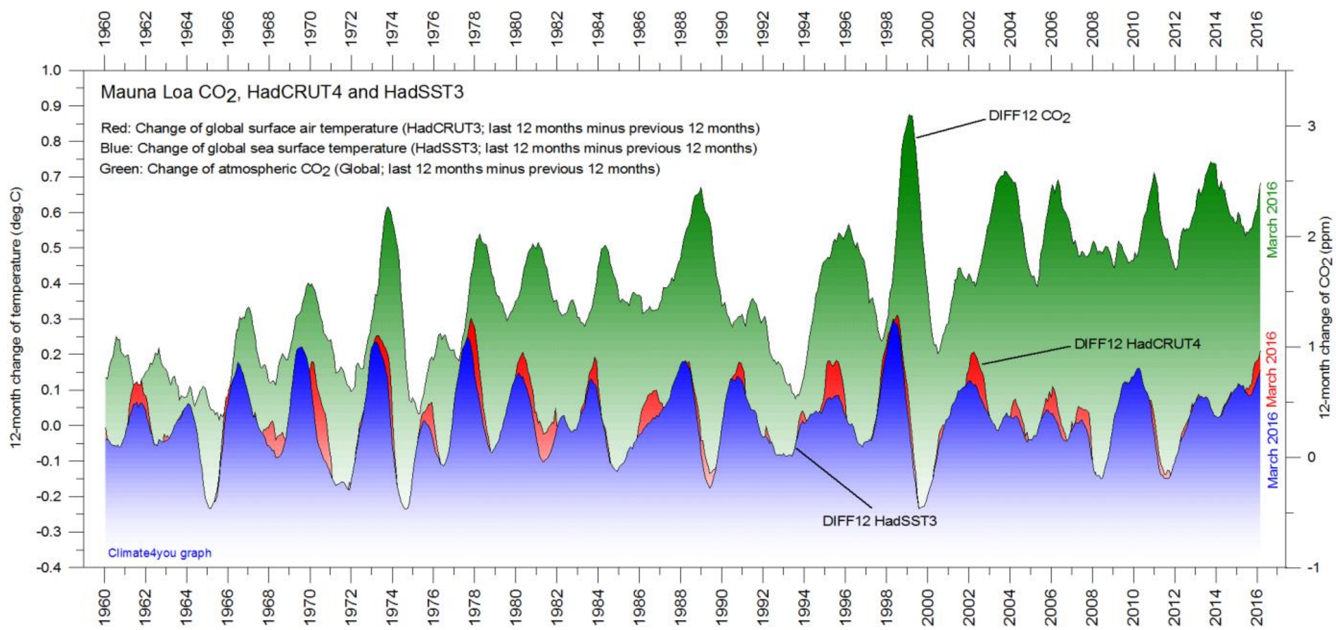
Atmospheric CO_2, updated to April 2016





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 phase relation between atmospheric CO_2 and global temperature, updated to March 2016

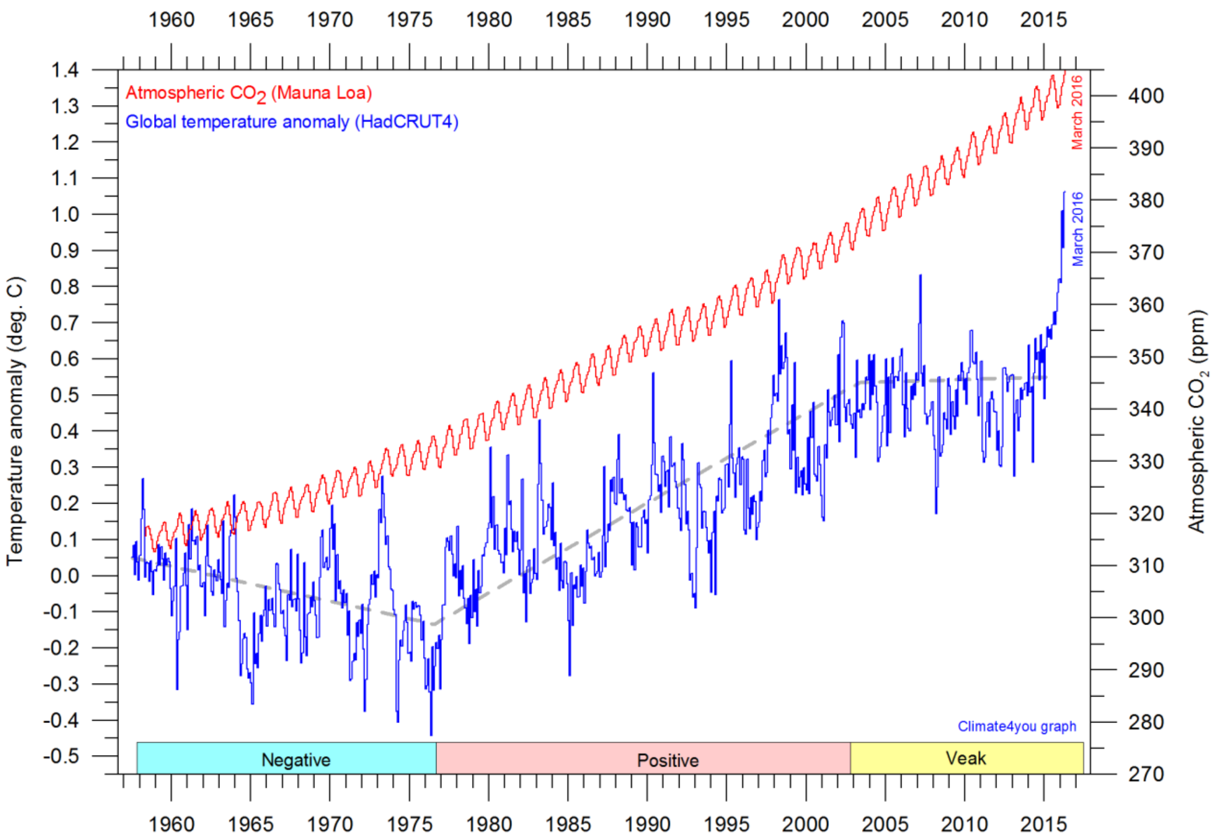


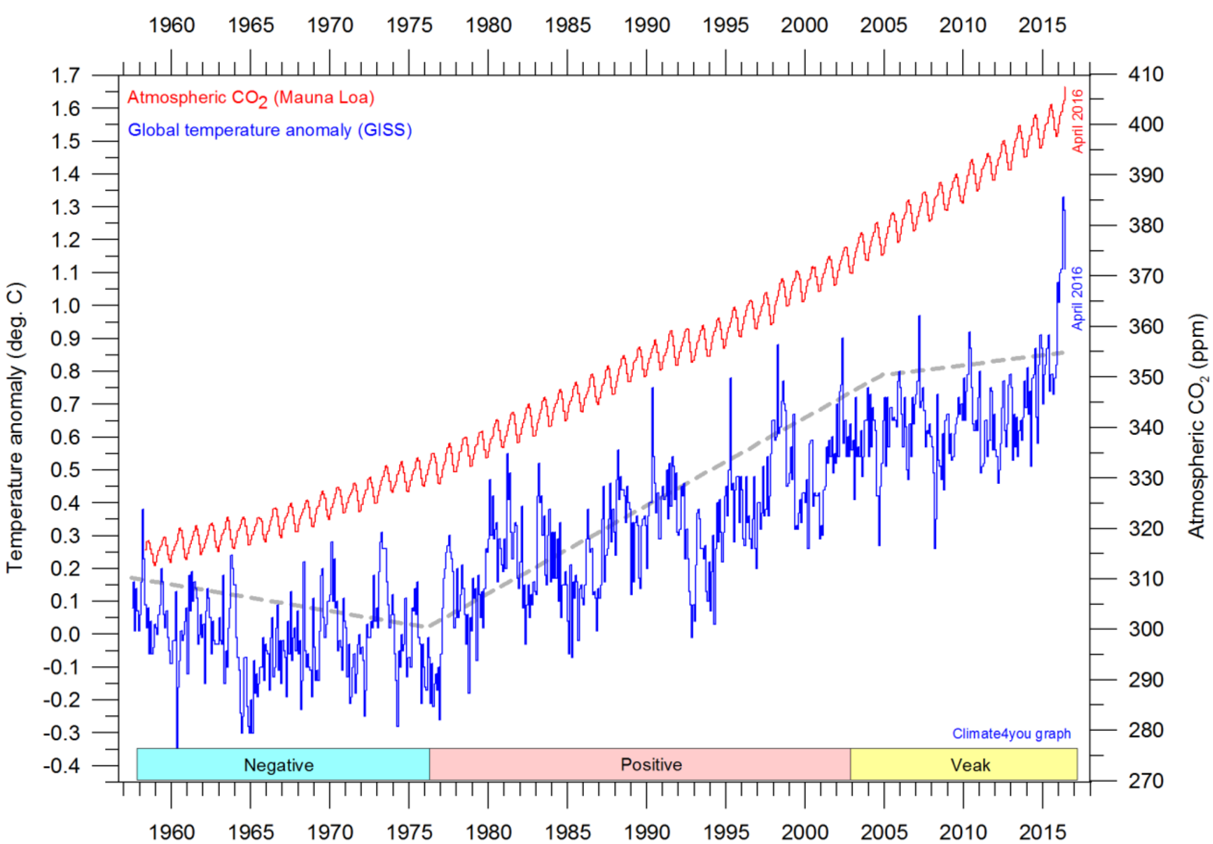
12-month change of global atmospheric CO_2 concentration (Mauna Loa; green), global sea surface temperature (HadSST3; blue) and global surface air temperature (HadCRUT4; red dotted). All graphs are showing monthly values of DIFF12, the difference between the average of the last 12 month and the average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

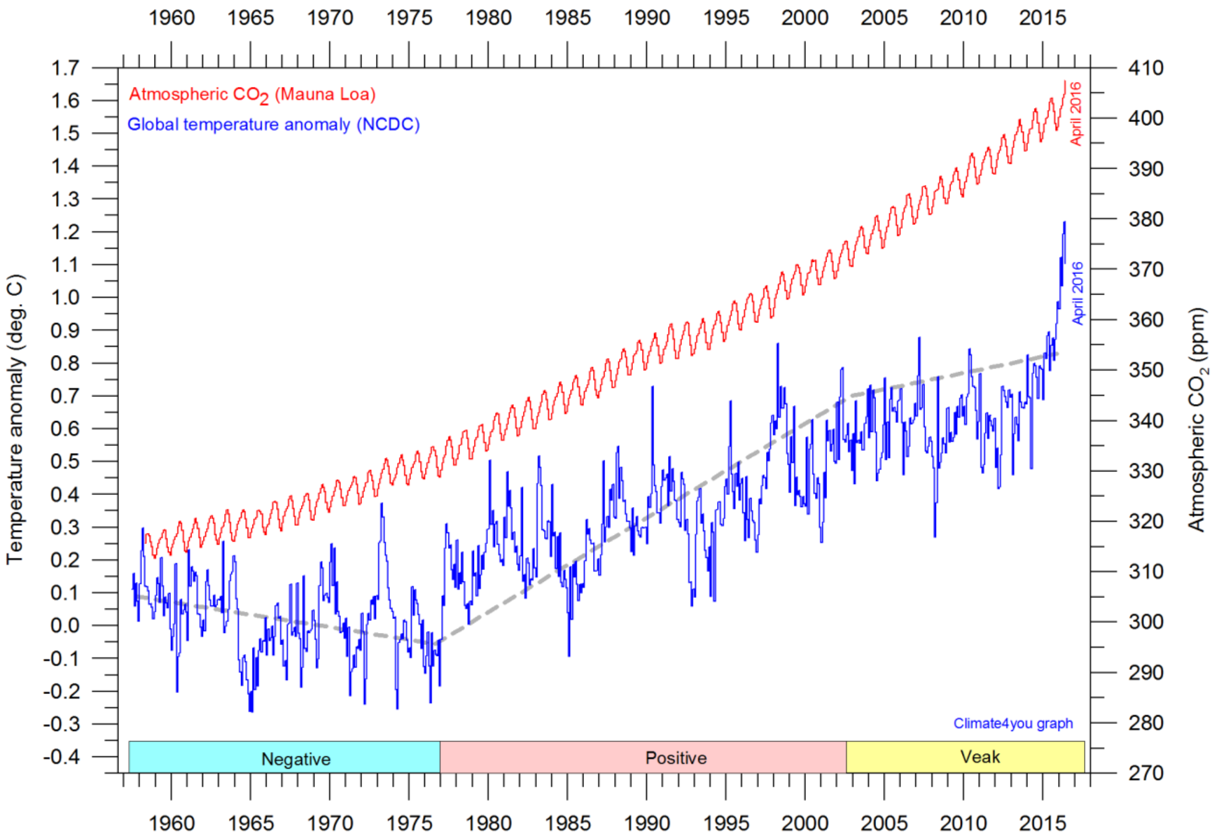
References:

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 surface air temperature and atmospheric CO_2, updated to April 2016







Diagrams showing HadCRUT4, GISS, and NCDC monthly global surface 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 diagrams. 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. Please note that the HadCRUT4 diagram is not yet updated beyond March 2016.

Most climate models assume the greenhouse gas carbon dioxide CO_2 to influence significantly upon 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 period, as other effects (oceanographic, 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.

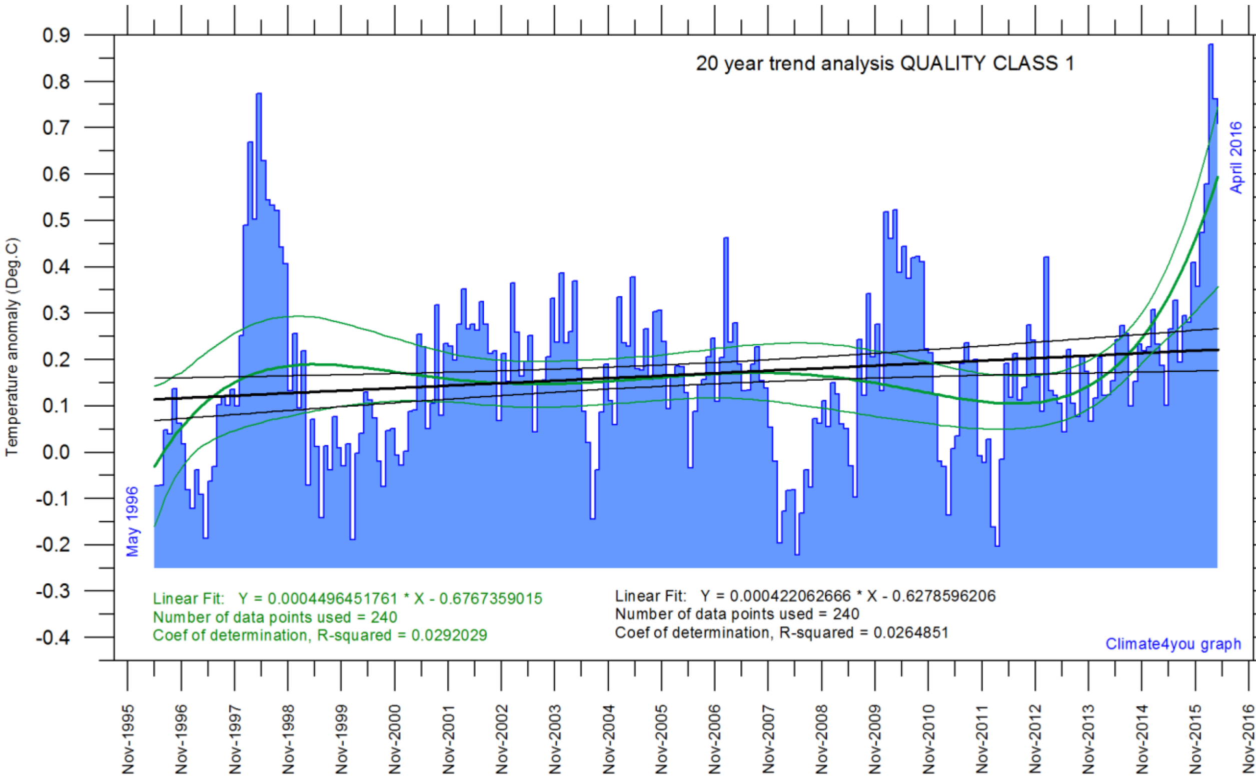
What exactly defines the critical length of a relevant time period to consider for evaluating the alleged importance of CO_2 remains elusive, and still represents a topic for debate. However, the critical period length must be inversely proportional to the temperature sensitivity of CO_2, including feedback effects. If the net temperature effect of atmospheric CO_2 is strong, the critical time 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 in all likelihood was important. Had the global temperature instead been decreasing, politic support for the hypothesis would have been difficult to obtain.

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 sufficient 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.

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 April 2016



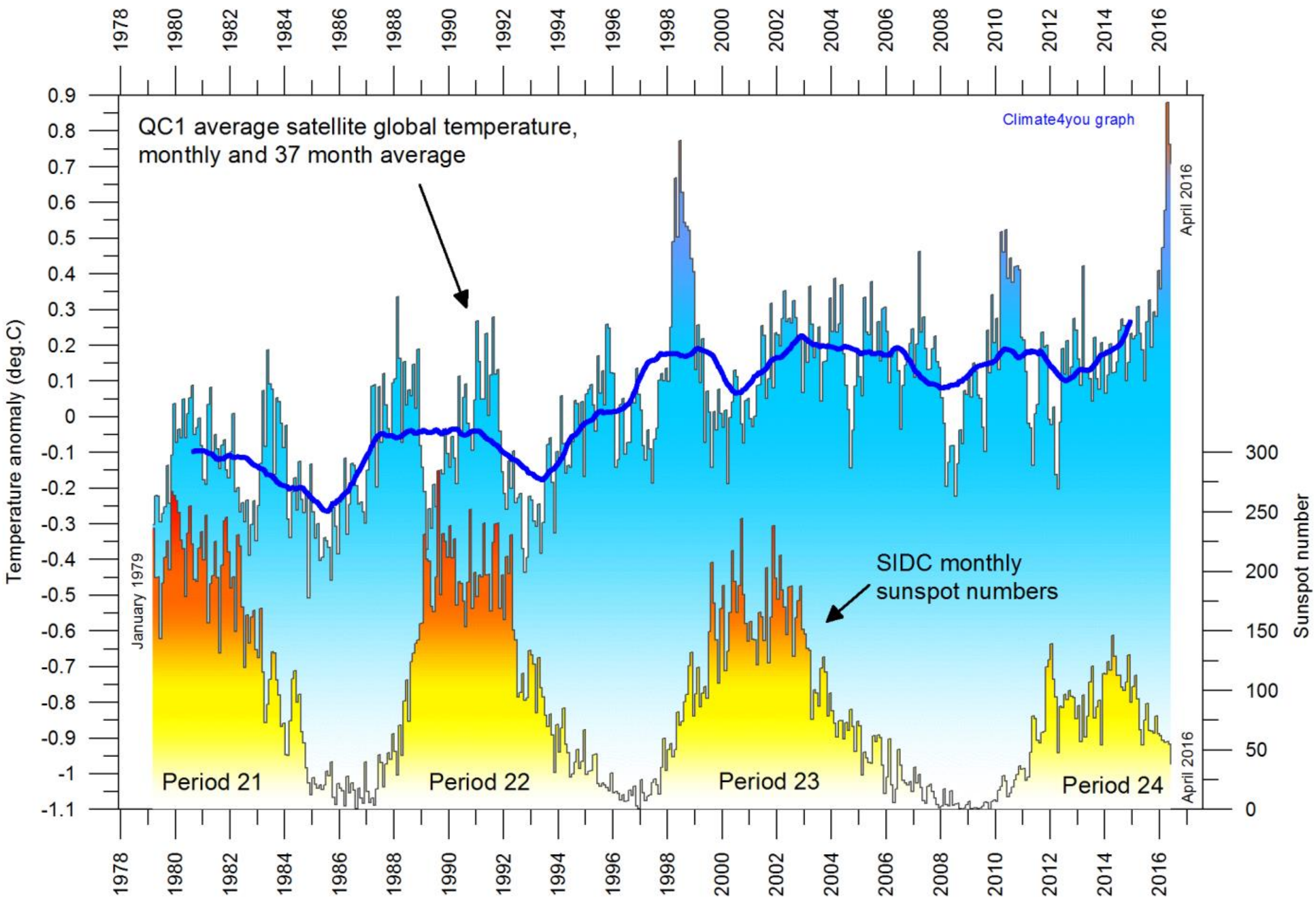
Last 20 years global monthly average air temperature according to Quality Class 1 (UAH and RSS; see p.10) global monthly temperature estimates. The thin blue line represents the monthly values. The thick black line is the linear fit, with 95% confidence intervals indicated by the two thin black lines. 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).

The question if the global surface air temperature still increases, or if the temperature has levelled out during the last 15-18 years, is often mentioned in the current climate debate. The above diagram 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 limited 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 April 2016



Variation of global monthly air temperature according to Quality Class 1 (UAH and RSS; see p.10) 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 yr average. The asymmetrical temperature 'bump' around 1998 is influenced by the oceanographic El Niño phenomenon in 1998.

Climate and history; one example among many

1789-1793: The French Revolution; Part 1

French Jacques-Louis David of the National Assembly taking the Tennis Court Oath on June 20, 1789 (left). The storming of the Bastille July 14, 1789 (right).

The political and socioeconomic nature of the French Revolution in 1789 is disputed among historians. But most historical analyses identify a number of economic factors as being important among the causes of the Revolution.

The French King Louis XV had fought many wars, thereby significantly weakening the French national economy. The country had been virtually bankrupted by first the Seven Years' Was and then the American War. The national debt had grown to huge proportions. The social burdens caused by war included the huge war debt, made worse by the monarchy's military failures and ineptitude, and the lack of social services for war veterans. High unemployment and high bread prices, causing more money to be spent on food and less in other areas of the economy was another important factor for widespread social unrest. In addition, there was widespread resentment of royal absolutism, there was resentment by the ambitious professional and mercantile classes towards noble privileges and dominance in public life, and there was resentment of clerical privilege and aspirations for freedom of religion. And then, of cause, there was the almost total failure of Louis XVI and his advisors to deal effectively with any of these problems.

Widespread famine and malnutrition among the most dissatisfied groups of the French population in the months immediately before the Revolution were presumably the single igniting factor. Since the huge Laki volcanic eruption in Iceland 1784-1785 summers had been cool in Europe and harvest poor. It was however in France, that several of the following weather extremes seem to have been most serious. 1785 produced the coldest March recorded in much of Europe, and extended what was already an outstandingly severe winter. This was followed by a year of drought, with only 67 per cent of the expected annual precipitation falling in Paris (Lamb 1995). This resulted in a forage crisis on the French farms, and many cattle had to be slaughtered. The French peasants at that time ate bread made of rye or oats, and only the upper classes were able to afford wheaten bread. Even so the dearth produced by the failing harvest meant that about 55 per cent of the poorer classes' earnings went on bread alone. To make things even worse, in 1789 the price for bread was increased from 8 to 14 sous. This caused widespread dissatisfaction, to put it mildly.

In 1786 the French government ran out of ready access to lenders, and the minister of finance was forced to inform Louis XVI that the situation could only be corrected by imposing taxes. In 1787 Louis XVI's therefore attempted to solve the worsening financial situation by introducing a new land tax that would, for the first time, include a tax on the property of nobles and clergy, instead of the poor classes. These rich groups were, however, not entirely happy with this initiative. In fact, the attempt to raise taxes provoked a furious outcry from the men of property, in particular, the nobility. The direct cause of the French Revolution was thus not the state's attack on the poor, but on the rich.

After bitter exchanges, the King was forced to Summon the Estates-General, a kind of national assembly of the three estates, which had last been convened at the beginning of the 17th century, to get his way (Harvey 2006). In the time leading up to the planned convention in 1788 there was growing concern that the King and the government would attempt to fix an assembly to its liking. To avoid this, the Parliament of Paris proclaimed that the Estates-General would have to meet according to the forms observed at its last meeting, without any changes. In addition, there was discussions about how to vote. Fuelled by such disputes, resentment between the elitists and the liberals began to grow.

Things were now beginning taking their own course, driven by peoples feeling of injustice. The assembly, now meeting as the Communes (English: "Commons"). On the 17 June they declared themselves the National Assembly, an assembly not of the Estates but of "the People." They invited the other orders to join them, but made it clear they intended to conduct the nation's affairs with or without them.

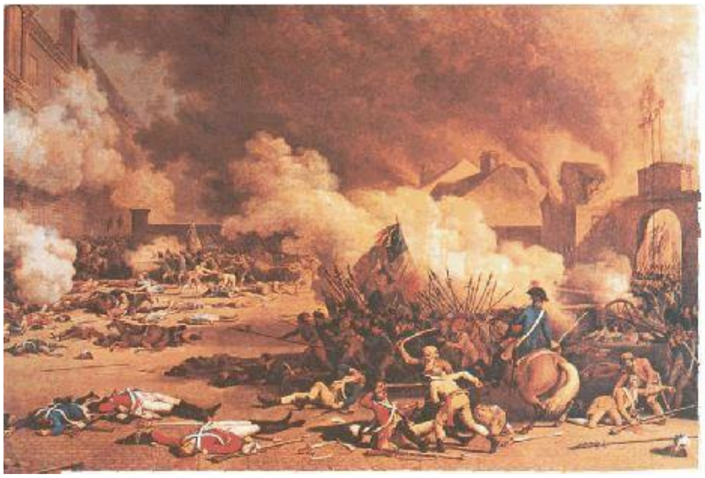
In an attempt to put a brake on this threatening development Louis XVI tried to prevent the Assembly from convening by ordered the closure of the Salle des États where the Assembly met. The official excuse was that the carpenters needed to prepare the hall for a royal speech in two days. The cool and wet summer did not encourage the Assembly to conduct an outdoor meeting, so it was decided to move the deliberations to a nearby indoor tennis court. This is where the famous Tennis Court Oath was given on June 20, 1789. It was decided not to end the meeting before they had given France a constitution. Most of the representatives of the clergy soon joined the meeting, as did 47 members of the nobility. Messages of support for the Assembly poured in from Paris and other French cities. On 9 July the Assembly reconstituted itself as the National Constituent assembly.

By this time, Jaques Necker was in his second turn as finance minister. To calm public feelings, he suggested that that the royal family should live according to a more modest budget than hitherto. Louis XVI was, however, not inclined to follow this suggestion and fired Necker. The following day (July 12) he completely reorganised the finance ministry.

Many Parisians presumed Louis's actions to be the start of a royal coup by the conservatives and began open rebellion when they heard the news the next day. They were also afraid that arriving Royal soldiers had been summoned to shut down the National Constituent Assembly, which was meeting at Versailles. The Assembly went into non-stop session to prevent eviction from their meeting place. Paris was soon consumed with riots, anarchy, and widespread looting.

On July 14, 1789, the insurgents set their eyes on the weapons and ammunition depots inside the Bastille fortress, which also was a symbol of tyranny by the monarchy. After several hours of combat, the prison fell in the afternoon. Rumours were that a high number of political prisoners was held here, but only seven prisoners was found, among them two noblemen kept for immoral behaviour, and one murder suspect.

Confronted with this rapid development, the King and his military supporters sensibly backed down and attempted to reconciliate with the people. The president of the Assembly at the time of the Tennis Court Oath became the city's mayor under a new governmental structure known as the commune. On October 6, 1789, the King and the royal family moved from Versailles to Paris under the protection of the National Guards, thus legitimising the National Assembly.

The Paris Commune and the storming of the Tuileries Palace on August 10, 1792 (left). The return of the royal family to Paris on June 25, 1791, coloured copperplate after a drawing of Jean-Louis Prieur (right).

Many French nobles, however, were not impressed by this apparent reconciliation of King and people. They began to flee the country, some of whom began plotting civil war within the kingdom and agitating for a European coalition against France.

The Revolution also brought about a massive shifting of powers from the Roman Catholic Church to the state, and the remaining clergy was turned into employees of the State and required to take an oath of loyalty to the constitution. The pope never accepted the new arrangement, and it led to a schism between those clergies who swore the required oath and accepted the new arrangement and those who refused to do so.

In late 1790, several small counter-revolutionary uprisings broke out and futile efforts took place to turn all or part of the army against the Revolution. The French army, however, faced considerable internal turmoil. The new military code, under which promotion depended on seniority and proven competence (rather than on nobility) alienated some of the existing officer corps, who left the country or became counter-revolutionaries from within.

Louis XVI was basically opposed to the course of the Revolution, and on the night of 20 June 1791 the royal family fled from Paris disguised as servants, while their servants were dressed as nobles. However, the next day the King was recognised and arrested, and with his family paraded back to Paris under guard, still dressed as servants. Back in Paris, the Assembly provisionally suspended the King, which together with Queen Marie Antoinette remained held under guard.

On the night of 10 August 1792, insurgents, supported by a new revolutionary Paris Commune, assailed the Tuileries, where the royal family was held. The King and queen ended up prisoners, and a short meeting in the Legislative Assembly suspended the monarchy. On September 20, 1792, the monarchy was officially abolished and France declared a republic.

Louis XVI were accused of being conspiring with the enemies of France, and on January 17, 1793 he was condemned to death for "conspiracy against the public liberty and the general safety" by a close majority in the now ruling Convention. The execution was carried out 21 January, which lead to declarations of war from several European countries. Queen Marie Antoinette was executed on 16 October 1793.

References:

Lamb, H.H. 1995. *Climate, History and the Modern World.* Routledge, London, 2nd edition, 433 pp.

Harvey, R. 2006. *The Wars of Wars. The epic struggle between Britain and France 1789-1815*. Constable & Robinson Ltd., London, 962 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@geo.uio.no)

May 20, 2016.