

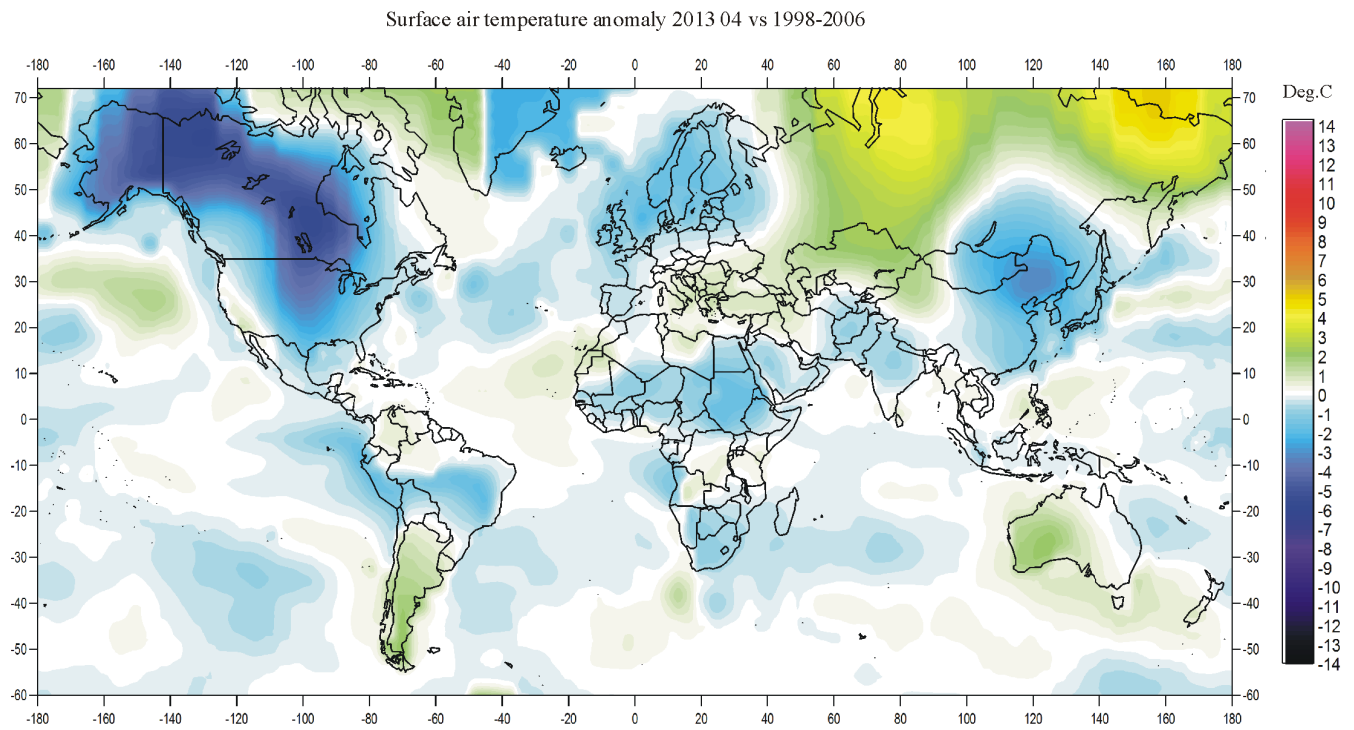
Climate4you update April 2013



Contents:

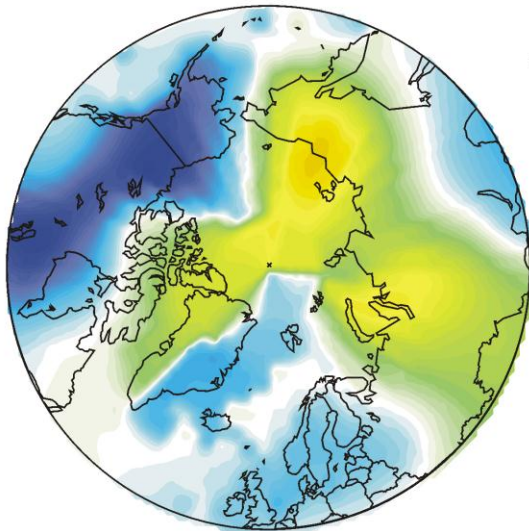
Page 2:	April 2013 global surface air temperature overview
Page 3:	Comments to the April 2013 global surface air temperature overview
Page 4:	Lower troposphere temperature from satellites
Page 5:	Global surface air temperature
Page 9:	All in one
Page 10:	Global sea surface temperature
Page 13:	Global ocean heat content uppermost 700 m
Page 14:	North Atlantic heat content uppermost 700 m
Page 15:	Zonal lower troposphere temperatures from satellites
Page 16:	Arctic and Antarctic lower troposphere temperatures from satellites
Page 17:	Arctic and Antarctic surface air temperatures
Page 20:	Arctic and Antarctic sea ice
Page 22:	Global sea level
Page 23:	Northern Hemisphere weekly snow cover
Page 24:	Atmospheric CO ₂
Page 25:	Global surface air temperature and atmospheric CO ₂
Page 28:	Last 20 year monthly surface air temperature change
Page 29:	Climate and history; one example among many. <i>May 1941: Circumnavigating a storm centre; Bismarck's sortie into the North Atlantic</i>

April 2013 global surface air temperature overview

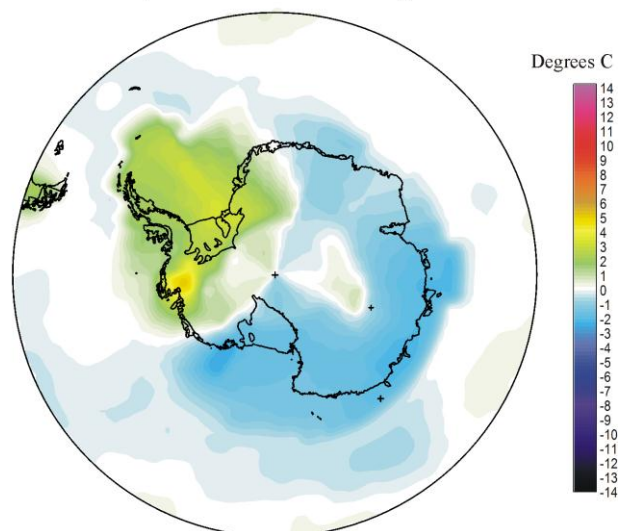


2

Air temperature 201304 versus average 1998-2006



Air temperature 201304 versus average 1998-2006



April 2013 surface air temperature compared to the average 1998-2006. Green-yellow-red colours indicate areas with higher temperature than the 1998-2006 average, while blue colours indicate lower than average temperatures. Data source: [Goddard Institute for Space Studies](#) (GISS)

Comments to the April 2013 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 period 1998-2006 is 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 affected by the relatively cold period 1945-1980. Almost any comparison with such a low average value will therefore appear as high or warm, and it will be difficult to decide if and where modern surface air temperatures are increasing or decreasing at the moment. Comparing with a more recent period overcomes this problem. In addition to this consideration, the recent temperature development suggests that the time window 1998-2006 may roughly represent a global temperature peak. If so, negative temperature anomalies will gradually become more and more widespread as time goes on. However, if positive anomalies instead gradually become more widespread, this reference period only represented a temperature plateau.

In the other diagrams 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 records have a much

longer record length, which may be inspected in greater detail on www.Climate4you.com.

April 2013 global surface air temperatures

General: On average, global air temperatures were somewhat below the 1998-2006 average, although with large regional differences

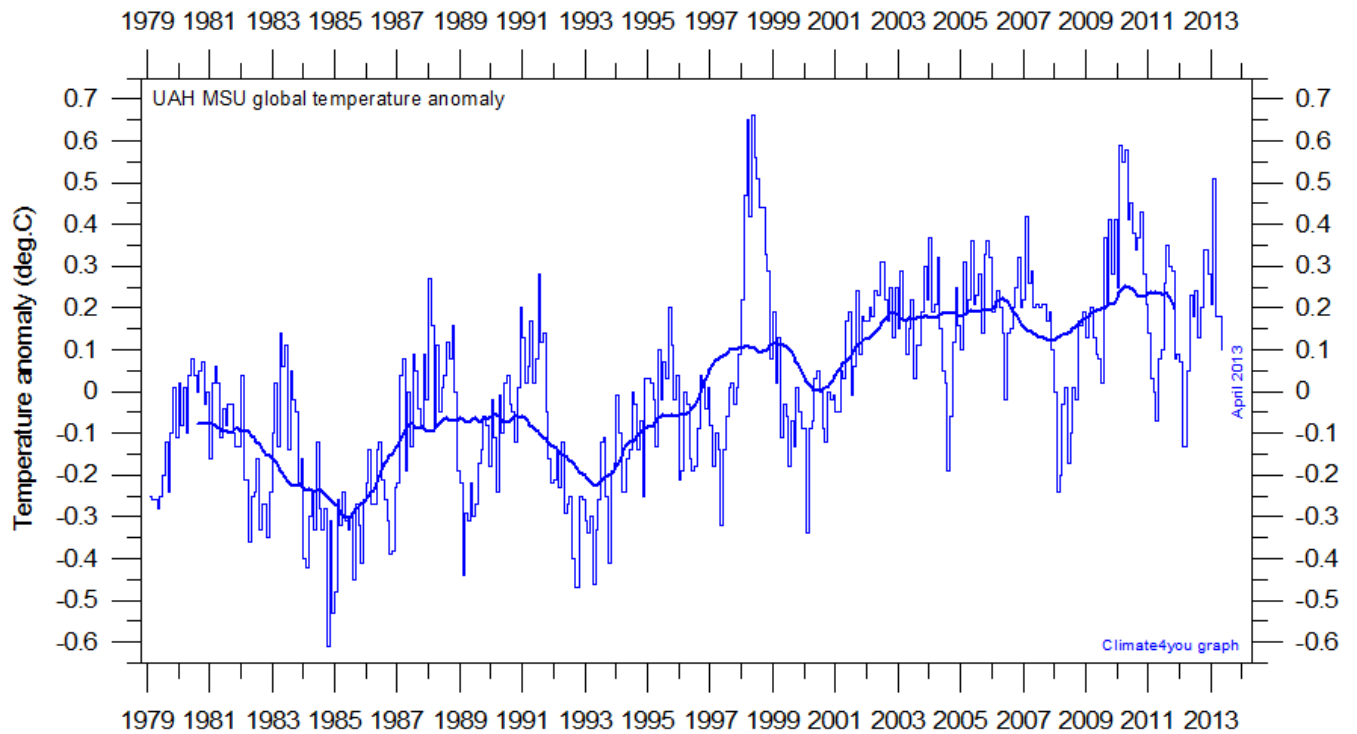
The Northern Hemisphere was characterised by big temperature contrast between individual regions. Most of North America, Europe and China experienced below average temperatures, while major parts of Russia and Siberia were relatively warm. Especially North America was unseasonally cold. Parts of the Arctic had below average temperatures, while other parts had above average temperatures. The marked limit between warm and cold areas along the axis of the Greenland Ice Sheet represents an artefact derived from the GISS interpolation technique and should not be over interpreted.

Near Equator temperatures conditions were near or below the 1998-2006 average.

The Southern Hemisphere was mainly at or below average 1998-2006 conditions. The only important exception from this was West Australia and southern South America, which experienced temperatures slightly above the 1998-2006 average. The Antarctic continent generally experienced below average temperatures, although large regions around the Antarctic Peninsula and adjoining parts of West Antarctica were relatively warm.

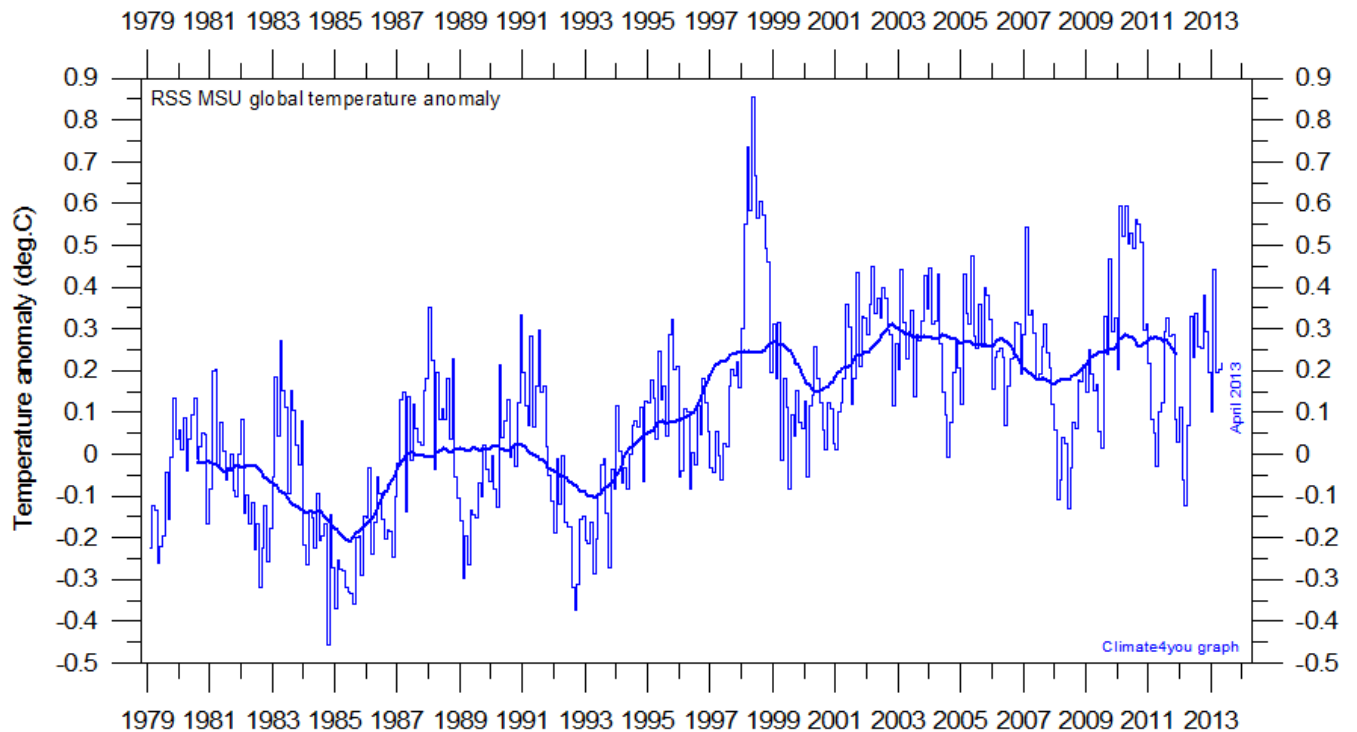
The global oceanic heat content has been rather stable since 2003/2004 (page 13).

Lower troposphere temperature from satellites, updated to April 2013



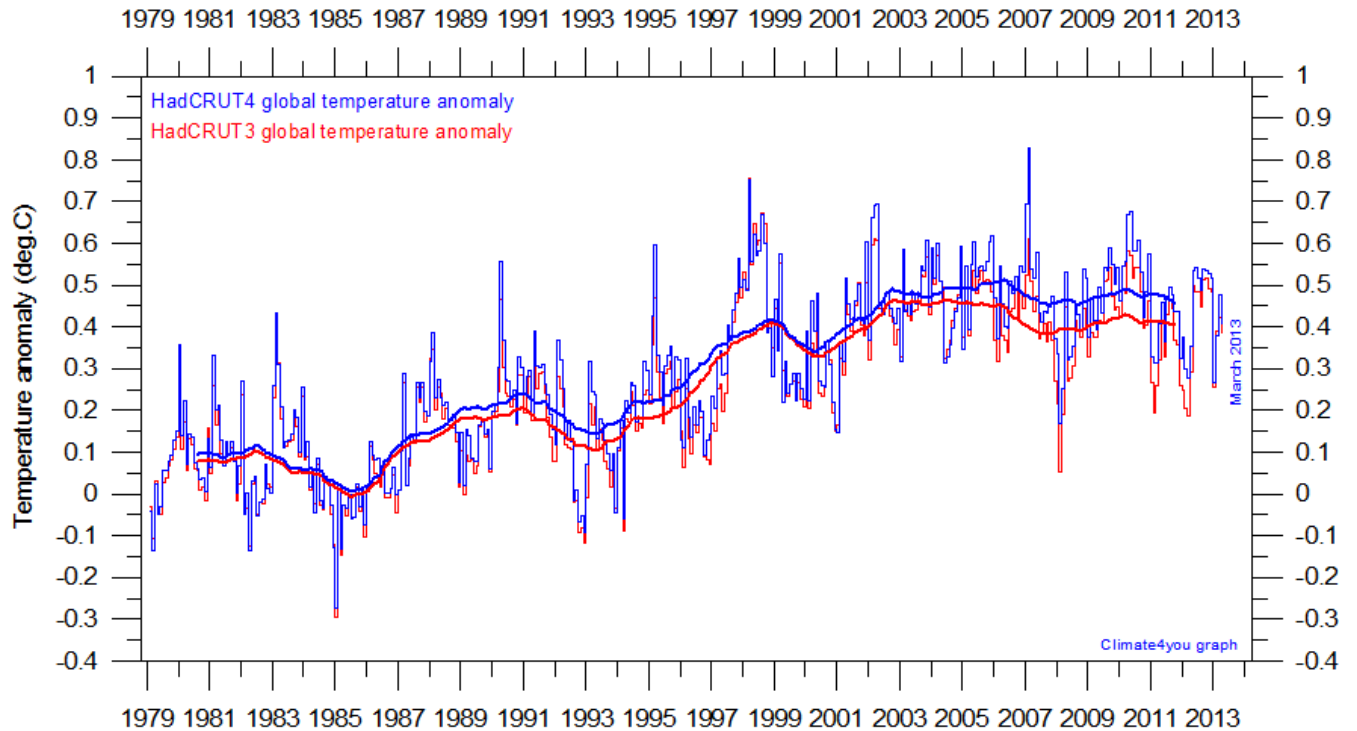
Global monthly average lower troposphere temperature (thin line) since 1979 according to [University of Alabama](#) at Huntsville, USA. The thick line is the simple running 37 month average.

4



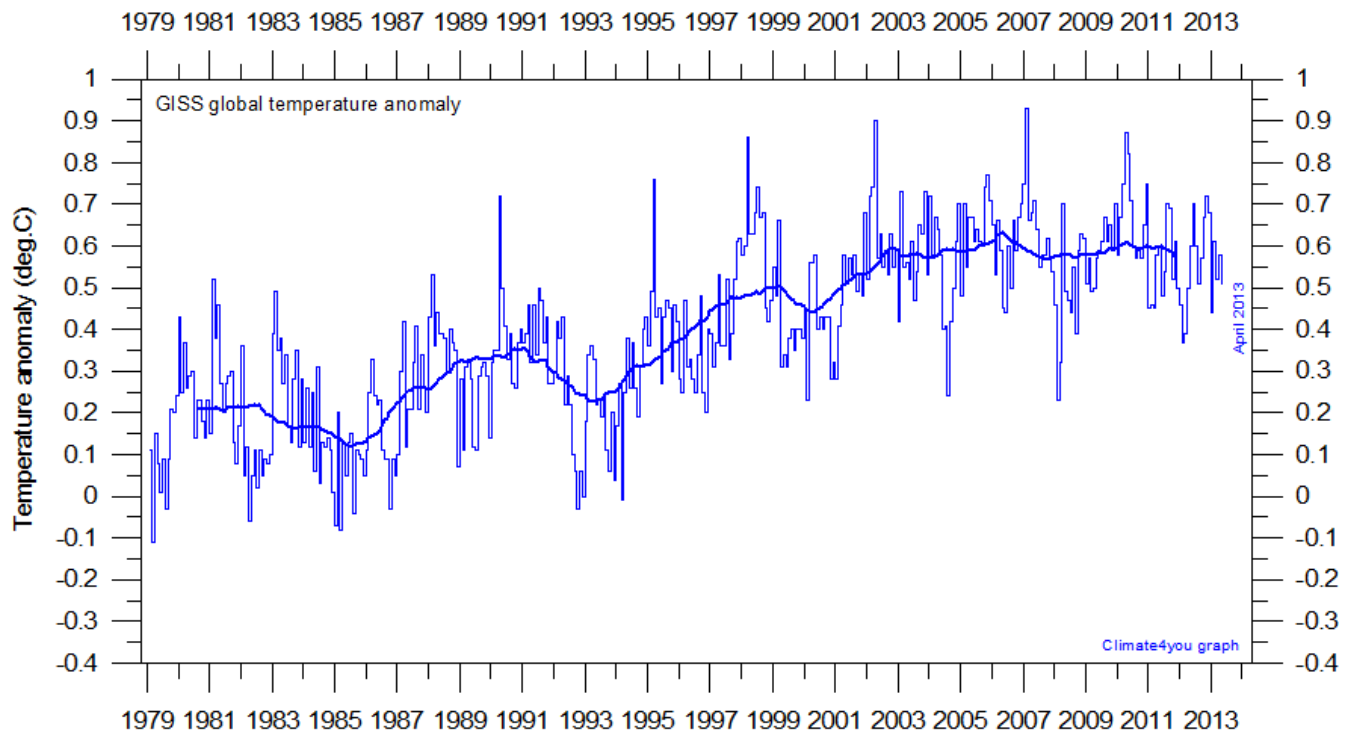
Global monthly average lower troposphere temperature (thin line) since 1979 according to according to [Remote Sensing Systems](#) (RSS), USA. The thick line is the simple running 37 month average.

Global surface air temperature, updated to April 2013

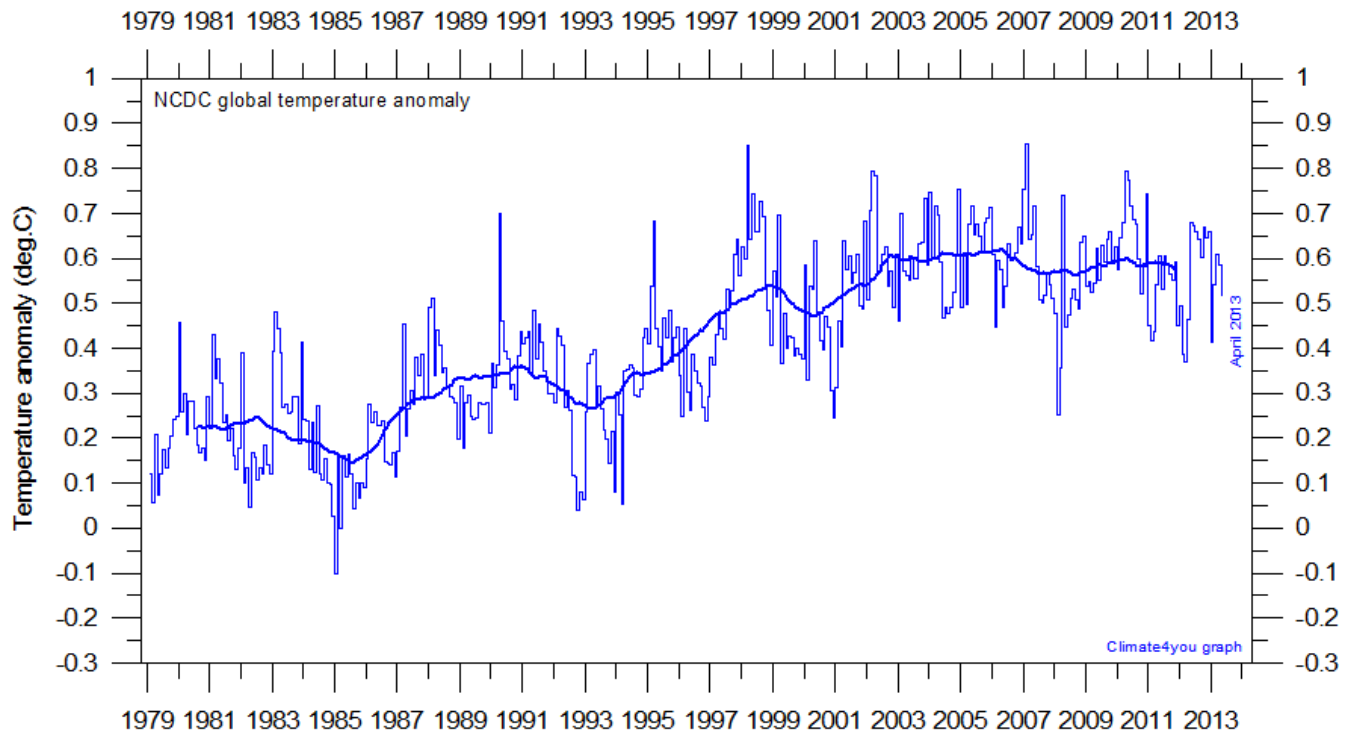


Global monthly average surface air temperature (thin line) since 1979 according to according to the Hadley Centre for Climate Prediction and Research and the University of East Anglia's [Climatic Research Unit \(CRU\)](#), UK. The thick line is the simple running 37 month average. Version HadCRUT4 (blue) is now replacing HadCRUT3 (red). Please note that this diagram has not been updated beyond March 2013.

5



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. 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](http://www.ncdc.noaa.gov) (NCDC), USA. The thick line is the simple running 37 month average.

A note on data record stability:

All the above temperature estimates display changes when one compare with previous monthly data sets, not only for the most recent months as a result of supplementary data being added, but actually for all months back to the very beginning of the records. Presumably this reflects recognition of errors, changes in the averaging procedure, and the influence of other phenomena.

None of the temperature records are stable over time (since 2008). The two surface air temperature records, NCDC and GISS, show apparent systematic changes over time. This is exemplified the diagram on the following page showing the changes since May 2008 in the NCDC global surface temperature record for January 1915 and January 2000, illustrating how the difference between the early and late part of the temperature records gradually is growing by administrative means.

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

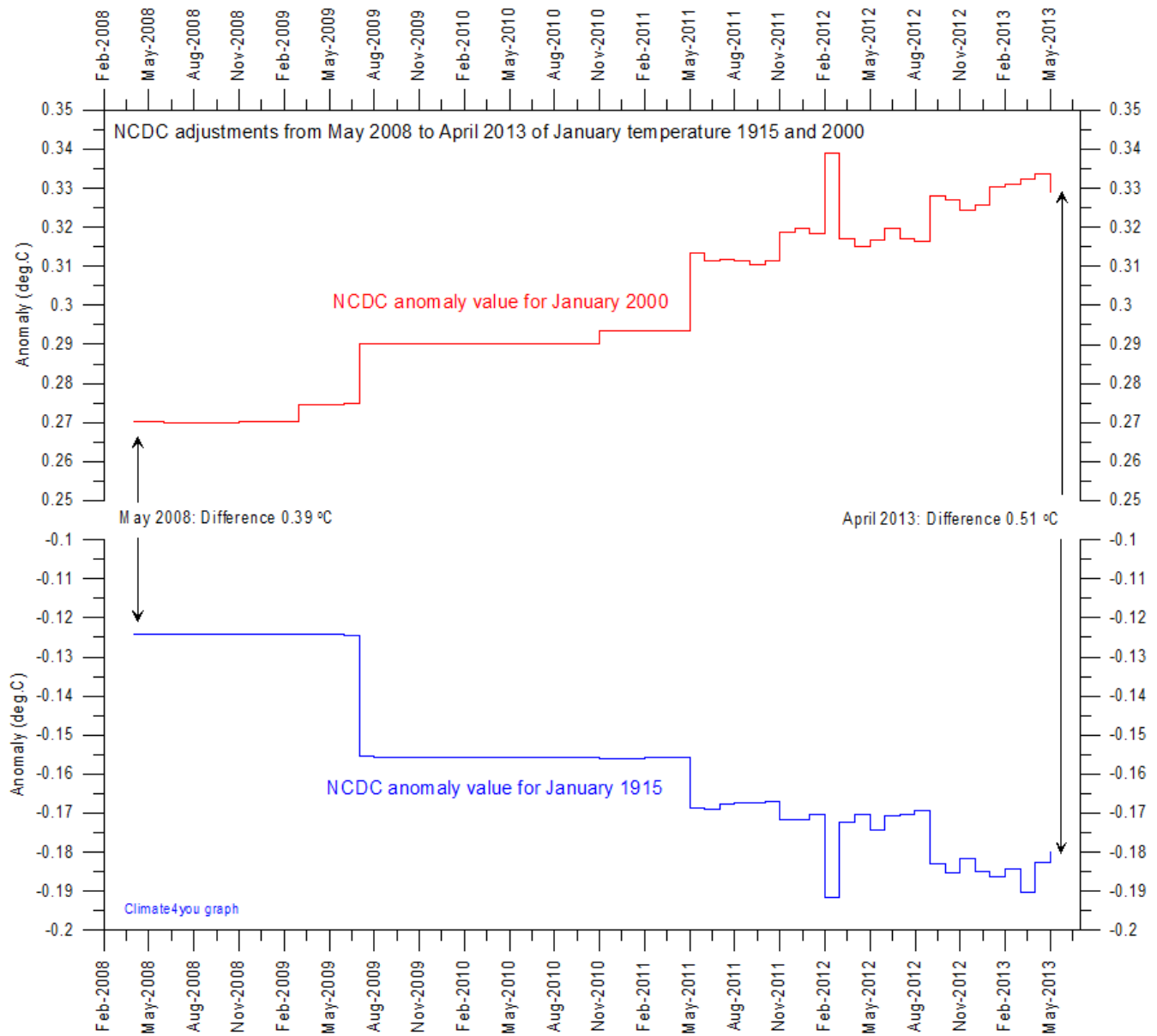


Diagram showing the adjustment made since May 2008 by the [National Climatic Data Center](#) (NCDC) in the anomaly values for the two months January 1915 and January 2000.

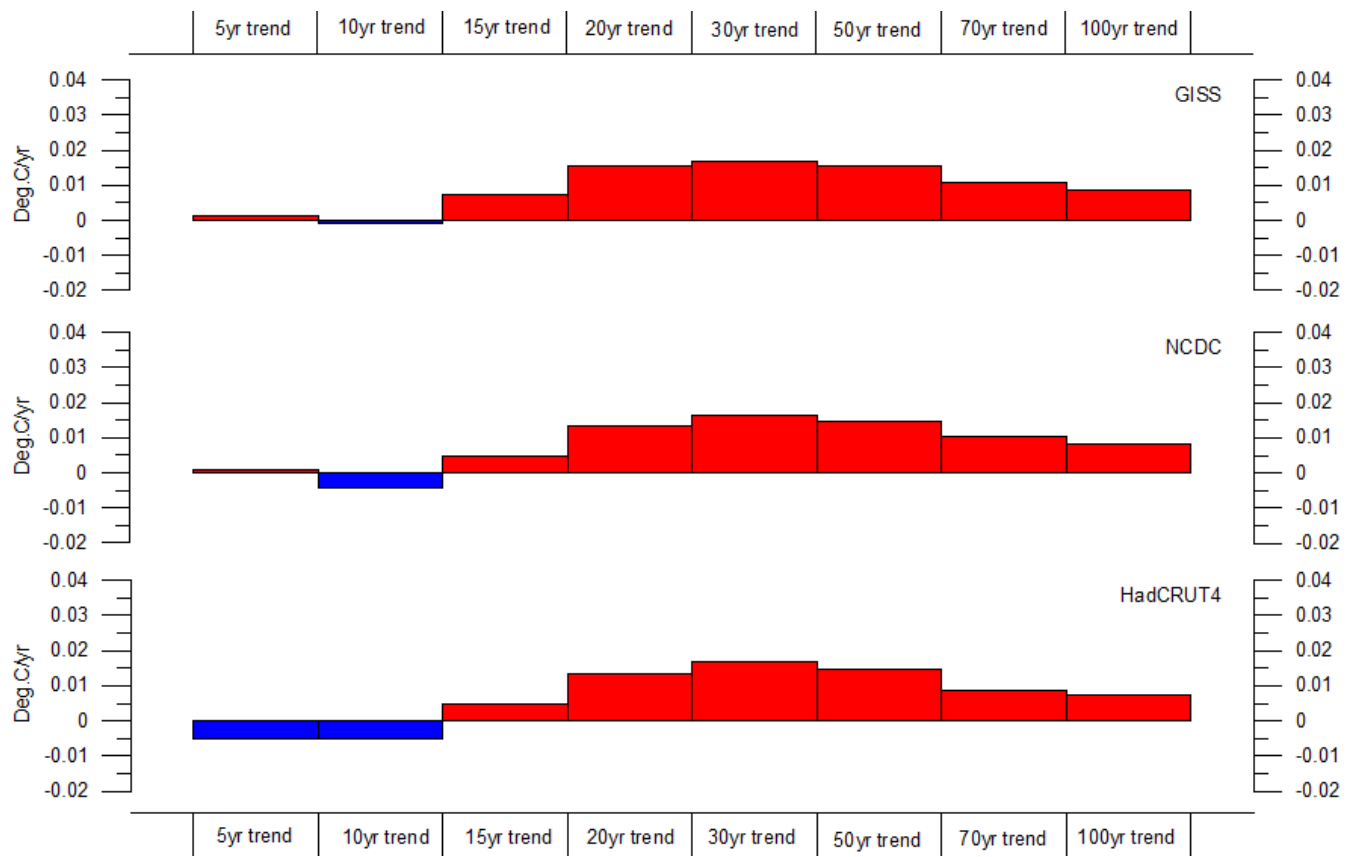
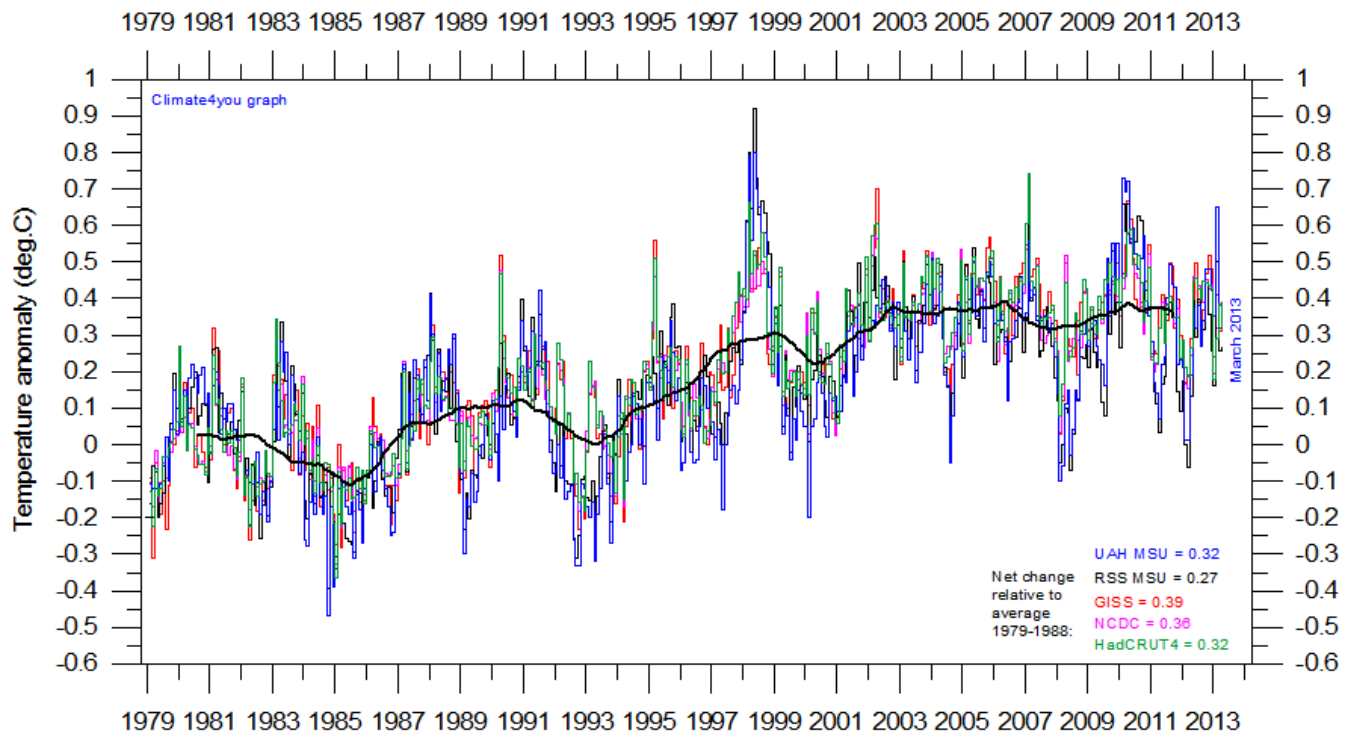


Diagram showing the latest 5, 10, 20, 30, 50, 70 and 100 yr linear annual global temperature trend, calculated as the slope of the linear regression line through the data points, for three surface-based temperature estimates (GISS, NCDC and HadCRUT4). Last month included in all analyses: March 2013.



9

Superimposed plot of all five 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 (10 years) from January 1979 to December 1988. 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.

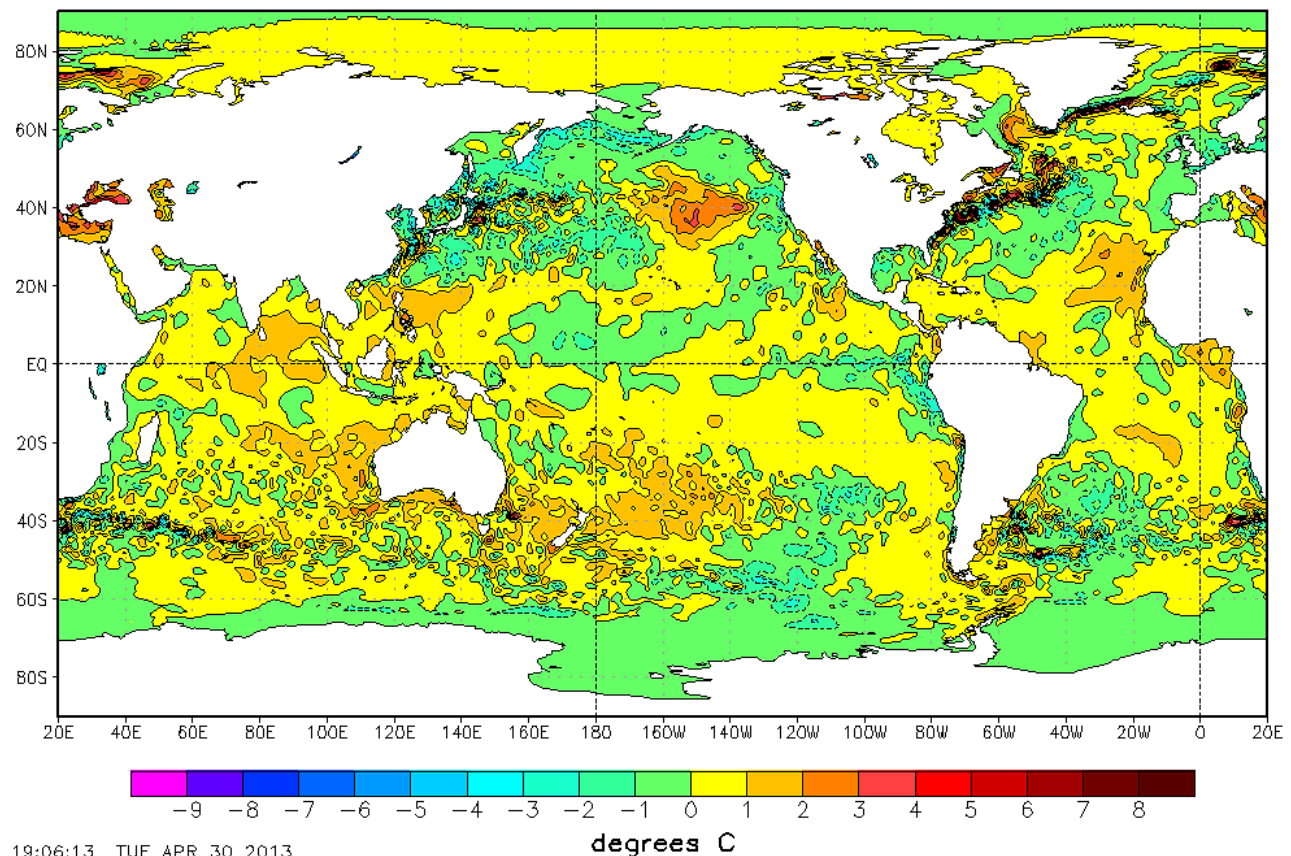
It should be kept in mind that satellite- and surface-based temperature estimates are derived from different types of measurements, and that comparing them directly as done in the diagram above therefore in principle may be problematical. However, as both types of estimate often are discussed together, the above diagram may nevertheless be of some interest. In fact, the different types of temperature estimates appear to agree quite well 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.

All five global temperature estimates presently show an overall stagnation, at least since 2002. There has been no increase in global air temperature since 1998, which however was affected by the oceanographic El Niño event. This 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 within the coming years. Time will show which of these two possibilities is correct.

Global sea surface temperature, updated to late April 2013

NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch

RTG_SST Anomaly (0.5 deg X 0.5 deg) for 30 Apr 2013



Sea surface temperature anomaly on 30 April 2013. Map source: National Centers for Environmental Prediction (NOAA).

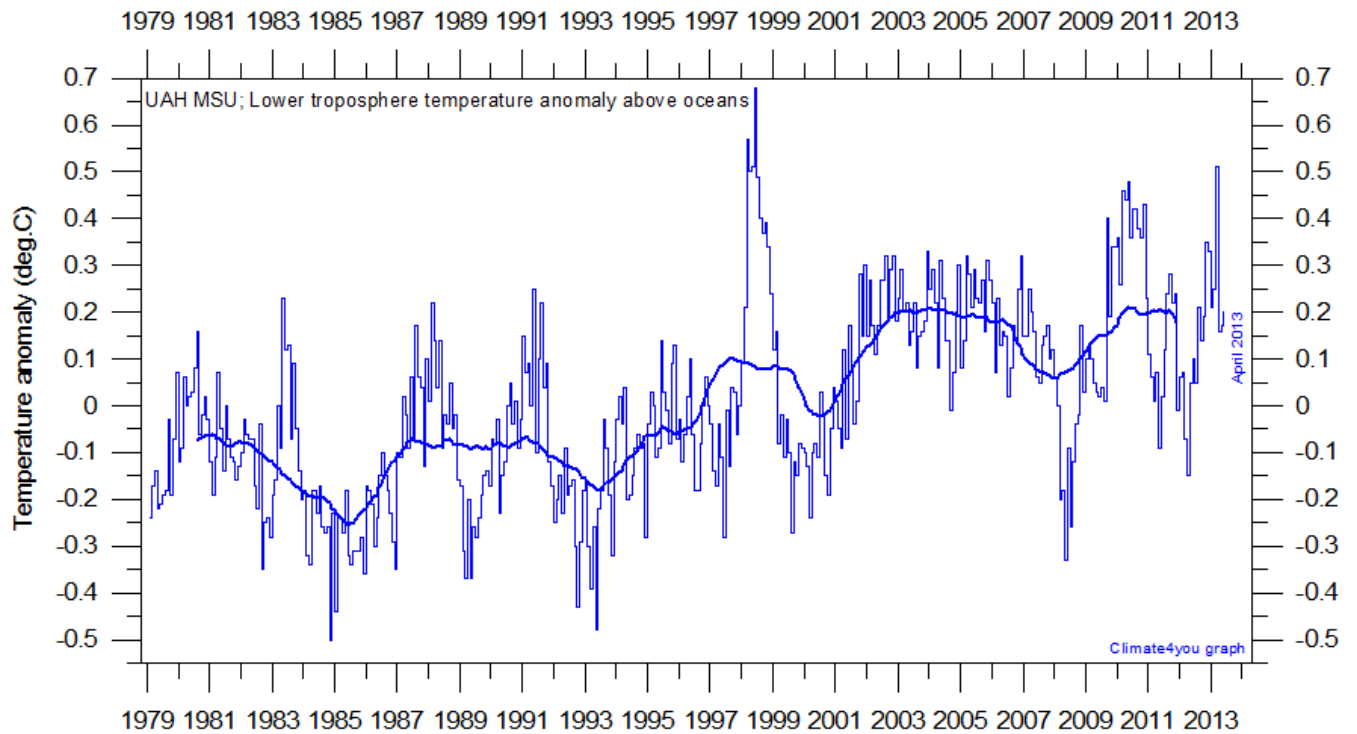
A clear ocean surface temperature asymmetry is apparent between the two hemispheres, with relatively warm conditions in the northern hemisphere, and relatively cold conditions in the southern hemisphere, but with large regional differences.

Because of the large surface areas involved especially near Equator, the temperature of the surface water in these regions clearly affects the global atmospheric temperature (p.3-5).

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

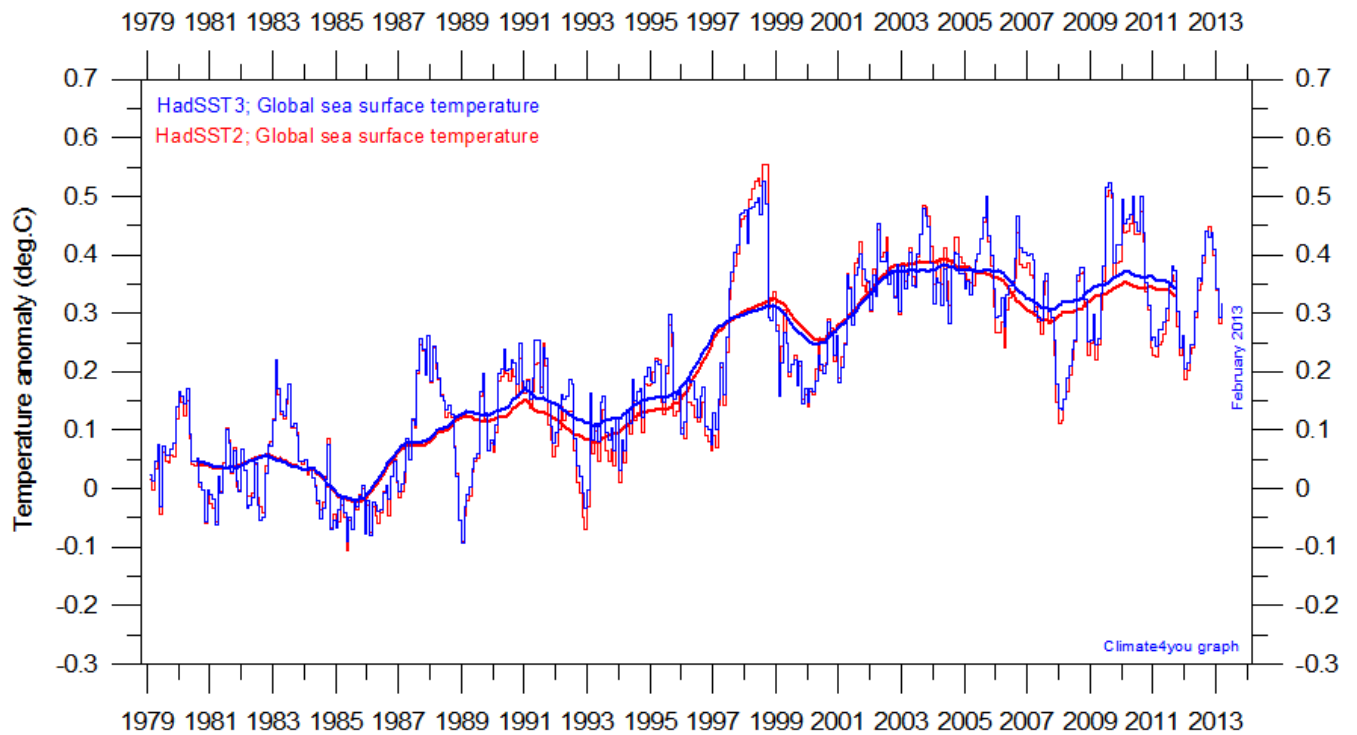
stated. Whenever Earth experiences cold La Niña or warm El Niño episodes (Pacific Ocean) major heat exchanges takes place between the Pacific Ocean and the atmosphere above, eventually showing up in estimates of the global air temperature.

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

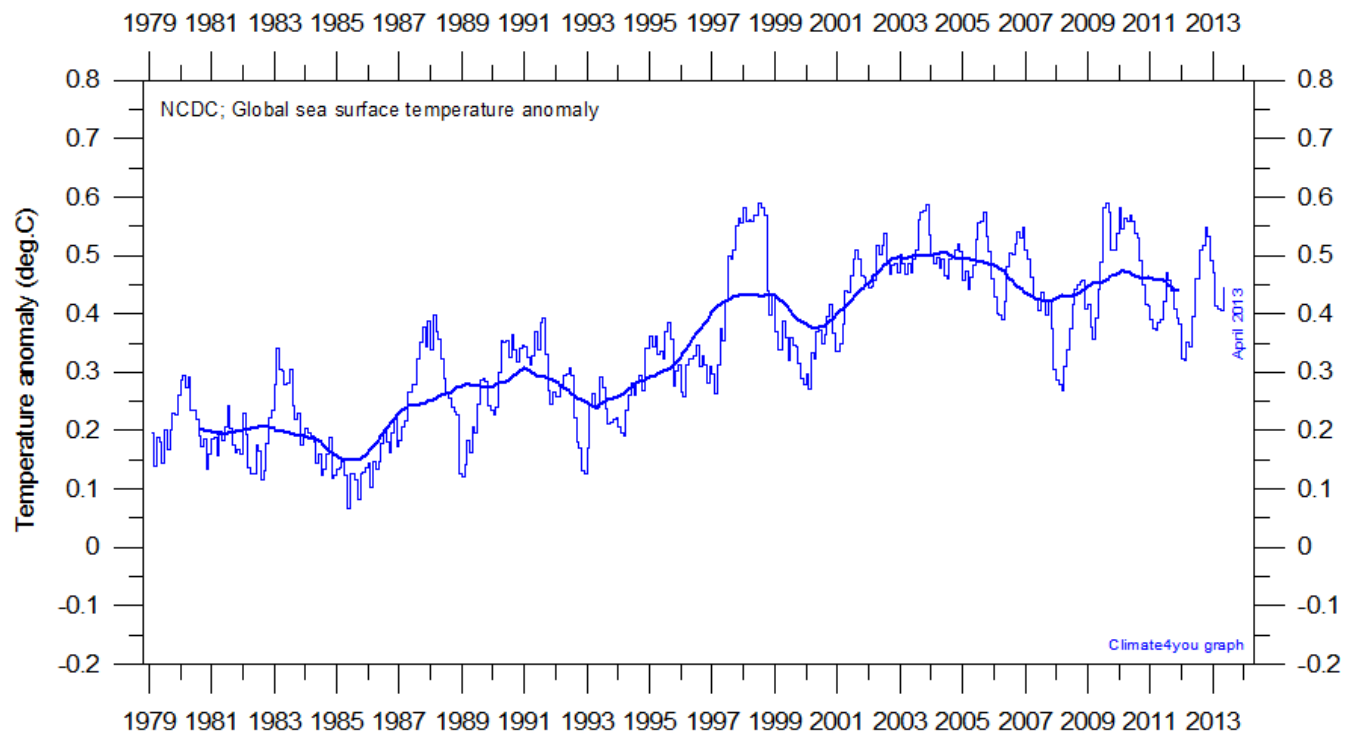


Global monthly average lower troposphere temperature over oceans (thin line) since 1979 according to [University of Alabama](#) at Huntsville, USA. The thick line is the simple running 37 month average.

11



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. Please note that this diagram is not updated beyond February 2013.



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.

What causes the large variations in global satellite temperature compared to global surface air temperature? A good explanation was provided by [Roy Spencer](#) in March 2012:

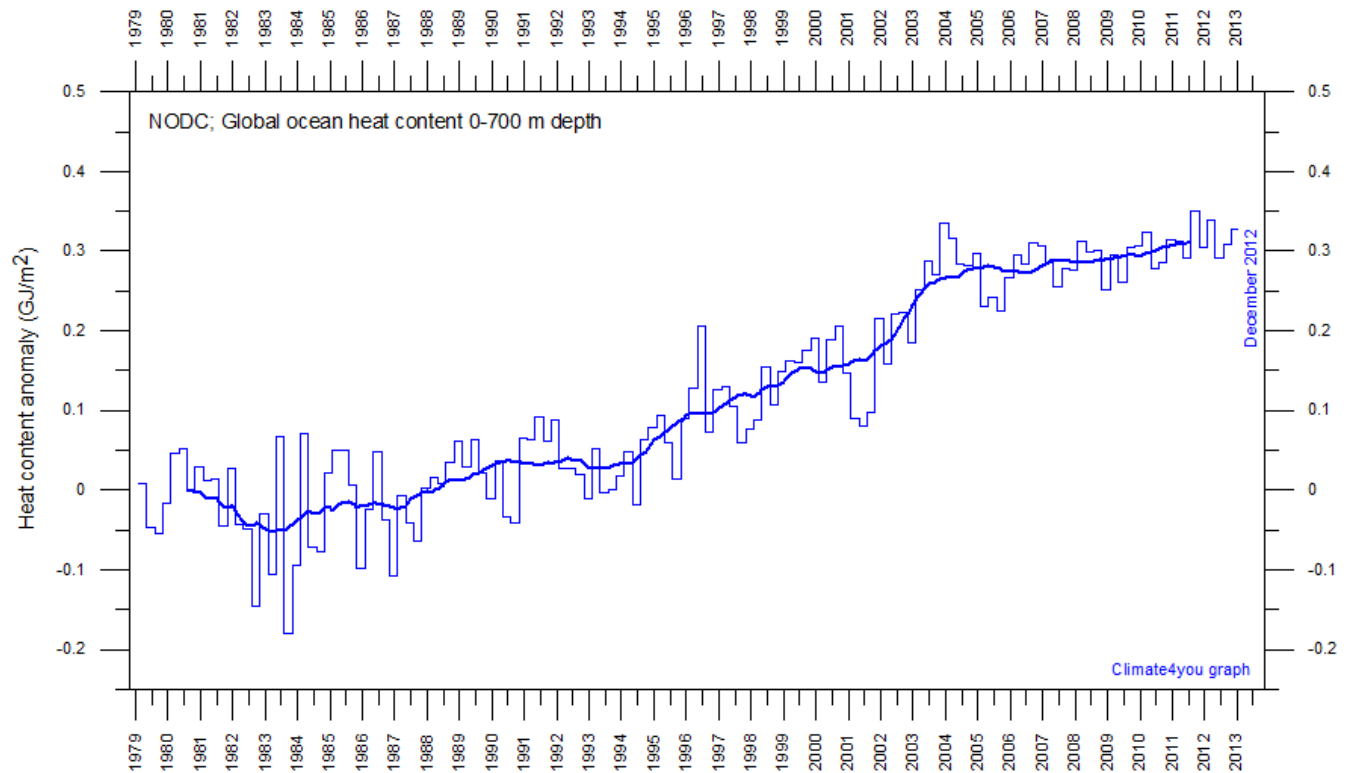
“These temperature swings are mostly the result of variations in rainfall activity. Precipitation systems, which are constantly occurring around the world, release the latent heat of condensation of water vapor which was absorbed during the process of evaporation from the Earth’s surface.

While this process is continuously occurring, there are periods when such activity is somewhat more intense or widespread. These events, called Intra-Seasonal Oscillations (ISOs) are most evident over the tropical Pacific Ocean.

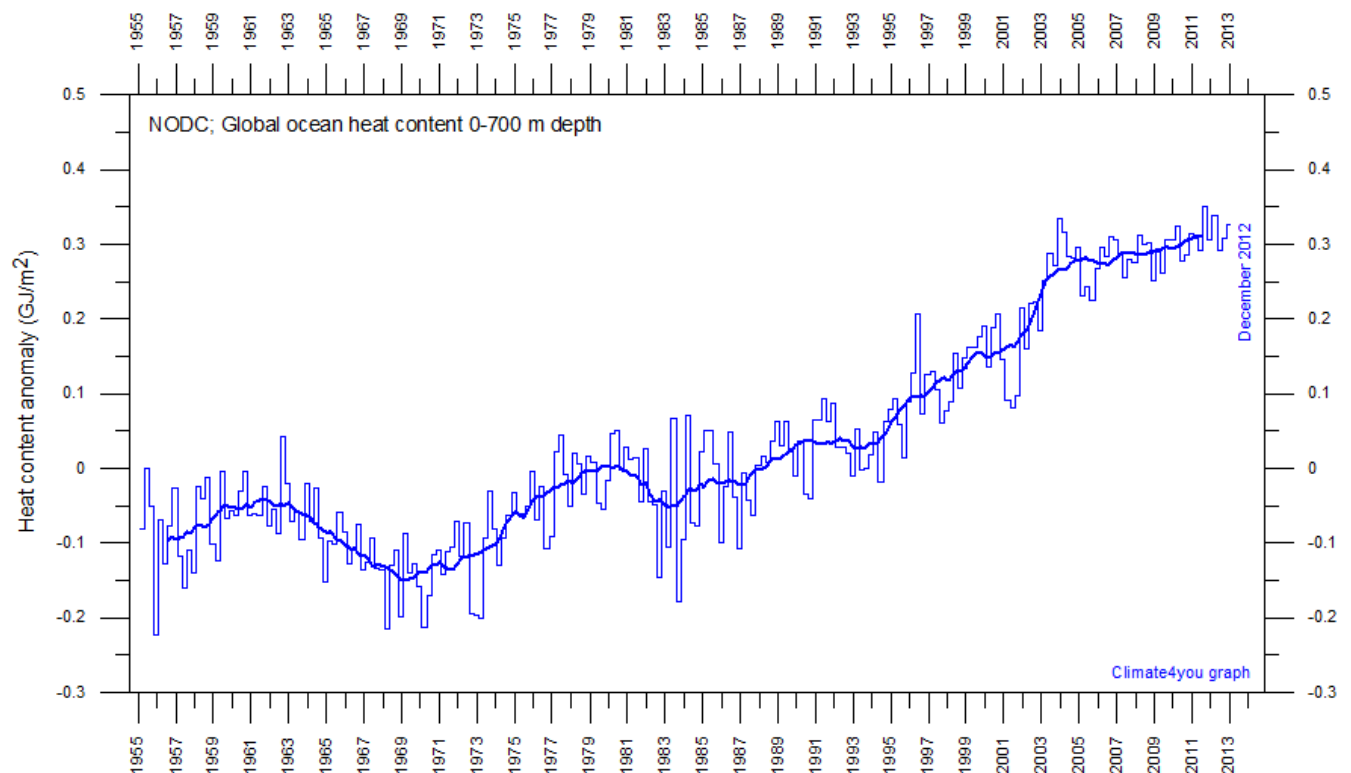
During the convectively active phase of the ISO, there are increased surface winds of up to 1 to 2 knots averaged over the tropical oceans, which causes faster surface evaporation, more water vapor in the troposphere, and more convective rainfall activity. This above-average release of latent heat exceeds the rate at which the atmosphere emits infrared radiation to space, and so the resulting energy imbalance causes a temperature increase.

During the convectively inactive phase, the opposite happens: a decrease in surface wind, evaporation, rainfall, and temperature, as the atmosphere radiatively cools more rapidly than latent heating can replenish the energy.”

Global ocean heat content uppermost 700 m, updated to December 2012

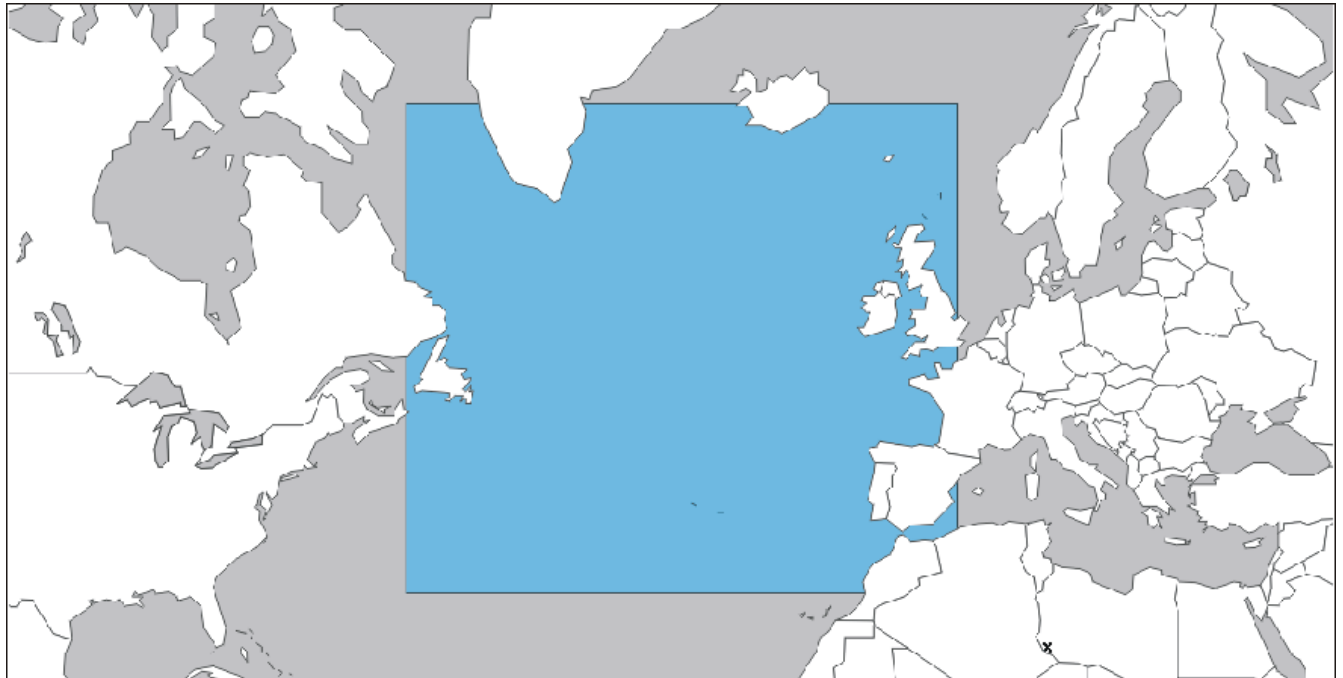


Global monthly heat content anomaly (GJ/m²) in the uppermost 700 m of the oceans since January 1979. Data source: National Oceanographic Data Center(NODC).

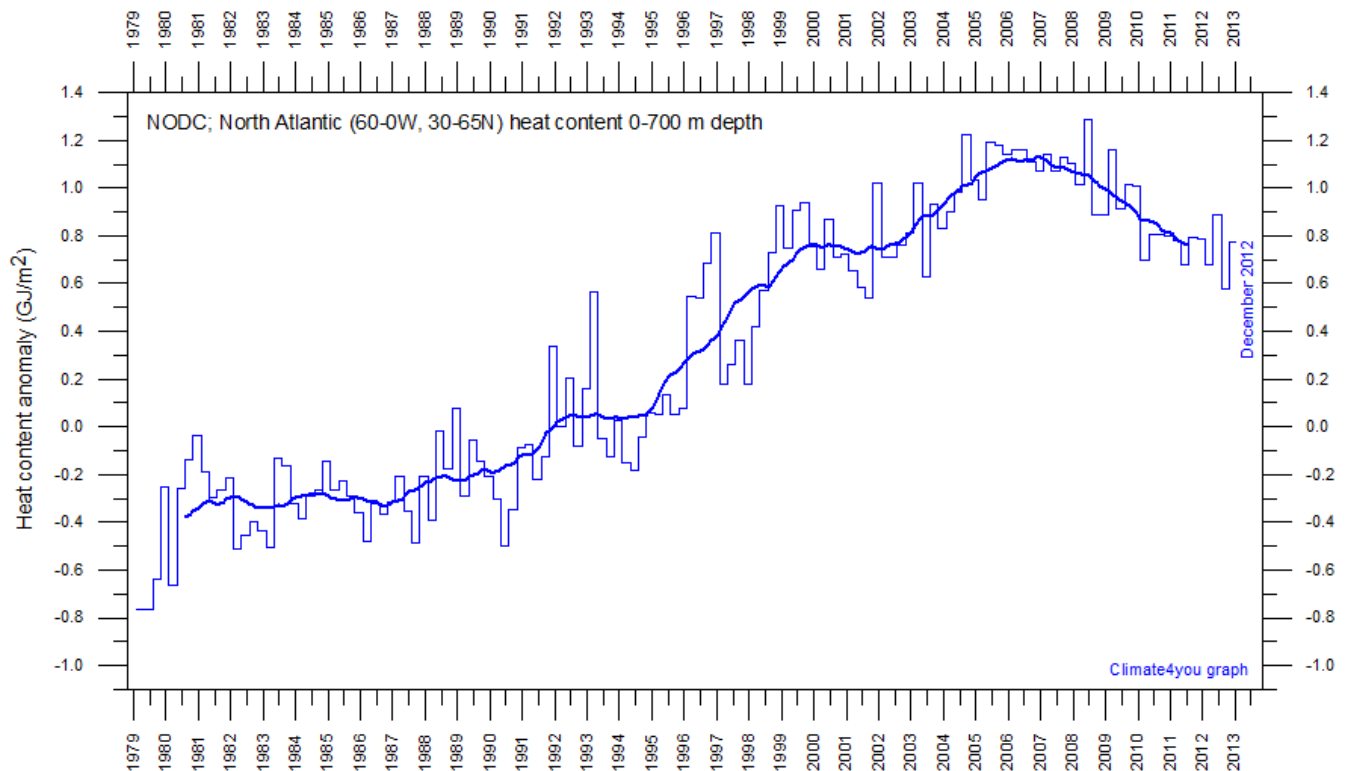


Global monthly heat content anomaly (GJ/m²) in the uppermost 700 m of the oceans since January 1955. Data source: National Oceanographic Data Center(NODC).

North Atlantic heat content uppermost 700 m, updated to December 2012

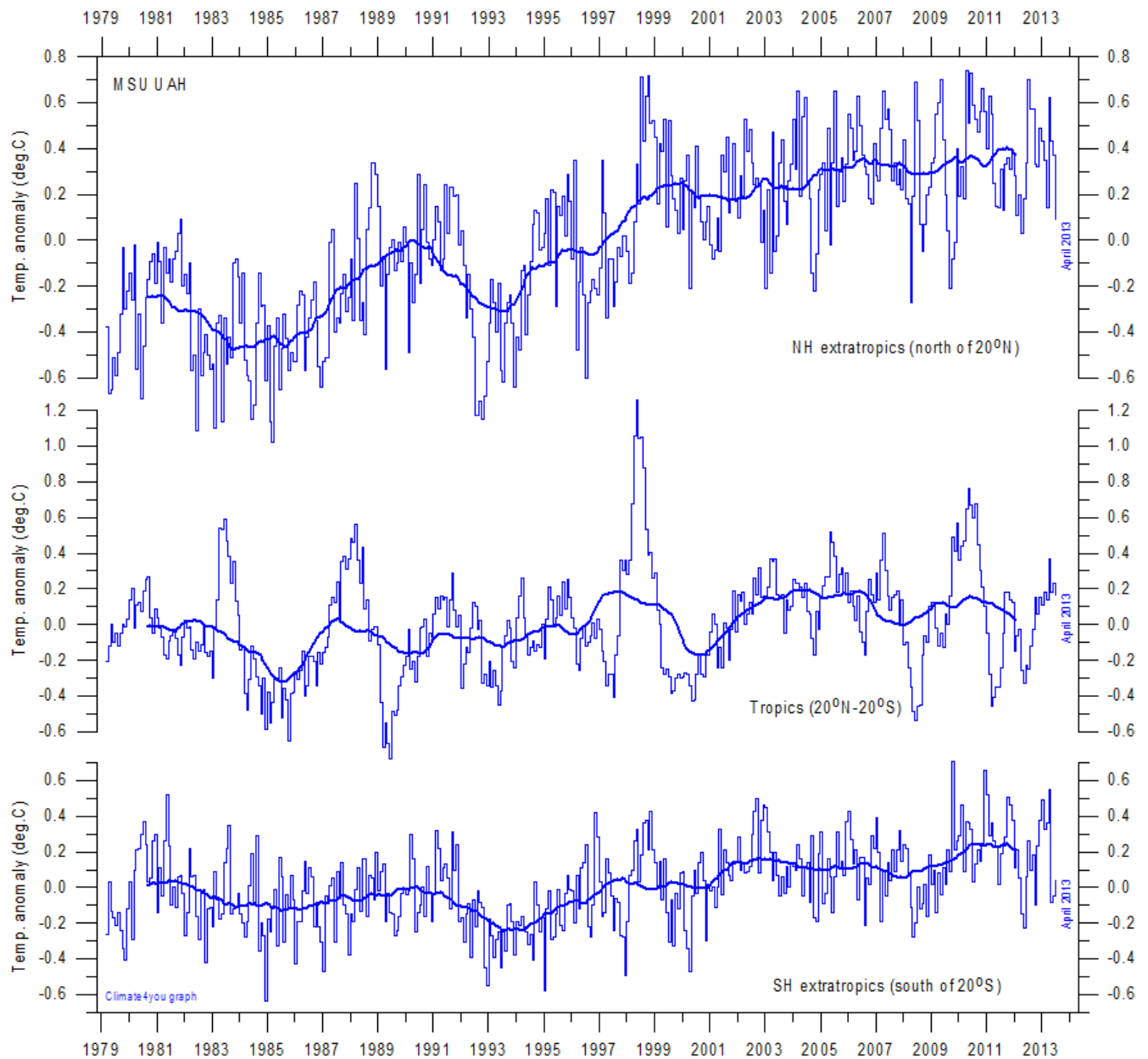


14



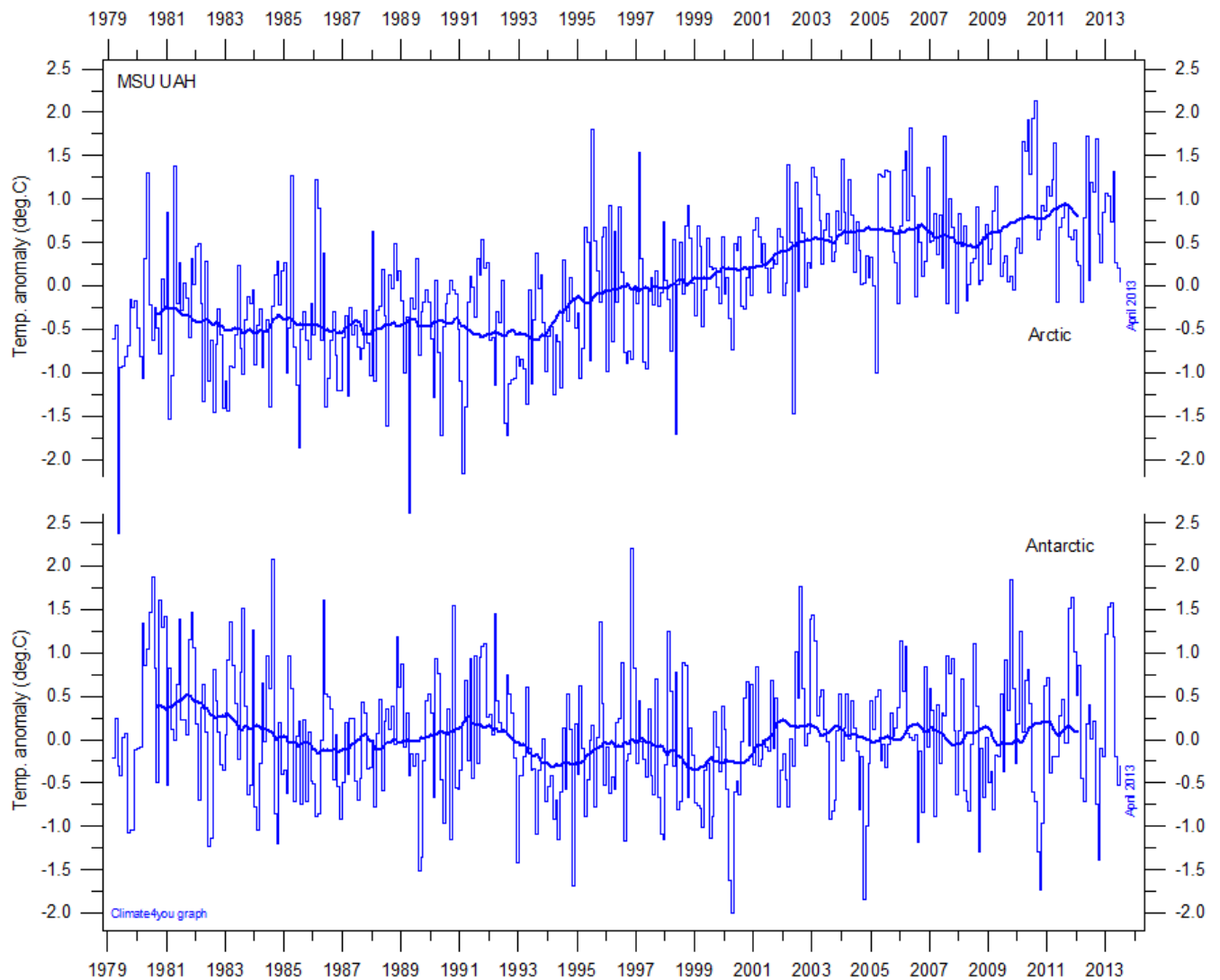
Global monthly heat content anomaly (GJ/m²) in the uppermost 700 m of the North Atlantic (60-0W, 30-65N; see map above) ocean since January 1979. The thin line indicates monthly values, and the thick line represents the simple running 37 month (c. 3 year) average. Data source: [National Oceanographic Data Center](http://www.nodc.noaa.gov) (NODC). Last month shown: December 2012.

Zonal lower troposphere temperatures from satellites, updated to April 2013



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 yr average. Reference period 1981-2010.

Arctic and Antarctic lower troposphere temperature, updated to April 2013



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 yr average.

Arctic and Antarctic surface air temperature, updated to February 2013

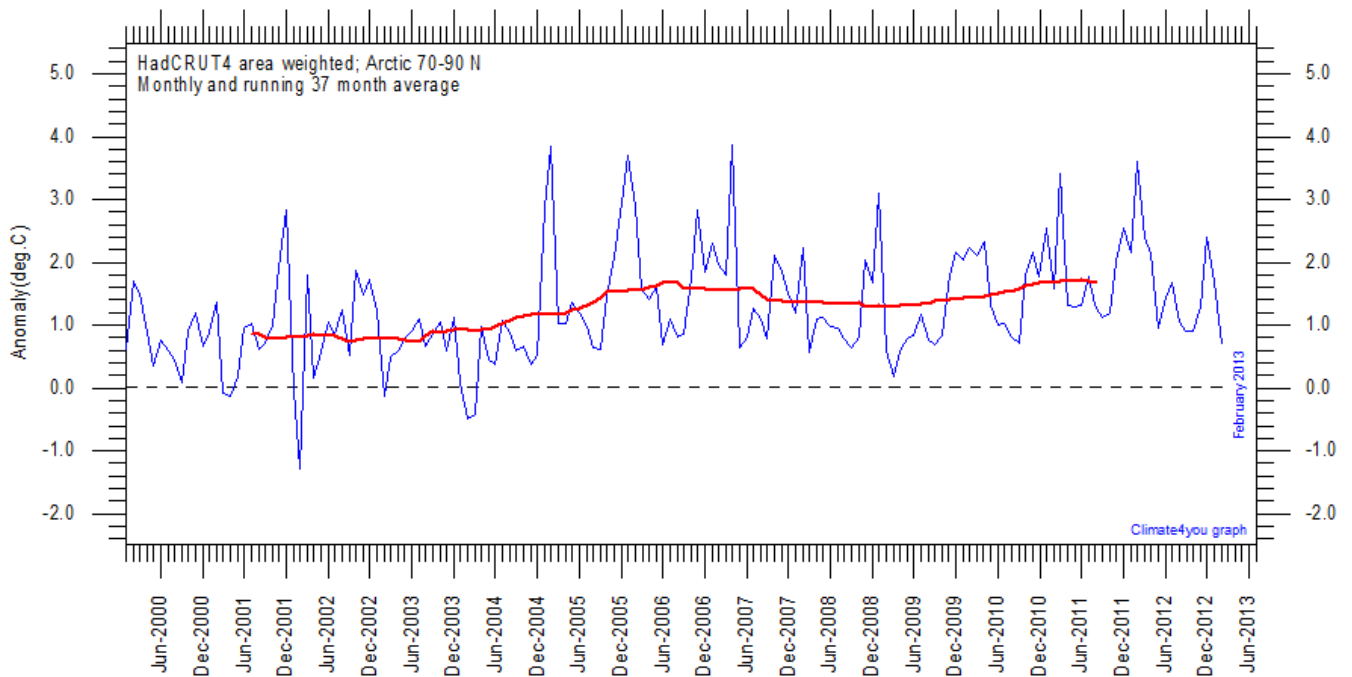


Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4](#)) since January 2000, in relation to the WMO [normal period](#) 1961-1990. The thin blue line shows the monthly temperature anomaly, while the thicker red line shows the running 37 month (c.3 yr) average.

17

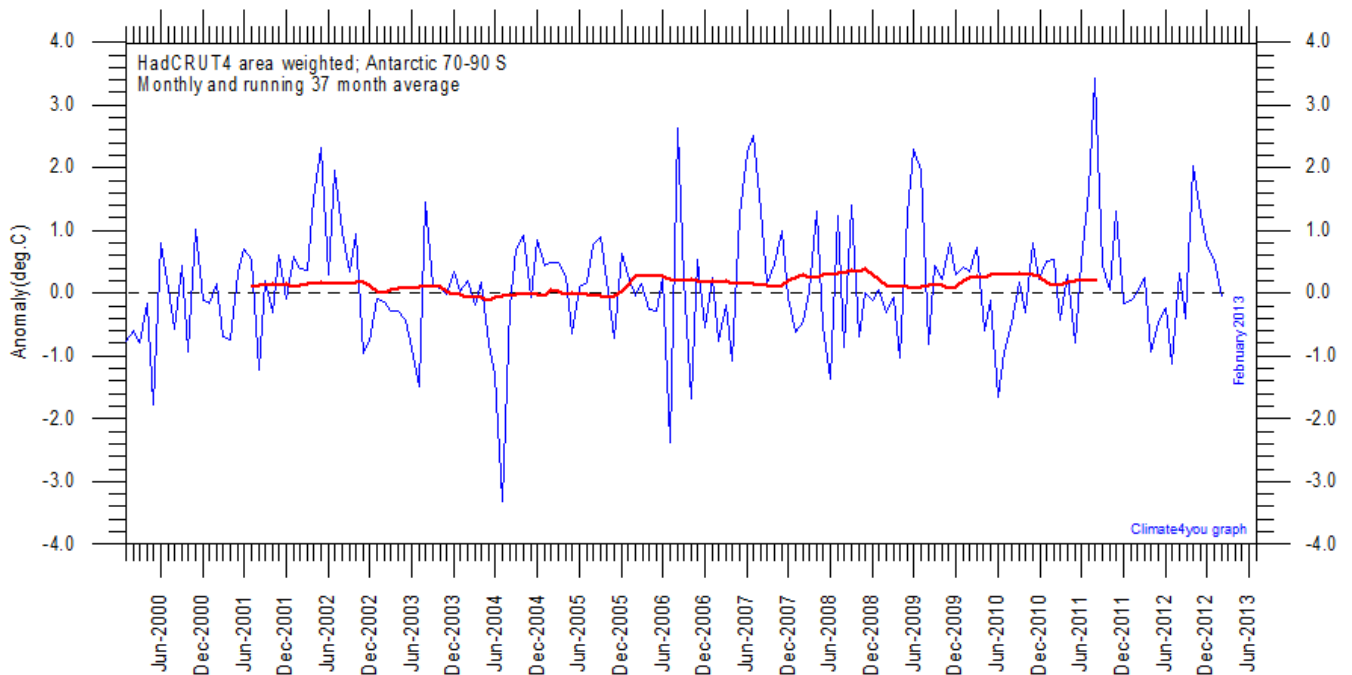


Diagram showing area weighted Antarctic (70-90°S) monthly surface air temperature anomalies ([HadCRUT4](#)) since January 2000, in relation to the WMO [normal period](#) 1961-1990. The thin blue line shows the monthly temperature anomaly, while the thicker red line shows the running 37 month (c.3 yr)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

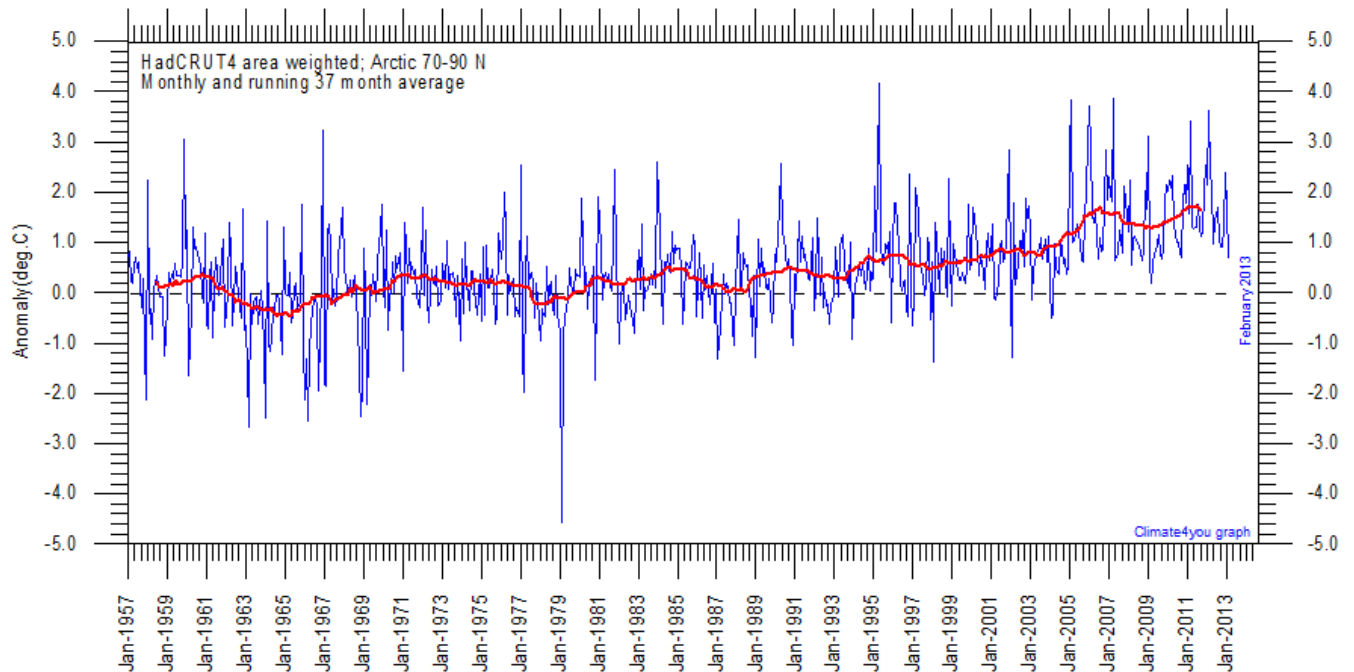


Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4](#)) since January 1957, in relation to the WMO [normal period](#) 1961-1990. The thin blue line shows the monthly temperature anomaly, while the thicker red line shows the running 37 month (c.3 yr) average.

18

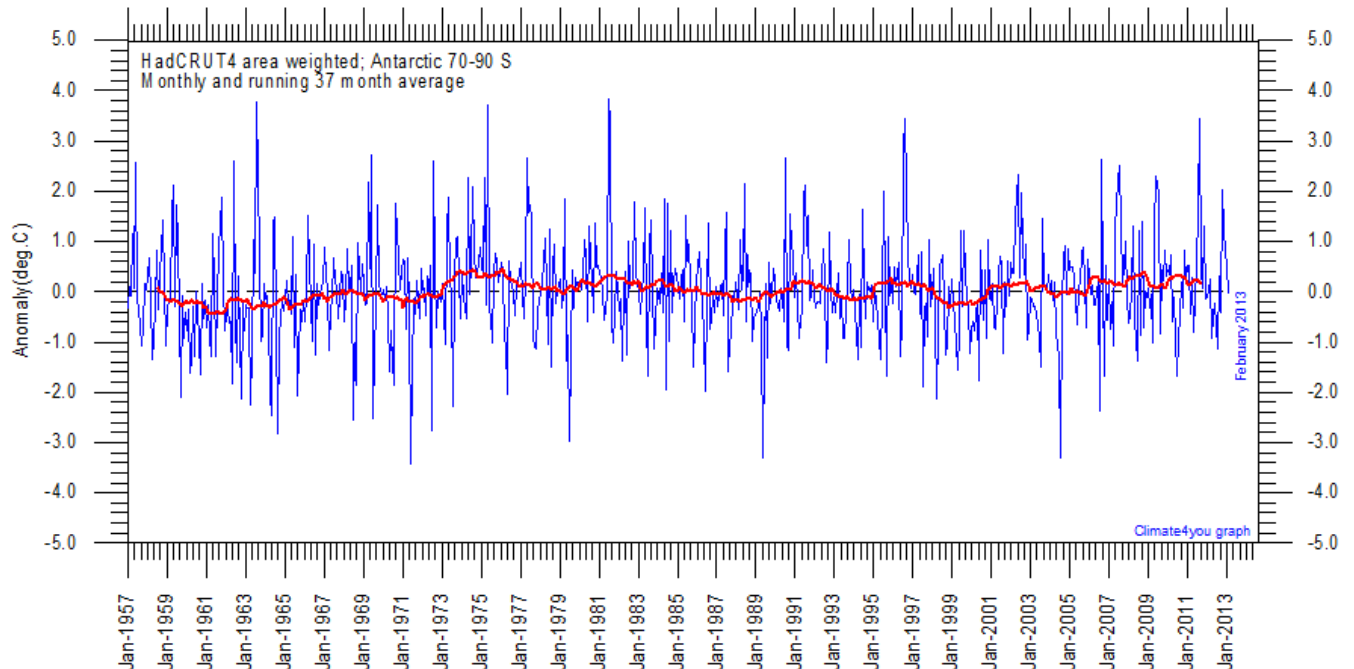


Diagram showing area weighted Antarctic (70-90°S) monthly surface air temperature anomalies ([HadCRUT4](#)) since January 1957, in relation to the WMO [normal period](#) 1961-1990. The thin blue line shows the monthly temperature anomaly, while the thicker red line shows the running 37 month (c.3 yr)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

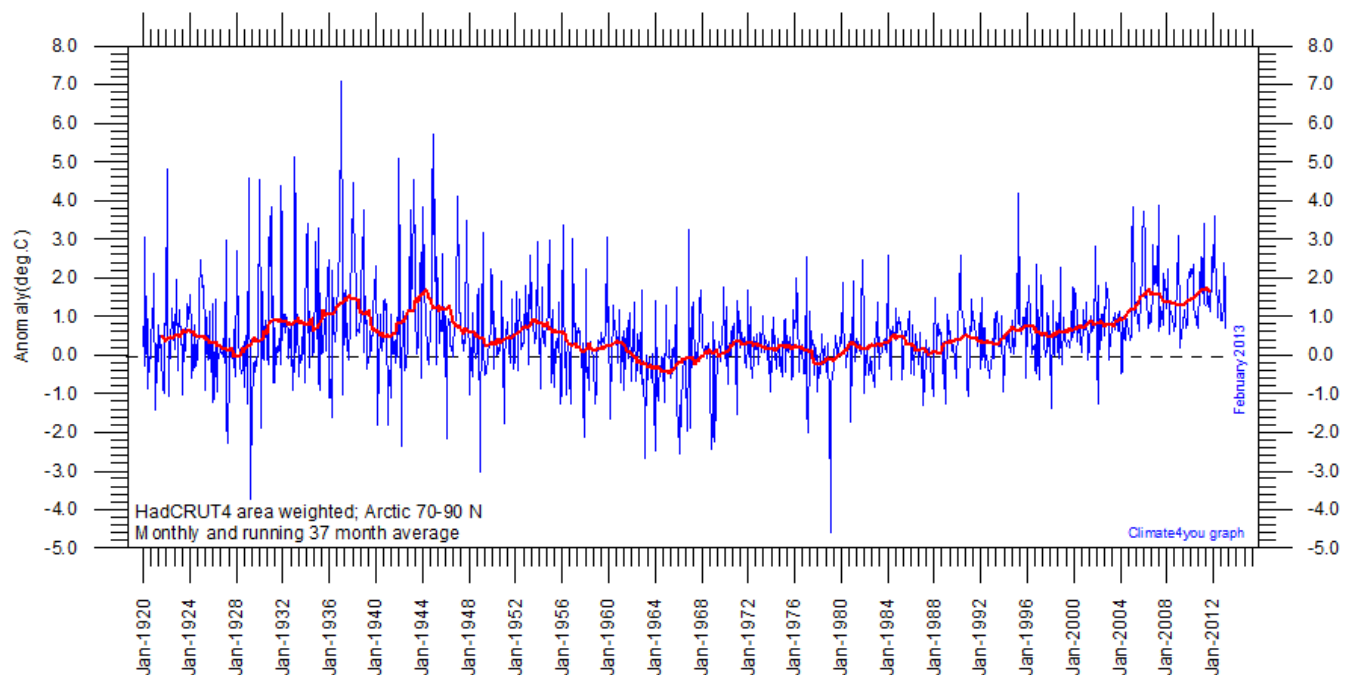


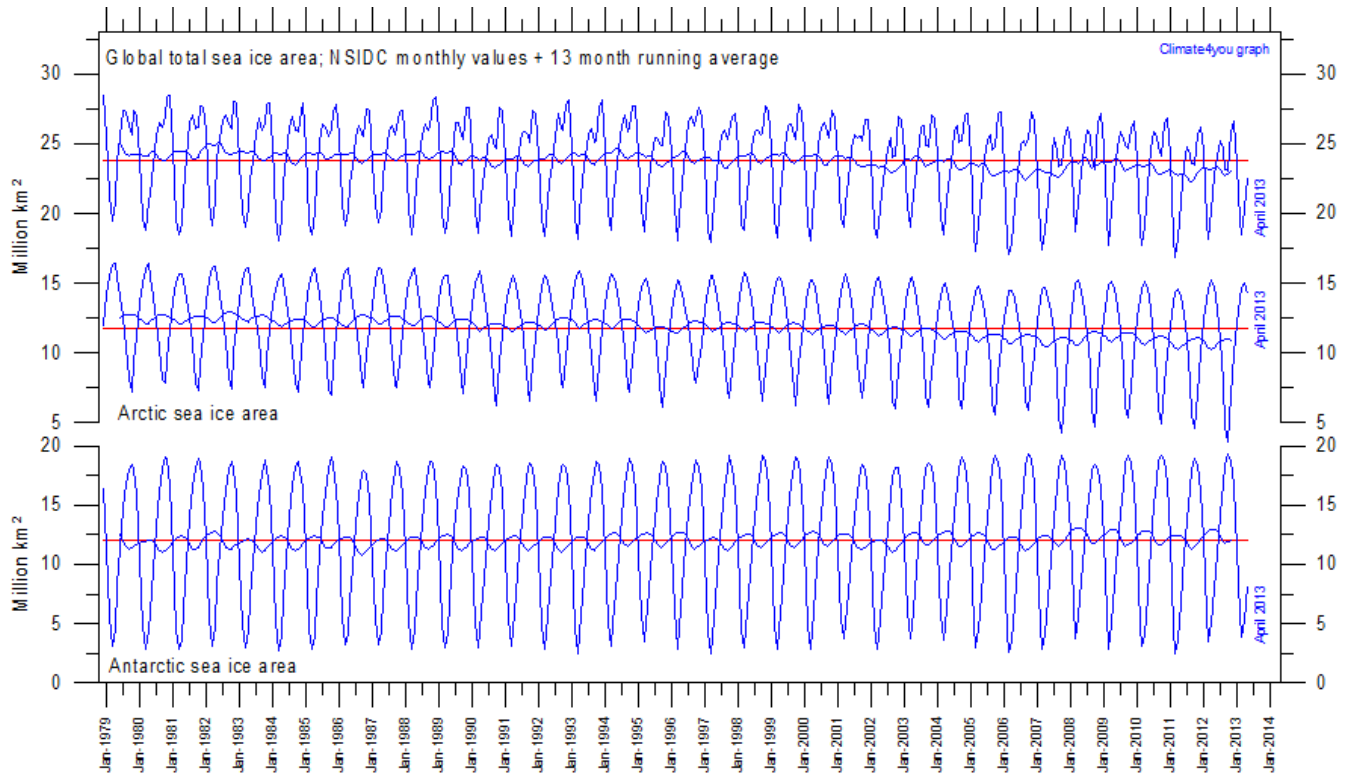
Diagram showing area weighted Arctic (70-90°N) monthly surface air temperature anomalies ([HadCRUT4](#)) since January 1920, in relation to the WMO [normal period](#) 1961-1990. The thin blue line shows the monthly temperature anomaly, while the thicker red line shows the running 37 month (c.3 yr) average. 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 [Gillett et al. 2008](#) which calculated a simple average, with no consideration to the surface area represented by the individual 5°x5° grid cells.

Literature:

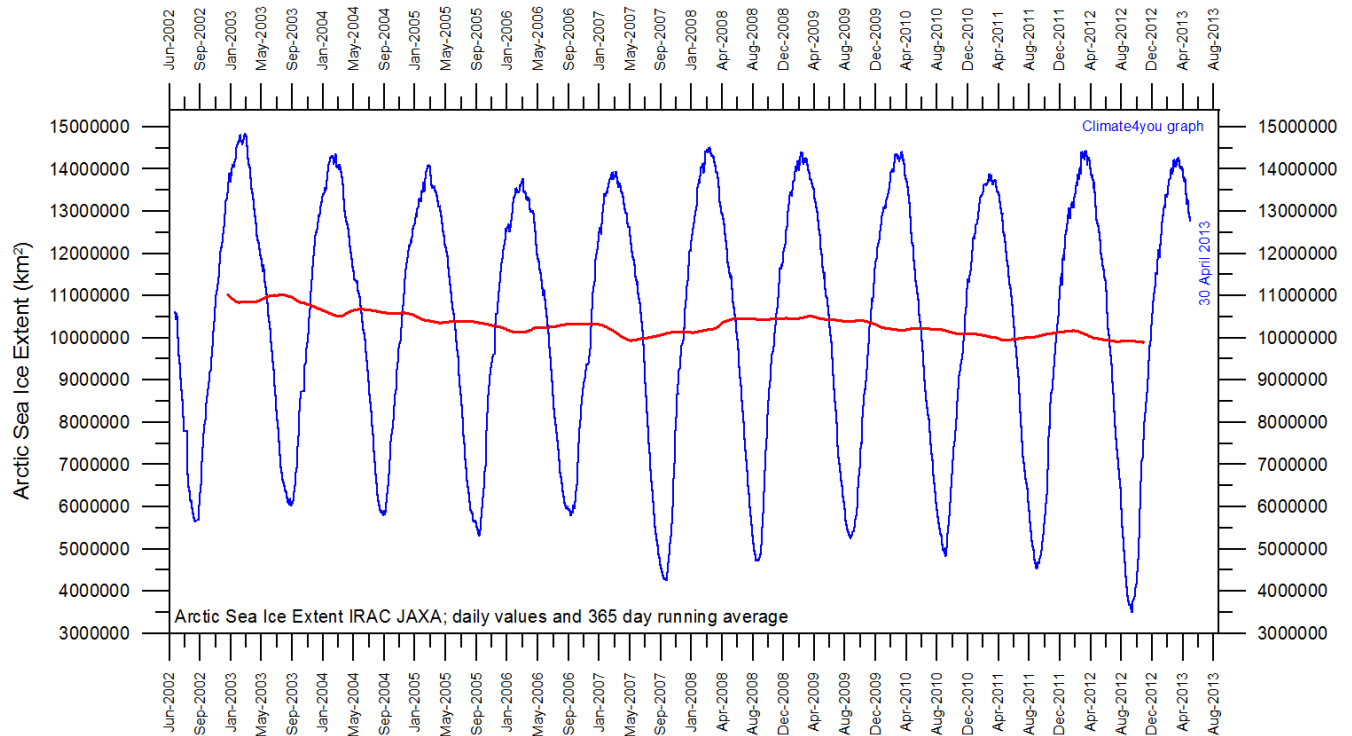
Gillett, N.P., Stone, D.A., Stott, P.A., Nozawa, T., Karpechko, A.Y.U., Hegerl, G.C., Wehner, M.F. and Jones, P.D. 2008. Attribution of polar warming to human influence. *Nature Geoscience* 1, 750-754.

Arctic and Antarctic sea ice, updated to April 2013



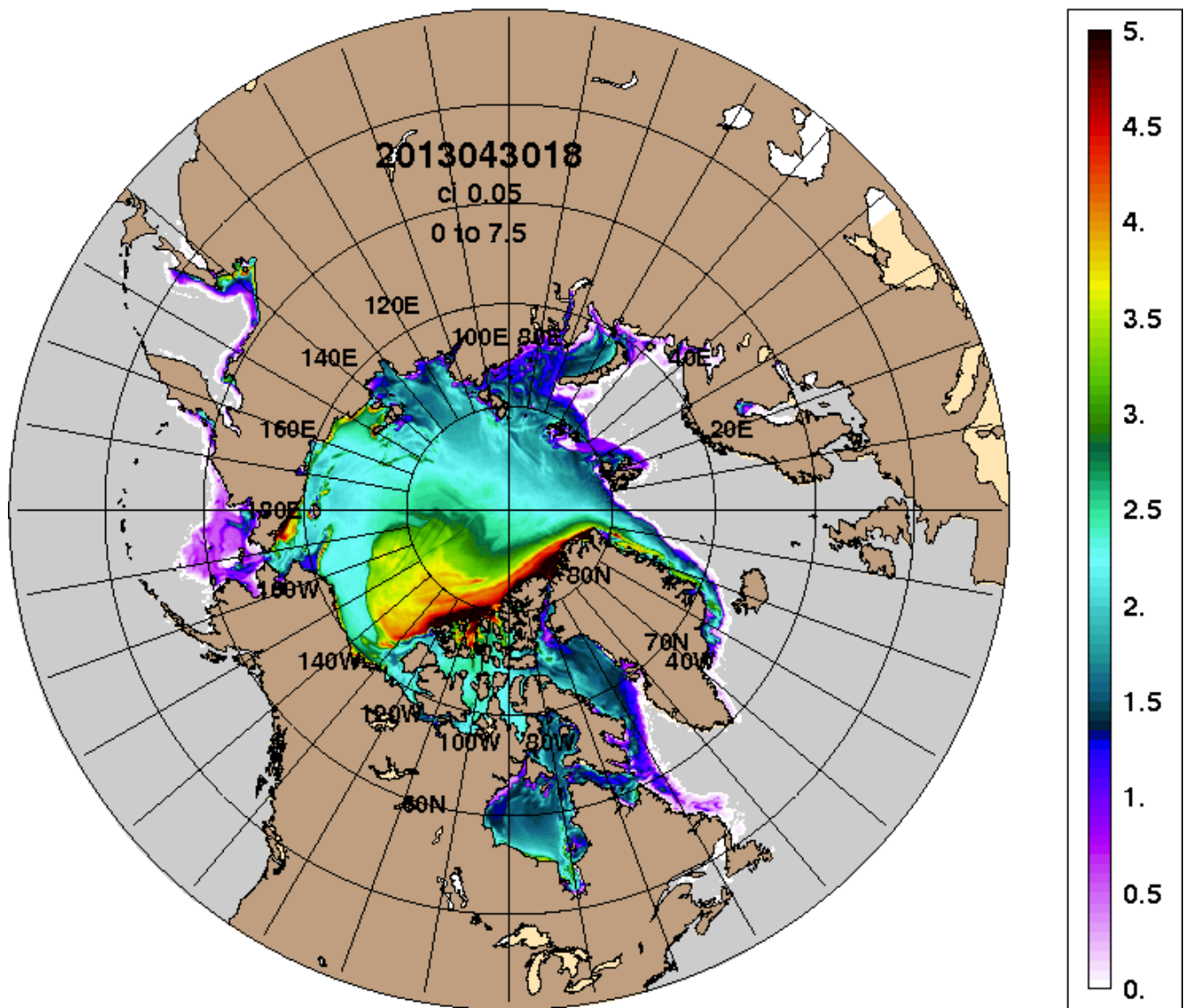
Graphs showing monthly Antarctic, Arctic and global sea ice extent since November 1978, according to the [National Snow and Ice data Center \(NSIDC\)](#).

20



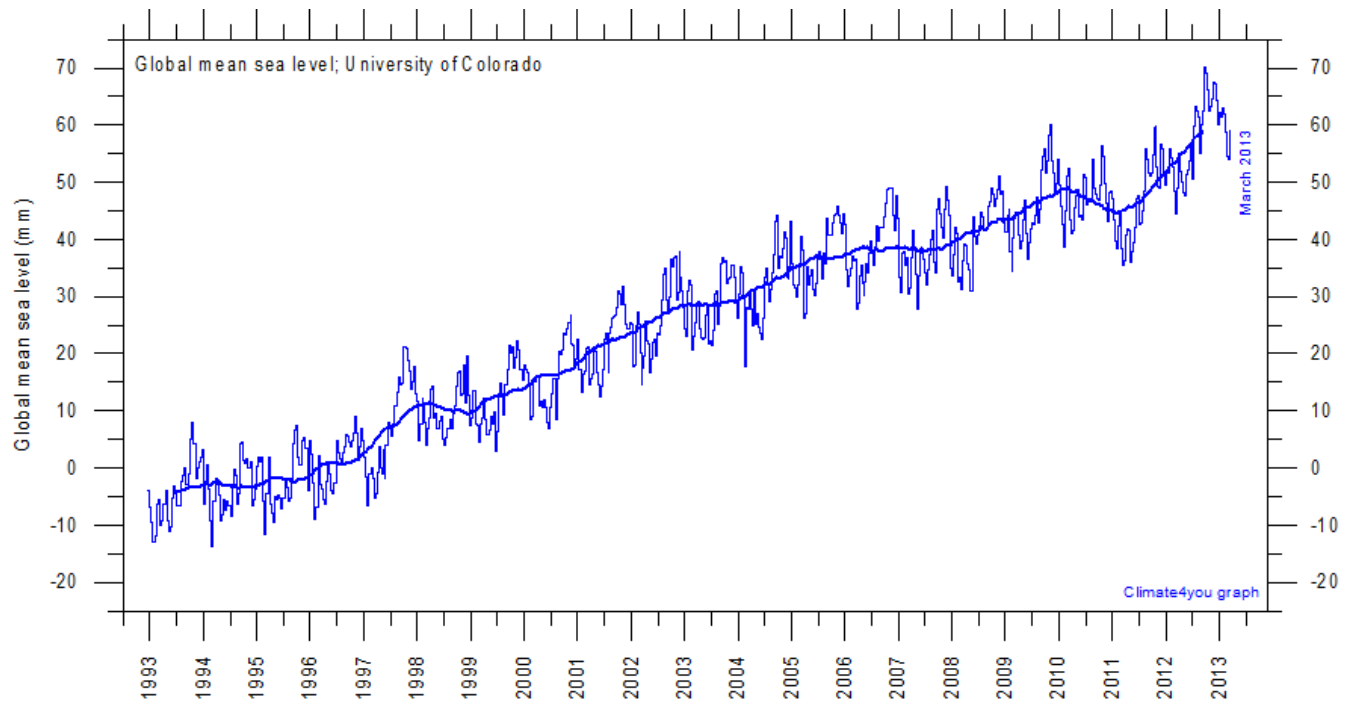
Graph showing daily Arctic sea ice extent since June 2002, to April 30, 2013, by courtesy of [Japan Aerospace Exploration Agency \(JAXA\)](#).

ARCC0.08-03.5 Ice Thickness (m): 20130430



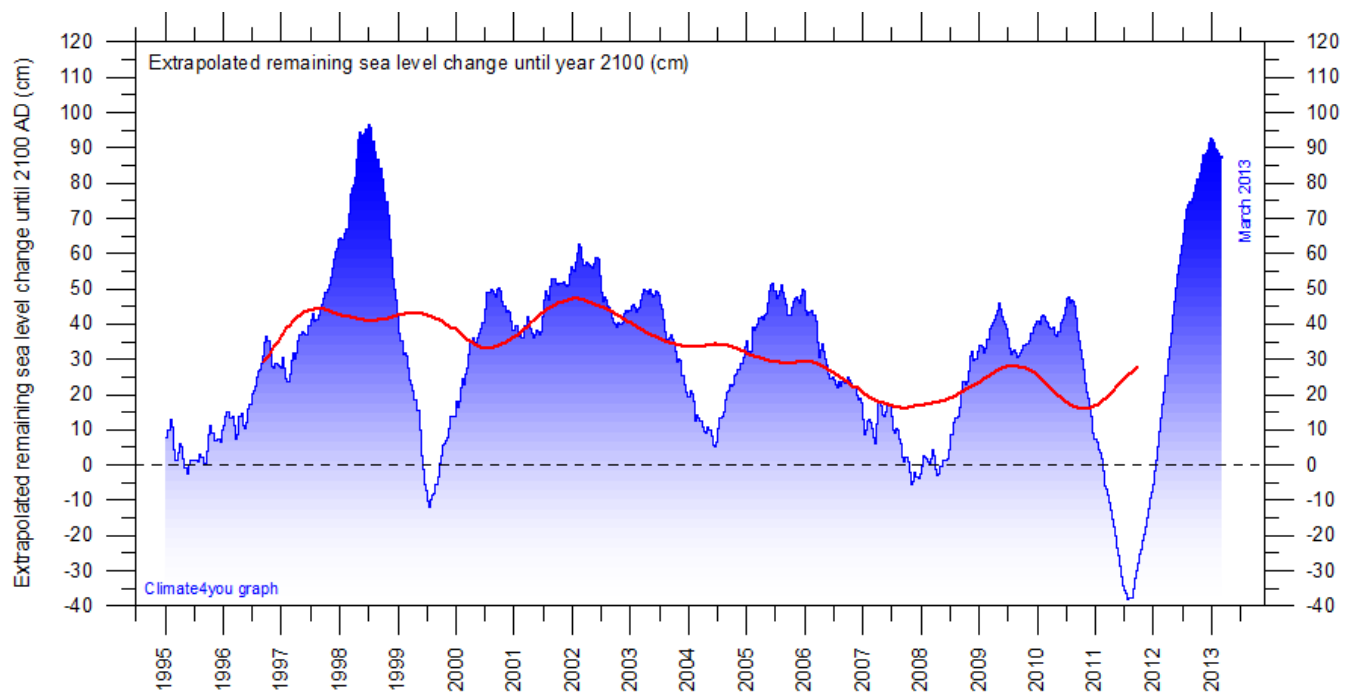
Northern hemisphere sea ice extension and thickness on 30 April 2013 according to the [Arctic Cap Nowcast/Forecast System](#) (ACNFS), US Naval Research Laboratory. Thickness scale (m) is shown to the right.

Global sea level, updated to March 2013



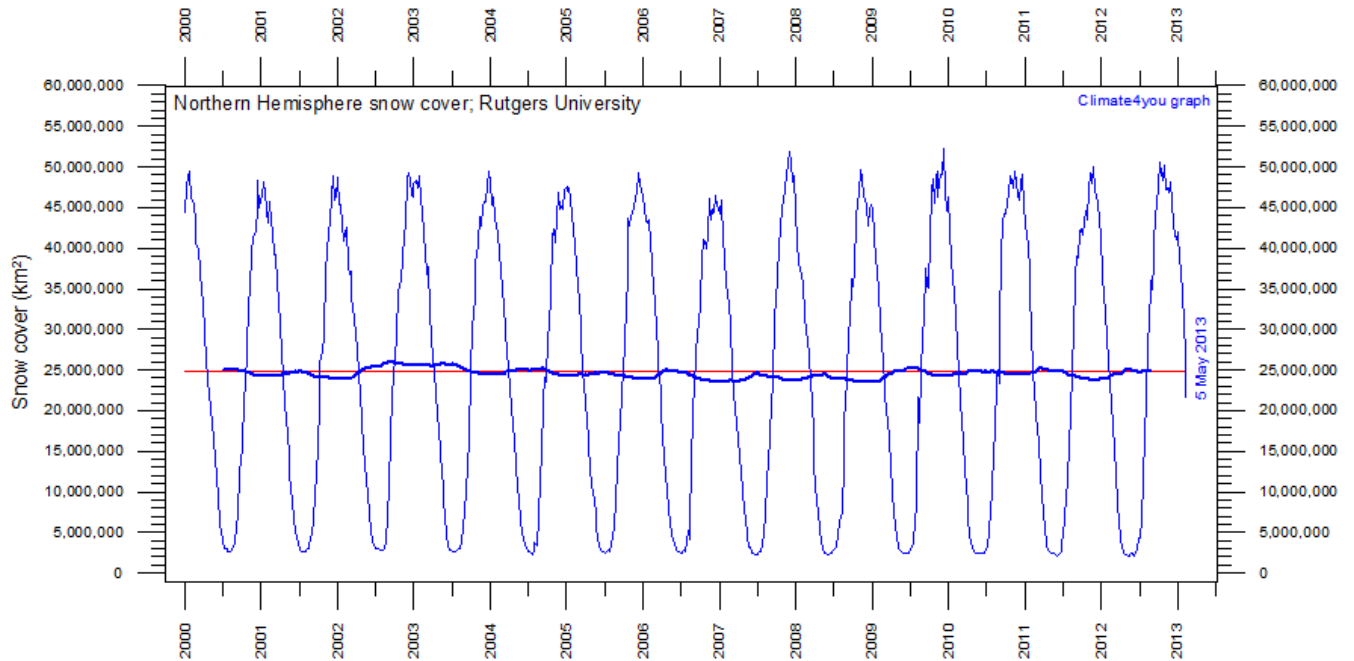
Global monthly sea level since late 1992 according to the Colorado Center for Astrodynamics Research at [University of Colorado at Boulder](http://www.ccar.colorado.edu/), USA. The thick line is the simple running 37 observation average, nearly corresponding to a running 3 yr average.

22



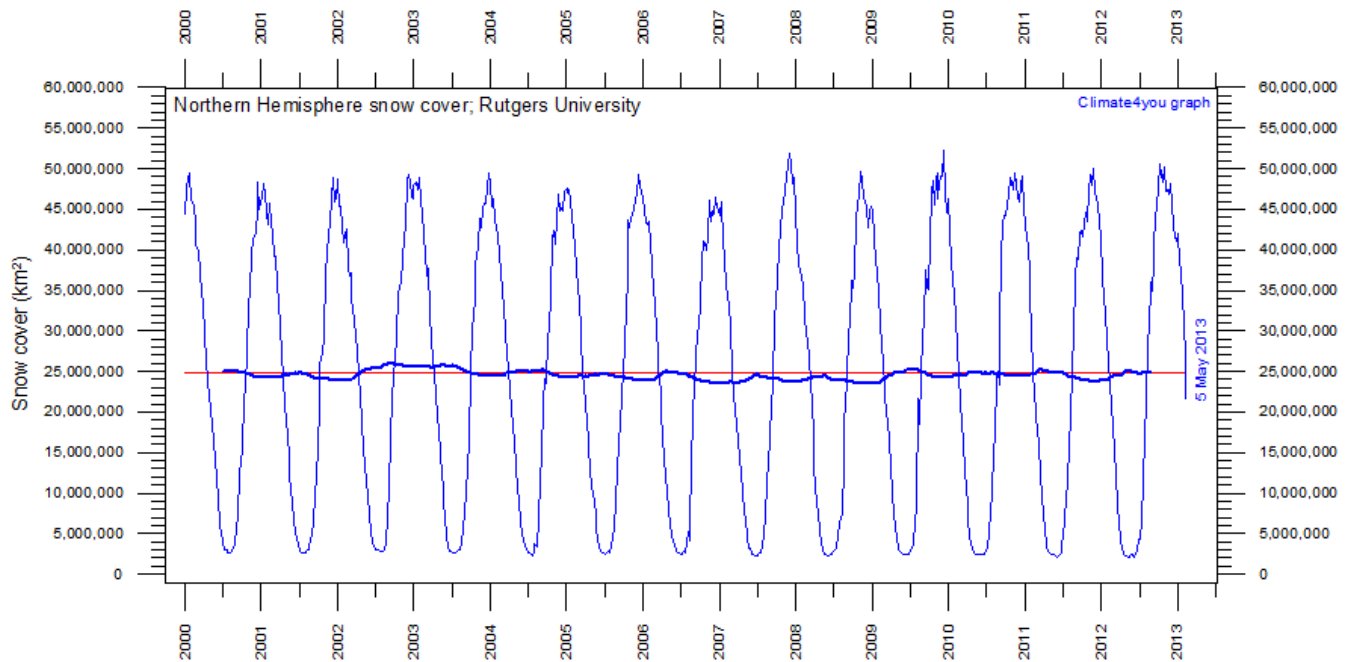
Forecasted change of global sea level until year 2100, based on simple extrapolation of measurements done by the Colorado Center for Astrodynamics Research at [University of Colorado at Boulder](http://www.ccar.colorado.edu/), USA. The thick line is the simple running 3 yr average forecast for sea level change until year 2100. Based on this (thick line), the present simple empirical forecast of sea level change until 2100 is about +29 cm.

Northern Hemisphere weekly snow cover, updated to early May 2013



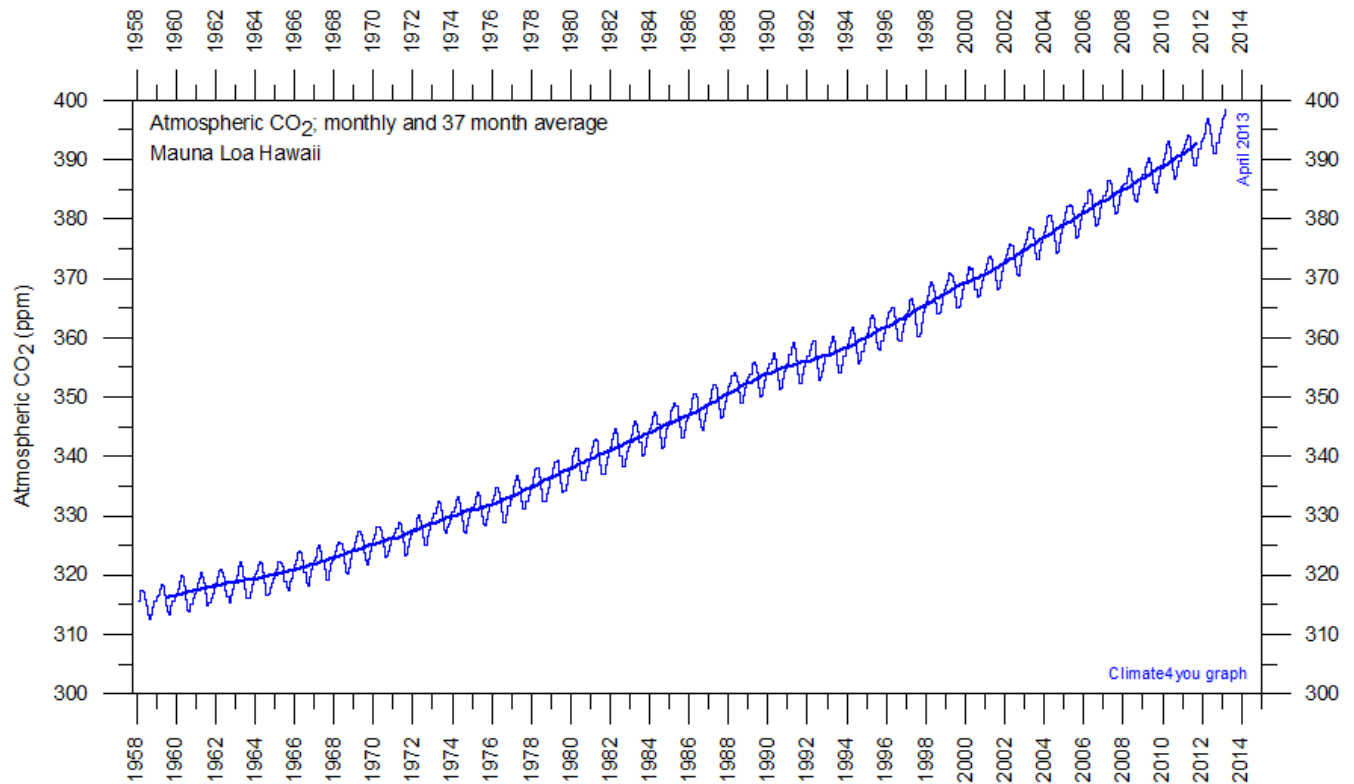
Northern hemisphere weekly snow cover since January 2000 according to Rutgers University Global Snow Laboratory. The thin blue line is the weekly data, and the thick blue line is the running 53 week average (approximately 1 year). The horizontal red line is the 1972-2012 average.

23

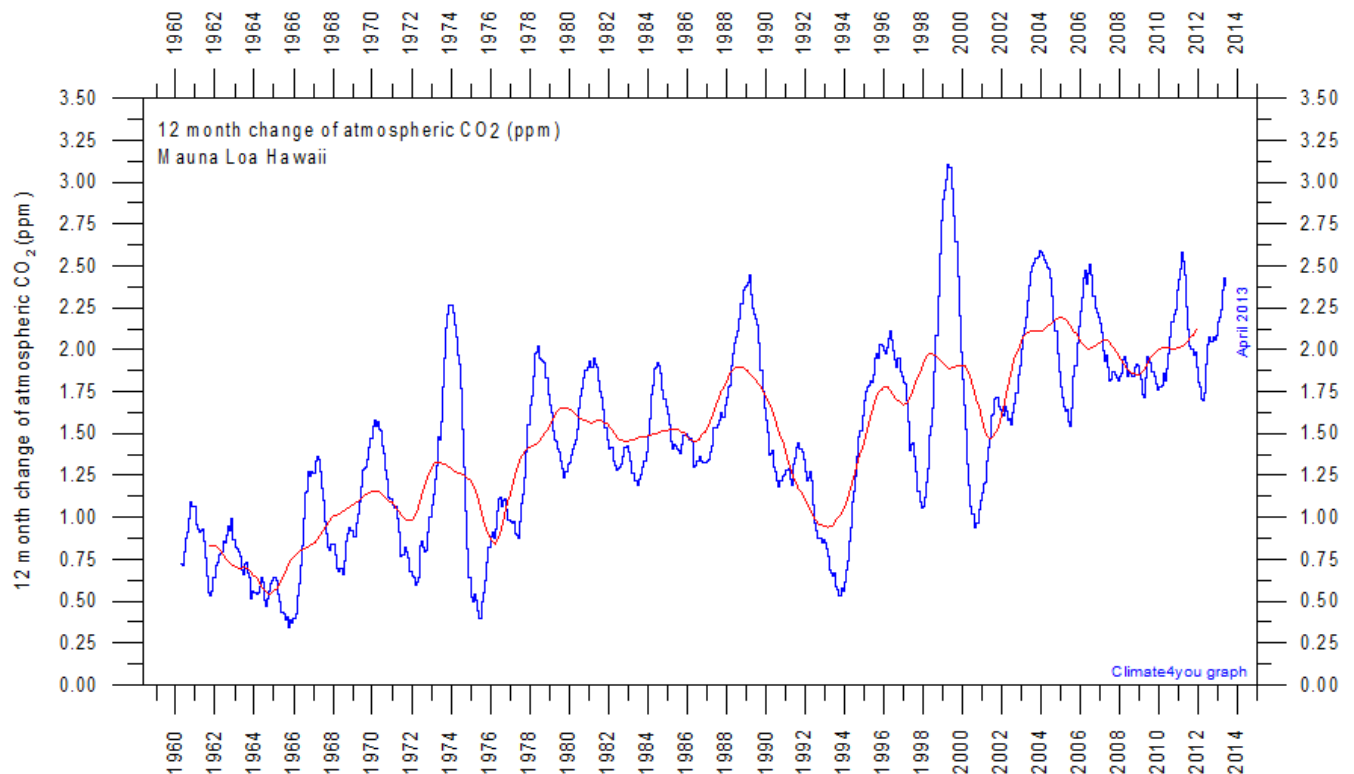


Northern hemisphere weekly snow cover since January 1972 according to Rutgers University Global Snow Laboratory. The thin blue line is the weekly data, and the thick blue line is the running 53 week average (approximately 1 year). The horizontal red line is the 1972-2012 average.

Atmospheric CO₂, updated to April 2013

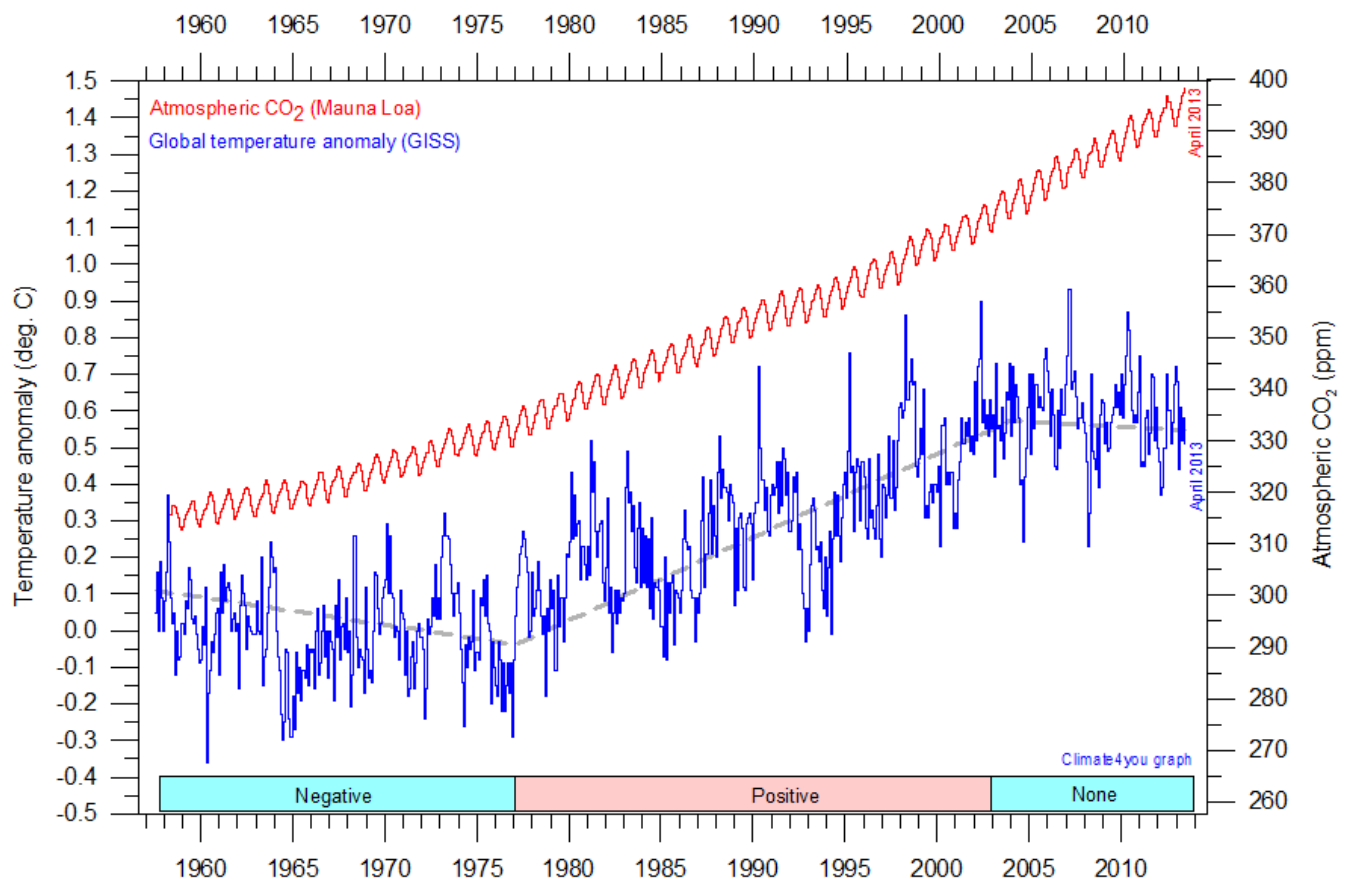
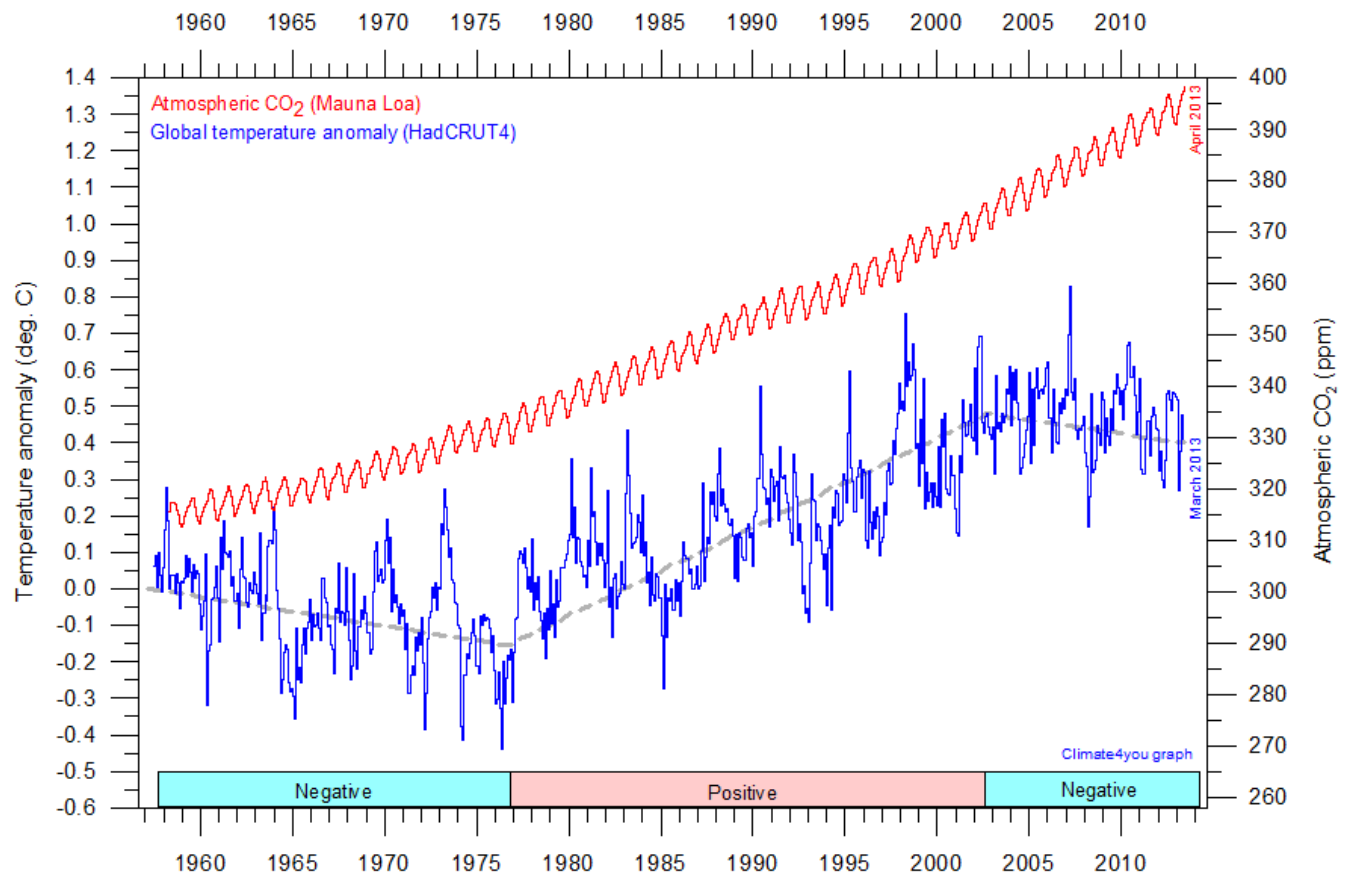


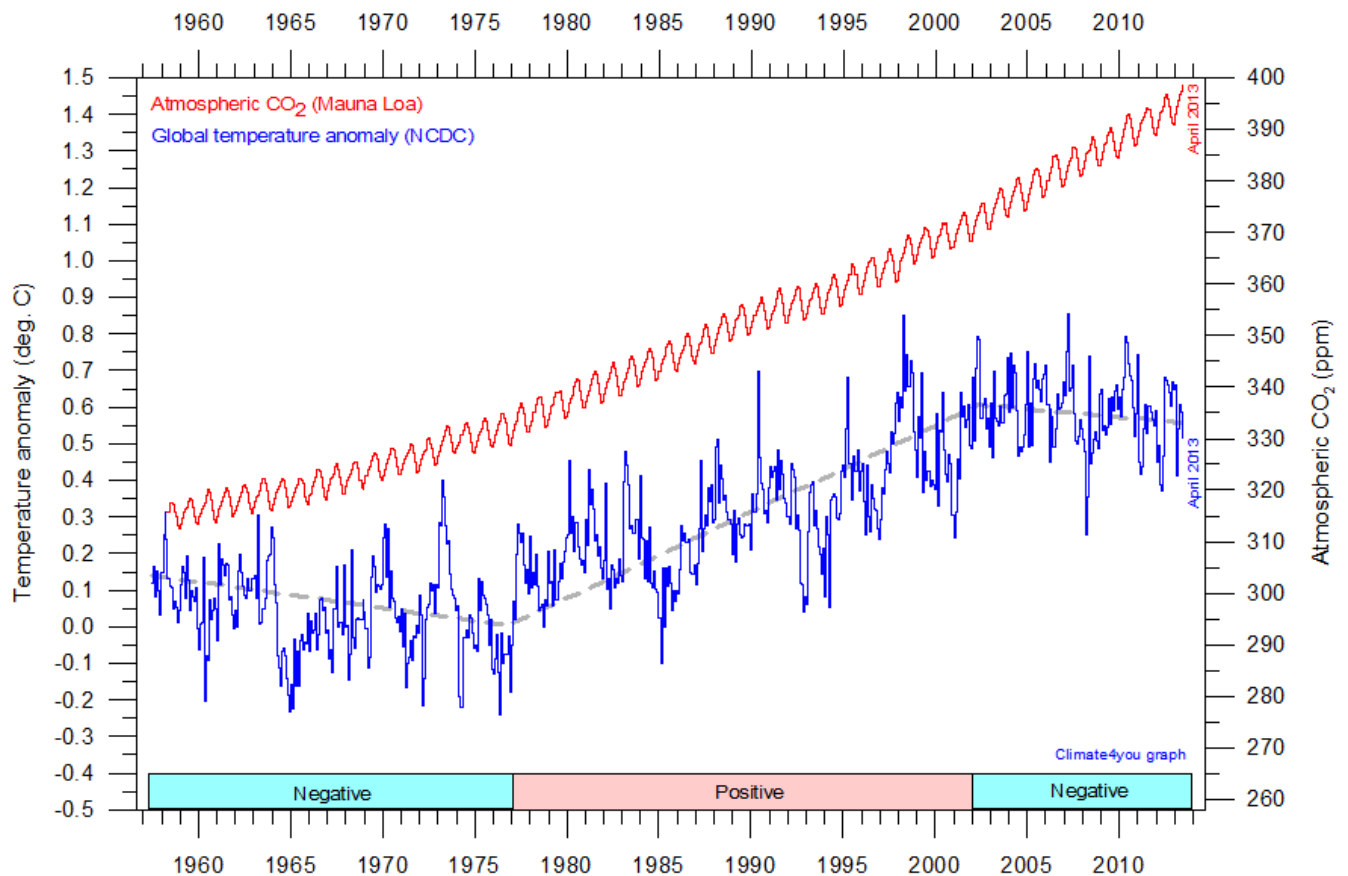
24



Monthly amount of atmospheric CO₂ (upper diagram) and annual growth rate (lower diagram); average last 12 months minus average preceding 12 months, blue line) of atmospheric CO₂ since 1959, according to data provided by the [Mauna Loa Observatory](#), Hawaii, USA. The red line is the simple running 37 observation average, nearly corresponding to a running 3 yr average.

Global surface air temperature and atmospheric CO₂, updated to April 2013





Diagrams showing HadCRUT3, GISS, and NCDC monthly global surface air temperature estimates (blue) and the monthly atmospheric CO₂ content (red) according to the [Mauna Loa Observatory](#), Hawaii. The Mauna Loa data series begins in March 1958, and 1958 has therefore been chosen as starting year for the diagrams. Reconstructions of past atmospheric CO₂ concentrations (before 1958) are not incorporated in this diagram, as such past CO₂ 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 CO₂ and global surface air temperature, negative or positive. Please note that the HadCRUT4 diagram has not been updated beyond March 2013.

26

Most climate models assume the greenhouse gas carbon dioxide CO₂ to influence significantly upon global temperature. It is therefore relevant to compare different temperature records with measurements of atmospheric CO₂, 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 CO₂ on short time scales such as just a few years. It is of course equally inappropriate to present new meteorological record values, whether daily, monthly or annual, as support for the hypothesis ascribing high

importance of atmospheric CO₂ for global temperatures. Any such short-period 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 CO₂ remains elusive, and is still a topic for discussion. However, the critical period length must be inversely proportional to the temperature sensitivity of CO₂, including feedback effects. If the net temperature effect of atmospheric CO₂ is strong, the critical time period will be short, and vice versa.

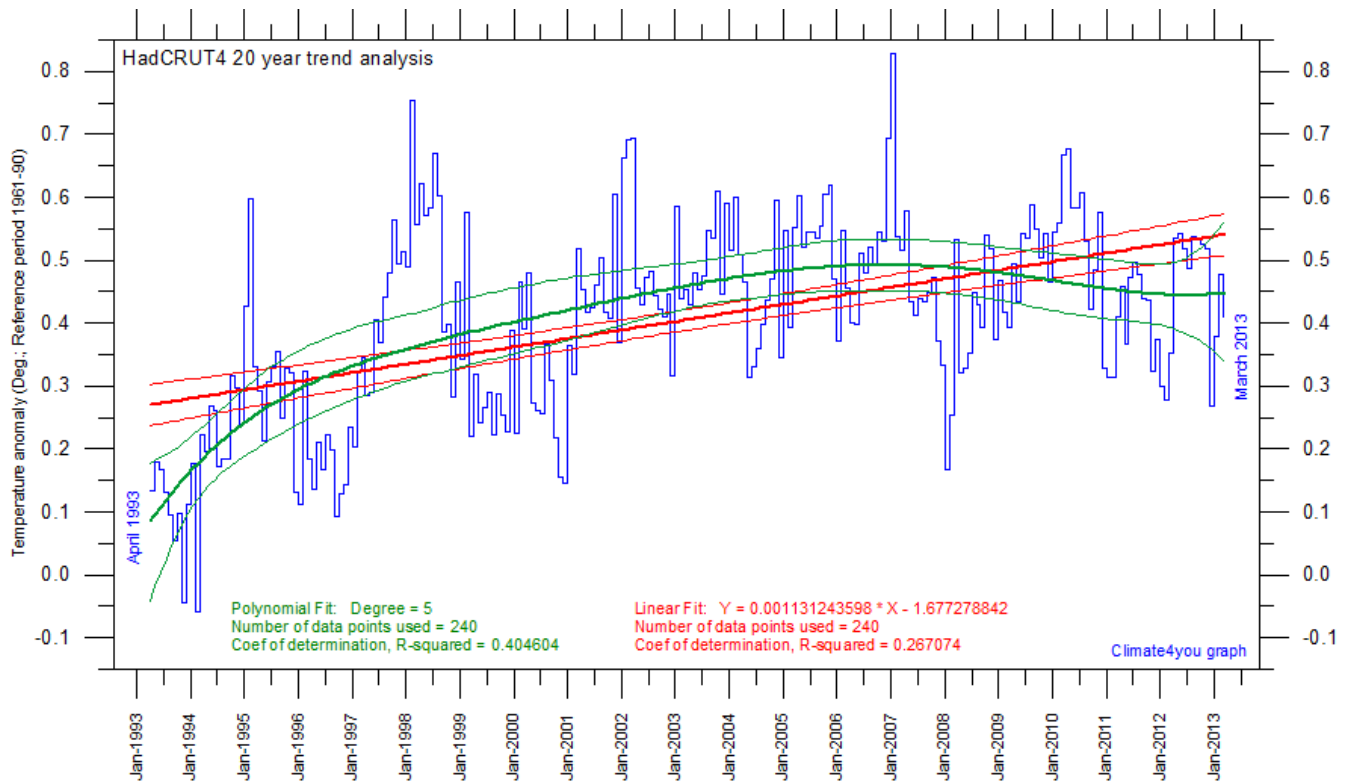
However, past climate research history provides some clues as to what has traditionally been considered the relevant length of period over which to compare temperature and atmospheric CO₂. After about 10 years of concurrent global temperature- and CO₂-increase, IPCC was established in 1988. For obtaining public and political support for the CO₂-hypothesis the 10 year warming period leading up to 1988 in all likelihood was important. Had the global temperature instead been decreasing, political support for the hypothesis would have been difficult to obtain.

Based on the previous 10 years of concurrent temperature- and CO₂-increase, many climate

scientists in 1988 presumably felt that their understanding of climate dynamics was sufficient to conclude about the importance of CO₂ 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 CO₂ 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 CO₂ has been indicated in the lower panels of the diagrams above.

Last 20 year monthly surface air temperature changes, updated to March 2012



28

Last 20 years global monthly average surface air temperature according to Hadley CRUT, a cooperative effort between the [Hadley Centre for Climate Prediction and Research](#) and the [University of East Anglia's Climatic Research Unit \(CRU\)](#), UK. The thin blue line represents the monthly values. The thick red line is the linear fit, with 95% confidence intervals indicated by the two thin red 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 is given in the lower part of the diagram (note that the linear trend is the monthly trend).

From time to time it is debated if the global surface temperature is increasing, or if the temperature has levelled out during the last 10-15 years. The above diagram may be useful in this context, and it clearly 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.

May 1941: Circumnavigating a storm centre; Bismarck's sortie into the North Atlantic



The German battleship Bismarck near Bergen, seen from the heavy cruiser Prinz Eugen. Probably this photo was taken in the late afternoon on 21 May 1941, shortly before the two ships departure into the Norwegian Sea. The crew of Bismarck had been busy the whole day by painting a new camouflage pattern (note the fake bow wave behinds the ships real bow). The photo is taken towards E, about 2 km NE of the present Flesland Airport. The wave pattern as well as the anchored ship's orientation reveals air flow from S at the time when the photo was taken. Picture source: www.bismarck-class.dk.

After finishing her sea trials in the Baltic in early April 1941, the German battleship *Bismarck* was ready for her first sortie into the Atlantic. It was planned that *Bismarck* together with the likewise new heavy cruiser *Prinz Eugen* and the two small battleships *Gneisenau* and *Scharnhorst* should form a rapid and powerful unit. This rather formidable force would operate together during a three-month raid in the North Atlantic, commencing in April, representing a serious threat against British supply routes from USA and Canada. *Gneisenau* and *Scharnhorst* had recently completed a successful sortie into the North Atlantic under the command of Admiral Günther Lütjens, eventually making harbour in Brest, in occupied France. It was foreseen that *Bismarck* and *Prinz Eugen* together should attempt breaking out into the open North Atlantic south of Iceland via the Norwegian Sea, while *Gneisenau* and *Scharnhorst* at the same time would steam out from Brest. Timing was essential, as the long summer nights at northern latitudes rapidly were approaching, making the breakout

difficult. Again Admiral Lütjens should be in command.

Then misfortune struck. *Scharnhorst* had developed metallurgical boiler problems at the end of the previous mission, and it was now realised that the engine refit would take at least until June. Then on April 6 *Gneisenau* was severely damaged in Brest by British air raids, and was also out of action for several months. Few days later *Prinz Eugen*, just ending her final sea trials in the Baltic, was damaged by a mine near Kiel. The whole action 'Rheinübung' had to be delayed until at least early May.

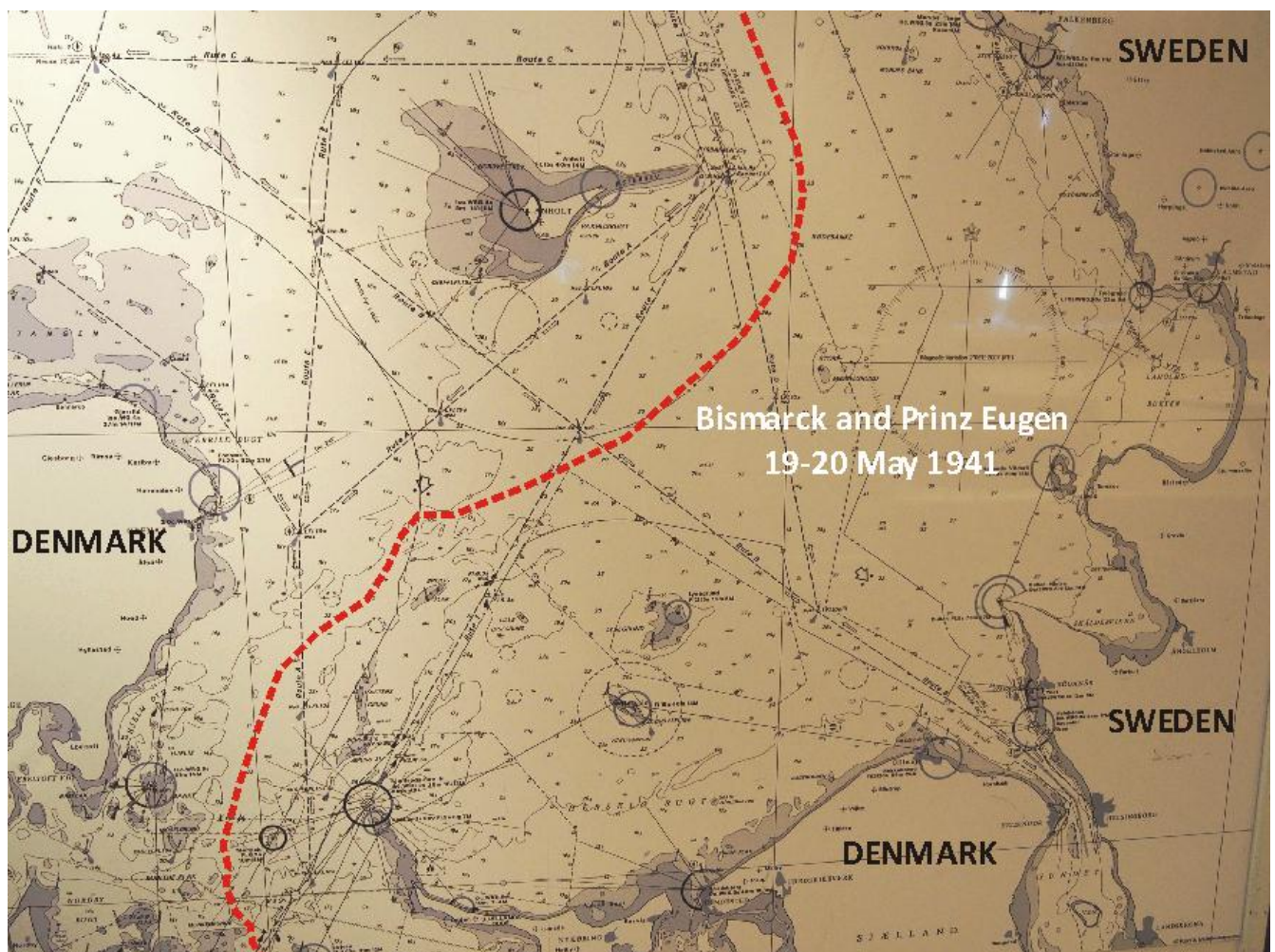
It quickly was realised that neither *Gneisenau* nor *Scharnhorst* would be able to participate in the planned raid, but after repair *Prinz Eugen* would be able to make it. Under these circumstances Admiral Lütjens preferred to postpone the whole operation until the other new heavy German battleship, *Tirpitz*, was ready in July. Grand Admiral Erich Raeder however ordered him to proceed without

delay, although the strength of his battle force now was severely reduced; better now than later, when the USA may have entered the war and changed the whole strategic situation. Realising how perilously the operation would be for *Bismarck* and *Prinz Eugen* under these changed circumstances, the commander of *Tirpitz*, Kapitän zur See Karl Topp, several times asked the naval high command for permission to let his new battleship join the battle force, even though *Tirpitz's* sea trials were not yet fully completed, but in vain.

The repair work on *Prinz Eugen* caused some additional delay, but, finally, late 18 May 1941

Bismarck and *Prinz Eugen* sortied separately from Gotenhafen (now Gdynia, Poland). They were joined on 19 May by a minesweeping flotilla and three destroyers, which would accompany them to Norway.

While sailing through Danish waters 19-20 May on *Bismarck* Captain Lindemann was confronted with the geomorphological results of recurrent natural climate variations 18-19,000 years ago. Remarkably, this was to have major effects on the later developments of the German naval raid.



Bathymetrical map showing the route (dotted red) taken by Bismarck and Prinz Eugen in southern Kattegat in May 1941. Shallow water depths are indicated by grey colour. Depths in meters.

At the maximum of the last glacial period (known as the Weichselian in Europe) about 22-23,000 years ago, the Scandinavian Ice Sheet advanced

across the present Kattegat Sea between Sweden and Denmark, to reach a maximum position about halfway across Jutland, the main western part of

Denmark. During the following retreat towards NE, natural climatic variations from time to time made the ice sheet readvance, producing a number of marked terminal moraines in the Kattegat area. Several of these now submarine moraine ridges are still clearly visible on bathymetric maps, and make navigation through Danish waters a challenging experience for large ships, especially before the invention of GPS.

In May 1941 *Bismarck* was deep in the water, being fully supplied for a three-month raid, and without doubt the draft of the ship exceeded 10 m. Theoretically, *Bismarck* might possibly have taken a route north in the western part of Kattegat, keeping good distance to Swedish territorial waters, as the minimum water depth for a 'deep water' route along the east coast of Jutland is about 11 m. However, when a large ship enters shallow water, an airplane wing effect occurs, but opposite, sucking the ship towards the bottom. Probably Captain Lindemann knew that he therefore would risk hitting big boulders protruding from the glacial sediments below, and correctly concluded that this was not an attractive route for *Bismarck*, although the distance to Sweden would make visual observations of the German flotilla impossible from there. He therefore decided instead to take a route south and east of the Danish island Anholt, where water depth exceeds 17 m at the most shallow point, shortly south of Anholt.

Bismarck and *Prinz Eugen* both successfully navigated these difficult waters on 19-20 May, but this took them near Swedish territorial waters. In the evening the German ships therefore had a short visual encounter with the Swedish cruiser *Gotland*. Without further events, the German flotilla reached a small fjord near Bergen in western Norway around noon 21 May.

Prinz Eugen refuelled from a supply ship, while *Bismarck* did not. *Prinz Eugen* had a limited cruising range of about 10,000 km (at 18 knots), while *Bismarck's* range was longer, about 17,000 km (at 19 knots). *Bismarck* might have refuelled at Bergen, but presumably under the impression of the developing meteorological situation, Admiral Lütjens decided to proceed as fast as possible in the evening of 21 May, without spending time on refuelling. In May 1941 Germany had several

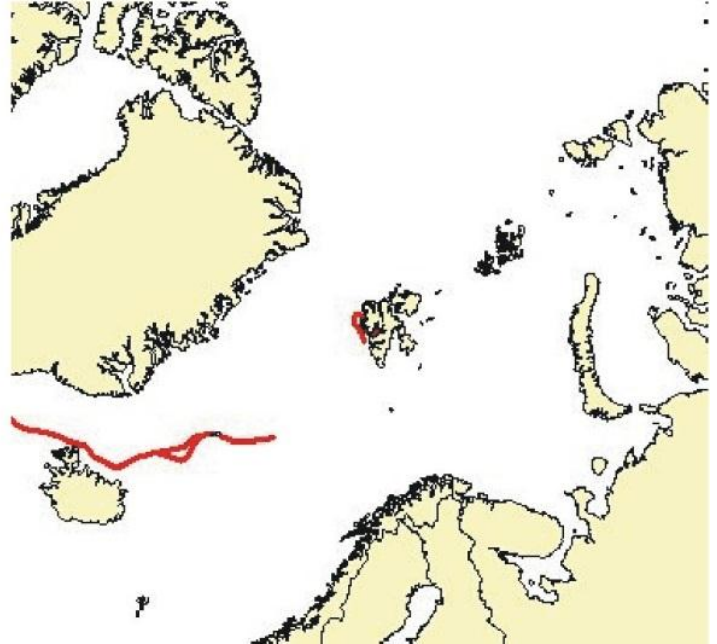
refuelling ships stationed at various positions in the North Atlantic, and *Bismarck* could later refuel at one of these.

One important reason for the hasty departure from Bergen probably was that Admiral Lütjens feared that his operation had been compromised by the chance meeting with the *Gotland* in Kattegat. If so, this would reduce his chances for a passage to the North Atlantic undetected by the British Royal Air Force and Royal Navy. In fact, within hours after the encounter the British Admiralty in London was alerted via sources in Sweden and ordered ships from the Home Navy to sea, including the battlecruiser *Hood* and the battleship *Prince of Wales*, which were ordered to take up a position south of Iceland. A message from the German B-Dienst intelligence headquarters informed Admiral Lütjens that at least several Royal Air Force squadrons had been alerted to the presence of a German naval battle force in southern Norway.

Another reason for the hasty departure was probably a Luftwaffe meteorological officer who boarded *Bismarck* at Bergen, bringing the latest updated meteorological information for the North Atlantic region. With the increasing duration of daylight in the northern latitudes in late May, it was crucial that the weather be sufficiently overcast to hamper British aerial and surface reconnaissance. The Luftwaffe officer reported favourable conditions for a breakout into the Atlantic, provided *Bismarck* and *Prinz Eugen* moved quickly. A large warm high pressure air mass had become stagnant off the coast of the eastern United States, a classic "Bermuda high", which sent warm air masses north across eastern USA with cities like Washington, New York and Boston experiencing a heat wave. In contrast, huge polar air masses were situated over Greenland. These two air masses were colliding along a frontal zone in the North Atlantic, causing the rapid development of a deep low pressure area with a powerful cyclone near Iceland, associated with strong wind, severe icing conditions and strong turbulence as high as 7 km, and snow, rain showers and widespread fog below the clouds (Garzke and Dulin 1994). This was almost ideal weather conditions for the planned breakout into the North Atlantic.

Thus, Admiral Lütjens had several good reasons for leaving Bergen rapidly, but whatever the exact reason, the failure to top off *Bismarck*'s fuel tanks was later to prove to be a crucial omission. *Bismarck* and *Prinz Eugen* left Bergen by 19:30 on 21 May 1941, heading first N and later NW into the

Norwegian Sea. Because of the developing low pressure near Iceland the wind was from astern, and the weather with rain, low clouds and fog. At certain times the fog reduced the sight to only 3-400 m.



32

Bismarck with search light pointed to the rear seen from *Prinz Eugen* during the traverse of the Norwegian Sea on 22 May 1941 (left; exactly 72 years ago). Sea ice boarder between Iceland and Greenland on 20 May 1941 (right figure; source: <http://acsys.npolar.no/ahica/quicklooks/>). The existence of this unique archive of former Arctic sea ice limits are thanks to the painstaking work of Dr. T. Vinje at the Norwegian Polar Institute.

To maintain formation and safe distance, the two ships had to turn on their searchlights. By this *Prinz Eugen* was able to follow closely in the wake of *Bismarck* at relatively high speed, about 24 knots. It was important to reach the Denmark Strait between Iceland and Greenland, before the weather improved and the British Royal Navy was in place to intercept. At 23:22 on 22 May *Bismarck* and *Prinz Eugen* were north of Iceland and changed course directly to W. In the morning of 23 May they increased speed to 27 knots and changed course toward SW, now heading for the northern part of the Denmark Strait between Iceland and Greenland, the most hazardous part of the attempted breakout. Simultaneously the wind turned into NE (Müllenheim-Rechberg 2005), indicating that the German ships now were NW of the developing storm centre.

At 15:00 on 23 May *Bismarck* and *Prinz Eugen* ships suddenly came out of the fog, and sailed into clear air with more than 5 km visibility, except for scattered snow showers. Not exactly the best weather for a breakout, but demonstrating that the two ships now had entered the cold air masses on the NW side of the developing storm centre further south. A few kilometres to the east, however, there was still low visibility with low clouds and fog, and the two ships must at that time have been sailing only a few kilometres NW of the meteorological front between the two air masses.

At 18:11 alarm was sounded on *Bismarck*; a ship was sighted on starboard side. A few minutes later, however, the ship turned out to be an iceberg. The eastern limit of the arctic sea ice along East Greenland had been reached. Usually the sea ice along East Greenland has its maximum extension in

late March or early April, so it was only short time after the seasonal maximum. At 19:00 the limit of the dense sea ice was reached, and the two ships now had to make frequent changes of their course to avoid collisions with heavy ice floes while still proceeding at high speed. *Prinz Eugen* was later reported to develop noise from one of its three propeller shafts while sailing in the ice, perhaps because one of the propellers received light damage from contact with an ice floe (Schmalenbach 1998). Further W the summit of the Greenland Ice Sheet could be seen clearly in *Bismarck's* visual range-finding equipment (Müllenheim-Rechberg 2005).

Both *Bismarck* and *Prinz Eugen* were equipped with a new type of German radar, and at 19:22 indications of a ship to port were picked up. This turned out to be the heavy British cruiser *Suffolk*, which recently had been equipped with a new, powerful version of British radar, and now began

following the German ships from a position to the rear, keeping out of firing range. At 20:30 *Suffolk* was joined by a second British cruiser, *Norfolk*. The German ships increased the speed to more than 30 knots, and *Bismarck* fired five rounds with its heavy 38 cm guns towards this new target, which appeared on the port side to the rear. Unfortunately, the pressure blast from the two forward main gun towers pointed obliquely astern damaged the forward radar on *Bismarck*, so she now only had the rear radar left. Admiral Lütjens therefore ordered *Prinz Eugen* to take up position in front of *Bismarck*, so the German ships still had radar capacity to probe the ocean ahead. The British ships send a stream of position reports to London, and to the two heavy warships *Hood* and *Prince of Wales*, which was south of Iceland, in an excellent position to intercept the German flotilla shortly SW of Iceland in the early morning of 24 May.



Battlecruiser HMS Hood (47,430 tonnes).

Prince of Wales was a brand-new ship with a partially-trained crew and still not quite reliable main battery turrets. *Hood* was constructed in 1920, but later modernised, and in 1940 recognised as being the pride of the British Royal British Navy. *Hood* was constructed to combine the speed of a cruiser with the firepower of a battleship, and she was able to outrun as well as outgun *Bismarck*. Her main weak point was the relatively thin main deck

armour, making the ship vulnerable for steeply plunging projectiles fired over long distances. In contrast, *Bismarck* was constructed to take as well as give severe punishment at all distances, as would later be demonstrated.

Around 5:00 on 24 May hydrophones on *Prinz Eugen* picked up sounds of propellers from two

fast-moving heavy vessels approaching on the port bow. At 05:45 the German and British ships got each other in sight. The wind was now from a northerly direction, and the German ships were still

running with the wind and waves. The still developing low pressure centre was now to the east.



Bismarck photographed from Prinz Eugen during the battle at Iceland, 24 May 1941. Note the narrow and almost invisible steam trail emitted by the funnel, indicating that turbines are driving the ship at maximum speed (30+ knots). To the right a 70 m high water impact fountain from one of Prince of Wales 35.6 cm projectiles is seen. Bismarck's top trained gunners are firing with 22 second intervals (Berthold 2005), and the previous salvo cloud is seen to the right. The smoke from the next salvo is seen just above the rear deck of Bismarck. Bismarck is on a southerly course, and the wave pattern shows the wind to be from N. The fact that Bismarck is able to outrun the smoke cloud shows that the wind speed is less than 15 m/s when the photo was taken. Bismarck is 241 m long, roughly corresponding to the distance to the previous salvo smoke cloud to the right in the picture. So within 22 seconds Bismarck at 30+ knots was able to outrun the tail wind with about 11 m/s, suggesting the northerly wind to be light, about 4 m/s, as is also suggested by the wave pattern.

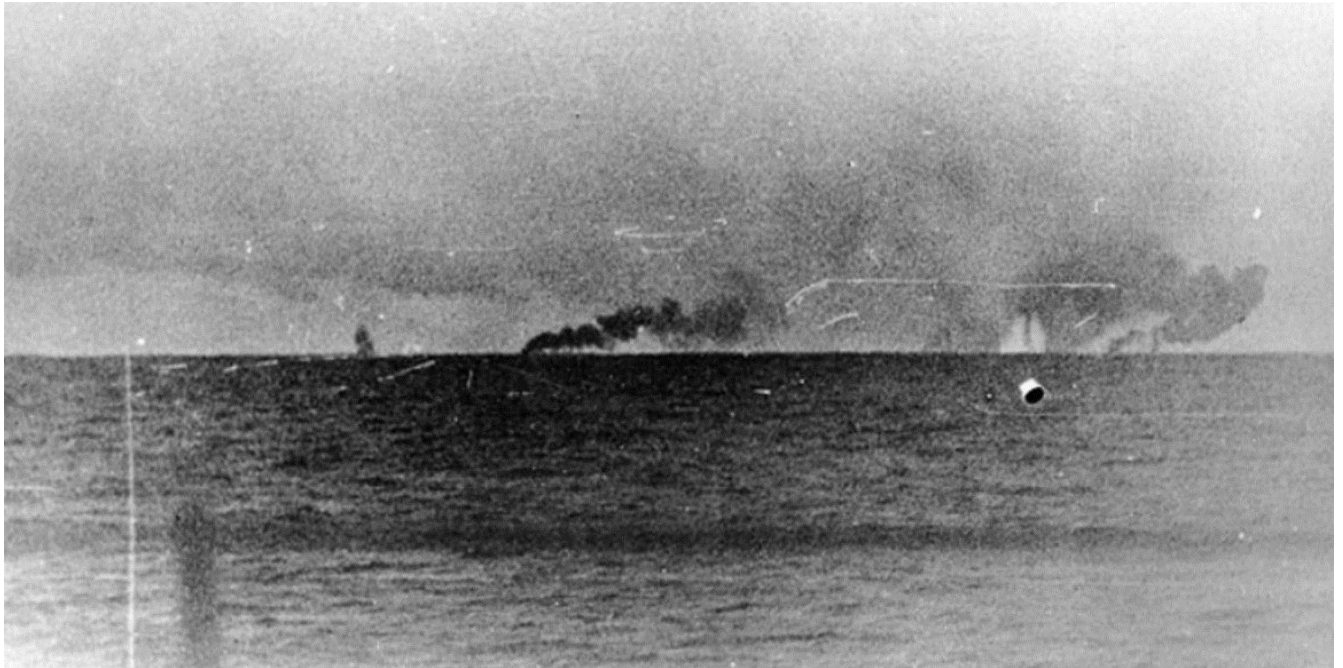
Hood and Prince of Wales were commanded by Vice Admiral Lancelot Holland, who decided to close the range to *Bismarck* as fast as possible, to avoid being exposed to steeply plunging projectiles for an extended period in a long-range gunnery engagement. At shorter range the projectiles would fly at shallow angle, where the heavy side armour of *Hood* would be able to protect her efficiently. Both British ships therefore steered directly towards *Bismarck* and *Prinz Eugen* at full speed, even though this meant that they only were able to

use their forward guns during the approach run, while the two German ships could use all their heavy artillery. A classical 'crossing the T' situation, made famous by Admiral Horatio Nelson during the battle at Trafalgar, 21 October 1805, but at Iceland on 24 May 1941 it was the German ships that had the better tactical position.

During the approach run Admiral Holland ordered *Hood* and *Prince of Wales* to fire against the leading German ship, assuming this to be their main

opponent, *Bismarck*. All modern heavy German warships at that time displayed similar profile, which obviously made Admiral Holland target the British fire on the smaller *Prinz Eugen*, instead of

targeting on the more dangerous *Bismarck*. The Commander of *Prince of Wales* however recognised the error, and rapidly turned his fire on *Bismarck*.



35

Photo taken 24 May 1941 06:03 from *Prinz Eugen*, looking east. To the left the smoke from the explosion of *Hood* is seen. The stern of *Hood* is still visible above the water to the left of the smoke plume. To the right smoke emitted by *Prince of Wales* is seen. The battleship itself is almost hidden behind water sprouts from one of *Bismarck*'s salvos. The northerly wind is clearly shown by the smoke clouds.

At a distance of about 18 km Admiral Holland decided to turn sharply to port, to enable all his guns to engage. However, at 05:58 while turning *Hood* was hit by a salvo from *Bismarck*. One or several projectiles penetrated the weak main deck armour and ignited an ammunition magazine below. *Hood* erupted in a violent explosion, breaking the mighty ship in two. Three minutes later *Hood* disappeared below the surface, with only three men surviving from a crew of 1397. Both *Bismarck* and *Prinz Eugen* rapidly shifted their combined fire towards *Prince of Wales*, who was severely hit several times, and attempted to escape in easterly direction at full speed. Instead of giving pursuit and much to Captain Lindemann's dismay, Admiral Lütjens however decided to break off the battle. He was under the general order to avoid exposing his ships to serious danger, which might impede his later ability to operate efficiently in the North Atlantic. As it turned out, *Bismarck* had actually being hit by *Prince of Wales*, seriously

limiting the fuel available and causing the flooding of one boiler room, reducing her top speed to 28 knots.

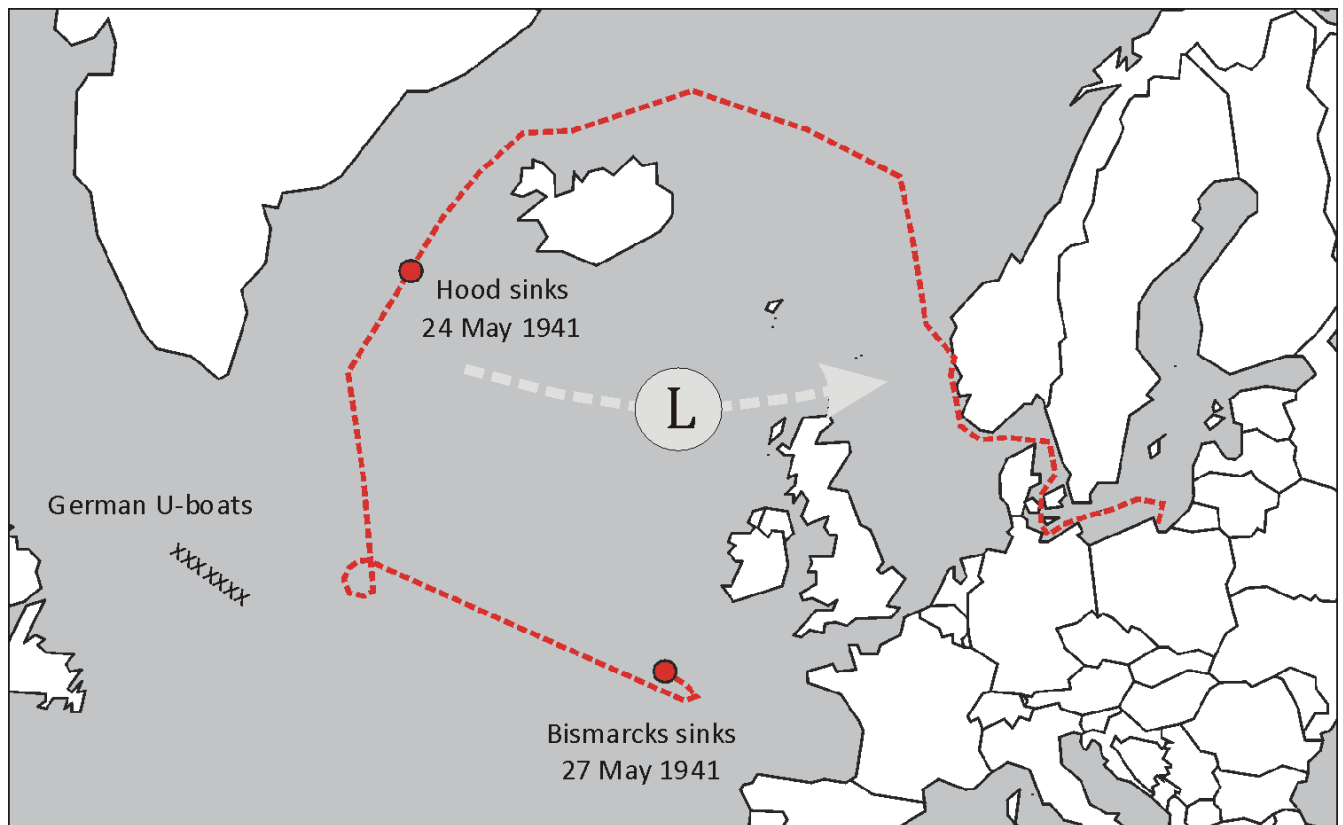
While the battle damage on *Bismarck* was still being evaluated, the two German ships proceeded in SW direction at 28 knots, still shadowed by *Suffolk* and *Nordfolk*. Admiral Lütjens was now becoming highly impressed by the efficiency of the new British radar. Apparently it was almost impossible to escape from especially *Suffolk*, who had the more modern equipment, bringing the entire mission in jeopardy. Admiral Lütjens therefore planned to draw the two British cruisers across a line of seven German submarines, waiting shortly south of Greenland, exactly with this situation in mind (Dönitz 1997).

However, before reaching the waiting line of submarines Admiral Lütjens realised how seriously

Bismarck's fuel situation had become, partly due to the loss of available fuel, partly due to the lack of refuelling while at Bergen, but also because the British radar virtually made it virtually impossible to rendezvous unnoticed with a German supply ship waiting near Greenland. He had no guarantees that both pursuing British cruisers would be taken out by the submarines. The only option left for *Bismarck* apparently was to head directly for the German naval base in St.Nazaire, France, keeping an economical speed of about 20 knots. Presumably *Bismarck* was in no real danger for

running out of fuel before reaching France, but this might rapidly change, should a sea battle develop en route, where the ship had to make use of full speed for an extended period. The course was therefore changes from SW to SSE.

The weather was slowly becoming windier from N with low clouds and fog, and when entering a bank of dense fog at 03:00 in the early morning of 25 May, *Bismarck* at full speed turned starboard in a wide curve, while *Prinz Eugen* proceeded on a southerly course, undamaged and as fast as ever.



The route of battleship *Bismarck* 18-27 May, 1942. The approximate track of the storm centre is indicated.

Due to the still limited range of *Suffolk's* radar, both German ships actually managed to avoid being tracked and escaped. The radarmen on *Suffolk* were used to losing contact with *Bismarck* for short periods as their ship zigzagged to avoid possible U-boat attacks. The fact that *Bismarck* and *Prinz Eugen* disappeared at 03:00 therefore initially did not alarm them very much, but at 05:00 they had to admit that contact with the German ships had in fact been lost permanently. At that time *Bismarck* was far behind *Suffolk* to the north,

sailing across her own wake and taking a SE course for St. Nazaire in France. *Prinz Eugen* was far ahead in the North Atlantic, where she would do what raiding it could.

Actually, *Prinz Eugen* successfully made it to one of the German supply ships further south in the North Atlantic, but as the fuel she received turned out to be of low quality, she soon developed serious boiler problems and had to return to Brest in France on the 30 May (Schmalenbach 1998).

Having lost radar contact, *Suffolk* for several hours navigated in a systematic search pattern, attempting to relocate *Bismarck*, but without success. On *Bismarck*, however, the radar room reported receiving the radar emissions from *Suffolk*, and Admiral Lütjens therefore wrongly concluded that *Bismarck* was still under radar surveillance. Radar was at that time a new technical concept, and presumably it was not realised on *Bismarck* that the reflected signal was too weak to be received by *Suffolk*. Lütjens in the morning of 25 May therefore decided that he could just as well send a long radio transmission back to the German High Naval Command, explaining details of the previous battle and *Bismarck*'s present fuel predicaments. This prolonged (about 30 minutes) German radio transmission quite unanticipated provided British radio-direction finding stations with the opportunity of plotting *Bismarck*'s position.

However, a serious plotting error was made, as the initial plotting of the measured bearing lines was done on a Mercator projection map, instead of using a gnomonic map (displays all great circles as straight lines), which is required to plot such lines of bearing correctly. The plotting error turned out to be quite substantial, giving the false impression that *Bismarck* was heading back towards Norway via the sea between Iceland and the Faroes. So therefore the entire British Home Fleet steamed at full speed in a northerly direction, while *Bismarck* in reality was proceeding steadily towards SE. Never underestimate the importance of using appropriate cartography. When the cartographic error eventually was recognised in the afternoon, *Bismarck* was way ahead of all heavy British warships. In addition, because of the large detour, several of these were beginning to run low on fuel. It looked as if *Bismarck* in spite of all odds would make it safely to St. Nazaire, saved by the Mercator map projection!

The weather was now stormy with winds of force 9 from NW and overcast, as *Bismarck* came into the air flow on the rear side of the strong storm centre now approaching Europe. Initially this highly unpleasant weather aided *Bismarck* in her escape in the night to 25 May, but her course was downwind and large following seas caused a large yaw response and significant rolling. During trials in the Baltic, *Bismarck* had demonstrated problems

with directional instability due to the propeller and rudder setup, and the combing effects of the storm, the following seas and this slight directional instability, necessitated substantial rudder usage to maintain the desired course towards France throughout 25 May. Presumably, the downwind ride in the heavy sea was not too pleasant for *Bismarck*'s crew with its sickening, corkscrew motion.

On the morning of 26 May the British Navy Force "H" called up from Gibraltar was slightly north of *Bismarck*'s position, but without knowing it. The battlecruiser *Renown*, the aircraft carrier *Ark Royal* and the light cruiser *Sheffield* had crossed *Bismarck*'s track a few hours ahead of *Bismarck* and were by chance close to her when a Catalina flying boat finally spotted her at 10:30 on 26 May.

Swordfish planes from *Ark Royal* then were alerted to carry out a torpedo attack on *Bismarck* during the afternoon. The attack was carried out as planned, but unfortunately it turned out that the ship being attack was not *Bismarck*, but the British heavy cruise *Sheffield*, which was also in the area. The error was recognized in the very last moment, and three torpedoes already launched luckily all failed. So a new attack had to be organized on *Bismarck*. But first all airplanes had to come back to *Ark Royal*, refuel and rearm and it looked as if *Bismarck* in the meantime was going to disappear into the night darkness. However, precisely at sunset in the evening of 26 May 1941 *Bismarck* became exposed to a determined torpedo attack by 15 Swordfish planes from *Ark Royal*. The attack was carried out in almost unbearable weather conditions, wind force 9 from NW, low clouds and waves 8-13 m high.

Although hampered by high waves and diminishing visibility, Captain Lindemann remarkably at high speed outmanoeuvred most of the torpedoes coming almost synchronously from different directions, but in the final moments of the attack *Bismarck* took two torpedo hits; one of the torpedoes did not cause any serious damage, but the final torpedo hit the rear of the ship near the two rudders. The transient whipping response caused by this torpedo hit was stunning as the hull acted like a springboard, and severe structural damage was sustained in the stern structure. Possibly part of the stern settled on the rudders

below, jamming those beyond any chance of repair (Garzke and Dulin 1994). Both rudders jammed at a position of 12 degrees to port, as the *Bismarck* was in the process of turning to evade a portside torpedo attack, and she made two full circles before reducing speed. Once speed was reduced, the ship unavoidably assumed a NW course into the strong wind, directly towards her pursuers, as the intensity of the storm increased even more.

The heavy sea and the damage done to the stern made it impossible for the damage control teams to correct the jammed rudders, as they were unable to enter the flooded steering compartments. Subsequent attempts to control the course of *Bismarck* by the propellers failed also because of the strong wind which forced the ship into a course against to the wind, a weakness which already had been identified during the sea

trials in the Baltic. It has later been suggested that *Bismarck* perhaps might have reached France over the stern, by sailing in aft direction with the three undamaged propellers rotating in a special setup to compensate for the jammed rudders. However, this would probably have been extremely difficult – if not impossible – due to the stormy weather, and also to the fact that all intakes for cooling water were designed with forward movement in mind. Sailing aft over the stern for an extended period might therefore have resulted in the turbines overheating. As it was, there was no other option than let the turbines rotate at slow speed ahead to ensure sufficient cooling, although this constantly brought *Bismarck* closer to her pursuers. The turbines and the propellers were the only remaining means by which *Bismarck* to some degree could at least reorientate herself during the coming battle.



The battleship Rodney firing at Bismarck in the morning of 27 May 1941. Bismarck is seen in the distance, emitting smoke from fires, and slowly heading towards the NW storm at 5-7 knots. Rodney is on an easterly course, and the smoke cloud from the last salvo is rapidly blown ahead of the ship by the NW storm.

The only thing which realistic might have saved *Bismarck* at this point was a change of wind to easterly direction. Instead of slowly moving towards her pursuers throughout the following night, she would then probably have been able to make headway against the wind in easterly direction with a speed of 15-20 knots. By this *Bismarck* would have been about 3-400 km further

to the east next morning, much closer to the French coast with its potential protection by the German Luftwaffe. In addition, and perhaps more important, she might technically have been out of reach for several of the British warships, which during the final battle in the morning of 27 April were dangerously low on fuel and therefore had to leave the scene before *Bismarck* actually sunk.

However, due to the prevailing meteorological situation, there was no possibility for such a change in wind direction to occur in the night between 26 and 27 May 1941. As noted by one of the survivors from Bismarck, Baron v. Müllenheim-Rechberg (Müllenheim-Rechberg 2005), *Bismarck* had strangely been running with a tail wind for almost the entire sortie into the North Atlantic, circumnavigating the storm centre.

In the morning of 27 May 1941 *Bismarck* was surrounded by a significant part of the Royal Navy. She sank at 10:39 after being scuttled by her own crew, having lost all defensive capacity after putting up a magnanimous fight throughout the

night with several destroyers and with two battleships since 08:47, all under completely hopeless conditions. Only 113 of the total crew of 2065 were rescued.

The wreck of *Bismarck* was discovered on 8 June 1989 by Dr. Robert D. Ballard, resting in upright position on the sediment covered bottom of the Atlantic Ocean some 900 km west of Brest at a depth of nearly 5 km. A large submarine landslide was released when *Bismarck* hit the bottom in late May 1941, today covering several square kilometres of the ocean floor.

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All the above diagrams with supplementary information, including links to data sources and previous issues of this newsletter, are available on www.climate4you.com

Yours sincerely,

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May 22, 2013.