HISTORICAL TEMPERATURE TRENDS IN ANTARCTICA

SPPI
Science & Public Policy Institute
"science-based policy for a better world"

SPPI & CO_2SCIENCE ORIGINAL PAPER ♦ October 30, 2013

HISTORICAL TEMPERATURE TRENDS IN ANTARCTICA

Citation: Center for the Study of Carbon Dioxide and Global Change. "Historical Temperature Trends in Antarctica." Last modified October 30, 2013. http://www.co2science.org/subject/a/summaries/antarcticatemp.php.

From the birth and death of ice ages to the decadal meanderings of modern-day weather patterns, studies of Antarctica bear witness to the fact that the atmosphere's CO_2 concentration is not a major player in bringing about significant changes in earth's climate; and in what follows, the case for this proposition is presented in the form of brief reviews of pertinent studies directed, first of all, at glacial periods, then the singular Holocene, and finally the past few decades.

From the birth and death of ice ages to the decadal meanderings of modern-day weather patterns, studies of Antarctica bear witness to the fact that the atmosphere's CO_2 concentration is not a major player in bringing about significant changes in earth's climate.

GLACIAL PERIODS

The study of Antarctic temperatures has provided valuable insight into - and spurred contentious debate on - issues pertaining to global climate change. Key among early pertinent findings was the observation of a large-scale correlation between proxy air temperature and atmospheric CO_2 measurements obtained from ice cores drilled in the interior of the continent. In the mid- to late-1980s, this broad correlation dominated much of the climate change debate; and many a climate alarmist jumped on the global warming bandwagon, claiming that the gross CO_2-temperature correlation proved that changes in atmospheric CO_2 concentration caused corresponding changes in air temperature, and that future increases in the air's CO_2 content due to anthropogenic CO_2 emissions would therefore intensify global warming.

This contention, however, was challenged by Idso (1989), who wrote - in reference to the very data that were used to support the claim - that "changes in atmospheric CO_2 content never precede changes in air temperature, when going from glacial to interglacial conditions; and when going from interglacial to glacial conditions, the change in CO_2 concentration actually lags the change in air temperature (Genthon *et al.*, 1987)." Hence, he concluded that "changes in CO_2 concentration cannot be claimed to be the cause of changes in air temperature, for the appropriate sequence of events (temperature change *following* CO_2 change) is not only never present, it is actually violated in [at least] half of the record (Idso, 1988)."

Some ten years later, Petit *et al*. (1999)[1] reconstructed histories of surface air temperature and atmospheric CO_2 concentration from data obtained from a Vostok ice core that covered the prior 420,000 years, determining that during glacial inception "the CO_2 decrease lags the temperature decrease by several thousand years" and that "the same sequence of climate forcing operated during each termination." Likewise, while working with sections of ice core records from around the times of the most recent three glacial terminations, Fischer *et al*. (1999)[2] found that "the time lag of the rise in CO_2 concentrations with respect to temperature change is on the order of 400 to 1000 years during all three glacial-interglacial transitions."

Thus, by the turn of the century (and *millennium*), the bottom of the poorly-constructed bandwagon had begun to fall apart, as the evidentiary glue that held it together began to weaken. Advances in ice-coring instrumentation and techniques had improved considerably; and newer studies with finer temporal resolution began to reveal that, if anything, increases (decreases) in air temperature drive increases (decreases) in atmospheric CO_2 content, and not vice versa, as suggested, for example, by the work of Indermuhle *et al*. (2000)[3] and Monnin *et al*. (2001)[4]. And a severe blow was thus dealt to the climate-alarmist community, as a major tenant of the CO_2-induced global warming hypothesis was shown to be contradicted by real-world observations.

By the turn of the century (and millennium), the bottom of the poorly-constructed bandwagon had begun to fall apart … and a severe blow was thus dealt to the climate-alarmist community, as a major tenant of the CO_2-induced global warming hypothesis was shown to be contradicted by real-world observations.

A further good example of this relationship was provided by Caillon *et al*. (2003), who showed that during Glacial Termination III, "the CO_2 increase lagged Antarctic deglacial warming by 800 ± 200 years." And although this finding, in their words, "confirms that CO_2 is not the forcing that initially drives the climatic system during a deglaciation," they and many others continued to hold to the view that the *subsequent* increase in atmospheric CO_2 - which is believed to be due to warming-induced CO_2 outgassing from the world's oceans - serves to amplify the warming that is caused by whatever it is that prompts the temperature to rise in the first place. This belief, however, is founded on unproven assumptions about the strength of CO_2-induced warming; and it is

[1] http://www.co2science.org/articles/V2/N12/C1.php.
[2] http://www.co2science.org/articles/V2/N8/C3.php.
[3] http://www.co2science.org/articles/V3/N37/C1.php.
[4] http://www.co2science.org/articles/V4/N8/C1.php.

applied without any regard for biologically-induced negative climate feedbacks that can occur in response to atmospheric CO_2 enrichment.

THE HOLOCENE

Focusing on a more recent time interval, Yoon *et al.* (2002)[5] wrote that "the maritime record on the Antarctic Peninsula shelf suggests close chronological correlation with Holocene glacial events in the Northern Hemisphere, indicating the possibility of coherent climate variability in the Holocene." And in much the same vein, Khim *et al.* (2002)[6] stated that "two of the most significant climatic events during the late Holocene are the Little Ice Age (LIA) and Medieval Warm Period (MWP), both of which occurred globally (Lamb, 1965; Grove, 1988)," while further noting that "evidence of the LIA has been found in several studies of Antarctic marine sediments (Leventer and Dunbar, 1988; Leventer *et al*., 1996; Domack *et al*., 2000)."

To this list of scientific journal articles documenting the existence of the LIA in Antarctica can Khim *et al*.'s own paper be added, for it also demonstrates the presence of the MWP in Antarctica, as well as earlier cold and warm periods of similar intensity and duration. Hence, it is becoming ever more difficult for climate alarmists to continue to claim that these several-hundred-year cold and warm periods were confined to lands bordering the North Atlantic Ocean. They clearly were *global*; and they clearly demonstrate the reality of the likely solar-induced millennial-scale climatic oscillation that is manifest in the post-1850 warming of the world that climate alarmists misconstrue as having been caused by the concomitant rise in the air's CO_2 content.

To further drive home this point, Stenni *et al.* (2002)[7] examined a number of paleoclimatic indicators in two firn cores that were retrieved from the Talos Dome area of East Antarctica in 1996, with accurate dating being provided by non-sea-salt sulfate spikes associated with well-documented volcanic eruptions and with tritium activity associated with known atmospheric thermonuclear bomb tests. The results of their work were compared with those based on other East Antarctic ice core records obtained from Dome C EPICA, Taylor Dome and the South Pole; and, in the words of the seven scientists, the several records suggested cooler climate conditions between the middle of [the] 16th and the beginning of [the] 19th centuries, which might be related to the Little Ice Age (LIA) cold period." And after discussing still other findings, they concluded that "more and more evidence coming from ice core records, glacier extension and other proxy records are leading to the idea that the Antarctic continent or at least East Antarctica also experienced the LIA cool episode," out of which the continent (like the rest of the world) began to emerge into what is now known as the Current Warm Period (CWP).

One year later, Cremer *et al.* (2003)[8] reconstructed a history of environmental change in the southern Windmill Islands, East Antarctica, based upon diatom assemblages obtained from two long and well-dated sediment cores removed from two marine bays, comparing their findings with those of studies of several other parts of Antarctica. This work revealed, in the words of

[5] http://www.co2science.org/articles/V5/N52/C3.php.
[6] http://www.co2science.org/articles/V6/N6/C1.php.
[7] http://www.co2science.org/articles/V5/N48/C2.php.
[8] http://www.co2science.org/articles/V6/N38/C2.php.

the four researchers, that "the diatom assemblage in the upper sediments of both cores indicates Neoglacial cooling from ~1000 cal yr BP," and that this latest thousand-year period "is generally marked by distinct cooling leading to glacial re-advances, more extensive sea-ice, lower precipitation, and lower bioproductivity." In addition, they report that "this climatic deterioration is visible in nearly all available Antarctic terrestrial and marine records (e.g. Ingolfsson *et al.*, 1998; Jones *et al.*, 2000; Roberts *et al.*, 2000, and references therein)."

Shortly thereafter, Roberts *et al.* (2004)[9] conducted a fossil diatom analysis of an 82-cm sediment core that covered the approximate time period 2000-1700 ^{14}C yr BP and was removed from the deepest part of Beall Lake in the northern Windmill Islands in one of the more significant ice-free oases on the East Antarctic coastline, samples of which were radiocarbon dated and corrected for the Antarctic reservoir effect. And based on the species of diatoms found in this sample, they inferred the existence of a multi-centennial period of warmth that was characterized by summer temperatures they describe as being "much higher than present summer temperatures." Supporting this inference, they also noted that observations made at both Casey and Law Dome indicated that "during the late Holocene, a warm period existed with precipitation and summer temperatures higher than at present (Goodwin, 1993)." And to make this point perfectly clear, they concluded their report by stating that "the diatom-inferred Holocene palaeosalinity record from Beall Lake indicates that the late Holocene warm period was much warmer than at present." And the dates they give for this period suggest that it was part of the well-known Roman Warm Period.

> *The US, British and Italian researchers say their findings indicate "warmer-than-present climate conditions" at the times and locations of the identified presence of the southern elephant seal, and that it would have been exposed to environments substantially warmer than present.*
>
> *Their data also indicate that the level of this warmth … was not intense enough to drive the seals from Antarctica.*

Two years later, Hall *et al.* (2006)[10] collected skin and hair - and even some whole-body mummified remains - from Holocene raised-beach excavations at various locations along

[9] http://www.co2science.org/articles/V7/N37/C3.php.
[10] http://www.co2science.org/articles/V9/N47/C1.php.

Antarctica's Victoria Land Coast, which they identified by both visual inspection and DNA analysis as coming from southern elephant seals (*Mirounga leonina*), and which they analyzed for age by means of radiocarbon dating. Data from fourteen different locations within Hall *et al*.'s study region - which they describe as being "well south" of the seals' current "core sub-Antarctic breeding and molting grounds" - indicate that the period of time they denominate the *Seal Optimum* began about 600 BC and ended about AD1400, "broadly contemporaneous with the onset of Little Ice Age climatic conditions in the Northern Hemisphere and with glacier advance near [Victoria Land's] Terra Nova Bay," although they found evidence of southern elephant seal presence stretching all the way back to the mid-Holocene.

The US, British and Italian researchers say their findings indicate "warmer-than-present climate conditions" at the times and locations of the identified presence of the southern elephant seal, and that "if, as proposed in the literature, the [Ross] ice shelf survived this period, it would have been exposed to environments substantially warmer than present." Their data also indicate that the level of this warmth, which began with the inception of the Roman Warm Period and ended with the demise of the Medieval Warm Period, was so significant that the intervening Dark Ages Cold Period - which is readily evident in various types of paleoclimate data obtained from many places around the world - was not intense enough to drive the seals from Antarctica.

THE PAST FEW DECADES

Another significant impediment to the CO_2-induced global warming hypothesis comes from the instrumental temperature record of *the more recent past*. This second major setback for climate alarmists derives from the contradiction between observed and model-predicted Antarctic temperature trends of *the past few decades*. According to nearly all climate models, CO_2-induced global warming should be most evident in earth's polar regions; but analyses of Antarctic near-surface and tropospheric air temperatures tell a *radically* different story.

Doran *et al*. (2002)[11], for example, examined temperature trends in the McMurdo Dry Valleys of Antarctica over the period 1986 to 2000, reporting a phenomenal *cooling* rate of approximately 0.7°C per decade. This dramatic rate of cooling, as they describe it, "reflects longer term continental Antarctic cooling between 1966 and 2000." In addition, the 14-year temperature decline in the dry valleys occurred in the summer and autumn, just as most of the 35-year cooling over the continent as a whole (which did not include any data from the dry valleys) also occurred in the summer and autumn.

In another study, Comiso (2000)[12] assembled and analyzed Antarctic temperature data obtained from 21 surface stations and from infrared satellites operating since 1979, finding that for all of Antarctica, temperatures had declined by 0.08°C and 0.42°C per decade, respectively.

[11] http://www.co2science.org/articles/V5/N5/C1.php.
[12] http://www.co2science.org/articles/V3/N12/C1.php.

And in a contemporary study, Thompson and Solomon (2002)[13] also reported a cooling trend for the interior of Antarctica.

In spite of the decades-long cooling that has been observed for the continent as a whole, one region of Antarctica has bucked the mean trend and actually *warmed* over the same time period: the Antarctic Peninsula/Bellingshausen Sea region. But is the temperature increase that has occurred there evidence of CO_2-induced global warming? No, it is not; and this is why.

According to Vaughan *et al*. (2001)[14], "rapid regional warming" has led to the loss of seven ice shelves in this region during the past 50 years. However, they note that sediment cores from 6000 to 1900 years ago suggest that the Prince Gustav Channel Ice Shelf - which collapsed in this region in 1995 - "was absent and climate was as warm as it has been recently," when, of course there was much *less* CO_2 in the air than there is now.

Although it is tempting for some people to cite the 20th century increase in atmospheric CO_2 concentration as the cause of the recent regional warming, to do so without providing an explanatory mechanism, according to Vaughan *et al*., "is superficial." And so it is, especially in light of the work of Thompson and Solomon (2002)[15], who suggest that much of the warming can be explained by "a systematic bias toward the high-index polarity of the SAM," or Southern Hemispheric Annular Mode, such that the ring of westerly winds encircling Antarctica has recently been spending more time in its strong-wind phase.

This was also the conclusion of Kwok and Comiso (2002)[16], who reported that over the 17-year period 1982-1998, the SAM index shifted towards more positive values (0.22/decade), and who additionally noted that a positive polarity of the SAM index "is associated with cold anomalies over most of Antarctica with the center of action over the East Antarctic plateau." At the same time, however, the Southern Oscillation (SO) index shifted in a negative direction, indicating "a drift toward a spatial pattern with warmer temperatures around the Antarctic Peninsula, and cooler temperatures over much of the continent." Thus, the researchers concluded that the positive trend in the *coupled* mode of variability of these two indices represents a "significant bias toward positive polarity." And they add that the SAM "has been shown to be related to changes in the lower stratosphere (Thompson and Wallace, 2000)," and that "the high index polarity of the SAM is associated with the trend toward a cooling and strengthening of the Southern Hemisphere stratospheric polar vortex during the stratosphere's relatively short active season in November," which is pretty much the same hypothesis that was set forth by Thompson and Solomon (2002).

Much more recently, Mulvaney *et al*. (2012)[17] drilled an ice core to the bed of the ice cap on James Ross Island, which lies just off the northeastern tip of the Antarctic Peninsula, next to an area that has experienced a series of recent ice-shelf collapses. And based on deuterium/hydrogen isotope ratios of the ice (ðD), they developed a temperature history of the

[13] http://www.co2science.org/articles/V5/N20/C2.php.
[14] http://www.co2science.org/articles/V4/N39/C3.php.
[15] http://www.co2science.org/articles/V5/N20/C2.php.
[16] http://www.co2science.org/articles/V6/N8/C1.php.
[17] http://www.co2science.org/articles/V16/N10/C1.php.

region that spans the entire Holocene and extends into the last glacial period. This work revealed that "the Antarctic Peninsula experienced an early Holocene warm period followed by stable temperatures, from about 9200 to 2500 years ago, that were similar to modern-day levels." They also found that "the high rate of warming over the past century is unusual (but not unprecedented) in the context of natural climate variability over the past two millennia." More specifically, they state that "over the past 100 years, the James Ross Island ice-core record shows that the mean temperature there has increased by 1.56 ± 0.42°C," which ranks as one of the fastest (upper 0.3%) warming trends since 2000 years before present, according to a set of moving 100-year analyses that demonstrate that "rapid recent warming of the Antarctic Peninsula is highly unusual although not outside the bounds of natural variability in the pre-anthropogenic era." And even though the temperature of the northern Antarctic Peninsula has risen at a rate of 2.6 ± 1.2°C over the past half-century, they say that "repeating the temperature trend analysis using 50-year windows confirms the finding that the rapidity of recent Antarctic Peninsula warming is unusual but not unprecedented."

Antarctica as a whole appears to be in the midst of a cooling trend, based on the study of Watkins and Simmonds (2000), who analyzed region-wide changes in sea ice.

Reporting on trends in a number of Southern Ocean sea ice parameters over the period 1987 to 1996, they found statistically significant increases in sea ice area and total sea ice extent, as well as an increase in sea ice season length since the 1990s.

But returning to *Antarctica as a whole*, it appears to be in the midst of a *cooling* trend, based on the study of Watkins and Simmonds (2000)[18], who analyzed region-wide changes in sea ice. Reporting on trends in a number of Southern Ocean sea ice parameters over the period 1987 to 1996, they found statistically significant increases in sea ice area and total sea ice extent, as well as an increase in sea ice season length since the 1990s. Combining these results with those from a previous study revealed the trends to be consistent back to at least 1978. And in another study of Antarctic sea ice extent, Yuan and Martinson (2000)[19] report that the net trend in the mean Antarctic ice edge over the last 18 years has been an equator-ward expansion of 0.011 degree of latitude per year.

[18] http://www.co2science.org/articles/V4/N6/C1.php.
[19] http://www.co2science.org/articles/V3/N12/C2.php.

Jumping ahead four years, Liu *et al*. (2004)[20] used sea ice concentration data retrieved from the scanning multichannel microwave radiometer on the Nimbus 7 satellite and the spatial sensor microwave/imager on a number of defense meteorological satellites to develop a quality-controlled history of Antarctic sea ice variability covering an entire 22-year solar cycle (1979-2002) that included different states of the Antarctic Oscillation and several ENSO events, after which they evaluated total sea ice extent and area trends by means of linear least-squares regression. As for what they learned from this endeavor, they report that "overall, the total Antarctic sea ice extent (the cumulative area of grid boxes covering at least 15% ice concentrations) has shown an increasing trend (~4,801 km^2/yr)." In addition, they determined that "the total Antarctic sea ice area (the cumulative area of the ocean actually covered by at least 15% ice concentrations) has increased significantly by ~13,295 km^2/yr, exceeding the 95% confidence level," while noting that "the upward trends in the total ice extent and area are robust for different cutoffs of 15, 20, and 30% ice concentrations (used to define the ice extent and area)."

Shortly thereafter, Turner *et al*. (2005)[21] used a "new and improved" set of Antarctic climate data, which is described in detail by Turner *et al*. (2004), to examine "the temporal variability and change in some of the key meteorological parameters at Antarctic stations." This exercise revealed a warming at low elevations on the western coast of the Antarctic Peninsula that they described as being "as large as any increase observed on Earth over the last 50 years," which at the Faraday (now Vernadsky) station was about 2.5°C. *However*, they noted that the "region of marked warming is quite limited and is restricted to an arc from the southwestern part of the peninsula, through Faraday to a little beyond the tip of the peninsula."

Outside of the Antarctic Peninsula, however, they report "there has been a broad-scale change in the nature of the temperature trends between 1961-90 and 1971-2000." Specifically, they report that of the ten coastal stations that have long enough records to allow 30-year temperature trends to be computed for both of these periods, "eight had a larger warming trend (or a smaller cooling trend) in the earlier period." In fact, *four of them changed from warming to cooling*, as did the interior Vostok site; and at the South Pole the rate of cooling intensified by a factor of six. So over the latter part of the 20th century, i.e., the period of time that climate alarmists claim was host to the most dramatic global warming of the past two millennia, fully 80% of the Antarctic coastal stations with sufficiently long temperature records revealed either (1) *an intensification of cooling* or (2) *a reduced rate of warming*, while four coastal sites and one interior site actually shifted from warming to cooling. And all this occurred in one of the planet's high-latitude polar regions, where CO_2-induced global warming has repeatedly been predicted to be more strongly expressed than any other place on the face of the planet.

One year later, Schneider *et al*. (2006)[22] utilized 200 years of sub-annually-resolved ð18O and ðD records from precisely-dated ice cores obtained from Law Dome, Siple Station, Dronning Maud Land and two West Antarctic sites of the United States component of the International Trans-Antarctic Scientific Expedition to create a 200-year-long Antarctic temperature

[20] http://www.co2science.org/articles/V7/N24/C1.php.
[21] http://www.co2science.org/articles/V8/N24/C1.php.
[22] http://www.co2science.org/articles/V9/N40/EDIT.php.

reconstruction representing the main part of the continent. The results of this significant undertaking, following application of a multi-decadal low-pass filter to the yearly data, are presented in the figure below, along with the similarly-treated data of the Southern Hemisphere instrumental temperature record, where the zero line represents the 1961-1990 climatological means of the two records.

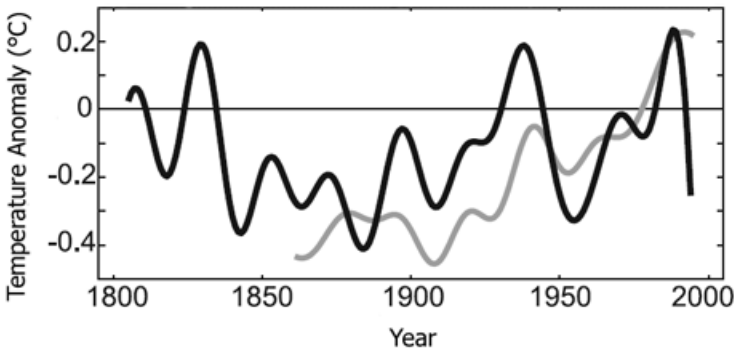


Figure 1. Mean temperature histories of Antarctica (dark line) and the Southern Hemisphere (lighter line), adapted from the paper of Schneider et al. (2006).

In reference to this figure, its developers say "it is notable that the reconstructed Antarctic temperature record is in phase with the Southern Hemisphere mean instrumental record." This statement roughly describes the relationship between the two histories, *but only until 1990*, after which the Antarctic temperature history takes a "nosedive" and dramatically diverges from the Southern Hemisphere record. The seven scientists also say that the Antarctic temperature reconstruction "provides evidence for long-term Antarctic warming," and if all the data they had were those that stretch from 1840 to 1990, one might be inclined to believe them. However, when their "before and after" data are included, this statement is readily seen to be *false*.

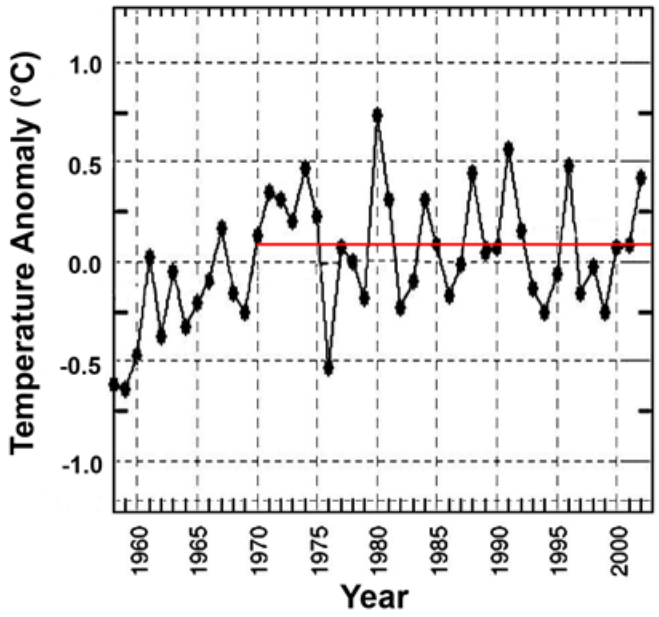
So what do Schneider *et al*.'s data *really* suggest? First of all, their data suggest there was nothing unusual, unnatural or unprecedented about any Antarctic temperatures of any part of the 20th century. Second, their data demonstrate it was significantly colder in Antarctica near the end of the 20th century than it was in the early decades of the 19th century (when the air's CO_2 concentration was about 100 ppm less than it is currently), while the data of others indicate it may be even colder there today.

Forging ahead one more year, Chapman and Walsh (2007)[23] used monthly surface air temperatures from manned and automatic weather stations along with ship/buoy observations from the high-latitude Southern Hemisphere to develop a gridded database with resolution appropriate for applications ranging from spatial trend analyses to climate change impact assessments. These data came from a total of 460 locations in the Southern Hemisphere, where temperatures over *land* were obtained from 19 manned stations of the World Monthly Surface Station Climatology network, most of which were located in coastal areas of the Antarctic continent, plus 73 stations of the Automated Weather Station network, many of which were

[23] http://www.co2science.org/articles/V10/N51/C1.php.

situated further inland. Temperatures over the sea, on the other hand, were obtained from the International Comprehensive Ocean-Atmosphere Data repository. And of particular importance in their melding of these diverse data, the two researchers used *correlation length scaling* "to enhance information content while limiting the spatial extent of influence of the sparse data in the Antarctic region."

The final results of Chapman and Walsh's efforts in this regard are presented in the figure below.



Annual surface air temperature anomalies relative to the 1958-2002 mean for the region of the Southern Hemisphere extending from 60 to 90°S. Adapted from Chapman and Walsh (2007).

The data in this figure clearly indicate a post-1958 warming of Antarctica and much of the surrounding Southern Ocean. From approximately 1970 to the end of the record, however, temperatures of the region simply fluctuated around an anomaly mean of about 0.12°C, neither warming nor cooling, which observation is truly amazing, in light of the fact that the region of study includes the Antarctic Peninsula, which experienced *phenomenal* warming during this period. Nevertheless, the mean surface air temperature of the *entire* region *changed not at all*, over a period of time that saw the air's CO_2 concentration rise by approximately 47 ppm (about 15% of its 1970 value, as per the Mauna Loa CO_2 record. Clearly, therefore the entire continent of Antarctica, together with much of the Southern Ocean that surrounds it, has been *completely oblivious* to the supposedly "unprecedented" radiative impetus for warming supposedly produced by anthropogenic emissions of CO_2 and other greenhouse gases over the last three decades of the 20th century ... and even a bit beyond.

Concentrating on the spring-summer period of November/December/January, Laine (2008)[24] determined 1981-2000 trends of Antarctic ice-sheet and sea-ice surface *albedo* and

[24] http://www.co2science.org/articles/V11/N25/C1.php.

temperature, as well as sea-ice *concentration* and *extent*, based on Advanced Very High Resolution Polar Pathfinder data in the case of ice-sheet surface albedo and temperature, and the Scanning Multichannel Microwave Radiometer and Special Sensor Microwave Imagers in the case of sea-ice concentration and extent, which analyses were carried out for the continent as a whole, as well as for five longitudinal sectors emanating from the south pole: 20°E-90°E, 90°E-160°E, 160°E-130°W, 130°W-60°W, and 60°W-20°E.

This work revealed, in the words of Laine, that "all the regions show negative spring-summer surface temperature trends for the study period," and that "the slight cooling trends seem to be parallel with the results of Comiso (2000), who studied Antarctic temperature trends using both satellite and station data." In addition, the Finnish researcher says that "the sea ice concentration shows slight increasing trends in most sectors, where the sea ice extent trends seem to be near zero." And as a result of these several findings, it is not surprising that Laine also reported that "the Antarctic region as a whole and all the sectors separately show slightly positive spring-summer albedo trends."

Contemporaneously, Monaghan and Bromwich (2008)[25] reviewed what has been learned about snowfall and near-surface air temperature over the past five decades in Antarctica. This they did *because*, in their words, "snowfall is the largest contributor to the growth of the ice sheets, and near-surface temperature controls surface melting, which in turn has important impacts on the stability of Antarctic ice shelves and glaciers," which ultimately impact global sea level. And what did their review reveal?

The two researchers from the Byrd Polar Research Center of Ohio State University (USA) began by noting that "instrumental records indicate statistically insignificant seasonal and annual near-surface temperature changes over continental Antarctica from the late 1950s through 2000," citing the work of Turner *et al*. (2005). On the *Antarctic Peninsula*, on the other hand, temperature measured at the Faraday/Vernadsky station rose at the phenomenal rate of 0.56°C per decade from 1951 to 2000. However, the peninsula comprises a mere 4% of the continent's total surface area; and its warming, although dramatic, is thus but a small-scale anomaly.

In describing another study of the temperature history of Antarctica, Monaghan and Bromwich report that "Chapman and Walsh (2007) performed an objective analysis of Antarctic near-surface temperatures from the early 1950s through 2002 and found that the overall Antarctic temperature trends depend on the period for which they are calculated, being positive prior to 1965 (through 2002), and mainly negative thereafter, although never statistically significant for any period." Similarly, after citing the work of Kwok and Comiso (2002) with skin temperature records derived from Advanced Very High Resolution Radiometer instrumentation flown aboard polar-orbiting satellites, the work of Schneider *et al*. (2006) with temperatures derived from ice-core stable isotopes, and the work of Monaghan *et al*. (2008) that blended the instrumental temperature record with model reanalysis temperature fields, they concluded that "overall there have not been statistically significant Antarctic near-surface temperature trends since the International Geophysical Year" of 1957-58.

[25] http://www.co2science.org/articles/V11/N43/EDIT.php.

Turning their attention to snowfall, Monaghan and Bromwich note that "atmospheric models have been the primary tool for assessing temporal variability," and they report that the latest such studies of Antarctic snowfall "indicate that no statistically significant increase has occurred since ~1980," citing the analyses of Monaghan *et al*. (2006) and van de Berg *et al*. (2005), although there have been cyclical changes related to similar changes in temperature. And when the two variations are compared on decadal time scales, it appears that snowfall over Antarctica could possibly rise by as much as 5% for each 1°C increase in temperature.

So what might the future hold for Antarctic snowfall in a warming world?

The two researchers say that "if global climate model projections of 2-3.5°C temperature increases over Antarctica by the end of this century are accurate" - which is something that is highly debatable - "a ~10%-20% increase in snowfall might be expected if the 1960-2004 sensitivity relationship holds." And in this regard, they note that "a 15% increase of Antarctic snowfall would mitigate an additional ~1 mm per year [rise] of global sea level in 2100 compared to today." When all is said and done, therefore, the fantastic *multi-**meter*** rise in sea level predicted by Al Gore and James Hansen to occur *this century* appears to be *pure fantasy*, and even more so, in light of Monaghan and Bromwich's ultimate observation that "a widespread signal of Antarctic climate change is not obvious over the past ~50 years."

When all is said and done, therefore, the fantastic multi-meter rise in sea level predicted by Al Gore and James Hansen to occur this century appears to be pure fantasy, and even more so, in light of Monaghan and Bromwich's ultimate observation that "a widespread signal of Antarctic climate change is not obvious over the past ~50 years."

Jumping ahead a full four years, we find Sinclair *et al*. (2012)[26] writing that "although the Antarctic ice sheet plays a pivotal role in the global ocean and atmospheric circulation systems and their response to warming climates, there are few long-term observations of surface temperature across the continent," which they say is "particularly true for areas pole-ward of the Antarctic Peninsula because of the sparsity of scientific bases and problems associated with satellite measurements of surface temperature (Mayewski *et al*., 2009)." Consequently, for this important part of the world, they assert there is a "pressing need for a better understanding of climate variability and the forcings that underlie these changes."

[26] http://www.co2science.org/articles/V15/N41/C1.php.

In search of this understanding, Sinclair *et al*. studied isotope-temperature relationships at a site on the Whitehall Glacier in northern Victoria Land (72°54'S, 169°5'E) on a flat ice divide about 12 km from the nearest seasonally-open water. Working with an ice core drilled to a depth of 105 meters there in 2006/2007, they developed a well-calibrated isotope-temperature relationship that they used to reconstruct annual temperatures, as well as summer (December-February) and cold season (April-September) for the 125-year span of their data. And over the full length of their record, the three researchers say, with respect to temperatures, that they could find "no significant trends between 1882 and 2006." Neither were there any significant trends in either summer or cold season temperatures since 1958. However, they say there was "a decrease in cold season temperatures of -1.59°C ± 0.84°C/decade at 90% confidence (p = 0.07) since 1979," which *cooling*, in their words, was "coincident with a positive trend in the southern annular mode, which is linked to stronger southerly winds and increased sea ice extent and duration in the western Ross Sea," which they say "is one of the few regions experiencing a significant positive trend in sea ice and a negative trend in sea surface temperatures," citing Comiso *et al*. (2011).

In conclusion, and in light of the many findings of the diverse studies cited above, it is clear that the temperature history of Antarctica provides no evidence for the CO_2-induced global warming hypothesis. In fact, it argues strongly against it. But what if the Antarctic *were* to warm as a result of some natural or anthropogenic-induced change in earth's climate? What would the consequences be?

For one thing, it would likely help to increase both the number and diversity of penguin species (Smith *et al*., 1999[27]; Sun *et al*., 2000[28]), and it would also tend to increase the size and number of populations of the continent's only two vascular plant species (Xiong *et al*., 2000[29]). With respect to the continent's great ice sheets, there would not be much of a problem either, as not even a warming event as dramatic as 10°C is predicted to result in a net change in the East Antarctic Ice Sheet (Näslund *et al*., 2000[30]), which suggests that climate-alarmist predictions of catastrophic coastal flooding due to the melting of the world's polar ice sheets are way off the mark when it comes to representing reality.

REFERENCES

Caillon, N., Severinghaus, J.P., Jouzel, J., Barnola, J.-M., Kang, J. and Lipenkov, V.Y. 2003. Timing of atmospheric CO_2 and Antarctic temperature changes across Termination III. *Science* **299**: 1728-1731.

Chapman, W.L. and Walsh, J.E. 2007. A synthesis of Antarctic temperatures. *Journal of Climate* **20**: 4096-4117.

[27] http://www.co2science.org/articles/V3/N9/C5.php.
[28] http://www.co2science.org/articles/V4/N7/B1.php.
[29] http://www.co2science.org/articles/V3/N13/B1.php.
[30] http://www.co2science.org/articles/V4/N6/C2.php.

Comiso, J.C. 2000. Variability and trends in Antarctic surface temperatures from in situ and satellite infrared measurements. *Journal of Climate* **13**: 1674-1696.

Comiso, J.C., Kwok, R., Martin, S. and Gordon, A.L. 2011. Variability and trends in sea ice extent and production in the Ross Sea. *Journal of Geophysical Research* **116**: 10.1029/2010JC006391.

Cremer, H., Gore, D., Melles, M. and Roberts, D. 2003. Palaeoclimatic significance of late Quaternary diatom assemblages from southern Windmill Islands, East Antarctica. *Palaeogeography, Palaeoclimatology, Palaeoecology* **195**: 261-280.

Domack, E.W., Leventer, A., Dunbar, R., Taylor, F., Brachfeld, S. and Sjunneskog, C. 2000. Chronology of the Palmer Deep site, Antarctic Peninsula: A Holocene palaeoenvironmental reference for the circum-Antarctic. *The Holocene* **11**: 1-9.

Doran, P.T., Priscu, J.C., Lyons, W.B., Walsh, J.E., Fountain, A.G., McKnight, D.M., Moorhead, D.L., Virginia, R.A., Wall, D.H., Clow, G.D., Fritsen, C.H., McKay, C.P. and Parsons, A.N. 2002. Antarctic climate cooling and terrestrial ecosystem response. *Nature* advance online publication, 13 January 2002 (DOI 10.1038/nature710).

Fischer, H., Wahlen, M., Smith, J., Mastroianni, D. and Deck B. 1999. Ice core records of atmospheric CO_2 around the last three glacial terminations. *Science* **283**: 1712-1714.

Genthon, C., Barnola, J.M., Raynaud, D., Lorius, C., Jouzel, J., Barkov, N.I., Korotkevich, Y.S. and Kotlyakov, V.M. 1987. Vostok ice core: Climatic response to CO_2 and orbital forcing changes over the last climatic cycle. *Nature* **329**: 414-418.

Goodwin, I.D. 1993. Holocene deglaciation, sea-level change, and the emergence of the Windmill Islands, Budd Coast, Antarctica. *Quaternary Research* **40**: 70-80.

Grove, J.M. 1988. *The Little Ice Age*. Cambridge University Press, Cambridge, UK.

Hall, B.L., Hoelzel, A.R., Baroni, C., Denton, G.H., Le Boeuf, B.J., Overturf, B. and Topf, A.L. 2006. Holocene elephant seal distribution implies warmer-than-present climate in the Ross Sea. *Proceedings of the National Academy of Sciences USA* **103**: 10,213-10,217.

Idso, S.B. 1988. Carbon dioxide and climate in the Vostok ice core. *Atmospheric Environment* **22**: 2341-2342.

Idso, S.B. 1989. *Carbon Dioxide and Global Change: Earth in Transition*. IBR Press, Tempe, AZ.

Indermuhle, A., Monnin, E., Stauffer, B. and Stocker, T.F. 2000. Atmospheric CO_2 concentration from 60 to 20 kyr BP from the Taylor Dome ice core, Antarctica. *Geophysical Research Letters* **27**: 735-738.

Ingolfsson, O., Hjort, C., Berkman, P.A., Bjork, S., Colhoun, E., Goodwin, I.D., Hall, B., Hirakawa, K., Melles, M., Moller, P. and Prentice, M.L. 1998. Antarctic glacial history since the Last Glacial Maximum: an overview of the record on land. *Antarctic Science* **10**: 326-344.

Jones, V.J., Hodgson, D.A. and Chepstow-Lusty, A. 2000. Palaeolimnological evidence for marked Holocene environmental changes on Signy Island, Antarctica. *The Holocene* **10**: 43-60.

Khim, B-K., Yoon, H.I., Kang, C.Y. and Bahk, J.J. 2002. Unstable climate oscillations during the Late Holocene in the Eastern Bransfield Basin, Antarctic Peninsula. *Quaternary Research* **58**: 234-245.

Kwok, R. and Comiso, J.C. 2002. Spatial patterns of variability in Antarctic surface temperature: Connections to the South Hemisphere Annular Mode and the Southern Oscillation. *Geophysical Research Letters* **29**: 10.1029/2002GL015415.

Laine, V. 2008. Antarctic ice sheet and sea ice regional albedo and temperature change, 1981-2000, from AVHRR Polar Pathfinder data. *Remote Sensing of Environment* **112**: 646-667.

Lamb, H.H. 1965. The early medieval warm epoch and its sequel. *Palaeogeography, Palaeoclimatology, Palaeoecology* **1**: 13-37.

Leventer, A., Domack, E.W., Ishman, S.E., Brachfeld, S., McClennen, C.E. and Manley, P. 1996. Productivity cycles of 200-300 years in the Antarctic Peninsula region: Understanding linkage among the sun, atmosphere, oceans, sea ice, and biota. *Geological Society of America Bulletin* **108**: 1626-1644.

Leventer, A. and Dunbar, R.B. 1988. Recent diatom record of McMurdo Sound, Antarctica: Implications for the history of sea-ice extent. *Paleoceanography* **3**: 373-386.

Liu, J., Curry, J.A. and Martinson, D.G. 2004. Interpretation of recent Antarctic sea ice variability. *Geophysical Research Letters* **31**: 10.1029/2003GL018732.

Mayewski, P.A., Meredith, M.P., Summerhayes, C.P., Turner, J., Worby, A., Barrett, P.J., Casassa, G., Bertler, N.A.N., Bracegirdle, T., Naveira Garabato, A.C., Bromwich, D., Campbell, H., Hamilton, G.S., Lyons, W.B., Maasch, K.A., Aoki, S., Xiao, C. and van Ommen, T. 2009. State of the Antarctic and Southern Ocean Climate System (SASOCS). *Reviews of Geophysics* **47**: 10.1029/2007RG000231.

Monaghan, A.J. and Bromwich, D.H. 2008. Advances in describing recent Antarctic climate variability. *Bulletin of the American Meteorological Society* **89**: 1295-1306.

Monaghan, A.J., Bromwich, D.H., Chapman, W. and Comiso, J.C. 2008. Recent variability and trends of Antarctic near-surface temperature. *Journal of Geophysical Research* **113**: 10.1029/2007JD009094.

Monaghan, A.J., Bromwich, D.H. and Wang, S.-H. 2006. Recent trends in Antarctic snow accumulation from Polar MM5 simulations. *Philosophical Transactions of the Royal Society A* **364**: 1683-1708.

Monnin, E., Indermühle, A., Dällenbach, A., Flückiger, J, Stauffer, B., Stocker, T.F., Raynaud, D. and Barnola, J.-M. 2001. Atmospheric CO_2 concentrations over the last glacial termination. *Nature* **291**: 112-114.

Mulvaney, R., Abram, N.J., Hindmarsh, R.C.A., Arrowsmith, C., Fleet, L., Triest, J., Sime, L.C., Alemany, O. and Foord, S. 2012. Recent Antarctic Peninsula warming relative to Holocene climate and ice-shelf history. *Nature* **489**: 10.1038/nature11391.

Näslund, J.O., Fastook, J.L and Holmlund, P. 2000. Numerical modeling of the ice sheet in western Dronning Maud Land, East Antarctica: impacts of present, past and future climates. *Journal of Glaciology* **46**: 54-66.

Petit, J.R., Jouzel, J., Raynaud, D., Barkov, N.I., Barnola, J.-M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V.M., Legrand, M., Lipenkov, V.Y., Lorius, C., Pepin, L., Ritz, C., Saltzman, E., and Stievenard, M. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399**: 429-436.

Roberts, D., McMinn, A., Cremer, H., Gore, D.B. and Melles, M. 2004. The Holocene evolution and palaeosalinity history of Beall Lake, Windmill Islands (East Antarctica) using an expanded diatom-based weighted averaging model. *Palaeogeography, Palaeoclimatology, Palaeoecology* **208**: 121-140.

Roberts, D., McMinn, A. and Zwartz, D. 2000. An initial palaeosalinity history of Jaw Lake, Bunger Hills based on a diatom-salinity transfer function applied to sediment cores. *Antarctic Science* **12**: 172-176.

Schneider, D.P., Steig, E.J., van Ommen, T.D., Dixon, D.A., Mayewski, P.A., Jones, J.M. and Bitz, C.M. 2006. Antarctic temperatures over the past two centuries from ice cores. *Geophysical Research Letters* **33**: 10.1029/2006GL027057.

Smith, R.C., Ainley, D., Baker, K., Domack, E., Emslie, S., Fraser, B., Kennett, J., Leventer, A., Mosley-Thompson, E., Stammerjohn, S. and Vernet M. 1999. Marine ecosystem sensitivity to climate change. *BioScience* **49**: 393-404.

Stenni, B., Proposito, M., Gragnani, R., Flora, O., Jouzel, J., Falourd, S. and Frezzotti, M. 2002. Eight centuries of volcanic signal and climate change at Talos Dome (East Antarctica). *Journal of Geophysical Research* **107**: 10.1029/2000JD000317.

Sun, L., Xie, Z. and Zhao, J. 2000. A 3,000-year record of penguin populations. *Nature* **407**: 858.

Thompson, D.W.J. and Solomon, S. 2002 . Interpretation of recent Southern Hemisphere climate change. *Science* **296**: 895-899.

Thompson, D.W.J. and Wallace, J.M. 2000. Annular modes in extratropical circulation, Part II: Trends. *Journal of Climate* **13**: 1018-1036.

Turner, J., Colwell, S.R., Marshall, G.J., Lachlan-Cope, T.A., Carleton, A.M., Jones, P.D., Lagun, V., Reid, P.A. and Iagovkina, S. 2004. The SCAR READER project: towards a high-quality database of mean Antarctic meteorological observations. *Journal of Climate* **17**: 2890-2898.

Turner, J., Colwell, S.R., Marshall, G.J., Lachlan-Cope, T.A., Carleton, A.M., Jones, P.D., Lagun, V., Reid, P.A. and Iagovkina, S. 2005. Antarctic climate change during the last 50 years. *International Journal of Climatology* **25**: 279-294.

van de Berg, W.J., van den Broeke, M.R., Reijmer, C.H. and van Meijgaard, E. 2005. Characteristics of the Antarctic surface mass balance (1958-2002) using a regional atmospheric climate model. *Annals of Glaciology* **41**: 97-104.

Vaughan, D.G., Marshall, G.J., Connolley, W.M., King, J.C. and Mulvaney, R. 2001. Devil in the detail. *Science* **293**: 177-179.

Watkins, A.B. and Simmonds, I. 2000. Current trends in Antarctic sea ice: The 1990s impact on a short climatology. *Journal of Climate* **13**: 4441-4451.

Xiong, F.S., Meuller, E.C. and Day, T.A. 2000. Photosynthetic and respiratory acclimation and growth response of Antarctic vascular plants to contrasting temperature regimes. *American Journal of Botany* **87**: 700-710.

Yoon, H.I., Park, B.-K., Kim, Y. and Kang, C.Y. 2002. Glaciomarine sedimentation and its paleoclimatic implications on the Antarctic Peninsula shelf over the last 15,000 years. *Palaeogeography, Palaeoclimatology, Palaeoecology* **185**: 235-254.

Yuan, X. and Martinson, D.G. 2000. Antarctic sea ice extent variability and its global connectivity. *Journal of Climate* **13**: 1697-1717.

Cover rendition of Antarctica from NASA,
as posted to Wikimedia Commons.