EVIDENCE OF A MEDIEVAL WARM PERIOD IN ANTARCTICA

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Was there a Medieval Warm Period somewhere in the world in addition to the area surrounding the North Atlantic Ocean, where its occurrence is uncontested? This question is of utmost importance to the ongoing global warming debate, for if the Medieval Warm Period is found to have been a *global* climatic phenomenon, and if the locations where it occurred were as warm in medieval times as they are currently, there is no need to consider the temperature increase of the past century as anything other than the natural progression of the persistent millennial-scale oscillation of climate that regularly brings the earth several-hundred-year periods of modestly higher and lower temperatures that are totally independent of variations in atmospheric CO_2 concentration. Consequently, we here review the findings of several studies that have found evidence for the Medieval Warm Period in a region that is as far away from lands bordering on the North Atlantic Ocean as one could possibly get, i.e., Antarctica.

If the Medieval Warm Period is found to have been a global climatic phenomenon, and if the locations where it occurred were as warm in medieval times as they are currently, there is no need to consider the temperature increase of the past century as anything other than the natural progression of the persistent millennial-scale oscillation of climate that regularly brings the earth several-hundred-year periods of modestly higher and lower temperatures that are totally independent of variations in atmospheric CO_2 concentration.

Hemer and Harris (2003)[1] extracted a sediment core from beneath the Amery Ice Shelf, East Antarctica, at a point that is currently about 80 km landward of the location of its present edge. In analyzing the core's characteristics over the past 5,700 ^{14}C years, the two scientists observed a peak in absolute diatom abundance in general, and the abundance of *Fragilariopsis curta* in particular-which parameters, in their words, "are associated with increased proximity to an area of primary production, such as the sea-ice zone"-at about 750 ^{14}C yr B.P., which puts the time of maximum Ice Shelf retreat in close proximity to the historical time frame of the Medieval Warm Period.

Khim *et al*. (2002)[2] likewise analyzed a sediment core removed from the eastern Bransfield Basin just off the northern tip of the Antarctic Peninsula, including grain size, total organic carbon content, magnetic susceptibility, biogenic silica content, ^{210}Pb geochronology, and radiocarbon (^{14}C) age, all of which

[1] http://www.co2science.org/articles/V6/N21/C1.php.
[2] http://www.co2science.org/articles/V6/N6/C1.php.

data clearly depicted, in their words, the presence of the "Little Ice Age and Medieval Warm period, together with preceding climatic events of similar intensity and duration."

Working in the same general region of the continent, Hall *et al.* (2010)[3] write that "over the past 50 years, the Antarctic Peninsula warmed ~2°C," and that resultant rapid ice breakups "have destroyed several small, thin ice shelves fringing the Antarctic Peninsula (i.e., Cook and Vaughan, 2009, and references therein)," leading them to ask, "is the recent warming of the Antarctic Peninsula unique in the Holocene?"

In an effort to place the current ice recession in a broader context, the three researchers "examined organic-rich sediments exposed by the recent retreat of the Marr Ice Piedmont on western Anvers Island near Norsel Point," where glaciers "have been undergoing considerable retreat in response to the well-documented warming." There, they "obtained moss and reworked marine shells from natural sections within 26 meters of the present ice front," as well as "both peat and reworked shells from sediments exposed in a tunnel beneath the residual ice mass," samples of which were radiocarbon-dated and the results converted to calendar years.

The results they obtained by these means indicated peat from the overrun sediments dated to between 707 ± 36 and 967 ± 47 cal. yr B.P.," which led them to conclude, "ice was at or behind its present position at ca. 700-970 cal. yr B.P. and during at least two earlier times, represented by the dates of shells, in the mid-to-late Holocene." Then, in language pure and simple, the three researchers say their findings imply that "the present state of reduced ice on the western Antarctic Peninsula is not unprecedented." This leads them to pose another important question: "How widespread is the event at 700-970 cal. yr B.P.?"

Much of the southernmost portion of the Earth likely experienced a period of significantly enhanced warmth within the broad timeframe of the planet's global MWP. And this interval of warmth occurred when there was far less CO_2 and methane in the atmosphere than there is today.

In answering their own query, the researchers respond that (1) "Khim *et al*. (2002) noted a pronounced high-productivity (warm) event between 500 and 1000 cal. yr B.P. in magnetic susceptibility records from Bransfield Basin," (2) "dates of moss adjacent to the present ice front in the South Shetland Islands (Hall, 2007) indicate that ice there was no more extensive between ca. 650 and 825 cal. yr B.P. than it is now," (3) "evidence for reduced ice extent at 700-970 cal. yr B.P. is consistent with tree-ring data from New Zealand that show a pronounced peak in summer temperatures (Cook *et al*., 2002)," (4) "New Zealand glaciers were retracted at the same time (Schaefer *et al*., 2009)," and (5) their most recent findings "are compatible with a record of glacier fluctuations from southern South America, the continental landmass closest to Antarctica (Strelin *et al*., 2008)." In light of these several observations, therefore, it would appear that much of the southernmost portion of the Earth likely experienced a period of

[3] http://www.co2science.org/articles/V13/N41/C1.php.

significantly enhanced warmth within the broad timeframe of the planet's global MWP. And this interval of warmth occurred when there was *far* less CO_2 and methane in the atmosphere than there is today.

In one additional study from the Antarctic Peninsula, Lu *et al.* (2012)[4] constructed "the first downcore $\delta^{18}O$ record of natural ikaite hydration waters and crystals collected from the Antarctic Peninsula (AP)" that they say were "suitable for reconstructing a low resolution ikaite record of the last 2000 years." According to the group of nine UK and US researchers, *ikaite* "is a low temperature polymorph of calcium carbonate that is hydrated with water molecules contained in its crystal lattice," and they write that "ikaite crystals from marine sediments, if collected and maintained at low temperatures, preserve hydration waters and their intact crystal structures, both of which have the potential to provide isotopic constraints on past climate change." So what did they find?

The authors report that "the ikaite record qualitatively supports that both the Medieval Warm Period and Little Ice Age extended to the Antarctic Peninsula." They also state that the "most recent crystals suggest a warming relative to the LIA in the last century, possibly as part of the regional recent rapid warming," but they add that "this climatic signature is not yet as extreme in nature as the MWP," suggesting that even the dramatic recent warming of the AP may not yet have returned that region to the degree of warmth that was experienced there during the MWP, when the atmosphere's CO_2 concentration was more than 100 ppm *less* than it is today.

As Hall and Denton describe it, "the Wilson Piedmont Glacier was still less extensive than it is now," demonstrating that the climate of that period was in all likelihood considerably warmer than it is currently.

Examining a different region of the continent, Hall and Denton (2002)[5] mapped the distribution and elevation of surficial deposits along the southern Scott Coast of Antarctica in the vicinity of the Wilson Piedmont Glacier, which runs parallel to the coast of the western Ross Sea from McMurdo Sound north to Granite Harbor. The chronology of the raised beaches they studied was determined from more than 60 ^{14}C dates of incorporated organic materials they had previously collected from hand-dug excavations (Hall and Denton, 1999); the record the dates helped define demonstrated that near the end of the Medieval Warm Period, "as late as 890 ^{14}C yr BP," as Hall and Denton describe it, "the Wilson Piedmont Glacier was still less extensive than it is now," demonstrating that the climate of that period was in all likelihood considerably warmer than it is currently.

Several years later, but also working in the Ross Sea region of Antarctica, Bertler *et al.* (2011)[6] obtained new deuterium (δD) data acquired via analysis of the top fifty meters of a 180-meter-long ice core that had been extracted from the ice divide of Victoria Lower Glacier in the northernmost McMurdo Dry Valleys, which they converted to temperature data by means of a

[4] http://www.co2science.org/articles/V15/N30/C2.php.
[5] http://www.co2science.org/articles/V5/N45/C1.php.
[6] http://www.co2science.org/articles/V14/N45/C3.php.

temperature-isotope relationship developed by Steig *et al*. (1998) from data obtained from the Taylor Dome ice core record. In doing so, Bertler *et al*. report that they identified three distinct time periods in their record: the last 150 years of the Medieval Warm Period (AD 1140 to 1287), the Little Ice Age (AD 1288 to 1807), and the Modern Era (AD 1808 to 2000). And with respect to the Medieval Warm Period, they write that "the McMurdo Dry Valleys were 0.35°C warmer during the MWP than during ME, accompanied by warmer conditions in the Ross Sea." The three researchers also note that "a magnetic susceptibility record from Palmer Deep marine core (PD92 30MS) also supports warmer MWP conditions, this time in Drake Passage (Domack and Mayewski, 1999)."

Noon *et al*. (2003)[7] used oxygen isotopes preserved in authigenic carbonate retrieved from freshwater sediments of Sombre Lake on Signy Island (60°43'S, 45°38'W) in the Southern Ocean to construct a 7,000-year history of that region's climate. This work revealed that the general trend of temperature at the study site has been downward. Of most interest to the present discussion, however, is the millennial-scale oscillation of climate that is apparent in much of the record. This climate cycle is such that approximately 2,000 years ago, after a thousand-year gap in the data, Signy Island experienced the relative warmth of the last vestiges of the Roman Warm Period, as delineated by McDermott *et al*. (2001) on the basis of a high-resolution speleothem $\delta^{18}O$ record from southwest Ireland. Then comes the Dark Ages Cold period, which is also contemporaneous with what McDermott *et al*. observe in the Northern Hemisphere, after which the Medieval Warm Period appears at the same point in time and persists for the same length of time that it does in the vicinity of Ireland, whereupon the Little Ice Age sets in just as it does in the Northern Hemisphere. Finally, there is an indication of late twentieth century warming, but with still a long way to go before conditions comparable to those of the Medieval Warm Period are achieved.

Two years later, Castellano *et al*. (2005)[8] derived a detailed history of Holocene volcanism from the sulfate record of the first 360 meters of the Dome Concordia ice core that covered the period 0-11.5 kyr BP, after which they compared their results for the past millennium with similar results obtained from eight other Antarctic ice cores. Before doing so, however, they normalized the results at each site by dividing their several volcanic-induced sulfate deposition values by the value produced at that site by the AD 1816 Tambora eruption, in order to reduce deposition differences among sites that might have been induced by differences in local site characteristics. This work revealed that most volcanic events in the early last millennium (AD 1000-1500) exhibited greater among-site variability in normalized sulphate deposition than was observed thereafter.

Citing Budner and Cole-Dai (2003) in noting that "the Antarctic polar vortex is involved in the distribution of stratospheric volcanic aerosols over the continent," Castellano *et al*. say that assuming the intensity and persistence of the polar vortex in both the troposphere and stratosphere "affect the penetration of air masses to inland Antarctica, isolating the continental area during cold periods and facilitating the advection of peripheral air masses during warm periods (Krinner and Genthon, 1998), we support the hypothesis that the pattern of volcanic

[7] http://www.co2science.org/articles/V6/N30/C3.php.
[8] http://www.co2science.org/articles/V9/N9/C2.php.

deposition intensity and geographical variability [higher values at coastal sites] could reflect a warmer climate of Antarctica in the early last millennium," and that "the re-establishment of colder conditions, starting in about AD 1500, reduced the variability of volcanic depositions."

Describing this phenomenon in terms of what it implies, Castellano *et al*. say "this warm/cold step could be like a Medieval Climate Optimum-like to Little Ice Age-like transition." They additionally cite Goosse *et al*. (2004) as reporting evidence from Antarctic ice-core δD and $\delta^{18}O$ data "in support of a Medieval Warming-like period in the Southern Hemisphere, delayed by about 150 years with respect to Northern Hemisphere Medieval Warming." And the researchers conclude by postulating that "changes in the extent and intra-Antarctic variability of volcanic depositional fluxes may have been consequences of the establishment of a Medieval Warming-like period that lasted until about AD 1500."

A year later, Hall *et al*. (2006)[9] collected skin and hair (and even some whole-body mummified remains) from Holocene raised-beach excavations at various locations along Antarctica's Victoria Land Coast, which they identified by both visual inspection and DNA analysis as coming from southern elephant seals, and which they analyzed for age by radiocarbon dating. By these means they obtained data from 14 different locations within their study region-which they describe as being "well south" of the seals' current "core sub-Antarctic breeding and molting grounds"-that indicate that the period of time they denominate the Seal Optimum began about 600 BC and ended about AD1400, the latter of which dates they describe as being "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."

In describing the significance of their findings, the US, British, and Italian researchers say they are indicative of "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," which would have included both the Roman Warm Period and Medieval Warm Period.

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[9] http://www.co2science.org/articles/V9/N47/C1.php.

Advancing one year closer to the present, Williams *et al*. (2007)[10] presented methyl chloride (CH_3Cl) measurements of air extracted from a 300-m ice core that was obtained at the South Pole, Antarctica, covering the time period 160 BC to AD 1860. In describing what they found, the researchers say "CH_3Cl levels were elevated from 900-1300 AD by about 50 ppt relative to the previous 1000 years, coincident with the warm Medieval Climate Anomaly (MCA)," and that they "decreased to a minimum during the Little Ice Age cooling (1650-1800 AD), before rising again to the modern atmospheric level of 550 ppt." Noting that "today, more than 90% of the CH_3Cl sources and the majority of CH_3Cl sinks lie between 30°N and 30°S (Khalil and Rasmussen, 1999; Yoshida *et al*., 2004)," they say "it is likely that climate-controlled variability in CH_3Cl reflects changes in tropical and subtropical conditions." They go on to say that "ice core CH_3Cl variability over the last two millennia suggests a positive relationship between atmospheric CH_3Cl and *global* [italics added] mean temperature."

As best as can be determined from the graphical representation of their data, the peak CH_3Cl concentration measured by Williams *et al*. during the MCA is approximately 533 ppt, which is within 3 percent of its current mean value of 550 ppt and well within the range of 520 to 580 ppt that characterizes methyl chloride's current variability. It may therefore be validly concluded that the mean peak temperature of the MCA (which is herein referred to as the Medieval Warm Period) over the latitude range 30°N to 30°S-and possibly over the entire globe-may not have been materially different from the mean peak temperature so far attained during the Current Warm Period.

There is nothing that is unusual, unnatural or unprecedented about the current level of Earth's warmth, which further suggests that the historical increase in the atmosphere's CO_2 concentration may not have had anything to do with concomitant 20th-century global warming.

In one final study, Hall (2007)[11] presented "radiocarbon and geomorphologic data that constrain [the] late-Holocene extent of the Collins Ice Cap on Fildes Peninsula (King George Island, South Shetland Islands: 62°10'51"S, 58°54'13"W)," which, in her words, "yield information on times in the past when climate in the South Shetland Islands must have been as warm as or warmer than today," based on field mapping of moraines and glacial deposits adjacent to the ice cap, as well as radiocarbon dates of associated organic materials. Such data, according to Hall, "indicate ice advance after ~650 cal. yr BP (AD ~1300)," which she notes is "broadly contemporaneous with the 'Little Ice Age', as defined in Europe." She also says that this was "the only advance that extended beyond the present ice margin in the last 3500 years, making the Little Ice Age in that part of the world likely the coldest period of the current interglacial. And the fact that "the present ice cap margin ... is still more extensive than it was prior to ~650 cal. yr BP" led her to conclude that the climate prior to that time -- which would have comprised the Medieval Warm Period -- may have been "as warm as or warmer than present." And this conclusion,

[10] http://www.co2science.org/articles/V10/N43/C3.php.
[11] http://www.co2science.org/articles/V11/N29/C3.php.

along with the findings of the other studies reviewed herein, suggests there is nothing that is *unusual, unnatural* or *unprecedented* about the current level of Earth's warmth, which further suggests that the historical increase in the atmosphere's CO_2 concentration may not have had anything to do with concomitant 20th-century global warming.

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Cover photo of an Antarctic iceberg provided by Microsoft.