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Paleoclimate and Recent Temperatures

3. Paleoclimate and Recent Temperatures

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Introduction

The Intergovernmental Panel on Climate Change (IPCC) claims average Northern Hemisphere temperatures during the second half of the twentieth century were “likely the highest in at least the past 1,300 years” (IPCC 2007). Later in its report, the IPCC again states “it is likely that the 20th century was the warmest in at least the past 1.3 kyr.”

In the 2009 report of the Nongovernmental International Panel on Climate Change (NIPCC), Idso and Singer (2009) contested the IPCC claims by presenting “a thorough examination of temperature records around the world” illustrating the global presence of a significant Medieval Warm Period (MWP) during which temperatures exceeded those of the twentieth century. The book cited hundreds of scientific papers documenting the MWP in Africa, Antarctica, the Arctic, Asia, Europe, North America, and South America. The authors also reported satellite temperature data showing a much more modest warming trend in the last two decades of the twentieth century and a dramatic decline in the

warming trend in the first decade of the twenty-first century.

In this chapter, we cover this ground once again, highlighting papers not addressed in the 2009 NIPCC report or published after its preparation. After reviewing new evidence of a global MWP, we present evidence of a “Little Medieval Warm Period” that began sometime in the early 1400s, and then address two issues specific to the global temperature debate.

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IPCC. 2007. *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by S. Solomon, et al. Cambridge, UK: Cambridge University Press.

3.1. Medieval Warm Period

The Medieval Warm Period (MWP) is the name typically used to describe a period of warmth in Earth's history that occurred approximately 1,000 years ago. The degree of warmth during that time varied from region to region, and hence its consequences were manifested in a variety of ways. The IPCC has downplayed or ignored the MWP because its existence threatens its core hypothesis of CO₂-induced global warming.

If it can be shown that approximately 1,000 years ago, when there was about 28 percent less CO₂ in the atmosphere than there is currently, temperatures throughout much of the world were just as high as (or even higher than) they were over the latter part of the twentieth century (and continuing to the present), then there is nothing unusual, unnatural, or unprecedented about the current level of Earth's warmth. The warming of the late twentieth/early twenty-first century would more logically be viewed as the recurrence of whatever natural cyclical phenomenon created the equal or even greater warmth of the MWP and other warm periods that preceded it.

3.1.1. North America

McGann (2008) analyzed a sediment core retrieved from the western portion of South Bay near San Francisco International Airport (37°37.83'N, 122°21.99'W) for the presence of various foraminifers as well as oxygen and carbon stable isotopes and numerous trace elements found in the tests of *Elphidium excavatum*. She found "the climate of south bay has oscillated numerous times between warm and dry, and cool and wet conditions over the past 3870 years" and "both the Medieval Warm Period and the Little Ice Age are evident." More specifically, she identifies the MWP as occurring from AD 743 to 1343 and the LIA as occurring in two stages: AD 1450 to 1530 and AD 1720 to 1850. In addition, she states the timing of the MWP "correlates well with records obtained for Chesapeake Bay (Cronin et al., 2003), Long Island Sound (Thomas et al., 2001; Varekamp et al., 2002), California's Sierra Nevada (Stine, 1994), coastal northernmost California (Barron et al., 2004), and the San Francisco Bay estuary in north bay at Rush Ranch (Byrne et al., 2001), and south bay at Oyster Point (Ingram et al., 1996)." As for the more recent past, McGann notes "near the top of the core" foraminiferal abundances suggest, "once again, regional warming has taken

place." However, that warming does not appear to have returned the region to the level of sustained warmth it enjoyed during the peak warmth of the MWP.

Moving north to Alaska, Clegg et al. (2010) conducted a high-resolution analysis of midge assemblages found in the sediments of Moose Lake (61°22.45'N, 143°35.93'W) in the Wrangell-St. Elias National Park and Preserve in the south-central portion of the state, producing a record of reconstructed mean July temperatures (T_{July}) for the past six thousand years. In examining the latter half of that record, as portrayed in Figure 3.1.1, from 2,500 cal BP to the present, there is a clear multi-centennial oscillation, with its peaks and valleys defining the temporal locations of the Roman Warm Period, the Dark Ages Cold Period, the Medieval Warm Period, the Little Ice Age—during which the coldest temperatures of the entire interglacial or Holocene were reached—and, finally, the start of the Current Warm Period, which is still not expressed to any significant degree compared to the Medieval and Roman Warm Periods.

In discussing their results, the seven scientists write, "comparisons of the T_{July} record from Moose Lake with other Alaskan temperature records suggest that the regional coherency observed in instrumental temperature records (e.g., Wiles et al., 2008; Gedalof and Smith, 2001; Wilson et al., 2007) extends broadly to at least 2000 cal BP," while noting that climatic events such as the LIA and the MWP occurred "largely synchronously" between their T_{July} record from Moose Lake and a $\delta^{18}\text{O}$ -based temperature record from Farewell Lake on the northwestern foothills of the Alaska Range.

In considering these findings, it is instructive to note that even with the help of the supposedly unprecedented anthropogenic-induced increase in the atmosphere's CO₂ concentration that occurred over the course of the twentieth century, the Current Warm Period has not achieved the warmth of the MWP or RWP, which suggests the climatic impact of the twentieth-century increase in the air's CO₂ content has been negligible. The warming that defined the Earth's recovery from the global chill of the LIA—which should have been helped by the concurrent increase in the air's CO₂ content—appears no different from the non-CO₂-induced warming that brought the planet out of the Dark Ages Cold Period and into the Medieval Warm Period.

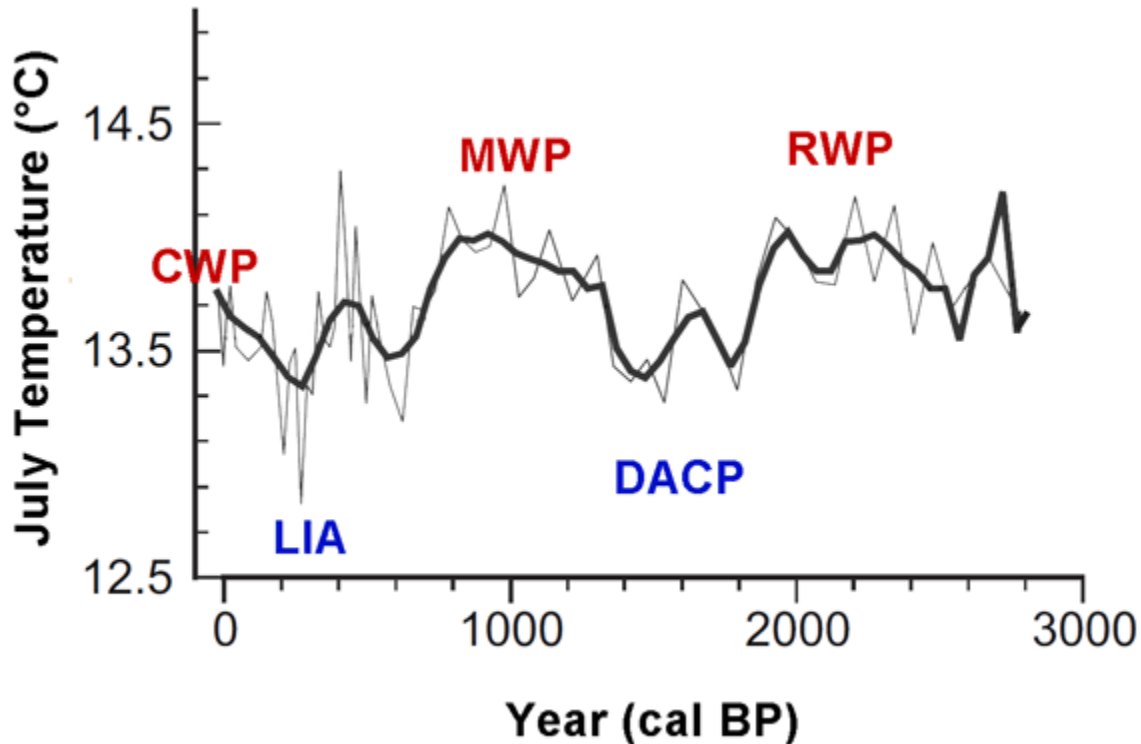


Figure 3.1.1. Mean July near-surface temperature (°C) vs. years before present (cal BP) for south-central Alaska (USA). Adapted from Clegg et al. (2010).

Working nearby in Canada, Edwards et al. (2008) wrote, “Northern Hemisphere climate is believed to have fluctuated from being generally mild on average in the early millennium (the classic Medieval Warm Period) to being cool and variable during the subsequent Little Ice Age, followed by recent warming.” To see to what extent western Canada had followed this basic pattern over the past thousand years, they employed a coupled isotope response-surface model “to resolve multi-dimensional patterns of climate variability using carbon- and water-isotope time series developed from tree-ring cellulose,” based on “16 subfossil snags and living-tree sequences of *Picea engelmannii* (Engelmann spruce) from upper alpine treeline sites near Athabasca Glacier and subfossil material from the forefield of Robson Glacier plus living and snag material of *Pinus albicaulis* (whitebark pine) adjacent to Bennington Glacier, spanning AD 951–1990.”

The results of this climate reconstruction revealed that “high inferred winter temperatures ~AD 1100–1250 stand out in particular, corresponding with the Medieval Climate Anomaly,” with the four

researchers adding the “climate shifted broadly in western Canada from warm in winter and atmospherically moist during the growth season during medieval times to being cool in winter and atmospherically dry during the growth season in the subsequent Little Ice Age.” Nevertheless, they note “independent proxy hydrologic evidence suggests that snowmelt sustained relatively abundant streamflow at this time in rivers draining the eastern Rockies,” while during the Medieval Warm Period there was “evidence for reduced discharge in rivers draining the eastern Rockies and extensive hydrological drought in neighboring western USA.” Finally, they write, “declining streamflow in rivers draining the eastern Rockies over the past century (Rood et al., 2005) may indicate that conditions are in the process of returning to a similar state,” which suggests the Current Warm Period has not yet achieved the more extreme climatic status of the Medieval Warm Period.

Edwards et al.’s results thus delineate the classic cycling of climate that brought the Earth the Medieval Warm Period and subsequent Little Ice Age as well as the twentieth-century transition to the Current Warm

Period, all independent of the air's CO₂ content. Edwards et al.'s data clearly indicate that both the minimum temperature of winter and the yearly average of the winter minimum and summer maximum temperature were greater during the Medieval Warm Period than they were during the late twentieth century, between which times the air's CO₂ concentration rose by approximately 100 ppm and still could not force a temperature increase equal to that of a thousand years ago.

Whitlock et al. (2008) analyzed "geochemical, stable-isotope, pollen, charcoal, and diatom records" further south in North America, from high-resolution cores obtained from Crevice Lake (45.000°N, 110.578°W), with the goal of reconstructing "the ecohydrologic, vegetation, and fire history of the watershed for the last 2650 years to better understand past climate variations at the forest-steppe transition" in "the canyon of the Yellowstone River in northern Yellowstone National Park [YNP]." Their results indicated the Crevice Lake region experienced "a warm interval with dry winters between AD 600 and 850, followed by less dry but still warm conditions between AD 850 and 1100." In addition, they write, "other studies in YNP indicate that trees grew above present-day treeline and fires were more frequent in the Lamar and Soda Butte drainages between AD 750 and 1150," citing Meyer et al. (1995).

As for the modern period, the seven researchers say their data indicate "the last 150 years of environmental history since the formation of YNP have not been anomalous within the range of variability of the last 2650 years, and many of the proxy indicators suggest that 19th and twentieth century variability at Crevice Lake was moderate compared with earlier extremes." In fact, they note that with the possible exception of the charcoal record, "all of the data show greater variability in the range of ecosystem conditions prior to the establishment of the YNP in 1872."

In another study, based on isotopic soil carbon measurements made on 24 modern soils and 30 buried soils scattered between latitudes 48 and 32°N and longitudes 106 and 98°W, Nordt et al. (2008) developed a time series of C₄ vs. C₃ plant dynamics for the past 12,000 years in the mixed and shortgrass prairie of the U.S. Great Plains. They did this because, as they describe it, the percent of soil carbon derived from C₄ plants corresponds strongly with summer temperatures as reflected in the soil carbon pool, citing the work of Nordt et al. (2007) and von

Fischer et al. (2008). As a result, they were able to devise a history of the relative warmth of the climate of the region over this protracted period. This history suggested the region of study was slightly warmer during parts of both the Medieval and Roman Warm Periods than it has yet been in modern times, and that it was significantly warmer during a sizeable portion the mid-Holocene Thermal Maximum or Climatic Optimum, as it is sometimes called.

Other studies have documented a Medieval Warm Period in Greenland. Norgaard-Pedersen and Mikkelsen (2009), for example, measured and analyzed several properties of a sediment core retrieved from the deepest basin of Narsaq Sound (60°56.200'N, 46°09.300'W) in southern Greenland from which they were able to infer various "glacio-marine environmental and climatic changes" that had occurred over the prior 8,000 years. Their results revealed the existence of two periods (2.3–1.5 ka and 1.2–0.8 ka) that "appear to coincide roughly with the 'Medieval Warm Period' and 'Roman Warm Period'" and they identified the colder period that followed the Medieval Warm Period as the Little Ice Age and the colder period that preceded it as the Dark Ages Cold Period.

Citing the works of Dahl-Jensen et al. (1998), Andresen et al. (2004), Jensen et al. (2004), and Lassen et al. (2004), the two Danish scientists said "the cold and warm periods identified in [those researchers' studies] appear to be more or less synchronous to the inferred cold and warm periods observed in the Narsaq Sound record," providing even more evidence for the reality of the naturally occurring phenomenon that governs this millennial-scale oscillation of climate that has been identified throughout the world.

A little closer to the present, Vinther et al. (2010) introduced the report of their study by writing, "during the past 10 years studies of seasonal ice core $\delta^{18}\text{O}$ records from the Greenland ice sheet have indicated, that in order to gain a firm understanding of the relationships between Greenland $\delta^{18}\text{O}$ and climatic conditions in the North Atlantic region, it is important to have not only annually resolved, but seasonally resolved ice core $\delta^{18}\text{O}$ data." Therefore, working with 20 ice core records from 14 different sites, all of which stretched at least 200 years back in time, as well as near-surface air temperature data from 13 locations along the southern and western coasts of Greenland that covered approximately the same time interval (1784–2005), plus a similar

temperature dataset from northwest Iceland (said by them to be employed “in order to have some data indicative of climate east of the Greenland ice sheet”), Vinther et al. proceeded to demonstrate that winter $\delta^{18}\text{O}$ was “the best proxy for Greenland temperatures.”

Based on that determination, plus three longer ice core $\delta^{18}\text{O}$ records (DYE-3, Crete, and GRIP), the seven scientists developed a temperature history extending more than 1,400 years back in time. From that history they determined “temperatures during the warmest intervals of the Medieval Warm Period,” which they defined as occurring “some 900 to 1300 years ago, “were as warm as or slightly warmer than present day Greenland temperatures.”

Last, Kobashi et al. (2010) write, “in Greenland, oxygen isotopes of ice (Stuiver et al., 1995) have been extensively used as a temperature proxy, but the data are noisy and do not clearly show multi-centennial trends for the last 1,000 years, in contrast to borehole temperature records that show a clear ‘Little Ice Age’ and ‘Medieval Warm Period’ (Dahl-Jensen et al., 1998).” However, they note nitrogen (N) and argon (Ar) isotopic ratios— $^{15}\text{N}/^{14}\text{N}$ and $^{40}\text{Ar}/^{36}\text{Ar}$, respectively—can be used to construct a temperature

record that “is not seasonally biased, and does not require any calibration to instrumental records, and resolves decadal to centennial temperature fluctuations.” Kobashi et al. further describe the development of such an approach, after which they use it to construct a history of the past thousand years of central Greenland surface air temperature, based on values of isotopic ratios of nitrogen and argon previously derived by Kobashi et al. (2008) from air bubbles trapped in the GISP2 ice core that had been extracted from central Greenland (72°36'N, 38°30'W).

Figure 3.1.2 depicts the researchers’ reconstruction of central Greenland’s surface temperature history. As best as can be determined from this representation, the peak temperature of the latter part of the Medieval Warm Period—which actually began some time before the start of their record, as demonstrated by the work of Dansgaard et al. (1975), Jennings and Weiner (1996), Johnsen et al. (2001), and Vinther et al. (2010)—was about 0.33°C greater than the peak temperature of the Current Warm Period and about 1.67°C greater than the temperature of the last decades of the twentieth century. In addition, it is worth noting that between

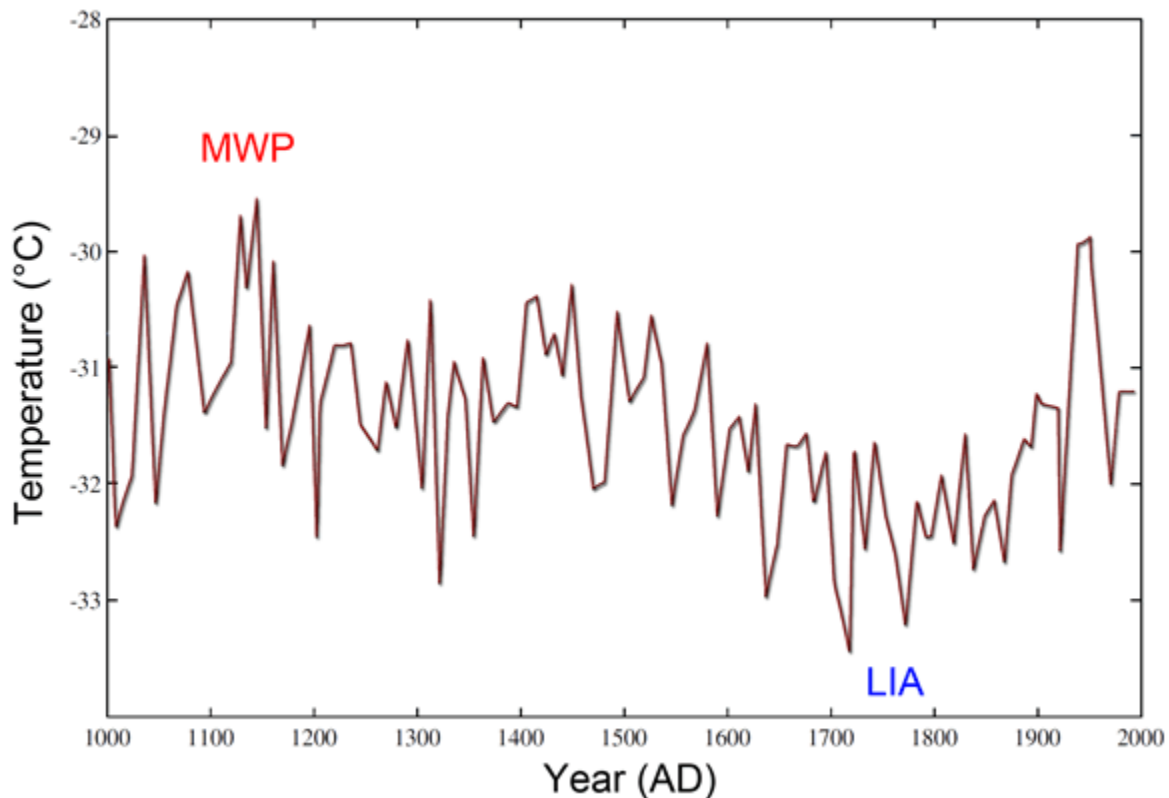


Figure 3.1.2. Central Greenland surface temperature reconstruction for the last millennium. Adapted from Kobashi et al. (2010).

about 1400 and 1460 there was also a period of notable warmth in Kobashi et al.'s temperature reconstruction, which aligns well with the Little Medieval Warm Period, the peak temperature of which was about 0.9°C greater than the temperature of the last decades of the twentieth century and the first decade of the twenty-first century.

These findings, in the words of Kobashi et al., “show clear evidence of the Medieval Warm Period and Little Ice Age in agreement with documentary evidence,” and those data clearly show that the Medieval Warm Period in North America was at times considerably warmer than the Current Warm Period has been to date, and that even the Little Medieval Warm Period was considerably warmer than the last decades of the twentieth century and first decade of the twenty-first century.

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3.1.2. Europe

We begin our examination of Europe with the study of Axford et al. (2009), who note “the idea of a widespread and spatially coherent ‘Medieval Warm Period’ (MWP) has come under scrutiny in recent years,” while “it remains a viable hypothesis that a period of relative warmth in northwestern Europe and the northern North Atlantic region helped facilitate Norse expansion across the North Atlantic from the ninth to thirteenth centuries, including settlement of Iceland and Greenland” and “subsequent cooling contributed to the demise of the Norse settlements on Greenland.” To further explore the subject, they developed a regional climatic record from a sediment core retrieved from Lake Stora Vioarvatn in northeast Iceland (66°14.232'N, 15°50.083'W) in the summer of 2005, based on chironomid assemblage data—which were well correlated with nearby measured temperatures over the 170-year instrumental record—and total organic carbon, nitrogen, and biogenic silica content. This work revealed the occurrence of “warm temperatures in the tenth and eleventh centuries, with one data point suggesting temperatures slightly warmer than present.” They also discovered “temperatures were higher overall and more consistently high through much of the first millennium AD.”

In discussing their findings, the Icelandic, U.K., and U.S. scientists state, “the historical perception of a significant medieval climate anomaly in Iceland may be primarily a reflection of the human perspective,” in that “Iceland was settled ca. AD 870, during a period of relative warmth that was followed by many centuries of progressively colder and less hospitable climate,” that “had the Norse settled Iceland 1000 years earlier, the MWP might be viewed only as a brief period of climatic amelioration, a respite from a shift to colder temperatures that began in the eighth century,” near the end of several centuries of even greater warmth. In any event, and viewed from either perspective, it is clear there is nothing unusual or unnatural about the region's present-day temperatures, which the researchers say “do not show much recent warming.”

In another significant study, Bonnet et al. (2010) developed a high-resolution record of ocean and climate variations during the late Holocene in the Fram Strait (the major gateway between the Arctic and North Atlantic Oceans, located north of the Greenland Sea)—based on detailed analyses of a sediment core recovered from a location (78°54.931'N, 6°46.005'E) on the slope of the western continental margin of Svalbard—that permitted the reconstruction of sea surface temperature (SST) conditions in both summer and winter. These histories were nearly identical and showed oscillations between -1°C and 5.5°C in winter and between 2.4°C and 10.0°C in summer; their graphical results indicate that between 2,500 and 250 years before present (BP), the mean SSTs of summers were warmer than those of the present about 80 percent of the time, while the mean SSTs of winters exceeded those of current winters approximately 75 percent of the time, with the long-term (2,250-year) means of both seasonal periods averaging about 2°C more than current means. The highest temperatures, however, were recorded during a warm interval that persisted from about AD 500 to 720, during the very earliest stages of the Medieval Warm Period, when the peak summer and winter temperatures of the MWP both exceeded the peak summer and winter temperatures of the first several years of the twenty-first century by about 3°C.

Moving to Finland, Haltia-Hovi et al. (2010) constructed detailed chronological histories of several magnetic properties of two sediment cores taken from Finland's Lake Lemmijärvi (63°37'N, 29°06'E), as well as a history of their total organic carbon content. Based on their analyses, they discovered a "conspicuous occurrence of fine magnetic particles and high organic concentration" evident around 4,700–4,300 Cal. yrs BP. This time interval, in their words, "is broadly coincident with glacier contraction and treelines higher than present in the Scandinavian mountains according to Denton and Karlen (1973) and Karlen and Kuylénstierna (1996)." They report from that time on toward the present, there was a "decreasing trend of magnetic concentration, except for the slight localized enhancement in the upper part of the sediment column at ~1,100–900 Cal. yrs BP," where the year zero BP = AD 1950.

Changes of these types in prior studies have been attributed to magnetotactic bacteria (e.g. *Magnetospirillum* spp.), which Haltia-Hovi et al. describe as "aquatic organisms that produce internal,

small magnetite or greigite grains" used "to navigate along the geomagnetic field lines in search of micro or anaerobic conditions in the lake bottom," as described by Blakemore (1982) and Bazylinski and Williams (2007). They further state the studies of Snowball (1994), Kim et al. (2005), and Paasche et al. (2004) "showed magnetic concentration enhancement, pointing to greater metabolic activity of these aquatic organisms in the presence of abundant organic matter." This is also what Haltia-Hovi et al. found in their study; they report the "concentration of organic matter in the sediment is highest, together with fine magnetic grain sizes, in the time period 1,100–900 Cal. years BP." This time interval, they say, "is associated with warmer temperatures during the Medieval Climate Anomaly according to the varve parameters of Lake Lemmijärvi," citing the precise core-dating by varve-counting work of Haltia-Hovi et al. (2007). Taken together, these observations strongly suggest the peak warmth of the Medieval Warm Period (about AD 850–1050) was very likely somewhat greater than that of the Current Warm Period.

In another study, Larocque-Tobler et al. (2010) write that to better describe the amplitude of temperature change during the past millennium, "new records to increase the geographic coverage of paleoclimatic information are needed" and "only by obtaining numerous high-resolution temperature records will it be possible to determine if the 20th century climate change exceeded the natural pre-industrial variability of European climate." To help achieve this important goal, they proceeded to obtain another such temperature record based on an analysis of fossil chironomids (non-biting midges) identified and quantified in four sediment cores extracted from the bed of Lake Silvaplana (46°26'56"N, 9°47'33"E) in the Upper Engadine (a high-elevation valley in the eastern Swiss Alps). This analysis produced a detailed history of that region's mean July air temperature over the last millennium.

The results of this effort indicate, as the five researchers describe it, "at the beginning of the record, corresponding to the last part of the 'Medieval Climate Anomaly' (here the period between ca. AD 1032 and 1262), the chironomid-inferred mean July air temperatures were 1°C warmer than the climate reference period (1961–1990)," which would also make them warmer than most subsequent temperatures. And in looking at their graphs of 20- and 50-year running means, it can be seen that the

peak warmth of the Medieval Warm Period exceeded that of the Current Warm Period by approximately 0.5°C in the case of 20-year averages and 1.2°C in the case of 50-year averages. Consequently, Larocque-Tobler et al. conclude, “there is no evidence that mean-July air temperature exceeded the natural variability recorded during the Medieval Climate Anomaly in the 20th century at Lake Silvaplana.” They note similar results “were also obtained in northern Sweden (Grudd, 2008), in Western Europe (Guiot et al., 2005), in a composite of Northern Hemisphere tree-ring reconstructions (Esper et al., 2002) and a composite of tree rings and other archives (Moberg et al., 2005).”

A few years earlier in Italy, Frisia et al. (2005) developed a 17,000-year record of speleothem calcite $\delta^{18}\text{O}_\text{C}$ data they obtained from a cave stalagmite located at the southeast margin of the European Alps (45°37'05" N, 13°53'10" E), which they calibrated against “a reconstruction of temperature anomalies in the Alps” developed by Luterbacher et al. (2004) for the last quarter of the past millennium. This work revealed—among several other things (due to the great length of time involved)—the occurrence of the Roman Warm Period and a Medieval Warm Period that was broken into two parts by an intervening central cold period. The five researchers say both portions of the Medieval Warm Period were “characterized by temperatures that were similar to the present.”

Also working in Italy, Giraudi (2009) examined “long-term relations among glacial activity, periglacial activity, soil development in northwestern Italy’s alpine River Orco headwaters, and downvalley floods on the River Po,” based on “studies carried out by means of geological and geomorphologic surveys on the glacial and periglacial features,” including a sampling of soils involved in periglacial processes that “provided a basis for development of a chronological framework of late Holocene environmental change” and an analysis of “a stratigraphic sequence exposed in a peat bog along the Rio del Nel” about 1 km from the front edge of the Eastern Nel Glacier. Among several interesting findings, these undertakings allowed Giraudi to determine that between about 200 BC and AD 100—i.e., during the Roman Warm Period—“soils developed in areas at present devoid of vegetation and with permafrost,” indicative of the likelihood that temperatures at that time “probably reached higher values than those of the present.” He also concluded

“analogous conditions likely occurred during the period of 11th–12th centuries AD, when a soil developed on a slope presently characterized by periglacial debris,” while noting “in the 11th–12th centuries AD, frost weathering processes were not active and, due to the higher temperatures than at present or the longer duration of a period with high temperatures, vegetation succeeded in colonizing the slope.”

These several studies from Europe provide evidence for the millennial-scale oscillation of climate that has operated throughout glacial and interglacial periods alike, producing century-scale periods when temperatures were as warm as they are at present, or even warmer, even though the air’s CO_2 content was much lower at those earlier times than it is today.

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3.1.3. Asia

Arid Central Asia (ACA, an inland zone in central Asia from the Caspian Sea in the west to the southern Mongolian Plateau in the east), according to Chen et

al. (2010), is “a unique dry-land area whose atmospheric circulation is dominated today by the westerlies” and is “one of the specific regions that are likely to be strongly impacted by global warming,” which could greatly impact its hydrologic future. In an attempt to understand such potential impacts, Chen et al. evaluated the “spatial and temporal patterns of effective moisture variations,” using 17 different proxy records in the ACA and synthesizing a decadal-resolution moisture curve for this region over the past millennium, employing five of the 17 records based on their having “reliable chronologies and robust proxies.”

The nine researchers report that the effective moisture (precipitation) in the ACA has a generally inverse relationship with the temperature of the Northern Hemisphere, as portrayed by Moberg et al. (2005); China, as portrayed by Yang et al. (2002); and Central Asia, as portrayed by Esper et al. (2007). That is to say, as they describe it, the “wet (dry) climate in the ACA correlates with low (high) temperature.” Stating it in yet another way, they indicate the ACA “has been characterized by a relatively dry Medieval Warm Period (MWP; the period from ~1000 to 1350 AD), a wet little Ice Age (LIA; from ~1500–1850 AD),” and “a return to arid conditions after 1850 AD,” which has been slightly muted—but only “in some records”—over the past 20 years by an increase in humidity.

Given such findings, Chen et al. propose that “the humid LIA in the ACA, possibly extending to the Mediterranean Sea and Western Europe, may have resulted from increased precipitation due to more frequent mid-latitude cyclone activities as a result of the strengthening and equator-ward shift of the westerly jet stream ... coupled with a decrease in evapotranspiration caused by the cooling at that time,” a cooling brought about by the gradual demise of the Medieval Warm Period. This in turn speaks volumes about the great significance of that centuries-long period of much-lower-than-present atmospheric CO₂ concentration but of equivalent or even greater warmth than that of the Current Warm Period. This ultimately suggests the twentieth-century increase in the air’s CO₂ content may have had little, or maybe even nothing, to do with twentieth-century global warming.

Also exploring the Medieval Warm Period in China, Hong et al. (2009) indicate that “because it is a distinct warm period nearest to the modern warming period and happened before the Industrial Revolution,

it naturally becomes a [source of] comparison with modern warming.” And in this regard, they add, “a universal concern in academic circles is whether it also existed outside the European region and whether it is a common phenomenon.” In a study designed to broach both questions, they extracted cores of peat from a location close to Hani Village, Liuhe County, Jilin Province, China (42°13’N, 126°31’E) and used those cores to develop, as they describe it, “a peat cellulose $\delta^{18}\text{O}$ temperature proxy record proximately existing for 14,000 years.”

Their efforts revealed, first, that the MWP had indeed held sway on the Chinese mainland over the period AD 700–1400, peaking at about AD 900. And the eight researchers report that phenological data from east China (Ge et al., 2006) and tree-ring records from west China (Yang et al., 2000) also indicate “the temperature on the Chinese mainland was distinctly warmer during the MWP.” In fact, they say MWP temperatures were as much as “0.9–1.0°C higher than modern temperatures (Zhang, 1994).”

With respect to the entire 14,000-year period, Hong et al. write, “sudden cooling events, such as the Older Dryas, Inter-Allerod, Younger Dryas, and nine ice-rafted debris events of the North Atlantic”—which are described by Stuiver et al. (1995) and Bond et al. (1997, 2001)—“are almost entirely reiterated in the temperature signals of Hani peat cellulose $\delta^{18}\text{O}$.” They state, “these cooling events show that the repeatedly occurring temperature cooling pattern not only appeared in the North Atlantic Region in the high latitudes, but also in the Northwest Pacific Region in the middle latitudes,” indicating the recurring cooling and warming pattern did indeed occur “outside the European region” and that this climatic oscillation was “a common phenomenon.”

Several years earlier, Hong et al. (2000) had used a 6,000-year peat cellulose $\delta^{18}\text{O}$ record derived from nearby Jinchuan Town, Huinan County, Jilin Province, China (42°20’N, 126°22’E) to identify $\delta^{18}\text{O}$ periodicities of 86, 93, 101, 110, 127, 132, 140, 155, 207, 245, 311, 590, 820 and 1,046 years, which they described as being “similar to those detected in solar excursions,” and which they considered to be “further evidence for a close relationship between solar activity and climate variations on timescales of decades to centuries.” These findings were highly praised by Fairbridge (2001), who noted “almost identical equivalents are seen in solar emission periodicities and their harmonics, e.g., 86.884 years = 40×2.172 year Quasi Biennial Oscillation (QBO) as

well as in the lunar tidal/apsides beat frequency (17.3769 years) which also matches closely with most of the longer spectral peaks, e.g., 140 (139) years, 207 (208.5), 311 (312.8), 590 (590.8) and 1046 (1042.6) years.” And for these spectacular spectral findings, Fairbridge wrote, “Hong et al. deserve the appreciation of the entire Holocene community.”

In another significant study, Liu et al. (2005) compared Ge et al.’s (2003) reconstructed winter half-year temperature anomalies in the central region of eastern China (25–40°N, east of 105°E) for the last 1,000 years with simulated anomalies of the same parameter, which they obtained from the ECHO-G global atmosphere-ocean coupled climate model that was driven by time-varying external forcings, including solar radiation, volcanic eruptions, and greenhouse gas concentrations (CO_2 and CH_4) for the same time period. And in conducting their analysis, they report, “the Medieval Warm Period (MWP) during 1000–1300 A.D., the Little Ice Age (LIA) during 1300–1850 A.D. and the modern warming period after 1900 A.D. are all recognizable from both the simulated and reconstructed temperatures.” In addition, they indicate the anomalies associated with the LIA and the modern warming simulated by the model are “in good consistency” with their reconstructed counterparts. However, they note that “in the earlier MWP, significant discrepancies exist between the simulation and the reconstruction.” More specifically, they say, “the simulated temperature anomaly in the 20th century is higher than that of the Medieval Warm Period, while the reconstructed temperature in the 20th century is lower.”

The seven scientists say the two different results “provide two different interpretations regarding the amplitude of recent global warming,” noting “one states that the 20th century warming has exceeded the normal range of the climate change, and it will result in catastrophic impact on human beings if warming continues,” whereas the other suggests “the current climate change has not yet exceeded the range of natural climate change in the past millennium.” As the real-world evidence for a warmer-than-present Medieval Warm Period continues to accumulate, it is becoming increasingly difficult to support the claim that current temperatures are unnaturally high due to rising anthropogenic CO_2 emissions.

In one final study of China, Ge et al. (2010) developed three regional composite temperature reconstructions that extended back in time a full two millennia (Northeast, Tibet, Central East), one that

extended back approximately 950 years (Northwest), and one that went back about 550 years (Southeast). With respect to the three reconstructions that extended through the Medieval Warm Period and the one that extended into but not through it, the six scientists report: (1) in the Northeast there was a warm period “between approximately 1100 and 1200 that exceeded the warm level of the last decades of the 20th century”; (2) in Tibet there was a “warming period of twenty decadal time steps between the 600s and 800s” that was “comparable to the late 20th century”; (3) in the Central East there were two warm peaks (1080s–1100s and 1230s–1250s) that had “comparable high temperatures to the last decades of the 20th century,” although the graph of their data indicates these two periods were in fact warmer than the last decades of the twentieth century; and (4) in the Northwest, “comparable warm conditions in the late 20th century are also found around the decade 1100s.” These findings make it clear there is nothing unusual, unnatural, or unprecedented about China’s current level of warmth.

From China we proceed to Japan, where Aono and Saito (2010) “investigated documents and diaries from the ninth to the fourteenth centuries to supplement the phenological data series of the flowering of Japanese cherry (*Prunus jamasakura*) in Kyoto to improve and fill gaps in temperature estimates based on previously reported phenological data.” They then “reconstructed a nearly continuous series of March mean temperatures based on 224 years of cherry flowering data, including 51 years of previously unused data, to clarify springtime climate changes.” In addition, they estimated still other cherry full-flowering dates “from phenological records of other deciduous species, adding further data for six years in the tenth and eleventh centuries by using the flowering phenology of Japanese wisteria (*Wisteria floribunda*).”

Their temperature reconstruction “showed two warm temperature peaks of 7.6°C and 7.1°C, in the middle of the tenth century and at the beginning of the fourteenth century, respectively,” and they say “the reconstructed tenth century temperatures [AD 900–1000] are somewhat higher than present temperatures after subtracting urban warming effects.” Finally, they note “the general pattern of change in the reconstructed temperature series in this study is similar to results reported by previous studies, suggesting a warm period in Asia

corresponding to the Medieval Warm Period in Europe.”

In a separate study, Daimaru et al. (2002) wrote, “in snowpatch grasslands, plant distributions follow the contours of the snowmelt gradient around summer snowpatches,” producing “similarly steep gradients in plant productivity and topsoil (e.g. Billings and Bliss, 1959; Helm, 1982; Kudo, 1991; Stanton et al., 1994.)” In fact, they note “in the subalpine zone of northeastern Japan, sites where the snow cover disappears after July are usually occupied by ‘snowpatch bare grounds’ with extremely poor vegetation cover” that is “encircled by snowpatch grassland,” citing Yamanaka (1979). As a result, they write, “litter fall and the organic content in topsoil decrease toward the center of a snowpatch because the period for plant growth becomes shorter with delay in the time of snow disappearance,” so that in current “snowpatch grasslands, peaty topsoil is restricted to sites where snowmelt comes early.” And as a result of this, the unique situation provided by a snowpatch often can provide a good opportunity for paleoclimatic reconstructions based on vertical profiles of soil characteristics at various locations along transects moving outwards from summer snowpatches.

Consequently, working in a snowpatch grassland within a shallow depression of landslide origin on the southeastern slope of Japan’s Mt. Zarumori (~39.8°N, 140.8°E), Daimaru et al. dug 27 soil pits at various locations in and around the central location of the snowpatch, carefully examining what they found and determining its age based on ¹⁴C dating and tephrochronology. They state, “peaty topsoils were recognized at seven soil pits in the dense grassland, whereas sparse grassland lacked peaty topsoil” and “most of the buried peat layers contained a white pumice layer named ‘To-a’ that fell in AD 915.” This observation, plus their ¹⁴C dating, led them to conclude the buried peat layers in the poor vegetation area indicate “warming in the melt season” as well as “a possible weakened winter monsoon in the Medieval Warm Period,” which their data suggest prevailed at the site they studied throughout the tenth century, AD 900–1000. They write, “many studies have reported climatic signals that are correlated with the Medieval Warm Period from the 9th to 15th centuries in Japan,” suggesting the possibly weakened winter monsoon of AD 900–1000 also may have been a consequence of the warmer temperatures of that period.

In a Japanese study using sediment cores from Lakes Ni-no-Megata (39°57'N, 139°43'E) and San-no-Megata (39°56'N, 139°42'E) located on the Oga Peninsula of northeastern Japan, Yamada et al. (2010) measured several sediment properties, including sulfur content and coarse mineral grains. The former served as a proxy for paleo-Asian summer monsoon activity, and the latter was a proxy for paleo-Asian winter monsoon activity over the last two millennia. Upon examining these data, Yamada et al. found evidence for a cold/dry interval stretching from AD 1 to 750, a warm/humid interval from AD 750 to 1200, and another cold/dry interval from AD 1200 to the present. These intervals could represent, respectively, as they describe them, “the Dark Ages Cold Period (DACP), the Medieval Warm Period (MWP) and the Little Ice Age (LIA).”

In further discussing their findings, the six scientists say they complement those of Kitagawa and Matsumoto (1995), whose study of tree-ring records in southern Japan “suggested the existence of one warm interval at AD 750-1300 and two cold intervals at AD 200-750 and AD 1600-1800,” as well as the findings of Sakaguchi (1983), whose study of the pollen record of peaty sediments in central Japan revealed “an unusual warm interval (AD 700-1300) and a cool interval (ca. AD 250-700).” In addition, they write, the “strong summer monsoon and weak winter monsoon at Lakes Ni-no-Megata and San-no-Megata from AD 750-1200 correlates with the lower $\delta^{18}\text{O}$ values from Wangxiang Cave (Zhang et al., 2008) and lower values of minerogenic clastic content (Chu et al., 2009).”

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3.1.4. Africa

Working with the vertical sediment profile of Ocean Drilling Program Hole 658C, which was cored off Cap Blanc, Mauritania (20°45'N, 18°35'W) at a water depth of 2,263 meters, DeMenocal et al. (2000) analyzed samples of two centimeters' length (equivalent to 50 to 100 years resolution) for various parameters, including planktonic foraminiferal assemblage census counts, from which they calculated warm- and cold-season sea surface temperatures throughout the entire Holocene, based on transfer functions derived from faunal analyses of 191 other Atlantic core tops. This work revealed a series of abrupt millennial-scale cooling events followed by compensatory warming events that “appear to have involved the entire North Atlantic basin (O'Brien et al., 1995; Keigwin, 1996; Bond et al., 1997; Bianchi and McCave, 1999; Bond et al., 1999), recurred with a $\sim 1500 \pm 500$ year period throughout glacial and interglacial intervals (O'Brien et al., 1995; Bond et al., 1997; Bianchi and McCave, 1999; Bond et al., 1999), were accompanied by terrestrial climate changes (COHMAP Members, 1988; Gasse and Van Campo, 1994), and involved large-scale ocean and atmosphere reorganizations that were completed within decades or centuries (Alley et al., 1993).” The four researchers remark, “these climate perturbations continue to persist during ‘our time’.” With respect to the MWP, they state it was “marginally warmer than present.”

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3.1.5. South America

Sepulveda et al. (2009) write, “deciphering climate variability in the Southern Hemisphere and particularly from southern South America—the only continental land mass lying between 38°S and the Antarctic Circle—is crucial for documenting the inter-hemispheric synchronicity of recent abrupt climate changes and thereby determining their ultimate cause(s),” as well as for “predicting future abrupt climate changes.” Thus, they conducted what they describe as “a high-resolution multi-proxy study including the elemental and isotopic composition of bulk organic matter, land plant-derived biomarkers, and alkenone-based sea-surface temperature (SST) from a marine sedimentary record obtained from the Jacaf Fjord in northern Chilean Patagonia [44°20.00'S, 72°58.15'W],” in order to develop “a detailed reconstruction of continental runoff,

precipitation and summer SST spanning the last 1750 years.”

The Chilean, German, and U.S. scientists report their work revealed two distinct climatic conditions: “a relatively dry/warm period before 900 cal yr BP (higher runoff and average SST 1°C warmer than present day) and a wet/cold period after 750 cal yr BP (higher runoff and average SST 1°C colder than present day),” which they associated with the Medieval Warm Period and Little Ice Age, respectively.

In commenting on their findings, Sepulveda et al. write, “the reasonably good correlation between our results (particularly SST) and other continental and marine archives from central-south Chile, Peru, and Antarctica ... confirms the occurrence of globally important climatic anomalies such as the Medieval Warm Period and the Little Ice Age.” In addition, their SST data indicate the current level of warmth in that part of the world still has a long way to go before equaling the warmth experienced there a thousand and more years ago, suggesting the region's current level of warmth is neither unprecedented nor unnatural, and that it therefore need not be CO₂-induced.

Working in the same area but one year earlier, Rebolledo et al. (2008) analyzed changes in marine productivity and terrestrial input in a study of sediment cores retrieved from the Jacaf Channel (44°S, 72°W) of Chilean Northern Patagonia that represented the past 1,800 years. The results they obtained clearly depicted two productivity/climate modes. The first period—prior to 900 cal yr BP and including the Medieval Warm Period—was characterized by “decreased marine productivity and a reduced continental signal, pointing to diminished precipitation and runoff,” while the second period—between 750 cal yr BP and the late 1800s, and including the Little Ice Age—was characterized by “elevated productivity and an increased continental signal, suggesting higher precipitation and runoff.” In addition, their data clearly showed the MWP and LIA were “separated by a relatively abrupt transition of ~150 years.”

In addition to providing another demonstration of the reality of the MWP and LIA in Earth's Southern Hemisphere, the Chilean, German, and U.S. scientists say the good correspondence between their record and “other paleoclimate studies carried out in South America and Antarctica demonstrates that the Chilean fjord area of Northern Patagonia is not just sensitive

to local climatic variability but also to regional and possibly global variability.”

In another study from South America, Kellerhals et al. (2010) write, “to place recent global warming into a longer-term perspective and to understand the mechanisms and causes of climate change, proxy-derived temperature estimates are needed for time periods prior to instrumental records and regions outside instrumental coverage,” noting, in this regard, that “for tropical regions and the Southern Hemisphere ... proxy information is very fragmentary.”

To help fill this data void, the six scientists developed what they describe as “a reconstruction of tropical South American temperature anomalies over the last ~1600 years ... based on a highly resolved and carefully dated ammonium record from an ice core that was drilled in 1999 on Nevado Illimani [16°37'S, 67°46'W] in the eastern Bolivian Andes,” noting “studies from other remote ice core sites have found significant correlations between NH_4^+ concentration and temperature for Siberia and the Indian subcontinent for preindustrial time periods,” citing the work of Kang et al. (2002) and Eichler et al. (2009). As for calibrating and validating the NH_4^+ -to-°C transfer function, they say they used “the Amazon Basin subset of the gridded HadCRUT3 temperature data set,” which is described by Brohan et al. (2006).

In describing their results, Kellerhals et al. state “[1] the most striking features in the reconstruction are the warm temperatures from ~1050 to ~1300 AD [the MWP] compared to the preceding and following centuries, [2] the persistent cooler temperatures from ~1400 to ~1800 AD [the LIA], and [3] the subsequent rise to warmer temperatures [of the Current Warm Period] which eventually seem to exceed, in the last decades of the 20th century, the range of past variation.” Consequently, and although the MWP in this particular instance was found to be slightly cooler than it is currently, they add, the “relatively warm temperatures during the first centuries of the past millennium and subsequent cold conditions from the 15th to the 18th century suggest that the MWP and the LIA are not confined to high northern latitudes,” but that they “also have a tropical signature.” These observations add to the growing body of evidence that demonstrates the global extent of the millennial-scale oscillation of climate that produced both the MWP and the LIA, and which has likely been responsible for the bulk of the warming that has established the Current Warm Period.

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3.1.6. Antarctica

Hall et al. (2010) write, “over the past 50 years, the Antarctic Peninsula warmed ~2°C” and 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 Narsel 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 “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.?”

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, it would appear 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. This interval of warmth occurred when there was far less CO₂ and methane in the atmosphere than there is today.

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3.1.7. Northern Hemisphere

In the 27 November 2009 issue of *Science*, Michael Mann and eight coauthors (Mann et al., 2009) describe how they used a global climate proxy network consisting of data derived from ice core, coral, sediment, and various other records to reconstruct a Northern Hemispheric surface air temperature history covering the past 1,500 years for the purpose of determining the characteristics of the Little Ice Age and Medieval Warm Period. They used Mann’s “Nature trick” of Climategate fame, truncating the reconstructed temperature history near its end and replacing it with modern-day instrumental data, so the last part of the record cannot be validly compared with the earlier portion.

This subterfuge is unwarranted. And in its current application, it’s not just from 1981 or 1961 onwards that the ruse is applied; it’s applied all the way from 1850 to 1995, the period of overlap between the

proxy and instrumental records that was used to calibrate the proxy data. Therefore, since the proxy data were available to 1995, the reconstructed near-surface air temperature history should also have been plotted to 1995, in order to be able to make valid quantitative comparisons between the degree of warmth of the Current and Medieval Warm Periods.

So why wasn't this clearly superior method of data analysis employed? Perhaps to hide the decline in the reconstructed temperature history that was evident in the latter decades of some of the proxy data. And why was that done? Perhaps to get rid of the Medieval Warm Period, because knowledge of the existence of higher temperatures during the MWP makes it much more difficult for most rational people to believe the planet's current level of warmth is due to its high atmospheric CO₂ concentration.

Even with the greatly biased “apples and oranges” comparison utilized by Mann et al., the nine researchers were forced to acknowledge that the warmth over a large part of the North Atlantic, Southern Greenland, the Eurasian Arctic, and parts of North America during the Medieval Warm Period was “comparable to or exceeds that of the past one-to-two decades in some regions.”

Nevertheless, the “*Nature* trick” of Mann et al. allows climate alarmists to continue to underestimate

the true level of warmth of the MWP, allowing the IPCC and United Nations to continue to contend Earth's current temperatures are the greatest the planet has experienced over the past millennium or more, when the vast majority of real-world data clearly show otherwise.

To see what the record shows as having happened over the Northern Hemisphere if “apples and apples” are compared, we turn to the study of Fredrik Ljungqvist (2010) of Stockholm University's Department of History, who developed a 2,000-year temperature history of the extra-tropical portion of the Northern Hemisphere (the part covering the latitudinal range 30–90°N) (see Figure 3.1.3) based on 30 temperature-sensitive proxy records with annual to multidecadal resolution, including two historical documentary records, three marine sediment records, five lake sediment records, three speleothem $\delta^{18}\text{O}$ records, two ice-core $\delta^{18}\text{O}$ records, four varved thickness sediment records, five tree-ring width records, five tree-ring maximum latewood density records, and one $\delta^{13}\text{C}$ tree-ring record, but not employing tree-ring width records from arid and semi-arid regions, because they may have been affected by drought stress and may not show a linear response to warming if higher summer temperatures significantly reduced the availability of water, as is

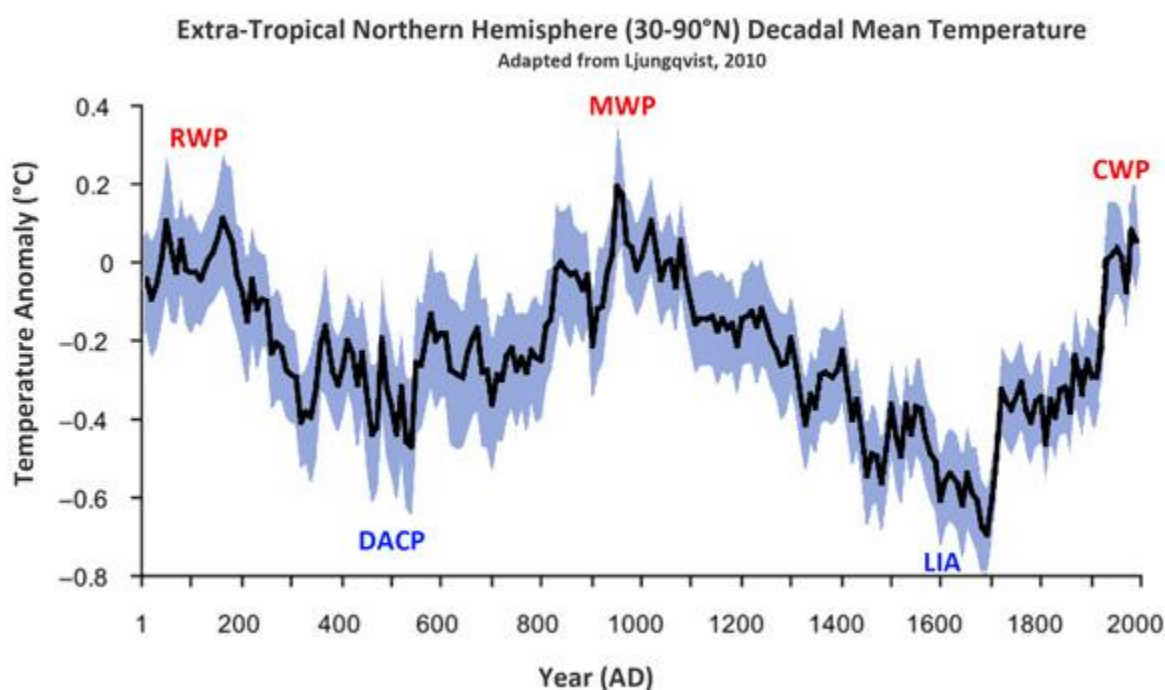


Figure 3.1.3. Reconstructed extra-tropical (30–90°N) mean decadal temperature relative to the 1961–1990 mean of the variance-adjusted 30–90°N CRUTEM3+HadSST2 instrumental temperature data of Brohan et al. (2006) and Rayner et al. (2006). Adapted from Ljungqvist (2010).

suggested by the work of D'Arrigo et al. (2006) and Loehle (2009).

In discussing this temperature history, Ljungqvist states it depicts “a Roman Warm Period c. AD 1–300, a Dark Age Cold Period c. AD 300–800, a Medieval Warm Period c. AD 800–1300 and a Little Ice Age c. AD 1300–1900, followed by the twentieth-century warming.” These alternating warm/cold periods, in his words, “probably represent the much discussed quasi-cyclical c. 1470 ± 500-year Bond Cycles (Bond and Lotti, 1995; O'Brien et al., 1995; Bond et al., 1997, 2001; Oppo, 1997),” which “affected both Scandinavia and northwest North America synchronically (Denton and Karlen, 1973)” and have “subsequently also been observed in China (Hong et al., 2009a,b), the mid-latitude North Pacific (Isono et al., 2009) and in North America (Viau et al., 2006), and have been shown to very likely have affected the whole Northern Hemisphere during the Holocene (Butikofer, 2007; Wanner et al., 2008; Wanner and Butikofer, 2008), or even been global (Mayewski et al., 2004).”

Ljungqvist also notes “decadal mean temperatures in the extra-tropical Northern Hemisphere seem to have equaled or exceeded the AD 1961–1990 mean temperature level during much of the Roman Warm Period and the Medieval Warm Period” and “the second century, during the Roman Warm Period, is the warmest century during the last two millennia.” He adds, “the highest average temperatures in the reconstruction are encountered in the mid to late tenth century,” which was during the Medieval Warm Period. He warns the temperature of the last two decades “is possibly higher than during any previous time in the past two millennia,” but he adds “this is only seen in the instrumental temperature data and not in the multi-proxy reconstruction itself,” which is akin to saying this possibility presents itself only if one applies Michael Mann's “*Nature* trick” of comparing “apples and oranges,” which is clearly not valid.

This new study of Ljungqvist is especially important because it utilizes, in his words, “a larger number of proxy records than most previous reconstructions” and “substantiates an already established history of long-term temperature variability.” All of these facts, taken together, clearly demonstrate there is nothing unusual, unnatural, or unprecedented about the planet's current level of warmth.

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3.1.8. Other Temperature Records

Four additional studies that don't fall under the previous seven sections of this chapter shed light on temperature reconstructions of the Medieval Warm Period.

In a lengthy review paper (Wanner et al., 2008), 18 climate scientists—from 13 research institutions in Switzerland, Germany, the United Kingdom, Belgium, and Russia—developed what they describe as “a general framework for understanding climate changes during the last 6000 years,” and they ended their analysis of the several hundred papers they cited with a summary consisting of two main points, the

second of which is most germane to the topic of the Medieval Warm Period.

Wanner et al. concluded, “at decadal to multi-century timescales, climate variability shows a complex picture with indications of a possible role for (i) rapid changes of the natural forcing factors such as solar activity fluctuations and/or large tropical volcanic eruptions, (ii) internal variability including ENSO [El Niño Southern Oscillation] and NAO [North Atlantic Oscillation], (iii) changes of the thermohaline circulation, and (iv) complex feedback mechanisms between ocean, atmosphere, sea ice and vegetation.” They also report “notable swings occurred between warm and cold periods, especially the hemispheric-scale warming leading into the Medieval Warm Period and subsequent cooling into the Little Ice Age.” The latter period, they note, “appears at least to be a hemispheric phenomenon.” Finally, they say model simulations support the inference that the Little Ice Age “may have been brought about by the coincidence of low Northern Hemisphere orbital forcing during the Late Holocene with unusually low solar activity and a high number of major volcanic events.”

Continuing consideration of the sun as a cause for millennial-scale climate perturbations were Dergachev and Raspopov (2010a,b), who analyzed the degree of harmony among earlier reconstructions, as well as their individual correlations with various indices of solar activity. Following this protocol, they initially demonstrated that climate reconstructions that rely heavily on tree-ring data do not agree very well with each other; and when they are compared to ice core data they appear to lose much of the low-frequency signal that is preserved in that other medium.

The Russian researchers next noted a detailed 750-year temperature reconstruction from an ice core in Siberia agrees well with measures of solar modulation based on sunspot number and carbon-14 and Be-10 estimates, and that the agreement is remarkable at multidecadal time scales. They then examined borehole thermometry data, noting that although such data lose annual- and decadal-scale detail, the temperature history thereby derived agrees well over recent decades with local instrumental data. In addition, they found that multiple boreholes from around the world agree with each other on the scale of the last millennium, which shows borehole-derived temperatures are a valid and consistent representation of reality.

Finally, the two scientists compared the solar indices of the past millennium with the borehole temperature reconstructions, demonstrating the borehole data and solar indices agree on the long-term temperature pattern of the past thousand years. Thus the two parameters imply the existence of a solar-induced Medieval Warm Period (MWP) around AD 1000 to 1300 and a Little Ice Age (LIA) in the 1600s to 1700s. Their study confirms the existence of a global MWP and demonstrates the link between the MWP-LIA oscillation and solar activity. In addition, it indicates the MWP was roughly as warm as—or warmer than—it has been to date during the Current Warm Period.

We note that in past IPCC reports, temperature reconstructions by scientists such as Mann, Bradley, Hughes, Jones, and Esper are claimed to be “remarkably consistent.” Bürger (2010) decided this opinion needed to be more rigorously evaluated, and to do so he analyzed the data contained in Figure 3.1.4.

Working with eight graphs from the IPCC and adding two more, he determined the calibration process during the instrumental period would bias the degree of agreement because the graphs were all fixed to largely agree during this period. Therefore, he examined only the period before 1850. In order to examine the shapes of the curves rather than arbitrary offsets, he rescaled them all to unit variance and centered them on zero, after which he computed the spectral coherence of each pair, and then—from the

similarity matrix—he conducted a clustering analysis.

Five clusters were formed by the 10 reconstructions, with three in the largest and one in the smallest cluster. Members within a cluster were similar at the 95 percent confidence level, based on standard tests. All of the clusters, however, were significantly incoherent with each other, not merely at some points but at virtually all timescales of fluctuation, from decadal to centennial oscillations. Thus, it is not meaningful to speak of somehow “averaging” the different reconstructions, whether by eye or numerically, because the incoherence will lead to a canceling out of the supposed climate signals in each, leaving merely a close-to-flat line.

This incoherence means one cannot claim that the different temperature reconstructions are all “right” or “agree” in any sense of the word, and attempts to use these reconstructions for attribution studies or to calibrate climate models will give different results for any particular choice of reconstruction. The results of Bürger’s work suggest the reconstructions differ so much that there is no way to draw meaningful conclusions from them, nor can it be determined which one or ones is or are right.

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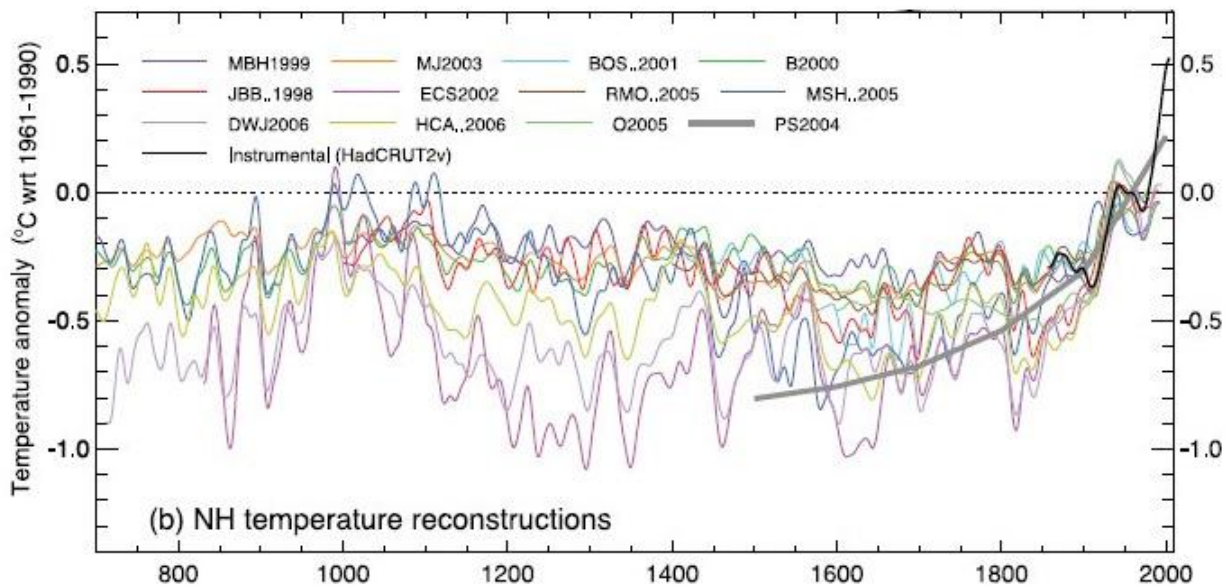


Figure 3.1.4. IPCC spaghetti graph from Fig. 6.10 of Working Group 1.

Reconstruction of the Earth's surface temperature based on data of deep boreholes, global warming in the last millennium, and long-term solar cyclicity. Part 1. Experimental data. *Geomagnetism and Aeronomy* **50**: 383–392.

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3.2. The Little Medieval Warm Period

Research from locations around the world reveal a significant period of elevated air temperatures that immediately preceded the Little Ice Age, during a time that has come to be known as the Little Medieval Warm Period. A discussion of this topic was not included in the 2009 NIPCC report, but we include it here to demonstrate the existence of another set of real-world data that do not support the IPCC's claim that temperatures of the past couple of decades have been the warmest of the past one to two millennia.

In one of the more intriguing aspects of his study of global climate change over the past three millennia, Loehle (2004) presented a graph of the Sargasso Sea and South African temperature records of Keigwin (1996) and Holmgren et al. (1999, 2001) that reveals the existence of a major spike in surface air temperature that began sometime in the early 1400s. This abrupt and anomalous warming pushed the air temperatures of these two records considerably above their representations of the peak warmth of the twentieth century, after which they fell back to pre-spike levels in the mid-1500s, in harmony with the work of McIntyre and McKittrick (2003), who found a similar period of higher-than-current temperatures in their reanalysis of the data employed by Mann et al. (1998, 1999).

In another study that reveals the existence of this period of higher-than-current warmth, D'Arrigo et al. (2004) developed a maximum latewood density (MXD) chronology for the period 1389 to 2001,

based on cores obtained from white spruce trees growing near the treeline on the eastern Seward Peninsula of Alaska, a portion of which data (1909–1950) were calibrated against May–August temperatures measured at Nome and then used to convert the entire MXD chronology to warm-season temperatures. They found a two-decade period of close-to-twentieth-century-warmth in the mid-1500s that was preceded by a decade of warmth, greater than that of the mid-twentieth century, in the latter part of the 1400s.

In a subsequent study from the same region, D'Arrigo et al. (2005) derived a new tree-ring width dataset from 14 white spruce chronologies covering the years 1358–2001. These data were then combined with additional tree-ring-width chronologies from northwest Alaska to produce two versions of a much longer data series that extended to AD 978. The first chronology was created using traditional methods of standardization (STD), which do not perform well in capturing multidecadal or longer climate cycles, while the second chronology utilized the regional curve standardization (RCS) method, which better preserves low-frequency variations at multidecadal time scales and longer. With respect to the STD- and RCS-derived temperature histories, each of them revealed, in the words of D'Arrigo et al., “several intervals of persistent above-average growth that broadly coincide with the timing of the late Medieval Warm Period.” The warming is much more pronounced in the RCS chronology, where the greatest warmth occurred in the early to middle 1200s, with lesser peaks in the early to middle 1100s and early 1400s (the Little Medieval Warm Period).

Additional evidence for this previously unheralded warm period was obtained by Silenzi et al. (2004). Working with Vermetid reefs on the northwest coast of Sicily, they obtained oxygen isotopic data they interpreted in terms of sea surface temperature (SST) variations. These data indicated that in the early to mid-1500s, SSTs in this region were warmer than they are currently. Likewise, Gray et al. (2004) developed a reconstruction of the leading mode of low-frequency North Atlantic (0–70°N) SST variability, known as the Atlantic Multidecadal Oscillation (AMO), for the period 1567–1990. Based on tree-ring records from regions known to border on strong centers of AMO variability, including eastern North America, Europe, Scandinavia, and the Middle East, this record too displayed an intense warm phase, in this case between 1580 and 1596, the unmatched

strength of which is clearly evident in reconstructed North Atlantic SST anomalies.

Many other studies have found much the same thing. Helama et al. (2002), for example, reconstructed midsummer temperatures for the last 7,500 years using the long Scots pine ring-width chronology from northern Finland derived by Eronen et al. (2002). Their record revealed the twentieth century was indeed warm compared to the mean of the entire period (about 0.6°C warmer). However, there were three other hundred-year periods that were warmer still, the last of which (AD 1500–1600) falls within the general time frame of what we call the Little Medieval Warm Period.

In a novel paper published in *Nature*, Chuine et al. (2004) used recorded dates of grape harvests in Burgundy, France to reconstruct mean spring–summer (April–August) air temperatures for that location on a yearly basis from 1370 to 2003, employing what they call “a process-based phenology model developed for the Pinot Noir grape.” The resulting temperature history is significantly correlated with mean summer air temperatures deduced from tree rings in central France, the Burgundy portion of a spatially distributed multiproxy temperature reconstruction, and observed summer air temperatures in Paris, central England, and the Alps. The thermal interconnectedness of these sites gives the new temperature history an important regional significance, the most intriguing aspect of which is the existence of much warmer-than-present air temperatures at various times in the past, most notably from the late 1300s through the early 1400s and over a large portion of the 1600s.

In another pertinent paper, Bartholy et al. (2004) meticulously codified and analyzed historical records collected by Antal Rethly (1879–1975), a Hungarian meteorologist who spent the greater portion of his long professional career assembling more than 14,000 historical records related to the climate of the Carpathian Basin. With respect to the temperature history they thereby derived, they report “the warm peaks of the Medieval Warm Epoch and colder climate of the Little Ice Age followed by the recovery warming period can be detected in the reconstructed temperature index time series.” In addition, they write, “a warm episode in the 16th century [was] detected in both annual- and seasonal-scale analysis of the 50-year distribution of warm and cold conditions,” which would again be the Little Medieval Warm Period.

Regarding North America, Luckman and Wilson (2005) updated a regional temperature history, originally developed in 1997, using new tree-ring data from the Columbia Icefield region of the Canadian Rockies. The update also employed different standardization techniques, including the regional curve standardization method that better captures low-frequency variability (centennial- to millennial-scale) than that reported in the initial study. In addition, the new dataset added more than one hundred years to the chronology, which now covers AD 950–1994. This tree-ring record was found to explain 53 percent of May–August maximum temperature variation observed in the 1895–1994 historical data and was thus considered a good proxy indicator of such temperatures. Based on this relationship, the record showed considerable decadal- and centennial-scale temperature variability, where generally warmer conditions prevailed about 1350–1450 (the Little Medieval Warm Period). Of more than passing interest is that the warmest summer of this record occurred in 1434, when it was 0.23°C warmer than the next warmest summer, which occurred in 1967.

Focusing on a different climate parameter, but one that is highly correlated with temperature, Blundell and Barber (2005) utilized plant macrofossils, testate amoebae, and degree of humification as proxies for environmental moisture conditions to develop a 2,800-year “wetness history” from a peat core extracted from Tore Hill Moss, a raised bog in the Strathspey region of Scotland. The most clearly defined and longest interval of sustained dryness of this entire record stretches from about AD 850 to AD 1080, coincident with the well-known Medieval Warm Period, and the most extreme wetness interval occurred during the depths of the last stage of the Little Ice Age, which was one of the coldest periods of the Holocene. Of most interest to the subject of this section, however, is the period of relative dryness centered on about AD 1550, which corresponds to the Little Medieval Warm Period and implies the existence of significant warmth at that time.

In a somewhat different study, Munroe (2003) replicated and analyzed six photographs taken in 1870 near the subalpine forest-alpine-tundra ecotone in the northern Uinta Mountains of Utah, USA, in an attempt to quantify the redistribution of vegetation that occurred there between the end of the Little Ice Age and the Current Warm Period. After achieving

this objective, he used his findings to infer the nature of regional climate change over the past 130 years. Before concluding, however, he directed his attention to what he describes as “downed logs, *in situ* stumps, and upright delimbed boles on the north side of Bald Mountain [that] indicate a treeline up to 60 m higher than the modern level,” which he determined, on the basis of the modern atmospheric lapse rate, “corresponds to an increase of mean July temperature of 0.4°C.”

With respect to these subfossil relics, Munroe writes, many of them “have been severely abraded by windblown ice, giving the impression of considerable antiquity,” noting “similar wood from elsewhere in the Rocky Mountains has been taken as evidence of higher treeline during the early Holocene climatic optimum, or ‘altithermal’ (Carrara et al., 1991).” However, he reports, a sample cut from one of the stumps was radiocarbon-dated to only about 1550, and “the actual germination of the tree may have occurred a century or more before AD 1550.” That places the warm period indicated by the subfossil wood in approximately the same time interval as the warm periods identified in all the prior studies we have discussed. In addition, Munroe remarks, “a higher treeline in the northern Uintas shortly before AD 1550 is consistent with contemporaneous evidence for warmer-than-modern climates in the southwestern United States (Dean, 1994; Petersen, 1994; Meyer et al., 1995; Pederson, 2000).”

In yet another study that provides indirect evidence for the existence of this century-scale Little Medieval Warm Period, Fleitmann et al. (2004) developed a stable isotope history from three stalagmites in a cave in Southern Oman that provided an annually resolved 780-year record of Indian Ocean monsoon rainfall. Over the last eight decades of the twentieth century, when global temperatures rose dramatically as the Earth emerged from the Little Ice Age and entered the Current Warm Period, this record reveals Indian Ocean monsoon rainfall declined dramatically. It further indicates the other most-dramatic decline coincided with the major temperature spike that is evident in the temperature histories discussed above.

Pla and Catalan (2005) analyzed chrysophyte cyst data collected from 105 lakes in the Central and Eastern Pyrenees of northeast Spain to produce a Holocene history of winter/spring temperatures in that part of the world. Their work revealed a significant oscillation in winter/spring temperatures in which the

region’s climate alternated between warm and cold phases over the past several thousand years. Of particular note were the Little Ice Age, Medieval Warm Period, Dark Ages Cold Period, and Roman Warm Period. The warmest of these intervals was the Medieval Warm Period, which started around AD 900 AD and was about 0.25°C warmer than it is currently. After the Medieval Warm Period, temperatures fell to their lowest values of the entire record (about 1.0°C below present), and then they began to warm but remained below present-day values until the early nineteenth and twentieth centuries—with one exception. A significant warming was observed between 1350 and 1400, when temperatures rose a full degree Celsius to a value about 0.15°C warmer than the present, during the Little Medieval Warm Period.

In a contemporaneous study, Chen et al. (2005) studied the chemical composition of sediments deposited in Lake Erhai (25°35′–25°58′N, 100°05′–100°17′E), the largest fault lake in the western Yunnan Province of China. They applied Principal Component Analysis to the concentrations of 21 major and minor elements found in the sediments, thereby deriving historical variations in temperature and precipitation over the period AD 1340–1990. In doing so, they found an initial period (1340–1550) of relatively high temperature and low rainfall—the Little Medieval Warm Period.

Also in China, but working several years earlier with the top 2 cm of a 20-cm-long stalagmite collected from Shihua Cave near Beijing, Ku and Li (1998) obtained annually resolved $\delta^{18}\text{O}$ data covering the past five centuries. Based on their analyses of these and other pertinent data, they determined that fluctuations of the $\delta^{18}\text{O}$ data over periods of less than ten years “reflect changes in precipitation, whereas on coarser time scales (>50 years), the stalagmite $\delta^{18}\text{O}$ records temperature variations.” This finding led them to conclude “the period AD 1620–1900 was cold and periods 1520–1620 and 1900–1994 were warm.” From their graphical representations of these two warm periods, it appears the earlier period—the Little Medieval Warm Period—was probably just a tad warmer than it was over the last two decades of the twentieth century.

Sharma et al. (2005) used $\delta^{13}\text{C}$ values of sphagnum remains from peat deposits located along a sequence of beach ridges of Lake Superior in North America to reconstruct changes in regional water balance from about 1,000 to 3,500 years BP, after

which they compared their findings with water-level reconstructions of adjacent Lake Michigan derived by Baedke and Thompson (2000) from sedimentological studies. In doing so they found maxima of sphagnum $\delta^{13}\text{C}$ values in peat deposits developed from 3,400 to 2,400 years BP and from 1,900 to 1,400 years BP, which closely match two periods of Lake Michigan high-water stands evident in the lake level record of Baedke and Thompson. These two periods coincide with the cooler climatic conditions that prevailed on either side of the Roman Warm Period, the most recent of which is the well-known Dark Ages Cold Period. This latter cold high-water period was then followed by a period of low water and declining $\delta^{13}\text{C}$ values, which coincides with the well-known Medieval Warm Period that ultimately gave way to the Little Ice Age. Thereafter, there are no more $\delta^{13}\text{C}$ data, but the lake level data reveal a third low-level stand of Lake Michigan from about 600 to 500 years BP, which coincides with the Little Medieval Warm Period.

Using the regional curve standardization technique applied to ring-width measurements of both living trees and relict wood, Büntgen et al. (2005) developed a 1,052-year summer (June–August) temperature proxy from high-elevation Alpine environments in Switzerland and the western Austrian Alps (between $46^{\circ}28'$ to $47^{\circ}00'\text{N}$ and $7^{\circ}49'$ to $11^{\circ}30'\text{E}$). This exercise revealed the presence of warm conditions from the beginning of the record in AD 951 up to about AD 1350, which the authors associated with the Medieval Warm Period. Thereafter, temperatures declined and an extended cold period known as the Little Ice Age ensued and persisted until approximately 1850—with one brief exception. For a few short decades in the mid- to late-1500s, there was an uncharacteristically warm episode, the temperatures of which were exceeded only at the beginning and end of the 1,052-year record, during the Medieval and Current Warm Periods. This warm episode was the Little Medieval Warm Period.

Holzhauser et al. (2005) “for the first time,” in their words, presented high-resolution records of variations in glacier size in the Swiss Alps together with lake-level fluctuations in the Jura mountains, the northern French Pre-Alps, and the Swiss Plateau in developing a 3,500-year climate history of west-central Europe, beginning with an in-depth analysis of the Great Aletsch glacier, the largest glacier in the European Alps.

Near the beginning of the time period studied, the three researchers report, “during the late Bronze Age Optimum from 1350 to 1250 BC, the Great Aletsch glacier was approximately 1000m shorter than it is today.” They note “the period from 1450 to 1250 BC has been recognized as a warm-dry phase in other Alpine and Northern Hemisphere proxies (Tinner et al., 2003).” Then, after an intervening cold-wet phase, when the glacier grew in both mass and length, they note, “during the Iron/Roman Age Optimum between c. 200 BC and AD 50,” perhaps better known as the Roman Warm Period, the glacier again retreated and “reached today’s extent or was even somewhat shorter than today.”

Next came the Dark Ages Cold Period, which they say was followed by “the Medieval Warm Period, from around AD 800 to the onset of the Little Ice Age around AD 1300.” The latter cold-wet phase was “characterized by three successive [glacier length] peaks: a first maximum after 1369 (in the late 1370s), a second between 1670 and 1680, and a third at 1859/60,” after which the glacier began its latest and still-ongoing recession in 1865. They note written documents from the fifteenth century AD indicate that at some time during that hundred-year interval “the glacier was of a size similar to that of the 1930s,” which latter period in many parts of the world was as warm as today or even warmer, in harmony with the increasing body of evidence suggesting a Little Medieval Warm Period manifested itself during the fifteenth century within the broader expanse of the Little Ice Age.

Weckstrom et al. (2006) developed a high-resolution quantitative history of temperature variability over the past 800 years, based on analyses of diatoms found in a sediment core retrieved from a treeline lake (Lake Tsuolbmajavri) located in Finnish Lapland. The result, in their words, “depicts three warm time intervals around AD 1200–1300, 1380–1550 and from AD 1920 until the present.” Of these intervals, they “associate the warmth of the 13th century with the termination phase of the Medieval Warm Period and the rapid post-1920 temperature increase with the industrially induced anthropogenic warming,” the last decade of which climate alarmists typically tout as having been the warmest such period of the last two millennia. Most interestingly, however, Weckstrom et al.’s data indicate the peak warmth of the AD 1200–1300 termination phase of the MWP was about 0.15°C warmer than the peak warmth of the post-1920 period. Even more interesting is that the

peak warmth of the AD 1380–1550 period—the Little Medieval Warm Period—was warmer still, at 0.25°C above the peak warmth of the post-1920 period.

Working with a sediment core extracted from the northeastern slope of the Cariaco Basin (10°45.98'N, 64°46.20'W), Black et al. (2007) derived an 800-year Mg/Ca history of the planktic foraminifer *Globigerina bulloides*, which they correlated with spring (March–May) sea surface temperatures (SSTs) measured between AD 1870 and 1990. This ultimately allowed them to reconstruct an 800-year SST history of the region. A plot of their findings is reproduced in Figure 3.2.1. As may readily be seen, it reveals dramatic twentieth-century warming, the prior Little Ice Age, and (at the beginning of the plot) what they describe as “the end of the Medieval Warm Period.” What stands out most boldly of all, however, is the remarkable rise and fall of the region’s SST that occurred between the Medieval Warm Period and the Little Ice Age, during the Little Medieval Warm Period.

Barron and Bukry (2007) derived high-resolution records of diatoms and silicoflagellate assemblages spanning the past 2,000 years from analyses of sediment cores extracted from three sites on the eastern slope of the Gulf of California. In all three cores the relative abundance of *Azpeitia nodulifera* (a

tropical diatom whose presence suggests higher sea surface temperatures) was found to be far greater during the Medieval Warm Period than at any other time over the 2,000-year period studied. In addition, the first of the cores exhibited elevated *A. nodulifera* abundances from the start of the record to about AD 350 (during the latter part of the Roman Warm Period) and between AD 1520 and 1560 (during what we have denominated the Little Medieval Warm Period). By analyzing radiocarbon production data, Barron and Bukry also determined the changes in climate they identified likely were driven by solar forcing.

Two years later, Richey et al. (2009) derived two decadal-resolution foraminiferal Mg/Ca sea surface temperature (SST) records covering the past six to eight centuries from two locations in the northern Gulf of Mexico—the Fisk Basin (27°33.0'N, 92°10.1'W) and the Garrison Basin (26°40.5'N, 93°55.5'W)—which they compared with the earlier Pigmy Basin (27°11.6'N, 91°24.5'W) Mg/Ca SST record of Richey et al. (2007). The results for all three Gulf of Mexico locations were pretty much the same: all revealed the occurrence of Little Ice Age temperatures in the mid-1700s that were 2–3°C cooler than present-day temperatures, in harmony with the results obtained by the various temperature

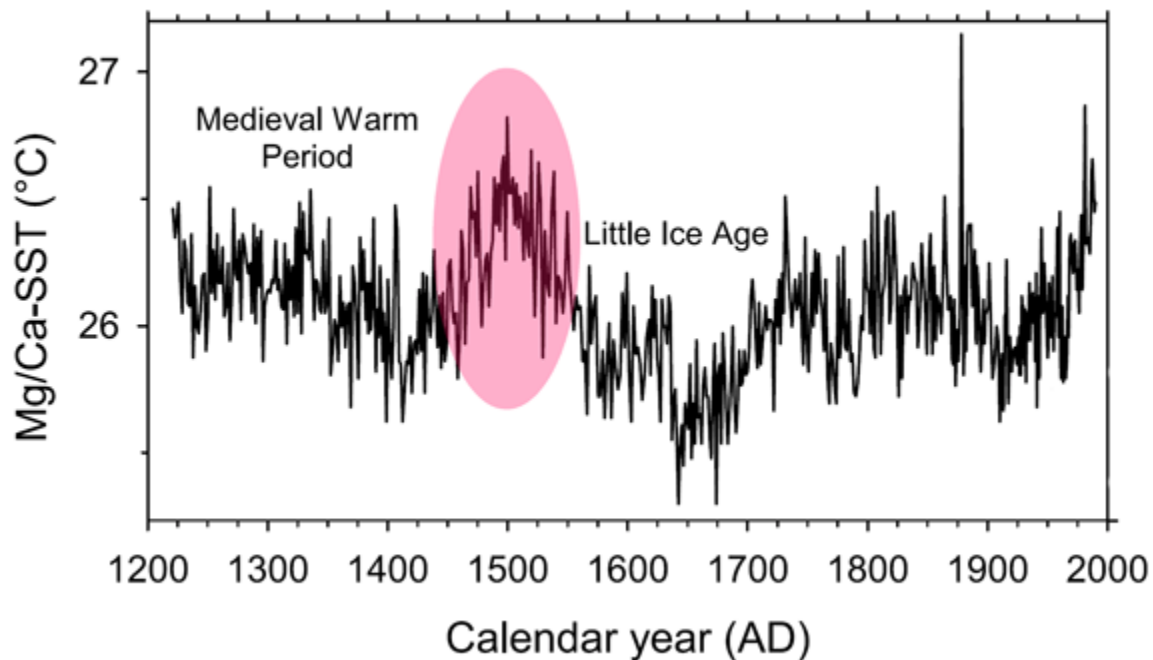


Figure 3.2.1. The 800-year Mg/Ca-derived SST history of the northeastern slope of the Cariaco Basin. Adapted from Black et al. (2007).

reconstruction techniques employed in the other studies they cited. More germane to the topic at hand, the authors found “Little Ice Age cooling in all three Gulf of Mexico Mg/Ca records is preceded by an interval of warmth in which Mg/Ca is as high or higher than the mean Gulf of Mexico core-top value.” This warm interval, which falls between about AD 1450 and 1600, represents the region’s Little Medieval Warm Period.

Also in 2009, Siklosy et al. conducted a complex trace element and stable carbon and oxygen isotope analysis of a stalagmite recovered from a cave (Kiskohat Shaft) located in northeast Hungary at the southern rim of the Bükk Highland (48°4.086’N, 20°29.422’E), with dating provided by ^{230}Th - ^{234}U determinations made along the growth direction of the stalagmite. Results indicated the highest oxygen isotope values occurred around AD 1000–1150, which they identified as the Medieval Warm Period, while the coldest years, which they associated with the Little Ice Age, prevailed from about AD 1550 to 1700. With respect to the Little Medieval Warm Period, their results revealed a 50-year period of approximately AD 1450–1500, which was almost as warm as the MWP.

In another study, Saenger et al. (2009) developed an absolutely dated and annually resolved record of sea surface temperature (SST) from the Bahamas (25.84°N, 78.62°W), based on a 440-year time series (1552–1991) of coral (*Siderastrea siderea*) growth rates, which they found to possess “an inverse correlation with instrumental SST,” a relationship verified by “applying it to an *S. siderea* colony from Belize (17.50°N, 87.76°W).” This work revealed that “temperatures were as warm as today from about 1552 [where their record begins, somewhere in the midst of the Little MWP] to 1570.”

A year later, Yang et al. (2010) developed a tree-ring-width history spanning AD 1377–1998 from Tibetan juniper (*Cupressus gigantea*) trees growing at a site (29°22’N, 94°16’E) just north of the deep gorge of the Yarlung Tsangbo River of southeast Tibet, from which they developed a linear regression model between ring-width and mean January–June temperature that accounts for 35 percent of the variance of this parameter over the period 1961–1998. According to the authors, the tree ring history revealed a number of relatively warmer and cooler intervals throughout its 622-year record, among the former of which were several that exceeded late twentieth-century warmth. The two most striking of

these short-term warm periods were 1443–1466 and 1482–1501, and as best as can be determined from the graphical representations of their data, annual temperatures during the second of these two warm periods exceeded those of the late twentieth century by as much as 0.75°C, while 11-year smoothed temperatures of the first of the two warm periods exceed those of the late twentieth century by as much as 0.3°C.

From a broad sediment shelf at a water depth of 56 meters in the main basin of Loch Sunart—a fjord on the northwest coast of Scotland (56°40.20’N, 05°52.22’W)—Cage and Austin (2010) extracted several sediment cores from which they developed a continuous record of various physical and chemical properties of the sediment, which spanned the last millennium and extended to AD 2006. Of particular interest are the $\delta^{18}\text{O}$ measurements made on the shells of the benthic foraminifer *Ammonia beccarii*, because prior such data—when operated upon by the palaeotemperature equation of O’Neil et al. (1969)—yielded bottom-water temperatures that had been judged by Cage and Austin (2008) to be “the most realistic water temperature values for infaunal benthic foraminifera from Loch Sunart.”

The results of the two researchers’ most recent efforts revealed the most distinctive feature of the Loch Sunart temperature record was an abrupt warming at AD 1540 that led to a temperature anomaly of 1.1°C above the long-term mean from AD 1540–1600. This period was preceded within the interval AD 1445–1495 by some of the coldest temperatures of the past 1,000 years.

Noting “the rate and magnitude of the inferred warming at AD 1540 ... is similar to the rate of change and magnitude observed during the late twentieth century,” Cage and Austin (2010) concluded “changes in twentieth century marine climate cannot yet be resolved from a background of natural variability over the last millennium,” which is another way of saying that late twentieth-century warming—which has not further manifested itself over the first decade of the twenty-first century—was not unusual enough to validly ascribe it to the concomitant increase in the air’s CO₂ content.

It is clear that the Medieval Warm Period and the earlier Roman Warm Period were not the only eras to exhibit surface air temperatures that equaled or eclipsed those of the twentieth century. These warmer-than-present eras achieved their higher temperatures without any help from elevated

atmospheric CO₂ concentrations, which were fully 100 ppm less than they are today. Consequently, whatever caused the warmth of those prior eras could be maintaining the warmth of the present era, relieving CO₂ of that undeserved responsibility.

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3.3. Recent Temperature Trends

Has the global warming of the past century, and especially of the past few decades, been as dramatic as the IPCC claims it has been, leading to unprecedented high temperatures and unsurpassed temperature variability? In the prior two sections of this chapter we evaluated this claim as it pertained to the past thousand years, with specific focus on the Medieval Warm Period (approximately 800–1200

AD) and the Little Medieval Warm Period (approximately 1400–1550 AD). Here, we evaluate it with respect to temperatures of the past few decades, once again limiting our discussion to papers published after the 2009 NIPCC report.

Wood et al. (2010) constructed a two-century (1802–2009) instrumental record of annual surface air temperature within the Atlantic-Arctic boundary region, using data obtained from “recently published (Klingbjør and Moberg, 2003; Vinther et al., 2006) and historical sources (Wahlen, 1886)” that yielded “four station-based composite time series” that pertain to Southwestern Greenland, Iceland, Tornedalen (Sweden) and Arkhangel’sk (Russia). This operation added 76 years to the previously available record, the credibility of which result, in Wood et al.’s words, “is supported by ice core records, other temperature proxies, and historical evidence.” In examining the record, the U.S. and Icelandic researchers found “an irregular pattern of decadal-scale temperature fluctuations over the past two centuries,” of which the early twentieth-century warming (ETCW) event—which they say “began about 1920 and persisted until mid-century”—was by far “the most striking historical example.”

Wood et al. write, “as for the future, with no other examples in the record quite like the ETCW, we cannot easily suggest how often—much less when—such a comparably large regional climate fluctuation might be expected to appear.” Nevertheless, they say that if past is prologue to the future, “it would be reasonable to expect substantial regional climate fluctuations of either sign to appear from time to time,” and therefore “singular episodes of regional climate fluctuation should be anticipated in the future.” This implies any rapid warming that may subsequently occur within the Atlantic-Arctic boundary region need not be due to rising greenhouse gas concentrations, as it could be caused by the same unknown factor that caused the remarkable ETCW event.

Wood and Overland (2010) write, “the recent widespread warming of the earth’s climate is the second of two marked climatic fluctuations to attract the attention of scientists and the public since the turn of the 20th century,” and that the first of these—“the major early 20th century climatic fluctuation (~1920–1940)” —has been “the subject of scientific enquiry from the time it was detected in the 1920s.” In addition, they write, “the early climatic fluctuation is particularly intriguing now because it shares some of

the features of the present warming that has been felt so strongly in the Arctic.”

To learn more about the nature of both warmings, Wood and Overland reviewed what is known about the first warming through what they describe as “a rediscovery of early research and new assessments of the instrumental record,” which allowed them to compare what they learned about the earlier warming with what is known about the most recent one.

With respect to the first of the two warmings, the U.S. researchers say “there is evidence that the magnitude of the impacts on glaciers and tundra landscapes around the North Atlantic was larger during this period than at any other time in the historical period.” In addition, they report, “the ultimate cause of the early climatic fluctuation was not discovered by early authors and remains an open question,” noting “all of the leading possibilities recognized today were raised by the 1950s, including internal atmospheric variability, anthropogenic greenhouse gas (CO₂) forcing, solar variability, volcanism, and regional dynamic feedbacks (e.g. Manley, 1961).” However, they note, “greenhouse gas forcing is not now considered to have played a major role (Hegerl et al., 2007).” Thus they suggest “the early climatic fluctuation was a singular event resulting from intrinsic variability in the large-scale atmosphere-ocean-land system and that it was likely initiated by atmospheric forcing.”

Wood and Overland conclude the “early climatic fluctuation is best interpreted as a large but random climate excursion imposed on top of the steadily rising global mean temperature associated with anthropogenic forcing.” However, it could just as easily be concluded that the steadily rising global mean temperature was Earth’s natural recovery from the global chill of the Little Ice Age.

White et al. (2010) published a comprehensive review of past climate change in Earth’s north polar region. They began their work by describing how “processes linked with continental drift have affected atmospheric circulation, ocean currents, and the composition of the atmosphere over tens of millions of years” and how “a global cooling trend over the last 60 million years has altered conditions near sea level in the Arctic from ice-free year-round to completely ice covered.” They also report “variations in Arctic insolation over tens of thousands of years in response to orbital forcing have caused regular cycles of warming and cooling that were roughly half the size of the continental-drift-linked changes” and that,

in turn, this glacial-interglacial cycling “was punctuated by abrupt millennial oscillations, which near the North Atlantic were roughly half as large as the glacial-interglacial cycles.” Finally, they note “the current interglacial, the Holocene, has been influenced by brief cooling events from single volcanic eruptions, slower but longer lasting changes from random fluctuations in the frequency of volcanic eruptions, from weak solar variability, and perhaps by other classes of events.”

In comparing the vast array of past climate changes in the Arctic with what the IPCC claims to be the “unprecedented” anthropogenic-induced warming of the past several decades, White et al. conclude, “thus far, human influence does not stand out relative to other, natural causes of climate change.” In fact, they state, the data “clearly show” that “strong natural variability has been characteristic of the Arctic at all time scales considered,” and they reiterate the data suggest “that the human influence on rate and size of climate change thus far does not stand out strongly from other causes of climate change.”

Ladd and Gajewski (2010) evaluate the position of the Arctic front—defined as “the semi-permanent, discontinuous front between the cold Arctic air mass and the intermediate Polar air mass, bounded in the south by the Polar Front (Oliver and Fairbridge, 1987)”—based on gridded data obtained from the National Center for Environmental Prediction/National Center for Atmospheric Research reanalysis (NNR) for each July between 1948 and 2007, and from 1958 to 2002 using data from the European Centre for Medium-Range Weather Forecasts ERA-40, as well as the period 1948-1957 “for comparison with the results of Bryson (1966).”

The two researchers report “the position of the July Arctic front varies significantly through the period 1948–2007,” but they find it does so “with a mean position similar to that found by Bryson (1966),” which “close similarity,” as they describe it, “is striking, given that the Bryson study was completed over 40 years ago.” Indeed. This front is in the part of the world that theory and computer models predict should be warming faster than nearly all other parts of the globe. If the IPCC’s claim were true that the Earth warmed at a rate and to a level that was unprecedented over the past two millennia, it is highly unlikely the Arctic front would have remained stationary for more than four decades.

Box et al. (2009), using “a set of 12 coastal and 40 inland ice surface air temperature records in

combination with climate model output,” identified “long-term (1840–2007) monthly, seasonal, and annual spatial patterns of temperature variability over a continuous grid covering Greenland and the inland ice sheet.” They then compared “the 1919–32 and 1994–2007 warming episodes” and made “a comparison of Greenland ice sheet surface air temperature temporal variability with that of the Northern Hemisphere average,” obtaining the near-surface air temperature history of Greenland reproduced Figure 3.3.1, along with the corresponding history of Northern Hemispheric near-surface air temperature.

Based on the results depicted in the figure, the four researchers determined “the annual whole ice sheet 1919–32 warming trend is 33% greater in magnitude than the 1994–2007 warming,” and “in contrast to the 1920s warming, the 1994–2007 warming has not surpassed the Northern Hemisphere anomaly.” They note, “an additional 1.0°–.5°C of annual mean warming would be needed for Greenland to be in phase with the Northern Hemisphere pattern.” Thus there does not appear to be anything unusual, unnatural, or unprecedented about the nature of Greenland’s 1994–2007 warming episode. It is much less impressive than the 1919–1932 warming, and it is even less impressive when it is realized that the atmosphere’s CO₂ concentration rose by only about 5 ppm during the earlier period of stronger warming but by fully 25 ppm (five times more) during the later period of weaker warming.

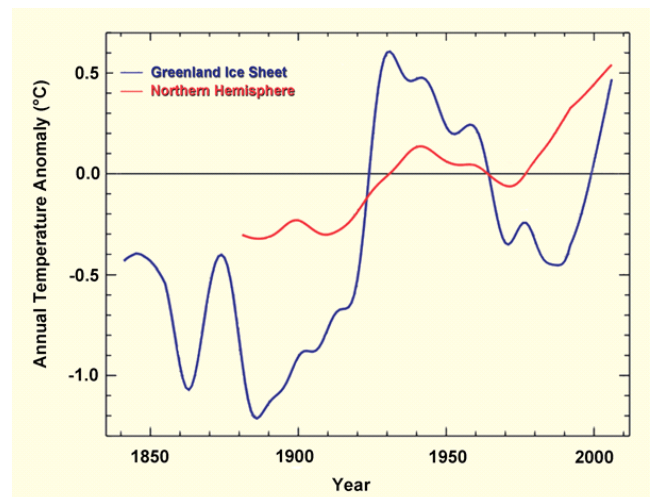


Figure 3.3.1 Low-pass-filtered Greenland and Northern Hemispheric near-surface air temperature anomalies with respect to the 1951–1980 base period vs. time. Adapted from Box et al. (2009).

A long succession of climate models has consistently suggested that anthropogenic-induced global warming should be significantly amplified in Earth's polar regions and that the first signs of man's expected impact on the world's weather should be manifest in that part of the planet. Yet research on Antarctic climate just prior to 2009 found the Antarctic Peninsula was warming rapidly but the rest of Antarctica was not (Chapman and Walsh, 2007; Monaghan et al., 2008). While the warming of the peninsula was deemed to be a "canary in the coal mine" by alarmists, the lack of warming over the rest of the continent posed a difficult challenge in reconciling observational data with model projections of CO₂-induced global warming. However, the sparseness of weather stations across this huge continent left great uncertainty about these conclusions.

Against this backdrop, Steig et al. (2009) provided a method to increase the density of data by utilizing Advanced Very High Resolution Radiometer (AVHRR) satellite data to provide spatial and temporal data infilling. Their analysis claimed to show warming was in fact spread over much of West Antarctica, a result that would be in harmony with theory and climate models. Their result was featured on the cover of *Nature* magazine and widely covered in the press as "proof" that warming in Antarctica was worse than thought. But was it?

O'Donnell et al. (2011) investigated the Steig et al. paper, finding they made statistical and analytical mistakes, including (a) improper calibration, (b) spatial structure differences between the infilling operation and recovery of gridded estimates, and (c) suboptimal determination of regularization parameters. The net effect of these errors was to improperly model spatial correlation of the data, which produced a spurious warming in West Antarctica and altered other spatial patterns and trend statistics. Specifically, O'Donnell et al. say "our results—including the strong Peninsula warming, insignificant cooling to neutral trend in the Ross region, and generally insignificant trends elsewhere on the continent—compare more favorably to Chapman & Walsh (2007) and Monaghan et al. (2008) than [Steig et al.]," which leaves the majority of Antarctica showing very little trend, or in other words, no discernible response to rising greenhouse gas concentrations.

In a paper titled "A strong bout of natural cooling in 2008" published in *Geophysical Research Letters*,

Perlwitz et al. (2009) discuss the "precipitous drop in North American temperature in 2008, commingled with a decade-long fall in global mean temperatures." The authors begin their narrative by noting there has been "a decade-long decline (1998–2007) in globally averaged temperatures from the record heat of 1998," citing Easterling and Wehner (2009). In further describing this phenomenon, they note U.S. temperatures in 2008 "not only declined from near-record warmth of prior years, but were in fact colder than the official 30-year reference climatology (-0.2°C versus the 1971–2000 mean) and further were the coldest since at least 1996."

With respect to the geographical origin of this "natural cooling," as they describe it, the five researchers point to "a widespread coolness of the tropical-wide oceans and the northeastern Pacific," focusing on the Niño 4 region, where they report "anomalies of about -1.1°C suggest a condition colder than any in the instrumental record since 1871."

The researchers then push ahead in search of the cause of the global and U.S. coolings that sparked their original interest, seeking out what connects them with other more primary phenomena, the anomalous and significant oceanic coolings. Perlwitz et al. first discount volcanic eruptions, noting "there were no significant volcanic events in the last few years." Next, they write that solar forcing "is also unlikely," because its radiative magnitude is considered to be too weak to elicit such a response. And these two castaway causes thus leave them with "coupled ocean-atmosphere-land variability" as the "most likely" cause of the anomalous coolings.

In regard to Perlwitz et al.'s dismissal of solar forcing, however, the jury is still out with respect to the interaction of the solar wind with the influx of cosmic rays to Earth's atmosphere and their subsequent impact on cloud formation, which may yet prove to be substantial (as discussed earlier in this chapter). And with respect to their final point, the suite of real-world ocean-atmosphere-land interactions is highly complex and also not fully understood. Indeed, there may even be important phenomena operating within this realm of which the entire scientific community is ignorant. Some of those phenomena may be strong enough to compensate for anthropogenic-induced increases in greenhouse gas emissions, so that other natural phenomena dictate the ever-changing state of Earth's climate

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3.4 Urban Heat Islands

Population growth and the clustering of people in cities can lead to localized warming from changes in land structure and land use that is both more rapid and much greater (by as much as an order of magnitude) than what the IPCC characterizes as the “unprecedented” warming of the twentieth century.

In the 2009 NIPCC report, Idso and Singer (2009) highlighted scores of studies demonstrating the impact of this phenomenon on temperatures and how population-growth-induced warming—spread across the world—is often incorrectly construed to be CO₂-induced global warming. Here we highlight three additional papers investigating this phenomenon, beginning with a study of the urban heat island along the U.S./Mexico border.

Mexicali City borders the United States at the northern end of Mexico’s Baja California. It is an urban settlement that had its beginnings in the first decade of the twentieth century. At that time it had an area of approximately 4 km²; by 1980 it covered an area in excess of 40 km², and by 2005 it covered more than 140 km².

Working with daily records of maximum and minimum temperature from six weather stations in Mexicali City and its surroundings covering the period 1950–2000, and with a climatic network of rural and urban weather stations in Mexicali and its valley and the Imperial Valley, California, over the contemporary period (2000–2005), Garcia Cueto et

al. (2009) characterized the spatial and temporal development of the city's urban heat island over the latter half of the twentieth century and the first five years of the twenty-first century. They found Mexicali City "changed from being a cold island (1960–1980) to a heat island with a maximum intensity of 2.3°C in the year 2000, when it was compared with rural weather stations of Imperial, California." They note "the replacement of irrigated agricultural land by urban landscapes, anthropogenic activity and population growth, appear to be the major factors responsible for the observed changes." And from the "more updated information (2000–2005)," they learned "the greatest intensity of the urban heat island was in winter with a value of 5.7°C, and the lowest intensity in autumn with 5.0°C."

In another study, Rosenzweig et al. (2009) compared "the possible effectiveness of heat island mitigation strategies to increase urban vegetation, such as planting trees or incorporating vegetation into rooftops, with strategies to increase the albedo of impervious surfaces." With respect to the magnitude of the problem they were seeking to address, they report "surface air temperatures elevated by at least 1°C have been observed in New York City for more than a century (Rosenthal et al., 2003; Gaffin et al., 2008), and the heat island signal, measured as the difference between the urban core and the surrounding rural surface air temperature readings taken at National Weather Service stations, averages ~4°C on summer nights (Kirkpatrick and Shulman, 1987; Gedzelman et al., 2003; Gaffin et al., 2008)," with the greatest temperature differences typically being sustained "between midnight and 0500 Eastern Standard Time (EST; Gaffin et al., 2008)." And on a day that they studied quite intensively (14 August 2002), they report that 0600 EST "the city was several degrees warmer than the suburbs, and up to 8°C warmer than rural areas within 100 km of the city."

With respect to mitigation strategies, the 12 researchers determined "the most effective way to reduce urban air temperature is to maximize the amount of vegetation in the city with a combination of tree planting and green roofs." Based on modeling studies of these approaches, for example, they estimated this strategy could reduce simulated citywide urban air temperature by 0.4°C on average, and 0.7°C at 1500 EST, while reductions of up to 1.1°C at 1500 EST could be expected in some Manhattan and Brooklyn neighborhoods, "primarily

because there is more available area in which to plant trees and install vegetated roofs."

These several findings reveal New York City already has experienced an urban-induced warming equivalent to what is predicted to occur by the end of the current century as a result of business-as-usual greenhouse gas emissions, and that planting additional vegetation throughout the city would likely moderate its thermal environment more than all of the greenhouse-gas emissions reductions the world's governments are ever likely to make.

Most urban heat island (UHI) studies have evaluated its magnitude by means of ground-based measurements of near-surface air temperature made at urban and rural weather stations, where the urban-rural air temperature difference is expressed most strongly at night. Imhoff et al. (2010), however, employed satellite-based measurements of surface temperature and found this alternative form of the UHI was most strongly expressed during the day.

Specifically, in a study of 38 of the most populous cities in the continental United States and their rural surroundings, Imhoff et al. obtained land surface temperature (LST) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on NASA's Earth Observing System (EOS) satellites, which they used in a spatial analysis to assess UHI skin temperature amplitude and its relationship to development intensity, size, and ecological setting over three annual cycles (2003–2005), where urban impervious surface area (ISA) was obtained from the Landsat TM-based NLCD 2001 dataset. Their results indicated a city's fractional ISA was a good linear predictor of LST for all cities in the continental United States in all biomes except deserts and xeric shrublands, and that the fraction of ISA explained about 70 percent of the total variance in LST for all cities combined, with the highest correlations (90 percent) in the northeastern United States, where urban areas are often embedded in temperate broadleaf and mixed forests.

They also determined the largest urban-rural LST differences for all biomes occurred during the summer around midday, and the greatest amplitudes were found for urban areas that displaced forests (6.5–9.0°C) followed by temperate grasslands (6.3°C) and tropical grasslands and savannas (5.0°C). Finally, they determined the contrast between urban cores and rural zones was typically "accentuated during the time when the vegetation is physiologically active, especially in forested lands" and "the amplitude of the

UHI is significantly diminished during the winter season when vegetation loses its leaves or is stressed by lower temperatures.” Consequently, and based on these findings, Imhoff et al. concluded “the use of ISA as an estimator of the extent and intensity of urbanization is more objective than population density based methods and can be consistently applied across large areas for inter-comparison of impacts on biophysical processes.”

Considering each of the three studies described above, plus a host of others discussed in the 2009 NIPCC report, it is difficult to see how the IPCC (2007) can claim to have ferreted out all significant influences of the world’s many and diverse urban heat islands from the temperature databases they use to portray the supposedly unprecedented warming of the past few decades.

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3.5 El Niño/Southern Oscillation

Computer model simulations have given rise to three claims regarding the influence of global warming on El Niño/Southern Oscillation (ENSO) events: (1) global warming will increase the frequency of ENSO events, (2) global warming will increase the intensity of ENSO events, and (3) weather-related disasters will be exacerbated under El Niño conditions. The 2009 NIPCC report (Idso and Singer, 2009) tested the validity of these assertions and demonstrated they are in conflict with the observational record. In this section we highlight several studies that suggest the virtual world of ENSO, as simulated by state-of-the-art climate models, is at variance with reality, once again drawing upon studies not included in, or published subsequent to, the 2009 NIPCC report.

Examining the subject over the past 3,500 years, Langton et al. (2008) used geochemical data—obtained from a sediment core extracted from the shallow-silled and intermittently dysoxic Kau Bay in Halmahera, Indonesia (1°N, 127.5°E)—to reconstruct century-scale climate variability within the Western Pacific Warm Pool. In doing so, they found “basin stagnation, signaling less El Niño-like conditions, occurred during the time frame of the Medieval Warm Period (MWP), from ca. 1000 to 750 years BP,” which was “followed by an increase in El Niño activity that culminated at the beginning of the Little Ice Age ca. 700 years BP.” Thereafter, their record suggests “the remainder of the Little Ice Age was characterized by a steady decrease in El Niño activity with warming and freshening of the surface water that continued to the present.” And they say “the chronology of flood deposits in Laguna Pallcacocha, Ecuador (Moy et al., 2002; Rodbell et al., 1999), attributed to intense El Niño events, shows similar century-scale periods of increased [and decreased] El Niño frequency.”

The nine researchers concluded “the finding of similar century-scale variability in climate archives

from two El Niño-sensitive regions on opposite sides of the tropical Pacific strongly suggests that they are dominated by the low-frequency variability of ENSO-related changes in the mean state of the surface ocean in [the] equatorial Pacific.” And that “century-scale variability,” as they describe it, suggests global warming typically tends to retard El Niño activity, while global cooling tends to promote it.

In a contemporaneous study, Nicholls (2008) prefaced his contribution to the topic by noting there has been a “long-running debate as to how the El Niño-Southern Oscillation (ENSO) might react to global warming,” and “the focus in most model studies on ENSO and climate change has been on whether the Pacific will tend to a more permanent El Niño state as the world warms due to an enhanced greenhouse effect.” In an attempt to resolve the issue, Nicholls examined “trends in the seasonal and temporal behavior of ENSO, specifically its phase-locking to the annual cycle over the past 50 years,” where phase-locking, in his words, “means that El Niño and La Niña events tend to start about April–May and reach a maximum amplitude about December–February,” which is why he examined trends in ENSO indices for each month of the year.

The Australian researcher determined “there has been no substantial modulation of the temporal/seasonal behavior of the El Niño-Southern Oscillation”—as measured by the sea surface temperature averaged across the region 5°S–5°N by 120°W–170°W, and the Southern Oscillation Index (the non-standardized difference between sea level pressures at Tahiti and Darwin)—over the past 50 years, during what he describes as “a period of substantial growth in the atmospheric concentrations of greenhouse gases and of global warming.” Nicholls’ finding that “the temporal/seasonal nature of the El Niño-Southern Oscillation has been remarkably consistent through a period of strong global warming” clearly repudiates the early climate-model-derived inferences of Timmermann et al. (1999), Collins (2000a,b), and Cubasch et al. (2001) that global warming will increase both the frequency and intensity of ENSO events. Those projections (not surprisingly) followed fast on the heels of the powerful 1997–98 El Niño described by some as “the strongest in recorded history” (Jimenez and Cortes, 2003).

Lee and McPhaden (2010) reported “satellite observations suggest that the intensity of El Niño events in the central-equatorial Pacific (CP) has

almost doubled in the past three decades,” citing the work of Cane et al. (1997) and Cravatte et al. (2009), while noting this phenomenon “appears to be consistent with theoretically predicted change of the background sea surface temperature under global warming scenarios.” To test this hypothesis, they used satellite observations of sea surface temperature (SST) over the past three decades “to examine SST in the CP region, distinguishing between the increases in El Niño intensity and changes in background SST.”

In conducting their analysis, the two U.S. researchers discovered the SSTs in the CP region during El Niño years were becoming significantly higher while those during La Niña and neutral years were not. Therefore, they reasoned “the increasing intensity of El Niño events in the CP region is not simply the result of the well-documented background warming trend in the western-Pacific warm pool,” but “it is the increasing amplitude of El Niño events that causes a net warming trend of SST in the CP region.” In light of these findings, they suggest “at least for the past three decades, the warming of the warm pool in the CP region is primarily because of more intense El Niño events in that region.” In addition, they report “in contrast to the CP region, the intensity of El Niño events in the EP region does not have a warming trend, and even has a cooling trend (though not significant at the 90% level of confidence) over the three-decade period.” Thus, they conclude further investigation is needed “to understand these issues better, given the uncertainty surrounding causal mechanisms and the implications the observed changes have for global climate and societal impacts.”

In a contemporaneous study focusing more on the modeling of ENSO behavior, Collins et al. (2010) reviewed the findings of what they describe as “a hierarchy of mathematical models [that] have been used to explain the dynamics, energetics, linear stability and nonlinearity of ENSO,” while noting “complex coupled global circulation models have become powerful tools for examining ENSO dynamics and the interactions between global warming and ENSO.”

Those powerful tools revealed, among other things, that “the tropical easterly trade winds are expected to weaken; surface ocean temperatures are expected to warm fastest near the equator and more slowly farther away; the equatorial thermocline that marks the transition between the wind-mixed upper ocean and deeper layers is expected to shoal; and the

temperature gradients across the thermocline are expected to become steeper.” However, they state “it is not yet possible to say whether ENSO activity will be enhanced or damped, or if the frequency of events will change.” Nor, it could be added, whether their several expectations will ever come to pass, as Collins et al. conclude “it is not clear at this stage which way ENSO variability will tip,” adding, “as far as we know, it could intensify, weaken, or even undergo little change depending on the balance of changes in the underlying processes.”

An even more damning assessment of the state of the ENSO modeling enterprise was given by Jin et al. (2008), who investigated the overall skill of ENSO prediction in retrospective forecasts made with ten different state-of-the-art ocean-atmosphere coupled general circulation models (CGCMs)—which they describe as “coupled ocean-land-atmosphere dynamical seasonal prediction systems”—with respect to their ability to “hindcast” real-world observations for the 22 years from 1980 to 2001.

The results indicated, according to the 12 U.S., South Korean, and Japanese researchers, that almost all models have problems simulating the mean equatorial sea surface temperature (SST) and its annual cycle. In fact, they write, “none of the models we examined attain good performance in simulating the mean annual cycle of SST, even with the advantage of starting from realistic initial conditions,” while noting “with increasing lead time, this discrepancy gets worse” and “the phase and peak amplitude of westward propagation of the annual cycle in the eastern and central equatorial Pacific are different from those observed.” What is more, they find “ENSO-neutral years are far worse predicted than growing warm and cold events” and “the skill of forecasts that start in February or May drops faster than that of forecasts that start in August or November.” They and others refer to this behavior as “the spring predictability barrier,” which gives an indication of the difficulty of what they are attempting to do.

Given these findings, Jin et al. conclude “accurately predicting the strength and timing of ENSO events continues to be a critical challenge for dynamical models of all levels of complexity,” revealing that even the best ocean-atmosphere CGCMs are presently unable to make reasonably accurate predictions of ENSO occurrence and behavior.

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