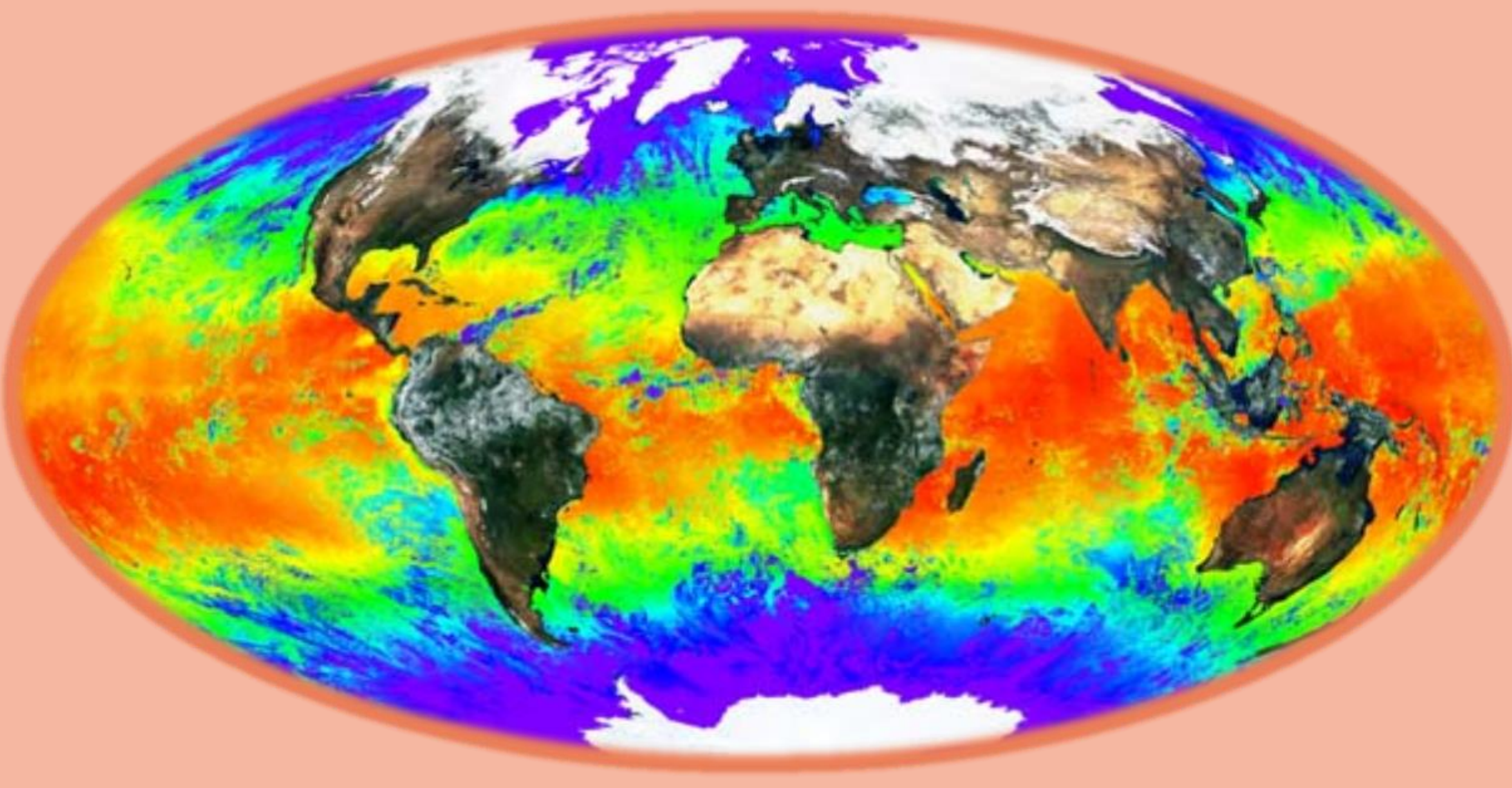
THE GLOBAL MEDIEVAL WARM PERIOD



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THE GLOBAL MEDIEVAL WARM PERIOD

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Between the 10th and 14th centuries AD, earth's average global temperature may have been warmer than it is today, according to the analyses of Lamb (1977, 1984, 1988) and Grove (1988). The existence of this *Medieval Warm Period* was initially deduced from historical weather records and proxy climate data from England and Northern Europe. Interestingly, the warmer conditions associated with this interval of time are also known to have had a largely beneficial impact on earth's plant and animal life. In fact, the environmental conditions of this time period have been determined to have been so favorable that it was often referred to as the *Little Climatic* ***Optimum*** (Imbrie and Imbrie, 1979; Dean, 1994; Petersen, 1994; Serre-Bachet, 1994; Villalba, 1994).

The degree of warming associated with the Medieval Warm Period varied from region to region; and, hence, its consequences were manifested in a number of different ways (Dean, 1994). In Europe, temperatures reached some of the warmest levels of the last 4,000 years, allowing enough grapes to be successfully grown in England to sustain an indigenous wine industry (Le Roy Ladurie, 1971). Contemporaneously, horticulturists in China extended their cultivation of citrus trees and perennial herbs further and further northward, resulting in an expansion of their ranges that reached its maximum extent in the 13th century (De'er, 1994). Considering the climatic conditions required to successfully grow these species, it has been estimated that annual mean temperatures in the region must have been about 1.0 °C higher than at present, with extreme January minimum temperatures fully 3.5 °C warmer than they are today (De'er, 1994).

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In North America, tree-ring chronologies from the southern Canadian Rockies have provided evidence for higher treelines and wider ring-widths between AD 950 and 1100, suggesting warmer temperatures and more favorable growing conditions (Luckman, 1994). Similar results have been derived from tree-ring analyses of bristlecone pines in the White Mountains of California, where much greater growth was recorded in the 11th and 12th centuries (Leavitt, 1994). By analyzing $^{13}C/^{12}C$ ratios in the rings of these trees, it was also found that soil moisture conditions were more favorable in this region during the Medieval Warm Period (Leavitt, 1994). Simultaneous increases in precipitation were additionally found to have occurred in monsoonal locations of the United States desert southwest, where there are indications of increased lake levels from AD 700-1350 (Davis, 1994). Other data document vast glacial retreats during the

MWP in parts of South America, Scandinavia, New Zealand and Alaska (Grove and Switsur, 1994; Villalba, 1994); and ocean-bed cores suggest that global sea surface temperatures were warmer then as well (Keigwin, 1996a, 1996b).

In the area of human enterprise, the climatic conditions of the MWP proved providential. The Arctic ice pack, for example, substantially retreated, allowing the settlement of both Iceland and Greenland; while alpine passes normally blocked with snow and ice became traversable, opening trade routes between Italy and Germany (Crowley and North, 1991). Contemporaneously, on the northern Colorado Plateau in America, the Anasazi Indian civilization reached its climax, as warmer temperatures and better soil moisture conditions allowed them to farm a region twice as large as is presently possible (MacCracken *et al*., 1990).

A little later, but proving to be much more geographically-inclusive, Huang and Pollack (1997)[1] searched the large database of terrestrial heat flow measurements compiled by the International Heat Flow Commission of the International Association of Seismology and Physics of the Earth's Interior for measurements suitable for reconstructing an average ground surface temperature history of the planet over the prior 20,000 years. Working with a total of 6,144 qualifying sets of heat flow data obtained from every continent, they produced a *global* climate reconstruction, which they said was independent of other proxy interpretations and of any preconceptions or biases as to the nature of the actual climate history. And within this reconstruction of what they called "a global climate history from worldwide observations," the two researchers found strong evidence that the MWP was indeed warmer than it had been during any prior portion of the 20th century by as much as 0.5°C.

Three years later, in the introduction to their paper on solar irradiance variations over the last 1200 years, Bard *et al*. (2000)[2] listed some of the many different types of information that had been used to reconstruct past solar variability, including "the envelope of the SSN [sunspot number] 11-year cycle (Reid, 1991), the length and decay rate of the solar cycle (Hoyt and Schatten, 1993), the structure and decay rate of individual sunspots (Hoyt and Schatten, 1993), the mean level of SSN (Hoyt and Schatten, 1993; Zhang *et al*., 1994; Reid, 1997), the solar rotation and the solar diameter (Nesme-Ribes *et al*., 1993), and the geomagnetic aa index (Cliver *et al*., 1998)," while also noting that "Lean*et al*. (1995) proposed that the irradiance record could be divided into 2 superimposed components: an 11-year cycle based on the parameterization of sunspot darkening and facular brightening (Lean *et al*., 1992), and a slowly-varying background derived separately from studies of sun-like stars (Baliunas and Jastrow, 1990)."

In their own paper, however, Bard *et al*. used an entirely different approach. Rather than directly characterizing some aspect of solar variability, certain *consequences* of that variability were assessed. Specifically, they noted that magnetic fields of the solar wind deflect portions of the primary flux of charged cosmic particles in the vicinity of the earth, leading to reductions in the creation of *cosmogenic nuclides* in earth's atmosphere, with the result that histories of the

[1] http://www.co2science.org/articles/V3/N22/C3.php.
[2] http://www.co2science.org/articles/V6/N36/EDIT.php.

atmospheric concentrations of ^{14}C and ^{10}Be can be used as proxies for solar activity, as had been noted many years previously by Lal and Peters (1967).

In employing this approach to the problem, Bard *et al*. first created a 1200-year history of cosmonuclide production in earth's atmosphere from ^{10}Be measurements of South Pole ice (Raisbeck *et al*., 1990) and the atmospheric $^{14}C/^{12}C$ record as measured in tree rings (Bard *et al*., 1997). This record was then converted to Total Solar Irradiance (TSI) values by "applying a linear scaling using the TSI values published previously for the Maunder Minimum," when cosmonuclide production was 30-50% above the modern value. The end result of this approach was an extended TSI record that suggests, as they describe it, that "solar output was significantly reduced between 1450 and 1850 AD, but slightly higher or similar to the present value during a period centered around 1200 AD." Hence, they concluded their study by stating that "it could thus be argued that irradiance variations may have contributed to the so-called "little ice age" and "medieval warm period."

Contemporaneously, and also noting that "the most direct mechanism for climate change would be a decrease or increase in the total amount of radiant energy reaching the earth," Perry and Hsu (2000)[3] developed a simple solar-luminosity model and used it to estimate total solar-output variations over the past 40,000 years. The model was derived by summing the amplitude of solar radiation variance for fundamental harmonics of the eleven-year sunspot cycle throughout an entire 90,000-year glacial cycle, after which the model output was compared with geophysical, archaeological and historical evidence of climate variation during the Holocene. And the result?

Model output was well correlated with the amount of carbon 14 (which is produced in the atmosphere by cosmic rays that are less abundant when the sun is active and more abundant when it is less active) in well-dated tree rings going back to the time of the Medieval Warm Period (about AD 1100), which finding, in the words of the two researchers, "supports the hypothesis that the sun is varying its energy production in a manner that is consistent with the superposition of harmonic cycles of solar activity." The model output was also well correlated with the sea-level curve developed by Ters (1987). Present in both of these records over the entire expanse of the Holocene was a "little ice age"/"little warm period" cycle with a period of approximately 1,300 years. In addition, the climate changes implied by these records correlated well with major historical events. Specifically, the researchers noted that "great civilizations appear to have prospered when the solar-output model shows an increase in the sun's output," while they said that such civilizations "appear to have declined when the modeled solar output declined."

In further discussing their findings, Perry and Hsu commented that "current global warming commonly is attributed to increased CO_2 concentrations in the atmosphere." *However*, as they continued, "geophysical, archaeological, and historical evidence is consistent with warming and cooling periods during the Holocene as indicated by the solar-output model." And they thus concluded that the idea of "the modern temperature increase being caused solely by an increase in CO_2 concentrations appears questionable."

3 http://www.co2science.org/articles/V3/N35/C1.php.

One year later, at the beginning of the new millennium, [Bond *et al*. (2001)][4] broached the question of what had been responsible for the approximate 1500-year cycle of global climate change that had been intensely studied in the North Atlantic Ocean and demonstrated to prevail throughout both glacial and interglacial periods alike. This they did in a study of (1) ice-rafted debris found in three North Atlantic deep-sea sediment cores and (2) cosmogenic nuclides sequestered in the Greenland ice cap (^{10}Be) and Northern Hemispheric tree rings (^{14}C).

Based on arduous analyses of the deep-sea sediment cores that yielded the variable-with-depth amounts of three proven proxies for the prior presence of overlying drift-ice, the scientists were able to *discern*, and with the help of an accelerator mass spectrometer *date* a number of recurring alternate periods of relative cold and warmth that wended their way throughout the 12,000-year expanse of the entire Holocene. And in doing so, they determined that (1) the mean duration of the several *complete* climatic cycles thus delineated was *1340 years*, and that (2) the cold and warm nodes of the most recent of these oscillations were "broadly correlative with the so called 'Little Ice Age' and 'Medieval Warm Period'."

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The signal accomplishment of the ten scientists' study was their linking of these millennial-scale climate oscillations - and their imbedded centennial-scale oscillations - with similar-scale oscillations in cosmogenic nuclide production, which are known to be driven by oscillations in the energy output of the sun. In fact, Bond *et al*. were able to report that "over the last 12,000 years virtually every centennial time-scale increase in drift ice documented in our North Atlantic records was tied to a solar minimum." And in light of this observation, they concluded that "a solar influence on climate of the magnitude and consistency implied by our evidence could not have been confined to the North Atlantic," suggesting that the cyclical climatic effects of the variable solar inferno are experienced throughout the world.

At this point of their paper, the international team of scientists had pretty much verified that in spite of the contrary claims of a host of climate alarmists, the Little Ice Age and Medieval Warm Period were (1) real, (2) global, (3) solar-induced, and (4) but the latest examples of alternating intervals of relative cold and warmth that stretch back in time through glacial and interglacial periods alike. And because these several subjects were of such great significance to the debate

[4] http://www.co2science.org/articles/V4/N48/EDIT.php.

over climate model-predicted consequences of anthropogenic CO_2 emissions, Bond and his band of researchers went on to cite *additional* evidence in support of the implications of their work.

With respect to the global extent of the climatic impact of the solar radiation variations they detected (topics 2 and 3 above, with 1 implied), they made explicit reference to confirmatory studies conducted in Scandinavia, Greenland, the Netherlands, the Faroe Islands, Oman, the Sargasso Sea, coastal West Africa, the Cariaco Basin, equatorial East Africa, and the Yucatan Peninsula, demonstrating thereby that the footprint of the solar impact on climate that they documented extends "from polar to tropical latitudes." Also in support of topic 3, they noted that "the solar-climate links implied by our record are so dominant over the last 12,000 years ... it seems almost certain that the well-documented connection between the Maunder solar minimum and the coldest decades of the Little Ice Age could not have been a coincidence," further noting that their findings support previous suggestions that both the Little Ice Age and Medieval Warm Period "may have been partly or entirely linked to changes in solar irradiance."

Another point reiterated by Bond *et al*. was that the oscillations in drift-ice they studied "persist across the glacial termination and well into the last glaciation, suggesting that the cycle is a pervasive feature of the climate system." At two of their coring sites, in fact, they identified a series of such cyclical variations that extended throughout all of the *previous* interglacial and were "strikingly similar to those of the Holocene." Here, they could also well have cited the work of Oppo *et al*. (1998), who observed similar climatic oscillations in a sediment core that covered the span of time from 340,000 to 500,000 years before present, and that of Raymo *et al*. (1998), who pushed back the time of the cycles' earliest known occurrence to well over one million years ago.

So how do the small changes in solar radiation inferred from cosmogenic nuclide variations bring about such significant and pervasive shifts in earth's global climate? In answer to this question, which had long plagued proponents of a solar-climate link, Bond *et al*. described a scenario whereby solar-induced changes high in the stratosphere are propagated downward through the atmosphere to the earth's surface, where they likely provoke changes in North Atlantic Deep Water formation that alter the global Thermohaline Circulation. And in light of the plausibility of this scenario, they suggested that the solar signals "may have been transmitted through the deep ocean as well as through the atmosphere, further contributing to their amplification and global imprint."

Concluding their landmark paper, the ten scientists stated that the results of their study "demonstrate that the earth's climate system is highly sensitive to extremely weak perturbations in the sun's energy output," noting that their work "supports the presumption that solar variability will continue to influence climate in the future." It is readily evident, therefore, that the study of Bond *et al*. provides ample ammunition for defending the premise that the global warming of the past century or so may well have been nothing more than the *initial stage* of the solar-mediated recovery of the earth from the global chill of the Little Ice Age, and that any *further* warming of the planet that might occur would likely be nothing more than a *continuation* of the same solar-mediated cycle that appears to be ushering the globe into the next Medieval-like Warm Period.

In a contemporary study that focused its attention directly on the *sun*, Rigozo *et al*. (2001)[5] described how they (1) reconstructed a history of sunspot numbers for the last 1000 years "using a sum of sine waves derived from spectral analysis of the time series of sunspot number R*z* for the period 1700-1999," and how from this record they (2) derived the strengths of a number of parameters related to various aspects of solar variability over the past millennium.

In discussing their findings, the four researchers said that "the 1000-year reconstructed sunspot number reproduces well the great maximums and minimums in solar activity that are identified in cosmonuclide variation records, and, more specifically, in the epochs of the Oort, Wolf, Sporer, Maunder, and Dalton Minimums, as well as the Medieval and Modern Maximums, the latter of which they described as "starting near 1900." In a bit more detail, they reported that the mean sunspot number for the Wolf, Sporer and Maunder Minimums was 1.36, and that for the Oort and Dalton Minimums it was 25.05; while for the Medieval Maximum it was 53.00, and for the Modern Maximum it was 57.54. Compared to the average of the Wolf, Sporer and Maunder Minimums, therefore, the mean sunspot number of the Oort and Dalton Minimums was 18.42 times greater; while that of the Medieval Maximum was 38.97 times greater, and that of the Modern Maximum was 42.31 times greater. Similar strength ratios for the solar radio flux were 1.41, 1.89 and 1.97, respectively; and for the solar wind velocity, the corresponding ratios were 1.05, 1.10 and 1.11, while for the southward component of the interplanetary magnetic field they were 1.70, 2.54 and 2.67.

Clearly, both the Medieval and Modern Maximums in sunspot number and solar variability parameters stand out head and shoulders above all other periods of the past thousand years, with the Modern Maximum slightly besting the Medieval Maximum. Due to the many empirical evidences for climate modulation by solar variability, therefore, it is only to be expected - *on this basis* - that yet-future temperatures may well prove to *ultimately* be higher than at any other time during the past millennium. Since other factors also come into play, however, and since the Medieval and Modern Maximums were not all that different, this conclusion may not turn out to be precisely correct. In any event, the observations of Rigozo *et al*. and those of Bond *et al*. suggest that there is no need for invoking variations in the air's CO_2 content as the primary cause of mean global temperature variations during any period of the past thousand or more years.

One year later in a *very* important study, Esper *et al*. (2002)[6] employed an analysis technique that allows accurate long-term climatic trends to be derived from individual tree-ring series that are of much shorter duration than the potential climatic oscillation being studied; and they applied this technique to over 1200 tree-ring series derived from 14 different locations scattered over the extratropical region of the Northern Hemisphere.

Two separate chronologies were thus developed: one from trees that exhibited age trends that were weakly linear and one from trees with age trends that were more nonlinear. The results, in their words, were "two nearly independent tree-ring chronologies covering the years 800-

5 http://www.co2science.org/articles/V4/N52/C2.php.
6 http://www.co2science.org/articles/V5/N13/EDIT.php.

1990," which were "very similar over the past ~1200 years." These tree-ring histories were then calibrated against Northern Hemispheric (0 to 90°N) mean annual instrumental temperatures from the period 1856-1980 to make them compatible with the temperature reconstructions of Mann *et al*. (1998, 1999), which were being cited by climate alarmists as indicating that current temperatures were greater than any previously experienced over the prior thousand years.

So what did the results show? The biggest difference between the Esper *et al*. and Mann *et al*. temperature histories was the degree to which the coolness of the global Little Ice Age was expressed. It was much more evident in the record of Esper *et al*., and its significantly lower temperatures were what made the Medieval Warm Period stand out more dramatically in their temperature reconstruction. Also, they noted that "the warmest period covers the interval 950-1045, with the peak occurring around 990." And this finding, in their words, "suggests that past comparisons of the Medieval Warm Period with the 20th-century warming back to the year 1000 have not included all of the Medieval Warm Period and, perhaps, not even its warmest interval."

In commenting on these findings in a companion "perspective" paper, Briffa and Osborn (2002) made several important points. First, they acknowledged the fact that "the last millennium was much cooler than previously interpreted" and that "an early period of warmth in the late 10th and early 11th centuries is more pronounced than in previous large-scale reconstructions." In fact, the Esper *et al*. record made it abundantly clear that the peak warmth of the MWP was equivalent to the warmth of the late 20th and early 21st centuries.

This fact reaffirmed the point raised by Idso (1988), i.e., that there is no need to invoke CO_2-induced global warming as a cause of the planet's recovery from the global chill of the Little Ice Age. "Since something other than atmospheric CO_2 variability was ... clearly responsible for bringing the planet into the Little Ice Age," as he phrased it, "something other than atmospheric CO_2 variability may just as well have brought the planet out of it." And that something else, as suggested by Esper *et al*., was probably "the 1000- to 2000-year climate rhythm (1470 ± 500 years) in the North Atlantic, which may be related to solar-forced changes in thermohaline circulation," as had been described by Bond *et al*. (2001).

Briffa and Osborn also noted that Esper *et al*.'s record clearly showed that the warming of the 20th century was simply "a continuation of a trend that began at the start of the 19th century." In addition, the Esper *et al*. record indicates that the Northern Hemisphere warmed in a consistent near-linear fashion over this entire 200-year period, contrary to the climate-alarmist claim of unprecedented warming over only the last century. Hence, the new data did great damage to the claim that CO_2-enhanced greenhouse warming was responsible for the temperature increase that brought the planet out of the Little Ice Age, since the increase in the air's CO_2 concentration over this period was highly *non*-linear, rising by only 10 to 15 ppm over the 19th century, but by fully 70 to 75 ppm over the 20th century, with no analogous increase in the latter period's rate of warming.

Finally, Briffa and Osborn stated that "we need to know why it was once so warm and then so cool, before we can say whether 21st-century warming is likely to be nearer to the top or the bottom of the latest IPCC [predicted temperature] range." Actually, we probably already know the answer to this question, because the extremes of warmth and coolness to which they refer were likely caused by "solar-forced changes in thermohaline circulation," as suggested by Esper *et al*. and described by Bond *et al*. In any event, it is becoming ever more clear with each passing day that these significant climatic changes were not caused by changes in the air's CO_2 content.

Publishing close to the same time as Brifa and Osborn were Krenke and Chernavskaya (2002)[7], who presented an impressive review of what was known about the Medieval Warm Period and Little Ice Age, both throughout the world in general and within Russia in particular, based upon written historical evidence, glaciological evidence, hydrologic evidence, dendrological data, archaeological data and palynological data. With respect to the world as a whole, they concluded from these materials that, "concerning the Medieval Warm Period (MWP), it is currently known that, from the 9th century to, apparently, the mid-15th century, the climatic conditions were warmer than during most of the subsequent five centuries, including the early 20th century." In some places, in fact, it was even warmer during the MWP than it was during the *latter* part of the 20th century. For example, they note that "the northern margin of boreal forests in Canada was shifted by 55 km [north] during the MWP, and the tree line in the Rocky Mountains in the southern United States and in the Krkonose Mountains was higher by 100-200 m than that observed at the present time."

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With respect to the temperature reconstructions of Mann *et al*. (1998, 1999), the two members of the Russian Academy of Sciences said that "the temperature averaged over the 20th century was found to be the highest among all centennial means, although it remained within the errors of reconstructions for the early millennium." However, they pointedly remind us that "one should keep in mind that the reconstructions of the early period were based nearly entirely on tree-ring data, which, because of the features of their interpretation, tend to underestimate low-frequency variations, so the temperatures of the Medieval Warm Period were possibly underestimated," after which they go on to provide yet additional evidence for that conclusion, reporting that "the limits of cultivated land or receding glaciers have not yet exceeded the level characteristic of the early millennium."

Concentrating on data from within Russia, Krenke and Chernavskaya reported large differences in a number of different variables between the period of the Little Ice Age and the preceding Medieval Warm Period. With respect to the annual mean temperature of northern Eurasia, they report an MWP to LIA drop on the order of 1.5°C. They also indicate that "the frequency of severe winters reported was increased from once in 33 years in the early period of time, which corresponds to the MWP, to once in 20 years in the LIA," while additionally noting that "the

[7] http://www.co2science.org/articles/V6/N30/C1.php.

abnormally severe winters [of the LIA] were associated with the spread of Arctic air masses over the entire Russian Plain." Finally, they note that the data they used to draw these conclusions were "not used in the reconstructions performed by Mann*et al*.," which perhaps explains why the Mann *et al*. temperature history of the past millennium does not reproduce the Little Ice Age nearly as well as does the more appropriately derived temperature history of Esper *et al*. (2002).

Last of all, and in contradiction of yet another of Mann *et al*.'s contentions, Krenke and Chernavskaya unequivocally stated, based on the results of their comprehensive study of the relevant scientific literature, that "the Medieval Warm Period and the Little Ice Age existed globally."

One year later, Soon and Baliunas (2003)[8] reviewed an immense wealth of evidence pertaining to the climatic and environmental history of the earth over the last millennium. And in doing so, they found that "the assemblage of local representations of climate establishes both the Little Ice Age and Medieval Warm Period as climatic anomalies with worldwide imprints, extending earlier results by Bryson *et al*. (1963), Lamb (1965), and numerous intervening research efforts." In addition, they found that "across the world, many records reveal that the 20th century is probably not the warmest nor a uniquely extreme climatic period of the last millennium," which is also the story told by the Medieval Warm Period Project[9] of *co2science.org*.

Stepping ahead one more year, Mayewski *et al*. (2004)[10] examined some fifty globally distributed paleoclimate records in search of evidence for what they called *rapid climate change* (RCC) over the Holocene. This terminology is not to be confused with the rapid climate changes typical of glacial periods, but is used in the place of what the sixteen researchers call the "more geographically or temporally restrictive terminology such as 'Little Ice Age' and 'Medieval Warm Period'." Hence, RCC *events*, as they also refer to them, are multi-century periods of time characterized by extremes of thermal and/or hydrological properties, rather than the much shorter periods of time during which the changes that led to these situations took place. So what did they learn?

Mayewski *et al*. identified six RCCs during the Holocene: 9000-8000, 6000-5000, 4200-3800, 3500-2500, 1200-1000 and 600-150 cal yr BP, the last two of which intervals are, in fact, the "globally distributed" Medieval Warm Period and Little Ice Age, respectively. And in speaking further of these two periods, they noted that "the short-lived 1200-1000 cal yr BP RCC event coincided with the drought-related collapse of Maya civilization and was accompanied by a loss of several million lives (Hodell *et al*., 2001; Gill, 2000), while the collapse of Greenland's Norse colonies at ~600 cal yr BP (Buckland *et al*., 1995) coincides with a period of polar cooling."

With respect to the *causes* of these and other Holocene RCCs, the international team of scientists concluded that "of all the potential climate forcing mechanisms, solar variability superimposed on long-term changes in insolation (Bond *et al*., 2001; Denton and Karlen, 1973;

8 http://www.co2science.org/articles/V6/N10/C3.php.
9 http://www.co2science.org/data/mwp/mwpp.php.
10 http://www.co2science.org/articles/V7/N51/C3.php.

Mayewski *et al*., 1997; O'Brien *et al*., 1995) seems to be the most likely important forcing mechanism." In addition, they made a point of declaring that "negligible forcing roles are played by CH_4 and CO_2," and that "changes in the concentrations of CO_2 and CH_4 appear to have been more the result than the cause of the RCCs."

Advancing yet another year, Braun *et al*. (2005)[11] noted that many palaeoclimate records from earth's North Atlantic region depict a millennial-scale oscillation of climate, which during the last glacial period was highlighted by Dansgaard-Oeschger events that regularly recurred at approximately 1,470-year intervals, as reported by Rahmstorf (2003)[12]. And because of the consistency of their occurrence, it was generally believed that these well-tuned periodic events were orchestrated by similarly-paced solar activity; but a major problem with this idea was that no known solar process or orbital perturbation exhibited the periodicity of the Dansgaard-Oeschger events. And this is where Braun *et al*. (2005) enter the picture, performing an analysis that successfully explains this dichotomy.

Noting that the periods of the well-known DeVries-Suess and Gleissberg solar cycles (~210 and 87 years, respectively) are close to prime factors of 1,470 years, the team of eight German scientists opined that "the superposition of two such frequencies could result in variability that repeats with a 1,470-year period." In fact, they did more than *opine* about the matter; they proceeded to *show*, in their words, that "an intermediate-complexity climate model with glacial climate conditions simulates rapid climate shifts similar to the Dansgaard-Oeschger events with a spacing of 1,470 years when forced by periodic freshwater input into the North Atlantic Ocean in cycles of ~86 and ~210 years." And to be perfectly clear about what this finding means, the researchers said that their *goal* in this exercise was "not aimed at suggesting a certain mechanism for solar influence on freshwater fluxes," as they describe it, but merely to demonstrate that "the glacial 1,470-year climate cycles could have been triggered by solar forcing despite the absence of a 1,470-year solar cycle," which objective they admirably achieved.

For the same reason, and also without specifying a particular mechanism, Braun *et al*.'s exercise suggests that the similarly-paced millennial-scale oscillation of climate that has reverberated throughout the Holocene (but with less perfect regularity) is also driven by the combinatorial effect of the DeVries-Suess and Gleissberg solar cycles. In fact, the German scientists say that the stimulus for their idea that "a multi-century climate cycle might be linked with century-scale solar variability comes from Holocene data," citing the work of Bond *et al*. (2001), who had found that "over the last 12,000 years virtually every centennial time-scale increase in drift ice documented in our North Atlantic records was tied to a solar minimum," and who concluded that "a solar influence on climate of the magnitude and consistency implied by our evidence could not have been confined to the North Atlantic," suggesting that the cyclical climatic effects of the variable solar inferno are experienced throughout the entire world.

So what are some of the better-known climatic manifestations of this cyclical solar-powered phenomenon? Bond *et al*. reported that the climatic oscillation's most recent cold node and the

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11 http://www.co2science.org/articles/V9/N1/EDIT.php.

12 http://www.co2science.org/articles/V6/N36/C1.php.

warm node that preceded it were "broadly correlative with the so called 'Little Ice Age' and 'Medieval Warm Period'." Likewise, Rahmstorf also stated that "the so-called 'little ice age' of the 16th-18th century may be the most recent cold phase of this cycle."

The final logical extension of these observations should be obvious to all: the global warming of the past century or so, which propelled the earth out of the Little Ice Age and into the Current Warm Period, was in all likelihood a result of the most recent upswing in this continuing cycle of solar-induced climate change. Hence, there is no longer any need to consider the historical rise in the atmosphere's CO_2 concentration as being the primary driver of 20th-century warming. Like everything else climate alarmists lump along with it, the much-maligned greenhouse gas was merely "along for the ride" on earth's eternally-oscillating climatic roller coaster whose operator is *the sun*.

There is no longer any need to consider the historical rise in the atmosphere's CO_2 concentration as being the primary driver of 20th-century warming. Like everything else climate alarmists lump along with it, the much-maligned greenhouse gas was merely "along for the ride" on earth's eternally-oscillating climatic roller coaster whose operator is the sun.

Pausing to evaluate the status of the climate change conundrum that *still* plagues the community of climate science investigators, Esper *et al.* (2005)[13] weighed in with their thoughts on why there are significant differences among various climatic reconstructions and what it might likely take to reduce various uncertainties in order to gain a more complete and correct understanding of temperature changes over the past thousand years.

According to the six scientists, we understand (for the most part), the *shape* of long-term climate fluctuations better than their *amplitudes*. For example, nearly all 1000-year temperature reconstructions capture the major climatic episodes of the Medieval Warm Period, Little Ice Age and Current Warm Period; but for various reasons they exhibit differences in the degree of climatic warming or cooling experienced in the transitions between them, which for decadal means may amount to as much as 0.4 to 1.0°C. Among the list of action items they believe will help to reduce these discrepancies are their suggestions to (1) reduce the calibration uncertainty among the proxies, (2) ensure the accurate preservation and assessment of low-to-high frequency variation in proxy data, (3) use appropriate frequency bands to best fit instrumental data, (4) avoid the use of regional tree-ring and other palaeo-records in which long-term trends (low-frequency variations) are not preserved, (5) select instrumental data with which to compare proxy records to avoid incorrect alterations to the observational data

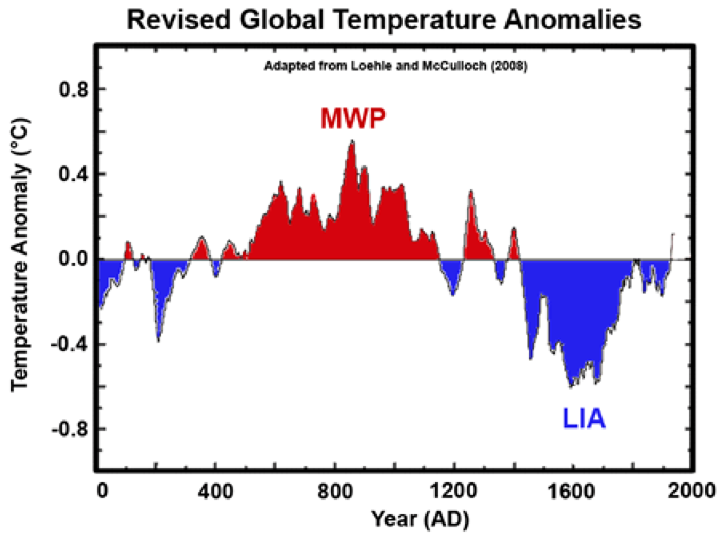
13 http://www.co2science.org/articles/V9/N1/C1.php.

that can result from homogeneity adjustments and methodological differences, and (6) obtain more proxy data that cover the full millennium and represent the same spatial domain as the instrumental target data.

Why are these points so important? As stated by Esper *et al*., knowledge of the correct amplitude of the major climatic episodes of the past millennium is "critical for predicting future trends." And why? Because if it can be shown that the amplitudes of the major historical climate episodes were as large as, or even greater than, that of 20th-century global warming, there would be what they describe as a "redistribution of weight towards the role of natural factors in forcing temperature changes, thereby relatively devaluing the impact of anthropogenic emissions and affecting future predicted scenarios." And if that turns out to be the case, efforts to reduce greenhouse gas emissions via national or international agreements, such as the Kyoto Protocol, "would be less effective than thought." In fact, they could even be *counterproductive*, in view of the significant boost to agricultural production that is provided by the aerial *fertilization effect* of atmospheric CO_2 *enrichment*, which will likely be sorely needed to provide the food required to support the planet's growing population in the years and decades to come.

Two years later, using data from eighteen 2000-year-long proxy temperature series from all around the world that were *not* developed from tree-ring data (which provide significant interpretive challenges), Loehle (2007)[14] smoothed the data in each series with a 30-year running mean, converted the results thereby obtained to *anomalies* by subtracting the mean of each series from each member of that series, and then derived the final mean temperature anomaly history defined by the eighteen data sets by a simple averaging of the individual anomaly series. The results obtained by this procedure depicted the Medieval Warm Period and Little Ice Age quite clearly, with the peak warmth of the MWP being approximately 0.3°C warmer than the peak warmth of the 20th century. And in a subsequent paper that improved somewhat on Loehle's original study, Loehle and McCulloch (2008) obtained the results depicted below, where it can be seen that (while instrumental data are not strictly comparable), the rise in 29-year-smoothed global data from NASA GISS from 1935 (the end point of the figure below) to 1992 (with data from 1978 to 2006) is 0.34°C, and that "adding this rise to the 1935 reconstructed value, the MWP peak still remains 0.07°C above the end of the 20th-century values, though the difference is not significant."

[14] http://www.co2science.org/articles/V11/N5/C1.php.



Mean relative temperature history of the globe. Adapted from Loehle and McCulloch (2008).

Shortly thereafter, based on data obtained from hundreds of moisture-sensitive Scots pine tree-ring records originating in Finland, and using *regional curve standardization* (RCS) procedures, Helama *et al.* (2009)[15] developed what they described as "the first European dendroclimatic precipitation reconstruction," which "covers the classical climatic periods of the Little Ice Age (LIA), the Medieval Climate Anomaly (MCA), and the Dark Ages Cold Period (DACP)," running all the way from AD 670 to AD 1993. These data indicate, as they described it, that "the special feature of this period in climate history is the distinct and persistent drought, from the early ninth century AD to the early thirteenth century AD," which interval "precisely overlaps the period commonly referred to as the MCA, due to its geographically widespread climatic anomalies both in temperature and moisture." In addition, they wrote that "the reconstruction also agrees well with the general picture of wetter conditions prevailing during the cool periods of the LIA (here, AD 1220-1650) and the DACP (here, AD 720-930)."

In discussing their findings, the three Finnish scientists noted that "the global medieval drought that we found occurred in striking temporal synchrony with the multi-centennial droughts previously described for North America (Stine, 1994; Cook *et al.*, 2004, 2007), eastern South America (Stine, 1994; Rein *et al.*, 2004), and equatorial East Africa (Verschuren *et al.*, 2000; Russell and Johnson, 2005, 2007; Stager *et al.*, 2005) between AD 900 and 1300." Noting further that "the global evidence argues for a common force behind the hydrological component of the MCA," they report that "previous studies have associated coeval megadroughts during the MCA in various parts of the globe with either solar forcing (Verschuren *et al.*, 2000; Stager *et al.*, 2005) or the ENSO (Cook *et al.*, 2004, 2007; Rein *et al.*, 2004; Herweijer *et al.*, 2006, 2007; Graham *et al.*, 2007, Seager *et al.*, 2007)," stating that "the evidence so far points to the medieval solar activity maximum (AD 1100-1250), because it is observed in the $\Delta^{14}C$ and ^{10}Be series recovered from the chemistry of tree rings and ice cores, respectively (Solanki *et al.*, 2004)."

15 http://www.co2science.org/articles/V12/N14/C3.php.

And so the evidence continues to mount for a *global* and *solar-induced* Medieval Warm (and Dry!) Period, which likely eclipsed (in both categories) what the world has so far experienced during the Current Warm Period.

About this same time, Esper and Frank (2009)[16] took the Intergovernmental Panel on Climate Change (IPCC) to task for concluding in their fourth assessment report (AR4) that, relative to modern times, there was "an increased heterogeneity of climate during medieval times about 1000 years ago." This finding, if true, would be of great significance to the ongoing debate over the cause of 20th-century global warming, *because*, in the words of Esper and Frank, "heterogeneity alone is often used as a distinguishing attribute to contrast with present anthropogenic warming." On the other hand, if the IPCC's contention is false, it would mean that the warmth of the Current Warm Period is not materially different from that of the Medieval Warm Period (MWP), suggesting there is no need to invoke anthropogenic CO_2 emissions as the cause of earth's current warmth, which does not yet appear to have reached the level experienced a thousand years ago (when there was much less CO_2 in the air than there is today).

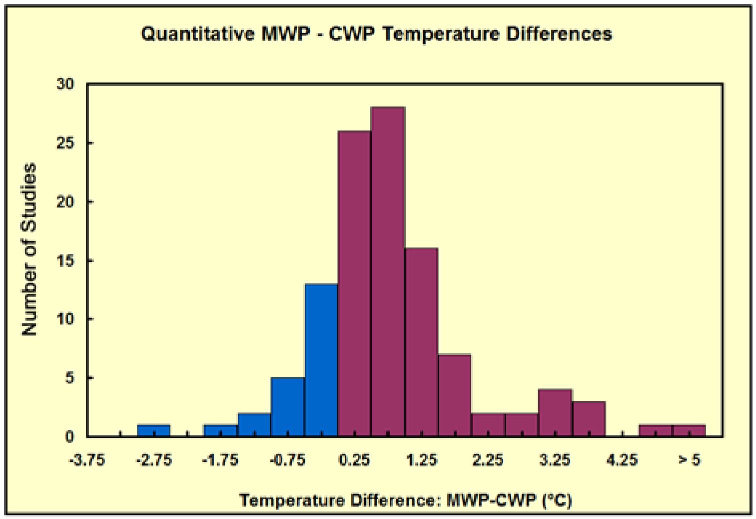
So what did the two Swiss scientists find? By means of various mathematical procedures and statistical tests, Esper and Frank were able to demonstrate that the records reproduced in the AR4 "do not exhibit systematic changes in coherence, and thus cannot be used as evidence for long-term homogeneity changes." And even if they could be thus used, they say "there is no increased spread of values during the MWP," and that the standard error of the component data sets "is actually largest during recent decades." Consequently, the two researchers concluded that their "quantification of proxy data coherence suggests that it was erroneous [for the IPCC] to conclude that the records displayed in AR4 are indicative of a heterogeneous climate during the MWP."

Nevertheless, the homogeneity issue remained *unresolved* back in 2009; for as Esper and Frank also noted, "an estimation of long-term spatial homogeneity changes is premature based on the smattering of data currently available." And that is why the *Center for the Study of Carbon Dioxide and Global Change* continues to post (at co2science.org) results of new studies that provide additional data on the Medieval Warm Period. And as may be seen from the ever-expanding archived results of the Center's Interactive Map and Time Domain Plot[17], the MWP is looking ever more *global* with each passing week.

Also, as shown in the figure below, it is looking ever more *over-powering* in terms of *peak* temperature.

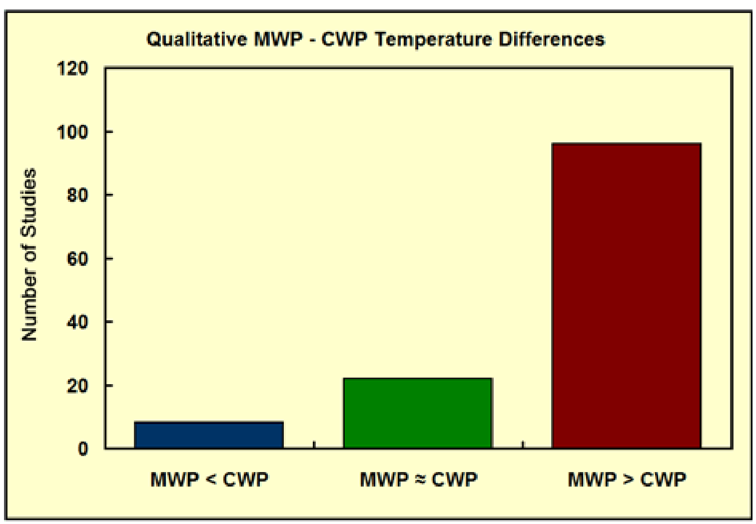
[16] http://www.co2science.org/articles/V12/N23/EDIT.php.

[17] http://www.co2science.org/data/timemap/mwpmap.html.



The distribution, in 0.5°C increments, of studies that allow one to identify the degree by which peak Medieval Warm Period temperatures either exceeded (positive values, red) or fell short of (negative values, blue) peak Current Warm Period temperatures, as of August 2013.

And in cases where only a *qualitative* assessment of the relative magnitudes of peak MWP temperatures and peak CWP temperatures can be obtained from published studies of the subject, the Center tabulates their findings as shown in the figure below, where once again the MWP overpowers the CWP.



The distribution of studies that only allow one to determine whether peak Medieval Warm Period temperatures were warmer than (red), equivalent to (green), or cooler than (blue) peak Current Warm Period temperatures.

In a more recent study, Rosenthal *et al*. (2013) report that "instrumental records show that the increase in ocean heat content (OHC) accounts for ~90% of the expected warming of [the] Earth, thereby demonstrating that OHC more reliably represents the response of Earth's energy budget to radiative perturbations than do surface temperatures." In addition, they note that "subsurface water masses are directly ventilated in the high-latitude oceans, where they average the highly variable surface conditions, thereby providing an integrated measure of long-term trends."

Taking advantage of these facts, Rosenthal *et al*. (2013) used Mg/Ca measurements of the benthic foraminifer *Hyalinea balthica* obtained from "a suite of sediment cores along bathymetric transects in the Makassar Strait and Flores Sea in Indonesia to document changes in the temperature of western equatorial Pacific subsurface and intermediate water masses throughout the Holocene [0 to 10 thousand years before the present (ky B.P.)]," while noting, in this regard, that "this region is well suited to reconstruct Pacific OHC, as thermocline and intermediate water masses found here form in the mid- and high-latitudes of both the northern and southern Pacific Ocean and can be traced by their distinctive salinity and density as they flow toward the equator."

In discussing their findings three researchers write that "water masses linked to North Pacific and Antarctic intermediate waters were warmer by 2.1 ± 0.4°C and 1.5 ± 0.4°C, respectively, during the middle Holocene Thermal Maximum [HTM] than over the past century," and that "both water masses were ~0.9°C warmer during the Medieval Warm Period [MWP] than during the Little Ice Age and ~0.65°C warmer than in recent decades." And in addition to providing further evidence for the greater warmth of the Medieval Warm Period compared to that of the Current Warm Period, Rosenthal *et al*. write that "the inferred similarity in temperature anomalies at both hemispheres is consistent with recent evidence from Antarctica (Orsi *et al*., 2012), thereby supporting the idea that the HTM, MWP and LIA were global events."

At the end of the day, then, it would indeed appear that the peak warmth of the *global* Medieval Warm Period clearly exceeded that of the *global* Current Warm Period. Additional support for this conclusion can be found in the other reviews and summaries we have written on this topic, found under the many subheadings of the Medieval Warm Period[18] in our website's Subject Index.

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[18] http://www.co2science.org/subject/m/subject_m.php.

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