# SOLAR INFLUENCE ON EUROPEAN TEMPERATURES

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We begin this review of the Sun's influence on European temperatures with the study of Holzhauser *et al*. (2005)[1], who 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, starting with an in-depth analysis of the Great Aletsch glacier, which is the largest of all glaciers located in the European Alps.

Near the beginning of the time period studied, the three researchers report that "during the late Bronze Age Optimum from 1350 to 1250 BC, the Great Aletsch glacier was approximately 1000 m shorter than it is today," noting that "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 unnamed cold-wet phase, when the glacier grew in both mass and length, they say that "during the Iron/Roman Age Optimum between c. 200 BC and AD 50," which is 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," which 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," following which the glacier began its latest and still-ongoing recession in 1865. In addition, they state that 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, or even warmer than, it is today. Data pertaining to the Gorner glacier (the second largest of the Swiss Alps) and the Lower Grindelwald glacier of the Bernese Alps tell much the same story, as Holzhauser *et al*. report that these glaciers and the Great Aletsch glacier "experienced nearly synchronous advances" throughout the study period.

*A comparison between the fluctuations of the Great Aletsch glacier and the variations in the atmospheric residual $^{14}C$ records supports the hypothesis that variations in solar activity were a major forcing factor of climate oscillations in west-central Europe during the late Holocene.*

[1] http://www.co2science.org/articles/V9/N20/EDIT.php.

With respect to what was responsible for the millennial-scale climatic oscillation that produced the alternating periods of cold-wet and warm-dry conditions that fostered the similarly paced cycle of glacier growth and retreat, the Swiss and French scientists report that "glacier maximums coincided with radiocarbon peaks, i.e., periods of weaker solar activity," which in their estimation "suggests a possible solar origin of the climate oscillations punctuating the last 3500 years in west-central Europe, in agreement with previous studies (Denton and Karlén, 1973; Magny, 1993; van Geel *et al*., 1996; Bond *et al*., 2001)." And to underscore that point, they conclude their paper by stating that "a comparison between the fluctuations of the Great Aletsch glacier and the variations in the atmospheric residual $^{14}C$ records supports the hypothesis that variations in solar activity were a major forcing factor of climate oscillations in west-central Europe during the late Holocene."

In another study of paleoclimate in western Europe, Mauquoy *et al*. (2002a)[2] extracted peat monoliths from ombrotrophic mires at Lille Vildmose, Denmark (56°50'N, 10°15'E) and Walton Moss, UK (54°59'N, 02°46'W), which sites, being separated by about 800 km, "offer the possibility of detecting supraregional changes in climate." From these monoliths, vegetative macrofossils were extracted at contiguous 1-cm intervals and examined using light microscopy. Where increases in the abundances of *Sphagnum tenellum* and *Sphagnum cuspidatum* were found, a closely spaced series of $^{14}C$ AMS-dated samples immediately preceding and following each increase was used to "wiggle-match" date them (van Geel and Mook, 1989), thereby enabling comparison of the climate-induced shifts with the history of $^{14}C$ production during the Holocene.

Results indicated the existence of a climatic deterioration that marked the beginning of a period of inferred cool, wet conditions that correspond fairly closely in time with the Wolf, Sporer, and Maunder Minima of solar activity, as manifest in contemporary $\delta^{14}C$ data. The authors report "these time intervals correspond to periods of peak cooling in 1000-year Northern Hemisphere climate records," adding to the "increasing body of evidence" that "variations in solar activity may well have been an important factor driving Holocene climate change."

Two years later, Mauquoy *et al*. (2004)[3] reviewed the principles of $^{14}C$ wiggle-match dating, its limitations, and the insights it has provided about the timing and possible causes of climate change during the Holocene. Based upon their review, the authors stated that "analyses of microfossils and macrofossils from raised peat bogs by Kilian *et al*. (1995), van Geel *et al*. (1996), Speranza *et al*. (2000), Speranza (2000) and Mauquoy *et al*. (2002a, 2002b) have shown that climatic deteriorations [to cooler and wetter conditions] occurred during periods of transition from low to high delta $^{14}C$ (the relative deviation of the measured $^{14}C$ activity from the standard after correction for isotope fractionation and radioactive decay; Stuiver and Polach, 1977)." This close correspondence, in the words of the authors, again suggests that "changes in solar activity may well have driven these changes during the Bronze Age/Iron Age transition around c. 850 cal. BC (discussed in detail by van Geel *et al*., 1996, 1998, 1999, 2000) and the 'Little Ice Age' series of palaeoclimatic changes."

2 http://www.co2science.org/articles/V5/N51/C1.php.
3 http://www.co2science.org/articles/V7/N7/C2.php.

Working with a marine sediment core retrieved from the southern Norwegian continental margin, Berstad *et al*. (2003)[4] reconstructed sea surface temperatures (SSTs) from $\delta^{18}O$ data derived from the remains of the planktonic foraminifera species *Neogloboquadrina pachyderma* (summer temperatures) and *Globigerina bulloides* (spring temperatures). Among other things, the authors' work depicted a clear connection between the cold temperatures of the Little Ice Age and the reduced solar activity of the concomitant Maunder and Sporer solar minima, as well as between the warm temperatures of the most recent 70 years and the enhanced solar activity of the concomitant Modern solar maximum, which they clearly implied in their paper is a causative connection, as is also implied by the recent Sunspot number reconstruction of Usoskin *et al*. (2003)[5].

In working with two sediment cores extracted from the seabed of the eastern Norwegian Sea (~64°N, 3°E), Sejrup *et al*. (2010)[6] developed a 1000-year proxy temperature record "based on measurements of $\delta^{18}O$ in *Neogloboquadrina pachyderma* (dextral form), a planktonic foraminifer that calcifies at relatively shallow depths within the Atlantic waters of the eastern Norwegian Sea during late summer," which they compared with the temporal histories of various proxies of concomitant solar activity. In discussing the rationale for their study, the authors write that "the proxy record of solar variability from cosmogenic nuclides and telescopic observations of sunspots explains a substantial fraction of reconstructed Northern Hemisphere temperature variability during the pre-Industrial portion of the last millennium, with a simulated range of up to 0.4°C for plausible irradiance scaling and climate sensitivity," citing Crowley (2000) and Ammann *et al*. (2007); but they add that "at both the intra- and supra-decadal timescales there appear to be regional responses to solar forcing that are significantly larger than the global or hemisphere-scale response," citing Shindell *et al*. (2001), Woods and Lean (2007) and Tung and Camp (2008).

*The $\delta^{18}O$ proxy record of near-surface water temperature was found to be "robustly and near-synchronously correlated with various proxies of solar variability spanning the last millennium," with decade- to century-scale temperature variability of 1 to 2°C magnitude revealing that it was the Sun that outshined nearly all other forcings of climate change in this region of the Earth over the past millennium.*

Results of Sejrup *et al*.'s analysis revealed that "the lowest isotope values (highest temperatures) of the last millennium are seen ~1100-1300 A.D., during the Medieval Climate Anomaly, and again after ~1950 A.D." In between these two warm intervals, of

[4] http://www.co2science.org/articles/V7/N3/C1.php.
[5] http://www.co2science.org/articles/V7/N2/C1.php.
[6] http://www.co2science.org/articles/V14/N12/C2.php.

course, were the colder temperatures of the Little Ice Age, when oscillatory *thermal* minima occurred at the times of the Dalton, Maunder, Sporer and Wolf *solar* minima, such that the $\delta^{18}O$ proxy record of near-surface water temperature was found to be "robustly and near-synchronously correlated with various proxies of solar variability spanning the last millennium," with decade- to century-scale temperature variability of 1 to 2°C magnitude revealing that it was the *Sun* that *outshined* nearly all other forcings of climate change in this region of the Earth over the past millennium.

Nearby in Finland, Haltia-Hovi *et al*. (2007)[7] extracted sediment cores from beneath the 0.7-m-thick ice platform on Lake Lehmilampi (63°37'N, 29°06'E) in North Karelia, eastern Finland, after which they identified and counted the approximately 2,000 annual varves contained in the cores and measured their individual thicknesses and mineral and organic matter contents. These climate-related data were then compared with residual $\Delta^{14}C$ data derived from tree rings, which serve as a proxy for solar activity.

According to Haltia-Hovi *et al*., their "comparison of varve parameters (varve thickness, mineral and organic matter accumulation) and the activity of the Sun, as reflected in residual $\Delta^{14}C$ [data] appears to coincide remarkably well in Lake Lehmilampi during the last 2000 years, suggesting solar forcing of the climate," as depicted in the figure below for the case of varve thickness. What is more, the low deposition rate of mineral matter in Lake Lehmilampi in AD 1060-1280 "possibly implies mild winters with a short ice cover period during that time with minor snow accumulation interrupted by thawing periods." Likewise, they say that the low accumulation of organic matter during this period "suggests a long open water season and a high decomposition rate of organic matter." Consequently, since the AD 1060-1280 period shows the lowest levels of both mineral and organic matter content, and since "the thinnest varves of the last 2000 years were deposited during [the] solar activity maxima in the Middle Ages," it is difficult not to conclude that that period was likely the warmest of the past two millennia in the part of the world studied by the three scientists.

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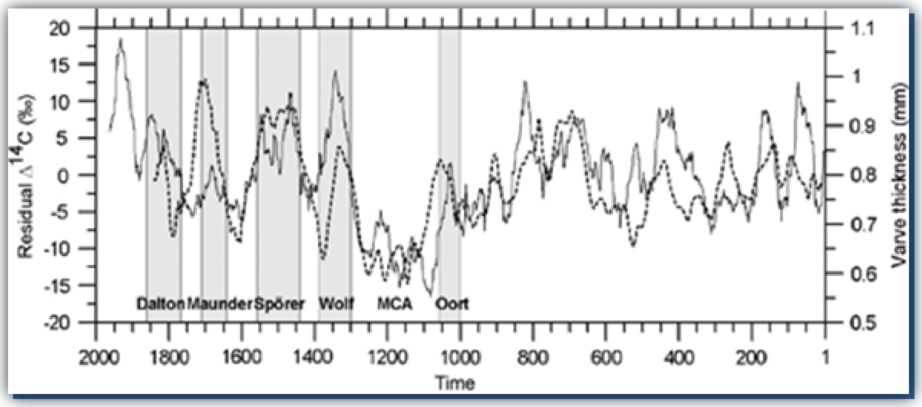
7 http://www.co2science.org/articles/V10/N25/C2.php.




*Residual Δ*[14]*C data (dashed line) and varve thickness (smooth line) vs. time, specifically highlighting the Oort, Wolf, Sporer, Maunder and Dalton solar activity minima, as well as the "Medieval Climate Anomaly (also referred to as Medieval Warm Period)," during the contemporaneous "solar activity maxima in the Middle Ages." Adapted from Haltia-Hovi et al. (2007). Hanna et al. (2004)*[8] *analyzed several climatic variables over the past century in Iceland in an effort to determine if there is "possible evidence of recent climatic changes" in that cold island nation. Results indicated that for the period 1923-2002, no trend was found in either annual or monthly Sunshine data. Similar results were reported for annual and monthly pressure data, which exhibited semi-decadal oscillations throughout the 1820-2002 period but no significant upward or downward trend. Precipitation, on the other hand, appears to have increased slightly, although the authors question the veracity of the trend, citing a number of biases that have potentially corrupted the database.*

With respect to temperature, however, the authors indicate that of the handful of locations they examined for this variable, all stations experienced a net warming since the mid-1800s. The warming, however, was not linear over the entire time period. Rather, temperatures rose from their coldest levels in the mid-1800s to their warmest levels in the 1930s, whereupon they remained fairly constant for approximately three decades. Then came a period of rapid cooling, which ultimately gave way to the warming of the 1980s and 1990s. However, it is important to note that the warming of the past two decades has not resulted in temperatures rising above those observed in the 1930s. In this point the authors are particularly clear, stating emphatically that "the 1990s was definitely *not* the warmest decade of the 20th century in Iceland, in contrast to the Northern Hemisphere land average." In fact, a linear trend fit to the post-1930 data would indicate an overall temperature decrease since that time.

As for what may be responsible for the various trends evident in the data, Hanna *et al*. note the likely influence of the Sun on temperature and pressure values in consequence of their finding a significant correlation between 11-year running temperature means and Sunspot numbers, plus the presence of a 12-year peak in their spectral analysis of the pressure data, which they say is "suggestive of solar activity."

[8] http://www.co2science.org/articles/V7/N44/C2.php.

Noting that "solar activity during the current sunspot minimum has fallen to levels unknown since the start of the 20th century," and that "the Maunder minimum (about 1650-1700) was a prolonged episode of low solar activity which coincided with more severe winters in the United Kingdom and continental Europe," Lockwood *et al*. (2010)[9] write that "motivated by recent relatively cold winters in the UK," they investigated the possible connection between these severe winters and low solar activity, identifying "regionally anomalous cold winters by detrending the Central England temperature record using reconstructions of the northern hemisphere mean temperature." In doing so, the team of researchers discovered that "cold winter excursions from the hemispheric trend" do indeed "occur more commonly in the UK during low solar activity, consistent with the solar influence on the occurrence of persistent blocking events in the eastern Atlantic," and they state that "colder UK winters (relative to the longer-term trend) can therefore be associated with lower open solar flux (and hence with lower solar irradiance and higher cosmic ray flux)." They are quick to note, however, that "this is a regional and seasonal effect relating to European winters and not a global effect." Nevertheless, the four researchers conclude that since "average solar activity has declined rapidly since 1985 and cosmogenic isotopes suggest an 8% chance of a return to Maunder minimum conditions within the next 50 years (Lockwood, 2010)," their results suggest that, "despite hemispheric warming, the UK and Europe could experience more cold winters than during recent decades."

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In another study, Mangini *et al*. (2005)[10] develop a highly resolved 2,000-year $\delta^{18}O$ proxy record of temperature obtained from a stalagmite recovered from Spannagel Cave in the Central Alps of Austria. Results indicated that the lowest temperatures of the past two millennia occurred during the Little Ice Age (AD 1400-1850), while the highest temperatures were found in the Medieval Warm Period (MWP: AD 800-1300). Furthermore, Mangini *et al*. say that the highest temperatures of the MWP were "slightly higher than those of the top section of the stalagmite (1950 AD) and higher than the present-day temperature." At three different points during the MWP, their data indicate temperature spikes in excess of 1°C above present (1995-1998) temperatures.

9 http://www.co2science.org/articles/V14/N26/C1.php.
10 http://www.co2science.org/articles/V8/N30/EDIT.php.

Mangini *et al*. additionally report that their temperature reconstruction compares well with reconstructions developed from Greenland ice cores (Muller and Gordon, 2000), Bermuda Rise ocean-bottom sediments (Keigwin, 1996), and glacier tongue advances and retreats in the Alps (Holzhauser, 1997; Wanner *et al*., 2000), as well as with the Northern Hemispheric temperature reconstruction of Moberg *et al*. (2005). Considered together, they say these several datasets "indicate that the MWP was a climatically distinct period in the Northern Hemisphere," emphasizing that "this conclusion is in strong contradiction to the temperature reconstruction by the IPCC, which only sees the last 100 years as a period of increased temperature during the last 2000 years."

In yet another refutation of the theory of $CO_2$-induced global warming, Mangini *et al*. found "a high correlation between $\delta^{18}O$ and $\delta^{14}C$, that reflects the amount of radiocarbon in the upper atmosphere," and they note that this correlation "suggests that solar variability was a major driver of climate in Central Europe during the past 2 millennia." In this regard, they report that "the maxima of $\delta^{18}O$ coincide with solar minima (Dalton, Maunder, Sporer, Wolf, as well as with minima at around AD 700, 500 and 300)," and that "the coldest period between 1688 and 1698 coincided with the Maunder Minimum." Also, in a linear-model analysis of the percent of variance of their full temperature reconstruction that is individually explained by solar and $CO_2$ forcing, they found that the impact of the Sun was fully 279 times greater than that of the air's $CO_2$ concentration, noting that "the flat evolution of $CO_2$ during the first 19 centuries yields almost vanishing correlation coefficients with the temperature reconstructions."

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Two years later, Mangini *et al*. (2007)[11] updated the 2005 study with additional data after which they compared it with the Hematite-Stained-Grain (HSG) history of ice-rafted debris in North Atlantic Ocean sediments developed by Bond *et al*. (2001), finding an undeniably good correspondence between the peaks and valleys of their $\delta^{18}O$ curve and the HSG curve. The significance of such correspondence is evidenced by the fact that Bond *et al*. reported 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."

Other researchers have found similar periodicities in their climate proxies. Turner *et al*. (2008)[12], for example, found an ~1500 year cycle in a climate history reconstructed from sediment cores extracted from two crater lake basins in central Turkey, which they indicate

[11] http://www.co2science.org/articles/V10/N31/C1.php.
[12] http://www.co2science.org/articles/V12/N1/C5.php.

"may be linked with large-scale climate forcing" such as that found in the North Atlantic by Bond *et al*. (1997, 2001). In addition, McDermott *et al*. (2001)[13] found evidence of millennial-scale climate cycles in a $\delta^{18}O$ record from a stalagmite in southwestern Ireland, as did Sbaffi *et al*. (2004)[14] from two deep-sea sediment cores recovered from the Tyrrhenian Sea, which latter proxy corresponded well with the North Atlantic solar-driven cycles of Bond *et al*. (1997).

Nearby in the Mediterranean Sea, Cini Castagnoli *et al*. (2002)[15] searched for possible solar-induced variations in the $\delta^{13}C$ record of the foraminifera *Globigerinoides rubber* obtained from a sea core located in the Gallipoli terrace of the Gulf of Taranto (39°45'53"N, 17°53'33"E, depth of 178 m) over the past 1,400 years. Starting at the beginning of the 1,400-year record, the $\delta^{13}C$ values increased from about 0.4 per mil around 600 A.D. to a value of 0.8 per mil by 900 A.D. Thereafter, the $\delta^{13}C$ record remained relatively constant until about 1800, when it rose another 0.2 per mil to its present-day value of around 1.0 per mil.

Using statistical procedures, the authors were able to identify three important cyclical components in their record, with periods of approximately 11.3, 100, and 200 years. Comparison of both the raw $\delta^{13}C$ and component data with the historical aurorae and sunspot time series, respectively, revealed that the records are "associable in phase" and "disclose a statistically significant imprint of the solar activity in a climate record." Three years later, Cini Castagnoli *et al*. (2005)[16] extended the $\delta^{13}C$ temperature proxy from the Gulf of Taranto an additional 600 years, reporting an overall phase agreement between the climate reconstruction and variations in the sunspot number series that "favors the hypothesis that the [multi-decadal] oscillation revealed in $\delta^{13}C$ is connected to the solar activity."

In order to gain some insight into the character and potential forcing of short-term climatic and oceanographic variability in the southern Italian region of the Mediterranean Sea during the Roman Classical Period (60 BC - 200 AD), Chen *et al*. (2011)[17] developed a high temporal resolution (4-year) sea surface temperature (SST) history based on a dinoflagelate cyst record obtained from a well-dated sediment core retrieved from a site in the Gulf of Taranto located at the distal end of the Po River discharge plume (39°50.07'N, 17°48.05'E). Results of the analysis revealed an era of "high stable temperatures between 60 BC and 90 AD followed by a decreasing trend between 90 AD and 200 AD." And "consistent to earlier findings for the region," they say that "local air temperature during the Roman Period might have been warmer than that of the 20th century." With respect to a potential cause of this temperature swing, the authors say "the observation of strong 11 years cyclicity in our records together with a strong visual correlation of our temperature and river discharge records with the global variation in $\delta^{14}C$ anomalies suggest that solar activity might have been an important climate forcing factor during this time."

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13 http://www.co2science.org/articles/V4/N50/C1.php.

14 http://www.co2science.org/articles/V7/N6/C2.php.

15 http://www.co2science.org/articles/V5/N38/C3.php.

16 http://www.co2science.org/articles/V9/N2/C1.php.

17 http://www.co2science.org/articles/V15/N24/C2.php.

Desprat *et al*. (2003)[18] conducted a high-resolution pollen analysis of a sediment core retrieved from the central axis of the Ria de Vigo in the south of Galicia (42°14.07'N, 8°47.37'W) to study the climatic variability of the last three millennia in northwest Iberia. According to the authors, over the past 3,000 years there was "an alternation of three relatively cold periods with three relatively warm episodes." In order of their occurrence, these periods were described by the authors as the "first cold phase of the Subatlantic period (975-250 BC)," which was "followed by the Roman Warm Period (250 BC-450 AD)," which was followed by "a successive cold period (450-950 AD), the Dark Ages," which "was terminated by the onset of the Medieval Warm Period (950-1400 AD)," which was followed by "the Little Ice Age (1400-1850 AD), including the Maunder Minimum (at around 1700 AD)," which "was succeeded by the recent warming (1850 AD to the present)." Based upon this "millennial-scale climatic cyclicity over the last 3000 years," which parallels "global climatic changes recorded in North Atlantic marine records (Bond *et al*., 1997; Bianchi and McCave, 1999; Chapman and Shackelton, 2000)," Desprat *et al*. conclude that "solar radiative budget and oceanic circulation seem to be the main mechanisms forcing this cyclicity in NW Iberia."

Finally, and also working in Spain, Morellon *et al*. (2011)[19] say that "in the context of present-day global warming, there is increased interest in documenting climate variability during the last millennium," since "it is crucial to reconstruct pre-industrial conditions to discriminate anthropogenic components (i.e., greenhouse gases, land-use changes) from natural forcings (i.e., solar variability, volcanic emissions)." Against this backdrop Morellon *et al*. conducted a multi-proxy study of several short sediment cores they recovered from Lake Estanya (42°02'N, 0°32'E) in the Pre-Pyrenean Ranges of northeast Spain, which "provides a detailed record of the complex environmental, hydrological and anthropogenic interactions occurring in the area since medieval times." More specifically, they say that "the integration of sedimentary facies, elemental and isotopic geochemistry, and biological proxies (diatoms,

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*These relationships suggest that there is little reason to attribute 20th-century global warming to the concomitant increase in the air's $CO_2$ content. Natural variability appears quite capable of explaining it all.*

18 http://www.co2science.org/articles/V6/N43/C2.php.
19 http://www.co2science.org/articles/V15/N6/C2.php.

chironomids and pollen), together with a robust chronological control, provided by AMS radiocarbon dating and $^{210}Pb$ and $^{137}Cs$ radiometric techniques, enabled precise reconstruction of the main phases of environmental change, associated with the Medieval Warm Period (MWP), the Little Ice Age (LIA) and the industrial era." So what did they find?

The thirteen researchers identified the MWP as occurring in their record from AD 1150 to 1300, noting that their pollen data reflect "warmer and drier conditions," in harmony with the higher temperatures of the Iberian Peninsula over the same time period that have been documented by Martinez-Cortizas *et al*. (1999), the higher temperatures of the Western Mediterranean region found by Taricco *et al*. (2008), and the global reconstructions of Crowley and Lowery (2000) and Osborn and Briffa (2006), which "clearly document warmer conditions from the twelfth to fourteenth centuries," which warmth, in the words of Morellon *et al*. is "likely related to increased solar irradiance (Bard *et al*., 2000), persistent La Niña-like tropical Pacific conditions, a warm phase of the Atlantic Multidecadal Oscillation, and a more frequent positive phase of the North Atlantic Oscillation (Seager *et al*., 2007)."

Following hard on the heels of the MWP, Morellon *et al*. note the occurrence of the LIA, which they recognize as occurring from AD 1300 to 1850. And here they report that, on the Iberian Peninsula, "lower temperatures (Martinez-Cortizas *et al*., 1999) characterize this period," which "coincided with colder North Atlantic (Bond *et al*., 2001) and Mediterranean sea surface temperatures (Taricco *et al*., 2008) and a phase of mountain glacier advance (Wanner *et al*., 2008)." And following the LIA they identify the transition period of AD 1850-2004 that takes the region into the Current Warm Period.

In discussing all three of these distinctive periods, they say that "a comparison of the main hydrological transitions during the last 800 years in Lake Estanya and solar irradiance (Bard *et al*., 2000) reveals that lower lake levels dominated during periods of enhanced solar activity (MWP and post-1850 AD) and higher lake levels during periods of diminished solar activity (LIA)." And *within* the LIA, they note that periods of higher lake levels or evidence of increased water balance occurred during the solar minima of Wolf (AD 1282-1342), Sporer (AD 1460-1550), Maunder (AD 1645-1715) and Dalton (AD 1790-1830).

In light of these several observations it would appear that the multi-centennial climate oscillation uncovered by Morellon *et al*. has been driven by a similar oscillation in solar activity, as well as by multi-decadal solar activity *fluctuations* superimposed upon that longer-period *oscillation*. And these relationships suggest that there is little reason to attribute 20th-century global warming to the concomitant increase in the air's $CO_2$ content. Natural variability appears quite capable of explaining it all.

In conclusion, paleoclimatic studies from Europe provide more evidence for the global reality of solar-induced temperature oscillations pervading both glacial and interglacial periods, which oscillations are looking more and more likely as the primary forcing agent responsible for driving temperature change during the Current Warm Period. The concurrent historical increase in the air's $CO_2$ content, on the other hand, is likely little more than a bit player.

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