Medieval Warm Period in China

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MEDIEVAL WARM PERIOD IN CHINA

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The Medieval Warm Period (MWP) was a global climatic anomaly that encompassed a few centuries on either side of AD 1000, when temperatures in many parts of the world were even warmer than they are currently. The degree of warmth and associated changes in precipitation, however, varied from region to region and from time to time; and, therefore, the MWP was manifest differently in different parts of the planet. In this Summary, what occurred in China is reviewed.

Using a variety of climate records derived from peat, lake sediment, ice core, tree-ring and other proxy sources, Yang *et al*. (2002)[1] identified a period of exceptional warmth throughout China between AD 800 and 1100. Yafeng *et al*. (1999)[2] also observed a warm period between AD 970 and 1510 in $\delta^{18}O$ data obtained from the Guliya ice cap of the Qinghai-Tibet Plateau, while Hong *et al*. (2000)[3] developed a 6000-year $\delta^{18}O$ record from plant cellulose deposited in a peat bog in the Jilin Province (42° 20' N, 126° 22' E), within which they found evidence of "an obvious warm period represented by the high $\delta^{18}O$ from around AD 1100 to 1200 which may correspond to the Medieval Warm Epoch of Europe."

Xu *et al*. (2002)[4] also determined, from a study of plant cellulose $\delta^{18}O$ variations in cores retrieved from peat deposits at the northeastern edge of the Qinghai-Tibet Plateau, that from AD 1100-1300 "the $\delta^{18}O$ of Hongyuan peat cellulose increased, consistent with that of Jinchuan peat cellulose and corresponding to the 'Medieval Warm Period'." In addition, Qian and Zhu (2005)[5] analyzed the thickness of laminae in a stalagmite found in Shihua Cave, Beijing, from whence they inferred the existence of a relatively wet period running from approximately AD 940 to 1200.

Hong *et al*. (2000) had also reported that, at the time of the MWP, "the northern boundary of the cultivation of citrus tree (*Citrus reticulata* Blanco) and *Boehmeria nivea* (a perennial herb), both subtropical and thermophilous plants, moved gradually into the northern part of China, where it has been estimated that the annual mean temperature was 0.9-1.0°C higher than at present." And considering the climatic conditions required to successfully grow these plants, they further noted that annual mean temperatures in that part of the country during the Medieval Warm Period 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, citing De'er (1994).

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1 http://www.co2science.org/articles/V5/N39/C2.php.
2 http://www.co2science.org/articles/V4/N11/C3.php.
3 http://www.co2science.org/articles/V3/N13/C4.php.
4 http://www.co2science.org/articles/V6/N4/C3.php.
5 http://www.co2science.org/articles/V5/N15/C1.php.

Chu *et al*. (2002)[6] studied the geochemistry of 1400 years of dated sediments recovered from seven cores taken from three locations in Lake Huguangyan (21°9'N, 110°17'E) on the low-lying Leizhou Peninsula in the tropical region of South China, together with information about the presence of snow, sleet, frost and frozen rivers over the past 1000 years obtained from historical documents. And in doing so, they discovered, as they put it, that "recent publications based on the phenological phenomena, distribution patterns of subtropical plants and cold events (Wang and Gong, 2000; Man, 1998; Wu and Dang, 1998; Zhang, 1994) argue for a warm period from the beginning of the tenth century AD to the late thirteenth century AD," as their own data also suggested. In addition, they noted there was a major dry period from AD 880-1260, and that "local historical chronicles support these data, suggesting that the climate of tropical South China was dry during the 'Mediaeval Warm Period'."

One year later, Paulsen *et al*. (2003)[7] used high-resolution $\delta^{13}C$ and $\delta^{18}O$ data derived from a stalagmite found in Buddha Cave (33°40'N, 109°05'E) to infer changes in climate in central China over the prior 1270 years; and among the climatic episodes evident in their data were, in their words, "those corresponding to the Medieval Warm Period, Little Ice Age and 20th-century warming, lending support to the global extent of these events." And in terms of timing, the dry-then-wet-then-dry-again MWP began about AD 965 and continued to approximately AD 1475.

Also working with a stalagmite, this one from Jingdong Cave about 90 km northeast of Beijing, and in the same year, Ma *et al*. (2003)[8] assessed the climatic history of the past 3000 years at 100-year intervals on the basis of $\delta^{18}O$ data, the Mg/Sr ratio, and the solid-liquid distribution coefficient of Mg. This work revealed, as they describe it, that between 200 and 500 years ago, "air temperature was about 1.2°C lower than that of the present," but that between 1000 and 1300 ago, there was an equally aberrant but *warm* period that "corresponded to the Medieval Warm Period in Europe."

Based on 200 sets of phenological and meteorological records extracted from a number of historical sources, many of which are described by Gong and Chen (1980), Man (1990, 2004), Sheng (1990) and Wen and Wen (1996), Ge *et al*. (2003)[9] produced a 2000-year history of winter half-year temperature (October to April, when CO_2-induced global warming is projected to be most evident) for the region of China bounded by latitudes 27 and 40°N and longitudes 107 and 120°E. This expansive work revealed a significant warm epoch that lasted from the AD 570s to the 1310s, the peak warmth of which was "about 0.3-0.6°C higher than present for 30-year periods, but over 0.9°C warmer on a 10-year basis."

In yet another contemporaneous study, Bao *et al*. (2003)[10] utilized proxy climate records (ice-core $\delta^{18}O$, peat-cellulose $\delta^{18}O$, tree-ring widths, tree-ring stable carbon isotopes, total organic carbon, lake water temperatures, glacier fluctuations, ice-core CH_4, magnetic parameters, pollen assemblages and sedimentary pigments) obtained from twenty prior studies to derive a

[6] http://www.co2science.org/articles/V5/N46/C1.php.
[7] http://www.co2science.org/articles/V6/N28/C3.php.
[8] http://www.co2science.org/articles/V6/N34/C2.php.
[9] http://www.co2science.org/articles/V6/N47/EDIT.php.
[10] http://www.co2science.org/articles/V6/N48/EDIT.php.

2000-year temperature history of the northeastern, southern and western sections of the Tibetan Plateau. In each case, there was more than one prior 50-year period of time when the mean temperature of each region was warmer than it was over the most recent 50-year period. In the case of the northeastern sector of the Plateau, all of the maximum-warmth intervals occurred during the Medieval Warm Period; while in the case of the western sector, they occurred near the end of the Roman Warm Period, and in the case of the southern sector they occurred during both warm periods.

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Also publishing in the same year, Zhu *et al*. (2003)[11] described their work with a sediment core that had been extracted from lake Chen Co in the Yamzhog Yum Co drainage basin of southern Tibet in the delta of the Kaluxiong River. This core was dated by comparing sedimentary rates measured by ^{210}Pb and absolute time horizons measured by ^{137}Cs (Wan 1997, 1999; Benoit and Rozan, 2001), after which several environmentally-related magnetic properties of sections of the core were measured and analyzed. This work revealed what they called a "Middle Ages Warm-period" (around ca. 1120-1370 AD) that was followed by what they described as "an intensively cold stage during ca. 1550-1690 AD, a cold-humid stage from ca. 1690-1900 AD and a warm-dry stage since ca. 1900 AD." But they note that the warm period of the past century was not as warm as the earlier 250-year warm period of the Middle Ages.

One year later, based on a relationship between the shell-length of the ostracod *Limnocythere inopinata* and the salinity of the water in which it lives - which was developed by Yin *et al*. (2001) from data gathered from fifty lakes of different salinities scattered across the Tibetan Plateau - the salinity history of Qinghai Lake (the largest inland saline lake in China) was reconstructed for the period AD 1100-2000 by Zhang *et al*. (2004)[12], who used ostracod shell-length data derived from a 114-cm sediment core to discover that "low salinity during 1160-1290 AD showed the humid climate condition [of] the Medieval Warm Period in this area, while the high salinity during 1410-1540 AD, 1610-1670 AD and 1770-1850 AD [prevailed during] the three cold pulses of the Little Ice Age with a dry climate condition," where the

[11] http://www.co2science.org/articles/V7/N12/C2.php.
[12] http://www.co2science.org/articles/V7/N38/C2.php.

evidence for the occurrence of these warm and cold intervals came from the climate change studies of Yao *et al*. (1990) and Wang (2001).

Of special interest in this regard is the fact that Qinghai Lake's modern salinity has not even reached the *halfway* point of the distance between the near-record high salinity of the last cold extreme of the Little Ice Age and the record low salinity experienced during the Medieval Warm Period, which suggests that the level of warmth recently experienced in this region of China is nowhere near that experienced there during the Medieval Warm Period, when, of course, there was much less CO_2 in the air than there is currently. Also, it is instructive to note that the salinity drop that marks the "beginning of the end" of the last stage of the Little Ice Age began sometime prior to 1850, in harmony with the Northern Hemisphere temperature history of Esper *et al*. (2002), but in striking contradiction of the Northern Hemisphere temperature history of Mann *et al*. (1998, 1999), which does not depict any increase in temperature until after 1910, some 60 years later.

Contemporaneously, Ge *et al*. (2004)[13] introduced their important study of two thousand years of reconstructed winter half-year temperatures of eastern China by stating that "it is important to study the temperature change during the past 2000 years for understanding the issues such as the greenhouse effect and global warming induced by human activities," stating additionally that "China has advantages in reconstructing historical climate change for its abundant documented historical records and other natural evidence obtained from tree rings, lake sediments, ice cores, and stalagmites." That said, what did they find?

Perhaps the five climate scientists' most fundamental finding was the existence of "an about 1350-year periodicity in the historical temperature change," which revealed a number of multi-century warm and cold periods. Preceding the Modern Warm Period, for example, was the Little Ice Age (LIA), which "in China," in their words, "began in the early 14th century (the 1320s) and ended in the beginning of the 20th century (the 1910s)." It included four cold stages and three short warming phases. The LIA, in turn, was preceded by the Medieval Warm Period, which Ge *et al*. say "began in the 930s and ended in the 1310s." It was composed of two warm stages, each of over 100 years duration, and a shorter intervening cold stage.

Continuing further back in time, the Chinese scientists found a cold period from the 780s to the 920s and a warm period from the 570s to the 770s, which was in turn preceded by a cold period from the 210s to the 560s, which they say "was the only one comparable with [the] LIA for the past 2000 years." This ultra-cold spell, of course, was the Dark Ages Cold Period that followed on the heels of the Roman Warm Period.

Since one of the purposes of their study was "to test whether the warming in the 20th century has exceeded the maximum magnitude in the past 2000 years," Ge *et al*. considered this question in some detail. At the centennial scale, they report that "the temperature anomaly of the 20th century is not only lower than that of the later warm stage of the Medieval Warm Period (the 1200s~1310s), but also slightly lower than that of the warm period in the Sui and

[13] http://www.co2science.org/articles/V8/N12/EDIT.php.

Tang dynasties (the 570s~770s) and the early warm stage of the Medieval Warm Period (the 930s~1100s)."

On a 30-year scale, they likewise report that "the warmest 30-year temperature anomaly in the 20th century is roughly equal to the warmest 30-year one in the Sui and Tang dynasties warm period, but a little lower than that of the Medieval Warm Period." And on the decadal scale, they say that "the warmest decadal temperature anomaly in the 20th century is approximately at the same level of the warmest decade of the early stage of the Medieval Warm Period."

Last of all, Ge *et al*. additionally note that "although the warming rate in the early 20th century has reached 1.1°C per century, such a rapid change is not unique during the alternation from the cold period[s] to the warm period[s]" of the prior 2000 years. For example, they report that the per-century warming rate from the 480s~500s to the 570s~590s was 1.3°C, while that from the 1140s~1160s to the 1230s~1250s was 1.4°C, and that from the 1650s~1670s to the 1740s~1760s was 1.2°C.

In discussing the implications of these several observations of pre-20th-century faster-than-recent warmings and higher-than-recent temperatures, Ge *et al*. say that their analysis "gives a different viewpoint from that 'the 20th century is the warmest century in the past 1000 years', presented by IPCC, and is of great significance for better understanding the phenomena of the greenhouse effect and global warming etc. induced by human activities." And what would that "different viewpoint" be? In the words of Ge *et al*., "the temperature of the 20th century in eastern China is still within the threshold of the variability of the last 2000 years," which observation clearly indicates that the Chinese data provide no evidence for the hypothesis that the eastern part of the country's 20th-century warming - *or even a small part of it* - was human-induced.

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Publishing concurrently, Jin *et al*. (2004)[14] analyzed percent organic carbon and Rb/Sr ratios in a sediment core extracted from the deepest part of Daihai Lake (112°32'-112°48'E, 40°28'-40°39'N) in Inner Mongolia, which is described by them as being located "in the transitional zone between semi-arid and semi-humid conditions that is sensitive to East Asian monsoon variability." And in doing so, they found that the data they obtained "support two distinct Little Ice Age cooling events centered at ~850 yr BP and ~150 yr BP," as well as "the Medieval Warm Period between 1200 and 900 yr BP," which they say "was warmer than the present, with higher chemical weathering than at present," additionally citing the study of Jin *et al*. (2002) to this effect.

[14] http://www.co2science.org/articles/V8/N15/C1.php.

Two years later, Liu, Z. *et al*. (2006)[15] developed a quantitative reconstruction of temperature changes over the past 3500 years based on alkenone distribution patterns in a sediment core retrieved from China's Lake Qinghai (37°N, 100°E), based on the alkenone unsaturation index ($U^{k}37$) and its simplified form ($U^{k'}37$), which they say "have been calibrated to growth temperatures of marine alkenone producers (Prahl *et al*., 1988)" and "to temperature changes in lacustrine settings on a regional scale (Chu *et al*., 2005; Zink *et al*., 2001)." And as a result of this effort, they were able to state that their temperature record "based on $U^{k'}37$ clearly shows oscillating warm/cold periods," with periods at 0-200 yr BP, 500-1100 yr BP and 1500-2000 yr BP that were relatively warm and "could be related to the 20th-century warm period, the Medieval Warm Period, and the Roman Warm Period," while "cold periods at 200-500 yr BP and 1100-1500 yr BP corresponded to the Little Ice Age and the Dark Ages Cold Period." In addition, they say their data indicate that the peak warmth of the Roman Warm Period exceeded the temperature of the latter part of the 20th century by about 0.4°C, while the peak warmth of the Medieval Warm Period exceeded the temperature of the latter part of the 20th century by nearly 1°C. And the existence of this millennial-scale oscillation of climate, with its prior periods of higher-than-current temperatures, clearly demonstrates that there is nothing unusual about earth's present climatic state, *except* that it is surprisingly *cool*, considering how much more CO_2 there is in the air nowadays than there was during the *warmer* Medieval and Roman Warm Periods.

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Contemporaneously, the "other" Liu team (Liu, Y. *et al*., 2006[16]) used three well-dated *Sabina Przewalskii* ring-width chronologies derived from a total of 77 trees growing in three locations near Dulan, China, on the northeastern Tibetan Plateau (36.0-36.3°N, 98.2-98.6°E), to reconstruct annual precipitation variations in that region over the period AD 850-2002, after which they compared their results with instrumental temperature data for the same region over the period of temporal overlap.

Working with 10-year moving averages, the thirteen scientists found that precipitation and temperature were "significantly correlated with r = 0.85 (p<0.0001), after the precipitation lagged temperature for 2 years." Hence, they went on to produce a 40-year moving average curve that was "significantly correlated with seven temperature curves of the Northern Hemisphere," which led them to conclude that their 40-year smoothed reconstruction "could be regarded as the millenary temperature curve for the northeastern Tibetan Plateau."

[15] http://www.co2science.org/articles/V10/N15/C1.php.
[16] http://www.co2science.org/articles/V9/N39/C2.php.

In viewing Liu, Y. *et al*.'s final "millenary temperature curve," it can readily be seen that the 40-year-averaged temperature proxies in the vicinity of AD 915 are definitely greater than those at the end of the 20th century, which comprise the next highest peak of the record. Thus, this study represents another specific instance where peak temperatures of the Medieval Warm Period likely were greater than peak temperatures of the 20th century. And as a result, it becomes ever more clear that there is no compelling reason to believe that 20th-century global warming was in any way dependent upon the 20th-century increase in atmospheric CO_2 concentration, which was far, far less a thousand or more years ago, when it was even warmer than it is today.

Moving ahead one more year, Jin *et al*. (2007)[17] studied "the evolutionary history of permafrost in the central and eastern Qinghai-Tibetan Plateau since the end of the late Pleistocene, using relict permafrost and periglacial phenomena along the Qinghai-Tibet Highway from Gomud to Lhasa, the Qinghai-Kang (western Sichuan) Highway from Xi'ning to Yusu, adjacent areas, and the Xinjiang-Tibet Highway from Yecheng to Lhasa." Among their many findings were their descriptions of (1) permafrost and deduced environmental conditions during "the Megathermal period in the middle Holocene (~8500-7000 to ~4000-3000 years BP)," as well as (2) "the warm period in the later Holocene (1000 to 500 years BP)." And in comparing environmental and permafrost characteristics of those periods of elevated warmth with those of the present, the three researchers from the Chinese Academy of Sciences report that during the Megathermal period of the middle Holocene, "the total areas of permafrost then were about 40-50% of those at present," while "mean annual air temperatures were ~2-3°C higher." Likewise, they report that during the warm period of the late Holocene, "the retreating of permafrost resulted in a total permafrost area of ~20-30% less than at present," while mean annual air temperatures were "1.5-2.0°C warmer than at present."

Contemporaneously, and working with ring-width and $\delta^{13}C$ data derived from long-lived Qilian juniper (*Sabina przewalskii* Kom.) trees located in the middle Qilian Mountains of China (37-39°N, ~99-103°E) at the convergence of the Qinghai-Xizang Plateau, the Inner Mongolia-Xinjiang Plateau and the Loess Plateau, Liu *et al*. (2007)[18] reconstructed a 1000-year temperature history of the region that captured about 75% of the temperature variance over the calibration period 1960-2000 and correlated extremely well with the Northern Hemisphere temperature reconstruction of Esper *et al*. (2002). As the six scientists describe it, the two sets of reconstructed temperature data (theirs and Esper *et al*.'s) "reveal that the Medieval Warm Period and Little Ice Age were synchronous in China and the Northern Hemisphere." In addition, they note that the two warmest intervals in their temperature reconstruction were 1060-1150 and 1900-2000, with corresponding peaks occurring around 1100 and 1999 that are essentially identical. However, their results do not extend as far back in time as those of Esper *et al*., which rise to their highest level prior to the time that Liu *et al*.'s history begins. And in light of that fact, Liu *et al*. conclude that their reconstructed temperature history "has not included all of the Medieval Warm Period and, perhaps, not even its warmest period."

[17] http://www.co2science.org/articles/V10/N46/C2.php.
[18] http://www.co2science.org/articles/V11/N10/C2.php.

Also publishing in the same year, Ge *et al*. (2007)[19] reviewed proxy temperature records of China that spanned the entire Holocene, while focusing most intensively on the last two millennia. This they did because it is widely believed that "increasing concentrations of greenhouse gases in the atmosphere are causing higher global atmospheric temperatures," and, therefore, "paleoclimate data are essential for both checking the predictions of climate models and characterizing the natural variability of [earth's] climate system." And as a result of this effort, they found that the warmest period of the Holocene occurred between 9600 and 6200 years ago, during portions of which, in the words of Ge *et al*., temperatures "were about 1°C-5°C higher than the present in China." They also reported that "during the past two millennia, a warming trend in the 20th century was clearly detected, but the warming magnitude was smaller than the maximum level of the Medieval Warm Period," which they describe as having occurred between AD 900 and 1300. What is more, they say that "the modern warm period has lasted [only] 20 years from 1987 to 2006," and that the annual mean temperature series of China since AD 1880 indicates that the country was actually *warmer in the mid-1940s than it was at the time of their study*.

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One year later, Tan *et al*. (2008)[20] developed a precipitation history of the Longxi area of the Tibetan Plateau's northeast margin since AD 960 based on an analysis of Chinese historical records, after which they compared the result with the same-period Northern Hemisphere temperature record and contemporaneous atmospheric ^{14}C and ^{10}Be histories. This work revealed, in their words, that "high precipitation of Longxi corresponds to high temperature of the Northern Hemisphere, and low precipitation of Longxi corresponds to low temperature of the Northern Hemisphere." And, therefore, they used their precipitation record to infer a Medieval Warm Period that stretched from about AD 960 to 1230, with temperature peaks in the vicinity of AD 1000 and 1215 that clearly exceeded the 20th-century peak temperature of the Current Warm Period. They also found "good coherences among the precipitation variations of Longxi and variations of atmospheric ^{14}C concentration, the averaged ^{10}Be record and the reconstructed solar modulation record," which findings harmonize, in their words, with "numerous studies [that] show that solar activity

[19] http://www.co2science.org/articles/V11/N11/C2.php.
[20] http://www.co2science.org/articles/V11/N25/C3.php.

is the main force that drives regional climate changes in the Holocene," in support of which statement they attached 22 other scientific references. Ultimately, then, the four scientists concluded that the "synchronous variations between Longxi precipitation and Northern Hemisphere temperature may be ascribed to solar activity, " which apparently produced a Medieval Warm Period that was both longer and stronger than what has been experienced to date during the Current Warm Period in the northeast margin of the Tibetan Plateau.

About this same time, working with a stalagmite found in China's Wanxiang Cave (33°19'N, 105°00'E) - which Zhang *et al*. (2008)[21] say is located on the fringes of the area currently affected by the Asian Monsoon and is thus sensitive to (and integrates broad changes in) that annually-recurring phenomenon - the seventeen researchers developed a $\delta^{18}O$ record with an average resolution of 2.5 years that "largely anti-correlates with precipitation" and runs continuously from AD 190 to 2003. Even more important than establishing its close ties with precipitation, however, Zhang *et al*. demonstrated that the record "exhibits a series of centennial to multi-centennial fluctuations broadly similar to those documented in Northern Hemisphere temperature reconstructions, including the Current Warm Period, Little Ice Age, Medieval Warm Period and Dark Age Cold Period." And when one compares the peak warmth thus implied by their data for the Current and Medieval Warm Periods, it is readily seen that the Medieval Warm Period comes out on top as having been the warmer of the two.

In another important set of comparisons, Zhang *et al*. superimposed their $\delta^{18}O$ record upon individual plots of Northern Hemispheric temperature as derived by Esper *et al*. (2002), Moberg *et al*. (2003) and Mann and Jones (2003). In the first of these comparisons, the two records closely mimicked each other, with both of them indicating greater peak warmth during the Medieval Warm Period than during the Current Warm Period. The same was likewise true of the second comparison; and in the third comparison the records also closely mimicked each other over the vast majority of their expanse. Over the last decades of the 20th century, however, the temperatures of the Mann and Jones record rise far above the temperatures implied by the Zhang *et al*. record (and, therefore, those of the Esper *et al*. and Moberg *et al*. records as well), which suggests that this *anomalous behavior* of the Mann and Jones record is likely indicative of its possessing a *major defect* that is not found in the other three datasets. And that defect is likely Mann and Jones' use of *directly-measured* as opposed to *reconstructed* temperatures over their record's last few decades, which leads to their anomalous end-point "oranges" not telling the same story as that told by everyone else's "apples."

Another point of great interest about the Zhang *et al*. record is that it "correlates with solar variability, Northern Hemisphere and Chinese temperature, Alpine glacial retreat, and Chinese cultural changes." And since none of the last four phenomena can influence the first one, it stands to reason that *solar variability* is likely what has driven the variations in every other factor mentioned. In fact, in a commentary that accompanied Zhang *et al*.'s article, Kerr (2008) stated that the Zhang *et al*. record had been described by other researchers as "amazing," "fabulous," and "phenomenal," and that it "provides the strongest evidence yet for a link among sun, climate, and culture." In addition, it provides equally strong evidence for *at least*

[21] http://www.co2science.org/articles/V11/N53/EDIT.php.

the Northern-Hemispheric extent of the Medieval Warm Period and its greater and more persistent warmth than that of the Current Warm Period.

Also publishing in the same year, Ma *et al*. (2008)[22] analyzed multi-proxy data, including, in their words, "^{14}C, grain size, microfossil, plant seeds, and geochemical elements" - which they obtained from sediment retrieved from excavations made in the dry lake bed of Lop Nur China's West Lake (40°27'129" N, 90°20'083" E) - in order "to amply discuss," as they describe it, "the climate and environment changes during the MWP," or Medieval Warm Period, which they identified as occurring between AD 900 and 1300. This effort indicated that the "sedimentary environment was stable around the MWP, with weak storm effect," while "the upper and lower sediments showed frequent strong storm effect." They also report that "microfossils and plant seeds were abundant in this stage [MWP], which indicated a warm and humid fresh or brackish lake environment." Thereafter, they say that "in the late period [AD 1300 to 1650], the environment turned worse, storm effect was intensified ... and the climate began to dry, leading to shriveling and death of many plants such as red willows." Over the period AD 1100 to 1300, therefore, Ma *et al*. concluded that "the environment was the best," stating that "temperature was almost the same [as] or a little higher than nowadays," providing yet another example of the widespread occurrence of the Medieval Warm Period which they describe as "one of the most significant climate episodes in the world."

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Finally moving ahead a year, Yang *et al*. (2009)[23] synthesized proxy records of temperature and precipitation in arid central Asia over the past two thousand years, focusing on the relationship between temperature and precipitation on timescales ranging from annual to centennial. With respect to *temperature*, they report that "the most striking features are the existence of the Medieval Warm Period (MWP) and the Little Ice Age (LIA)," as well as the earlier Roman Warm Period (RWP) and Dark Ages Cold Period (DACP), plus what they call "a recent warming into the 20th century" that they identify as the Current Warm Period (CWP). As for *precipitation*, the five researchers say that the MWP "corresponded to an anomalously dry period whereas the cold LIA coincided with an extremely wet condition." Once again, therefore, we have a substantive body of evidence for the *natural, non-CO_2-induced, millennial cycling of climate* that has alternately brought the world into - and then out of - the Roman Warm Period, the Dark Ages Cold Period, the Medieval Warm Period and the Little Ice Age, which gives one extremely good reason to believe that the continuation of that cycle has likely brought the planet into the Current Warm Period, and that this natural phenomenon will ultimately bring the world out of its latest extended "heat wave," sometime in the future.

[22] http://www.co2science.org/articles/V12/N1/C2.php.
[23] http://www.co2science.org/articles/V12/N20/C3.php.

Also hard at work around this time were Hong *et al*. (2009)[24], who wrote of the Medieval Warm Period 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 that "a universal concern in academic circles is [1] whether it also existed outside the European region and [2] whether it is a common phenomenon." Thus, 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 them to develop "a peat cellulose $\delta^{18}O$ temperature proxy record proximately existing for 14,000 years."

These efforts revealed, first of all, 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 that "the temperature on the Chinese mainland was distinctly warmer during the MWP." In fact, they say that MWP temperatures were as much as "0.9-1.0°C higher than modern temperatures (Zhang, 1994)."

Secondly, Hong *et al*. write that "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 $\delta^{18}O$." And they state that "these cooling events show that the repeatedly occurring temperature cooling [and warming] 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 that the recurring warming and cooling did indeed occur "outside the European region" and that it truly was "a common phenomenon."

Last of all, Hong *et al*. (2009) write that the earlier paper of Hong *et al*. (2000) - which describes a 6,000-year peat cellulose $\delta^{18}O$ record derived from nearby Jinchuan Town, Huinan County, Jilin Province, China (42°20'N, 126°22'E) - identified $\delta^{18}O$ periodicities of 86, 93, 101, 110, 127, 132, 140, 155, 207, 245, 311, 590, 820 and 1046 years, which they indicate "are similar to those detected in solar excursions," and which they consider "further evidence for a close relationship between solar activity and climate variations on timescales of decades to centuries."

These latter findings were shortly thereafter highly praised by Fairbridge (2001), who noted that "almost identical equivalents are seen in solar emission periodicities and their harmonics, e.g., 86.884 years = 40 x 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 that "Hong *et al*. deserve the appreciation of the entire Holocene community." And so it is that the case for a *global* and *solar-induced* Medieval Warm Period grows ever stronger, as it also does for *all* of the similar warm periods that preceded it over the prior 13,000 years, which makes the case for a *similar* origin for the Current Warm Period ever more likely as well.

[24] http://www.co2science.org/articles/V13/N37/C1.php.

Then there was the study of Liu *et al*. (2009)[25]. Based on Qilian juniper (*Sabina przewalskii*) tree-ring width chronologies obtained from both living trees and archaeological wood located in the mid-eastern Tibetan Plateau (which data were calibrated against measured air temperatures for the period AD 1958-2000), Liu *et al*. obtained a mean annual temperature history of the region spanning the 2,485-year period 484 BC - AD 2000, which they demonstrated to be well correlated with several temperature histories of the Northern Hemisphere. And in contrast to climate-alarmist claims that temperatures near the end of the 20th century (which have not since been eclipsed) were unprecedented over the past couple of millennia, the eight researchers reported that there were *four* periods that had average temperatures similar to "or even higher than" the mean of AD 1970-2000, beginning with the warm period AD 401-413, which they say "was the warmest period within the last 2.5 thousand years." And in further support of their "even higher than" statement, they noted that an archaeological documentary record from Loulan in Xinjiang province showed that pomegranate (a vitamin-C rich fruit) was employed as currency during the Eastern Jin Dynasty (AD 317-589), because the appearance of pomegranate during that period "suggests that the temperature at that time was higher than nowadays," citing Zhang and Zhang (2006). In addition, they indicate that the *rate* of warming that led to the early ultra-warm period of their record was "unprecedented in the last 2500 years." And the last of the four ultra-warm periods was also slightly warmer than it was at the end of the 20th century.

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On another note, Liu *et al*. report that the high-temperature intervals of the AD 400-1000 period in the mid-eastern Tibetan Plateau were what could be described as *relatively good times*, as they indicate that the downfalls of most of the major dynasties in China coincided with intervals of low temperature, or at least the *beginnings* of their downfalls did, citing in this regard the demise of the Qin, Three Kingdoms, Tang, Song (North and South), Yuan, Ming and Qing Dynasties. And so we have yet another set of instances where "warm" was nearly always better than "cold," and where pre-20th century warmth was equal to, or even greater than, earth's current level of warmth.

With the passage of yet another year, Ge *et al*. (2010)[26] wrote that "knowledge of past climate can improve our understanding of natural climate variability and also help address the question of whether modern climate change is unprecedented in a long-term context," which is perhaps the most burning scientific question of our day. In addition, they said that "regional proxy temperature series with lengths of 500-2000 years from China have been reconstructed using tree rings with 1-3 year temporal resolution, annually resolved stalagmites, decadally resolved ice-core information, historical documents with temporal resolution of 10-30 years, and lake

[25] http://www.co2science.org/articles/V15/N10/C2.php.
[26] http://www.co2science.org/articles/V13/N17/C2.php.

sediments resolving decadal to century time scales," noting that "these proxies provide quantitative estimates of past climate through statistical calibration against instrumental temperature measurements."

Based on these findings, and dividing the country into five sections, Ge *et al*. developed three 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 only went back about 550 years (Southeast). And in the case of the three sections of China that extended through the Medieval Warm Period and the one that extended into but not through it, the six scientists report that (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 that these two periods were actually *warmer* than the last decades of the 20th century, and (4) in the Northwest, "comparable warm conditions in the late 20th century are also found around the decade 1100s."

Since portions of two of the four sections of China for which temperature reconstructions extended far enough back in time to sample the Medieval Warm Period exhibited temperatures comparable to those of the late 20th century, and since portions of two other sections actually revealed parts of the Medieval Warm Period to have been *warmer* than the late 20th century, it is clear that there is nothing unusual, unnatural or unprecedented about the country's current level of warmth. Thus, by the reasoning set forth by Ge *et al*. in the introduction to their study, there is no compelling reason to attribute late 20th-century warmth in that sprawling country to 20th-century increases in the air's CO_2 concentration, nor to attribute it to concomitant increases in any other greenhouse gases.

One year later, Zhou (2011)[27] - who is with the State Key Laboratory of Severe Weather of the Chinese Academy of Meteorological Sciences in Beijing - wrote in an introductory editorial in a special issue of the *Chinese Science Bulletin* (October 2011) that "research on global climate change has been at the frontier of the contemporary sciences," and within this context he further stated that "debate has focused on whether the greenhouse effect produced by human activities is a major factor responsible for modern climate warming."

After investigating this question, Zhou reported that "in 2009, the major project 'Research on tree-ring and millennium climate change in China' was implemented under the support of the National Natural Science Foundation of China." And noting that eight articles published in this special issue of the *Bulletin* "present partly preliminary results obtained by the pht articles "reveal some characteristics and regularities of changes in temperature and precipitation in China and in East Asian monsoons over the past 1000 years" that qualify as "notable conclusions," of which, however, he lists *only two*. But those two are extremely important, since he finds that (1) "temperatures in the Medieval Warm Period are comparable to those in

[27] http://www.co2science.org/articles/V15/N3/C3.php.

the current warm period over China," and that (2) "the effect of solar activity on climate cannot be neglected in any period of the millennium."

Last of all and most recently, Wang *et al*. (2012)[28], in an initial explanation about why they did what they did, write that "lakes are excellent sensors of environmental change," and that "lake sediments can provide well-resolved records of change on different time scales," noting that "crater and maar lakes are especially sensitive to climate change because typically they have a small catchment area and limited inflow/outflow." Moreover, they say that such lakes "often provide high-resolution records due to limnological processes favorable to the development and preservation of seasonally laminated sediments," citing Zolitschka *et al*. (2000) in this regard. And they add that "diatoms are excellent indicators of environmental conditions and have been widely used to reconstruct Holocene climate variability," citing Smol and Cumming (2000), Battarbee *et al*. (2001) and Mackay *et al*. (2003).

> *Wang et al.'s work demonstrated – for yet another part of the planet – that late 20th-century warmth even with the help of an extra 100 ppm of CO_2, was less than that of the MWP, which makes it extremely difficult to believe that earth's current level of warmth largely owes its existence to anthropogenic CO_2 emissions, as the world's climate alarmists continue to claim it does.*

Focusing on Lake Erlongwan, one of eight maar lakes in the Long Gang Volcanic Field of Jilin Province, NE China (42°18'N, 126°21'E) - which they describe as a closed dimictic lake that occupies an area of 0.3 km^2 and has a small catchment (0.4 km^2) with no natural inflows or outflow - Wang *et al*. thus retrieved a 66.5-cm-long sediment core from its central, deepest region in 2001, which they dated with the help of radiometric ^{210}Pb, ^{137}Cs and ^{14}C analyses, and which they analyzed for diatom species and quantities. Although they note, in this regard, that diatoms "are generally not known to be very sensitive to water temperature," they indicate that "climate affects the physical properties of the lake water column, especially as it controls the seasonal durations of ice cover, water column mixing and stratification, which all have profound effects on the availability of nutrients and light necessary for algal photosynthesis and growth," so that "climate has an indirect influence on the composition and productivity of phytoplankton, especially non-motile organisms such as diatoms." And it was these facts that thus allowed them to make "a detailed qualitative paleolimnological interpretation of the Lake Erlongwan sediment sequence based mainly on the growing body of literature that focuses on the ecology of planktonic diatoms, especially their responses to climate-driven changes in limnology."

In carrying out their plan, the ten researchers found that "three intervals were identified by their diatom assemblages and correspond within dating uncertainties to the Medieval Warm Period, the Little Ice Age and the 20th century warming trend." During the MWP, they further

[28] http://www.co2science.org/articles/V15/N43/C2.php.

indicate that "the duration of the summer was longer while the spring and autumn were shorter than the 20th century." And they unequivocally declare that "the period between ca. AD 1150 and 1200 was the warmest interval of the past 1000 years." Therefore, in view of the fact that prior to the time of their study there was no record of mean annual temperatures from NE China covering the past 1000 years with the same resolution as their diatom record, Wang *et al*.'s work demonstrated - for yet another part of the planet - that late 20th-century warmth *even with the help of an extra 100 ppm of* CO_2, was less than that of the MWP, which makes it *extremely* difficult to believe that earth's current level of warmth largely owes its existence to anthropogenic CO_2 emissions, as the world's climate alarmists continue to claim it does.

In concluding this summary, it should be evident from the results of the many studies reviewed herein that for a considerable amount of time during the Medieval Warm Period, most (if not all) parts of China exhibited warmer conditions than those of modern times. And since those earlier high temperatures were obviously caused by something other than elevated atmospheric CO_2 concentrations, whatever was responsible for them could easily be responsible for the warmth of today. Indeed, evidence piled upon evidence speaks to the reality of a *global* millennial-scale oscillation of climate that is totally independent of the air's CO_2 concentration. And, therefore, there is every reason to believe that the most recent warming phase of this cycle, which led to the demise of the Little Ice Age and the birth of the Current Warm Period, was totally *natural* and *not* the result of the coincidental increase in the air's CO_2 content that was produced by the burning of the fossil fuels that drove the engines of the Industrial Revolution.

REFERENCES

Bao, Y., Brauning, A. and Yafeng, S. 2003. Late Holocene temperature fluctuations on the Tibetan Plateau. *Quaternary Science Reviews* **22**: 2335-2344.

Battarbee, R.W., Jones, V.J., Flower, B.P., Cameron, N.G., Bennion, H., Carvalho, L. and Juggins, S. 2001. Diatoms. In: Smol, J.P., Birks, H.J.B. and Last, W.M. (Eds.). *Tracking Environmental Change Using Lake Sediments*. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 155-201.

Benoit, G. and Rozan, T.F. 2001. ^{210}Pb and ^{137}Cs dating methods in lakes: a retrospective study. *Journal of Paleoliminology* **25**: 455-465.

Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M.N., Showers, W., Hoffmann, S., Lotti-Bond, R., Hajdas, I. and Bonani, G. 2001. Persistent solar influence on North Atlantic climate during the Holocene. *Science* **294**: 2130-2136.

Bond, G., Showers, W., Cheseby, M., Lotti, R., Almasi, P., deMenocal, P., Priore, P., Cullen, H., Hajdas, I. and Bonani, G. 1997. A pervasive millennial-scale cycle in North Atlantic Holocene and Glacial climate. *Science* **278**: 1257-1266.

Chu, G., Liu, J., Sun, Q., Lu, H., Gu, Z., Wang, W. and Liu, T. 2002. The 'Mediaeval Warm Period' drought recorded in Lake Huguangyan, tropical South China. *The Holocene* **12**: 511-516.

Chu, G., Sun, Q., Li, S., Zheng, M., Jia, X., Lu, C., Liu, J. and Liu, T. 2005. Long-chain alkenone distributions and temperature dependence in lacustrine surface sediments from China. *Geochimica et Cosmochimica Acta* **69**: 4985-5003.

De'er, Z. 1994. Evidence for the existence of the medieval warm period in China. *Climatic Change* **26**: 289-297.

Esper, J., Cook, E.R. and Schweingruber, F.H. 2002. Low-frequency signals in long tree-ring chronologies for reconstructing past temperature variability. *Science* **295**: 2250-2253.

Fairbridge, R.W. 2001. Six millennia in Chinese peats, relating to planetary-solar-luniterrestrial periodicities: a comment on Hong, Jiang, Liu, Zhou, Beer, Li, Leng, Hong and Qin. *The Holocene* **11**: 121-122.

Ge, Q., Wang, S., Wen, X., Shen, C. and Hao, Z. 2007. Temperature and precipitation changes in China during the Holocene. *Advances in Atmospheric Sciences* **24**: 1024-1036.

Ge, Q., Zheng, J., Fang, X., Man, Z., Zhang, X., Zhang, P. and Wang, W.-C. 2003. Winter half-year temperature reconstruction for the middle and lower reaches of the Yellow River and Yangtze River, China, during the past 2000 years. *The Holocene* **13**: 933-940.

Ge, Q.S., Zheng, J.-Y., Hao, Z.-X., Shao, X.-M., Wang, W.-C. and Luterbacher, J. 2010. Temperature variation through 2000 years in China: An uncertainty analysis of reconstruction and regional difference. *Geophysical Research Letters* **37**: 10.1029/2009GL041281.

Ge, Q.S., Zheng, J.Y. and Liu, J. 2006. Amplitude and rhythm of winter half-year temperature change in eastern China for the past 2000 years. *Advances in Climate Change Research* **2**: 108-112.

Ge, Q., Zheng, J., Man, Z., Fang, X. and Zhang, P. 2004. Key points on temperature change of the past 2000 years in China. *Progress in Natural Science* **14**: 730-737.

Gong, G. and Chen, E. 1980. On the variation of the growing season and agriculture. *Scientia Atmospherica Sinica* **4**: 24-29.

Hong, B., Liu, C.-Q., Lin, Q.-H., Yasuyuki, S., Leng, X.-T., Wang, Y., Zhu, Y.-X. and Hong, Y.-T. 2009. Temperature evolution from the $\delta^{18}O$ record of Hani peat, Northeast China, in the last 14000 years. *Science in China Series D: Earth Sciences* **52**: 952-964.

Hong, Y.T., Jiang, H.B., Liu, T.S., Zhou, L.P., Beer, J., Li, H.D., Leng, X.T., Hong, B. and Qin, X.G. 2000. Response of climate to solar forcing recorded in a 6000-year $\delta^{18}O$ time-series of Chinese peat cellulose. *The Holocene* **10**: 1-7.

Jin, H.J., Chang, X.L. and Wang, S.L. 2007. Evolution of permafrost on the Qinghai-Xizang (Tibet) Plateau since the end of the late Pleistocene. *Journal of Geophysical Research* **112**: 10.1029/2006JF000521.

Jin, Z.D., Shen, J., Wang, S. and Zhang, E. 2002. The Medieval Warm Period in the Daihai area. *Journal of Lake Sciences* **14**: 216-221.

Jin, Z., Wu, J., Cao, J., Wang, S., Shen, J., Gao, N. and Zou, C. 2004. Holocene chemical weathering and climatic oscillations in north China: evidence from lacustrine sediments. *Boreas* **33**: 260-266.

Kerr, R.A. 2008. Chinese cave speaks of a fickle sun bringing down ancient dynasties. *Science* **322**: 837-838.

Liu, X., Shao, X., Zhao, L., Qin, D., Chen, T. and Ren, J. 2007. Dendroclimatic temperature record derived from tree-ring width and stable carbon isotope chronologies in the Middle Qilian Mountains, China. *Arctic, Antarctic, and Alpine Research* **39**: 651-657.

Liu, Y., An, Z.S., Linderholm, H.W., Chen, D.L., Song, M.H., Cai, Q.F., Sun, J.S. and Tian, H. 2009. Annual temperatures during the last 2485 years in the mid-eastern Tibetan Plateau inferred from tree rings. *Science in China Series D Earth Science* **52**: 348-359.

Liu, Y., An, Z., Ma, H., Cai, Q., Liu, Z., Kutzbach, J.K., Shi, J., Song, H., Sun, J., Yi, L., Li, Q., Yang, Y. and Wang, L. 2006. Precipitation variation in the northeastern Tibetan Plateau recorded by the tree rings since 850 AD and its relevance to the Northern Hemisphere temperature. *Science in China: Series D Earth Sciences* **49**: 408-420.

Liu, Z., Henderson, A.C.G. and Huang, Y. 2006. Alkenone-based reconstruction of late-Holocene surface temperature and salinity changes in Lake Qinghai, China. *Geophysical Research Letters* **33**: 10.1029/2006GL026151.

Ma, C-M., Wang, F-B., Cao, Q-Y., Xia, X-C., Li, S-F. and Li, X-S. 2008. Climate and environment reconstruction during the Medieval Warm Period in Lop Nur of Xinjiang, China. *Chinese Science Bulletin* **53**: 3016-3027.

Ma, Z., Li, H., Xia, M., Ku, T., Peng, Z., Chen, Y. and Zhang, Z. 2003. Paleotemperature changes over the past 3000 years in eastern Beijing, China: A reconstruction based on Mg/Sr records in a stalagmite. *Chinese Science Bulletin* **48**: 395-400.

Mackay, A.W., Jones, V.J. and Battarbee, R.W. 2003. Approaches to Holocene climate reconstruction using diatoms. In: Mackay, A.W., Battarbee, R.W., Birks, H.J.B. and Oldfield, F. (Eds.). *Global Change in the Holocene*. Arnold, London, United Kingdom, pp. 294-309.

Man, M.Z. 1998. Climate in Tang Dynasty of China: discussion for its evidence. *Quaternary Sciences* **1**: 20-30.

Man, Z. 1990. Study on the cold/warm stages of Tang Dynasty and the characteristics of each cold/warm stage. *Historical Geography* **8**: 1-15.

Man, Z. 2004. *Climate Change in Historical Period of China*. Shandong Education Press, Ji'nan, China.

Mann, M.E., Bradley, R.S. and Hughes, M.K. 1998. Global-scale temperature patterns and climate forcing over the past six centuries. *Nature* **392**: 779-787.

Mann, M.E., Bradley, R.S. and Hughes, M.K. 1999. Northern Hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations. *Geophysical Research Letters* **26**: 759-762.

Mann, M.E. and Jones, P.D. 2003. Global surface temperatures over the past two millennia. *Geophysical Research Letters* **30**: 10.1029/2003GL017814.

Moberg, A., Sonechkin, D.M., Holmgren, K., Datsenko, N.M. and Karlen, W. 2005. Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. *Nature* **433**: 613-617.

Paulsen, D.E., Li, H.-C. and Ku, T.-L. 2003. Climate variability in central China over the last 1270 years revealed by high-resolution stalagmite records. *Quaternary Science Reviews* **22**: 691-701.

Prahl, F.G., Muehlhausen, L.A. and Zahnle, D.L. 1988. Further evaluation of long-chain alkenones as indicators of paleoceanographic conditions. *Geochimica et Cosmochimica Acta* **52**: 2303-2310.

Qian, W. and Zhu, Y. 2002. Little Ice Age climate near Beijing, China, inferred from historical and stalagmite records. *Quaternary Research* **57**: 109-119.

Sheng, F. 1990. A preliminary exploration of the warmth and coldness in Henan Province in the historical period. *Historical Geography* **7**: 160-170.

Smol, J.P. and Cumming, B.F. 2000. Tracking long-term changes in climate using algal indicators in lake sediments. *Journal of Phycology* **36**: 986-1011.

Stuiver, M., Grootes, P.M. and Braziunas, T.F. 1995. The GISP2 $\delta^{18}O$ climate record of the past 16,500 years and the role of the sun, ocean, and volcanoes. *Quaternary Research* **44**: 341-354.

Tan, L., Cai, Y., An, Z. and Ai, L. 2008. Precipitation variations of Longxi, northeast margin of Tibetan Plateau since AD 960 and their relationship with solar activity. *Climate of the Past* **4**: 19-28.

Wan, G.-J. 1997. The ^{210}Pb dating to modern deposits. *Journal of Quaternary Science* **17**: 230-239.

Wan, G.-J. 1999. The ^{137}Cs dating with annual resolution to modern deposits - a case study in Er hai and Hongfeng Lake in Yunnan. *Journal of Quaternary Science* **19**: 73-80.

Wang, L., Rioual, P., Panizzo, V.N., Lu, H., Gu, Z., Chu, G., Yang, D., Han, J., Liu, J. and Mackay, A.W. 2012. A 1000-yr record of environmental change in NE China indicated by diatom assemblages from maar lake Erlongwan. *Quaternary Research* **78**: 24-34.

Wang, S.W. 2001. *Advances in Modern Climatological Studies*. China Meteorological Press, Beijing, China, pp. 127-131.

Wang, S.W. and Gong, D.Y. 2000. The temperature of several typical periods during the Holocene in China. *The Advance in Nature Science* **10**: 325-332.

Wen, H. and Wen, H. 1996. *Winter-Half-Year Cold/Warm Change in Historical Period of China*. Science Press, Beijing, China.

Wu, H.Q. and Dang, A.R. 1998. Fluctuation and characteristics of climate change in temperature of Sui-Tang times in China. *Quaternary Sciences* **1**: 31-38.

Xu, H., Hong, Y., Lin, Q., Hong, B., Jiang, H. and Zhu, Y. 2002. Temperature variations in the past 6000 years inferred from $\delta^{18}O$ of peat cellulose from Hongyuan, China. *Chinese Science Bulletin* **47**: 1578-1584.

Yafeng, S., Tandong, Y. and Bao, Y. 1999. Decadal climatic variations recorded in Guliya ice core and comparison with the historical documentary data from East China during the last 2000 years. *Science in China Series D-Earth Sciences* **42 Supp.**: 91-100.

Yang, B., Braeuning, A., Johnson, K.R. and Yafeng, S. 2002. General characteristics of temperature variation in China during the last two millennia. *Geophysical Research Letters* **29**: 10.1029/2001GL014485.

Yang, B., Kang, X.C. and Shi, Y.F. 2000. Decadal climatic variations indicated by Dulan tree-ring and comparison with other proxy data in China of the last 2000 years. *Chinese Geographical Science* **10**: 193-201.

Yang, B., Wang, J., Brauning, A., Dong, Z. and Esper, J. 2009. Late Holocene climatic and environmental changes in arid central Asia. *Quaternary International* **194**: 68-78.

Yao, T.D., Xie, Z.C., Wu, X.L. and Thompson, L.G. 1990. Climatic change since Little Ice Age recorded by Dunde Ice Cap. *Science in China, Series B* **34**: 760-767.

Yin, Y., Li, W.C., Yang, X.D. *et al*. 2001. Morphological responses of *Limnocythere inopinata* (Ostracoda) to hydrochemical environment factors. *Science in China, Series D* **44** (supplement): 316-323.

Zhang, D.E. 1994. Evidence for the existence of the Medieval Warm Period in China. *Climatic Change* **26**: 287-297.

Zhang, E., Shen, J., Wang, S., Yin, Y., Zhu, Y. and Xia, W. 2004. Quantitative reconstruction of the paleosalinity at Qinghai Lake in the past 900 years. *Chinese Science Bulletin* **49**: 730-734.

Zhang, P., Cheng, H., Edwards, R.L., Chen, F., Wang, Y., Yang, X., Liu, J., Tan, M., Wang, X., Liu, J., An, C., Dai, Z., Zhou, J., Zhang, D., Jia, J., Jin, L. and Johnson, K.R. 2008. A test of climate, sun, and culture relationships from an 1810-year Chinese cave record. *Science* **322**: 940-942.

Zhang, X.W. and Zhang, J.B. 2006. *Handbook of Xinjiang Weather*. Meteorological Press, Beijing, China.

Zhou, XJ. 2011. The characteristics and regularities of the climate change over the past millennium in China. *Chinese Science Bulletin* **56**: 2985.

Zhu, L.-p., Zhang, P.-z., Xia, W.-l., Li, B.-y. and Chen, L. 2003. 1400-year cold/warm fluctuations reflected by environmental magnetism of a lake sediment core from the Chen Co, southern Tibet, China. *Journal of Paleolimnology* **29**: 391-401.

Zink, K.G., Leythaeuser, D., Melkonian, M. and Schwark, L. 2001. Temperature dependency of long-chain alkenone distributions in recent to fossil limnic sediments and in lake waters. *Geochimica et Cosmochimica Acta* **65**: 253-265.

Zolitschka, B., Brauer, A., Negendank, J.F.W., Stockhausen, H. and Lang, A. 2000. Annually dated late Weichselian continental paleoclimate record from the Eifel, Germany. *Geology* **28**: 783-786.

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