On the coherence of natural climate cycles of the past 1ka in multiple proxies from central Europe, the Arctic and east Asia.

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Abstract

We find evidence for multi-centennial climate cycles within the ages commonly described as the Medieval Warming Period and the Little Ice Age. We compare six proxy temperature records and find evidence for synchronicity of ˜200-year cycles in the northern hemisphere. The first two data sets are (1) a reconstruction from an ice core in the Colle Gnifetti (CG) glacier on the Swiss-Italian border (Bohleber et al 2018), and (2) length records of the Great Aletsch glacier (GAG), Switzerland (Holzhauser, 2009). A third is a proxy (3) by Cabedo-Sanz et al (2016) using the biomarker IP25 in sea sediments north of Iceland, which serves as a proxy for drift ice and hence arguably for Arctic ice areal coverage. Further temperature proxies for (4) all-China (Ge et al, 2017), (5) north China and (6) central China (Wang et al, 2018) provide a distribution of coverage over the non-tropical northern hemisphere. These six regional temperature proxy data sets are also compared with the G7 global temperature reconstruction (Ludecke and Weiss, 2017). Prominent minima in temperature proxy data occur circa 1350CE (all 6 proxies), 1480-1520CE (4 proxies), 1650-1700CE (all 6 proxies) and 1800-1860CE (all 6 proxies). The last three of these are also visible in the G7 global temperature reconstruction. Over the period 1550-1949 CE the Pearson correlation coefficients for the IP25 (Arctic ice) data with the GAG and the all-China temperature proxy are 0.69 and 0.70 respectively; these high correlations in data sets from opposite sides of the globe suggest a global cause rather than regional internal variability. Since 1600CE we note that IP25 (Arctic ice) and the CG temperature proxy lag the glacier record by 17 and 10 years respectively; that lag is counterintuitive and may reflect precipitation variations in the Alps preceding the temperature drop, or it may be attributable to uncertainties in age dating between the data sets. Power spectral analysis shows the dominant centennial periods in the data sets are centered at 180, 240 and 500 which (within dating uncertainties) may relate to the ˜160 year Jose cycle, the 208-year de Vries cycle and possible 350 and 500 year cycles previously recognized in solar activity via study of terrestrial cosmogenic isotopes. The consistency between the spectral maxima of temperature proxies studied here and spectral maxima of cosmogenic isotopes, supports the hypothesis of some association of these cycles with an "astronomical clock", although the mechanism of possible forcing remains a subject for further study.

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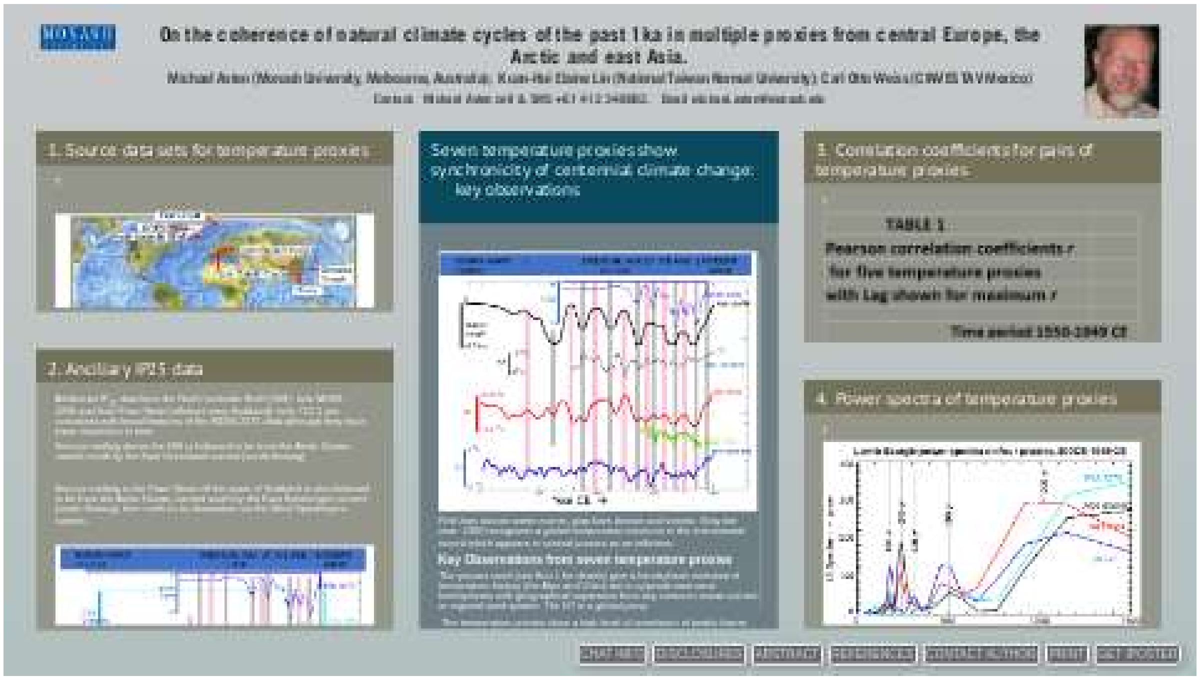

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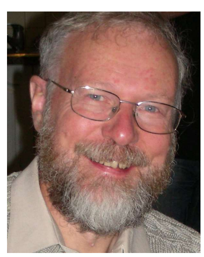

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ABSTRACT

We find evidence for multi-centennial climate cycles within the ages commonly described as the Medieval Warming Period and the Little Ice Age. We compare six proxy temperature records and find evidence for synchronicity of ~200-year cycles in the northern hemisphere. The first two data sets are (1) a reconstruction from an ice core in the Colle Gnifetti (CG) glacier on the Swiss-Italian border (Bohleber et al 2018), and (2) length records of the Great Aletsch glacier (GAG), Switzerland (Holzhauser, 2009). A third is a proxy (3) by Cabedo-Sanz et al (2016) using the biomarker IP25 in sea sediments north of Iceland, which serves as a proxy for drift ice and hence arguably for Arctic ice areal coverage. Further temperature proxies for (4) all-China (Ge et al, 2017), (5) north China and (6) central China (Wang et al, 2018) provide a distribution of coverage over the non-tropical northern hemisphere. These six regional temperature proxy data sets are also compared with the G7 global temperature reconstruction (Ludecke and Weiss, 2017).

Prominent minima in temperature proxy data occur circa 1350CE (all 6 proxies), 1480-1520CE (4 proxies), 1650-1700CE (all 6 proxies) and 1800-1860CE (all 6 proxies). The last three of these are also visible in the G7 global temperature reconstruction.

Over the period 1550-1949 CE the Pearson correlation coefficients for the IP25 (Arctic ice) data with the GAG and the all-China temperature proxy are 0.69 and 0.70 respectively; these high correlations in data sets from opposite sides of the globe suggest a global cause rather than regional internal variability. Since 1600CE we note that IP25 (Arctic ice) and the CG temperature proxy lag the glacier record by 17 and 10 years respectively; that lag is counterintuitive and may reflect precipitation variations in the Alps preceding the temperature drop, or it may be attributable to uncertainties in age dating between the data sets.

Power spectral analysis shows the dominant centennial periods in the data sets are centered at 180, 240 and 500 which (within dating uncertainties) may relate to the ~160 year Jose cycle, the 208-year de Vries cycle and possible 350 and 500 year cycles previously recognized in solar activity via study of terrestrial cosmogenic isotopes. The consistency between the spectral maxima of temperature proxies studied here and spectral maxima of cosmogenic isotopes, supports the hypothesis of external forcing of these cycles by an "astronomical clock", although the mechanism of that forcing remains a subject for further study.

1. SOURCE DATA SETS FOR TEMPERATURE PROXIES

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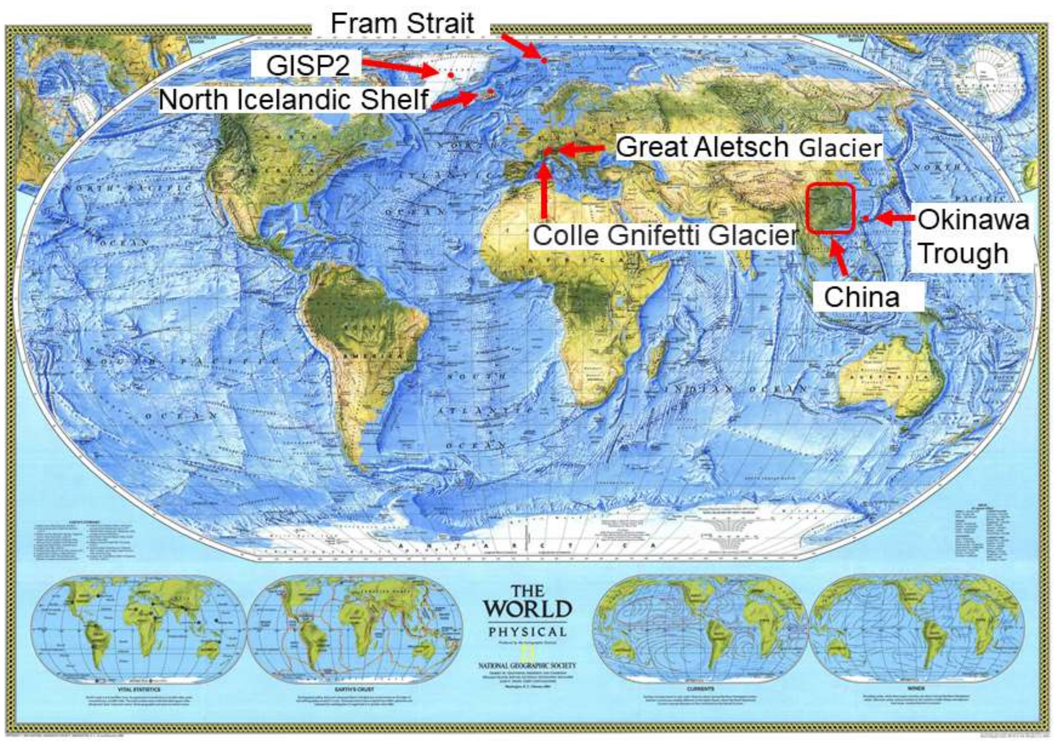


Essential data used in this study:

- IP_{25}-2275 (Ice Proxy with 25 carbon atoms) from hole MD99-2275, North Icelandic Shelf (Cabedo-Sanz et al 2016).

- Lower termination of the Great Aletsch Glacier, The European Alps (Holzhauser, 2009).

- Proxy temperature from an ice core "CG" at the Colle Gnifetti glacier, European Alps, 50 km south of the Aletsch glacier (Bohleber et al, 2018). Plotted data is proxy from Ca2+ content in dust particles, smoothed with 30year running average.

- Proxy temperatures for all China "Ge China" (Ge et al, 2017)

- Proxy temperatures from historical records ("Reaches"), North China (Lin et al, 2018, Wang et al, 2018)

- Proxy temperatures from historical records ("Reaches"), Central China (Lin et al, 2018, Wang et al, 2018)

-Global proxy temperature reconstruction "LW G7" (Ludecke and Weiss, 2017)

Additional data:

IP_{25}-2269 (Ice Proxy with 25 carbon atoms) from hole MD99-2269, North Icelandic Shelf (Cabedo-Sanz et al 2016).

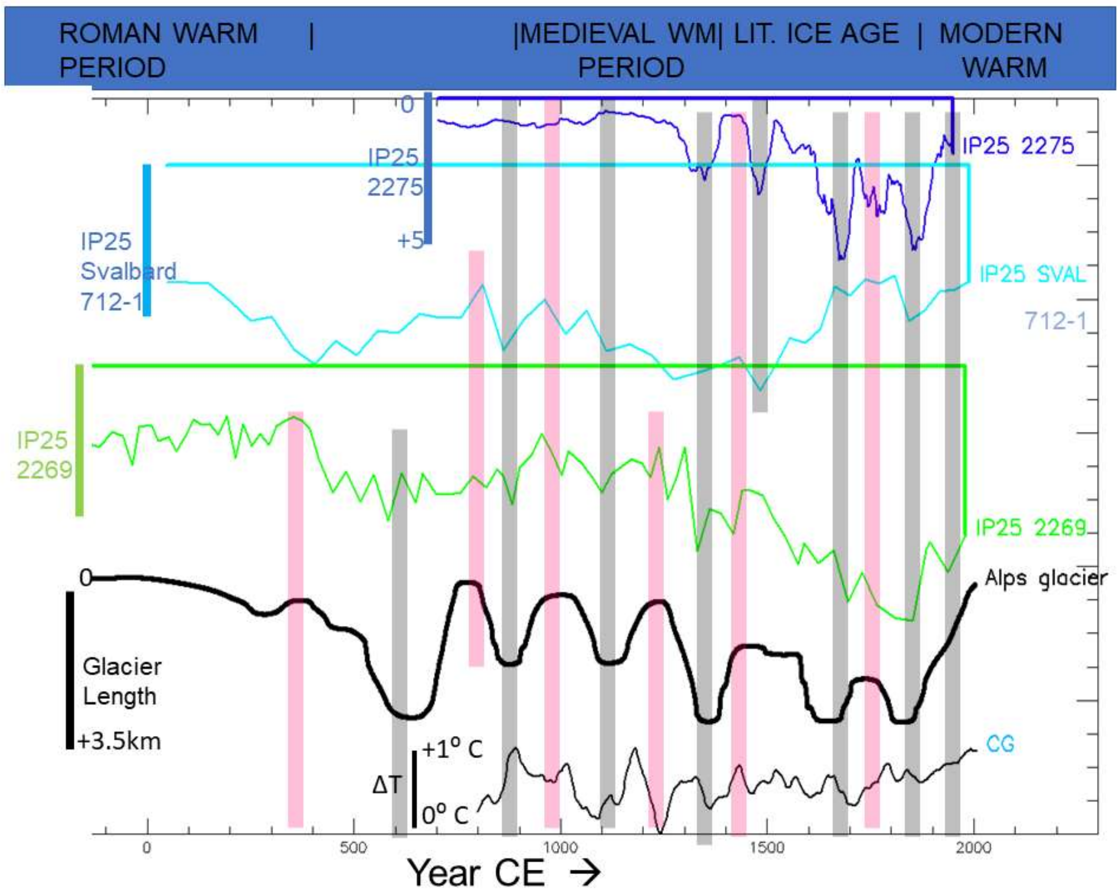
IP_{25}-712 (Ice Proxy with 25 carbon atoms) from hole 712, Fram Strait (Cabedo-Sanz and Belt, 2016).

2. ANCILIARY IP25 DATA

Additional IP_{25} data from the North Icelandic Shelf (NIS) hole MD99-2269 and from Fram Strait (offshore west Svalbard) hole 712-1 are consistent with broad features of the MD99-2275 data although they have lower resolution in time.

Sea ice melting above the NIS is believed to be from the Arctic Ocean, carried south by the East Greenland current (south-flowing).

Sea ice melting in the Fram Strait off the coast of Svalbard is also believed to be from the Arctic Ocean, carried south by the East Spitzbergen current (south-flowing), then north to its destination via the West Spitzbergen current.



Pink bars denote warm events, gray bars denote cool events. Gray bar near 1960 recognizes a global temperature minimum in the instrumental record which appears in several proxies as an inflection.

IP_{25} data for hole MD99-2275 is unusually high resolution, sampled at 2 yr intervals near surface (20th century), increasing to ~5 yr sampling at base of hole (8th century). Data displayed here is smoothed with a 11-year running average (22 yr smoothing, increasing to 110 yr smoothing).

IP_{25} data for hole MD99-2269 is much more coarsely sampled; no smoothing is applied in the above plot. Likewise IP_{25} data for the Fram Strait (Svalbard) hole 712-1 is coarsely sampled and is not smoothed in this plot.

Despite its low resolution the IP_{25} record for MD99-2269 replicates the maxima and minima of the high-resolution MD99-2275 plot, and provides additional confirmation in the Arctic record of the Medieval and Roman warming periods, and the post-Roman Dark Ages pessimum circa 500-700 CE.

The alignment of IP_{25} data for Fram Strait hole 712-1 with data from the North Icelandic Shelf is less convincing, possibly due to the more complex travel path for drift ice from Arctic to melting point.

SEVEN TEMPERATURE PROXIES SHOW SYNCHRONICITY OF CENTENNIAL CLIMATE CHANGE: KEY OBSERVATIONS

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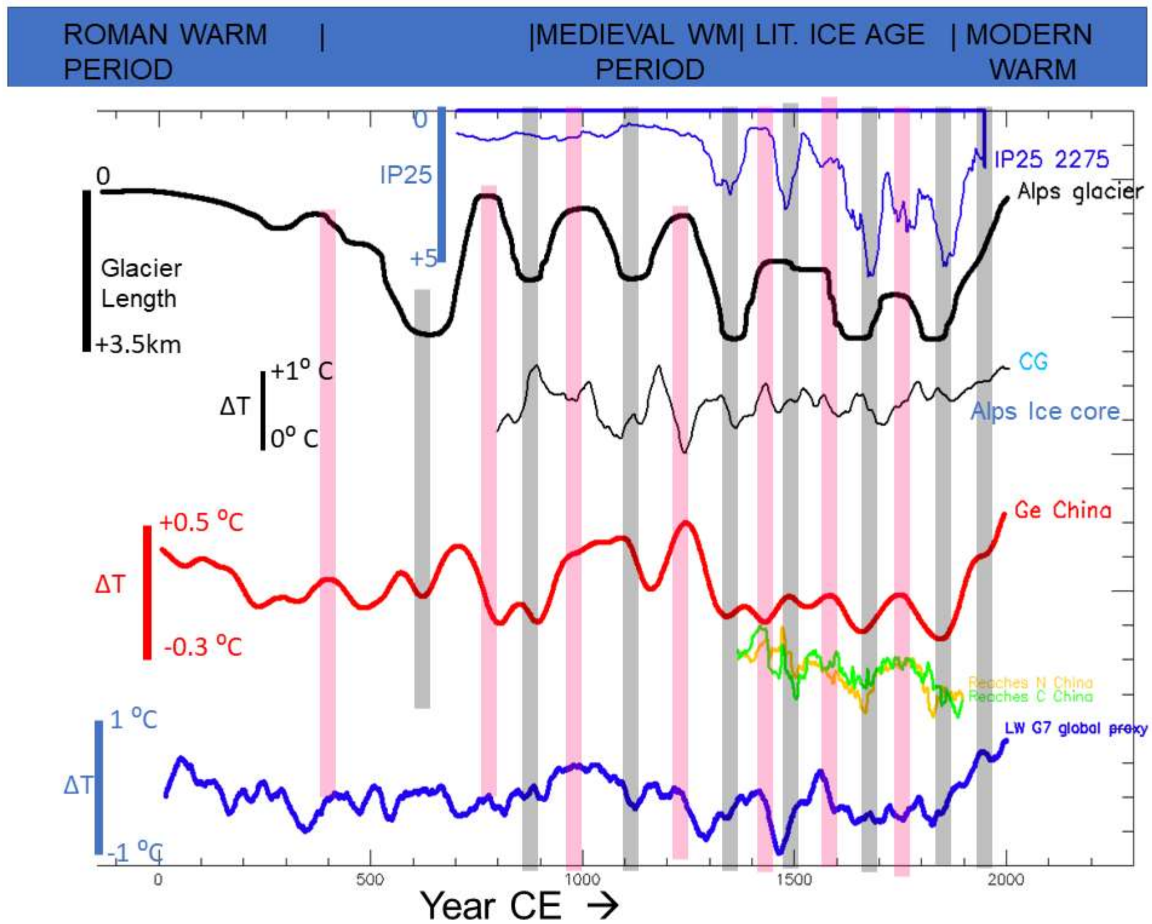

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Key Observations from seven temperature proxies

The proxies used (see Box 1 for details) give a hemispheric overview of temperature history (the Alps and China are in opposite east-west hemispheres with geographical separation from any common ocean current or regional wind system. The G7 is a global proxy.

The temperature proxies show a high level of correlation of peaks (warm periods) and troughs (cool periods) for times later than 800 CE

The temperature proxies show a very high level of correlation of maxima and minima for times later than 1550 CE

See correlation matrix (Box 3, right) for quantitative comparisons

Notable minima: 880, 1100, 1350, 1480, 1580, 1850, 1950 CE

Notable maxima: 400, 980, 1220, 1430, 1580, 1750 CE

Spectral analysis studies (Box 4, right) show these proxies have clear spectral maxima at the astronomical periods known from cosmic ray studies as the Suess–de Vries (200–250 yr) period, the Jose cycle (155–185 yr), and the Eddy cycle (800–1200 yr). (The Eddy cycle is poorly resolved on these plotted data sets but is affirmed where a full 2000 yr data set is available).

The consistency between the spectral maxima of temperature proxies studied here and spectral maxima of cosmogenic isotopes (Box 4, right), supports the hypothesis of external forcing of these cycles by an "astronomical clock", although the mechanism of that forcing remains a subject for further study.

3. CORRELATION COEFFICIENTS FOR PAIRS OF TEMPERATURE PROXIES

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TABLE 1

Pearson correlation coefficients *r* for five temperature proxies with Lag shown for maximum *r*

Time period 1550-1949 CE

X=	**Alps**		**China**	
	Lag (yr)	*r*	Lag (yr)	*r*
Y				
IP25-2275	17	0.69	5	0.7
Alps-glacier			0	0.89
CG-icecore	10	0.22	10	0.21
Ge China	0	0.89		
LW-G7 global proxy	0	0.79	0	0.73

Time period 800-1949 CE

X=	**Alps**		**China**	
	Lag (yr)	*r*	Lag (yr)	*r*
Y				
IP25-2275	10	0.71	15	0.58
Alps-glacier			-20	0.77
CG-icecore	-80	0.21	-80	0.33
Ge China	20	0.77		
LW-G7 global proxy	-27	0.52	-45	0.59

Lags between data sets:

The Alps glacier and the China proxy curves show high to very high correlation, and there is no detectable lag between them after 1550 CE (despite the *a priori* expectation that the glacier length might lag temperature change due to delays in adjustment of glacier mass balance). Correlation over the period 800-1949 CE incorporating the Medieval Warming Period indicates a lag of 20 years.

The correlation of the Alps CG ice core with the Aletsch glacier length is surprisingly low (Pearson r ~ 0.2). We do not have an explanation for this at present.

Cool events since 1550 CE in the Arctic (inferred from high IP_{25} values -minima on the plotted curve) appear to lag the Alps glacier and China proxy curves by ~25 years, although formal correlation coefficients using both warm and cool data show small lags ~10 years.

4. POWER SPECTRA OF TEMPERATURE PROXIES

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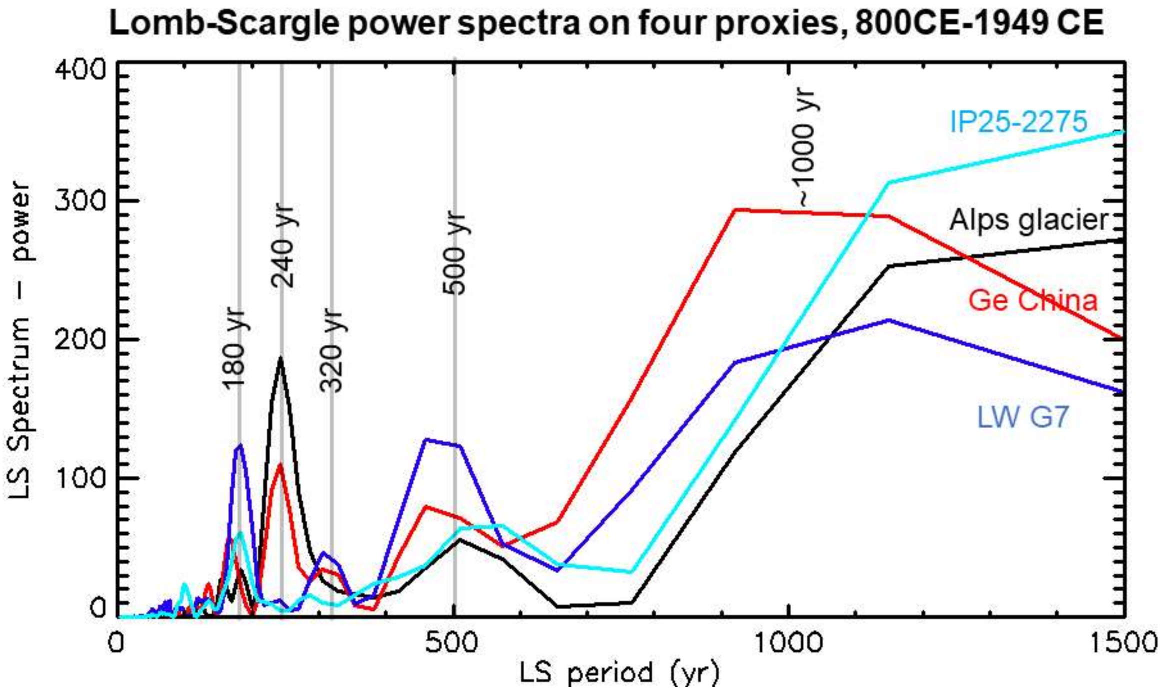

Time span 800 - 1949 CE:

Power spectra for the European Alps glacier (black) and China (red) show similar maxima at 240 yr, 500 yr and ~ 1000 yr periods.

The global temperature proxy LW G7 has a pair of maxima at 180 & 320 yr period, plus the same 500 yr and ~ 1000yr spectral maxima

The IP_{25} record for the North Icelandic Shelf hole MD99-2275 shows similar spectral maxima at 180 yr and 500 yr periods (the data set is too short to allow estimation of a 1000 yr period).

The consistency in spectral maxima supports the results from correlation studies and strongly supports a hypothesis that these four data sets are influenced by the same hemispheric or global drivers of natural cycles of climate change. There is no support for a hypothesis that European, Arctic and China temperature records are subject to independent regional influences on their centennial-millennial climate variations.

Significance of observed correlations and spectral maxima in the centennial-millennial range

Babich et al (2016) studied five proxy temperature data sets for the extra-tropical northern Hemisphere and found quasi-periodic variations with periods 1000, 500, 350, 200 years, where the 1000 and 200 yr periods were most pronounced.

Spiridonov et al (2019) studied centennial and millennial length cycles in temperatures interpreted from pollen records in Central Europe (Lithuania), and found the most consistent periodicities were characterized by periods lasting between 201 and 240 years.

The new results presented here, using different European, Arctic and China data sets, plus the LW G7 global proxy temperature data sets, are wholly consistent with the results discussed by Babich et al (2016) and Spiridonov et al (2019).

Possible mechanisms for the hemispheric/global centennial-millennial temperature variations

Scafetta (2020) reviews the dynamic interactions of planets and sun and finds gravitational influences on the sun show a series of periodicities in the range 2300 to 55 years. He reviews observational data showing periodicities in observed solar activity at these periodicities. While mechanisms are not yet established for explaining the magnitude of such influences on global temperature cycles, the correlation of planetary periodicities with observed temperature cycles is an observational fact.

Three of the planetary periodicities noted by Scafetta (2020) are the Eddy cycle (800–1200 yr), Suess–de Vries (200–250 yr), and Jose cycle (155–185 yr). It is an observational fact that these three periodicities occur in our current study (see figure above) of temperature proxy data of the past 1200 years. McCracken et al (2013; 2014) see similar periods in paleo-cosmic-ray (PCR) records via cosmogenic 10Be and 14C. The PCR record also shows the Gleissberg cycle (80–100 year) which is too high in frequency to be identified in the temperature proxies analysed in this paper. However McCracken et al (2014) note the PCR record also has cycles of period 350 and 510 yr which are attributable to 4th and 6th sub-harmonics of the Gleissberg cycle; it is therefore of note that our temperature proxy spectra in the figure above also show observational evidence for spectral maxima at 320 and 500 yr periods. (A 500 yr period is also observed in the independent European proxy temperature data of Babich et al, 2016).

The nature of the driving mechanism from planetary motions to earth temperature cycles remains a work for future study but the existence of the "astronomical clock" at periods observed in the proxy records increases the likelihood that the observed temperature cycles are a fully global phenomenon.

DISCLOSURES

The authors thank Prof Simon Belt of the University of Plymouth for suplying IP25 data from the North Icelandic Shelf and the Fram Strait, and for providing background information on Arctic ice movements.

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