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Centennial Cycles Observed in Temperature Data from Antarctica to Central Europe

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Abstract: Fourier analyses of worldwide temperature proxy data show a multitude of spectral lines, indicating multi-periodic dynamics of the climate system. The proxy data investigated in this study all show an approximately 200 year period, which has been related to the solar De Vries/Suess cycle. This cycle is consistent with temperature measurements from about 1750 to present, suggesting that the solar De Vries/Suess cycle is of importance for the recent and near future climate variations.

Zusammenfassung: Fourier Analysen von weltweiten Temperatur-Proxydaten für verschiedene Regionen der Erde weisen eine große Zahl von Spektrallinien auf, die die Dynamik des Klimasystems auf unterschiedlichen Zeitskalen (multiperiodisch) widerspiegeln. Die in dieser Studie untersuchten Proxydaten zeigen durchweg eine Periodizität von ungefähr 200 Jahren, wie sie mit dem solaren De Vries/Suess-Zyklus in Verbindung gebracht werden kann. Diese Periodizität lässt sich auch in instrumentellen Temperaturmessungen ab etwa 1750 bis heute erkennen, was einen Einfluss des De Vries/Suess-Zyklus' auf die vergangene und zukünftige Temperaturentwicklung wahrscheinlich macht.

INTRODUCTION

In recent years a sizeable number of studies have revealed periodic climate variations by analysing proxies of temperatures, rainfalls, droughts etc. (Kern et al. 2012, Cliver et al. 1998, Raspopov et al. 2008, Knudsen et al. 2011, Novello et al. 2012, Wagner et al. 2001). These studies concerned local proxies such as stalagmites, tree-rings, sediments, ice cores, biotic and instrumental temperatures. Because the most pronounced cycle of solar activity is the about 200 year De Vries/Suess cycle (Steinhilber & Beer 2013), we have looked for this about 200 year periodicity in the records of more globally distributed temperature proxies with a time resolution of one year and going back at least to the year 0 AD/BP. In particular we used the following datasets:

1) Christiansen & Ljundquist (2012): multiproxies, locally distributed over the Northern Hemisphere, covering the years 0 to 1973 AD, in the following "Chr/Lju".
2) Buentgen et al. (2011): tree-rings from the European Alps, covering the years -499 BP/AD to 2003 AD, in the following "Bue".
3) Cook et al. (2000): tree-rings from Tasmania, covering -1600 BP/AD to 1991, in the following "Cook".
4) Petit et al. (1999): ice-cores from the Antarctic Vostok station, covering the last 420,000 years, in the following "Petit".
5) Lüdecke et al. (2013): instrumental temperatures of six stations in central Europe, covering the years from approximately 1750 to 2011, in the following "M6".

RESULTS

Figure 1 (Zhao & Feng 2015) shows the Lomb-Scargle spectrum (Lomb 1976, Scargle 1982) for the last 11,000 years of "Petit", revealing a large number of spectral lines. Besides peaks at about 300, 480, 520 and 730 years, in particular spectral lines around the about 200 year period (188 and 204 years) sticks out, which exceed the 99 % confidence level.

The two upper and the lower left panel of Figure 2 show the spectra of "Chr/Lju", "Bue", and "Cook", where the about 200 year cycle is apparent, exceeding the 99 % and 95 % confidence level, respectively. The spectrum of "M6" in the lower right panel of Figure 2 has a much reduced frequency resolution due to the relatively shorter time span covered, compared to those of the proxy data, but prominently shows a about 200 year-period spectral line as well. However, there are reasons why this prominent line could be the result of artifacts, particularly, since the data span only one full period of a 200 year cycle. However, the appearances of the periodicity in the proxy data, on the one hand, and the correspondence of the recent temperatures with the solar activity with its dominant 200 year De Vries/Suess cycle (Steinhilber & Beer 2013), on the other hand, make it likely that the measured temperature variations of "M6" are essentially a section of a continuing about 200 year periodicity. We note that in general a certain distribution of the cycle frequencies is to be expected since the cycle period and phases vary over time as demonstrated for the solar De Vries/Suess cycle covering 8000 years (Steinhilber et al. 2012, Suess 1980).

Figure 3 shows the transformation from the frequency domain to the time domain for "M6", using only the six strongest cycles represented by the strongest peaks in the lower right panel of Figure 2, as given in Lüdecke et al. (2013, Tab. 1). It demonstrates a rather precise agreement with the measurements. It has often been suggested that the agreement between reconstruction and measurements is trivial and meaningless, since the reconstruction represents merely a low pass filtered version of the measurements. Although the chosen strongest cycles are in the low frequency range, the reconstruction means not merely a low pass filtering. The data may or may not contain secular components in addition to the cycles. The agreement of the reconstruction, which only uses cycle com–ponents with the measurement record, would indicate that the

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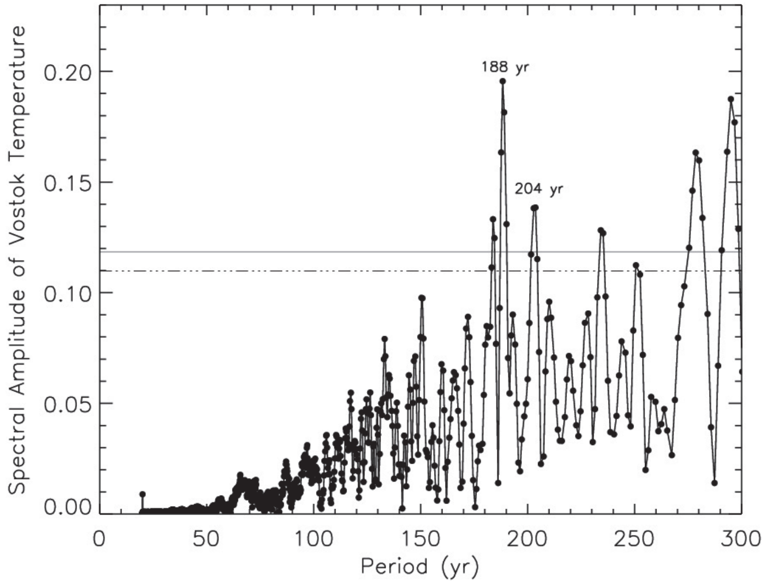

Fig. 1: Spectral power (in arbitrary units) of the Antarctic Vostok ice core temperature data over the last 11,000 years (PETIT et al. 1999). The gray and black (solid, chain-dotted) horizontal lines indicate the 95 % and 99 % confidence levels, exceeding random noise (Monte-Carlo simulations).

Abb. 1: Spektrale Stärke der Daten des antarktischen Vostok Eisbohrkerns über die letzten 11.000 Jahre (PETIT et al. 1999) in willkürlicher Einheit. Die graue durchgezogene und schwarze strichpunktierte horizontale Linien markieren die 99 % bzw. 95 % Konfidenzgrenzen gegenüber statistischem Rauschen (Monte-Carlo Simulation).

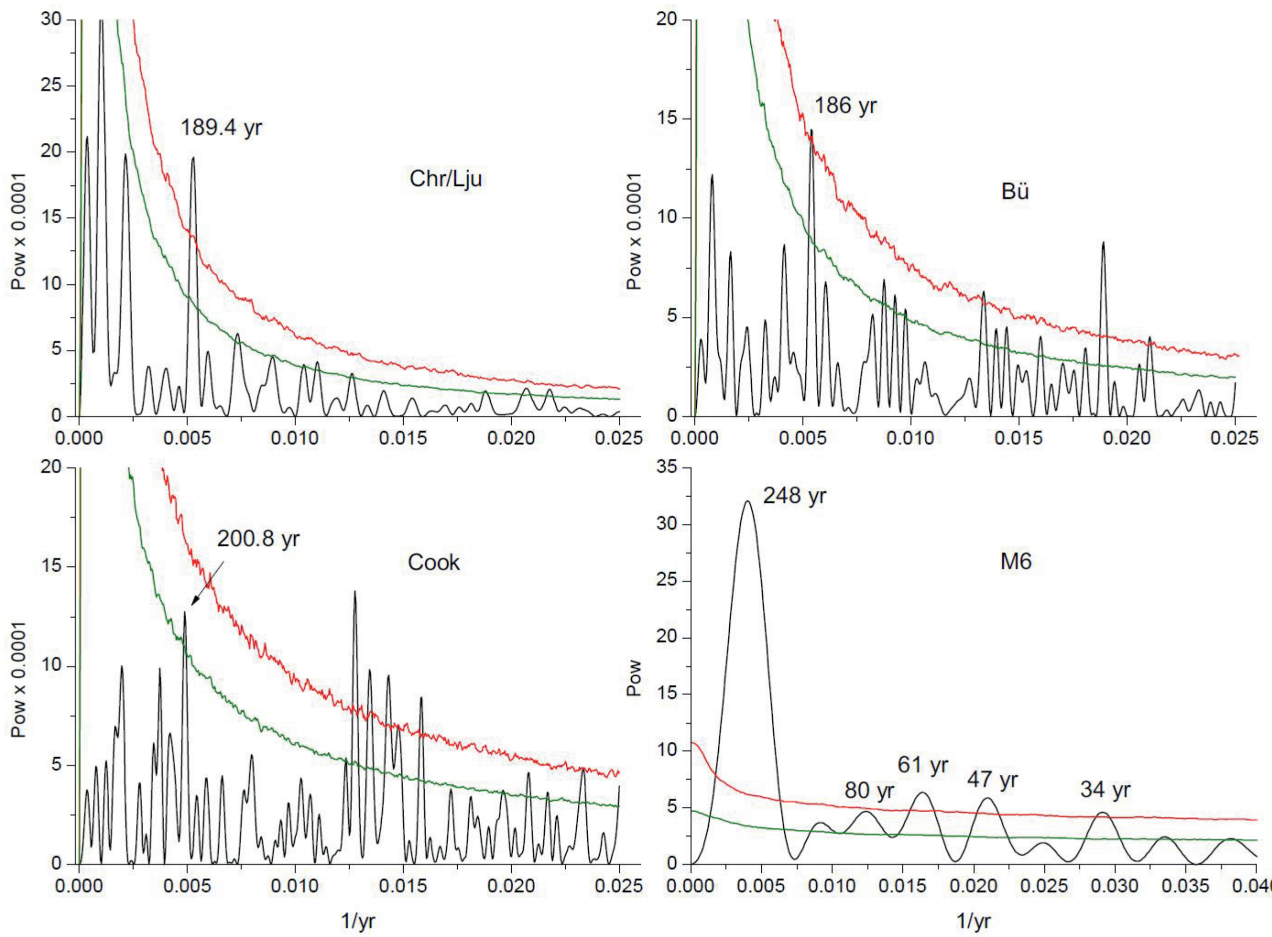

Fig. 2: Left upper panel: Spectral power of the temperature multiproxy data from 0 to 1973 AD ("Chr/Lju"), covering much of the Northern Hemisphere (CHRISTIANSEN & LJUNDQUIST 2012). Right upper panel: Spectral power of the temperature proxy data from -499 to 2003 BP/AD ("Bue") as tree-rings from the European Alps (BUENTGEN et al. 2011). Left lower panel: Spectral power of the temperature proxies from -1600 to 1991 BP/AD ("Cook") as tree-rings from Tasmania (COOK et al. 2000). Right lower panel: Spectral power of six instrumental temperature records from central Europe from ~1750 to 2011 ("M6"). All spectral powers are in arbitrary units. The green and red lines indicate the 99 % and 95 % confidence levels (LÜDECKE et al. 2013).

Abb. 2: Links oben: Spektrale Stärke der "Chr/Lju" Temperaturreihe von 0 to 1973 n. Chr., die weite Teile der Nordhemisphäre abdeckt (CHRISTIANSEN & LJUNDQUIST 2012). Rechts oben: Spektrale Stärke der "Bue" Temperaturreihe von 499 v.Chr. bis 2003 n.Chr. aus Baumringen der Europäischen Alpen (BUENTGEN et al. 2011). Links unten: Spektrale Stärke der "Cook" Temperaturreihe von 1600 v.Chr. bis 1991 n.Chr. aus Baumringen von Tasmanien (COOK et al. 2000). Rechts unten: Spektrale Stärke von sechs instrumentellen Temperaturreihen Zentraleuropas "M6" von ~1750 bis 2011 n.Chr. Alle spektralen Stärken in willkürlichen Einheiten. Die grünen und roten Linien markieren die 95 % und 99 % Konfidenzlinien gegenüber statistischem Rauschen (LÜDECKE et al. 2013).

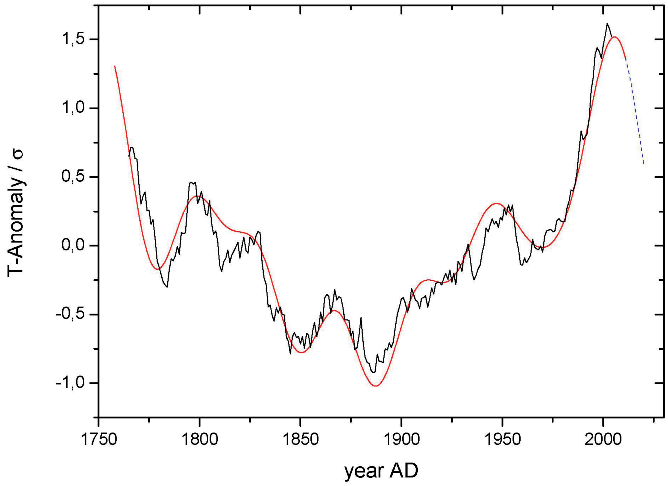

Fig. 3: 15-years running mean of the six instrumental temperature records ("M6", Lüdecke et al. 2013) in black, and time domain reconstruction using the six strongest frequency components (in red) of the spectrum, shown in the right lower panel of Figure 2.

Abb. 3: Gleitendes Mittel (15 Jahr Fenster) der sechs mitteleuropäischen Temperaturmessreihen "M6" (Lüdecke et al. 2013) in schwarz und Rekonstruktion unter ausschließlicher Benutzung der sechs stärksten Komponenten des Spektrums in Abbildung 2 in rot.

recent temperature variations are exclusively due to cycles and that secular components are absent. However, it has also been suggested that secular components could be hidden in the 200 year cycle.

CONCLUSION

We have analysed proxy data, extending over a large part of the globe, indicating multi-periodic climate dynamics. Based on least squares deviations between the data and a single sine we find that the dataset of "Chr/Lju" represents a 33 % fraction of a full sine, "Bue" a 27 % fraction and "Cook" a 17 % fraction (100 % as complete agreement with a sine and assuming that the deviations of the data from a sine function are real climate variations and not merely measurement noise). If the deviations were dominantly measurement noise, the 200 year cycle would represent a larger percentage. If the instrumental data in Figure 3 in fact represent a section of a continuing 200 year cycle, the contribution of this cycle to the recent temperature changes would be substantial. In addition, Figure 3 also implies an about 65 year cycle, indicative for the Atlantic Multidecadal Oscillation (AMO) or the Pacific Decadal Oscillation (PDO). The latter, together with the approximately 200 year cycle, appears to dominate the recent temperatures.

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