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Palaeogeography, Palaeoclimatology, Palaeoecology

Volume 259, Issue 1, 17 March 2008, Pages 6-16

The influence of the de Vries (~200-year) solar cycle on climate variations: Results from the Central Asian Mountains and their global link

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https://doi.org/10.1016/j.palaeo.2006.12.017

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Abstract

Long-term climatic changes related to solar forcing were examined using millennium-scale palaeoclimatic reconstructions from the Central Asian mountain region, i.e. summer temperature records for the Tien Shan mountains and precipitation records for the Tibetan Plateau. The reconstructions were based on juniper tree-ring width records, i.e. *Juniperus turkestanica* for the Tien Shan and *Sabina przewalskii* for the Tibetan Plateau. The data were processed using spectral and wavelet analysis and filtered in the frequency range related to major solar activity periodicities. The results obtained for various tree-ring chronologies indicate palaeoclimatic oscillations in the range of the de Vries (~210-year) solar cycles through the last millennium.

The quasi-200-year variations revealed in the palaeoclimatic reconstructions correlate well (R^2=0.58–0.94) with solar activity variations ($\Delta^{14}C$ variations). The quasi-200-year climatic variations have also been detected in climate-linked processes in Asia, Europe, North and South America, Australia, and the Arctic and Antarctica. The results obtained point to a pronounced influence of solar activity on global climatic processes.

Analysis has shown that climate response to the long-term global solar forcing has a regional character. An appreciable delay in the climate response to the solar signal can occur (up to 150years). In addition, the sign of the climate response can differ from the solar signal sign. The climate response to long-term solar activity variations (from 10s to 1000s years) manifests itself in different climatic parameters, such as temperature, precipitation and atmospheric and oceanic circulation. The climate response to the de Vries cycle has been found to occur not only during the last millennia but also in earlier epochs, up to hundreds of millions years ago.

Introduction

The ~200-year solar cycle (de Vries cycle) is commonly believed to be one of the most intense solar cycles. Variation of cosmogenic isotopes ^{14}C and ^{10}Be concentration in terrestrial archives carry information about the past periodicity of solar activity. Using $\Delta^{14}C$ variations (radiocarbon concentration) in tree-rings Vasil'ev et al. (1999) and Muscheler et al. (2003) inferred that the ~200-year solar activity cycle (de Vries cycle) is a dominant cycle during the Holocene. The deep solar minima (Maunder, Spörer, Wolf) can be regarded as manifestations of the de Vries cycle during the past few millennia (Eddy, 1976). By examining ^{10}Be concentration in Greenland ice as a proxy for solar activity variations,

Wagner et al. (2001) traced the development of this periodicity between 50,000 and 25,000 years ago. Their findings suggest that the de Vries cycle persisted over even longer timescales.

Sonett and Suess (1984) showed the existence of a correlation between the spectra of ^{14}C concentration and the radial growth of tree rings of bristlecone pines from eastern California at ~200-year periodicity. Palaeoclimatic data obtained in recent years further demonstrate the connection between ~200-year solar activity periodicity and other climatic parameters (see, for example, Schimmelmann et al., 2003). The temporal synchrony between the Maunder, Spörer, and Wolf minima and the expansion of Alpine glaciers (Haeberli and Holzhauser, 2003) further point to a climate response to the deep solar minima. A similar conclusion was inferred from analysis of glacier expansion in Alaska (Wiles et al., 2004). However, the climate response to a solar signal can vary from one region to another. Wiles et al. (2004) showed that regional climate responses to the de Vries cycle can markedly differ in phase even at distances of several hundred kilometers. This can result from the nonlinear character of the atmosphere–ocean system response to solar forcing. The possibility of a regional response to de Vries cycles is supported by model simulations which examine the effect of variations in solar irradiance on the atmosphere–ocean system (Waple et al., 2002). Similar conclusions were inferred from analysis of solar forcing of the climate during the Maunder Minimum (Shindell et al., 2001).

It is therefore necessary to carry out analysis of a climate response to the de Vries periodicity for different regions of the Earth and compare the results with the data obtained by simulation. The goal of this paper is to analyze climate variations in Central Asia that may be related to the ~200-year solar cycle.

Section snippets

Methods

To reveal the long-term climatic changes that occurred during the last millennium, we used variations in tree ring widths of junipers from two mountain regions of Central Asia: the Tien Shan mountains and the Qinghai-Tibetan Plateau (Fig. 1). The distance between the regions where the dendrochronological data were collected is approximately 2000 km.

We analyzed tree ring growth for two types of junipers: for *Juniperus turkestanica* (variations of summer temperatures) in the high timberline in the …

Results

The $\Delta^{14}C$ record, the three ΔR chronologies for the Tien Shan mountains, and precipitation reconstruction for the Qiaghai-Tibetan Plateau are shown in Fig. 2. Solar minima are indicated by peaks in ^{14}C concentration (Fig. 2a); the Maunder minimum refers to the period of highest ^{14}C concentration around 1700 AD, with the Spörer and Wolf minima occurring around 1500 AD and 1300 AD, respectively. The earliest ^{14}C peak, ~1050 AD, reflects the Oort minimum, and the two smaller peaks after 1800 AD…

Discussion and the 200-year cycle globally

The dynamic spectra of changes in solar activity and climatic processes estimated from millennium-long tree-ring records for Central Asia are similar, pointing to potential relationships. The above results, based upon temperature and precipitation sensitive tree-ring data from the central Asian mountain regions show significant variability at wavelengths around 200 years. We link the variability at these periodicities with the de Vries solar cycle.

The response of precipitation variations to…

Conclusions

Analysis of long-term dendrochronological data for two Central Asia mountain regions (the Tien Shan and Qinghai-Tibetan Plateau) obtained by four independent research teams has demonstrated the presence of ~200-year climatic

variations. These variations show a high correlation (R=0.58–0.94) with a similar solar periodicity (de Vries period) inferred from the radiocarbon concentration that is modulated by temporal variations in solar activity.

Review of published palaeoclimatic data shows that…

Acknowledgements

We thank Greg Wiles for valuable discussion and providing us with one of his figures, Gerard Versteegh, William Gosling and an anonymous reviewer for constructive comments and criticisms, and W.D Dean for permission to use his figure. This work was supported by the European Commission (Program INTAS, Projects DENDROLAB and CAMBIFORRUS), the Russian Foundation for Basic Research (projects 06-04-48792a, 06-02-16268a, 06-05-64200a), the Russian Academy of Sciences (Program N 16 “Changes of…

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References (41)

NybergJ. *et al.*
Late Holocene changes in precipitation and hydrography recorded in marine sediments from the northern Caribbean Sea
Quaternary Research (2001)

RaspopovO.M. *et al.*
Periodicity of climate conditions and solar variability derived from dendrochronological and other palaeoclimatic data in high latitudes
Palaeogeography Palaeoclimatology Palaeoecology (2004)

AndersonR.Y.
Possible connection between surface wind, solar activity and the Earth's magnetic field
Nature (1992)

AndersonR.Y.
The varve chronometer in Elk Lake record of climatic variability and evidence for solar-geomagnetic-^{14}C-climate connection

Cini CastagnoliG. *et al.*
On the solar origin of the 200y Suess wiggles: Evidence from thermoluminescence in sea sediments
Il Nuovo Cimento (1998)

CookE.R. *et al.*
The ‘segment length curse' in long tree-ring chronology development for palaeoclimatic studies
The Holocene (1995)

CookE.R. *et al.*
Inter-decadal climate oscillations in the Tasmanian sector of the Southern Hemisphere: evidence from tree rings over the past three millennia

DeanW.E.
Rates, timing, and cyclicity of Holocene eolian activity in north-central United States: evidence from varved lake sediments
Geology (1997)

DergachevV.A. *et al.*

Some Problems of the Choice of the Optimal Model of the Carbon Dynamic Reservoir. Preprint No. 91
(1975)

EddyJ.A.
The Maunder minimum
Science (1976)

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