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Variations in climate parameters at time intervals from hundreds to tens of millions of years in the past and its relation to solar activity

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Abstract

Unique palaeoclimatic data with annual time resolution as tree ring widths and annual varve deposits are analyzed in order to reveal periodicities in climatic processes at tens to hundreds of million years ago. The climatic periodicities thus found are compared with the solar and climatic periodicities observed at present.

Introduction

At present a large body of palaeoclimatic data with annual time resolution is available. As a rule, these data relate to the time interval of the last 10–15 thousand years. At the start of the 20th century the founder of dendrochronology A.E. Douglas discovered that there was a ~11-year cyclicity in radial tree ring growth, and he attributed this periodicity to the climatic effect of the 11-year solar cycle (Schwabe cycle) (Douglass, 1919, Douglass, 1919; 1926; 1936). In later years he and other researchers analyzed dendro-chronological and other palaeoclimatic materials with layered structure (varves, aerosol densities in Greenland and Antarctic ice cap layers, etc.) and revealed indications of climatic variations corresponding to fundamental solar activity cycles: 22–23 years (Hale cycle), 80–100 years (Gleissberg cycle), ~200 years (Suess-deVries cycle) and ~2300–2400 years (Hallstattzeit cycle) (Ol', 1969; Shiyatov, 1975; Sonett and Suess, 1984; Pudovkin and Lubchich, 1989; Dergachev and Chistyakov, 1993; Dergachev, 1996; Cook et al., 1997; Hoyt and Schatten, 1997, Cini Castagnoli et al., 1998; White et al., 2000; Roig et al., 2001; Raspopov et al., 2001; Vasiliev and Dergachev, 2002; Ogurtsov et al., 2002a, Ogurtsov et al., 2002b; Schimmelmann et al., 2003; Prasad et al., 2004; Raspopov et al., 2004; Vasiliev et al., 2004; Wiles et al., 2004; Raspopov et al., 2005; Shao et al., 2005; Dergachev, 2006, Dergachev et al., 2007; Raspopov et al., 2008). Note that periodicities of around 30 and 17–18 years rather often can be observed in climatic oscillations as well. The former is referred to as the Brückner cyclic. The 17–18-year periodicity can be attributed to the effect of cyclicity in lunar tides (lunar Saros cycle – 18.6 years) (Currie, 1993; Cook et al., 1997; Hoyt and Schatten, 1997). On the other hand, both periodicities are close to combination of the frequencies of the solar Gleissberg and Hale cycles (Raspopov et al., 2001).

Thus, climatic variations can be a useful indicator of the existence of solar activity periodicities. This climatic indicator can be used to estimate solar forcing during time intervals for which other methods are inapplicable. Direct measurements of variation in solar activity (sunspot observations) cover only an interval of about the last 400 years, and cosmogenic ^{14}C and ^{10}Be isotopes widely used for estimation of solar activity in the past have a half-life period of

5730 and about 1.5 million years. For this reason, they cannot be used to analyze variations in solar activity during the time intervals of millions of years in the past. Indirect information on cyclicities in solar activity during those time intervals can be obtained from analysis of climatic variations.

The aim of this work was to analyze unique palaeoclimatic data with time resolution from one to several years for the time interval from 250 to 12 million years in the past. These data are annual variations in varve thicknesses (about 250 million years old) from West Texas (USA) (Dean, 2000), ring width variations of fossil cypress (~68–70 million years old) found in a coal mine in the Province of Alberta (Canada) (http://www.technology.gov.ab.ca/en/student_projects_265.cfm↗), and variations in ring width of the fossil Douglas fir (about 12 million years old) exhibited at the National Museum of Natural History in Washington (USA). In our study all three types of palaeoclimatic data were subjected to spectral and wavelet analysis with the aim of revealing climatic periodicities in the past. The data obtained were compared with present-day solar and climatic periodicities.

Section snippets

Climatic variations around 250 million years ago

To analyze climatic variations around 250 million years ago (the Permian period), the curve of annual varve thickness variations for 800-year time interval was used (Dean, 2000).

Fig. 1a presents the map with configurations and positions of continents in the Permian period (Scotese, 2001) in which the asterisk shows the site where varve cores related to the Permian Castle Formation were collected. At that time it was at near-equatorial latitudes, and today it is in West Texas (USA).

Fig.1b shows…

Climatic variations around 68–70 million years ago

Analysis of climatic variations 68–70 million years ago is based on the data on ring width variations of a fossil cypress that grew at the territory of the Province of Alberta in Canada (http://www.technology.gov.ab.ca/en/student_projects_265.cfm↗). The cypress (Fig. 4a) was found in a coal mine several kilometers from the Battle River power station in the eastern part of the Province of Alberta (53°N, 114°W). The cypress is dated back to the late Cretaceous period (68–70 million years ago) the…

Climatic variations around 12 million years ago

The National Museum of Natural History in Washington (USA) exhibits a cut of a fossil tree – Douglas fir. The age of the sample is dated back to 12 million years (the Middle Miocene epoch – 16–11 million years ago). The fossil tree was found in Washington state, USA (47°N, 120°W). Configurations and positions of continents in the Middle Miocene epoch were similar to the present-day ones (Fig. 9a). However, there was a connection between South and North America. North America and Eurasia were…

Discussion

Analysis of climatic periodicities for the time intervals tens and hundreds of million years ago show that these periodicities correspond to modern solar periodicities in spite of different climatic conditions and configurations and positions of continents of our planet around 12, 68–70, and 250 million years ago. The climate was 2–3 °C warmer than the modern one 12 million years ago, 5–6 °C warmer in the late Cretaceous period (68–70 million years ago), and 2 °C warmer in the Permian period (250…

Conclusions

We found that the most intense climatic oscillations in the past (tens and hundreds of millions of years ago) had quasi-two hundred year and quasi-secular periodicities. These climatic oscillations are most likely due to the influence of the Suess-deVries and Gleissberg solar cycles on climatic processes, because the climatic response to these solar cycles are observed irrespective of considerable changes in configurations and positions of continents and, hence, internal processes in the…

Acknowledgements

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2020, Advances in Space Research

Citation Excerpt :

…As for the samples of more ancient fossils, i.e., rings of fossil trees, quasiperiodic components corresponding to the Schwabe and Hale cycles were repeatedly found in their thickness variations, but no systematic simultaneous shifts in their values relative to these cycles were revealed. For example, the spectrum of variations in the ring width of the fossil Douglas fir (about 12 million years old) exhibited at the National Museum of Natural History in Washington (USA) was found to have a double peak (9–12 years) with an average value of 10.5 years at a series length of 380 rings, and the spectrum of the ring width variations of fossil cypress (68–70 million years old) from a coal mine in the Province of Alberta (Canada) had two peaks of 9 and 20 years at a length series of 150 rings (Raspopov et al., 2011). Dergachev et al. (2016) built and studied the spectra of eight samples of fossil trees that grew in the Gobi Desert (Mongolia) about 100–150 million years ago (Keller and Hendrix, 1997), and quasi-harmonic components with the periods similar to basic solar activity cycles of our days were revealed (9- and 11-, 20- and 22-year periods).…

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Palaeoclimate and solar activity cyclicity 100-150 million years ago

2016, Advances in Space Research

Citation Excerpt :

…Information on the environmental and climate change in the past can be obtained from numerous natural archives, such as ring widths of fossil trees, lake and marine varves, aerosol concentrations in the Greenland ice and the Antarctic ice sheets, because the annual radial tree growth, varve thickness, etc. are determined by such characteristics of the environment as temperature, humidity, and illumination. In particular, analysis of variations in the ring widths of fossil trees the age of which is tens and hundreds of millions of years has shown that the palaeoclimatic data exhibit the periodicities characteristic of the modern solar activity (Dergachev, 2006; Dergachev et al., 2007; Raspopov et al., 2010, 2011, 2013a,b). The studies of variations in the cosmic ray fluxes modulated by the solar activity have demonstrated that the changes in the level of the Earth's atmosphere ionization caused by these fluxes affect such atmospheric processes as cloud formation, thunderstorms, and tropical storms, i.e., weather and climate conditions (Sloan, 2013; Gurevich et al., 2013; Makrantoni et al. 2013; Antonova and Kryukov, 2013; Kavlakov, 2012).…

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2013, Palaeogeography, Palaeoclimatology, Palaeoecology

Citation Excerpt :

…The c. 200 yr periodicity is also present as changes in varve thickness in the Permian Castile Formation (Dean, 2000) and manifested as variations in tree-ring thickness in the 68–70 Ma yr old cypress stump record from Alberta (Raspopov et al., 2011). During both periods of geologic time, the c. 200 yr cycle was strong enough to modulate the amplitudes of other periodicities

(Raspopov et al., 2011). A. c. 208 yr signal also occurs in the Late Miocene-aged paleoclimate record of Paleo-Lake Pannon (Kern et al., 2012)….

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Temporal derivative of Total Solar Irradiance and anomalous Indian summer monsoon: An empirical evidence for a Sun-climate connection

2011, Journal of Atmospheric and Solar-Terrestrial Physics

Citation Excerpt :

…Meehl and colleagues mainly show that although globally averaged solar forcing at the top of the atmosphere of 0.2 W m−2 is too small to affect the climate system, but that locally, through both cloud-free region in subtropical Pacific and coupled air–sea mechanism that ultimately creates even larger cloud-free region (figure 4 in Meehl et al., 2008), the net solar flux at the surface can often has values at least a factor of 5–10 times larger than the top of the atmosphere forcing. Several other researchers have also carefully evaluated and highlighted the complex pathways and processes that may be involved in physical Sun–climate relations (van Loon et al., 2004; Perry, 2007; Miyahara et al., 2008; Usoskin and Kovaltsov, 2008; Mendoza and Velasco, 2009; Courtillot et al., 2010; de Jager et al., 2010; Harrison and Usoskin, 2010; Ogurtsov et al., 2011; Raspopov et al., 2010; Usoskin et al., 2010; Yamaguchi et al., 2010). Potential solar processes that may affect climate include biological and chemical modulations of marine phytoplankton emissions of dimethylsulphide (DMS), the sensitivity of meteorological and climatic change to magnetic polarity cycles of the Sun, the dependence of tropospheric temperature and condition on the particular nature of both toroidal and poloidal magnetic field components of the Sun, the modulation of tropospheric ionization, surface-atmospheric electricity and cloud microphysics and cover by incoming galactic cosmic rays.…

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