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Influence of Solar Luminosity Variation on Glaciations and Time Shifting of Termination-II

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Abstract

Calcite speleothems luminescence depends exponentially upon soil temperatures that are determined primarily by solar visible and infrared radiation. So microzonality of luminescence of speleothems is used as an indirect Solar Insolation (SI) proxy index

We measured a luminescent solar insolation proxy record in a speleothem (JC11) from Jewel Cave, South Dakota. This record has been dated by 6 TIMS U/Th dates with 2 sigma error of 0.8-5.5 kyrs. It covers 89300-138600 yrs B.P. with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record. This record exhibit a very rapid increasing in solar insolation at 139 kyrs +/- 5.5 kyrs (2 sigma error) responsible for the termination II. This increasing is preceding the one suggested by the Orbital theory with about 10 kyrs and is due to the most powerful cycle of the solar luminosity with duration of 11.5 kyrs superposed on the orbital variations curve. Solar luminosity variations appear to be as powerful as orbital variations of solar insolation and can produce climatic variations with intensity comparable to that of the orbital variations.

Introduction

M.Milankovitch demonstrated that orbital variations of the Earth's orbit cause significant variations of the amount of solar radiation received by the Earth's surface (solar insolation- SI). Scientists consider that glacial periods (ice ages) are result of such variations. The orbital components which cause variations of solar insolation are: eccentricity, precession and Earth's obliquity.

Recent measurements of a cave deposit from Devils Hole (DH), USA which is the best dated paleoclimatic record, demonstrated that the end of the former glaciation (Termination II) came 10 000 year before the moment suggested by the orbital theory (WINOGRAD ET AL, 1992).

Until recently there were no quantitative proxy records able to demonstrate how big were variations of the solar luminosity in geological time scales. SHOPOV (1987) was the first one to introduce a technique for preparation of such records.

Methods and Material Studies

Calcite speleothems (stalagmites etc.) usually display luminescence which is produced by calcium salts of humic and fulvic acids derived from soils above the cave. These acids are released by the decomposition of humic matter. Rates of decomposition depend exponentially upon soil surface temperatures that are determined primarily by solar infrared radiation. So the microzonality of luminescence of speleothems can be used as an indirect Solar Activity (SA) index (SHOPOV, 1987).

Time series of the SA index "Microzonality of Luminescence of Speleothems" are obtained by Laser Luminescence Microzonal analysis (LLMZA) of cave flowstones (SHOPOV, 1987). LLMZA allows measurement of luminescence time series with duration of hundreds of thousands years , and nevertheless the time step for short time series can be as small as 6 hours (SHOPOV et al., 1994) allowing resolution of 3 days.

Results and Analyses

We measured a luminescent solar insolation proxy record in a speleothem (JC11) from Jewel Cave, South Dakota, USA (SHOPOV et al.,1998, STOYKOVA et al., 1998). This record covers 89300- 138600 yrs BP (fig. 1b) with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record.

We extracted orbital variations from the JC11 record by a band-pass Tukey filter set for frequencies of 41, 23 and 19 kyrs. So the remaining signal contains only SL self-variations. The most powerful cycle in this record with period of 11.5 kyrs appears to be a bit more powerful than the precession cycle and a bit less than the total orbital component of the SI variations.

This TIMS U/Th dated JC11 record exhibits a very rapid increasing in solar insolation at 139 kyrs ±5.5 kyrs BP (95% confidence level) responsible for the termination II. This increasing precedes that one suggested by the Orbital theory with about 10 kyrs and is due to the most powerful cycle of the solar luminosity with period of 11.5 kyrs superposed on the orbital variations curve. This cycle was found previously to be the most intensive one in the $\Delta^{14}C$ calibration record and was interpreted to be of geomagnetic origin. Our studies suggest that this is a solar cycle modulating the geomagnetic field. The Devils Hole ^{18}O record suggests that termination II had happened at 140±3 kyrs B.P. It follows precisely the shape of our experimental solar insolation record. This result is confirmed by an other U/Th dated luminescent solar insolation proxy record in a speleothem from a Duhlata cave, Bulgaria (fig.1c) 10 000 km far form the JC11 site. These records suggest that the solar luminosity contribution to the solar insolation curves has been severely underestimated.

The Orbital theory has 2 presumptions:

1. That the solar luminosity is constant during geological periods of time.
2. That the Earth behaves as an absolute solid body independently of the orbital variations.

Recent studies demonstrate that both these presumptions are not precise. Direct satellite measurements of the solar constant demonstrated that it varies with time as much as 0.4% during the observation time span (HICKEY et al., 1980), but there are experimental data suggesting that it varied much greater during geological periods (STUIVER et al., 1989).

In order to compare quantitatively intensities of all cycles presented in our data we designed a special algorithm and relevant computer program, which plots the periodogram in coordinates (Cycle Intensity/Period). Calculated periodograms of the JC11 luminescent record demonstrated, that the 11,500-yr cycle has intensity of several orders of magnitude higher, than the observed century and sub- century cycles.

The best theoretical calculations of the orbital variations of the solar insolation have been made by BERGER (1978, 1992). His theoretical curves explain about 1/2 of the signal in the existing proxy paleotemperature records (IMBRIE et al., 1993) derived from sea cores and polar ice. But a more precise correlation demonstrates that a significant part of it is not due to the components of the orbital variations (IMBRIE et al., 1992, 1993) in such proportions as in the theoretical solar insolation curves. In order to overcome this disagreement IMBRIE (1985) introduced his ETP index of orbital variations, which is a sum of separate components of orbital variations in proportions other than those suggested by Milankovitch theory. IMBRIE (1985) does not offer an explanation why the real ratio between the orbital variations is different from the theoretical one.

Increasing of the ice volume and related sea level change during glaciations produces changes in the inertial moment of the Earth and resulting changes in the speed of Earth's rotation (TENCHOV et al., 1993). Orbital variations cause also some deformation of the solid Earth and redistribution of the Ocean masses (MORNER, 1983). In result theoretical curves can be used only for qualitative reference. For quantitative correlation it is necessary to use experimental records of the solar insolation, because they contain also variations of the solar luminosity and number of others not covered by the Orbital theory.

Conclusions

Solar luminosity variations contribute to Earth's heating almost as much as the orbital variations of the Earth's orbit (Milankovitch cycles). Their most prominent cycle (with period of 11,500 yrs) must be also taken into account for a proper explanation of the timing of the last deglaciation. Speleothem records (being the best dated paleoclimatic records) may serve as a reliable tool for studying the mechanisms of formation and precise timing of glaciations.

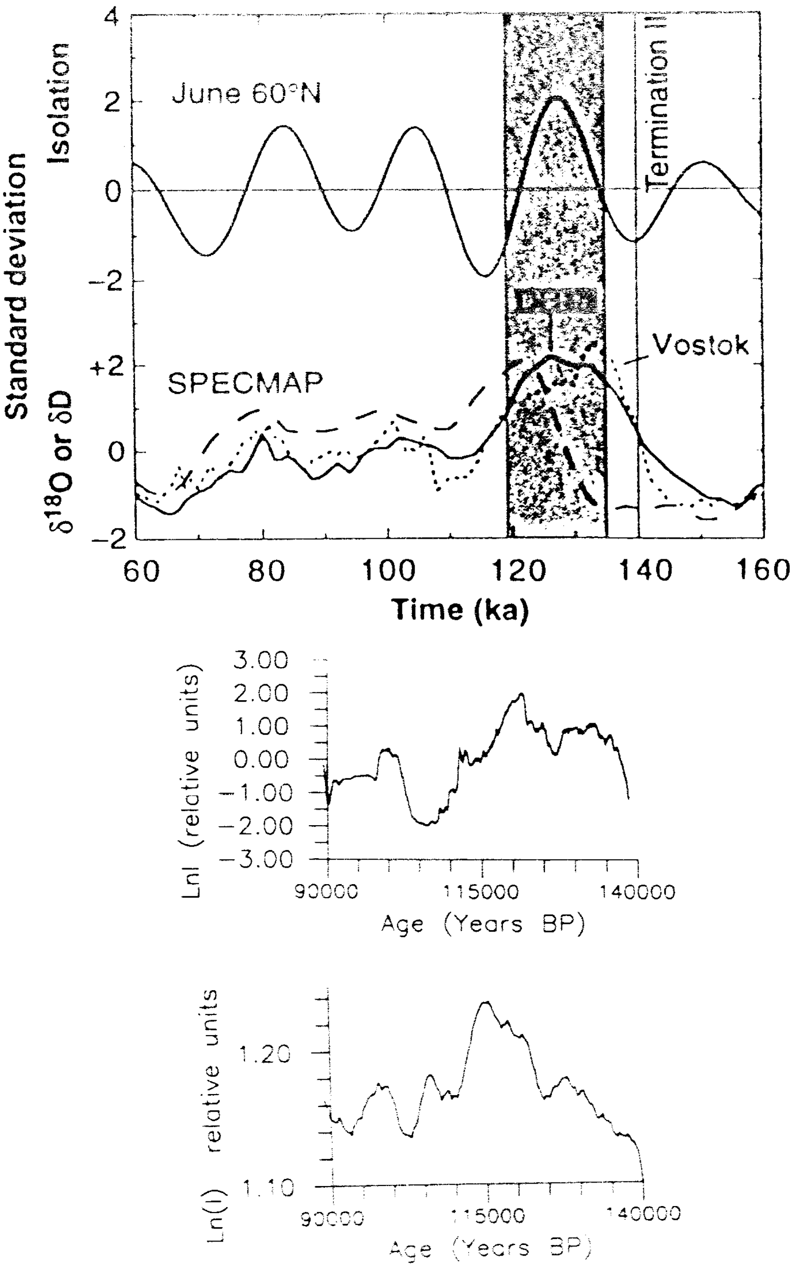

Figure 1. (a) The theoretical insolation curve compared to Devils Hole (DH-11), Vostok, and SPECMAP stack stable isotope curves (Winograd et al.,1992). Shading represents high sea level stands (at or above modern levels). (b) Jewel Cave (South Dakota) JC11. It is TIMS U/Th dated in 6 points with 2σ error varying from 0.8 kyrs (for 89.3 kyrs BP) to 5.5 kyrs (for 138.7 kyrs BP). (c) Duhlata Cave (Bulgaria), DC-2 luminescence Solar Insolation proxy record. It is TIMS U/Th dated in 4 points with 2σ error varying from 1 kyr (for 89.3 kyrs BP) to 23 kyrs (140 kyrs BP).

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