Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 915

Long-term Variations in Solar Magnetic Activity: Is There a Sun-Climate Connection?

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Introduction

Variations in the weak general magnetic field of the Sun that stretches across the heliosphere and the earth's magnetic field inversely modulate the incoming galactic cosmic ray (GCR) flux on the earth. Modulation of cosmic ray particles with energies above ~1 GeV/n leads to changes in the terrestrial production rates of cosmogenic radionuclides such as ^{14}C and ^{10}Be formed due to the interaction of cosmic ray particles with atmospheric N and O. It follows that by determining the long-term variations in the production rates of cosmogenic radionuclides one can estimate temporal changes in the solar magnetic activity, provided that the variations in geomagnetic-dipole strength for the same time-period are known, a functional relationship between geomagnetic-dipole strength, cosmogenic radionuclide production rate, and solar modulation is available, and the GCR flux has remained constant over the time-period of interest. Due to its long half-life ($t_{1/2}$ = 1.5 x 10^6 yr), short mean residence time in the atmosphere, and simple geochemical cycle, ^{10}Be is a suitable cosmogenic radionuclide for investigating the long-term variations in solar magnetic activity. Extensive ^{10}Be data have become recently available for continental and marine sediments and ice-cores. In order to uniquely determine the variations in the solar magnetic activity, it is also necessary that the established long-term production rates of ^{10}Be and corresponding variations in the geomagnetic-dipole strength are based on absolute time determinations and the records are not related to each other through parameters other than the ones described above (such as climate).

Data

For the present study, we will utilize the recently established globally stacked record of $^{230}Th_{ex}$-normalized ^{10}Be deposition in deep marine sediments that yields relative variations in ^{10}Be production rate over the past 200 kyr (Frank et al., 1997). A long-term record of relative variations in geomagnetic field intensity over the past 200 kyr has been obtained recently from a globally stacked paleo-magnetic record reconstructed from marine sediments (Guyodo and Valet, 1996). As the stacking serves to enhance signal-to-noise ratio and eliminate flaws present in individual record, we assume that any climatic signal in the above records is substantially reduced, if not completely eliminated.

Following the data presented by Lal (1988), an equation can be written relating the cosmogenic radionuclide production rate, the geomagnetic field strength and a solar modulation factor (ϕ, the energy lost by cosmic ray particles while traversing the heliosphere and reaching the earth's orbit).

Results and Conclusions

A normalized solar modulation factor (ϕ/ϕ_0) was calculated at every 1 kyr time-step between 2 and 200 kyr. The ^{10}Be production rate and geomagnetic field strength data were normalized at 5 kyr. For the purpose of normalization, the calculation assumes that ϕ_0 (at 5 kyr) = 450 MeV. Figure 1 shows a fit through the data that is compared with $\delta^{18}O$ values for the deep oceans (Martinson et al., 1987). It is apparent that: (1) The solar modulation factor has varied by more than a factor of four over the past 200 kyr, (2) Colder periods coincide with relatively lower solar modulation, and (3) Glacial to interglacial transitions are marked by an increasing solar modulation that peaks at the interglacial.

There is a direct but not one-to-one relationship between solar modulation factor and solar activity (Lal, 1988). A recent study points out that since 1964 the cosmic ray flux has decreased by 3.7% and the total magnetic flux leaving the sun has increased by 41% (Lockwood et al., 1999). If this proportionality also holds for >1 Gev/n cosmic rays, our observations would imply large changes in the solar open magnetic flux during the last 200 kyr. The mechanisms linking the solar magnetic activity and terrestrial climate are of current interest and are being actively sought (e.g., Soon et al., 2000 and references therein). Our results suggest that long-term variations in solar open magnetic flux may have affected terrestrial climate and may ultimately help elucidate the pace of glacial-interglacial transitions.

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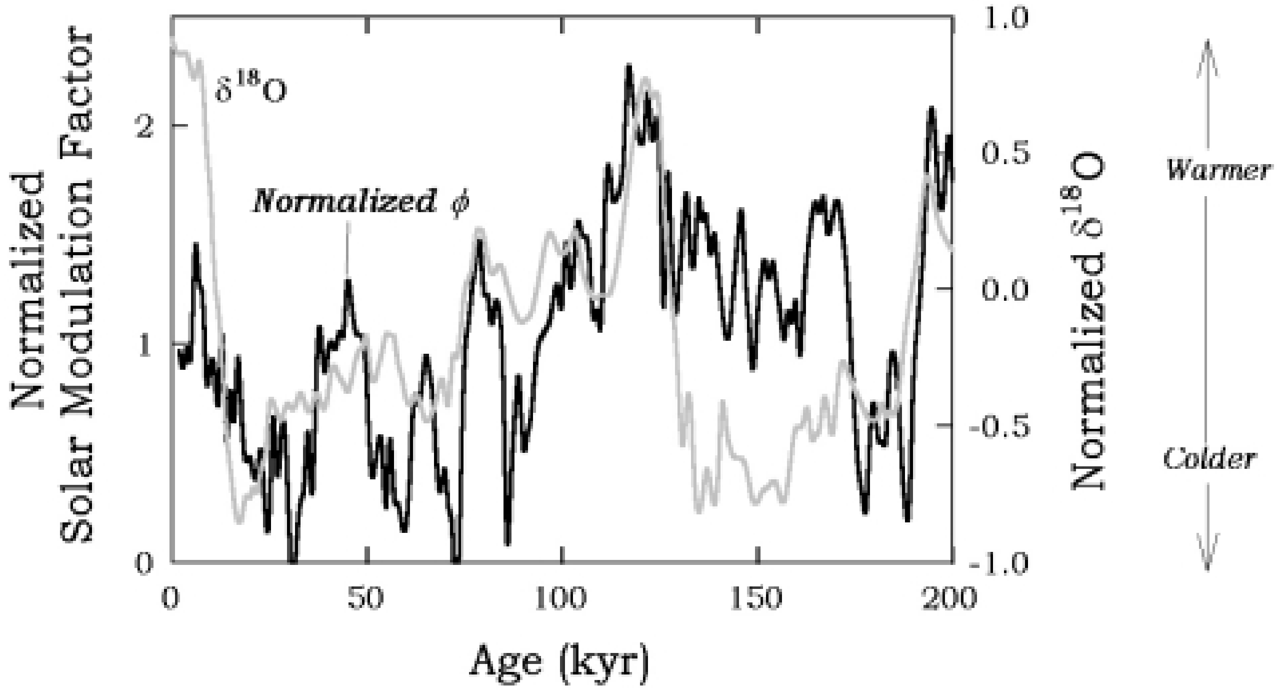

Figure 1. A comparison between the calculated solar modulation factor and the stacked oxygen-isotope record of the oceans.

Frank M, Schwarz B, Baumann S, Kubik PW, Suter M & Mangini A, *Earth. Planet. Sci. Lett.*, **149**, 121-129, (1997).

Guyodo Y & Valet JP, *Earth. Planet. Sci. Lett.*, **143**, 23-36, (1996).

Lal D, *Soc. Ital. Fis. Bologna*, **95**, 216-233, (1988).

Lockwood M, Stamper R & Wild MN, *Nature*, **399**, 437-439, (1999).

Martinson DG, Pisias NG, Hays JD, Imbrie J, Moore Jr TC & Shackleton NJ, *Quat. Res*, **27**, 1-29, (1987).

Soon W, Baliunas S, Posmentier ES & Okeke P, *New Astron*, **4**, 563-573, (2000).