The Cycle of 2402 Years in Solar Motion and its Response in Proxy Records

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ABSTRACT. A solar-terrestrial and climatic cycle of about 2400 years has up till now been of uncertain origin. Recent results indicate it is caused by solar inertial motion. The first basic cycle of solar motion is the cycle of 178.7 years. The longer cycle, over an 8000 years interval, is found to average 2402.2 years. Within each cycle an exceptional segment of 370 years has been found characterised by a looping pattern by trefoil or quasitrefoil geometry. Solar activity, evidenced by 14C tree-ring proxies, shows stationary pattern. Solar motion is computable in advance, so this provides a basis for future predictive assessments.

KEY WORDS: solar motion, long-term solar variability, the 2402 years cycle, long-term predictive assessments.

Introduction

To find a cause of solar-terrestrial (ST) and climatic variability is a key task for solar physics, geophysics and climatology.

It is now generally accepted that the two most prominent long-term cycles are permanently present in ST and climatic variability: a cycle of about 200 (160–210) years and a cycle of about 2400 (2200–2600) years - e.g. Sonett, 1991. These studies have been made on the basis of indirect, proxy records. An origin of the prominent and permanently present period of about 2400 years has been still notsettled (solar?, geomagnetic?, extraheliospheric?, etc.) or even enigmatic; the underlying 'forcing' being so far unknown.

The solar inertial motion (SIM) (motion of the Sun around the mass centre of the Solar System) is caused by varying positions, predominantly, of the giant planets (Jose, 1965). The varying positions of the giant planets (Jupiter (J), Saturn (S), Uranus (U), Neptune (N)) force the Sun to move inside a circular area

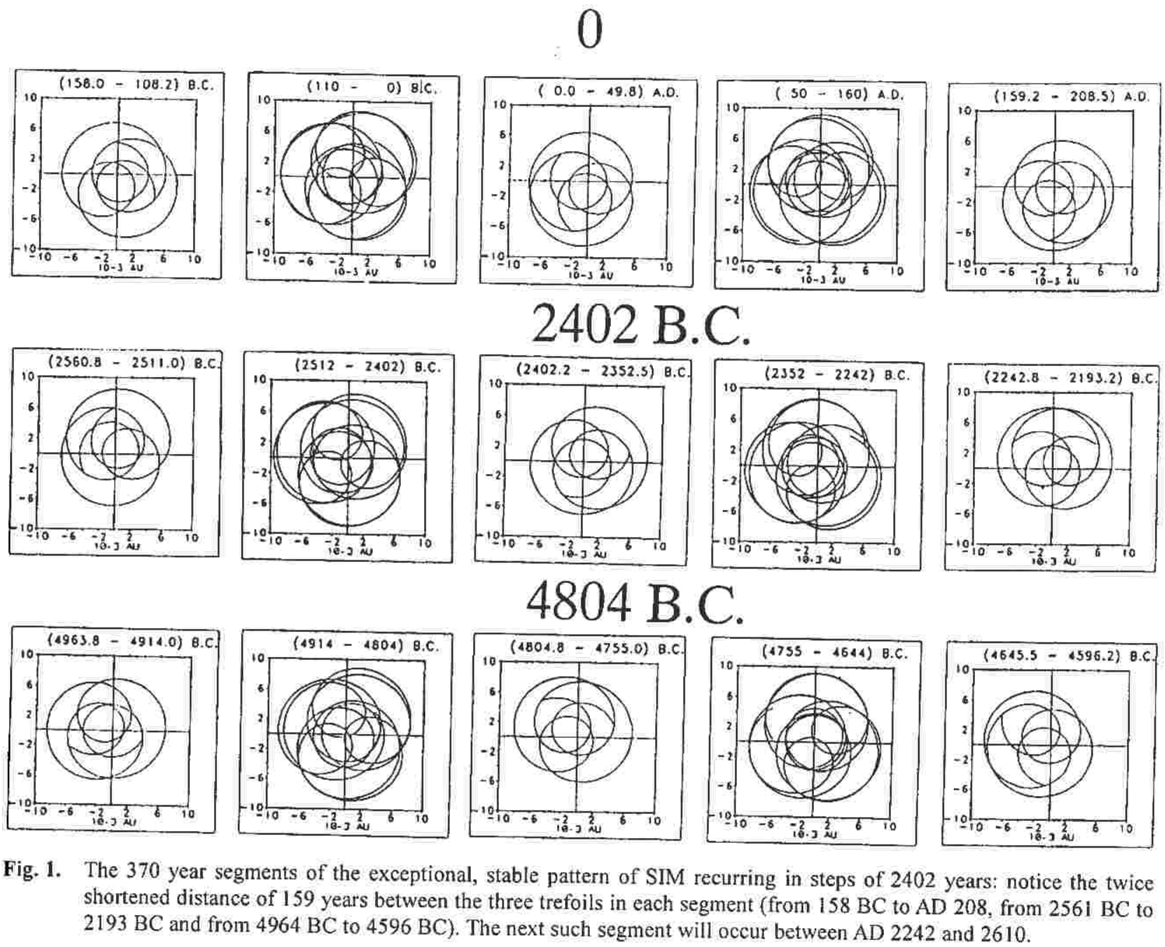

Fig. 1. The 370 year segments of the exceptional, stable pattern of SIM recurring in steps of 2402 years: notice the twice shortened distance of 159 years between the three trefoils in each segment (from 158 BC to AD 208, from 2561 BC to 2193 BC and from 4964 BC to 4596 BC). The next such segment will occur between AD 2242 and 2610.

which has a diameter of 0.02 AU (astronomical unit) or 3.10^6 km or 4.3 solar radii. The SIM is computable in advance, a great advantage that opens up a possibility of establishing predictive assessments.

The first basic cycle of 178.7-yr in SIM and its response in ST and climatic variability

Besides the motion characteristics, the geometry of solar orbit is, above all, required to be taken into account. A key of solution consists in separation of SIM into two basic orbital types (Charvátová, 1990), the ordered (according to JS motion order (117.3°, 19.86 years)- in a trefoil) and the disordered. The Sun enters into the orbital trefoils with a spacing on the average of 178.7 years and moves along a trefoil (its one loop) about 50 years (10 years), respectively. After separation, the SIM itself started to be legible and fixed in time as a precise and homogeneous basis suitable for solar-terrestrial and climatic studies.

It was noticed that the intervals of disordered SIM coincide with the prolonged minima in solar activity. The Sun moving along the same orbits during the trefoil intervals of the 18th century (1734–1785) and the 20th century (1913–1964) (taken from minimum to minimum of the sunspot cycles), created nearly the same sets of five 10-years sunspot cycles (Charvátová, 1990, 1995a, 1997a,b): cycles No. -1 to 3 and cycles No. 15 to 19. Small deviations can above all be ascribed to lower quality of sunspot numbers in the 18th century.

Volcanic activity shows an attenuation during the trefoil intervals of SIM (Charvátová, 1995a,b, 1997a) and surface air temperature shows long-term maxima in the centres of the trefoil intervals (Charvátová and Střeštík, 1995).

The second basic cycle of 2402-yr in SIM and its response in proxy records

On the very long (millennial) time scale only indirect, proxy records are available. Radiocarbon production in the atmosphere and consequently in tree-rings, is owing to a cosmic ray flux which has significantly varied, being in inverse relationship with solar activity. Radiocarbon record in tree-rings provides thus a reliable archive of past solar activity. Surface air temperature is recorded by tree-ring widths, ^{18}O in ice cores, etc..

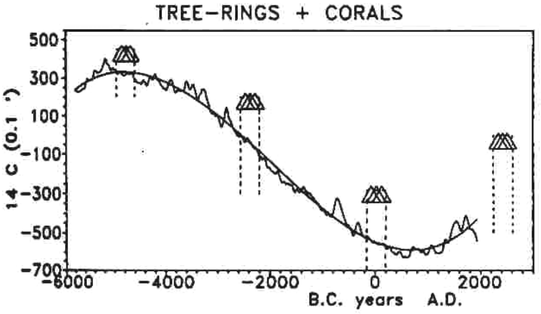

Fig. 2. Marine model ^{14}C ages calculated from the bidecadal atmospheric tree-ring data and a smoothing spline from coral data (Stuiver and Braziunas, 1993). The most stationary parts of the record coincide with the very exceptional segments of SIM. They are denoted by the dashed vertical lines and by three triangles.

The regularity of the 178.7 years cycle is sometimes disturbed: the 178.7 years basic cycle was twice shortened to 159 years and during the intermediate intervals the Sun moved along an orbit that is not too far from a trefoil. These 370 years segments of exceptional and nearly stable motion of the Sun (along a trefoil to quasitrefoil orbit) have been found to recur in steps of 2402 years, the mean value being 2402.2 years.

Fig.1 displays the last three such segments: the first from 158 BC to AD 208, the second from 2561 to 2193 BC and the third from 4964 to 4596 BC. The solar orbits are the same in all three cases, if we imagine them after a rotation. The next such segment will occur between the years AD 2242 and 2610.

The properties of the 370 years segment (exceptionality and approximate stability) are found in the corresponding intervals of the proxy (^{14}C) record and provide evidence about the SIM response and indicate that the SIM could be a cause of solar variability also on millennial scale.

Fig. 2 represents the data of marine model ^{14}C ages calculated from atmospheric tree-ring data with a smoothing spline through coral data taken from Stuiver and Braziunas (1993) since 6000 BC. One can see that the most stationary parts of the record occurred precisely during the 370 years exceptional segments of SIM.

Predictive assessments up to AD 2610 and conclusion

SIM, computable in advance, offers predictive possibilities, so far, of course, only as analogies with the results found for the previous eight millennia. After AD 2085, the Sun will move into the orbital trefoil. The activity series of the cycles No. 15–19 should be repeated.

The next 370 year exceptional segment will occur after AD 2242. Until AD 2610, approximately stationary activity should occur as a repetition of solar behaviour during the previous exceptional segments (Fig. 2). The high solar activity cycles length of 10 years could prevail.

As has been shown in Charvátová (1995a,b, 1997a), the SIM could mediate predictions also for terrestrial phenomena including the climatic. A very long-term epoch of above average surface air temperature similar to that pointed out e.g. by Larra and Villalba (1993) around the beginning of our era could also occur after 2240.

The results of this paper show that the SIM could be considered as the cause of solar variability. Not static, but a dynamic Sun should be taken into account. The results indicate that so far unsettled source of about 2400 years cycle in ST and climatic phenomena can be in SIM.

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Modelling the Physical and Biogeochemical Impacts of a Freshwater Discharge in the North Atlantic with a Model of Intermediate Complexity

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ABSTRACT. An ocean-atmosphere climate model was coupled to a biogeochemical model of the ocean carbon cycle to study the physical and biogeochemical effects of a massive freshwater discharge in the North Atlantic Ocean. The experiment consists in discharging a total freshwater amount of 6×10^6 km^3 between 45 and 70°N over 1000 years. The discharge induces a complete shutdown of the thermohaline circulation and a substantial cooling of the North Atlantic while Atlantic intermediate waters become warmer and saltier. These physical consequences modify the biological activity. For instance, Net Primary Production (NPP) in the North Atlantic drops by 50%. Besides, the vertical gradient of dissolved inorganic carbon (DIC) and nutrient concentration is strengthened as a response to the reduction of vertical mixing in that area and enhanced advection of Antarctic Bottom Water. The recovering of thermohaline circulation after the discharge is characterized by an overshoot accompanied by a maximum in Net Primary Production.

KEY WORDS: climate model, carbon cycle, thermohaline circulation, Heinrich event.

Introduction

Paleoclimate data analysis have shown that over the last 60,000 years the Earth's climate experienced a series of abrupt events which were characterized by changes in ocean circulation, sea surface and air temperature as well as atmospheric CO_2 concentration. It appears also that most of these events (and in particular the Heinrich events) are associated with massive iceberg discharges in the North Atlantic. However, the chronology of the various climatic processes implied in abrupt events remains a difficult question and climate modeling could provide interesting insight. In this study, the MoBidiC climate model from Louvain-la-Neuve is used to explore the impacts of a massive freshwater discharge in the North Atlantic on the ocean circulation, temperature, salinity as physical impacts but also on biological tracers distribution in the ocean.

The climate model

In order to study the transient behaviour of the interactions between the major climatic component at the millenium time scale it was necessary to develop a model requiring reasonable computing cost. The physical model used in this study (Gallée et al., 1991; Tulkens, 1998; Crucifix et al., 2000) includes a latitude-altitude grid and a sectorial representation of the Earth Surface: each zonal band is divided in sectors associated to continents, ice sheets and ocean basins. This model includes a zonally averaged, two levels quasi-geostrophic atmosphere, a continental surface model that also calculates the snow cover and vegetation distribution, a zonally averaged, primitive equation model of the ocean circulation in the three major basins and, finally, a thermodynamic-dynamic sea ice model.

The biological component represents the cycling of dissolved organic carbon (DOC), particulate organic carbon (POC), carbonates ($CaCO_3$), phosphates (PO_4, taken as the biolimiting nutrient), oxygen and alkalinity. In the euphotic zone, a Michaelis-Menten kinetics formulation parameterized as in Maier-Reimer (1993) controls the Net Primary Production (NPP) of organic matter. Half of the organic matter is produced as POC remineralizing instantaneously in the water column as in Martin et al. (1987). The other half is produced as DOC. Remineralization of DOC follows a first order kinetic-law cali-