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Influence of solar activity on climate : Poles to Tropics

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सार – सौर गतिविधियाँ भूमंडल के आस–पास जलवायु की विविधता के लिए प्रत्यक्ष अथवा अप्रत्यक्ष रूप से उत्तरदायी होती है। सौर गतिविधियों और पुराजलवायविक अनुमानित आँकड़ों के मध्य इस प्रकार की समानताओं के प्रमाण ध्रुवीय क्षेत्रों के साथ–साथ उष्णकटिबंधी क्षेत्रों से भी मिले है जिससे जलवायु गतिकों में सौर प्रभाव का पता चला है। तथापि सौर गतिविधियों में पुराजलवायविक आँकड़ों और अनरूपी विभिन्नताओं को उत्पन्न करने के लिए व्यापक भौगोलिक क्षेत्र में इन खोजों को और अधिक सुदृढ़ करने की आवश्यकता है। ध्रुवीय क्षेत्र से उष्णकटिबंधी क्षेत्र तक सौर गतिविधियों और जलवायु परिवर्तनों के मध्य अंतिम रूप से अनुकूल और सत्याभासी कारणात्मक सम्पर्कों को प्राप्त करने के लिए अनुमानित आँकड़ों पर एक सही समय को नियंत्रित करने की आवश्यकता है।

ABSTRACT. Solar activities are directly or indirectly responsible for climate variability around the globe. Evidences of such correspondences between solar activities and palaeoclimatic proxy data have been reported from polar as well as tropical regions, suggesting solar influence over climate dynamics. However, these findings need to be further strengthened by covering vast geographical region for generating palaeoclimatic data and corresponding variations in solar activities. A better time control on proxy data is essential to arrive at conclusive understanding and plausible causal linkages between solar activity and climate changes from poles to tropics.

Key words – Solar activity, Climate change, Poles, Tropics, Sunspot.

1. Introduction

Energy from the Sun is very important to the Earth as it warms our planet by heating the surface, the oceans and the atmosphere. This energy to the atmosphere drives the weather. The climate is also strongly affected by the amount of solar radiation received at Earth and changes based on the Earth's albedo, (*i.e.*, how much radiation is reflected back from the Earth's surface and clouds).

The amount of radiation given off by the Sun changes with solar activity like solar flares or sunspots. Solar activity is known to vary in cycles, like the 11-yr sunspot cycle and many longer cycles. Weather is the current atmospheric conditions, including temperature, rainfall, wind and humidity for a given area, while climate is the general weather conditions over a longer period. Attempts have been made to understand the influence of Sun on various weather phenomenon and to find a link between changes in Earth's weather and solar variability. However, there have been some contradictory findings such as studies of the relationship between the number of sunspots and changes in wind patterns or between cosmic rays and clouds and therefore, the influence of solar variation on Earth's climate was looked with mixed success.

2. Solar activity and climate

Space weather may also, in the long term, affect the Earth's climate. Solar ultra-violet, visible and heat radiation are the primary factors for the Earth's climate, including global average temperatures and these energy sources appear to be quite constant. However, it has been observed that a correlation exists between the solar magnetic activity, which is reflected in the sunspot frequency and climate parameters at the Earth. Sunspots have been recorded through several hundreds of years which makes it possible to compare their variable frequency to climate variations in the past.

Friis-Christensen and Lassen (1991) demonstrated that the correlation between the northern hemisphere land surface air temperature and solar activity was markedly improved when the sunspot number was replaced by the length of the solar cycle as an index of the long-term variability of the Sun, and it was concluded that this parameter appears to be a plausible indicator of long-term changes in the total energy output of the Sun.

Several attempts have been made to extend the sunspot record back in time. Since the occurrence of low-latitude auroral display is known to be controlled by solar activity it has been generally accepted that they may be used as proxy data in the study of the 11-year sunspot variation. Sunspot numbers prior to 1750 as well as epochs of maxima and minima have been computed from catalogues of auroral sightings from Central Europe and East Asia, but the reliability of this data set has been questioned (Eddy 1976). However, an improved record of the number of auroral nights for the past 500 years exhibited the secular variation of low-latitude aurora during 1500-1948 AD and established that there is a clear indication of a decadal variation of the number of auroras also prior to 1750 AD (Silverman, 1992). Subsequently, based on earlier observations, the epochs of minimum occurrence of low-latitude auroral display and sunspots during the period between 1500-1948 AD, were estimated (Lassen and Friis-Christensen, 1995).

3. Temperature and solar cycle

The solar cycle lengths have been compared with time series of climate data in order to extend the examination of the assumed association between climate and solar variability as far back in time.

A comprehensive reconstruction of the northern hemisphere temperature since 1579 was achieved by using several local temperature measurements together with proxy data from many places in the northern hemisphere and by performing a multi-regressional analysis of the data, resulted in a set of empirical formulas relating each proxy data series to the measured northern hemisphere temperature. Using this set of empirical relations the temperature for the northern hemisphere was calculated (Groveman and Landsberg, 1979).

Obviously, the reconstruction of the northern hemisphere temperature must be less accurate than the modern record. Groveman and Landsberg (1979) gave a standard error of 0.2-0.3° C for the single annual averages. Besides this, variations due to internal oscillations in the climate, El Nino effects, volcanic eruptions, etc. also play some role in determining earth's temperature. Taking these variations into consideration, the comparison between the temperature record and the solar activity indicated a good association between the long-term variations in the temperature and in the solar cycle length record, albeit the coincidence may be less obvious during the pre-instrumental period than for the modern instrumental record. The northern hemisphere land air temperature has varied with solar cycle length since the last decades of the sixteenth century. The temperature decreases with increasing solar cycle length in an aproximately linear manner.

A comparison of solar cycle length with phenological data has been presented by Hameed and Gong (1993). These authors utilized the data of blossoming of plants noted in personal diaries and other documents originating from the area of the Middle and Lower Yangtze River Valley with records of the last day of snow event in the spring season of each year between 1720 and 1800. The combined data sets made it possible to estimate the long-term variation of spring temperature in the region from 1580 to 1920 AD. A strong co-variation between the spring temperature in Central China and the length of the solar cycle since 1750 AD, was noticed. Fig. 1 indicates correspondence between solar activity and global mean temperature.

4. Indications of solar influence on climate in polar regions

An important parameter in the modeling of climate variations is the extent of the Arctic sea-ice. The ice occupied a large part of the Greenland Sea. Ice-charts of this type covering the summer months have been published since the last decades of the nineteenth century from reports of observations from ships, later supplemented by airplane reconnaissance. The drift ice in the Greenland Sea (the East-Greenland ice) sometimes approaches the coast of Iceland. Reports of the occurrence of this Iceland ice have been collected by several authors and the records consist of an index based on a combination of duration and extent along the coast of Iceland of the drifting ice from the Greenland Sea on an annual basis during the last millennium.

A relatively ice-free period in the 15^{th} century was followed by a period of increasing amounts of ice culminating in the 19^{th} century ("The Little Ice Age") and ending with an abrupt fall in the present century indicating a clear tendency for the two parameters of temperature and sea ice extent to vary in agreement with the hypothesis that short solar cycles correspond to higher global temperature and reduced amount of sea-ice.

Dansgaard *et al.* (1975) compared temperature variations derived from the ^{18}O concentration in snow fallen in Central Greenland with temperatures in Iceland during the period of 900-1970 AD. It was further concluded that most of the pronounced medium frequency oscillations back to 900 AD were essentially in phase, so that the ^{18}O curve is representative of climatic changes far

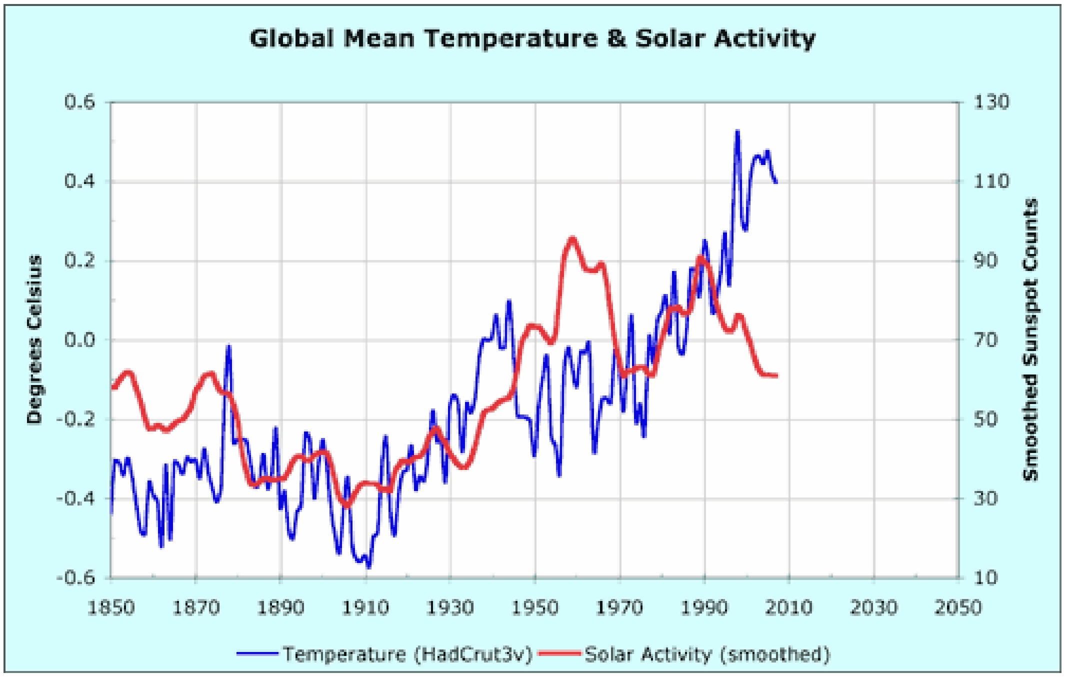


Fig.1. Graphs showing mean global temperature and solar activity since 1850

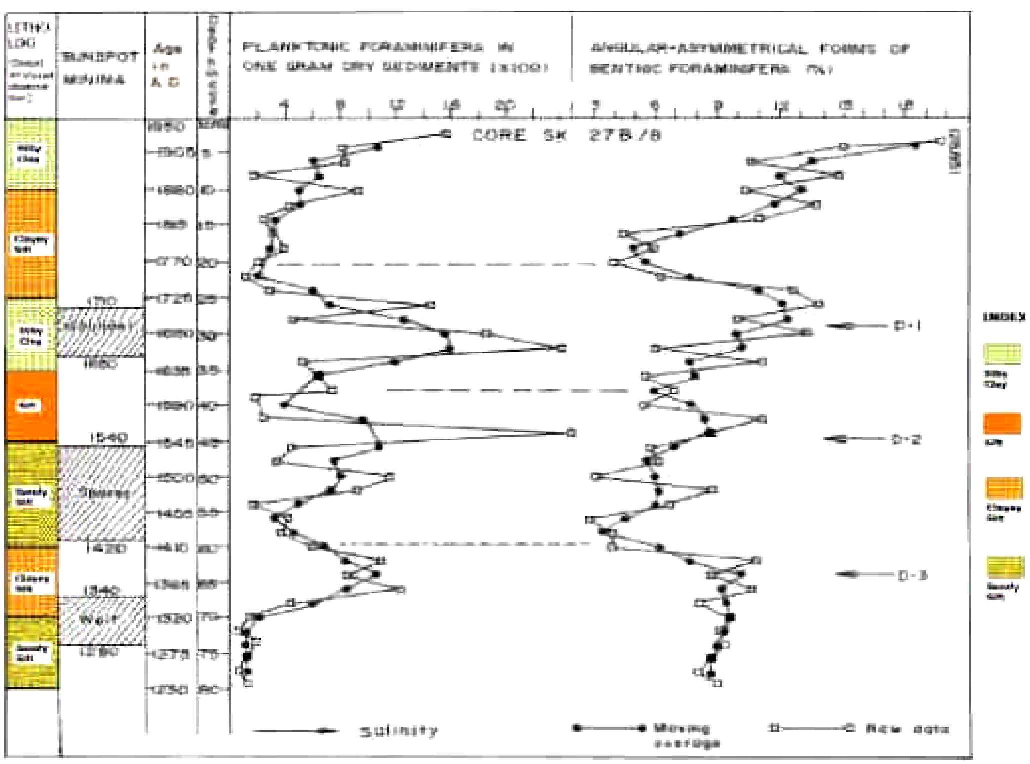
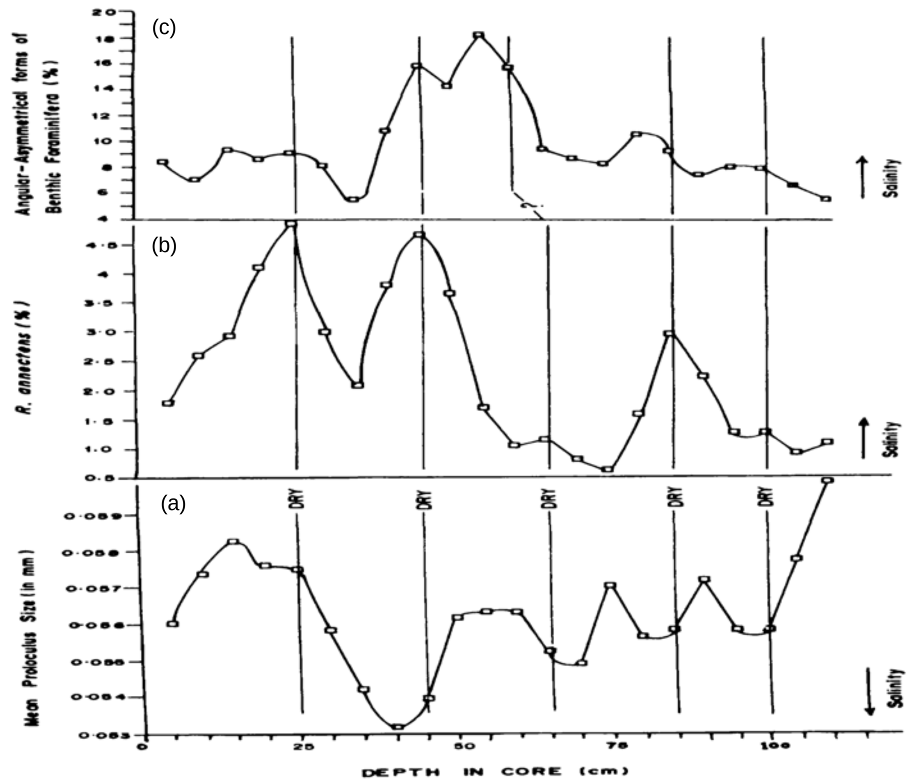


Fig. 2. Correspondence between tropical Indian monsoonal pattern derived through proxy indicators and solar activity (adopted from Khare and Nigam, 2006).



Figs. 3(a-c). Cyclic variations in the intensity of the tropical Indian monsoons reconstructed on the basis of proxy paleomonsoonal tracers namely (a) mean proloculus size (b) abundance of indicator species Rotalidium annectens and (c) abundance of angular-asymmetrical forms of benthic foraminifera (after Nigam *et al*., 1995)

beyond the Greenland area. Accordingly, the temperature data derived from the ice-core in Central Greenland like the variation of sea-ice extent at Iceland have varied with the medium length solar activity during most of a 500 year period.

5. Indications of solar influence on climate in tropical region

Changes in spottiness of the sun already observed over several centuries have lead to any attempts to correlate solar changes and earthly variables such as climates (Dunbar *et al*., 1994; Stuiver *et al*., 1997). The last millennium has witnessed well known major solar activity (changes in the sunspot). Albeit, the research on the extent and intensity of climatic variability over the last thousand years has experienced a renewed vigour (Cioccale, 1999; Quin and Zhu, 2002; Mackay *et al*., 2005), nevertheless, the attempts to correlate century level climatic variations and solar activity of the last millennium are limited (Stuiver and Quay, 1980; Blackford and Chambers, 1995) and as such no significant attempt is made to decipher the influence (if any) of major periods of sunspot minima namely Wolf, Sporer and Maunder during the last thousand years in tropical regions and specially on Indian monsoonal rainfall, the most important constituent of climate in the tropics (Martin *et al*., 1997). This may perhaps be due to paucity of the desired rainfall data for pre-instrumental era for which one needs to rely on various climate sensitive proxies. The microfossils contained in the coastal marine sediments having higher sedimentation rate, have emerged out as the potential candidates for inferring paleoclimatic conditions with higher resolution (Fairbanks and Wiebe, 1980; Jiang *et al*., 2001). Accordingly, earlier studies carried out in tropics attempted to generate high resolution foraminiferal data in laminated sediments of the last millennium from the shelf region off central west coast of India. These studies further attempted to explore the possibility of any linkage between the inferred climatic conditions and the solar variability in the past.

Foraminiferal studies on a shallow water sediment core (SK 27B/8) off Karwar, central west coast of India have revealed significant changes in the monsoonal precipitation during the last around 720 years. The results showed some possibility of linkage of monsoonal precipitation with solar variability during this period (Khare and Nigam, 2006). Similarly in another sediment core collected from the Eastern Arabian Sea (SK 44/13) at latitude 14°43.80'N and longitude 74°2.65'E, foraminiferal tracers indicated that the average signature of relatively better monsoonal precipitation at around 1400-1410 AD, 1575-1590 AD and 1750 AD with intermittent dry phases from around (1290-1355 AD), (1425-1535 AD) and (1600-1665 AD). These initial inferences when compared with the solar variability (Wolf, Sporer and Maunder sunspot minima) during the last thousand years, perhaps hinted for a possible linkage between the rainfall pattern and solar variability (Khare, In Press). Fig. 2 indicates correspondence between tropical Indian monsoonal pattern derived through proxy indicators and solar activity (adopted from Khare and Nigam, 2006).

In an earlier study evidences for 77-year cycles of droughts in India were retrieved by using foraminiferal plaeomonsoonal tracers in a 1.15 m long core collected from 20 m water depth off Karwar on the western continental shelf of India during the recent past with fine time resolution. These established parameters (indicating salinity fluctuations, thus runoff from rivers due to the monsoonal precipitation over catchment area) were angular-asymmetrical morpho-group, directly proportional to salinity, the mean proloculus size of Rotalidium annectens (Parker and Jones), inversely proportional to salinity and abundance of indicator species R. annectens (Parker and Jones), directly proportional to salinity. These parameters showed considerable fluctuations in the core (representing about 450 years) indicating variations in paleo-monsoons in a cyclic manner (around 77 years). Attempts to establish correlation between inferred paleomonsoonal precipitation with known climatic cycles affecting the earth's climate suggested a possible link with the Gleissberg solar cycle of around 80 ± 10 years, which has already been noted in various other climatic records (Nigam and Khare 1995). Fig. 3 indicates cyclic variability in the tropical Indian monsoonal pattern derived through proxy indicators and its possible modulation by the existing solar cycle popularly known as the Gleissberg Cycle (adopted from Nigam and Khare 1995).

6. Conclusions

It may be put forth that solar activity may play some role in triggering climate changes and controlling climate dynamics. However, since most of these correspondences are based on proxy indicators with some limitations on time control. Therefore in order to arrive at a comprehensive reasoning of the influential role of solar activities on climate changes from polar regions to tropics a number of similar studies from geographically distinct locations and with firm time control need to be undertaken.

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