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The Role of Sun on Climate Change

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Abstract: **Sunspots are the coldest part of the Sun and usually develop in pairs. The magnetic field in Sunspots stores energy that is released in solar flares/coronal mass ejections. As a result, solar source activities usually occur in a cycle that mimics the 11-year Sunspot cycle. The solar energy that drives the weather system, scientists naturally wondered whether they might connect climate changes with solar variations. The Sun is the primary driver of Earth's space weather. Storms on the Sun, in the form of solar flares/coronal mass ejections, can launch showers of radiation and powerful magnetic fields into interplanetary space. Space weather comes as short-lived storms which can last minutes to hours to days. The Sun also undergoes cycles in its level of activity that span years to decades, causing longer-term variations in space weather. Finally, the Sun has changed substantially over the multi-billion year history of our solar system, producing long-term 'climate change' effects on our space weather. The variations of length of the solar cycle, carbon dioxide and temperature in the Earth's atmosphere are discussed.**

I INTRODUCTION

The Sun is ever-changing, turbulent star. Activities of Sunspots, solar flares and other parameters on the Sun are all driven by magnetic fields. Emission from the Sun can directly impact on the near-earth environment on atmosphere. Interruptions to power supplies, damage to satellites and disruption to communications may have significant social and economical impacts. The Sun surface at times was covered by darker, irregular shaped region that were termed Sunspots. Sunspot most often forms in groups and typically last for a few weeks or months.

The magnetosphere and upper atmosphere of the Earth can be considerably perturbed by the variations in the solar wind caused by disturbances on the Sun. Changes in the orientation of the interplanetary magnetic field and major increase in the velocity and density of solar wind particles striking the magnetosphere and results in the geomagnetic storms. These storms are seen at the surface of the Earth as perturbations in the components of the geomagnetic field, caused by electric currents flowing in the magnetosphere and upper atmosphere. In addition, the redistribution of particles and fields produces the storms in the ionosphere and thermosphere. Global thermospheric storm winds and composition changes are driven by energy injection at high latitudes. Storm effects may penetrate downwards to the lower thermosphere and may even perturb the mesosphere. Many of the ionospheric changes at mid-latitude can be understood as a response to thermospheric perturbations. A typical mid-latitude ionospheric storm has a positive phase in F2 peak electron density (NmF2) and total electron content (TEC), followed by a negative phase, particularly in the summer hemisphere. At low latitudes, the positive phase may be longer and the negative phase absent altogether. However, there are substantial variations in this scenario from storm-to-storm, depending on location, level of solar activity, magnitude of the geomagnetic disturbance, season of occurrence, local time, time of day of the commencement and duration of the storm.

The solar energy from the Sun is the primary source, which drives the space weather that occurs in the Sun's atmosphere and may also influence the Earth's atmosphere to a greater extent. Storms on the Sun, in the form of solar flares and coronal mass ejections, can launch showers of radiations and powerful magnetic fields into interplanetary space. Weather on Earth is the set of ever-changing ambient conditions in our atmosphere. Its elements include temperature, air pressure, wind speed and direction, humidity, precipitation and so on. Space weather is the set of ever-changing ambient conditions in the space within our solar system. Its elements include electromagnetic radiation, the solar wind of charged particles that flows outward from the Sun, and the force of the interplanetary magnetic field, which spirals outward from our parent star.

Due to the global warming, changes occur for large scale weather systems on Earth, especially the surface temperature enhances by the increase of carbon dioxide, CO_2, in the atmosphere. The galactic cosmic rays enhances the amount of C^{14} in the atmospheric CO_2 and also in vegetation. During the increased solar activity close to solar cycle maximum years, earth is better shielded from the cosmic rays than during the minimum years, and results in the variation of the amount of C^{14} which leads to a decrease during minima. Thus the C^{14} content of, for example, annual rings of old trees may reveal interesting information about the Sun's performance during the last few millennia. Some studies have indicated that there is a connection between long term climate change and Sun's activity (Friis-Christensen and Lassen, 1991; Lassen and Friis-Christensen, 1995). One possible mechanism is that during high activity levels the decreased amount of galactic cosmic rays could lead to reduced cloud formation in the atmosphere, and hence increase in temperature.

The studies of solar-terrestrial impacts are great area of interest because it is concern with space weather environment. Radiation from space storms can endanger astronauts and can damage and destroy satellites, such as those used for cell phone communications. Some electrical power grids have been knocked out of commission by especially powerful solar storms. Such storms can be sources of beauty as well as destruction. The marvelous displays of the aurora are caused by collisions of particles energized by solar storms with gases in Earth's upper atmosphere.

A. Climate Change

The basic components that influence the Earth's climatic system can occur externally from extraterrestrial systems and internally from ocean, atmosphere and land systems. The external change may involve variation in the Sun's output which would externally vary the amount of solar radiation received by the Earth's atmosphere and surface. Internal variations on the Earth's climatic system may be caused by changes in the concentrations of atmospheric gases, mountains building, volcanic activity, and changes in surface or atmospheric albedo.

B. Variations in Solar Output

Sunspots are huge magnetic storms that are seen as dark (cooler) areas on the Sun's surface. These spots may be of diameter 37000 km and appear as dark spots within the photosphere, the outermost layer of the Sun. The photosphere is about 400 km deep and provides most of our solar radiation. The layer is about 6000 K at the inner boundary and 4200 K on the outside. The temperature within sunspots is about 4600 K. The number of sunspots peaks every 11.1 years. There is a strong radial magnetic field within a sunspot and the direction of the field reverses in alternate years within the leading sunspots of a group. So the true sunspot cycle is 22.2 years. The number and size of Sunspots show cyclical patterns, reaching a maximum about every 11, 22, 88 and 176 years. The solar activities vary with Sunspot cycles. The measurements made with a solar telescope from 1976 to 1980 showed that during this period, as the number and size of Sunspots increased, the Sun's surface cooled by about 6 K. Apparently, the Sunspots prevented some of the Sun's energy from leaving its surface. However, these findings tend to contradict observations made on longer time scales. Observations of the Sun during the middle of the Little Ice Age (1650-1750) indicated that very little Sunspot activity was occurring on the Sun's surface. The Little Ice Age was a time of a much cooler global climate and some scientists correlate this occurrence with a reduction in solar activity over a period of 88 or 176 years. Measurements have shown that these 88 and 176 year cycles influence the amplitude of the 11 year Sunspot cycle. During solar activity maximum years, maximum transient solar activity i.e. solar flares, solar proton events and coronal mass ejections is released from the Sun and enters the earth's magnetosphere which is found to be responsible for producing large geomagnetic storms. In solar activity minimum years, a few geomagnetic storms are observed due to the presence of coronal interaction regions (Pandey et al., 2010). It is hypothesized that during times of low amplitude, like the Maunder Minimum, the Sun's output of radiation is reduced. Observations by astronomers during this period (1645-1715) noticed very little Sunspot activity occurring on the Sun.

In 1801 William Herschel attempted to correlate the annual number of sunspots to the price of grain in London. The most common parameters used to define climate and have been rainfall and temperature, and these have been utilized in many of the Sun-weather studies. The 11-year cycle of the number of sunspots was first demonstrated by Heinrich Schwabe 1789-1875) in 1843. There have been several periods during which sunspots were rare or absent, most notably the Maunder minimum (1645-1715), and less markedly the Dalton minimum (1795-1820). During the Maunder minimum the proportional concentration of radio-carbon (^{14}C) in the Earth's atmosphere was slightly higher than normal, causing an underestimate of the radio-carbon date of objects from those periods. By means of the premise of excess ^{14}C concentrations in independently dated material such as tree rings, other minima have been found at times prior to direct sunspot observations, for instance the Sporer minimum from 1450 to1540 (Eddy, 1981).

Incidentally, the Sporer, Maunder, and Dalton minima coincide with the colder periods of the Little Ice Age are explained through the greenhouse effect. This made us to link the influence of sunspots on the Earth's climate (Verschuren et al. 2000; Neff et al. 2001; Rajesh and Dutta, 2003). Intuitively one may assume that total solar irradiance would decrease as the number of (optically dark) sunspots increased. However, direct satellite measurements of irradiance have shown just the opposite to be the case. This means that more sunspots deliver more energy to the atmosphere, so that global temperatures should rise. According to current theory, sunspots occur in pairs as magnetic disturbances in the convective plasma near the Sun's surface. Magnetic field lines emerge from one sunspot and re-enter at the other spot. Also, there are more sunspots during periods of increased magnetic activity. At that time more highly charged particles are emitted from the solar surface, and the Sun emits more UV and visible radiation. Direct measurements are uncertain, but estimates are that the Sun's radiant energy varies by up to 0.2% between the extremes of a sunspot cycle. The periodicity of the sunspot number, and hence that of the circulation in the solar plasma, relates to the rotation of the Sun about the centre of gravity of whole solar system, taking 11.1 years on average. Sometimes the Sun is up to a million kilometres from that centre, and sometimes it more or less coincides, leading to different conditions of turbulence within the photosphere. The transition from one condition to the other affects the number of sunspots.

During periods of maximum Sunspot activity, the Sun's magnetic field is strong. When Sunspot activity is low, the Sun's magnetic field weakens. The magnetic field of the Sun also reverses every 22 years, during a Sunspot minimum. The Milankovitch theory suggests that normal cyclical variations in three of the Earth's orbital characteristics are probably responsible for some past climatic change. The basic idea behind this theory assumes that over time these three cyclic events vary the amount of solar radiation that is received on the Earth's surface. The first cyclical variation, known as eccentricity, controls the shape of the Earth's orbit around the Sun. The orbit gradually changes from being elliptical to being nearly circular and then back to elliptical in a period of about 100,000 years. Second cyclical variation results from the fact that, as the Earth rotates on its polar axis, it wobbles like a spinning top changing the orbital timing of the equinoxes and solstices**.** Finally, the third cyclical variation is related to the changes in the tilt (obliquity) of the Earth's axis of rotation over a 41,000 year period.

Periods of a larger tilt result in greater seasonal climatic variation in the middle and high latitudes. At these times, winters tend to be colder and summers warmer. Colder winters produce less snow because of lower atmospheric temperatures. As a result, less snow and ice accumulates on the ground surface. Moreover, the warmer summers produced by the larger tilt provide additional energy to melt and evaporate the snow that fell and accumulated during the winter months. In conclusion, glaciers in the Polar Regions should be generally receding, with other contributing factors constant, during this part of the obliquity cycle.

Not only does the increased brightness of the Sun tend to warm the Earth, but also the solar wind (a stream of highly energetic charged particles) shields the atmosphere from cosmic rays, which produce 14C. So there is more 14C when the Sun is magnetically quiescent. This explains why 14C samples from independently dated material are used as a way of inferring the Sun's magnetic history. Lane et al. (1994) indicates that the combined effects of sunspot-induced changes in solar irradiance and increases in atmospheric greenhouse gases offer the best explanation yet for the observed rise in average global temperature over the last century.

C. Variations of Atmospheric CO_2

The world's most current data available for the atmospheric CO_2 is from measurements at the Mauna Loa Observatory in Hawaii. Monthly mean CO_2 concentrations are determined from daily averages for the number of CO_2 molecules in every one million molecules of dried air and without considering the water vapor in air. Annual mean CO_2 concentrations are the arithmetic mean of the monthly averages for the year. The annual mean rate of growth would represent the sum of all CO_2 added to, and removed from, the atmosphere during the year by human activities and by natural processes. There is a small amount of month-to-month variability in the CO_2 concentration that may be caused by anomalies of the winds or weather systems arriving at Mauna Loa. This variability would not be representative of the underlying trend for the northern hemisphere which Mauna Loa is intended to represent. The estimated uncertainty in the Mauna Loa annual mean growth rate is 0.11 ppm/yr.

The amount of CO_2 that can be held in oceans is a function of temperature. CO_2 is released from the oceans when global temperatures become warmer and diffuses into the ocean when temperatures are cooler. Initial changes in global temperature were triggered by changes in received solar radiation by the Earth through the Milankovitch cycles. The increase in CO_2 then amplified the global warming by enhancing the greenhouse effect. The long term climate changes represent a connection between the concentrations of CO_2 in the atmosphere and mean global temperature. CO_2 is one of the more important gases responsible for the greenhouse effect. Certain atmospheric gases, like carbon dioxide, water vapor and methane, are able to alter the energy balance of the Earth by being able to absorb long wave radiation emitted from the Earth's surface. Without the greenhouse effect, the average global temperature of the Earth would be a cold -18 °C rather than the present 15 °C.

Human activities like the burning of fossil fuels, conversion of natural prairie to farmland, and deforestation have caused the release of CO_2 into the atmosphere. From the early 1700's, CO_2 has increased from 275 ppm to 393 ppm in the middle of 2010. The variation of CO_2 concentration is shown in Fig. 1. From the plot, exponential growth of CO_2 concentration with period can be observed. The higher concentrations of CO_2 in the atmosphere will enhance the greenhouse effect making the planet warmer. According to computer climate models, if the globe will warm up by 1.5 - 4.5 °C then CO_2 concentration can reaches the of 600 ppm by the year 2050.

The global surface temperature anomalies are plotted in Fig. 2. Here, the temperature anomaly means a departure from a reference value or long-term average. A positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that the observed temperature was cooler than the reference value. The temperature data for the land and sea surface obtained from the Global Historical Climate Network are used to compute the temperature anomalies. The result reveals that the there exist a temperature anomaly by 1.5 C from its mean values.

D. Sunspots and climate prediction

It is not so clear why the Sun spends part of its time in a magnetically quiescent state, and whether the sunspot minima occur with a regularity that is sufficient to predict when the next quiescent episode might occur. At present there is no concern about another Little Ice Age. Recent satellite measurements of solar brightness show an increase from the previous cycle of sunspot activity to the current one, indicating that the Earth is receiving more energy from the Sun. The current rate of increase of solar irradiance continues until the mid 21th century, then the surface temperatures will increase by about 0.5 C (Wilson, 1997). This is small, but not a negligible fraction of the expected greenhouse warming. The relationship between cycle length and Earth temperatures is not well understood. Lower-than normal temperatures tend to occur in years when the sunspot cycle is longest, as confirmed by records of the annual duration of sea-ice around Iceland. The cycle will be longest again in the early 2020's.

Table 1 gives a catalogue of sunspot cycles 1–23 and several characteristics of sunspot cycles are presented. It is clear that the length of solar cycle, position of solar maxima of sunspot cycle from the beginning of sunspot cycle and maximum sunspot number differ from cycle to cycle. Some similarities are observed in particular sunspot cycles, which is a good base for prediction of future sunspot cycles. The variation in length of sunspot cycles 1–23 is shown in Fig. 3. It is clear from this figure that the 11-year period is not constant, but varies between 9 and 13.67 years. Sunspot cycle 23 is similar to sunspot cycle 20 in the way it rises and falls. Sunspot cycle 20 took about four years to peak and about seven years to descend to its minimum. A major part of the sunspot cycle 23's most intense solar activity occurred 3.5–4.5 years after solar maximum. The sunspot cycles 17 and 20 reveal remarkable and intense solar activity in the late stages of both cycles. Sunspot cycles 17 and 20 are very similar in sunspot amplitude to sunspot cycle 23.

References

[1]. Eddy, J.A. 1981: Climate and the role of the Sun. In Rotberg and Rabb 1981, 145-167.

[2]. Feldman, U., Landi, E. and Schwadron, N. A., Journal of Geophysical Research, 2005, 110, 7109.

[3]. (Friis-Christensen E. and Lassen, K., 1991. Length of the solar cycle, an indication of solar activity closely associated with climate, Science, 254, 698-700.

[4]. Lane, L.J., Nichols, M.H. and Osborn, H.B., 1994, Time series analyses of global change data. Environ. Pollution, 83, 63-68.

[5]. Lassen, K. and Friis-Christensen, E., 1995, , J. Atmos. Terr. Phys., 57, 835-845.

[6]. Neff, U., Burns, S. J., Mangini, A., Mudelsee, M., Fleitmann, D. and Matter, A., 2001. Strong coherence between solar variability and the monsoon in Oman between 9 and 6 K year ago. Nature, 2001, 411, 290–293.

[7]. Pandey, S.K., Rahul Shrivastava, Borkar, L. K., Tripathi, A. K. , Aka Tripathi and Dubey, S. C., 2010. Study of sunspots and sunspot cycles 1–24, Current Science, 98, 1496-1499.

[8]. Rajesh Agnihotri and Koushik Dutta, 2003. Centennial scale variations in monsoonal rainfall (Indian, east equatorial and Chinese monsoons): Manifestations of solar variability, current Science, 85, 459-463.

[9]. Verschuren, D., Laird, K. R. and Cumming, B. F., Rainfall and drought in equatorial east Africa during the past 1100 years. Nature, 2000, 403, 410–414.

[10]. Willson, R.C. 1997. Total solar irradiance trend during solar cycles 21 and 22. Science, 277, 1963-1965

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Table 1: Characteristic properties of solar cycle 1-23

Solar cycle number	Starting of solar cycle (mm/yr)	Solar maximum (mm/yr	Ending of solar cycle (mm/yr)	Maximum number of sunspots	Position of solar max. (years)	Length of solar cycle (years)
1	3/1755	6/1761	5/1766	85.9	6.33	11.25
2	6/1766	9/1769	5/1775	106.1	3.33	9.00
3	6/1775	5/1778	8/1784	154.4	3.0	9.25
4	9/1784	2/1788	4/1798	132	3.5	13.67
5	5/1798	2/1805	7/1810	47.5	6.83	12.25
6	8/1810	4/1816	4/1823	45.8	5.75	12.75
7	5/1823	11/1829	10/1833	67.0	6.58	10.5
8	11/1833	3/1837	6/1843	138.3	3.41	9.67
9	7/1843	2/1848	11/1855	124.7	4.66	12.42
10	12/1855	2/1860	2/1867	95.8	4.25	11.25
11	3/1867	8/1870	11/1878	139	3.5	11.75
12	12/1878	12/1883	2/1890	63.7	5.0	11.25
13	3/1890	1/1893	12/1901	85.1	2.91	11.83
14	1/1902	2/1906	7/1913	63.5	4.16	11.58
15	8/1913	8/1917	7/1923	103.9	4.0	10.0
16	8/1923	4/1928	8/1933	77.8	4.75	10.08
17	9/1933	4/1937	1/1944	114.4	3.66	10.42
18	2/1944	5/1947	3/1954	151.6	3.66	10.17
19	4/1954	3/1957	9/1964	190.2	3.0	10.5
20	10/1964	11/1968	5/1976	195.9	4.16	11.67
21	6/1976	12/1979	8/1986	155.4	3.25	10.25
22	9/1986	7/1989	5/1996	157.6	2.91	10.0
23	6/1996	7/2000	9/2007	119.6	4.16	11.33

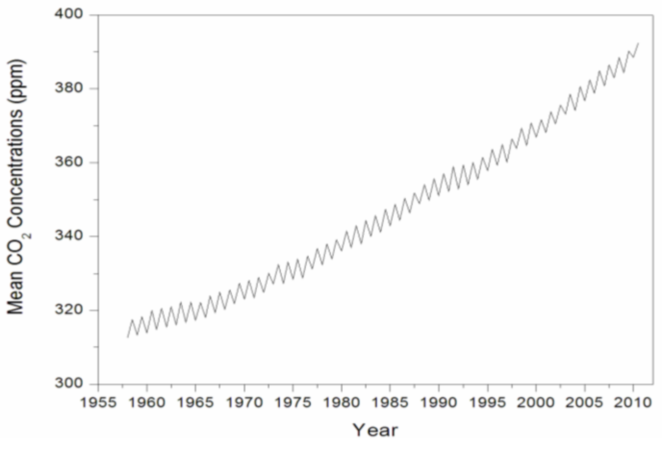

Fig. 1: Variation of CO_2 concentration at Mauna Loa

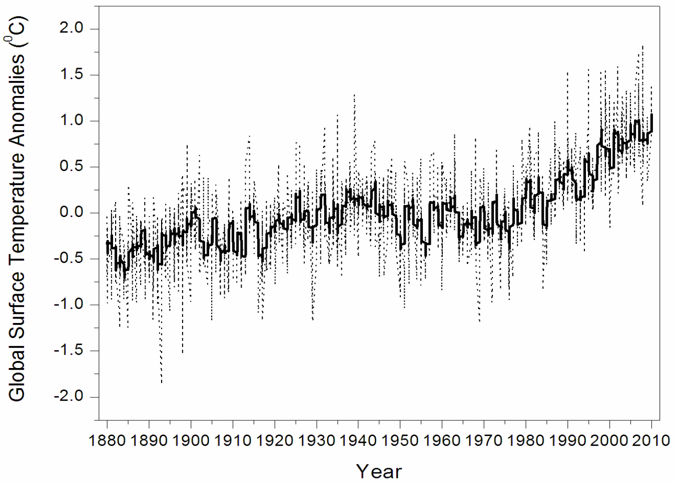

Fig 2: Global surface temperature anomalies. The monthly means are represented on dotted lines whereas smoothed thick line represents the annual variation.

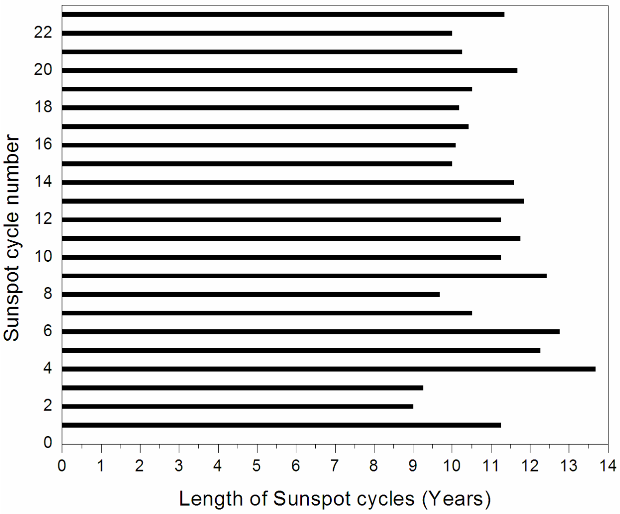

Fig. 3: The variation in length of sunspot cycles 1–23