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The Sun and its Activities

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ABSTRACT: The objective of this paper" THE SUN AND ITS ACTIVITIES" is to explain the solar activities. The paper aims to provide the reading with the main elements; that characterize the peculiar structures, the prominences and their environment as deduced from observations of solar radiations/solar activities.

As modern life is very technology dependent, so studying solar activity becomes a big concern. It is well known that the technology of satellites for telecommunication and human space activities are very sensitive to solar eruptions. For all these reasons, the past decade has seen the development of space weather as a new branch of science aimed at forecasting solar activity and its consequences on earth.

Key words: solar activity, solar eruptions, solar radiations

INTRODUCTION

This topic is selected to review because of many reasons. Firstly, the solar activities/solar flares have not only affected a particular region on earth, but they pertained to the entire earth. Secondly, people are not much aware about the existence of solar flares produced by the Sun. So the immense effects of solar flares must be known to every conscious man.

The first key concept is to understand that what are solar activities, how they occur, and what their effects on earth are.

The Sun plays a fundamental role in our life on Earth. The electromagnetic radiation emitted by the Sun is our primary source of energy. These electromagnetic radiations heat the Earth's surface which leads to the temperature gradients, and drives the climate system. The Sun also emits continuously and sometimes explosively Plasma from its surface. This plasma, called solar wind, carries solar magnetic fields. It forms the heliosphere, which acts as a magnetic shield against the galactic cosmic rays. As the galactic cosmic rays are not good for earth or near-earth space so, naturally the intensity of these rays get reduced firstly, by the heliosphere and secondly, by the geomagnetic field (Earth's magnetic field) (5) .

The Sun appears much more complicated and active than a static hot plasma ball and imbibes a great variety of non stationary active processes. Such transient non stationary processes are known as solar activities, in contrast to the so called "quiet" Sun. Solar activity includes active transient and long lived phenomenon on the solar surface such as spectacular solar flares, sunspots, prominences, coronal mass ejections (CMEs) etc.

Although scientists were not sure and had a little bit of information about the existence of strange spots on the Sun since the early 17th century but it was only in the 19th century when the scientists recognized that the solar activity varies during the course of 11 years solar cycle. Solar variability was later found to have many different manifestations including the fact that the "solar constant", or the total solar irradiance, TSI (the amount of total incoming solar electromagnetic radiation in all wavelengths per unit area at the top of the atmosphere) is not a constant.

THE SUN

The **Sun** is a huge gaseous globe situated at the center of the solar system, like a star and with an effective temperature of about 5800K. It is almost perfectly spherical, having a diameter of about 1,392,684 km around 109 times that of earth and its mass is 1.989×10^{30} kilograms, (approximately 330,000 times the mass of Earth) which accounts for about 99.86% of the total mass of the Solar System. Chemically, about three quarters of the Sun's mass consists of hydrogen, while the rest is mostly helium. So it owes its energy due to internal hydrogen-helium fusion reactions. All matter present in the Sun is in the form of gas and plasma because of its high temperature (11). This makes it possible for the Sun to rotate faster at its equator (about 25 days) than it does at higher latitudes (about 35 days near its poles).The differential rotation of Sun's latitudes causes its magnetic field lines to get twisted together over time increases their magnetic field strength and makes them buoyant. As a result these magnetic field loops rise to erupt from the Sun's surface, block the convective flow of energy, cooling their region of photosphere and thus triggers the formation of Sun's dramatic sunspots and solar prominences. This twisting action creates the solar dynamo and an 11 year solar cycle of magnetic activity, as the Sun's magnetic field reverses itself about every 11years.

The physics of convection near the surface of the Sun is also greatly influenced by the fact that

The solar surface is a radiating surface, where the mode of energy transport all of a sudden changes from convective – with energy being carried by moving fluid – to radiative – with energy carried by essentially free-streaming photons (3).

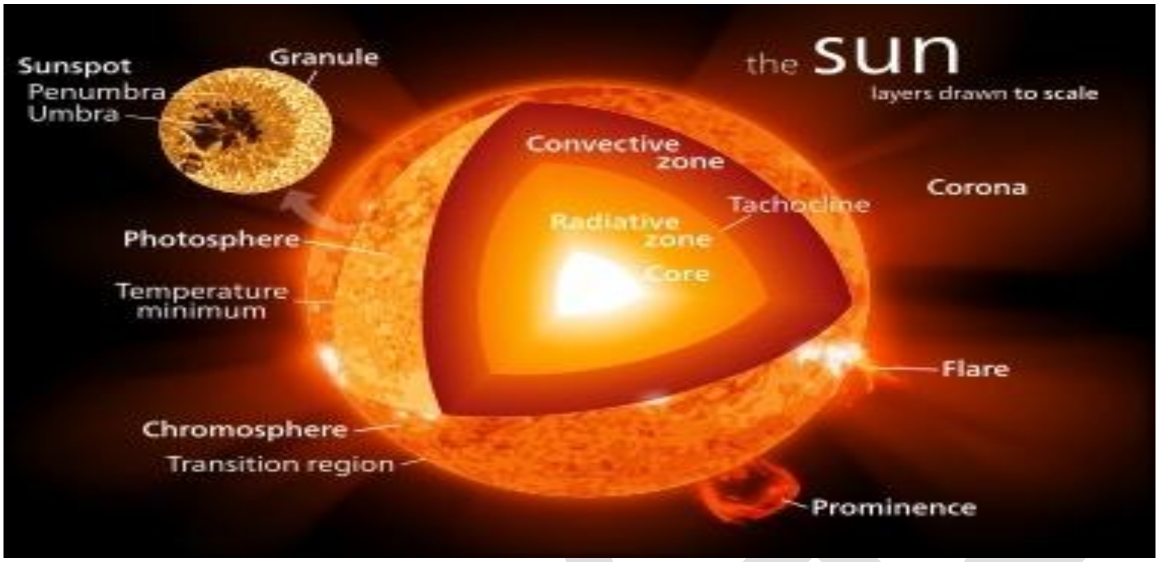
The solar magnetic field extends much beyond the Sun itself. The magnetized solar wind plasma carries Sun's magnetic field into the space and forms interplanetary magnetic field.

Parts of Sun

The Sun mainly consists of three parts: the photosphere, the chromospheres and the corona. The photosphere is a visible surface of Sun, having temperature of about 6400K. Above it there are regions which are transparent to light; the chromospheres and the corona. The chromospheres may be seen during eclipses; it extends about 2000km above the photosphere and has a temperature up to 50,000K. The corona having a temperature of about 1.5×10^6 K is observable for more than 10^6 km but in fact has no apparent termination (10).

The Sun is surrounded by a hot, tenuous irregular cloud of plasma called solar corona. This hot corona continuously expands in space creating the solar wind (a stream of charged particles).The magnetic field of Sun leads to many effects, collectively called solar activity. Solar activity includes Sunspots on the surface of Sun, solar flares, and solar winds or CME (corona mass ejection). Being the prime determinant of space weather, solar activity clearly has enormous technical, scientific, and financial impact on activities ranging from space exploration to civil aviation and everyday communication (4).

The Sun and Its Zones:



SUN SPOTS

The Sun is always active and its variable activity can be easily observed by the sunspots. The best example known for that is the era of Maunder minima (little ice age), when the Sun nearly stopped forming sunspots (7).

There are some well defined regions on Sun's surface that appear darker than their surroundings because of lower temperature and are called as sunspots. Here, convection is inhibited by strong magnetic fields, reducing energy transport from the hot interior to the surface. Also at the sunspot the magnetic field strength can be up to3500 gauss (approximately 7000 times the average strength of the magnetic field at the earth's surface).The magnetic field causes strong heating in the corona, forming active regions (2).

The sun spots occur in the active region of Sun. The active regions which are about 200,000 km (in longitude) and 50,000 km (latitude) in size, contains large number of flux tubes .Each of these tubes is confined magnetically and carries electric currents of 10^9 amperes or even more. Dissipation of their magnetic energy causes locally heated areas in the active regions, the so called faculae, which have temperature around 10,000 k, as compared to other parts of solar surface. Because of their higher temperature the faculae is source of relatively strong UV radiations.

When the solar activity is high, it is called solar maxima and when the solar activity is low, it is called solar minima.

The number of sunspots is not constant, but varies with the solar cycle. During solar maxima the number of sunspots increases and they move closer to the equator of the Sun. Sunspots usually exist in groups with two sets of spots of opposite magnetic polarity. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is stronger in the darker parts of the sunspots-the umbra. The field is weaker and more horizontal in the lighter parts-the penumbra. The magnetic polarity of the leading sunspot alternates at every solar cycle, so it is north magnetic pole in one solar cycle and a south magnetic pole in the next one. Sun spots and solar activity also appear to cluster in "active longitudes". It is noticed that new active regions grow in areas previously occupied by old active regions and this can result in a periodic signal that is evident in sun spot number record (12).

SOLAR FLARES

When the field lines become distorted, they get upthrusted and ascended, and then they penetrate the surface of Sun in a variety of spectacular forms, one of which is solar flares. In simpler terms, a great magnitude of plasma from the surface of Sun is released, outwards. When this plasma returns back to the surface of Sun, it encounters with denser material located in the chromospheres or the second uppermost layer of the Sun between the photosphere and the corona. This interaction ejects great quantity of energy in the form of electromagnetic radiation called solar flares and more powerful solar flares i.e. coronal mass ejections. The energy released during a flare is typically ten million times greater than the energy released from a volcanic explosion. In fact in just a few minutes a flare can heat a material to many millions of degrees and can release as much energy as a billion megatons of TNT (13). Solar flares can occur everywhere on the Sun, in active regions, penumbras, on the boundaries of the magnetic network of the quiet Sun, and even in the network interior.

There are different types of flare which are classified depending upon their intensity, like X-class flares, M-class flares and C-class flares. The largest flare is the X-flare. M-Class flares are smaller and C-Class flares are tenth the intensity of the M- Class flares (8).

CORONAL MASS EJECTIONS (CME)

Coronal mass ejection (CME) is another feature of nuclear activity within the Sun; related to but not caused by solar flares. In a CME plasma is emitted from the active centre, sometimes over a large region of solar surface that may span longitudinal intervals of more than 90 degree. The CMEs carry magnetic fields along with, which tends to fill the heliosphere (the magnetically closed region around the solar system). These interplanetary magnetic fields slowly diffuse away. The rate of occurrence of CMEs correlates with solar activity, but the size scales of CMEs are much larger and their latitude distributions different than those of near surface activity like flares or active regions (6). The CMEs may be important to understand the Sun-Earth relations, because the CME changes the magnetic components of the heliosphere in an important way, while this happens during fairly long period of time because of slow diffusion (2).

Coronal mass ejections are more likely to have a significant effect on our activities than solar flares because they carry more material into a larger volume of interplanetary space, increasing the likelihood that they will interact with the Earth. CMEs typically drive shock waves that produce energetic particles that can be damaging to both electronic equipment and astronauts that venture outside the protection of the Earth's magnetic field (1).

While a flare alone produces high-energy particles near the Sun, a CME can reach the Earth and disturb the Earth's magnetosphere, setting off a geomagnetic storm. Often, these storms produce surges in the power grid and static on the radio and if the waves of energetic particles are strong enough, they can overload power grids and drown out radio signals. This type of activity can affect the region from ground to sky and ship to shore and can also disturb navigational communication, military detection, and early warning systems.

Observing the ejection of CMEs from the Sun provides an early warning of geomagnetic storms. Recently, with SOHO, it has been possible to observe continuously the emission of CMEs from the Sun and determine if they are aimed at the Earth.

Effects on Earth

Solar activity impacts us in many ways. It poses hazards to our satellites in space, our technology on the ground, and even ourselves as we venture into space. Solar activity has well-known impacts on Earth's magnetosphere, ionosphere and terrestrial climate.

Terrestrial Organisms

The impact of the solar cycle on living organisms has been investigated and is found to have some connections with human health.

The amount of ultraviolet UVB light at 300 nm reaching the Earth varies by as much as 400% over the solar cycle due to variations in the protective ozone layer. In the stratosphere, ozone is continuously regenerated by the splitting of O_2 molecules by ultraviolet light. During a solar minimum, the decrease in ultraviolet light, received from the Sun leads to a decrease in the concentration of ozone, allowing increased UVB to penetrate to the Earth's surface.

Radio Communication

Sky wave modes of radio communication operate by bending (refracting) radio waves (electromagnetic radiation) through the Ionosphere. During the "peaks" of the solar cycle, the ionosphere becomes increasingly ionized by solar photons and cosmic rays. This affects the path (propagation) of the radio wave in complex ways which can either facilitate or hinder local and long distance communications. Forecasting of sky wave modes is of considerable interest to commercial marine, aircraft communications, amateur radio operators, and shortwave broadcasters. These users utilize frequencies within the High Frequency or 'HF' radio spectrum which are most affected by these solar and Ionospheric variances. Although TV and commercial radio broadcasts are rarely affected, longer distance communication, like ground-to-air, ship-to-shore, Voice of America, and amateur radio, are frequently disrupted (9). A number of military systems, like early warning, over-the-horizon radar, and submarine detection, are greatly hampered during times of high solar activity.

Terrestrial climate

Both long-term and short-term variations in solar activity are hypothesized to affect global climate, but it has proven extremely challenging to directly quantify the link between solar variation and the earth's climate. The topic continues to be a subject of active study.

Early research attempted to find a correlation between weather and sunspot activity, mostly without notable success. Later research has concentrated more on correlating solar activity with global temperature. Most recent, research suggests that there may also be regional climate impacts due to the solar cycle. Measurements from the Spectral Irradiance Monitor on NASA's Solar Radiation and Climate Experiment shows that solar UV output is more variable over the course of the solar cycle than scientists had previously thought, resulting in, for example, colder winters in the US and southern Europe and warmer winters in Canada and northern Europe during solar minima.

There are three suggested mechanisms by which solar variations are hypothesized to have an effect on climate:

- Solar irradiance changes directly affect the climate ("Radioactive forcing").
- Variations in the ultraviolet component: If the UV component varies more than the standard level, this might cause an effect on climate.

- Effects mediated by changes in cosmic rays (which are affected by the solar wind) such as changes in cloud cover.

Although the changes in total solar irradiance and solar variations seems too small to produce significant climatic effects but there is good evidence as well that , to some extent, the earth's climate heats and cools as the solar activity rises and falls.

Effects on spacecraft

Satellites are placed in orbits that are above most of Earth's atmosphere so that there is little frictional drag affecting them. Communications satellites, in geosynchronous orbits, are about 6 Earth radii up. The Low-orbiting satellites, which speed up around the earth every 2 hours or so, are barely above the Earth's atmosphere. During times of high solar activity there is an increase in ultraviolet radiation and auroral energy input, and this heat up the Earth's atmosphere, causing it to expand. The low-orbiting satellites then encounter increased drag which causes them to drop in their orbits (9).The high satellites, in geosynchronous orbits, are not subject to drag from atmospheric heating, but they are subjected to the solar wind. These satellites are usually well protected from solar wind particles by the magnetosphere which normally has a minimum thickness of about 10 Earth radii. But when a surge in the solar wind reaches Earth, the front side of the magnetosphere can be compressed or eroded away to a thickness of about 4 Earth radii. This places the high satellites outside the protective shield of the magnetosphere. The impact of high speed particles has a corrosive effect on satellites, and charge buildup can result from these particles. Electrical discharges can arc across spacecraft components causing damage. If astronauts on a space mission are above the shielding effect produced by the Earth's magnetic field, the radiation from a CME would also be dangerous to humans; many future mission designs (e.g., for a Mars Mission) therefore incorporate a radiation-shielded "storm shelter" for astronauts to protect them during such a radiation event.

In view of the problems in space flight occurring during high solar activity, prediction of the latter becomes more and more important.

CONCLUSION

The sun is the only star which can be studied in great detail and thus can be considered as proxy for cool stars. Quite a number of dedicated ground based and space born experiments are being carried out to learn more about solar variability. Studying and modeling solar activity can increase the level of our understanding of nature. On the other hand study of solar activity is not of purely academic interest, it directly affects the terrestrial environment also. Although changes in the sun are barely visible without the aid of precise scientific instruments but the changes in solar cycle has a great impact on many aspects of our lives. In particular, the heliosphere is mainly controlled by the solar magnetic field. This leads to the modulation of galactic cosmic rays (GCRs) by the solar magnetic activity. Additionally, eruptive and transient phenomenon in the sun can lead to sporadic acceleration of energetic particles with greatly enhanced flux. Such processes can modify the radiation on earth and need to be taken into account for planning and maintaining space missions and even transpolar jet flights.

For a complete understanding of the solar atmosphere or environment, ideally all of its layers should be observed at the same time but because of spatial extent and vastly differing temperatures of its layers, multi wavelength and multi resolution observations are needed. And unfortunately they are not always available.

Radiation from the Sun ultimately provides the only energy source for the Earth's atmosphere and changes in solar activity clearly have the potential to affect climate. Changes in total solar irradiance (TSI) undoubtedly impact the Earth's energy balance but uncertainties in the historical record of TSI means that the magnitude of even this direct influence is not well known. Variations in solar UV radiation impact the thermal structure and composition of the middle atmosphere but still the detailed responses about the temperature and ozone concentration are not well established. Although, various theories are now being developed by which the direct solar impacts on the atmosphere can be observed but the influences are complex and nonlinear. Hence, many questions still remain arise like, to what extent, where, and when the solar influence can occur.

Further advances in this field require work on a number of fronts. One important issue is to establish a precise magnitude total solar irradiance (TSI). This may be achieved by careful analysis and understanding of the satellite instruments involved in collecting data over the past two-and-a-half solar cycles and current solar cycle.

At last we can say that there are many areas where work is needed to be done.
Obviously the first one is the Sun because there are still a lot of mysteries about what is going inside the Sun, what triggers flares and why the Sun spots form actually. The second one is interplanetary medium filled with solar wind plasma and the third one is geomagnetosphere. The last two domains are also directly or indirectly related to the Sun and its activities. So we hope for a comprehensive model for the Sun, its activities and the Earth, which is seriously a problem for the physicists of future.

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