IMPACTS OF SOLAR CYCLE

Impacts

The sun's magnetic field structures its atmosphere and outer layers all the way through the corona and into the solar wind. Its spatiotemporal variations lead to a host of phenomena collectively known as solar activity. All of solar activity is strongly modulated by the solar magnetic cycle, since the latter serves as the energy source and dynamical engine for the former.

Surface magnetism

Sunspots may exist anywhere from a few days to a few months, but they eventually decay, and this releases magnetic flux in the solar photosphere. This magnetic field is dispersed and churned by turbulent convection, and solar large-scale flows. These transport mechanisms lead to the accumulation of the magnetized decay products at high solar latitudes, eventually reversing the polarity of the polar fields.

The dipolar component of the solar magnetic field is observed to reverse polarity around the time of solar maximum, and reaches peak strength at the time of solar minimum.

Sunspots, on the other hand, are produced from a strong toroidal (longitudinally-directed) magnetic field within the solar interior. Physically, the solar cycle can be thought of as a regenerative loop where the toroidal component produces a poloidal field, which later produces a new toroidal component of sign such as to reverse the polarity of the original toroidal field, which then produces a new poloidal component of reversed polarity, and so on.

Solar irradiance

The total solar irradiance (TSI) is the amount of solar radiative energy impinging on the Earth's upper atmosphere. It is observed to vary in phase with the solar cycle, with yearly averages going from 1365.5 Watt per square meter at solar minimum, up to of 1366.6 at solar maximum, with fluctuations about the means of about +/- 1 Watt per square meter on timescales of a few days. The min-to-max variation, at the 0.1% level, is far too small to affect Earth's climate, but it is worth keeping in mind that continuous reliable measurements of the TSI are only available since 1978; the minimum and maximum levels of solar activity have been remained roughly the same from then to now, spanning cycle 21 through 23.

Interestingly, the Sun is slightly brighter at solar maximum, even though sunspots are darker than the rest of the solar photosphere.

This is because at solar maximum, a great many magnetized structures other than sunspots appear on the solar surface and many of them, such as faculae and active elements of the network, are brighter than the photosphere. They collectively end up slightly overcompensating for the overall irradiance deficit associated with the larger but less numerous sunspots. Recent observations indicate that the primary driver of TSI changes is the varying photospheric coverage of these different types of solar magnetic structures , although contributions from long-timescale variations associated with a deep-seated physical process, such as cycle-mediated small changes in the efficiency of convective energy transport, cannot be ruled out entirely as yet.

Short-wavelength radiation

With a temperature 5870 kelvins, the unmagnetized regions of the Sun's atmosphere emit very little short-wavelength radiation, such as extreme ultraviolet (EUV) and X-Rays. This is no longer the case where magnetic fields are present, magnetized regions being observed to emit short-wavelength radiation. Since surface coverage of magnetic structures varies markedly in the course of the cycle, the level of diffuse, non-flaring solar UV, EUV and X-Ray flux is modulated accordingly Figure 5 illustrates this variations for soft X-Ray, as observed by the Japanese satellite YOHKOH. Similar cycle-related variations are observed in the flux of solar UV or EUV radiation, as observed for example by the SOHO or TRACE satellites.

Even though it only accounts for a minuscule fraction of the total solar irradiance, the impact of solar UV, EUV and X-Ray radiation on the Earth's upper atmosphere are profound. The solar UV flux is a major driver of stratospheric chemistry, and the ionosphere responds strongly to increases in ionizing radiation, through heating and changes in electrical conductivity.

Solar radio flux

Emission from the Sun at centimetric (radio) wavelength is due primarily to coronal plasma trapped in the magnetic fields overlying active regions . The F10.7 index is a measure of the solar radio flux per unit frequency at a wavelength of 10.7cm, near the peak of the observed solar radio emission. It represents a measure of diffuse, nonradiative heating of the coronal plasma trapped by magnetic fields over active regions, and is an excellent indicator of overall solar activity levels. The solar F10.7 cm record extends back to 1947, and is the longest direct record of solar activity available, other than sunspot-related quantities.

It has been proposed that 10.7 cm solar flux can interfere with point-to-point terrestrial communications. "The Effect of 10.7 cm Solar Radiation on 2.4GHz Digital Spread Spectrum Communications", NARTE News, Volume 17 Number 3 July - October 1999.

Radio Communications Interference

Solar flares also create a wide spectrum of radio noise; at VHF (and under unusual conditions at HF) this noise may interfere directly with a wanted signal. The frequency with which a radio operator experiences solar flare effects will vary with the approximately 11-year sunspot cycle; more effects occur during solar maximum (when flare occurrence is high) than during solar minimum (when flare occurrence is very low). A radio operator can experience great difficulty in transmitting or receiving signals during solar flares due to more noise and different propagation patterns.

Geoeffective eruptive phenomena

The solar magnetic field structures the corona, giving it its characteristic shape visible at times of solar eclipses. Complex coronal magnetic field structures evolve in response to fluid motions at the solar surface, and emergence of magnetic flux produced by dynamo action in the solar interior. For reasons not yet understood in detail, sometimes these structures lose stability, leading to coronal mass ejections into interplanetary space, or flares, caused by sudden localized release of magnetic energy driving copious emission of ultraviolet and X-ray radiation as well as energetic particles. These eruptive phenomena can have a significant impact on Earth's upper atmosphere and space environment, and are the primary drivers of what is now called space weather.

The occurrence frequency of coronal mass ejections and flares is strongly modulated by the solar activity cycle. Flares of any given size are some 50 times more frequent at solar maximum than at minimum. Large coronal mass ejections occur on average a few times a day at solar maximum, down to one every few days at solar minimum The size of these events themselves does not depend sensitively on the phase of the solar cycle. A good recent case in point are the three large X-class flares having occurred in December 2006, very near solar minimum; one of these (an X9.0 flare on Dec 5) stands as one of the brightest on record.

Cosmic ray flux

The outward expansion of solar ejecta into interplanetary space provides overdensities of plasma that are efficient at scattering high-energy cosmic rays entering the solar system from elsewhere in the galaxy.

Since the frequency of solar eruptive events is strongly modulated by the solar cycle, the degree of cosmic ray scattering in the outer solar system varies in step. As a consequence, the cosmic ray flux in the inner solar system is anticorrelated with the overall level of solar activity. This anticorrelation is clearly detected in cosmic ray flux measurements at the Earth's surface.

Some high-energy cosmic rays entering Earth's atmosphere collide hard enough with molecular atmospheric constituents to cause occasionally nuclear spallation reactions. Some of the fission products include radionuclides such as ^{14}C and ^{10}Be, which settle down on Earth's surface. Their concentration can be measured in ice cores, allowing a reconstruction of solar activity levels into the distant past . Such reconstructions indicate that the overall level of solar activity since the middle of the twentieth century stands amongst the highest of the past 10,000 years, and that Maunder minimum-like epochs of suppressed activity, of varying durations have occurred repeatedly over that time span.

Impact on Biosphere and human circadian cycle

The impact of Solar cycle on living organisms is covered in part by interdisciplinary studies in the fields of science known as Chronobiology, Heliobiology, and Astrobiology.

In 1924 Alexander Chizhevsky, graduate of Medical School at Moscow University, published interdisciplinary works: "Physical factors behind the process of history" and "Epidemiological catastrophes and periodic activity of the Sun" studying cycles in living organisms in connections with **solar cycle** and cycle of lunar phases. Chizhevsky developed a new discipline, Heliobiology, a branch of Astrobiology. In 1939 Chizhevsky was elected Honorary President of International Congress in Biological Physics, for his 1936 publication *The Terrestrial Echo of Solar Storms,* 366 pp. 1976, Moscow, (First published in 1936 in Russian. However, soon Chizhevsky was arrested by the Soviet government and exiled to Siberia under the dictatorship of joseph Stalin. Chizhevsky's publications were censored and his 1930s research of blood and electromagnetic parameters of erythrocytes in connection with cycles in human circadian system was banned, it was published 40 years later, in 1973. Chizhevsky's 1928 publication "Influence of Cosmos on human psychoses" was censored in the Soviet Union, albeit in 2003 this work was referenced in Journal of Circadian Rhythms article.

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