1. History

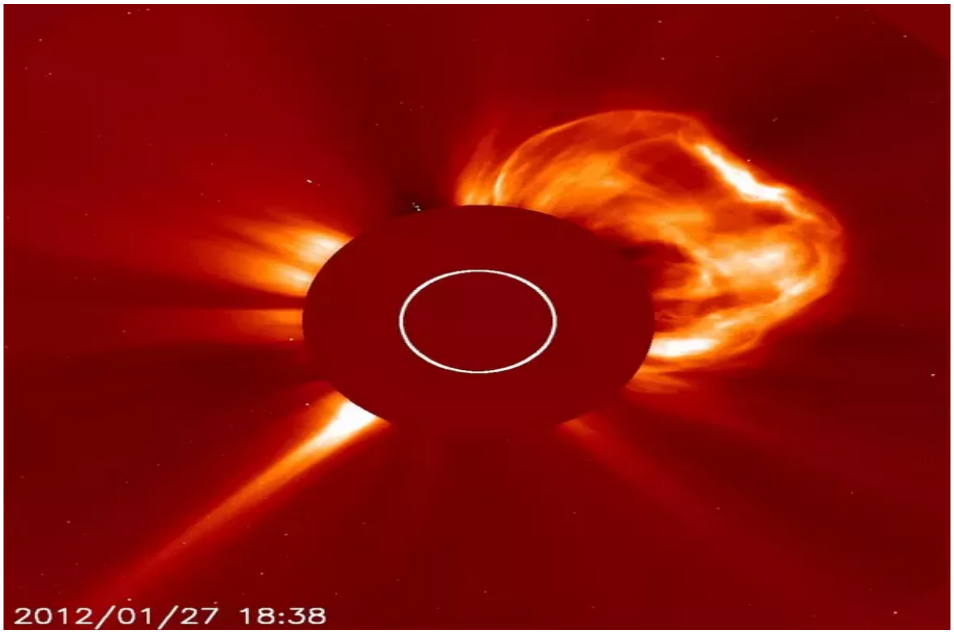
The term ‘space weather’ came into being about 25−30 years ago to denote, by analogy with ‘meteorological weather’, a complex process of space phenomena and processes affected by varying sun activity. In its broad sense, the term refers to entire an heliosphere whose limits are determined by expanding fluxes of solar plasma. In its narrow, usual sense, the term applies to the Earth environment and, to be more exact, to the space subjected to geomagnetic field influence, i.e. to the Earth’s magnetosphere.
The concept of space weather covers a wide range of phenomena directly affecting human activity. They include satellite damage, radiation hazards for astronauts and airline passengers, telecommunication problems, outages of power and electronic systems, effects in the atmospheric processes, and even some evidence of impact on human health.
The study of space weather began with systematic observation of three natural phenomena: the aurorae (also called the northern or southern lights), Earth’s magnetic field, and sunspots (dark regions observed on the surface of the Sun). Because aurorae can be seen with the unaided eye, they have been observed for thousands of years, though the systematic study of the aurorae didn’t begin until the sixteenth century. Development of the sensitive compass and telescope in the early seventeenth century made possible the discovery of the nature of Earth’s magnetic field and sunspots.

The understanding of space weather traces its roots to connections between these three phenomena. The first tentative connections were made in the middle of the nineteenth century. For the last 150 years, we have slowly expanded our knowledge of the Sun and Earth’s space environments and, in so doing, have begun to develop a physical model of the Sun–Earth connection.

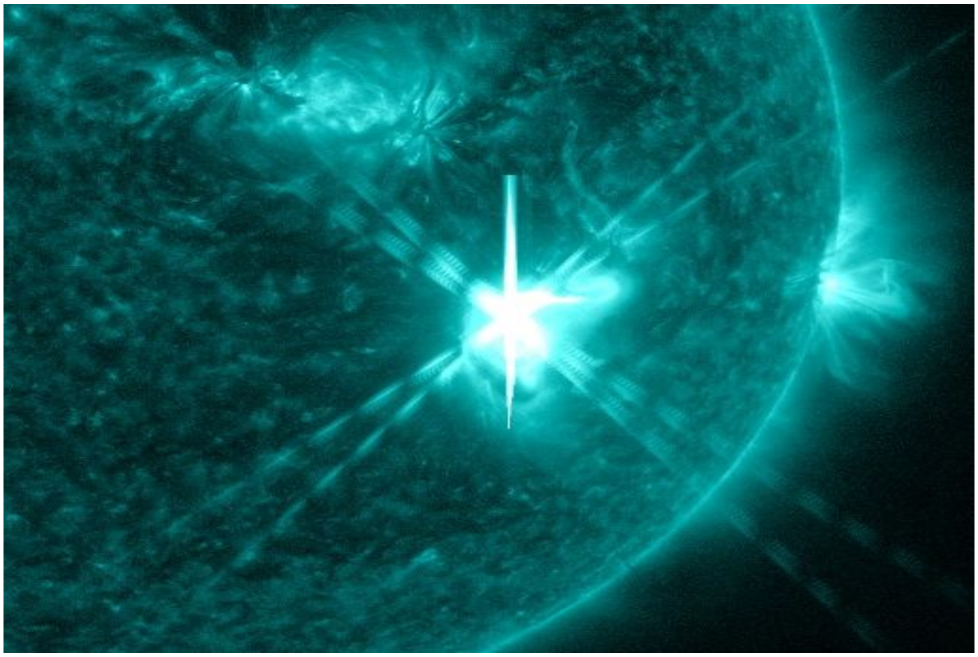
2. Solar Events and Solar-Terrestrial Interactions

2.1 Coronal Mass Ejections and Solar Flare

A Coronal Mass Ejection is plasma ejected from the sun’s surface due to explosions and fluctuations in the solar magnetosphere. It mainly consists of energetic protons, essentially hydrogen atoms stripped off their electron. It is essentially a massive cloud of hot gas moving away from the sun.



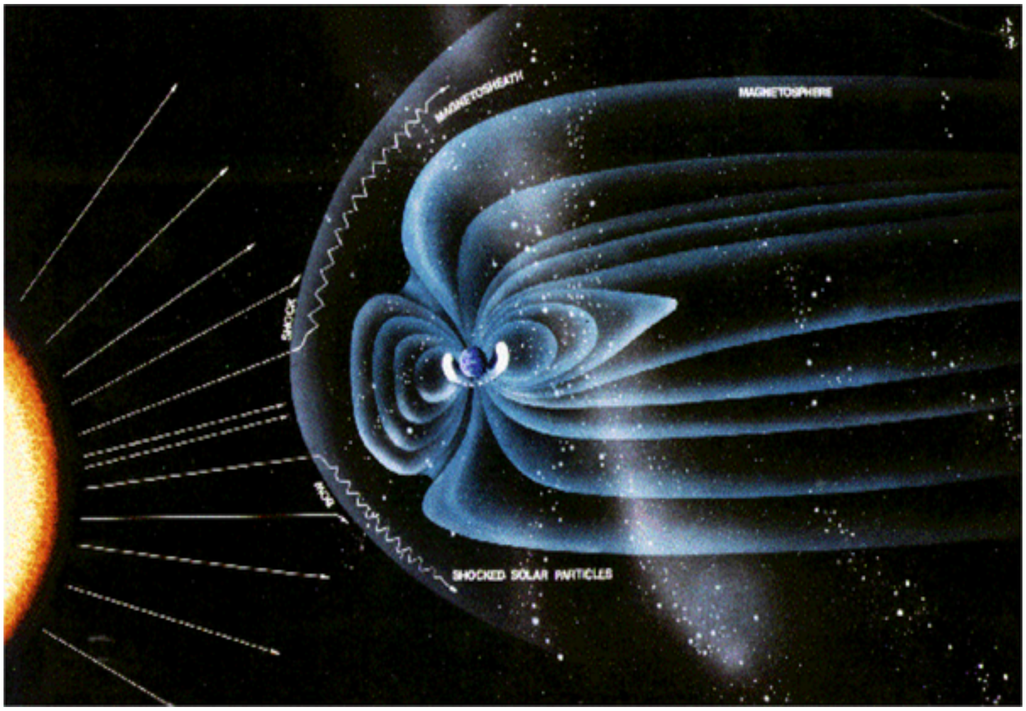
A solar flare on the other hand is a massive burst of radiation across all wavelengths and appears as a bright blinding flash on photographs taken by satellites. They are caused by the conversion of magnetic potential energy to photons when the "ribbons" of magnetic field lines overlap. The colors are fake in the below image.



To put it in a nutshell CMEs are clouds of plasma hurled out by the sun while solar flares are brief intense eruptions of electromagnetic radiation. Both are caused by disturbances in the sun's magnetic field though the definite cause of CMEs haven't been discovered yet.

2.2 Solar Wind

The solar wind is largely composed of charged particles, which interact with the geomagnetic field. Most of the particles are steered round the Earth without getting too close.

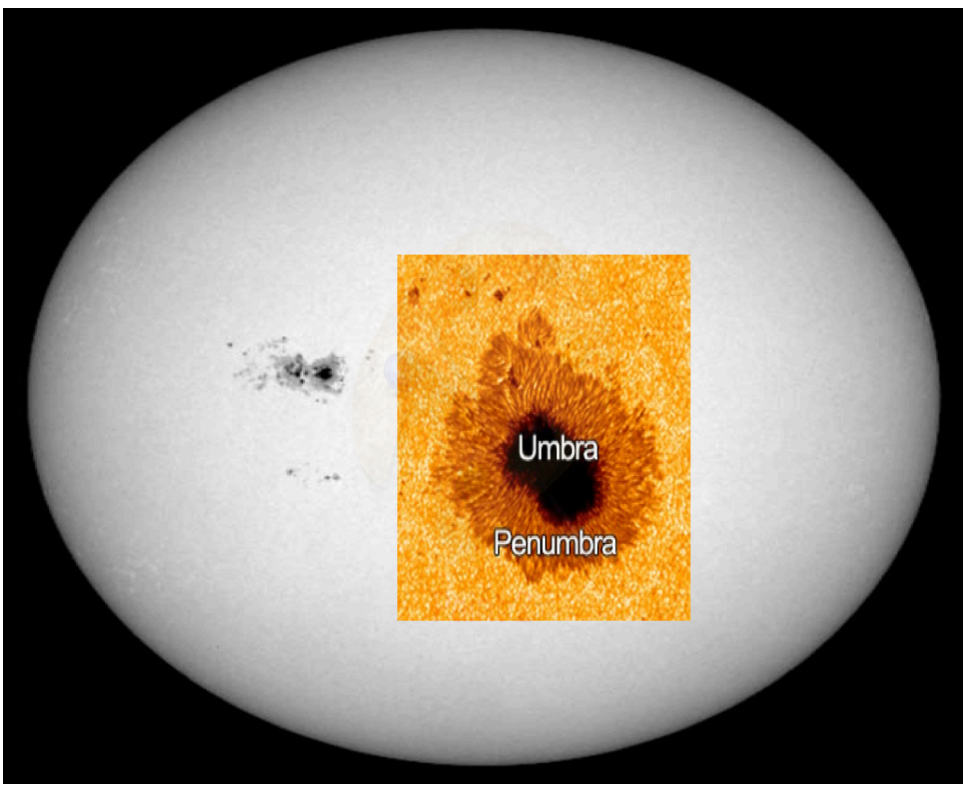


When there is a flare on the Sun, charged particles can get through the magnetic and interact with the upper atmosphere, giving rise to aurora displays.

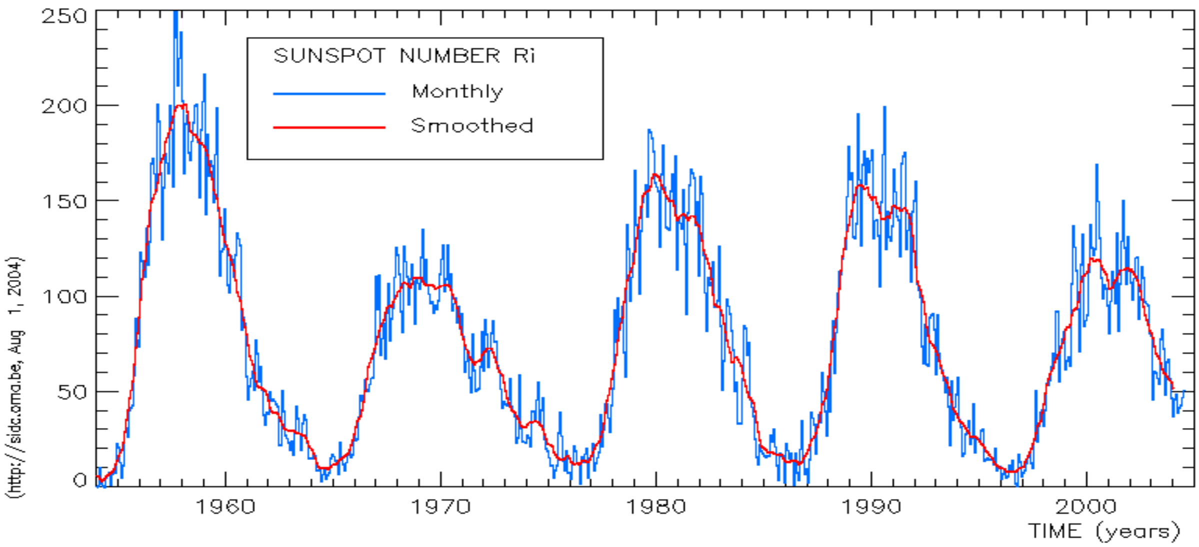
It the solar wind is further increased by, say, a coronal mass ejection, the Earth's magnetic field can be severely overcome, and the charged particles get much closer to the ground and cause parasitic currents to flow in long conductors such as power lines. This can cause destructive failures of the power system costing millions of pounds and months of time to repair.

2.3 Sunspots

Sunspots are dark regions on the photosphere associated with strong magnetic fields and lower temperature than the rest of the photosphere. thus, may be regarded as surface regions where the magnetic energy is concentrated. the sunspots are made up of dark central regions known as the umbra and outer lighter regions called penumbra as illustrated in Figures below

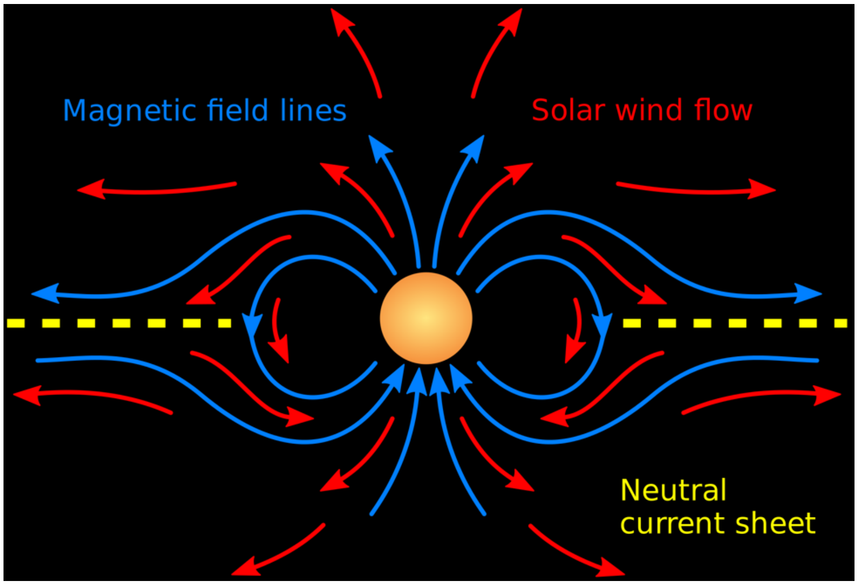


Wolf found that the length of the solar cycle was closer to 11.1 years. more recently, it has been acknowledged that the length of the individual cycle is not constant, but may vary between 9 and 12 years. Usually the rise of sunspot activity (the time between a minimum and subsequent maximum) is of shorter duration than the fall-time (time between maximum and the following minimum), with a few exceptions.



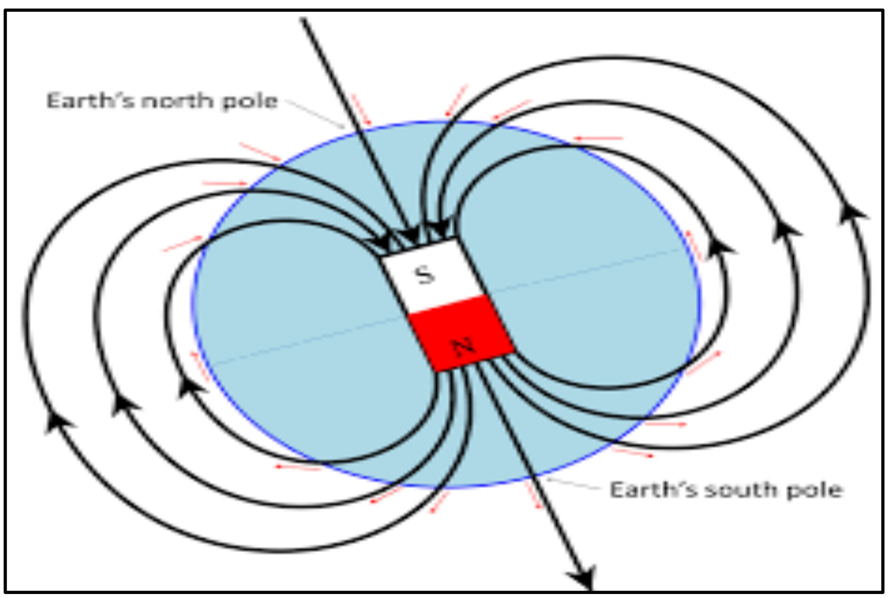
2.4 The Sun's Magnetic Field

The Sun has a very large and very complex magnetic field. The magnetic field at an average place on the Sun is around 1 Gauss, about twice as strong as the average field on the surface of Earth (around 0.5 Gauss). Since the Sun's surface is more than 12,000 times larger than Earth's, the overall influence of the Sun's magnetic field is vast.
The magnetic field of the Sun actually extends far out into space, beyond the furthest planet (Pluto). This distant extension of the Sun's magnetic field is called the Interplanetary Magnetic Field (IMF). The solar wind, the stream of charged particles that flows outward from the Sun, carries the IMF to the planets and beyond. The solar wind and IMF interact with planetary magnetic fields in complex ways, generating phenomena such as the aurora.



2.5 Earth's Magnetic Field

Earth has a magnetic field. If you pretended that Earth had a gigantic bar magnet inside of it (it doesn't really, of course), you would have a pretty good idea about the approximate shape of Earth's magnetic field. Earth's magnetic field is slightly tilted with respect to the planet's spin axis; there is currently a difference of about 11° between the two. Because of this difference, the Geographic North Pole and the North Magnetic Pole are not actually in the same place; likewise, for the South Poles. This means that compasses do not always point directly towards True North.
the motions of molten metals in the Earth's core generate our planet's magnetic field. Movement of molten iron and nickel generates electrical and magnetic fields that produce Earth's magnetism. The flows of these molten metals in Earth's outer core are not perfectly steady over time, so Earth's magnetic field changes over time as well. The North and South Magnetic Poles wander over time; the North Magnetic Pole moved some 1,100 km (684 miles) during the 20th century. The strength of Earth's magnetic field varies as well; it has been decreasing slightly ever since around 1850. Over the course of Earth's history, the magnetic field has actually reversed itself many times, with North becoming South and vice versa!



2.6 Solar Radiation Storms

Charged particles, including electrons and protons, can be accelerated by coronal mass ejections and solar flares. These particles bounce and gyrate their way through space, roughly following the magnetic field lines and ultimately bombarding Earth from every direction. when electrons and protons get launched at incredibly high speeds up to several 10.000 km/s. These radiation storms can bridge the Sun-Earth distance in as little time as 30 minutes and last for multiple days.

2.7 Geomagnetic Storms

The geomagnetic storm is a temporary disturbance of Earth's magnetic field typically associated with enhancements in the solar wind. These storms are created when the solar geomagnetic storms is CMEs which stretch the magnetosphere on the nightside causing it to release energy through magnetic reconnection. Disturbances in the ionosphere are usually associated with geomagnetic storms.