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.

1. Structure of the Sun: Interior and atmosphere

We can make direct observations of the solar surface and atmosphere. The primary means of study of these regions is analysis of absorption lines in the solar spectrum. By studying these lines, we know the composition of the Sun to very high accuracy. (Table 1) lists the five most common elements in the Sun and their relative abundance. Hydrogen is by far the most common, followed by helium. The Standard Solar Model suggests that these abundances are representative throughout the Sun except in the core where thermonuclear reactions continuously change the composition. The Sun contains all of the natural elements found on Earth and in the periodic table.

The Sun contains 1.9×10^{30} kg of material – over 99% of the total mass in the Solar System – or about 300 000 Earth masses. The regions of the Sun are illustrated in Figure 1. Table 2 shows some of the Sun's physical characteristics.

Table 1: The five most common elements in the Sun

Element	Symbol	Relative abundance
hydrogen	H	92.1%
helium	He	7.8%
oxygen	O	0.061%
carbon	C	0.030%
nitrogen	N	0.0084%

Table 2: Solar properties

radius	696 000 km
mass	1.9×10^{30} kg
average density	1410 kg m^{-3}
distance from Earth	150 000 000 km (or 1 astronomical unit)
surface temperature	5800 K
luminosity	3.86×10^{26} W

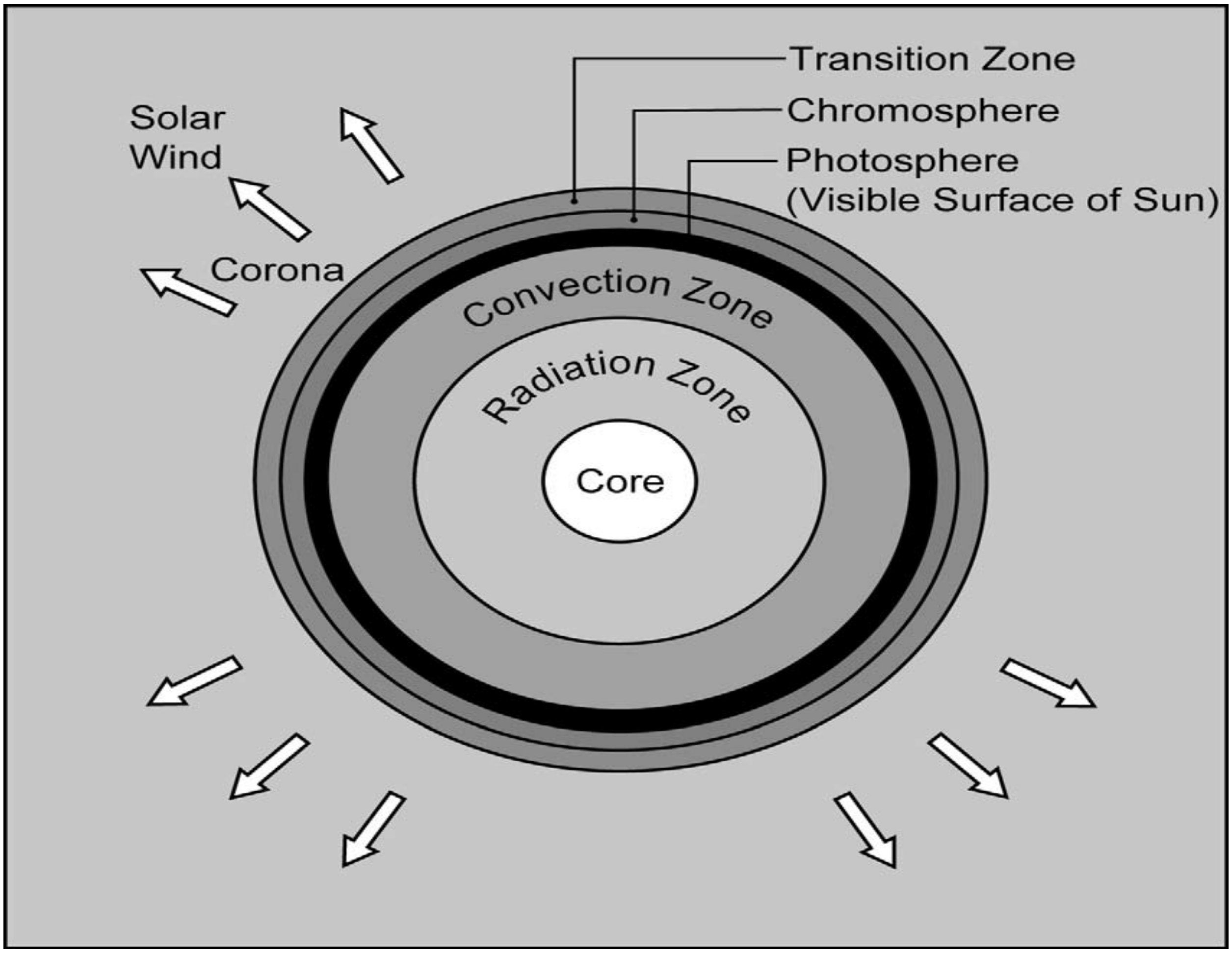

Figure 1: The main regions of the Sun. The regions inside the Sun are defined by how energy is transferred from the core to the surface. The regions of the Sun's atmosphere are defined by their density and temperature.

1.1 Interior

The Sun's interior is divided into three main regions: the convection zone, the radiation zone, and the core. The next sections describe these regions.

Convection and radiation zones

Below the photosphere, the visible surface of the Sun, extending down about 200000 km, is the convection zone. This region undergoes convective motion (hot gas rising and cooler gas sinking) similar to a pot of boiling water. Convection is the process that transports heat through bulk fluid motion. Energy from the outer layer of the Sun is transported by convection to the solar surface where it can radiate out into space. Below the convection region is the radiation zone, where energy is transported primarily by electromagnetic photons. The convection zone begins where the flux of radiation energy is so high that the energy Convection and radiation zones cannot easily make its way through the gas, hence convection begins in order to transport the energy through bulk motions of the solar material.

The core

The Sun's core is an extremely hot, dense mass of atomic nuclei and electrons. Its temperature is about 15,000,000 K, and it is thought to be some 150 times as dense as water. The pressure is enormous. Normally, protons in atomic nuclei repel each other because they have the same electrical charge. Under the great density and pressure in the Sun's core, however, nuclei can collide and fuse into new and heavier nuclei. This is a type of thermonuclear reaction called a fusion reaction.

The basic fusion process in the Sun involves a series of reactions in which four hydrogen nuclei are ultimately converted into one helium nucleus. The mass of the helium nucleus is about 0.7 percent less than that of the four hydrogen nuclei. This 0.7 percent of the mass is changed into energy. Every second the Sun converts almost 700 million tons of hydrogen into about 695 million tons of helium. Nearly 5 million tons of mass—0.7 percent of 700 million tons—are converted to energy. Some of this energy heats the plasma in the core and some escapes into space as nearly massless, electrically neutral particles called neutrinos. Some of the energy is in the form of gamma-ray photons. These photons travel outward from the core through a zone in which the energy is carried mainly by radiation. Ultimately, the energy is emitted at the surface in many different wavelengths.

the Sun emits the same amount of energy in one second that Earth would produce at the current rate in over 900 000 years. Put another way, the Sun emits the equivalent of 100 billion one-megaton nuclear bombs every second.