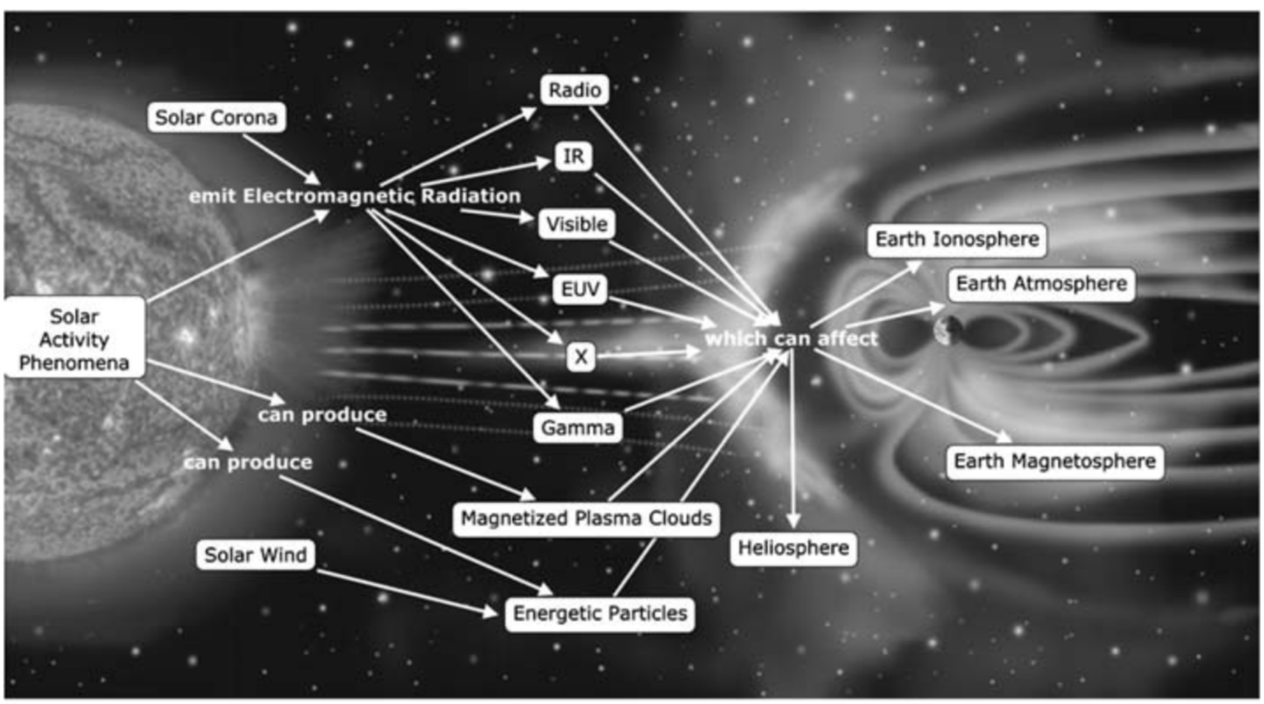
Solar–Terrestrial Relationships

Solar-terrestrial relationships deal with the influence of the Sun and solar activity on our terrestrial environment. The driving force is the input of energy and matter into geospace.

The statistical or physical links between events that occur on the sun and a response observed on the earth, primarily in the atmosphere.

The effects of solar activity on the Earth and its magnetic field. The largest effects originate from magnetic disturbances which travel out from the Sun and produce geomagnetic storms as they interact with the Earth's magnetosphere. A sharp increase in the strength of the Earth's magnetic field at the start of a storm results from a compression of the field on the sunward side. Disturbances occur world-wide and may continue for a day or so. there are also side-effects to these phenomena, such as the influence of solar energetic and auroral particles on the chemistry of the atmosphere, or the uproar caused in our technical environment due to severe geomagnetic disturbances. Other connections exist, too, relating solar cycle variations to weather and climate.



1. Magnetosphere

The magnetosphere is a large plasma cavity generated by the Earth's magnetic field and the solar wind plasma (Fig. 3.1). The streaming solar wind compresses the dayside portion of the Earth's field and generates a tail which is many hundreds of Earth radii long. The basic mechanism for the formation of the magnetosphere is fairly simple: The Earth's magnetic dipole field is exposed to a stream of charged particles. The entire magnetosphere is subject to only two boundary conditions: (a) The boundary between the magnetosphere and the streaming solar wind and (b) the boundary of the magnetosphere and the neutral atmosphere. The basic structural elements of the magnetosphere are:

- The Bow Shock and the Magnetosheath
- The Magnetopause
- The Magnetotail - Magnetic Substorms
- The Inner Magnetosphere - Magnetic Storms

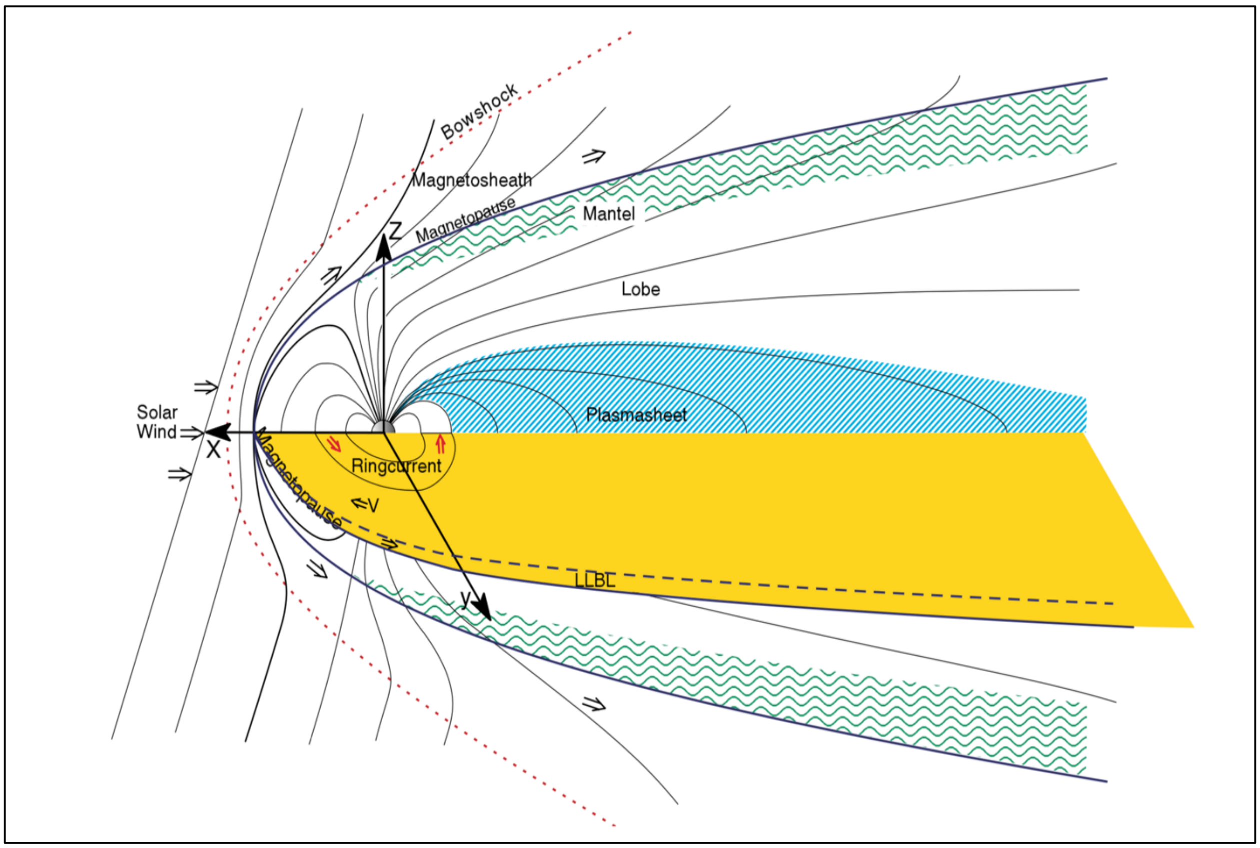
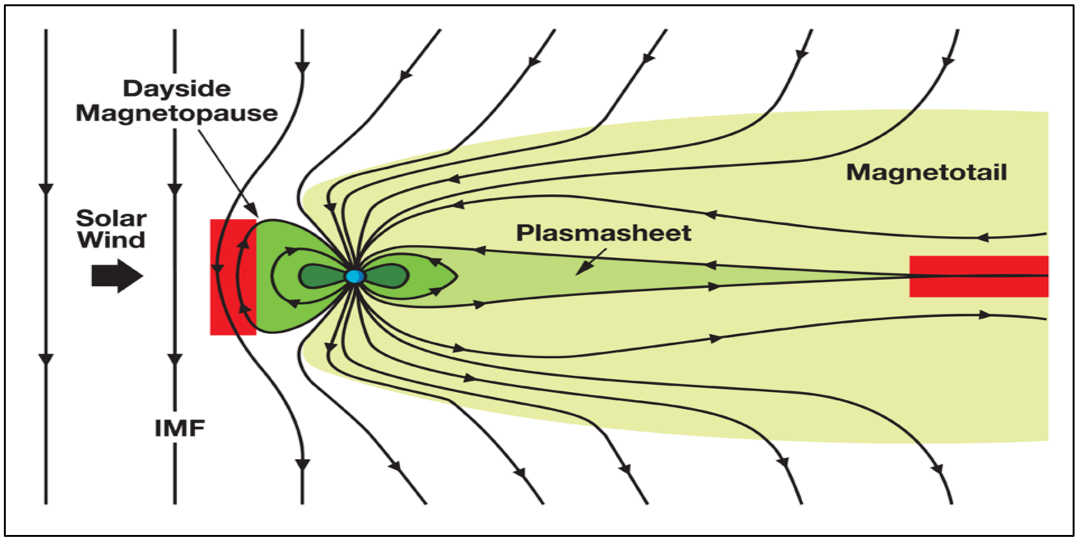


Fig. 3.1. Sketch of the structure of the magnetosphere.

The Bow Shock and the Magnetosheath are not actually part of the magnetosphere proper but form an outer layer embedding the magnetosphere. The solar wind plasma travels usually at super-fast speeds (faster than the fast mode speed) relative to the magnetosphere. Therefore, a standing shock wave forms around the magnetosphere just as in front of an aircraft traveling at supersonic speeds. The bow shock is the shock in front of the magnetosphere and the magnetosheath is the shocked solar wind plasma. Therefore it is not directly the solar wind plasma which constitutes the boundary of the magnetosphere but the strongly heated and compressed plasma behind the bow shock.

The Magnetopause is the actual boundary between the shocked solar wind and the magnetospheric plasma. However, the magnetosphere is not closed in terms of the magnetic field but there is considerable magnetic flux crossing the magnetopause. Thus it is not easy to define this boundary in precise mathematical terms. The boundary permits a certain amount of solar wind plasma entry. This entry is easier along magnetic field lines. The magnetopause is a highly important region because the physical processes at this boundary control the entry of plasma, momentum, energy into the magnetosphere.

The Magnetotail is the long tail-like extension of the magnetosphere on night side. Since the magnetic field points toward the Earth in the northern lobe and away in the southern lobe there is a current in the westward direction. Because of this structure there is considerable energy stored in the magnetic field in the magnetotail. During magnetically quiet times convection is typically slow and the energy in the plasma flow is only a tiny fraction of the overall energy density. The magnetotail plays a particularly important role in so-called magnetospheric substorms. Substorms are an important aspect for space weather because of large perturbations in magnetic and electric fields and because of the generation of high energy particle populations.



<u>The Inner Magnetosphere</u> is different from most of the magnetosphere in that the magnetic field is mostly dipolar and perturbations of the field are small compared to the average dipole field. However, there can still be large amounts of energy stored in this region in particular during magnetic storms. During such times the ring current (current due to gradient curvature drifts of charged particles around the Earth) intensifies strongly and is responsible for strong magnetic perturbations at low geomagnetic latitudes on the Earth.

A storm is a large and long duration (few days) perturbation of the magnetosphere which leads to a strong compression and a contraction of the magnetosphere. Characteristic is a strong amplification of the ring current and the associated magnetic field measured at equatorial latitudes. Aurora is typically visible at much lower latitudes. Storms are associated with larger solar flares and/or coronal mass ejections (CME's).