Geomagnetic storms

Introduction

Geomagnetic activity can be divided into two main categories, storms and substorms. Storms, the main contributors to space weather, are initiated when enhanced energy transfer from the solar wind (and related IMF) into the magnetosphere leads into intensification of ring current. The ring current development can be monitored with the Dst index. The following storm definition has been proposed by Gonzales et al. (1994):

Storm is an interval of time when a sufficiently intense and long-lasting interplanetary convection electric field leads, through a substantial energization in the magnetosphere-ionosphere system, to an intensified ring current strong enough to exceed some key threshold of the quantifying storm time Dst index.

Storm strength	Dst [nT]	Bz [nT]	dT [h]
Intense	-100	-10	3
Moderate	-50	-5	2
Small (typical substorm!)	-30	-3	1

The electric field mentioned is composed of solar wind velocity V and southward IMF (Bz). Of these, the magnetic field is found to be more important, indicating that the mechanism for the energy transfer includes magnetic field merging. The thresholds and driving parameters could then be as as shown in the table.

According to the classical substorm injection hypothesis, ring current is enhanced via energization and injections of plasma sheet particles from the tail towards the inner magnetosphere during substorms, which are typical for storm times. However, this view has been under attack for some time now, and according to the works by Iyemori and Rao (1996) and Siscoe and Petschek (1997) the substorm expansion phases act as energy dissipation term and the southward IMF as an input term in the energy balance equation (see also McPherron, 1997).

The largest storms are often related to coronal mass ejections from the Sun (e.g., Gosling et al., 1991). In these cases, the related enhancements of solar wind velocity accompanied by southward IMF direction result into Sudden Storm Commencements (SSC). These storms are typically nonrecurrent or transient. The more moderate storms are often recurrent, i.e., they recur with the solar rotation period; see geomagnetic activity fo r more discussion about the observed periodicities in activity.

During a storm, auroral ovals become greatly disturbed, broadening and expanding equatorwards, particularly on the nightside. This brings the aurora to the skies of middle and low latitudes (see great aurora).

Phases of a storm

Storms are typically divided into three distinct phases according to the signatures in Dst:

- Initial phase
  - lasting from minutes to hours; Dst increases to positive values up to tens of nT
  - dayside magnetopause is compressed inward (perhaps by several Re), with the following effects:
    - magnetohydrodynamic waves are launched, and they propagate into the magnetosphere
    - particle anisotropies favouring, e.g., certain Pc 1 wave type, are created
- Main phase
  - lasting from half an hour to several hours; Dst can reach negative values of hundreds of nT
  - ring current is built up
  - strong cross-tail electric field pushes the plasmapause closer to the Earth, and peels off the outer layers of the old plasmasphere
  - large, radially outward (in equatorial plane) pointing electric field builds up at the earthward edge of the plasma sheet - ring current system
    - this results into particularly deep mid-latitude nighside ionospheric trough
- Recovery phase
  - lasting from tens of hours to a week; Dst gradually returns to the normal level
  - ring current ions are gradually lost:
    - the expanding plasmasphere brings cold ionospheric plasma in connection with the ring current, resulting into ion-cyclotron wave growth and scattering of the ring current ions into the loss cone
    - ring current become energetic neutral atoms due to charge-exchange with the cold neutral hydrogen
  - Periodically structured Pc1 pulsations seen

References

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See also Wikipedia on storms.