MAGNETOSPHERE BEHAVIOUR DURING THE RECOVERY PHASE OF GEOMAGNETIC STORMS

JESÚS AGUADO, CONSUELO CID, YOLANDA CERRATO, ELENA SAIZ
Departamento de Física. Universidad de Alcalá, E-28871 Alcalá de Henares, SPAIN

Abstract: This study is dedicated to the recovery phase of geomagnetic storms. During this phase the terrestrial magnetosphere, which was previously disturbed by a highly magnetized plasma flow from the solar surface, recovers its quiet state. The Dst index, which is a measurement of the magnetic field on terrestrial equator, follows an exponential trend during this phase. Our results shown that there is a dependence between the recovery time and the intensity of the storm.

Keywords: Geomagnetic storms – Dst index – Space Weather –Recovery phase.

1 Introduction

When solar wind disturbances reach the Earth, several changes takes place in terrestrial magnetosphere. If the interplanetary magnetic field (IMF) B_z component goes southward, a reconnection process takes place. As a result, particles are injected into the inner magnetosphere trough the magnetotail, and the ring current encircling the Earth is enhanced. This enhancement is observed on the terrestrial surface as a decrease in the geomagnetic field horizontal component, which is the signature of a magnetic storm. This depression can be measured by the Dst index ([1], [2]), which is constructed using measurements from four low-latitude ground observatories.

The Dst index is considered as a proxy of the energy stored in the ring current ([3], [4]), so the main variations of Dst index during a geomagnetic storm can be interpreted as a measurement of the kinetic energy of the particles which are introduced into the ring current.

Taking into account the energy balance of the ring current, Burton et al. [5] proposed the following equation for Dst evolution

$$\frac{dDst^*}{dt} = Q(t) - \frac{dDst^*}{\tau} \tag{1}$$

where Dst^* corresponds to Dst index corrected of dynamic pressure effect and other magnetospheric currents. In that way, Equation 1 obtain the temporal variation of

Dst^* as a combination of a source term ($Q(t)$, called injection function) and a loss term proportional to the own Dst index, with a characeristic decay time τ.

Two different phases can be distinguised in a typical geomagnetic storm: main phase and recovery one. During the main phase, $Q(t)$ is the most important term in equation 1 and there is energy release form solar wind to the magnetosphere. By contrary, the term Dst^*/τ is the most significant during the recovery phase. In this work we concentrate our attention on the recovery phase. Several physical processes are involved in this phase where energy losses take place, such as charge exchange with neutral atoms, Coulomb scattering, resonant interactions with plasma waves , and flow-out ions ([6], [7], [8]). All of them are averaged in the τ parameter called recovery time.

Burton et al. [5] provided one of the first estimations for the recovery time value, τ= 7 hours. From the statistical analysis of different data sets, other values of the recovery time have been obtained ([9], [10], [11]), but the dependence of tau value with the intensity of the storm, as measured by Dst, has never been considered.

2 Data set and analysis procedure

The hourly Dst data series from World Data Center in Kyoto have been used to identify intense magnetic storms, that is, those storms where the minimum value reached by Dst index (or Dst peak) is less than -100 nT [6]. The period under investigation is from 27 th November 1963 to 31 th December 2003, where Dst final data are available.

As our interest is focused in the study of the recovery phase of storms, we should remove from our study all those events where a huge energy injection takes place during the recovery phase. Then, because most of the storms return to the original quiet situation after 48 hours, we have considered in our study only storms which were separated at least that interval. When the time between two (or more) consecutive values of $Dst_{peak} < -100$ nT were closer than 48h, the event is known as a double (multiple) step storm. All these last events have been removed from our study. With these criteria a total of 227 events have been identified and constitute the set of storms to be analyzed, without taking into consideration their solar origin (CMEs or/and coronal holes).

For the study of the recovery phase of intense geomagnetic storms a superposed epoch analysis is applied. For this purpose the set of events has been divided into five subsets based on the intensity of the storm. The first four subsets include the storms with Dst peak in the range from -100 nT to -300 nT incrementing 50 nT each one, and the storms with $Dst_{peak} < -300$ nT make up the fifth subset. A new time scale has been defined, where t = 0 corresponds to the hour when Dst peak is reached for each event. The interval studied for every storm extends 48 hours after the peak of the storm. Into each subset, a Dst mean value has been calculated for each hour by the average of the Dst values of the corresponding hour from all the events of the subset. As a result, we have an average storm for each subset (Figure 1).

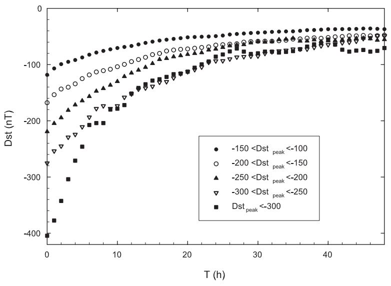

Figure 1: The five 'average storms' as representatives of each intensity interval.

3 How the recovery time depends on the intensity of the storm

Our study of the dependency of the recovery time on the intensity of the storm starts analyzing the recovery phase of storms of every set separately. As we mentioned above, only the second term in equation 1 is involved in the stage of the geomagnetic storms selected as explained above, and then Dst* can be fitted to an exponential function with τ as a parameter. As dynamic pressure effect is not significant during this phase, this exponential profile is also expected for Dst. Figure 1 shows that this behavior is followed by the five average storms, as expected. However, it seems that quiet state will soon recover the stronger the storm.

We have fitted the recovery phase of the five average storms by a standard least-squares procedure, getting a τ value for every subset. Then, with the aim of studying the dependence of tau with the strength of the storm, we have plotted both magnitudes (Figure 2). A linear relationship arises just in a first look, which is well-established with a regression procedure. The cross correlation factor is $r^2 = 0.93$.

4 Conclusions

In this work we study the differences that arise at the recovery phase of intense geomagnetic storms depending on their intensity, as measured by Dst index. Using

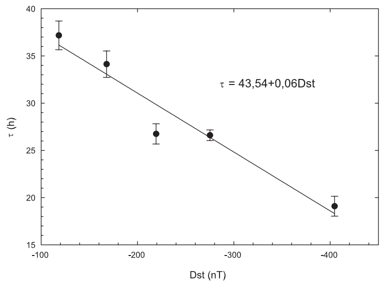

Figure 2: The recovery time obtained from the fitting of the 'average storms' versus the intensity of the storm. For the intensity of each set has been considered the mean Dst_{peak} value of the interval. The linear regresion results are also shown.

superposed epoch analysis, we have shown that, although Dst follows an exponential law in different subsets, as described in literature, the recovery time is different in each subset and the most intense storms have the lower recovery time. In the base of our results, there is a linear dependence between the recovery time and the intensity of the storm.

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