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A NEW SOLAR WIND-MAGNETOSPHERE COUPLING FUNCTION

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Abstract

Several works have pointed out recently that IMF Bz variations favor the energy entrance from solar wind to magnetosphere. However, the coupling functions proposed in literature depend only on southern Bz value. In this work a new coupling function is proposed that includes two different terms. Assuming that one of the terms is the Burton injection function, the other one has been considered as linearly related to the standard deviation of Bz. All the intense geomagnetic storm events from solar cycle 23 have been considered in the determination of the new empirical coupling function.

Introduction

- The disturbance storm time (*Dst*) index has been widely used as an indicator of geomagnetic activity. *Dst**, obtained after removing the contribution from other current systems represents the geomagnetic activity of the ring current during geomagnetic storms
- Burton et al. (1975) proposed a model based on the energy balance of the ring current in which the temporal evolution of the *Dst** index can be obtained. In the model, an injection function, *Q(t)*, and a term proportional to own *Dst** index, as representative of the loss term with recovery time τ, play roles of supply and loss rates of energy in the ring current respectively

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

- Previous studies (Burton et al, 1975; O´Brien and McPherron, 2000, 2002) have proposed a variety of empirical injection functions proportional to dawn-dusk electric field component (*Ey* = *VBs* where Bs is southern IMF *Bz*); otherwise, there is no contribution of energy from the solar wind to the magnetosphere. In some cases, also the solar wind pressure have been considered (Wang et al., 2003). In the same way, a variety of recovery times have been proposed
- While the first term on the right of (1) is the most important during the main phase of a geomagnetic storm, the second one is the most significant during the recovery phase. At least in the first stages of the geomagnetic storm, the small values of the *Dst** allows to neglect the term of losses. By assuming Burton´s injection function, equation (1) can be easily integrated

$$\Delta Dst \approx \int_{\Delta t} Q(t)dt \approx -5.4 \sum Ey \Delta t$$

with *Ey* expressed in mV/m and *Δt* in hours)

- More recent studies point out that during intense geomagnetic storms, not only large *Ey* values but also temporal variation of *Bz* are important suppliers of energy from the solar wind to the magnetosphere (Saiz et al., 2008). Although to separate how much each one contributes to the ring current disturbance is not a easy task, in this work, and not ever having been proposed, we propose an injection function that takes into account both contributions.

Event selection and criteria

As high resolution is important for variations of *Bz* and geomagnetic activity index as well, we have selected:

a) 5 minutes resolution data from OMNIweb database for plasma parameters

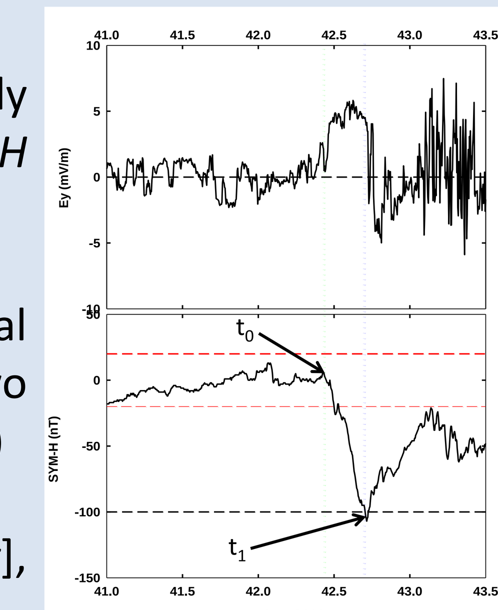
b) all intense geomagnetic storms occurred during solar cycle 23 with $SYM\text{-}H_{peak} \leq -100$ nT, excluding those events where

- a second peak appears before *SYM-H* reaches -100 nT
- the onset of the storm is far from quiet time values ($|\langle SYM\text{-}H \rangle| > 20$ nT the day before the onset) or with gaps at interplanetary data in the time interval: $[t_{onset} - t_{SYM\text{-}H \geq -100\,nT}]$

A sample of 30 events have been analised

Procedure

Since we are interested in the variation of *SYM-H* because of the injection of energy, we only consider the time interval between the onset of the storm, t_0, and the time, t_1, when the *SYM-H* index reaches the value of -100 nT (although the peak value of the storm could be lower)

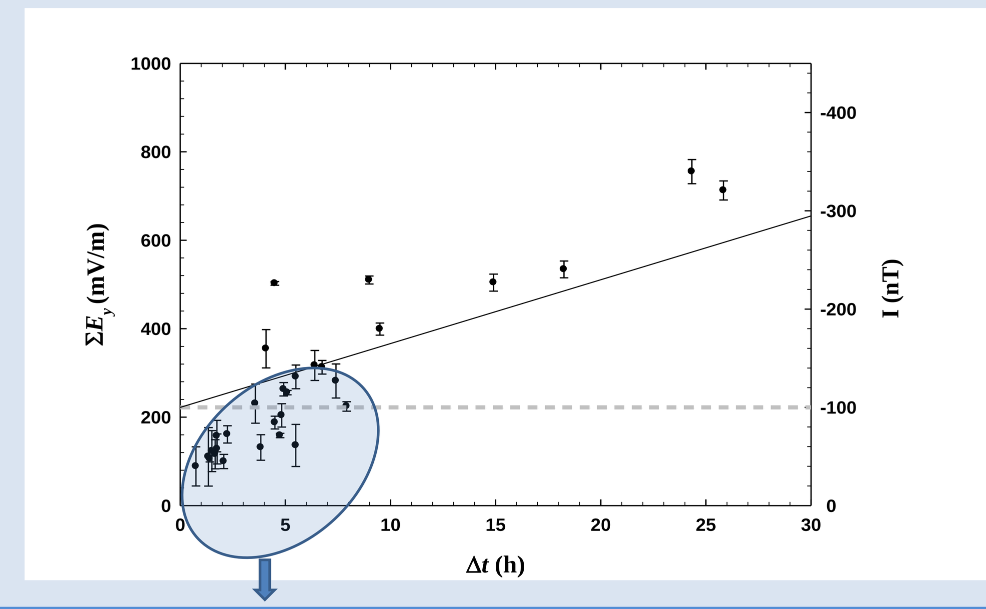


In order to establish a cause-effect relationship between *Ey* and *SYM-H* decrease in t_1-t_0 interval taking into account the delay in the magnetosphere response to the solar wind disturbance, two extreme delays are been considered: 15 min (Price et al., 1993) and 60 min (Gonzalez et al., 1989)

For each delay, δt = 15 min or δt = 60 min , we have computed $\sum Ey$ for the interval $[t_0-\delta t, t_1-\delta t]$, that is, $\sum Ey_{15}$ or $\sum Ey_{60}$, respectively

Experimental $\sum Ey$ value was obtained as the mean value:

$$\sum E_y = \frac{1}{2}\left(\sum E_{y15} + \sum E_{y60}\right)$$



From Burton´s injection function and $\sum Ey$, the integral *I* in the interval $[t_0, t_1]$ was calculated:

$$I = -0.45 \sum E_y$$

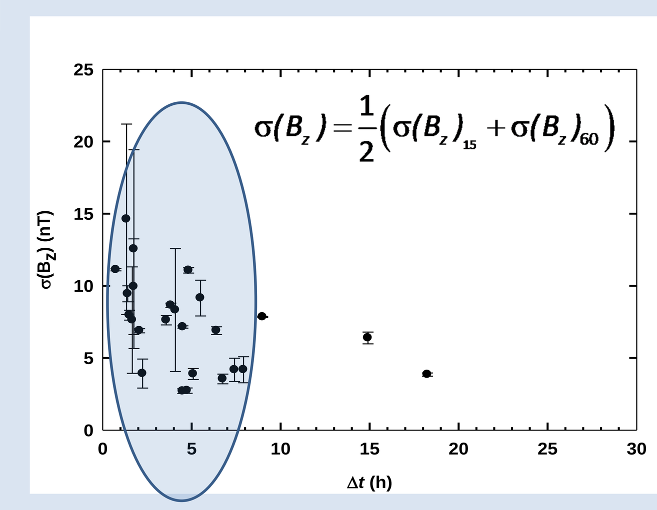
were *I* is expressed in nT and *Ey* in mV/m

Theoretical expectations from Burton's equation (1) are shown by

a) Solid black line: including losses
b) Dashed grey line: neglecting losses

Cumulated *Ey* is not enough to explain how *SYM-H* reaches the value of at least -100 nT!

But..... those events that are unable to explain that *SYM-H* reaches the value -100 nT with a small $\sum Ey$, show a great standard deviation in *Bz*, as a consequence of its fluctuation just before the onset or during the main phase development of the geomagnetic storm (shock, sheath, interacting structures …)



Our proposal for the injection function

$$I = a \sum Ey \Delta t + b\sigma(B_z)$$

The new injection function includes two contributions:

the first term includes dependence on convective electric field *Ey* as the Burton´s injection function
the second term includes linear dependence on B_z variations through its standard deviation

Conclusions

- Injection functions with solely dependence on *Ey* can not account the energy input from the solar wind to the magnetosphere when a great decrease in *SYM-H* or *Dst* indices takes place in short time intervals
- According to Faraday´s law, for a complete injection function, it is appropriate adding two terms that account for *Ey* and *Bz* variation contributions

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