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Superposed Epoch Analysis of High Latitude Ionospheric Joule Heating during Major Geomagnetic Storms over three Solar Cycles

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Abstract. Superposed epoch analysis (SPEA) is commonly used to determine some basic structure in a collection of geophysical time series. The present study tries to analyze ionospheric Joule heating response at high latitudes, to the prevailing solar wind and IMF conditions on the basis of SPEA. Major geomagnetic storms (CME driven) over three consecutive solar cycles (SC 22, 23 and 24) have been selected. Ascending phase, solar maximum, and declining phase are investigated separately, for each solar cycle, to find out crucial controlling parameters for the generation of high-latitude ionospheric Joule heating. SPEA results show that, IMF parameters such as IMF B_y, IMF B_z, IMF clock angle and solar wind parameters such as dynamic pressure and proton density influence Joule heating production rate significantly. Meanwhile, the relentlessness of the other parameters such as IMFB_t and solar wind bulk speed show that they have poor impact on Joule heating.

Keywords. ionospheric Joule heating, interplanetary magnetic field, solar wind dynamic pressure, proton density

1. Introduction

Energy flow from solar wind is the one which determines the dynamics of the magnetosphere-ionosphere (MI) system (Vanhamaki *et al.* 2012). Ionospheric Joule heating, one of the major dissipation channel in the MI sytem (Tankanen *et al.* 2002), depends strongly on ionospheric convection patterns (Weimer 2005) which is varying with solar wind and IMF features. Geomagnetic perturbations which are produced as a result of interaction of magnetosphere with solar wind and IMF parameters enhance ionospheric currents causing fluctuations in ionospheric Joule heating.

In the present study, superposed epoch of ionospheric Joule heating during different phases of solar cycles (SC 22, 23 and 24) have been analyzed.

2. Data and methodology

Solar wind and plasma parameters are taken from OMNI database (http://omniweb.gsfc.nasa.gov/form/dxl.html). Dst index and AE index are taken from WDC, Kyoto, Japan (http://wdc.kugi.kyoto.u.ac.jp/). Table 1 represents interplanetary and solar wind conditions for superposed epoch analysis.

Table 1. Interplanetary/ Solar wind conditions for superposed epoch analysis

No. of years	Zero epoch time	SW and IMF parameters
1986-2015	min Dst	B_y, B_z, B_t, IMF clock angle, v, P and ρ

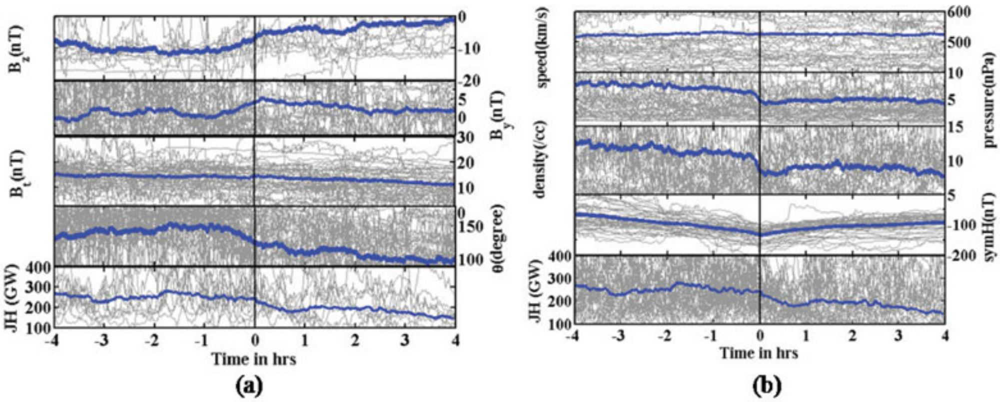

Figure 1. Superposed epoch trace of observed (a) IMF conditions and (b) solar wind conditions during 46 intense geomagnetic storms events. The vertical line marks the zero epoch time.

3. Overview

Figure 1 shows superposed epoch trace of (a) IMF parameters and (b) solar wind parameters along with ionospheric Joule heating during 46 intense geomagnetic storms for the years 1986-2015. The main and recovery phases of each event is restricted to 4 hours. It can be noted that ionospheric Joule heating is high during main phases than during recovery phases and is maintaining a level of 280 GW in the main phases. Similar variations are observed in cases of IMF B_z, IMF B_y and IMF clock angle as well as solar wind proton density and solar wind dynamic pressure which synchronise well with Joule heating. However, no such fluctuations are observed for the parameters such as IMF B_t and solar wind bulk speed and which are steady for the epoch hours. Our result is consistent with the recent investigations by Boudouridis *et al.* (2003) and Palmroth *et al.* (2004).

Similar superposed epoch analysis are carried out for ascending, solar maximum and declining phases of the three solar cycles. It can also be shown that cumulative probability distribution of the aforesaid parameters are high in ascending phases when compared with that in the solar maximum and declining phases.

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