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On the principal factors that determine ionospheric superstorms effects

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Ionosphere response to geomagnetic storms, known as ionospheric storms, is a very interesting geophysical event. The most prominent effects produced by intense geomagnetic storms at middle and low-latitudes is dayside ionosphere uplift with concurrent movements of the equatorial ionization anomaly (EIA) crests and anomalously strong TEC increase within the crests of the EIA. However, such significant dayside ionosphere changes were observed during only a few geomagnetic storms for the previous solar cycle. In connection with that, a very interesting question has been opened: what are the most important reasons for the drastic ionosphere changes to be developed and whether there is a “preferred” geographic longitude for the formation and occurrence of ionosphere superstorm effects?

It is known that the primary cause of geomagnetic storms and the dayside ionosphere uplift are dawn-to-dusk electric fields associated with the passage of southward directed IMF Bz. Generally speaking, the electric field is composed of two factors: the solar wind velocity and the southward IMF. It has been empirically shown that intense storms with a peak Dst<-100 nT are primarily caused by large Bz<-10 nT with duration greater than 3 hours (Gonzalez and Tsurutani, Planetary and Space Science, 35, 9, 1987). In addition, the electric fields seem to be modulated by the solar wind ram pressure, so that solar wind density, besides Bz IMF and solar wind velocity, plays an important role in the ring current intensification. For this study, from geomagnetic storms that occurred in 2000-2005, we selected those with sharp decrease of IMF Bz below -12-15 nT of duration about 3 hours and with the consequent drop of Dst index to no more than -120-150 nT. The selected 18 events vary in season by their occurrence and in time by a storm onset, so we can analyze seasonal and longitudinal features of TEC response to geomagnetic storms and discuss possible reasons for the observed difference in TEC response to geomagnetic storms.

We used data of the CHAMP and SAC-C satellites along with data of satellite altimeters TOPEX and Jason-1. As a result, we obtained 3-dimensional visualization of the ionosphere plasma redistribution during strong geomagnetic storms and good possibility to study in detail the dayside “super-fountain effect” (SFE).

We observed severe enhancements of the equatorial TEC (up to 50-60%) with concurrent traveling of the EIA crests for a distance up to 15° of latitude during the “Halloween storms” of 29-31 October 2003 and during intense geomagnetic storms of 21 October 2001, 6 November 2001, 7-8 September 2002 and 20 November 2003. These events were accompanied by increase of TEC above 715 km 2-3 times compared to quiet-time TEC level. Large enhancements in the equatorial and mid-latitude TEC were observed also during events of 30-31 March 2001, 19-20 April 2002 and 7-8 November 2004. However, TEC response to the other of the selected events was not so well pronounced: generally, we observed formation of the dual-peak EIA structure with concurrent increase of the near-equatorial TEC up to 80 TECU. However, the peaks did not travel far from each other, i.e. were located within their normal position.