Penetration electric fields and global ionospheric disturbances during super magnetic storms

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Magnetic storms represent the largest disturbances in the magnetosphere and ionosphere. The interplanetary magnetic field (IMF) is generally southward during the main phase of magnetic storms, and the interplanetary electric field can penetrate to the low-latitude ionosphere for many hours without decay. Penetration electric fields play a very important role in the storm-time redistribution of the global ionospheric plasma. We will present the ionospheric observations by the Millstone Hill and Jicamarca incoherent scatter radars and global GPS network during several super storms. The eastward penetration electric field in the dayside ionosphere during continuously southward IMF moves the equatorial F-region plasma upward, enhancing the fountain effect and creating a very deep depletion of the plasma density and total electron content (TEC) over the equator in the evening sector. The ionospheric plasma density is significantly increased at lower midlatitudes, particularly in the Atlantic sector near dusk, and TEC (e.g., over Florida) can be increased from a quiet-time value of 40 TECu to a storm-time value of 200-300 TECu. The enhanced ionospheric plasma density is convected toward local noon, forming an enhanced TEC band termed the ionospheric plume. The high plasma density from the low latitudes enters the polar cap and generates the polar tongue of ionization. We will show how the electric field controls these storm-time ionospheric processes; these extremely large ionospheric disturbances cannot be explained with the "conventional" positive and negative storm phases related to neutral wind disturbances. On the other hand, atmospheric disturbances indeed have profound effects on the ionosphere. We will present some simultaneous measurements of neutral O/N2 changes with the TIMED GUVI instrument and discuss the possible contribution from thermospheric winds to the ionospheric disturbances. We will further discuss how to separate the relative contributions from electric fields and neutral disturbances.