Low-latitude signature of storm enhanced density on 8 November 2004

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Anomalous enhancement of ionospheric total electron content (TEC) can be hazards for advanced GPS applications, such as satellite based augmentation systems (SBASs), WAAS in the US, MSAS in Japan, because of increased trans-ionospheric radio wave propagation delays. There are several possible mechanisms of TEC enhancement. Among them, ionospheric disturbances owing to disturbed electric fields are significant, such as prompt penetrating (PP) and disturbance dynamo (DD) electric fields, both during geomagnetically disturbed periods. TEC increases simultaneously in a wide latitude range when the PP electric field directs eastward in sunlit hours. Another TEC disturbance is so-called storm enhanced density (SED). SED also occurs associated with geomagnetic disturbances, but it is after sunset, and the mechanism is not well understood in contrast with TEC enhancement in simple PP electric field events. A significance of SED in SBAS is that the TEC enhancement occurs in a narrow channel of several-degree width in longitudes, which disables differential corrections of ionospheric delay using a coarse grid system.

We have analyzed TEC by using a dense GPS receiver network, GEONET, which consists of more than 1000 receivers and covers whole Japan. TEC was evaluated at each quarter hour in 32 meshes having 2X2 degrees in longitude and latitude which divide the observational area. During a great geomagnetic storm on 8 November 2004, a severe TEC disturbance occurred at the longitudes of Japan. After the sunrise, TEC greatly enhanced several times owing to PP electric fields and the high level of TEC persisted beyond the sunset at lower latitudes. After the sunset, TEC suddenly increased again. The TEC enhancement occurred nearly simultaneously in the whole latitude range, i.e., from 27 to 45 degrees, centered at 2000JST and persisted for 1.5 hours. However, it was quite different in many aspects from any TEC enhancement caused by PP electric fields ever observed. The peak TEC value was the largest at higher latitudes, and reached 90 TEC units at 45 degrees N. During magnetically quiet periods, TEC on the same condition of latitude and local time was only 5 TEC units. The poleward gradient of TEC was opposite to that of TEC enhancement caused by a PP electric field, in which the gradient is equatorward. Simultaneous height increases commonly observed during PP electric field events was not observed in the present case. The TEC enhanced region moved towards west at the rate of 8 degrees/hr, half the movement of sunset terminator.

This great TEC enhancement after the sunset was interpreted as a low latitude signature of SED. A narrow channel of TEC-enhanced region might pass near Hokkaido, which is the north-east end of the observation area. Another interesting feature observed during the TEC enhancement was night time E layer at 150 km with foE of about 1.5 MHz. An intense nighttime E layer ionization, and thus a large Pedersen conductivity, could intensify the disturbance dynamo efficiency to create the intense northward electric field. A combined effect of strong disturbance dynamo, the persistent daytime TEC enhancement due to the PP electric field, and another PP electric field directed eastward after sunset might transport dense equatorial plasma to higher latitudes. So far, SEDs were reported at the American longitudes, which suggested a hypothesis that Brazilian magnetic field anomaly plays a role in the formation of SED. However, present observation indicates that SED can be formed any area on the earth, as the equatorial geomagnetic field intensity at Japan's meridian is the largest among the other longitudes.