Relationship between the large TEC fluctuation and ionospheric echoes observed by the SuperDARN radars during a geomagnetic storm

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In order to investigate a global distribution of ionospheric irregularities in the auroral zone and midlatitudes during a geomagnetic storm which occurred on May 27-28, 2017 with the minimum SYM-H value of -140 nT, we analyzed global navigation satellite system (GNSS) total electron content (TEC) data and midlatitude SuperDARN radar data at Adak Island East (ADE), Adak Island West (ADW), Blackstone (BKS), Christmas Valley East (CVE), Christmas Valley West (CVW), Fort Hays East (FHE), Fort Hays West (FHW), Hokkaido West (HKW), and Hokkaido East (HOK). In this study, we calculate the GNSS-Rate of TEC Index (ROTI) as a good indicator of existence of ionospheric irregularities with the TEC data. Here, ROTI is defined as the standard deviation of rate of TEC (the TEC fluctuations per minute) [Pi et al., 1997]. We compared two-dimensional polar maps between the ROTI and the ionospheric field-aligned irregularity (FAI) echo intensity observed by the SuperDARN radars. The ROTI enhancement appears at the auroral oval and the equatorward wall of midlatitude trough during the main phase of the geomagnetic storm from 22:00 UT on May 27 until 04:00 UT on May 28. The FAI echoes with the intensity of more than 15-20 dB is also observed with correspondence to the enhanced ROTI region in the afternoon to midnight sectors (14 - 23 h MLT: magnetic local time) in North America. The enhanced ROTI and FAI regions move equatorward as the geomagnetic storm develops. However, after 04:00 UT on May 28, the ionospheric FAI echoes almost disappear in spite of existence of the enhanced ROTI region. This suggests that the ionospheric irregularity with decameter-scale disappears after 04:00 UT on May 28, or that radio waves transmitted by the SuperDARN radars are absorbed by enhanced plasma density in the D-region associated with high energy electron precipitation after 04:00 UT on May 28. However, we need further studies on the increasing electron density in D-region during this period in order to verify this hypothesis.

More interestingly, another enhanced ROTI region with a scale of 600 km appears at 30^o geomagnetic latitude (GMLAT) in North America at 1:00 UT on May 28, corresponding to the main phase of the geomagnetic storm. The enhanced ROTI region almost coincides with a region where TEC decreases by 15 TECU. This observational fact suggests that the plasma bubble having the enhanced ROTI value extends up to 50^{o}N (GMLAT) at 2:30 UT during the main phase of the geomagnetic storm. After that, the plasma bubble propagates westward at a velocity of 355 m/s and enters the midlatitude trough near 4:00 UT. When the enhanced ROTI region enters the field of view of the SuperDARN radar at FHE near 2:30 UT, FAI echoes are suddenly observed at the location of the ROTI enhancement. The FAI echoes in the enhanced ROTI region moved westward at a velocity of approximately 300 m/s. This velocity almost coincides almost with the westward velocity of the enhanced ROTI region.

From these analysis results, it is suggested that the spatial distribution of ionospheric irregularities as seen in the ROTI data has good correlation with that of the FAI echoes observed by the SuperDARN radars, and that the plasma bubble originating from the equatorial ionosphere can be observed by midlatitude SuperDARN radars during large geomagnetic storms.