Dependence of ionospheric responses on solar wind dynamic pressure during geomagnetic storms using GNSS-TEC data

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It is well known that plasma density irregularities in the ionosphere affect radio wave propagations between global navigation satellite system (GNSS) satellites and receivers, causing the positioning error. Therefore, it is important to predict temporal and spatial variations of the ionospheric plasma density irregularities. During geomagnetic storms, the ionospheric plasma density irregularities often become active in various latitudes, for example, plasma density fluctuations in the auroral region due to an auroral particle precipitation and in the low-latitude region due to an appearance of plasma bubbles. Although a contribution of the variation of interplanetary magnetic field (IMF) to the activity of these irregularly has been studied, that of solar wind dynamic pressure is still unknown.
We performed a superposed epoch analysis of solar wind, IMF, geomagnetic index, and the rate of total electron content (TEC) index (ROTI) derived from GNSS-TEC data during geomagnetic storms from 2000 to 2018 (617 events) in order to clarify the dependence of ionospheric responses on solar wind dynamic pressure. In this analysis, we defined the time of the SYM-H minimum as the zero epoch time. The 617 events were classified according to the integrated value of a dawn-dusk (Ey) component of interplanetary electric field (IEF) for 12 hours before the zero epoch time. We selected 233 events with an integrated value of IEF Ey in a range of 1000–2000 mV/m*min to minimize the IEF Ey dependence. The 233 events were also classified according to whether the integrated value of solar wind dynamic pressure for 12 hours before the zero epoch time exceeded 2200 nPa*min (high pressure: 117 events) or not (low pressure: 116 events). As a result, during the main phase of geomagnetic storms, high-latitude ROTI enhancements indicating the auroral oval extended to more equatorward (2–3° in geomagnetic latitude) in the dusk and midnight sectors for the high pressure condition than for the low pressure condition. This result indicates that the two-cell convection region at a height of the ionosphere which is identified by the auroral oval extended to lower latitudes for the high pressure condition than for the low pressure condition. This suggests that the magnetospheric convection electric field and associated ionospheric convection electric field is stronger as the solar wind dynamic pressure becomes large. On the other hand, low-latitude ROTI enhancements indicating plasma bubbles extended to more poleward (1–2° in geomagnetic latitude) in the dusk–midnight sectors for the high pressure condition than for the low pressure condition. Assuming that a latitudinal extension of plasma bubbles depends on the intensity of eastward electric field in the low-latitudes, this result suggests that a penetration of convection electric field from the high-latitudes to equator is large under the high dynamic pressure condition. From the above discussion, not only IEF Ey but also solar wind dynamic pressure plays an important role in the temporal and spatial variations of ionospheric response during geomagnetic storms.

Keywords: geomagnetic storm, solar wind dynamic pressure, rate of TEC index (ROTI), plasma bubble, auroral oval, electric field

