Substorm poleward expansion aurora

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Height-dependent ionospheric variations in the vicinity of night-side poleward expansion aurora around substorm onset

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The ionospheric responses to a substorm onset are among the most widely studied phenomena of space physics because of abrupt changes in the polar ionospheric dynamics; but still remains many controversial issues. The onset can be fairly easily identified from global auroral images. Temporal development of the horizontal pattern related with nightside hemispheric auroral power have been studied using data from satellites, ground-based optical and radio instruments. However, height-dependencies in the polar ionosphere have not been fully understood yet, although they may be important for understanding impacts to the thermosphere and undiscovered feedback from the ionosphere/thermosphere to the magnetosphere. Statistical analysis was made of data from the European Incoherent Scatter (EISCAT) UHF radar at Tromsoe, Norway (69.9^{o}N, 19.2^{o}E) for understanding common features in the ionospheric response to the substorm expansion onset. This presentation particularly focuses on height dependencies of the ionospheric parameters around the poleward-expanding aurora. The EISCAT data were obtained from dark-night measurements along the magnetic field line, and 27 events were selected between 2006 and 2010. The onset time of poleward expansion aurora was manually defined for each event as sudden increase of the EISCAT-derived electron density in the E region coinciding with auroral passing over the zenith at Tromsoe. Please note that the onset time adopted in this study is different from so-called substorm onset time determined from the ground-based magnetometer data. A superposed epoch analysis was made of the electron density and the ion/electron temperatures from the EISCAT radar between -60 min and +60 min from individual onset times (i.e. the onset time corresponds to t = 0). Mean values were calculated within a 10-min bin. The statistical analysis showed that temporal developments considerably depend on altitudes and the ionospheric parameters. The electron density in the E region has a peak at +30 $<$t $<$+60 min rather than just after the onset. In the F region and the E-F transition region (between E and F regions), the electron density starts to increase before the onset (at -30 min), although increases of the E-region electron density are not clearly seen yet. The electron density in the F region keeps a high level by +60 min. In the E-F transition region, the electron density remains at a maximum level by +30 minutes, then decreasing at +30 $<$t $<$+60 min. Coinciding with the electron-density decreases in the E-F transition region, the electron density at 100-110 km increases probably in association with the pulsating aurora. The ion-temperature increase can be seen mainly at t = -10 min due to frictional heating in association with enhancements of the perpendicular electric field. At that time, the electron temperature at 110 km height shows an obvious peak due to the Farley-Buneman instability, which also suggests presence of strong perpendicular electric field. These ion/electron temperature enhancements along with strong electric fields clearly suggest that the Pedersen current acts as an ionospheric closure current outside adjacent to poleward edge of the poleward-moving aurora, and that dissipation of electromagnetic energy originated from the magnetosphere results in natural ionospheric heating via ion-neutral collisions. Of particular interest for the electron-temperature variation is abrupt increases of the height gradient above 250 km after -30 min. In this paper we will also present results from a few case studies to compare with the statistical results.