Generation mechanism of ionospheric/lower-thermospheric variations around substorm onset

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This presentation discusses physical mechanisms to generate ionospheric and lower-thermospheric variations around the substorm onset, in particular, focusing on phenomena in the vicinity of night-side poleward expanding aurora. 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. Some previous studies have proposed a general idea of the ionospheric current system. The field-aligned current (FAC) flows upward and downward inside and outside of the arc, respectively. The Pedersen current is induced by the perpendicular electric field, mapped down from the acceleration region in the magnetosphere, between the upward and downward FAC as the ionospheric closure current. The Pedersen current plays an essential role for the energy conversion of plasmas from the kinetic energy to the thermal energy by the Joule- and frictional-heating processes. Therefore the ionospheric temperature is expected to be maximized in the Pedersen-current region. We made a statistical analysis on data from the European Incoherent Scatter (EISCAT) UHF radar, and obtained the consensus of the ion-temperature peak due to enhancements of the perpendicular electric field or the Pedersen current.

Enhancement of the thermal energy of plasmas is coincident with that of neutral particles in a partially-ionized and collision-dominant system such as the thermosphere. One may think that the thermal-energy increase in the thermosphere results in wind accelerations; but this scenario is an outstanding question. Then we made a statistical analysis on data from a Fabry-Perot interferometer (FPI; 557.7 nm) at the Tromsoe EISCAT radar site. The statistical analysis showed a clear peak coincident with the ion-temperature peak due to the Joule/frictional heating processes. It is thus concluded that the thermal energy increase due to the Joule/frictional heating process is a trigger of the wind variation.

Lorentz force is also an important term in the ion momentum equation. We discussed its effect on the wind variation using the statistical results from the EISCAT radar and the FPI. The statistical analysis of FPI showed that the horizontal wind velocity changed the direction from southwestward to southward decreasing its magnitude, which means northeastward acceleration. Since presumable directions of the Hall and Pedersen currents around the substorm onset time are westward and southward, respectively, the total ionospheric current is southwestward. Thus at the beginning, **U**.(**J**x**B**), which is equal to **J**.**E** - **J**.**E'**, was almost zero because the wind velocity is parallel to **J**x**B**. It suggests that the whole electromagnetic energy flux (**J**.**E**) originated in the magnetosphere is converted to Joule heating (**J**.**E'**). However, as changing the wind direction from southwestward to southward with time, **U**.(**J**x**B**) has some positive values, suggesting that **J**.**E** is also gradually converted to Lorentz force (**J**x**B**/rho) [rho: neutral density] in the ionosphere/thermosphere. Development of the Lorentz-force effect should relate to delay of the momentum transfer from ions to neutral particles by collisions; but quantitatively incomprehensible yet because the development is faster than the expected from the ion-momentum equation.