Modulation of ionosphere-plasmasphere interaction by weak magnetic storms: Mid-latitude effects in European and Japanese longitudinal sectors

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The interaction of the ionosphere with the plasmasphere is very important in determining the state and behavior of both the spheres at mid-latitudes. Consequently, numerous works have studied magnetic storm impacts on this interaction. However, the attention is usually paid to strong storms exclusively and the main considered effects are (1) the depletion of the plasmasphere and its further refilling by plasma from the ionosphere and (2) heating of electrons in the ionosphere by additional heat flows from the plasmasphere caused by enhanced ring current heating.

There has not been any research concerning weak storm impacts on the ionosphere-plasmasphere interaction at mid-latitudes to date. Several case studies report the changes in plasma temperatures and ion densities/fractions in the topside ionosphere during minor storms caused by high-speed solar wind streams (HSS). Ionosphere expansion caused by HSS-related heating of the thermosphere (Heelis & Sojka, 2011) and ionosphere (Hajra et al., 2017) was considered to be the main driver of the observed variations. There were no attempts to study the role of possible changes in ionosphere-plasmasphere interaction.

Earlier, using the observational data of Kharkiv (49.6°N, 36.3°E) incoherent scatter (IS) radar we found notable increases of the night-time upper (O^+/H^+) transition height H_T coincident with the occurrence of the weak magnetic disturbances after analysing ten equinoxes at solar minimum solar cycles 23/24 (Kotov et al., 2015). A strong positive correlation between the changes of H_T and F2-layer peak height h_mF_2 was found. However, those observational data were very limited in time and it was impossible to examine if the coupled variations of H_T and h_mF_2 were affected by the storm-induced changes in the ionosphere-plasmasphere interaction.

In this work, we study several periods which cover both the magnetically quiet and disturbed conditions and show that even weak magnetic storms are capable of modulating the ionosphere-plasmasphere fluxes, which may lead to remarkable manifestations at mid-latitudes. We revealed the mechanisms of such modulation by observational constrained simulations with field line interhemispheric plasma (FLIP) physical model and data of Kharkiv IS and Japan MU radars. The key factor is the F2-layer peak motion caused by the storms.

It should be noted that one important aspect is concerned with the generation of acoustic-gravity waves (AGWs) in the auroral region during magnetic disturbances and storms. Propagating from below, AGWs transfer momentum and energy and have ionospheric signatures observed as traveling ionospheric disturbances (TIDs). AGWs/TIDs significantly affect the dynamics of the thermosphere and ionosphere, since their energy deposition is often comparable with that from such processes as winds and tides (Yigit and Medvedev, 2009). Burleigh et al., 2018 reported an indirect modulation of ion upflow/downflow owing to gravity waves but that was for a strong storm.

A number of magnetic storm induced AGW/TID events have been observed over both European and Japanese regions using ionosonde, IS, MU and GPS-TEC techniques. Variations in both the F2-peak electron density (up to 30 % in amplitude) and height (up to 10 % in amplitude) were identified. Based on FLIP simulation results, we showed that such quasiperiodic changes in ionospheric parameters can modulate ionosphere-plasmasphere fluxes that lead to changes in ion fractions in the topside ionosphere.

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