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Ionospheric Features Diagnosed by Radio Tomography during Strong Geomagnetic Disturbances

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During the periods of geomagnetic storms, the ionosphere has a particularly complicated and rapidly changing structure. Each storm is marked by its own set of specific manifestations, which reflect rearrangement of the dynamical pattern of the ionosphere and strong perturbations in its parameters. The complexity and global scale of the ionospheric processes that occur during the storms call for the nonlocal methods for diagnosing the spatiotemporal structure of the ionospheric disturbances. Here, we present the results of studying the ionospheric structure by the methods of low orbital radio tomography (RT).

The ionospheric radio tomography is rapidly developing during the last two decades. Due to the sufficiently high satellite velocity ($\sim$7.9 km/s) and, correspondingly, quite fast (compared to the characteristic times of the ionospheric processes) passage of the satellite through the ionospheric region under study, the radio tomographic approach is suitable for making nearly instantaneous (covering an interval of 5-10 min) 2D snapshots of the ionosphere in the altitude-latitude plane. The vertical and horizontal resolution of RT is 30-40 km and 20-30 km, respectively.

We consider the ionospheric manifestations of strong geomagnetic storms (1991-2012) in different regions worldwide including the European part of Russia and North America. We note that during the geomagnetic disturbances, the ionosondes frequently show unstable operation. In contrast to the ionosondes that use HF radio waves, the RT methods are suitable for imaging the ionosphere even during severe solar and geophysical disturbances.

During the periods of strong perturbations, RT detected various wavelike structures, travelling ionospheric disturbances, and different manifestations of acoustic gravity waves in the ionosphere. Using the RT methods, the wave effects of particle precipitation were analyzed, and plasma flows were estimated. Radio tomographic imaging of the ionosphere during severe disturbances reveals multiextremal spotty patterns with steep wall-like gradients in electron density in the north. Thin enhancements of electron concentration that are elongated by hundreds of kilometers along the magnetic field lines and attain dozens of kilometers in the transversal direction are identified.

The complexly structured ionospheric trough with a tilted polar wall shifted towards the equator is revealed. Many RT reconstructions show the ionospheric trough to split. For example, the RT imaging of the storm of March 24-28, 1991 indicates that the ionospheric structures that are normally typical of the subauroral and auroral ionosphere (the troughs and anomalous ionization in the F-region) reached middle latitudes at that time. During the strongest geomagnetic storm on October 30-31, 2003, the ionosphere over the European part of Russia was marked by anomalously high electron concentration; the distribution of electron density in the region of increased ionization was extremely complicated in space and highly variable in time.

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