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Calculations of the Ionospheric Response to the Geomagnetic Storms and Their Impact on the HF Radiowave Propagation

Abstract:
Geomagnetic storms produce significant changes in the thermosphere-ionosphere system and therefore have a great impact on the space radiocommunication, radiolocation, navigation, and operation of the GLONASS/GPS satellite navigation systems.

In this study, the parameters of the ionosphere-plasmasphere system during geomagnetic storms on May 1–3, 2010 and September 26–30, 2011 were calculated using the Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP). The GSM TIP model provides an opportunity to determine the global response of total, ionospheric and plasmaspheric, electron content and ionospheric F2 layer peak parameters to geomagnetic disturbances. Storm-time ionospheric disturbances obtained from the model show good agreement with the data obtained from GPS TEC and ionosondes observations all over the Earth as well as their temporal variability in the various longitudinal sectors.

We studied the formation mechanism of positive and negative ionospheric disturbances at low, mid and high latitudes during different phases of geomagnetic storms. We also study the effect of the geomagnetic storm on radiocommunication by modeling radiowave propagation (RWP) in the medium produced by GSM TIP model.

Two methods are used to model RWP. The first method involves solving the eikonal equation by method of characteristics for each of the two normal modes of the radio wave in the geometrical optics approximation. It is shown that the presence of the F1 layer in the high-latitude ionosphere and the F3 layer in the low-latitude ionosphere leads to a significant increase in the path length of the radio wave propagating through the interlayer wave channel (the region between F1 and F2 or F2 and F3 layers). This method of RWP modeling can be combined with the shooting method and then used in the applications where point-to-point radio wave ray tracing is needed. However, the problem with the shooting method is that there is no general rule of how to change the radio wave shooting direction so as to systematically converge to the desired target point.

We used another approach for point-to-point radio wave tracing which is based on direct minimization of the optical path length. The idea of the method is to iteratively transform the initial trajectory to an optimal shape, while the endpoints of the trajectory are kept fixed during the calculations in accordance with the boundary conditions. The two methods for RWP modeling have been compared to each other, producing similar results but different performance depending on the applications.

In conclusion, we expect that the joint use of GSM TIP model and methods for RWP modeling

can be applied to various problems including prediction of the impact of space weather events on the radio wave propagation path.

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