Geophysical Research Abstracts
Vol. 16, EGU2014-16425-1, 2014
EGU General Assembly 2014

Semi-empirical model of Traveling Ionospheric Disturbances

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A multiscale semi-empirical model of traveling ionospheric disturbances (TIDs) is developed. Large and medium scale TIDs are different stages of an initial perturbation generated by the same source. The model is based on the following assumptions: (1) TIDs are generated by acoustic gravity waves (AGWs) and propagate as pressure waves; (2) time intervals between adjacent extrema of atmospheric pressure oscillations in a disturbance source are constant; (3) the pressure extrema propagate from the source up to $\sim$ 14000 km at a constant horizontal velocity; (4) the velocity of each extremum is determined only by its number in a TID train.

The model was validated using literature data on disturbances generated by about twenty surface and high altitude nuclear explosions, two volcano explosions, one earthquake and by energetic proton precipitation events in the magnetospheric cusp of the northern hemisphere. Model tests using literature data show that the spatial and temporal TID periods may be predicted with an accuracy of 12%.

Adequacy of the model was also confirmed by our observations collected using transionospheric sounding. The following parameters of TIDs: the spatial period, amplitude and front inclination angle in a vertical plain increase with decreasing latitude in almost all observations made during the two solar cycles in the range of latitudes $\sim 33 - 66^{\circ}$ N. This indicates that the sources of most TIDs of natural origin are located at high-latitudes. The semi-empirical model predicts the sawtooth pieces on time dynamics of spatial TID periods observed in our transionospheric radiosounding experiments. Directly proportional relationship between the amplitude and horizontal spatial period of TIDs was observed during the minimum and maximum of solar activity.

Diurnal and seasonal variability of the TID occurrence, defined as ratio of TID events to the total number of observations for the corresponding period, is not observed. However, the TID occurrence was growing from $\sim$ 50% in 1987 to $\sim$ 98% in 2010. The results of other studies asserting that the TID occurrence does not depend on the number of sunspots and magnetic activity are confirmed. The TID occurrence has doubled over the period from 1987 to 2010 indicating increasing solar activity which is not associated with sunspot numbers. The dynamics of spatial horizontal periods was studied in a range of 150 – 35000 km. The minimum values of the horizontal scale of TIDs do not exceed $\sim$ 150 – 200 km, predicted by our model and confirmed by observations.