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# Investigation of the ionospheric variability prior to strong seismic events in Japan and Russian Far East region

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The problem of the earthquake forecast still remains one of the major unsolved tasks of modern geophysics. In view of the last disastrous earthquakes the urgency of development and perfection of the forecast methods does not decrease. The numerous researches of the last years convincingly proved the existence of connection between processes in the Earth lithosphere and disturbances in the atmosphere and ionosphere. It is shown that during the earthquake preparatory phase the numerous abnormal changes of fields and parameters of the near-ground space are revealed (e.g., see reference list in [1-2]).

In this paper the analysis of the ionosphere's variability prior to strong earthquakes is presented. We have studied more than 20 seismic events that occurred during the years 2003-2010 in the regions of Japan and the Far East of Russia. Recent works on lithosphere-ionosphere interactions show that we need to have an integrated approach of examination different kinds of ground-based and satellite observations in order to raise the reliability of the observed seismo-ionospheric effects. For the given research we propose to use integrated processing of the ionospheric data from different sources: total electron content (TEC) data obtained on the basis of regular GPS/GLONASS observations of IGS stations located in Japan region, ionospheric E and F2 layers peak parameters, derived from data of Japan ionosonde network and electron density profiles, obtained by FORMOSAT-3/COSMIC radio occultation measurements, as well as analysis of the numerical simulations results.

Nowadays the majority of the ionospheric research activities are based on the measurements of GPS/GLONASS radio signals. The restored estimate of GPS-derived TEC is a very useful parameter to analyze the ionosphere variability both in global and regional scales. There are many advantages of GPS technique – 1) very dense network of GPS ground-based receivers (a few thousands all over the world); 2) continuous and regular measurements; 3) possibility to create and analyze global/regional maps of TEC with high temporal and spatial resolution. Also GPS TEC data are actively used for seismo-ionosphereic research. In that way, a lot of pre-seismic and co-seismic effects were registered by use of GPS TEC observations, e.g. [1].

In the given research we analyzed variation of vertical GPS TEC over separate GPS stations as well

as regional TEC maps. Time series of TEC and TEC maps were processed and compared with 15-days backward running median, geomagnetically disturbed days were excluded. Some general peculiarities of the ionospheric effects associated with seismic activity are found out. The pre-seismic behavior of TEC was detected within several days before the main event. In the majority of cases there was revealed the appearance of positive effect in the form of local enhancement of electron concentration over considered region. For example, Figure 1 illustrates differential TEC maps for September 20-25, 2003 prior to M8.3 Hokkaido earthquake of September 25, 2003. Anomaly appeared as the local TEC enhancement situated in the vicinity of the forthcoming earthquake epicenter. These structures occurred during 5 days prior to the shock at the same interval of local time. At the process of the earthquake approach the amplitude of modification was increased, and it has reached more than 60-80% level relative to the non-disturbed conditions 18 hours before EQ.

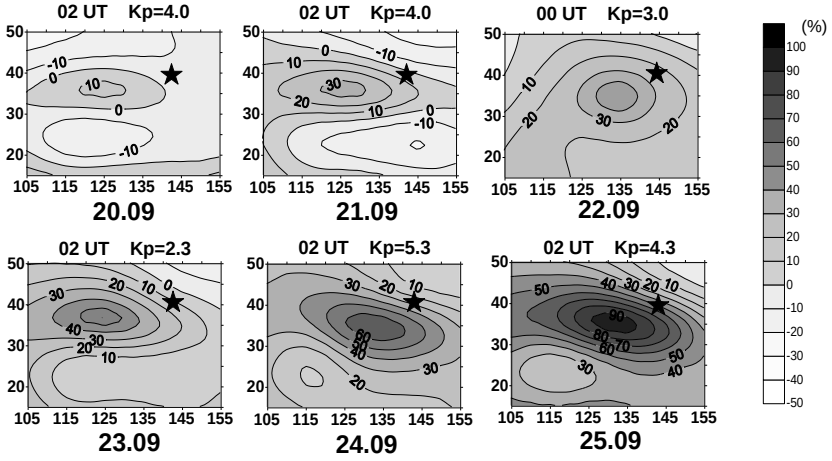


Fig. 1: Differential TEC maps (in percents) for September 20-25, 2003.

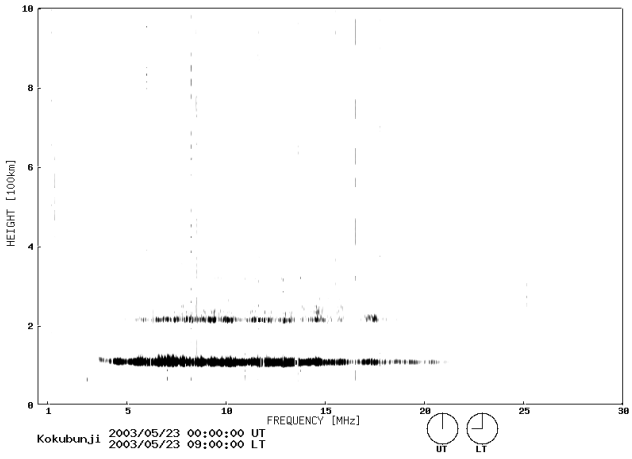


Fig. 2: Ionogram with foEs increase over 20 MHz observed at 0900 LT on May 23, 2003 at Kokubunji.

Seismo-ionospheric effects were also observed at the E region of the ionosphere (altitudes 100-120

km). One of the main feature registered in this region is the appearance of strong sporadic E layer several days before the earthquake [1,3]. Here we also analyzed variations of the critical and blanketing frequencies of Es layer before and after seismic events. Figure 2 illustrates an example of the occurrence of dense sporadic E layer 2 days prior to the May 26, 2003 Miyagi-Oki (Japan) M7.0 earthquake. Anomalous increase of the critical frequency of sporadic E layer (foEs) up to 20.9 MHz (4 times higher than monthly median) was registered at the nearest Kokubunji ionosonde (~400 km from the epicenter point).

In the given report there was sum up results retrieved from different ionospheric parameters indicating the presence or absence of any anomalous effects for every considered case. We think that only use of multi-instrumental measurements database will allow to increase probability of seismoionospheric effects' detection. Special attention will be given to the interpretation of results within the frameworks of physical models, in particular, with simulation results retrieved by use of the UAM (Upper Atmosphere Model) - the global three-dimensional numerical model of the Earth's upper atmosphere [4].

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