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PHYSICAL INTERPRETATION AND NUMERICAL MODELING OF THE IONOSPHERIC EARTHQUAKE PRECURSORS

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Abstract. The paper presents the results of the investigation of the anomalous ionospheric TEC variations as pre-earthquake signatures for the strong shock seismic events (of the magnitude M5 or larger). The hypothesis has been set that the vertical drift of the F2-layer ionospheric plasma under influence of the zonal electric field of presumably seismic origin has been the main reason for the observed disturbances in the TEC. This hypothesis has been checked by means of numerical modeling with the global 3D time-dependent Upper Atmosphere Model. Two kinds (dipole-like and monopole-like) of the presumably seismic electric field sources have been taken into consideration. The simulated results have been compared with the GPS TEC observational data for the Kithira (Source Greece) earthquake of January 8, 2008 (M6.8). It has been shown that the effects from the dipole-like electric field sources agreed well with the observations whereas monopole-like (positive) sources do not reproduce some features and underestimate the magnitude.

Introduction

A number of papers reported anomalous variations of different parameters of the ionosphere associated with the strong seismic phenomena. The analysis we present in this paper mainly concerns the effects in the F2-layer of the ionosphere and in the TEC (Total Electron Content) due to availability of vast amount of the GPS (Global Positioning System) TEC observational data and its global spatial coverage (*Dow et al.,* 2005). These effects were reported to be associated with the earthquakes and look like local large-scale anomalous statistically significant TEC variations relative to the non-disturbed level at the near-epicenter area for a few days before the main shock event (*Pulinets et al.,* 2003, 2004; *Liu et al.*, 2004; *Zakharenkova et al.,* 2007). We set a hypothesis that the vertical drift of F2-region ionospheric plasma upward (downward) under the influence of the zonal electric field of presumably seismogenic origin directed to the east (west) is possibly the main reason of the appearance of the observed anomalous local TEC reduction (increase) (*Namgaladze et al.*, 2008). To check the hypothesis we carried out a series of numerical experiments by means of the global time-dependent 3D self-consistent Upper Atmosphere Model (UAM) (*Namgaladze et al.*, 1988).

Simulations and discussion

In our simulations we intended to obtain the electric fields generating the disturbances in the TEC similar to the observed ones. All UAM model runs were made in a self-consistent mode. The electric fields were simulated by setting different additional electric potential sources at the given nodes of the grid (at the height of 175 km above the Earth's surface). They were turned on at 00 UT and acted in the constant regime for 24 hours. Two kinds (dipole- and monopole-like) of the additional sources were taken into account for nine geometric configurations. Two magnitudes of the additional electric potential sources were taken into consideration: (1) 10 kV for dipole-like sources and (2) 10 kV and 20 kV for monopole-like sources. We carried out numerical simulations for the geomagnetically quiet conditions. Some of the modeled configurations generated rather similar to each other responses in the TEC of the ionosphere. To clarify the analysis we present here only the results for four distinctive geometric configurations (Fig. 1) – two (Fig. 1a-1b) for dipole-like and two (Fig. 1c-1d) for monopole-like (positive) additional presumably seismogenic electric potential sources.

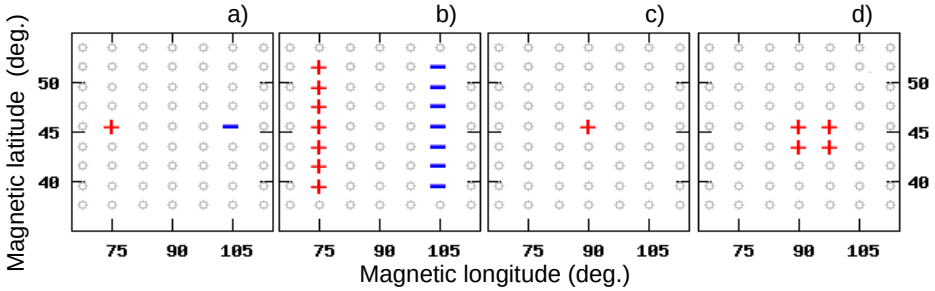

Fig. 1. Numerical grid and additional electric field sources: plus sign (+) for additional positive charges; minus sign (-) for negative charges; other (gray points) – not modified grid nodes.

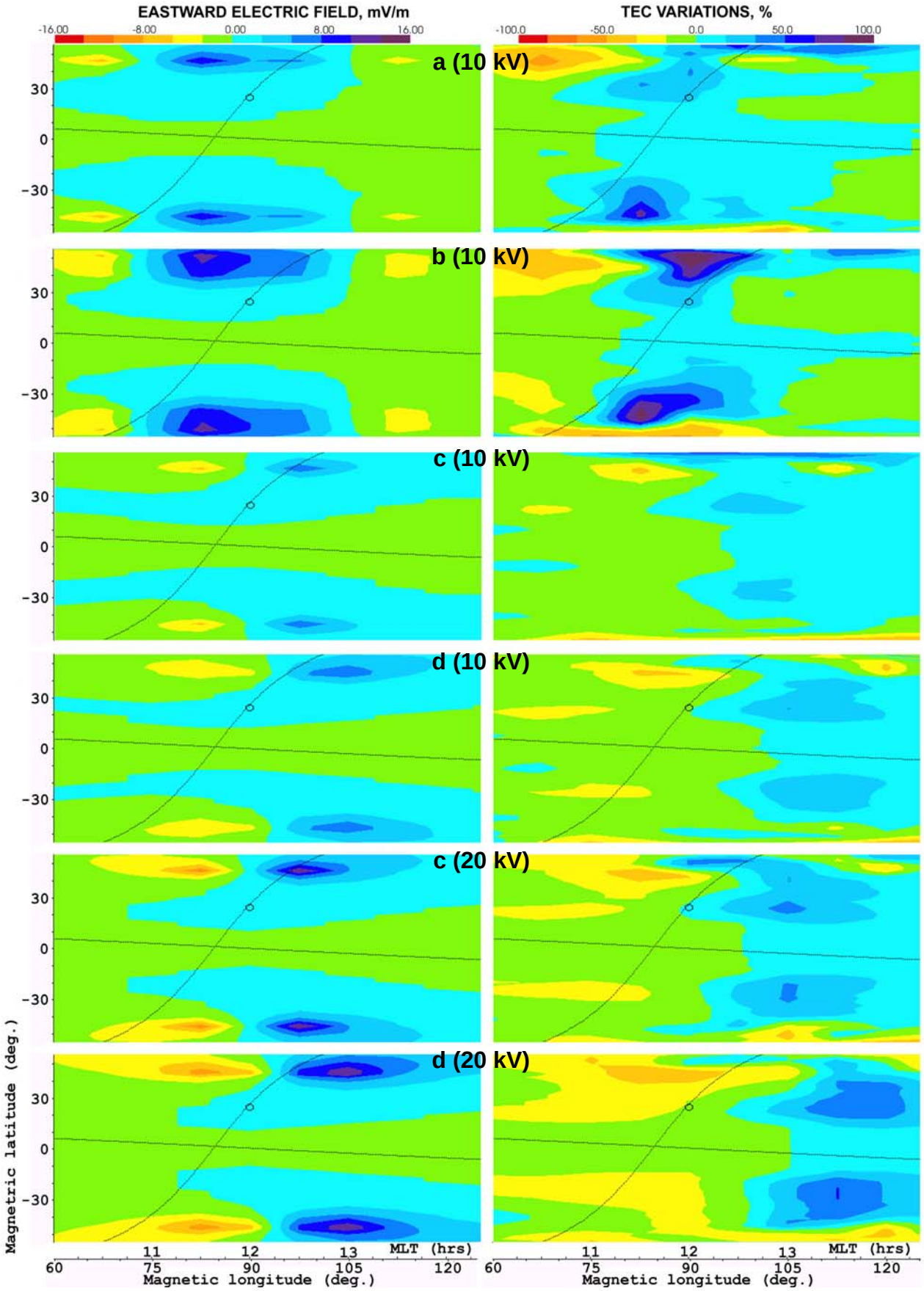

Fig. 2. The eastern component of the electric field (left column) and corresponding TEC variations (%) relative to the non-disturbed level (right column) for the corresponding geometric configurations: (1) a, b – dipole-like and (2) c, d – monopole-like for additional electric potential of +10 kV and +20 kV.

As it is shown in Fig. 2 the magnitude of the eastern component of the electric field is less or equal to 16 mV/m and reaches the peak value only in the small isolated regions. These magnitudes of the electric field agree with (*Sorokin et al.*, 2005) estimations and rocket measurements of the intensive electric fields at the E-layer of the ionosphere (*Yokoyama et al.*, 2002) associated with the seismic activity. Dipole-like sources (10 kV) generate stronger variations in the TEC in comparison with the monopole-like (positive) electric field sources (for both cases of magnitudes of +10 and +20 kV).

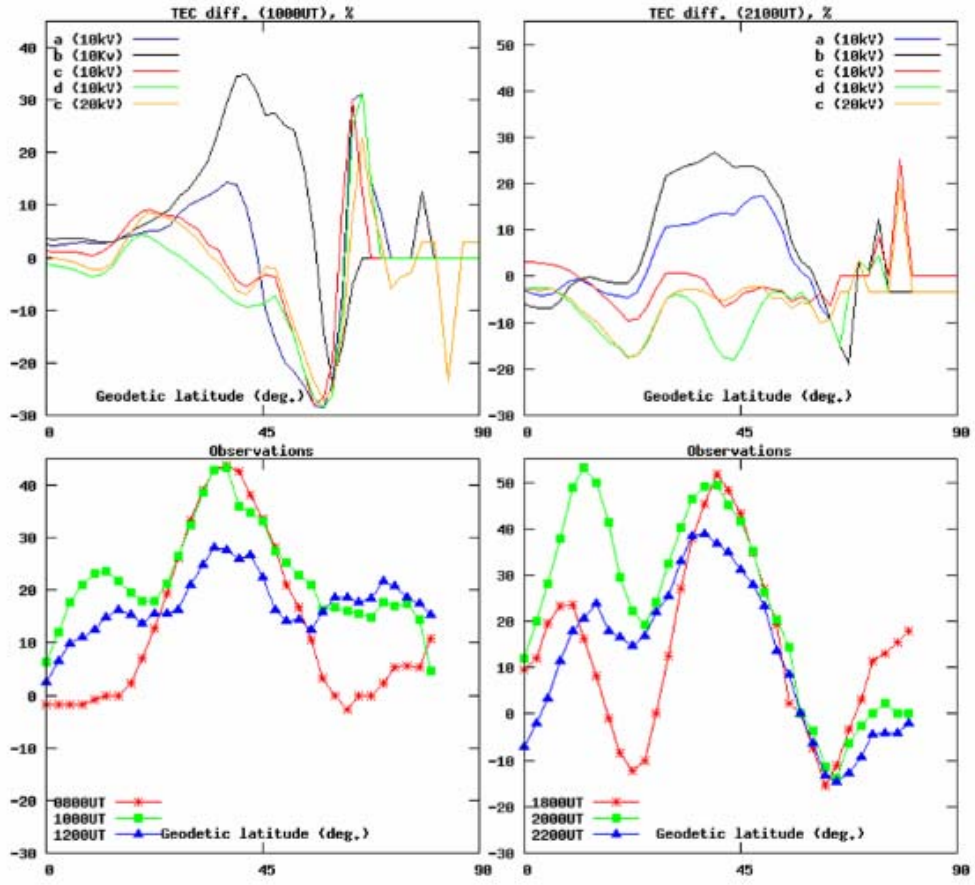

Fig. 3. Latitudinal TEC variations (%) relative to the non-disturbed level: (1) UAM calculations (top panel) for 1000UT (left) and 2100UT (right) and (2) GPS TEC day-time (left) and night-time (right) observations (bottom panel).

We can see in Fig. 3 that dipole-like sources repeat the form of the observations and maxima/minima locations for both day-time and night-time cases. The TEC variations magnitudes generated by that sources agree with the GPS TEC data in bounds of the observational (measurement's) errors or at least in the range of parameter's natural variability.

Monopole-like (positive) additional electric field sources do not reproduce the magnitude of the TEC variations and the structure (lose of some features) of the observed ones for the day-time and night-time conditions as well. The increase of the magnitudes of the additional electric potential sources from +10 kV to +20 kV does not refine agreement.

Conclusions

Our model calculations have shown that dipole-like additional electric field sources generate very similar responses in the TEC variations of the ionosphere to the observed ones. It might be also possible to reveal better agreement by varying the geometric positions and the magnitudes of the additional sources. Modeled magnitudes of the eastern electric field component are less or equal to 16 mV/m that agree well enough with the other authors' estimations and rocket measurements.

Monopole-like (positive) additional electric potential sources do not reproduce some of the observational data characteristics (such as maxima/minima and their locations and the magnitude) as well. The increase of the

additional electric potential from +10 kV to +20 kV for those cases has weak influence and does not improve the agreement.

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