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FORMATION MECHANISMS OF EARTHQUAKE IONOSPHERIC PRECURSORS IN TEC

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Abstract. The given investigations confirm the formation mechanisms of earthquake ionospheric precursors by small-scale internal gravity waves and/or by the penetration of seismogenic vertical electric field from the atmosphere into the ionosphere.

1 INTRODUCTION

The hot discussions about the existence of the seismo-ionospheric precursors are carried out now. These discussions can be resolved only by detailed analysis of experimental data of various ionospheric parameters before earthquakes. In the last years, an international intensive research in the new science field of seismo-ionospheric precursors has been carried out in many countries[1]. Nowadays using of the GPS technique may effectively contribute to the study of different kind of the ionospheric variations, in particular associated with seismic activity. The total electron content (TEC) variations can be used to detect the seismo- ionospheric anomalies. It is shown[2] , that for strong middle-latitude earthquakes the effects in TEC look like local changes in electron concentration which

maxima are located in immediate proximity from epicentral area. Precursory effects of strong near-equatorial earthquakes might be in the form of deepening and widening of electron concentration minimum over the magnetic equator and displacement of Equatorial Ionization Anomaly (EIA) crests[1]. The problems of physical explanation and possible formation mechanisms of the seismo- ionospheric effects are under discussion now and solved in this study.

2 POSSIBLE FORMATION MECHANISMS OF THE EARTHQUAKE IONOSPHERIC PRECORSORS

It has been come out with the assumption[3], that the most probable formation mechanism of TEC disturbed areas, observable prior strong earthquakes, is the vertical transport of F2- region ionospheric plasma under the zonal electric field action. The geomagnetic conjugacy of the ionospheric precursors of earthquakes[1] and effects in equatorial anomaly[2] which development is controlled by the zonal electric field are strong arguments in favor of this hypothesis. Besides, the analysis of model calculation results[3] testifies in favour of this hypothesis. There is a question how such electric fields can arise in the ionosphere prior to earthquakes? Now it is no a single meaning answer to this question. Therefore for understanding the formation mechanism of earthquake ionospheric precursor it is needed to understand the physical processes of lithosphere-atmosphere-ionosphere coupling some days before earthquakes. The physical models of lithosphere-atmosphere-ionosphere coupling some days prior to earthquakes are reviewed[1,4]. However, till now there is no common opinion concerning to the formation mechanism of local large-scale earthquake ionosphere precursors. Some basic hypotheses for the explanation of this mechanism have been offered.

1. The internal gravity waves (IGWs) of seismogenic origin with the period ∼13 hours were offered as the formation mechanism of earthquake ionosphere precursors[5]. These IGWs are generated due to non-stationary inflow of lithosphere gases into the atmosphere prior to earthquake. This mechanism can explain the ionospheric phenomena occurring on the great distances from earthquake epicentre.

2. It is offered the formation mechanism of earthquake ionosphere precursors by internal gravity waves with the period from several minutes up to tens minutes[6]. By such waves, it is possible to try to explain the formation of earthquake ionosphere precursors in the near epicentre area.

3. The formation mechanism of earthquake ionosphere precursors by seismogenic electric field with amplitude from units up to tens mV/m is described in detail[1]. The seismogenic electric field occurrence in the ionosphere is connected with vertical turbulent transfer of the charged aerosols injected into the atmosphere and radioactive substances (isotopes of radon) during the preparation of earthquake. The problems

of electric field penetration from lithosphere into the ionosphere prior to earthquakes were considered[7].

4. The abnormal electro-magnetic fields and emissions have been offered as one more possible formation mechanism of ionosphere precursors of strong earthquakes[8]. It is concluded[5] that this mechanism is found to be insufficient because of the weak intensity of lithosphere radio emissions.

Due to local character of large-scale earthquake ionospheric precursor, the two of those mechanisms can consider the small-scale IGWs and/or the seismogenic electric field[5]. In this study we used those two mechanisms at numerical experiments for reproduction of observed changes in the TEC prior strong mid-latitude Greece 2006 and Wenchuan 2008 earthquakes and near-equatorial Sumatra 2004 and Peru 2005 earthquakes. The calculations were carried out with use of the Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP)[9]. We consider the three variants of seismogenic sources input near to epicenter area; the small-scale IGWs; the penetration of vertical electric field (E_{vert}) from the atmosphere into the ionosphere; the superposition of the first and second variants.

3 CALCULATION RESULTS AND DISCUSSION

In Fig. 1 it is shown the global maps of TEC disturbances for two UT moments calculated in the model with taken into account IGWs, the propagated E_{vert} and their superposition, and also observed by GPS one day prior to earthquake in Greece. The comparison of calculation results with the set of the internal gravity waves in near-epicentre area and GPS TEC measurements data has revealed the good agreement: the presence and absence of the geomagnetic conjugacy effects simultaneously in calculations and in experiment; good qualitative similarity of the disturbance global picture in calculations and in experiment; the quantitative agreement of local TEC disturbances in the near epicentre area; the presence of significant disturbances at geomagnetic equator prior to strong middle-latitude earthquake both in model and in experiment. It is possible to note a good agreement of calculation results at the set of penetration of E_{vert} and its superposition with IGWs with experiment in near- epicenter area and not good agreement in magneto-conjugated point.

In Fig. 2 it is shown the TEC variations above station kunm (near to Wenchuan earthquake epicentre) calculated in the model with taken into account the penetrated Evert (first two days) and its superposition with IGWs, and also observed by GPS on the time period of Wenchuan earthquake. It is visible that with use of these two mechanisms we can reproduce as negative effects in TEC observed 5-6 day prior to earthquake, and positive TEC disturbances observed 2-3 days before earthquake.

Fig. 3 presents the meridian section of TEC spatial structure at the geographic longitude $\lambda = 75$W calculated in the model with taken into account IGWs, the penetrated

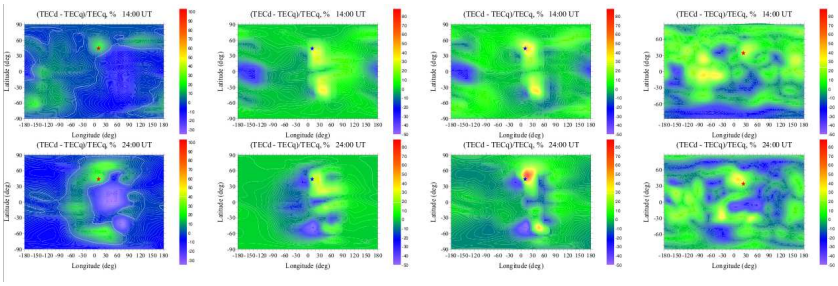

Figure 1: From left to right: TEC disturbances calculated with taken into account IGWs, E_{vert} and their superposition and observed by GPS one day prior to earthquake in Greece.

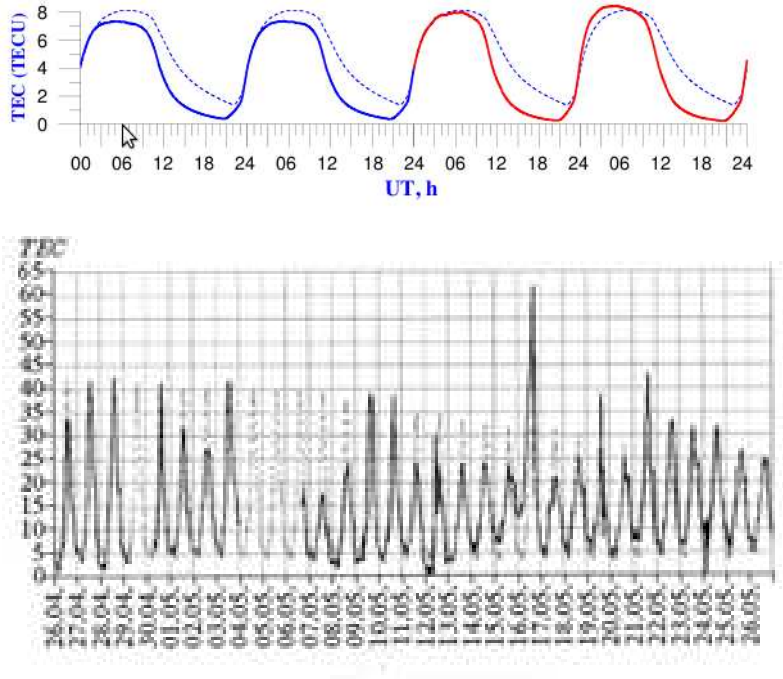

Figure 2: TEC above kunm prior Wenchuan earthquake: top - model, bottom - experiment. Dottes lines -quiet and median, E_{vert} (blue), IGWs and E_{vert}(red), actual GPS data(solid)

E_{vert}, and observed by GPS for the case of Peru earthquake of 26September 2005. Under the action of near-equatorial seismogenic sources the equatorial anomaly is strengthen by deepening of electron concentration minimum over the magnetic equator and displacement of EIA crests to middle latitudes. The penetration of E_{vert} produce the graeter effect in EIA. The calculation results are in a good qualitative agreement with experiment.

REFERENCES

[1] S.A. Pulinets and K. Boyarchuk, *Ionospheric precursors of earthquakes*, Berlin: Springer, 2004.

[2] I.E. Zakharenkova, A. Krankowski and I.I. Shagimuratov, *Modification of the low-*

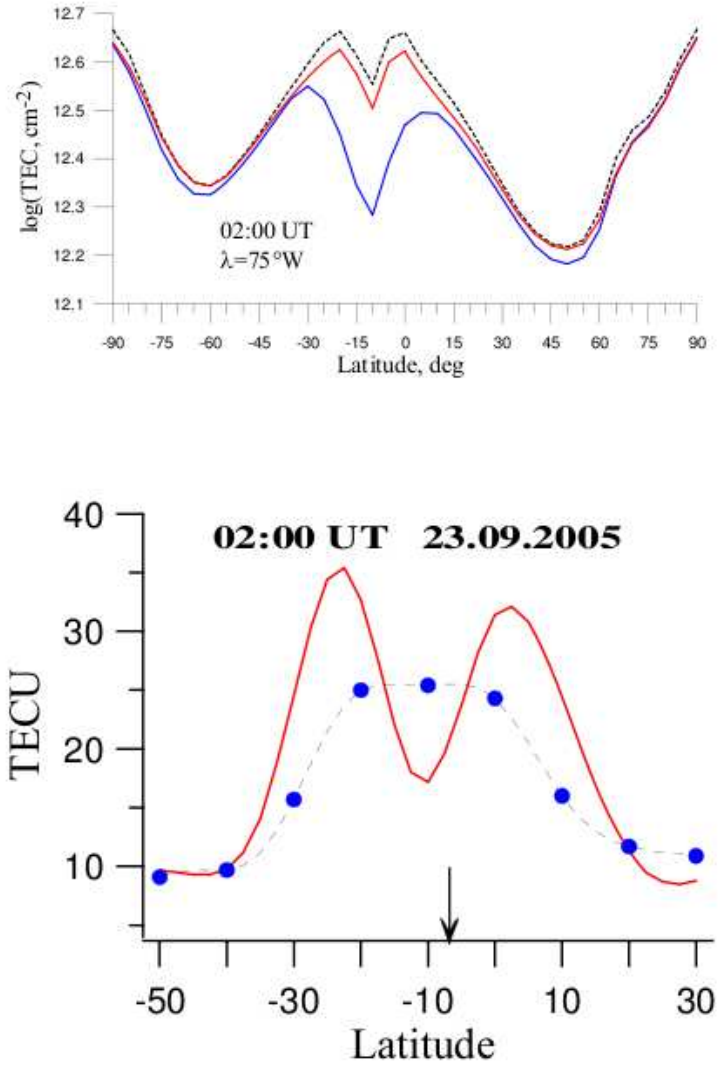

Figure 3: TEC latitudinal profiles prior Peru earthquake: top-model, bottom-experiment. Dotted lines-quiet and median, E_{ver} (blue), IGWs and actual GPS data (red).

latitude ionosphere before December 26, 2004 Indonesian earthquake, Natural Hazards and Earth System Sciences, 6, 817-823 (2006).

[3] A.A. Namgaladze, M.V. Klimenko, V.V. Klimenko and I.E. Zakharenkova, *Physical mechanism and mathematical modeling of earthquake ionospheric precursors registered in total electron content*, Geomagn. Aeron., 49, 252-262 (2009).

[4] M. Hayakawa, *VLF/LF radio sounding of ionospheric perturbations associated with earthquakes*, Sensors, 7, 1141-1158 (2007).

[5] N.N. Pertsev, S.L. Shalimov, *Generation of atmospheric gravitational waves in a seismo- active region and its influence on the ionosphere*, Geomagn. Aeron., 36, 111-118 (1996).

[6] E.A. Mareev, D.I. Iudin and O.A. Molchanov, *Mosaic source of internal gravity waves associated with seismic activity* In: M. Hayakawa and D. Molchanov (eds.), Seismo-Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling), Tokyo: Terra Scientific Publishing Company, 2002, 335-342.

[7] V.V. Grimalsky, M. Hayakawa, V.N. Ivchenko, Y.G. Rapoport and V.I. Zadorozhnii, *Penetration of an electrostatic field from the lithosphere into ionosphere and its effect on the D-region before earthquakes*, J. Atmos. Solar-Terr. Phys., 65, 391-407 (2003).

[8] M. Hayakawa and Y. Fujinawa, *Electromagnetic phenomena related to earthquake prediction*, Tokyo: Terra Scientific Publishing Company (TERRAPUB), 1994.

[9] A.A. Namgaladze, Yu.N. Korenkov, V.V. Klimenko, I.V. Karpov, F.S. Bessarab, V.A. Surotkin, T.A. Glushchenko and N.M. Naumova, *Global model of the thermosphere-ionosphere-protonosphere system*, Pure and Applied Geophysics, 127, 219-254 (1988).