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NUMERICAL MODELING OF THE ALASKA 1964 EARTHQUAKE IONOSPHERIC PRECURSORS

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Abstract. In this research, we used the numerical experiments for reproduction of observed changes in the ionosphere prior to strong high-latitude earthquake on Alaska in 1964. As formation mechanism of such ionosphere disturbances, we consider the penetration of the vertical electric field of seismogenic origin from below into the ionosphere, which is connected with occurrence in the ionosphere of electric potential irregularity in the near-epicenter area. The numerical experiments have shown, that the account of such electric potential irregularity in the ionosphere in near-epicenter area allows reproducing the morphology of ionospheric disturbances observed in the period of seismic activity.

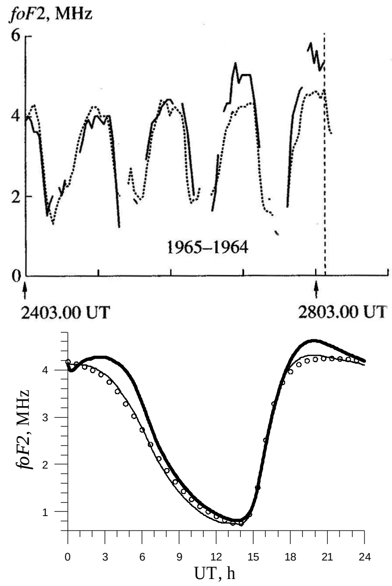

Fig. 1. Top – diurnal variations in the critical frequency *foF2* at Anchorage station during March 24–28, 1964 (solid curve) and March 24–28, 1965 (dotted curve). Vertical line (dashes) marks the underground shock instant on the UT axis. Bottom – calculation results. Circles – without seismogenic sources. Thin and thick lines – with penetrated vertical electric field at electric potential irregularity, which equals 10 and 30 kV, relatively.

Introduction

Earlier in (Klimenko and Klimenko, 2009) we had been presented the model calculation results of the ionospheric disturbances prior to the strong Alaska Good Friday earthquake of 1964. As formation mechanism of such ionosphere disturbances, we considered the zonal electric field and small-scale internal gravity waves with small amplitude in the near-epicenter area. This earthquake occurred on Friday, March 27 (local time). It happened at a point with coordinates 61.1° N and 147.6° W, had a magnitude M_w=9.2 and became one of the first earthquake on which the ionospheric researchers have turned a fixed attention (Davies, Baker, 1965; Leonard, Barnes, 1965). In the given research as formation mechanism of ionosphere disturbances prior to this strong earthquake, we considered the penetration of vertical electric field of seismogenic origin from lithosphere into the Earth's ionosphere.

Formation mechanism of local large-scale ionospheric precursors of earthquakes

From the analysis of research results (see reviews e.g. Liperovsky et al., 1992; Pulinets, Boyarchuk, 2004; Hayakawa, 2007; Liperovsky, 2008), submitted by Klimenko and Klimenko (2009), it follows that as formation mechanisms of ionospheric disturbances prior to earthquakes one can be considered only:
1) the penetration of seismogenic electric fields into the Earth's ionosphere;
2) the small-scale IGWs with small amplitude.
In (Namgaladze, 2007) it has been come out with the assumption, that the most probable formation mechanism of areas of disturbed N_mF2 and Total Electron Content (*TEC*), observable prior to 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 (Pulinets et al., 2003) is strong argument in favor of this hypothesis. Besides, the analysis of model calculation results in (Namgaladze et al., 2009; Klimenko and Klimenko, 2009) testifies in favor of this hypothesis. It is necessary to notice, that the direct penetration of zonal electric fields of seismogenic origin into the Earth's ionosphere before strong earthquakes does not yet find the experimental acknowledgement. There is a question, how such zonal electric fields can arise in the ionosphere prior to earthquakes? There is a lot of experimental evidences and theoretical estimations of penetration of vertical electric field from the atmosphere into the ionosphere before earthquakes (Chmyrev et al., 1989; Grimalsky et al., 2003; Pulinets, Boyarchuk, 2004; Pulinets, 2009). Such penetration of vertical electric field is connected with the formation of large-scale irregularity of ionosphere potential over the near-epicenter area. In (Harrison, 2002) it is shown that the potential difference from ground

surface to the ionosphere at height of 60 km can exceed more than 250 kV. This large-scale irregularity of ionosphere potential leads to the formation of horizontal electric fields (zonal and meridional electric fields). Therefore in this study we used the numerical experiments with the setting of conditions of vertical electric field penetration into the ionosphere above earthquake epicenter area for reproduction of observed changes in the ionosphere prior to the strong high-latitude earthquake on Alaska in 1964.

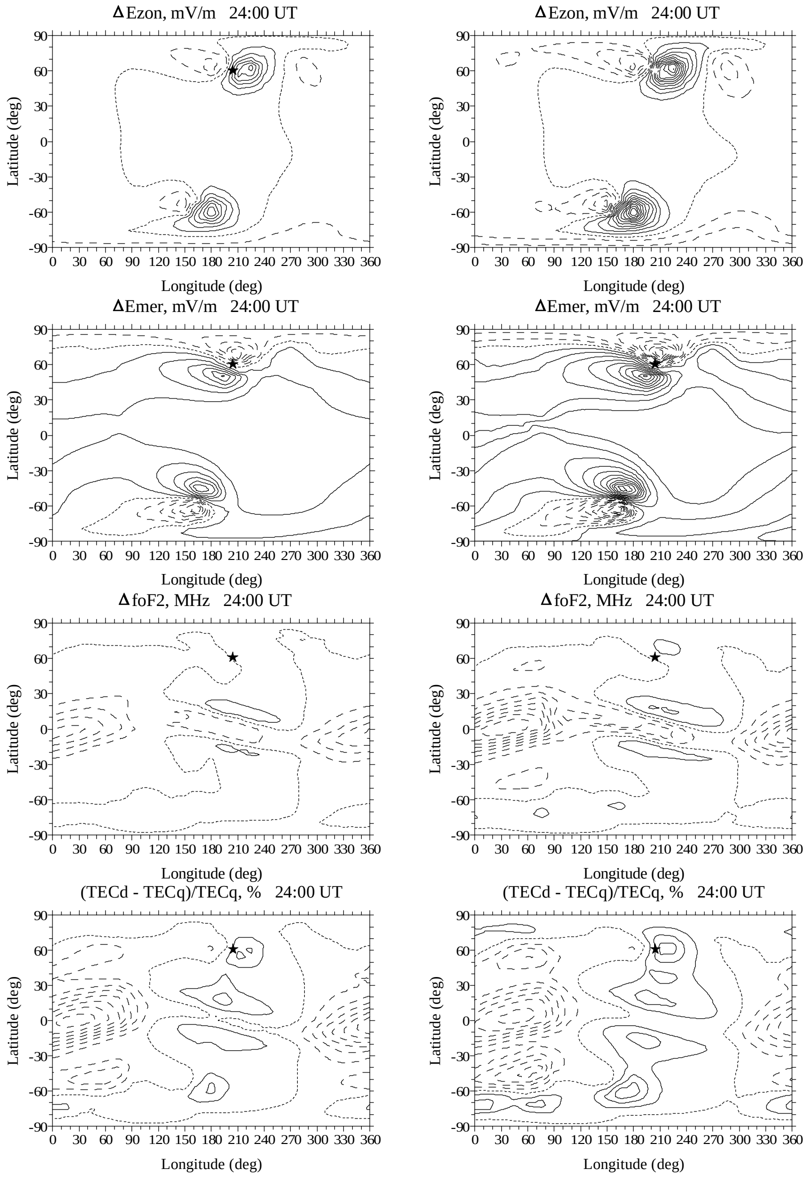

Fig. 2. Calculation results of DE_{zon}, DE_{mer}, *DfoF2* and *DTEC* with penetrated vertical electric field at electric potential irregularity, which equals 10 kV (left panel) and 30 kV (right panel). Isolines steps: 0.5 mV/m, 0.2 MHz and 5% (left panel), 1 mV/m, 0.2 MHz and 10% (right panel). Dashed lines – negative values, solid lines – positive values, dotted lines – zero values. Asterisk – earthquake epicenter position.

The statement of a problem and model simulations

The calculations were carried out with use of the Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP) developed in West Department of IZMIRAN. The model GSM TIP was described in detail by Namgaladze et al. (1988) and modified by Klimenko et al. (2006). The irregularity of ionosphere potential we can set at height of 175 km (very much above 60 km). Therefore we account the decrease of this potential with height growth. So we consider the irregularity of electric potential in the ionosphere with value of 10 or 30 kV in the epicenter area at height of 175 km.

We set the irregularity of electric potential in the ionosphere in spatial grid point above earthquake epicenter and in two nearest grid points in the longitudinal section of earthquake epicenter, and also in the magneto-conjugated points. These sources of vertical electric field joined and did not change within 24 hours. All calculations were carried out for quiet geomagnetic conditions of the spring equinox at low solar activity.

Comparisons of simulation results with experimental data

Fig. 1 presents the diurnal variation in critical frequency of *F2*-layer, *foF2*, above station Anchorage obtained in calculation results with electric potential irregularity, which equals 10 and 30 kV, and without seismogenic sources and observed in experiment before earthquake and the same data at the next year. It is visible a good agreement of *foF2* disturbances obtained in calculation results and observed in experiment prior to earthquake. Daytime increase in *foF2* obtained in calculations at the set of irregularity of the electric potential, which equals 30 kV better agreed with observational data, than at the set of 10 kV.

Fig. 2 shows the calculation results of the global disturbances of zonal DE_{zon} and meridional DE_{mer} electric field, *DfoF2* and global deviations of total electron content *dTEC*, obtained at 24 UT at the set of irregularity of electric potential, which equals 10 kV and 30 kV. In both cases, the formation of local cloud-shape increase in *foF2* is visible. The calculation results are in a good agreement with experimental data observed prior to Alaska earthquake with use of Alouette-1 satellite and ionosondes. It is possible to note the better agreement of calculation results obtained with use of irregularity in electric potential, which equals 30 kV. Also the positive disturbances in *TEC* in near-epicenter and magneto-conjugated areas are visible. These positive disturbances in *foF2* and in *TEC* are formed by disturbances of eastward electric field in near-epicenter area. Negative disturbances are formed on both sides from area of positive disturbances by the westward electric field. Meridional component of the electric field leads to the drift in a longitudinal direction of irregularity in the electron concentration, formed under the action of zonal electric field component.

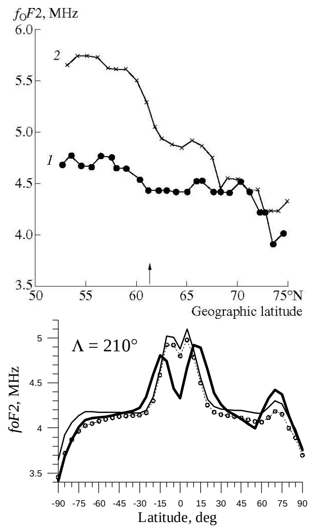

Fig. 3. Top – comparison of latitudinal distributions of *foF2* for two neighboring orbits of the Alouette-1 satellite on March 27, 1964: curve 1 Δλ = –20°, Δt = –30.5 h; and curve 2 Δλ = +5.5°, Δt = –29 h. An arrow shows the earthquake latitude. Bottom – calculation results. Thin and thick lines – with penetrated vertical electric field at electric potential irregularity, which equals 10 and 30 kV, respectively.

Fig. 3 presents the calculation results and experimental data from Allouette-1 of latitudinal distributions in *foF2* in the longitude of earthquake epicenter. It is visible a good agreement of calculation results with experimental data. It is possible to note that in both latitudinal profiles the increase in *foF2* exists in near-epicenter area.

Let consider the effects of additional sources of seismogenic origin on the global distribution of zonal current in the ionosphere (Fig. 4). It is visible the increase of eastward auroral and equatorial electrojets near the longitude of earthquake epicenter. It is possible to note the grater effect in zonal current for the case of irregularity in electric potential, which equals 30 kV.

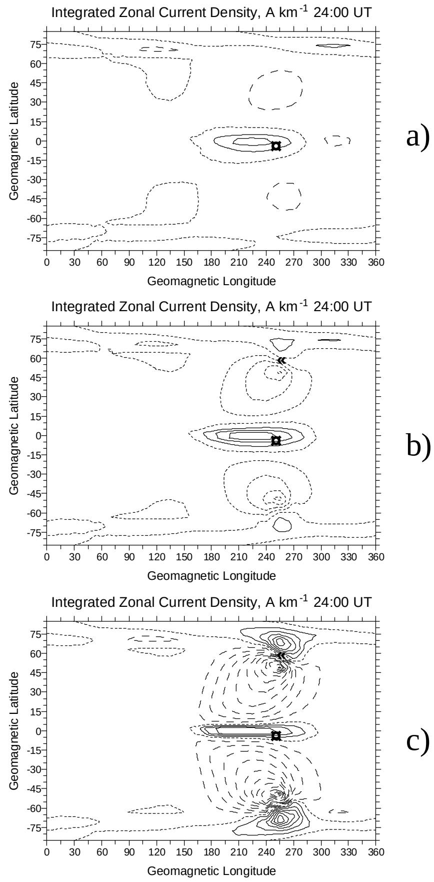

Fig. 4. Calculated global maps of integrated zonal current density obtained: a) without seismogenic sources; b) and c) with penetrated vertical electric field at electric potential irregularity, which equals 10 and 30 kV, respectively. Isolines step is 10 A/km. Dashed lines – negative values, solid lines – positive values, dotted lines – zero values. Asterisk – earthquake epicenter position.

Conclusion

Earlier by means of numerical experiments it has been confirmed, that local disturbance in zonal electric fields (Namgaladze et al., 2009; Klimenko and Klimenko, 2009) or small-scale IGWs (Klimenko and Klimenko, 2009) allows to reproduce the morphology of ionospheric perturbations observed prior to strong earthquakes. At the analysis of these numerical results, the generation mechanisms of such zonal electric fields and IGWs were not discussed.

In this study we used the numerical experiments with the setting of conditions of vertical electric field penetration into the ionosphere above earthquake epicenter area. The simulations were carried out with use of the model GSM TIP. It is shown, that the effects of this seismogenic source in *foF2* in near-epicenter area are very similar with observational data prior to Alaska earthquake. So it is shown that the penetration of vertical electric field from lithosphere into the ionosphere can reproduce the ionospheric disturbances observed prior to the strong high-latitude Alaska earthquake. There is a question on opportunity of penetration of a vertical electric field from Earth surface into the ionosphere.

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