Ionospheric effects from different seismogenic electric field sources

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Abstract

The results of numerical simulations of the impact of different seismogenic electric field sources on TEC (Total Electron Content) of the ionosphere are presented. The external electric currents flowing between the faults and the ionosphere were used as lower boundary condition for the electric potential equation of the UAM (Upper Atmosphere Model). Different configurations and magnitudes of these currents were investigated. According to the UAM calculations, the vertical electric current with density of about 2×10^{-8} A/m^2 over the earthquake epicenter area of about ~200 km × ~4000 km may create electric fields generating the observed TEC increases up to ~50%.

1. Introduction

Some models of "lithosphere-atmosphere-ionosphere" coupling have been developed for the physical interpretation of the seismo-ionospheric precursors' appearance [1-4]. Many authors [e.g. 5-8] use the hypothesis of the seismogenic electric field related with the vertical turbulent transportation of the injected aerosols and radioactive particles (radon isotopes) or with so called positive holes [9]. We have tried to model the ionospheric effects created by the electric field generated by external electric currents of different spatial configurations and magnitudes.

2. Numerical simulations

The Upper Atmosphere Model (UAM) [10-12] describes the mesosphere, thermosphere, ionosphere, plasmasphere and inner magnetosphere of the near-Earth space environment as a single system by means of numerical integration of the corresponding time-dependent three-dimensional continuity, momentum and heat balance equations for neutral, ion and electron gases as well as the equation for the electric field potential. It covers the height range from 80 km up to $15R_E$ (Earth' radii) and takes into account the offset between the geographic and geomagnetic axes of the Earth.

Numerical simulations has been carried out by means of switching-on of the additional external electric currents sources at the lower boundary (80 km above the Earth' surface) in the UAM electric potential equation which has been solved numerically jointly with all other UAM equations (continuity, momentum and heat balance) for neutral and ionized gases.

The external electric currents flowing between the lower atmosphere and ionosphere over the earthquake epicenter area (or faults) have been used as the model input for the calculations of the ionospheric electric field and corresponding TEC variations. Several spatial configurations and magnitudes of these currents have been taken into consideration: (1) "point" current (equivalent to one cell source) sources of different signs and magnitudes, given in a single node of the numerical grid and (2) "line" sources.

According to UAM simulations point current sources with magnitudes of about 10^{-5} A/m^2 and 10^{-6} A/m^2 given in a single grid node (corresponds to one grid cell – 5 deg. × 2 deg., approximately 500 km × 200 km; and averaged vertical electric current density of 5×10^{-6} A/m^2 and 5×10^{-7} A/m^2 respectively) induced the very extreme and unrealistic TEC disturbances and too power vertical drift. Point sources of 10^{-9} A/m^2 and 5×10^{-9} A/m^2 triggered TEC disturbances not exceeding 15-25% by magnitude.

The "line" kind sources have been simulated as the vertical external current with magnitude of 4×10^{-8} A/m^{-2} directed from the ionosphere to the Earth set at 9 numerical grid nodes along the magnetic parallel of the earthquake epicenter with 5 deg. longitudinal step. It corresponds to the external electric current density of 2×10^{-8} A/m^{-2}

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set on the region of approximately ~200 km × ~4000 km (2 deg. along the meridian and 9 deg. along the parallel). The generated TEC disturbances have reached ~20-50% by magnitude depending on the current spatial distribution and lifetime.

According to UAM model results, the additional electric potential generated by the corresponding external electric current existed at night-time but not at day-time (near noon hours). Terminator coming and corresponding changes of the ionospheric conductivity related to the approaching of the well-conducting sunlit ionosphere led to the depression and full disappearance down to zero of the additional electric potential. Corresponding TEC disturbances repeated the behavior of the electric potential but with 2 hours lag. Simulation results are shown in Fig. 1.

To built difference maps (of the electric potential, zonal and meridional electric field and TEC) we firstly performed regular calculation without any additional electric current sources (set as lower boundary condition) to use the results as quiet background values. Then we simulated the upper atmosphere state disturbed with the "line" electric field sources turned on and, finally, calculated the regional difference maps, presented in Fig. 1.

As one can see [Fig. 1], we have set the external electric current at the Northern hemisphere only but have obtained the effects both at the Northern and Southern hemispheres. The generated electric potential disturbances are equal at both hemispheres due to the electrical equipotentiality of the geomagnetic field lines while the TEC disturbances are not. TEC variations are significantly more intensive at the magnetically conjugated region. Positive TEC structures reached up to 30-40% at the near-epicenter area and up to ~50% at the magnetically conjugated region. TEC depressions were also obtained near the TEC increase regions. Zonal electric field was in general of about 5 mV/m by amplitude and did not exceed 10 mV/m. Meridional component of the electric field was mainly of about 10 mV/m and did not exceed 15 mV/m by magnitude (absolute value).

The obtained estimations for the electric field are smaller then in [6-7] or [9]. According to V.M. Sorokin [6-7], the external current density of about 10^{-6} A/m^2 (decreased by exponent to zero at the region boundary) at the area of about 200 km in radius is required to create the electric field of about several mV/m in the ionosphere. Our estimations is significantly smaller then 10-100 A/km^2 proposed by F. Freund [9].

Simulated TEC enhancements at least qualitatively agree with the GPS (Global Positioning System) TEC anomalous disturbances observed before the Haiti Jan.12, 2010 earthquake [13]. Modeled positive structures have reached the amplitude and structure of the observations but have occupied a rather less spatial region. Both modeled and observed TEC disturbances have been located near the earthquake epicenter and near the magnetically conjugated point being more intensive at the summer hemisphere. They both disappear at the day-time. Their shapes of isolines and magnitudes may differ but not drastically depending on the input electric current location and intensity. The discrepancies between model results and observations could be explained by too simplified representation of external electric current source and its acting regime.

3. Conclusions

Series of numerical experiments with the Upper Atmosphere Model was carried out using external electric current of different spatial configurations and magnitudes as input for modeling. It was shown that point electric current sources larger than 10^{-6}A/m^2 given in a single grid node generated too strong TEC disturbances and vertical drift. Similar point sources but with densities less than 10^{-9}-10^{-8} A/m^2 generated TEC disturbances not exceeding 10-20%. Those values were smaller than ones usually taken into consideration in pre-earthquake TEC modifications studies.

According to the UAM simulations, the vertical electric current with density of about 2×10^{-8} A/m^2 flowing between the fault and the ionosphere set at the area of about ~200 km × ~4000 km may create electric fields generating the TEC increases up to ~50% at night-time as observed before Haiti Jan. 12, 2010 earthquake. Terminator and subsolar point coming caused generated by external electric current electric potential depression down to full destruction. TEC disturbances were also modified: "escaped" from terminator to dark-side of the ionosphere with following full destruction, but with time lag relative to the electric potential. After the night coming the electric potential and corresponding TEC disturbances restored. That means the external electric current is unable to generate TEC modifications at day-time.

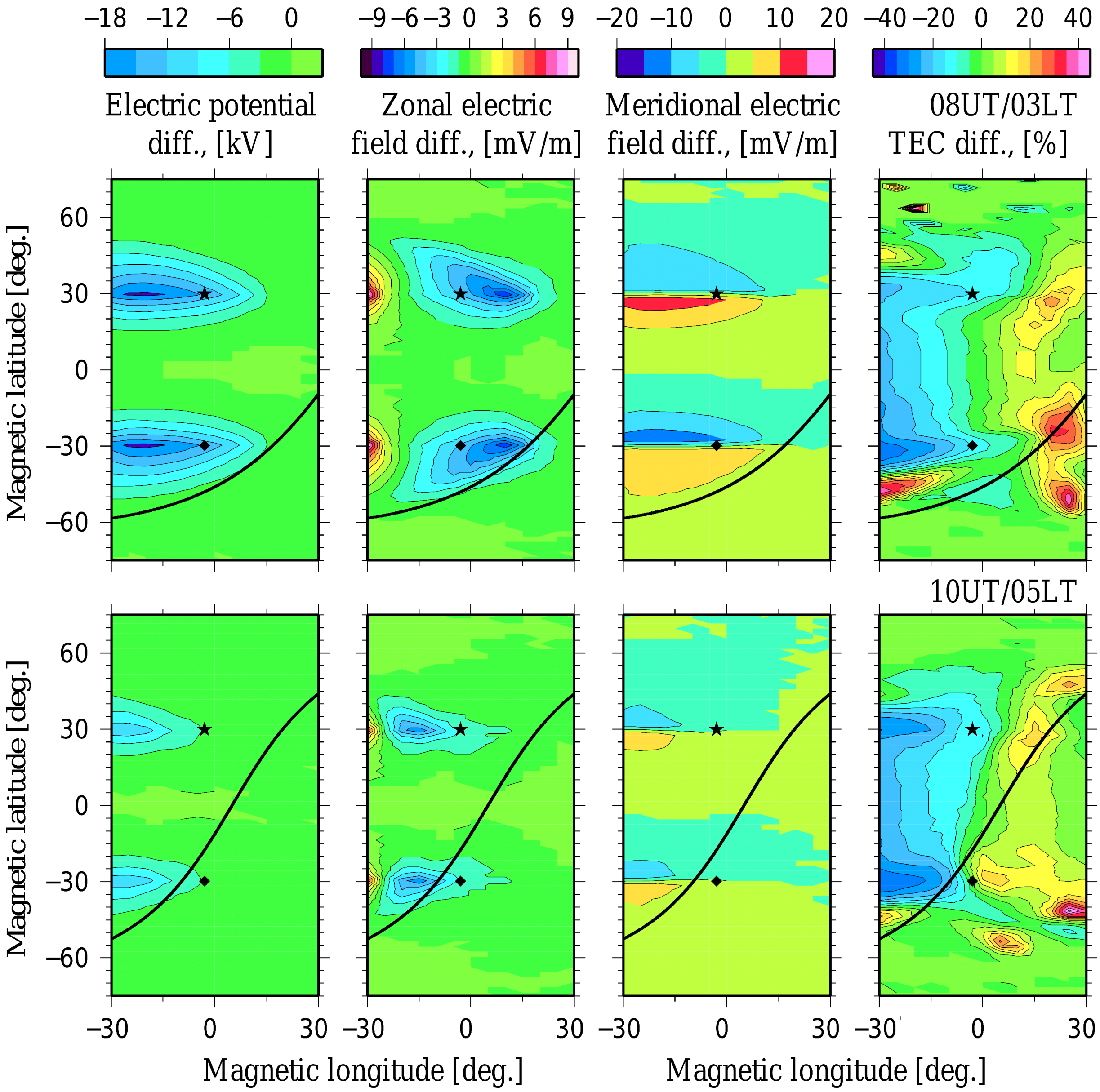

Fig. 1. Modeled (from left to right) (1) electric potential difference map; (2) zonal and (3) meridional components of the electric field generated by external electric current flowing between the Earth and the ionosphere and (4) regional map of the TEC deviations relative to the non-disturbed conditions for the 08UT/03LT (top panel) and 10UT/05LT (bottom panel). Star – the earthquake epicenter position (Haiti). Diamond – the magnetically conjugated point. Black curve – the terminator.

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All figures were generated using General Mapping Tools [14].

5. References

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