PHYSICAL INTERPRETATION OF THE TEC DISTURBANCES OBSERVED BEFORE STRONG EARTHQUAKES

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Abstract. The observed before strong EQs ionosphere Total Electron Content (TEC) relative disturbances have the following features according to many papers. They are (1) long-living (6-8 hours) and (2) strong (>30–50% by magnitude). (3) They happen near the EQs’ epicenter and often (in ~60% cases) magnetically conjugated to it areas; anomalies (4) occupy areas of about 1000 km in latitude vs. 2500 km in longitude. (5) Their shape and locations are rather stable. (6) The anomalies do not propagate along the magnetic meridians. (7) TEC relative disturbances dominate at night-time, reduce with sunlit ionosphere income and restore with sunset terminator coming. (8) Positive disturbances usually dominate. We interpret these features basing on the physics of the F2-layer of the ionosphere because TEC depends mainly on NmF2. Night-time NmF2 disturbances are mainly driven by the ion O⁺ loss in the ion-molecular reactions O⁺ with N₂ and O₂. The N₂ and O₂ densities and corresponding loss rates may be changed by income of the molecules from the high-latitude regions or by the vertical plasma movements. Neutral atmosphere horizontal movements should produce ionosphere disturbances traveling along meridians (TIDs). The electromagnetic \([E \times B]\) drift of the F2-layer plasma is able to generate more localized ionosphere disturbances related with the electric field sources locations. Electric fields of 4–10 mV/m are required to generate noticeable NmF2 and TEC disturbances. The vertical electric currents magnitude required to generate such fields and TEC disturbances according to the UAM modeling is about several 10⁻⁸ A/m². If such currents exist, all the above mentioned features can be naturally explained in terms of \([E \times B]\) drift mechanism.

Introduction

The observed before strong EQs ionosphere Total Electron Content (TEC) relative disturbances have the following features according to many papers (Liu et al., 2000, 2006, 2011; Pulinets and Boyarchuk, 2004; Zakharenkova et al., 2008; Zolotov et al., 2011, 2012; Namgaladze et al., 2011, 2012; Romanovskaya et al., 2012 – this issue).

They are
- long-living (6–8 hours) and
- strong (>30–50% by magnitude).
- They happen near the EQs’ epicenter and often (in ~60% cases) magnetically conjugated to it areas;
- anomalies occupy areas of about 1000 km in latitude vs. 2500 km in longitude.
- Their shape and locations are rather stable.
- The anomalies do not propagate along the magnetic meridians.
- TEC relative disturbances dominate at night-time, reduce with sunlit ionosphere income and restore with sunset terminator coming.
- Positive disturbances usually dominate.
- At low latitudes the equatorial anomaly form is changed.

We interpret these features basing on the physics of the F2-layer of the ionosphere because TEC depends mainly on the maximal ionospheric electron density NmF2. Night-time NmF2 disturbances are mainly driven by the ion O⁺ losses in the ion-molecular reactions O⁺ with N₂ and O₂. The N₂ and O₂ densities and corresponding loss rates may be changed by income of the molecules from the high-latitude regions or by the vertical plasma movements.

Neutral atmosphere horizontal movements should produce ionosphere disturbances traveling along meridians (TIDs). TIDs have the well known features of the large scale internal gravity waves: time periods of about 20-200 min and horizontal propagation velocity of about 700 m/s. No such features are revealed in the TEC variations observed before strong EQs.
The only possibility to create the long living, not propagating TEC disturbances like observed before strong EQs is the electromagnetic ionospheric F2-region plasma drift. In the middle latitudes the upward electromagnetic drift, created by the eastward electric field, leads to the increase of the NmF2 and TEC due to the plasma transportation to the regions with lower concentration of the neutral molecules and, consequently, with lower loss rate of dominating ions O+ in the ion-molecular reactions. The electric field of the opposite direction (westward) creates the opposite – negative – effect in NmF2 and TEC. At low latitudes the increase of the eastward electric field leads to the deepening of the equatorial anomaly minimum due to the intensification of the fountain-effect. Not only vertical but as well zonal and meridional components of the \( E \times B \) plasma drift play an important role in the electron density and TEC disturbances formation (see paper by Karpov et al. [2012], this issue).

The geomagnetically conjugated effects in the earthquake related TEC variations as well as the earthquake related ionospheric equatorial anomaly modifications support strongly the idea on the electric field of the seismogenic origin as the main cause of the TEC anomalies observed before the earthquakes. Therefore the corresponding electric field localized near the future EQ epicenter should exist. The magnitude of this field should be of about several mV/m.

**How is the electric field generated?**

**Can the earthquakes (EQs) and their preparation processes be the sources of the electricity?**

Yes, they can due to the radioactive radon emanation (Pulinets, 1998; Pulinets and Boyarchuk, 2004; Sorokin et al., 2007) and “positive holes” mechanism by Freund (2011) both acting as air ionization sources over the faults.

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**Figure 1.** The scheme of the Global Electric Circuit.

Fig.1 shows a standard scheme of the Global Electric Circuit (GEC). Total current in GEC is of about 1 kA. It keeps the ionosphere under electric potential of about +250±50 kV relatively the Earth. FACs (Field Aligned Currents) generated by solar wind and magnetosphere create the outer part of the GEC. It keeps the ionosphere under electric potential of about +250±50 kV relatively the Earth. Much stronger vertical electric currents between the Earth and ionosphere (up to 1-10 nA/m\(^2\)) are reported sometimes (see references in paper by Karpov et al., 2012, this issue). The ionospheric effects of such large currents were simulated using modern numerical models like as GSM TIP, UAM and SAMI2 (Namgaladze et al., 2007, 2009a, 2009b; Namgaladze and Zolotov, 2012; Kuo et al., 2011; Liu et al., 2011; Zolotov at al., 2012; Karpov et al., 2012). All features of the relative TEC disturbances observed before strong earthquakes were reproduced in these calculations based on the electromagnetic drift mechanism.
Figure 1. TEC disturbance (%) maps for January 9-12, 2010 before the Haiti earthquake of Jan. 12, 2010 (21:53UT). Star denotes the earthquake epicenter position. Diamond – magnetically conjugated to it point. Black curve – the terminator. Orange circle – the subsolar point position. According to Namgaladze et al. (2012).

Figure 2. TEC disturbance (%) maps for 30.12.2010-02.01.2011 before EQs in Argentina 01.01.2011, 06:56LT (right star) & Chile 02.01.2011, 17:20 LT (left star). According to Namgaladze et al. (2012).
Figure 3. TEC relative deviations (%) from background undisturbed conditions for 02UT/11LT-24UT/09L (from left to right) March 8-11 (from top to bottom), 2011. Big star denotes the earthquake epicenter position. Other stars – other earthquakes’ epicenters. Black curve – terminator. Orange circle – the subsolar point position. According to Zototov et al. (2012).

Figure 4. TEC relative deviations (%) over background conditions for 02UT/05LT-24UT/03L (from left to right) Oct. 20-23 (from top to bottom), 2011 (before Turkey Van Oct. 23 EQ). Star denotes the earthquake epicenter position. Diamond – the magnetically conjugated point. Black curve – terminator line. Orange circle – the subsolar point position. According to Zototov et al. (2012).
Figure 5. UAM simulated electric potential disturbances (top row), corresponding model TEC relative deviations (%) over undisturbed state (middle row) in comparison with GPS observed TEC disturbances (bottom row). According to Namgaladze et al. (2012).

Figure 6. UAM simulated electric potential disturbances (top row), corresponding model TEC relative deviations (%) over undisturbed state (middle row) in comparison with GPS observed TEC disturbances (bottom row). According to Namgaladze et al. (2012).
Conclusions

Thus, these TEC variations can be considered as the strong EQs precursors. For their existence, electric fields of 4-10 mV/m are required in the ionosphere and corresponding vertical currents between the Earth and ionosphere of about $2 \times 10^8$ A/m² are necessary over the area of about 200 km in latitude and 2500 km in longitude. Such currents are very large and require power ionization sources, but they exist (see paper by Karpov et al., 2012, this issue) and play an important role in the global electric circuit, possibly not less important than thunderstorms. At last, it is necessary to notice that ionospheric electron density and TEC anomalies created by the seismogenic electric fields influence on the ULF and ELF wave propagation as well as on the geomagnetic field variations before EQ’s thus inducing many various kinds of the geo-electromagnetic precursors of EQ’s.

References


Karpov M.I., A.A. Namgaladze, and O.V. Zolotov (2012), Three-dimensional structure of the ionospheric electron density disturbances created by the vertical electric currents flowing between the Earth and the ionosphere. This issue.


