

The TEC signatures as strong seismic event precursors

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Abstract

The paper presents the authors' view on the TEC (Total Electron Content) disturbances considered as seismic precursors. The “traditional” pre-earthquake signatures are extended with the terminator-related effects: the coming of the terminator and subsolar point triggers the shift and migration of the TEC anomalies towards the night-zone, followed with their shape modification and full destruction at the near-noon hours at the near-epicenter and geomagnetically conjugated regions.

1. Introduction

The extensive studies of the ionospheric earthquake precursors in the GPS (Global Positioning System) TEC (Total Electron Content) measurements (e.g., see review [1]) revealed that for strong mid-latitudinal earthquakes the seismo-ionospheric anomalies very often look like (i) local long-living TEC enhancements or decreases that are situated near the vicinity of the earthquake epicenter area. The amplitude of plasma modification reaches the values of 30-90% relative to the non-disturbed level. Positive modifications of the TEC usually dominate according to [2]. (ii) The vertical projection of the epicenter position does not mandatory coincide with the maximum phenomenon's manifestation location. (iii) The zone of the anomaly maximum manifestation extends larger than 1500 km in latitude and 3500-4000 km in longitude. The shapes and dimensions of the disturbed areas are kept rather stable. (iv) The size of the area depends on the earthquake's magnitude according to Dobrovolsky formula. (v) Similar effects at the magnetically conjugated area are often reported. (vi) The anomalies are reported from several days or hours to couple of weeks before the earthquake release moment. (vii) In case of the strong low-latitudinal earthquakes there are effects related to the modification of the ionospheric F2-region equatorial anomaly: increase or decrease of the equatorial anomaly with trough deepening or filling [1,3].

Many authors (e.g. [4-5]) 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 [6]. We consider [7] that the most probable reason of the observed before the earthquakes TEC disturbances is the vertical drift of the F2-region ionospheric plasma under the influence of the zonal electric field of seismogenic origin. In the middle latitudes the upward electromagnetic drift, created by the eastward electric field, leads to the increase of the TEC due to the plasma transportation into 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 the TEC. In the low latitude regions (near the geomagnetic equator) the increase of the eastward electric field leads to the deepening of the equatorial anomaly minimum (“trough” over the magnetic equator in the latitudinal distribution of electron concentration) due to the intensification of the fountain-effect.

2. The “extended” TEC signature

We previously investigated a few special cases of the TEC modifications before strong seismic events: (i) New Zealand Earthquake, Nov. 22, 2004 [8]; (ii) Southern Greece Jan. 8, 2006 earthquake [9]; (iii) China May 12, 2008 earthquake[10]; (iv) Haiti Jan. 12, 2010 earthquake (see Fig. 1)[10]. And now we are looking for main phenomenological features for some recent earthquakes - Argentina Jan. 01, 2011 and Chile Jan. 02, 2011 earthquakes (see Fig. 2).

In both these Figures 1 and 2 we see the mutual arrangement of the TEC anomalies with subsolar point and terminator: (i) the “ban” time takes place for the anomalies to exist corresponding to the subsolar point being at the near-epicenter area. At the near-noon hours anomalous TEC deviations disappeared down full destruction. (ii) There is a link between the anomalous region and terminator: in general, with the terminator coming we see depression of the anomalies and their shift from the terminator towards the night-sector. After the terminator leave we see the anomalies renewal.

The described features suite well the proposed physical mechanism and correspond to the model results obtained with the Upper Atmosphere Model (UAM)[11-12]. Using this model we have calculated electric fields generated by external electric current of seismic origin flowing between the faults and ionosphere and their ionospheric TEC effects. According to the UAM simulations [13] for the case of Haiti Jan. 12, 2010 earthquake, the vertical electric current with density of about 2×10^{-8} A/m² flowing between the fault and the ionosphere set at the area of about ~ 200 km \times ~ 4000 km may create electric fields generating the TEC increases up to $\sim 50\%$ at night-time as observed before Haiti Jan. 12, 2010 earthquake. Terminator and subsolar point effects are also reproduced. The “ban”-effect also agree with the [14]. Terminator and subsolar point coming corresponds to the approaching of the sunlit ionosphere. It leads to the corresponding disappearance of the seismogenic electric field generated by external electric current of seismic origin both in the model results and observations. After that the TEC anomalies disappear with the time delay of about 4 hours.

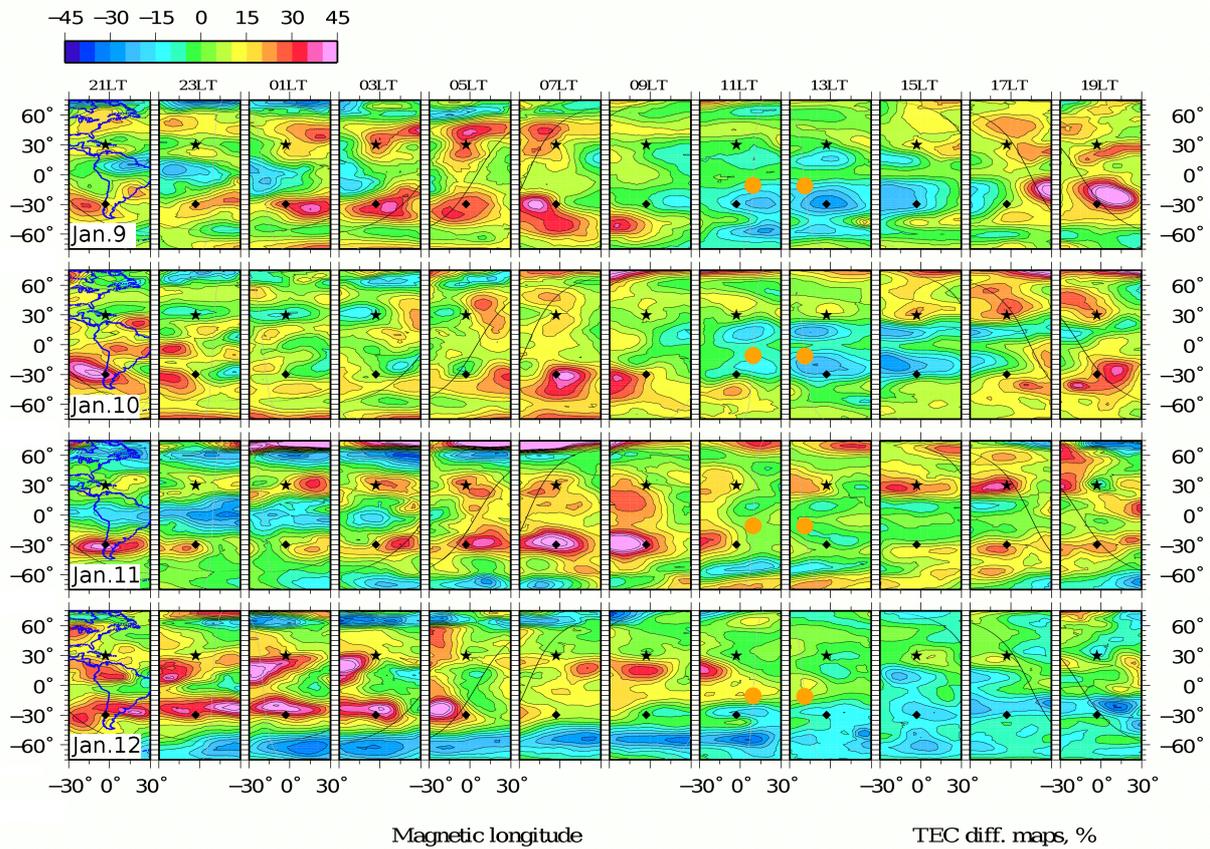


Fig. 1. TEC disturbance (%) maps for January 9-12, 2010 (from top to bottom) before the Haiti earthquake of Jan. 12, 2010 (21:53UT).
 Star – the epicenter position. Diamond – the magnetically conjugated point.
 Orange circle – the subsolar point. Black curve – the terminator.

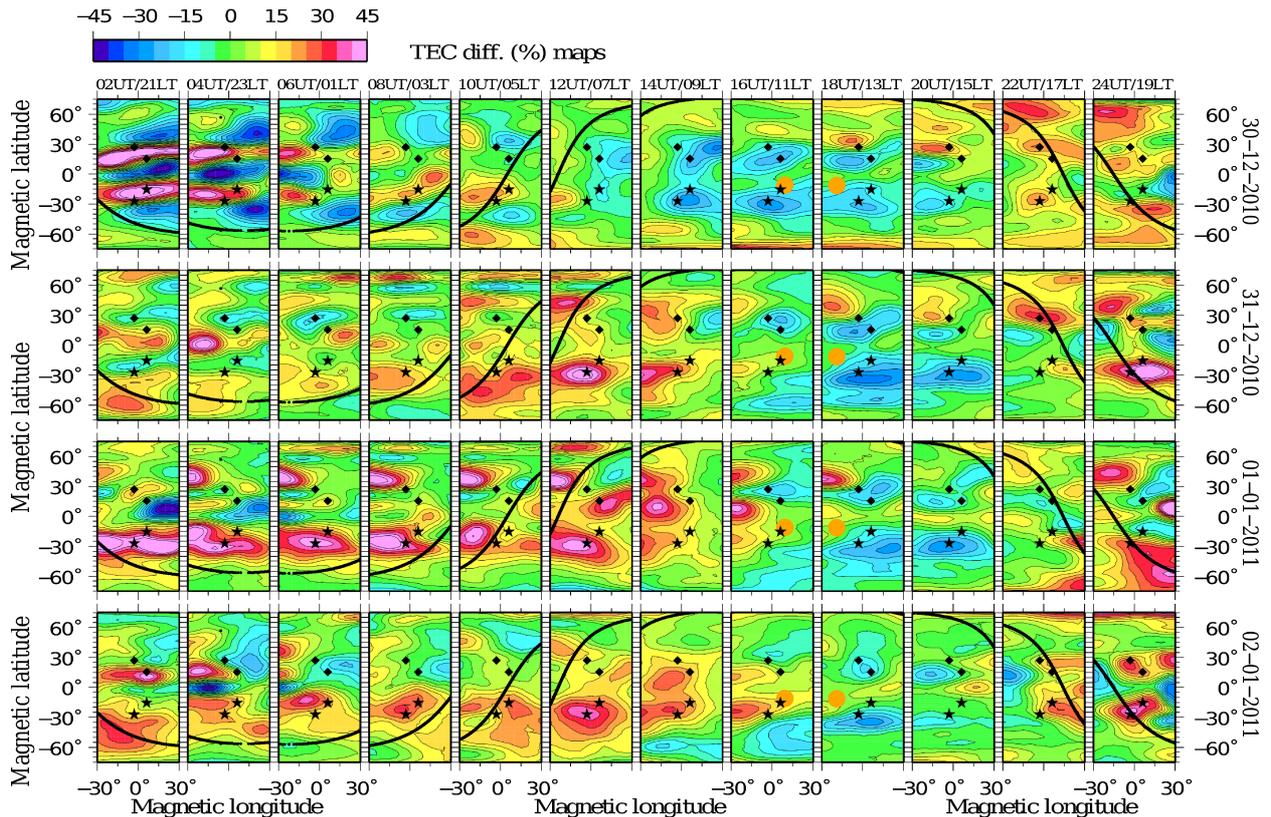


Fig.2 Regional TEC difference maps for 30.12.2010-02.01.2011 (from top to bottom), 02 UT-24 UT (from left to right) before the Argentina Jan. 01, 2011, 09:56UT and Chile Jan. 02, 2011, 20:20 UT earthquakes. The star – the epicenter position for Argentina (right star) and Chile (left star) earthquakes. Diamond – corresponding magnetically conjugated point. Orange circle – the subsolar point. Black curve – the terminator line.

3. Conclusions

Basing on the TEC difference maps analysis for a few special cases of strong earthquakes a new feature have been added to the usually cited TEC pre-seismic modification template: the “ban” time and the anomaly “escape” from the terminator; their restoration with the terminator leave.

Therefore, we expect the following signature for the TEC seismo-precursors: the (1) appearance of the TEC anomaly at the TEC maps linked to some geographical area during at least 4-6 hours at night-time (2) followed by the magnetically conjugated effects. (3) The effects of opposite sign should take place around the dominating disturbance area. (4) Subsolar point and terminator approaching should degrade the anomaly.

4. Acknowledgments

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