EMSEV 2012
Gotemba Kogen Resort, Gotemba, Japan
October 1–4, 2012
Abstract 5-03p

On the Total Electron Content seismo-electromagnetic disturbances

GPS-observed anomalous TEC variations before M 9.0 Great Tohoku March 11, 2011 earthquake

O.V. Zolotov [1)], B.E. Prokhorov [2,3)]

1) *Physics Department, Murmansk State Technical University, 183010 Murmansk, RUSSIA; e-mail: ZolotovO@gmail.com*
2) *Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, GERMANY*
3) *University Potsdam, Applied Mathematics, Interdisciplinary Center for Dynamics of Complex Systems (DYCOS), 14476 Potsdam, GERMANY*

This investigation is devoted to the main TEC features' analysis prior to the near the East Coast of Honshu (Great Tohoku), Japan , M 9.0, March 11, 2011 05:46 UT / 14:46 LT, (38.297°N, 142.372°E), D 30 km earthquake. To estimate pre-earthquake TEC variations we have built differential TEC maps relative to the quiet background conditions. We used global ionospheric maps (GIM) of the TEC provided by the NASA in IONEX format as the initial data for processing. The background TEC values (i.e. undisturbed conditions) were calculated as 7-days UT-grouped running observations' medians before the current calculation moment.

To reveal main features of the TEC relative disturbances before the M 9.0 Great Tohoku March 11 earthquake we analyzed TEC disturbances (%) maps for March 08-11, 2011 (see also [1]). As it follows from the maps, on March 8, 2011 anomalies took place as positive structures along the parallel and situated both sides of the geomagnetic equator. Those anomalies existed during 04 UT / 13 LT – 20 UT / 05 LT, spatially occupied up to ~20˚×~25˚ (latitude × longitude) reaching values from >40% up to >60% in Northern hemisphere; and up to ~15˚×25˚ (latitude × longitude) reaching magnitudes from ~30% up to >50%; they firstly were formed at the near-epicenter areas, then their magnitude increased. During 08 UT / 17 LT – 12 UT / 21 LT the anomalies spread out along the parallel at both hemispheres, occupying a larger region. There is a strong tendency to fulfill the equatorial ionization (Appleton) anomaly from 12 UT / 21 LT, and from 18 UT / 03 LT one can see a completely formed unite positive structure occupying ~30˚×25˚ (magnetic longitude × magnetic latitude) and up to 60% by magnitude. The TEC anomaly comprised an ellipse-like region with the earthquake round its borders. That disturbances are stronger in Northern hemisphere, the terminator and subsolar point income trigger the reduction of the anomaly up to its' almost full destruction. The forms of the anomaly are kept rather stable, the magnitude initially grows, then stays constant or slightly decreases until the sunset terminator come. The passages of the sunrise terminator and later of the subsolar point degraded the TEC anomaly and led to its almost full decay in the case of March 09, i.e. on the day of the M 7.2 March 09, 02:45 UT / 11:45 LT earthquake (happened at nearly the same exact positions of the M9 March 11) and the M6.5, (6.022°S, 149.659°E), 21:24 UT / 06:24 LT earthquakes. On March 10, 2011 during 10-14 UT / 19-23 LT some strong positive disturbances that moved from high-to-low latitudes existed. We attributed them to the geomagnetic activity.

Therefore we may conclude that the most pronounced anomalies happened on March 8, 2011 during 04 UT – 20 UT in form of TEC increases. The TEC anomalies kept the following features: 1) local long-living TEC increases near the earthquake near-epicenter and magnetically conjugated areas. These anomalies do not propagate along the meridians' direction. The amplitude of plasma modification reaches the values of >40-60%. 2) The vertical projection of the epicenter position does not coincide with the maximum phenomenon's manifestation location. The structure and spatial sizes of the disturbed areas are kept rather stable. 3) There are effects related to the modification of the ionospheric F2-region equatorial anomaly. 4) There are strong subsolar point and terminator-related effects. We also compared our results for this EQ with Xu et al. [2] investigation. The results are in agreement, but a few minor discrepancies exist: they speak nothing about terminator and subsolar point-related effects; some minor differences in TEC magnitudes and lifetime. We expect this is because paper [2] analyzed TEC deviations in absolute units (namely, TECu) and used different sliding window size (27 days) to calculate the TEC quiet background variation.

There are a few channels of penetration of the earthquake preparation processes' impact through the underlying neutral atmosphere into ionosphere: 1) wave channel including AGW; 2) electromagnetic channel. It should be noted that each mechanism does not prohibit other channels of penetration and combined action is possible, but authors usually expect one channel to dominate and make major deposit into anomalies' formation. A discussion may be found in, e.g., in [3-5, 6-8].

Namgaladze et al. [6-8] consider that the most probable reason of the NmF2 and TEC disturbances observed before the earthquakes 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 NmF2 and TEC due to the plasma transport to the regions with lower loss rates of dominating ions O^+ in the ion-molecular reactions. The electric field of the opposite direction creates negative effects in NmF2 and TEC.

In the low latitude regions the increase of the eastward electric field leads to the deepening of the Appleton anomaly minimum ("trough" over the magnetic equator in the latitudinal distribution of electron concentration) due to the intensification of the fountain-effect. Numerical simulations [6-9] using 3D time-dependent Upper Atmosphere Model [10-13] showed that additional eastward electric fields of about ~1-4 mV/m in case of the low-latitudes and ~4-10 mV/m in case of the mid-latitudes are required to produce the observed TEC disturbances. They exceed the background quiet fields (of about 0.2 and 1 mV/m, correspondingly), but they are noticeably smaller than the quiet high-latitude electric fields of magnetospheric origin (15-25 mV/m) obtained in the model calculations. Model simulated seismogenic electric fields' magnitudes agree with satellite observations, rocket measurements of large intense electric fields in the E layer of ionosphere and ionosonde data-derived electric fields' estimations as well as with recent other authors' simulations.

This electromagnetic [**E**×**B**]-drift mechanism naturally explains 1) the magnetic conjugation of the reported anomalies, 2) terminator and subsolar point-related effects, 3) Appleton anomaly modifications, 4) the linkage of the anomalies to the fixed geo-position, 5) and life-time of the anomalous phenomena. Nevertheless, the origin of these seismo-induced ionospheric electric fields' disturbances is still under heavy discussion. The most often debated electromagnetic mechanisms relay on idea of local (regional) change of the resistance of the neural atmosphere column over the epicenter area (due to radon or other radioactive gases injection [3] or near-Earth impact of so called "positive holes"[14]) and corresponding appearance of the vertical electric current.

References

[1.] O.V. Zolotov, A.A. Namgaladze, B.E. Prokhorov, Total electron content disturbances prior to Great Tohoku March 11, 2011 and October 23, 2011 Turkey Van earthquakes and their physical interpretation, Proceedings of the MSTU, Vol. 15, N. 3, 583-594, 2012. arXiv: 1205.6118

[2.] T. Xu, Chen Z., Li Ch., Wu J., Hu Ya., Wu Z., GPS total electron content and surface latent heat flux variations before the 11 March 2011 M9.0 Sendai earthquake, Adv. Space Res., Vol. 48, 1311-1317, 2011. doi: 10.1016/j.asr.2011.06.024

[3.] S. Pulinets, Boyarchuk K., Ionospheric Precursors of Earthquakes, Springer, Berlin, Germany, 315 p., 2004.

[4.] V.A. Liperovsky, Pokhotelov O.A., Meister C.-V., Liperovskaya E.V., Physical models of coupling in the lithosphere-atmosphere-ionosphere system before earthquakes, Geomagnetism and Aeronomy, Vol. 48. N. 6, 2008, 795-806. doi:10.1134/S0016793208060133

[5.] M. Hayakawa, Hobara Y., Current status of seismo-electromagnetics for short-term earthquake prediction. Geomatics, Natural Hazards and Risk, Vol. 1, N. 2, 115-155, 2010. doi:10.1080/19475705.2010.486933.

[6.] A.A. Namgaladze, Shagimuratov I.I., Zakharenkova I.E., Zolotov O.V., Martynenko O.V., Possible mechanism of the TEC enhancements observed before earthquakes, XXIV IUGG General Assembly, Perugia, Italy, 02-13 July 2007, Session JSS010, 2007.

[7.] A.A. Namgaladze, Klimenko M.V., Klimenko V.V., Zakharenkova I.E., Physical mechanism and mathematical modeling of earthquake ionospheric precursors registered in total electron content, Geomagnetism and Aeronomy, Vol. 49, N. 2, 252-262, 2009a. doi:10.1134/S0016793209020169

[8.] A.A. Namgaladze, Zolotov O.V., Zakharenkova I.E., Shagimuratov I.I., Martynenko O.V., Ionospheric total electron content variations observed before earthquakes: Possible physical mechanism and modeling, Proc. of the MSTU, Vol. 12, N. 2, 2009b, 308-315. ArXivID: 0905.3313 URL: http://goo.gl/A8cLx

[9.] O.V. Zolotov, Namgaladze A.A., Zakharenkova I.E., Martynenko O.V., Shagimuratov I.I., Physical interpretation and mathematical simulation of ionospheric precursors of earthquakes at midlatitudes, Geomagnetism and Aeronomy, Vol.52, N 3, 390-397, 2012. doi: 10.1134/S0016793212030152

[10.] A.A. Namgaladze, Korenkov Yu.N., Klimenko V.V., Karpov I.V., Bessarab F.S., Surotkin V.A., Glushchenko T.A., Naumova N.M., Global model of the thermosphere-ionosphere-protonosphere system, Pure and Applied Geophysics, Vol. 127, N 2/3, 219-254, 1988. doi:10.1007/BF00879812

[11.] A.A. Namgaladze, Korenkov Yu.N., Klimenko V.V., Karpov I.V., Surotkin V.A., Naumova N.M., Numerical modeling of the thermosphere-ionosphere-protonosphere system, J. Atmos. Terr. Phys., Vol. 53, N. 11/12, 1113-1124, 1991. doi:10.1016/0021-9169(91)90060-K

[12.] A.A. Namgaladze, Martynenko O.V., Volkov M.A., Namgaladze A.N., Yurik R.Yu., High-latitude version of the global numeric model of the Earth's upper atmosphere, Proc. of the MSTU, Vol.1, N 2, 23-84, 1998a. URL: http://goo.gl/8x9f2

[13.] A.A. Namgaladze, Martynenko O.V., Namgaladze A.N., Global model of the upper atmosphere with variable latitudinal integration step, Int. J. of Geomagnetism and Aeronomy, Vol. 1, N. 1, 53-58, 1998b.

[14.] F.T. Freund, Kulahci I.G., Cyr G., Ling J., Winnick M., Tregloan-Reed J., Freund M.M., Air ionization at rock surfaces and pre-earthquake signals. Journal of Atmospheric and Solar-Terrestrial Physics, Vol. 71, 1824–1834, 2009.