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Abstract 3-10

The geomagnetic field and TEC anomalies connected with the strong earthquakes

E. V. Vorontsova

Research Station RAS, 720049, Kyrgyzstan, Bishkek-49, KYRGYZSTAN

A lot of scientific articles study correlation of seismic activity with variations of different components of the Earth's magnetic field. More often this is correlation with a single factor, such as secular variations, Sq-variations, Wolf's numbers, Kp- and Ap- indices, as well as with the frequency and origin times of geomagnetic storms, etc. However, this analysis does not give a complete pattern of the Earth's crust processes. To select and estimate the contribution of planetary geomagnetic processes and local responses and calculate the ratio of the external field T_e and telluric variations δT_i, we have to use data of remote and local stations[]. Moreover, the *ionosphere* conditions such as the total electron content (TEC), wind's velocity, the conductivity and current's density play the role.

At present, when the network of permanent dual-frequency receivers of the navigation system GPS (f_1 = 1575.42 MHz and f_2 = 1227.60 MHz) is widely spread, monitoring of the total electron content became much easier. The method of calculating TEC [2] is based on the dependence of the refractive index (n) of electromagnetic waves from the free electron concentration (N_e) and the wave frequency (f):

$$n=\sqrt{(1-80.8N_e/f^2)}\approx 1-40.308N_e/f^2.$$

The measured ways at the frequencies f_1 and f_2 are $S_1=n_1S_0\approx(1-40.308N_e/f1^2)*S_0$ and $S_2=n_2S_0\approx(1-40.308N_e/f2^2)*S_0$, respectively, where S_0 - a true satellite-receiver distance. Excluding the S_0 and integrating, we find the total electron content TEC_0:

$$TEC_0=\frac{1}{40.308}\frac{f_1^2f_2^2}{f_1^2-f_2^2}(L_1*\lambda_1-L_2*\lambda_2+S_{const}+\delta S),$$

where L_1 and L_2 - the numbers of complete turns of phase, λ_1 and λ_2 – the wavelengths (m) for frequencies f_1 and f_2 , S_{const} - some unknown initial phase ways (m) and δS - error in determining the phase ways (m). To determine S_{const}, which is the same as phase ambiguity resolution, code measurements P_1 and P_2 are used: $\delta S=\delta S_1+\delta S_2=(P_1-L_1\lambda_1)-(P_2-L_2\lambda_2)=(P_1-P_2)-(L_1\lambda_1-L_2\lambda_2)$. Taking into account the ballistics of the navigation satellite, we obtain:

$$TEC=TEC_0*\cos[\arcsin(R_z\cos\theta/(R_z+h_{max}))],$$

where R_z – Earth's radius, h_{max} – the height of maximum electron density, θ – the height of satellite visibility. To construct a continuous series variations of TEC with the least noise (because of the satellite's location near the horizon), we used only observations with θ equal to 57 °-90 °.

The investigation of this series allows to detect seismic-ionospheric disturbances before and after strong earthquakes [3,4]. Fig. 1a shows the variations of TEC after the Nura's earthquake, K = 13.25 (Ml = 6.6), which occurred at 15 hours 52 minutes 5 October 2008, the epicenter's latitude is 39.62 N, longitude is 73.67 E. The level of geomagnetic disturbance was weak: Kp = 1. There is a sharp increase the amplitude of variations in 5-10 minutes on the nearest (126.5 km) to the epicenter GPS-station OSHK (40.53 N, 72.78 E), after ~ 1 hour oscillations are damped. On the other (more distant) stations such variations are not observed, that indicates the seismo-ionospheric character.

Using data from several GPS-receivers we can determine the velocity of the ionospheric disturbance (ID), and in a combination with the observations of the geomagnetic field T - to calculate the density the ionospheric current and the conductivity of the ionosphere. Suppose that receivers are located at a distance R from each other, and the time between the observations of ionospheric disturbances is Δt. The distance traveled by ID in the ionosphere is equal $R_{ion} \approx R*(h_{orb}- h_{max})/h_{orb}$, where the h_{orb} – height of the satellite's orbit, h_{max} – the height of maximum electron density. Taking the average values h_{orb}=20000 km, h_{max}=300 km, we have $R_{ion} \approx 0.985R$. Then the velocity of the ID is $v \approx 0.985R/\Delta t$.

The movement of electrons causes the electric current density $j=\sigma E$ [5], where σ is conductivity (also depends on the TEC) and $E=\mu_0[v \cdot H]$ – the intensity of the electric field. The magnetic field is formed by the homogeneous current sheet of density j, must have a value of $\delta H=j/2$. Taking into account that the observed field by applying a field-induced currents about 1.5 times greater than the external, then the observed field is $\delta H=3j/2$. Therefore, the conductivity of the ionosphere may be calculated as $\sigma=2\delta H/3\mu_0 [vH]$.

For example, consider the calculation conductivity of the ionosphere for GPS-stations POL2 (42.68 N, 74.69 E) and CHUM (42.99 N, 74.75 E). The variation of *TEC* and the full vector of the geomagnetic field *T* are shown in Fig. 1b, long-period trends have been removed. The variations of TEC_{POL2} and TEC_{CHUM} diverge and the time delay Δt is change in time. For t_A and t_B Δt=5.5 min, R = 35.7216 km, then $v \approx 0.985R/\Delta t \approx 106.623$ m/s. The observed variation of the geomagnetic field is equal δH=**6** nT, H=40 A/m, then $\sigma \approx 120$ S/m.

Thus, the complex analysis of the total variations of the geomagnetic field T and TEC allows to calculate the parameters of ionospheric disturbances and currents, and can be used to more effectively searching ionospheric oscillations associated with the strong earthquakes.

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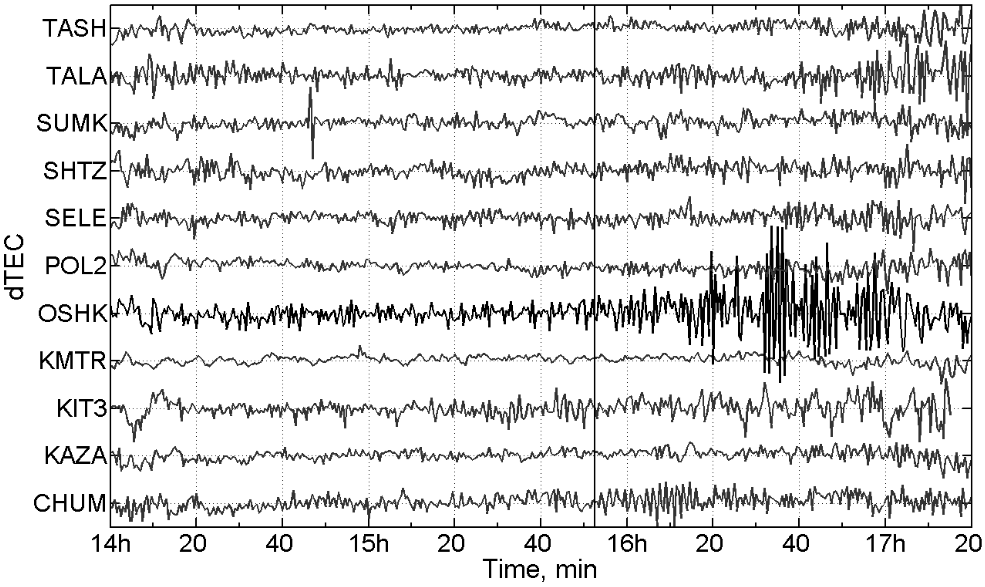
A



B

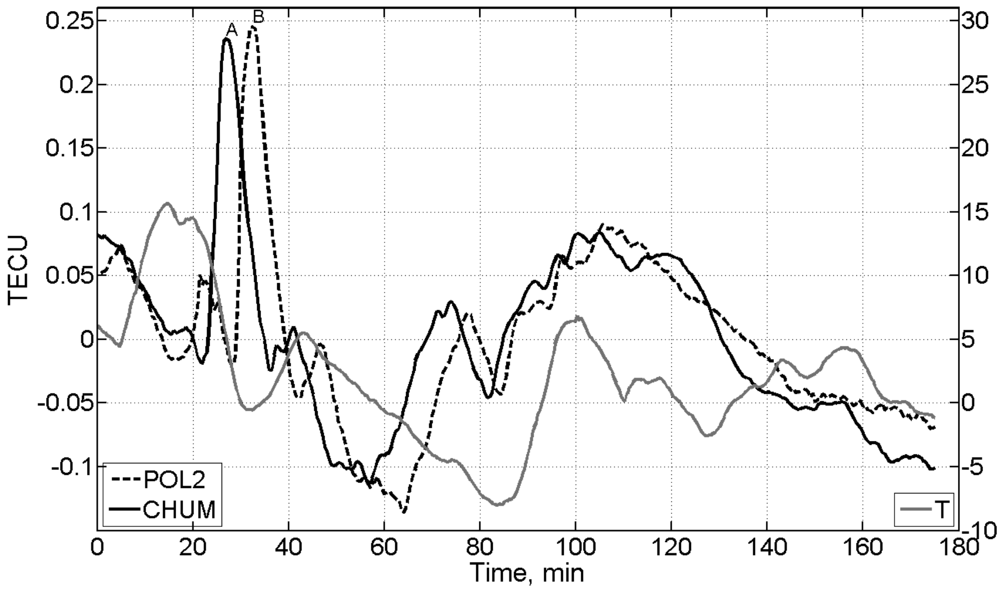


Fig. 1a: Variations dTEC during the Nura earthquake.

Fig. 1b: Variations TEC and the total vector of the geomagnetic field T.