# PRE-SEISMIC ACTIVITY EFFECTS ON THE EQUATORIAL ANOMALY

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ABSTRACT

It is well known that equatorial anomaly is very sensitive to the electric field effects of different origin. The revealed recently quasistatic anomalous electric field which appears at the areas of seismic activity (Pulinets et al., 1998 a), and existing possibility of its penetration at the heights of the ionosphere (Pulinets et al., 2000) opens the question on the effects of the seismogenic electric field in equatorial regions of the ionosphere. For the first time the effects associated with the seismic activity in equatorial ionosphere were registered with the help of topside sounding onboard Intercosmos-19 satellite (Pulinets et al., 1991) and then were supported by other data sources (Depueva and Ruzhin, 1995). It was demonstrated in (Pulinets et al., 1998 b) that the seismo-ionospheric variations are very sensitive to the local time what means that the positive or negative deviations from undisturbed state could be observed as dependence on the local time. The present study demonstrates that the different effects associated with the seismic activity could be observed such as equatorial anomaly development (increasing of $foF2_{crest}/foF2_{trough}$), equatorial anomaly vanishing (drop of $foF2_{crest}/foF2_{trough}$) up to complete crest disappearance. Simultaneous ground-based measurements on the latitudinal chain of ionospheric stations demonstrate the same effect as observed by topside sounding. The crest disappearance was demonstrated also by recent studies of last disastrous earthquakes at Taiwan by GPS total electron content measurements (Liu et al., 2000). Sometimes the distortions of the anomaly in the form of additional crest formation were observed as well.

## EXPERIMENTAL BACKGROUND

We used the data of topside sounding from Intercosmos-19 satellite (1979-1981) (Pulinets, 1989). The parameters of an orbit (inclination of 74°, rotation period ~100 minutes) provided that the local time of intersection by the satellite of the equatorial plane during several sequential orbits was practically the same. It allowed for fixed LT to obtain the quasi-meridional cuts of an ionosphere, displaced from each other by ~25 degrees of a longitude. In a data set considered, the vertical sounding was accomplished every 64 seconds. During this time the satellite was displaced along an orbit by ~3.6 degrees of a latitude. We selected several cases of strong earthquakes in the Pacific area for different local times to reveal the possible dependence on the local time, which was detected for the middle latitudes. Intervals of low magnetic activity were selected for analysis, and the data from such passes of the satellite were taken as reference to compare with periods preceding the strong earthquakes (M>5). The topside vertical profiles were calculated also to determine effects in peak height variations as well as to build the vertical cross-sections of the ionosphere. To reconstruct the total profile of electron concentration, the special technique was used described in (Radicella et al., 2000). The list of experimental data used for the present study is shown in Table 1

## EQUATORIAL ANOMALY SHAPE VARIATIONS BEFORE THE STRONG EARTHQUAKES

Figure 1 demonstrates the anomaly development while approaching to the earthquake moment in the form of trough deeping (Fig.1 a) during afternoon hours, or in the form of crest development (Fig.1 b) during night-time. The triangles on the figures relate to the pass closest in time to the earthquake moment. The opposite situation is demonstrated in Figure 2. One can see in Figure 2 a the satellite data demonstrating disappearance of the anomaly crest in southern hemisphere before the earthquake, and in Figure 2 b – the crest disappearance is registered at the northern hemisphere by latitudinal chain of ground-based ionosondes. It was demonstrated recently that the same effect is observed in latitudinal TEC variations which were studied by the set of GPS receivers at Taiwan area before the last strong earthquakes at Taiwan (Liu et al., 2000).

| N | Date of EQ | Place of shock | | Time, UT,h.min. | Magn. | h.km | Intercosmos-19 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | φ,° | λ,° | | | | Date of registr. | Pass of registr. | Time,LT,h | Δt,h | Δλ° |
| 1 | **20.03.79** | 7.6 | 126.6 | 08.53 | 5.3 | 147 | 14.03.79 | 226 | 1.6 –2.6 | -135 | 0 |
| | | | | | | | 19.03.79 | 299 | 1.6 –2.6 | -16.5 | -15 |
| | | | | | | | 19.03.79 | 299 | 1.6 –2.6 | -13 | +10 |
| | **20.03.79** | 7.6 | 126.6 | 08.53 | 5.3 | 147 | 14.03.79 | 226 | 14 - 15 | -148 | -19 |
| | | | | | | | 19.03.79 | 299 | 14 - 15 | -4 | -9 |
| | | | | | | | 19.03.79. | 299 | 14 - 15 | 2.5 | +16 |
| 2 | **6.07.79** | 3.6 | 126.6 | 10.07 | 5.1 | 68 | 5.07.79 | 1845 | 17 – 17.5 | -27 | -23 |
| | | | | | | | 6.07.79 | 1860 | 17 –17.5 | -3.5 | -32 |
| | | | | | | | 6.07.79 | 1860 | 17 -17.5 | -2 | -8 |
| 3 | **12.03.80** | -15.2 | -75.7 | 4.27 | 5.5 | 37 | 5.03.80 | 5389 | 17.5-18.5 | -150 | -2 |
| | | | | | | | 9.03.80 | 5446 | 17.5-18.5 | 52.5 | +12 |
| | | | | | | | 10.03.80 | 5461 | 17.5-18.5 | -30.5 | +1 |
| 4 | **24.05.80** | 3.6 | 126.5 | 8.24 | 5.2 | 69 | 20.05.80 | 6474 | 15.5-16.5 | -96 | -2.5 |
| | | | | | | | 20.05.80 | 6475 | 15.5-16.5 | -96 | +22 |
| | | | | | | | 21.05.80 | 6490 | 15.5-16.5 | -72 | +13 |
| | | | | | | | 22.05.80 | 6503 | 15.5-16.5 | -66 | -22 |
| | | | | | | | 23.05.80 | 6517 | 15.5-16.5 | -27.5 | -11 |
| | | | | | | | 23.05.80 | 6519 | 15.5-16.5 | -24 | +10 |
| | **24.05.80** | 3.6 | 126.5 | 8.24 | 5.2 | 69 | 20.05.80 | 6488 | 3.5 – 4.5 | -84 | +3 |
| | | | | | | | 21.05.80 | 6503 | 3.5 – 4.5 | -61.5 | -6 |
| | | | | | | | 22.05.80 | 6517 | 3.5 – 4.5 | -38.5 | -12 |
| 5 | **16.07.80** | 5.9 | 127.2 | 6.31 | 5.2 | 117 | 15.07.80 | 7286 | 17 - 18 | -36.5 | -7 |
| | | | | | | | 16.07.80 | 7301 | 17 - 18 | -11.5 | +8 |
| | | | | | | | 18.07.80 | 7331 | 17 - 18 | +34.5 | -10 |

NOTES: 1. Δt -sign "– " effect registered before, and sign "+" effect registered after the shock;
2. Δλ- sign "– " satellite pass eastward and sign "+" pass westward from epicenter longitude

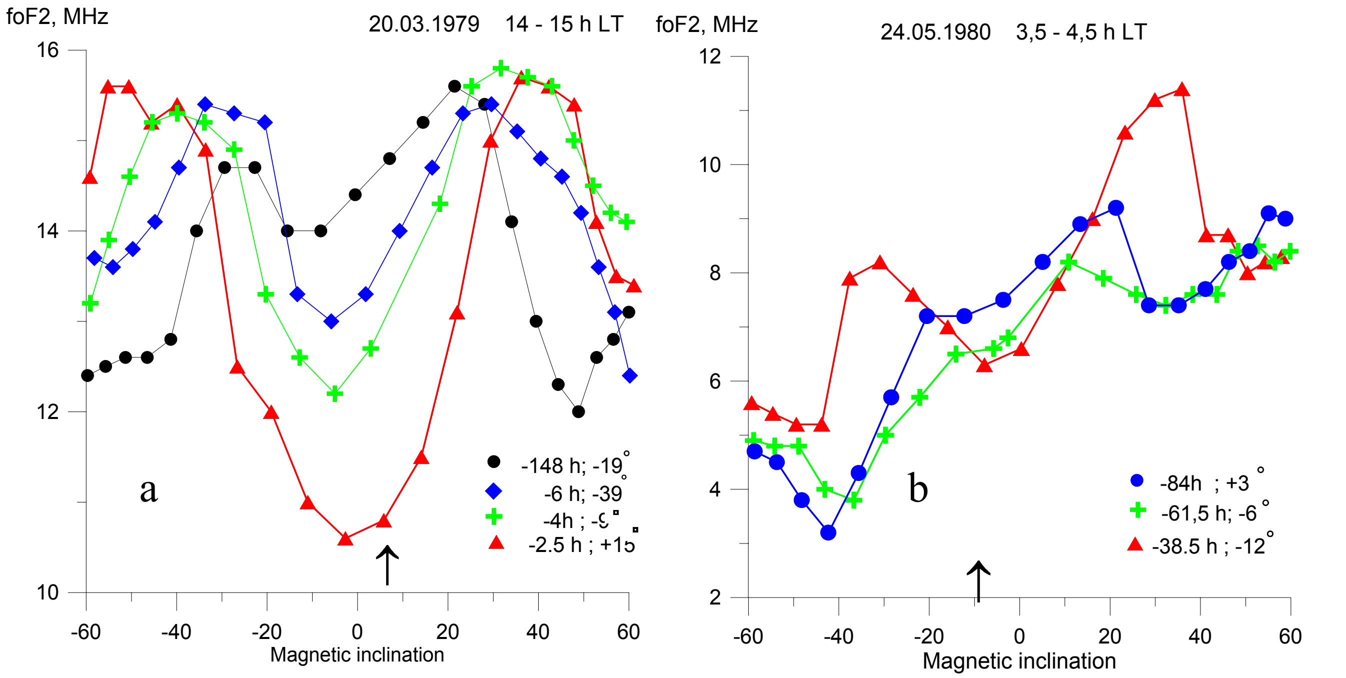



Fig.1 Variations of the equatorial anomaly shape on the height of F2-layer peak revealed from Intercosmos-19 satellite topside sounding data before strong earthquakes in the vicinity of geomagnetic equator. a – before the earthquake on 20.03.1979, afternoon hours, b – before earthquake on 24.05.1980, night—time conditions. Earthquakes parameters are indicated in Table 1. Arrow indicates the epicenter latitudinal position.

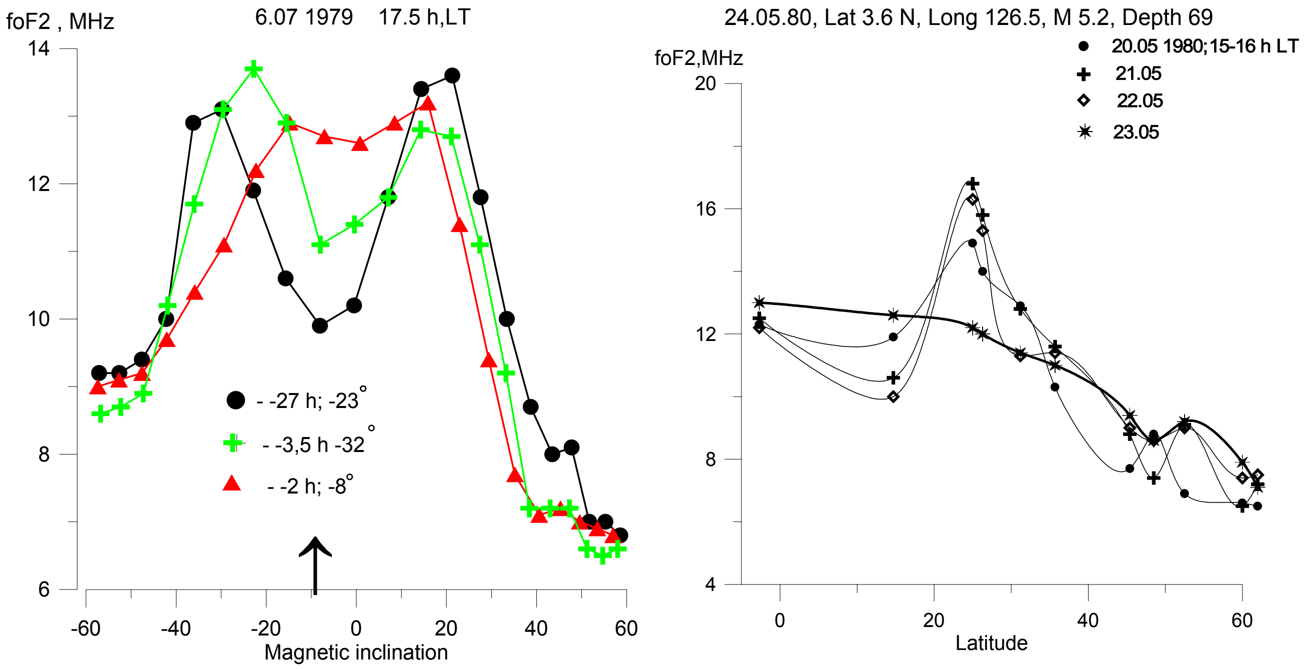



Fig.2 Examples of anomaly crest disappearance before the strong earthquakes. a – satellite data for the earthquake on 06.07.1979; b – results of ground-based soundings for several consecutive days on the chain of vertical sounding ionosondes for earthquake on 20.05.1980

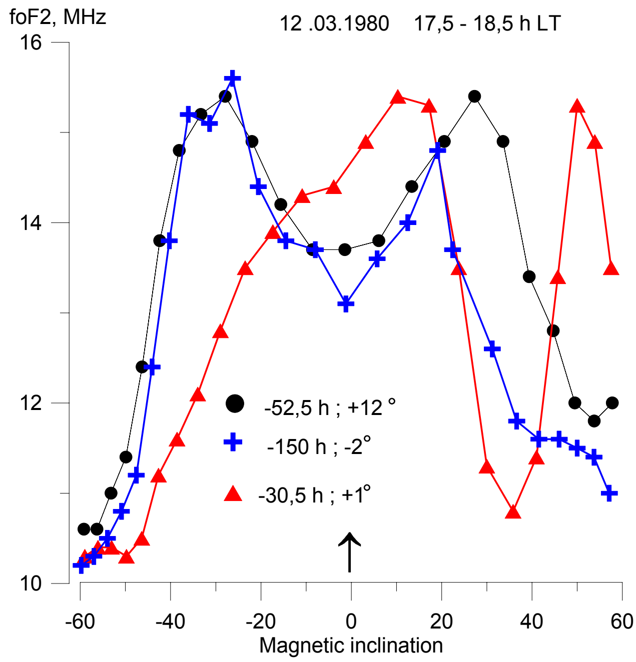



Fig.3 Example of the equatorial anomaly distortion observed several days before the earthquake in equatorial region of Southern America on 12.03.1980

Sometimes the striking equatorial anomaly distortions could be observed, and one of the examples of such distortion is presented in Figure 3. One can observe the disappearance of the southern crest of the anomaly, the enormous shift of the anomaly trough to the North, and formation of the additional crest far to the North from its original position. Resuming the current paragraph we can state that from three days up to several hours before the approaching earthquake in equatorial region the strong modification of the equatorial anomaly shape could be observed. In general, the observed effects could be divided by three groups: equatorial anomaly amplification, equatorial anomaly vanishing, and equatorial anomaly distortion, expressed in the form of changing of position of the trough and crests.

## MODIFICATION OF THE VERTICAL DISTRIBUTION OF ELECTRON CONCENTRATION BEFORE EARTHQUAKE IN EQUATORIAL IONOSPHERE

Topside profiles calculated from the topside vertical ionograms demonstrate the existence of the profiles modification over the earthquake preparation disturbed region as well. Two examples of such modification are shown in Figure 4. They differ by sign of ΔfoF2. At the left panel one can see the negative deviation of the critical frequency associated with the F2 layer rising before the earthquake. The right panel demonstrates the opposite situation. The earthquake stimulated modification is observed in the form of increasing of the critical frequency and lowering of F2 layer. Nevertheless the both cases have the common feature which is expressed in the profile model parameters. As it was shown by Radicella et al. (1998) the topside profile could be approximated by Epstein function.

$$N(z) = 4.0 * \frac{N_0 \exp\left(\frac{z}{B2u}\right)}{\left(1+\exp\left(\frac{z}{B2u}\right)\right)^2}$$

where *B2u* characterizes the topside layer thickness and changes linearly with the height: $B2_u=B_0+k\times z$, $z = h- h_{max}$ One can clearly see from the results of modeling that in both cases (drop or growth of the critical frequency) the modified profiles have substantially larger magnitude of $B2_u$ what implies the changes of the ion composition in F-layer during the seismically disturbed periods. It means that the data of topside sounding could be parameterized and the time intervals and spatial areas suspicious in earthquake preparation could be selected from the raw data.

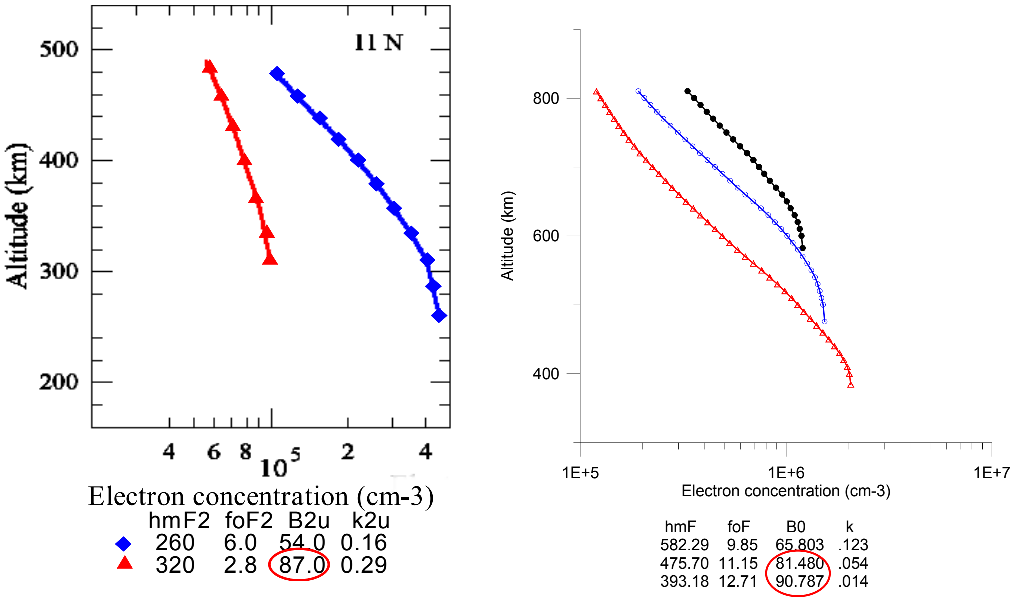
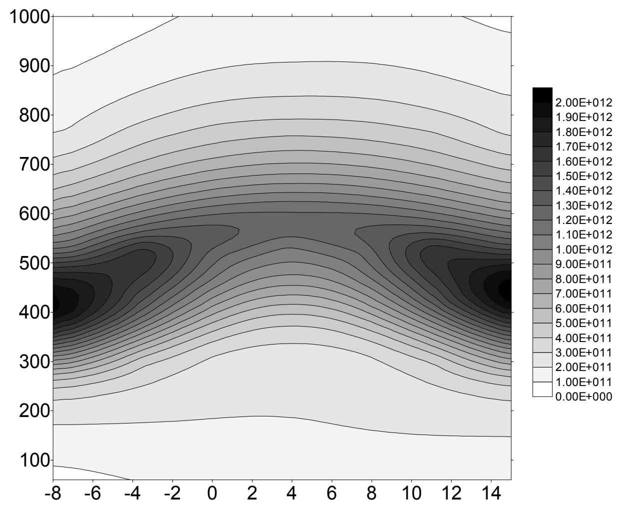



Fig. 4 Examples of the vertical profiles of electron concentration modification before the strong earthquakes in equatorial region. ▲Indicates the modified profile in comparison with undisturbed one. The modified profiles are characterized by increased value of $B2_u$ parameter

## QUASI - TOMOGRAPHIC RECONSTRUCTION OF THE VERTICAL STRUCTURE OF THE IONOSPHERE

The technique described in Radicella et al., (2000), permits to make the reconstruction of the total profile of the vertical electron concentration, and consecutive ionograms along the satellite pass give possibility to produce the vertical cross-section of the ionosphere. We built such cross-sections for the case presented in Figure 2a and the results are shown in Figure 5. The three consecutive reconstruction are presented: 27 hours before the earthquake, 3.5 hours and 2 hours before respectively. One can clearly see the filling of the anomaly trough with earthquake time approaching. The difference between the third and the first distributions is shown in Figure 6 and clearly demonstrates the substantial vertical redistribution of the ionization and formation of maximum over the approaching earthquake epicenter position. We can also mark the depletion formation on heights of 400-600 km.



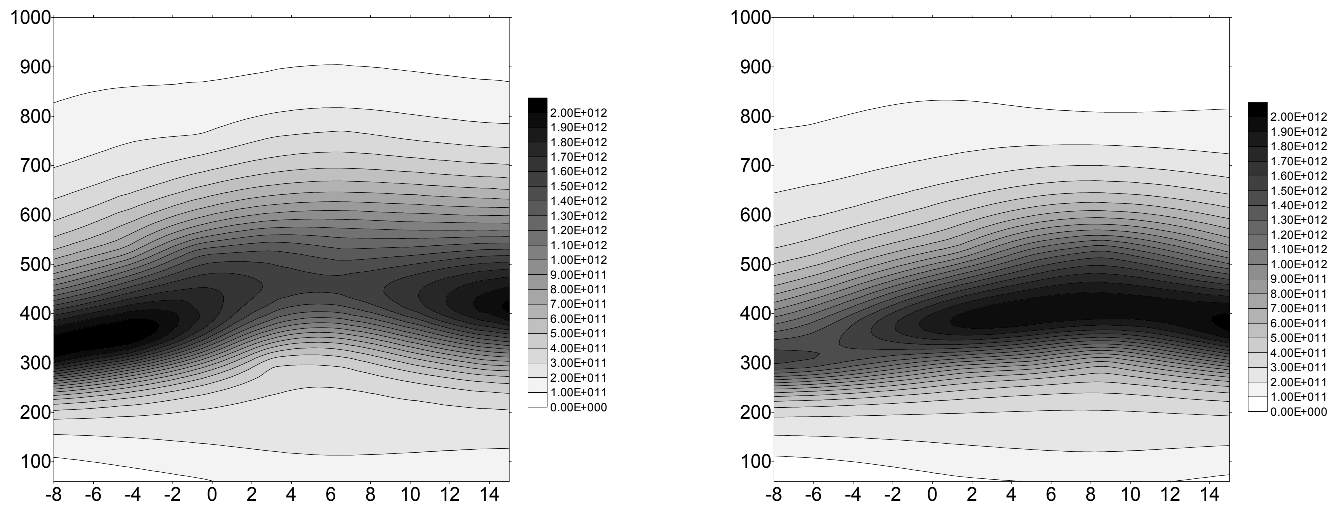


Fig.5 Consecutive cross-sections of the ionosphere at the longitude of the anticipated earthquake

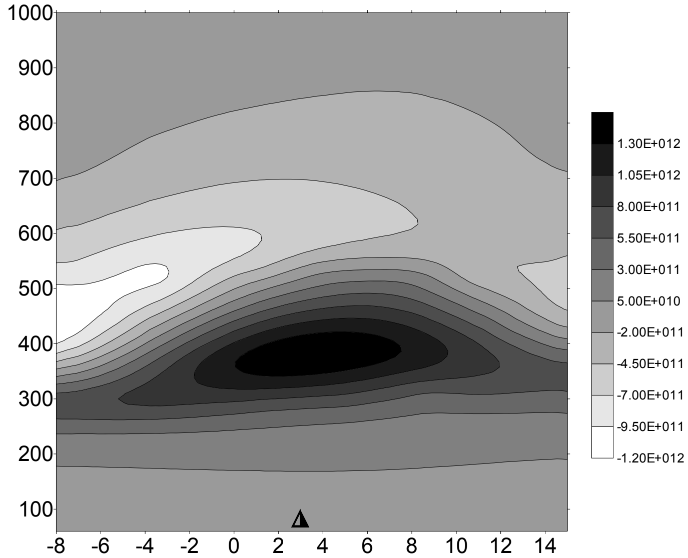



Fig. 6 Latitude-altitude distribution of electron concentration difference between 05.07.1979 and 06.07.1979over the seismically active areas

CONCLUSION

The strong modification of the equatorial anomaly structure before the strong earthquakes (M > 5) was revealed from analysis of topside sounding data of the Intercosmos-19 satellite. It includes the changes of the equatorial anomaly shape on the heights of F2 layer peak. Depending on the local time the anomaly could be or amplified or damped in comparison with undisturbed conditions. The cases of distortion with shifting of latitudinal position of trough and crests were registered also. The modification is observed at all heights of the topside ionosphere what implies the vertical redistribution of the plasma concentration. The most sensitive parameter indicating the equatorial anomaly modification before the seismic events is the $B2_u$ parameter characterizing the topside profile semithickness. It substantially grows over the seismically active areas by a factor of 1.5. The observed features of the equatorial anomaly modification are supported by the data of ground-based vertical sounding, as well as by the GPS TEC measurements.

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