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Spatiotemporal features of seismoionospheric anomalies in the F-layer, Japan region

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One of the urgent problems of geophysics is the study of lithospheric-ionospheric connections. Most studies paid attention to the precursors of strong shallow earthquakes; short-term ionospheric effects caused by the passage of seismic waves were also noted.

Variations in ionospheric parameters that occur several days to several hours before earthquakes have been repeatedly described in the literature [1,2]. Both an increase and a decrease in the ionization density were observed before earthquakes [3,4]. Moreover, the maximum values ionospheric anomalies do not correspond typically to the epicentral region, and the amplitude of them do not always increase by the time of the earthquake. Variations that occur after earthquakes have rarely received attention[5].

The task of the work is to identify the spatio-temporal areas of seismoionospheric effects before and after earthquake at distances of up to 3000 km from the epicenter, and to assess their reliability.

We analyze the diurnal variation of foF2 in the vicinity of earthquakes M6+ using hourly ionospheric foF2 data obtained at the ground-based vertical sounding (VS) station Kokubunji (Tokyo) for 1957-2020. The ISC GEM earthquake catalog (1957-1975) and the GCMT earthquake catalog (1976-2020) were used; both these catalogs provide the moment magnitude Mw. Days when geomagnetic disturbances ΣKp >25 and subsequent days were excluded. For each hour, deviations of foF2 from the moving median were considered, normalized to the same median Δf_i = ($foF2_i$ - median(foF2))/median (foF2), where median(foF2) is the median of foF2 values over the period (-7, +7) days for every i-th hour. The median was calculated if there were at least 8 values out of 15 possible hourly values.

An overlay of Δf epochs was carried out and a two-dimensional picture was obtained depending on the distance from the station to the epicenter and on the time (-10, +10) days before and after the event. We exclude the repetition of the same time intervals. We sort earthquake by magnitude, starting with the strongest. We will select (-240, +240) hours before and after the strongest earthquake and exclude these values from further analysis; then we repeat this procedure for the next largest earthquake.

By averaging we obtain a two-dimensional picture for earthquakes with M7+ (114 earthquakes), M(6.5...7) (201 earthquakes), M(6...6.5) (767 earthquakes), the distance step was chosen to be 1000 km, for earthquakes M(6...6.5), the distance step was chosen to be 500 km. The reliability of the obtained seismic-ionospheric anomalies at 95% and 99% levels was calculated using the method of modeling a random process.

An increase of foF2 before and a decrease after earthquakes was observed at the distances up to 2000 km. The amplitudes of the effects are 1-2%. In many works it was concluded that the area of manifestation of seismoionospheric effects is limited by the Dobrovolsky radius R_D=exp(M). The presented work shows that the maximum manifestation of the effect also occurs outside this area.

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