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On long-term variations of foF2 in the mid-latitude ionosphere before strong earthquakes

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Abstract. The statistical analysis of the variations of the dayly-mean frequency of the maximum ionospheric electron density foF2 is performed in connection with the occurrence of (more than 60) earthquakes with magnitudes $M > 6.0$, depths $h < 80$ km and distances from the vertical sounding station $R < 1000$ km. For the study, data of the Tokyo sounding station are used, which were registered every hour in the years 1957-1990. It is shown that, on the average, foF2 decreases before the earthquakes. One day before the shock the decrease amounts to about 5 %. The statistical reliability of this phenomenon is obtained to be better than 0.95.
Further, the variations of the occurrence probability of the turbulization of the F-layer (F spread) are investigated for (more than 260) earthquakes with $M > 5.5$, $h < 80$ km, $R < 1000$ km. For the analysis, data of the Japanese station Akita from 1969-1990 are used, which were obtained every hour. It is found that before the earthquakes the occurrence probability of F spread decreases. In the week before the event, the decrease has values of more than 10 %. The statistical reliability of this phenomenon is also larger than 0.95. Examining the seismo-ionospheric effects, here periods of time with weak heliogeomagnetic disturbances are considered, the Wolf number is less than 100 and the index $\Sigma\, K_p$ is smaller than 30.

1 Introduction

In a series of works, the behaviour of characteristic parameters of the ionosphere during earthquake preparation times has been studied. In this connection, the critical foF2-frequency - one of the parameters normally measured by vertical sounding - is often chosen. This frequency is the plasma frequency at the ionospheric F2-peak. Analyses of modifications of mean values of foF2 to prove if they might be precursors of sufficiently strong earthquakes were performed in a number of works. A decrease of the critical frequency foF2 before a few earthquakes was demonstrated by Hobara and Perrot (2005), Liperovsky et al. (1992), Ondoh (2000), Rios et al. (2004), Sing et al. (2004). On the other side, Pulinets and Boyarchuk (2004) noticed an increase of foF2 before an extremely strong earthquake. A statistical investigation of the foF2-decrease in the afternoon before Taiwan earthquakes was performed by Liu et al. (2006). These investigations were carried out for earthquakes with different ranges of magnitudes.

The aim of the present work is to prove the foF2-decrease statistically for Japanese earthquakes and to determine which are the magnitudes of the earthquakes yet connected with an observable modification of the mean foF2 frequency before a shock. Further, the pre-seismic mean temporal change of the turbulization of the F-layer, the F-spread, is studied.

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2 Method of analysis of foF2 frequency

In the present work earthquakes with depths of $h < 80$ km and distances R to the sounding station smaller than 1000 km are divided into two groups, earthquakes with epicenters under the bottom of the sea (marine earthquakes) and with epicenters below land (land earthquakes). Each of these groups is again divided into three parts - events with magnitudes $M > 6.5$, with $6.5 \geq M > 6.0$, and with $6.0 \geq M > 5.5$. The ionospheric data were obtained by the station Kokubunji ($\varphi = 35.7^o$ N, $\lambda = 139.5^o$ E, years 1957-1990, http://www.rl.ac.uk.wdcc1/data.html). Ionospheric effects of earthquakes are usually superposed by solar and geomagnetic disturbances. Thus, only days with not too large solar and geomagnetic disturbances are taken into account. What means "not too large" is interpreted differently by different investigators. Here only days with Wolf numbers less than 100 and $\Sigma\, K_p < 30$ are used in the study. Making such an assumption, more than half of the available experimental data are analysed.

In the present work, dayly-mean values $\langle$foF2$\rangle$ of foF2 are analysed. For any earthquake, a time interval from 10 days

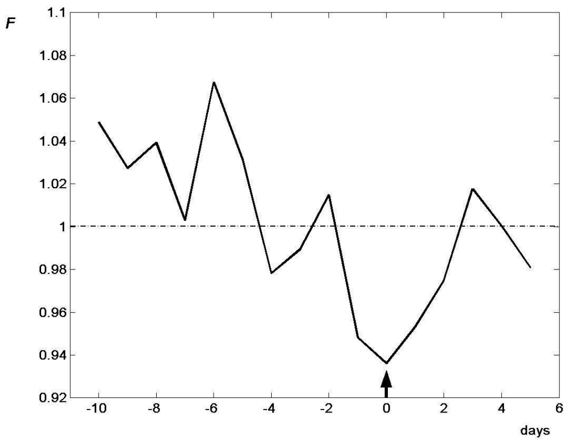

Fig. 1. Result of the superposition of epoches for earthquakes with epicenters below sea. 12 events with $M > 6.5$, $R < 1000$ km and $h < 80$ km are analyzed.

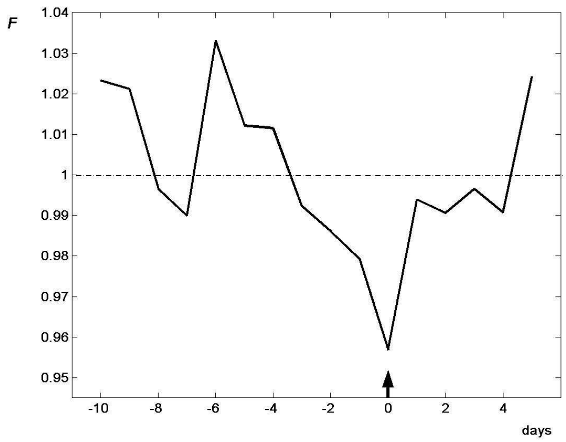

Fig. 2. Result of the superposition of epoches for earthquakes with epicenters below sea. 43 events with $6.5 > M > 6$, $R < 1000$ km and $h < 80$ km are analyzed.

before the event up to 5 days after the event are taken into account. The values of one day are normalized by the mean value of the whole time interval, if the number of "quiet" days amounts to more than half of the whole time interval (more than 6 days in this case). Thus, for any earthquake a series of undimensional numbers $F_i = \langle \text{foF2} \rangle_i / \langle \text{foF2} \rangle_{total}$ is calculated. Further, the method of superposed epoches for earthquakes of each group of events is applied. As result a time-dependend function $F(t)$ is found, which is presented in corresponding figures.

3 Decrease of foF2 for earthquakes with epicenters below sea

Twelfe events with magnitudes $M > 6.5$ occurred in the years 1957-1990, two of them even at the same day. In Fig. 1, $F(t)$ for earthquakes with $M > 6.5$, $h < 80$ km and $R < 1000$ km are considered. Indeed, the dayly-mean values of foF2 statistically decrease. This phenomenon starts one week before the event, and the minimum occurs on the day of the earthquake. This result is in agreement with the findings of the works by Sing et al. (2004) and Hobara and Parrot (2005). An analogeous result, we find for somewhat weaker marine earthquakes with $6.0 < M < 6.5$ (43 events, see Fig. 2). On the other hand, for earthquakes with lesser magnitudes $6.0 > M > 5.5$, $R < 1000$ km and $h < 80$ km (225 events) no decrease of $\langle \text{foF2} \rangle$ is found for the day of the shock.

4 Decrease of foF2 for earthquakes with epicenters below land

In Japan strong earthquakes with epicenters below land happen less frequently than below sea. During the considered period of time 1957-1990 under "quiet" heliomagnetic and geomagnetic conditions, only one event with $M > 6.5$ and six events with $6.5 > M > 6.0$ occurred. Fig. 3 shows the result of the superposition of epoches for this 7 earthquakes. Further, for less strong earthquakes with $6.0 > M > 5.5$ (30 events), an analogeous decrease of $\langle \text{foF2} \rangle$ towards the day of the shock is not found. Summarizing the earthquakes with epicenters below sea and below land, which meet the condition $M > 6.0$, into one group, one obtains a statistically reliable result: The dayly-mean values of foF2 decrease about one week before the earthquake.

To prove the foF2-decrease statistically, the method of the modelling of random processes is applied. Therefore 300 series of events are constructed, each consisting of 62 virtual earthquakes. For each series, in analogy to the temporal behaviour of real earthquakes, a temporal behaviour is found. On this basis, the standard deviation σ of the statistical foF2-decrease is calculated. In Fig. 4, the value of 2σ is presented. The decrease of foF2 shows values beyond this value, consequently the statistical reliability of the effect is larger than 0.95.

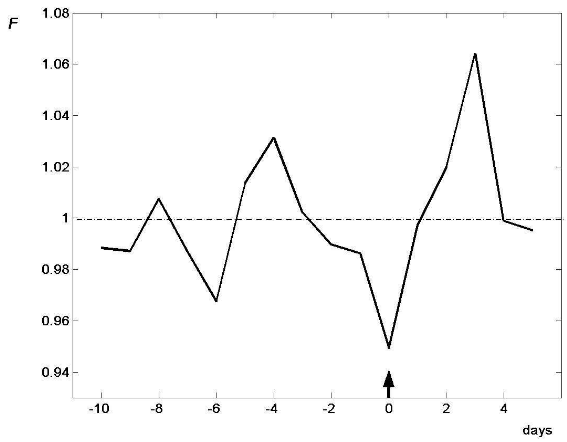

Fig. 3. Result of the superposition of epoches for earthquakes with epicenters below land. 7 events with $M > 6$, $R < 1000$ km and $h < 80$ km are analyzed.

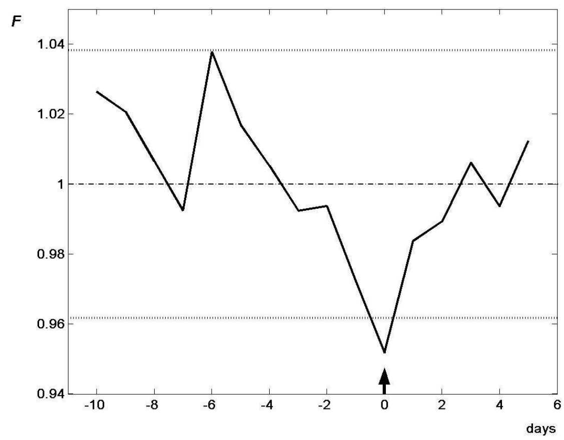

Fig. 4. Result of the superposition of epoches for earthquakes with epicenters below sea and below land. 68 events with $M > 6$, $R < 1000$ km and $h < 80$ km are analyzed. Solid line - temporal behaviour of F_i, the dotted lines show the interval of reliability 2σ (2 standard deviations)

5 Variability of the turbulization of the F-layer before earthquakes

As characteristic parameter of the turbulization of the F-layer, the F-spread phenomenon may be used. F-spread is observed as diffusivity of the traces of the F-layer on ionograms. The most important characteristic of F-spread is its occurrence probability which is studied here. The occurrence probability of F-spread equals the ratio of the number of F-spread observations to the number of observations of F2-layer tracks on the ionograms. Sometimes F-spread is comparatively weak and the observers can determine an exact value of foF2. At other times F-spread can be so intensive that an foF2-value cannot be found. Using data obtained every hour, one can calculate the occurrence probability of F-spread for some time interval.

F-spread is mainly observed at night. As illustration, Fig. 5 shows the number of F-spread observations as function of the local time for the years 1969-1990 (station Akita, $\varphi = 39.7^o$ N, $\lambda = 140.1^o$ E.). Thus it is reasonable to investigate F-spread only for nighttime. Here the occurrence probability of F-spread is calculated for each night. For the night a time interval from 23 LT until 5 LT is chosen. Besides, only F-spread on days with comparatively weak solar and geomagnetic disturbances is considered, for Wolf numbers < 100 and $\Sigma K_p < 30$. Using the method of superposition of epoches, described above, the mean occurrence probability of earthquakes with $M > 5.5$, $R < 1000$ km, $h < 80$ km is calculated. During the considered time interval, 226 of such earthquakes are registered. For every earthquake, a time interval from 30 days before the shock to 30 days after the event is taken into account. Fig. 6 shows the mean occurrence probability P of F-spread for all 60 analysed days. Besides, a smoothed curve of the mean value over 5 days $\hat{P}$ is presented. Almost one week before the earthquakes a minimum of the mean occurence probability of F-spread is observed. The decrease of $\hat{P}$ amounts to more than 10 %. To prove this result statistically, again the method of modelling of random processes is applied. Here, 300 series of events are constructed, each consisting of 226 virtual earthquakes. Then, the standard deviation σ of the decrease of $\hat{P}$ is calculated. The interval of reliability 2σ of the mean-square deviations of $\hat{P}$ is also presented in Fig. 6. It is to be seen that the statistical reliability of the decrease of the F-spread observation probability is larger than 0.95.

6 Conclusions

In the present work, ionospheric effects connected to 62 strong earthquakes with $M > 6.0$, which took place in Japane, are analysed. The epicenters of the earthquakes were situated below sea and below land. It is shown that about 7-5 days before the events, the dayly-mean values of foF2 decrease. The relative minimum of the foF2 value occurs on the day of the earthquake.

The observed decrease of the foF2 values seems to be a consequence of a specific heating of the ionosphere by specific currents, which are excited by earthquake preparation processes during their last phase.

Further, foF2-variations of more than 260 less strong earthquakes with $6.0 > M > 5.5$ are studied. For these events no decrease of the dayly mean foF2 values during the

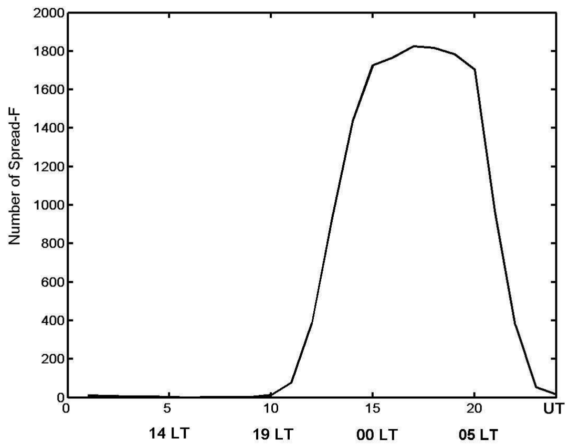

Fig. 5. Number of F-spread observations in the years 1969-1990 as function of the local time.

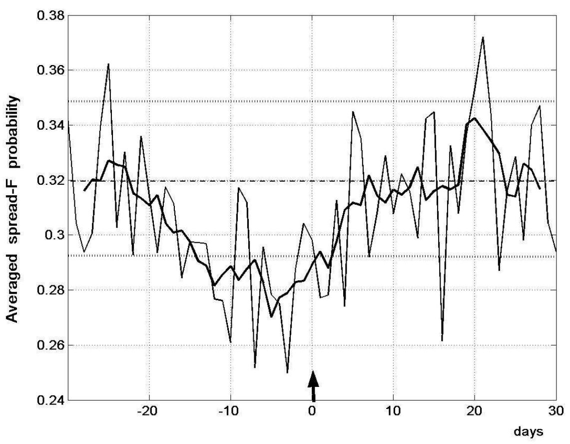

Fig. 6. Mean occurrence probability of F-spread P during the time interval from 30 days before the earthquake until 30 days after the event. $\hat{P}$ (thick solid line) presents the mean value of P over 5 days. The dotted lines give the interval of reliability 2σ (mean-square deviations of $\hat{P}$). Earthquakes with $M > 5.5$, $R < 1000$ km, $h < 80$ km are considered.

earthquake preparation phase is obtained. This is valid for earthquakes with epicenters below sea and below land separately.

On the other hand, for the weaker earthquakes with $6.0 > M > 5.5$, $R < 1000$ km, a decrease of the turbulization of the ionospheric F-layer (that means of F-spread) is found 10-5 days before the shock. This effect has a maximum about one week before the shock.

The statistical reliability of both investigated seismo-ionospheric phenomena, the decrease of the foF2 values and the decrease of the F-layer turbulization is larger than 0.95.

Thus, considering earthquake precursors, it is more reliable to analyse the turbulization of the F-layer, because the turbulization of the F-layer may be registered already for rather weak earthquakes.

References

Hobara Y. and Parrot M.: Ionospheric perturbations linked to a very powerful seismic event, J. Atmos. Terr. Phys., 67, 677-685, 2005.

Liperovsky V.A., Pokhotelov O.A., and Shalimov S.L., Ionospheric precursors of earthquakes, Nauka, Moscow, 1992.

Liu J.Y., Chen Y.I., Chuo Y.J., and Chen C.S.: A statistical investigation of preearthquake ionospheric anomaly, J. Geophys. Res., 111, A05304, doi:10.1029/2006.

Ondoh T.: Seismo-ionospheric phenomena, Adv. Space Res., 26 (8), 1267-1272, 2000.

Pulinets S.A. and Boyarchuk K.A.: Ionospheric precursors of earthquakes, Springer, Berlin, 2004.

Rios V.H., Kim V.P., and Hegai V.V.: Abnormal perturbations in the F2 region ionosphere observed prior to the great San Juan earthquake of 23 November 1977, Adv. Space res., 33, 323-327, 2004.

Singh B., Kushwah V., Singh O.P., Lakshmi D.R., and Reddy B.M.: Ionospheric perturbations caused by some major earthquakes in India, Physics and Chemistry of the Earth, 29, 537-550, 2004.