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GEOPHYSICS

Nonlinear Effects of the Motion of Macroscale Seismogenic and Anthropogenic Inhomogeneities in the F2 Region of the Ionosphere

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INITIAL DATA

The authors of [1–4] developed the geophysical interpretation of the generation and motion of macroscale ionization inhomogeneities in the ionosphere (MIIIs) in the altitude region of maximal electron concentration. The objects are detected on the basis of pulse variations δf_c of the critical frequency f_c in the F2 region. The data obtained at planetary chains of automatic ionospheric stations (AISs) confirmed the hypothesis about the appearance of positive MIIIs (extension of electron concentration) in the vicinity of the epicenters of catastrophic earthquakes ($M > 5$) recorded 10–15 h prior to the main shock (more than 50 cases were analyzed). After this, MIIIs with horizontal sizes of $(1–4) \cdot 10^3$ km and vertical sizes of ~100 km move along the great circle arc with a near-sonic velocity. The great circle is orthogonal to the lithospheric plate boundary closest to the epicenter. The appearance of negative MIIIs immediately after the earthquake was considered for the first time in [5] and later in [3, 4]. Below, we consider the problems related to the dynamic characteristics of the seismogenic and anthropogenic MIIIs (after nuclear explosions). The results of this consideration indicate the existence of nonlinear effects during the MIII motion.

POSITIVE MACROSCALE INHOMOGENEITY OF IONOSPHERE IONIZATION PRECEDING THE EARTHQUAKE IN KOBE (JAPAN) ON JANUARY 16, 1995

The catastrophic earthquake in Kobe (Japan; $M = 6.9$; January 16, 1995;20:47 UT) occurred under conditions of magnetic perturbation before and after the earthquake. The locations of the Eurasian AIS are shown in the world chart in Mercator projection (Fig. 1, fragment *A*), where *1* denotes detection of the local pulse, *2* denotes lack of detection, and *3* denotes detection during magnetic perturbation. Detection corresponds to pulses with a duration of 1–4 hr and amplitude $R = [\delta f_c(t)]_{\max} > 20\%$, the onset of which calculated from the moment $t_0 = 15$ h prior to the event is proportional to the distance from the AIS to the epicenter if all AISs are grouped near a certain mean great circle arc (MGCA), shown by dashed line in fragment *A* of Fig. 1. Function $R(t)$ over intervals $\Delta t = \pm 6$ h calculated from the corresponding point on the MGCA determined by equation $t - t_0 = \frac{D}{V}$, where $V = 10^3$ km/h and D is the distance from the AIS to the epicenter, is shown in fragment *B*. The numbers in fragments *A* and *B* are related to the same AIS. AIS no. 17 located at a distance of 21500 km is not shown in fragment *A*. Let us discuss the peculiarities of the data in fragment *B*. A significant displacement of the maximum with respect to the point on the MGCA was distinguished only at AIS no. 10. At all other AISs (nos. 8, 11–17), the maxima are located on the MGCA. Conservation of the shape of the pulses over the motion interval considered here is worth attention. Dependence $R(D)$ is shown in fragment *C* (the points correspond to individual AISs, the dashed line connects them, and the intervals corresponding to mag-

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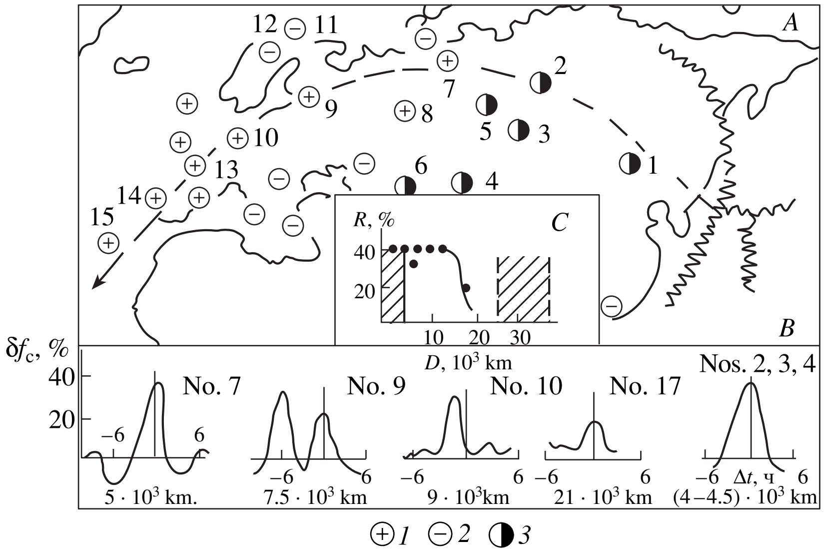

Fig. 1. Experimental data on the value of relative perturbation $\delta f_c(t)$ during the magnetic perturbation period.

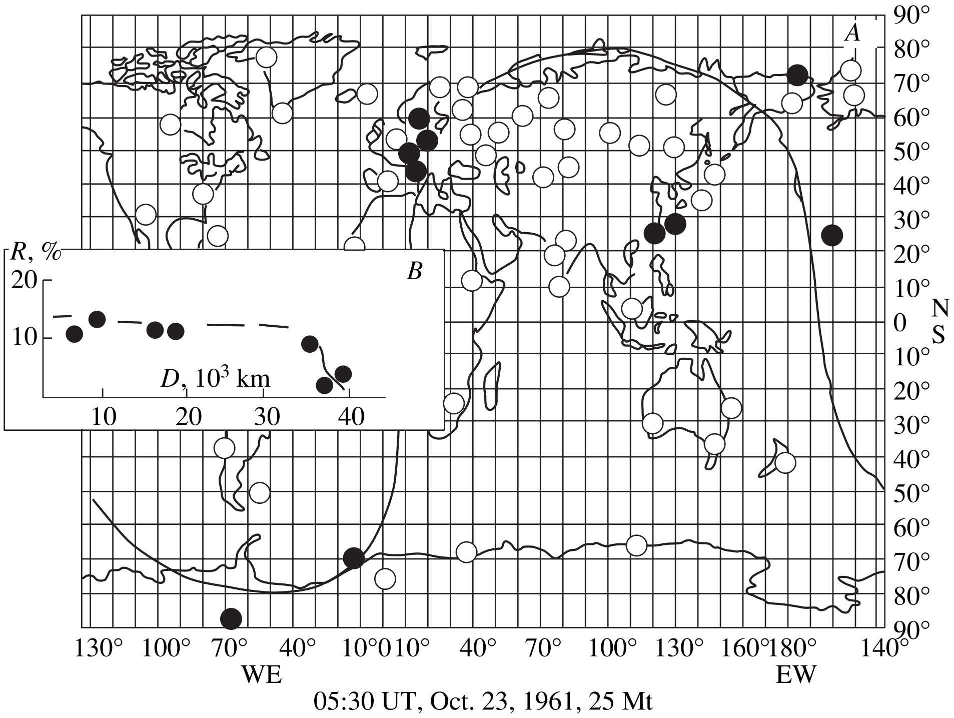

Fig. 2. Experimental data on ionosphere perturbation $\delta f_c(t)$ in the period after a nuclear explosion of megaton class.

netic perturbations are hatched). It is important that the amplitude of the pulses R over an interval of 4000–13 000 km is practically constant. The pulses at AIS nos. 2 and 3 are located within the magnetic perturbation interval similarly as AIS no. 4 presented in fragment A, i.e., it is likely that MIIIs probably pass through the magnetic perturbation regions without changing their shape and amplitude. The law of the decrease in $R(D)$ after the end of the horizontal interval cannot be determined from the data of fragment C. At the same time, it is reasonable to cite paper [6], in which the authors consider the recording of the MIII that appeared north of New Zealand and was sequentially recorded by AISs located in Australia, Malaysia (this AIS was onboard the *Mir* satellite), India, and Rome. The MIII passed on this route without attenuation. However, AISs in Slough (England) and Iceland located near the MGCA did not record this MIII. This means that the MIII passed over 18 000 km and disappeared after 1000 km along this track. Thus, the data in fragment *B* can be considered as an argument confirming the concept that the MIII considered here ceased to exist in the neighborhood of AIS no. 17.

NEGATIVE MACROSCALE INHOMOGENEITY OF IONOSPHERE IONIZATION APPEARING AFTER A NUCLEAR EXPLOSION OF MEGATON CLASS

It was supposed that a negative MIII similar to those after catastrophic earthquakes should appear after a nuclear explosion of megaton class. In this relation, the data from the worldwide AIS network were considered in periods of subaerial explosions of megaton class in Novaya Zemlya. The locations of AISs that recorded a negative MIII (dark circles) after the nuclear explosion on October 23, 1961 (25 Mt, 05:30 UT [7]), and those that did not record this MIII (open circles) are shown in Fig. 2 (fragment *A*). Here, one can note the same grouping of pulses as in the case considered above, but, naturally, without the time interval prior to the event. A graph of the amplitude $R(D)$ of the moving pulse-versus-distance relationship is shown in fragment *B*. One can see the interval over which the negative MIII disappears, which is the same as for the positive MIII in [6]. It is noteworthy that the estimate of the disappearance time (~1 h) obtained in both cases is close to the relaxation time caused by longitudinal diffusion. In addition, the data in fragment *A* make it possible to estimate the upper limit of the transverse dimensions of the negative MIII—5000 km between AISs in Alaska and Hokkaido and 3000 km between AISs on the Falkland Islands and Antarctic coast (i.e., the horizontal dimensions of the negative anthropogenic MIII are the same as the size of the positive seismogenic MIII). It is likely that they do not change along the entire pathway of the object motion. We note that different parts of the MIII trajectory are located at different angles with respect to the Earth's magnetic field. However, the MIII motion pattern after a journey of 10 000–15 000 km along the MGCA is not so distinct for other nuclear explosions (58 and 1 Mt).

CONCLUSIONS

The main conclusion is as follows. The hypothesis of nonlinear effects during the motion of macroscale ionospheric inhomogeneities in the F2 region has been confirmed experimentally. Conservation of the shape and dimension of macroscale inhomogeneities, lack of attenuation during their motion, and cessation of their existence over a short interval of the trajectory have been distinguished. In a certain sense, the objects are metastable because of the hypothetical superthreshold soliton instability of the ionospheric plasma. Lack of interaction between the objects and Earth's magnetic field suggests that the absence of real macroscale displacement of particles of the medium occurs during displacements of the objects.

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REFERENCES

1. Yu. K. Kalinin and N. P. Sergeenko, Dokl. Akad. Nauk **387**, 105 (2002) [Dokl. Earth Sci. **387**, 965 (2003)].
2. U. K. Kalinin, A. A. Romanchuk, N. P. Sergeenko, and V. N. Shubin, J. Atmosph. Solar-Terrest. Phys. **65**, 1175 (2003).
3. Yu. K. Kalinin, N. P. Sergeenko, and A. V. Sazanov, Geomagn. Aeron. **44**, 239 (2004) [Geomagnet. Aeron. **44**, 216 (2004)].
4. Yu. K. Kalinin, N. P. Sergeenko, and A. V. Sazanov, Geomagn. Aeron. **44**, 331 (2004) [Geomagnet. Aeron. **44**, 303 (2004)].
5. R. S. Leonard and R. A. Barnes, J. Geophys. Res. **70**, 1250 (1965)
6. N. P. Danilkin, U. K. Kalinin, N. G. Katanaeva, et al., Int. J. Geomagn. Aeron. **5**, 1 (2004).
7. *Herald of the Research Institute of Regional Medical–Ecological Problems* (Moscow, 1994) [in Russian].