Short-temporal Magnetosphere-ionosphere Predictors of Catastrophic Earthquakes

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Abstract— The analysis of ionosphere-geomagnetic predictors of catastrophic earthquakes is carried out. Formation of traveling large-scale irregularities of the electronic concentration of the positive sign in the main peak of the ionosphere and increase of the local magnetic field near epicenter of earthquakes are illustrated. For the first time splashes AE-index characterizing amplitude of the auroral electrojet 15–17 hours prior to the moment of the main push are found out. Existence of this effect on examples of nuclear explosions on various latitudes zones is confirmed. The possible physical mechanisms of occurrence of the apparent effects with use of literary data on satellite observations in the magnetosphere and radiating belts are discussed.

1. INTRODUCTION

There was the considerable quantity of the researches devoted to search of predictors of earthquakes in the ionosphere and the geomagnetic field last years. Possible physical mechanisms of observable effects were discussed. Works can be divided conditionally into two approaches: one approach is connected with studying of effects of the internal source located in Earth's crust [1], other approach is directed on research of the external reasons of the earthquakes, assuming that non-stationary geoeffective processes on the Sun and influence of fluctuations of the interplanetary environment on the change of seismic activity [2].

Geophysical predictors are expedient for dividing into three groups: the precursors predicting earthquakes in the very long-temporal future, long-temporal predictors of earthquakes and short-temporal predictors of earthquakes. This work concerns studying short-temporal magnetosphere-ionosphere predictors of earthquakes with advance time approximately 10–15 hours.

2. THE ANALYSIS OF IONOSPHERE-GEOMAGNETIC PREDICTORS OF EARTHQUAKES

In [3, 4] it is established that traveling large-scale irregularities of electronic concentration of the positive sign are formed in the main peak of the ionosphere 10–15 hours prior to the moments of catastrophic earthquakes with magnitude $M \geq 5$ and localization of ~ 1 thousand km to earthquake epicenter. Irregularities are characterized by contrast of 15–50% against the background electronic concentration, the horizontal sizes are 1–3 thousand km, speed of horizontal moving is the order of sound speed. They are the closed objects and can move on the distances exceeding radius of the Earth, up to round-the-world movements.

The main source of the information about ionosphere irregularities are files of critical frequencies of the ionosphere F2 layer on the world network of ionosphere stations of vertical sounding. At the analysis the relative variations $\delta f_0 F2$ are calculated, that excludes regular seasonal and daily variations. For the description of geomagnetic conditions Dst, and AE-indexes were used. Dst — the index characterizes occurrence and development of the large-scale planetary geomagnetic storm. For identification of effects of substorms in the ionosphere we used the AE-indexes. We were considered the periods of disturbance at $AE > 100\,\mathrm{nT}$ [5].

$\delta f_0 F2(t)$ variations during 10–12.08.1985 on of Japan, Irkutsk, Tomsk, Sverdlovsk, Moscow ionosphere stations are resulted on Fig. 1. This is the example when irregularities $\delta f_0 F2(t) > 0$ appeared before catastrophic earthquakes were considered as predictors of the earthquakes. At this time there were three earthquakes with magnitudes $M \geq 6$ in of Pacific ocean, moments of their beginning are noted by vertical straight lines. In Fig. 1 three groups of impulses near to dotted straight lines are allocated. In all three cases some hours prior to earthquakes there were positive indignations with amplitude $15 \div 20\%$, traveling with the speed to 1000 km/hour on distances of 7–8 thousand km. This result corresponds to that rare situation when movement of the irregularities appeared before earthquakes, coincides with chains of stations of the vertical sounding of ionosphere located along the sublatitude arch of the big circle. This figure illustrates character of alternation of impulses from three various sources. Except described seismic - ionosphere effects,

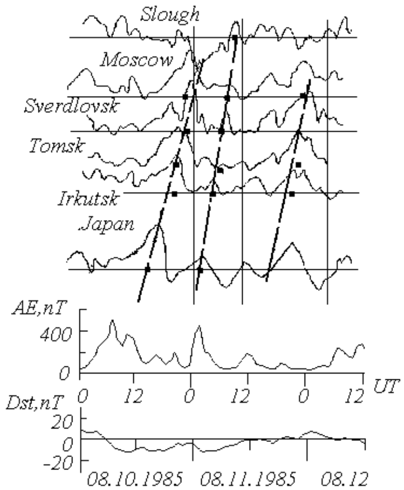

Figure 1: Ionosphere-geomagnetic conditions during earthquakes 08.10–12.1985.

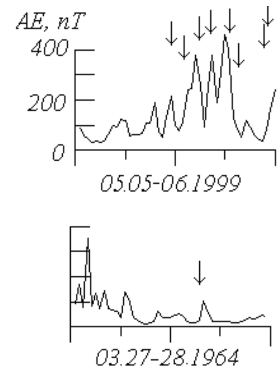

Figure 2: Geomagnetic conditions during earthquakes 05.06.1999 (see the table) and 03.27–28.1964.

on practically quiet geomagnetic background ($Dst \leq 10\,\mathrm{nT}$) 10.08 and 11.08 there were two geomagnetic substorms with amplitudes $AE \sim 500$ and $400\,\mathrm{nT}$, and both substorms have occurred 17 and 13 hours accordingly prior earthquakes.

AE-indexes during time of "parade of earthquakes" 05.05–06.1999 are showed on Fig. 2. Characteristic of these earthquakes are resulted in the table. The moments of the beginning of earthquakes are noted in the Fig. 2 by arrows. It is visible, that AE has increased to $\sim 130\,\mathrm{nT} \sim 15$ hours prior to first jolt, further AE-splashes before all earthquakes also are observed. On the right on Fig. 2 geomagnetic characteristics during Alaska earthquake with magnitude $M = 8.5$ which was the subject of attention of many researchers (for example, [6]) are resulted. It is visible, that before this earthquake AE splash also is observed.

The beginning, geographical coordinates, the depth and magnitudes of 9 earthquakes on 05.06.1999.

No.	**beginning, UT**	**φ, degrees**	**λ, degrees**	**d, km**	**M**
1	040123.88	19.25	145.53	164	5.00
2	041926.72	56.48	−152.86	24	5.10
3	065446.12	−11.22	66.08	10	5.30
4	090508.29	−32.79	−179.37	109	5.20
5	111530.98	−5.32	141.76	40	5.20
6	132132.30	−34.02	−178.97	33	5.50
7	135635.70	−5.25	141.71	33	5.10
8	230053.12	29.50	51.88	33	6.30
9	231324.85	29.40	51.90	33	5.30

3. THE ANALYSIS OF GEOMAGNETIC EFFECTS OF NUCLEAR DETONATIONS

For comparison we will consider behaviour of magnetosphere AE-index at artificial created situations with emitting of high energy particles in the ionosphere at experimental nuclear detonations.

Let's address to the analysis of geomagnetic conditions during nuclear detonations on high-latitude Novaya Zemlya nuclear experimental range. On Fig. 3(a) AE-indexes variations during 2 explosions are resulted. Both explosions of the megaton class, explosion 10.23.1961 have been made in air, explosion 10.27.73 — in the drill. By arrows in Fig. 3 the moments of explosions are shown. It is visible, that explosion in air was accompanied by AE splash to $\sim 100\,\mathrm{nT}$, explosion in the drill — to $AE \sim 600\,\mathrm{nT}$.

On Fig. 3(b), AE-indexes during nuclear explosions on Semipalatinsk and Nevada experimental ranges are resulted. From drawing obviously, that at middle latitudes nuclear explosions are

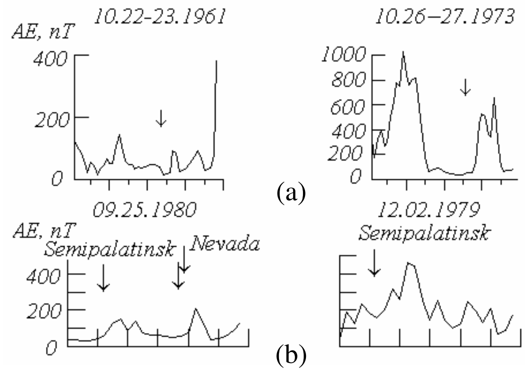

Figure 3: (a) Behaviour of the AE-index during nuclear explosions on Novaya Zemlya experimental range; (b) near Semipalatinsk and Nevada experimental ranges.

accompanied by effects in behaviour of the AE-index.

4. DISCUSSION

All observable splashes in the AE-index in preparation of earthquakes and during nuclear explosions can testify about seismic-magnetosphere communications.

Let's consider research experiments with nuclear explosions which were spent for studying of capture of energetic particles [7] by the magnetic field of the Earth such as it occurs at strong earthquakes. These particles appeared at 200–600 km altitudes over sea level. As the result of such explosions artificial radiating belts were created which, as well as natural radiating belts, represent the zone of huge concentration of the charged particles round the Earth, basically energetic electrons and protons.

At the first moment the particles formed at nuclear explosion in the ionosphere, are emitted in some certain point of Space. In some seconds they usually spread along the power line of the geomagnetic field corresponding to position of nuclear explosion. And in some hours at the expense of drift round the Earth they extend on all longitudes and form the "coverlet" shrouding the Earth. At the same time, the measurements made on "Ariel" satellite, have shown, that electrons of high energy arising after nuclear explosion, very quickly appeared at high latitudes [8]. And in that case the AE-index should increase at nuclear explosions.

Formation of the charged particles does not stop and after the completion of reaction of division. Division splinters contain superfluous quantity of neutrons and consequently break up with electrons emission. Thus, after nuclear explosion electrons are formed within several minutes and even hours. Formation such electrons is the most important source of artificial radiating belts.

By preparation of strong earthquake in the ionosphere and magnetosphere, apparently, there are processes similar to the above described processes at emitting of particles from nuclear explosions, that is the fault tectonic zone of Earth's crust is formed at the expense of micro cracks and energy are given off more big than energy of nuclear explosion to atmosphere. It is known, that porous pressure of fluids essential influence on occurrence of earthquakes. Therefore by earthquake preparation some hours prior to the basic push often there is the emission of radon and some other gases containing in the structure elements of radiating disintegration from the depth of the tectonosphere in the atmosphere [9]. When there is the emanation of such gases on the eve of earthquake, particles of elements of radiating disintegration, also as well as after nuclear explosions, start to move in space and time. Thus process of preparation of earthquake is often accompanied by electromagnetic radiation which also actively promotes penetration of the charged particles into the ionosphere. It is possible to consider movement of these charged particles as superposition of almost circular rotation round the power line of the magnetic field, rectilinear movement along the power line of the field and drift across power lines.

Thus, radioactive particles, after their emission in atmosphere as the result of nuclear explosion or emanations of radon and other gases with presence in their structure of radioactive elements test on themselves influence of several forces. Drift of particles along power lines of the magnetic field including in auroral areas where the AE-index is fixed, leads to its increase. Satellites measurements have shown, what even during the quiet period, the high-latitude border grasped electrons corresponds approximately $\varphi \sim 75 \pm 2$ degrees northern and the southern latitude but should not settle down above 77 degrees of latitude.

It is known, that at longitudinal drift negative and positive charges drift in opposite directions. Therefore there is the division of charges and there is the azimuthal electric field. As the result there is the component of drift speed directed on radius from the centre of the Earth, that also promotes penetration of the charged particles from near surface of the Earth before earthquake in the ionosphere. Under some conditions in exosphere such drift can arise with the speed (V) from formula:

$$V = c(\mathbf{E} \times \mathbf{B})/B^2 \tag{1}$$

where ($\mathbf{E} \times \mathbf{B}$) — the multiplication of vectors of the electric and the geomagnetic field; c — the speed of the light. Drift of the charged particles under the influence of electric field is, as the rule, the prevailing kind of drift.

Formation positive irregularities of electronic concentration in the ionosphere in earthquake preparation period can be caused as emitting particles, and the processes similar to ionosphere effects from magnetosphere substorms (with growth AE). Electric fields of magnetosphere origins on ionosphere altitudes amplify in high latitudes to values of 200 mV/m, come on middle and even on equatorial latitudes, reaching there values of 10–15 mV/m at middle latitudes and 2–5 mV/m into the low latitudes. The amplitude of electric fields in 2–3 times more low in time of the typical not indignant conditions in the magnetosphere. Direct effects of strengthening of electric fields consist in redistribution of ionosphere plasmas by means of horizontal (in high latitudes) and vertical (in middle and low latitudes) carrying over, and also in Dgoul's heating of the neutral and ionic component owing to the ion-neutral friction. Increase of electronic concentration can be observed at the meridian electric field causing zone drift of plasma, and also to be the consequence of distribution of internal gravitational waves (in the afternoon at middle latitudes).

5. CONCLUSION

The analysis of ionosphere and geomagnetic data has shown, that the geophysical chain of the connected short-temporal, semidiurnal, magnetosphere, geomagnetic, ionosphere precursors of catastrophic earthquakes is observed. Tectonic preparation of earthquake can lead to generation magnetosphere substorms (AE-splashes) and to formation of large-scale traveling irregularities of electronic concentration in the main peak of the ionosphere. In the combination to other already studied precursors results of this work can be used in algorithms of the geophysical forecast of time of beginning and the place of the future earthquake.

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