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Earth electric field negative anomalies as earthquake precursors

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Abstract. In fair weather conditions, electric field potential gradient in the near-ground air takes positive values. Negative anomalies occur under the influence of different ionizing processes such as galactic cosmic ray flux and radioactive gas emanation from the ground. In the conditions of calm geomagnetic state and fair weather, anomalies can be used for earthquake forecast. In the paper, the efficiency of earthquake forecast based on negative anomalies is under the study. It was obtained that the efficiency of such a forecast during any weather conditions is 10%.

1 Introduction

Earth ionosphere has positive electric charge, and the Earth surface has a negative one. In fair weather conditions, electric field potential gradient (PG) in the near-ground air takes positive values. Annual diurnal PG is about 100 V/m. However, even in fair weather conditions, PG may take negative values under the impact of air ionization factors. Such factors are ionization by Galactic Cosmic Rays (GCR) and ionization by radioactive gases penetrating into the atmosphere from the soil. Fair weather conditions are determined as air temperature in the range from −50 to +50°C, pressure from 650 to 1080 gPa, cloud cover of not more than 3 balls, wind velocity up to 6 m/s, absence of thunderstorm, precipitation, fog, haze, mist, snowdrift, snowstorm.

Many authors mentioned electric field behavior changes as an earthquake precursor. For example, in 1966 anomalies of electric field before an earthquake were observed at Matsushiro observatory in Japan [1]. Those anomalies were mainly negative. The frequency of the anomalies was directly proportional to seismic activity recorded at the observatory.

Cases of both negative and positive PG anomalies were observed in the Caucuses [2].

The paper [3, 4] presents the results of continuous observations of quasistatic electric field intensity over the 20-year period in the vicinity of Beijing. Anomalies before earthquakes had clear form of a negative bay of the depth up to 500 V/m and lasted from several minutes to a ten of hours. They occurred from 2 to 40 days before the earthquakes with $M > 5$. Absence of anomalies coincides with seismically calm periods. Anomaly duration and amplitude were proportional to earthquake magnitude. When anomalies were observed over a large area, there could be two strong or a swarm of earthquakes.

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In the north of India, anomalous variations in the near-surface atmospheric vertical electric field were observed. They had the form of bay-like depressions in strength and were used as precursors of earthquakes in various studies [5].

Atmospheric noise in fair weather conditions is ±20 V/m [18]. Negative PG during fair weather conditions is an anomaly which should be explained. Kondo made an assumption [1] that the most likely reason of PG negative anomaly occurrence in fair weather conditions, absence of thunderstorm clouds and magnetic storms is emanation of radioactive gases from the upper layers of soil.

Surface air ionization caused by radon emanation into the atmosphere before earthquakes was investigated as one of the major sources of electric field variation in the works [6–8].

An increase of the electrical conductivity of surface air due to radon emissions, or ions emitted from rock stresses [9], is consistent with reduction of the PG, as explained by [10].

Mechanisms of PG negative anomaly occurrences during air intensive ionization are explained by the electrode effect theory [11, 12]. As a consequence of radon emanation, long-living ion complexes of opposite signs are formed in the near-ground layer of the atmosphere. Ions of different signs have different mobilities; generally the mobility of negative ions is 1.3-1.4-fold more than for positive ones. Under the action of the natural atmospheric electric field, positive ions would tend to move to the surface of the Earth, where they would recombine, but because of their low mobility, after some time, a spatial layer of positive ions will be formed at the surface, whereas the negative ions will move vertically upwards. In such a way, at the near-ground, an 'electrode layer' can be formed along with the local electric field which diminishes the natural atmospheric electric field.

In this paper we evaluate the efficiency of earthquake (EQ) forecast based on this indicator. We considr the behavior of these precursors in Kamchatka.

2 Measurement methods

Paratunka observatory is located in the south of Kamchatka peninsula (φ = 52.97° N; λ = 158.25° E). The electric field is measured by «Pole-2» sensor, developed at Voeykov Main Geophysical Observatory (Russia), and by CS110 developed by Campbell Scientific company (USA). Exploitation experience showed that measurements by both sensors are identical [17].

«Pole-2» was installed at the height of 3 m on a test field 200 away from an administrative building. The area around it with the radius of 12 m was cleared from trees. CS110 was installed at the height of 7 m on the roof of a technical building 10 m away from «Pole-2» sensor.

Figure 1 shows PG standard diurnal variation during fair weather conditions without anomalies (a), during days with precipitation (b) and during fair weather conditions with anomalies often accompanying earthquakes (c).

Negative anomaly is determined as follows. Initial measurements are carried out with 1-second interval. The signal is averaged with 10-min interval. Based on the form, bay-like anomalies with zero crossing to negative values without peaks were selected. There should be no significant changes of atmospheric pressure and such meteorological phenomena as thunderstorm, precipitation, fog, haze, mist, snowdrift, snowstorm. Kp and local K-index of geomagnetic activity is less than 5. In cases of doubt, graphs based on 1-second data were drawn. To interpret a signal, we used weather data of Paratunka observatory, observation journal, meteorological data of Gidromet (Russia) and satellite images.

For statistical processing, we selected the data only for the days with fair weather. Negative bays in PG measurements may appear during thunderstorm cloud passage over the observation site. Models of signals from thunderstorm clouds are described in the paper [20]. Such forms of signals were excluded from the data base of PG negative anomalies.

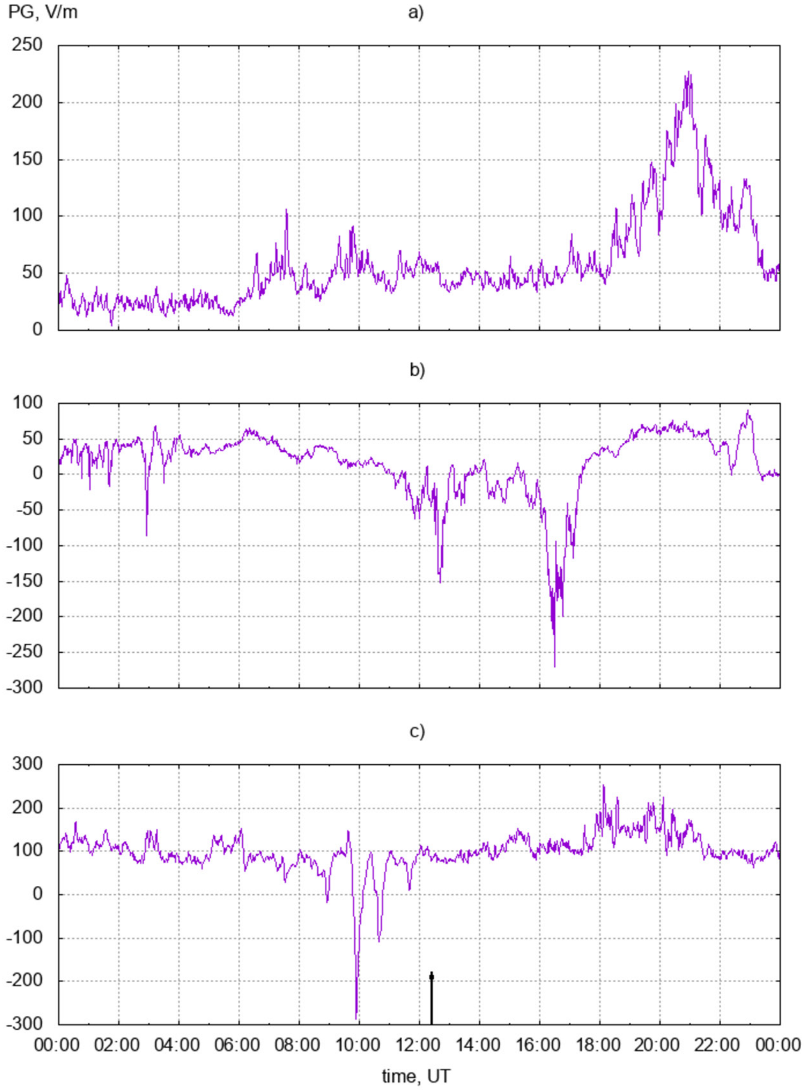

Figure 1. Standard diurnal variations of PG during fair weather conditions without anomalies (a), during the days with precipitation (b), during fair weather conditions with anomalies (c). Arrow indicate the earthquake time on October 24, 1999, $K = 12.4$

Negative bays in PG measurements may appear during magnetic storms [21]. In the paper we applied the local K-indexes of magnetic activity at Paratunka observatory included into Intermagnet. The investigations were carried out in Kamchatka region, thus, it is important to use local magnetic storminess data.

3 Main results and discussion

As a seismic event we considered a situation when during 24-h time interval one or several EQ of class $K > 11$ (local magnitude > 4.0) occurred and had epicenters in the area with the coordinates (45–55)° N, (155–165)° E, including GP recording site. We detected 103 cases of PG anomalous behavior for the period from January 1, 1997 to December 31, 2002 (i.e. over 2189). In 37 (36%) cases, earthquakes occurred 1-24 hours after an earthquake. This value is close to the result (31%) obtained by the authors [5]. This paper is a statistical study on precursory effects of earthquakes observed through the atmospheric vertical electric field in northeast India.

We estimate seismic activity during that period. We divide the period of 2189 days into 2189 similar intervals. As a seismic event we take a situation when one or several EQ of class $K > 11 (M > 4)$ with epicenters in the area with the coordinates (45–55)° N, (155–165)° E occurred in the time interval without reference to weather conditions. The region of seismic events was chosen so as to maximize the precursor effect. Over the period under investigation, 409 seismic events occurred. If 409 seismic events occurred for 2189 intervals, we can assume that about 19 of them would occurred for 103 intervals. However, we detected 37.

We considered the statistical properties of negative anomalies of quasistatic electric field in the atmosphere within 24 hours before an earthquake. These anomalies can be referred to short-term forecast category. For them, there are no significant relations between such parameters as event lead time, anomaly value and earthquake magnitude M. Correlation coefficient between negative anomaly value and EQ class is 0.17. Correlation coefficient between negative anomaly value and the distance to EQ epicenter is 0.09. That shows the absence of any relation between the considered parameters. That is explained by the heterogeneity of stress-strain processes in the earth crust just before earthquakes. The heterogeneity manifests indirectly in the honeycombed structure of different geophysical parameters.

As for the nature of quasistatic electric field anomalies observed before EQ in Kamchatka, it is still unclear. Some models of this phenomenon were proposed in literature. First theoretical estimates of PG variations in the near-ground atmosphere as the result of radon concentration change were made in the paper [10]. All the following mechanisms also suggested radon as the main agent changing near-ground atmosphere conductivity and, consequently, the electric field. Its content in the earth crust and penetration into the atmosphere are tightly associated with deformation process state in the earth surface layers during active fracturing at the time of EQ preparation. Paper review on this mechanism was presented in [4].

Of great interest is the comparison of paper results with continuous long-term (20-year) observation data obtained in China [Hao et al., 1998]. In these publications the results agree both in PG anomaly form, their duration and partially in PG jump. Independence of PG bay decrease on earthquake class and on distance to an epicenter, obtained in Kamchatka, in contrast to Hao work, may be associated with data processing method. Here we consider the anomalies within 24 hours before a possible earthquake, whereas in Hao paper all the anomalies within 2-40 days before an event were taken into account. Geological peculiarity of Kamchatka region may also have its effect.

We estimate the efficiency of the method for EQ forecast based on negative anomalies. In 64% of case, no seismic events were observed after negative anomalies. It indicates low efficiency of the method. We evaluate the method using rounded values. About 400 seismic events occurred within 2000 days with any weather conditions. If during the half of the period the manifestation of such phenomena as precipitation, fog, haze, mist, snowstorm were observed, than 200 seismic events would occur within 1000 days of fair weather. Seismic events occur independently of local weather conditions. Thus, 200 events were dropped out due to weather conditions when the method does not work. About 40 events can be attributed to negative anomalies and 160 events are not associated with such anomalies. We obtain that 40/200 = 20% is the event forecast probability, and 160/200 = 80% of events are not associated with negative anomalies. If we take into account the days with disturbed meteorological state, the method efficiency is 40/400 = 10%, and the probability to miss an event is 90%. Thus, to improve the method efficiency, it is necessary to apply other kinds of observations.

4 Conclusions

Thus, the statistical analysis of PG negative anomalies in the near-ground atmosphere of Kamchatka showed that the efficiency of such a method for short-term forecast of earthquakes under any weather conditions is 10%.

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