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The physical nature of thermal anomalies observed before strong earthquakes

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Abstract

The paper examines the effect of air ionization on the thermal balance of the boundary layer of atmosphere. In seismically active areas the increased radon emanation from active faults and cracks before earthquakes is the primary source of air ionization. The problem is analyzed both on microscopic and macroscopic levels and in both cases the significant changes of the air relative humidity and air temperature are obtained. This happens due to the water molecules attachment to the newly formed ions (or in other words, condensation) which leads to the excretion of the latent heat. Obtained results permit us to explain the changes of the surface temperature and the surface latent heat flux increase before earthquakes observed by remote sensing satellites, as well as ground based measurements of the air temperature and relative humidity variations before the Colima earthquake (M7.6) of 2003 in Mexico, Hector Mine earthquake (M7.1) of 1999 in USA and Parkfield earthquake (M6) of 2004 in USA. These findings are also supported by the results of active experiments where the installation of artificial ionization of atmosphere is used.

Keywords: Air ionization; Radon; Latent heat; Thermal anomaly; Earthquake

1. Introduction

Thermal anomalies observed within the area of earthquake preparation a few days before the seismic shock (Tronin, 1999; Tramutoli et al., 2001; Tronin et al., 2004) usually were interpreted as the thermal flux deposited from the earth's crust in seismically active areas (Ouzounov and Freund, 2004). But discovered recently by Dey and Singh (2003) anomalous variations of the surface latent heat flux (SLHF) before earthquakes, involve the variations of air humidity which cannot be explained by the heat deposit from the crust and requires other interpretation. One can find the methodology of the latent heat estimation from remote sensing data in Schulz et al. (1997). At the same time the IR sensors used by remote sensing satellites, can register the changes of air temperature also as a part of the SLHF variations. The ambiguity of situation was resolved by the developed model of seismo-ionospheric coupling (Pulinets and Boyarchuk, 2004). The part of the model describing the generation of anomalous electric field in the zones of earthquake preparation involves the process of formation of gaseous aerosols with water molecules attachment, which is essentially connected with the latent heat variations. During these processes the large amount of heat (~800–900 cal/g) is released or consumed (Sedunov et al., 1997). Similar processes take place under action of cosmic rays on the atmosphere. Air ionization provided by cosmic rays results in formation of aerosols as condensation nuclei for clouds (Yu and Turco, 2001; Timofeev et al., 2003). In normal conditions when the number of

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large ionized ion clusters is small, the meteorological processes prevail. But when the concentration of hydrated particles created by radon ionization increases up to values 10^5–10^6 cm^{-3} (Pulinets and Boyarchuk, 2004) they provide an essential contribution in the SLHF variations up to anomalous values registered by satellites. The purpose of the present paper is to model the above mentioned processes and to compare with experimental measurements around the time of recent major earthquakes, as well as with the results of active experiments using the special equipment for artificial ionization of the atmosphere.

2. Long-term thermal effects associated with seismic activity

Mil'kis (1986) demonstrated the presence of thermal anomalies during the month (or season) of the strong earthquakes in the former Soviet Union. He used the data from more than 120 meteorological stations in Turkmenia, Uzbekistan and other regions of Central Asia. Using the assemblage of climatic elements (data from the meteorological stations in Turkmenia and Uzbekistan) their anomalous variations were studied around the time of the following earthquakes: Ashkhabad October 5, 1948 ($M = 7.3$); Gazly April 8 ($M = 7$), May 17 ($M = 7.2$) 1976; and March 20, 1984 ($M = 7$). Individual climatic parameters were studied also for the following earthquakes: Krasnovodsk July 8, 1895 ($M = 8.2$); Sarez February 18, 1911 ($M = 7.4$); Germab May 1, 1929 ($M = 7.2$); Kemine-Chuy June 20, 1938 ($M = 6.9$); Garm April 20, 1941 ($M = 6.4$); Chatkal November 2, 1946 ($M = 7.5$); Kazandzhik November 4, 1946 ($M = 7.0$); Tashkent April 26, 1966 ($M = 5.6$); Ashkhabad November 15, 1968 ($M = 5.6$); and Vyshko-Burun February 22, 1984 ($M = 6.0$). Fig. 1 presents his results of air temperature measurements (mean monthly temperature for long-term intervals – several tens of years). In every case the month when earthquake takes place is selected for analysis. It means that if an earthquake took place in January, the mean January temperature for several tens of years is monitored. One can see that within interval of tens of years the mean monthly temperature for the year of earthquake practically in all cases is anomalously high and is the local maximum for the multi-year interval.

The same long-term behavior of the mean monthly temperature was observed for the Colima earthquake in Mexico on 23 of January 2003 ($M = 7.8$). Fig. 2 demonstrates the 50-years interval of January mean monthly temperature at Manzanillo meteorological station (closest to the earthquake epicenter), and for year 2003 one can observe the absolute maximum of the temperature for the whole interval of presented records.

3. Short-term thermal effects

We analyzed the meteorological data around the time of Hector Mine earthquake M7.1 16 October 1999, USA, Colima earthquake M7.6 21 January 2003, Mexico, and Parkfield earthquake M6 28 September 2004, USA. More detailed information was collected for Colima earthquake. Data of three meteorological stations (air temperature and relative humidity) are presented in Fig. 3. Colima and Manzanillo stations are situated at a similar distance of the epicenter (60 and 55 km, respectively according to USGC location). And the third station (Cuernavaca) is near 900 km from the epicenter. One can easily see the difference. The first two stations (Fig. 3a and b) clearly show the sharp drop of relative humidity one week before the seismic shock, and no effect is observed at the third station (Fig. 3c). Taking into account that Manzanillo is at the ocean shore, the humidity of order of 40% at tropics is very unusual. We can mark also the absolute monthly minimum of air temperature at Colima Station on 13 of January, and temperature maxima at both stations on 14 and 15 of January. Relative humidity minimum at Colima coincides with the absolute monthly maximum at the same day of 14 January. The map of the surface air temperature distribution over Mexico for 1400 LT on 14 of January 2003 is shown in Fig. 4. The most remarkable feature of this distribution is the local temperature maximum close to the epicenter position of impending earthquake, and the temperature increase stretched along the coast in accordance with the subduction trench orientation.

The local time variations of the air temperature and relative humidity somehow mask the main effect connected with the radon variations and consequent changes of the atmosphere parameters. Therefore, we used the special parameter which reflects both the temperature and humidity variations, namely the daily temperature range – the difference between the daily temperature maximum and minimum. Variations of this parameter related to the earthquake moment is presented in Fig. 5a. One can see the local minimum 9 days before the earthquake what corresponds to the local maximum of the relative humidity, then the absolute maximum of the range which corresponds to the relative humidity minimum, and then the gradual drop of the temperature range up to the earthquake occurrence.

The presence of similar temperature variations was checked for the periods around the time of Hector Mine earthquake M7 (16 October 1999) and Parkfield earthquake in California M6 (28 September 2004). Same daily temperature range variations for two meteorological stations in the vicinity of Hector Mine earthquake epicenter (Borrego station) and in the vicinity of Parkfield earthquake (Paso Robles station) are shown in Fig. 5b and c, respectively. It is interesting to mark that the time intervals for characteristic points of range variations (dashed lines) for Colima earthquake and Hector Mine earthquake are identical.

Not occasional character of atmosphere parameters variations before earthquakes was confirmed recently by the satellite remote sensing measurements. Ouzounov et al. (2005) and Ouzounov et al. (2006) using the measurements of AVHRR instrument onboard the NOAA satellites demonstrated the temporal variations of ongoing longwave radiation (OLR) over the epicenters of strong earthquake at Taiwan M5.7, 12 February 2005, and catastrophic Suma-