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Specific variations of air temperature and relative humidity around the time of Michoacan earthquake M8.1 Sept. 19, 1985 as a possible indicator of interaction between tectonic plates

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Abstract

The recent development of the Lithosphere–Atmosphere–Ionosphere (LAI) coupling model and experimental data of remote sensing satellites on thermal anomalies before major strong earthquakes have demonstrated that radon emanations in the area of earthquake preparation can produce variations of the air temperature and relative humidity. Specific repeating pattern of humidity and air temperature variations was revealed as a result of analysis of the meteorological data for several tens of strong earthquakes all over the world. The main physical process responsible for the observed variations is the latent heat release due to water vapor condensation on ions produced as a result of air ionization by energetic α-particles emitted by ^{222}Rn. The high effectiveness of this process was proved by the laboratory and field experiments; hence the specific variations of air humidity and temperature can be used as indicator of radon variations before earthquakes.

We analyzed the historical meteorological data all over the Mexico around the time of one of the most destructive earthquakes (Michoacan earthquake M8.1) that affected the Mexico City on September 19, 1985. Several distinct zones of specific variations of the air temperature and relative humidity were revealed that may indicate the different character of radon variations in different parts of Mexico before the Michoacan earthquake. The most interesting result on the specific variations of atmosphere parameters was obtained at Baja California region close to the border of Cocos and Rivera tectonic plates. This result demonstrates the possibility of the increased radon variations not only in the vicinity of the earthquake source but also at the border of interacting tectonic plates. Recent results on Thermal InfraRed (TIR) anomalies registered by Meteosat 5 before the Gujarat earthquake M7.9 on 26 of January 2001 supports the idea on the possibility of thermal effects at the border of interacting tectonic plates.

Keywords: Tectonic plate; Radon; Ionization; Thermal anomaly

1. Introduction

Satellite technologies (GPS and InSAR) drastically improved our abilities to detect the tectonic deformations (Zhao et al., 2004; Johansen and Bürgmann, 2005). But they are able to detect only the surface deformations, and do not reflect the processes having place within the Earth's crust. At the same time it is possible to detect the tectonic activity using the indirect methods, for example, the radon activity (King et al., 1993). It was demonstrated that the radon gas geochemistry is a good indicator of the tectonic activity (Toutain and Baubron, 1998).

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Unfortunately, regular radon monitoring data are available only for very few places, so one should look also for the indirect methods of the radon activity monitoring. It was detected recently that there exist high correlation between the radon variations and the air temperature (Garavaglia et al., 2000) and between the radon variations and relative humidity (Prasad et al., 2005). The mechanism of such correlation was developed by Pulinets et al. (2006), and it was demonstrated both for the air temperature and the relative air humidity that means that the air temperature and humidity variations can serve as indicators of the radon activity. Dunajecka and Pulinets (2005) analyzed the meteorological data around the time of several strong earthquakes in Mexico, and confirmed experimentally the theoretical results of Pulinets et al. (2006). They observed the diminishing of the air humidity and increase of the air temperature few days before the strong earthquakes ($M \geq 7$) in Mexico that they interpreted as a result of radon activity. Except the physical mechanism Pulinets et al. (2006) revealed the typical pattern of atmospheric parameters variations before strong earthquakes analyzing the meteorological data around the time of recent major earthquakes (Fig. 1a).

One more confirmation of the connection between the increased tectonic activity, radon, and surface temperature are the results of satellite monitoring of the surface temperature around the time of strong earthquakes (Ouzounov and Freund, 2004; Tronin et al., 2004). The satellite infrared images demonstrate the increased temperature over the structure of active tectonic faults and its dynamics with time. Genzano et al. (2006), analyzing the Meteosat 5 satellite IR images for the time period close to the Gujarat earthquake (M7.9) on 26 of January 2001, detected the thermal anomalies not only within the area of earthquake preparation but also at the border of Eurasian and Indian tectonic plates.

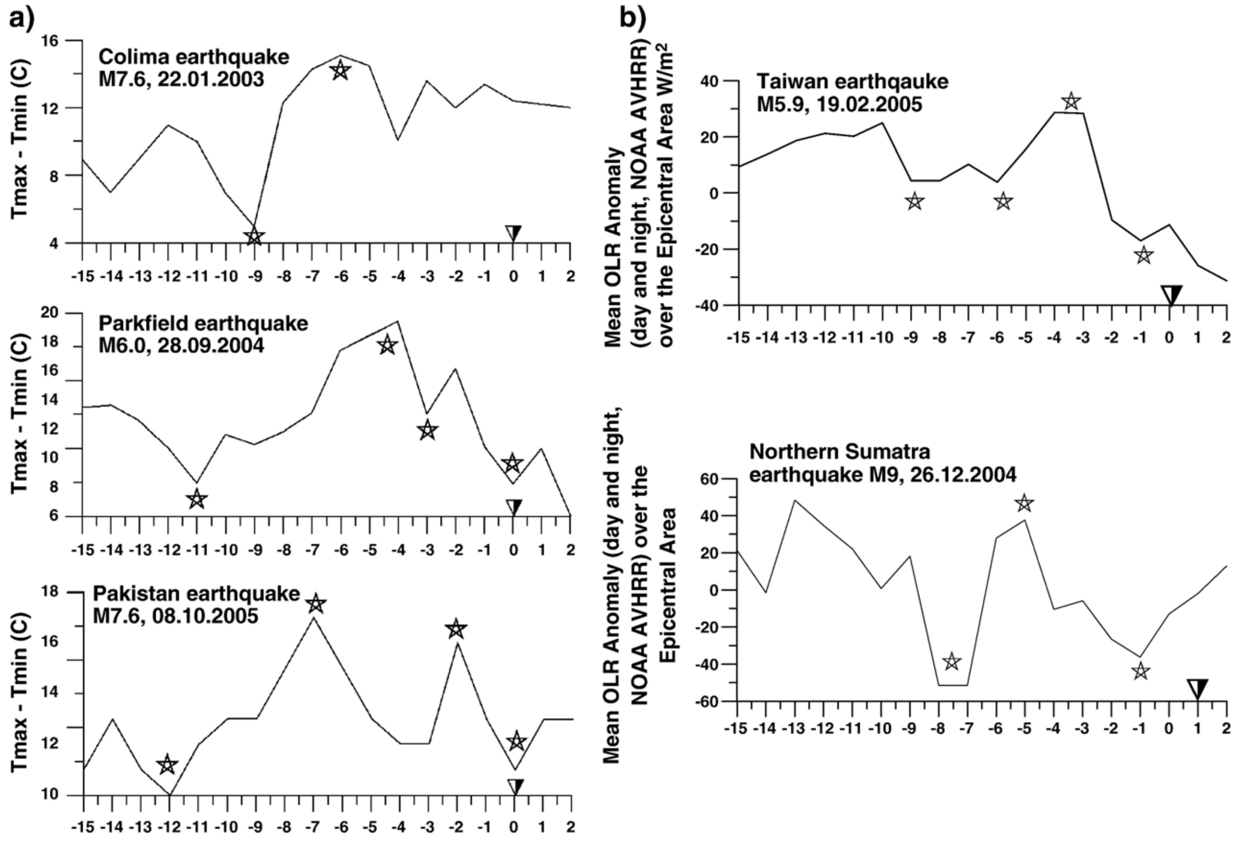

Fig. 1. a) Daily surface air temperature range variations registered close to the epicenters of strong earthquakes. From top to bottom: Colima earthquake M7.6 of 2003, (Mexico); Hector Mine earthquake M7.0 of 1999, (USA); Parkfield earthquake M6 of 2004, (USA). ▼ indicates the earthquake moment, stars indicate the parameters peculiarities which we interpret as precursors phenomena. b) Top panel – variations of Ongoing Longwave Radiation (OLR) over the epicenter of Taiwan earthquake M5.9, Feb. 18, 2005. Bottom panel – the same but for the Sumatra earthquake M9, Dec. 26, 2004. ▼ indicates the earthquake moment, stars indicate main characteristic moments of the range variations before earthquake.

In September of 2005 Mexico commemorated the 20-th anniversary of the tragic consequences of the Michoacan earthquake (M8.1) of September 19, 1985. Different scientific conferences and workshops were devoted to this event. Thereupon we analyzed the atmosphere parameters (relative humidity and air temperature) around the time of Michoacan earthquake to detect the variations possibly related to the increased radon activity before the seismic shock. Results of this analysis were presented at EMSEV International Workshop "Frontiers of Seismo-Volcano Electromagnetics", Puerto Vallarta, November 3–4, 2005, Mexico, and formed the basis of the present paper.

2. Michoacan earthquake of September 19, 1985, and tectonic configuration of the Central Mexico

The Michoacan earthquake of 19 September 1985 was the largest event that has occurred in Mexico since the Great Jalisco earthquake of 1932. It had the magnitude $M_S = 8.1$ and happened at 13:17:47 UTC close to the city Lazaro Cardenas in the point with coordinates 18.19°N and 102.53°W. The earthquake had a very shallow focus close to the trench and caused the tsunami with the wave height near 3 m at Zihuatanejo and 2.8 m at Lazaro Cardenas. The earthquake was followed by major aftershock of 21 September, with magnitude of 7.5, occurred at sea, approximately 100 km SE of the epicenter of the main event. The earthquake affected an area of 185×75 km^2 or approximately 13,875 km^2. Due to seismic wave spectral characteristics, propagation effect and sediment structure of the Mexico valley, it caused extremely strong damage and lot of causalities in Mexico City. According to some sources, the death toll from this earthquake may be as high as 35,000. Four hundred twelve buildings collapsed and another 3124 were seriously damaged in Mexico City. About 60% of the buildings were destroyed at Ciudad Guzman, Jalisco. Damage also occurred in the states of Colima, Guerrero, Mexico, Michoacan, Morelos, parts of Veracruz and in other areas of Jalisco. The earthquake was felt by approximately 20 millions of people.

The tectonic regime of central Mexico is dominated by the ongoing subduction of the Cocos plate beneath

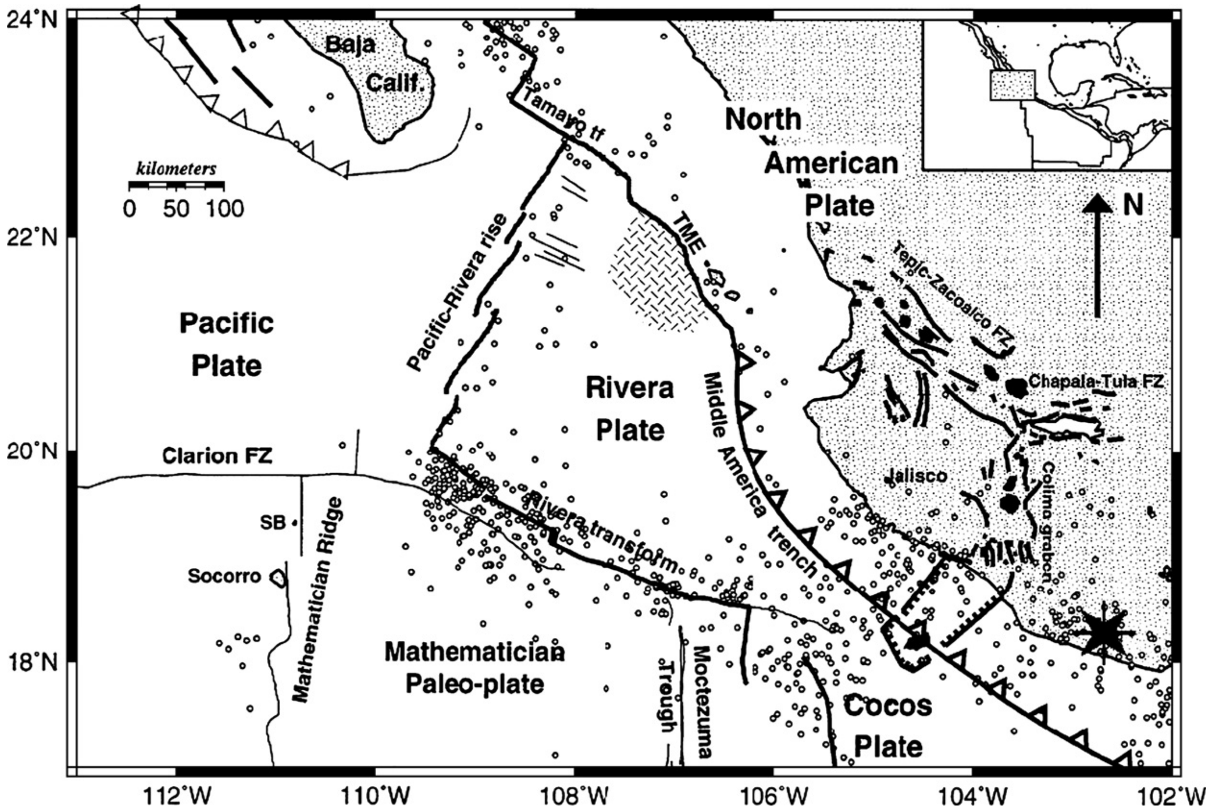

Fig. 2. Main tectonic features in the Rivera plate region (after DeMets and Traylen, 2000). Bold and thin lines represent active and inactive faults, respectively. Open circles show 1967–1999 teleseismically located earthquakes shallower than 60 km. ✶ indicates the position of Michoacan earthquake epicenter. Arrows show the direction of tectonic plates movement. The numbers near arrows show the velocity magnitude in mm/y.

the western margin of the North American plate. The Michoacan block is characterized by gradual decrease of the dip angle of the Cocos plate toward the southeast (Pardo and Suárez, 1995). There is some uncertainties on the northern part of the Cocos plate and the configuration of the border between the Cocos and Rivera plates (Novelo-Casanova, 2005). There is no agreement until now, whether the Rivera plate is independent, or it is a fragment of the Cocos plate (DeMets and Traylen, 2000). The tectonic configuration for the area between the Cocos and Rivera plates is shown in Fig. 2 (after DeMets and Traylen, 2000), the velocity vector values are taken from Bird (2003). One can see two main directions of tectonic movement — the subduction of Rivera and Cocos plates under the North American plate, and perpendicular movement at the border between the Rivera and Pacific plates; it is a spreading zone adjacent to the Baja California Sur peninsula.

3. Physical nature of the atmospheric anomalies connected with radon activity

The observed changes of relative air humidity and air temperature before strong earthquakes can be explained within the frame of the physical mechanism described in (Pulinets and Boyarchuk, 2004), and (Pulinets et al., 2006). The main reason of the observed variations is the air ionization produced by radon decay. It was marked yet in 1973 in the classical paper of Scholz et al. (1973) that radon emanation from the Earth's crust increases before earthquakes. Fig. 3a (Inan, 2005) demonstrates one of the most recent records of the radon flux variation before earthquakes in Turkey. One can see that the duration of the anomalous variations is of the order of 2–3 weeks. The radon flux reaches its peak, and at the falling edge of the observed peak the earthquake happens. We checked the atmospheric parameters for the Bandirma station (the first isolated event shown in

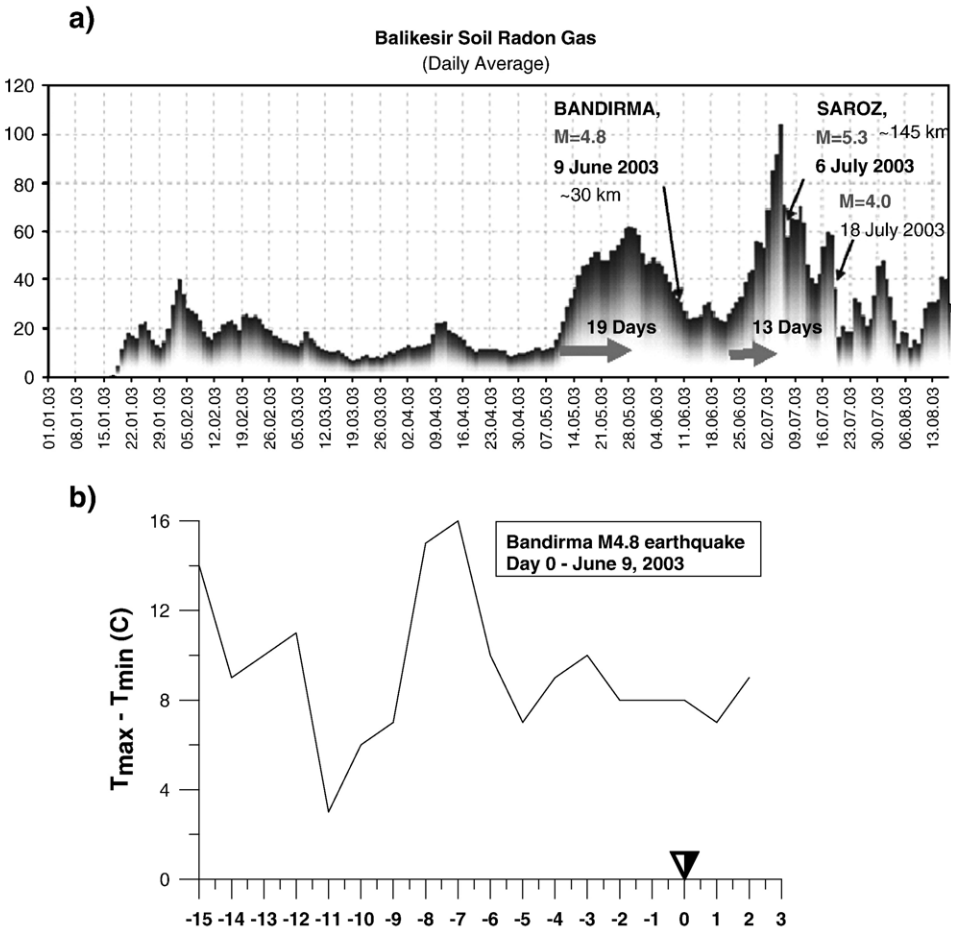

Fig. 3. a) Record of the radon flux close to the active tectonic fault in Marmara region of Turkey (after, Inan, 2005) around the time of several seismic shocks. b) Daily surface air temperature range variations registered at Bandirma station. ∇ indicates the earthquake moment.

Fig. 3a), and the daily temperature range for the time period of Bandirma earthquake is presented in Fig. 3b. One can see that it is very similar to the pattern presented in Fig. 1a.

The ions produced by radon ionization become the centers of water vapor condensation. More precisely, it is not pure condensation but so called hydration of the new formed ions. The hydration process does not need the vapor saturation as it is necessary for pure condensation. But due to the phase state transform of the water molecules from free vapor to be attached to the ions the latent heat of evaporation is released, the same as during the pure condensation. It makes up 2370 kJ/kg under the temperature of 300 K. As a result of condensation the air humidity drops and the temperature grows due to the latent heat of condensation release. After reaching the maximum of radon concentration, with approaching the time of seismic shock the radon flux diminishes, and the atmospheric conditions come to the normal state, what is accompanied by the rise of humidity and temperature drop just before the earthquake. Pulinets et al. (2006) modeled the relative humidity variations around the time of Colima earthquake in Mexico and obtained the quantitative correspondence with the experimental measurements. We should mention also, that every earthquake has its individual properties, so the observed variations should not be completely identical. Sometimes the anomalous radon release continues few days after earthquake (Zafrir et al., 2005), and we may expect the variations of air temperature and humidity associated with radon variations not only before the seismic shock, but also after it.

4. Experimental data and atmospheric parameters variations observed around the time of the Michoacan earthquake

4.1. Data description

The map of meteorological stations which data were processed during the present study is shown in Fig. 4. Due to destructive character of the Michoacan earthquake, the meteorological data for the closest proximity to the epicenter (Lasaro Cardenas city) were not conserved and we use the data from stations with closest proximity to epicenter 100–200 km. The most of the data were available only in the paper (hard copy) format

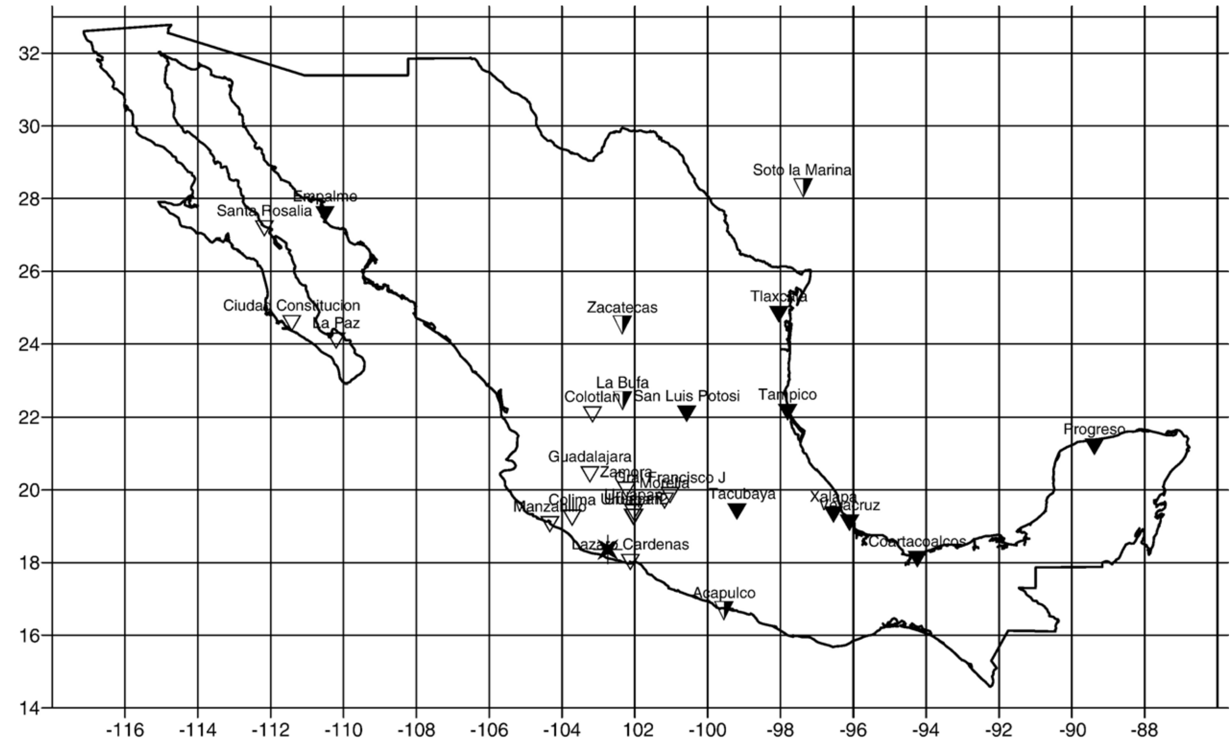

Fig. 4. The map of meteorological stations which data were used for the analysis. ✶ indicates the position of Michoacan earthquake epicenter. ▽ – the stations where observed variations manifest the agreement with "precursory pattern", ▼ – the stations where observed variations are opposite in amplitude, ∇ – the stations where variations are irregular.

and were digitized manually. Some of the data were available from the NOAA archives. Due to difficulties of the data recovery we wouldn't be able to make the statistical data analysis for the long period of observations and analyzed the data only for period of September 1985. To discriminate the variations possibly associated with the earthquake preparation process we used as the sample the pattern of temperature and humidity changes obtained by Pulinets et al. (2006) and Dunajecka and Pulinets (2005). As characteristic parameters we chose the variations of relative humidity and the daily range (difference between the daily temperature maximum and minimum) of the ground air temperature. Examples of the temperature range pattern one can see in Figs. 1a and 3b the characteristic maximum of daily temperature range is observed 1 week–5 days before the seismic shock, and its magnitude is from 16 to 20 °C.

4.2. Different types of atmospheric parameters variations

By the type of the observed variations of ground air temperature and relative humidity the stations can be divided in several groups:

- Two groups of stations which demonstrate so called "precursory behavior" – increase of the temperature range and relative humidity drop few days before the main shock. One group of stations concentrated close

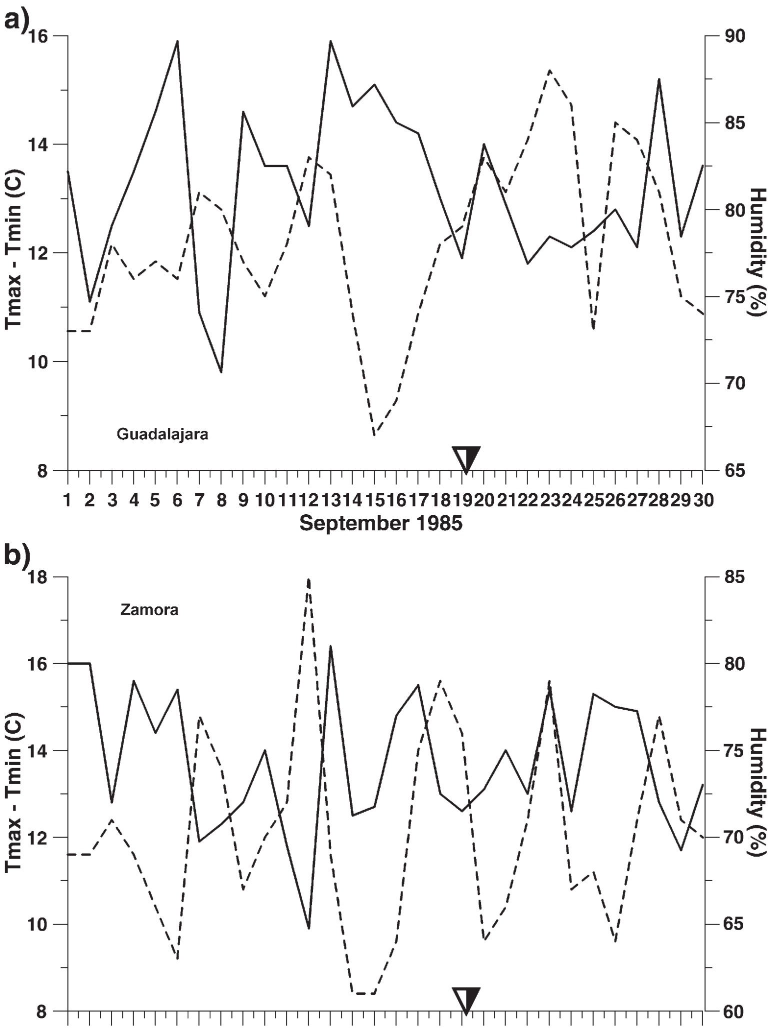

Fig. 5. a) Variations of the daily temperature range (solid line) and relative humidity (dashed line) at Guadalajara for September 1985. b) Variations of the daily temperature range (solid line) and relative humidity (dashed line) at Zamora for September 1985.

to the epicenter, another one – at Baja California (Rivera plate). At the map presented in Fig. 4 these stations are marked by white triangles.

- Stations demonstrating the opposite behavior at the same dates, i.e. decrease of the temperature range and increase of the relative humidity. In Fig. 4 the stations are marked by black triangles.
- Stations with no definite (oscillating character) variations of the same atmospheric parameters. In Fig. 4 the stations are marked by black and white triangles.

It is of special interest to study their spatial distribution over Mexico that probably may explain the tectonic deformations distribution before the Michoacan earthquake.

4.3. Variations close to the epicenter

The closest data we have are from stations to the north from epicenter: Uruapan, Morelia, Gral Francisco J., Zamora, Gudalajara. The seismic shock was so strong that even at these stations the data collection stopped on 19 of September. The only exclusions are Guadalajara and Zamora stations, which data are shown in Fig. 5. The solid line represents the daily range of the air temperature — difference between the maximum and

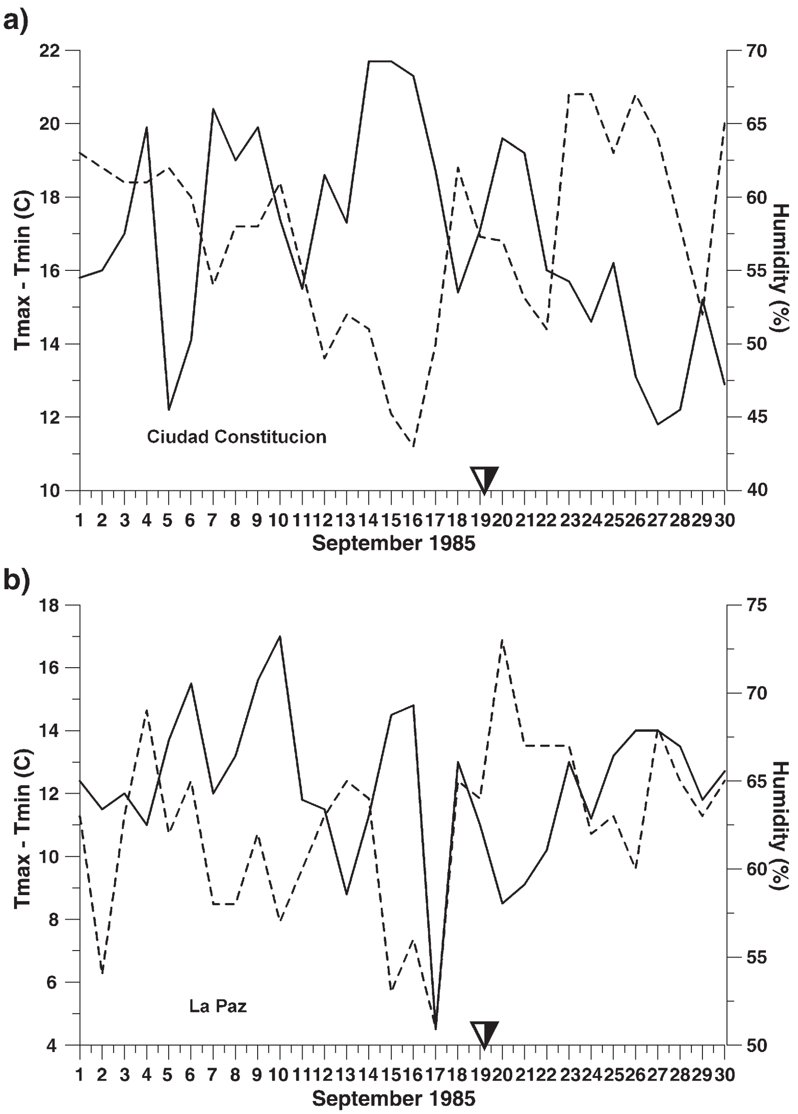

Fig. 6. a) Variations of the daily temperature range (solid line) and relative humidity (dashed line) at Ciudad Constitución for September 1985. b) Variations of the daily temperature range (solid line) and relative humidity (dashed line) at La Paz for September 1985.

minimum temperatures for the given day, and dashed line shows variations of the relative air humidity. The main features observed in the registered variations of atmospheric parameters are the drop of the relative air humidity 14 and 15 of September (the observed value of air humidity is lowest for the whole month of September), and increase of the daily temperature range up to the value near 16 °C. Similar variations are observed for other strong earthquakes in Mexico (Dunajecka and Pulinets, 2005) and in other parts of the world before earthquakes demonstrated both by the ground based measurements, and satellite remote sensing data (Fig. 1, after Pulinets et al., 2006).

4.4. Variations at Baja California Sur

The most interesting fact in the conducted study is that the same type of variations is observed at the distance more than 1000 km from the epicenter, at the Baja California peninsula. We present in Fig. 6 the same parameters as in Fig. 5 but for stations La Paz and Ciudad Constitución. One can see that on days 13–17 of September the monthly minimum of air humidity is observed at both stations, and at Ciudad Constitución the daily range of air temperature reaches almost 22 °C. If to interpret these results in terms of radon activity, one should suppose the high radon activity at Baja

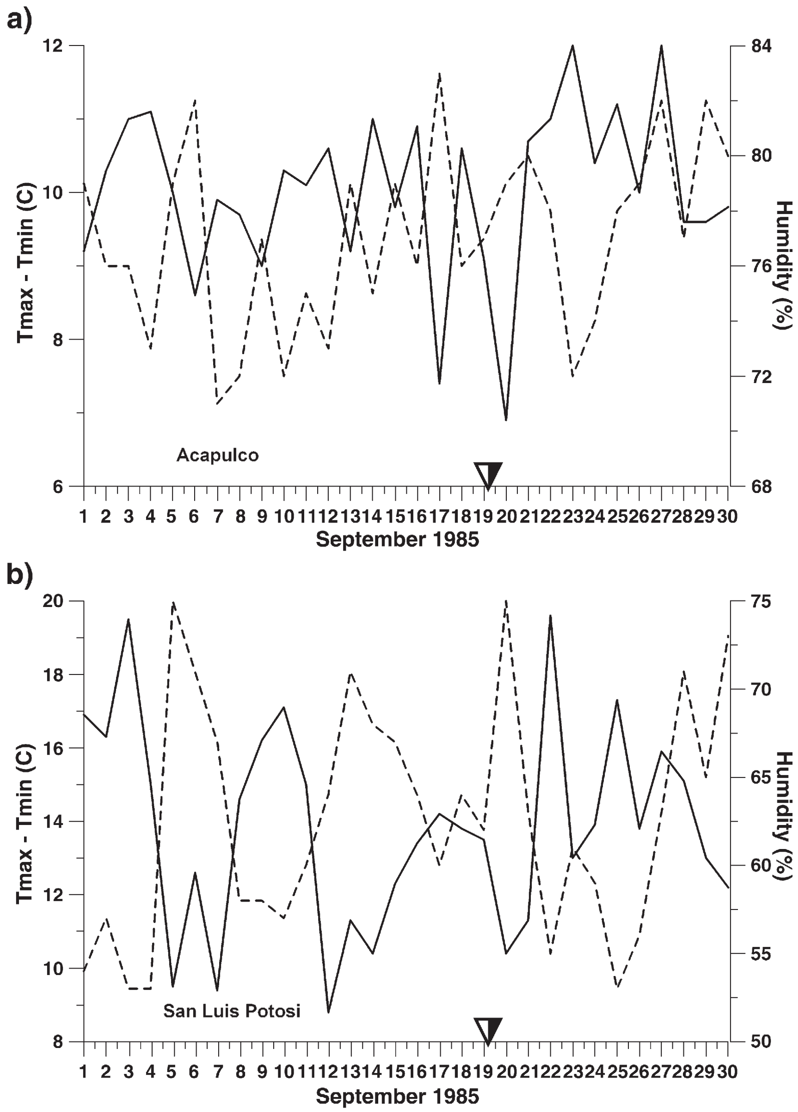

Fig. 7. a) Variations of the daily temperature range (solid line) and relative humidity (dashed line) at Acapulco for September 1985. b) Variations of the daily temperature range (solid line) and relative humidity (dashed line) at San Luis Potosi for September 1985.

California Sur before the Michoacan earthquake. Looking at Fig. 2 one can see that the southern part of the Baja California peninsula is close to the border of the Rivera plate. At this border the spreading deformation is observed.

4.5. The sector structure of the radon variations

Utkin (2000) analyzing the radon distribution around the San Andreas fault at California detected the strong irregularities expressed in the increased and decreased radon concentration in comparison with undisturbed conditions forming the sector structure. The similar picture we observe in distribution of the atmosphere parameters variations. The best illustration that the observed variations are not of the meteorological origin is the opposite in sign variations observed at the stations at very close distances. For example, at Acapulco we observe the gradual increase of relative humidity with the monthly maximum on 17 of September (Fig. 7a). This picture continues to the north, and the opposite variations to those close to epicenter one can see at San Luis Potosi (Fig. 7b). We can state that the longitude 100°W is the border where the humidity variations' sign changes from the negative to positive. All the stations including Veracruz, Xalapa, Tampico, Coartacoalcos, Puerto Pogreso, register increase of the relative humidity and decrease of the daily temperature range before the earthquakes.

5. Discussion

From the point of view of the existing conception of the earthquake preparation area (Dobrovolsky et al., 1979; Toutain and Baubron, 1998) for the earthquake with magnitude 8.1 practically all territory of Mexico is affected by the process of pre-earthquake deformation, so one may expect the radon anomalies associated with this deformation all over the country. The presented results are not the direct measurements but reflect the atmosphere reaction on the air ionization produced by radon. All techniques of the radon registration are indirect and are based mainly on the radioactive properties of radon. The alpha and gamma components of radon decay used for radon measurements, or photo plates — all of them have their own errors and limitations. For example, there are other sources of alpha and gamma particles, such as galactic cosmic rays. In this regard the variations of temperature and humidity associated with air ionization produced by radon can be regarded as one more indicator of radon variations along with traditional ones. Of course, the thermodynamic processes in the Earth's atmosphere are very complex and many other factors should be taken into account but one should keep in mind that in the thermal balance of atmosphere the latent heat comprises 48% in comparison with 43% provided by solar radiation. So any variations of the latent heat should be carefully taken into account. The remote sensing satellites data demonstrate the thermal anomalies for all recent major earthquakes all over the world and provide the strong support for our studies because they visualize the same variations which we observe by the ground based measurements. The large scale of the thermal anomalies observed by remote sensing satellites (Ouzounov and Freund, 2004; Genzano et al., 2006-this issue) confirm our findings on the spatial scale of the radon variations in Mexico around the time of Michoacan earthquake. One of the proxy to the daily temperature range can serve the Ongoing (or in some publications Outgoing) Longwave Radiation (OLR) which is satellite derived measurement of the radiative character of energy radiated from the warmer earth surface to cooler space. It is measured by radiometers installed onboard the polar orbiting and geostationary satellites in wideband (5–200 μm) or narrow bands (8–12 μm) on Terra and Aqua satellites). One can find the details on the OLR measurements technique in Lee et al. (2004); Ouzounov et al. (2007). As one can see in Fig. 1b, the temporal variations of OLR measured by Terra and Aqua satellites around the time of earthquake in Taiwan and mega earthquake of Northern Sumatra on December 26, 2004 are very similar to those of the daily temperature range presented in Figs. 1b and 3b, and the set of figures related to the first group of stations for the period of Michoacan earthquake. The shape and the time scales are practically identical that can be a confirmation of the common physical mechanism.

Increased or diminished radon concentration in comparison with undisturbed conditions produces decrease or increase of the relative air humidity, and as a consequence, the changes in the air temperature behavior. The observed distribution of the air temperature and humidity demonstrates the sector structure in agreement with the Utkin (2000) findings on the radon anomalies distribution before earthquakes. The large magnitude of atmospheric parameters variations registered at Baja California region may serve the possible indicator of increased tectonic activity at the border of Rivera and Pacific tectonic plates before the Michoacan earthquake.

6. Conclusion

The present paper is the case study of tectonic activity around the time of Michoacan earthquake of September 19, 1985. This study was accomplished to commemorate the 20-th anniversary of this tragic event. It is based on the developed recent theory of Lithosphere–Atmosphere–Ionosphere coupling which proved the possibility of near ground air temperature and humidity modification through the air ionization produced by increased radon emanation before earthquake. The data consideration and processing is based not only on the developed physical mechanism but also on the similarity of the atmospheric parameters variations registered for other earthquakes all over the world including the cases where the direct radon measurements were available. We clearly realize the limitations of the proposed technique. These first steps should be supported by more statistical studies, as well as by the further development of theoretical model. Nevertheless, the common pattern of specific variations of the air temperature and relative humidity obtained for several tens of strong earthquakes all over the world permits to look forward optimistically. The proposed technique could be easily checked by other investigators, what will increase the statistical significance of the obtained results.

The most important conclusion is that the process of earthquake preparation affects much larger territories than that of the seismic source including the different tectonic plates as we see for the Rivera plate border which activity is manifested by the variations observed at Baja California region.

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