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Atmospheric and thermal anomalies observed around the time of strong earthquakes in México

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RESUMEN

La teoría del acoplamiento litosfera-atmósfera-ionosfera enfoca su atención a los procesos que ocurren en la capa de la atmósfera más cercana al suelo. La ionización del aire producida por las emanaciones del radón desde la corteza terrestre inicia una cadena de procesos físico químicos que modifican de manera significativa la composición de las moléculas del aire así como la temperatura y la humedad atmosféricas. Estos cambios, como se ha detectado antes, ocurren en el área de preparación de los temblores fuertes una o dos semanas antes de que estos sucedan. Este trabajo es un intento para rastrear esos cambios utilizando datos meteorológicos obtenidos de estaciones cercanas a los epicentros de temblores fuertes en México (a menos de 200 km). Las anomalías atmosféricas fueron detectadas en intervalos de tiempo largos (varias decenas de años) y entre una y dos semanas antes de la ocurrencia de los temblores. Las variaciones de largo plazo revelan las anomalías para el año del temblor, mientras que las de corto plazo demuestran la dinámica cambiante de la temperatura y la humedad del aire antes de los temblores.

ABSTRACT

Recently developed theory of Lithosphere-Atmosphere-Ionosphere (LAI) coupling pays attention to the processes taking place within the near ground layer of atmosphere. Air ionization produced by radon emanating from the earth's crust launches the chain of physico-chemical processes which change significantly the composition of air molecules, as well as air temperature and humidity. All these changes, as it was detected earlier, take place one-two weeks before strong earthquakes occur within the area of earthquake preparation. The present paper is an attempt to track these changes using meteorological data collected at meteorological stations close to the epicenters (less than 200 km) of strong earthquakes in México. The atmospheric anomalies were detected both on long term intervals (several tens of years) and within one-two weeks before the earthquakes occur. The long term variations reveal the anomaly for the year of earthquake, while the short-term anomalies demonstrate the changing dynamics of air temperature and humidity before the earthquake.

Keywords: Ground surface air temperature, relative humidity, latent heat, precursors.

1. Introduction

The present paper was stimulated by complex studies of effects around the time of Colima M7.8 earthquake on January 22, 2003 (Pulinets *et al*., 2005), as well as by the world's scientific community growing interest in the anomalous variations of the ground surface Thermal Infrared Radiation (TIR) registered by remote sensing satellites before strong earthquakes (Tronin, 1999; Tramutoli *et al*., 2001; Dey and Singh, 2003; Ouzounov and Freund, 2004). Increased infrared emission from the ground surface is measured by remote sensing satellites and is observed within the area of earthquake preparation a few days before the seismic shock. This effect usually was interpreted as the thermal flux deposited from the earth's crust in seismically active areas (Ouzounov *et al*., 2003). But anomalous variations of the surface latent heat flux (SLHF) recently discovered (Dey and Singh, 2003), drastically changed the situation because they involve variations of air humidity which the heat deposit from the crust cannot provide. The problem was resolved by detailed multiparameter analysis around the time of Colima earthquake (Pulinets *et al*., 2005) where the anomalous variations of air temperature and humidity within the period two weeks before the seismic shock were clearly demonstrated. Analysis of meteorological data for several recent earthquakes in California (Pulinets *et al*., 2006) confirmed the results obtained for the Colima earthquake: the sharp variations of air temperature and relative humidity are observed within two weeks-10 days before the seismic shock with increased range of temperature changes (difference between the daily maximum and minimum temperature).

These anomalies leave their trace in historical long term data. Usually the month of earthquake stands out against the background of data for the same month but for other years within the interval of several tens of years. This effect was first marked by Mil'kis (1989) and checked by us in the present investigation.

2. Colima earthquake of January 22, 2003

We analyzed the air temperature and relative humidity using the data of meteorological observatories at Colima (19.22 N, 103.7 W) and Manzanillo (19.05 N, 104.32 W). The temperature variations are shown in Figure 1. Colima air temperature data were reduced to the sea level (the linear model was supposed with the gradient of one degree Celsius drop per 600 m of altitude). The increase of daytime air temperature in the epicentral area as well as the difference between the maximum and minimum temperatures one week prior to the earthquake event is found.

The relative humidity has been computed from due point data using the following equations (Sedunov *et al*., 1997):

$$E = 6.11 \cdot 10^{(7.5 \times Tdc \,/\, (237.7+Tdc))} \quad (1)$$

$$Es = 6.11 \cdot 10^{(7.5 \cdot Tc \,/\, (237.7 + Tc))} \quad (2)$$

$$RH\,(\%) = 100(E/Es) \quad (3)$$

where Tc and Tdc are the current temperature and current due point temperature, respectively. The relative humidity is calculated as the relation of vapor pressure and saturated vapor pressure.

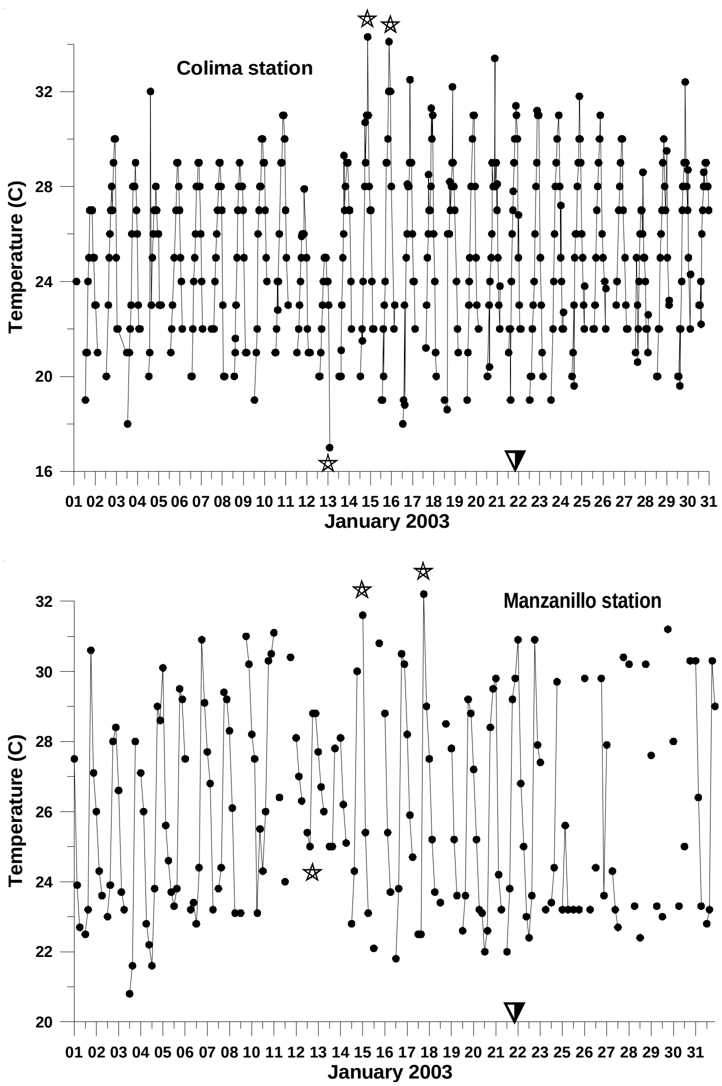

Fig. 1. Top panel: Ground air temperature at Colima station for January 2003. Bottom panel: The same at Manzanillo station. ▼ indicates the earthquake moment, stars indicate the parameters peculiarities, interpreted as precursor phenomena.

Figure 2 shows the variations of relative humidity for both stations. A sharp humidity drop is found at both stations on January 14 and 15, before it shows a background value on the day of earthquake of January 21, 2003. The relative humidity drop, lower than 50% for the station near the coast (Manzanillo), is very unusual. The observed increase of temperature and relative humidity drop is found to be local since relative humidity at Cuernavaca (18.92 N, 99.25 W), which is at the same latitude but 5 degrees to the East (Fig. 3), does not show any significant variations prior to the earthquake, except an increase in temperature immediately after earthquake that may be the thermal

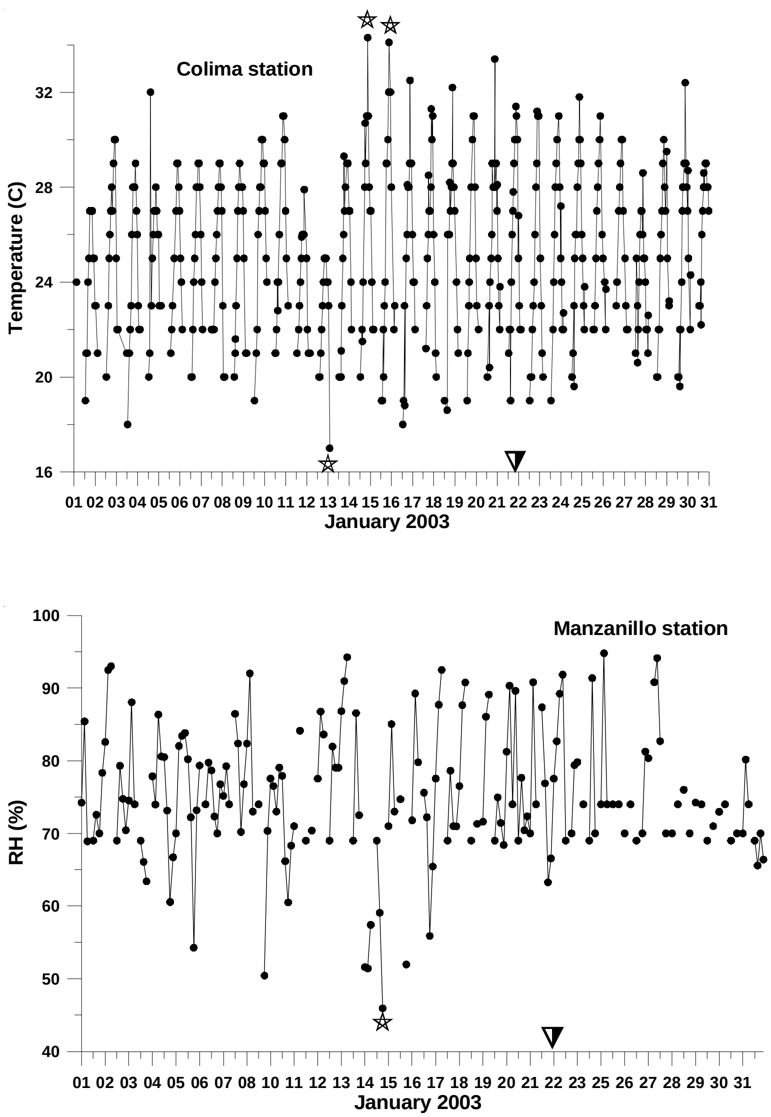

Fig. 2. Top panel: Relative humidity at Colima station for January 2003. Bottom panel: The same at Manzanillo station. ∇ indicates the earthquake moment, stars indicate the parameters peculiarities, interpreted as precursor phenomena.

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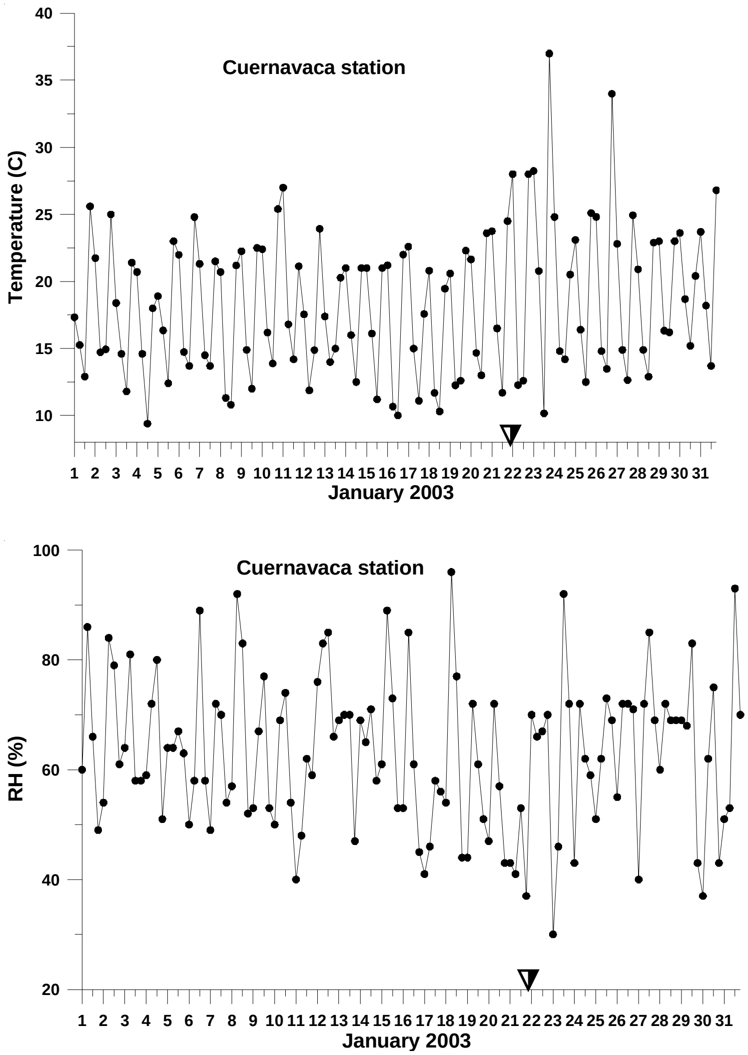


Fig. 3. Top panel: Ground air temperature at Cuernvaca station for January 2003. Bottom panel: Relative humidity at Cuernvaca station for January 2003. ▼ indicates the earthquake moment.

wave propagating from the epicenter area. The local anomaly of the thermal effect is also clearly seen in Figure 4, where the maximum daily temperature distribution over México on January 14, 2003, is shown using data from all country automatic meteorological observatories. Taking into account the altitude relief of México, the temperature measurements were reduced to the sea level. The maximum temperature anomaly is found over the epicenter of the impending earthquake, which is found to be elongated along the active tectonic fault. To demonstrate that the obtained temperature distribution is really anomalous, we built another map for the same local time 1400LT but for February 1, 2003 (Fig. 5). It demonstrates a completely different distribution with a normal gradient of temperature from North to South without structures aligned along the tectonic trench.

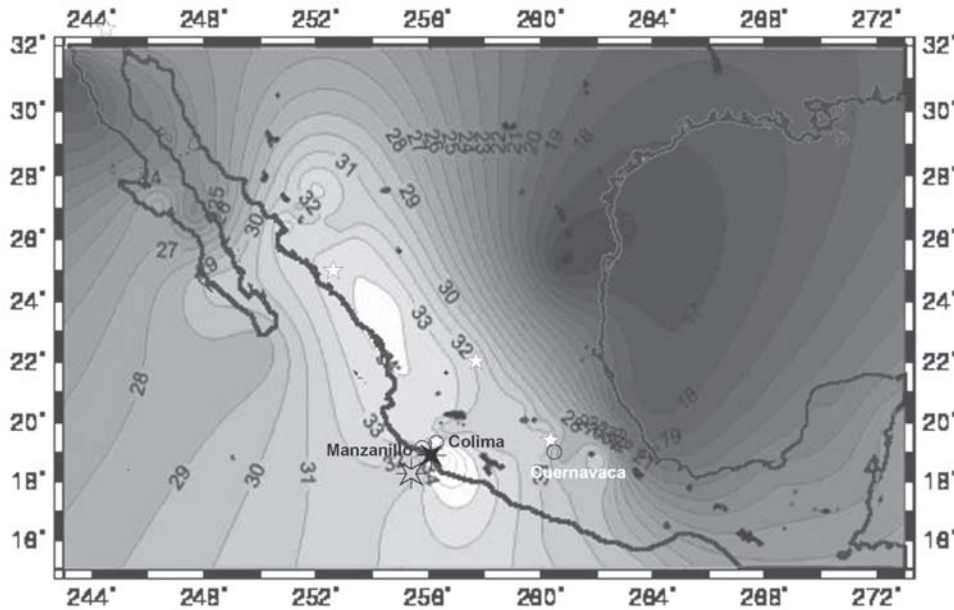


Fig. 4. Map of surface air temperature in México on January 14, 2003, at 1410 LT, reduced to the sea surface level. Stars indicate positions of INEGI GPS receivers; symbol ✶ epicenter positions determined by NSGS and SSN; circles show positions of meteorological stations at Manzanillo, Colima and Cuernavaca.

From Manzanillo data (bottom panel of Fig. 2) one can see the sharp increase of relative humidity reaching its maximum on January 18, 3 days before the seismic shock. These variations should be accompanied by changes of the surface latent heat flux, which were calculated by Dey and Singh (2003) for the case of Colima earthquake. Our data are in perfect agreement with the data of Dey and Singh (2003) who demonstrated the maximum of SLHF anomaly just on January 18 (Fig. 6).

3. Colima earthquake of January 30, 1973

It is interesting to compare the results of Colima earthquake of 2003 with another one, which happened very close 18.412 N, 103.019 W, had the same magnitude M7.6 and took place also in January, but in 1973. Unfortunately, from the historical data we were able to find only the daily maximum and minimum temperatures and relative humidity. The data are presented in Figure 7. The daily maximum and minimum temperatures are plotted in Figure 7a. One can see the sharp drop of the minimum temperature on January 21 (9 days before the seismic shock) similar to the temperature drop observed at Colima station in 2003 (Fig. 1) on January 14 (7 days before the shock). The process is accompanied by the continuous growth of the daily temperature range (Fig. 7b) which reaches its monthly maximum one day before the seismic shock simultaneously with the

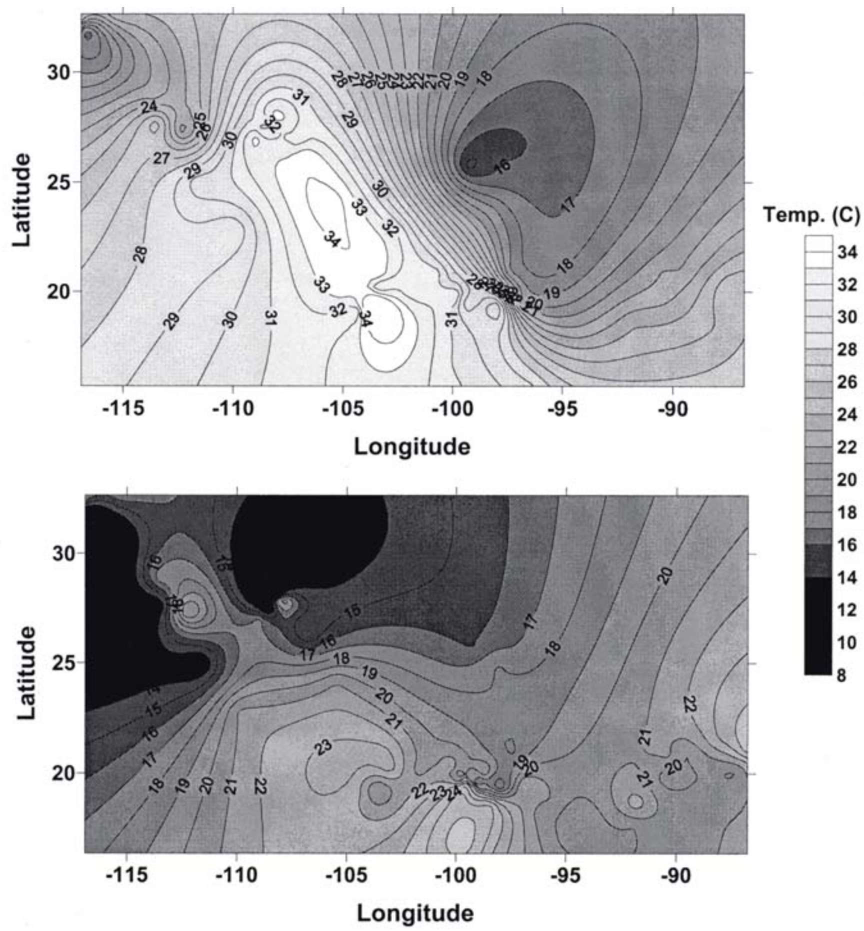


Fig. 5. Surface air temperature distribution over México. Top panel: at 1400 LT on January 14, 2003. Bottom panel: at 1400 LT on February, 1 2003. Both maps were prepared at the same temperature scale, shown at right.

monthly minimum of relative humidity (Fig. 7c). The similarity of the processes in 2003 and 1973 is noticeable, with the only difference that the humidity minimum in 2003 was reached much earlier before the seismic shock (7 days) in comparison with 1973 (one day).

4. Manzanillo earthquake of October 9, 1995

The period around the time of occurrence of the Manzanillo 1995 earthquake was very complex because in September-October 1994 the Pacific coast of México was very active. The Manzanillo earthquake was the strongest one from the series of earthquakes along the Pacific coast of México:

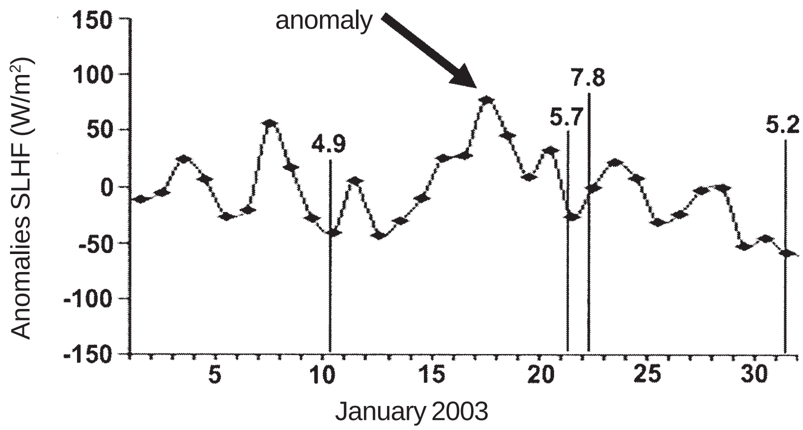
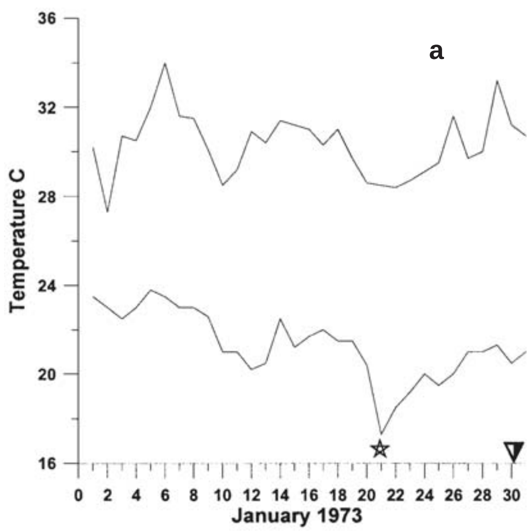
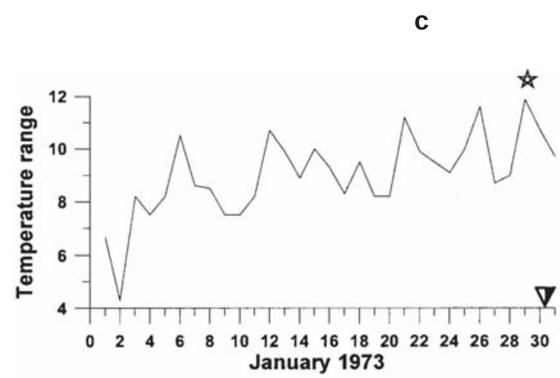


Fig. 6. Anomalous latent heat flux over Colima earthquake epicenter derived from the satellite remote sensing data for January 2003. The numbers over the curve indicate the magnitude of main shock, foreshocks and aftershocks of the Colima earthquake.





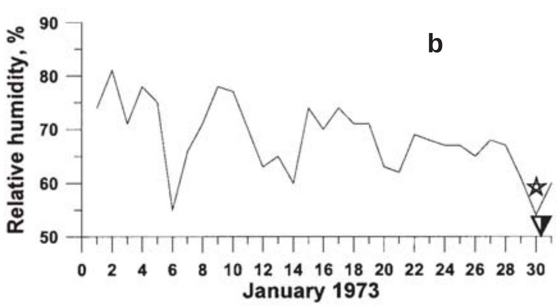


Fig. 7. a) Maximum and minimum daily temperatures at Manzanillo for January 1973, b) temperature range at Manzanillo for January 1973, c) relative humidity at Manzanillo for January 1973. ▼ indicates the earthquake moment, stars indicate the parameters peculiarities, interpreted as precursor phenomena.

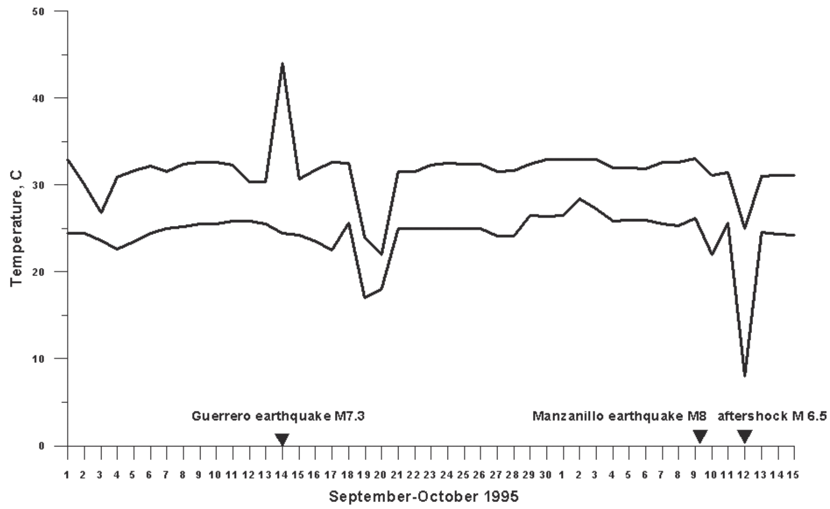


Fig. 8. Daily maximum and minimum temperatures at Manzanillo for September-October 1995. Triangles indicate the main seismic shocks.

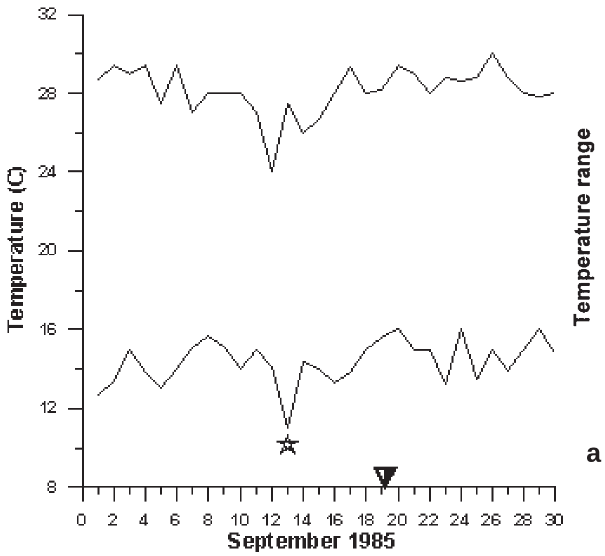
Guerrero earthquake M7.3 of September 14; Manzanillo earthquake M8 of October 9; Manzanillo aftershock M6 of October 12; Chiapas earthquake M7.1 of October 21, and Baja California earthquake M6.5 of October 23. So it is very difficult to consider the Manzanillo earthquake of 1995 as an isolated event. Looking at Figure 8, where the maximum and minimum temperatures at Manzanillo are shown, one can clearly see the interrelation of events between the Guerrero earthquake and the Manzanillo earthquakes. Incredible (probably historical) extremes were reached during September-October at Manzanillo: 44 °C maximum temperature on September 14 and 8 °C minimum daily temperature on October 12.

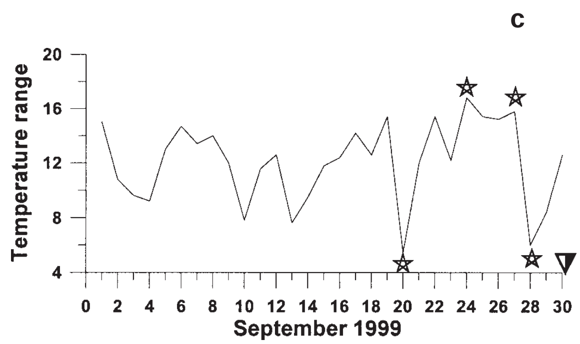
5. Michoacán earthquake of September 19, 1985

In modern history of México the Michoacán earthquake is probably the most tragic event from the point of view of its consequences. For this event we were able to find the data of Zamora station (19.97 N, 102.27 W) which is nearly 150 km from epicenter of Michoacán earthquake. The data presented in Figure 9 are very similar to the Colima 2003 event, with almost the same temporal characteristics. The sharp temperature changes started one week before the seismic shock with a maximum range of 6 days before the shock, and minimum humidity at the same time. Then humidity sharply grew to the date of earthquake manifesting the changes in surface latent heat flux.

6. Oaxaca earthquake September 30, 1999

The data of Oaxaca earthquake M7.5 on 30 of September 1999 completely support the previous





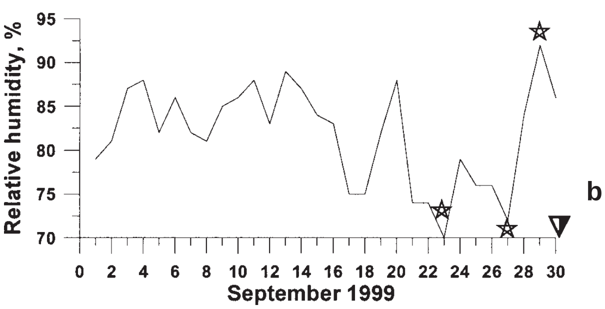
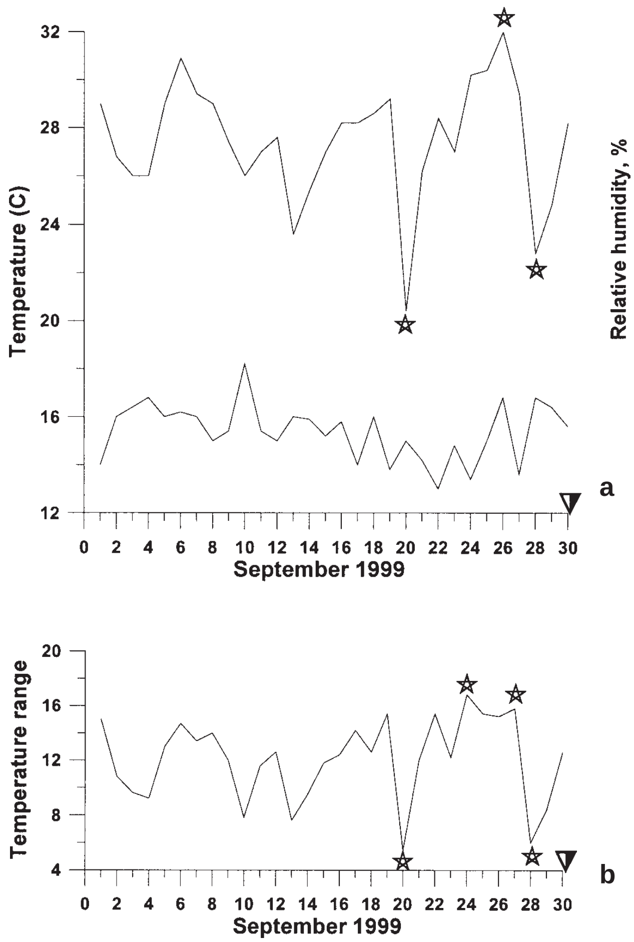


Fig. 9. a) Maximum and minimum daily temperatures at Zamora for September 1985, b) temperature range at Zamora for September 1985, c) relative humidity at Zamora for September 1985. ▼ indicates the earthquake moment, stars indicate the parameters peculiarities, interpreted as precursor phenomena.

results (see Fig. 10). One can see again the start of the temperature anomaly 10 days before the seismic shock, reaching the range maximum 6 days before the shock, and humidity minimum one week before the shock. And again, the humidity growth up to the date of earthquake.

The similarity of atmospheric parameters variations before strong earthquakes is explained by the fact that they have the common 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. Figure 11 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 in the order of 2-3 weeks. The radon flux reaches its peak, and at the falling edge of the observed peak the earthquake occurs.



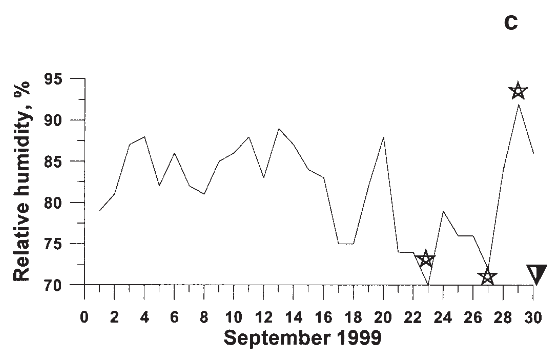


Fig. 10. a) Maximum and minimum daily temperatures at Oaxaca for September 1999, b) temperature range at Oaxaca for September 1999, c) relative humidity at Oaxaca for September 1999. ▼ indicates the earthquake moment, stars indicate the parameters peculiarities, interpreted as precursor phenomena.

The ions produced by radon ionization become the centers of water vapor condensation. As a result of condensation the air humidity drops and the temperature grows due to the latent heat of condensation release. This is what we observe in the meteorological data –drop of humidity and temperature rise. When the time of seismic shock approaches, 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 and obtained the quantitative correspondence with the experimental measurements. We also should mention 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 atmospheric anomalies not only before the seismic shock, but also after it, as it is seen in Figure 8.

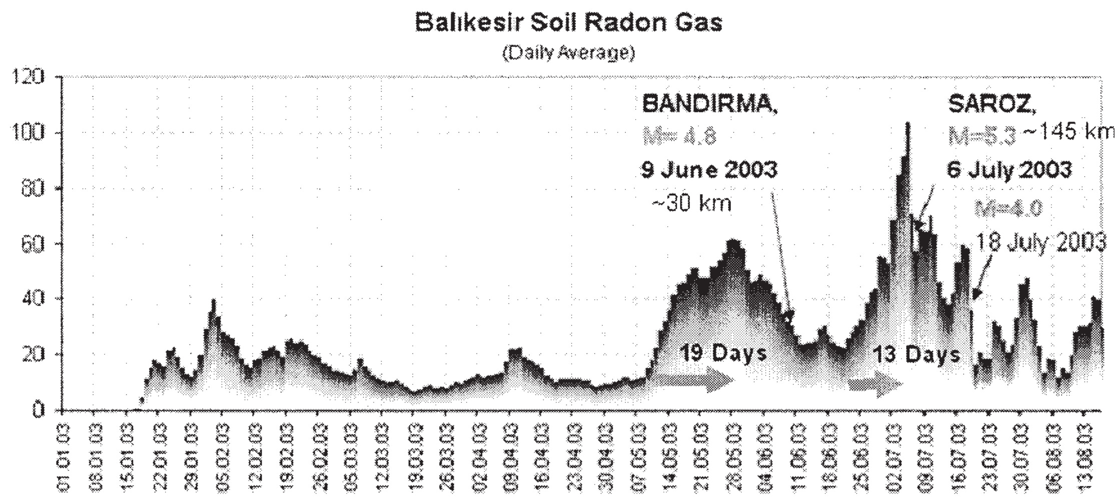


Fig. 11. Record of the radom flux close to the active tectonic fault in the Marmara region of Turkey around the time of several seismic shocks (after Inan, 2005).

7. Conclusions

The analysis of meteorological data (air temperature and relative humidity) for several strong earthquakes in México revealed the common features of atmosphere anomalies observed before earthquakes. These anomalies are expressed in the form of sharp changes of ground air temperature and relative humidity approximately one week before the seismic shock. These changes are accompanied by the increasing of temperature range (difference between daily maximum and minimum temperatures), and variations of relative humidity in the form of a humidity drop several days before earthquake, and then a growth up to the date of earthquake.

The more detailed analysis for Colima earthquake demonstrated the observed anomalies have local character. This conclusion confirms the earlier results obtained for several earthquakes all over the world by analysis of the topside sounding data (Pulinets and Legen'ka, 2004) and by remote sensing technique (Ouzounov and Pulinets, 2005). Mapping procedure using the groundbased and remote sensing satellite measurements demonstrated the position of atmospheric anomaly close to the epicenter of impending earthquake. The relative humidity growth observed by ground observatories can be measured by remote sensing satellites as the anomalous Surface Latent Heat Flux (SLHF). The observed anomalies are explained within the frame of the model proposed by Pulinets and Boyarchuk (2004), and Pulinets *et al*. (2006).

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