

# First results of the new type of measurements of atmospheric electric field in Mexico

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## ABSTRACT

Atmospheric electric field is one of the most important parameters of our environment giving information on the not only processes in the boundary layer of atmosphere but even in the ionosphere and magnetosphere of the Earth, solar wind, and also underground. It consists of the fields of different spatial scales (from tens of meters up to the global scale) and different origins, so one of the principle tasks of the electric field measurements is our ability to distinguish between the different sources of the measured electric field. The new type of the electric field sensor – rotating dipole was installed in different sites in Mexico: Institute of Geophysics, Mexico City, Coyuca and Zihuatanejo (Guerrero state) at the Pacific coast of Mexico. The regular measurements were started at the end of April of 2005. The paper presents the device description and the first results of electric field measurements including the attempts of their interpretation.

## INTRODUCTION

Atmospheric electric field is the part of the global electric circuit (Bering III et al., 1998) and is generated by the thunderstorm discharges creating the potential difference between the ground and ionosphere at the fair weather regions of order of 260 - 280 kV (Price, 2002). This field is directed down and in normal conditions in the pure air its intensity close to the ground surface is of order of 100-200 V/m. There exists the classical paradigm of the global electric circuit (Roble and Tzur 1986). But recent studies have demonstrated that the picture is not so clear as it seemed at the end of the 1980s (Bering III et al. 1998).

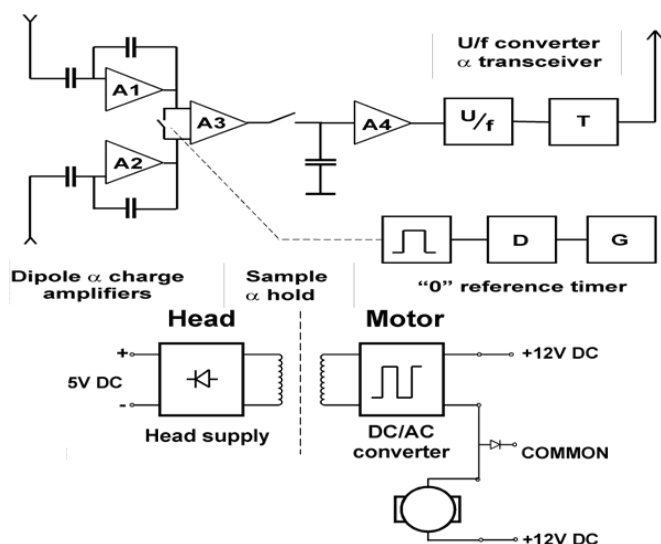


Fig.1 Upper panel – block diagram of the sensor's electronics. Lower panel – the electrical and mechanical components of the electric field sensor.

For example, small scale structures and pulsation of the atmospheric electric field are observed (Anisimov and Mareev, 2003).

Nevertheless the atmospheric electric field is one of the diagnostic tools for many applications. If the time resolution of the electric field measurements is sufficiently high, it is possible to study the number, intensity and polarity of the thunderstorm discharges what is very important for the further improvement of the global electric circuit model (Fullekrug, 2004) and for practical applications in lightning hazard warning

(Montanya et al., 2004). The increase of the atmospheric electric field in fair weather conditions is one of the indicators of aerosols presence in the atmosphere or the air pollution in general.

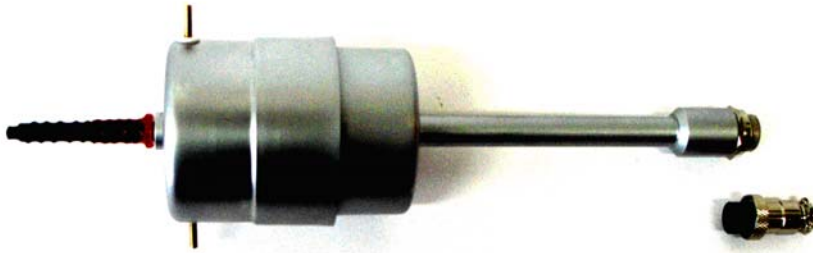


Fig. 2 External view of the electric field sensor of rotating dipole type.

It means that the electric field measurements may be a good indicator of air pollution (Sheftel et al., 1994) what is important for megapolis like Mexico city. The radioactive pollution can also be detected by the electric field measurements

(Boyarchuk et al., 1997). There are many indications on the strong variations of atmospheric electric field before earthquakes in the area of earthquake preparation (Rulenko, 2000, Smirnov, 2005) as well as during strong magnetic storms (Anisimov and Mareev, 2003). From the atmospheric electric field measurements in polar regions it is possible to derive the parameters of the solar wind (Michnowski et al., 2003). Even simply from enumeration of the sources of the atmospheric electric field variations it is clear that the problem of their separation is very complex. The purpose of the present paper is the analysis of the first results of the atmospheric electric field measurements in Mexico using the new technique of rotating dipole from the point of view of the identification of the electric field variations sources.

## ROTATING DIPOLE ELECTRIC FIELD SENSOR

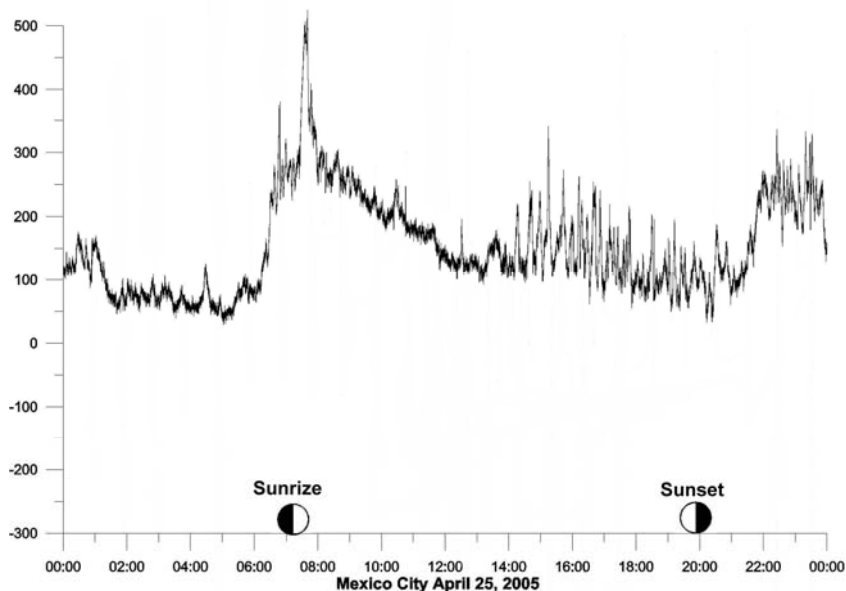


Fig. 3 Atmospheric electric field record on April 25 of 2005 made at Ciudad Universitaria, Mexico City

The electric field intensity sensor consists from couple of short conductive bars being the part of cylindrical rotor. Atmospheric electric field induces the surface charge on all conductive surfaces including the dipole bars. The surface charge density fulfils the formula:

$$\sigma = \varepsilon \cdot E$$

where:  $\sigma$  - surface charge density  
 $\varepsilon$  - dielectric constant of atmosphere

Figure1, and the photo of the device is presented in Figure 2.

Block diagram of the sensor head is shown in

The rotary motion of the dipole is forced by electric DC brushless motor with approx. 3000 RPM. Due to dipole rotation the boundary electric field on the bars surfaces as well as induced charges are alternated. The electric charge induced on both dipole bars is processed into voltage in charge amplifiers A1 and A2 respectively. The AC components of both voltages are transmitted to the input of the differential amplifier A3. The output voltage of the amplifier is proportional to the electric field intensity.

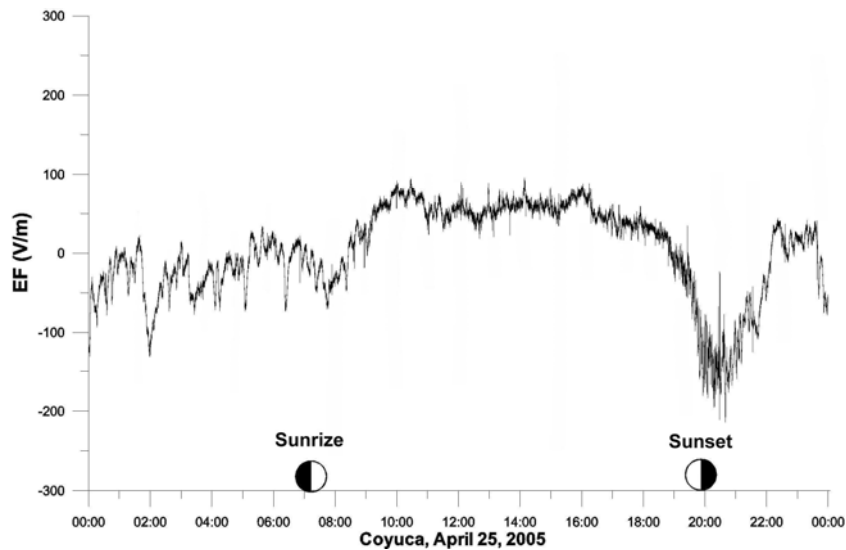


Fig. 4 Atmospheric electric field record on April 25 of 2005 made at Coyuca, State of Guerrero, Mexico

value of electric field in direction specified and output voltage of A4 follows the electric field variation. In the voltage – frequency converter (U/f) this voltage is precisely processed into pulses in frequency range from 5 kHz to 15 kHz.

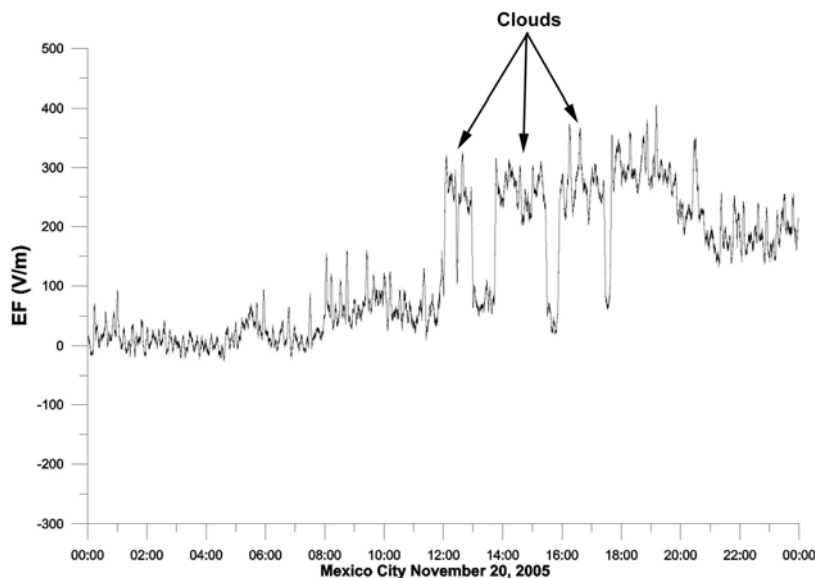


Fig. 5 Atmospheric electric field record on November 20 of 2005 made at Ciudad Universitaria, Mexico City

ADC card PCI-DAS08 of Measurement Computing was used with the SoftWire software of the same company.

Because of dipole bars rotation, the output voltage of A3 amplifier is alternating. In order to measure the electric field along the chosen direction, sampling of this voltage is necessary. Hence the sample & hold amplifier A4 is applied. Moments of sampling are correlated with the distinguished dipole position. The stepping voltage process in sample & hold amplifier is triggered by optocoupler pulses. Thus, samples represent the current

This frequency modulated signal is transmitted by the telemetry transmitter to the receiver. So the data are wireless transmitted what is the significant advantage to diminish the interferences. Two different frequencies (433.92 MHz or 916.5 MHz) for data transmission permit to use two field meters simultaneously at the same place. For the measurements presented in the paper the sampling frequency was 1 Hz, and for data acquisition the

## FAIR WEATHER ELECTRIC FIELD MEASUREMENTS

Figures 2 and 3 present the examples of electric field measurements on 25 of April 2005 at Mexico City and Coyuca (State of Guerrero) for the fair weather conditions.

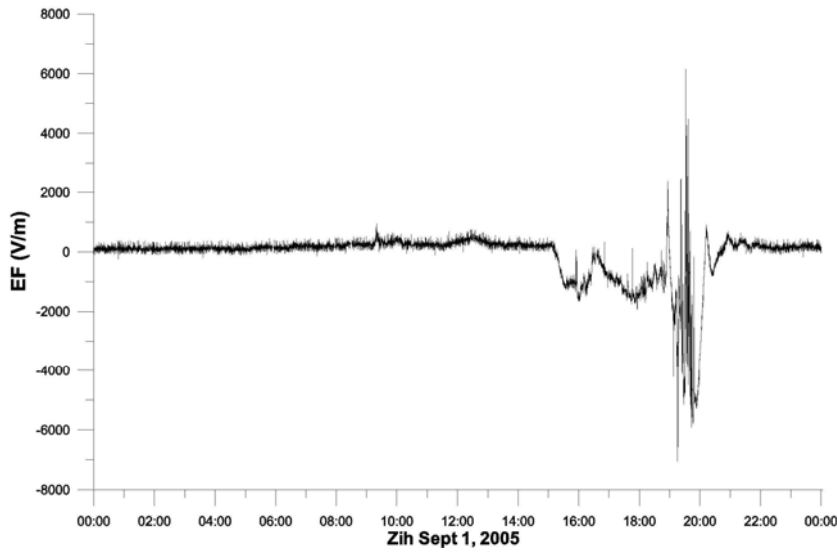


Fig. 6 Atmospheric electric field record on September 01 of 2005 made at Zihuatanejo, State of Guerrero

The difference between the Mexico city and Coyuca records is due to different humidity regimes at the elevated land site (Mexico city) and the Pacific coast (Coyuca). Variations associated with the sunrise and sunset are characteristic for all sites. Their amplitude varies from day to day but usually some variation of the atmospheric electric field at terminator time is observed. During the daytime the electric field at both stations is near 100 V/m.

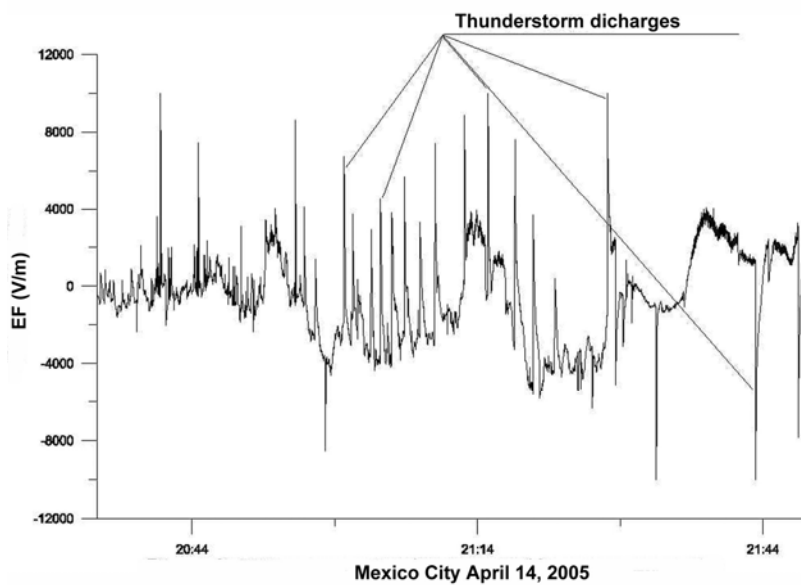


Fig. 7 Thunderstorm discharges registered at Mexico City (Ciudad Universitaria) on April 14, 2005

several electric field sensors close one to another.

One can see the common feature at both graphs – the deviation of the electric field during sunrise and sunset. These deviations are probably connected with the relative humidity changes (dew and fog), and in general with evaporation and condensation process which changes the spatial electric charge, and consequently the local electric field (Anisimov et al., 2005).

One can also observe the quasi-periodic variations of the electric field during afternoon hours at Mexico City. It is difficult to discriminate the spatial and temporal variations with only one sensor, but most probably the observed variations are associated with the small-scale electrical structures in the boundary layer reported in the literature (Anisimov et al., 1999). We will continue our studies of the small-scale structures of atmospheric electric field using the

## CLOUDS AND THUNDERSTORMS

It is well known that clouds are electrically charged what makes contribution in the atmospheric electric field while clouds are passing over the electric field sensor (Williams and Heckman, 1993). Figure 5 presents the clouds passing over the sensor at Mexico City at afternoon hours on 20 of November 2005. One can clearly see that during clouds passing the atmospheric electric field increases up to 300-350 V/m, and when the sky is clear, electric field drops to the background value.

But the thunderstorm clouds have much high electric potential what leads to variations of the electric field up to several tens of kV/m. At Figure 6 one can see the thunderstorm cloud passing over Zihuatanejo (Guerrero state) near 8 PM of the local time. One can see the complex structure of the electric charge of the cloud: the negative field (what corresponds to the positive cloud charge) at the both sides of the cloud, and positive field (what corresponds to the negative electric charge) at the middle of the cloud.

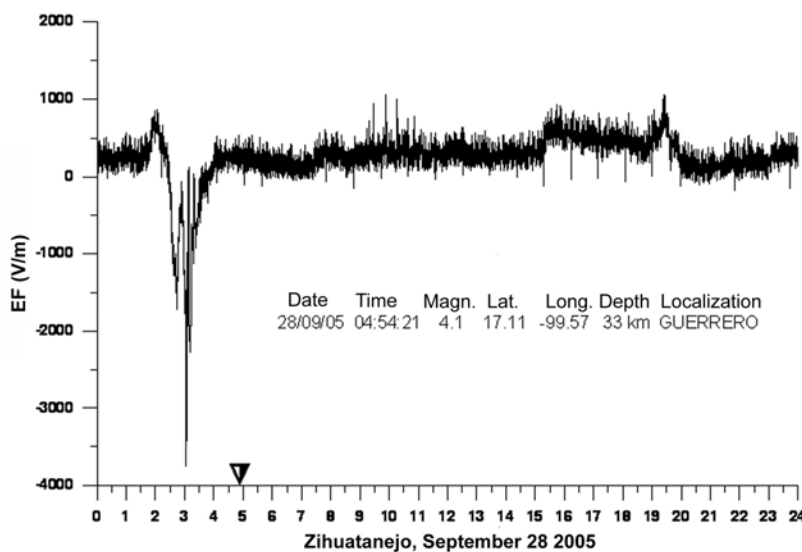


Fig. 8 Negative electric field anomaly registered at Zihuatanejo two hours before the seismic shock of M4.1 at Guerrero State, Mexico.

During a thunderstorm it is possible to observe the thunderstorm discharges, and charge recuperation by the cloud. It is possible to count the number of discharges, and to observe the discharges of both polarities which attributed to the normal (negative type discharges) and opposite (positive type discharges) when the red sprites are generated. Most flashes originate near the lower-negative charge center of the cloud and deliver negative charge to Earth.

However, the minor part of flashes (usually, at the dissipative part of storm) have opposite polarity (Rust et al., 2005). It is clearly seen in Figure 7. The series of positive pulses reflect the normal negative discharges, and at the end of the storm one can see the negative pulses which are the positive-type discharges. It is seen from the figure that the relaxation process after discharge is longer and takes few seconds.

## ANOMALOUS ELECTRIC FIELD POSSIBLY ASSOCIATED WITH EARTHQUAKES

It was reported in literature the anomalous electric field variations around the time of strong earthquakes (Kondo, 1968; Hao et al., 2000; Rulenko, 2000). The mechanism of the anomalous electric field generation is described in (Pulinets and Boyarchuk, 2004). One of the recent publications reports on the negative electric anomalies before strong earthquakes at Kamchatka (Smirnov, 2005).

During the observation period there were no strong ( $M > 5$ ) earthquakes close to the coast of Guerrero where our sensors are installed. Only several seismic shocks with the magnitude  $M > 4$  were registered in Guerrero during the observational period. For one of them we were able to

register the strong negative anomaly of the electric field two hours before the seismic shock  $M=4.1$  at the state of Guerrero (see Figure 8). It is too early to speak on its real association with the seismic event. The statistical studies are necessary. The only comment we can make at present moment that the observed variation is not similar nor to the cloud passing over the sensor, nor to the thunderstorm. At the same time this record is similar to cases reported by Smirnov (2005) when negative electric anomalies were observed around the time of strong earthquakes at Kamchatka.

At the present time we can propose the technology of the seismic-related electric field identification. For the strong seismic events one can expect the large scale electric field (up to several hundreds kilometers in spatial scale, Pulinets and Boyarchuk, 2004). So, the correlated measurements using the several sensors installed on the distance 50-100 km one from another in seismically active area will permit to solve the problem. All field variations associated with clouds have the local character, and can be easily filtered by such spatial correlated measurements, and only the large scale variations will be registered at least by two sensors simultaneously. Such measurements will be the subject of separate paper.

## CONCLUSIONS

We have presented only the preliminary results of atmospheric electric field measurements in Mexico established in 2005. The main goal of the paper is to demonstrate the abilities of the new type of measurements (the rotating dipole) to register the different phenomena in atmospheric electricity. Our goal is the data collection for the longer time intervals to be able to interpret the obtained results with more confidence and statistical confirmation. Nevertheless, at the present moment the parameters of different atmospheric phenomena can be clearly illustrated and estimated.

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