Strong variations of cosmic ray intensity during thunderstorms and associated pulsations of the geomagnetic field

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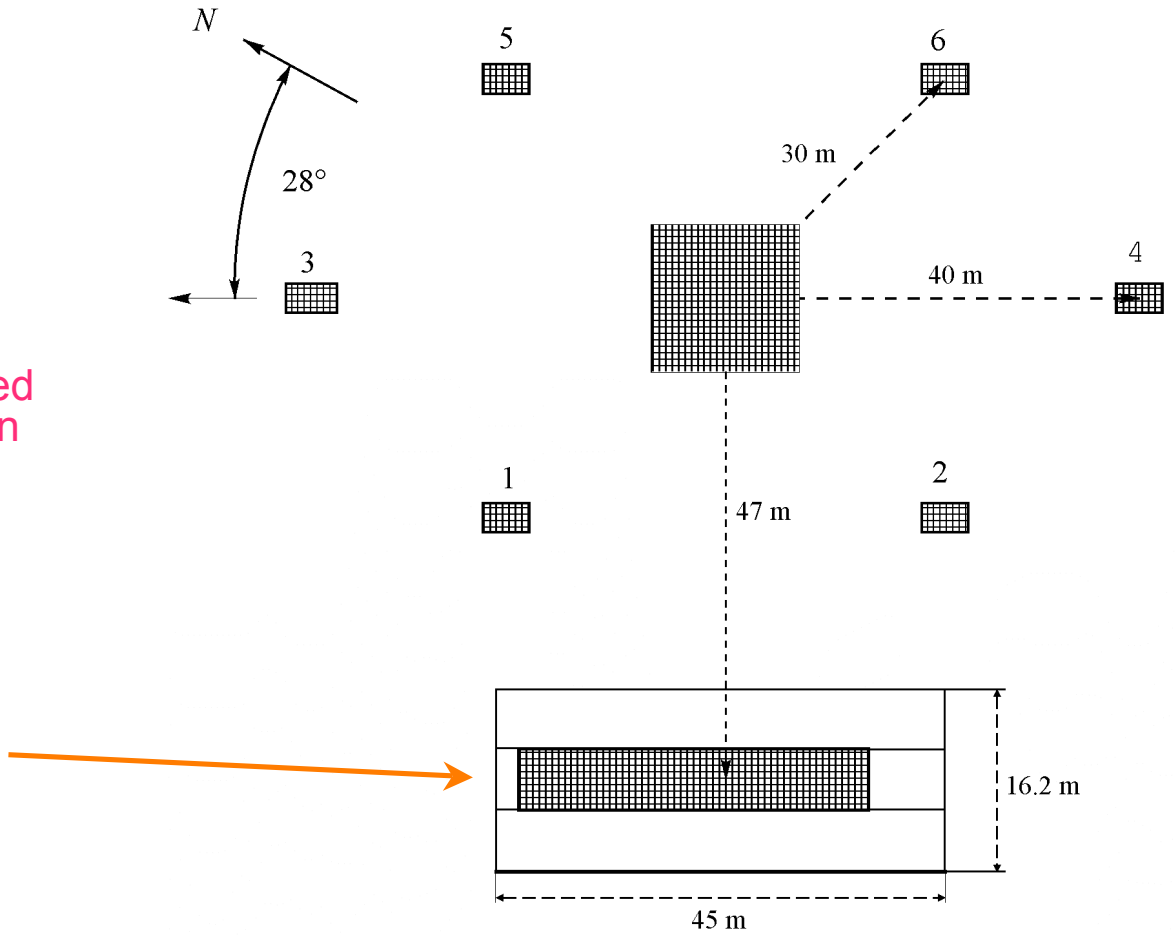
The Carpet Air Shower Array in the Experiment on Studying CR Variations during Thunderstorms

Central Carpet
(400 liquid scintillators)

Six huts
(108 scintillators of the same type at distances of 30 and 40 m from the center)

Meter of electric field and precipitation current is placed on the roof of the building in the array's center

Muon detector
(175 plastic sciltillators under a 2-m overburden of rock).
Energy threshold is 1 GeV.

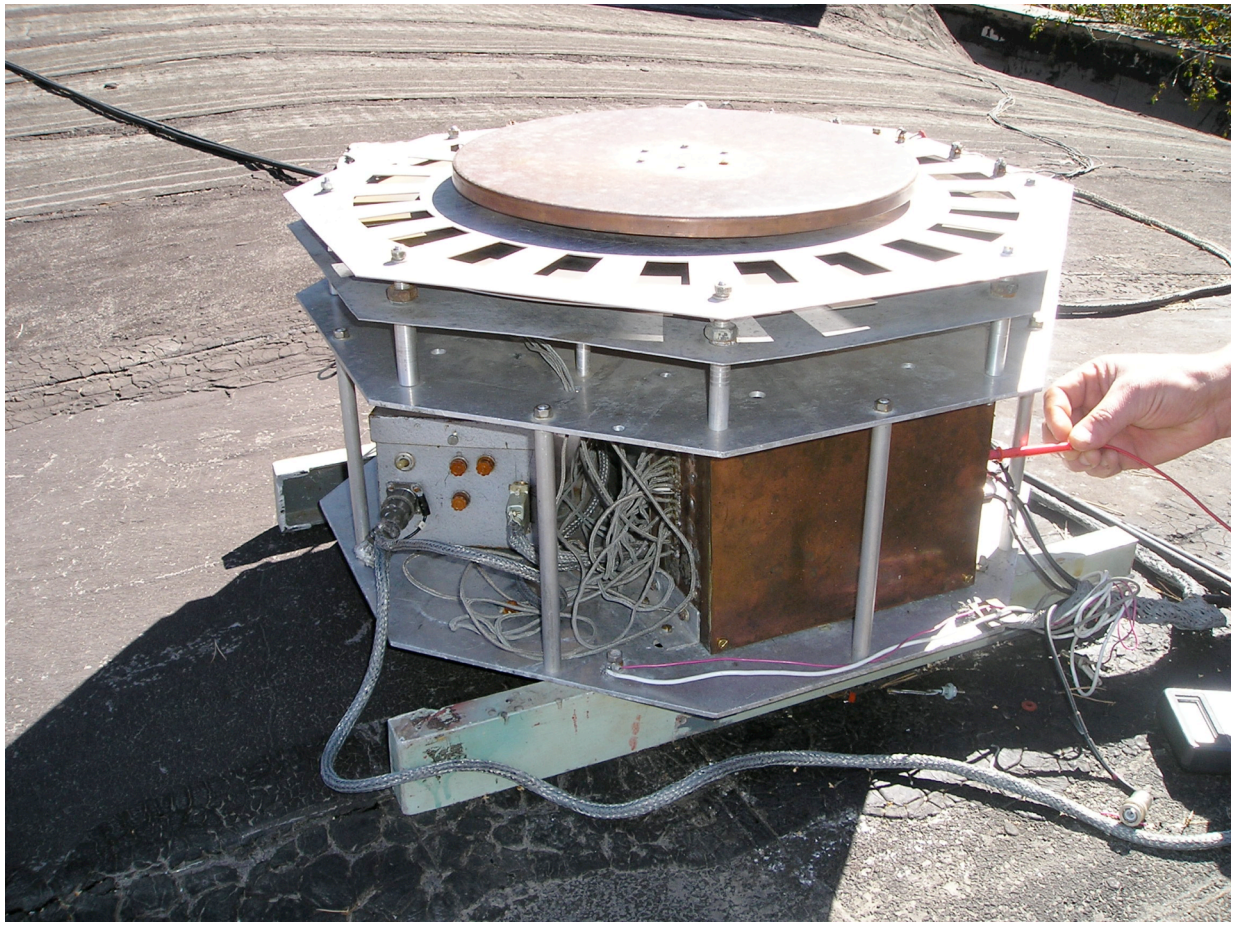


Universal instrument for measuring the near-ground electrostatic field of the atmosphere and precipitation electric current

Measurements of electrostatic and slowly variable field in the range from from -40 kV/m up to +40 kV/m with an accuracy of ~ 10 V/m.

Precipitation electric current is measured in the range from -50 nA/m^2 up to +50 nA/m^2 with an accuracy of ~ 10 pA/m^2.

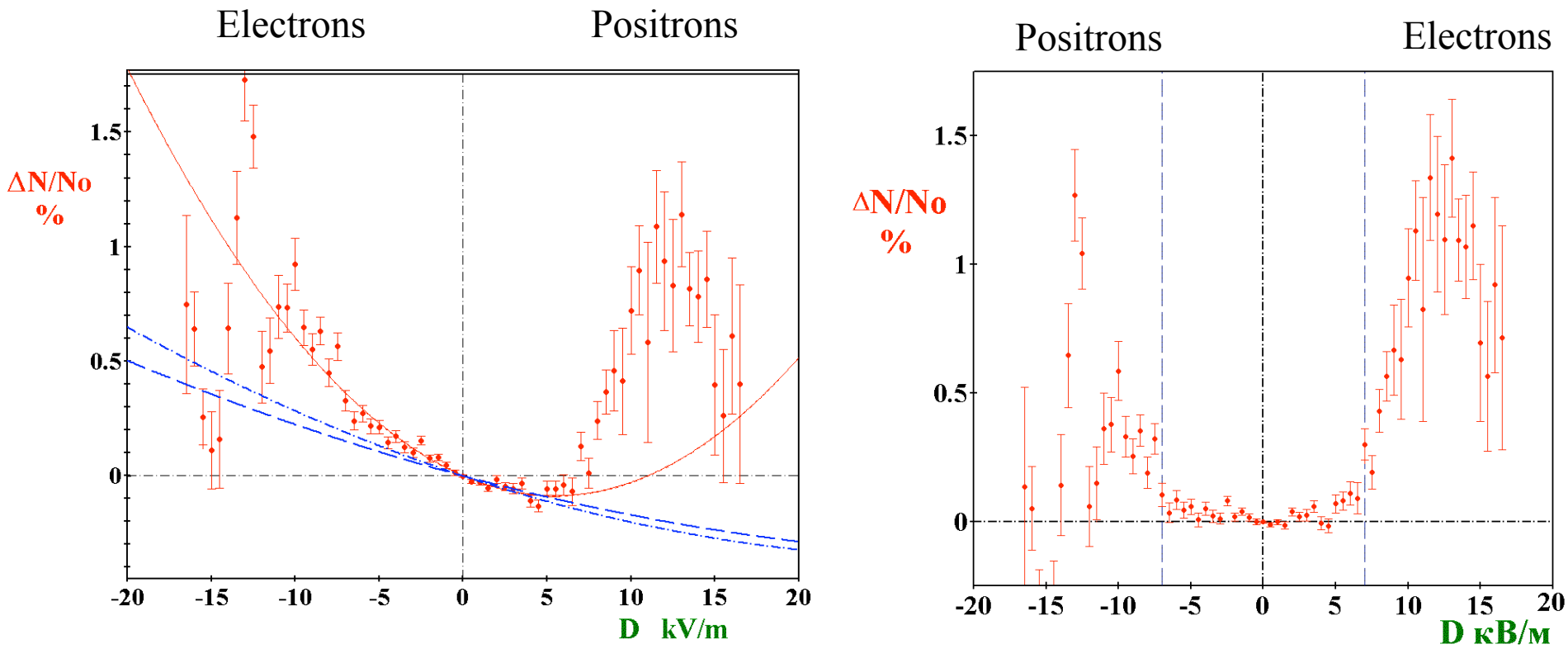
The instrument allows one to measure not only thunderstorm field but also the background (fair weather) electric field by a single method.



Correlation the intensity of soft CR component with near-earth electric field as measured and calculated (on the left panel). The difference (not explained by the spectrum transformation in the field near the ground surface) is shown on the right panel

Accelerated near the ground

Accelerated in the clouds



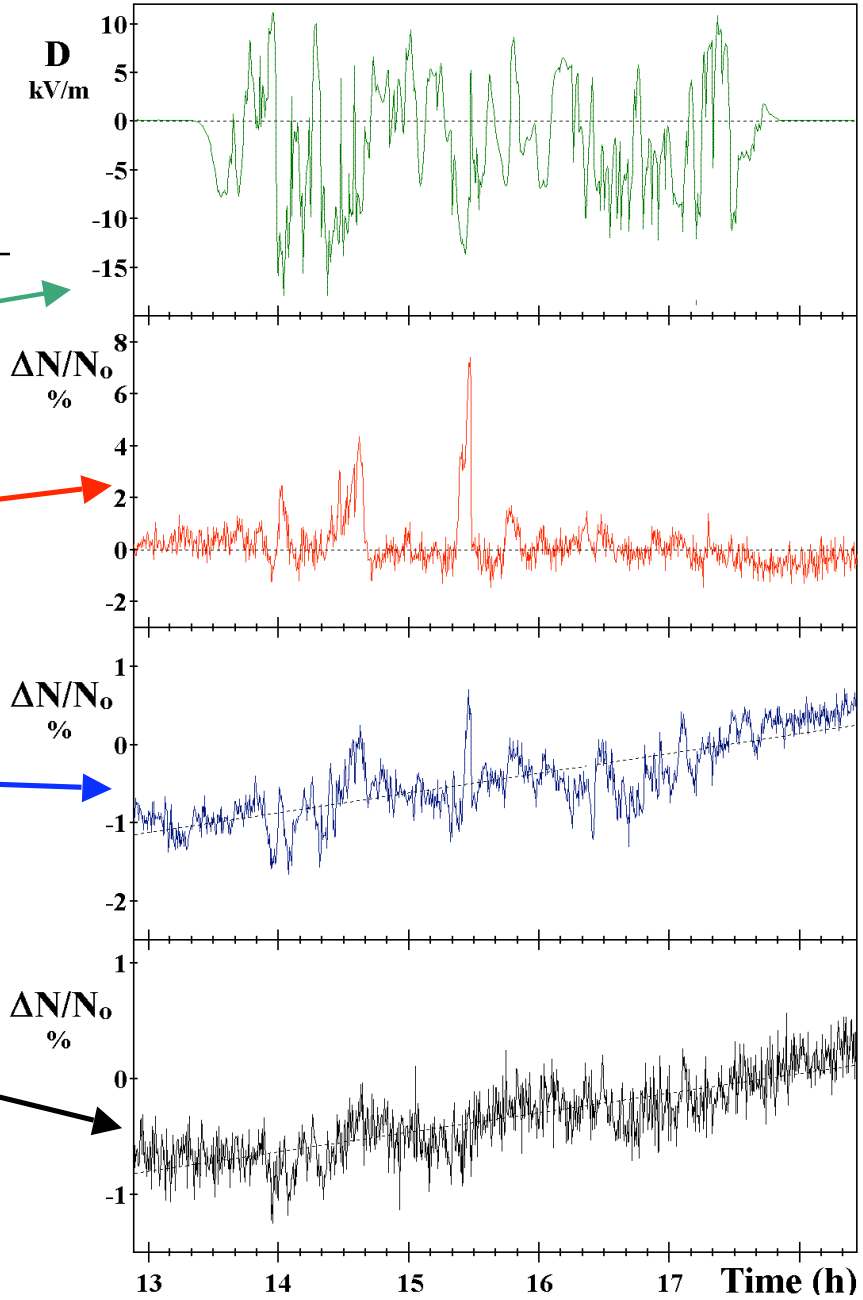
Thunderstorm on Sept 26, 2001, Baksan Valley (North Caucasus)

Electric field

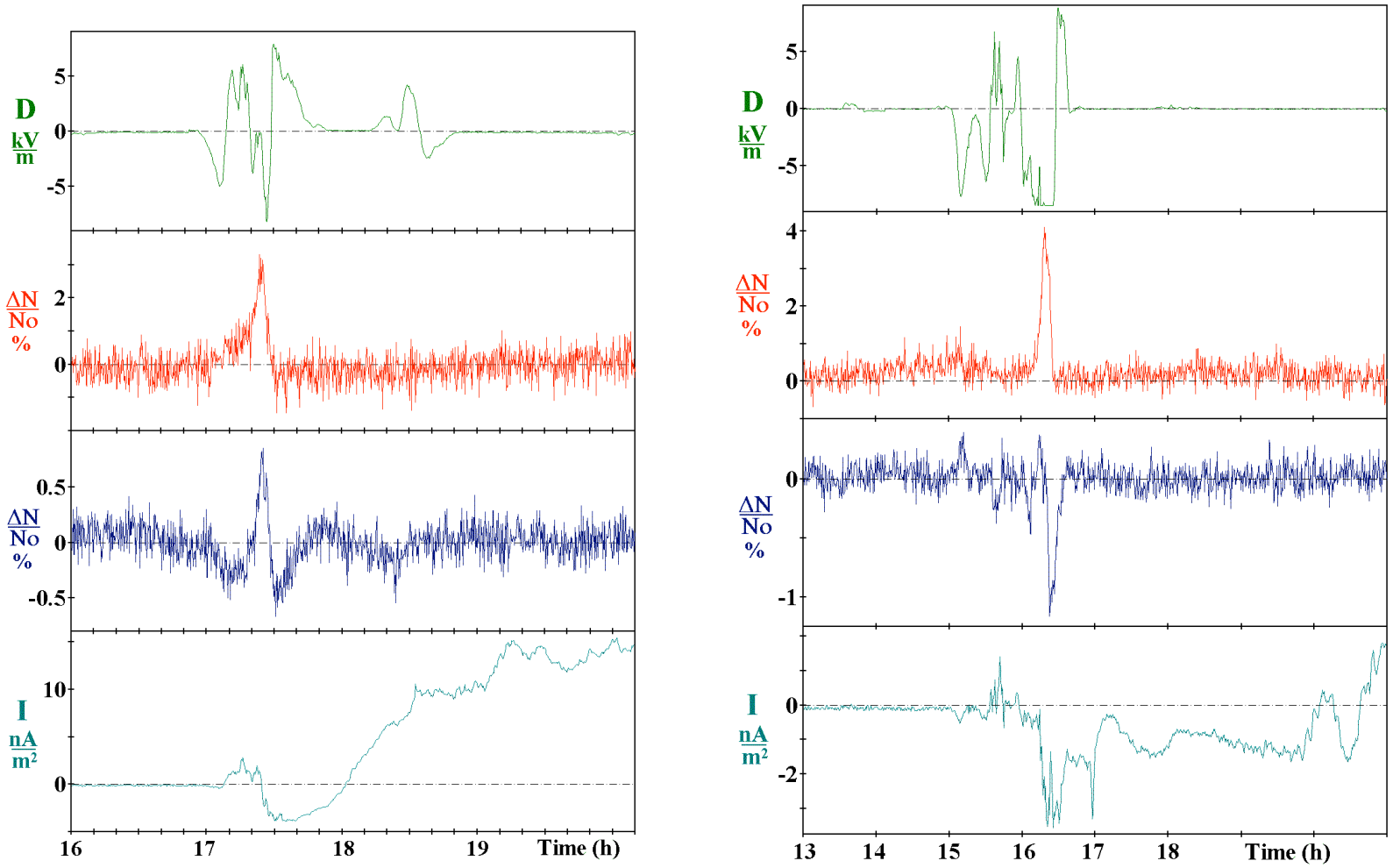
Soft component
(10-30 MeV)

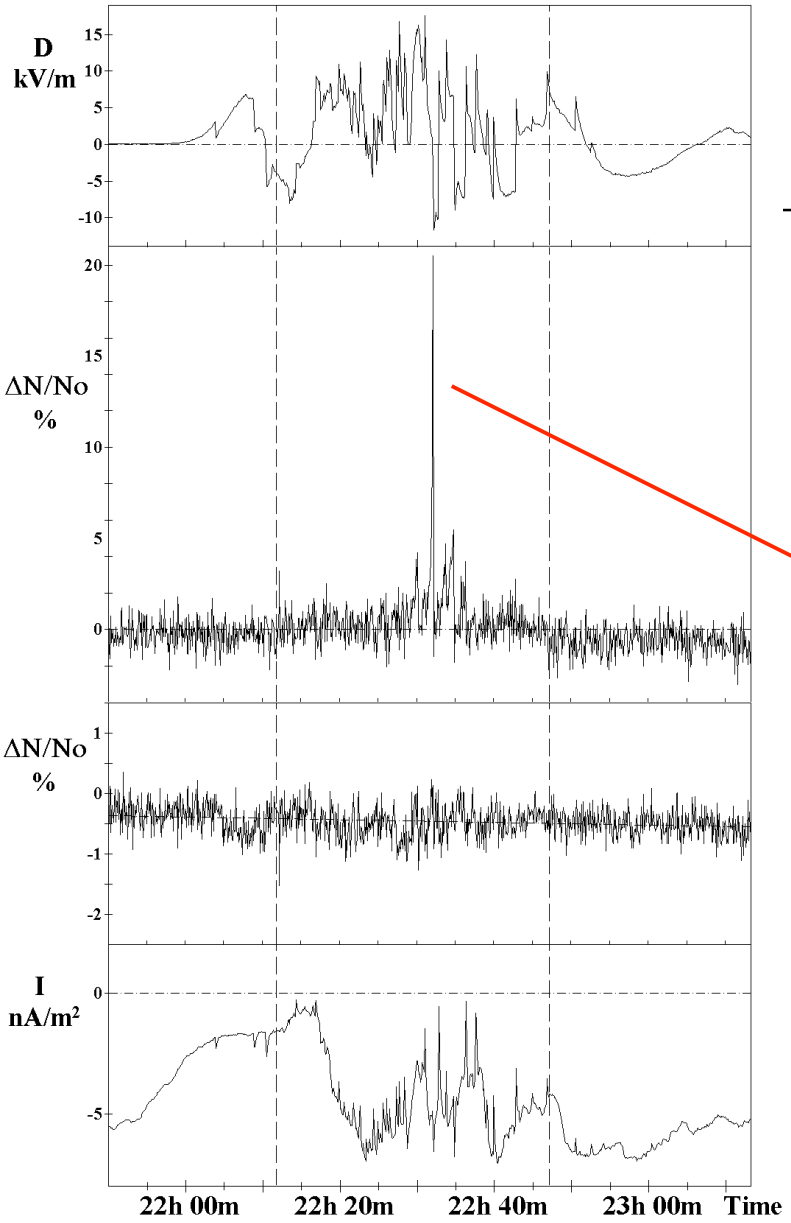
Hard component
(> 100 MeV)

Intensity of muons
(> 1 GeV)



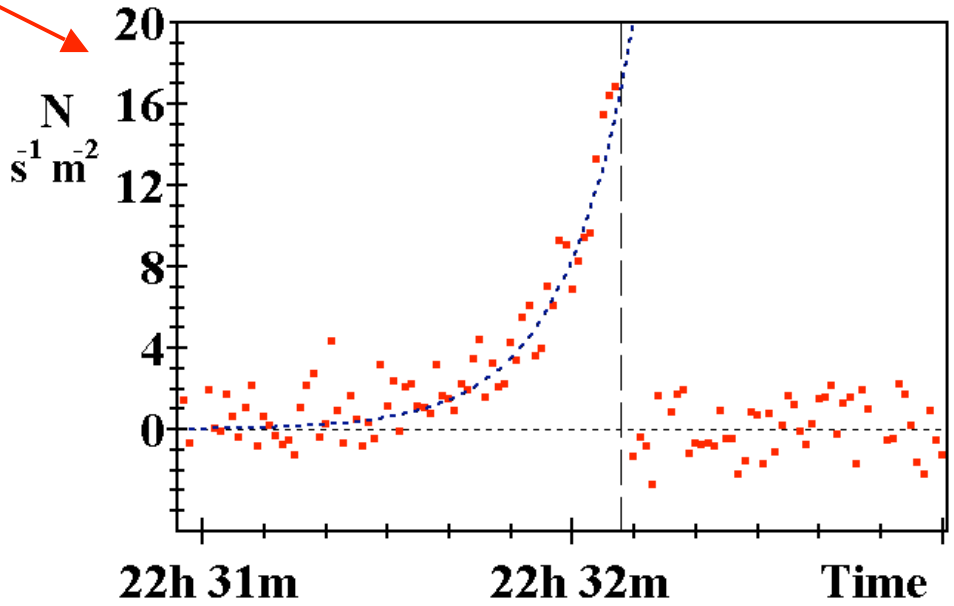
Events on June 18, 2008 (left, averaged over 15 s) and July 18, 2008 (right, averaged over 30 s)





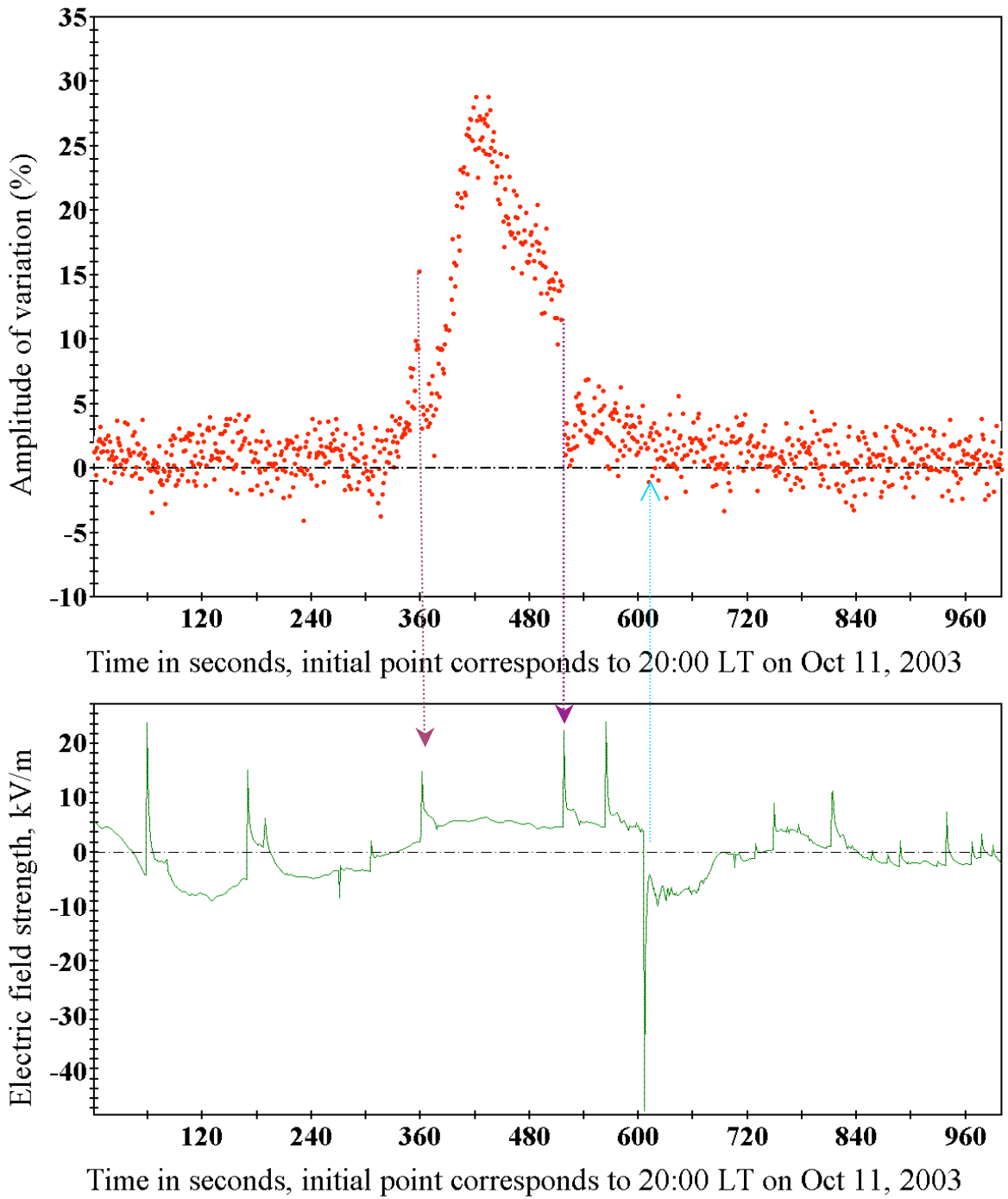
Sept 7, 2000 event

The large increase is exponential with high precision and has an abrupt stop at the instant of lightning

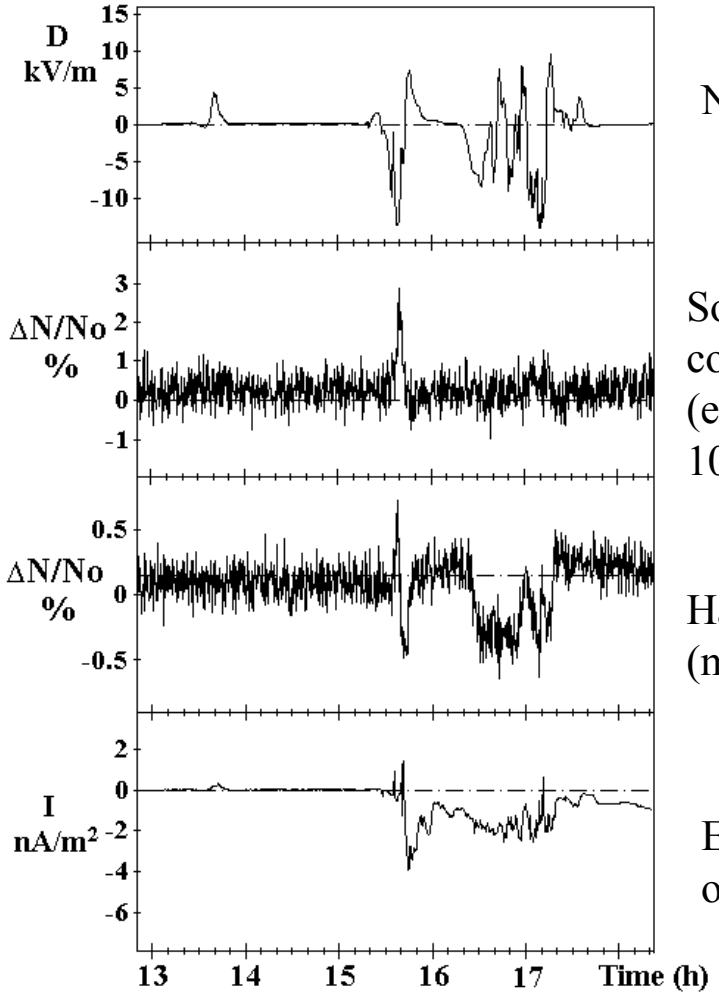


Different effect of lightning in the Oct 11, 2003 event

The estimates of minimum distances are 4.4 and 3.1 km for the two lightning having strong effect.
No effect is produced by the third nearby lightning.



Two examples of strong variations of muons during thunderstorms. The right plot (event on September 24, 2007) demonstrates clear correlation of the muon effect with lightning discharges.

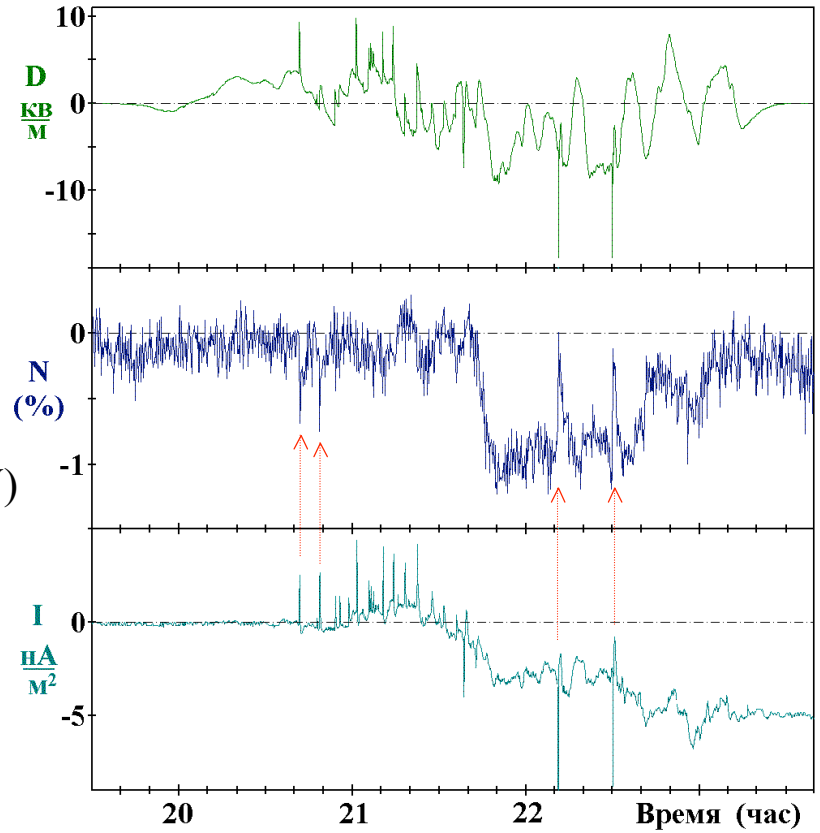


Near-earth electric field

Soft component (e^-, e^+, γ) 10-30 MeV

Hard component (muons > 100 MeV)

Electric current of precipitation



North-Caucasus Geophysical Observatory, Lab no. 1 of Schmidt Institute of Physics of the Earth

Located in a separate cavity of Baksan Neutrino Observatory at a distance of 4100 m from the entrance into horizontal mine. Three-component digital magneto-variation station is place on a concrete base in the center of the cavity and oriented along magnetic meridian.
Continuous recording of three components (h, d, и z) of the magnetic induction vector by separate sensors.
Frequency range from 0 to 1 Hz.
Random error of measurement at sampling with no shorter than 3 s is about 0.1 nT.
Relative time instability is 1-2 nT over year, and dynamical range is ± 2000 nT.

Thunderstorm activity and CR variations during three days (October 13-15, 2007). Averaging over 80-s intervals (one point).

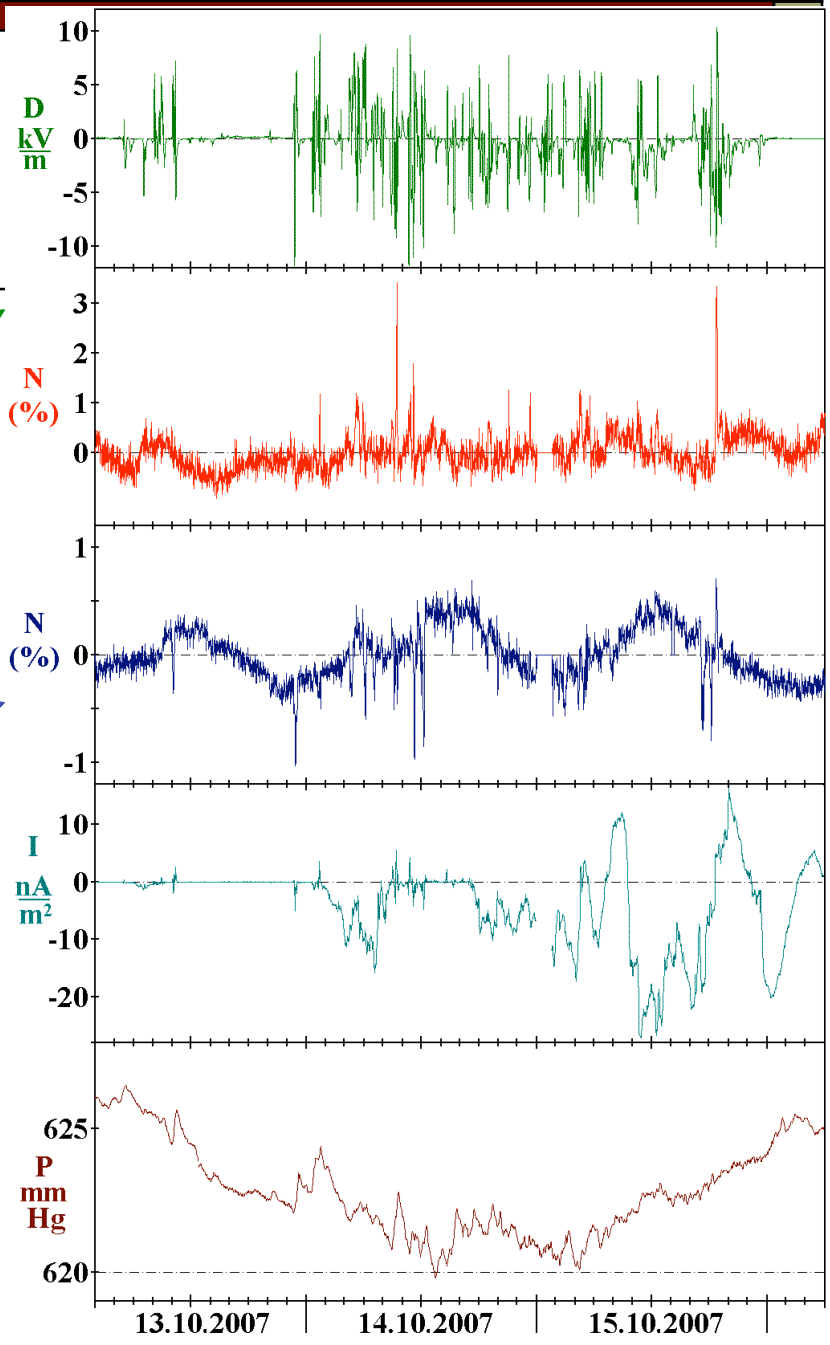
Near-ground electric field

Intensity of soft component (10-30 MeV)

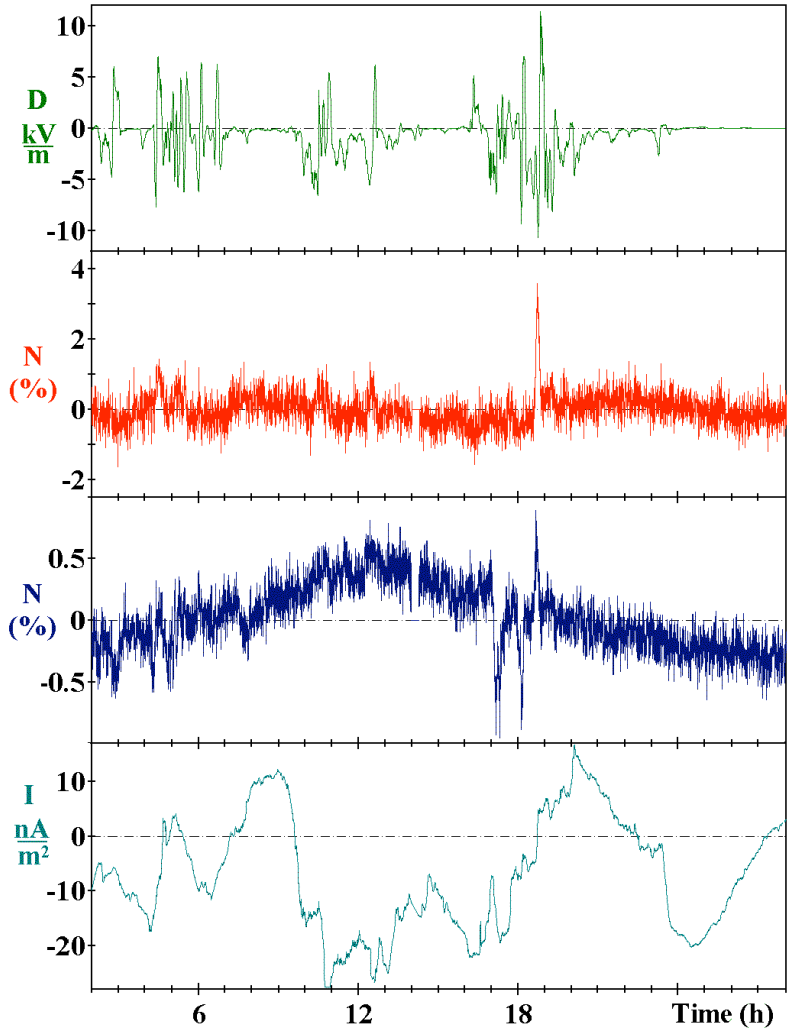
Hard component (> 100 MeV)

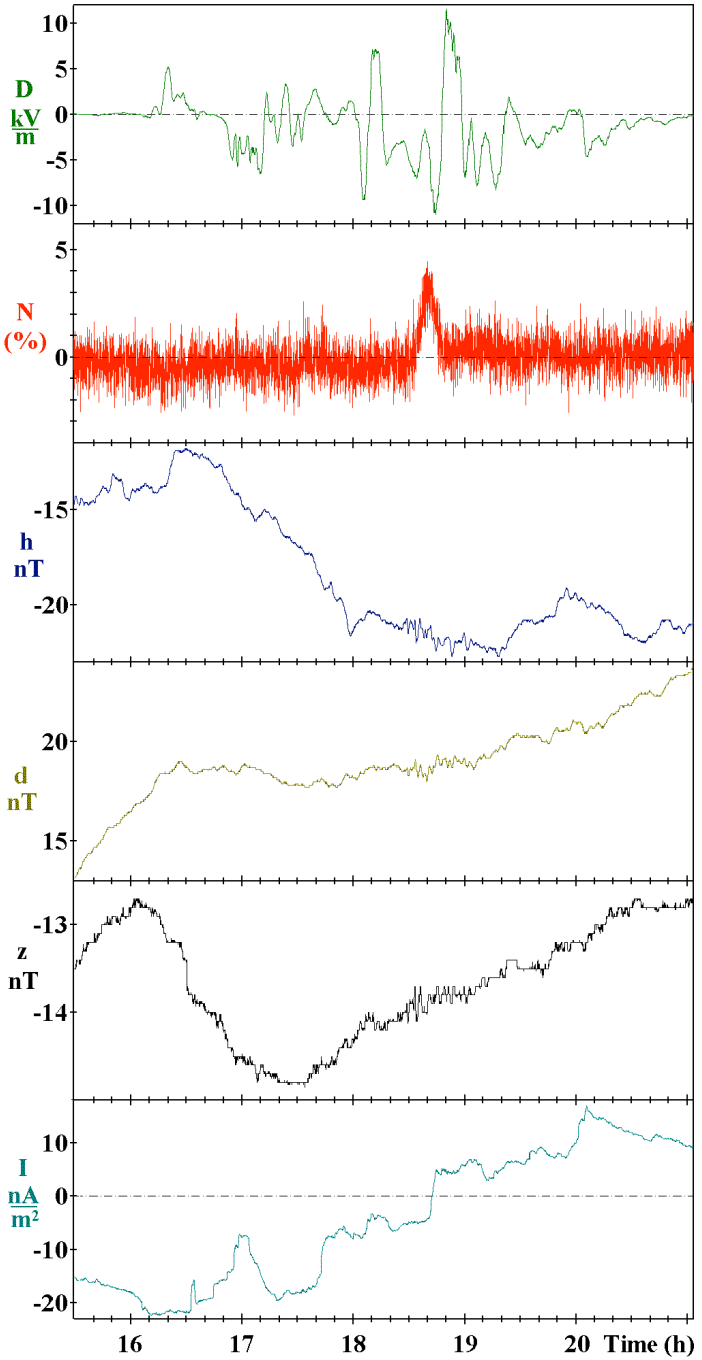
Precipitation electric current

Atmospheric pressure



Event on October 15, 2007
Averaging of data over 20-s (below) and 4-s intervals (on the right)

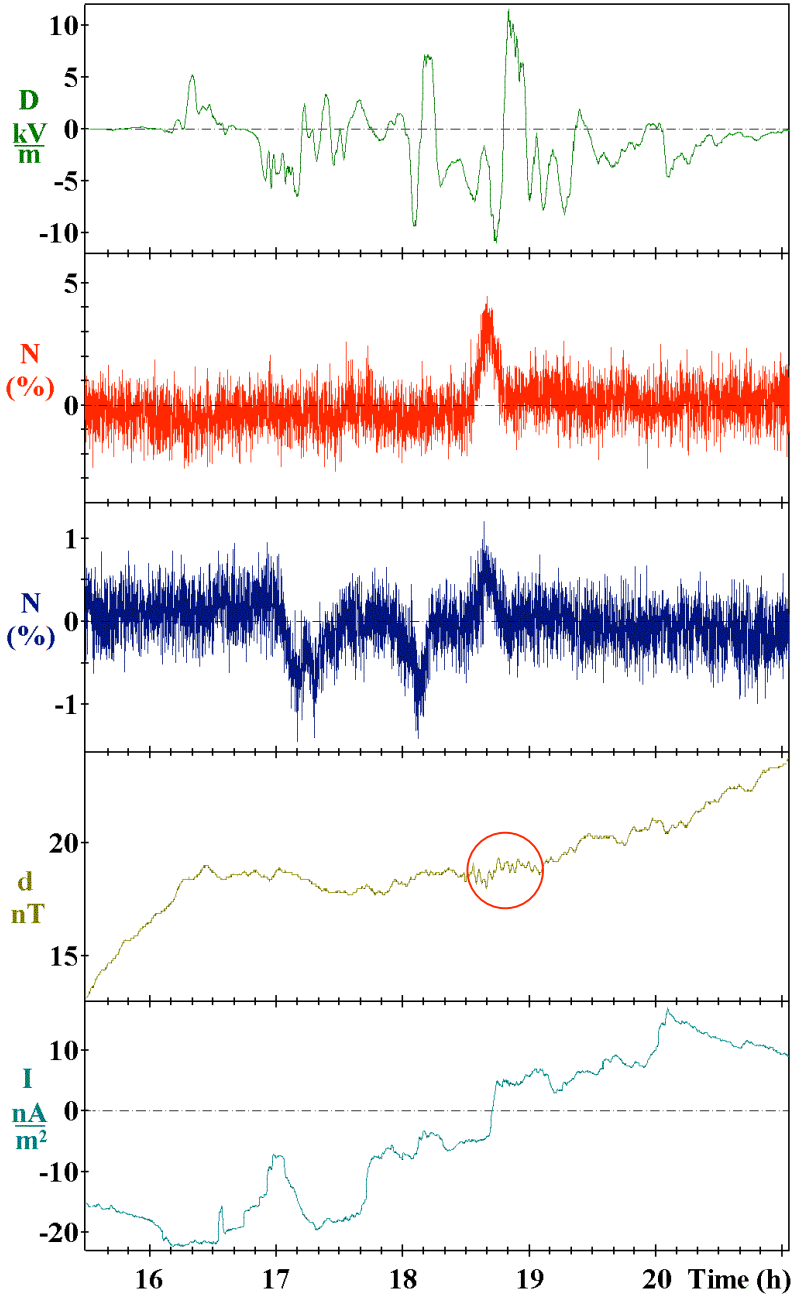




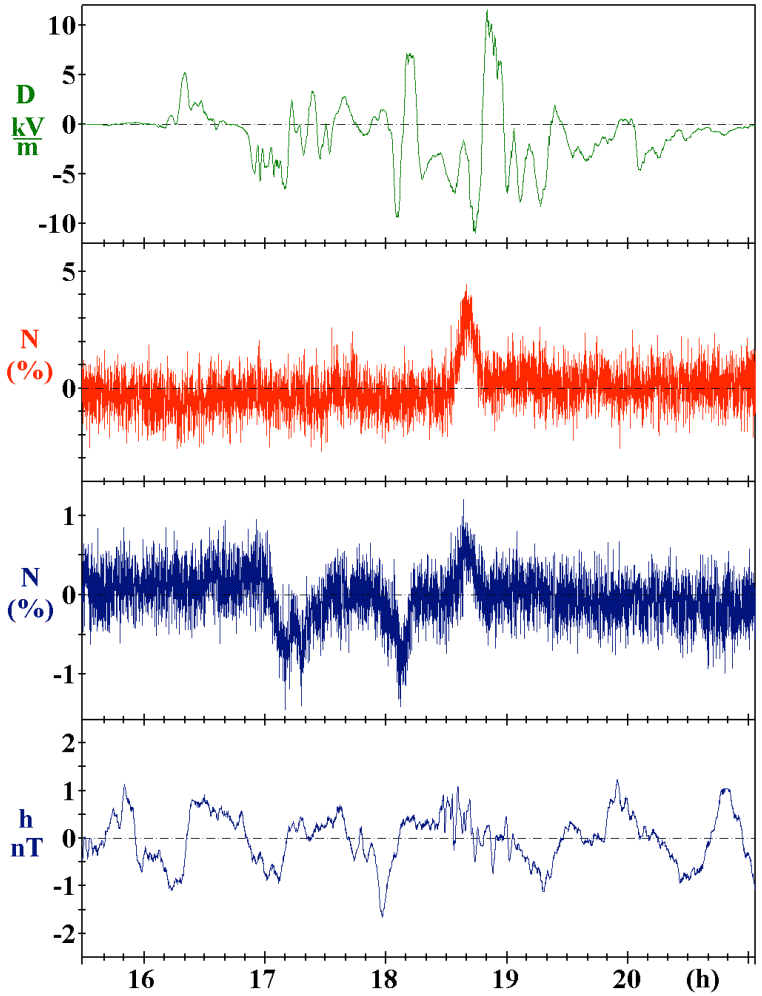
Event of October 15, 2007

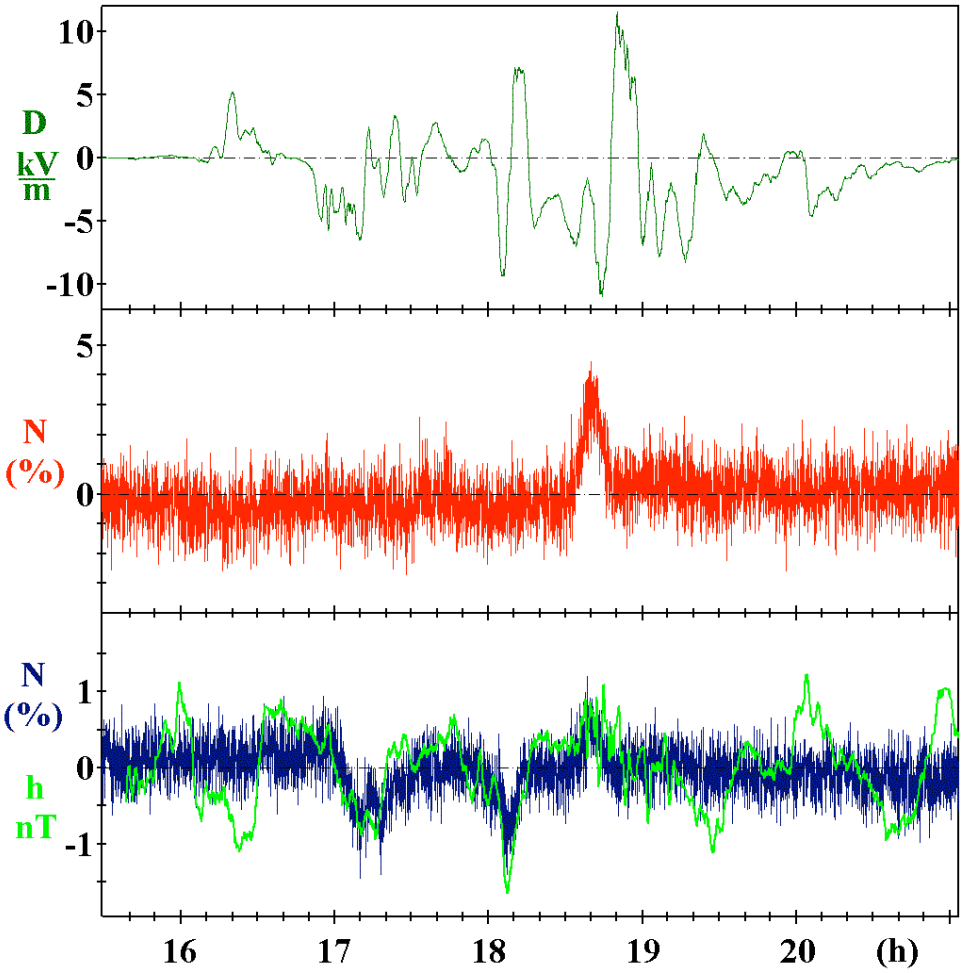
Classification of geomagnetic pulsations (amplitudes from a few tenths of nT up to tens of nT): regular (Pc) and irregular (Pi)

Pc	*Period, s*	*Pi*	*Period, s*
Pc1	0,2 - 5	Pi 1	1 - 40
Pc 2	5 -10	Pi 2	40 - 150
Pc 3	10 - 45	Pi 3	>150
Pc 4	45 - 150		
Pc 5	150 - 600		



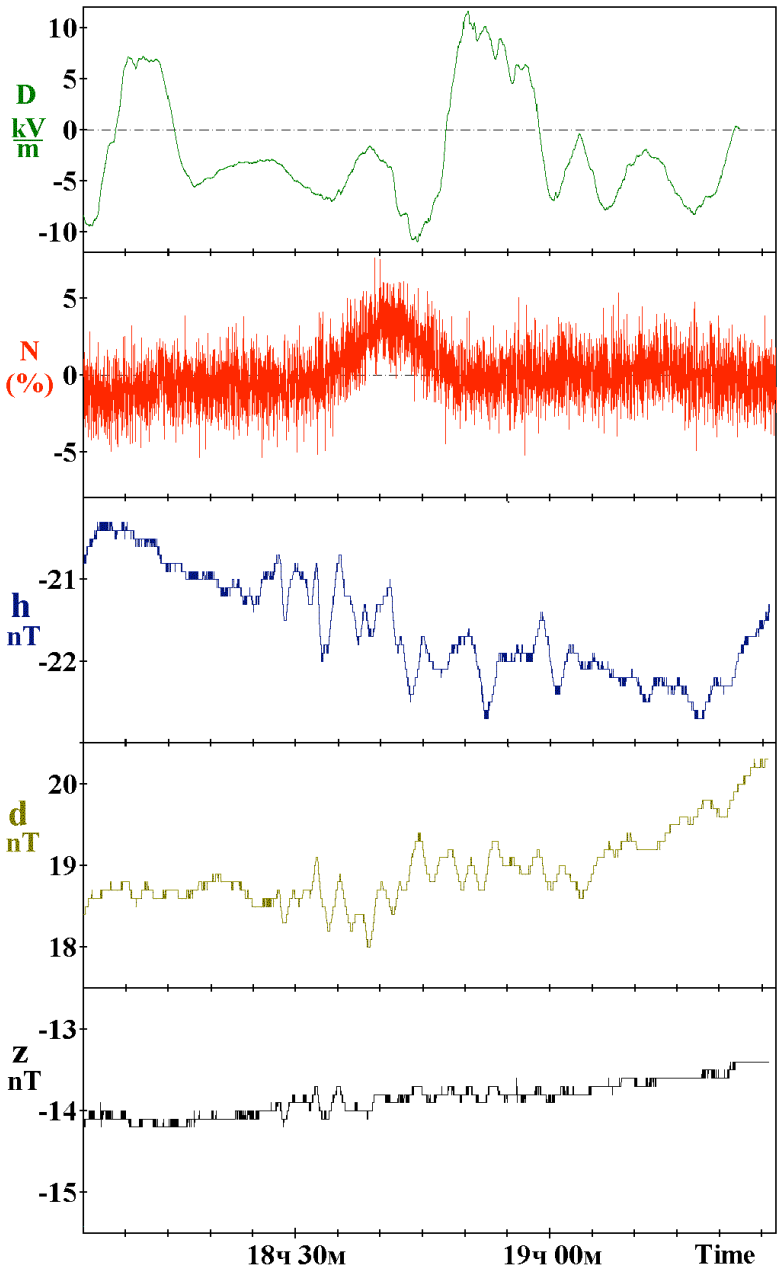
Event of October 15, 2007. Data are averaged over 4-s intervals. Daily trend is subtracted in the h-component plot (bottom panel below on the left) and this difference plot is overlapped on the plot of intensity of muons with a shift of 560 s (bottom panel below on the right).



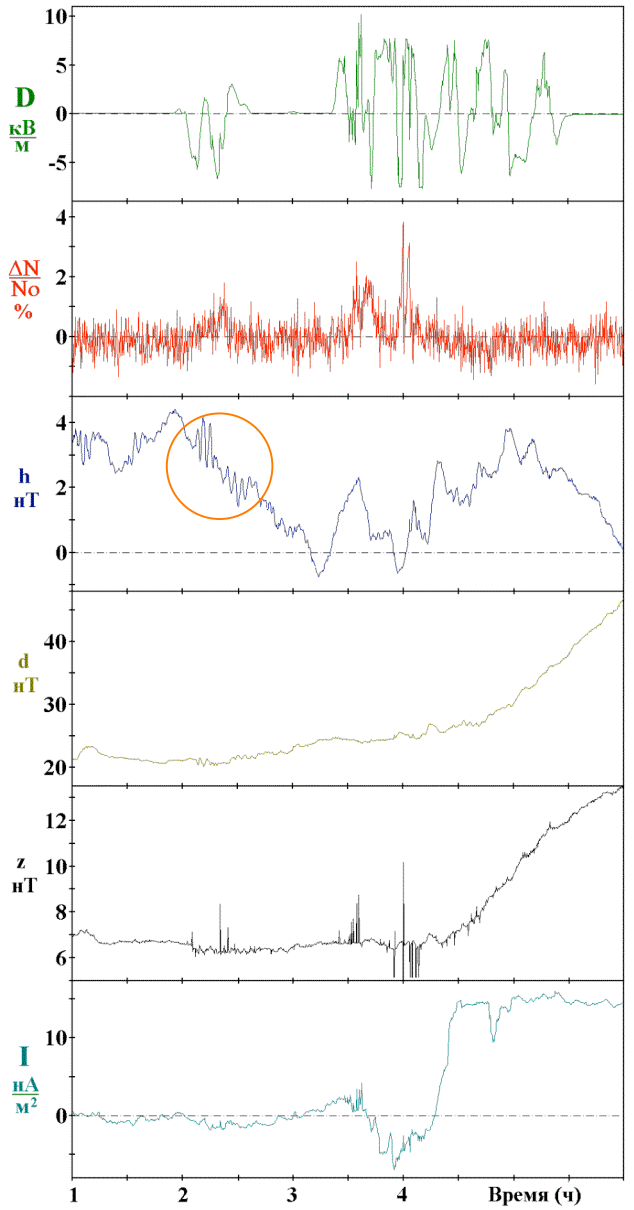


Event on October 15, 2007

Pulsations with a period of ~ 100 s in all three components of the geomagnetic field. The best time resolution (1 s).



One more example of possible pulsations with a small period. Event on August 1, 2008 (averaging 15 s in one point).



Conclusions

- Indications to existence of GM pulsations from thunderstorms:

  Fraser-Smith A.C., ULF magnetic fields generated by electrical storms and their significance to geomagnetic pulsation generation, Geophys. Res. Lett., 1003, vol. 20, no. 6, pp. 467-470, March 19, 1993.

- Search for such an effect with negative result:

  K.P. Garmash, S.G. Leus, E.A. Pakhomov, V.T. Razumenko, L.F. Chernogor, Fluctuations of the geomagnetic filed accompanying thunderstorms, Proc. of the 5th Russian Conference on Atmospheric Electricity, Vladimir, 2003, vol. 1, pp. 193-195.

In this talk we present a direct experimental proof of existence of geomagnetic pulsations associated with thunderstorm. Moreover, effects in cosmic rays possibly give a key to understanding the mechanism of generation of such pulsations.