Fast electric field waveforms of lightning discharges detected at Aragats mountain in Armenia

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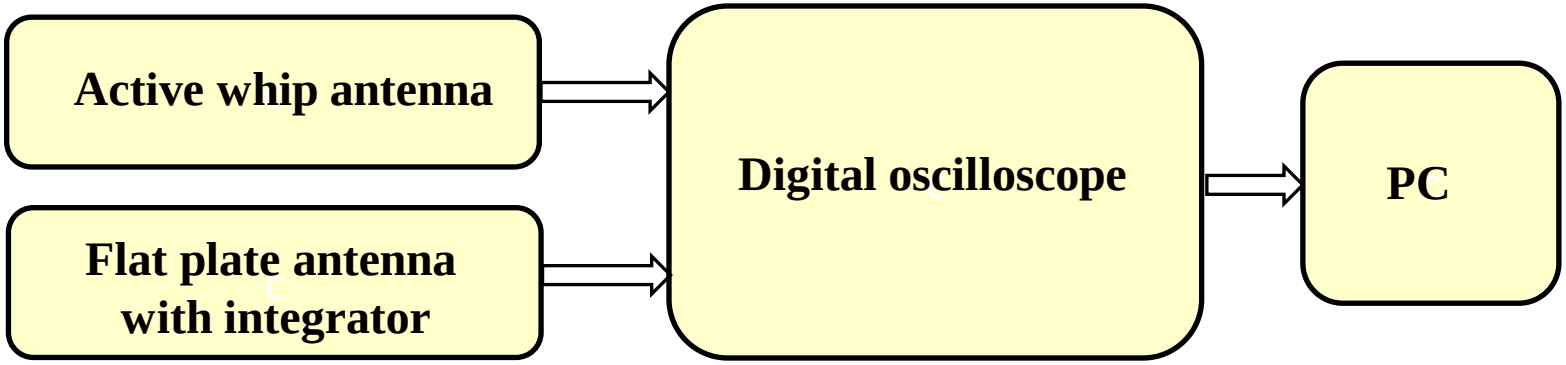
Outline

Fast and slow electric field changes of lightning discharges that terminate the Thunderstorm Ground Enhancement (TGE)

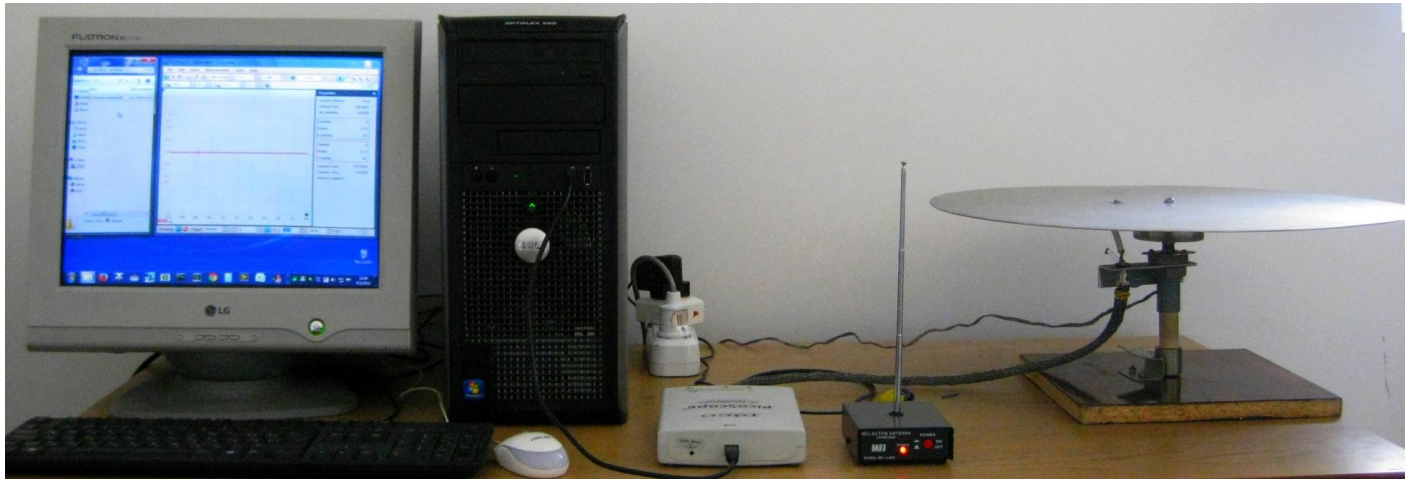
- **Instrumentation**
- **Fast electric field measurement**
- **Electric field mill**
- **Storm Tracker Lightning detector**
- **World Wide Lightning Location Network (WWLLN)**
- **Particle detector**

- **Observation data**

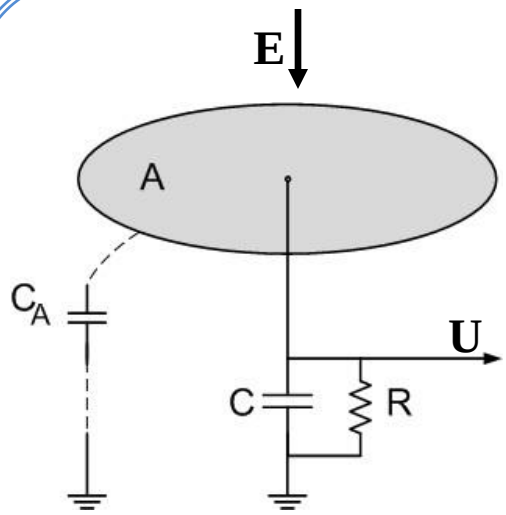
HF emission and wideband fast electric field detection system



MFJ-1022 active whip antenna is used for oscilloscope triggering.
Frequency range : from 300 KHz to 200MHz.



Wideband fast electric field measurement system



Diameter D=0.52m, Area A=0.21 m^2

Passive integrator: decay time constant RC=10 ms

C=10nF, R=1 MΩ - input impedance of the oscilloscope

The integrator is a high pass filter with cut-off frequency $f=1/(2\pi RC)=16$ Hz

U~E, U=1V ⟷ E≅500V/m

Useful frequency bandwidth of the measurement system:from 16 Hz to ≈ 50 MHz

Digital oscilloscope

Picoscope 3206, Memory depth 1MB

Capture length =5ms, including 1ms pre-trigger time

Sampling rate f_s=100MS/s, sampling interval=1/f_s=10ns

Recently installed, waiting for data

Picoscope 5244B, Memory depth 512 MB

Capture length =500ms , including 100ms pre-trigger time

Sampling rate f_s=62.5MS/s, sampling interval=1/f_s=16ns.

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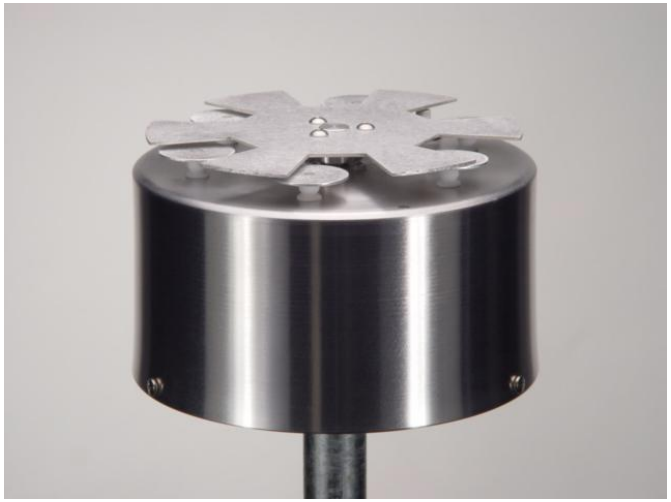
Boltek EFM-100 Atmospheric Electric Field Monitor



Log date, time and distance of nearby lightning.
Monitor lightning up to 38 km away.
Measurements are taken 20 times per second

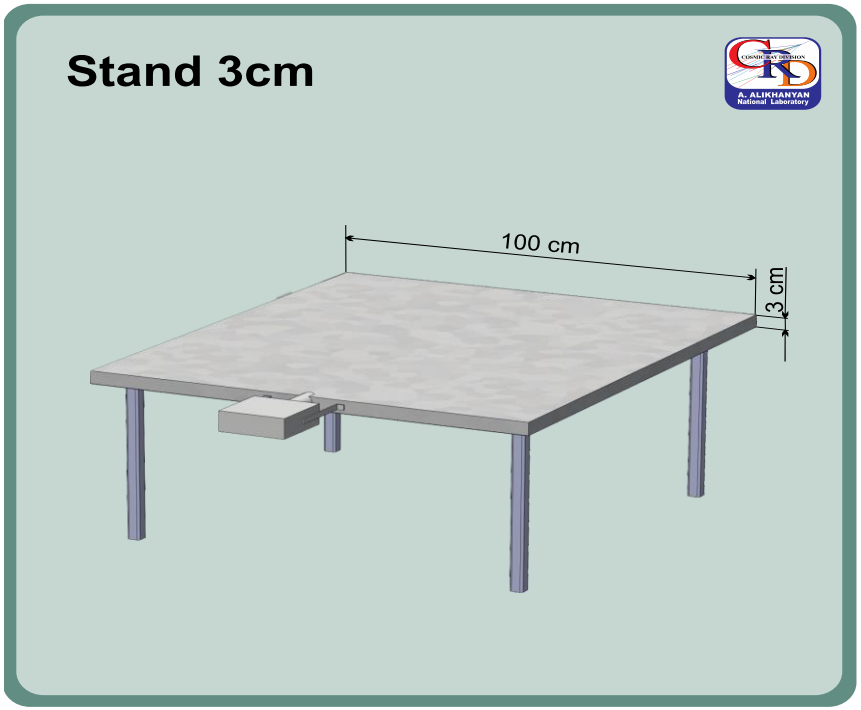
Boltek Storm Tracker Lightning detector

Long range detection up to 480 km away

Differentiates between cloud-cloud
and cloud-ground lightning strikes
(doubtful)

Particle detector

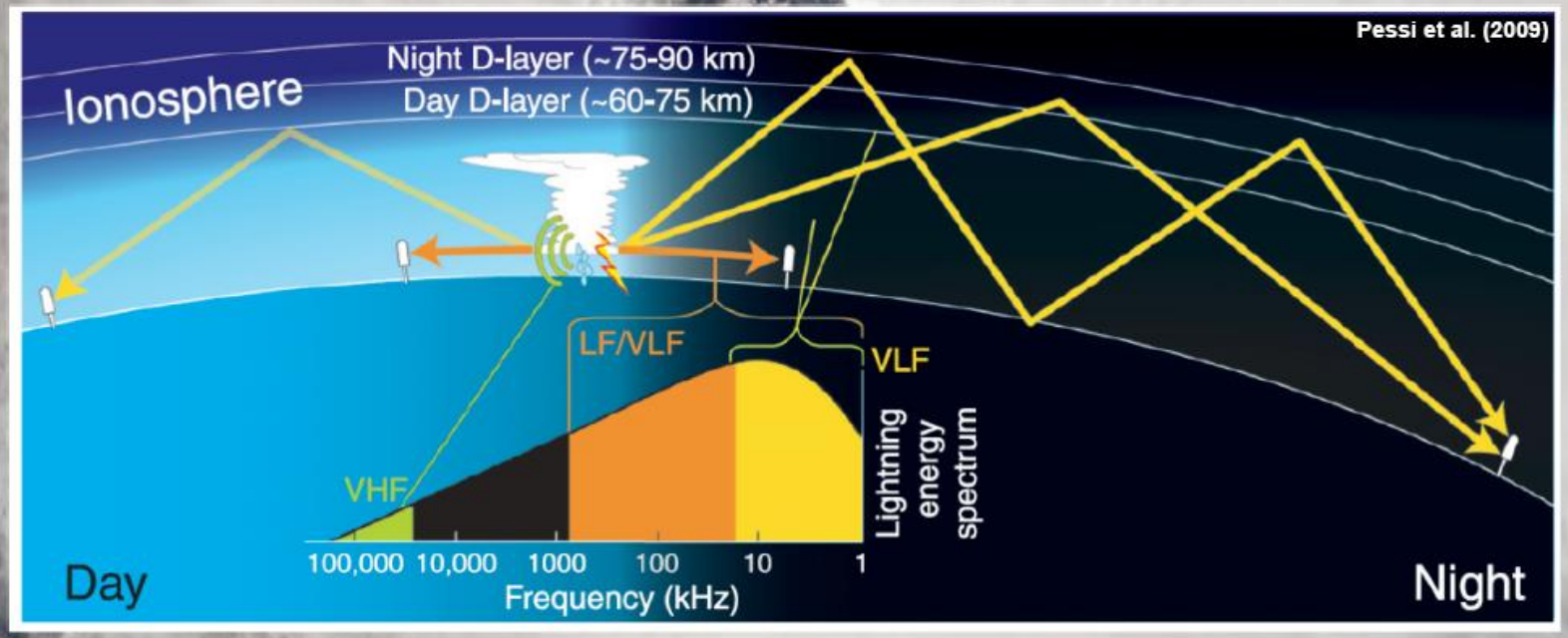
TGEs analyzed in the present study were observed by an outdoor 3 cm thick scintillator with a sensitive area of $1m^2$ operated in the particle counter mode.



The registration efficiency is ~99% for electrons and ~5% for gamma rays, the energy threshold is ~1MeV

World Wide Lightning Location Network (WWLLN)

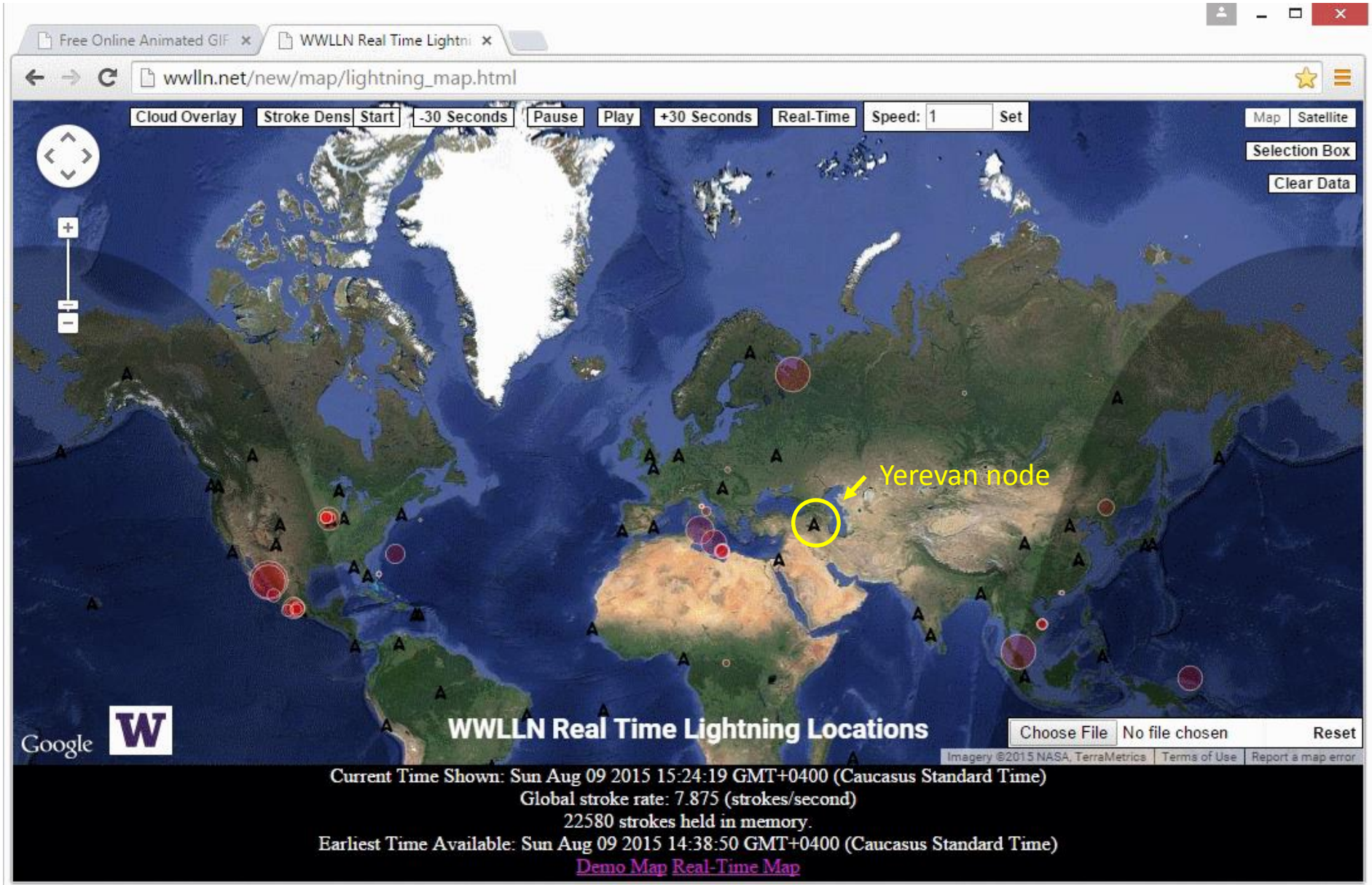
- The WWLLN ("woolen") is a global lightning network that detects the very low frequency (VLF; 3-30 kHz) emissions from lightning, known as sferics, that propagate long distances through the Earth-ionosphere waveguide.



Adapted from K.L.Corbosiero et al, University of California Los Angeles

The WWLLN is managed by the Department of Earth and Space Sciences at the University of Washington in Seattle, lead by Prof. Robert Holzworth.

Yerevan node of WWLLN was established in 2013.



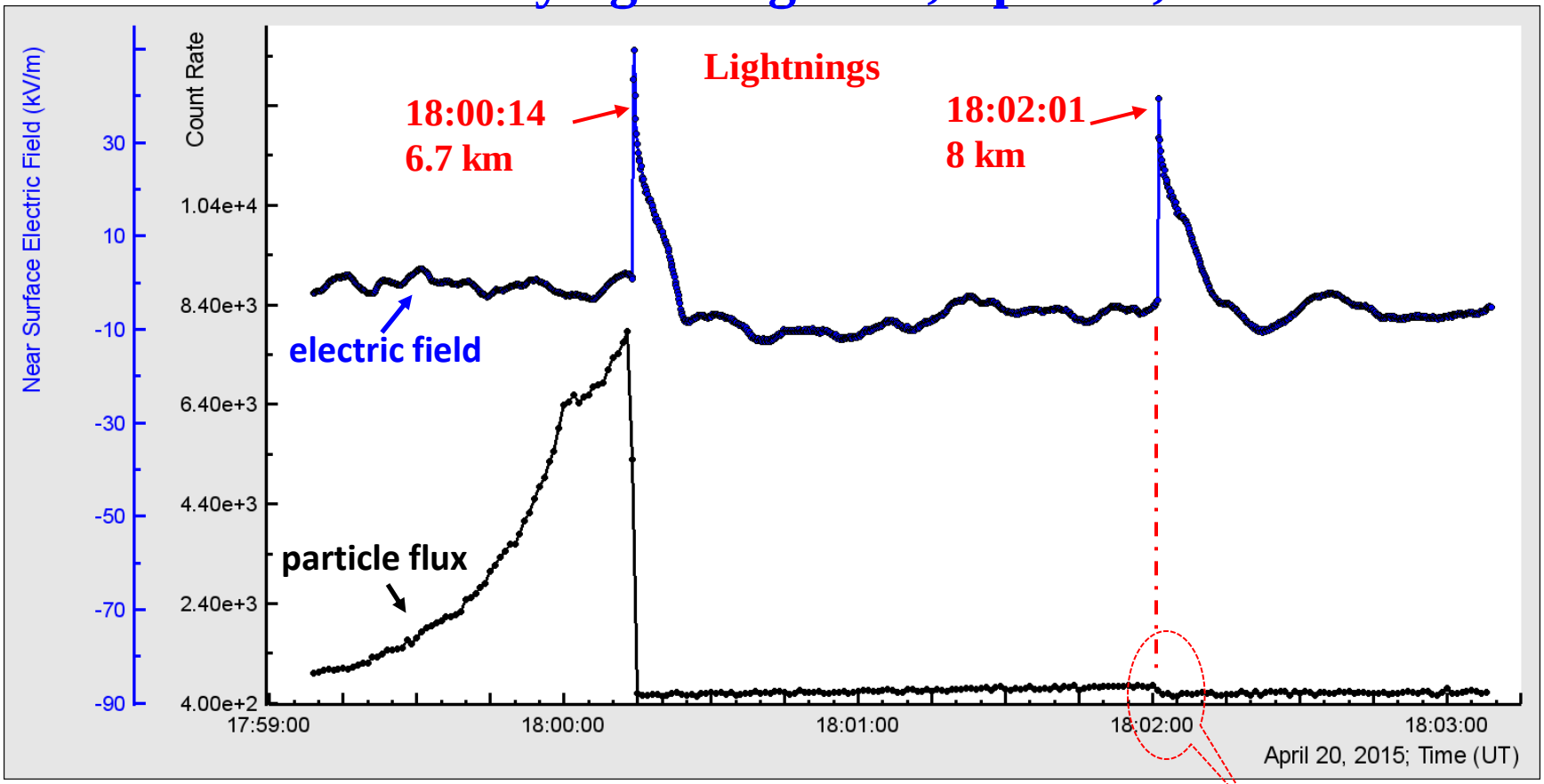
WWLLN data format

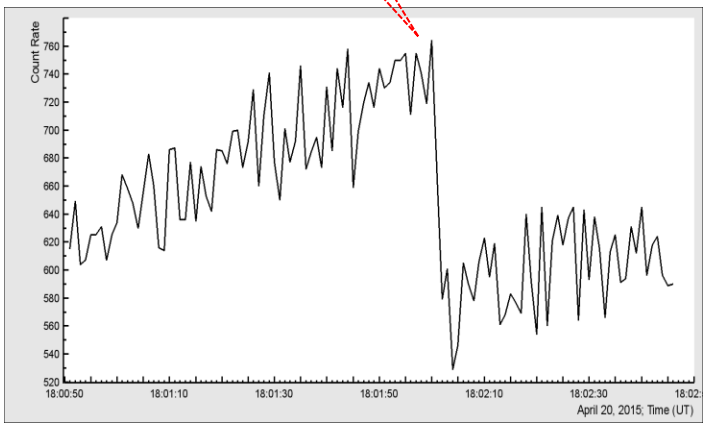
Date	Time (UT)	Latitude	Longitude	Residual fit error μs	Number of stations	Distance to Aragats station, km
2014/11/01	15:22:46.868845	40.3721°N	44.2815°E	10.4	7	13.9

Calculated as the great-circle distance between the two points with known geographical coordinates according to the "haversine" formula.

- The WWLLN detects all types of lightning strokes that have peak currents with magnitudes above ~35-40 kA.
- Lightnings detected at least by 5 stations of the network are included to the database
- Detection efficiency ≈10%
- Timing accuracy ±16μs
- Location accuracy 5-10 km

Thunderstorm Ground Enhancement terminated by lightning flash, April 20, 2015

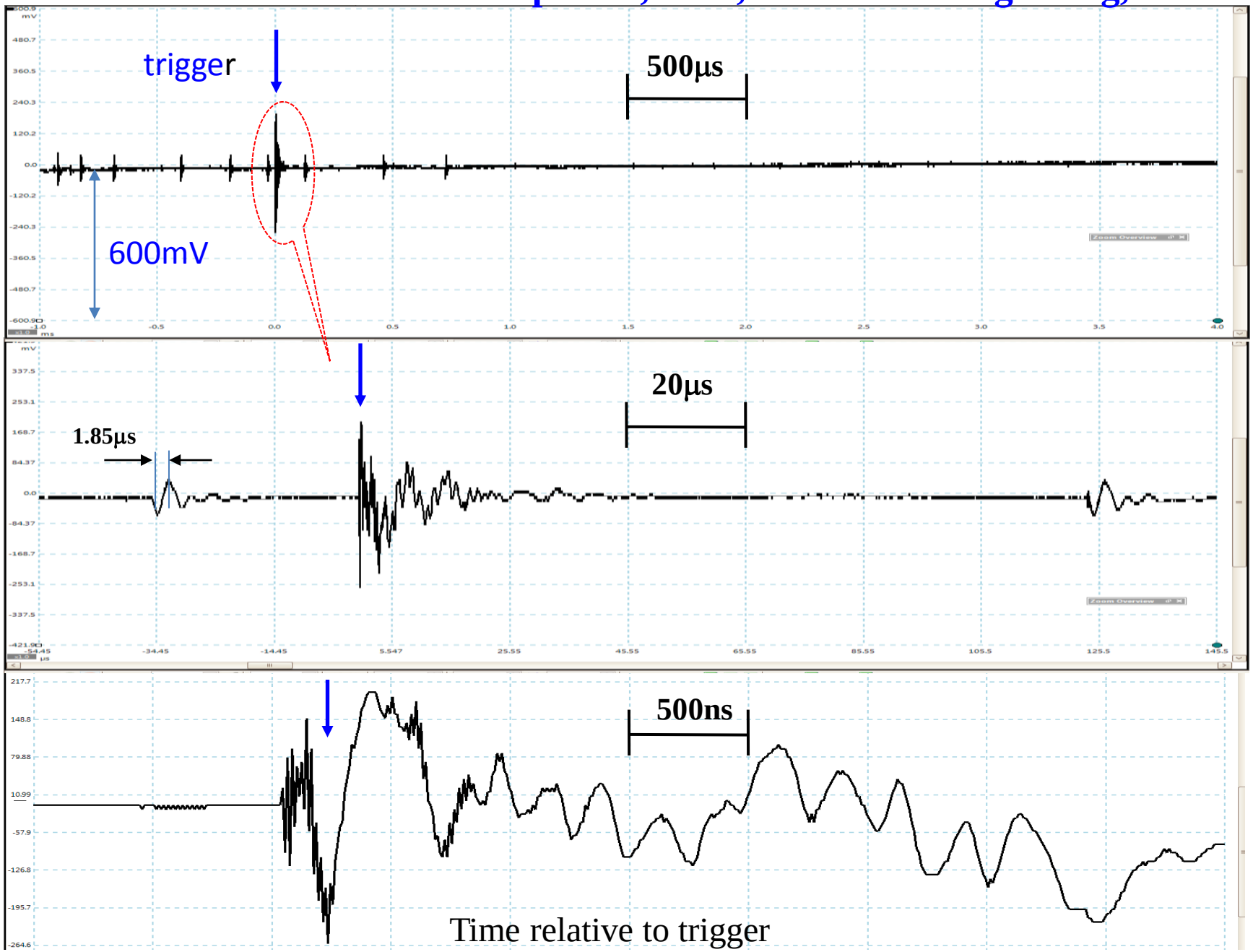




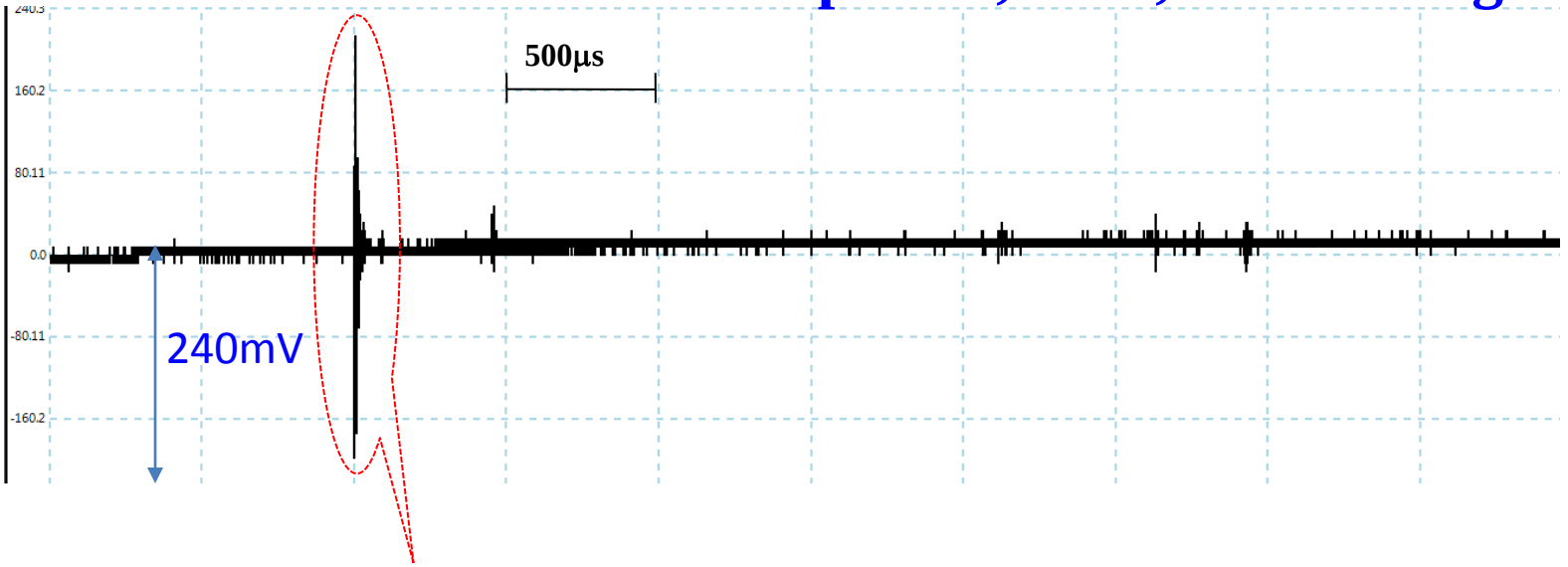
April 20, 2015 18:00:14 WWLLN data

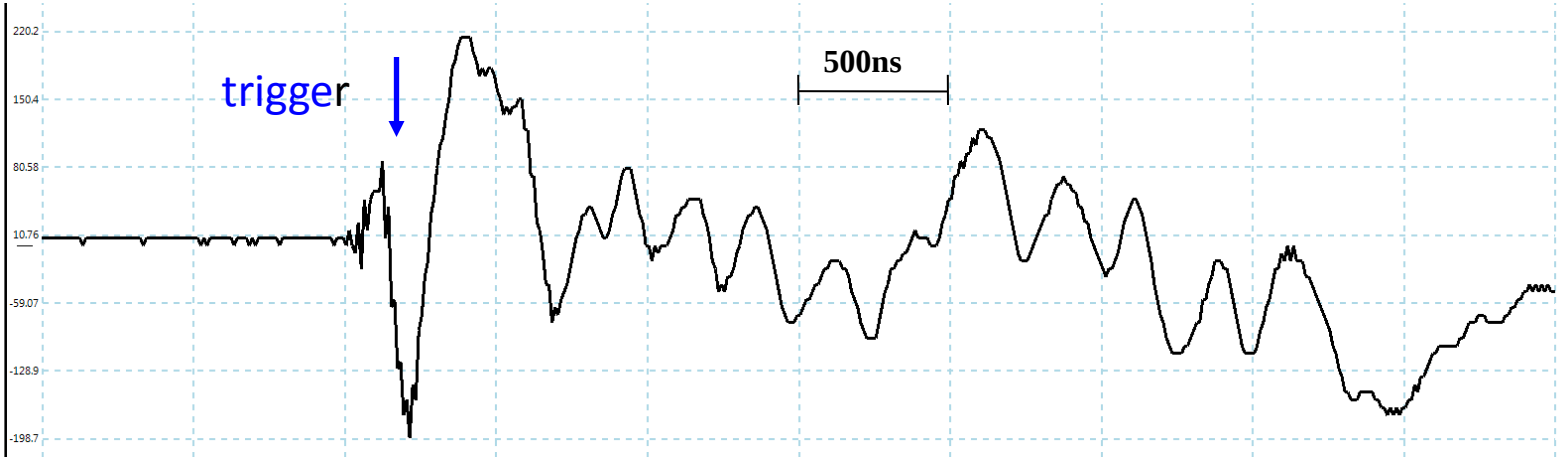
Date	Time	Lat	Long	ResErr	Nsta	Distance
'2015/04/20'	'18:00:14.757270'	[40.4719]	[44.1030]	[14.4000]	[12]	6.7km

Fast electric field waveform of April 20, 2015, 18:00:14.757 lightning, 6.7 km



Fast electric field waveform of April 20, 2015, 18:02:01 lightning





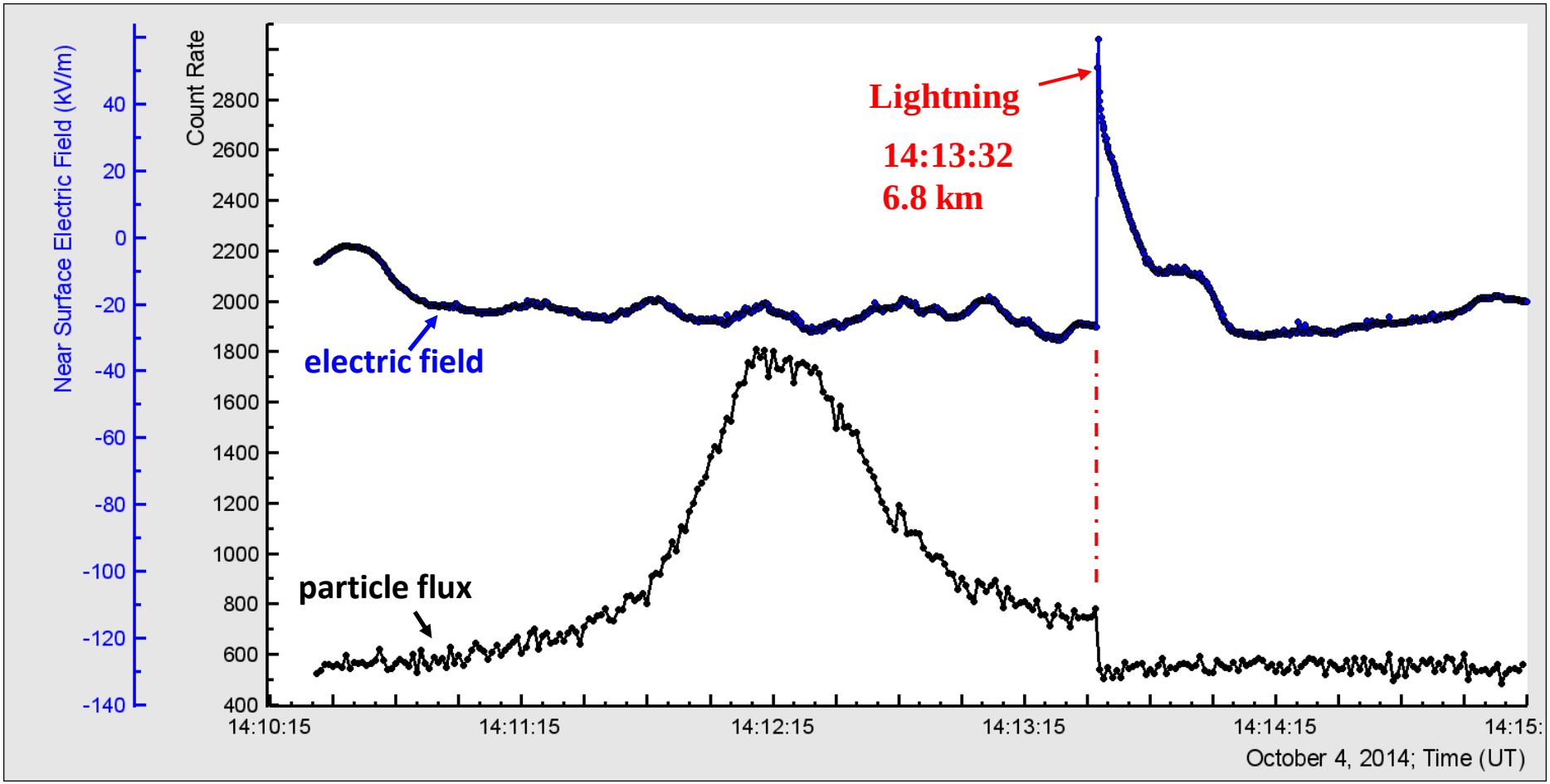
Time relative to trigger

Type and polarity of two lightnings of April 20, 2015 according to Storm tracker data

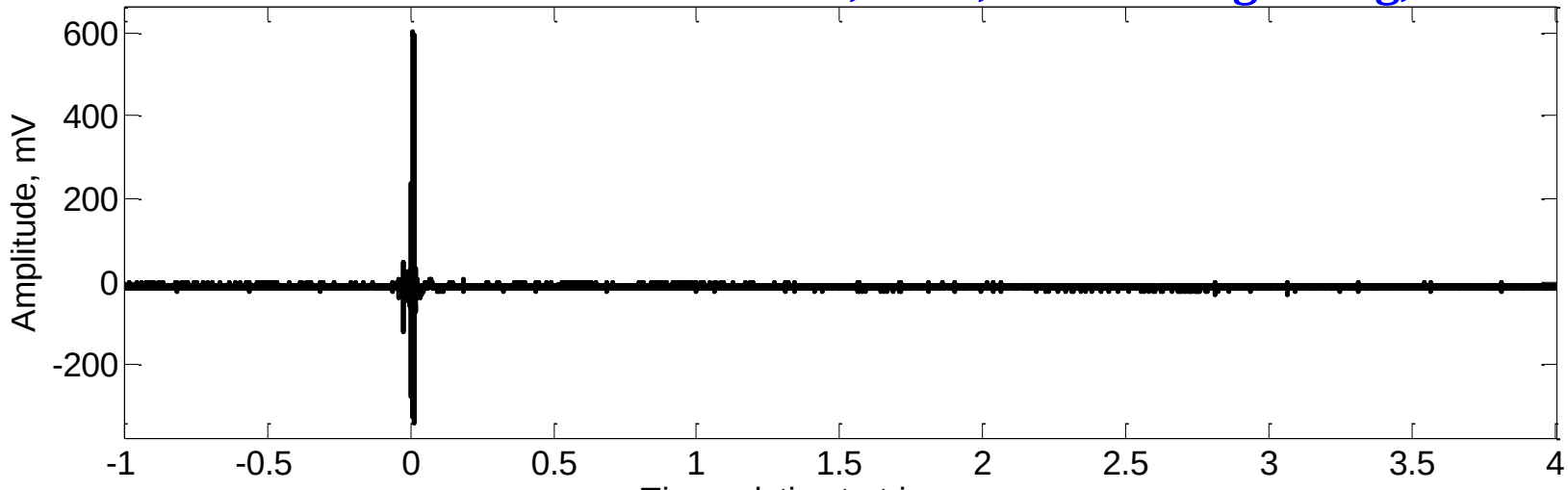
Date/Time	Strike Type (0 is CG and 1 is IC)	Strike Polarity (0 is positive and 1 is negative)
18:00:14.054	1	0
18:00:14.081	1	1
18:00:14.114	0	0
18:00:14.155	1	0
18:00:14.175	1	1
18:00:14.189	1	1
18:00:14.269	1	0
18:00:14.316	1	0
18:00:14.346	1	1
18:00:14.366	1	0
18:00:14.395	1	1
18:00:14.456	1	0

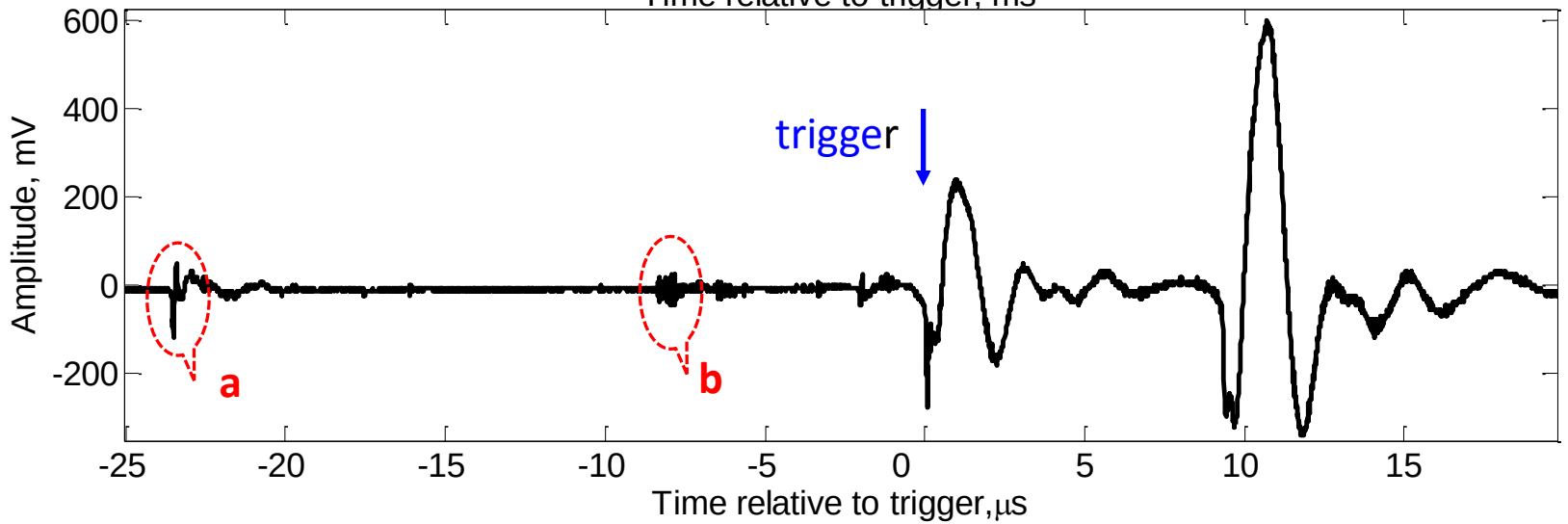
Date/Time	Strike Type (0 is CG and 1 is IC)	Strike Polarity (0 is positive and 1 is negative)
18:02:01.161	1	0
18:02:01.169	1	0
18:02:01.255	1	1
18:02:01.278	1	1
18:02:01.284	1	0
18:02:01.298	1	1
18:02:01.424	1	1
18:02:01.440	1	1
18:02:01.472	0	1
18:02:01.524	1	1
18:02:01.544	1	1
18:02:01.837	0	1
18:02:01.848	1	0
18:02:01.894	0	1
18:02:02.016	1	0

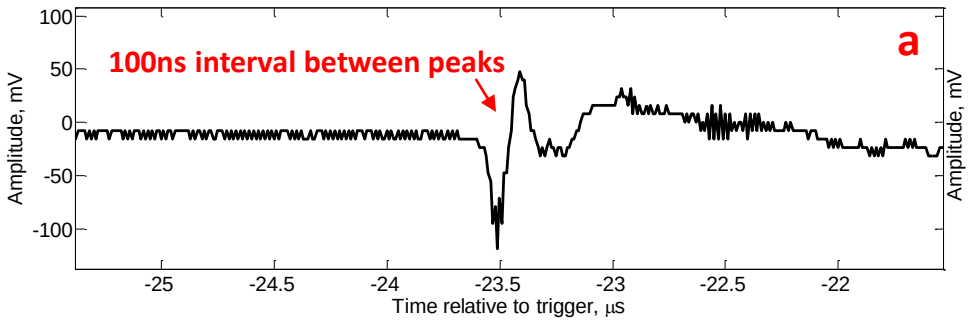
Thunderstorm Ground Enhancement terminated by lightning flash October 4, 2014

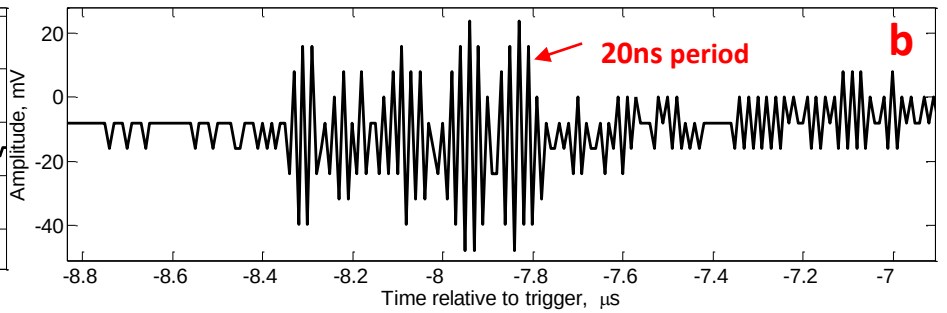


Fast electric field waveform of October 4, 2014, 14:13:32 lightning, ≈6.8km

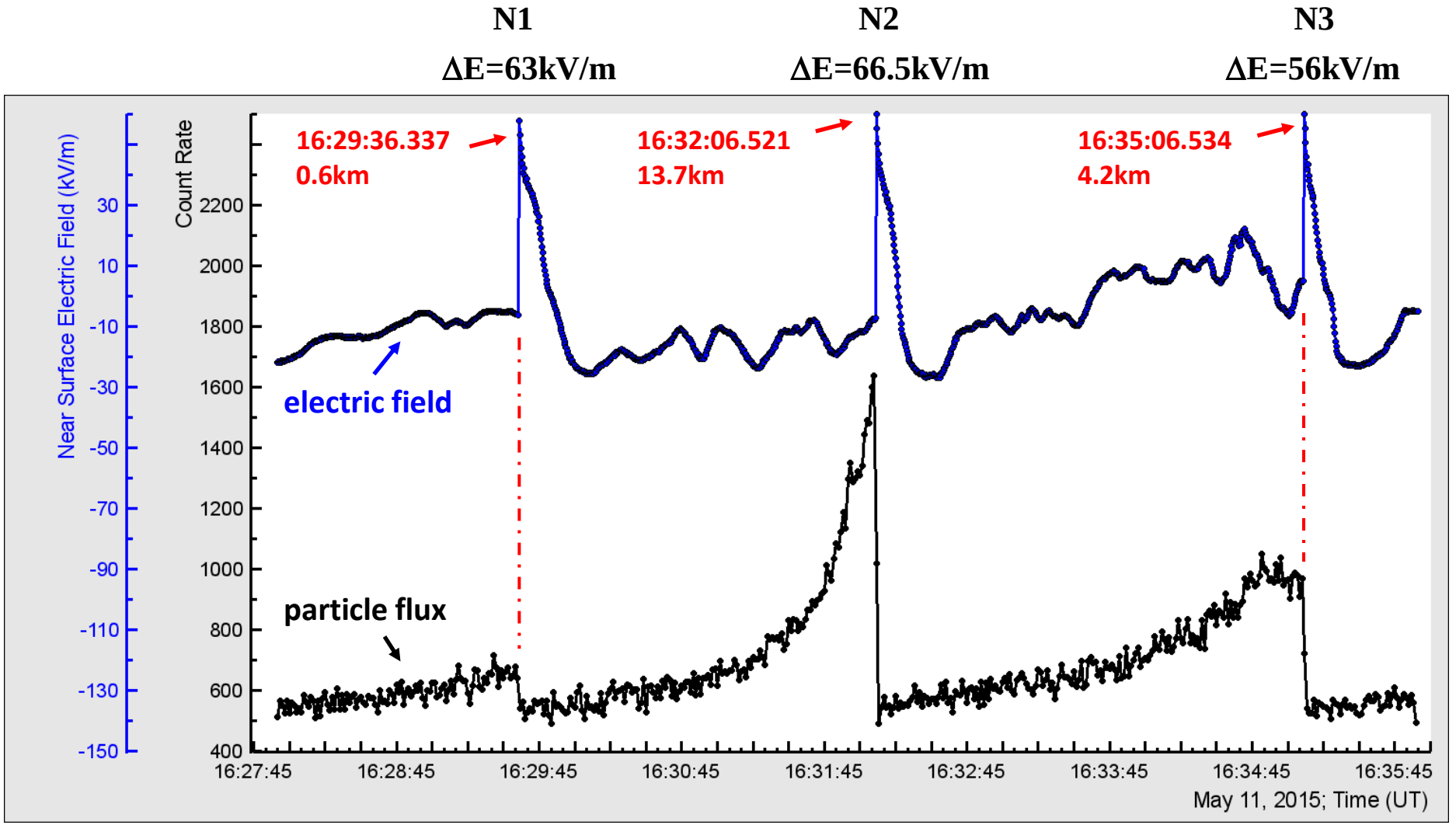




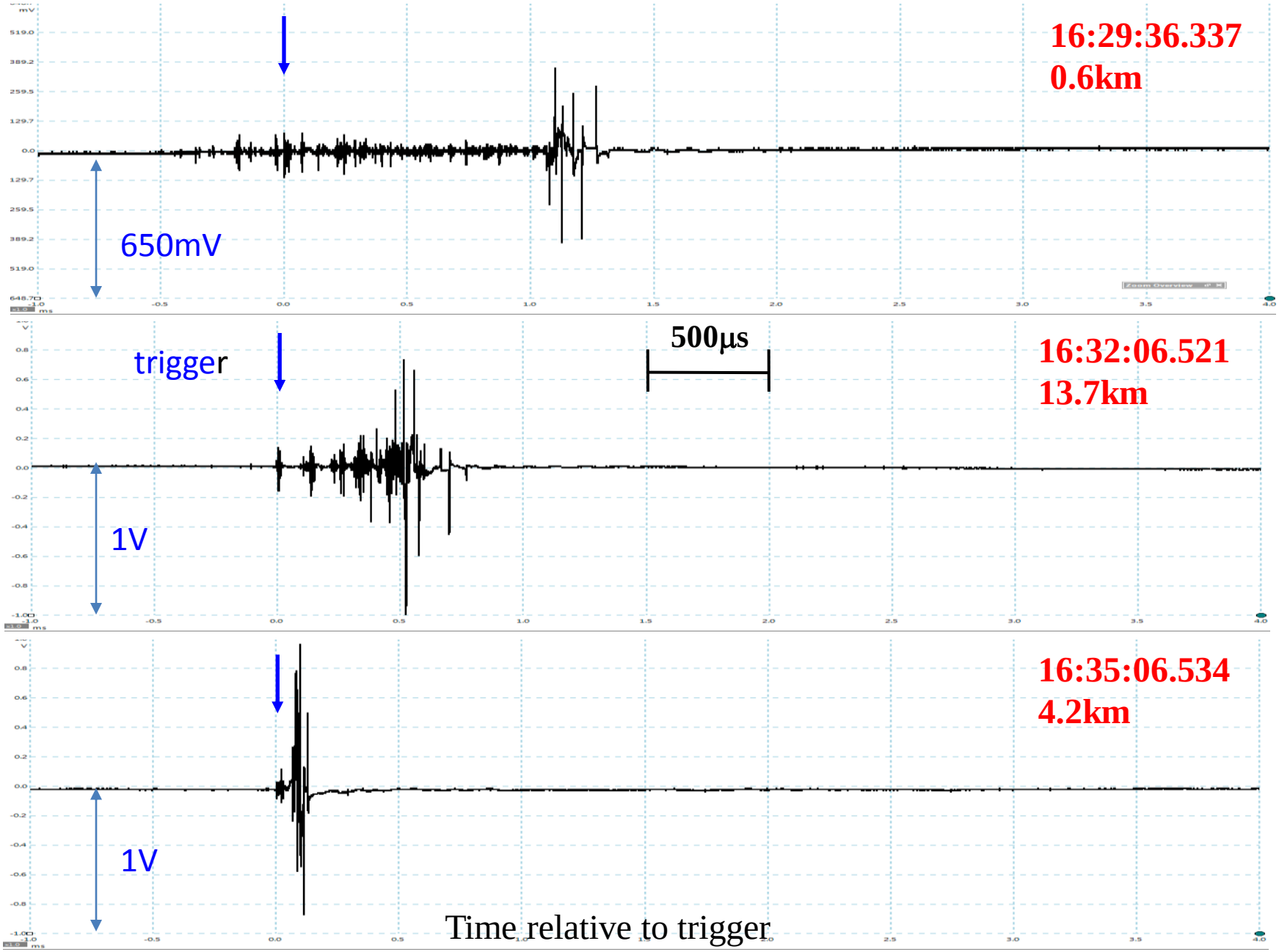




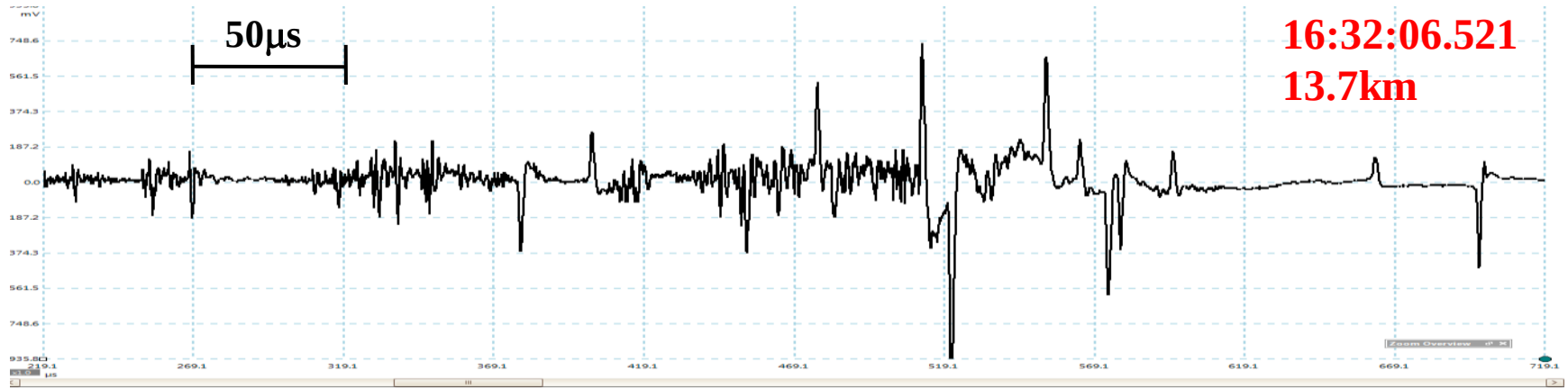
Thunderstorm Ground Enhancement terminated by lightning flash May 11, 2015

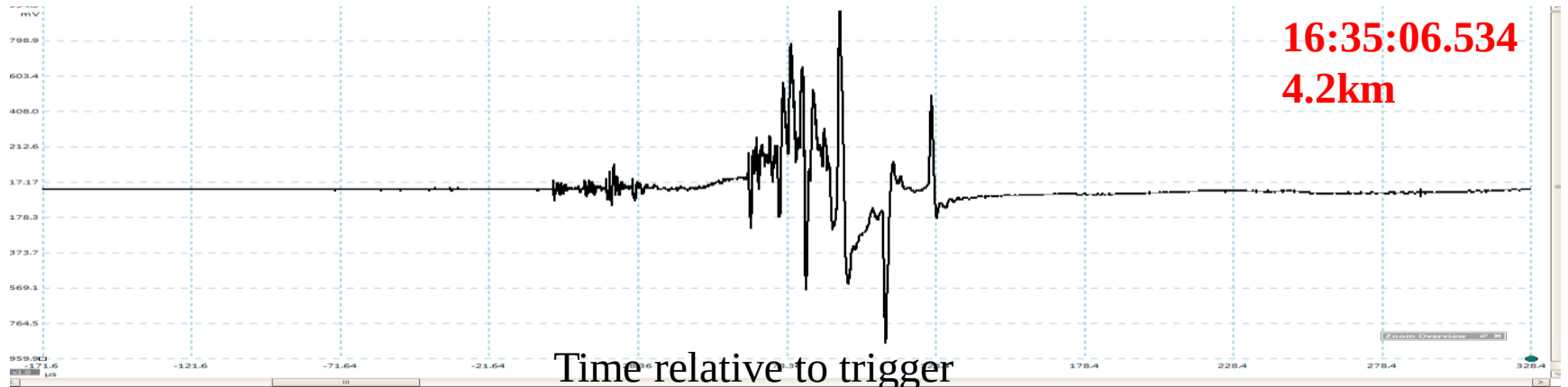


Fast electric field waveforms of three lightnings of May 11, 2015



Fast electric field waveforms of three lightnings of May 11, 2015 (10x zoom)



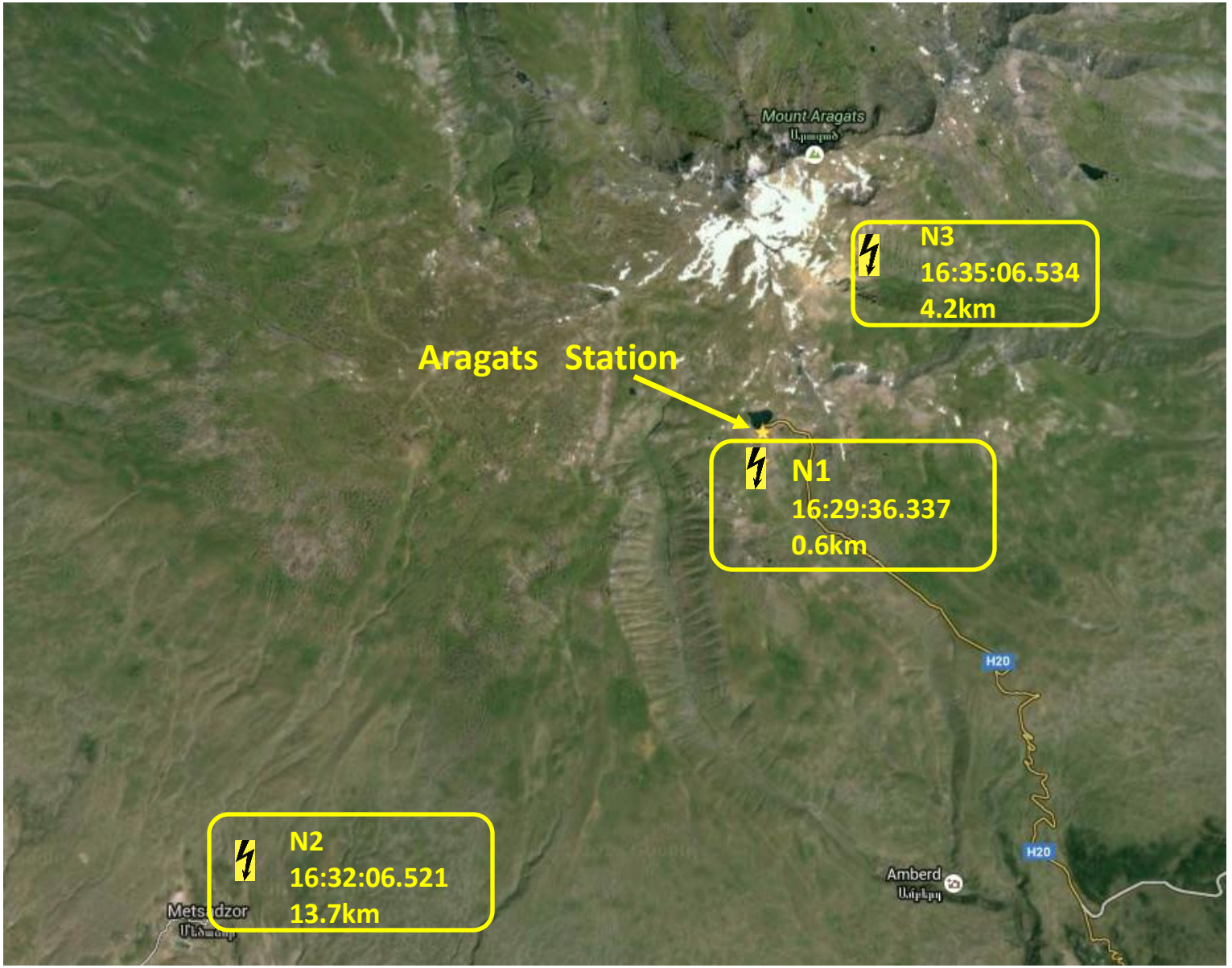


Time relative to trigger

Type and polarity of three lightnings of May 11, 2015 according to Storm tracker

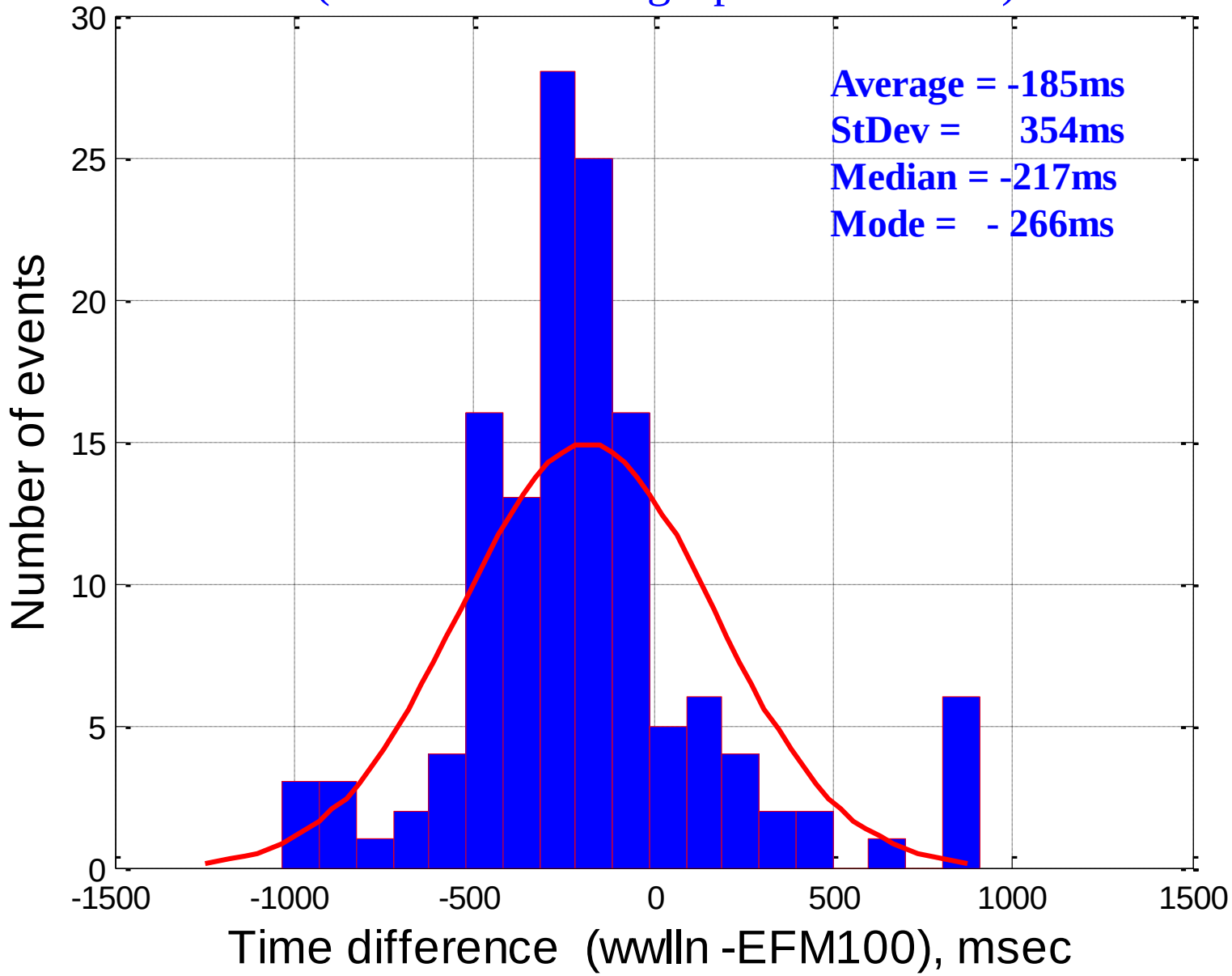
Date/Time	Strike Type (0 is CG and 1 is IC)	Strike Polarity (0 is positive and 1 is negative)	
16:29:36.399	1	1	
16:29:36.464	1	1	
16:29:36.572	1	0	wwlln stamp 16:29:36.337 and distance 0.6km
16:29:36.588	1	1	
16:29:36.635	1	1	
16:29:36.697	1	1	
16:32:06.519	1	1	
16:32:06.583	1	1	wwlln stamp 16:32:06.521 and distance 13.7km
16:32:06.662	1	1	
16:32:06.722	1	1	
16:32:06.831	1	1	
16:35:06.546	1	1	
16:35:06.561	1	0	
16:35:06.624	1	1	
16:35:06.670	1	0	
16:35:06.735	1	1	wwlln stamp 16:35:06.534 and distance 4.2km
16:35:06.750	1	1	
16:35:06.858	1	0	
16:35:06.873	1	1	
16:35:06.984	1	1	

Location of three lightnings of May 11 2015 according to WWLLN data



Time coincidences of WWLLN and EFM-100 field mill peaks

(137 events during April- June 2015)

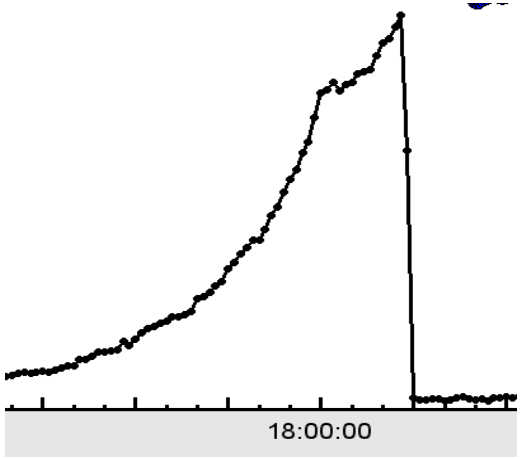


Main parameters of slow electric field changes for lightnings that had terminated TGEs

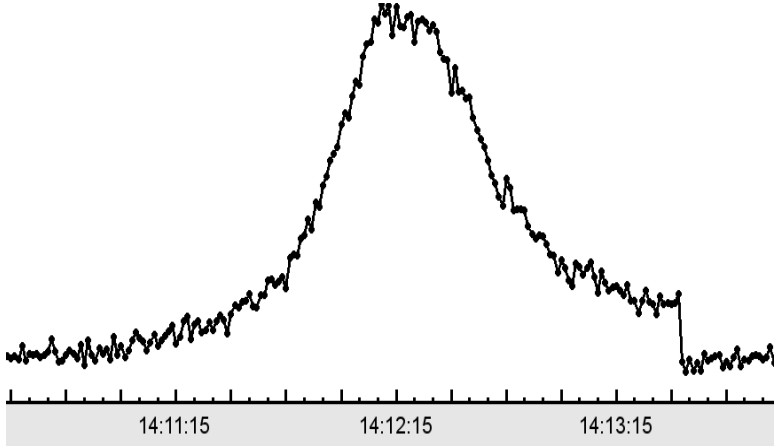
Date	Time	Distance to lightning [km]	Start electric field [kV/m]	Maximum electric field [kV/m]	(Maximum-Start) electric field [kV/m]	FWHM of field change [sec]
April 20, 2015	18:00:14	2	1.2	49.2	48	1.1
April 20, 2015	18:02:01	8	-3.4	39.2	42.6	1.2
Oct. 4, 2014	14:13:32	6.8	-25.5	58.5	84	5
May 11, 2015	16:29:36	0.6	-5.7	57.3	63	8
May 11, 2015	16:32:06	13.7	-6.5	60	66.5	6
May 11, 2015	16:35:06	4.2	5.5	61.5	56	5

Electric field change is positive ⟷ Decrease of negative charge overhead

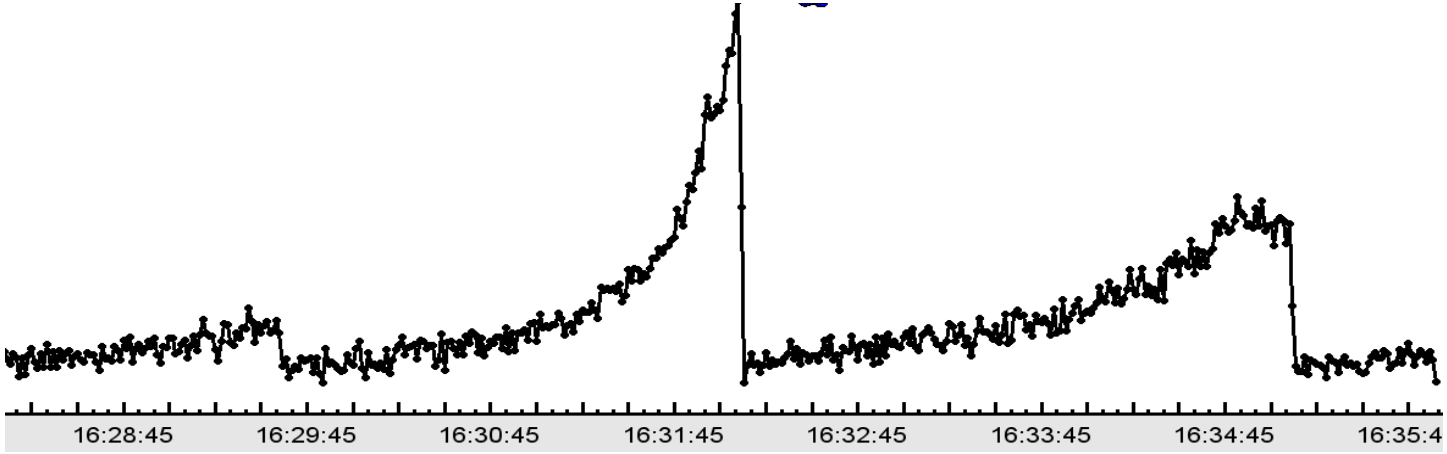
Termination of observed TGEs :
at the maximum, at the rising edge, at the falling edge



April 20,2015 , 18:00:14, 2 km



October 4 ,2014 , 14:13:32, 6.8km



May 11,2015 , 16:29:36, 0.6km 16:32:06, 13.7km 16:35:06 , 4.2 km

Summary and outlook

- All observed lightnings that abruptly terminate the TGE are negative. The electric field change at the ground is positive and it is attributable to decrease of negative charge overhead. The upward directed electric field which accelerates electrons downward is reduced by these lightnings

- Which types of lightning can terminate the particle flux, CG, IC, or both ?

- Which stage of lightning is responsible for the TGE termination?

- Waiting for fast electric field data with capture length of 500ms to analyze whole lightning flash

THANK YOU !