Neutron bursts associated with lightning cloud-to-ground discharges

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We present experimental results of the observations of the neutron flux bursts during the nearest thunderstorms in the years of 2009-2011.

The neutrons were detected on the Yakutsk station by the standard neutron monitor 24-NM-64.

The electric field during the thunderstorms were measured with the electrostatic fluxmeter near the monitor.

The second electrostatic fluxmeter was located at 4 km from the monitor, on the building of the institute. Both fluxmeters allow us to register lightning discharges within a radius of 10-15 km.

We have used one-second resolution data for electrostatic mill.

During the two storms a high-speed videos (300 fps) were recorded.
The standard neutron monitor 24-NM-64 located near the Yakutsk (61° 59.362' N; 129° 41.874' E). Altitude 94 m above sea level, geomagnetic cutoff threshold of 1.65 GeV. We have used one-minute resolution data for neutron monitor.

electrostatic fluxmeter placed on the building of the institute
The electrostatic fluxmeter has a measurement range of ±50 kV/m.
During the summer seasons of 2009-2011 thirty nine (39) thunderstorms were registered in the vicinity of the neutron monitor. In nine (9) of them the level of neutron flux has a fairly significant value. We registered 49 lightning strike with a neutron burst above $6\sigma$. 

![Bar chart showing the number of thunderstorms with neutron burst and the total number of thunderstorms by year.](chart.png)
Probability of different schematic types of variations of the electric field strength during the thunderstorm, and probability of the schematic types of thunderclouds that caused bursts in the neutron component.
Dynamic variation of electric field intensity in the case when cloud passed upon the electrostatic fluxmeter.
An example of neutrons bursts during lightning discharges. 
The top panel: the count rate of the neutron monitor. 
The bottom panel: the electric field strength.

During the lightning discharges some typical jumps are observed in the electric field, after which the field is restored to its original value in seconds.
Dependence of the neutron monitor counting rate from strange of atmospheric electric field during lightning discharges.

The short bursts of neutrons have been observed when electric field strength exceed the threshold level (≤ -16 kV / m).
The bursts of neutrons observed during the thunderstorm. 

The top panel: the count rate of the neutron monitor; 
The bottom panel: the electric field strength. 
Figures mark certain cloud-to-ground lightning strikes and corresponding photos showing the places of strikes.

The distances between the neutron monitor and the points of the strikes:
1 - 6.2 km, 
2 - 5.8 km, 
3 - 6.2 km.
The bursts of neutrons observed during the thunderstorm.

**The top panel:** the count rate of the neutron monitor;

**The middle panel:** the electric field strength.

**The bottom panel:** the magnetic field strength.
Spatial location of the points of lightning strikes during the thunderstorms of June 11, 2011 and June 12, 2011 relative to the neutron monitor. The distances between the neutron monitor (on floodplain valley) and the points of strikes (on terrace): 1 - 6.2 km; 2 - 5.8 km, 3 - 7.1 km; 4 - 6.2 km.
The scheme of the points of lightning strikes of June 11, 2011.
There are some strikes that not accompanied by neutron bursts. Strikes were clearly beyond the edge of the terrace. Due to partial uncertainty points of these strikes presented here as 1-4 areas. The heights of these areas are some less then the the height of points of strikes 5-8, while it’s location not far from the points 5-8.
The thunderstorm of June 12, 2011 with positive lightning discharges that had no response in the neutron component.

The top panel: the count rate of the neutron monitor;  
The meddle panel: the electric field strength.  
The bottom panel: high-speed video shots.  
The distance between the neutron monitor and the place of the strike (TV tower) in all three cases is 4.1 km.
Provisional results:

- The short neutron flux bursts were registered during thunderstorm discharges located at the short distance (5-7 km) from neutron monitor. The increase in the neutron flux reached 36% of the average level for the data of one minute resolution.

- The bursts were observed during a significant change in the electric field (there is the threshold level).

- Results indicated that terrain relief (and high buildings) can define the probability of observations the neutron flux bursts. This means that the origin neutrons were born near the earth surface.
In June 2012 there was five (5) storms. The three storms (3) observed bursts of neutrons in excess of the fluctuation level. For example - 01.06.12 14.06.12.
During a thunderstorm, 08/06/2012, neutron bursts were observed during the thunderstorm discharges with much lower electric fields strange than in 2010 and 2011.

![Graphs showing neutron and electric field data](image)
During a thunderstorm, 14.06.2012, we observed bursts of neutrons of positive lightning discharges (the first case), and at much lower electric fields than in 2010 and 2011.

Yakutsk, June 14, 2012

![Graph showing neutron counts and electric fields](image.png)
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Conclusion

• We have considered the experimental results of observation of the neutron component at sea level (94 m) and the electric field during the nearest thunderstorms in 2009 - 2011.

• The short neutron flux bursts were registered during the short-distance (5-7 km) lightning discharges. The bursts were observed during a significant change in the electric field (down to the threshold and more). The increase in the neutron flux reached 36% of the average level for the data of one minute resolution.

• It was established that all the neutron flux bursts were observed during the thunderstorms with the second type of electric structure of the cloud having a compact positive charge at the bottom. The bursts were mostly recorded in the second half of the thunderstorm.
Thank you for attention
During the storm, 01.06.2012, has failed electrostatic fluxmeter from near lightning.
Variations of neutrons during a thunderstorm near 12 June 2011.

5 minute resolution