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Investigation of muon flux variations associated with thunderstorm events according to MH URAGAN data

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Muon telescopes, muon hodoscopes and muonography

Moscow, June 28, 2019

Muon hodoscope URAGAN

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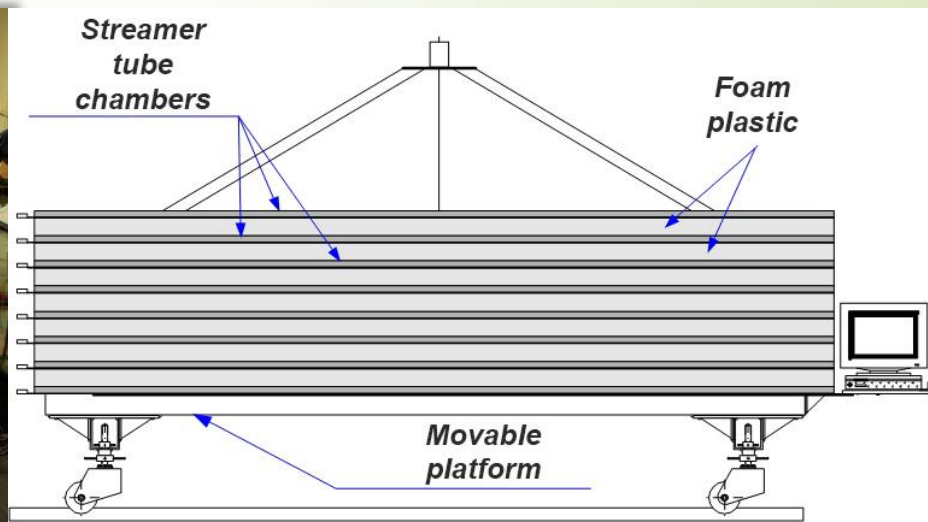
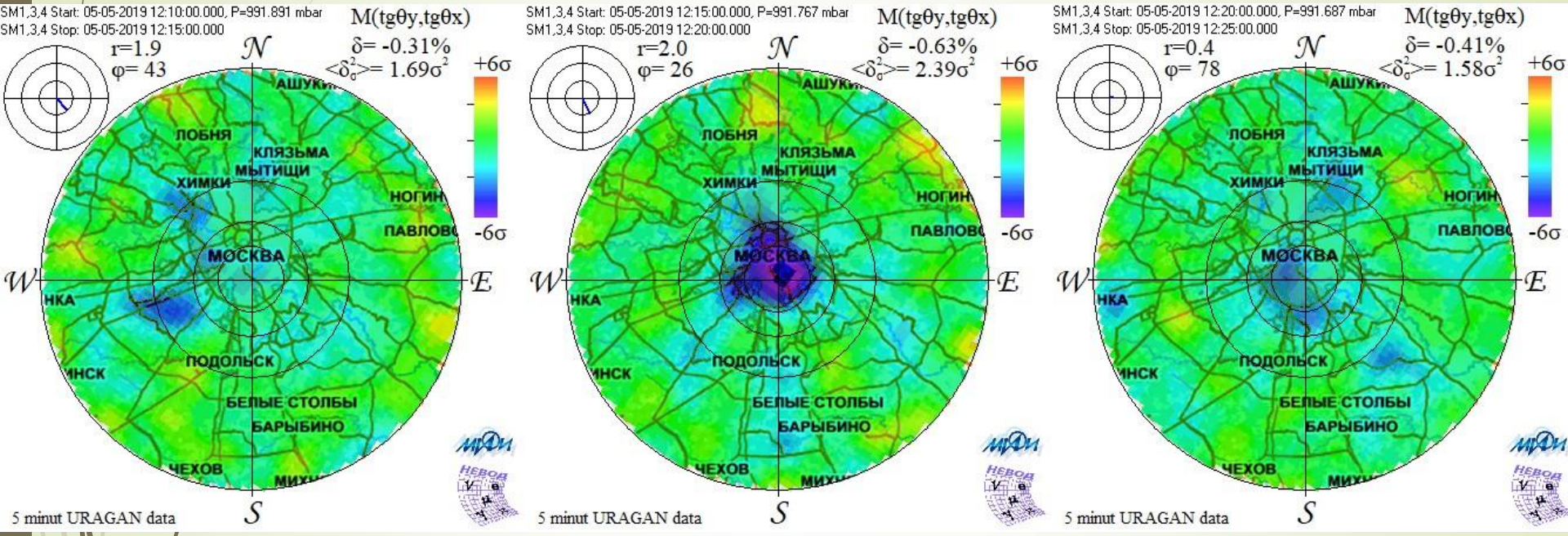
- **provides registration of muons with a high spatial and angular resolution (about 1 cm and 0.8°, respectively) in a wide range of zenith angles (from 0° to 84°)**
- **track parameters are reconstructed in real time and accumulated in a two-dimensional matrix for one minute interval. Such a matrix is a "muon picture" of the upper hemisphere**

characteristics reflecting the distortion of the distribution of the muon flux used in the analysis are:

- vector of local anisotropy (**A**) that indicates the average direction of muon arrival
- vector of relative anisotropy (**r**) that is the difference between the local anisotropy vector in the current time and its value averaged over a long period. **r**'s projection on the horizontal plane (r_{hor}) is also used.

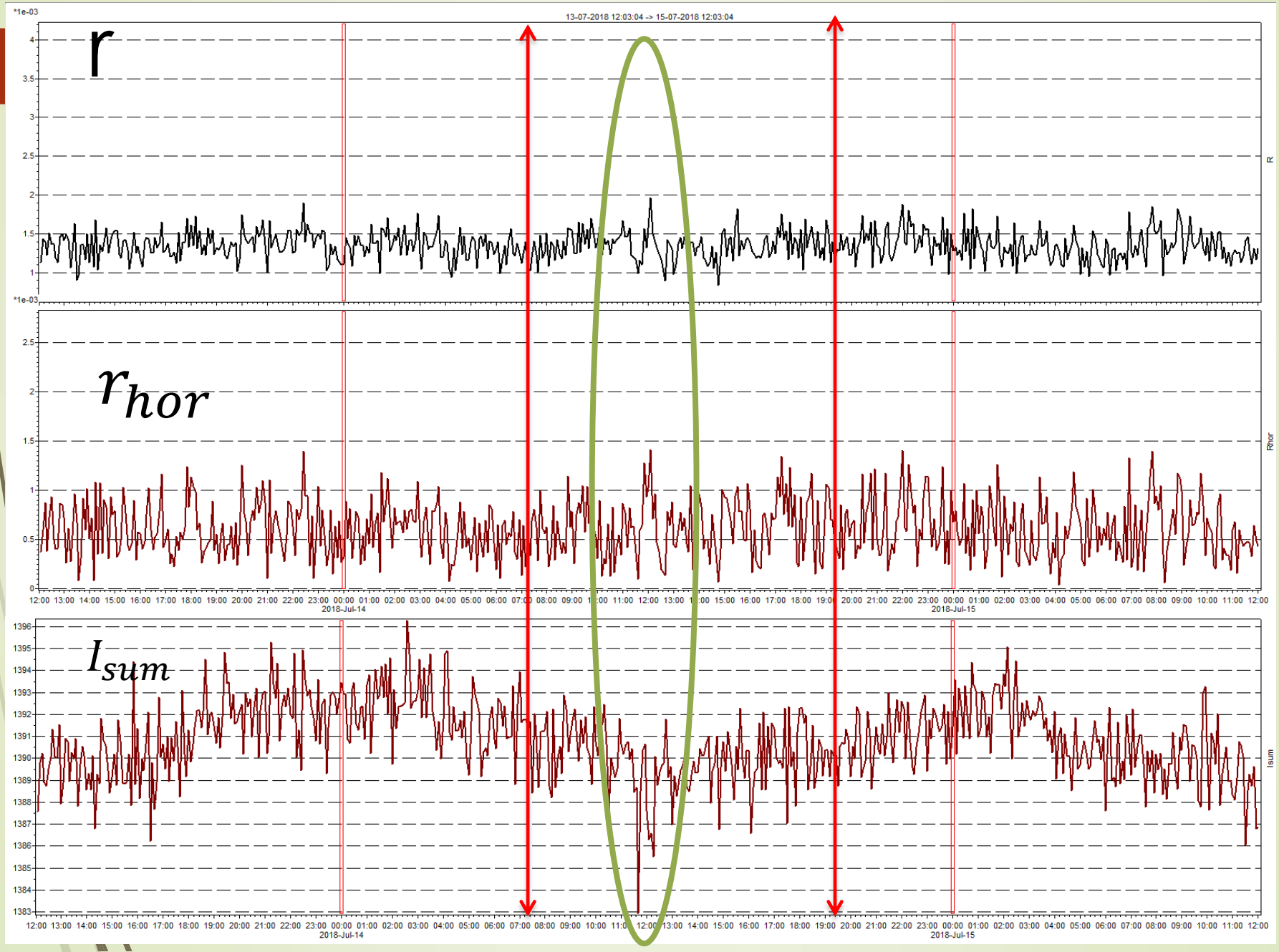


Muon snapshots (muonographs) 05/05/2019



Muonograph is a graphical representation of the matrix of variations of the angular distribution of the counting rate over the last 5 minutes (current matrix) with respect to the normalization matrix the preceding 24 hours in statistical error units

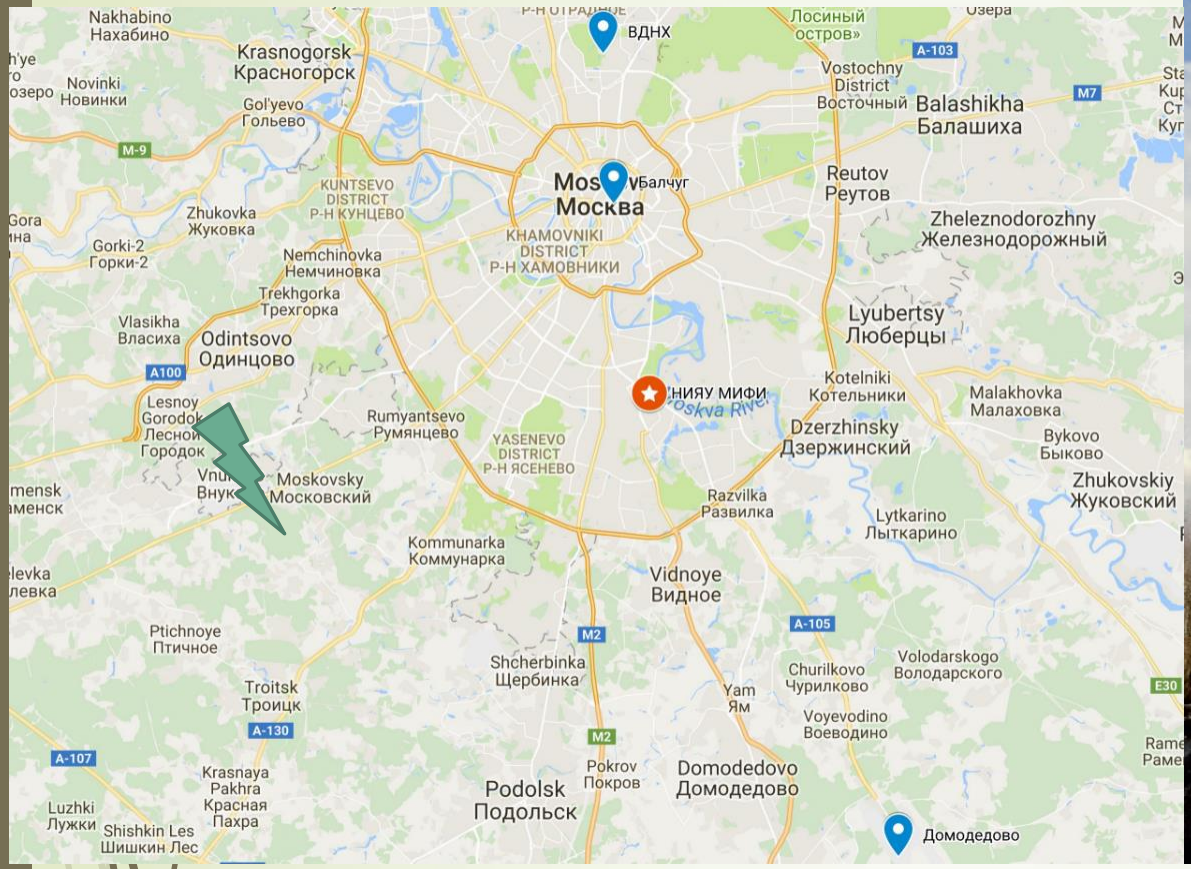
Time series of characteristics during a thunderstorms



Sources of meteorological information

5

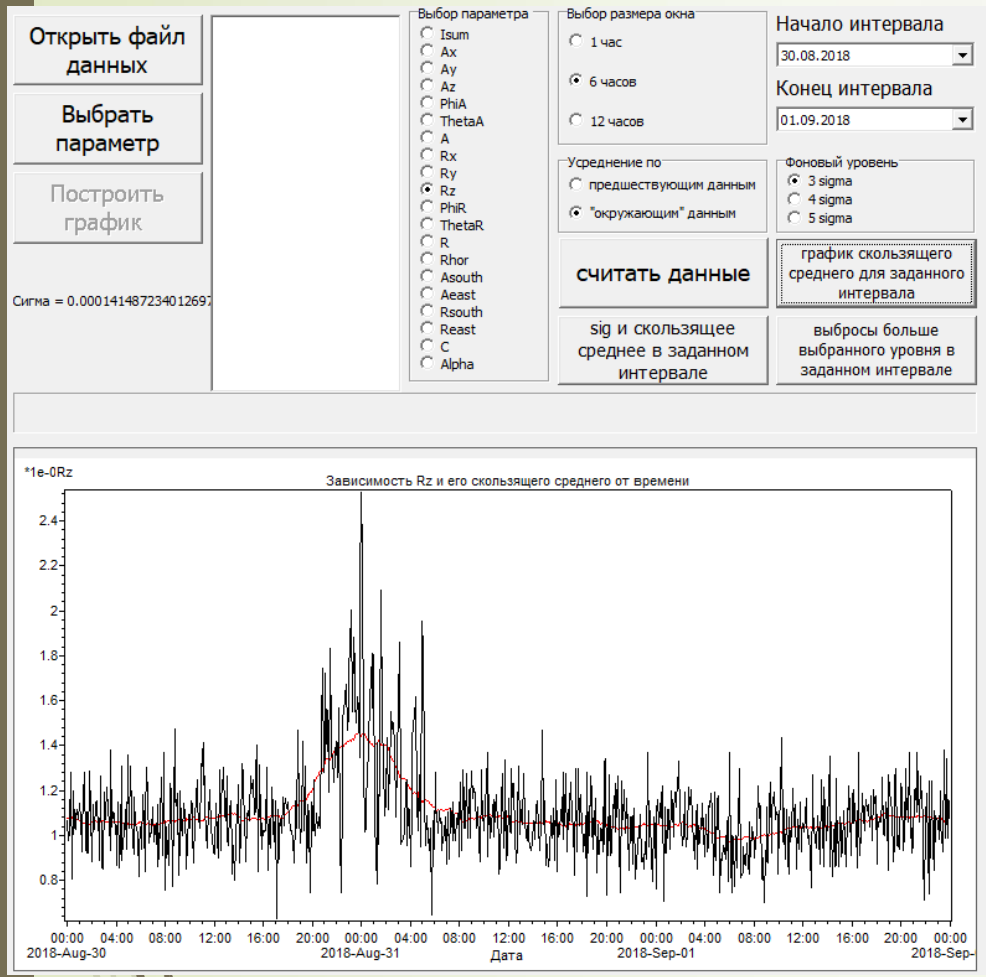
Moscow weather stations



- Weather archives are available
- The most significant weather events are noted

- a view range of 250 – 300 km
- a maximum detection height of about 20 km
- a high spatial resolution (0.5 – 1 km)

Automatic event selection



After analyzing the data for the spring-summer periods of 2014 - 2018, 173 thunderstorm events were found. It is 102 thunderstorm days vs. 135 (75%) thunderstorm days registered by 3 Moscow meteorological stations.

The effectiveness of automatic selection varies from 60% to 75% because of some inconsistencies in meteorological data.

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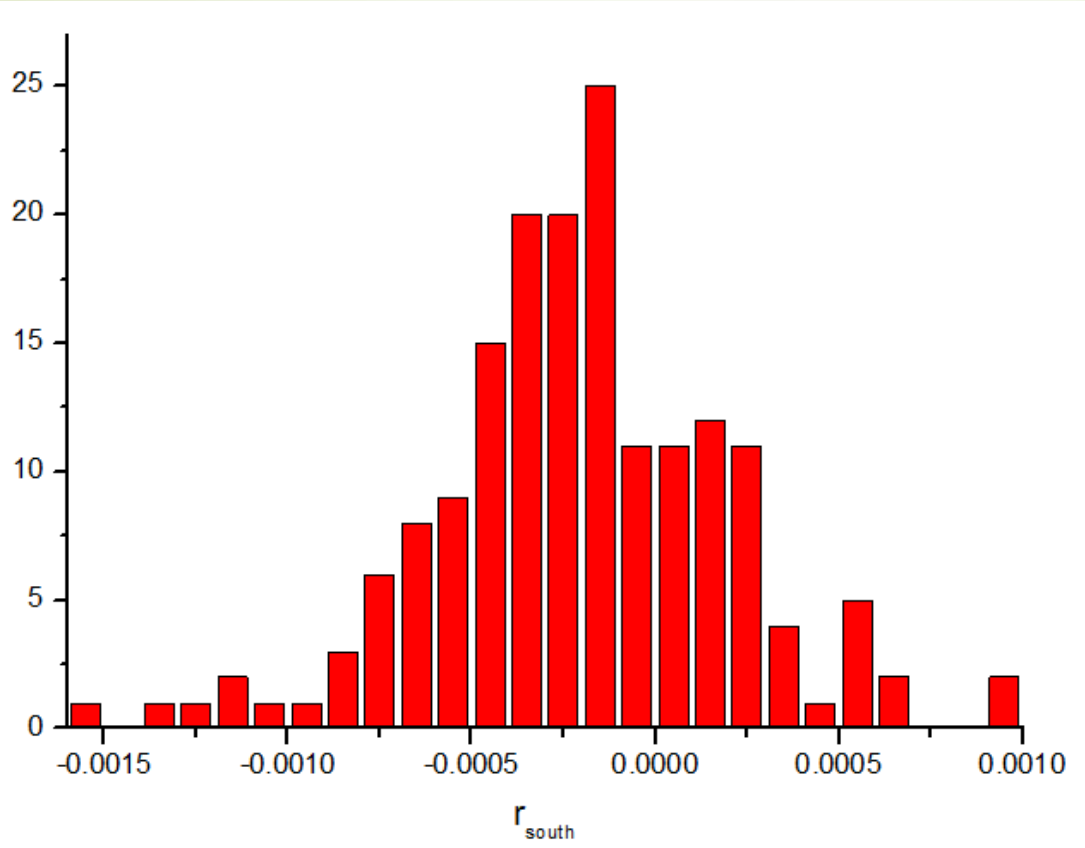
The percentage of detection without any weather registered by weather stations: 5% (8 of 173)

Selection of the most «powerful» events



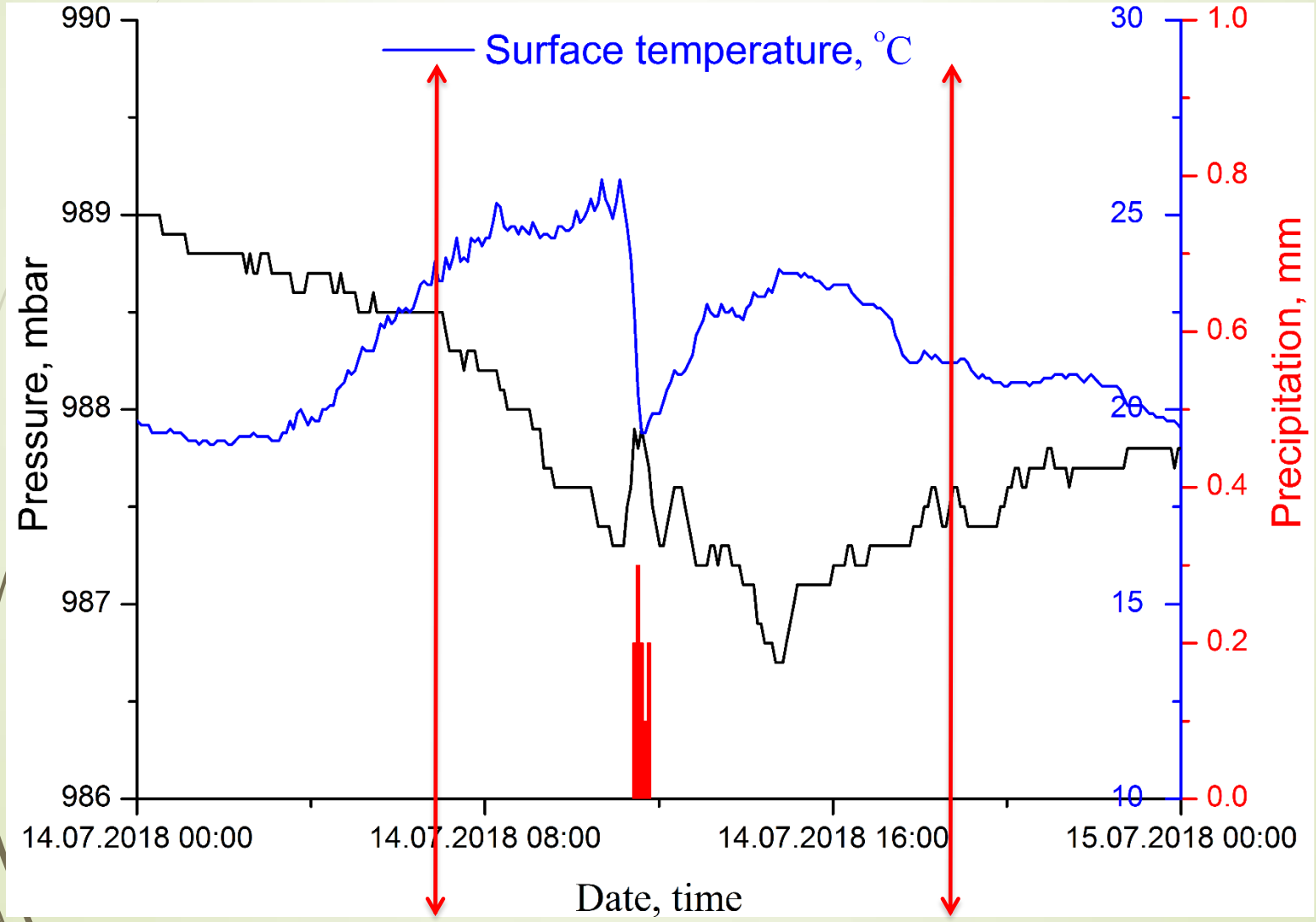
1	07.06.2014 20:00
2	07.06.2014 21:30
3	09.06.2014 11:30
4	15.06.2014 06:30
5	15.06.2014 11:00
6	13.09.2014 05:00
7	23.04.2015 06:00
8	27.06.2015 00:00
9	27.06.2015 01:00
10	27.06.2015 02:00
11	27.06.2015 03:00
12	13.07.2015 13:00
13	02.03.2016 15:30
14	17.09.2016 02:30
15	29.03.2017 00:30
16	14.08.2017 21:00
17	21.09.2018 04:00

Of the 561 thunderstorm events, 23 events were classified as “powerful” (4.1%); of 173 thunderstorm events selected by the thunderstorm event search program based on MH URAGAN data 17 events (10%) were classified as “powerful”.

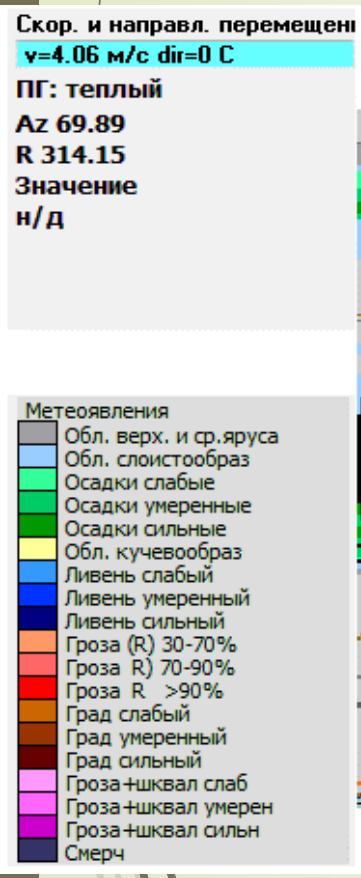
Condition of selection: deviation from the average by more than 3σ by at least one of the characteristics considered.

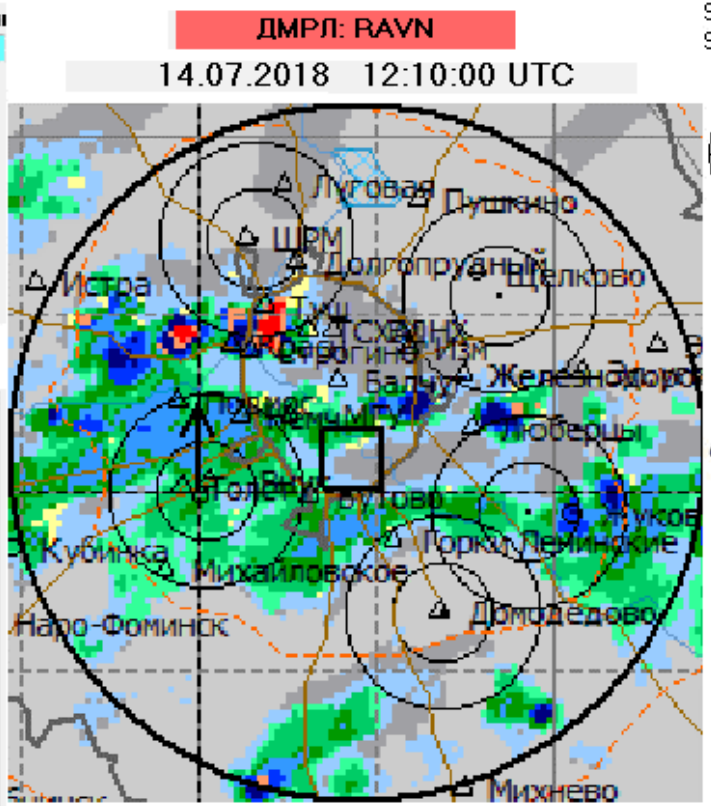
14.07.2018

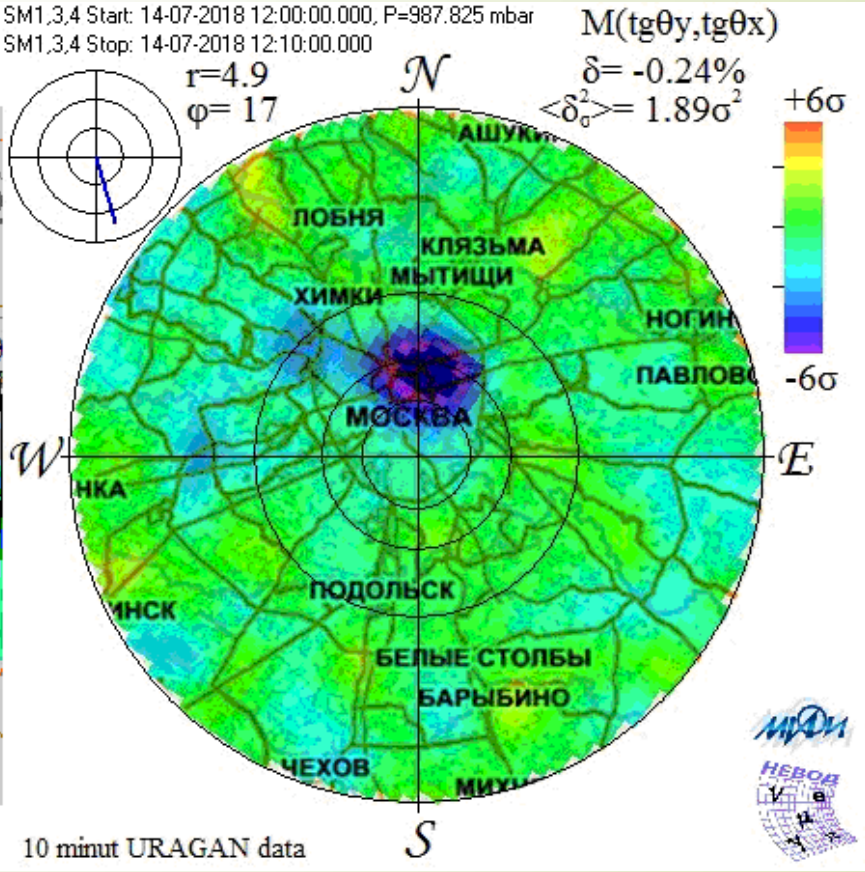
The thunderstorm was observed at the Domodedovo airport meteorological station at 14:00 (UTC time) and at the VDNKh meteorological station from 14:00 to 17:00



Comparison (11:30 – 13:10)







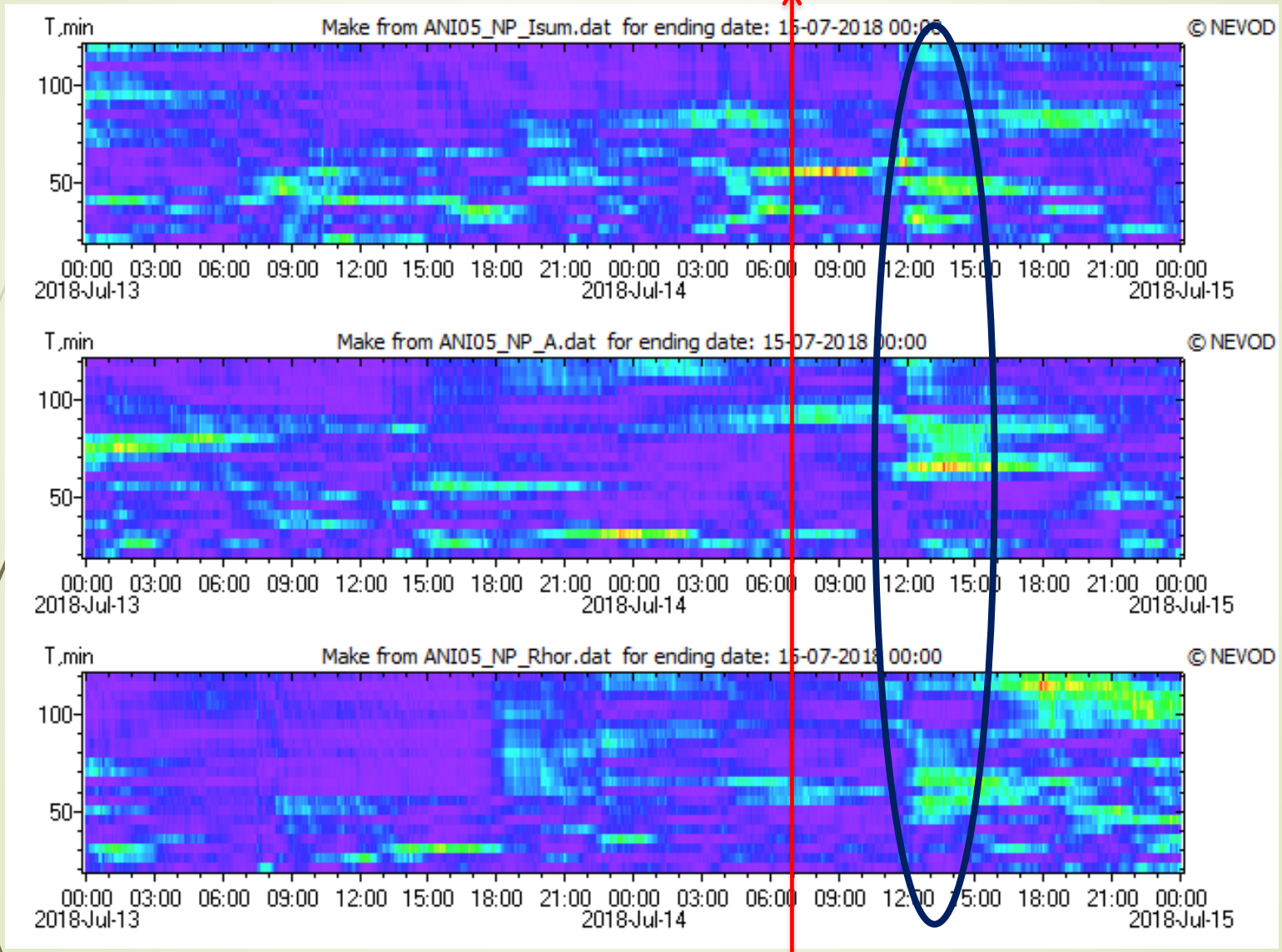
June28_Presentation_07_KachurA_Anim_1.gif

Wavelet analyses of URAGAN data

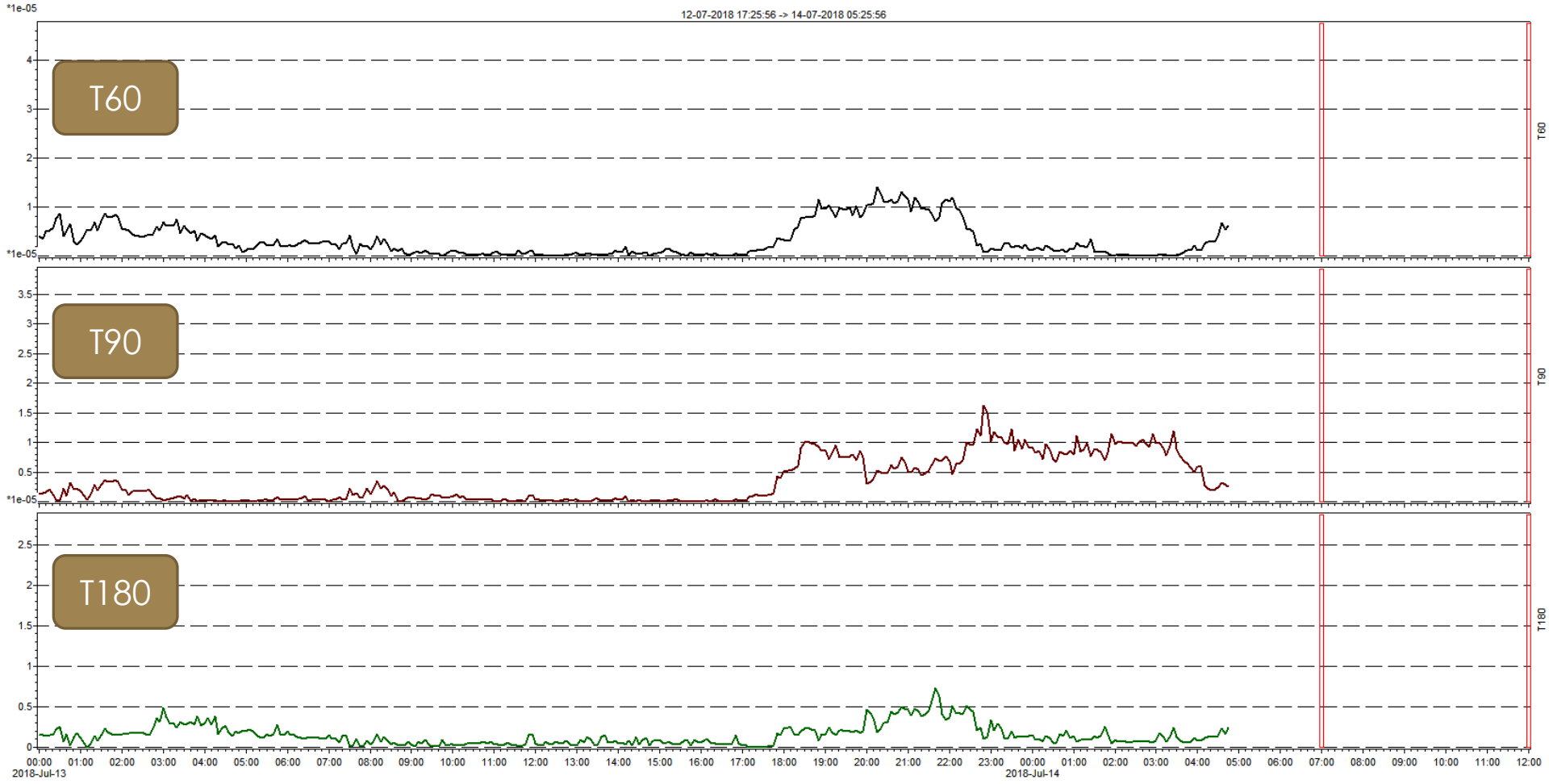
I_{sum}

A

r_{hor}

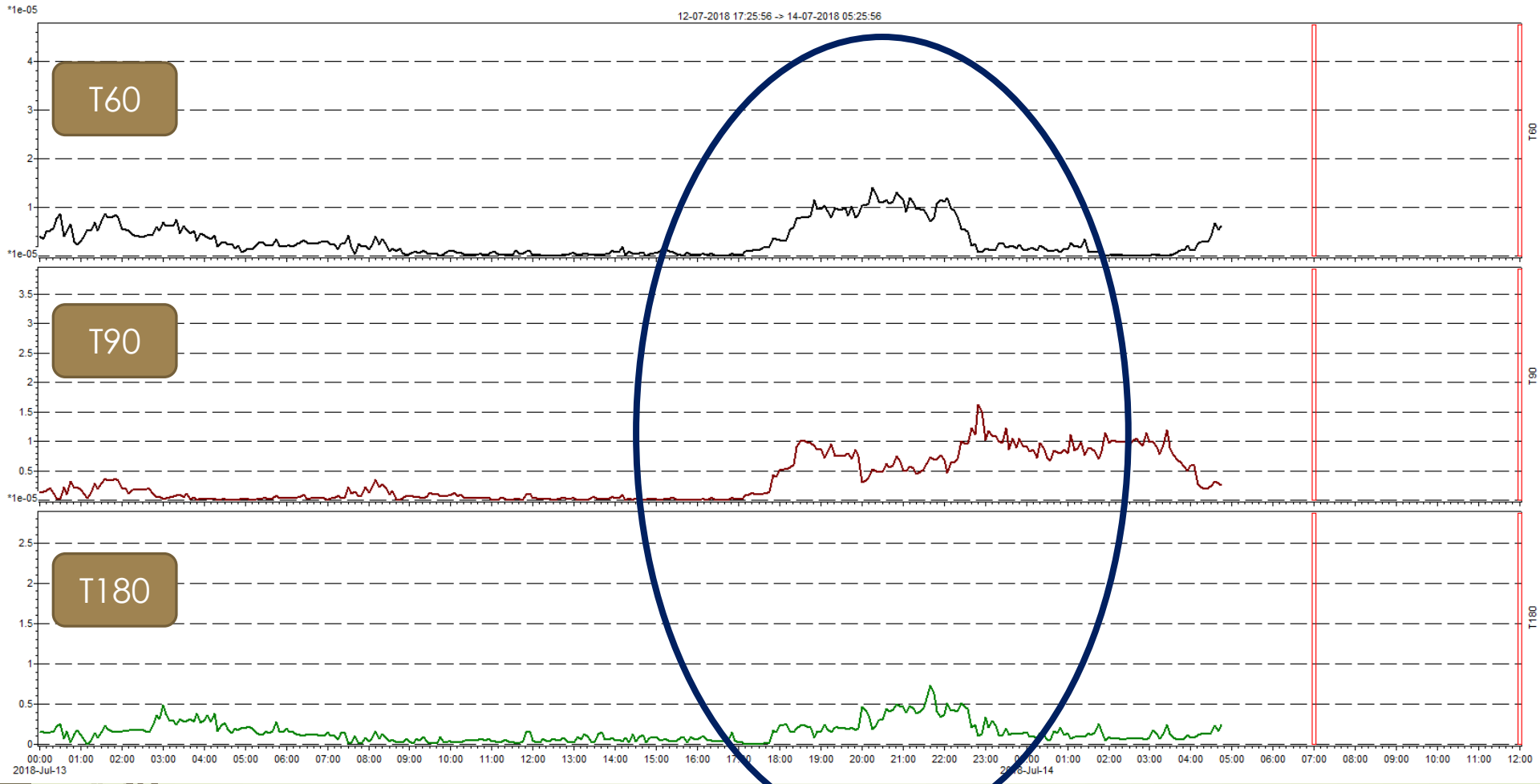


Wavelet analysis: r_{hor}

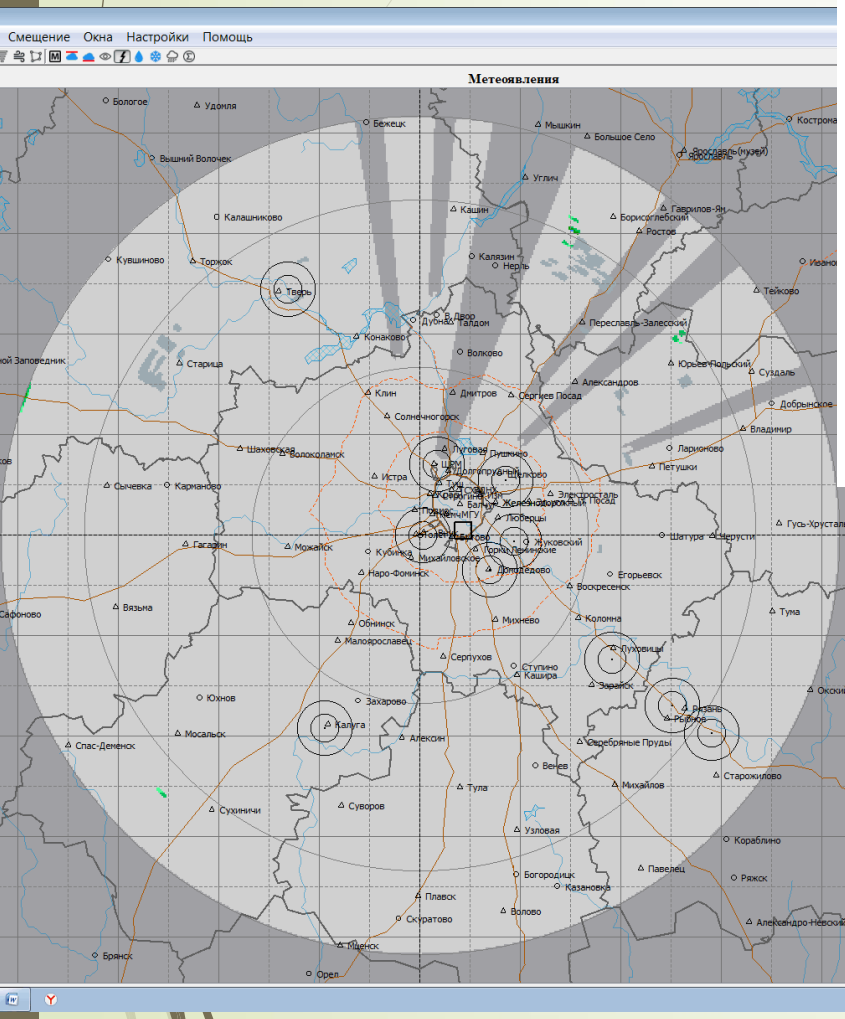


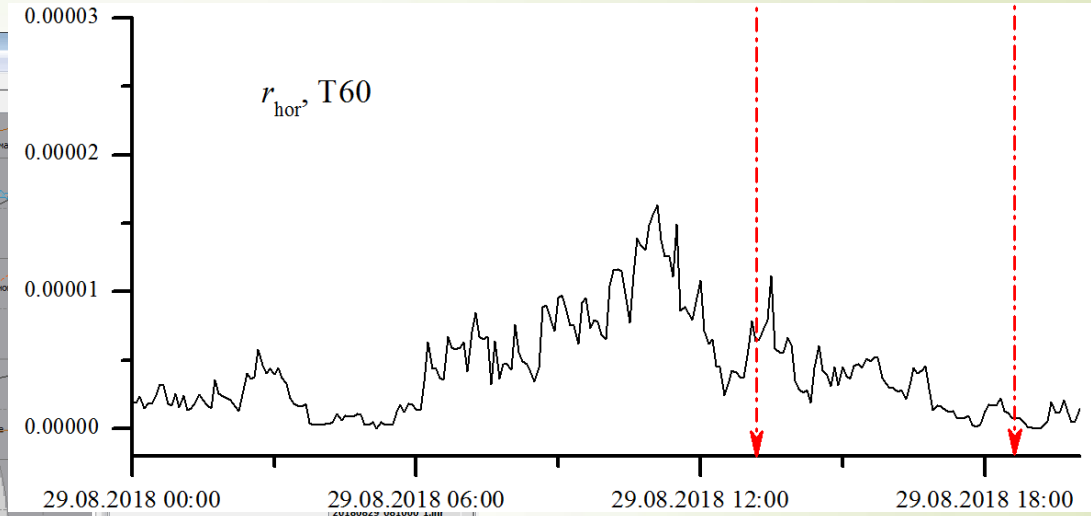
June28_Presentation_07_KachurA_Anim_2.gif

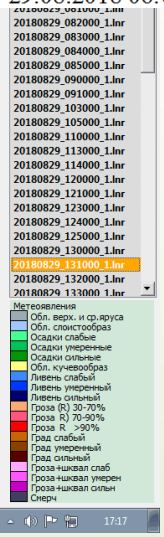
Wavelet analysis: r_{hor}



Thunderstorm activity outside the Moscow region, which is preceded by an increase in the power of the wavelet coefficient







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29.08.2018
13:10 – 18:40

June28_Presentation_07_KachurA_Anim_3.gif

Distant thunderstorms are most often preceded by the following periods of wave disturbances:
I_{sum}: 110-120 and 210 minutes.
A: 115, 150, 280, 290, 310 and 320 minutes.
r_{hor}: 100-115 minutes.

Simultaneously with distant thunderstorms, the following periods of wave processes most often appear:
I_{sum}: 115-120 and 170 minutes;
A: 160 and 310 minutes;
r_{hor}: 115 minutes.

- Characteristics of the muon flux provide a good reaction to the passage of a thunderstorm
- Wavelet analysis of different time series shows that before and during the passage of a thunderstorm there are periodic disturbances in the characteristics of the muon flux. Periods of those disturbances are ranging from 60 up to 320 minutes

Conclusions

- Obtained data demonstrate the possibility of using wavelet analysis of time series of muon flux characteristics as a tool for detecting or predicting thunderstorms.

- Those results can be used as a basis for the development of methods for the early detection of thunderstorm events by methods of muon diagnostics; they can also be used to exclude atmospheric effects in the study of outer space, the state of the magnetosphere and the heliosphere.

Thank you for your attention!

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Muon diagnostics

- **Formation of the muon flux: in the atmosphere at an altitude of 10 - 20 km**
- **The top of a typical thunderstorm cell: at a height of 8 - 12 km**

The muon flux is modulated by changes in the basic thermodynamic parameters of the atmosphere.

$$\frac{\Delta N_\mu}{N_\mu} = \beta_p \Delta p + \beta_T \Delta \mathrm{T}$$

The higher the temperature, the:
- higher pion generation point
- longer geometric path of the muon to the surface of the Earth
- higher probability of decay

The greater the pressure, the greater muons absorption (due to an increase the amount of substance)