High-energy events in the atmosphere and their relationship to the electrical structure of the cloud

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Numerical simulation of atmospheric phenomena accompanied by emission of energetic particles in thunderclouds is carried out using The Weather Research and Forecasting Model (WRF). A large observational data ensemble obtained in the Aragats Space Environmental Center is compared with numerical simulation results. The comparison enables to recover the distribution of the charged particles (hydrometeors) in the cloud with the use of ground level electric field measurement results. If there is a region with sufficiently strong field in a cloud, energetic particle avalanches could be generated and measured on the ground. Based on general assumptions about the avalanches multiplication mechanisms, a new evidence concerning cloud electric structure could be obtained.

Phenomenon of minute-scale intensification of energetic particle flux – thunderstorm ground enhancement (TGE) [1] is characterized by an excess of the flux over the background level of about 1-10%, typical duration is from tens of minutes to several hours. Understanding of the process of TGE formation is impossible without the knowledge on the electric field structure in a thundercloud which is very restricted due to the difficulties of direct measurements and absence of radar data so far. Calculations made with use of WRF could give to us a possibility to make estimations concerning cloud structure and compare them with measurement results.

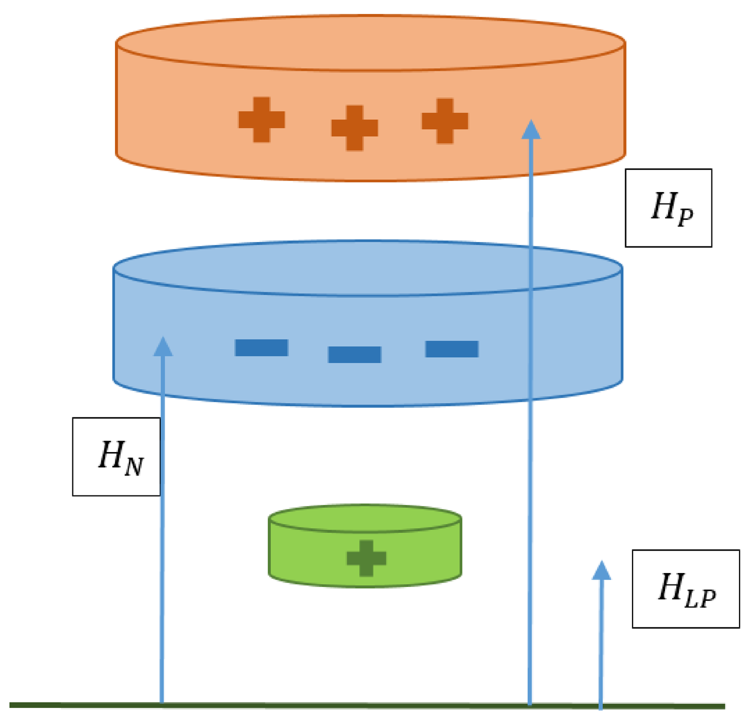

Fig 1. Three-layered cloud structure has proven to be a sufficiently non-complicated model of cloud charge distribution.

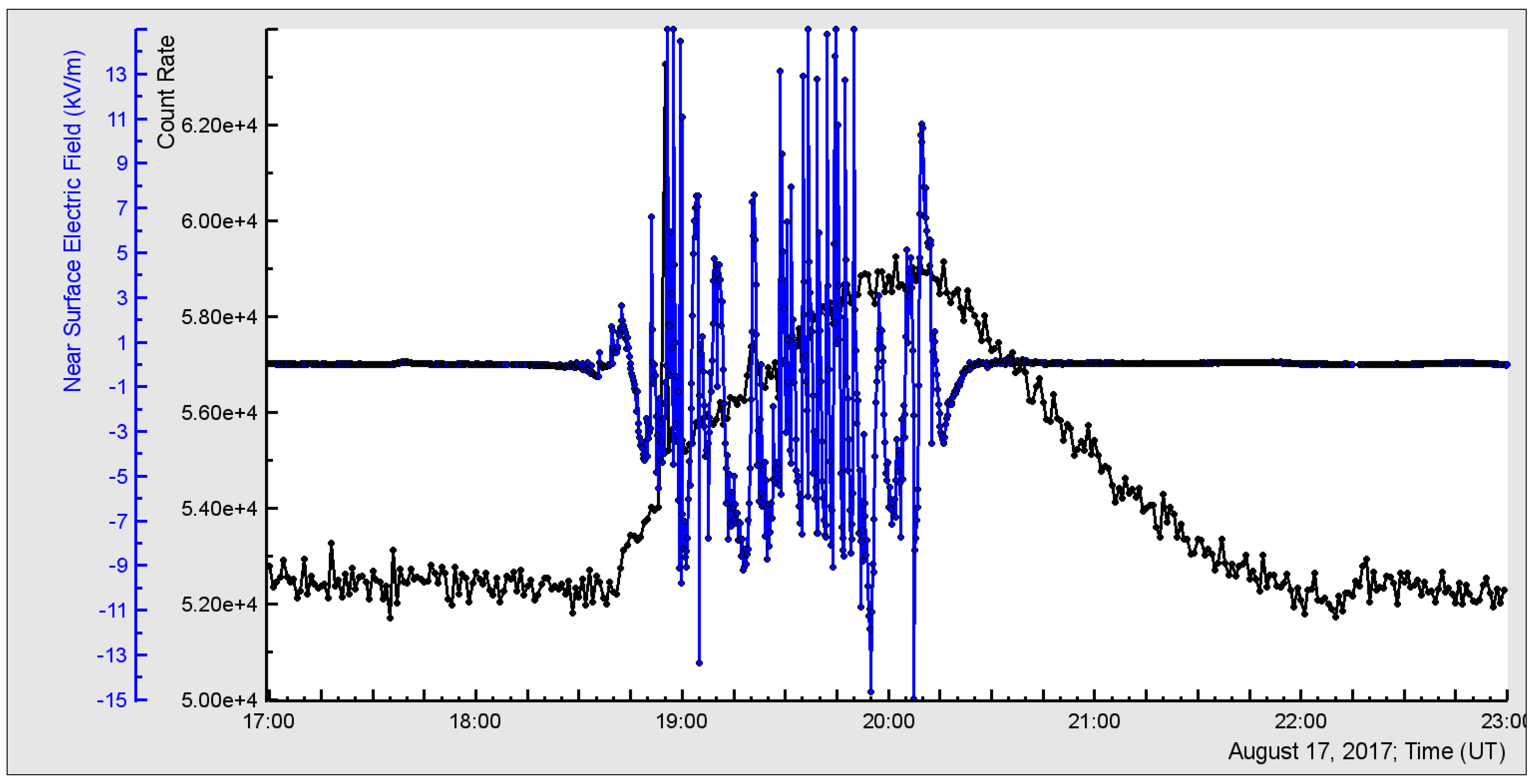

Fig 2. Ground-based measurements results for TGE of 17 August 2017.
(blue curve — electric field, black curve — count rate)

The Weather Research and Forecasting Model is an atmospheric modeling system designed for both meteorological research and numerical weather prediction [2]. WRF is suitable for a large number of applications from small scale problems to global modeling. The model is an accessible research tool involving multiple parameterizations of physical processes and serves a basic module for the development of new parameterizations and algorithms.

With use of the WRF model cloud particles spacial distribution could be recovered. For example, it was found that the cloud, which caused the TGE at 19:40 on 17 August 2017, consists mainly of particles of so called “snow”, “ice”, “graupel” and “rain” types (particles are divided on several types depending on their size and form). “Snow”, “ice” and “graupel” particles are located at approxmately 4 km height; “rain” - at 0.5 km. Clusters have a quite large vertical size: 2-4 km. (See Fig.3)

Good correspondence of simulation and measurements results for ground level electric field proves that specific charge of each fraction could be considered as conserved in time. For some events, separate electric field peaks could be explained by the impacts of certain particle types, which leads to possibility to recover the sign and absolute value of each significant fraction specific charge independently from other fractions charge recovery. Moreover, often the cloud structure recovered with means of WRF could be described as two-layered or three-layered, which is consistent with the assumption of avalanche generation in the strong field regions between the layers. The proposed technique enables to recover the charge values of the lower and the middle layers with use of the ground measurement results and calculations within the Weather Research and Forecasting Model.

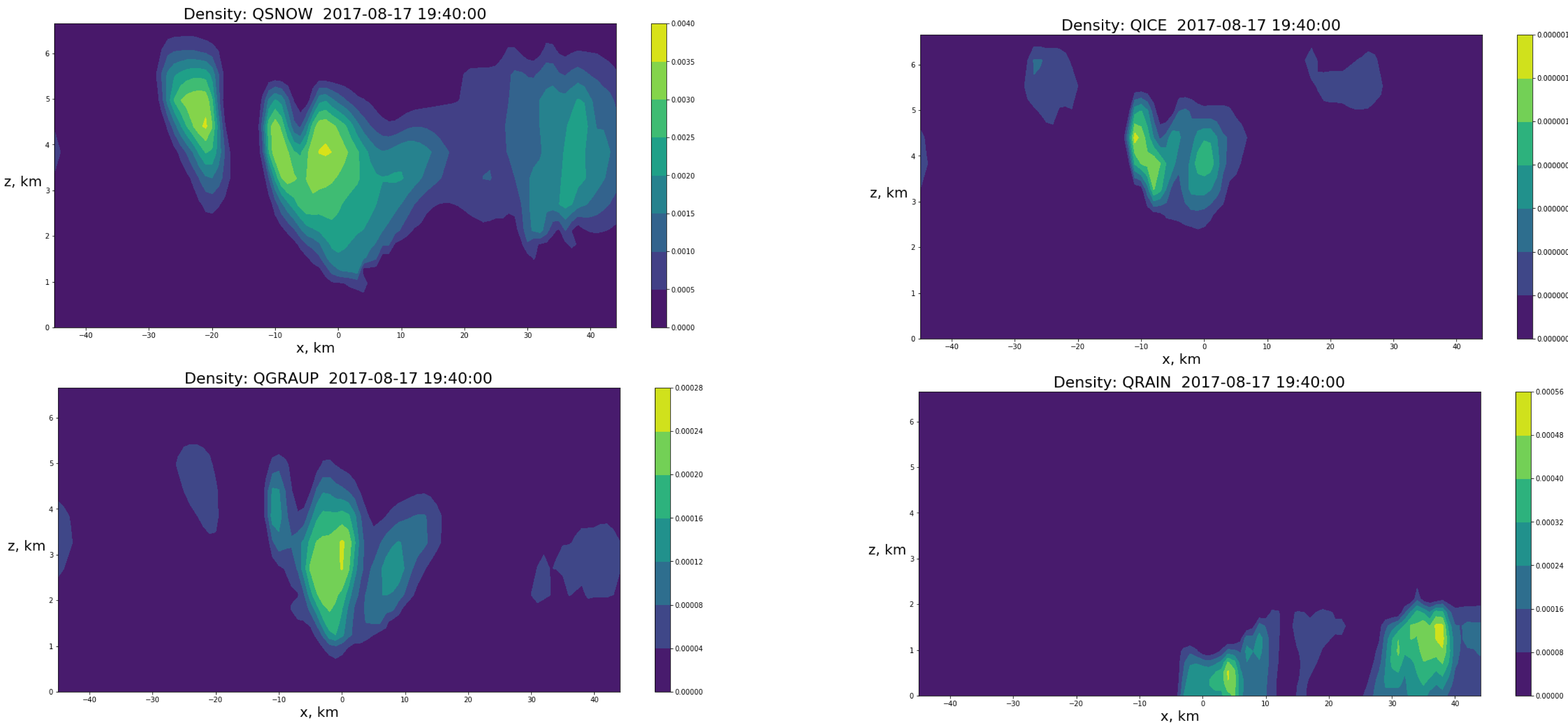

Fig 3. Spatial distribution of “snow”, “ice”, “graupel” and “rain” particles above the station at 19:40 of 17 August 2017.

References
[1] Chilingarian A.A. 2014, JASTP, 107, 68–76.
[2] www.mmm.ucar.edu/weather-research-and-forecasting-model