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Thunderstorm hail and lightning prediction parameters based on dual polarization Doppler weather radar data

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Convective storms can pose a high risk as they are often accompanied by lightning, heavy rain and hail. Weather radar has become an invaluable tool in the study of these storms because they are difficult to analyze based on regular meteorological data as they generally do not have large spatial dimensions, can have relatively short lifetime and can therefore be missed by the stations.
This work aims to build a basis for automatic lightning and hail prediction from Estonian radar data. To achieve this we used radar data for detecting the storm areas and derived a number of descriptive parameters for the detected storms. 15 different parameters for lightning and 13 for hail prediction were obtained. The parameters were then analysed and compared to find the best for lightning and hail prediction.

Study period included four years of data (2011-2014) from the summer period. In addition to the data from C-band dual polarization Doppler radar located in Sürgavere, Estonia lightning location data from Nordic Lightning Information System (NORDLIS) and vertical temperature profile information from Harku radiosoundings were used. Hail and graupel were estimated based on proxy data obtained from weather radar polarimetric observables. The compared parameters for lightning or hail prediction that were calculated for each detected storm cell were maximum PPI reflectivity, storm area, probability of hail, hail top height, graupel top height and 10 echo top height parameters with 5 dBZ steps from 0 dBZ to 45 dBZ.

Overall 123 360 individual storm cells were identified in the whole study period. The number of individual storm cells has a peak at 1300 UTC, which is late afternoon (1600 EEST) by local time and falls in line with the general knowledge of the convective storm development in the area. On average the storm cell areas are largest at 1800 UTC. Hail occurrence in the cells has a peak from 1200-1300 UTC while CG flash density in the cells is highest in the evening at 1900 UTC. The identified storms were divided to ones that had lightning activity within them and to ones without lightning activity to study the potential of obtained storm attributes for lightning risk indication. After the division 33.9 % of the storms were labelled as lightning active. Similar division was made based on hail occurrence in the cells for hail risk prediction analysis. Hail was detected in 25.9 % of the overall number of storm cells.

To asses the performance of the various storm attributes as lightning and hail predictors a number of dedicated skill metrics were used. Probability of detection (POD), false-alarm ratio (FAR) and critical success index (CSI) of different classifiers as a function of classification threshold were calculated.
We used the commonly employed way to evaluate the performance of weather warnings and looked for the highest CSI value among the parameters. For lightning the best CSI is obtained with Echo Top 20 when using the classification threshold 5000 m (CSI = 0.390, FAR = 0.563, POD = 0.783).
For hail the maximum CSI is obtained with cell maximum reflectivity at threshold value 48 dBZ (CSI = 0.554, FAR = 0.352, POD = 0.792). Probability of hail, which has been operationally used as a hail indicator in a number of NMS-s, did not show that good correlation with hail occurrence estimated from dual polarimetric data. The maximum CSI for probability of hail was 0.469 with FAR of 0.5 and POD 0.883 at probability threshold value 0.12.
Overall we found that larger storms are more prone to cause lightning and produce hail as higher minimum allowed storm area caused an increase in a priori probability of both hail and lightning