Abstract

Professional literature on the processing of precipitation data for the design and modeling of drainage systems clearly indicates the necessity of using precipitation atlases, which provide full and possibly spatially precise information on the rainfall depth (intensities) of design rainfall as a function of their duration and frequency (probability) of occurrence. Such atlases are difficult to develop for many areas of the world due to the lack of access to multi-year databases of rain gauge recordings at high temporal resolution of at least 10 minutes. Even in countries with developed meteorological services and relatively good coverage space by rainfall stations, the realization of rainfall atlases faces difficulties related to the discontinuity of individual measurement series and, above all, the complex workshop necessary to correctly interpolate spatial maxima of precipitation, modeled only the way of discretely at the locations of individual rain gauges. Moreover, there is an increasingly clear trend toward reducing the number of rain gauge networks due to the cost of operating ground-based instruments and the increasing focus on remote measurements using techniques of remote sensing, including satellite and radar measurements.

Considering the mentioned premises, a study was undertaken with the primary goal of comparing rainfall models based on measurement data from rainfall radars and rain gauges across Poland. At the beginning two research theses were formulated:

1. Maximum rainfall intensities and heights obtained from radar products can be estimates of equivalent maximum instantaneous rainfall intensities and heights from rain gauges,
2. Distribution series of maximum intensities rainfall intensities derived from radar products can be the basis for creating local precipitation models equivalent to local models developed based on rainfall series from rain gauges.

The research material used in the study was rainfall series recorded by rain gauges from the multi-year period 2007 - 2015 (part of the PANDa Atlas digital rainfall database) and time series of SRI and PAC radar products from the POLRAD system for 98 locations across Poland. A set of fourteen SRI and PAC products exported for the locations of PANDa project rain gauges within the range of the POLRAD system was available. In this set, the outputs were 10-min time series of POINT-type SRI and PAC values (in a given dimension of 1 km × 1 km pixel), as well as series of locally spatially corrected GRID-type values (analyzed in squares formed by combining nearby pixels, with sizes of 3 km × 3 km or 5 km × 5 km). The GRID-type SRI and PAC values were set as follows: the maximum from the entire GRID (max), the average value (avg), or the average value excluding pixels with no precipitation (avgNo0).

As part of my own research a sequence of analyses was carried out consisting of :

- Comparing the annual rainfall depth recorded by rain gauges and various radar products during months with positive temperatures (May through September),
- The conformity assessment in terms of the number and depth of rainfall events recorded by rain gauges and radar products,

- Analyzing the time correlation of the time series of radar products and the series of rainfall events against the reference series and the series of rainfall events from the rain gauges,
- Separating and mutually comparing the series of phase maxima's of rainfall from time series of radar products and rain gauge records for a hierarchy of 18 durations ranging from 10 minutes to 4320 minutes,
- Developing rainfall models (probabilistic D-D-F type models) by fitting six different types of statistical distributions, such as generalized gamma distribution, Weibull distribution (2-parameter), generalized exponential distribution (3-parameter), exponential distribution (2-parameter), log-normal distribution, generalized Pareto distribution,
- Identifying the best statistical distribution to describe the phase maximums extracted from rain gauge and radar registrations, and selecting the radar product that provides the highest consistency with the rainfall model based on local rain gauge data.

Conducting the above research sequence required working with large datasets, including the selection of 158,760 statistical distributions of maximum precipitation for 98 stations in Poland, for 18 durations of precipitation, 14 different radar products, and reference data from rain gauges. The evaluation of the quality of the selected distributions of maximum precipitation based on radar data and their similarity to the reference distributions from rain gauges was compared using informational criteria (AICc, BICc, and HQIC), test statistics (λ, $\chi 2$, and A-D), and error measures (MAE, MAPE, and MSE). The execution of all the mentioned tasks was made possible through the development of a custom software library called PANDAS POLRAD in Python.

The result of the research made it possible to confirm the theses of the work and to formulate eleven final conclusions. It was primarily found that in the case of small collections of maximum precipitation, separation using the POT method from short rain gauge series, as well as all 14 analyzed radar products in Poland, the exponential distribution is the best type to describe them. At the same time, regardless of the evaluation criterion used, the radar products predisposed to building precipitation models are the more advanced PAC-type hydrological products: PAC_GRID_5_max, PAC_GRID_3_max and PAC_POINT. In conclusion, it was emphasized that by assuming one universal type of statistical distribution, namely the exponential distribution, and a single universal radar product, namely PAC_GRID_5_max, for the entire country, one should expect an average mean absolute percentage error (MAPE) value (estimate from radar models for frequencies from C=1 year to C=10 years relative to the reference estimates from rain gauge models) to average around 30% for durations ranging from 10 minutes to 4320 minutes, across a set of 98 stations throughout Poland.

Keywords: weather radar, rain gauge, urban hydrology, rainfall maxima, rainfall models, rainfall atlases, D-D-F curves