# Drivers of extreme precipitation events in Poland



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#### Introduction:

The first aim of this paper is to investigate the relationship between daily and hourly precipitation extremes and air temperature in Poland with respect to the validity of Clausius– Clapeyron (C-C) scaling.

The second aim of the paper is to investigate the impact of circulation and transport of humidity on the extreme precipitation events occurrence in Poland based on data on 26 stations across Poland from the period 1951-2015.

Circulation types favouring high one. precipitation events

## Relationship between extreme hourly precipitation and air temperature

Westra et al. (2014) suggested that the intensity of subdaily rainfall is more sensitive to changes in local air temperature than daily-scale rainfall. For Polish data the exponential regression fits well at majority of stations. It means that the regression parameter a can be used for comparison of existing relation to C-C scaling. The intensity of precipitation/temperature relationship for the 95<sup>th</sup> percentile for each location is presented in Fig. 1. It can be observed that the scaling parameter is very close to 7% increase in 95<sup>th</sup> percentile of hourly precipitation amounts per 1°C increase in air temperature.

In case of 95<sup>th</sup> percentile there is only one exception from C-C scaling and only in warm season (green line on Fig. 2). In the case of 50<sup>th</sup> percentile the scaling is much weaker than C-C, specially if seasonal values are concerned. Greater scaling for the whole year than in both seasons may be a consequence of fact, that in Poland there is a big difference in processes leading to strong precipitation event in winter and summer. Different reaction of mean and extreme precipitation on air warming is also well seen on Fig.3 which presents the comparison of distributions of scaling parameter in relation to season (whole year, warm and cold periods) and percentile of precipitation totals (95<sup>th</sup> and 50<sup>th</sup>). In the case of median of hourly totals the increase of precipitation amount with increasing temperature can be observed only during cold part of the year and the whole year. In warm season the scaling parameter is close to zero. The increase of the 95<sup>th</sup> percentile of precipitation totals with increasing temperature is the stronger for annual values than in seasons. The interseasonal differences are expressed rather by higher dispersion of C-C scaling parameter in warm season than in the cold



0.12 -----



The analysis of circulation types conducive precipitation extremes is based on selection of days with high daily totals and then basing on the daily patterns of SLP, distinguishing circulation types using the Ward's k-mean method (Ward, 1963). To select days with precipitation extremes for each julian day the 95 percentile of precipitation totals in wet days (days with precipitation higher than 0.1 mm) was calculated using a data from a moving window of 31 days centred around this day. Then all days with totals exceeding 95 percentile were selected. This procedure was repeated for all stations. The days with threshold exceeded on at least 5 stations were finally used for the further analysis.

Furthermore, on the basis of the daily patterns of SLP, different circulation types that cause high precipitation events in Poland were distinguished. The analysis was performed separately for four seasons (spring MAM, summer JJA, autumn SON and winter DJF). Moisture transport was assessed using the methodology proposed by Phillips & McGregor (2011) basing on wind components and specific humidity taken from 850 hPa level. The SLP data as well as geopotential heights, wind components and specific humidity at 850 hPa level were taken from NCAR/NCEP reanalysis (Kalnay et al., 1996) from the area 30-70°N, 60°W-60°E and cover the period 1951-2015.

In winter three types were distinguished (Fig. 4). The first type is connected with intense North Atlantic Oscillation with stronger than usually low in the northern part of the North Atlantic and high in the middle latitudes of the North Atlantic. Such circulation enhances the humidity transport from the west or southwest to Poland. The second type accompanied precipitation extremes is related to stronger than usually north-western advections with deep low in the north spreading from northern Greenland to northern Europe through Atlantic Ocean and high pressure located over western Europe and nearby Atlantic. During third type low pressure center is located over central and western Europe, blocked by high pressure system over western Russia. Warm and humid air comes to Poland from the south. In summer only two types were distinguished (Fig. 5). The first type is connected with enhanced Azorian High spreading directly to the north-east along the coast moving out of the central Europe, where the relatively low pressure dominates. During such situation the warm and humid air comes to Poland from the south or south-west. During second type favoring precipitation extremes over Poland the negative anomalies of SLP spread over Scandinavia and the south-western advection of humis air is enhanced.



Fig. 3. Box and whiskers plots of C-C scaling parametrs for all stations. In each group annual values are on left, warm season in the middle and cold season on the right (value 0.04 means 4% increase in precipitation percentile per 1°C increase in the air temperature)

Fig. 2 Scaling of 95th (left column) and 50th (right column) percentiles of daily precipitation totals with mean air temperature at 2 m a.s.l. Annual values (upper row), warm season (IV-IX, middle row) and cold season (X-III, lower row), dashed blue lines indicate C-C scaling.

Fig. 1. The exponential regression fit for 95th (red) and 50th (black) percentile precipitation at selected sites (annual values – left column, summer – middle column, winter – right column), compared to the C-C relationship (dashed blue lines).





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Fig. 4. Mean SLP (A), SLP anomalies (B) and anomalies of thee humidity transport at 850hPa level (C) for three synoptic types causing high precipitation events in winter.



## Probability of extreme precipitation events for different circulation types

For each station 16 circulation types were distinguished with the method by Piotrowski (2009) indicating on character of circulation (cyclonic or anticyclonic) and direction of air mass advection at this particular location. Next the conditional probabilities of extreme precipitation occurrence at this location for each circulation type was assessed basing on the frequencies of circulation types and numbers of days with extreme precipitation (further PE95PP – Probability of Exceedance of 95<sup>th</sup> Percentile of daily Precipitation totals). The results (Fig 6) indicate that both in warm and cold parts of the year the cyclonic types were more favorable than anticyclonic. Also the directions of air mass advection fostering the high precipitation events are in accordance with previous findings: from the western and southern sectors in cold seasons and from the southern and eastern sectors in the warm seasons.





