Urban Water Interfaces (UWI)

IGB Leibniz-Institute of Freshwater Ecology and Inland Fisheries

Technische Universität Berlin

# Spatiotemporal patterns of short-duration heavy precipitation in Germany

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# Motivation

- Heavy rainfall events and the high variability of their occurrence have a significant effect on the urban water cycle and are commonly thought to increase in the future.
- The increasing risk of urban flash floods is a problem jointly faced by the urban infrastructure, water networks and -systems.
- A better understanding of the diurnal and seasonal precipitation cycles of short-duration heavy rainfall events is therefore required.

# Aims

- Identification of heavy rainfall events leading to **surface runoff** and **sewer overflow**
- The following questions should be addressed:

1) What is the **diurnal distribution** of very short heavy rainfall events in urban environments?
2) What is the **seasonal distribution** of very short heavy rainfall events in urban environments?
3) Is it possible to identify years that showed a particularly large number of heavy rainfall events?

# Approach and method

- Time-series analysis of precipitation durations of **10-min and 1-hour** for **22 meteorological stations**
- Precipitation data provided by German Weather Service (DWD)
- Time period: **2000-2018**
- Event selection by **peak-over-threshold-method (POT)**
  → 10-min-events: 9.3 mm
  → 1-hour-events: 20.1 mm
  → thresholds derived by KOSTRA -DWD

- Study site:

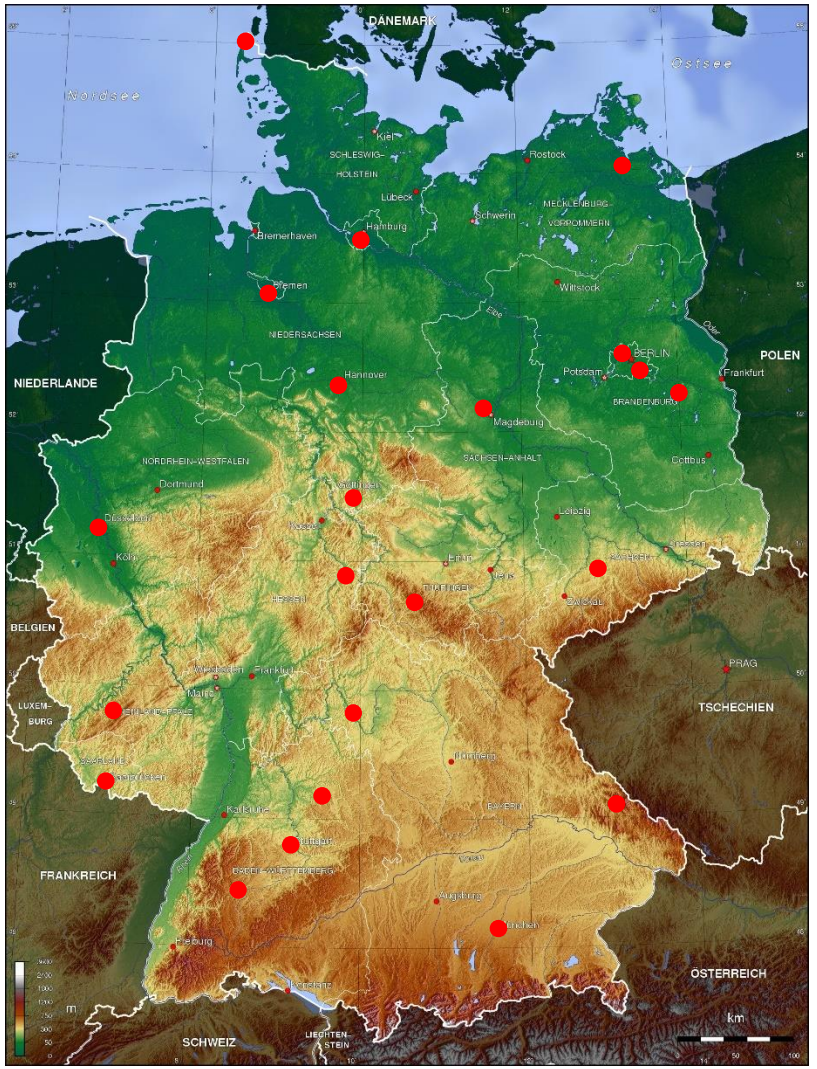



*Fig.1: Topographical map of Germany, red points mark locations of 22 meteorological stations [1].*

# Results : Diurnal distribution

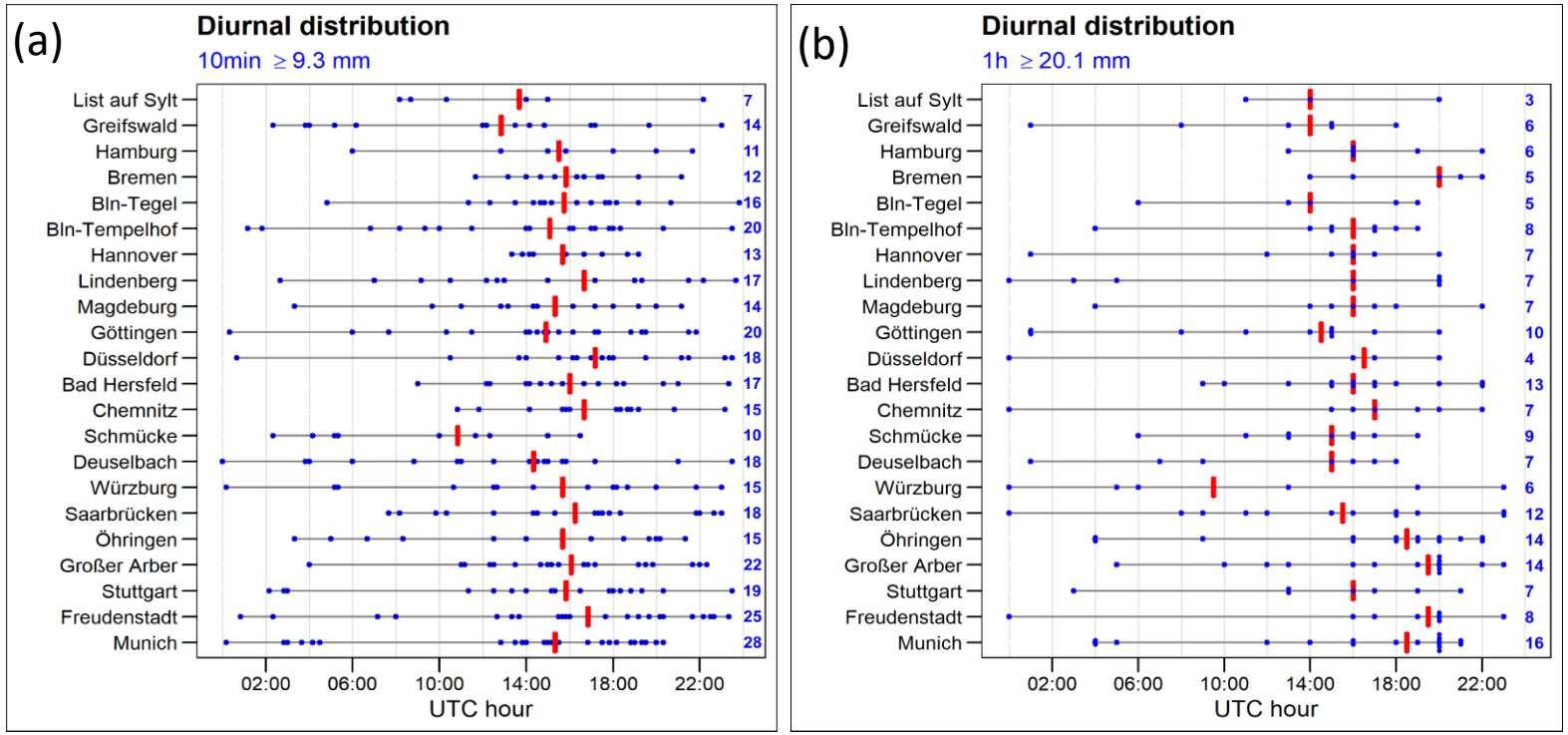



*Fig. 2: Diurnal distribution of short-duration heavy rainfall events across Germany of (a) 10-min duration with threshold of 9.3 mm and (b) 1-hour duration with threshold of 20.1 mm. Red mark represents the median, number of events are given in blue [2].*

- 79 % of heavy rainfall events occur in the afternoon and evening ($12^{00}$ – $22^{00}$)
- Selected stations show three dominant patterns:
  **1)** accumulation of events over 12h (predominantely in the afternoon)
  **2)** bimodal distribution (early morning and afternoon)
  **3)** homogeneous distribution of events over 24h

# Results : Frequency distribution

- Increase of frequency of events from the North to the South
- Predominant occurrence in the afternoon → subtle differences in frequency peaks and time ranges without heavy rainfall events

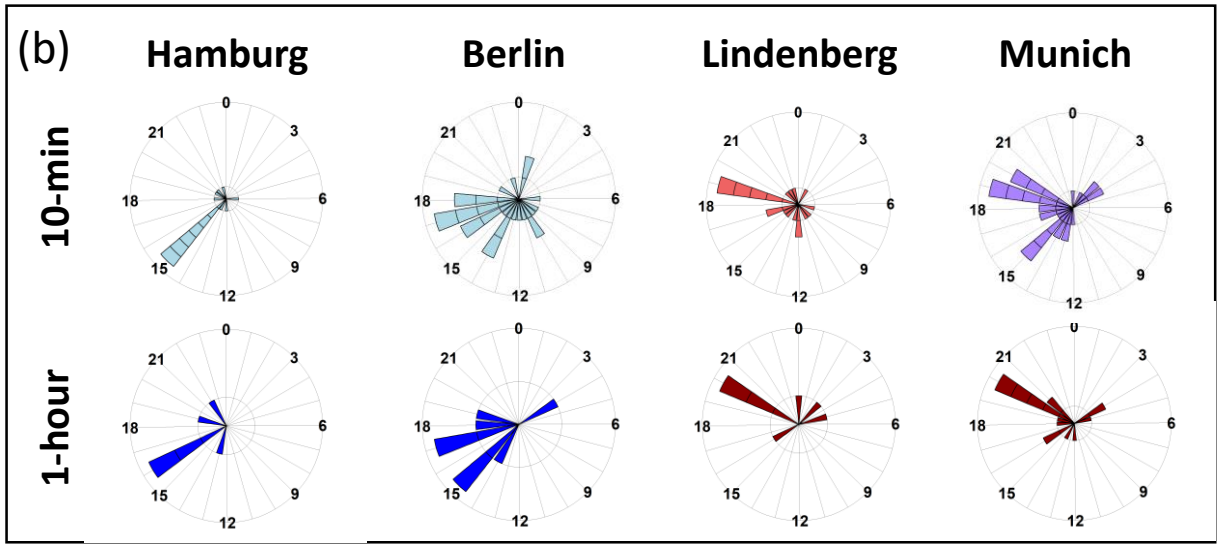
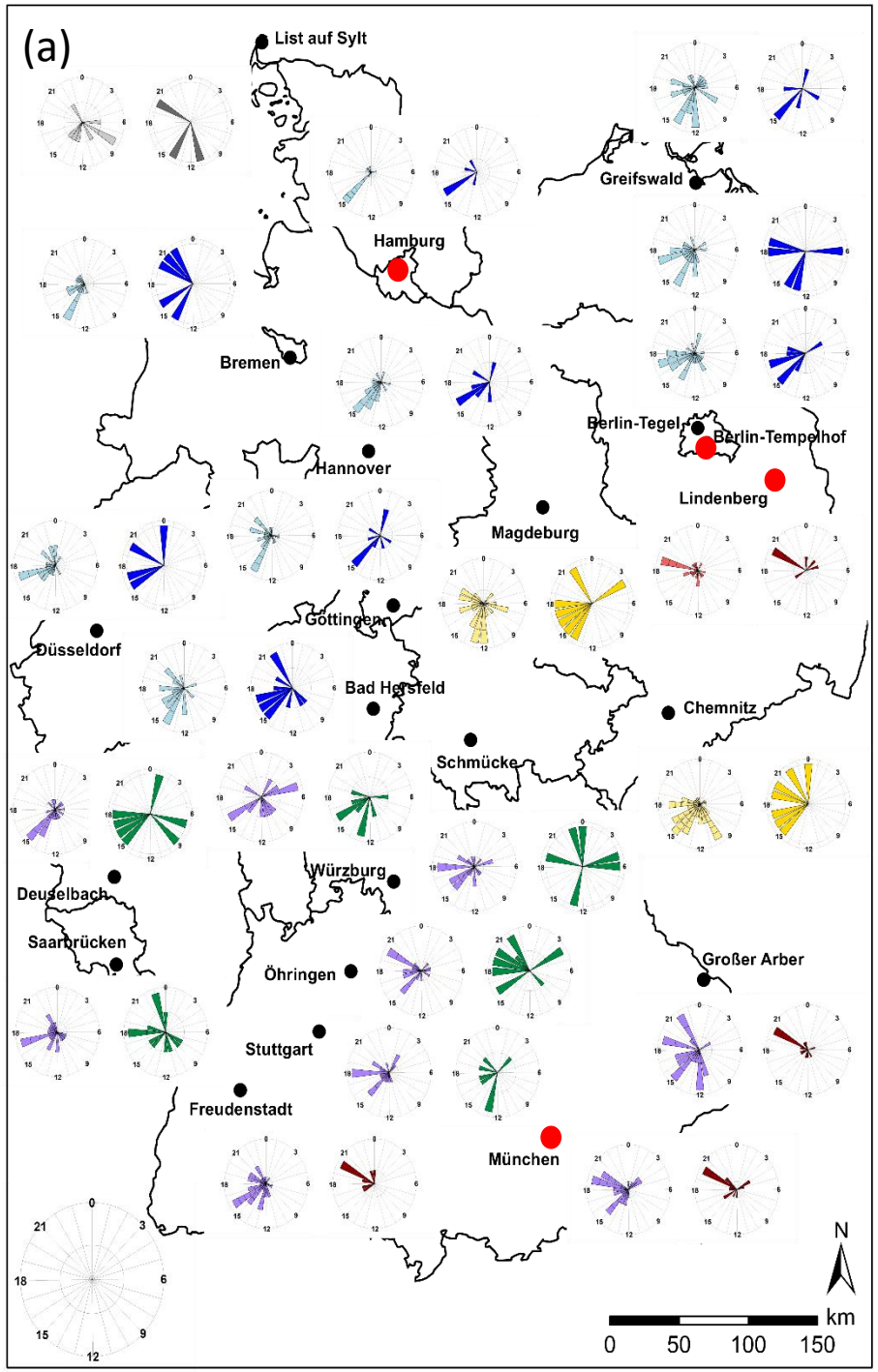



*Fig. 3: (a) Diurnal frequency distribution of short-duration rainfall events across Germany. Pie chart represents 24-hour clock, whereby right pie charts present 1-hour events (≥20.1mm) and left pie charts present 10-min events (≥ 9.3mm). Pie charts of the same colour present similar diurnal distribution patterns. (b) Extract from 2a (red stations) [2].*



# Results : Seasonal distribution

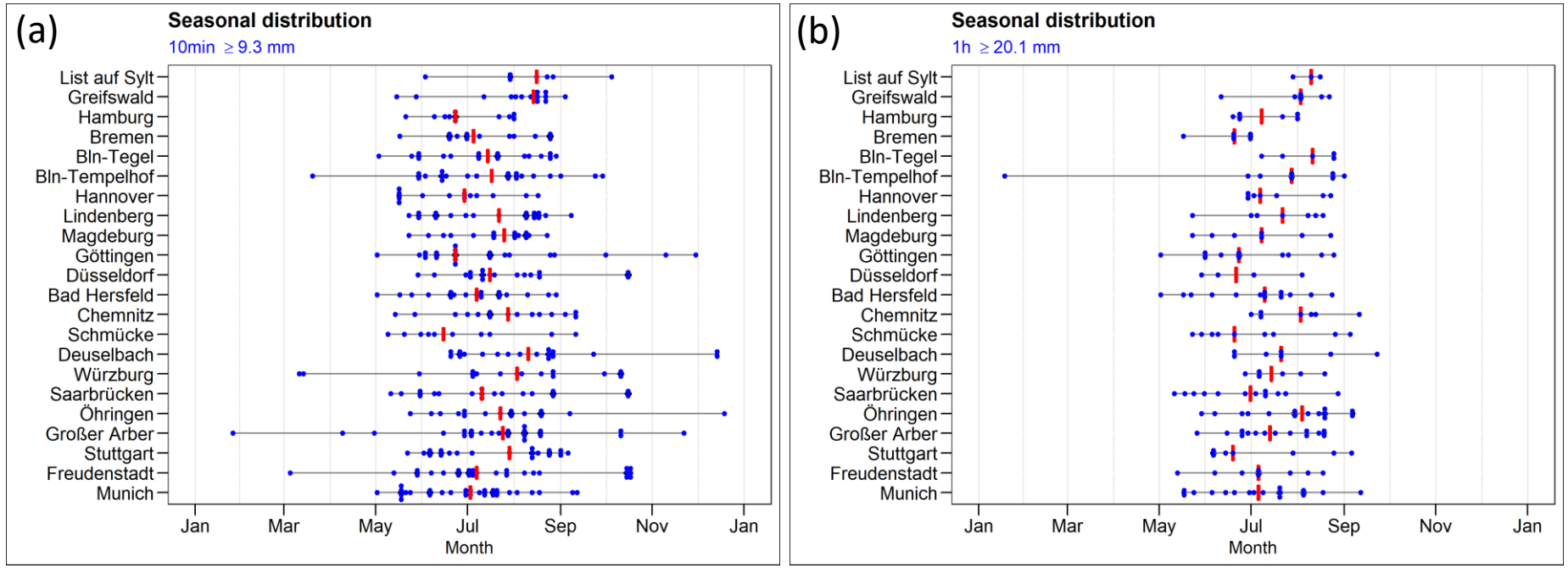



*Fig.4: Seasonal distribution of short-duration heavy rainfall events across Germany of (a) 10-min duration with threshold of 9.3 mm and (b) 1-hour duration with threshold of 20.1 mm. Red mark represents the median [2].*

- Most heavy rainfall events (92 % of 10-min and 99 % of 1-hour events) occur between May and September, 50-60 % in July-August
- 8 % of 10-min events occurs outside the upper mentioned time range
  → stations mainly located in the southern half of Germany

# Results : Annual distribution

- In average, 19 rainfall events of 10-min duration occurred per year
- 2 out of 19 years a small number of events occurred (2003, 2015)
- In 3 out of 19 years a relatively large number of heavy rainfall events occurred: 2005, 2007, 2017

- In average, 8 rainfall events of 1-hour duration occurred per year
- 6 out of 19 years a small number of events occurred (2000, 2001, 2003, 2004, 2008, 2015)
- 2 out of 19 years had maximun values (2016, 2018)

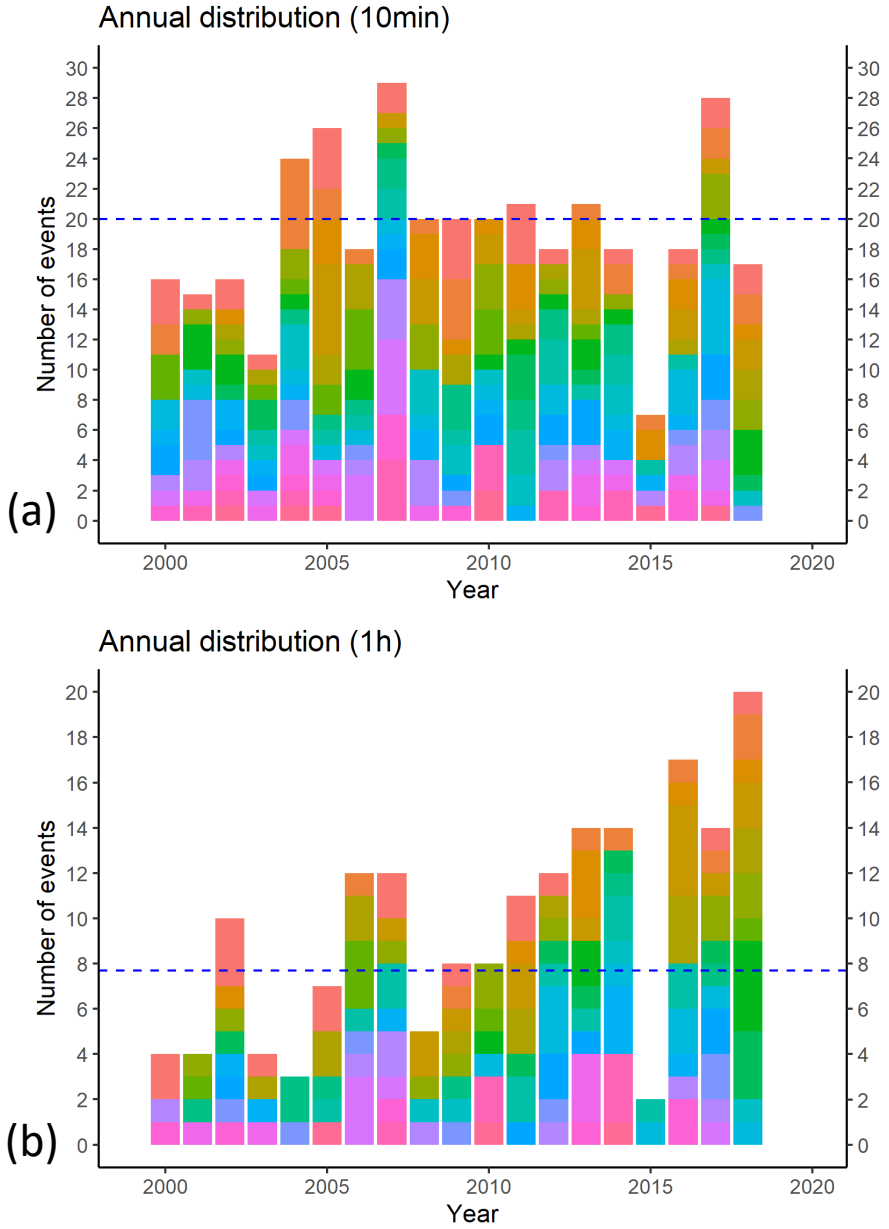



*Figure 5: Annual distribution of short-duration heavy rainfall events across Germany of (a) 10-min duration with threshold of 9.3 mm and (b) 1-hour duration with threshold of 20.1 mm. Dashed line represents average number of events [2].*

# Discussion & Conclusions

- Main reasons for observed distributions:
  1) **Solar energy** (sunshine duration and radiation):
     → More frequent short heavy rainfall events in the afternoon and summer season can be a sign for an intensification of convective precipitation processes in these periods
     → Strong correlation between the amount of solar energy (sunshine duration and radiation distribution) and diurnal timing of investigated events (stations with late frequency peak appear to be located in the southern regions)

- 2) **Large-scale weather conditions** [3] with main wind-direction from the SW, leading to a decrease of intense and frequent heavy rainfall events from South to North

- 3) **Other possible reasons:** Orography, Urban Heat Islands (UHI) and the effect of water bodies

The results help to narrow down the time window of flash flood incidents important for planning local and regional mitigation measures and urban drainage infrastructure.
The knowledge of their approximate timing will be useful to timely prepare for flash flood mitigation, e.g. by making sure retention storages are empty in July and August, and emergency services are on alert during specific hours during the day.

# References

[01] *https://de.wikipedia.org/wiki/Datei:Deutschland_topo.jpg, accessed on 27 April 2020*

[02] Haacke, N. & Paton, E.N. (subm.) Frequency analysis of diurnal, seasonal and annual variability of rainfall extremes in Germany.

[03] Ghada, W., Yuan, Y., Wastl, C., Estrella, N. & Menzel A. (2019) Precipitation Diurnal Cycle in Germany Linked to Large-Scale Weather Circulations. *Atmosphere*, 10(9), 545, DOI: 10.3390/atmos10090545.