Towards a new multi-sensor heavy rainfall statistics for Germany (KOSTRA-DWD-Hybrid): combining long-term rain gauge measurements with high-resolution radar data

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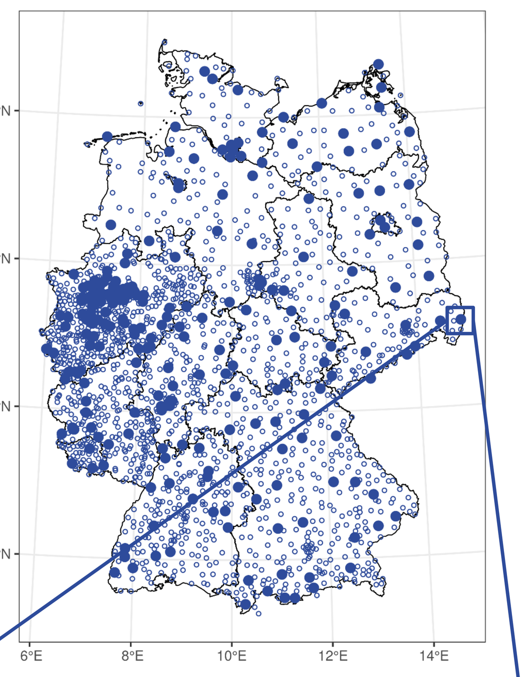
*As **heavy rainfall events (HREs)** become more frequent and intense with ongoing climate change, accurate and comprehensive analyses of their patterns, including the generation of **depth-duration-frequency (DDF)** curves, are crucial for enhancing our understanding of rainfall dynamics, assessing associated risk, and implementing effective mitigation strategies. DDF curves are essential for designing water management systems and facilities, such as dams, dikes, spillways, flood retention basins, and urban drainage systems. For Germany, this data is provided by **KOSTRA-DWD** (German: **Koordinierte Starkniederschlagsregionalisierung und -auswertung des Deutschen Wetterdienstes**), a product developed since the 1980s at the Department of Hydrometeorology of the Deutscher Wetterdienst.*

DATA CONSOLIDATION & QUALITY CHECKS



KOSTRA-DWD-2020

- ✓ The latest version, KOSTRA-DWD-2020, is based on the **annual maximum series (AMS)** from 1900 rain gauge stations. AMS were calculated for 22 rain durations ranging from 5 min to 7 days.
- ✓ Subsequently, the **generalised extreme value (GEV)** distribution was fitted to AMS of a particular duration. To account for the interconnectedness of HREs across different durations, the concept of Koutsoyiannis et al. (1998) was applied to smooth heavy rainfall statistics over all durations.
- ✓ Ultimately, GEV (ξ, α) and Koutsoyiannis (θ, η) parameters were interpolated using **kriging with external drift (KED)**, where stations with at least 50 years of records guided the primary interpolation, and stations with at least 10 years of records served as the external drift. DDF curves were then estimated for 9 return periods ranging from 1 to 100 years.

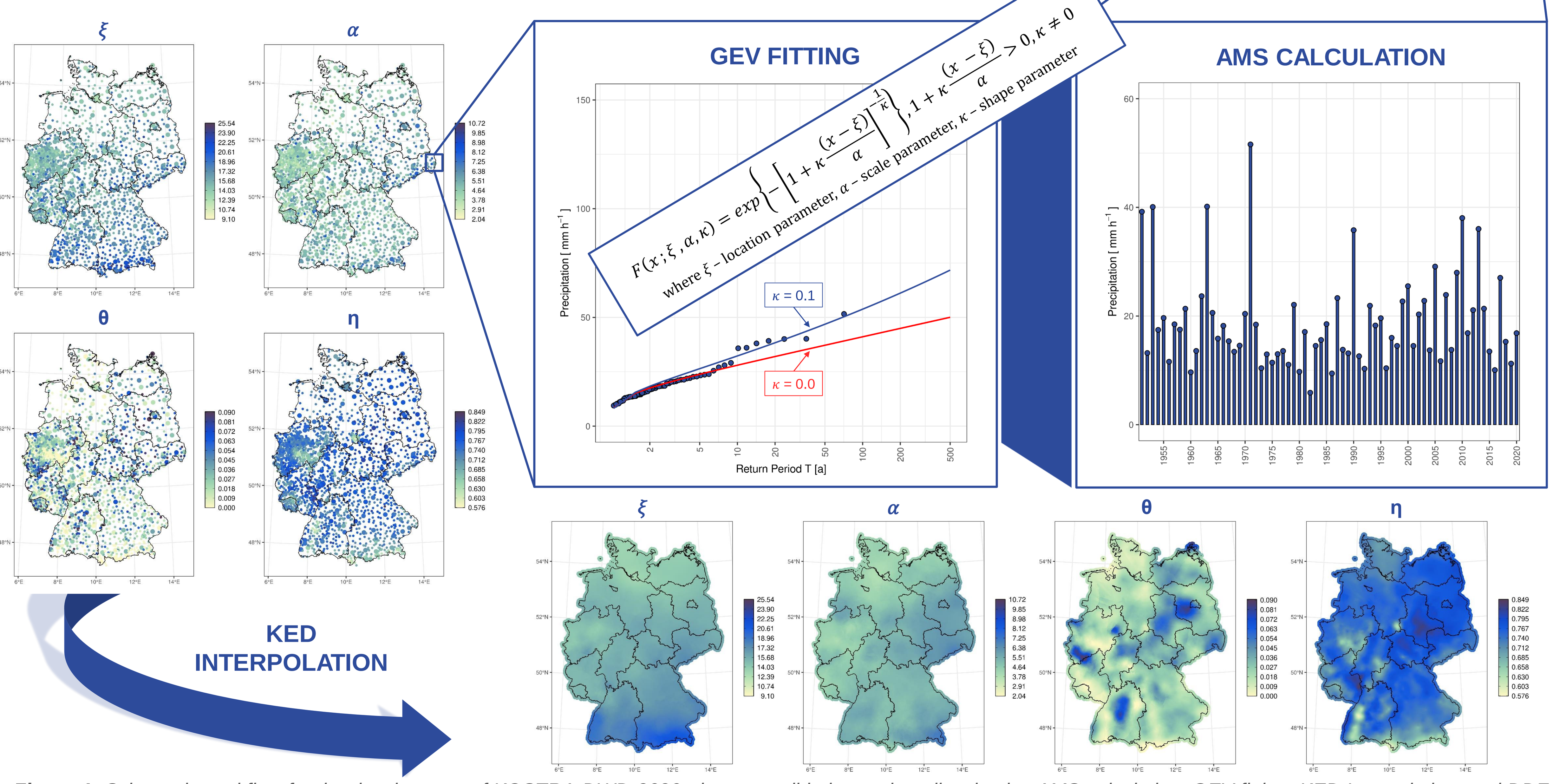


Figure 1: Schematic workflow for the development of KOSTRA-DWD-2020: data consolidation and quality checks, AMS calculation, GEV fitting, KED Interpolation, and DDF estimation.

KOSTRA-DWD-Hybrid

- ✓ Comparisons between DDF estimates derived from KOSTRA-DWD-2020 and radar data RADKLIM-YW (Winterrath et al., 2018) confirm that radar data yields quantitatively lower levels of DDF curves, mainly due to its shorter time series.
- ✓ Additionally, the spatial patterns of DDF estimates at short rain durations are not as strongly linked to orography as those at long rain durations.
- ✓ The new hybrid approach, referred to as **KOSTRA-DWD-Hybrid**, integrates radar data into the KED interpolation scheme. In this scheme, stations with at least 50 years of records still guide the primary interpolation, while radar data serve as the external drift.
- ✓ As a result, KOSTRA-DWD-Hybrid retains the higher DDF levels from station data while enhancing spatial variability through radar data application, effectively merging the strengths of both data sources.

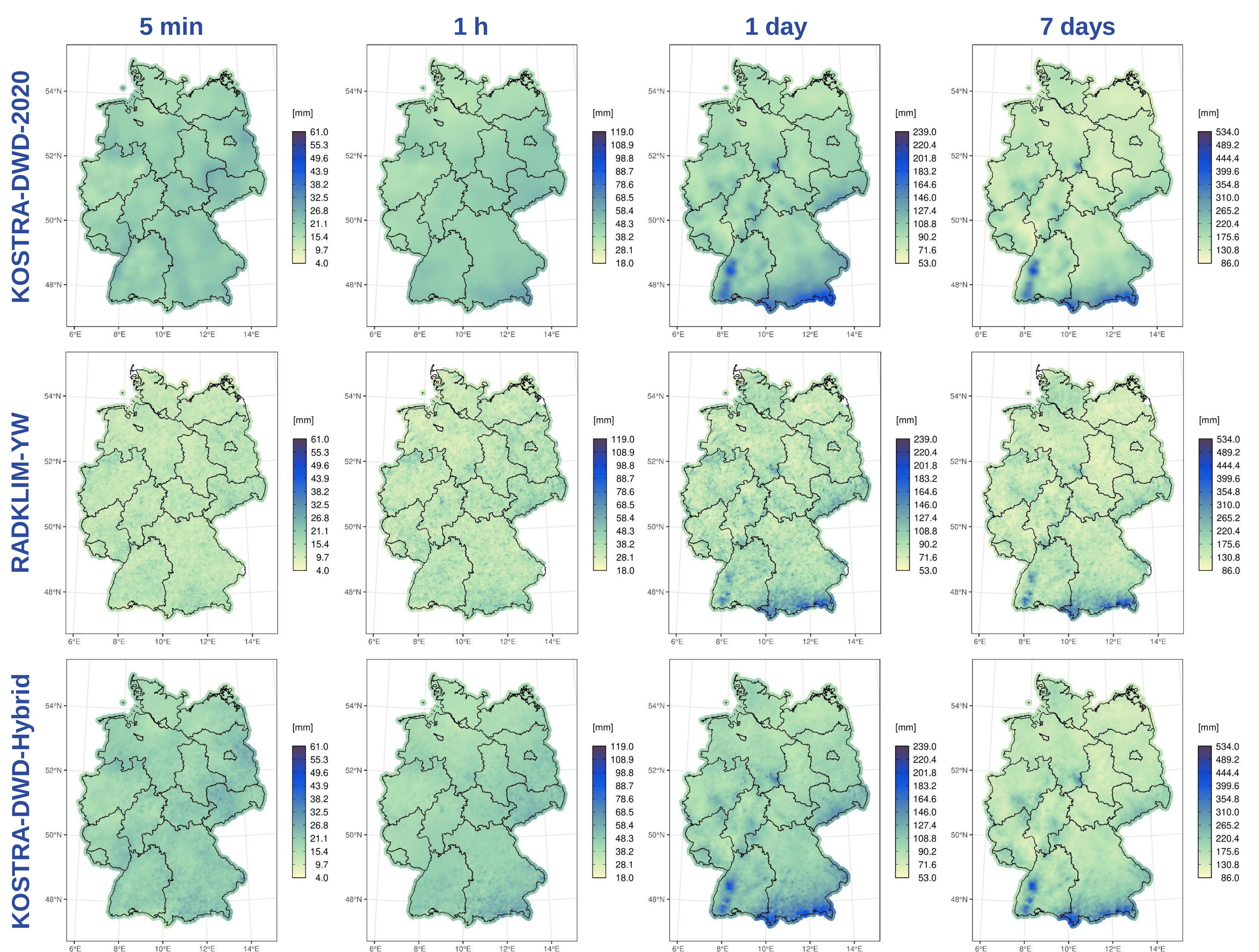


Figure 2: Comparison of DDF maps derived from KOSTRA-DWD-2020, RADKLIM-YW and KOSTRA-DWD-Hybrid for rain durations of 5 min, 1 h, 1 day, and 7 days, with a return period T=100a.

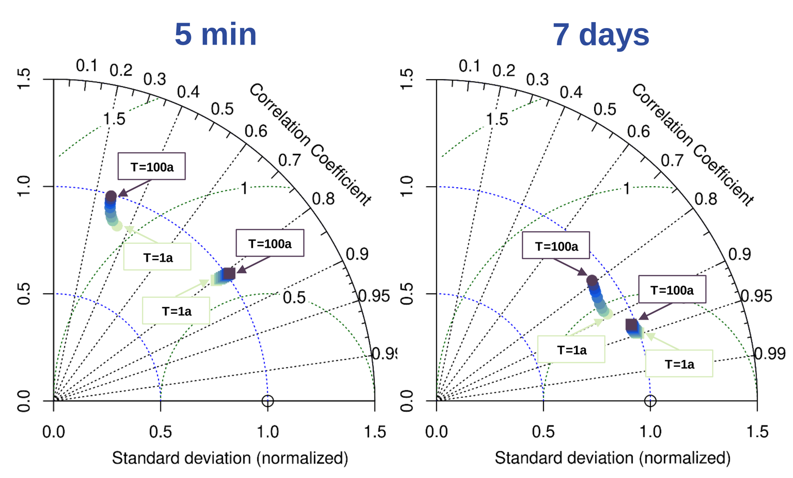


Figure 3: Taylor diagrams for DDF curves derived from KOSTRA-DWD-Hybrid (squares) and RADKLIM-YW (circles) for rain durations of 5 min and 7 days, with return periods ranging between T=1a and T=100a. KOSTRA-DWD-2020 serves as the reference.

REFERENCES

Koutsoyiannis et al., 1998, A mathematical framework for studying rainfall intensity-duration-frequency relationships. J. Hydrol. (206),118-135, https://doi.org/10.1016/S0022-1694(98)00097-3

Winterrath et al., 2018, RADKLIM Version 2017.002: Reprozessierte, mit Stationsdaten angeeichte Radarmessungen (RADOLAN), 5-Minuten-Niederschlagsraten (YW) http://doi.org/10.5676/DWD/RADKLIM_YW_V2017.002

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