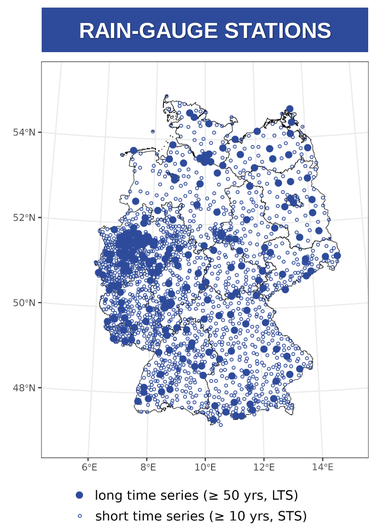
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Advances in the development of multi-sensor heavy rainfall statistics for Germany (KOSTRA-DWD-Hybrid): evaluation of radar-supported interpolation schemes

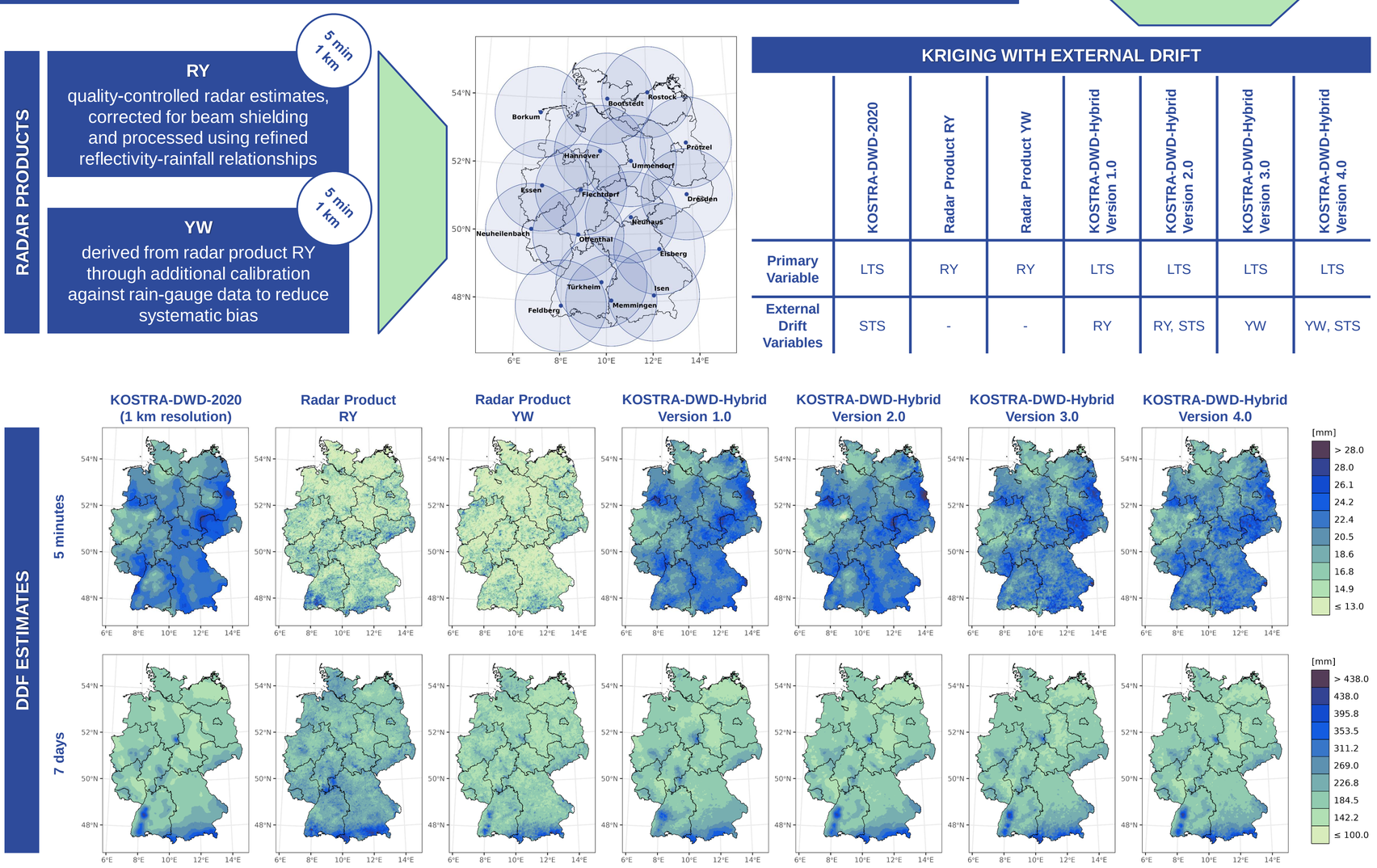
Angelika Palarz, Thomas Junghänel, Jennifer Ostermöller, Thomas Deutschländer

*As **heavy rainfall events** pose increasing challenges to society, ranging from localised flash floods to widespread flooding that disrupts critical infrastructure and services, accurate and comprehensive analyses of their patterns play a pivotal role in enhancing our understanding of rainfall dynamics, assessing associated risks, and implementing effective mitigation strategies. Among the most practical outcomes of these analyses are **depth-duration-frequency (DDF)** estimates, which serve as a key reference point for the planning and design of water management systems and facilities, such as dams, dikes, flood retention basins, and urban drainage networks. For Germany, DDF estimates are provided by **KOSTRA-DWD** (German: Koordinierte Starkniederschlagsregionalisierung und -auswertung des Deutschen Wetterdienstes), a product that has been developed since the 1980s by the Department of Hydrometeorology at the Deutscher Wetterdienst (DWD).*



Model Design: From Observations to Heavy Rainfall Statistics

- ✓ **KOSTRA-DWD-Hybrid builds on the latest release, KOSTRA-DWD-2020,** which provides DDF estimates for 22 rain durations from 5 minutes to 7 days and 9 return periods from 1 to 100 years, at a spatial resolution of 5 km (Junghänel et al. 2023).
- ✓ While KOSTRA-DWD-2020 relies on annual maximum series from 1,900 rain-gauge stations with 5-minute resolution data, **KOSTRA-DWD-Hybrid combines these station-based data with high-resolution radar products**, developing new multi-sensor heavy rainfall statistics for Germany.
- ✓ As part of this development, **we evaluate the performance of four radar-supported interpolation schemes**, all based on kriging with external drift, assessing DDF estimates together with the underlying GEV parameters (ξ, α) and scaling parameters (θ, η) proposed by Koutsoyiannis et al. (1998).
- ✓ Our results confirm that **all preliminary KOSTRA-DWD-Hybrid versions retain the typically higher DDF values from rain-gauge stations while enhancing spatial variability through high-resolution radar products**, effectively combining the strengths of both data sources.

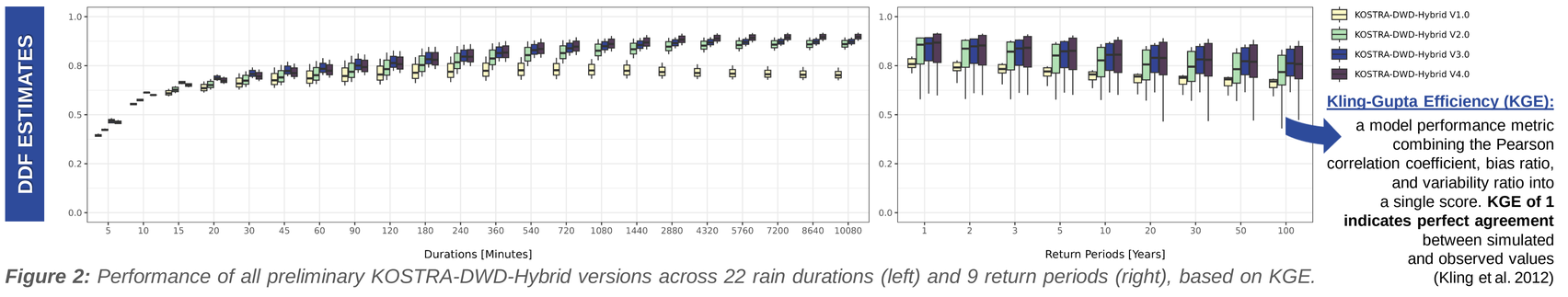


	KOSTRA-DWD-2020	Radar Product RY	Radar Product YW	KOSTRA-DWD-Hybrid Version 1.0	KOSTRA-DWD-Hybrid Version 2.0	KOSTRA-DWD-Hybrid Version 3.0	KOSTRA-DWD-Hybrid Version 4.0
Primary Variable	LTS	RY	RY	LTS	LTS	LTS	LTS
External Drift Variables	STS	-	-	RY	RY, STS	YW	YW, STS

Figure 1: *Data processing workflow of four preliminary KOSTRA-DWD-Hybrid versions, combining rain-gauge stations and radar products RY and YW (Winterrath et al., 2018). DDF estimates are shown for two example rain durations (5 minutes, 7 days) at a return period of 100 years.*

Model Performance: Evaluation of Radar-Supported Interpolation Schemes

- ✓ However, although the spatial representation of DDF estimates appears similar across all preliminary KOSTRA-DWD-Hybrid versions, **Leave-One-Out validation reveals notable discrepancies**, with Version 1.0 being the least and Version 4.0 the most reliable.
- ✓ The performance of all **preliminary KOSTRA-DWD-Hybrid versions exhibits a clear dependence on rain duration**, with short durations being the least reliable, while the influence of return period is much less pronounced.
- ✓ Evaluation of the underlying GEV and scaling parameters confirms that the **reduced reliability for short durations is mainly due to the scaling parameter θ**, which remains challenging to determine.



Kling-Gupta Efficiency (KGE): a model performance metric combining the Pearson correlation coefficient, bias ratio, and variability ratio into a single score. **KGE of 1 indicates perfect agreement** between simulated and observed values (Kling et al. 2012)

Figure 2: *Performance of all preliminary KOSTRA-DWD-Hybrid versions across 22 rain durations (left) and 9 return periods (right), based on KGE.*

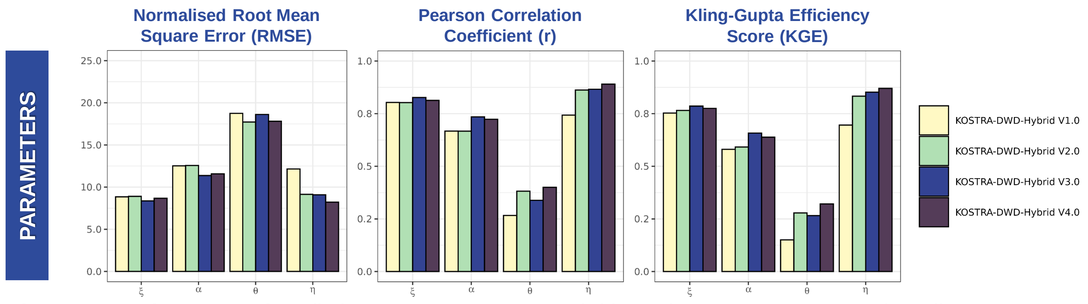


Figure 3: *Performance of preliminary KOSTRA-DWD-Hybrid versions across GEV and scaling parameters, based on normalised RMSE, r, and KGE.*

REFERENCES

Junghänel et al., 2023, Grids of return periods of heavy precipitation (design precipitation) over Germany (KOSTRA-DWD), version 2020. http://doi.org/10.5676/DWD/KOSTRA-DWD-2020

Kling et al., 2012, Runoff conditions in the upper Danube basin under an ensemble of climate change scenarios. J. Hydrol. (424), 264-277. https://doi.org/10.1016/j.jhydrol.2012.01.011

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, Radar-based quasi-gauge-adjusted five-minute precipitation rate climatology, version 2017.002. http://doi.org/10.5676/DWD/RADKLIM_YW_V2017.002

Angelika Palarz (angelika.palarz@dwd.de)
Deutscher Wetterdienst, Hydrometeorology