

# Extreme value frameworks for sub-hourly rainfall: comparison of predictive performance across Europe

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## 1. MOTIVATION

- Design rainfall often relies on extrapolating sub-hourly extremes beyond the observed record.
- Recently, the Metastatistical Extreme Value (MEV)<sup>1</sup> and Simplified MEV (SMEV)<sup>2</sup> distributions have been proposed as alternatives to traditional extreme value frameworks (here represented by the Generalized Extreme Value (GEV) distribution), but their predictive performance at sub-hourly scales is uncertain.
- Aim: Assess whether a single framework can be selected based on its ability to extrapolate beyond observed extremes across countries and durations.

## 2. DATA & METHODS

- 3,839 rain gauges across 13 European countries
- 1–15 min resolution; record length  $\geq 10$  years (median 18 years).
- Cross-validation to assess predictive performance for unseen extremes<sup>3</sup>. Random split: 1/3 training + 2/3 test; measure prediction error for the largest event in test data; repeat 1000 times (Fig. 1).
- Frameworks compared: GEV, MEV, SMEV (with left-censoring threshold = 0.75).

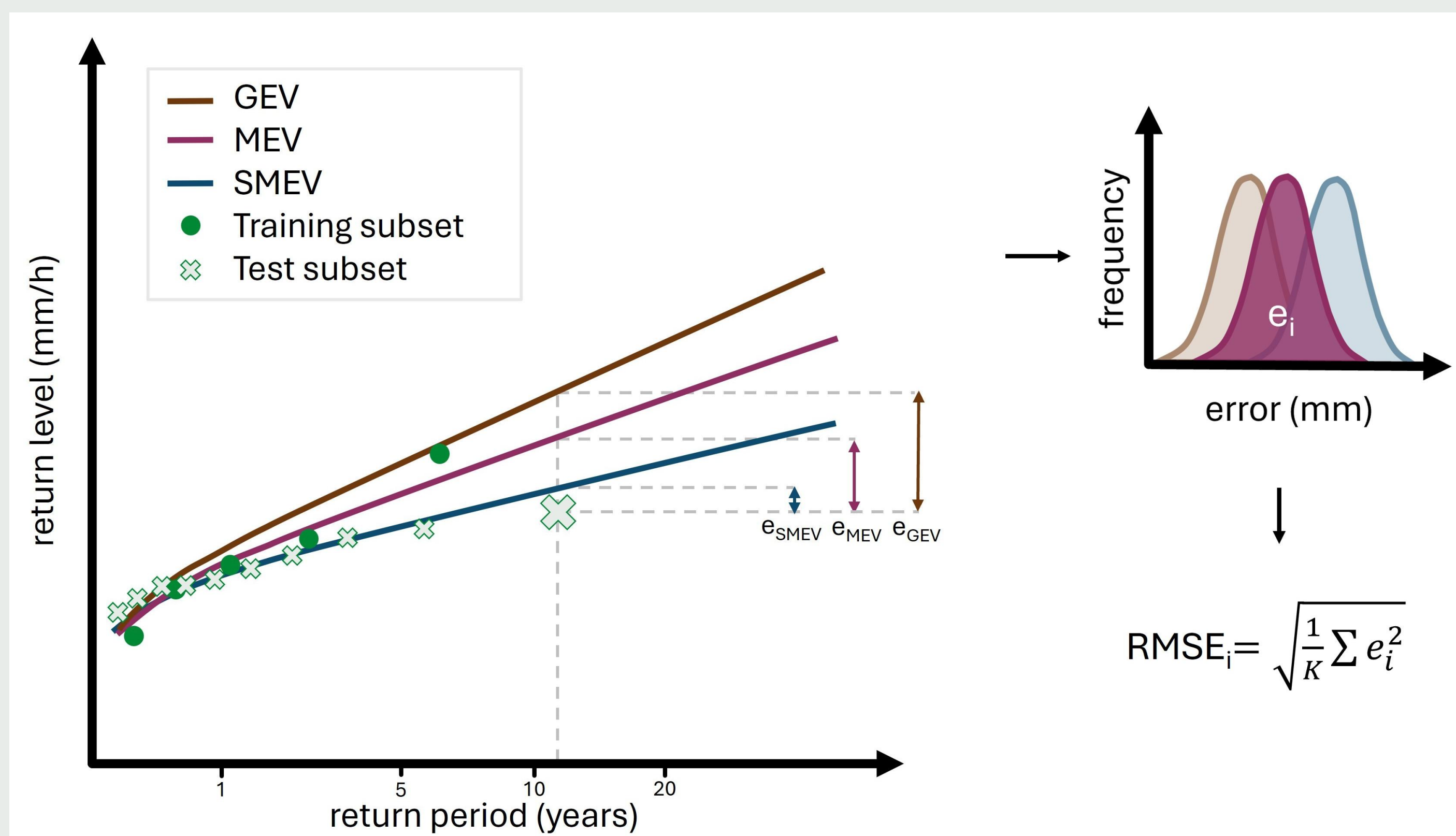


Figure 1. Cross-validation experiment. Each record is split by years into training (filled circles) and test (crosses). Models (GEV, MEV, SMEV) fitted to the training data predict the return level associated with the empirical return period (median plotting position) of the most extreme event in the test subset. Repeating the procedure yields a distribution of prediction errors, summarised by RMSE.

## 3. RESULTS

Duration	Denmark	Finland	Sweden	Estonia	Belgium	Germany	Switzerland	Poland	France	Austria	Ireland	Hungary	Norway
native	15%	4%	16%	6%	0%	4%	7%	11%	-4%	-6%	18%	14%	3%
30min	11%	12%	13%	3%	11%	13%	9%	0%	6%	10%	16%	18%	6%
1h	9%	15%	13%	-1%	9%	11%	2%	4%	2%	7%	4%	5%	-0%
3h	10%	11%	4%	17%	4%	4%	4%	1%	7%	-0%	31%	1%	11%
6h	8%	4%	1%	8%	10%	1%	7%	3%	7%	4%	19%	7%	20%
12h	11%	2%	4%	4%	10%	3%	9%	7%	6%	1%	10%	7%	12%

Figure 2. Predictive performance across durations and countries. Colours indicate the framework that most frequently achieves the lowest RMSE, with colour intensity indicating significance (Wilcoxon test, Benjamini–Hochberg-corrected). Values show the median station-level RMSE difference between winner and runner-up. The term “native” refers to the temporal resolution of the rainfall observations. Countries are ordered by the share of stations for which SMEV ranks first. Shared legend (Fig. 3) applies to this panel.

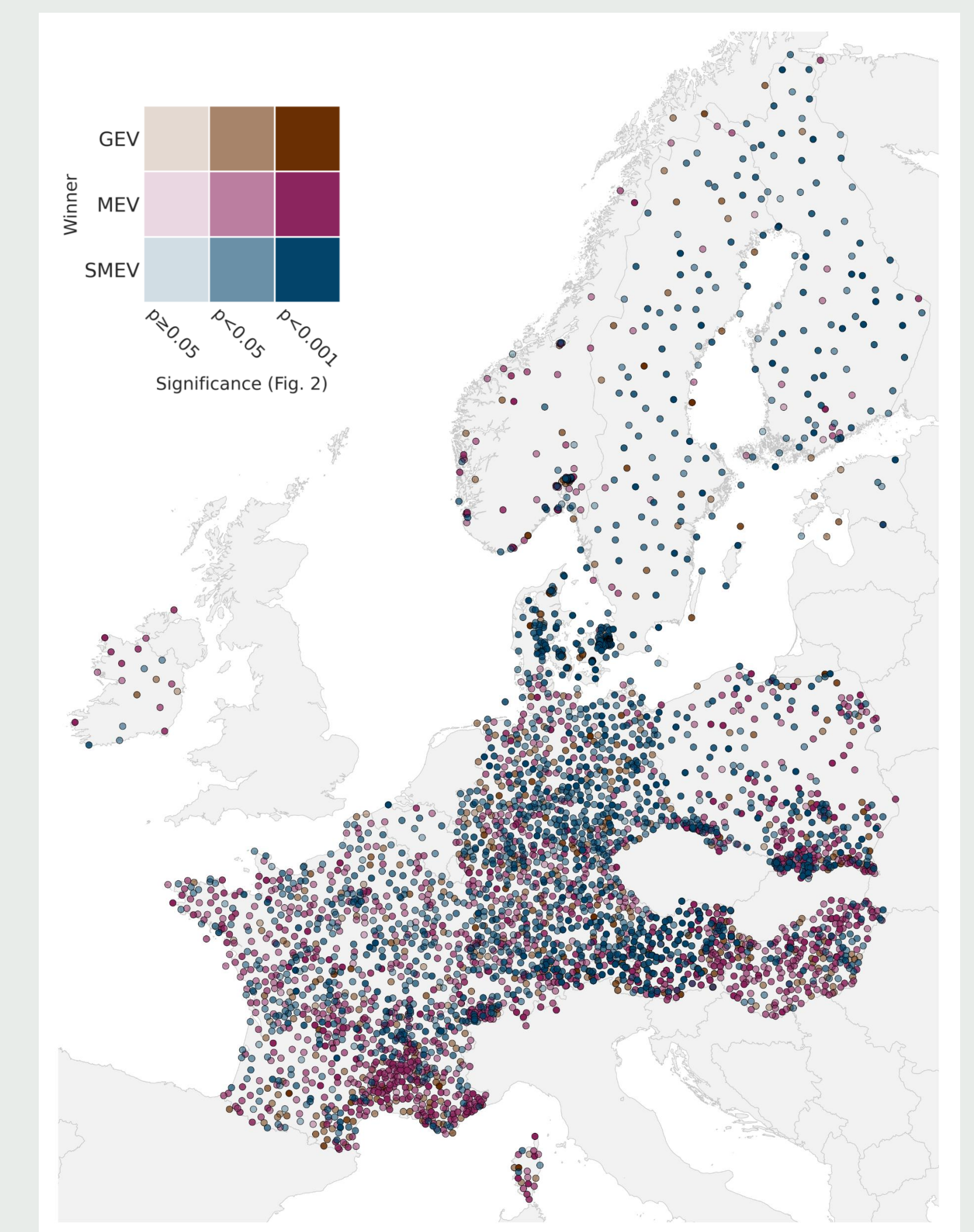


Figure 3. Station-level predictive winner across durations. Colors show the best-performing framework (GEV, MEV, SMEV), and transparency indicates how consistently the method performs best across durations (more opaque = more consistent).

- The best-performing framework varies across countries and durations, with SMEV frequently achieving the lowest RMSE at shorter durations ( $\leq 1$  hr) and MEV at longer durations ( $\geq 6$  hr) (Fig. 2).
- Median improvements between winner and runner-up frameworks are generally modest but statistically significant in  $\sim 70\%$  of country-duration combinations (Fig. 2).
- Station-level results reveal substantial spatial heterogeneity in the best-performing framework (Fig. 3).
- Relative predictive performance is robust to methodological choices (plotting position, record length, left-censoring, baseline framework and event definition; not shown).

## 4. CONCLUSION AND OPEN QUESTIONS

Results suggest that no single framework consistently outperforms the others across countries and durations. This raises two key questions:

- What drives differences in predictive performance across frameworks?
- How should frameworks be selected when performance varies?



## REFERENCES

- [1] Marani & Ignaccolo (2015)
- [2] Marra (2019)
- [3] Zorretto et al. (2016)

## DATA SOURCES

We gratefully acknowledge the national meteorological services and data providers listed below for access to sub-hourly rainfall observations.

**Table 1.** Data sources and characteristics of the rain gauge dataset.

Country	Data provider	Stations (n)	Native temporal resolution (min)	Median record length (years)
Austria	GeoSphere Austria	459	10	21
Belgium	Royal Meteorological Institute of Belgium	13	10	23
Denmark	Water Pollution Committee of the Danish Society of Engineers	162	1	19
Estonia	Estonian Environment Agency (Keskkonnaagentuur)	10	10	17
Finland	Finnish Meteorological Institute	96	10	16
France	Metéo-France	1124	6	19
Germany	Deutscher Wetterdienst	904	1	19
Hungary	HungaroMet	260	10	12
Ireland	Met Éireann	20	1	18
Norway	Norwegian Meteorological Institute	109	1	16
Poland	Polish Institute of Meteorology and Water Management – National Research Institute	405	10	14
Sweden	Swedish Meteorological and Hydrological Institute	124	15	27
Switzerland	MeteoSwiss	115	10	12