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Estimation of the design rainfall in ungauged sites using novel regionalization approaches: an application over Thessaly region, Greece

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1 INTRODUCTION

Ombrian curves (Koutsoyiannis and Iliopoulou, 2022) are a standard engineering tool linking rainfall intensity to timescale and return period, usually known as “intensity-duration-frequency” curves.

The construction of regional ombrian curves can follow two approaches: (a) the at-site, independent fitting approach combined with spatial interpolation methods to map the parameters over the region; (b) the regional fitting approach, which consists of pooling the data and obtaining a single model valid over the entire area. Having a single spatial model is a theoretically more powerful approach since it allows using all observations to limit uncertainty. To explicitly address the effect of the spatial dependence in the data, a new regional frequency analysis (RFA) framework has been proposed that allows high-order properties estimation from spatially correlated data by means of “knowable” moments or K-moments (Koutsoyiannis, 2019).

2 OBJECTIVE

Construct regional ombrian curves by integrating recent methods into a new framework for regional frequency analysis of rainfall extremes.

- Advanced estimation method of extreme values based on high-order moment estimation able to respect space dependence.
- Two interpolation methods.
- A formulation of ombrian curves revisited through recent theoretical developments (Koutsoyiannis and Iliopoulou, 2022).

CASE STUDY: Thessaly region (Greece), ≈ 13,700 km^2.

3 METHODOLOGY

GENERALIZED FORM OF OMBRIAN CURVES:

- **FOR PEAKS OVER THRESHOLD**

$$x = \frac{b(T)}{a(k)} = \lambda \frac{\left(\frac{T}{\beta}\right)^{\xi} - 1}{\left(1 + \frac{k}{\alpha}\right)^{\eta}}$$

- **FOR ANNUAL MAXIMA**

$$x = \lambda \frac{(-(\beta/\Delta)\ln(1 - \Delta/T))^{-\xi} - 1}{(1 + k/\alpha)^{\eta}}$$

with:

- T the return period;
- k the timescale;
- β a timescale parameter;
- λ an intensity scale parameter;
- $\xi > 0$ the shape parameter.

We applied two workflows, that differs in the spatial model used to describe the spatial variability of 24-h extremes. Both methodologies differ from the classical rainfall RFA being developed to take advantage of all the information, even those included in short and fragmented time series.

REGIONALIZATION METHOD n°1: PATCHED KRIGING (Libertino et al., 2018)

1. Detrending with elevation of the annual maxima
2. Sample variogram
3. Theoretical variogram
4. Rainfall data cube
5. Bias-correction
6. Computation of 24h mean rainfall depth

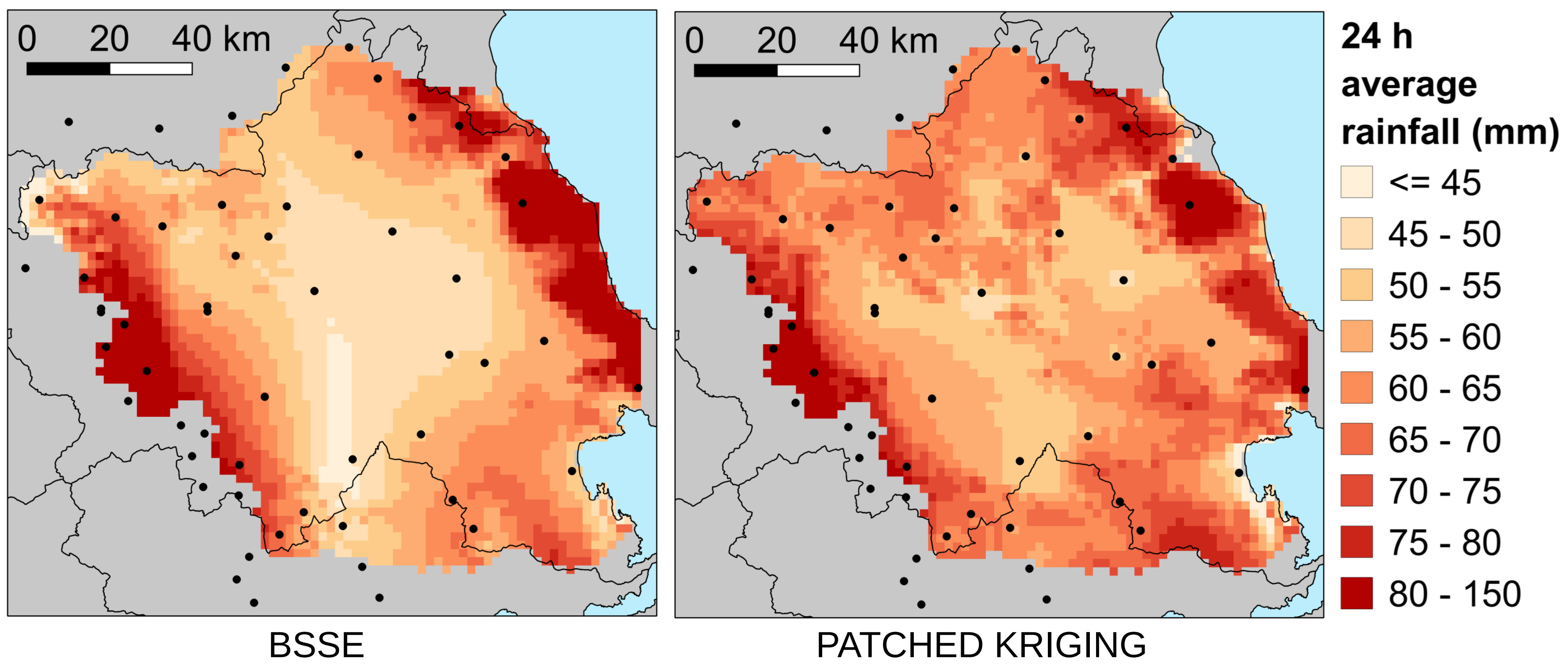
REGIONALIZATION METHOD n°2: BILINEAR SURFACE SMOOTHING (Malamos and Koutsoyiannis, 2016)

1. Application of BSSE (BSS with an explanatory variable, that is the elevation in this case)
2. Selection of the best model using the generalized cross-validation error
3. Computation of 24h mean rainfall depth

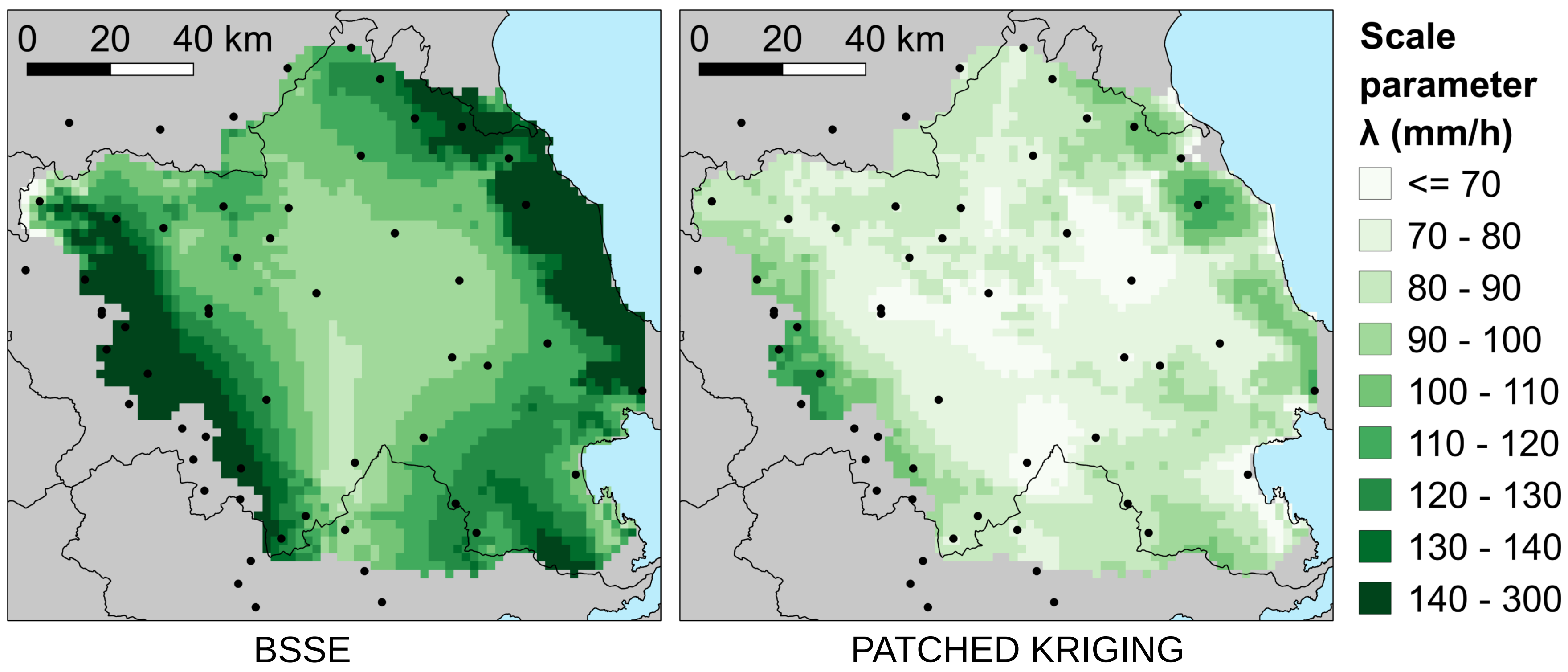
In both cases, rainfall quantiles are estimated using the method of K-moments (Koutsoyiannis, 2019), an advanced estimation framework that allows reliable high-order moment estimation considering space dependence.

$$K_p' \coloneqq pE[(F(\underline{x})^{p-1}\underline{x}]$$

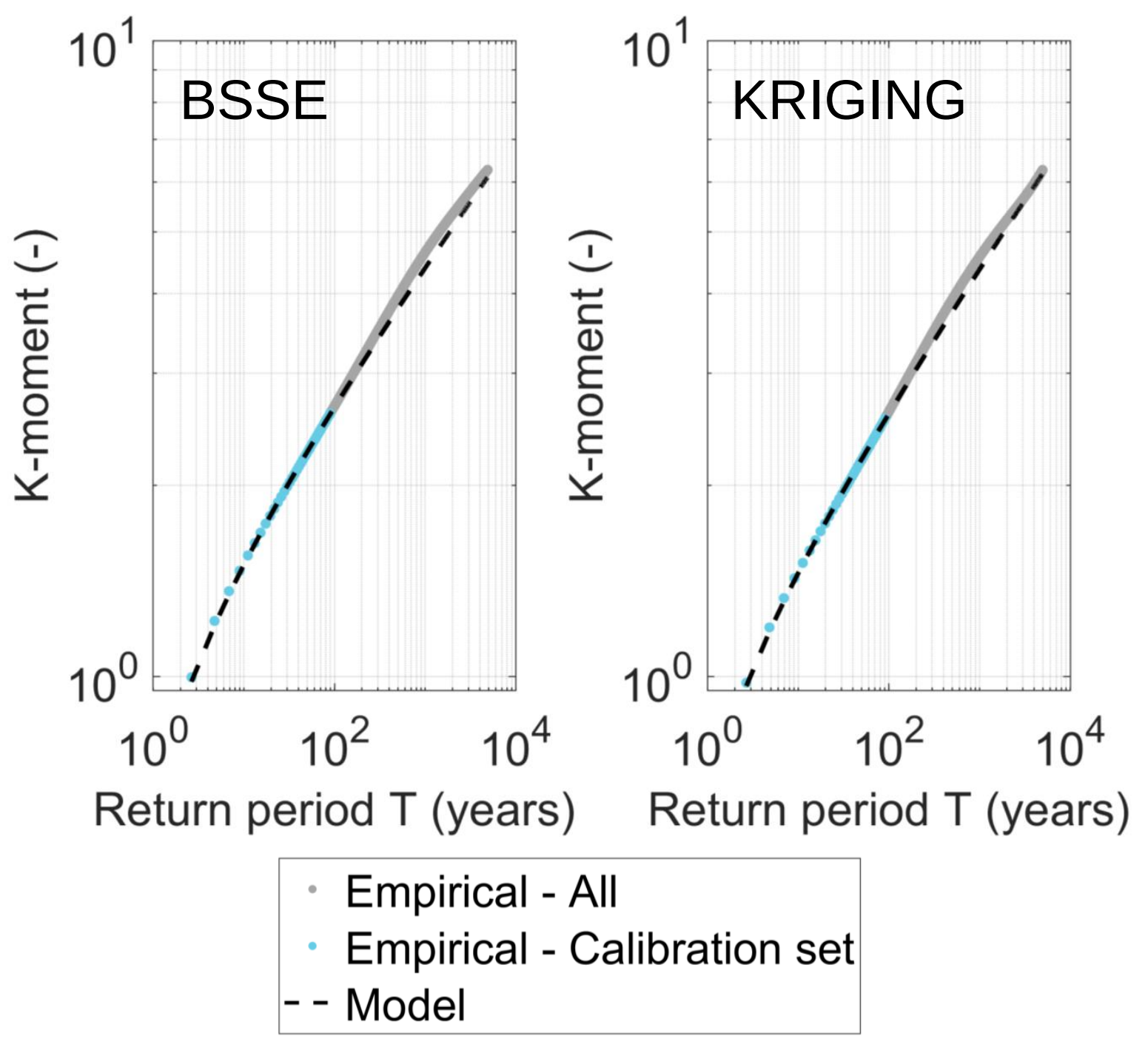
4 RESULTS



BSSE PATCHED KRIGING



BSSE PATCHED KRIGING



Parameter	BSSE	Kriging
α (h)	0.03	0.03
η (-)	0.64	0.64
ξ (-)	0.18	0.2
β (years)	0.013	0.006
λ (mm/h)	Spatially varying	

Timescale parameters obtained by Koutsoyiannis et al. (1998) procedure.

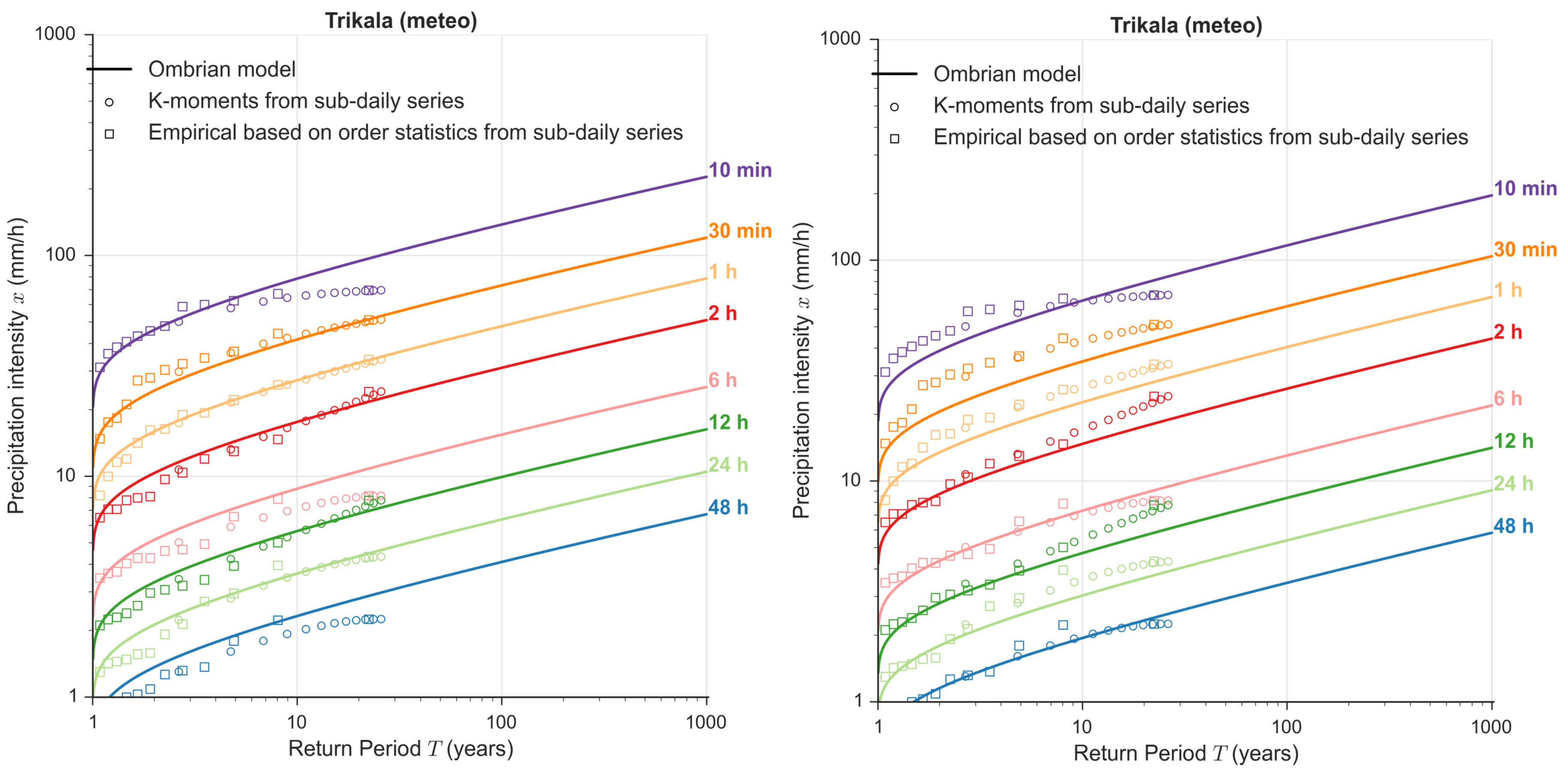
↓

Distribution parameters obtained by minimizing an error metric (MAE) between the theoretical quantiles and the empirical K-moments.

↓

Model calibration performed using the moment orders up to n_1 (here 42, corresponding to the average record length of all stations). Higher moments (in total 2305) are used for validation.

Theoretical and empirical distributions of annual maximum intensities at 10 min to 48 h scales. Left: BSSE used as spatial model. Right: Patched Kriging used as spatial model.



5 CONCLUSIONS

- No out-performing spatial model both in terms of 24 h mean rainfall depth interpolation (MAE_{BSSE} = 5.3 mm while $MAE_{KRIGING}$ = 3.9 mm) and K-moments estimation (MAE_{BSSE} = 0.00489 while $MAE_{KRIGING}$ = 0.00610).The Patched Kriging method resulted to lower λ estimates compared to BSSE, but, conversely, it provided a higher shape parameter ξ.
- The moments used in calibration are many more (42) than the ones used in regular moment fitting procedures (typically up to 3 or 4 orders).
- The models efficiently capture the spatial variability of extreme rainfall and their estimates are robust even under increased spatial uncertainty due to inconsistencies among the point data.

6 REFERENCES

- Koutsoyiannis D. (2019). Knowable moments for high-order stochastic characterization and modelling of hydrological processes, *Hydrol. Sci. J.*, 64, 19-33.
- Koutsoyiannis D., and T. Iliopoulou (2022). Ombrian curves advanced to stochastic modeling of rainfall intensity, *Rainfall*, 261-284.
- Koutsoyiannis D., D. Kozonis, and A. Manetas (1998). A mathematical framework for studying rainfall intensity-duration-frequency relationships, *J. Hydrol.*, 206, 118-135.
- Iliopoulou T., N. Malamos, and D. Koutsoyiannis (2022). Regional ombrian curves: design rainfall estimation for a spatially diverse rainfall regime, *Hydrology*, 9, 67.
- Libertino A., P. Allamano, F. Laio, and P. Claps (2018). Regional-scale analysis of extreme precipitation from short and fragmented records, *Adv. Water Resour.*, 112, 147-159.
- Malamos N., and D. Koutsoyiannis (2016). Bilinear surface smoothing for spatial interpolation with optional incorporation of an explanatory variable. Part 1: Theory, *Hydrol. Sci. J.*, 61, 519-526.