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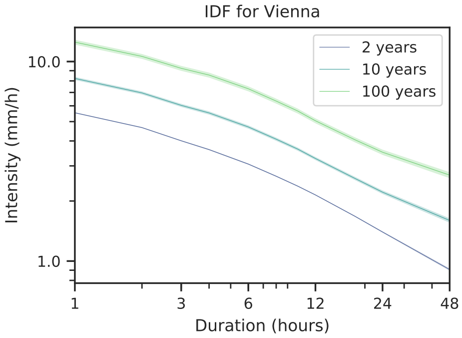
Intensity-Duration-Frequency curves at the global scale

IDF: extreme precipitation patterns



⚠ Critical for infrastructure sizing

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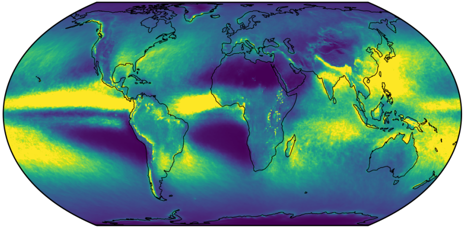
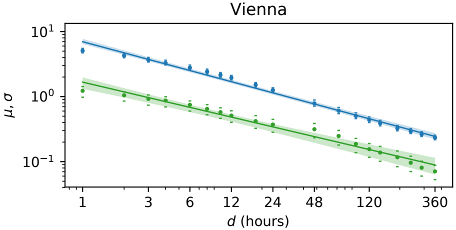
Two issues

- Rainfall records are short or incomplete
- ⚠ Doubtful sizing of infrastructure
- ➔ Use of global gridded data (ERA5)



- Most historical records are daily
- ⚠ Need finer temporal resolution
- ➔ Scaling in duration of precipitation



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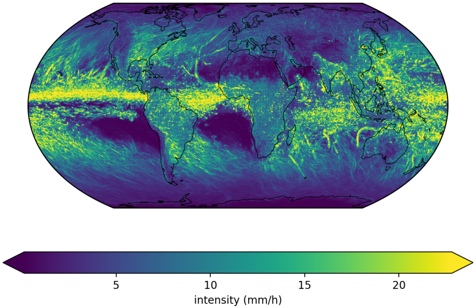
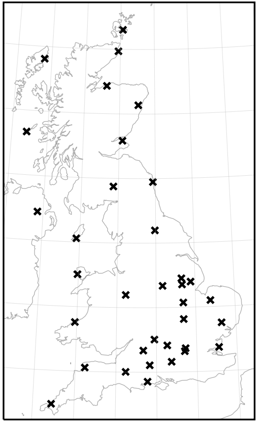
Input data

- 1979–2018 (40 years)
- Worldwide ERA5 (0.25°, hourly)
- 35 MIDAS stations over the UK (for comparison)



ERA5: max intensity in 2018



Location of the MIDAS gauges

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Parametrized eXtreme Rainfall (PXR)

- Based on ERA5 precipitation 1979–2018
- 0.25° (≈31 km), hourly
- Include goodness of fit
- Confidence intervals with bootstrap

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Download it on Zenodo!

PXR-2

- Two variables
- Discrete GEV parameters for 19 durations (1 h to 360 h)

PXR-4

- Four variables
- Based on duration scaling
- Continuous range of durations

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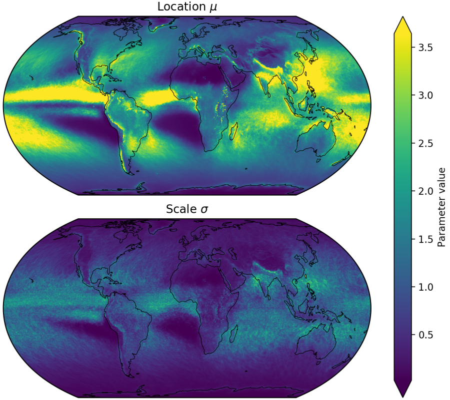
Global GEV parameters



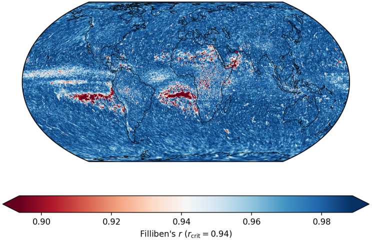
GEV parameters for for duration $d = 24\,\text{h}$

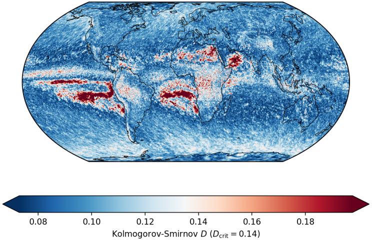
Spatial patterns (tropical cyclones, orographic rainfall, deserts etc.)

Global IDF curves

HS7.7/NH1.23 — PICO spot 5b

Goodness of fit of the GEV distribution





Mean of Filliben's r.
r_{crit} at the 5 % significance level from Heo *et al.* [1].

Mean of Kolmogorov–Smirnov's D.
D_{crit} at the 5 % significance level is obtained by Monte-Carlo simulation (Lilliefors test)

ℹ $\approx$5 % of rejection is expected at the 5 % significance level. [2]

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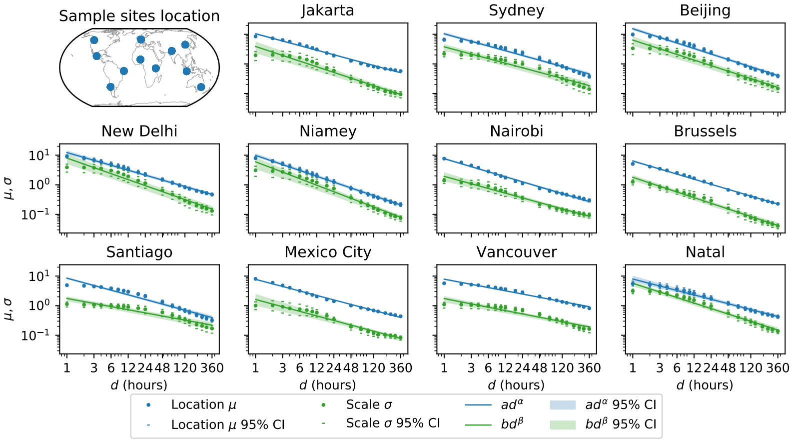
GEV parameters scaling



GEV parameters and their scaling in duration at a selection of cities (PXR). Uncertainty from bootstrap.

Strong scaling (globally, $r_\mu^2 > 0.91$ and $r_\sigma^2 > 0.88$)

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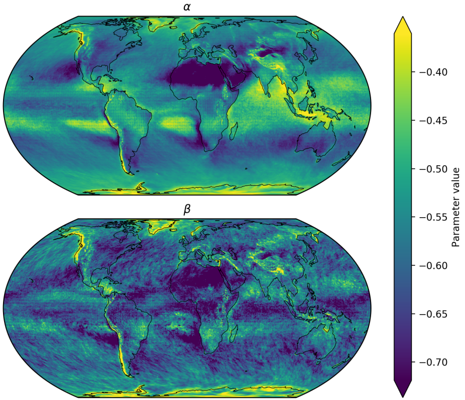
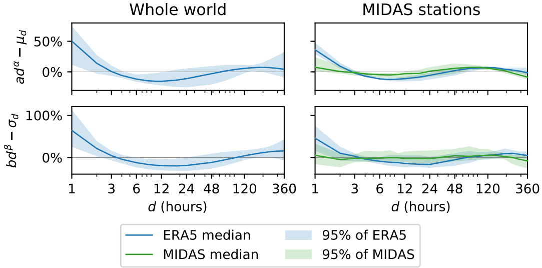
Global distribution of scaling parameters



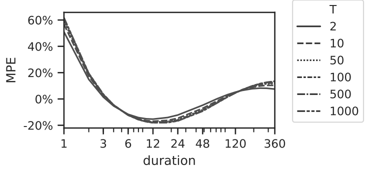
Scaling gradients (α, β) of the GEV parameters (μ, σ)

Spatial patterns (e.g. mountains, deserts)

Accuracy of the scaling property



Median percentage error between the scaled parameters and the parameters from fitting



Mean percentage error between intensities from PXR-4 (scaled) and PXR-2 (direct fitting)

Smaller error due to scaling with point data vs gridded data.

Difference due to characteristics of ERA5? (i.e. underestimation of short, intense precipitation)

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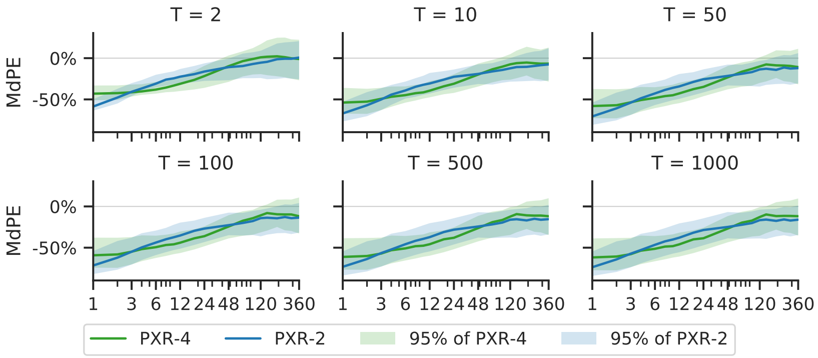
Comparison to gauges



Median Percentage Error of intensities between PXR and MIDAS gauges

ℹ Coherent with expected areal reduction factor [3].

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Theory

Estimation of GEV parameters

Annual Maxima Series follow a Generalized Extreme Value (GEV) distribution [4]:

$$F(I) = \begin{cases} \exp\left[-\left(\frac{I-\mu}{\sigma}\right)^{1/\kappa}\right] & \text{if } \kappa \neq 0 \\ \exp\left[\exp\left(-\frac{I-\mu}{\sigma}\right)\right] & \text{if } \kappa = 0 \end{cases}$$

I: rainfall intensity, μ: location, σ: scale and κ: shape.
If $\kappa = 0$: Gumbel. If $\kappa < 0$: Fréchet.
κ is sensitive to record length and therefore difficult to estimate [4, 5]. We set $\kappa = -0.114$ [4, 6].

μ, σ are estimated with the Probability-Weighted Moments [7].
The intensity (i.e. quantile) is then estimated with:

$$i(d, T) = \mu_d + \sigma_d y$$

$$y = \left\{1 - [-\ln(1 - 1/T)]^{\kappa}\right\} / \kappa$$

GEV parameters scaling

GEV parameters (μ, σ) scale in duration (d) [6, 8]:

$$\mu_d = ad^{\alpha} \qquad \sigma_d = bd^{\beta}$$

Therefore:

$$i(d, T) = ad^{\alpha} - bd^{\beta} y$$

The annual maxima are estimated for *19* durations (1 to 360 hours).
Then, (a, α, b, β) are found by linear regression on a log-log scale.

The confidence interval of both the GEV and scaling parameters are estimated via bootstrapping with 1000 samples.
In total, the GEV is fitted 19.7 billion times.

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Intensity-Duration-Frequency curves at the global scale

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Data on Zenodo

https://eartharxiv.org/w56b8/

Preprint on EarthArXiv

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Global IDF curves

HS7.7/NH1.23 — PICO spot 5b

1. Heo, J.-H., Kho, Y. W., Shin, H., Kim, S. & Kim, T. Regression equations of probability plot correlation coefficient test statistics from several probability distributions. *Journal of Hydrology* **355,** 1–15. ISSN: 0022-1694 (June 2008).
2. Bland, J. M. & Altman, D. G. Multiple significance tests: the Bonferroni method. *BMJ (Clinical research ed.)* **310,** 170. ISSN: 0959-8138 (Jan. 1995).
3. Pavlovic, S., Perica, S., St Laurent, M. & Mejía, A. Intercomparison of selected fixed-area areal reduction factor methods. *Journal of Hydrology* **537,** 419–430. ISSN: 00221694 (June 2016).
4. Papalexiou, S. M. & Koutsoyiannis, D. Battle of extreme value distributions: A global survey on extreme daily rainfall. *Water Resources Research* **49,** 187–201. ISSN: 00431397 (Jan. 2013).
5. Lu, L.-H. & Stedinger, J. R. Variance of two- and three-parameter GEV/PWM quantile estimators: formulae, confidence intervals, and a comparison. *Journal of Hydrology* **138,** 247–267. ISSN: 0022-1694 (Sept. 1992).
6. Overeem, A., Buishand, A. & Holleman, I. Rainfall depth-duration-frequency curves and their uncertainties. *Journal of Hydrology* **348,** 124–134. ISSN: 00221694 (2008).
7. Hosking, J. R. M., Wallis, J. R. & Wood, E. F. Estimation of the Generalized Extreme-Value Distribution by the Method of Probability-Weighted Moments. *Technometrics* **27,** 251–261. ISSN: 0040-1706 (Aug. 1985).
8. Menabde, M., Seed, A. & Pegram, G. A simple scaling model for extreme rainfall. *Water Resources Research* **35,** 335–339. ISSN: 00431397 (Jan. 1999).

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