Assessing Extreme Droughts: An Extreme Value Theory Analysis of Common Drought Indices

Paolo Besana[1], Hugues Goosse[1], Francesco Ragone[2], Johan Segers[3,4]

[1]UCLouvain, Earth and Life Insitute, Belgium
[2]University of Leicester, School of Computing and Mathematical Sciences, UK
[3]UCLouvain, LIDAM/ISBA, Belgium
[4]KU Leuven, Department of Mathematics, Belgium

EXALT

Why this work?

As part of the EXALT Project, this work focuses on **attributing extreme droughts** using **Extreme Value Theory**, leveraging its tools and limit theorems to extrapolate beyond observed data for rare, extreme events.

Here is shown the starting point of this research which has been the implementation of ***Peaks-over-Threshold method*** or *Pareto-tails modelling* to analyse the distribution and behaviour of extreme droughts events over Europe.

Data & Indices – What is a drought?

➔ **E-OBS** data (0.25° resolution) from **1950 to** 2024. From raw data we defined ***P3*** as **mean precipitation** [mm/day] **accumulated** over **3 months** to capture drought duration. For each location l and month m we define:

➔ **Index *D3*:** by subtracting the climatological mean of *P3* and dividing by its climatological standard deviation, mapping ***P3*** to its **standard version**.

$$D3(m,l) \stackrel{\text{def}}{=} \left(P3(m,l) - \mu^{clim}[P3](m,l)\right) / \, \sigma^{clim}[P3](m,l)$$

➔ **Index *SPI3***: obtained by **fitting a Gamma distribution** to non-zero precipitation, adjusting for the probability of zeros, and **applying a Gaussian quantile transformation**.

$$SPI3(m,l) \stackrel{\text{def}}{=} \Phi^{-1}\{p_0 + (1-p_0)\Gamma(P3(m,l))\}$$

Methods – Peaks-over-threshold

➔ GPD fitted to the **negated *D3*** series (**minima**), with **5% threshold** and MLE per grid point.

➔ **Declustering:** contiguous negative-valued months (or those separated by **up to 2 over-threshold months**) are treated as single events.

➔ We compute **fitted quantiles** from models (GPD for −*D3*, Gaussian for *SPI3*) and **reverse the normalization** process to express them in physical precipitation units, using **monthly mean and standard deviation for *D3*** (Figure 1), and the **inverse Gamma mapping for *SPI3***.

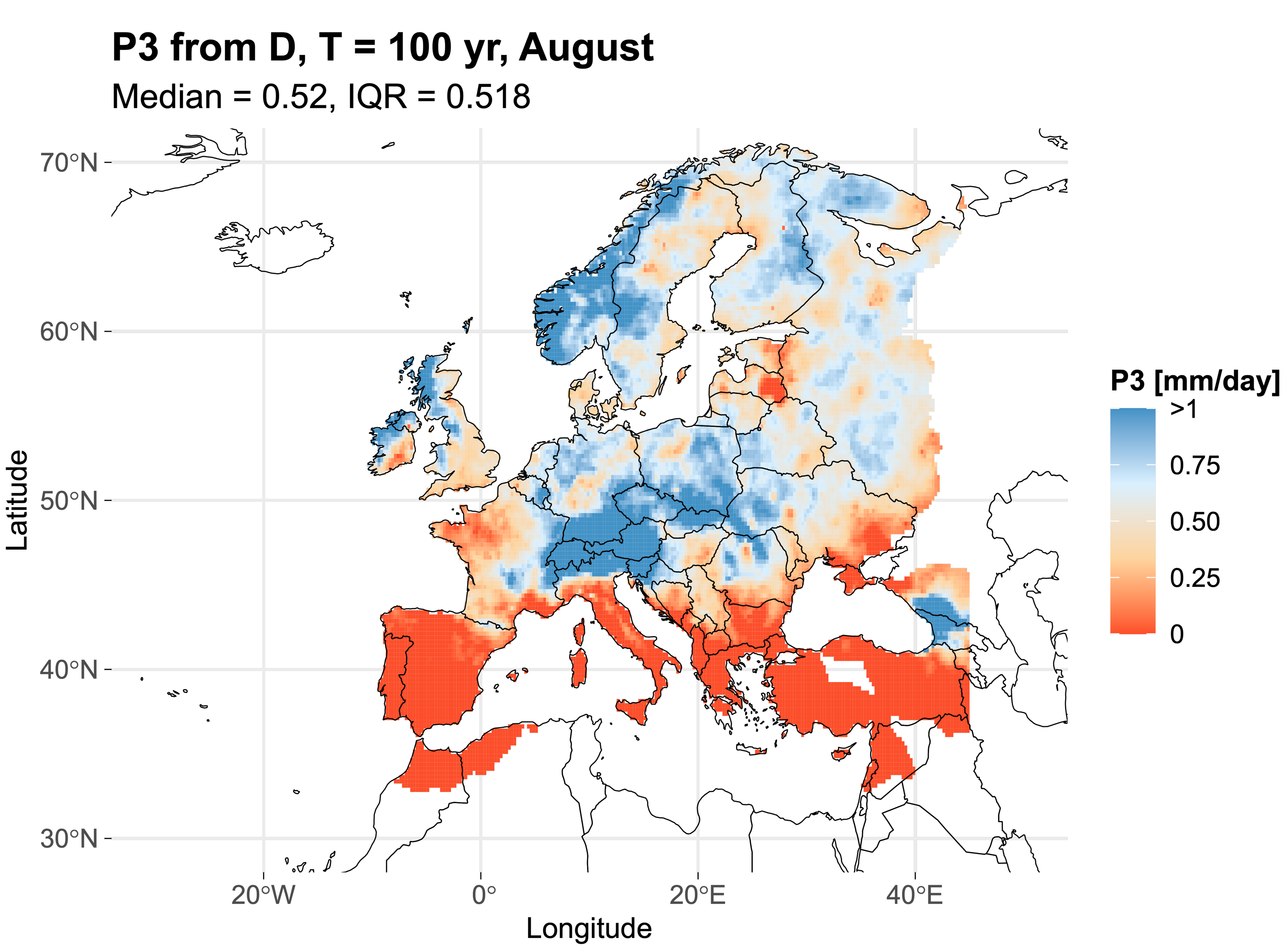

Figure 1. Return level of mean precipitation [mm/day] obtained inverting *D3* to *P3*. Fitting of the **GPD at 5%.**

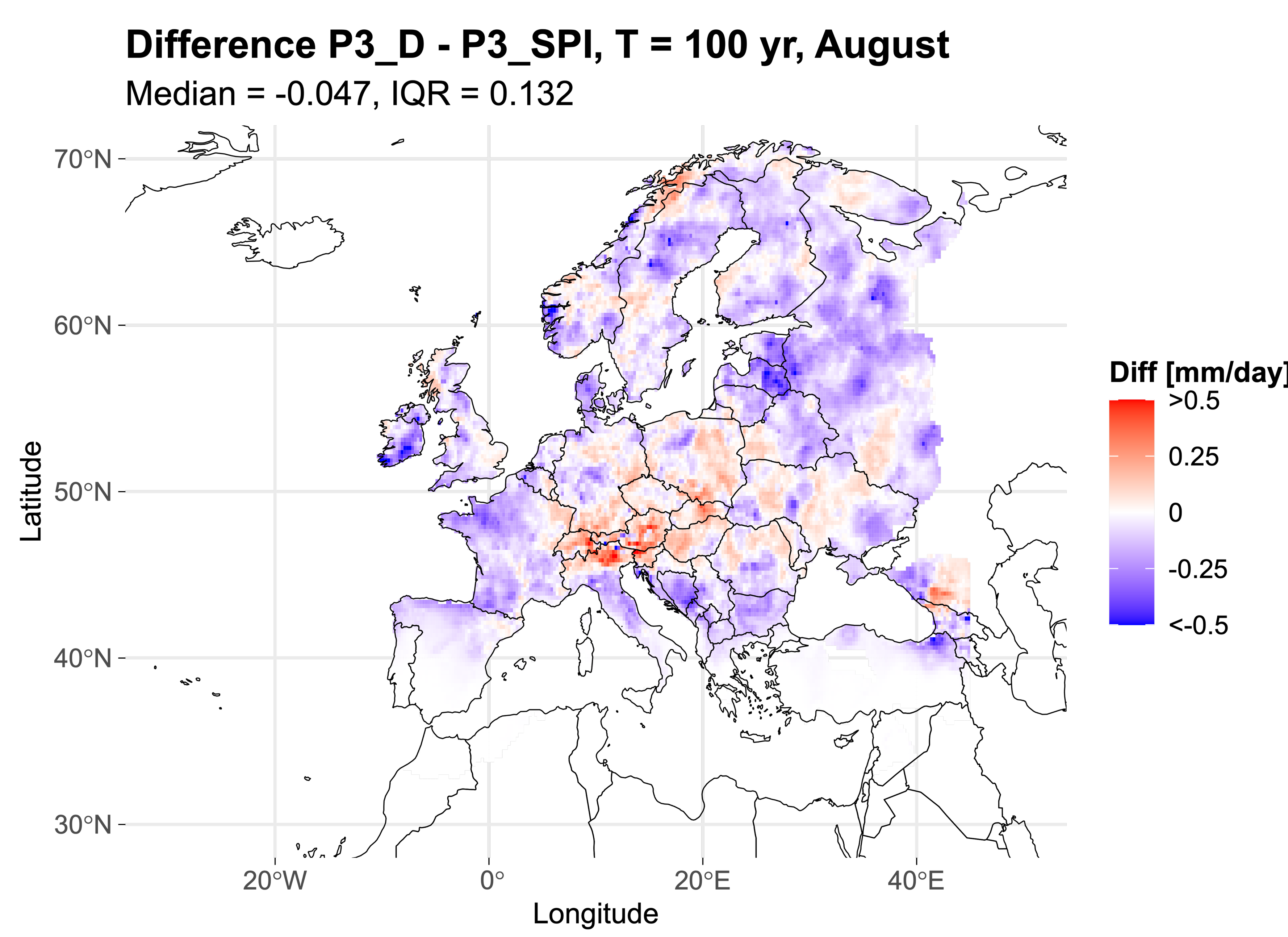

Figure 2. Difference between the return levels obtained inverting *D3* to *P3* and the ones obtained inverting *SPI3* to *P3*.

Results – What is the difference?

➔ Because of its mathematical definition, SPI fixes the tails and is incompatible with EVT.

➔ Divergence between *D3* and *SPI3* return levels (Figure 3), due to different tail models (GPD vs Gaussian). **SPI underestimates** drought severity (lack of precipitation) **compared to D**. A similar behaviour can be seen over the all Europe as the map of Figure 2 is mostly blue → *P3(D3) < P3(SPI3).*

➔ *WHAT IS NEXT?*

a. Use more advanced model to consider **spatial correlations and clustering.**
b. **More data**… we need longer time span to test the long perspective differences.

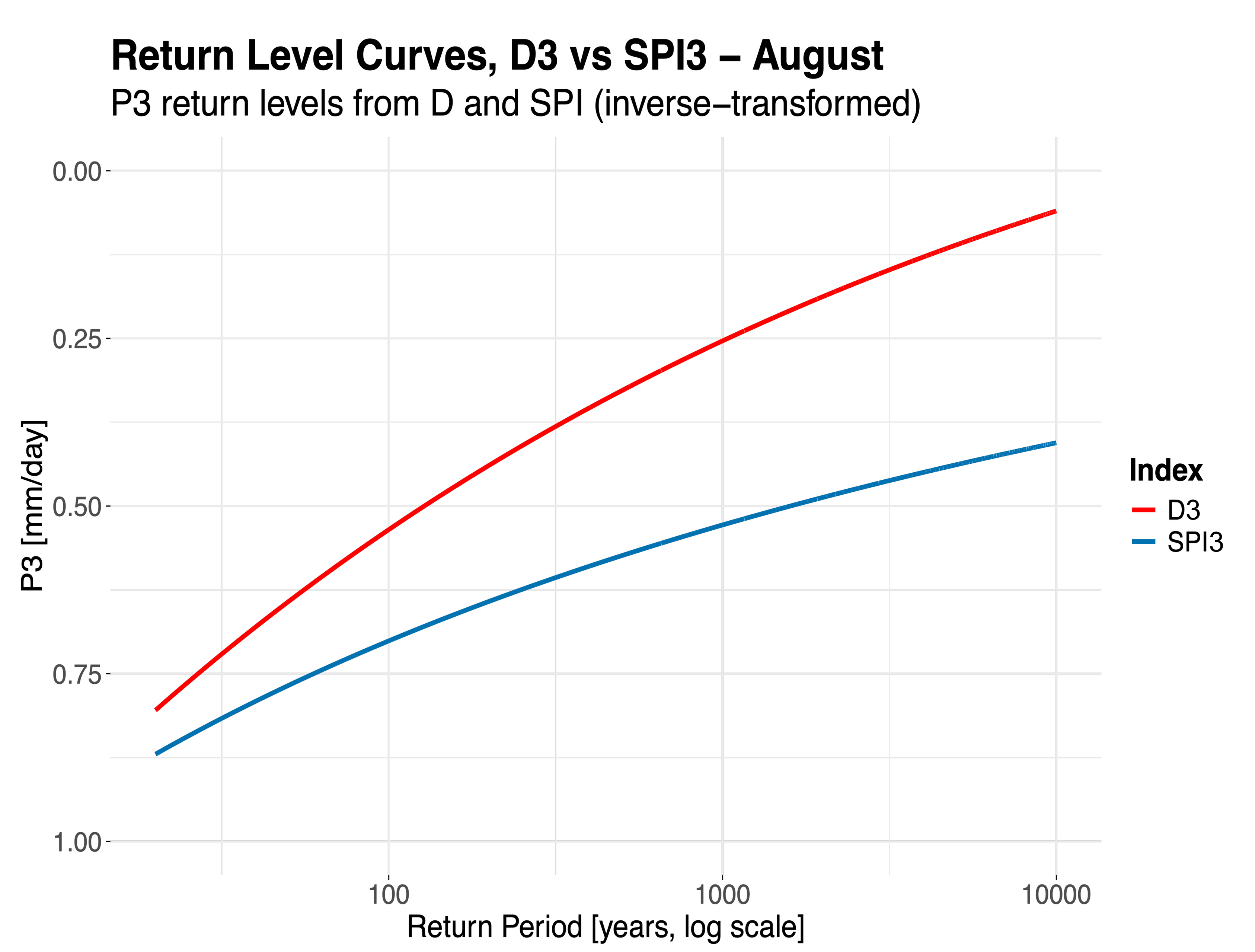

Figure 3. Direct comparison of the return levels of the D3 and SPI3. Example location of Brussels (50.85°N, 4.35°E). The indices have been inverted back into precipitation and August as been chosen as the most representative month.

References

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UCLouvain
paolo.besana@uclouvain.be
Earth and Climate