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A 108-year rainfall dataset, Intensity-Duration-Frequency Curves under uncertainty, and design storm generation for Limassol, Cyprus through an automated Python workflow

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INTRODUCTION & AIM

Accurate rainfall records producing Intensity-Duration-Frequency (IDF) curves, relating rainfall intensity to its duration and return periods, and derived design storms, are cornerstones of resilient hydraulic and urban drainage design. By translating long-term rainfall statistics into specific storm profiles, engineers can reliably design drainage systems (Alamanos et al., 2021; Varlas et al., 2024).

For the case of Limassol port, to our knowledge, there is no available IDF and storm generation tool or database, and with this research, we aim to fill this gap.

DATA PRE-PROCESSING

To create a sufficiently long, quality-controlled daily rainfall record (ideally 20–30 years or more) we drew on two complementary archives: Cyprus Department of Meteorology archives (raw gauge observations from the Limassol/Akrotiri station (ICAO LCRA / WMO 17601)) and\ECA&D (European Climate Assessment & Dataset - blended, quality-controlled daily station series for WMO 17601).

In hydrology, continuous precipitation or streamflow records are critical for analyses, yet gaps inevitably occur due to instrument failure, maintenance, or data-entry errors. Although in our case there were no missing values, a Python-based gap-filling tool was developed to facilitate future similar analyses (Alamanos, 2025).

Thus, we assembled a continuous 108-year (1916–2024) daily rainfall time-series for Limassol, Cyprus (Figure 1).

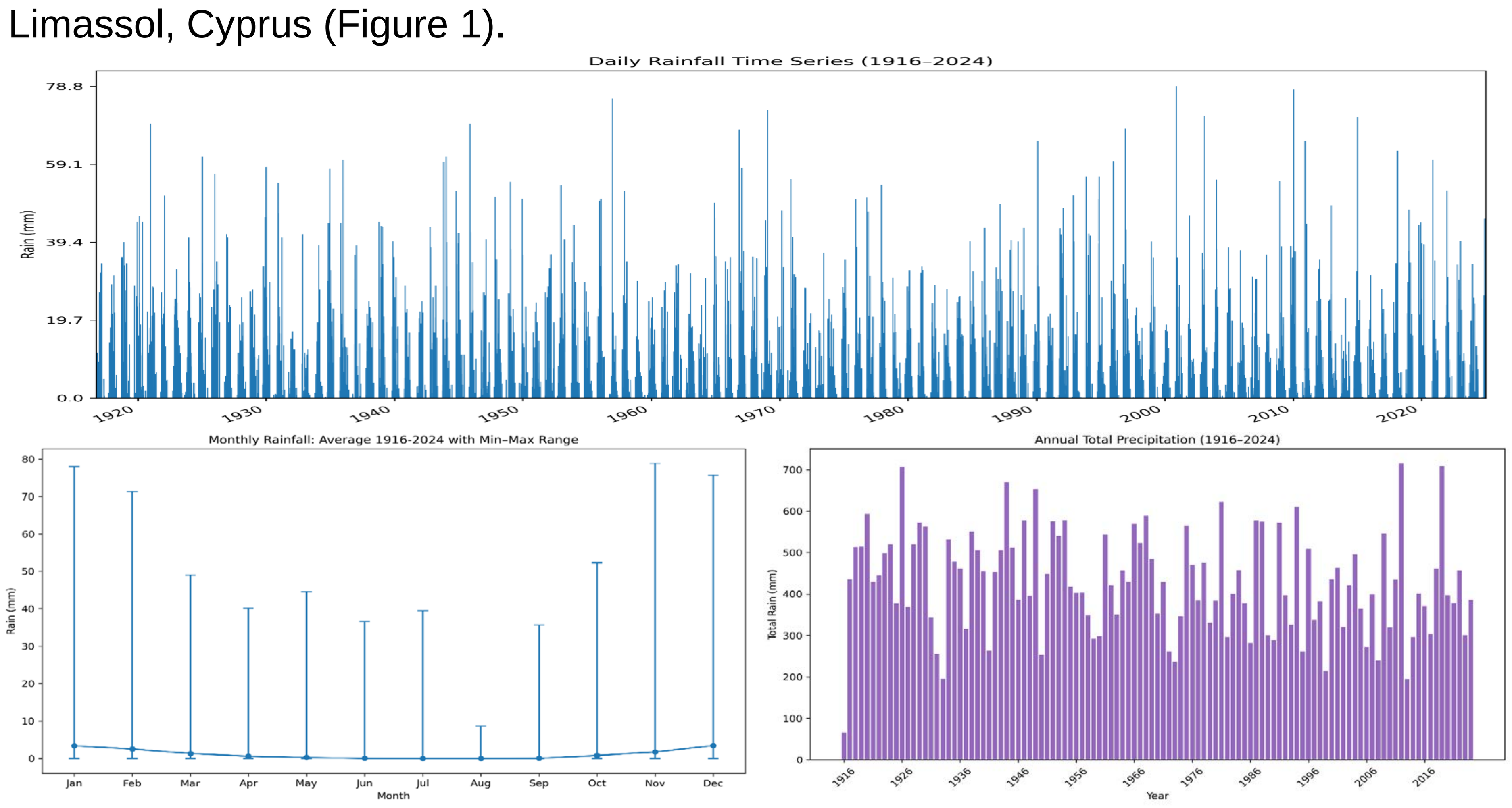
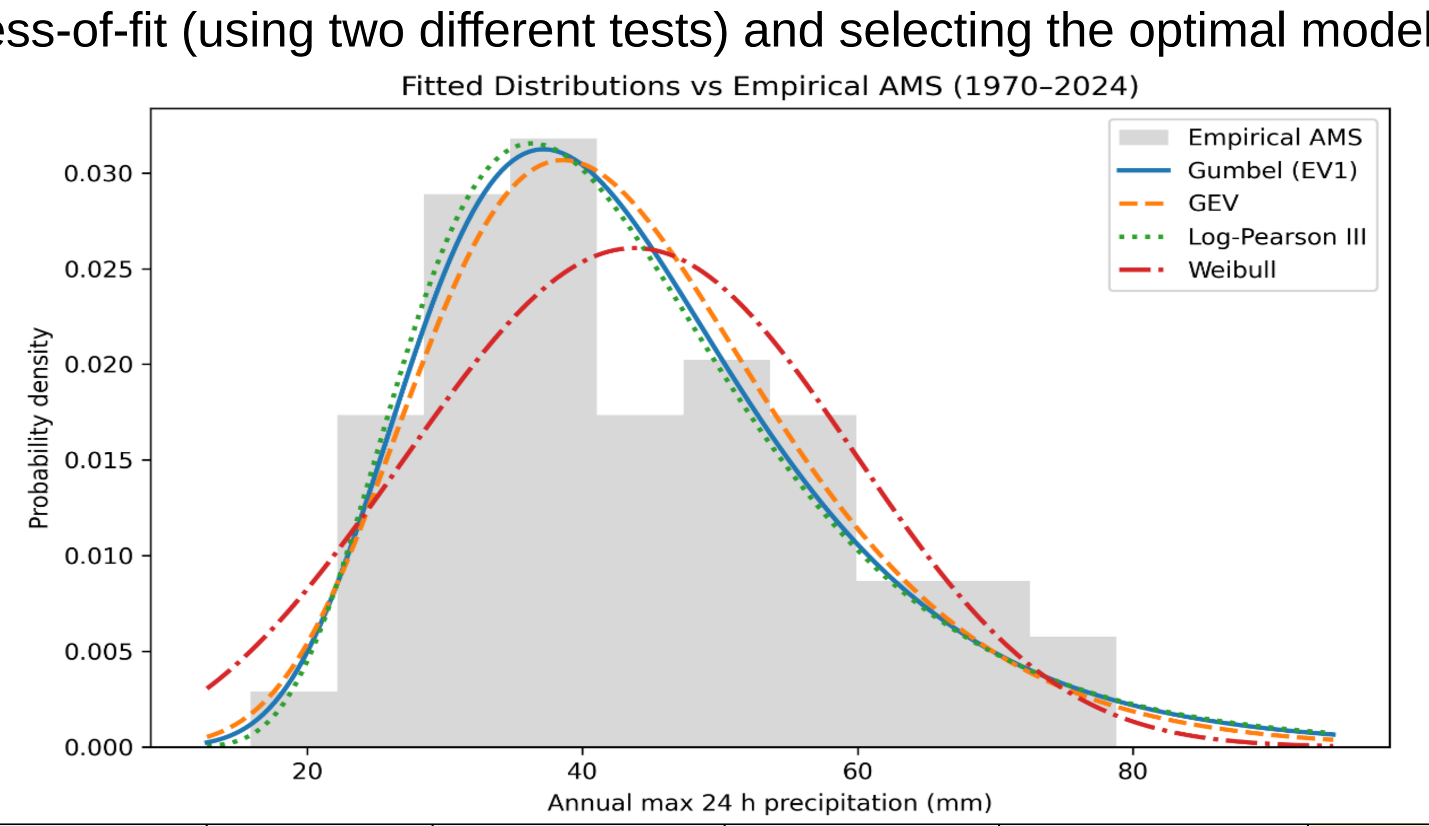


Figure 1. Daily, monthly, annual results of the precipitation time-series (1916-2024).

The first step for making IDF Curves is to get the annual maxima series, for two records lengths (1990–2024, 1970–2024), for this case.

A follow-up Python tool was developed for this purpose, which then fits the four most common distributions mentioned, and provides a summary table with their results (Gumbel, GEV, Log-Pearson III, and Weibull distributions). Moreover, it evaluates the goodness-of-fit (using two different tests) and selecting the optimal model (Figure 2).



Distribution	Chi2 stat	Chi2 p-value	KS stat	KS p-value	Ranking
Gumbel	3.26	0.953	0.050	0.998	#1* almost ec performance
GEV	3.86	0.921	0.058	0.987	#2
Log-Pearson III	3.10	0.960	0.055	0.993	#1* almost ec performance
Weibull	6.36	0.704	0.090	0.733	#4

Figure 2. Distributions' Fitting and Goodness-of-Fit tests results.

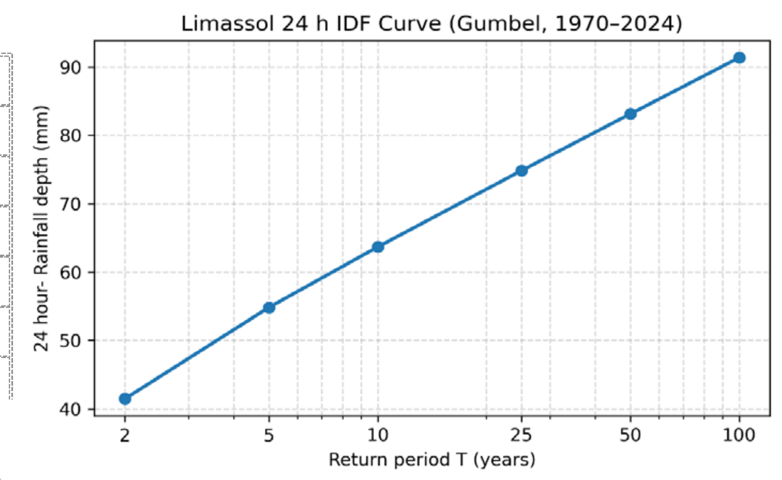
RESULTS & DISCUSSION

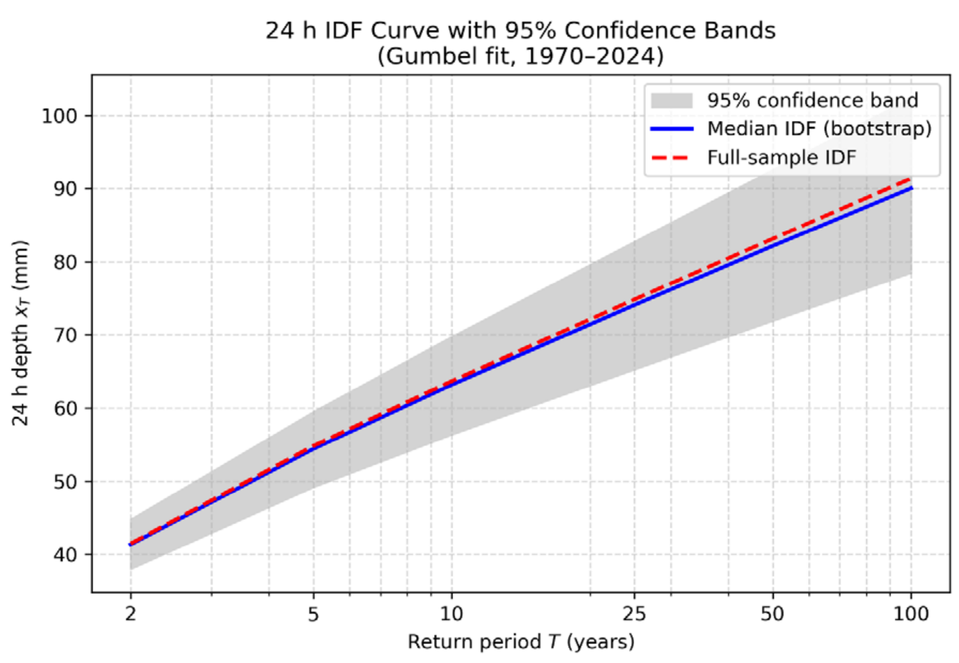
First, a Python-based gap-filling tool was developed to facilitate future similar analyses. It uses the three most common methods for filling missing values (mean imputation, linear interpolation, moving-average imputation), and generates statistics and plots to compare their performance. This step enhances the applicability of our approach, ensuring a continuous time-series (Alamanos and Papaioannou, 2025).

After the fitting of different distributions and the selection of the best-performing one, the IDF results can be produced. For each one, we produced 24-hour depth tables at multiple return periods and 95% confidence bounds via bootstrap resampling. Finally, we derived hyetographs for multiple return periods, using uniform hyetograph, symmetric triangular hyetograph, and Chicago gamma-shaped hyetograph methods (Figure 3).

Resulted 24 h IDF Table (Gumbel) and plot, with uncertainty:

Return period T (yr)	Depth x_T (mm/24 h)	Intensity (mm/h)
2	41.5	1.729
5	54.8	2.285
10	63.7	2.653
25	74.8	3.118
50	83.1	3.463
100	91.3	3.806





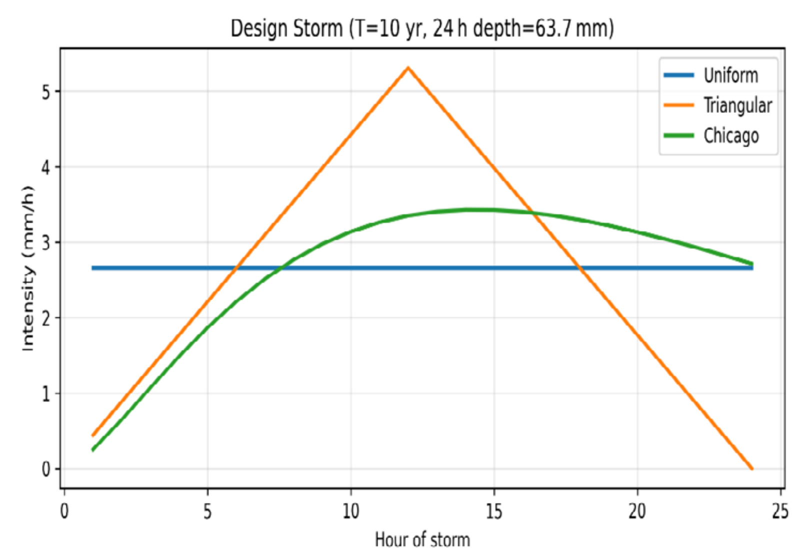


Figure 3. Indicative results for the 24-hour IDF table and the Curve for different return periods. The uncertainty (95% confidence band) results are also produced. The estimation of the peak discharge based on three different hyetographs is also presented, indicatively for a 10yr return period.

CONCLUSION

This work provides the first publicly available detailed hydro-meteorological dataset, IDF analysis, and suite of design storms for Limassol, filling a critical gap in local resilience planning.

All steps are incorporated into user-friendly Python scripts, that are readily adaptable to other regions, and will be publicly released to support robust hydrological modelling and infrastructure design.

The use of updated and work-ready tools for engineering design can help build resilience (Alamanos et al., 2025), and for the case of Limassol, this is a significant step for follow-up analyses.

FUTURE WORK / REFERENCES

- Alamanos, A. (2025). An automated Python workflow for hydro-meteorological, IDF Curves and design storm analysis. Repository: https://github.com/Alamanos11/Rainfall_IDF_DesignStorms DOI: 10.13140/RG.2.2.14223.70566
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