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Session HS7.4: Future hydroclimatic scenarios in a changing world

Precipitation changes in Greece over the past century; What type of stochastic description should we use?

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Abstract

- In the presence of long-range dependence, several difficulties emerge in stochastic methods, especially in intermittent and highly-skewed processes, such as precipitation, which cannot be fully supported by the established models in the literature.

- Here, we analyze a large set of rainfall data in Greece comprising ground records as well as non-conventional data from reanalyses and satellite, and we identify cluster periods of droughts and wet-years in both extreme tails, raising the challenge for their stochastic description.

- In this light, and after statistical analysis of the whole dataset, we apply the latest version of a genuine stochastic method (i.e., direct use of the process of interest without any transformation, and with a focus on the long-range dependence under various stochastic behaviours [1], and we discuss on the implications of the results for future hydrological design scenarios.

1. Introduction

- In the framework of the implementation of the European Union Flood Directive [2], and for the construction of the ombrian curves (rainfall intensity–timescale–return period relationships, or ese intensity–duration–frequency curves) for the entire Greek territory, we we analyze a large set of rainfall data in Greece comprising ground records as well as non-conventional data from reanalyses and satellite, and we identify cluster periods of droughts and wet-years in both extreme tails, raising the challenge for their stochastic description.

- The data consist 940 hydrometeorological stations, among which 783 stations were found to fulfil criteria of reliability, with some had sufficient length (of about 60 years or more) to allow the investigation of climatic variation and identification of possible climatic events. [3]

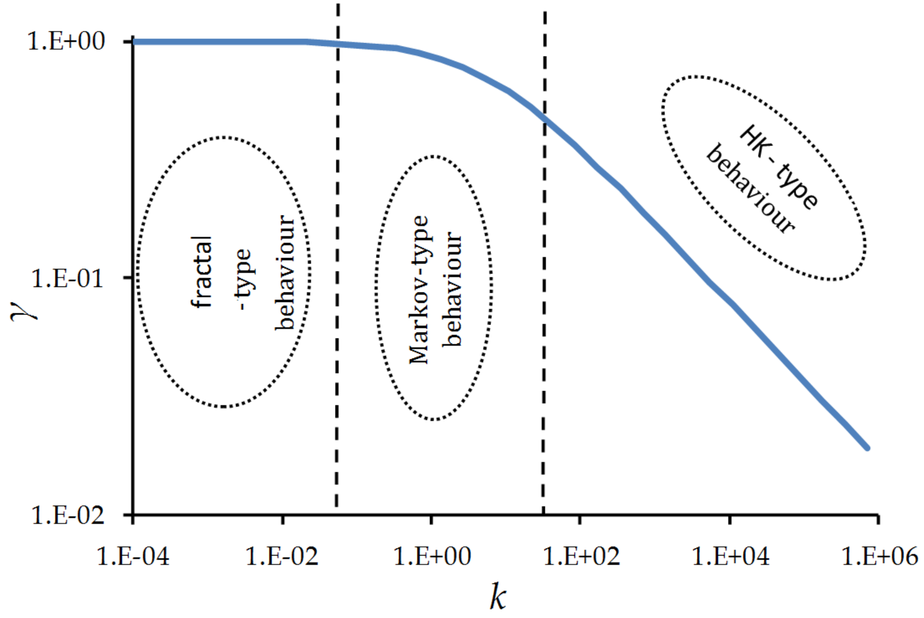
- Many methodologies for stochastic analysis exist in the literature, such as linear, non-linear –e.g., bivariate, multivariate copula–, decalcomania, swap, disaggregation, stationary-nonstationary; however, in the presence of long-range dependence [4,5], several difficulties emerge in stochastic methods, especially in intermittent and highly-skewed processes, such as precipitation, which cannot be fully supported by the established models in the literature.

- The proposed genuine stochastic method (i.e., direct use of the process of interest without any transformation, and with a focus on the long-range dependence) has the advantages/limitations of:

✓ Separate estimation of the dependence structure and the marginal distribution.
✓ Explicit simulation of both (no use of non-linear transformations).
✓ Exact representation of the correlation structure.
✓ Approximation of the marginal distribution through the preservation of moments.
✓ Simulation of certain aspects of the intermittent behaviour.

2. Genuine stochastic framework

The synthesis is accomplished using the implicit generation scheme presented in [1] for arbitrary marginal distribution and dependence structure trough the Symmetric-Moving-Average algorithm Here, is an example with the preservation of the first four moments [6].

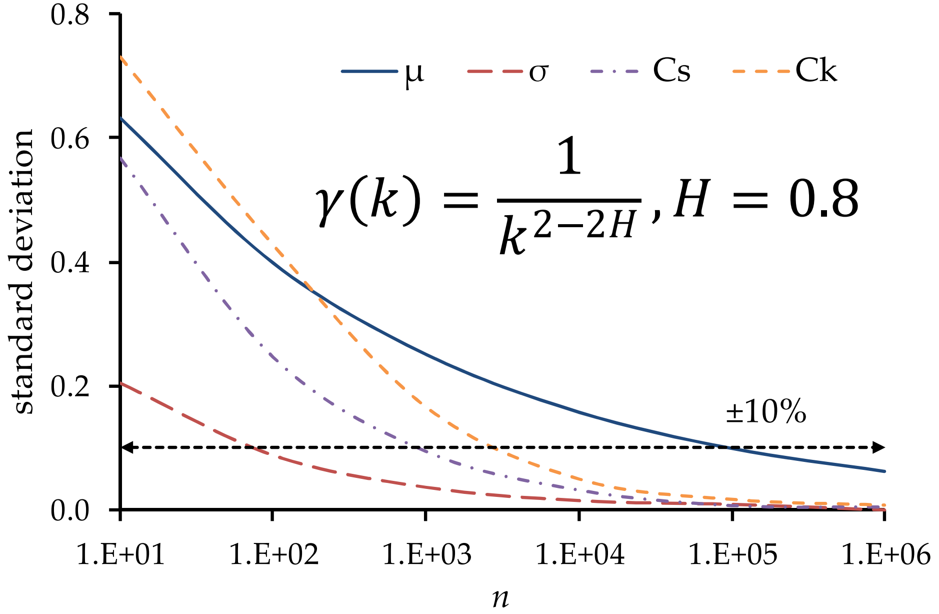


$$C_{s,\underline{v}} = \frac{\left(\sum_{j=-l}^{l} a_{|j|}^{2}\right)^{3/2}}{\sum_{j=-l}^{l} a_{|j|}^{3}} C_{s,\underline{x}}$$

$$C_{k,\underline{v}} = \frac{\left(\sum_{j=-l}^{l} a_{|j|}^{2}\right)^{2}}{\sum_{j=-l}^{l} a_{|j|}^{4}} C_{k,\underline{x}} - 6\,\frac{\sum_{j=-l}^{l-1} \sum_{k=j+1}^{l} a_{|j|}^{2}\, a_{|k|}^{2}}{\sum_{j=-l}^{l} a_{|j|}^{4}}$$

$$\underline{x}_i = \sum_{j=-l}^{l} a_{|j|} \underline{v}_{i+j}$$

where the process $\underline{x}$ is expressed through the sum of products of coefficients (not parameters) a_j and white noise terms v_i, where l theoretically equals infinity but a finite number can be used for preserving the dependence structure up to lag l.



3. Precipitation Dataset

Additionally, non-conventional data were also examined, such as reanalysis and satellite data, which had to be re-calibrated with ground data, and along with the monthly data of the Global Historical Climatology Network (GHCN) from neighbouring countries a set of 128 stations was finally created.

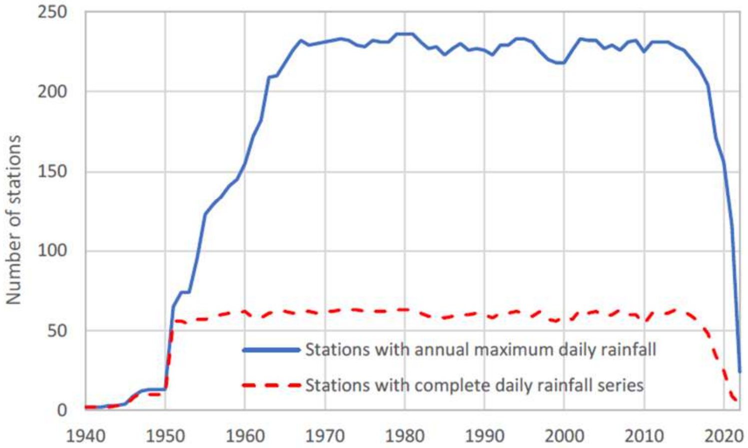


Figure 1. Number of stations with long maximum daily rainfall time series and with complete annual average daily time series in the entire Greek territory in the period 1940–2022. Before 1940, there were two stations, Athens and Thessaloniki.

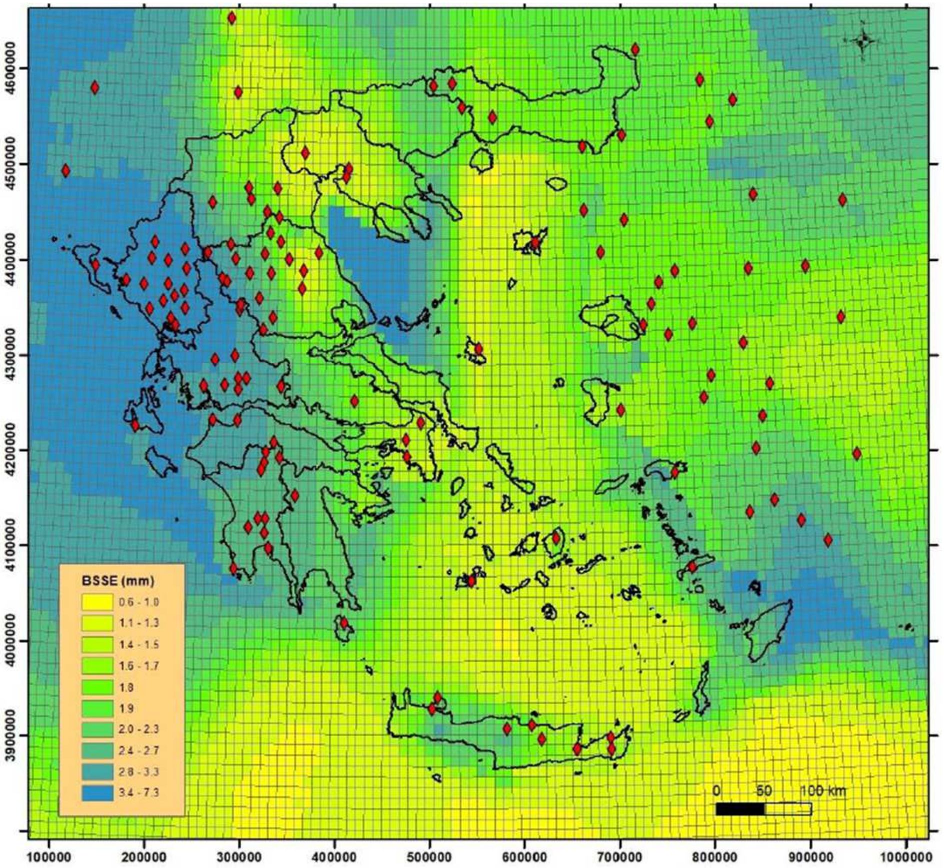


Figure 2. Map of geographical distribution of average daily precipitation produced by the BSSE method combining ground data at 128 stations (red diamonds) in Greece and neighbouring countries with IMERG satellite data. The black lines shown are the divides of the water districts of Greece. The colour divisions (classes) are based on quantile classification so that each class contains equal number of grid points. The lower class, 0.6–1.0 mm, is seen only in the sea (not on land).

4. Precipitation trends in the longest records

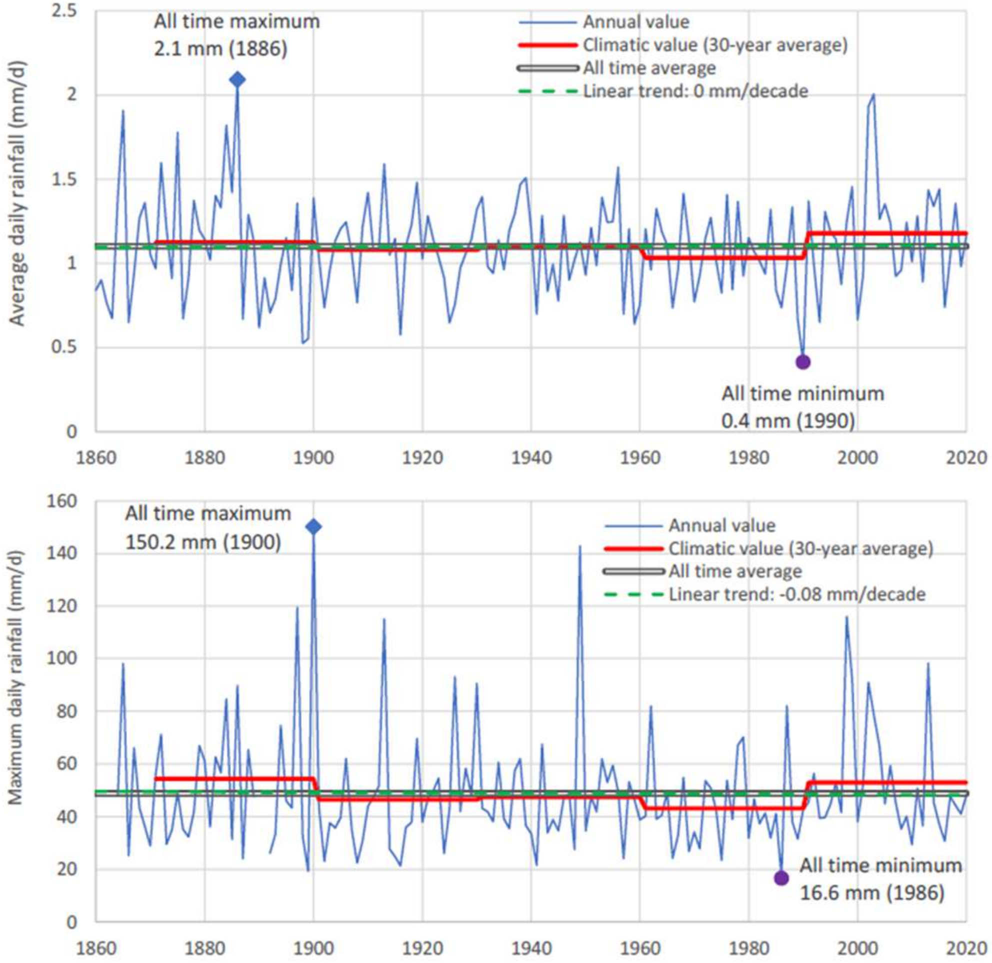


Figure 3. Time series of daily precipitation series in Athens at the Hill of Nymphs station of the National Observatory of Athens (average daily values start in 1860 with a total length of 161 years; daily and maximum daily values start in 1864 with a total length of 155 years). The graph also shows (a) the high and low records, (b) the climatic values (30-year averages), and (c) the fitted linear trends. (**Upper**): average daily rainfall; (**Lower**): maximum daily rainfall.

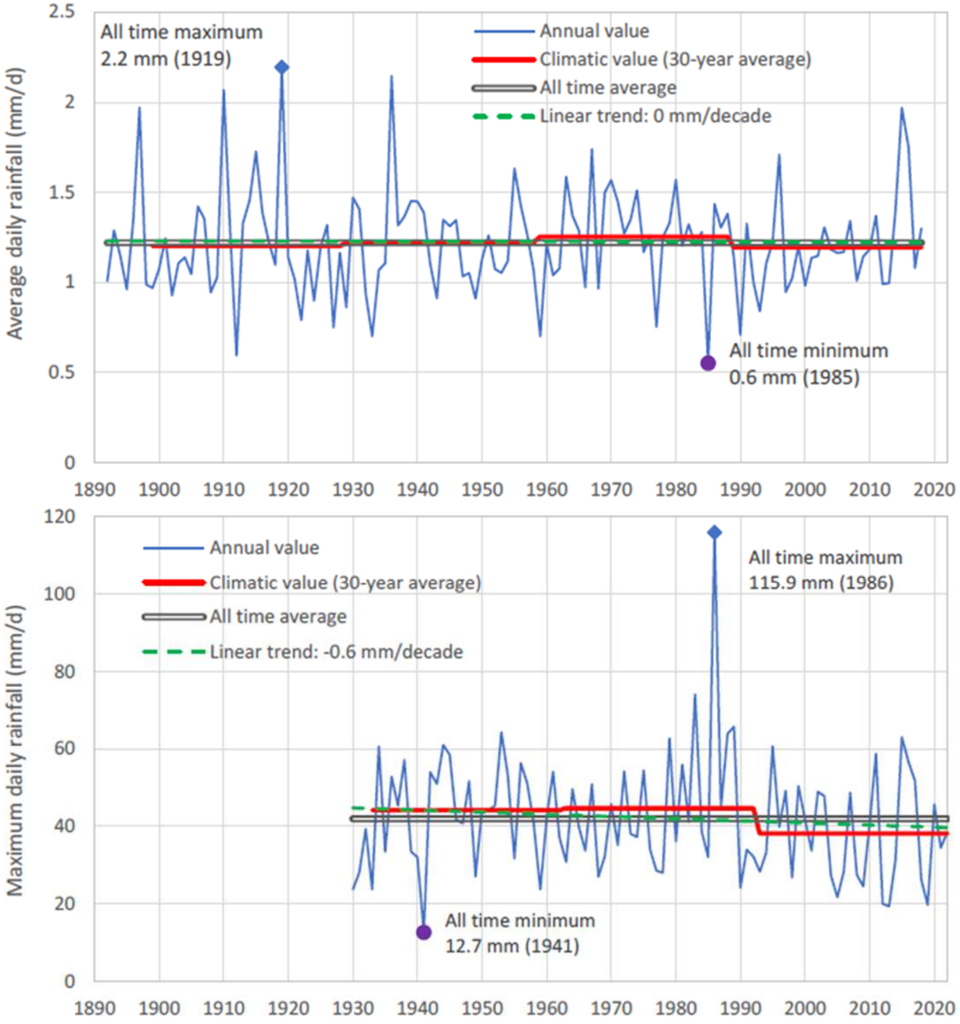


Figure 4. Time series of daily precipitation in Thessaloniki (average daily values start in 1892 with a total length of 127 years; daily and maximum daily values start in 1930 with a total length of 93 years). The graph also shows (a) the high and low records, (b) the climatic values (30-year averages), and (c) the fitted linear trends. (**Upper**): average daily rainfall; (**Lower**): maximum daily rainfall.

5. Maximum daily precipitation

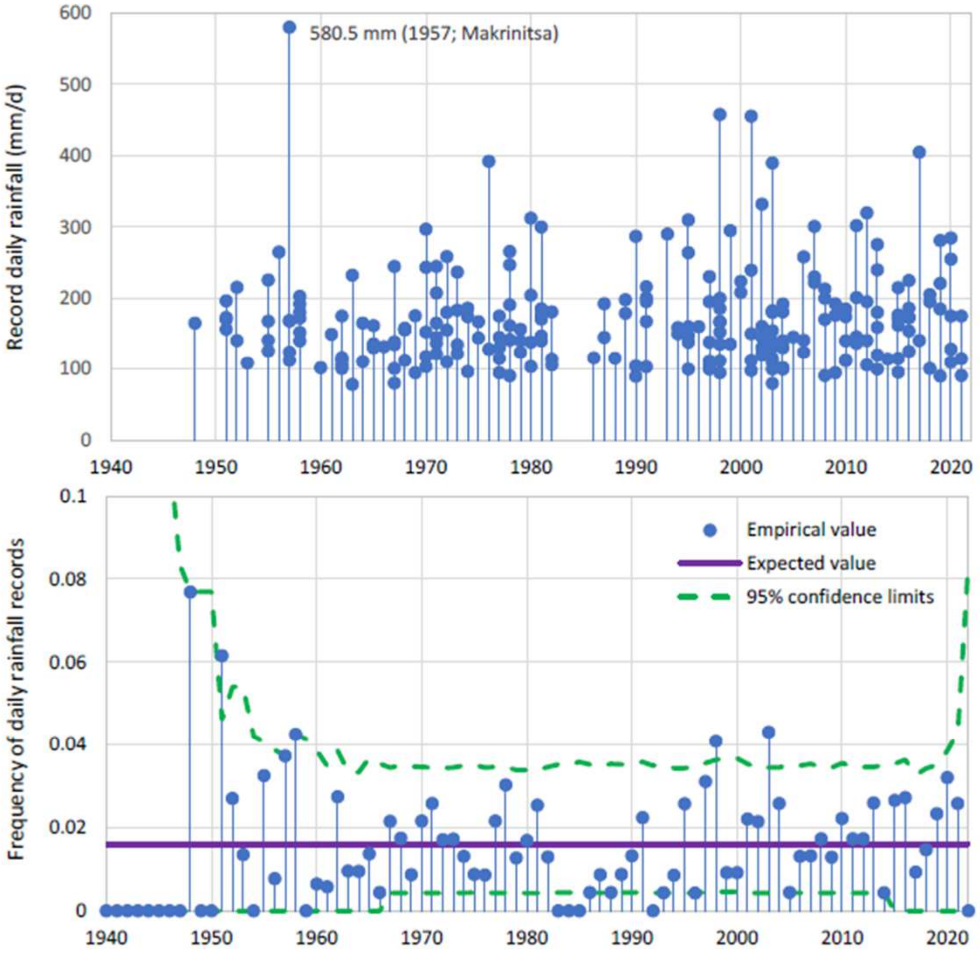


Figure 5. Records of maximum daily precipitation depth (**upper**) and frequency thereof per year (**lower**) for the 238 stations with long time series of annual maxima in the entire Greek territory. The confidence limits in the lower panel have been calculated from the binomial distribution, assuming independence and identical distribution.

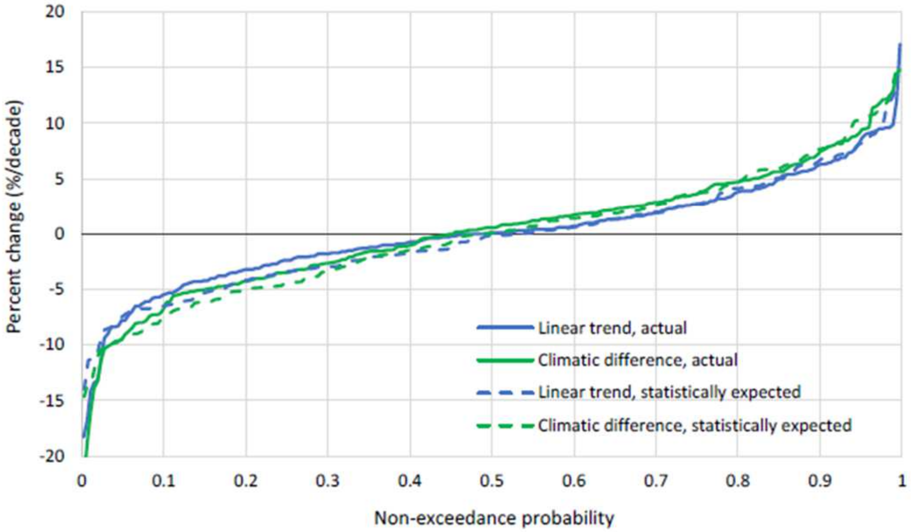


Figure 6. Probability distribution of the changes of annual maximum daily precipitation (as percentages of the all-time averages of the maximum rain depth) for the 238 stations with long time series of annual maxima in the entire Greek territory. Climate difference, expressed as a percentage per decade, is 1/3 of the difference between the last two 30-year climatic values. Statistical expectations have been estimated by the Monte Carlo method with the generalized extreme value distribution and a Hurst parameter of 0.60.

6. Long records of maximum daily and hourly precipitation

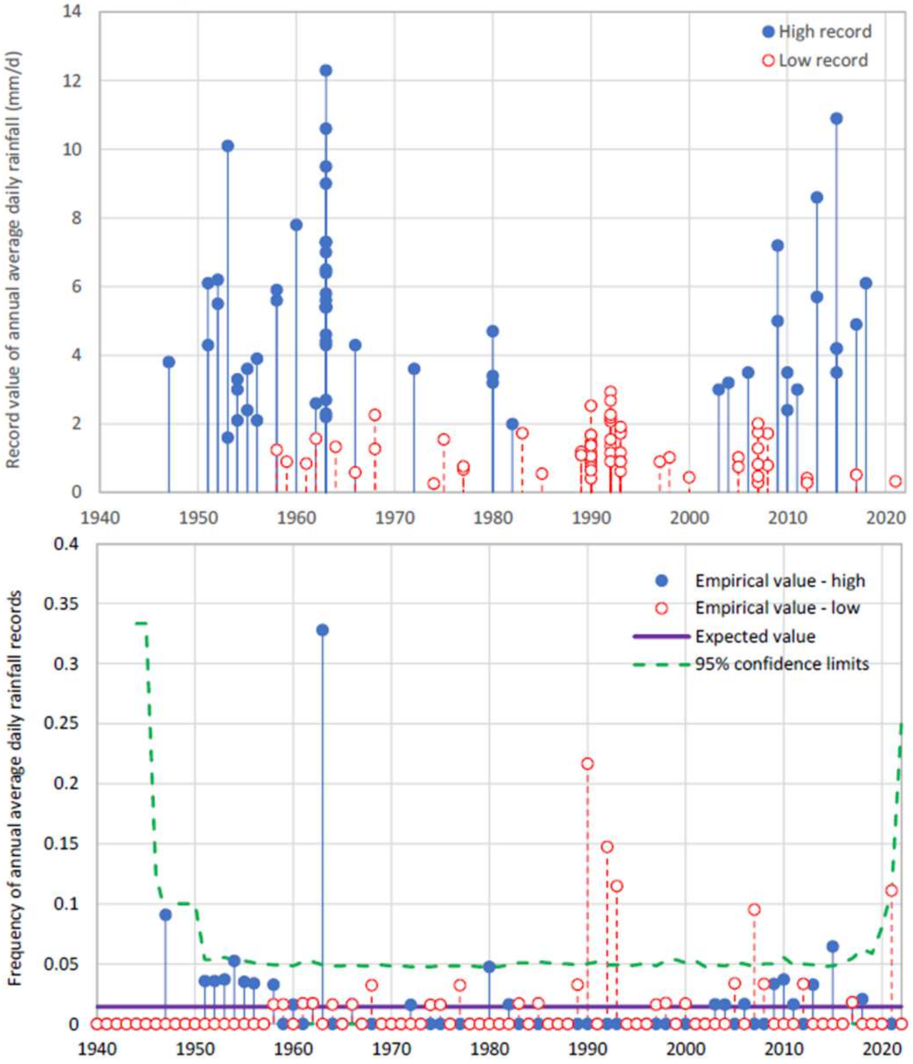


Figure 7. High and low records of average daily precipitation depth per year (**upper**) and frequency thereof per year (**lower**) for the 62 stations with long and complete daily or monthly time series in the entire Greek territory. The confidence limits in the lower panel have been calculated from the binomial distribution, assuming independence and identical distribution.

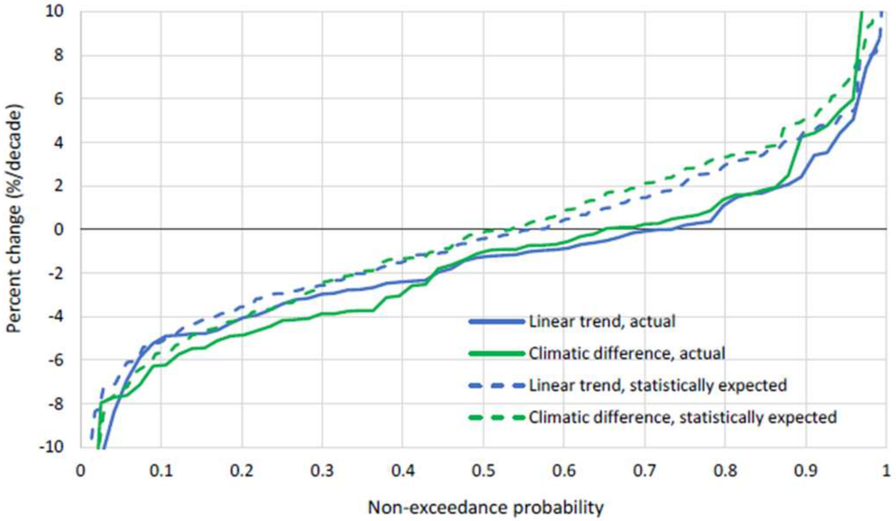


Figure 8. Probability distribution of the changes of annual average daily precipitation (as percentages of the all-time average rainfall depths) for the 62 stations with long time series of daily or monthly time series in the entire Greek territory. Climate difference, expressed as a percentage per decade, is 1/3 of the difference between the last two 30-year climatic values. Statistical expectations have been estimated by the Monte Carlo method with normal distribution and a Hurst parameter of 0.75.

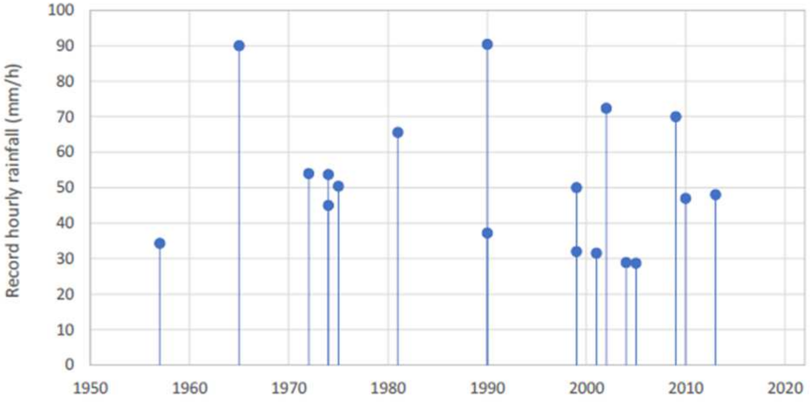


Figure 9. Records of maximum hourly precipitation depth for the 18 stations with long time series of hourly precipitation in the entire Greek territory.

7. Concluding remarks

- The two over-century-long rainfall time series of Greece (Athens and Thessaloniki) show that the record average and maximum rainfall depths occurred in the 19th or early 20th century.
- The current period can be characterized as normal without notable climatic events.
- Both the temporal distribution of record highs and climatic fluctuations thereof are in agreement with theoretical expectations under stationarity.
- There is a balance between positive and negative climatic trends, which may be physically justified by the presence of long-range dependence in the precipitation process.

➢ Please share your thoughts; what type of stochastic description should we use to simulate the precipitation process in Greece?

References

[1] D. Koutsoyiannis, and P. Dimitriadis, Towards generic simulation for demanding stochastic processes, Sci, 3, 34, doi:10.3390/sci3030034, 2021.

[2] European Commission. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks; L 288, 6.11.2007; Official Journal of the European Communities: Aberdeen, UK, 2007; p. 27.

[3] D. Koutsoyiannis, T. Iliopoulou, A. Koukouvinos, N. Malamos, N. Mamassis, P. Dimitriadis, N. Tepetidis, and D. Markantonis, In search of climate crisis in Greece using hydrological data: 404 Not Found, Water, 15 (9), 1711, doi:10.3390/w15091711, 2023.

[4] D. Koutsoyiannis, Revisiting the global hydrological cycle: is it intensifying?, Hydrology and Earth System Sciences, 24, 3899–3932, doi:10.5194/hess-24-3899-2020, 2020.

[5] P. Dimitriadis, D. Koutsoyiannis, T. Iliopoulou, and P. Papanicolaou, A global-scale investigation of stochastic similarities in marginal distribution and dependence structure of key hydrological-cycle processes, Hydrology, 8 (2), 59, doi:10.3390/hydrology8020059, 2021.

[6] P. Dimitriadis, and D. Koutsoyiannis, Stochastic synthesis approximating any process dependence and distribution, Stochastic Environmental Research & Risk Assessment, 32 (6), 1493–1515, doi:10.1007/s00477-018-1540-2, 2018.