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Fine Scale Rainfall Disaggregation in Greece using RBLRPM

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ABSTRACT

The fine-scale disaggregation of rainfall is an essential tool for hydrological applications because of the strong stochasticity that underlies natural hydrological phenomena and the scarcity of available data. In two study areas in Greece, the Random Bartlett-Lewis Rectangular Pulse Model (RBLRPM) is applied for two distinct distributions of the impulse intensity (Gamma and Exponential). The corresponding daily time series will be divided into hourly ones, and the HYETOS-R package will be used to assess the behavior of the alternative distributions based on the required statistical quantities.

1. Introduction

Data at fine temporal scales are essential to the accuracy and dependability of many hydrological applications, including the design of drainage systems, reservoirs, and flood control projects. The scarcity of precipitation data on precise time scales, particularly in Greece, is a serious issue. Hydrological applications therefore require the use of stochastic rainfall models at various time scales. These models have the advantage of being able to accurately describe the precipitation process using a limited number of parameters. An important, also, advantage of the RBLRPM is that it manages to adequately capture both the structure of the selected historical statistical parameters, as well as the probability of drought for various time scales, for an exclusive set of parameter values for each month, ensuring the temporal independence of the model.

2. Material and Methods

The disaggregation algorithm implemented by the HYETOS-R package is based on the Koutsoyiannis and Onof (2001) algorithm. In order to accurately replicate the historical time series with a larger time scale, the model consists of a Bartlett-Lewis model and an exact correction procedure that modifies the shorter synthetic time series (Grygier, Stedinger, 1988). Applying the adjusting procedure, to optimally compute the statistical parameters, requires a substantial computational effort that is reduced by simulating the time series with shorter periods for rainy events as opposed to the full duration. The assumption that storms follow a Poisson distribution and that there is independence between clustered rain days are two of the highly realistic assumptions that the Bartlett-Lewis model is found to accept. The chosen model in this research is the RBLRPM, which is an improved version of the Bartlett-Lewis Rectangular Pulse Model (BLRPM) (Rodriguez-Iturbe et al., 1988), differing in the way it models the random variable of pulse duration.

An enhanced version of the evolutionary annealing-simplex algorithm (Efstratiadis, Koutsoyiannis, 2002) is used to estimate the unique set of parameters of the Barlett-Lewis model for the two study areas (Thessaloniki and Heraklion), since it is a probabilistic heuristic optimization method that combines the effectiveness of hill-climbing techniques in convex regions with the robustness of rough response surface annealing simulation. The primary characteristic of the algorithm, which is based on the Simplex method, is that none of the moves are completely deterministic, which increases the possible rough search field of the iterative process.

3. Results and Discussion

For Thessaloniki, the Gamma distribution appears to fit the best for the driest month (June), but the Exponential distribution appears to preserve better the historical statistical features of the time series for the wettest month (January). The structure of the autocorrelation coefficient is not satisfactorily preserved, even though the Gamma distributions' deviations are not great in the case of the dry probability. Maintaining the structure of the autocorrelation coefficient is a crucial requirement, but the deviations of the coefficients of variation and skewness are comparable to those of an Exponential distribution. For example, the structure of the skewness coefficient and the probability of dry conditions are fully preserved when creating a daily synthetic time series of January assuming an Exponential distribution. The variation coefficient, in particular, appears to be overestimated by the model by 18%, with a 45% deviation from the historical coefficient in the case of skewness (Fig. 1a). Whereas the coefficients of variation and skewness (37% and 38%) are underestimated and deviate more from the historical ones, the deviations of the synthetic statistical characteristics for June seem to be larger than those of the corresponding rainy month and already of the autocorrelation coefficient (Fig. 1b).

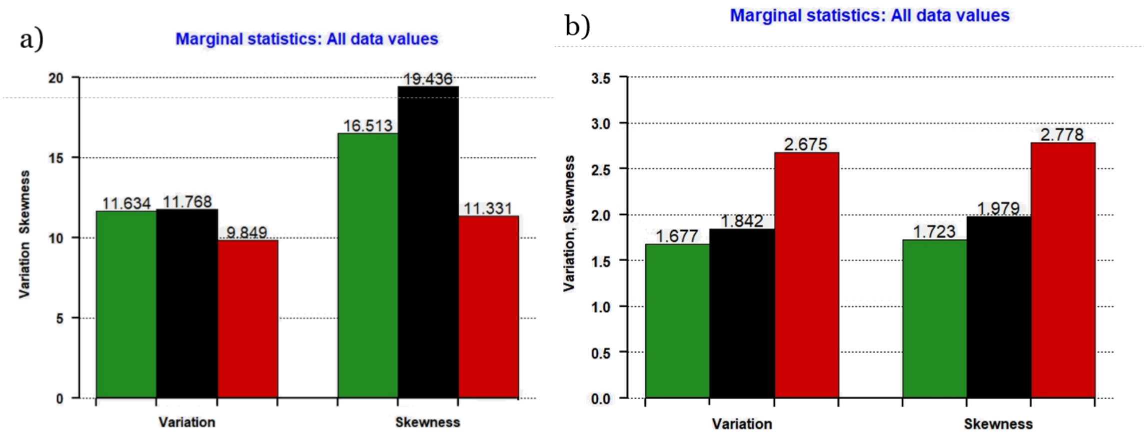

Fig. 1. Statistical Characteristics, considering that the intensity of the pulses follows the exponential distribution for: a) January and b) June (the diagrams for the volatility coefficient (left) and the asymmetry coefficient (right))

Conversely, the Gamma distribution is proved to be more appropriate for both months in the Heraklion region, since it maintains more satisfactorily the coefficients of variability and asymmetry, in addition to the structure of the autocorrelation coefficient at the time scales of 1, 6, 12 and 24 hours. Both distributions simulate dry probabilities equally well, fully preserving the structure of the skewness coefficient. For both the wettest and the driest month, the variation's deviation is less than 5% and the skewness is less than 15%. With the largest deviation occurring in the skewness and being only 7%, the model's performance in breaking down the daily synthetic time series into hourly is also very impressive, given that the structure of the statistical characteristics under study is fully preserved.

4. Conclusions

Based on this study, for the Greek region, the RBLRPM can preserve the essential statistical properties that control the daily structure of the precipitation and simulate precipitation to multiple aggregation scales using a single set of parameters, regardless of the historical time series' time scale. Specifically, it can preserve the coefficients of autocorrelation, variability, and asymmetry for the entire time series, as well as, for the rainy days individually, while maintaining the likelihood of rain, which is another crucial feature of the precipitation time series. Given that the independent intensities of the rectangular pulses follow a Gamma distribution, the results also demonstrate that most of the months of the study areas in Greece are better simulated. Nonetheless, the time series can also be divided using the Exponential distribution.

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