Coupling the strengths of optimization and simulation for calibrating Poisson cluster models

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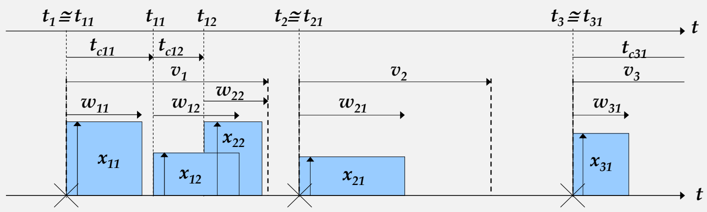
1. Abstract

To simulate rainfall at fine time scales stochastic approaches are usually enrolled. A leading scheme is the **Bartlett-Lewis model**, which belongs to the family of Poisson-cluster processes. Taking advantage of the simulation and optimization functionalities of **HyetosR** package, we evaluate the performance of two versions of BL model in representing the convective and frontal rainfall of Athens. We demonstrate that although these models reproduce the essential statistical characteristics of rainfall at the hourly as well as daily time scales (mean, variance, autocorrelation structure), they fail to preserve important temporal properties, such as the duration and time distance of rainfall events.

2. Rainfall generation via Bartlett-Lewis model

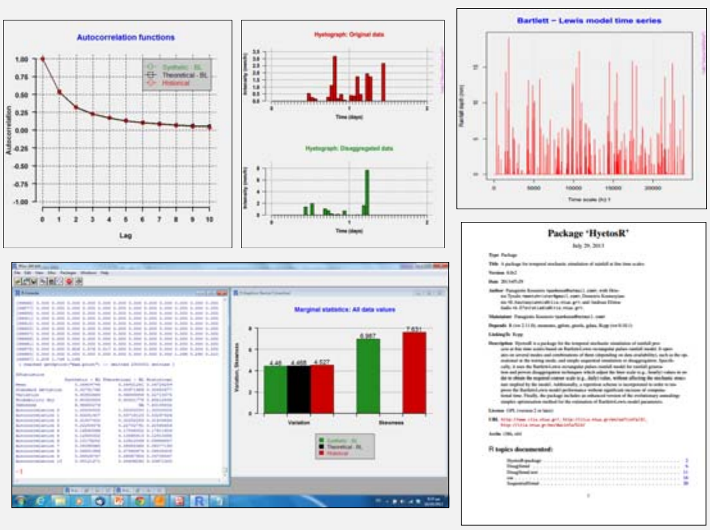
- Model assumptions (original version; Rodriguez-Iturbe *et al.*, 1987):
  - **Storm origins** t_i occur in a Poisson process, with rate λ
  - **Cell origins** t_{ij} occur in a Poisson process, with rate β
  - **Cell arrivals** terminate after time v_i, which is exponentially distributed (parameter γ)
  - **Cell durations** w_{ij} are exponentially distributed (parameter η)
  - **Cell intensities** x_{ij} are either exponentially or gamma distributed.
- In the modified version (Rodriguez-Iturbe *et al.*, 1988) η is assumed gamma distributed, with scale parameter v and shape parameter a, and varies for each event, such as β/η and γ/η remain constant.
- Model parameters are estimated via calibration, seeking to minimize the departures between the key theoretical and observed statistics.



3. HyetosR for stochastic simulation of rainfall

HyetosR is an open source software for **temporal stochastic simulation of rainfall** at fine time scales, which is implemented in **R** programming language (and part of code in **C++**). It supports three different versions of the Bartlett-Lewis (BL) model for the generation of synthetic rainfall events. Hyetos operates on several modes that enable **sequential simulation** or **disaggregation** (Koutsoyiannis & Onof, 2001).

The estimation of model parameters is employed through an enhanced version of the **evolutionary annealing-simplex** method (Efstratiadis & Koutsoyiannis, 2002). An explicit platform allows the user to configure the multiple arguments of the calibration problem (objective function, parameter bounds, population size, etc.)

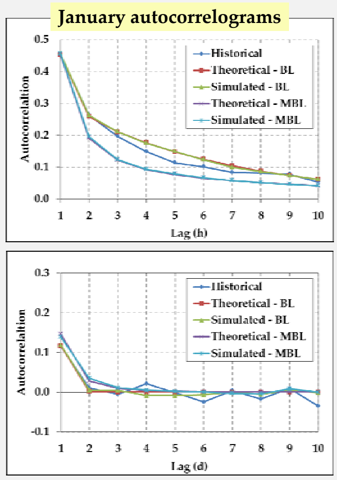


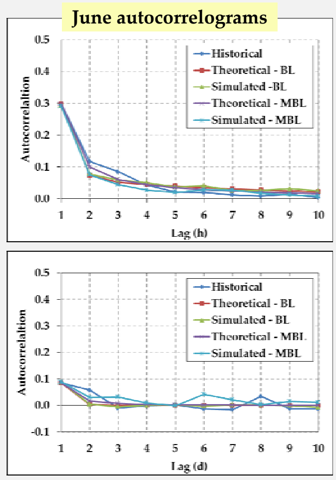
HyetosR is available at http://itia.ntua.gr/en/softinfo/3/

4. Case study: Simulation of Athens rainfall

We examined the performance of the original (BL) and modified (MBL) Bartlett-Lewis model using hourly rainfall data from the National Observatory of Athens (1927-1996), for two months with different meteorological behaviour (January, June). Model parameters were calibrated against the theoretical statistics (mean, standard deviation, autocovariance and probability dry), for 1 and 24 h. The simulated statistics were estimated from a synthetic series of 1000 years length.

	Historical	Theoretical – BL	Simulated – BL	Theoretical – RBL	Simulated – RBL	
Average (mm)	0.065	0.065	0.065	0.065	0.065	**January, Hourly statistics**
Standard deviation (mm)	0.458	0.458	0.458	0.458	0.458	
Coefficient of skewness	16.957	-	11.884	-	12.663	
Average (mm)	1.555	1.555	1.557	1.563	1.563	**January, Daily statistics**
Standard deviation (mm)	4.532	4.532	4.535	4.053	4.083	
Coefficient of skewness	5.301	-	4.235	-	5.289	
Average (mm)	0.015	0.015	0.015	0.015	0.015	**June, Hourly statistics**
Standard deviation (mm)	0.370	0.370	0.375	0.370	0.374	
Coefficient of skewness	50.578	-	47.684	-	49.428	
Average (mm)	0.365	0.365	0.360	0.365	0.365	**June, Daily statistics**
Standard deviation (mm)	2.694	2.694	2.822	2.692	2.638	
Coefficient of skewness	11.881	-		-		





5. Temporal characteristics of rainfall events

Both versions of the BL model fail to reproduce the significant variability of rainfall events, due to the overclustering of pulses. This also results to an over-estimation of probability dry, at the hourly and daily time scales (Fig. 1as well as the generation of rainfall events of shorter duration, and thus longer dry intervals (Figs. 2 and 3).

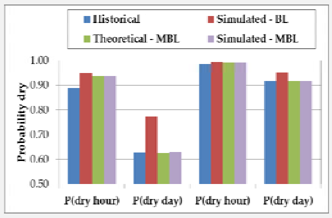


Fig. 1 Probabilities of dry hour and dry day for January (left) and June (right).

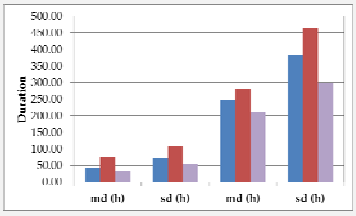


Fig. 2 Mean and standard deviation of dry time intervals for January (left) and June (right).

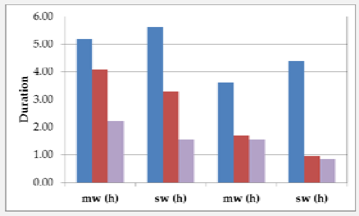


Fig. 3 Mean and standard deviation of duration of rainfall events for January (left) and June (right).

References

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