Interactive comment on “A Hybrid Stochastic Rainfall Model That Reproduces Rainfall Characteristics at Hourly through Yearly Time Scale” by Jeongha Park et al. (SC1)

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Received and published: 29 May 2018

Dear Dr. Nadav Peleg,

We sincerely appreciate your constructive comments on our manuscript. All your comments tremendously helped us to improve the quality of the article. Our response is as follow:

Comment 1. Is the rainfall generator capable of simulating the diurnal cycle of precipitation? I didn’t find a mention to it in the text.

Authors’ Response. We appreciate this comment. This rainfall generator was not designed to consider the diurnal cycle of precipitation. Diurnal pattern of rainfall could be integrated by introducing separate model parameter sets to for day and night period, but at the expense of model accuracy and parsimony. Therefore, we would like not to discuss the topic of rainfall diurnal pattern in this article.

Comment 2. You mentioned that “. . . Poisson cluster rainfall models are designed to reflect the original spatial structure of rain storms containing multiple rain cells” [page 3 line 5], which implies that the rainfall generator can be used in a multisite context. Yet, the examples and discussion are given for single sites. Can the model be used to simulate hourly rainfall at multi-sites? And if so, can you please provide some examples to the ability of the model to preserve the spatial structure of the rainfall?

Authors’ Response. The model is applicable only for a single site at the current stage, and we believe that the extension of the model to multiple sites may be treated in a separate research. As a matter of fact, there have been efforts to extend the point process models to generate spatially distributed rainfall. The first kind adopted the concept of spatial and temporal correlation (Rodriguez-Itrube et al., 1986), and the second kind adopts adopted the spatial concept in the stage of rain storm and cell generation (Cowpertwait, 1995). However, none of this research can account for the complex dynamics of storm movement. We believe that the recent models assuming movement of structured rain cells (Paschalis et al., 2013; Peleg and Morin, 2014) represent a considerable improvement, and that further research in this direction may ultimately resolve the problem of space-time rainfall generation in the near future.

Reference. Cowpertwait, P. S.: A generalized spatial-temporal model of rainfall based on a clustered point process, Proc.R.Soc.Lond.A, 450, 163-175, 1995.

Paschalis, A., Molnar, P., Fatichi, S. and Burlando, P.: A stochastic model for high-resolution space-time precipitation simulation, Water Resour. Res., 49, 8400-8417, 2013.

Peleg, N. and Morin, E.: Stochastic convective rain-field simulation using a high-resolution synoptically conditioned weather generator (HiReS-WG), Water Resour. Res., 50, 2124-2139, 2014.

Rodriguez-Iturbe, I., Cox, D. R. and Eagleson, P.: Spatial modelling of total storm rainfall, Proc.R.Soc.Lond.A, 403, 27-50, 1986.

Comment 3. In page 4, line 4, it is mentioned that ". . .Poisson cluster rainfall models have also been used to generate future rainfall scenario under climate change". How can the model be re-set to simulate rainfall for a future period following the methodology you are suggesting here?

Authors' Response. Thank you for your suggestion. The concept of Change Factor (CF) may be incorporated to extend our model for future rainfall generation. Here, the change factor represents the ratio of the future to the current rainfall depth, which are typically derived from the information drawn from the General Circulation Model result. Fatichi et al. (2011) also adopted this approach. This change factor may be applied between the first and the second module of our methodology.

Reference. Fatichi, S., Ivanov, V. Y. and Caporali, E.: Simulation of future climate scenarios with a weather generator, Adv. Water Resour., 34, 448-467, 2011.

Comment 4. You state that "Our hybrid model is not easy to implement because it requires extensive analysis of the correlation structure of the fine-scale rainfall statistics to fine-tune the MBLRP model to downscale the generated monthly rainfall" [page 26 line 20]. Can you give some further information in this direction? e.g. what is the minimum number of years that are required for a proper analysis of the statistics? How many gauges are required to cover a given area?

Authors' Response. Regarding the number of gauges, our model requires the records from one gauge to generate the rainfall time series at one gauge. It is one-to-one relationship. Regarding the minimum rainfall record length, we performed additional analyses. However, we would like to keep this information internally because a more extensive analysis targeting every model component is necessary to obtain a comprehensive answer, which may be addressed in a separate article.

Here, we provide a guideline on the length of the rainfall record that is required for successful implementation of the model. The key step of our model that is influenced by the rainfall record length is the algorithm to generate the monthly rainfall statistics to be used for model parameter estimation (Figure 5). This step is composed of a total of 14 linear regressions between various short-term rainfall statistics, and the reliability of these 14 linear regressions influences the subsequent steps, which eventually determines the overall model performance. The relationships between M_1 and V_1 and between M_1 and P_1 are especially important because they impose the greatest uncertainty among all 14 regressions (compare the data spreads of Fig.6a,b and those of the remaining plots of Fig. 6). For this reason, we investigated the sensitivity of the slope of these regression analyses to the rainfall record length. Figure SC1-1 summarizes the result. For both plots, the x-axis represents the rainfall record length, and the y-axis represents the relative error of the regression slope values. Here, the relative error was calculated through the following procedure: (a) Calculate the regression slope at one gauge based on all 30 years of rainfall record (1981-2010). This value was regarded as the true value; (b) Remove the record of the oldest year from the original rainfall data (1982-2010) and calculate the regression slope; (c) Calculate the absolute value of the difference between the regression slope of (a) and (b); (d) Repeat the process (b) and (c) for all 29 gauges and calculate the 5- (lower red line in Figure SC1-1), 50- (middle black line in Figure SC1-1), and 95-percentile (upper red line in Figure SC1-1) value of the 29 absolute values of regression slope difference; (e) Repeat the process (b) through (d) by subsequently removing additional one year of data (1983-2010, 1984-2010, 1985-2010, … , 2000-2010). Fig. SC1-1a and b corresponds to the regression analysis between M_1 and V_1, and M_1 and P_1. The result suggests that systematic bias is introduced in the regression slope values with the decrease in the size of the data set. When the record length was reduced from 30 years to 20 years, 4 to 8 percent, and 3 to 5 percent of systematic bias are introduced into the estimates of the slope of regression relating M_1 and V_1 and the one relating M_1 and P_1 respectively. The plot can be also used for quantifying the systematic bias corresponding to different record lengths.

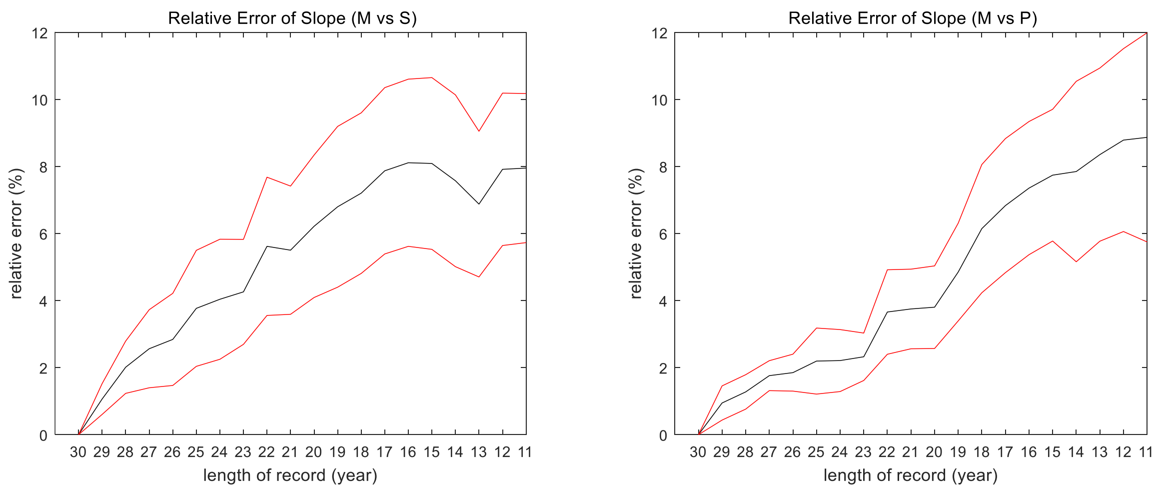

Figure SC1-1. The 5- (lower red line), 50- (middle black line), and 95- (upper red line) percentile of relative error of the regression slope values relating M1 and V1, and M1 and P1, respectively, that vary with the record length. The values can be regarded as the systematic bias introduced in the regression analysis as the record length decreases.

Comment 5. A short comment from my side – you mention in the introduction the importance of rainfall at small scales. The paper here focused on the hourly scale, and you mention in the conclusion that the model can be (with implementing some methods, as random cascades) also used to simulate rainfall at sub-hourly scales. It is maybe worth mentioning in this context that there are already several gridded sub-hourly rainfall generator models that are presented in the literature (e.g. Paschalis et al. 2013 – WRR; Peleg and Morin 2014 – WRR; Peleg et al. 2017 – JAMES; Benoit et al. 2018 - WRR) and to briefly discuss the advantages/limitations of using the tool you are suggesting for simulating rainfall at fine scales in comparison to the others.

Authors' Response. Thank you for your suggestion. We changed the manuscript as below.

Revised Contents.

[(old) page 26 line 18 / (new) page 30 line 5] … *Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO). Lastly, the genuine structure of our model that is composed of a large scale rainfall generation module and a downscaling module, may be integrated to existing space-time rainfall generators to enhance their ability to generate large temporal-scale rainfall variability (Burton et al., 2008, Müller and Haberlandt, 2015, Paschalis et al., 2013; Peleg and Morin, 2014; Peleg et al., 2017; Benoit et al., 2018).*

Reference. Benoit, L., Allard, D. and Mariethoz, G.: Stochastic Rainfall Modelling at Sub-Kilometer Scale, Water Resour. Res., 2018.

Burton, A., Kilsby, C., Fowler, H., Cowpertwait, P. and O'Connell, P.: RainSim: A spatial–temporal stochastic rainfall modelling system, Environmental Modelling & Software, 23, 1356-1369, 2008.

Müller, H. and Haberlandt, U.: Temporal rainfall disaggregation with a cascade model: from single-station disaggregation to spatial rainfall, J. Hydrol. Eng., 20, 04015026, 2015.

Paschalis, A., Molnar, P., Fatichi, S. and Burlando, P.: A stochastic model for high-resolution space-time precipitation simulation, Water Resour. Res., 49, 8400-8417, 2013.

Peleg, N. and Morin, E.: Stochastic convective rain-field simulation using a high-resolution synoptically conditioned weather generator (HiReS-WG), Water Resour. Res., 50, 2124-2139, 2014.

Peleg, N., Fatichi, S., Paschalis, A., Molnar, P. and Burlando, P.: An advanced stochastic weather generator for simulating 2-D high-resolution climate variables, Journal of Advances in Modeling Earth Systems, 9, 1595-1627, 2017.