# Evaluation of Multivariate Rainfall Disaggregation Performance Using MuDRain Model (Case Study: North East of Hormozgan Province)

**Hoda Bolouki[1], Mehdi Fazeli[2*]**

[1] Department of Civil Engineering, Faculty of Engineering, Yasouj University
[2] Department of Civil Engineering, Faculty of Engineering, Yasouj University

**ABSTRACT**

**High-resolution spatial and temporal precipitation data are essential for water engineering studies, hydrological modeling, and flood risk assessment, especially in tropical regions with complex rainfall patterns. Due to the lack of data, rainfall disaggregation is an important tool. In this study, the performance of multivariate rainfall disaggregation using MuDRain model and the effect of hourly correlation among stations on simulation accuracy in Hormozgan province were investigated. Comparison between observed and simulated hourly time series showed that the model evaluates the amount of daily precipitation accurately, but in most cases it simulated extreme amounts of precipitation less than the actual amounts. Furthermore, the enough number of heavy rainfall events has not been generated. Comparison of the results of selected dates with the highest rainfall showed that the Correlation (*R*) and Nash–Sutcliffe (*NSE*) Coefficients ranged from 0.1898 to 0.9319 and 0.0319 to 0.7251 respectively. Comparison of the hourly correlation impact showed that the accuracy of the model in simulating hourly precipitation was higher for time series having higher mean hourly correlation and the coefficients of *R* and *NSE* were 0.7816 and 0.5856, respectively, while these coefficients for time series with lower hourly correlation were 0.5155 and 0.2655 respectively. Generally, this model can be used with more confidence for areas with very high hourly correlations, in this case, the spatial correlation of the stations becomes an advantage, because utilizing the available hourly rainfall data in adjacent stations, it is possible to create series of realistic hourly rainfall at a desired station.**

**KEYWORDS**

**Hourly rainfall, Multivariate model, MuDRain, Rainfall disaggregation, Hormozgan province.**

* Corresponding Author: Email: fazeli@yu.ac.ir

## Introduction

Availability of spatial and temporal precipitation data with high resolution is very important for many cases, including hydrological and engineering plans such as dam and bridge design, flood estimation and frequency of their occurrence [1], urban runoff management and many other cases [2], and the necessity of having input data in short time intervals is prominent for many hydrological models. This is doubly necessary, especially in tropical regions due to the existence of very complex rainfall patterns. Therefore, the area studied in this research was the north east of Hormozgan province. To disaggregate the rainfall data in this region, multivariate rainfall disaggregation model (MuDRain) was used. Considering that there has not been any study on the effectiveness of the MuDRain model in Hormozgan province, the purpose of this research is to evaluate the effectiveness of this model in producing hourly rainfall data for the region and to evaluate the closeness of the simulated data to the real data. The required steps are as follows: preparing the required data to enter the model, processing, simulating and finally analyzing the output of the software.

## Methodology

In 2003, Koutsoyiannis et al. developed a simple multivariate rainfall disaggregation model. This model was implemented in MuDRain software with the assumption that daily rainfall can be well represented by an auto regressive process with a lag of one unit (AR(1)) [3]. Multivariate rainfall disaggregation model (MuDRain) is a method for spatio-temporal rainfall disaggregation. In particular, this method can be applied to obtain hourly rainfall series using the spatial adaptation feature at stations where only daily data are available [4].

To evaluate the performance of the MuDRain model, daily rainfall data of seven stations and hourly rainfall of six stations were used, and the model was evaluated to simulate the hourly rainfall of one station. In order to investigate the effect of hourly correlation between stations on simulation accuracy, three different time series were used, including the time series of Azar 1388 to 1396 (I), 12 months of 1395 (II), and 12 months of 1388 to 1396 (III).

Evaluation of model performance was done by comparing hourly data produced by the model and the observational data. A number of items including the output graphs, the correlation of observed and simulated hourly rainfall of each station compared to other stations, dry period ratio (number of hours without rain divided by the total number of hours), standard deviation, skewness coefficient and lag one autocorrelation of coefficient was calculated by the software. The indices of correlation coefficient (*R*) between observed and simulated precipitation for each station and Nash-Sutcliffe coefficient (*NSE*) were used to evaluate the efficiency of the model in generating hourly data for each time series. In order to evaluate the model efficiency in simulating the maximum rainfall and also to investigate the effect of correlation between stations on the accuracy of extreme rainfalls simulation, a number of maximum rainfalls related to each time series were selected. In addition to the indices mentioned in the previous section, the root mean square error (*RMSE*), mean square error (*MSE*) and mean absolute error (*MAE*) indices were also used.

## Results and Discussion

The comparison of observational and simulation statistics, including statistics of dry period ratio, standard deviation, skewness coefficient and lag one autocorrelation of coefficient showed that the model is highly accurate in reproducing statistical characteristics and the numbers related to the observational and simulated data of six stations are almost the same.

The comparison of observed and simulated dry period ratios in each time series showed that the model generates this ratio less than reality, as it distributes the precipitation corresponding to one day in more hours of the day. This comparison for Series I is shown in Figure 1. Also, the standard deviation and the coefficient of skewness in each time series are simulated to a lesser extent for the station without hourly time series.

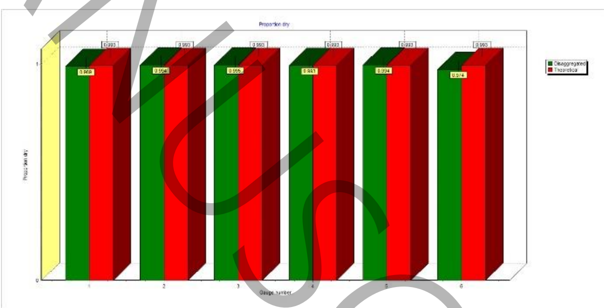

**Figure 1. Comparison of the dry period ratio of observed (used in the model) and simulated hourly rainfall series I**

The results related to the overall evaluation of the model's efficiency in simulating the hourly rainfall data of the station without hourly rainfall time series are listed in Table 1. The correlation coefficient between observed and simulated hourly precipitation and the Nash-Sutcliffe coefficient in series 1 is higher than the other time series.

Also, this coefficient is higher in time series 2 than time series 3. Here, the importance of hourly correlation between stations is revealed. By converting the simulated hourly time series to daily and comparing it to the observed daily time series, it can be seen that the model is able to retain the total rainfall of each day. The deduction is that in general, the total observed and simulated precipitation well match in each time series.

**Table 1. General evaluation of model efficiency in simulating hourly rainfall for a station without hourly time series**

| Type of time series input to the model | Number of disaggregate hours | *R* | *NSE* |
|---|---|---|---|
| I | 6480 | 0.7816 | 0.5856 |
| II | 8784 | 0.6335 | 0.3984 |
| III | 78888 | 0.5155 | 0.2655 |

The comparison of observed and simulated hourly time series showed that the model is highly accurate in maintaining the total height of daily precipitation, but in most cases it has simulated the extreme amounts of precipitation less than the actual value. Further, it has not created enough number of heavy rain events. The graphs of observation and simulation of 2 maximum precipitation for series I, II and III are shown in Figures 2 to 4.

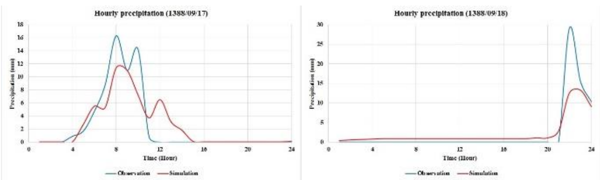


**Figure 2. Observational and simulation charts of the 2 maximum rainfalls related to series I**

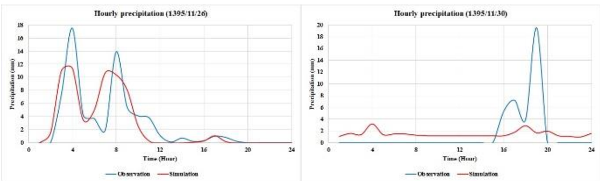


**Figure 3. Observational and simulation charts of the 2 maximum rainfalls related to series II**

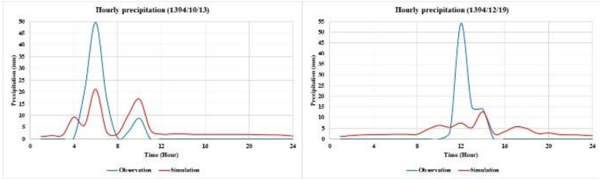


**Figure 4. Observational and simulation charts of the 2 maximum rainfalls related to series III**

The domain of employed indices were as follows: *R* ranged from 0.1898 to 0.9319, *NSE* from 0.0319 to 0.7251, *RMSE* from 2.5103 to 10.1634, *MAE* from 1.3583 to 4.8167 and *MSE* from 6.3017 to 103.2950. These results verify that the model's accuracy for simulating the maximum rainfall of the selected dates was not high.

## Conclusion

Due to the fact that the studied stations did not have a high hourly correlation, the accuracy of the model was not enough for simulation and the generated data are not suitable for use in designs that require accurate simulation of heavy rainfall. Generally, this model can be used with more confidence for regions with very high hourly correlations. In this case, the spatial correlation of the stations becomes an advantage, because utilizing the available hourly rainfall data in adjacent stations, it is possible to create series of realistic hourly rainfall at a desired station; Otherwise, if the hourly correlation is not enough, the model needs to be evaluated first.

## References

[1] D. Martins, M.L.T. Gandini, N.S. Kruk, P.I.B. Queiroz, Disaggregation of daily rainfall data for the Caraguatatuba city, in São Paulo State, Brazil, RBRH, 24 (2019).

[2] I.S. Hanaish, Multivariate Rainfall Disaggregation Using MuDRain Model: Malaysia Experience, International Journal of Civil, Mechanical Energy Science, 2(2) (2016).

[3] M. Ivković, A. Todorović, J. Plavšić, Improved input to distributed hydrologic model in areas with sparse subdaily rainfall data using multivariate daily rainfall disaggregation, Journal of Hydroinformatics, 20(4) (2018) 784-797.

[4] P. Fytilas, Multivariate rainfall disaggregation at a fine time scale, Graduate thesis, University of Rome "La Sapienza", Rome, (2002).