STOCHASTICS MODELLING OF RAINFALL PROCESS IN ASIA REGION: A SYSTEMATICS REVIEW

Hilda Ayu Pratikasiwi¹,²*, Elma Dwi Putri Sinaga¹, Hanny Nirwani¹, Milkah Royna¹, Perdinan Perdinan¹, and Akhmad Faqih¹

1 Department of Geophysics and Meteorology, Bogor Agricultural University, Indonesia
2 Research Center for Remote Sensing, Research Organization for Aeronautics and Space (LAPAN), National Research and Innovation Agency (BRIN), Indonesia

Email: hildapratikasiwi@apps.ipb.ac.id
Stochastics Modelling of Rainfall Process in Asia Region: A Systematics Review

complexity of climate system (especially rainfall) Asia & 2013-2022
n= 1571

Markov Chain, weather generator, probability distribution, ARIMA, and Bayesian model
n=30
Abstract

In recent years, the stochastic model has been growing due to the high complexity and dynamics of the atmosphere, especially the rainfall process. Various concepts have been applied to rainfall modeling, ranging from simplistic approaches to more complex models. It is important to understand different stochastic rainfall modeling approaches as well as their advantages and limitations. This paper determines the development of the latest stochastic rainfall models in the Asia region, where different concepts of stochastic rainfall models were highlighted. It reviews different methodologies used, including rainfall forecasting, spatio-temporal analysis, and extreme events. We selected 30 articles from 1,571 literature published between 2013-2022 from the Scopus database. The results show that the stochastic models often used in the literature consist of Markov Chain, Weather Generator, Probability Distribution, ARIMA, and Bayesian Model. In the recent development in Asia, stochastic models in rainfall modeling research are widely used to generate the occurrence and amount of rainfall data, statistical downscaling, future rainfall trends, and estimation of extreme values. The difference in Spatio-temporal, climate conditions, and the parameters model cause the performance of each model can be different.

Keywords: stochastics model; rainfall; systematics review; PRISMA; Asia
Introduction

A climate model is a simple way to understand the complexity of the climate system.

Stochastic models are an important topic and are widely used in more comprehensive climate predictions like rainfall prediction.

Research related to systematic reviews of stochastic climate models, especially rainfall models, is not yet available for the Asian region.
Methodology

Flowchart outlining protocol of review using PRISMA

- Records identified from Scopus database (n=1571)
- Records screened (n=1571)
- Reports assessed for eligibility (n=152)
- Studies include in review (n=30)
- Records Exclude (n=1419)
- Records exclude with reasons (n=122)

Exclusion due to:
- Location
- Other climate parameters
- Lack of focus on climate modelling
- Language
- Year
Results

Stochastic rainfall models are widely used to **downscale and generate** the occurrence and amount of rainfall data.

**Regression** models and **stochastic weather generators** are the most widely used statistical **downscaling** methods.

**Markov chain** is the **most popular** technique to generate rain occurrence because it is easy and simple.
Markov Chain

Markov chain describes the relationship between today’s state and the previous day (1 up to 5 days).

Although the first-order Markov chain is popular and satisfactory, some simulated dry spell results are slightly shorter than the observed results, which may be due to the short-term memory of the first-order Markov model.

The solution is to use a Markov chain of order 2 or higher to overcome this limitation.

Markov Chain has been improved and modified to increase the accuracy, like
- Modified Markov Models (MMM)
- Hidden Markov Model (HMM)
- Non-Hidden homogeneous Markov Models (NHMM)
- Decadal and Hierarchical Markov Chain (DHMC)
- Stochastic Daily Rainfall Model - Markov Chain Rainfall Event Model (SDRM-MCRE)
Probability Distribution

Parametric probabilities usually used to generate rainfall amounts include:
- one-parameter (exponential)
- two-parameter (Gamma, Weibull, Normal/Gaussian),
- three-parameter distributions (Mixed exponential, Hybrid Exponential, and normal Skewed).

Most studies mention that three parameters show better results than other models.

But, statistical tests proved no significant difference between the performance of one, two, and three-parameter distributions due to spatiotemporal differences that affect the application of the distribution.
Stochastic Weather Generator

- Weather generators use two approaches, Markov Chain and spell length
- WG using Markov chain approaches like WGEN, CLIMGEN, CLIGEN, WeaGETS, MulGETS, and spells length approaches like LARS-WG
- From several studies, models based on Markov chains have better performance than the spell length approach
- Stochastics Weather generators commonly used for Multisite are MSRG, MulGETS, and the new multivariate-multisite WG
- The STREAP WG model is usually for remote sensing data such as radar, to downscaling pixels for extreme rainfall.
- HiReS-WG is used to periodically generate rain fields with a high spatial and temporal resolution.
ARIMA

- ARIMA is a typical statistical analyses model that uses **time-series** data to predict future trend

- ARIMA model is a model that has been widely applied in rainfall data analysis for various purpose, especially in **drought** analysis

Bayesian

- Bayesian approach is used in many **hydrological** studies such as uncertainty quantification, water quality modeling, and hydroclimatic analysis

- The application of this Bayesian approach has previously been used to estimate snow depth and soil organic carbon content in **permafrost** areas

- Currently, the use of the Bayesian model has been modified to **improve** its **accuracy** in rainfall analysis
## Strengths and limitations of the stochastic model

| Model               | Advantages                                                                 | Limitations                                                                 |
|---------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Markov Chain        | • good in simulating monthly and annual rainfall events                    | • not accurate enough to run on areas with higher spatial and time scales.  |
|                     | • suitable for a comprehensive tropical monsoon climate                    | • GCM selection is still influenced by the availability of atmospheric variables on a daily time scale, |
|                     | • maintains rainfall characteristics from time series and rainfall events  | • The model tends to ignore variations in low-frequency rainfall.            |
|                     | • suitable for flood and drought risk assessment                            |                                                                             |
| Weather Generator   | • suitable for a local and heterogeneous area                               | • The model does not automatically determine the best limits, biases, and variances. |
|                     | • suitable for long-term approach (including climate change)               | • The selection of predictors is still poor                                  |
|                     | • has little average difference and is capable of capturing daily rainfall | • models often tend to underestimate extreme data.                          |
|                     | • able to simulate extreme precipitation                                   |                                                                             |
|                     | • suitable in semi-arid areas.                                              |                                                                             |
| Model          | Advantages                                                                 | Limitations                                                                 |
|---------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| ARIMA         | • capable of forecasting drought at different time scales.                  | • This model shows significant limitations for understanding the time series of generated rainfall. |
|               | • Widely used in arid areas                                                 |                                                                             |
|               | • ARIMA model offers various advantages over other approaches (such as moving averages, exponential smoothing, and neural networks, including predicting and more information about time-related changes) |                                                                             |
| Bayesian      | • can combine multiple bias corrections simultaneously                       | • daily rainfall forecasts are still a challenge                              |
|               | • Can project rainfall intensity with the effects of climate change.        |                                                                             |
|               | • effective for limited observations in cold areas                          |                                                                             |
| Probability Distribution | • Generate good correlations                                                |                                                                             |
|               | • not much effort is required to estimate parameters,                       |                                                                             |
|               | • suitable for simulating multi-site pre-precipitation events               |                                                                             |
Conclusions

- research related to stochastic models on rainfall modeling in Asia is very complex study
- stochastic model is the most widely used for climate data generation and statistical downscaling
- the rainfall data generator is used to estimate the occurrence and amount of rainfall
- various stochastic models that are often used in the literature consist of Markov chain, weather generators, probability distribution, ARIMA, and Bayesian model
- the performance of these stochastic models will be different for each region in Asia
- stochastic model is very flexible depending on user needs
Thank you

Department of Geophysics and Meteorology