IPB University
Bogor Indonesia

Department of
Geophysics and Meteorology

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

Hilda Ayu Pratikasiwi [1,2]*, Elma Dwi Putri Sinaga [1], Hanny Nirwani [1],
Milkah Royna[1], Perdinan Perdinan[1], and Akhmad Faqih[1]

1 Department of Geophysics and Meteorology, Bogor Agricultural University, Indonesia

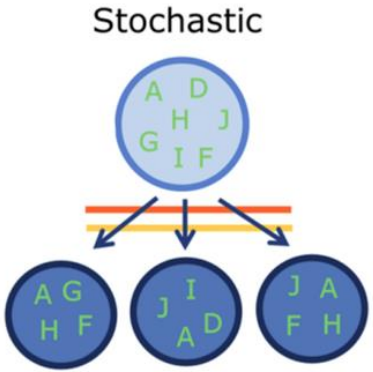
2 Research Center for Remote Sensing, Research Organization for Aeronautics and Space (LAPAN), National Research and Innovation Agency (BRIN), Indonesia

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



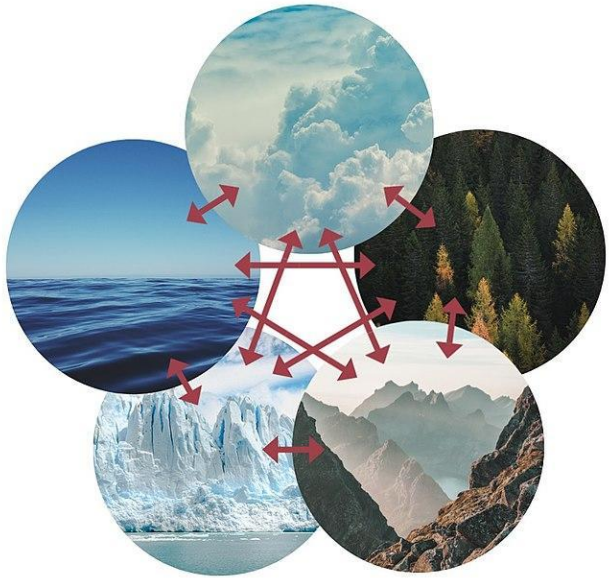
Markov Chain, weather generator, probability distribution, ARIMA, and Bayesian model
n=30

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



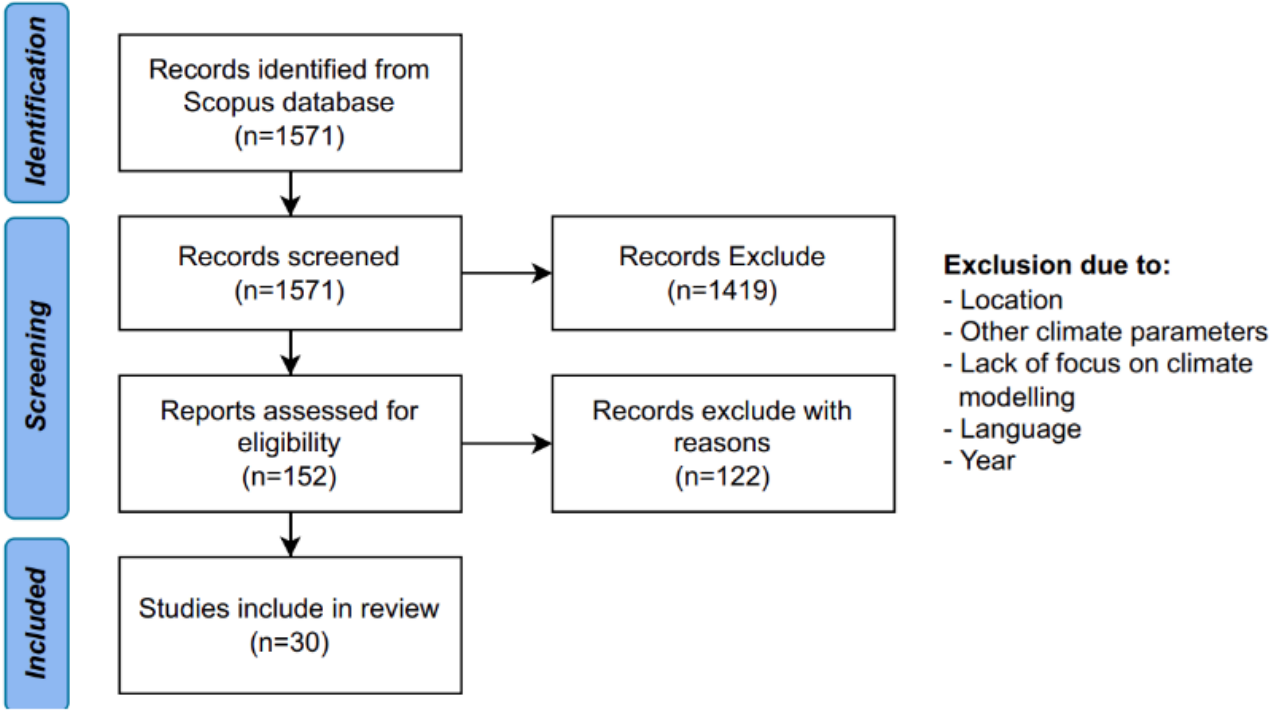
climate system

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



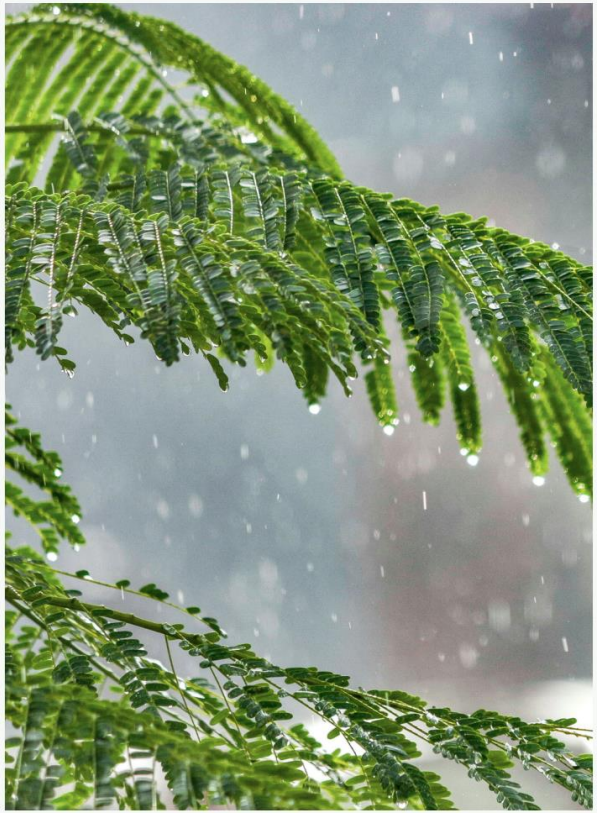
Flowchart outlining protocol of review using PRISMA

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

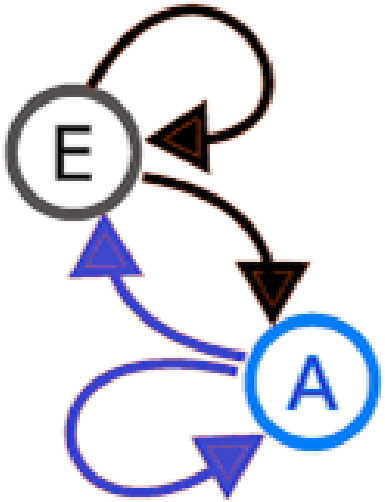
Markov chain describes the relationship between **today**'s state and the **previous** day (1 up to 5 days)

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 • suitable for a comprehensive tropical monsoon climate • maintains rainfall characteristics from time series and rainfall events • suitable for flood and drought risk assessment	• not accurate enough to run on areas with higher spatial and time scales. • GCM selection is still influenced by the availability of atmospheric variables on a daily time scale, • The model tends to ignore variations in low-frequency rainfall.
Weather Generator	• suitable for a local and heterogeneous area • suitable for long-term approach (including climate change) • has little average difference and is capable of capturing daily rainfall • able to simulate extreme precipitation • suitable in semi-arid areas.	• The model does not automatically determine the best limits, biases, and variances. • The selection of predictors is still poor • models often tend to underestimate extreme data.

ARIMA	• capable of forecasting drought at different time scales. • 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)	• This model shows significant limitations for understanding the time series of generated rainfall.
Bayesian	• can combine multiple bias corrections simultaneously • Can project rainfall intensity with the effects of climate change. • effective for limited observations in cold areas	• daily rainfall forecasts are still a challenge
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

IPB University
Bogor Indonesia

Department of Geophysics and Meteorology