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Daily Rainfall Prediction using Generalized Linear Bivariate Model - A Case Study

Jany George [a]*, Letha J. [b], Jairaj P. G. [c]

[a] *Research Scholar, Dept. of Civil Engineering, College of Engineering Trivandrum, Thiruvananthapuram, 695016, India*
[b] *Professor in Civil Engineering, Vice Chancellor, Cochin University of Science and Technology, Kochi, 682022, India*
[c] *Professor in Civil Engineering, College of Engineering Trivandrum, Thiruvananthapuram, 695016, India*

Abstract

The present study focuses on the simulation of daily rainfall series based on atmospheric predictors and historical data using a bivariate Generalized Linear Model. Temperature and precipitation data along with a set of covariates were made use of in generating the simulations. Probability of occurrence of rainfall was predicted using logistic regression models. The amount of rainfall on a rainy day was modelled using a gamma distribution. The covariates in the model comprise of different categories such as site effects for spatial variation, year effects allowing long term trends, month effects for seasonality, day effects with temporal auto correlation and atmospheric predictors. Rainfall series were generated for both future and past periods at multi sites simultaneously using atmospheric predictors. The model developed was applied in a typical catchment in the state of Kerala in India. The model simulations were acceptable on the basis of the performance evaluated using statistical analysis. The model can be used as a weather generator to simulate the daily rainfall series for both past and future periods.

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Keywords: Daily rainfall; Generalized Linear Models; atmospheric predictors; weather generator

1. Introduction

Water resources planning and management always rely on historic, current, and future states of precipitation on yearly monthly and daily timescales. Prediction of daily precipitation is a challenging task in water resource

* Corresponding author. Tel.: +91 9895733847
*E-mail address:*jany_george@yahoo.com

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management. Rainfall stands as one of the most unpredictable event even with the updated climatic models. The extent of uncertainty varies from model to model depending on the physical phenomenon of atmospheric conditions and the complexity associated with its mathematical modelling. Statistical models contribute to a great extent to reduce this uncertainty.

Even though General circulation Models(GCM) are regarded as the most credible tools to provide information of the atmospheric circulation systems on a global scale, the climatic variables like precipitation cannot be well modelled by the GCMs [1]. The common practice is to downscale the results from the GCMs either by dynamic downscaling through a nested high-resolution regional climate model (RCM) or through statistical downscaling [2]. Statistical downscaling can be classified into three types, weather generators, weather typing and transfer function [3]. Most of the works on downscaling were done on monthly timescales. Disintegration of the monthly values into daily time series is yet another challenging task.

Attempts have been made previously to predict the daily rainfall based on different methodologies. A multivariate downscaling model for precipitation and temperature scenarios based on atmospheric circulation indices [4]; simulation process coupled with atmospheric circulation patterns [5,6]; Markov process and gamma distribution [7] are some of the reported works in this area. As per the Intergovernmental Panel of Climate Change (IPCC) definition, a stochastic weather generator simulates time series of weather data for any location on the basis of the statistical characteristics of the historical weather at that particular location [8]. The first weather generator WGEN is introduced by Richardson [9] for generating the daily weather sequences. In a typical weather generator, the idea of Markov chain is used for precipitation occurrence with the transition matrix giving the probability of occurrence of rainfall. If the model predicts the day as rainy, the amount of rainfall on that rainy day is computed by gamma distribution with separate parameters of gamma distribution for each month of the year. The drawback of the Richardson-type weather generator is that it fails to explain adequately the length of dry and wet series [10]. Also these weather generators have a tendency to underestimate variability of seasonal means or totals. Another drawback is the underestimation of high return levels [11]. To improve the performance of weather generators, different approaches have been suggested which includes higher-order Markov chains, heavy-tailed intensity distributions, nonparametric modelling, approaches based on spell lengths, Generalized linear models (GLM) and Sub-daily weather generators. The Generalized linear models (GLM) comprise of classical structure weather generators within a flexible framework that permits many extensions to basic model structure [12].

In the present study, daily rainfall series were simulated using a weather generator based on Generalized Linear model in the catchment of Idukky reservoir in Kerala. The simulations were generated for the missing period from 1981 to 1995 using the atmospheric predictors derived from the National Centre for Environmental Prediction/ National Centre for Atmospheric Research (NCEP/NCAR) re-analysis data and also for a future period of 2013 to 2025 using the predictors derived from the Coupled Global Climate Model CGCM3 for IPCC SRES A2 scenario. The methodology adopted, model application and results of the study are discussed in the subsequent sessions.

2. Methodology

Daily rainfall is simulated using Generalized Linear Models for occurrence and intensity of rainfall and for temperature in three stages. A GLM, for a *nx1* vector of random variables $Y = (Y_1, Y2 \ldots, Y_n)$, is a model for the probability distribution generating Y [13]. Each of the Y s depends on p covariates, whose values are arranged in a *nxp* matrix X. The distribution of Y has the mean vector $\mu = (\mu_1, \mu_2, \ldots, \mu_n)$, which is related to X as in Eqn. (1).

$$g(\mu_i) = X_i\beta = \eta_i \tag{1}$$

The daily rainfall Y_i is assumed to be generated in the form of Eqn. (1) from the same family of distribution with mean μ_i with $g(\mu_i)$ as the link function and β a *px1* vector of coefficients. The members of η are called linear predictors. The distribution of each Y_i belongs to the exponential family, the family of all distributions with density function in the form of Eqn. (2) for some parameters ψ and Φ and functions $a(:)$, $b(:)$ and $c(:)$ [14].