Journal of Engineering Research and Education
Volume 11, 2019 [9-14]

Rainfall projection corresponding to climate scenarios based on Statistical Down-Scaling Model over Perlis, Malaysia

Zulkarnain Hassan[1*], Mohd Faez Mohd Mansor[1] and Ain Nihla Kamarudzaman[1]

[1]*Civil Engineering Programme, School of Environmental Engineering, Universiti Malaysia Perlis, Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis.*

ABSTRACT

General Circulation Models (GCMs) are used to modelling the responses of the climate system to different scenarios of greenhouse gas and aerosol. However, the model needs to downscale into a fine resolution daily rainfall series appropriate for local scale hydrological impact studies. In this study, Statistical Down-Scaling Model (SDSM) is used to downscale the GCMs simulations from Hadley Centre 3rd generation (HadCM3) with A2 and B2 scenarios for future rainfall over the area of Perlis, Malaysia. The SDSM model is able to simulate satisfactorily the daily rainfall series by giving the average coefficient of correlation (R^2) and standard error (SE) during the validation period are 0.11 and 9.88mm/day respectively. The study area is apparently will gain an increasing trend for annual mean rainfall on the 2020s and show the decreasing trend for annual mean rainfall for period 2050s and 2080s for both scenario emissions.

Keywords: General Circulation Models, Statistical Down-Scaling Model, Rainfall, HadCM3.

1. INTRODUCTION

General Circulation Models (GCMs), based on mathematical representations of atmosphere, ocean, and land surface processes, are considered the only credible tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. The GCMs is widely used in climate analysis, especially on the future of rainfall projection. A direct application of output from the GCMs is often inadequate because of the limited representation of mesoscale atmospheric processes, topography and land-sea distribution in GCMs [1]. Therefore, Statistical Down-Scaling (SDSM), in which using the statistical downscaling method is used in this study, to downscale the information from the GCMs to local scales.

The aim of this study is to project the rainfall projection corresponding to climate scenarios of the GCM output over Perlis, Malaysia. The SDSM model will be used to downscale Hadley Centre 3rd generation (HadCM3) with A2 and B2 scenarios. In the following sections, the materials and methods are introduced and followed with the results of the study. Then, the discussions and conclusion are presented.

*Corresponding Author: *zulkarnainh@unimap.edu.my*

2. MATERIALS AND METHODS

This study majored focus on the relationship of statistical downscaling approach, named Statistical Down-Scaling Model (SDSM) for the climate change scenarios of GCMs which is HadCM3 A2 and B2 scenarios with using daily precipitation data. All the methodology of this research is summarized in Figure 1.

2.1 Study Area and Data

The eleven (11) rainfall stations over Perlis, Malaysia have been selected as the studied stations. Perlis is selected as a study area since the area has a varies in climate, in which some area (Chuping) becomes the hottest area in Malaysia [2;3]. There is also a dam at a northern area and about half of Perlis, was paddy land and the main activities for Perlis are paddy farming. Therefore, assessing the impact of future climate change at this area will give an insight upon which appropriate decisions about the water resource management can be made. The details and locations of the rainfall stations are shown in Figure 2 and Table 1, respectively. 22 years of daily data series for daily rainfall (1980-2001) are used in this study and obtained from the Department of Irrigation and Drainage Malaysia (DID).

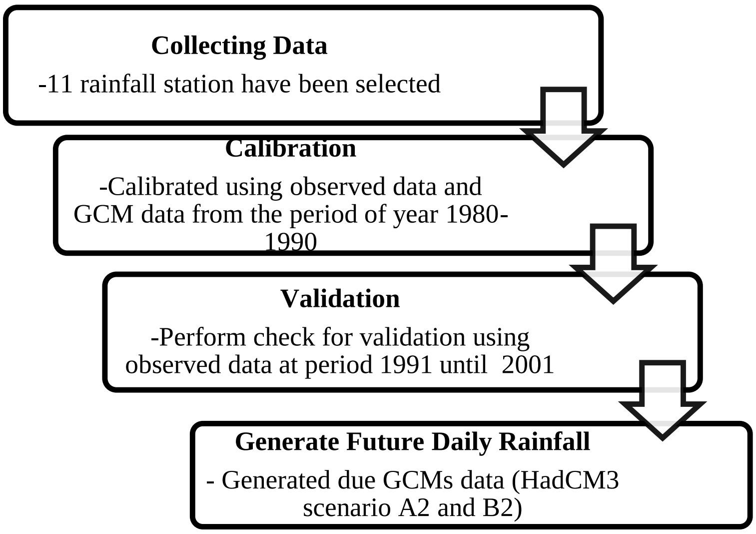


Figure 1. Summary methodology of the SDSM model.

For the GCM, Hadley Centered Coupled Model version 3 (HadCM3) is used in this study. The HadCM3 developed by Hadley Centre on 1999 and the model is a grid point model, in which has a horizontal resolution of 3.75 x 2.5 degrees in longitude and latitude with 1.25 x 1.25 degrees in the ocean. This component works well because it is composed of two components which is the atmospheric model and the ocean model. The simulation for this model often uses a 360-days calendar. HadCM3 is chosen because this model has been using widely around the world for investigating the climate in a certain area such as [4], that used HadCM3 for their climate change impact studies. It also provides the daily predictor which can be run for SDSM.

2.2 Development of SDSM

The SDSM model is developed by [5] and the model calibration process constructs downscaling models based on multiple regression equations, given daily weather data (the predictand) and regional–scale, atmospheric (predictor) variables. The conditional model is selected, whereby there is an intermediate process between the regional forcing and local weather (e.g., local precipitation amounts depend on the wet-/dry-day occurrence, which in turn depend on regional-scale predictors such as humidity and atmospheric pressure). The detailed method of the SDSM model can be referred to [6].

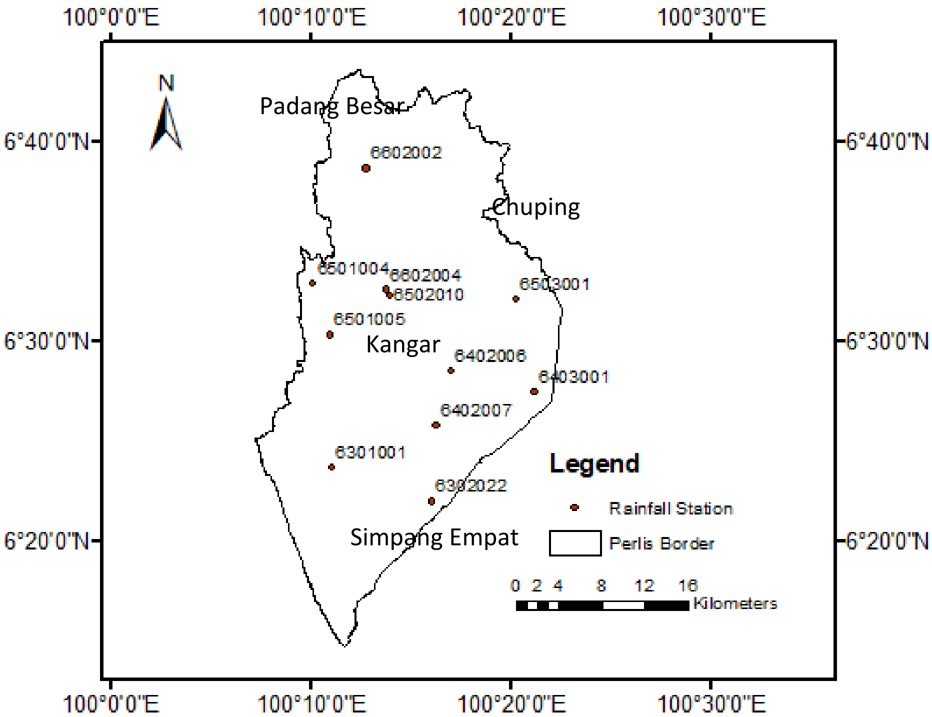


Figure 2. Location of observed rainfall stations.

Table 1 Name and location of rainfall station for downscaling model

No.	Station No.	Station Name	Longitude (E)	Latitude (N)
1.	6402006	Guar Nangka	100°17'00"	06°28'30"
2	6403001	Ulu Pauh	100°21'10"	06°27'30"
3	6402007	Arau	100°16'15"	06°25'50"
4	6503001	Ldg. Perlis Selatan	100°20'15"	06°32'10"
5	6501005	Abi Kg. Bahru	100°10'55"	06°30'20"
6	6502010	Bukit Temiang	100°13'55"	06°32'20"
7	6602002	Kaki Bukit	100°12'45"	06°38'40"
8	6602004	Sg. Jarum	100°13'45"	06°32'36 "
9	6501004	Abi	100°10'05"	06°32'55 "
10	6301001	Kg.Behor Lateh	100°11'01"	06°23'40"
11	6302022	Changkat Jawi	100°16'00"	06 ° 22'00"

During the model development (calibration and validation), the performance of the SDSM model can be evaluated based on the coefficient of determination (R^2) and standard error (SE), in which can be written as:

$$R^2 = 1 - \frac{\sum_t^n (Yt - Pt)^2}{\sum_{t-2}^n (Yt - y)^2} \quad (1)$$

$$SE = S\sqrt{\left[\frac{n-1}{n-2}\right][1 - R^2]} \quad (2)$$

where, Y_t is the observed rainfall occurrence at day t, y is the average Y_t of the value (fraction of wet days), P_t is the estimated rainfall probability for day t, n is the number of days in the record, S is the adjusted standard error of estimate values. The high correlation values (near to 1) indicate that the there is strong the relationship between observed and simulated rainfall, and the smallest SE identified that the predicted rainfall will equal or at least close to the observed rainfall.

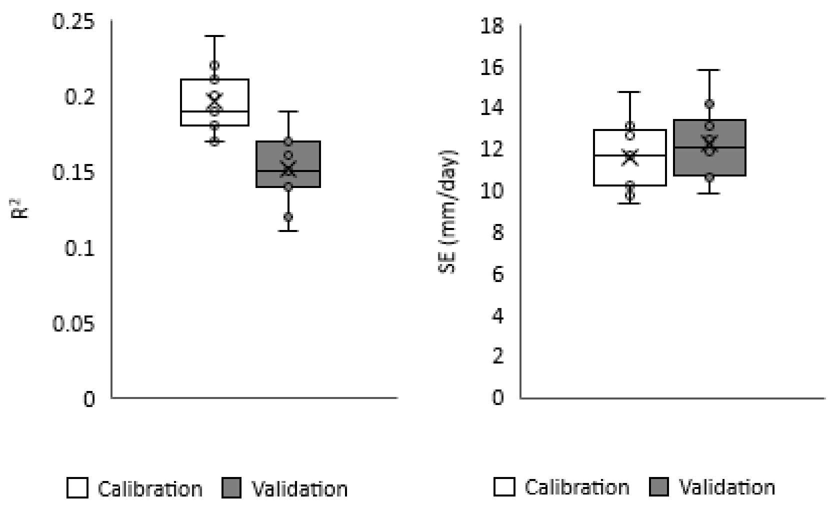
The regression weighted produced during the calibration process is applied to generate a future daily weather data. The study assumes that relationship between predictor and predictand under the observed conditions (during calibration) remains valid under the future climate conditions.

The regression weighted produced during the calibration process of the SDSM model is used to simulate the synthetic daily time series of rainfall using the GCM output. It is assumption that relate between predictor and predictand under the observed conditions remain valid under the future climate conditions. The ensembles of synthetic daily time series produced for HadCM3 A2 and B2 scenarios for period 139 years (1961 to 2099) will be average and divided into three periods, which are the 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099) for climate impact studies.

3. RESULTS AND DISCUSSIONS

3.1 Performance of the SDSM Model

Figure 3 shows the performance of the SDSM model using the coefficient of R^2 and standard error (SE) between observed and modelled daily rainfall. It is shown that the mean for R^2 and SE for all the station during calibration are 0.20 and 11.54 mm/day, respectively. Meanwhile, during the validation, the average for R^2 and SE are 0.15 and 12.28 mm/day, respectively. The result indicated that the SDSM model performs quite well in simulating the daily rainfall series, although the correlation between observed and simulated rainfall is low based on the R^2 ($R^2 <$ 0.2). These calibration and validation results are similar like studies by [7], that obtained the low correlation since the generating of conditional process of rainfall (e.g.: wet-dry days) is difficult to obtained [8].



(a) **(b)**

Figure 3. (a) R^2 and **(b)** SE between observed and simulated rainfall during the development of the SDSM model.

3.2 Generating Future Rainfall Corresponding to Future Emission

Figure 4 illustrates the comparison between the spatial distribution of current and projected annual rainfall over Perlis. From the figure, there is a remarkable spatial difference in term of annual rainfall between the current and projected. In the 2020s (Figure 4b and 4e), increasing of average annual rainfall by 17.8% for both scenarios as compared to the current period, is shown for most of the studied area, especially at Padang Besar and Simpang Empat. The increasing trend by 1.6-41.8% of annual rainfall will be continued for the 2050s and 2080s periods. However, some area will face the decreased of 0.9-11.8% of annual rainfall as compared to the current, such as the area near Kangar and Chuping. It will trigger the drought and water crisis in those areas that received the lowest intensity of annual rainfall. The trend of projected annual rainfall of this study is in consensus with the previous studies by [9] and [6].

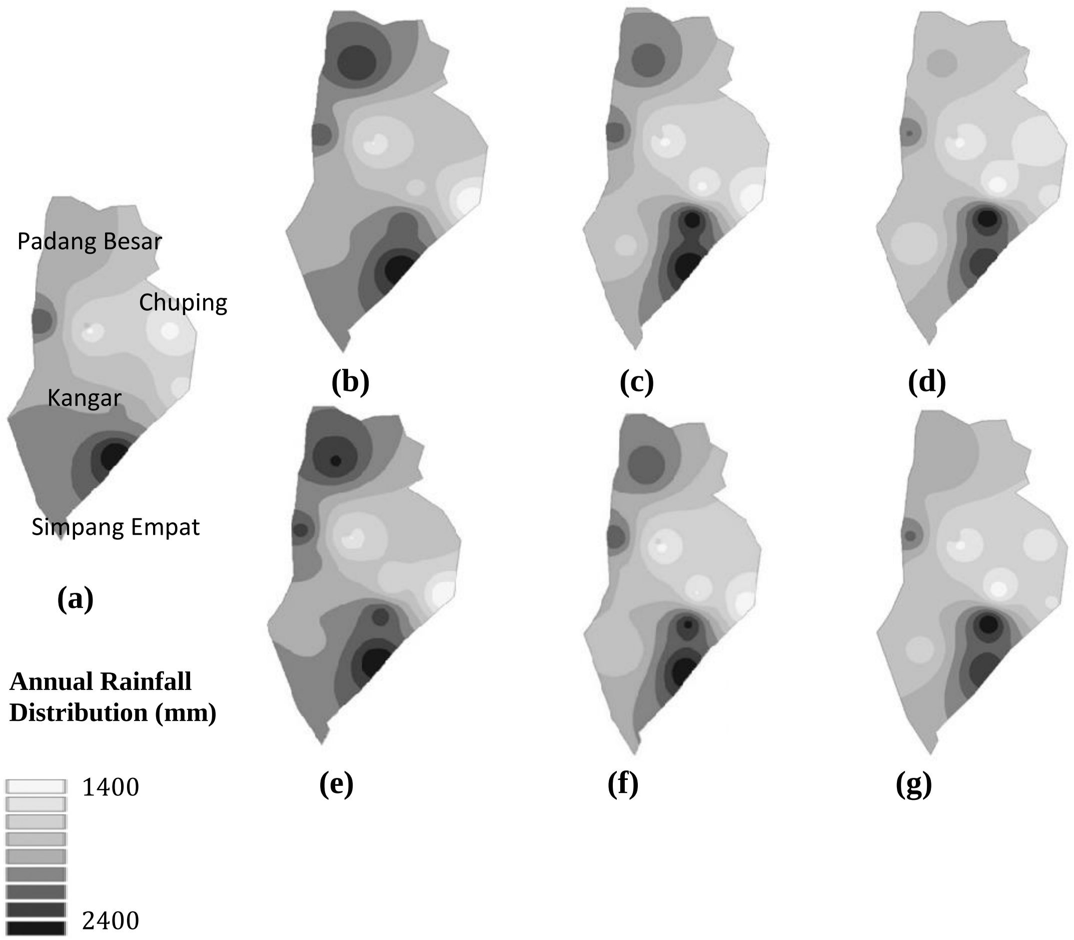


Figure 4. Spatial distribution of the annual mean rainfall for **(a)** current (1980-1990), **(b)** 2020s for A2, **(c)** 2050s for A2, **(d)** 2080s for A2, **(e)** 2020s for B2, **(f)** 2050s for B2, and **(g)** 2080s for B2

4. CONCLUSION

In general, the SDSM model is a feasibility tool to downscale and project the future rainfall corresponding the HadCM3 A2 and B2 scenarios. During the calibration and validation, the model has a capability to capture the observed daily rainfall well, based on the performance indicators such as R^2 and SE. This study also predicted that the area of Perlis will be facing the water crisis in the future, due to the lowest of annual rainfall received.

ACKNOWLEDGEMENT

The authors thank the Department of Irrigation and Drainage Malaysia (DID), Malaysia for providing the data.

REFERENCES

[1] Wild, M., Ohmura, A. & Cubasch, U. GCM-simulated surface energy fluxes in climate change experiments. *Journal of climate* **10**, 12 (1997) 3093-3110.
[2] Suhaila, J., Deni, S. M., Zin, W. W. & Jemain, A. A. Trends in peninsular Malaysia rainfall data during the southwest monsoon and northeast monsoon seasons: 1975–2004. *Sains Malaysiana* **39** 4 (2010) 533-542.
[3] Hassan. Z., Haidir, A., Mohd Saad, F. N., Ayob, A., Abdul Rahim, M. & Md. Ghazaly, Z. Spatial Interpolation of Historical Seasonal Rainfall Indices over Peninsular Malaysia. *E3S Web Conf.* **34** (2018) 02048
[4] Huang, J., Zhang, J., Zhang, Z., Sun, S. & Yao, J. Simulation of extreme precipitation indices in the Yangtze River basin by using statistical downscaling method (SDSM). *Theoretical and applied climatology* **108**, 3-4 (2012) 325-343.
[5] Wilby, R. L., Dawson, C. W. & Barrow, E. M. SDSM—a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling & Software* **17**, 2 (2002) 145-157.
[6] Hassan, Z., Shamsudin, S. & Harun, S. Application of SDSM and LARS-WG for simulating and downscaling of rainfall and temperature. *Theoretical and Applied Climatology* **116**, 1-2 (2014) 243–257.
[7] Hussain, M., Yusof, K. W., Mustafa, M. R. & Afshar, N. R. Application of statistical downscaling model (SDSM) for long term prediction of rainfall in Sarawak, Malaysia. *Water Resources Management* **8** (2015) 269.
[8] Tukimat, N. N. A., Othman, A. S., Ahmad, S. W. & Muthusamy, K. Evaluation of Climate Variability Performances using Statistical Climate Models. *Sains Malaysiana* **47**, 1 (2018) 77-84.
[9] Tukimat, N. N. A. & Harun, S. The projection of future rainfall change over Kedah, Malaysia with the statistical downscaling model. *Malaysian Journal of Civil Engineering* **23**, 2 (2011).