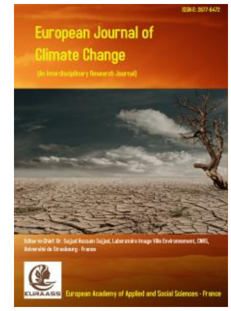
EUROPEAN JOURNAL OF CLIMATE CHANGE - VOL. 01 ISSUE 01 PP. 32-37 (2019)

European Academy of Applied and Social Sciences – www.euraass.com

European Journal of Climate Change

https://www.euraass.com/category/list-of-journals/ejcc



Research Article

A two-stage bias correction approach for downscaling and projection of daily average temperature

Mohd Khairul Idlan Muhammad[a*], Mohamad Rajab Houmsi[a], Ghaith Falah Ziarh[a], Muhammad Noor[a], Tarmizi Ismail[a], Sobri Harun[a]

[a] *Department of Hydraulics and Hydrology, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia.*

Received: 11 November 2018 / Revised: 13 February 2019 / Accepted: 10 April 2019

Abstract

Reliable projection of climate is essential for climate change impact assessment and mitigation planning. General Circulation Models (GCMs) simulations are generally downscaled into much finer spatial resolution for climate change impact studies at local and regional scales. The objective of the present study is to use a two-stage bias correction approach for downscale and project future changes of daily average temperature. The approach was applied for downscaling and projection of daily average temperature of Senai meteorological station located in Johor Bahru, Malaysia using a GCM of Coupled Model Intercomparison Project Phase 5 (CMIP5) under four representative concentration pathways (RCP) scenarios. The two-stage bias correction method was based on correction in mean factor and variability inflation factor. The model performances were assessed using different statistical measures including mean bias error (MBE), mean absolute error (MAE), root mean square error (RMSE), index of agreement (MD), Nash–Sutcliffe model efficiency (NSE) and coefficient of determination (R2). Results showed that the downscaling method could simulate historical daily average temperature at the station very well. The GCM projected an increase in daily average temperature by 1.4ºC, 2.2ºC, 2.5ºC, and 3.4ºC under RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios, respectively in the end of this century. It is expected that the finding of the study would help in climate change impact assessment and adopting necessary adaptation measures.

Keywords:

Climate change; statistical downscaling; daily average temperature; representative concentration pathways.

1. Introduction

Increased concentration of atmospheric greenhouse gases (GHG) has changed the global energy balance and consequently, the global climate (IPCC, 2013). It has been reported that the Earth's temperature has increased by 0.74°C in the last hundred years (1906-2005). The increase was much more significant after 1970, with a rate of 0.15°C/decade (IPCC, 2013). It has been projected that global mean temperature will continue to increase, which will affect other climatic variable (Wang et al., 2013; Wang et al., 2016; Shahid et al., 2016).

* *Corresponding author.* E-mail address: khairul_idlan1407@yahoo.com.my (M.K.I Muhammad)
Available online: 16 May 2019
DOI: https://doi.org/10.34154/2019-EJCC-0101-32-37/euraass.
Journal reference*: Eur. J. Clim. Ch.* 2019, 01(01), 32 – 37.
ISSN-E: 2677-6472.

Cite as: *Muhammad, M. K. I., Houmsi, M. R., Ziarh, G. F., Noor, M., Ismail, T., & Harun, S. (2019). A two-stage bias correction approach for downscaling and projection of daily average temperature, Eur. J. Clim. Ch. 01(01), 32 – 37.*

The climate of Malaysia is changing in line with global climate change (MOSTE, 2000, NAHRIM, 2006; Malaysian Meteorological Department, 2009; Mayowa et al., 2015). It has been reported that mean temperature of Malaysia has increased 0.18°C per decade since 1951 (MOSTE, 2000). A study by NAHRIM (2006) showed larger increase in minimum surface temperature of 1.5°C over the last 50 years for the Peninsular Malaysia compared to mean and maximum surface temperatures. It is anticipated that climate change will affect water resources, public health, agriculture, energy, infrastructure and many other sectors of Malaysia in a number of ways (Shahid et al., 2014; Shahid and Minhans, 2016; Shahid et al., 2017). It is required to take necessary measures to mitigate the impacts of climate change. However, the climate change impact and adaptation studies need reliable projection of future changes in climate at local scale. So, this emphasizes the need for future projection of climate in Malaysia.

Number of studies has been conducted in recent years for the projection of climate in Malaysia (MMD, 2009; Pour et al., 2014; Tukimat et al., 2017). MMD (2009) conducted climate simulations for the Malaysian region using nine coupled general circulation models (GCMs) based on the A1B scenario. The results indicate a temperature rise of 1.1 to 3.6°C in the Peninsular of Malaysia at the end of this century. A Regional Climate Model (RCM) which is known as PRECIS under A1B emission scenario also projected to increase in rainfall and temperature in the Peninsular Malaysia by the end of this century.

However, most studies have used RCM for projections of rainfall and temperature. Only few studies have been conducted so far to project temperature in Malaysia using statistical downscaling methods. The objective of the present study is to downscale daily average temperature of Johor Bahru of Malaysia using statistical method. for this purpose, a simple bias correction approach was used to improve the prediction skill. Couple Model Intercomparison phase 5 (CMIP5) known as BCC-CSM1-1 was used for projection of temperature under four representative concentration pathways scenarios namely, RCP2.6, RCP4.5, RCP6.0, and RCP8.5 in order to understand the possible changes in temperature of the city. Climate projection using RCP scenarios through statistical downscaling of GCM simulation is still new in Malaysia. Therefore, it is expected that the results obtained in this study will help in impact assessment and adaptation studies.

2. Methodology

2.1 Study area and data

Johor Bahru (1.49°N, 103.74°E) is a major city of Malaysia, located in the southern tip of the Malaysian peninsula. Location of Johor Bahru in the map of Malaysia is shown in Figure 1. Situated in the equatorial region, peninsular Malaysia has a tropical climate characterised by uniform high temperatures, high humidity and abundant rainfall (Obaid and Shahid, 2017). The heaviest rain spells are usually observed on the east coast of the peninsular Malaysia during the northeast monsoon season. On the other hand, the months of June and July during southwest monsoon are the driest period when most regions of the peninsular, except the southwest coastal region, experience minimum monthly rainfall of typically only 100 mm to 150 mm (Ahmed et al., 2017). Being an equatorial country, Malaysia experiences uniform temperature throughout the year. The annual variation is less than 2°C around the mean temperature of 27°C. The daily range of temperature is large, ranging from 5 to 10°C at the coastal stations and from 8 to 12°C at the inland stations. The excessive day temperatures, which are found in continental tropical areas, are never experienced. The mean monthly relative humidity in peninsular Malaysia ranges between 70 and 90% (Lim and Abu Samah, 2004).

Daily average temperature recorded at Senai station located at a corner of Johor Bahru city for the time period 1968-2012 were collected from Malaysian Meteorological Department. The data were initially screened through homogeneity test and found suitable for climate research.

Daily mean temperature simulated by GCM BCC-CSM1-1 (a GCM of Beijing Climate Center, China) at the nearest GCM grid point of Johor Bahru was used for the downscaling of historical temperature and projection of future temperature under different climate change scenarios. The BCC-CSM1-1 was downloaded from the website: http://cmip-pcmdi.llnl.gov/cmip5/

2.2 Methodology

The statistical downscaling of daily average temperature from a CMIP5 GCM BCC-CSM1-1 simulation under four RCP scenarios was conducted in order to assess future changes in temperature of Johor Bahru. The methodology used for this purpose is outlined below:

1. The GCM BCC-CSM1-1 simulated daily average temperature at the nearest GCM grid point of Johor Bahru was used as the predictor for downscaling model
2. Simple mean and variance correction methods were developed using historical rainfall and predictors of GCM runs for the historical period 1968-2012. Individual models were developed for downscaling temperature of each month separately. The models were validated with historical observe temperature data.

3. The bias correction models were used for downscaling BCC-CSM1-1 temperature simulations under four RCPs for the time period 2010-2099.
4. The mean variances of temperature during different time periods (2010 – 2039, 2040 – 2069, and 2070 – 2099) were analysed against historical period (1968 – 2000).

Figure 1: Location of Johor Bahru in the map of peninsular Malaysia.

Bias correction approach is most widely used for statistical downscaling of temperature (Pour et al., 2017). In the present study, a bias correction approach was used for downscaling temperature. The model for correct bias in the mean of temperature was developed using following equation:

$$T_{per} = \frac{mean_{obs}}{mean_{mod}} \, T_{mod} \quad (1)$$

Where, T_{per} is bias corrected temperature, T_{mod} is GCM simulated temperature, $mean_{obs}$ is the mean temperature during observed period (1968-2012), and $mean_{mod}$ is the mean of GCM simulated temperature during observed period. For correction of variance, GCM simulated temperature for base period is first standardized using following equation,

$$T_{std} = \frac{T_{mod} - mean_{mod}}{sd_{mod}} \quad (2)$$

Where, T_{std} is standardized GCM simulated temperature, and sd_{mod} is standard division of GCM simulated temperature. The standardization of GCM simulated temperature was de-standardized using mean and standard deviation of observed temperature for the base period.

3. Results

Daily observed and downscaled temperatures were converted to annual values. The annual time series of observed and downscaled temperatures were compared to show the efficiency of the model. The annual time series of observed and downscaled temperature is shown in Figure- 2. The figure show that the bias correction approach was able to downscale the GCM simulated temperature for historical period (1968-2012) reliably.

The performances of the downscaling model were numerically assessed by comparing the downscaled temperature for the period 1968-2012. Performances of downscaling model was statistically assessed according to biasness, magnitude of error and level of acceptance by using MAE, MBE, RMSE, Md, NSE, and R^2. The obtained results are given in Table 1. The table shows the model was successful to downscale temperature reliably in term of all statistical indices. Therefore, the model was used for downscaling of future projected temperature by GCM.

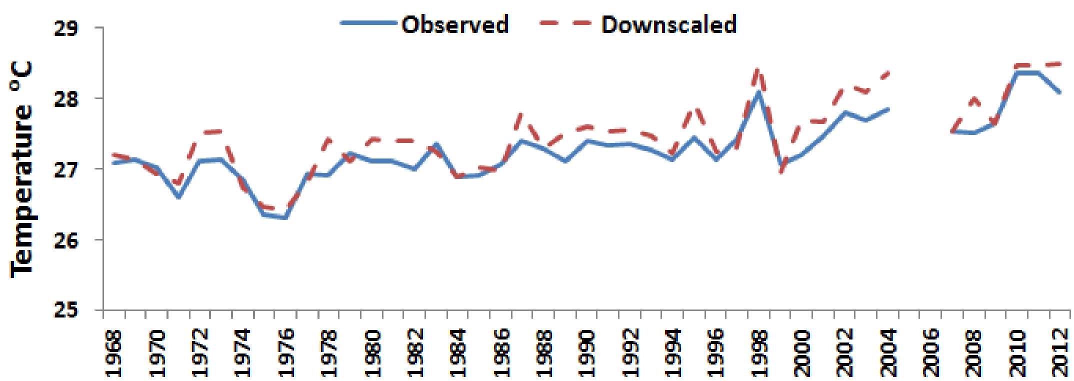


Figure 2: Comparison of annual observed and downscale average daily temperature.

Table 1: Validation of downscaling results through statistical indices.

Statistical Index	Value
MBE	0.03
MAE	0.59
RMSE	0.78
NSE	0.64
md	0.75
R2	0.71

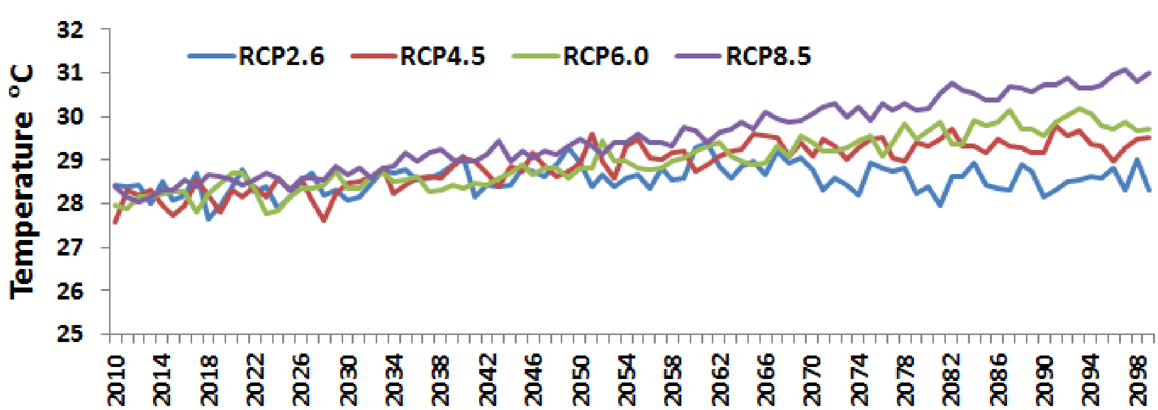


Figure 3: Projected temperature for the 2010 to 2099 period under different RCPs.

Projected temperature at Johor Bahru for the period 2010 to 2099 under different RCPs are shown in Figure 3. The figure shows different magnitude of changes in temperature under different RCPs. In order to quantify the changes, temperature data for the baseline period (1971-2000) and three projected periods namely, early part of this century (2010-2039), middle of this century (2040-2069) and the last part of this century (2070-2099). The results obtained are presented in Table 2.

The table shows an increasing trend in temperature at Johor Bahru due to climate change. Highest increase is projected under RCP8.5 in the last part of the century. The temperature is projected to increase gradually over the century. At the end of this century, the temperature is projected to increase in the range of 1.4 to 3.4°C under different scenarios.

Table 2: Changes in daily average temperature during different future periods under different climate change scenarios.

Period	Changes in Temperature (°C)			
	RCP2.6	RCP4.5	RCP6.0	RCP8.5
2010-2039	1.3	1.2	1.2	1.5
2040-2069	1.6	1.9	1.8	2.3
2070-2099	1.4	2.2	2.5	3.4

4. Conclusion

This paper presents the results obtained through downscaling of GCM projections of daily mean temperature at Senai station of Johor Bahru, peninsular Malaysia under different climate change scenarios. A two-stage bias correction approach namely, correction in mean and correction in variance were used for downscaling of temperature. The performance of the downscaling results using graphical and statistical measures reveals that the proposed bias correction models are reliable for downscaling temperature at Johor Bahru. Downscaling of GCM projection using bias correction model shows increasing trend in temperature at all future periods under all RCPs. Projecton of temperature using downscaling models revealed rises in temperature throughout the century under all RCP scenarios. The lowest increase was projected as 1.4°C fro RCP2.6 while the highest 3.4°C for RCP8.5 in the end of the present century. The rises in mean temperature may cause an increase in temperature related extremes in the region which could have several implicaitons in agriculture, water resoruces, public health and human well-being if proper adaptation measures are not take. The study can be extented to other meteorologial stations of Peninsular Malaysia for the assessment of climate change impacts on temperature of the region. Besides, the method can be used for the projection of daily temperature and temperature related extremes.

Acknowledgements

The authors wish to thank the Ministry of Education Malaysia and Universiti Teknologi Malaysia for assisting and financing this research with grant vote no. Q.J130000.2522.10H36.

References

Ahmed, A, Shahid, S., Harun, S.B., and Wang, X-J. (2015) Multilayer perceptron neural network for downscaling rainfall in arid region: A case study of Baluchistan, Pakistan. *Journal of Earth System Science,* 124 (6): 1325-1341.

Ahmed, K, Chung, E.S., Song, J.Y., and Shahid, S. (2017) Effective design and planning specification of low impact development practices using Water Management Analysis Module (WMAM): Case of Malaysia. Water 9 (3), 173

IPCC. (2007) Climate Change 2007: The Physical Science Basis. Summary for Policymakers, Contribution of the Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Mayowa, O.O., Pour, S.H., Shahid, S., Mohsenipour, M., Harun, S.B. and Ismail, T. (2015) Trends in rainfall and rainfall-related extremes in the east coast of peninsular Malaysia. *Journal of Earth System Science*, 124 (8): 1609-1622.

MMD (2009) Report on heavy rain occurrence that cause floods in Kelantan and Terengganu. Gong Kedak Forecast Office, Malaysian Meteorological Department (MMD).

NAHRIM . (2006) Study of the impact of climate change on the hydrologic regime and water resources of Peninsular Malaysia. Final Report Ministry of Natural Resources and Environment, 184 pp.

Obaid, H.A., and Shahid, S. (2017) Soil erosion susceptibility of Johor River basin.*Water and Environment Journal*

Pour, S.H., Harun, S.B., and Shahid, S. (2014) Genetic Programming for the Downscaling of Extreme Rainfall Events on the East Coast of Peninsular Malaysia. *Atmosphere*, 5(4): 914-936.

Pour, S.H., Shahid, S., and Chung, E.S. (2017) A hybrid model for statistical downscaling of daily rainfall Procedia Engineering 154, 1424-1430

Shahid, S. and Minhans, A. (2016) Climate change and road safety: a review to assess impacts in Malaysia. Jurnal Teknologi, 78(4): 1-8.

Shahid, S., Minhans, A. and Puan, O.C. (2014) Assessment of greenhouse gas emission reduction measures in transportation sector of Malaysia. Jurnal Teknologi, 70(4): 1-8.

Shahid, S., Pour, SH., Wang, X., Shourav, SA., Minhans, A., and Ismail, T. (2017) Impacts and adaptation to climate change in

Malaysian real estate. International Journal of Climate Change Strategies and Management 9 (1), 87-103

Shahid, S., Wang, XJ., Harun, SB., Ismail, T., Minhans, A. (2016) Climate variability and changes in the major cities of Bangladesh: observations, possible impacts and adaptation. Regional Environmental Change 16 (2), 459-471

Tukimat, N.N.A., Harun, S., Shahid, S. (2017) Modeling Irrigation Water Demand in a Tropical Paddy Cultivated Area in the Context of Climate Change. Journal of Water Resources Planning and Management 143 (7), 05017003

Wang, X.-J., Zhang, J., Shahid, S., Guan, E., Wu,Y., Gao, J., He, R. (2016) Adaptation to climate change impacts on water demand. Mitigation and Adaptation Strategies for Global Change, 21 (1): 81-99.