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Assessment on the Climate Change Impact Using CMIP6

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Abstract. The impact of global warming is resulting in flood, land slide, soil erosion and drought that are anticipated to become more intense and frequent. The history record shows that the flood has been occur repeatedly in this study area. The study of future climate needs to be done to a greater extent as a planning for the infrastructure and as mitigation actions on flood based on the future climate. The aims of this study, to ascertain the climate projection by CMIP6 are compatible to be subjected for the future climate and to identify the trend of future climate projection in Kemaman, Terengganu. The comprehensive study of future climate that using CMIP6 that consist of SSPs help in providing a clear explanation of future society's socio-economic appraisal in assessment modelling. The Sen's Slope Test were used to analyze the trend of future climate projection in this study area. In this study, we found out that the trend of future rainfall is increasing with the positive values of Sen's Slope Test. Study shows that the Sen's Slope Test values for eight (8) stations in Kemaman, which is Ban Ho, Hulu Jabor, Rumah Pam Paya Kempian, JPS Kemaman, Klinik Bidan Kg Ibok, SK Kemasek, Jambatan Tebak, and Jambatan Air Putih are 2.381, 1.158, 1.333, 1.252, 2.293, 1.06, 3.113, and 1.961 respectively. The frequency and intensity of forecasting rainfall also increasing compared to the historical data. In conclusion, the proper planning and mitigation action need to be done to minimize the losses that happen due to climate changes impacts.

1. Introduction

Global Climate Models (GCM) are commonly used to simulate historical, current, and forecast climates. They are based on physics, fluid dynamics, chemistry and several other fundamental rules [1]. GCMs can be chosen depending on their ability to simulate precipitation as well as temperature [2].

Coupled Model Intercomparison Project Modelling in Phase 6 (CMIP6) provides multi-model climate forecast based on various scenarios, which are a direct expression of society concerns about climate change mitigation, adaptation and implications of climate change [2]. In a study of CMIP6 models for synoptic climatological trends in Europe, researchers found that the model improved consistently in most situations, suggesting their capacity to capture important synoptic circumstances [3]. In a multi-model setting, the primary objective of CMIP is to better understand past, current, and future climate change resulting from natural, unforced variability or changes in radiative forcing [4].

CMIP6 are using Shared Socio-economic Pathway (SSPs) for the future scenario as its provide a clear explanation of future society's socio-economic evaluation, allowing larger research communities involved in assessment modelling, impacts, adaptation and vulnerability of human societies and natural ecosystems to collaborate more effectively [5]. Shared Socio-economic Pathway (SSPs) in CMIP6 is an additional social development routes in the future, as well as updated versions of Representative Concentration Pathways (RCPs) in CMIP5 [2]. Furthermore, there are driven by SSP-based scenarios developed using updated versions of integrated assessment models and based on updated data on recent emissions trend [6]. SSPs in CMIP6 is for climate modelling, which incorporates global economic and demographic trends, as well as greenhouse gas emissions. [7]. Each SSP forcing pathway combination indicates a comprehensive future climate and societal change circumstance that would be used to particular issues such as mitigation actions necessary to attain that particular climate findings, adaptation alternatives under that climate findings and assumed societal structures, and the existing implications or ecosystems [6].

MRI-ESM2-0 is the projection model of CMIP6 from Meteorological Research Institute, Ibaraki which is from Japan. It can produce the GCM resolution 1.125^0 x 1.125^0 [7]. From previous researcher [3], they found out that MRI-ESM2-0 model are the best model, in terms of broader and skinnier sections, the model is quite comparable to the observation, and hence a more appropriate estimate of Iran's precipitation.

For these warnings, the forecasting of precipitation can be explain the smallest variations in precipitation and accompanying extremes [2]. Hydrological, water resource, and river flow research might benefit from the ensemble of daily precipitation data. Precipitation patterns may be used to forecast future intensity, duration, and frequency, as well as evaluate the impact of climate change on human life. Furthermore, the study's findings will aid policymakers [8] [9], in reducing the effects of climate change.

Extreme precipitation and protracted dry periods are predicted to rise, thereby increasing the risk of flood, drought, water shortage, severe soil erosion, landslide, and hydrological hazard [3] [10] [9]. As a result, flood mitigation measured must be planned of time [10]. The aims of this study, to ascertain the climate projection by CMIP6 are compatible to be subjected for the future climate and to identify the trend of future climate projection in Kemaman, Terengganu.

2. Study area & data

2.1. Study Area

The Kemaman is located in Terengganu, Malaysia. The total area of Kemaman is 2535.59km^2 that located at latitudes 3° 50' N - 4° 35' N and longitudes 102° 50' E - 103° 40' E [11]. The catchment in Terengganu is controlled by the Northeast Monsoon which is happen from November until March every year and brings along heavy rainfall [12]. The northeastern monsoon, which occurs from November to March, and the southwest monsoon, which occurs from May to September influence Peninsular Malaysia's climate [9].

Kemaman have been chosen as study area due to several flood cases that happened in Kemaman in this recent year. Based on part studies [11], the worst flood have been occurred in December 2013 which is 80% of this district was flooded roughly. A number of areas in this district were reported to have river levels that were over the danger limit for an extended period of time, such as Ban Ho Bridge, Air Putih Bridge and Tebak Bridge [11].

Table 1. List of selected rainfall station for the climate projection in Kemaman, Terengganu.

Station Name	Coordinate		Station Number
	Latitude	Longitude	
Kg Ban Ho	04 08 00	103 10 30	4131001
Hulu Jabor	03 55 05	103 18 30	3933001
Rumah Pam Paya Kempian	04 34 05	102 58 45	4529001
JPS Kemaman	04 13 55	103 25 20	4234109
Klinik Bidan Kg Ibok	04 19 40	103 22 05	4333096
SK Kemasek	04 25 34	103 27 00	4434093
Jambatan Tebak	04 22 40	103 15 45	4332001
Jambatan Air Putih	04 16 15	103 11 55	4232002

2.2. Data

2.2.1. Rainfall Data.

Daily precipitation data from Department of Irrigation and Drainage (DID) Malaysia for eight (8) stations located in Kemaman, Terengganu from 1986-2020. The treatment of missing data for station Ban Ho, Hulu Jabor, Rumah Pam Paya Kempian, JPS Kemaman, Klinik Bidan Kg Ibok, Sk Kemasek, Jambatan Tebak, and Jambatan Air Putih have been done by using Inverse Distance Weighted (IDW) to make sure the data are reliable and compatible in the projection of historical and future rainfall model

2.2.2. CMIP6 Global Circulation Models (GCM).

The daily rainfall simulation of CMIP6 GCM is downloaded from https://esgfnode.llnl.gov/projects/cmip6/ (downloaded on 16th January 2022). The period of historical run of CMIP6 GCMs data from 1986-2014 was used for the comparison between historical data and historical run of CMIP6 GCMs data. For the projection of future precipitation of CMIP6 GCMs are extracted from 2015-2099 which is consist of three (3) types of Shared Socioeconomic Pathways (SSP), SSP126, SSP245, and SSP585. SSP126, SSP245, and SSP585 are the CMIP6 scenarios with lowest, moderate, and highest value respectively in term of anthropogenic radiative forcing by year 2100, global CO_2 concentration, global CO_2 emissions, with socioeconomic reasons. The type of model of simulation that have been chosen is MPI-ESM2 with variant label, r1i1p1f1 for the precipitation.

3. Methodology

Before starting the projection of CMIP6 GCMs model, the treatment of missing data of historical data is essential in contemplation of getting reliable data of forecasting precipitation. Therefore, the first phase in this study's approach is to encounter the treatment of missing data by using inverse distance weighted (IDW). Then, the projection of historical runs of rainfall of CMIP6 GCMs data (1988-2014) and the projection of future rainfall of rainfall of CMIP6 GCMs data (2015-2099)

3.1. Inverse Distance Weighted (IDW)
Inverse Distance Weighted (IDW) is the most straightforward and often used approach for the treatment of missing data, this is because the assumption is based on the values of nearby stations [13]. IDW also the most effective technique to deal with missing data compared to Expectation Maximization (EM) and Multiple Imputation (MI). The formula for IDW method as:

$$\mathrm{Vo}=\frac{\sum_{i=1}^{n}(\mathrm{Vi}/\mathrm{Di})}{\sum_{i=1}^{n}(1/\mathrm{Di})} \quad (1)$$

3.2. Climate projection by CMIP6
The projection of historical run and future run of rainfall are using Linear Scaling (LS) of bias correction. The ratio of monthly observed have been used to simulate the corrected bias data. Same as previous study [14], the difference between monthly observed and monthly simulated values is used to correct biases in the linear scaling approach and the difference is applied to the simulated data.

3.3. Trend Analysis
Sen's Slope Test have been used in this study in order to determine the trend analysis of future rainfall in Kemaman,Terengganu. The Sen's Slope technique estimates the slope of the trend using a linear model, and the variance of the residual should be constant across the time [15]. The equation of Sen's Slope as calculated as below:

$$Qi=\frac{Xj-Xk}{j-K}\ for\ i=1, \ldots\ldots \frac{\sum_{i=1}^{n}(\mathrm{Vi}/\mathrm{Di})}{\sum_{i=1}^{n}(1/\mathrm{Di})} \quad (2)$$

4. Result & Discussion

4.1. Climate Projection by CMIP6
The comparison between actual historical data of rainfall for eight (8) stations in Kemaman, Terengganu and historical run by using CMIP6 GCMs data from 1988-2014 have been carried out. The differentiation is being undergo in order to find the percentage error between two (2) set of data. The percentage error between actual historical data of rainfall and historical run by using CMIP6 GCMs data should be below than 20% to make sure it is compatible to proceed for projection of future rainfall modelling. The percentage errors between historical rainfall data and historical run of CMIP6 GCMs model from 1988-2014 for station Ban Ho, Hulu Jabor, Rumah Pam Paya Kempian, JPS Kemaman, Klinik Bidan Kg Ibok, Sk Kemasek, Jambatan Tebak, and Jambatan Air Putih are 1.2%, 7%, 0.4%, 4%, 4.6%, 2.6%, 0.5%, and 2.5% respectively. All eight (8) stations are achieving the percentage error between actual historical rainfall data and historical run of CMIP6 GCMs models below 20%. Therefore, the historical run of CMIP6 GCMs model are able to generate the rainfall modelling almost the same with the actual historical rainfall data. Its shows that the selection model is compatible to subjected to projection of future rainfall in this selected area. The result of comparison between historical data of rainfall for eight (8) stations in Kemaman, Terengganu and historical run by using CMIP6 GCMs data has been shown in Figure 1.
Next, the comparison between historical data for eight (8) stations in Kemaman, Terengganu and future climate projection by using CMIP6 GCMs model data from 2015-2020. The comparison has been proceeded in order to analyze the compatibility of future climate projection by using CMIP6 GCMs model data for the future climate projections with three (3) types of SSP which is SSP126, SSP245 and SSP585. Various SSPs in a particular matrix row will have unique characteristics of regional economic growth, energy system development, air quality policies, land usage, and other features, resulting in the same global average forcing outcome being attained by different ways in each case [6].

4.2. Climate Projection by CMIP6

The projection of future rainfall in Kemaman, Terengganu are divided into three (3) intervals years, which is 2020-2039 (Δ2030), 2040-2069 (Δ2050), and 2070-2099 (Δ2080) for three (3) types of SSPs which SSP128, SSP245, and SSP585 have been stated at Figure 2. Based on the result of forecasting the future rainfall, it shows the increasing volume and intensity of rainfall compared to historical volume of rainfall in Kemaman, Terengganu. Simultaneously, Figure 3 shows the result of Sen's Slope for the analysis rainfall trend in Kemaman, Terengganu which is also shows the increasing trend of future rainfall in this study area.

The analysis of trend of future rainfall in Kemaman, Terengganu are undergone by using Sen's Slope Test. From this analysis, the study shows the increasing trend for all eight (8) stations. The Sen's Slope value for eight stations, Ban Ho, Hulu Jabor, Rumah Pam Paya Kempian, JPS Kemaman, Klinik Bidan Kg Ibok, Sk Kemasek, Jambatan Tebak, and Jambatan Air Putih are 2.381, 1.158, 1.333, 1.252, 2.293, 1.06, 3.113, and 1.961 respectively. The result of analysis trend of future rainfall in Kemaman, Terengganu are undergone by using Sen's Slope Test has been shown in Figure 3. From the equation of Sen's Slope, it shows that the positive values of Sen's Slope show increasing trend of the data set.

It is correlate with the previous study, [9] found out that coastal region of peninsular Malaysia are more vulnerable to hydrological hazard compared to interior zones of peninsular Malaysia, which is, coastal region of peninsular Malaysia are expected to receives a lot of rainfall during northeastern monsoon compared to southwest monsoon and several area of study region are expected to having a flood situation. On the other hand, the study area in Egypt [10] found out that, along the Mediterranean coast shows that the increment of annual precipitation for the CMIP6 MME. Besides, in the arid basins of Iran, high intensity and high frequency of rainfall are anticipate under the SSP585 scenarios during 2061-2100 [3].

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Figure 1. Comparison between historical rainfall data and historical run CMIP6 GCMs model from 1988 until 2014

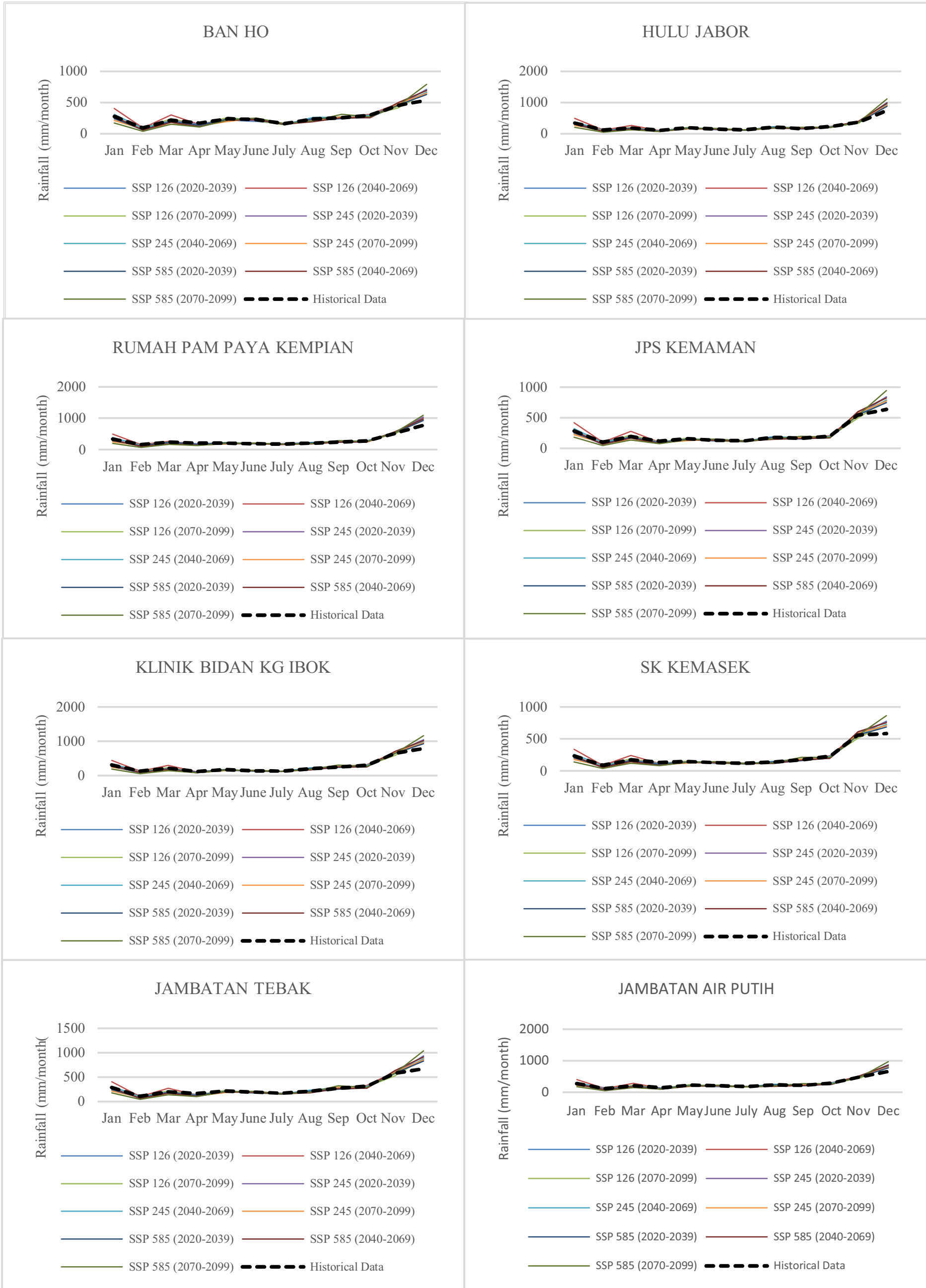

Figure 2. Result of projection for future rainfall for SSP126, SSP245, and SSP585 for three (3) interval years, 2020-2039, 2040-2069, and 2070-2099 in Kemaman, Terengganu.

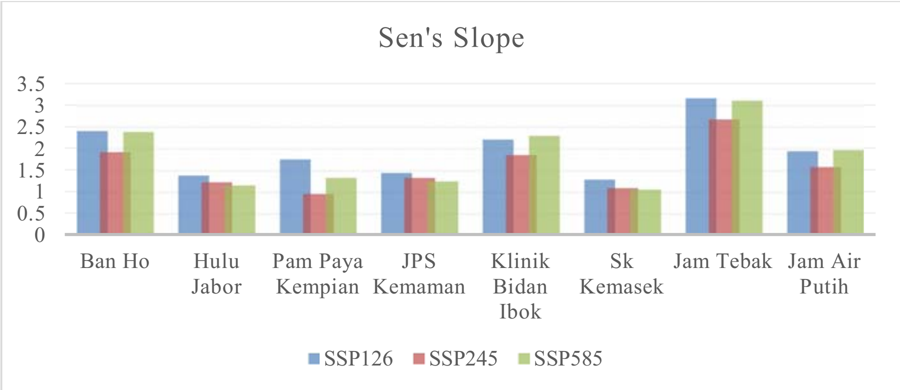

Figure 3. Sen's Slope result for the future rainfall in Kemaman, Terengganu for SSP126, SSP245, and SSP585

5. Conclusion

Eight (8) stations in Kemaman, Terengganu show the result of comparison between actual historical rainfall data and historical run of CMIP6 model with percentage error below than 20% and the projection of historical CMIP6 model almost the same with the actual historical data. It shows that the projection of CMIP6 model based on MRI-ESM2-0 can be used as predictor for the future projection climate. This is corresponding with the previous study, which CMIP6 up to delivers multi-model climate forecast based on numerous scenarios that directly reflect societal concerns about climate change, mitigation, adaptation, and repercussions [2]. In addition, the future projection of rainfall shows the increasing trend and intensity for the future rainfall by using Sen's Slope Test based on MRI-ESM2-0 types of models under CMIP6 models compared to historical data of rainfall in this study area. This model is capable to forecast the long-term trend of rainfall which is very crucial nowadays. In conclusion, the implement of action to manage the risk of climate change impacts need to be done immediately. The proper planning of infrastructures and mitigation plan of flood relief is needed to make sure that it is suitable and corresponding with the future climate.

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