PERFORMANCES DIFFERENCE ON CLIMATE BETWEEN AR4 AND AR5

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PERFORMANCES DIFFERENCE ON CLIMATE BETWEEN AR4 & AR5

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Thesis submitted in fulfillment of the requirements
for the award of the
B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude towards my supervisor Dr Nurul Nadrah Aqilah Binti Tukimat for her guidance, ideas, continuous encouragement and support in making this research possible. She was helpful in many ways in my research, from bright ideas towards consulting on how to approach problems to solve them. Also, she gave me an insight towards what should be called life-long learning experience. She had strict principles and a firm belief on what she was doing. I really appreciate the help that she has given to me and my teammates in completing our study. Without her progressive thinking and progressive attitude, I would never made it towards the end of the Bachelor’s Degree I’m currently pursuing.

A special gratitude I would like to forward towards my family especially my mum, Normah for their support through my ups and downs, making sure that they have my back whenever I needed them and plus, encouraging me to go further and surpass myself in all kinds of aspects. They’re also my backbone towards me finishing this study and helped me in understanding, having patience and finally, being the ones I can turn back to if I am in need of help.

My sincere thanks towards my teammates, Fatin & Basri in helping me finish this research and the cooperation in making the study more understandable, viable to simulate and support in me finishing the research.

I would like to acknowledge my housemates, Banglo 2 Tingkat inhabitants especially Ashrawi, Asyraf, Iswandy, Kumpulan Muzik UMP, including En Fakhruddin, En Rani, Izzat, Fazrul, Firdhaus for their tremendous support and confidence in me towards concluding my life here in UMP. I also would like to acknowledge their suggestions and comments, which was crucial for in completing the study.

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ABSTRAK

Intergovernmental Panel on Climate Change (IPCC) merevisi kesan gas rumah kaca (GHG) ke dalam sistem iklim dan mengeluarkan Laporan Penilaian Kelima (AR5) pada tahun 2014. Dengan AR5, perubahan iklim telah diklasifikasikan berdasarkan tahap radiasi memaksa dikenali sebagai Laluan Konsentrasi Perwakilan (RCP2.6, RCP4.5, dan RCP8.5). Versi ini sedikit berbeza dengan versi AR4 yang berdasarkan kumpulan GHG yang dikenali sebagai A1, B1, A2, dan B2. Pengubahsuaian dalam penilaian perubahan iklim akan menjejaskan ketepatan unjuran iklim dalam jangka panjang. Oleh itu, matlamat utama kajian ini adalah untuk menentukan kesan dalam penilaian perubahan iklim antara Laporan Penilaian Keempat (AR4) dengan AR5. Kajian itu difokuskan pada Malaysia Timur termasuk Kelantan dan Terengganu. Dalam kajian ini, Model Downscaling Statistik (SDSM) digunakan sebagai model iklim statistik untuk menilai perbezaan persembahan iklim. Sementara itu, model peredaran umum (GCM) yang disediakan oleh Pemodelan dan Analisis Iklim (CanESM2) digunakan untuk penjanaan iklim jangka panjang. Merujuk kepada hasil, ramalan p-u, r500, dan r850 adalah pembolehubah yang paling mempengaruhi dalam membentuk suhu tempatan dan hujan di kawasan. Ketepatan penjanaan iklim dikawal oleh% MAE yang lebih rendah dengan Korelasi tinggi (R) dalam keputusan yang dikalibrasi dan disahkan. Simulasi suhu berjaya menghasilkan 0.6%% MAE dengan R hampir 1.0. Sementara itu hujan di Terengganu dan Kelantan dihasilkan kurang daripada 14%% MAE dengan 0.99 R. Berdasarkan perbandingan prestasi antara GCM dan data sejarah, RCP4.5 (AR5) dan SRES A2 (AR4) telah dipilih sebagai tahap pemantauan radiasi terbaik di wakil Kelantan untuk AR yang berlainan. Sementara itu untuk Terengganu, RCP2.6 (AR5) dan SRES B2 (AR4) telah dipilih kerana prestasi% MAE yang paling kecil. Keputusan iklim yang diunjurkan dijangka mempunyai kenaikan minimum pada maksimum (0.79%), purata (0.43%) dan suhu min (0.2%). Curah hujan setempat memperlihatkan peningkatan pola dengan (9.37%) di Stesen Gunong Barat Bachok, (5.04%) untuk Stesen Rumah Pam Salor Pengkalan Kubor, (9.11%) untuk Stesen Sg. Simpang Ampat di Kelantan. Bagi Terengganu, pola menunjukkan kenaikan (4.43%) untuk Station Sek Men. Bukit Sawa, (5.25%) untuk Stesen Rumah Pam Pulau Musang, dan (42.07%) untuk Stesen Kg Peringat.

ABSTRACT

The Intergovernmental Panel on Climate Change (IPCC) revised the impact of greenhouse gases (GHGs) into the climate system and came out with the Fifth Assessment Report (AR5) in year 2014. By AR5, the climate changes impact were classified based on the level of radiation forcing known as Representative Concentration Pathways (RCP2.6, RCP4.5, and RCP8.5). This version was slightly difference with the AR4 version which based on the GHGs groups known as A1, B1, A2, and B2. The modification in the climate changes assessment will affecting the accuracy of the climate projection in the long term. Therefore, the main aim of this study was to determine the impact in the climate change assessment between Fourth Assessment Report (AR4) with AR5. The study was focused on Eastern Malaysia including Kelantan and Terengganu. In this study, the Statistical Downscaling Model (SDSM) was used as a statistical climate model to assess the differences of the climate performances. Meanwhile, the general circulation model (GCM) provided by Climate Modelling and Analysis (CanESM2) was used for the long-term climate generation. Referring to the results, the predictor of p-u, r500, and r850 are the most influence variables in forming the local temperature and rainfall at the regions. The accuracy of the climate generation was controlled by the lower %MAE with high Correlation (R) in the calibrated and validated results. The temperature simulation was successfully to produce 0.6% of %MAE with R close to 1.0. Meanwhile the rainfall at Terengganu and Kelantan were produced less than 14% of %MAE with 0.99 of R. Based on the comparison performances between GCMs and historical data, the RCP4.5 (AR5) and SRES A2 (AR4) have been selected as the best radiation forcing level at Kelantan representative for different ARs. Meanwhile for Terengganu, the RCP2.6 (AR5) and SRES B2 (AR4) have been selected due to least %MAE performances. The projected climate results were expected to have minimum increment in the max (0.79%), mean (0.43%) and min (0.2%) temperature. The local rainfall shows increasing pattern with (9.37%) in Station Gunong Barat Bachok, (5.04%) for Station Rumah Pam Salor Pengkalan Kubor, (9.11%) for Station Sg. Simpang Ampat in Kelantan. For Terengganu, the pattern shows an increment of (4.43%) for Station Sek Men. Bukit Sawa, (5.25%) for Station Rumah Pam Pulau Musang, and (42.07%) for Station Kg Peringat.

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%	Percentage
R	Correlation value

LIST OF ABBREVIATIONS

CIMP5	Coupled Intercomparison Model ver. 5
AR5	Fifth Assessment Report
AR4	Fourth Assessment Report
SRES	Special Report on Emission Scenarios
HadCM3	Hadley Center Coupled Model
RCP	Representative Concentration Pathways
CanESM2	Canadian Center for Climate Modelling Analysis

CHAPTER 1

INTRODUCTION

1.1 Introduction

Climate is the weather conditions of an area in general or for over a long period. Climate can be asses by long term study of the weather of a certain place. The climate can be assessed by a myriad of parameters including temperature, humidity, atmospheric pressure, wind and also precipitation. These parameters can lead us in deciding what the climate of the certain area is and in turn, from climate it was possible to gain the climate trend in which can be assess the changes of the climate towards the future. Climate trend depends on these parameters that can chance involuntary or voluntarily that depends on human actions. These trends can affect a certain area in many ways, such as the increase in temperature can lead to continued warming and many more. To assess these models, it was difficult as it requires to have a proper knowledge on how the cycle works and how are mankind going to interpret the data from General Circulation Model (GCM).

Climate is commonly defined as the weather over a long period. The standard averaging period was 30 years. The period can be lengthened or shorten the period depending on the purpose of the study. It also includes statistics, other than daily averages, such as the magnitudes of day-to-day or year to year variations. In climate, there stands a term called climate normal. These terms were actually a reference point for the climatologists to identify what went astray from the normal climate. A climate that follows the pattern of recent and past climates was a normal climate. In the span of 30 years used as the period of the study, if there are any unnatural occurrences of weather extremes such as heat waves, or heavy precipitation, it can be recorded into the journal for reference about the climate trend, and where the climate trend was heading.

Climate projection is another branch in climate change. Climate projection much more focuses on projections of the climate towards the future. Climate projections are mainly based on the current climate and the climate trend that was ongoing. Climate projection can be also defined as the stimulated response of the climate system to the scenario of future emission or concentration of greenhouse gases and aerosols, that are generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission, the concentration and the radiative forcing scenario used, which was based on assumptions concerning future socioeconomic and technological developments that may or may not be realized. Climate projection has been widely used since the early twentieth century where it is viable to predict the climate change by having calculated the emissions of gases in the atmosphere. Projection can also be determined by the increment of temperature of the atmosphere, whilst neglecting to project climate for the future, it can lead to several problems including decreased productivity in agricultural lands, submerging of suburban areas due to floods or heavy precipitation.

The scientific community has reached a 97% consensus that climate change is influenced by humans yet many people still doubt that this was true (Thompson, 2017).The problems that are in climate can be catastrophic if left unattended. The major climate problems are that there is no correct way of measuring projection in terms of climate. The climate itself presents a question to researchers. The climate itself was handled by the IPCC or the Intergovernmental Panel on Climate Change which was responsible for the climate projection in which the researchers, working for the IPCC assess the climate trend and calculate the climatic change to obtain the projected climate in the future.

The problem arises when there are inconsistencies in certain climatic trends in which can contribute to projection problems. Not forgetting, global climate problems also pave the way to the obstacle in generating climate projections. Such problems, including unnatural climate trends, caused by the presence of GHG in the stratosphere have curbed researchers advances in climate prediction. With the implementation of the Assessment Reports, specifically the Fourth Assessment Report, a system, namely SRES or the Special Reports on Emission Concentration was used to assess the climatic changes and the climatic problems thus being able to project the climate of the world. The system, is a cry away from perfectness, as the system overestimates the variables that are the guidelines to climate projection. With the implementation of the Fifth Assessment Report, a new system was constructed and it supersedes the SRES. The system, namely RCP focuses on the endpoints and up until now it has been accepted as a sound system by the IPCC. The time to time revision of the climate assessment is necessary due to several issues such as the policy-relevant calculation and overestimate responses of the GHG emissions forcing, reducing regional biases in temperature simulation, the correlation between observed and modelled mean precipitation, uncertainties of cloud processes (Tukimat *et. al.,* 2014).

1.2 Problem Statement

To the International Panel on Climate Change (IPCC) has assessed the amounts of greenhouse gases GHG in various areas of the world. And from these greenhouse gases, the researchers adopted four pathways that are the most prevalent in the stratosphere in today's community. There was a clear view on the increase of the Representative Concentration Pathways (RCPs) throughout the years. The four pathways that have been selected are used for climate modelling and research, which all of them describe different climate projection, all of these pathways consider the amount of GHGs that are emitted in the years to come. The four RCPs, namely RCP2.6, RCP4.5, RCP6 and RCP8.5 are labelled according to possible range of radiative forcing values in the year 2100 in relative to pre-industrial values.

Also assessed by the council of IPCC, the Fourth Assessment Report uses a system that is different from the system that was used in AR5. with the usage of SRES in AR4, the are quite many scenarios that can be obtained through these scenarios. SRES scenarios are emission scenarios developed by (Nakicenovic and Swart, 2000) and used, among others, as a basis for some of the climate projections used in the Fourth Assessment Report. This assessment system was obsolete and was superseded by the Fifth Assessment Report's system which uses the RCP or the Representative Concentration Pathways system. Still, both systems measure and record the increase of the values of GHG and the increase of other features and indicators that are used in measuring the effect of the GHG .

The basis of these projections differs from the AR4 and AR5. With both of these reports having different systems in order to calculate and to project the future climate, in SRES there were 4 scenarios owing to the growth of the population economic and demography. In the Fifth Assessment Report, the system takes account of the carbon dioxide usage and plotted out the levels of carbon dioxide in 4 different pathways.

Owing to computational constraints, the equilibrium climate sensitivity in a climate model is sometimes estimated by running an atmospheric general circulation model coupled to a mixed-layer ocean model, because equilibrium climate sensitivity is largely determined by atmospheric processes. (Pachauri, 2014). In order to attain a level of uniformity of the atmospheric process, care must be taken in order to not change or to not tamper with the data that has been obtained so that the readings and the generated GCMs would not be altered. Such alteration towards the data could mean that the generated GCMs would be faulty and then causing difficulties in determining the best RCP for the states that are involved in the study.

The next problem in climatic projection which is the climatic trends that are occurring out of general context. In this case, it was necessary to attain the best data for the purpose of the research. In turn, with the involvement of the monsoon in the area of the study and also with the involvement of the unnatural occurrences of the climate such as heat waves and heavy downpours, leading to difficult the computation and to project the climate of the area of the study.

The climate projection would be done according to the assessment report's climate agent. Since both assessment reports vary in their contents, the study encompasses what are the climate agents that supports AR4 projections and AR5 projections and then analyses the difference of both climate projections to give a clearer view on whether Kelantan and Terengganu follow which assessment report. This was done by comparing the climate agent of AR4 and AR5 and then projecting the climate of Kelantan and Terengganu following these two ARs as scenarios.

1.3 Objectives of The Study

The main aim of the study was to determine the impact in the climate change assessment by different Ars group. The objectives of the study are as follows: -

- To determine the best RCP and SRES for the local climate projection
- To generate the future climate trends at Terengganu & Kelantan using predictors of AR4 & AR5
- To analyse the performance differences between AR4 & AR5

1.4 Scope of Study

The scope of the study was focused on the eastern of Malaysia which are Kelantan and Terengganu. These states are chosen because of their disperse economy which also includes industrialization and rural industry. With the implementation of the Assessments Reports, it was plausible to determine the difference of the performance of Fourth and the Fifth Assessment Report. These areas have dispersed industries so it was imperative to determine what RCPs are best both of these states. In turn with the implementation of SRES, it was viable to observe the problem of having 2 scenarios given to a location because of the industrialization which produces more GHG are located suburban. The industries that do not generate GHG or generate a small amount of them are located outside of the state.

The GCM for AR4 that would be used is Hadley Centre Coupled Model ver. 3 and for AR5's GCM would be CanESM2. For the determination of AR5, the RCPs used in this study is RCP2.6, RCP4.5 and RCP8.6. For AR4, the SRES used is A2 and B2. These scenarios would be compared between each other to validate their differences and projected their graph of climate trends.

The GCM data was downscaled to RCM in order to get a clearer view of the regional climate performance and hence provide a solution to the study. The downscaling techniques used was dynamical downscaling which can be interpret as a non-statistical downscaling which can compute large amounts of dimensional data at once. Since the data also incorporates GHG into account, using statistical downscaling was the best way to portray the performance of the climate projection the result obtained as the results of the study. The models of the study follow the general GCM of Malaysia so it incorporates real details in order to get accurate results.

1.5 Significance of The Study

The study would deduct the best RCPs and the best SRES for both states Also, with the implementation of both assessment reports, it would be a clear cut between the performances of the both assessment reports in terms of how they grade the states and what was the projected carbon emission of the states. whether or not the states produce GHG and how much was emitted by the industrialization of the states be proven in the climate projection of these states.

With the findings of the Best RCP and the best SRES of these states, it would be possible to determine the differences of the performances between the RCP and SRES as well as assessing the impacts that would happen with the difference of these scenarios in action. Also, it would be plausible to determine the climate trend of these states by the projections thus enabling pre-emptive actions to be taken.

With the change of the climate, it was the best way for us to project the climate change for the next few years according to the amount of GHG produced and the climate trend that was happening in the states. In short, the significance of the study: I) projecting climate change and the climate trend of the two states ii) Determining and projecting the best RCPs for the two states for them to take action.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Climate change due to increasing greenhouse gas (GHG) concentrations in the atmosphere is a major concern in today's world (Hughes, 2003) (Sachindra *et al.*, 2013). Climate was a measurement of weather and it applies to all areas and regions of earth which encompasses of variety of weather. With the advancement of sciences and mathematical logic, future climate projection was possible as the patterns of the climate is recorded. Climate projection was available due to the trends that the weather was in this millennium. But the problem arises where there are inconsistencies in climate projection, such as extreme heat and extreme cold and intense precipitations that are actually an unnatural phenomenon in this day and age. These phenomena are due to human actions as the provocateur of these phenomenon. The scientific community has reached a 97% consensus that climate change was influenced by humans, yet many people still doubt that this was true. (J.E. Thompson, 2017). Although a consensus has been reached by the scientific community, to society, this matter still not really accepted. With these human activities going on and nothing to stop them, it is certain that global warming would be frequent due to human actions.

. To understand climate change and its projections, it is obligatory that one should be able to differentiate between weather and climate, climate variability, and climate change.(Jalota *et al.,* 2018) The subtle differences between these phrases are as follows, weather is the state of the atmosphere at a given time, in such, it is usually defined in terms of its temperature, atmosphere compositions, climate is the average weather over time which is collected. In this case, by having the weather everyday taken, the general trend of the climate can be assed in climate projection in the future. With these data and with statistical calculations an accurate representation of the climate in the future and hence devise a plan for the betterment of mankind to adapt or mitigate any bad climate that might happen in the future.

With every technological breakthrough, there are also problem that arise with it. With the implementation of the climate projection program in order to see the future climate, it is important to note that the term “uncertainty” has a generally negative connotation, implying that uncertainty is related to the poor knowledge of the problem and thus needs to be reduced as much as possible by advancing research.(Giorgi, 2010). Since there is a lack of knowledge on the projection of climate because it is governed by multiple parameters, most of them require analysis and require more intricate research upon. For the purpose of the research, it can relatively scope down the uncertainty in Greenhouse Gases GHG.

Since the industrialization period that has happened twice in the world, that there are gases or by-products of the production of certain items that are high in demand released in the air. These gases, such as carbon dioxide, carbon monoxide, nitrous oxide and many more. These gases, GHG are also one of the indicators that is used in future climate projection. Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. (Walz *et al.*, 2014)(IPCC, 2014) The human which are driven by 2 main key points which is production, and land use. In production, the GHG are produced by the production of a number of products that have these gases as their by-products. Next, the improper land use which includes deforestation of the forest.

In the Fourth Assessment Report, a system on SRES which is Special Report on Emission Scenarios. The IPCCs Special Report on Emissions Scenarios (SRES) was published in 2000 (IPCC, 2000), and contains a set of new projections of future greenhouse gas emissions: these projections supersede the IS92 family of projections. The starting point for each projection was a ‘‘storyline’’, describing the way world population, economies, political structure and lifestyles may evolve over the next few decades. SRES inconsistencies were that it is dependent on the possibility of energy sources becoming more dominant. In A1C, the scenarios are based on coal-driven society. Moreover, it does not take legislative action and government political actions into account, which if changed can affect the possibility of GHG emission.

2.2 Climate Projection

Climate projection, can be defined as the climate modelling, by climate modelling, it is plausible for mankind to anticipate and predict the climate in a few years' time as such it presents the opportunities to assess the impacts of the climate change which can be beneficial to mankind as also comes with choices to either to mitigate or to adapt to the changes that comes with the climate change. A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases GHG and aerosols, generally derived using climate models. (IPCC, 2014) This climate change is defined by a few parameters which also includes the emission of GHG of the specific region that is focused. In this case, both AR4 and AR5's climate projection by these parameters can be defined by taking account the differences of the parameters of climate projection in both AR4 and AR5.

One of the parameters in climate projection is the emission of GHG to the stratosphere which also includes natural emission and also human induced emission. The role of GHG in projecting the future climate is that the usage of system used to determine the severity of the emission of GHG, mainly carbon dioxide in the stratosphere. In AR4, a system called SRES is used. SRES refers to the scenarios described in the IPCC Special Report on Emissions Scenarios (SRES, 2000). The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions.(IPCC, 2014). These policies that were used does not include political and legislation factors which is the downturn of the policy. This means that the storyline of the region that has been assessed, does not change within time and no legislation and political actions are taken into accord. Whilst in AR5, the policy used is the RCP which is a newly developed policy from the SRES. RCPs are scenarios that include time series of emissions and concentrations of the full suite of GHG and aerosols and chemically active gases, as well as land use/land cover (Moss *et al*., 2008). This proves that AR5 also takes account of the what SRES has implemented, but also taken into accord of the political and the legislation advances of the country for a better projection of the climate.

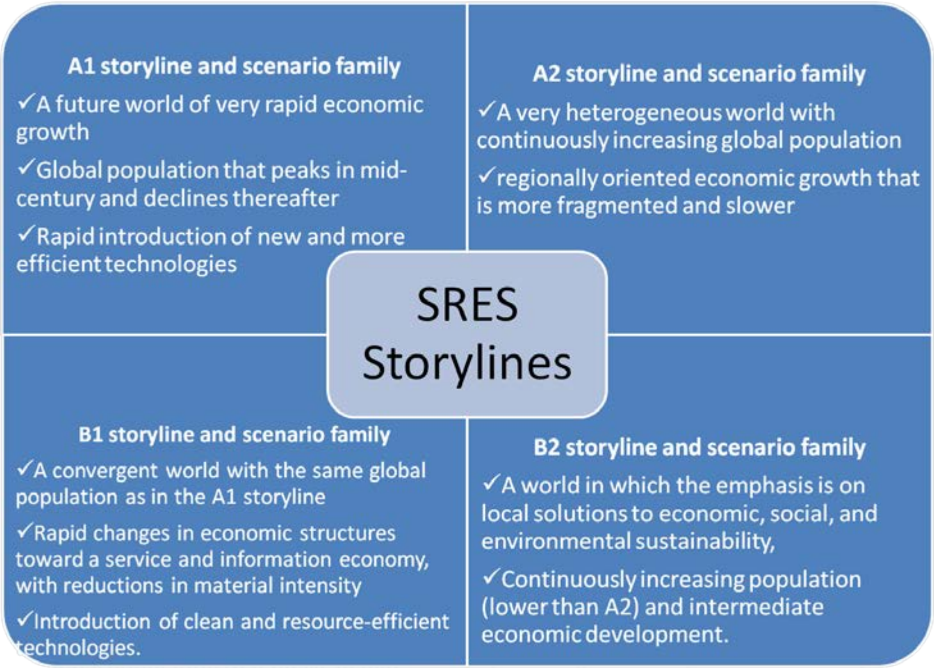


Figure 2.1 SRES Storylines

(weandclimate - WordPress.com)

Based on the picture above, SRES is about the projection of the future based on different storylines. In SRES policy, the storylines are the most accurate projection of the future and it ss divided into a few stories which represents the current state of the world then. In the first projection, which is A1, it is divided into 4 parts, namely A1, B, Ft and T projections. These projections depict the situation of the world in the future. In group A, it is described that the approaches are much more global and economic oriented and are less towards regional and environmental approach. By this, three more additional projections are produced which is A1B, A1FI, and A1T. A1B describes a much more balanced approach towards the future in terms of using energies. A1T focuses more on the non-fossil intensive energy sources such as renewable energies and such that it doesn’t release GHG into the stratosphere. The last scenario which is A1FI focuses on the future that is fossil intensive. These scenarios are used to best define the future of the country or region specified by following the storyline.

On the other hand, the A2 scenario involved the continuous increment in the population growth and regional oriented economic development.(Tukimat and Alias, 2016). The A2 scenario involves focus on regional growth that is based on fragmented technology but has the same growth as A1 scenario. In B1 and B2 scenario, both scenarios are more on towards the environment in which both scenarios emphasize more on economic growth same like the previous s 2 scenarios but much more focus on environmental solutions which can help in negating the release of GHG in to the air. The scenarios are taken upon the emission of GHG in the air of a certain area, and these data are recorded in order to be calculated to obtain the projected climate. The data that are obtained can be downscaled in order to obtain an accurate data on the region that have been specified.

In the Fifth Assessment Report uses a system called RCP or Representative Concentration Pathways. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5).(IPCC, 2014). These RCPs are also used in obtaining the projections of the climate in the future. RCPs have a variety of scenarios; these scenarios are much like storylines in which can defined by the emission of GHG. The more stringent case, RCP 8.5 is no doubt the RCP with the highest amount of GHG emission which is followed by intermediates, RCP 4.5 and RCP 6.0 and then by the least emission scenario RCP 2.6. these RCPs are based on the observations made daily of the emissions of GHG to the air. The types of GHG that are mainly observed is the carbon dioxide content that is produced daily and is released to the stratosphere daily.

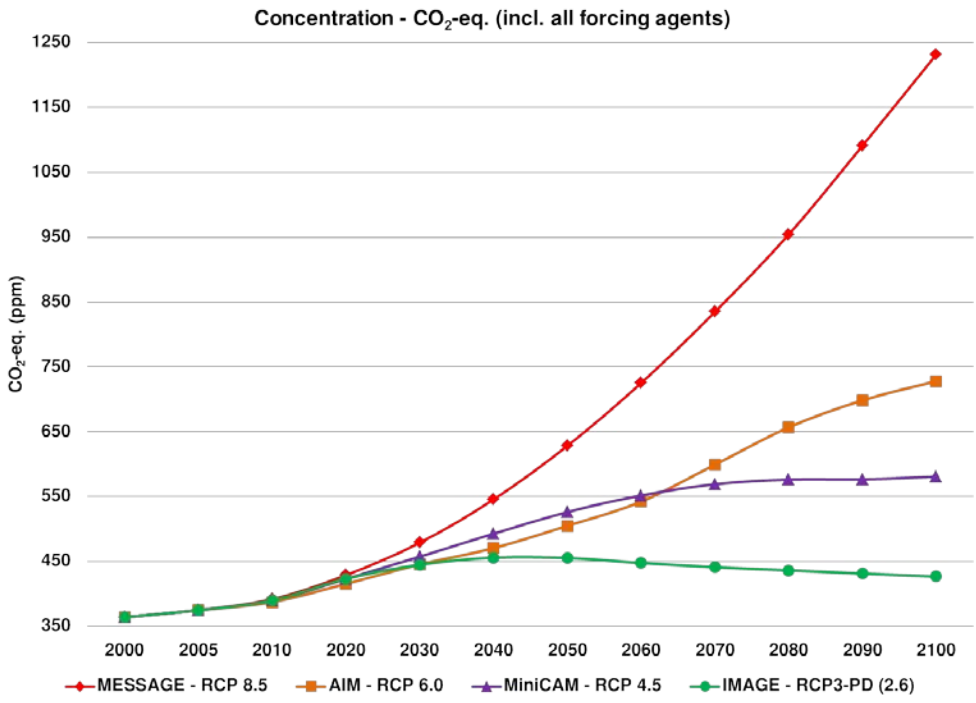


Figure 2.2 RCP Pathways in the Fifth Assessment Report (AR5)

(https://research.csiro.au/slrwavescoast/sea-level/future-sea-level-changes/)

Diagram above shows the different pathways for RCPs. Namely RCP 8.5 which is the CP with the highest CO_2 content followed by both intermediates, RCP 6.0 and RCP 4.5. the latter, which has the lowest amount of CO_2 emission is the RCP 2.6. these RCPs are the projection of the climate in the future if the amount of CO_2 follows the patters of the RCPs.

2.2.1 Increase in Temperature

The increase in the temperature of the world is now not a new phenomenon, researchers from over the world have observed and reported countless increase in temperatures from there are of study. The increase of temperature can be directly linked to the frequent heat waves that are a normal occurrence over the world. The increase in temperature could lead to much more climatic problems that can eventually affect human lifestyle. The increase in temperature can be associated with the involvement of humans in the carbon cycle in which the amount of GHG that are released is steadily increasing throughout the millennia. This activity can cause a phenomenon called the greenhouse effect and is also one of the precursors of global warming.

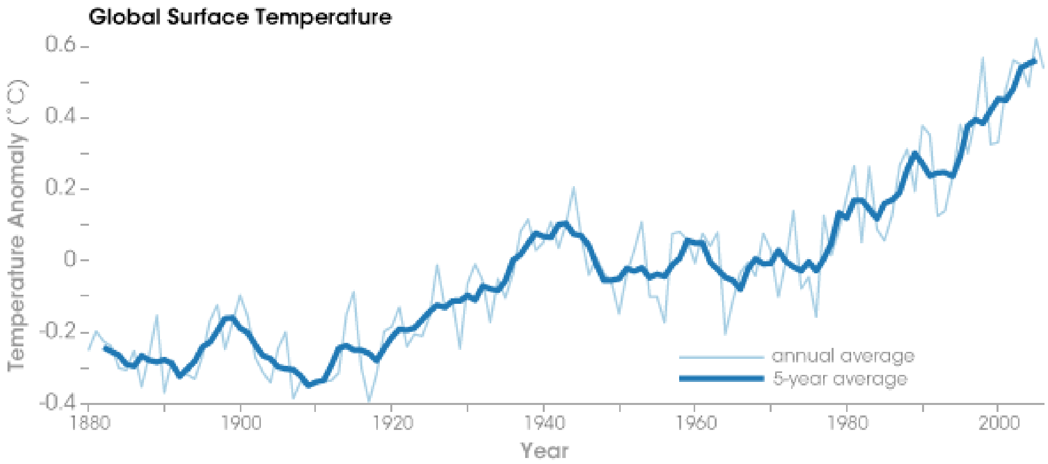


Figure 2.3 Global Surface Temperature

(https://www.metoffice.gov.uk/hadobs/hadcrut3/diagnostics/comparison.html)

Figure above shows the global surface temperature that is recorded from 1880 to 2000. There is a slow increment in the temperature in which there is a gradual increase in the annual average of the surface temperature and also the 5-year average of the surface temperature.

The increase in temperature can be directly linked towards the involvement of human activities during the industrialization era. With the industrialization era, and the founding of energies derived from fossil fuels and etc. these industries produce GHG that are the by-products of the items that are to be produced. The involvement of human activities in the industry has also accelerated the emission of CO_2 gas that is a GHG which can cause greenhouse effect. In the greenhouse effect, the trapped GHG affect the flow of solar energy and the heat energy in which the heat would be trapped in the stratosphere, causing heat waves to occur all over the globe. the process can occur many times considering the accumulated GHG in the stratosphere. The increase in GMST due to temperature lag for future forcing held constant is (0.09–0.19 K over 20 years; 0.12–0.26 K over 100 years).(Schwartz, 2018).

Even if the concentrations of all GHG and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.(IPCC, 2014) this sums that the amount of GHG that were released is enough to further increase the temperature of the globe by 0.1°C per decade without adding the values of GHG that were released from the factories. This slight incremental is enough proof that that the global increase in temperature is actually much nearer then what is anticipated. Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3] % per decade, with larger decreases in summer of 7.4 [5.0 to 9.8] % per decade. Mountain glaciers and snow cover on average have declined in both hemispheres.(IPCC, 2014). Also explains that with the increase in temperature, the Arctic sea ice has shrunk by 2.7% which is linked to the warming of the stratosphere mountain glaciers and the snow covers on the both hemisphere of the globe has declined because of the increase of the temperature of the globe and the common heat waves that are an unnatural occurrence in the globe.

The increase in temperature would cause a number of problems in the stratosphere. one of them is the rising of sea levels. This phenomenon occurs when the atmosphere is hotter than usual, causing polar ice caps to melt and hence increasing the water level. This is detrimental to humans as it may cause some of the earth’s land to be submerged by water if the situation is untreated and not paid attention to. Next the problem that is faced is the changing precipitation amount in several countries. Since the general understanding of precipitation that if precipitation depends on the amount of water evaporated which is directly linear to the amount of water exposed to the energy of the sun, can deduct that if more water is exposed to the energy or the rays that the sun is radiating, the rate of evaporation would increase, hence contributing to heavy downpours than usual rate hence increasing the amount of precipitation of several countries that experience monsoon seasons including Malaysia. This case brings both bad and good sides of climate as on it gives more water but too much of water could cause severe flood issues in the country. Also, uncontrolled downpour would result in expansion of desert in other dry regions as the precipitation shifts according to the wind paths around the globe.

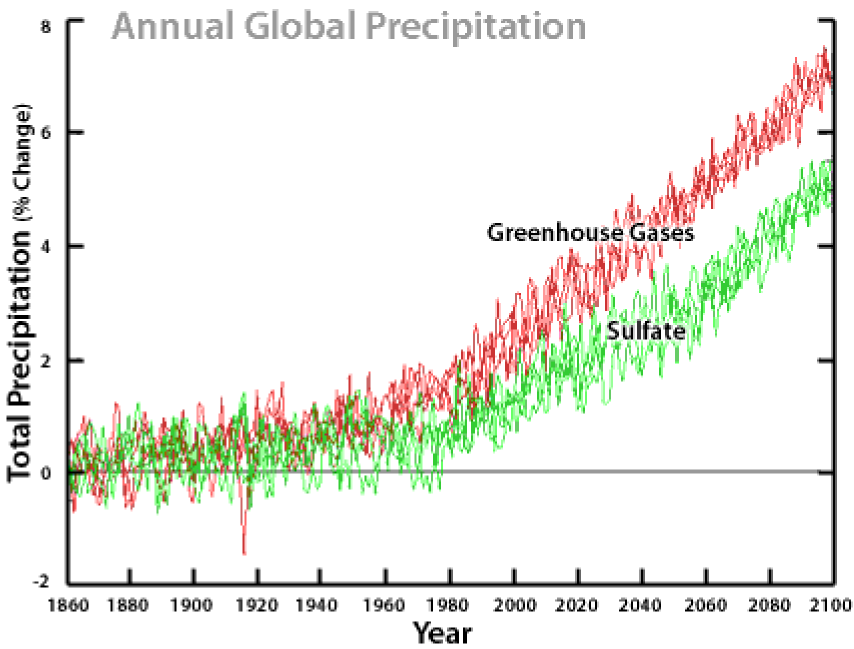


Figure 2.4 Annual Global Precipitation
(http://www.cotf.edu/ete/modules/climate/GCremote4.html)

The picture above shows the relationship between the total precipitation change and the amount of GHG and also sulphate in the air. With the presence of GHG in the air, the amount of precipitation increases as the amount of GHG increases.

Other changes that would happen are continuing retreat of glaciers at both polar ends of the earth, extreme weather conditions such as heat waves in certain places with high temperature initially which is dangerous to humans, draughts at certain places with minimal precipitation every year in which renders the place inhospitable due to the lack of water in the area. Wildlife are also affected by this increase in temperature causing climate change such as shifting of temperatures at a certain location in the ocean would cause the area inhabitable by the animals that were initially inhabiting the area due to temperature change.

Since the GHG are responsible for the depletion of the ozone layer in which humans depend upon from the sun deadly rays, it is safe to say that GHG are the culprit behind the reduction of the ozone layer as the blanket of protection that protects the earth.

2.2.2 Global Warming

Global warming is a phenomenon where the earth experiences intense warming period and it has its effects to the ecosystem the global warming is always associated with climate change where these two correlates with each other in terms of their capabilities and similarities of phenomenon that occurs due to what. Global warming is also defined as the increase in Earth's average surface temperature due to rising levels of greenhouse gases. In the Intergovernmental Panel on Climate Change (IPCC) 5^{th} Assessment Report states that the likely cause of global warming is actually driven by human actions since the mid-20^{th} century. These activities such as fossil fuel burning, open burning and the usage of refrigerators contribute to the rising levels of the greenhouse gases. These drive the levels of greenhouse gases to unprecedented levels in which affects the depletion of the ozone layer.

The relative changes in the indices related to extreme precipitation show significantly consistent linear changes with the global warming magnitude. Compared with the precipitation extremes, changes in temperature extremes are more strongly related to the global mean temperature changes. For the projection of the extreme precipitation changes, models show higher uncertainty than that in extreme temperature changes, and the uncertainty for the precipitation extremes becomes more remarkable when the global warming exceeds 5 °C. (Xiaoxin Wang and Dabang Jang 2017) this excerpt explains that with the increase in temperature, the precipitation also increases due to the amount of water evaporated hence making downpours more frequent in certain areas that its climate mainly consists of humid climate. But the precipitation rate is not really reliable because of the topography of certain areas that it's daytime is longer than its night time. Hence, the temperature of certain areas can be ascertained by observing the rainfall or the precipitation of the area. if they have a higher amount of rainfall than usual, it is viable to say that the temperature of the area was increased.

Under an additional 0.5 °C global warming, the projected increases of temperature in warmest day/night and coldest day/night are both more than 0.5 °C across almost the whole China. In Northwest China, Northeast China and the Tibetan Plateau, the projected changes are particularly sensitive to the additional 0.5 °C global warming, for example, multi-model mean increase in coldest day and coldest night would be about 2 times higher than a change of 0.5 °C global warming. (Chen Shi *et.al* 2018). This excerpt explains about the increase of temperature link to global warming. It is observed all over China that the amount of increase of temperature is directly linked to global warming whereas although the global warming can only go so far as 0.5°C but the daily temperature can rise more than that which means that the link between temperature increase and the global warming is verified as true.

IPCC holds that today's global warming is mainly due to anthropogenic activities rather than natural variability, which is emphasized by NIPCC.(Jian-Bin *et al.,* 2012a). The surface temperature observations since the mid-20th century support the hypothesis of anthropogenic impact, but for the last one hundred years or so, natural forcing such as solar activity, volcanic eruptions and thermohaline circulation variations also have had great influences on the Earth's climate, especially on inter-decadal timescales. There are differences between these points of views where the IPCC holds humanity account for the anthropogenic activities that ae the main cause of the global warming. These activities include open burning, fossil fuel burning and activities hat release greenhouse gases on air thus encouraging the depletion of the ozone layer thus increasing the potential risk of global warming. This differs from the NIPCC point of view as they consider the natural activities or phenomenon that are occurring on earth is the main cause of the global warming. These normal activities include solar activity, volcanic eruptions and etc. are the main cause of the global warming that has been occurring on earth since the mid-20th century hence further enforcing the theory that global warming is at large even before the industrialization era of the world.

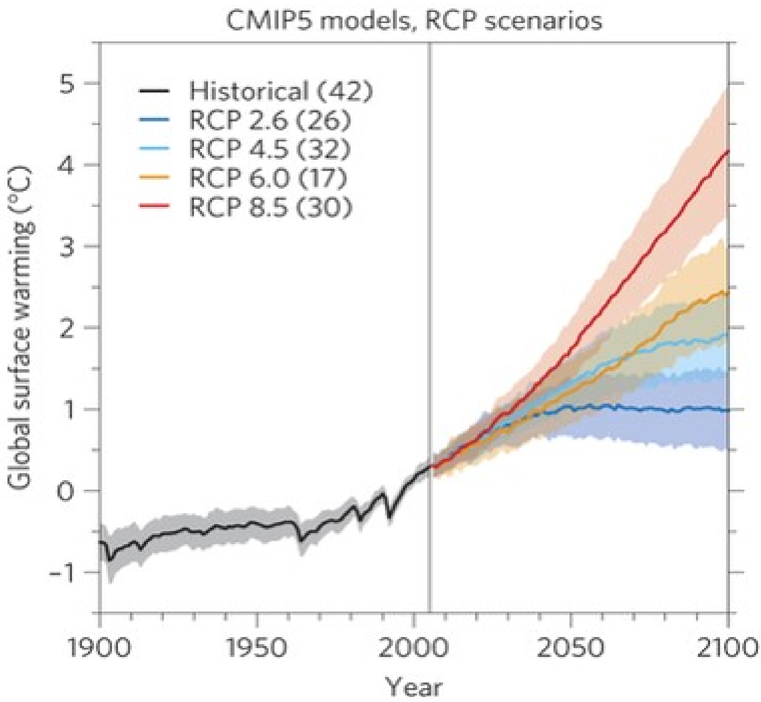


Figure 2.5 CIMP5 Models of RCP scenarios

(https://www.researchgate.net/figure/Intergovernmental-Panel-on-Climate-Change-IPCC-Graph-of-Future-Temperature-Change-under_fig2_310664999)

The figure above shows the global surface warming from the year 1900 towards the year 2100 (projected). The increase of the temperature or the global surface warming is because of the concentration and the continued emission of GHG that cover the stratosphere.

With the continued emission and the increment of the GHG that are present in the stratosphere, there would be continued increase of the temperature of the global surface. This trend follows of that RCPs in which it is expected to be a continuation of emission of GHG into the air and hence causing the stratosphere to have more quantities of GHG.

2.3 Greenhouse Gases

Greenhouse gases are gases that are by-products of the industry which contributes to the greenhouse effect that is happening worldwide. Direct emission of water vapor (a greenhouse gas) by human activities makes a negligible contribution to radiative forcing. (IPCC, 2014). These greenhouse gases contribute to the radiative forcing which is the mechanism of the greenhouse effect. The radiative forcing works as a precursor towards the greenhouse gases. Radiative forcing is an equilibrium between the heat absorbed by the earth to the heat released to the space. If the value for radiative forcing is positive, it means that the amount of heat the earth has absorbed is more than the amount of the heat that is released to the space. This makes the earth warmer and vice versa.

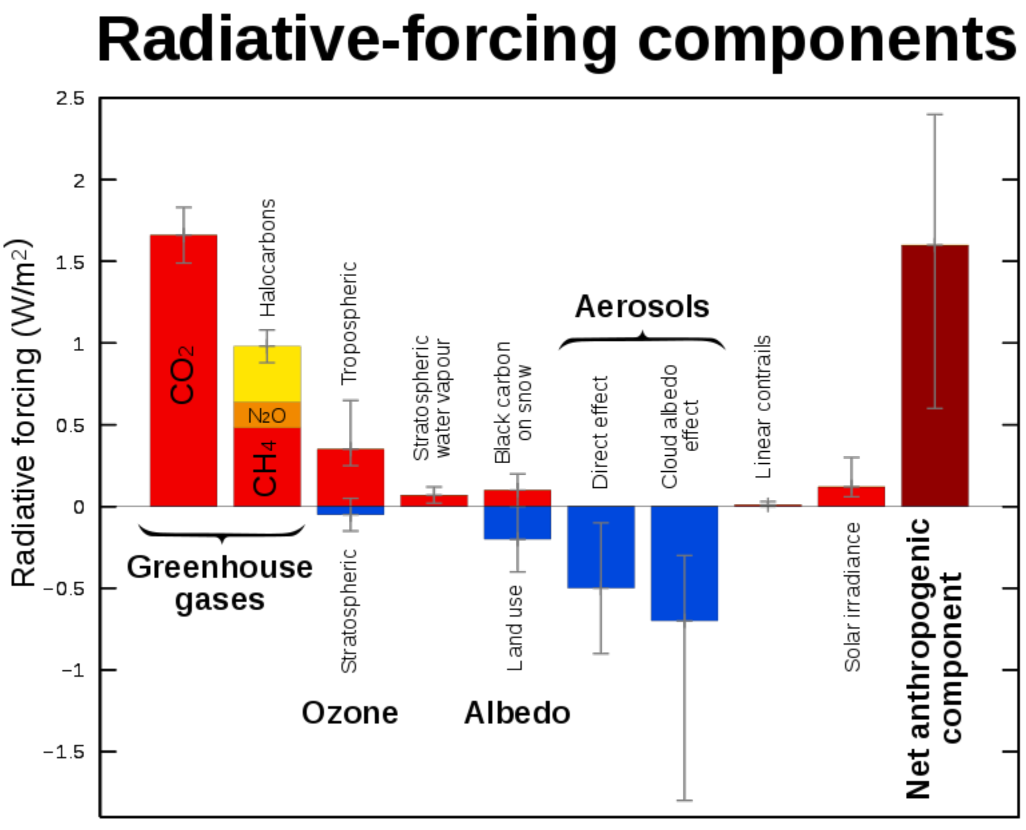


Figure 2.6 Radiative forcing elements in RCP

(https://en.wikipedia.org/wiki/Radiative_forcing)

Picture above shows the radiative forcing according to the gases that are available at the stratosphere. In the diagram, the components that has the most radiative forcing value is the GHG which is carbon dioxide, followed by halocarbons and nitrogen oxide and etc. the least radiative forcing component or the component which allows more heat to radiate to space is aerosols which allow the heat radiated from the sun to be radiated back towards space.

Some of GHG include carbon dioxide, methane, nitrous oxide, hydrofluorocarbon, perfluorocarbon, and sulphur hexafluoride. These gases normally exist in minimal quantities and are affected by the urbanization, population growth and the development of land in the region. These gases are not easy to dissipate, they take a long period of time to dissipate or to break down into simpler gases. These gases could stay in the stratosphere for long periods of time and can mix with other GHGs in order to form high concentration of GHGs in the atmosphere. so, it is a threat towards mankind as GHGs are actually what is causing the global warming towards the globe.

In addition, the global phenomenon that are widely occurring in Malaysia, in which the residents experience certain heat waves that are actually uncommon although the climate of the country is hot and humid. This phenomenon is called El Nino in which has occurred over a span of decades since the 1970 has bought one of the driest seasons in Malaysia which is 1963, 1997 and 2002. The drying of Peninsular Malaysia by this El Nino phenomenon cannot be stated as the worst phenomenon as the climate in the country is hot and humid, in which the residents of Malaysia experiences hot weather throughout the year, so this phenomenon that is occurring can be considered insignificant to Malaysia’s climate.

With the presence of GHGs that are lingering in the earth’s stratosphere, it is viable to say that GHGs production is man-made. Researchers working for the IPCC believes that the GHGs that are man-made as in they are by-products in the industry. Man-made items which uses coal or fossil fuels in burning to make the item produces the GHGs. As the amount of GHGs that is present in the stratosphere increases, the amount of radiative forcing increases and then it becomes a phenomenon in which is called greenhouse effect in which also can lead to global warming.

2.3.1 Components of These Gases

The effects of double CO_2 concentration on climate Swedish scientist Arrhenius in 1896 was the first to argue that the earth would become warming due to increased emissions of CO_2 from the burning of fossil fuels and other combustion processes [Arrhenius, 1896] (Jian-Bin *et al.*, 2012b) He estimated the global average temperature to rise about 8◦F (or 4.5◦C) in the scenario of double CO_2 concentration in atmosphere. It is usually called equilibrium climate sensitivity (ECS) and very close to the upper limits in the subsequent IPCC Assessment Reports, although this estimation was calculated only with a simple one-layer model at that time. From this citation, it is deduced that the main contributors of global warming are from the emission of CO_2 gases on the atmosphere. These emissions came from human activities such as fossil fuel burnings and etc. It can also be deduced that there are many other conspirators that are by-products of human's activities such as NO_2 and many more that contribute to the increase of temperature of the earth hence contributing to the global warming of the earth.

A pioneering research is Manabe and Wetherald [1975]. This paper investigated effects of double CO_2 concentration on the climate using climate models (usually named ECS experiments) and indicated that the global surface temperature would increase 2.93◦C. This value locates within the range (1.5–4.5◦C) and particularly is very close to the best estimation (3◦C) of the First World Climate Conference (FWCC) and the IPCC First Assessment Report (IPCC FAR) (Jian-Bin *et al*., 2012a). This explains that there are differences of views on things that make the global warming evident.

2.3.2 Climate Affected by These Models

From the title above, it is general knowledge that having greenhouse gases affects global warming in which it is evident in certain countries. These countries such as China in the Beijing province in which the temperature is increasing annually. This increase in temperature can be seen around the world in which the most evident is the polar regions in which the ice is melting annually. These climates that are evolving due to the phenomenon mentioned above is a natural occurrence throughout the world. In the modern age. A temperature rise of 5C would affect local, regional, and global ecosystems; sea levels and ocean currents; prevailing winds; fresh water supplies; agriculture; forests; fisheries; industry; transport; urban planning; demographics; and human health. John M Last (1993). This article describes about how an increase of temperature as minimal as 5C can affect the globe in different ways. Ecosystems that depends on water experience much more effect but ecosystems that are land based are no less affected by the change of the temperature. In this case, the ecosystems which depends on water would experience disturbances such as reduced levels of water promoting the deterioration of the ecosystem in which animals cannot live in. land ecosystems, such as desert biomes, grasslands biomes would experience deterioration in terms of there is insufficient water in these areas such that animals that live in the biomes cannot continue to live as the water supply becomes short due to the global warming scenario.

In the agriculture scenario, the global warming due to the greenhouse gases could cause reduced resource production in which with the heat increasing, crops would get drier than wetter because of the lack of water in these agricultural areas. This in term would lead to decreased productivity of the crops and hence the production from agricultural-dependent countries can eventually dissipate, meaning that the production of agriculture which is their main source of income through export, potentially would dissipate. The lack of moisture in soils also affects grain product. As grasslands get hotter, they dry out because of the heat and then would cause extreme biome changes or ecosystem changes. Then these lands would be deserted as the crops are not productive and the lands would become barren wastelands as more and more vegetation leaves the land and hence the biome is lost due to the effect of global warming caused by greenhouse gases.

In certain areas of Malaysia, it is observed that there are lots of deforestations occurring throughout the country for development. These developments include or housing precincts, sections, agricultural lands and even these deforestations occur for the value of the wood that is gained from the cutting of trees. These hardwoods are sold for a high price in the market for their aesthetical value and for various uses including furniture and many more. These deforestations impose a toll on the absorption of CO2 in which it decreases the rate of absorption of carbon dioxide that is already present in the air produce from many human induced activities and natural causes. This in turn would cause depletion of the ozone layer.

Another climate change that is affected by the global warming is the rise of the sea levels in several areas. These increase in sea levels are caused by the melting of polar ice caps that are happening in the Arctic and Antarctic areas of the earth. These polar ice melting has been ongoing for many years such that can be gradually see the differences of height of the polar ice caps which can be seen in photographs and in records containing information about the polar ice caps. This affected ice caps would gradually cause an increase of sea water which would cause the flooding of coastal areas. In worst case scenarios, the rise of waves that are occurring in certain coastal areas can be detrimental to residents living on the coasts.

2.4 General Circulation Model

Generally, two types of downscaling approaches are employed, which are known as dynamic and statistical methods. The dynamic downscaling techniques, such as nested or regional climate modelling, are performed by nesting a physically based, small spatial resolution regional climate model within the grid of a GCM output. (Najafi *et al.*, 2011).The function of GCM is also to explain the environment, the seas, topography living organisms and the solar influence and as well as other thing that are living under the Earth's atmosphere by using mathematical equations. In the computer. Furthermore, with the newly developed statistical equations that can be used in GCM, it is plausible to predict and project the planet's climate in the future. In global climate, it is accepted that small changes in the temperature, precipitation and the amount of GHG in one area could cause a lot of changes towards the climate in a specified area. GCM has been used in many studies regarding climatic changes to investigate the causes and to investigate, project and predict the future climate at a certain location. The researchers have done various researches regarding to the climate trends of a specific area, the causes of the trend and how it affects the projected climate in the future. The large grid scale of the model output ranges from 250km to 600km. thus, in order to gain an accurate representation of the GCM in a certain area that is in the grid scale of the model output, downscaling of the data is required in order to get an output of the area in research.

These models are created based on computation which rely on statistical data and mathematical equations in order to project the climate of a certain area. At first, mathematical ideas prove to be useful to predict and deduct the climate in 1920s but in 1950s, the weather forecasting proved to be easier with the use of digital computers in which the United States and parts of Europe fully utilized computer-generated weather forecasting. With the implementation of computers into climate projection which also includes sophisticated mathematical calculations and formulas, climate projection is possible and it is even plausible for mankind to prepare and to adapt or mitigate the effects of the climate in the near future.

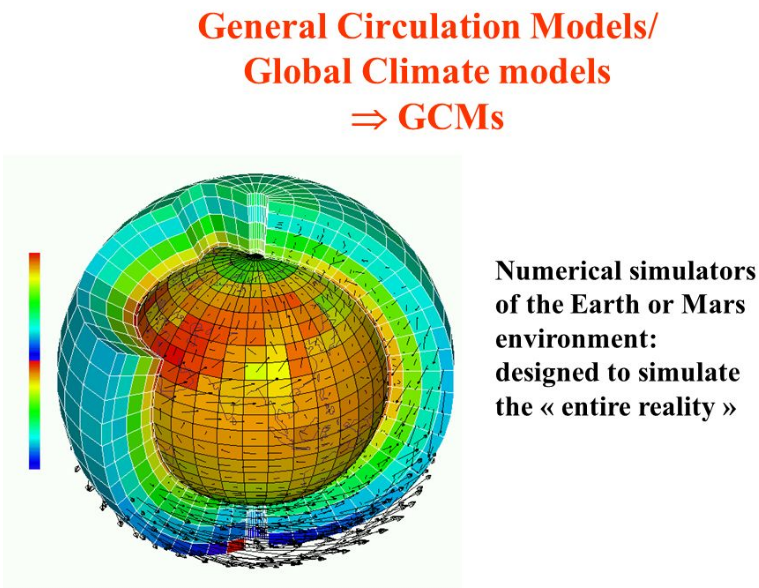


Figure 2.7 GCM concept

2.4.1 Fourth Assessment Report

The Fourth Assessment Report (AR4) is the fourth report in a series of reports pertaining to assess scientific, technical and socio-economic information concerning climate change, the effects of climate change and the options that are available to adapt and mitigate or curb the climate change. The report as it is, the largest and most detailed summary of climate change situation. It is produced by thousands of authors, editors and reviewers from a dozen of countries, citing more than 6000 scientific articles.

AR4 focuses on the climate itself as in whole. Since the publishment of AR4, the scientific understanding of past and future climate change has made substantial progress since the finalization of the IPCC WG1 AR4. New Knowledge includes improved analysis of prehistoric climate shifts, updated observations of recent climate change, better attribution of the causes of observed climate change to anthropogenic and natural factors, improved understanding of carbon cycle feedbacks and new projections of future changes in extreme weather events (Hans-Martin,2008) this excerpt of the article shows that after the publishment of AR4, there are many advances in the field of climate including the analyzation of prehistoric climate shifts, the observation towards unnatural occurrence in the climate, a better understanding of the causes of these unnatural climate change to anthropogenic and natural factors, the understanding of carbon cycle feedbacks, whether one imbalance of elements would affect the cycle or not and finally the projection of future climates according to the general climate trend nowadays. It is a substantial amount of advancement, but supposedly mankind has to anticipate the worst-case scenario for both the general trends and non-general trends and project what would happen in the few years to come and come up of a way to mitigate, to curb or to negate the bad effects of the climate change.

The average annual melting rate of mountain glaciers has doubled after 2000, in comparison with the already accelerated melting rates observed in the two decades before. [UNEP/WGMS, 2008]. This excerpt concludes that the rete of melting of polar ice caps since the establishment of AR4 continues to rise and is already accelerated from two decades before. The rate has now doubled due to the fast-paced industrialization nowadays hence provoking the increase of the rate of melting of the ice caps. Although several measurements have been taken, it is considerable that these actions have not bring any kind of benefit towards the betterment of the polar ice caps in the Arctic and the Antarctic. As a community that is well aware of the climate change and how it affects humans in later times, it is imperative to start proactive steps to mitigate, curb and to reduce the melting of the ice caps in the Arctic and Antarctic areas. This can be done by having several policies bout the emission of GHG in countries which mass produces GHG as a by-product. This step can be taken to actively counteract the effects of GHG on the melting of polar ice caps and help to mitigate and slow down the progress of the GHGs on the climate change and eventually slow down climate change to a reasonable rate.

2.4.2 Fifth Assessment Report

The Fifth Assessment Report (AR5) of the IPCC is the fifth report that supersedes the AR4. It is established in 2014 to assess the technical and the socio-economic information concerning the climate change, its potential effects and the options for adaptation and mitigation. The outline of the AR5 was developed through a scoping process which involved experts on climate change from the relevant disciplines and the users of the IPCC reports. People involved with the making of the fourth report were asked to give comments and observations in writing the submissions that were analysed by the panels. The submission began with the Working Group 1 on the Summary for the Policymakers and the Physical Science Basis. And to the other groups. There are 4 Working Groups and all of them worked on specific topics concerning climate change. Mainly the AR5 focuses on the update of knowledge on the scientific, technical and economic aspects of the climate change.

An understanding of the temporal and spatial characteristics of precipitation is hence central to water resources planning and management, especially given the evidence of climate change and variability in recent years (Liu *et al*., 2015). The rising atmospheric moisture content associated with warming might be expected to generate an increase in mean global precipitation (Almazroui *et al.*,2012). Both of these excerpts explain about the management of precipitation. With the increase of the atmospheric water content which is also associated with the global warming that is also the global trend of the climate nowadays. Further planning must be done in order to help plan for the heavy precipitation that would occur in the next few years. These precipitations have to be planned as to bring the best benefits toward agricultural planning, flood frequency analysis, flood hazard mapping, hydrological modelling and assessments of water resources. This in turn helps to negate excessive water if there is excessive precipitation and also helps to preserve water when heat waves strike frequently during the next few years to come.

Studies by (Gamoyo *et al*., 2015a) have projected likelihood of enhanced rainfall in East Africa. The results are supported by IPCC (2014) that this is due to global warming, which has resulted from increased anthropogenic emissions of greenhouse gases GHG. (Ayugi, Wang, & Chepkemoi, 2016) With this, it is a clear cut that the culprit behind the increased precipitation in the East Africa region. This precipitation increase is due to the interference of GHG in the area. This is quite uncertain as it is only a projection of the future by GCMs. These models can predict the outcome of the future by overseeing pattern of climate and the climate trends that accompany the climate and its frequency of it to occur.

2.4.3 Differences Between AR4 & AR5

AR4 or the Fourth Assessment Report uses the SRES system in which the emission scenarios are defined into 4 scenarios in which it uses the storyline approach where the researchers defined the storyline of human actions that might contribute to the contents of the GHG and hence to the mean global surface temperature. This approach takes account of human actions whether they are voluntarily or involuntarily. The researchers took the approach of defining the storyline of how the world would be in terms of sociography and demographically, how would the economy of the world would be, the resources used and the technology. Then they made up the implications of the GCM models which incorporates all of the guidelines above and then they made up possible emission scenarios based on the GCM models that have been altered with the storylines.

According to the IPCC-AR4, there is great uncertainty regarding the simulated rainfall. This uncertainty is a result of the lack of quality of the coupled ocean-atmosphere models in representing the amplitude and frequency of El Nino events, and primarily in representing the surface temperature variability. In addition, the IPCC-AR4 projections did not include the carbon cycle in the atmosphere-ocean system or the potential influence of vegetation and land use on the regional climate (Alves *et al.*, 2016). With this, it is evident there are loopholes in the model of AR4. The model requires more improvements thus the IPCC created AR5 to supersede the AR4.

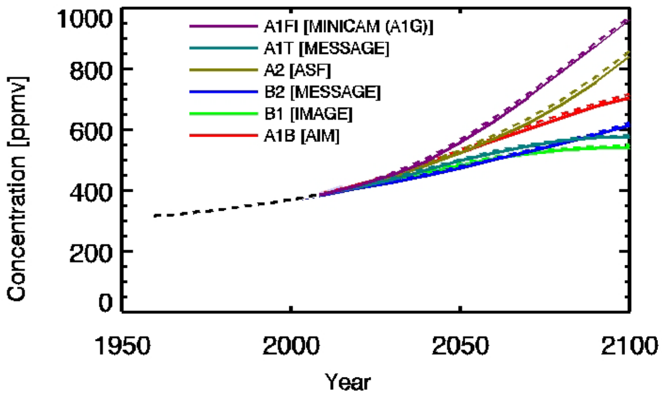


Figure 2.8 SRES emissions scenarios with the amount of GHG in every scenario (https://www.ipcc-data.org/observ/ddc_co2.html)

Recently, under the fifth phase of the Coupled Model Intercomparison Project (CMIP5) some global circulation models have been updated to deliver in the near-term experiments, as part of a forecast system, a full prediction of climate change (Vargas *et al., 2013).* In the AR5 or the Fifth Assessment Report, the IPCC devised a new system called the Representative Concentration Pathways or RCP. This RCP system involves all that was in SRES system but also involves policy handling and legislation of a certain area. this system uses an indirect approach in which the researchers used an endpoint to define the storyline. In SRES, the storyline was defined first by the researches but in RCP the storyline was created first followed by the "representative" way to get to the endpoint. Both RCP used the same measurement point in which they used carbon dioxide as the indicator for their pathways. The only difference in RCPs and SRES is the approach that is used by the researchers and their endpoints. The need to usefully interpret inconsistent model simulations has spurred numerous assessment efforts aimed at quantifying uncertainty in projections and increasing the reliability of projections. (Vavrus *et., al* 2015).

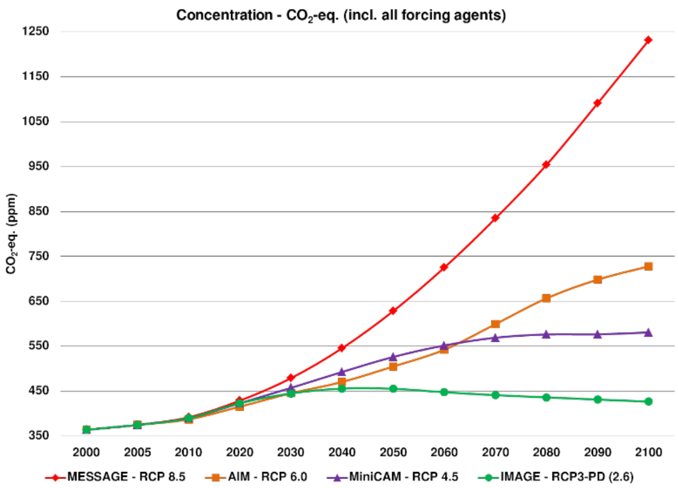


Figure 2.9 Graph of RCP scenarios againts carbon dioxide emissions (https://earthscience.stackexchange.com/questions/13577/are-we-now-and-or-have-we-been-in-the-rcp8-5-scenario)

2.4.4 General Circulation Model

A general circulation model (GCM) is a climate model which uses mathematical equations of the general circulation of the atmosphere or the ocean. The model uses equations to calculate thermodynamics or terms for energy sources (radiation, heat). These equations then become the base of the computer to stimulate the Earth's ocean or atmosphere. GCM are mainly use for weather forecasting, understanding climate and projecting climate change. This helps in predicting the future climate based on climate trends.

Generally, GCMs represent conditions related to biogeochemical processes, land surface, ocean, cryosphere and atmosphere on a geo-graphical grid, which covers the globe. Different GCMs use different climate modelling systems that depend on the representative institute which provides the related data. (Faiz *et al.*, 2018).By this statement it is seen that by having GCM can help in determining the conditions of a certain area interpreting the data gained. The GCM also gives an accurate model of the condition of the particular area that is being researched. In contrast, the GHG scenario and spatial resolutions of GCMs differ, making it hard to identify the current situation of an area without more in-depth experimentation.

The statistical downscaling methods based on statistical relationship between local/regional variables and large-scale climate information, while dynamical down-scaling methods employ regional climate models (RCMs) for limited regions with boundary conditions from GCM simulations (Maraun *et.al.*,2010). With the implementation of these two models, namely GCM and RCM, it is plausible to eliminate information that is out of bounds from the field of research or the research scope. Since the research scope is only towards certain areas so it is viable to generate regional climate models. These regional climate models require a systematic downscaling towards the desired region. Taking Malaysia as a whole, through systematic downscaling, the regional climate models of certain areas such as Kelantan, Negeri Sembilan, can be assessed and known. This systematic downscaling is done with precision such that it is easy to obtain RCMs easily without any blockades towards it.

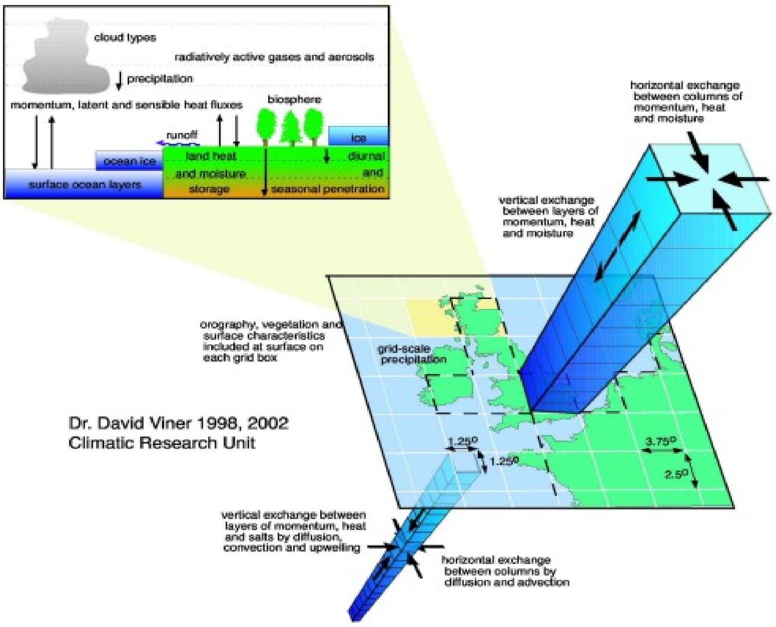


Figure 2.10 Gridlines in GCM models (https://jancovici.com/en/climate-change/predicting-the-future/what-is-a-climate-model-what-are-the-models-first-conclusions/)

GCMs offer reasonable simulations of climate variables at coarse spatial (e.g. continental and hemispheric) and temporal (annual and seasonal) scales. But, they are unable to provide information at local scale for impact studies of water resources at a drainage basin (Chen, Yu, and Tang, 2010). From this excerpt, it is reasonable for us to use GCMs as they offer simulations of climate variables at coarse spatial and temporal scales which fits the aim of the study which is to assess the climate trends of the area of study.

2.5 Types of Climate Model

GCMs represent atmospheric and ocean circulation in a series of equations describing physical properties of gases and fluids. Each set of equations is solved for a volume of air or water, typically with dimensions of hundreds of kilometres. (Hannah, 2015)As GCM oversees both air and water calculations, it can be divided into three parts which is atmospheric, oceanic and coupled GCM. Both atmospheric and oceanic models are as seen as models in their own respective environments but in coupled models, which incorporates both oceanic and atmospheric models and is regarded as an advanced model by certain researchers, joins these two environment models and their nature and the threats that come with them also.

2.5.1 Regional Climate Model

Climate models are models that use quantitative methods to stimulate the interactions of the drivers of the climate, this includes the atmosphere, ocean, ice and land surface. Generally, the Game or the General Climate Modelling which is modelling in a large scale. But to prioritize and eliminate other scopes that are not relevant with the scope, downscaling is used in the research. Downscaling is a term used by which data of the climate is used for fine spatial scales to create Regional Climate Modelling. In other words, a small scale GCM. The RCM encompasses all that the GCM has, the only difference between the two models is that one is general, meaning it is global in size whilst the latter is downscaled and perfect to focus on a specific region only. There are quite a few methods pertaining to the downscaling, which is by statistical downscaling or by dynamic downscaling.

Generally, RCM can be used with a grid box size of as little as 25 km or less. RCMs need to be supplied with the values of required fields at their boundaries, these data can be obtained through the global climate models or from observational data analysis. If predictions are to be made about the future climate, the data from the GCM must be obtained and downscaled. RCM requires its data to be supplied continuously so it is always run within a GCM that can provide a continuous supply of data.

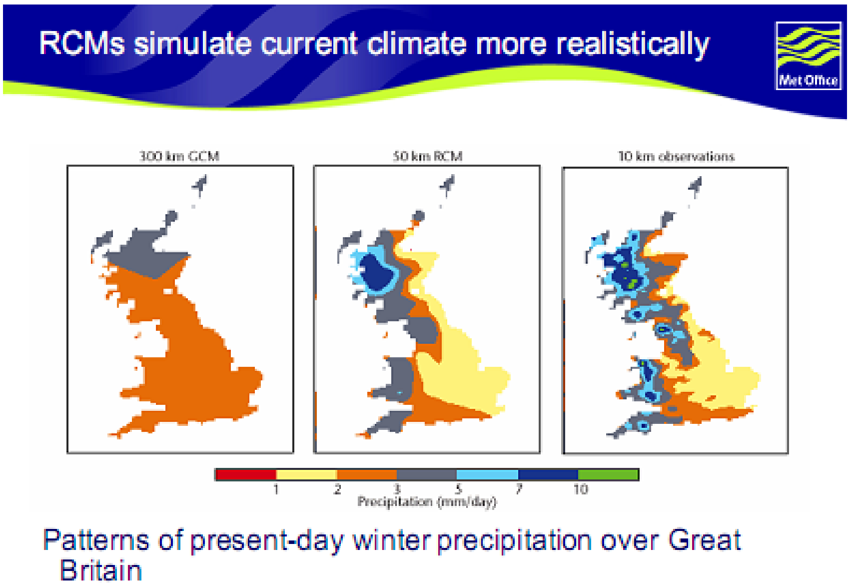


Figure 2.11 RCM Simulation example
(http://wikireedia.net/wikireedia/index.php?title=Regional_Climate_Modelling)

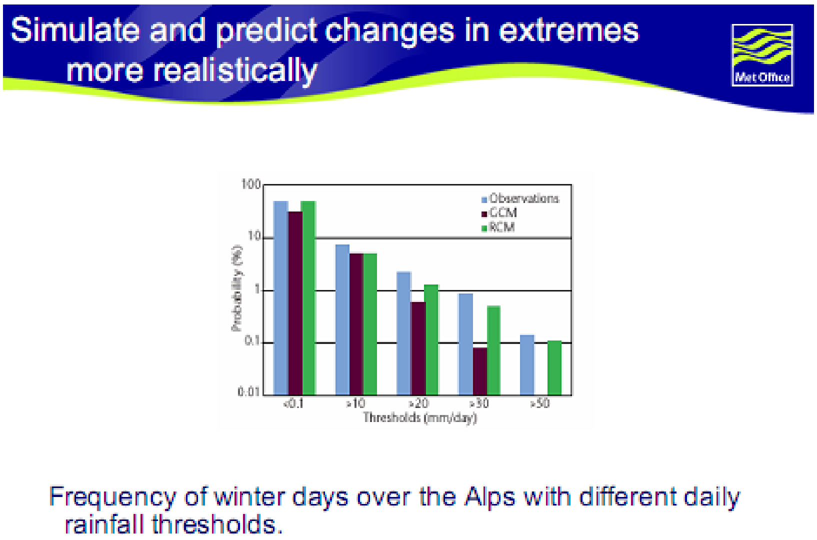


Figure 2.12 Graph of RCM Simulation

(http://wikireedia.net/wikireedia/index.php?title=Regional_Climate_Modelling)

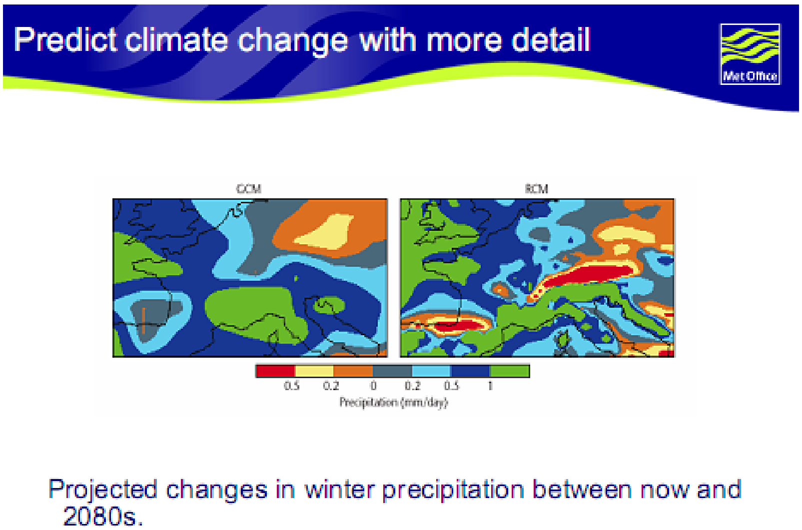


Figure 2.13 Projected change in precipitation

(http://wikireedia.net/wikireedia/index.php?title=Regional_Climate_Modelling)

2.5.2 Dynamic Downscaling

Dynamic Downscaling is a downscaling that produces a high-resolution global atmosphere models or regional climate models. The output of these models is self-consistent and does not involve the usage of relationships that are based on statistical evidence. Hence this method enables a more reliable further projections because it is not linearly dependent on evidence. This method also enables climate change to be made at finer spatial scales, meaning every inch and every nook and cranny for the changes in climate can be seen. It also provides complete information of the region that is currently being simulated.

Dynamical downscaling has been used by many countries, most of them use dynamical downscaling as a Weather Research and Forecasting (WRF). Of the examples of states that use WRF is New Zealand to study fire weather (Simpson *et.al.*,2014) in South Africa for vineyard studies (Bonnardot *et.al.*,2011: Soltanzadeh *et.al.*,2016), this proves that dynamic downscaling is a useful tool to dynamically downscale from the synoptic and larger scale atmosphere circulation in order to provide a high-resolution analysis of weather and climate in regions of complex terrain.

One of the issues for dynamical downscaling is that the amount of time needed for computing in order to achieve fine resolution. It takes up a lot of time since every GCM output for an area to be regionalized to specific areas on the Earth's surface by combining equations that are associated with continuity, momentum and thermodynamic process with surface characteristics of the region of interest such as terrain and the usage of land.

Dynamic downscaling techniques are associated with high computational costs (Sun and Chen, 2012) due to the complex physics-based structure of the RCMs. However, owing to the use of physics-based equations to relate the predictors (GCM outputs which are used as input to downscaling models) with predictands (outputs of downscaling models – e.g. precipitation), dynamic downscaling techniques are capable in producing more reliable climatic information at local scale. (Sachindra *et al.*, 2014). With dynamic downscaling, the models can be done but with a slower pace and an expense is needed

2.5.3 Statistical Downscaling

Statistical Downscaling is a downscaling system that makes use of derived relationships between the variable of interest (area, object of interest) with the larger-scale field. If a wind has a high correlation to precipitation, then the changes in the wind might infer changes to future precipitation. The computation requires a lot of information to be present at the time and it might not hold true under the changed climate conditions as such it is only linearly dependent towards equations based on statistical evidence. it is safe to say that if there were no climate change, then statistical downscaling would always be correct as it is reliant on equations that are linearly change without outside influence. So then if climatic change that is happening nowadays is taken account for, then the statistical downscaling might not be the best downscaling system to be used as it is linear. But for present times and studies, statistical downscaling is the best way to obtain RCM.

Statistical method of downscaling works by predicting local climate through establishing a relationship between smaller scale variables with larger scale variables. One of the methods of statistical downscaling is to use regression models and stochastic weather generators or weather typing (Le Roux *et al.,* 2018). Widely known for its capability to handle a large amount of multi-dimensional data, Support Vector Regression (SVR) statistical method is useful for areas which has a variety of data with different dimensions. SVR has been carried out in many cases such as vegetation mapping using temporal series by (Betheder *et al.* 2014), downscaling temperature (Anandhi *et al.*2010) and precipitation (Chen *et al.,* 2010).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The main aim for this study is to assess the difference of performance of AR4 and AR5 in terms of rainfall and temperature and find out the best RCPs representing Kelantan and Terengganu for the year.

The framework of this study consists of (1) Getting the data for the GCM for CIMP5 (CanESM2) and to run it under different scenarios. (2) Downscale the data by using the Statistical Downscaling Models (SDSM) (3) Identify the climate agent that is present in the scope of research and classify it according to the AR4 or AR 5 (4) Project the rainfall, the maximum and the minimum temperatures corresponding to the next 100 years and to be able to present a projected climate of the scope of the study. In the next few pages, the study area, data and models, methods are discussed.

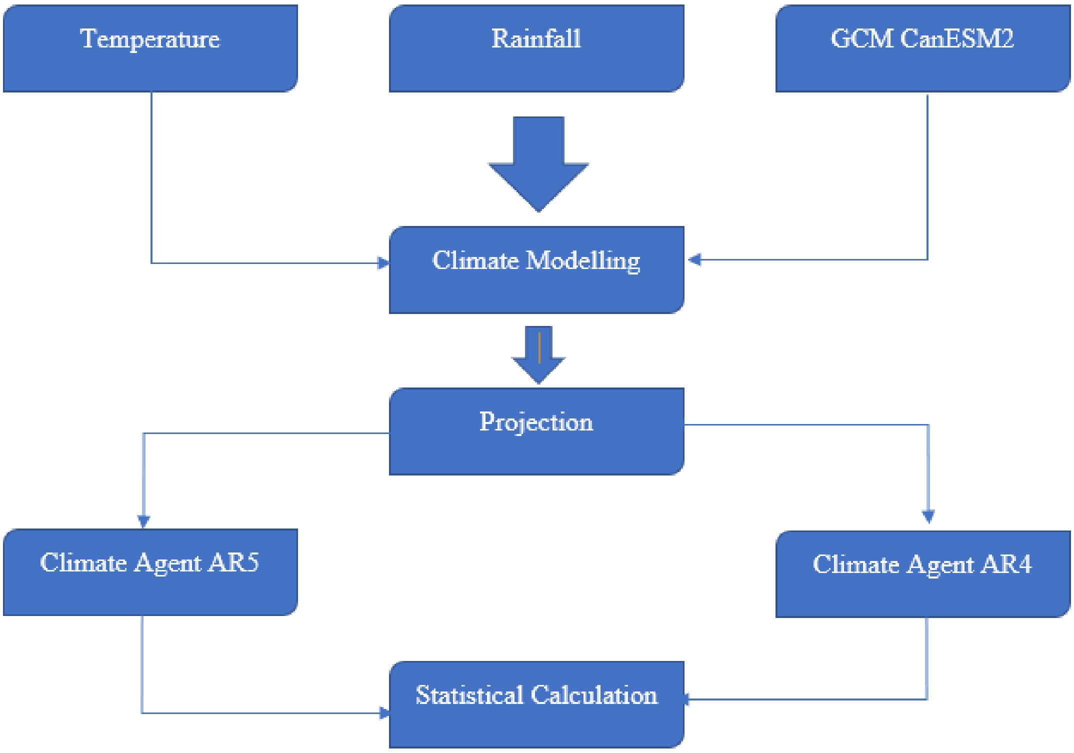


Figure 3.1 Methodology of the study

3.2 Statistical Downscaling Model (SDSM)

The Statistical Downscaling Model (SDSM) is a tool that was given out freely for those wanting to study climate simulation analysis. Its's creator, Wilby *et. al.* (2002) emphasized the models to be used widely in hydrological areas as it provides station climate information from the grid resolution GCM-scale output using multiple regression techniques. It has a relationship between GCM's variables which acts as it's predictors, while it acts as the predictands. Chu et. al. (2010).

The SDSM models are cost efficient since it is for free. It was also easy to compute and only requires a basic understanding of how the models work. It is a hybrid model as it requires us to determine the rainfall whether it occurs on which day and which day that it didn't rained.

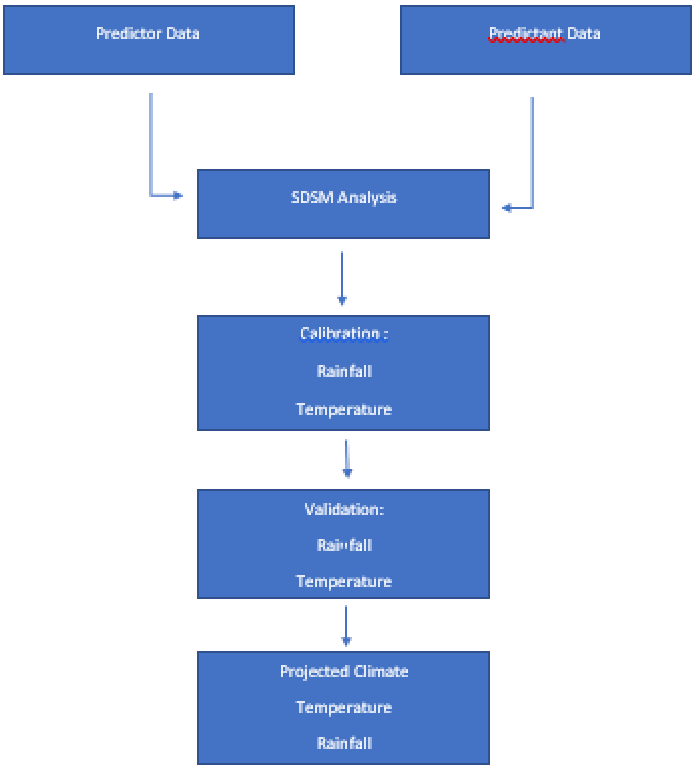


Figure 3.2 General layout of methodology coupled with SDSM usage

The climate projection would be presented in monthly or annually according to the demand of the analyst. By using SDSM, the standard error of estimation and the number of explained variance using bias correction variance inflation techniques can reduce standard error of estimate. SDSM does not require high computational skills but still from basic computing skills, high quality of projection results can be obtained. The advantages of the SDSM has made it a reliable tool for climate downscaling (Muluye, 2012, Samadi *et. al.* 2013, Tukimat and Harun, 2015). Thus, it was selected as the perfect downscaling tool to generate the projection of the climate of the study site.

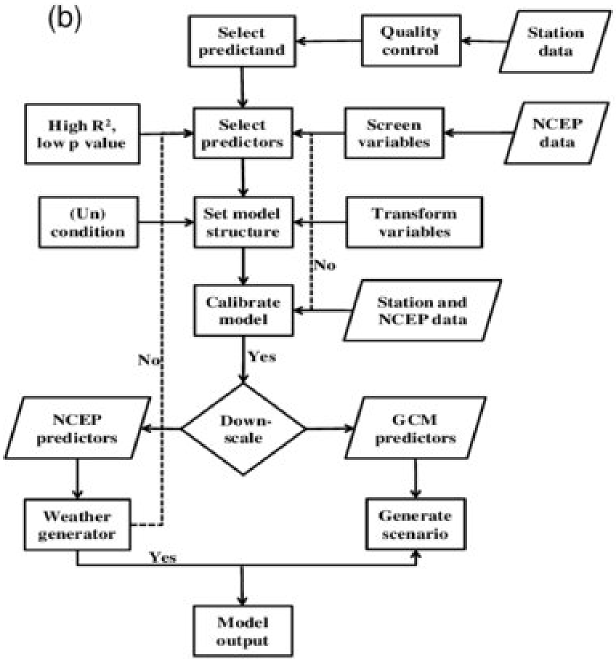


Figure 3.3 Full SDSM Methodlogy of the downscaling method

Figure above shows the schematic diagram of the methodology of the SDSM model. In order to downscale the model to local climate change, two types of data are required which was the temperature and the rainfall of the area of the study. These data are known as predictand and two sets of predictors. In the study, the temperature recorded at both Kelantan and Terengganu and rainfall stations throughout both counties were used as predictand. The selection of rainfall station on these two corresponding counties were based on the rainfall data in which the set of the data has to be complete in order to control the quality of the data and the originality of the data set. The data were presented in daily time series and can be converted into months, annual period for analysis purposes. The predictors were obtained from the National Centre for Environmental Prediction (NCEP) and was used for calibration and validation of the data. The GCM-variables were recalibrated and validated to generate the projection of future climate based on the expected increment of GHG at the region.

3.3 Atmospheric Characteristics of the GCMs

CIMP5 (CanESM2) has been chosen as a predictor variable in the Peninsular Malaysia. The location of Terengganu is at 5.207 latitude and 102.93 longitude. For Kelantan county the latitude is 5.858 and the longitude is 102.279.

The selection of prediction variables is shown in the table below. These predictors were the derivation of the daily reanalysis data set from the NCEP. The selection of the variables is the most arduous task of the SDSM as the different atmospheric predictors control different local variables and would affect the outcome of the predictand. To avoid this from happening towards the research, the predictors was chosen from sensible, consistent that correlates with the predictand and accurately modelled by GCMs (Wilby and Dawnson,2007).

Table 3.1 Predictor List

No.	Predictor Variable	Description of Predictor	No.	Predictor Variable	Description of Variable
1	Mslp	Mean sea level pressure	14	P5zh	500 hpa divergence
2	P_f	Surface air flow strength	15	P8_f	850 hpa airflow strength
3	P_u	Surface zonal velocity	16	P8_u	850 hpa zonal velocity
4	P_v	Surface meridional velocity	17	P8_v	850 hpa medional velocity

5	P_z	Surface vorticity	18	P8_z	850 hpa corticity
6	P_th	Surface wind direction	19	P850	850 geopotential height
7	P_zh	Surface divergence	20	P8th	850 hpa geopotential heght
8	P5_f	500 hpa airflow strength	21	P8zh	850 hpa divergence
9	P5_u	500 hpa zonal velocity	22	P500	Relative humidity at 500 hpa
10	P5_v	500 hpa meridional velocity	23	P850	Relative humidity at 850 hpa
11	P5_z	500 hpa vorticity	24	Rhum	Near surface relative humidity
12	P500	500 hpa geopotential height	25	Shum	surface specific humidity
13	P5th	500 hpa wind direction	26	Temp	Mean temperature at 2m

3.4 Construction of The Climate Change Scenario

The parameter of the distribution for a site with the changes of climate change using the GCM output to generate daily, monthly and annually meteorological based on the climate scenarios. The difference in emission projected by GCM was the changing parameters in the future and the baseline period is the weather observation. With relative changes including the current in the different statistical parameters are also prepared for each period in the GCM outputs.

3.5 Calibration & Validation Process in SDSM

Before performing the analysis, first performed calibration between runoff and rainfall that occurred in the Liliba Watershed in the city of Kupang and surrounding areas, so that the results of the analysis are expected to be like the real situation. From. (Sidharno, 2016).The calibration and validation in SDSM are important procedure during projecting climate. The mathematical equation from (Croarkin and Tobias 2012) the calibration is a process that measures the assigned values to the property of the artefact or the response of a in instrument relative to reference standards or to designate measurement process. The calibration precisely referred to the design/build among local data and the selected regional atmospheric variables based on multiple regression equations (Wilby and Dawson, 2007). The calibration was formulated using specific period as the basis to estimate the combination of predictor variable values in validation process. The main objective is to know the fundamental rules and the predictand-predictor relationship that is adequate to be as an original data.

The calibration and validation model were constructed from multiple screening processes aimed at determining the best predictors that corresponds towards the climate trend of the area. the calibration and validation must not exceed an error amount of more than 20% when compared with the historical data obtained. This was to avoid and mitigate the inaccuracy of predictors as a different graph of calibration and validation would project a different projection when compared with the historical projection hence making the projection unusable for the research purposes.

The calibrated model was used to build the predictand-predictor relationships in the analysis of SDSM. The relationships are used to stimulated and generated synthetic daily weather series by using weather generator. Therefore, the temperature was calibrated for the time period from of 1987-2017 which is the same for the calibration for the rainfall. By using the same GCM predictors variables in the calibration, the ensembles of synthetic daily weather series during the years are generated using scenario generator in the SDSM model.

After the calibration and validation of the model constructed with the screened predictors, the model was made sure to not have error percentage more than 20. The model which fulfil the criteria would be further processed within SDSM model in order to project the climate of the area. then the projected climate was compared with historical data to account the differences in temperature and rainfall of the area.

3.6 Location of Study

The location of the study area is at Terengganu and Kelantan counties. In Malaysia, the climate is hot and humid so the expected weather is to be either sunny or rain and since Malaysia is also influenced by the Monsoon thus making most parts of Malaysia receiving heavy downpour (Wang et. al, 2003; Kale and Hire, 2004; Sultan et. al. 2005; Colin et. al.;2010, Pai and Al-Tabba, 2010; Pattanaik and Rajeevan, 2010). The inter annual monsoon variations can be shown in the variation of climate that was present in the year to year variation of climate of the seasonal transition. Since Malaysia was a hot and humid country, the climate is mainly affected by the four seasons that happen across the world.

Both Kelantan and Terengganu are located near to the South China Sea. Therefore, the climate of these two areas are influenced by the northeast monsoon wind flow pattern. The monsoon season is from November to March, which is also known as the wet season of these two counties. With the country developing at a fast rate and the monsoon sweeping over 1/3 of the total months in a year, the temperature and the rainfall of the area should be affected by the amount of development that is currently ongoing. By referring to data that were historical, the rainfall distribution stations were not uniform but the rainfall pattern was similar throughout these two counties. Making it easier for us to get a hold of the circulation models with the rainfall data set.

Since the data distribution is set throughout both Kelantan and Terengganu, in order to assess the performance of these two counties through fully, the stations that were taken encompasses all the districts in the counties itself. With Kelantan having 11 districts whilst Terengganu having 7, a sound number of 3 was deduced to be the number of rainfall stations that were picked from these districts of these two counties. With the data set in hand, the research could be done in order to determine the difference of performance between AR4 and AR5 and also to find the best RCP representing both counties.

Figure 3.4 Map of Kelantan

Figure 3.5 Map of Terengganu

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses about the result and findings in regards to the calibration, validation and projection of future climate trends. There are three main points that would be discussed in this study as follows:

- The best RCPs and SRES for Kelantan and Terengganu are identified using Statistical Downscaling Model (SDSM).
- The future trend for intervals 2010-2039, 2040-2079 and 2080-2099 in Kelantan and Terengganu are generated by using SDSM.
- The performances of different RCPs and SRES are discussed and compared.

The study of climate change in Kelantan for historical years of rainfall was from year 2006-2016. This was the same for historical rainfall years in Terengganu. The historical temperature data used for analysis for Terengganu state was from year 1984-2013. The future trends of these stations were generated by the application of mathematical model simulation in order to gain the correlation between the local climate trend and the predictands at the specified grid by using SDSM.

Firstly, the stations were to undergo calibration and validation processes thus dividing them into two sub-parts. For rainfall in Kelantan, the calibration was performed at the year (2006-2011) which was the first sub-part of the analyzation. The second sub-part was done in the year (2012-2016) as validation. This was also true for Terengganu state in which the first 6 years of the historical data was enacted as calibration data whilst the latter was used as validation data. For temperature in Terengganu, the calibration was done from years (1984-1998) which spans about 15 years and the validation period was from year (1999-2013).

The process itself serves to obtain reliable projected results and to obtain the most influential predictand in influencing the trend of the rainfall/temperature. The years chosen as calibration and validation are due to data availability. With the selection of the best predictands to represent these stations, the best RCP between RCP 2.6, RCP 4.5, and RCP8.5 were selected for each station. The best SRES can also be selected between A2 and B2. The climate projections for all stations were generated from 2010-2099 by using GCM predictors.

Table 4.1 List of Stations with Data, name and calibration & validation year

Types of station	Data year	Name of station	Calibration year	Validation year
Temperature (Kelantan)	1984-2013	Kota Bharu	1984-1998	1999-2013
Rainfall (Kelantan)	2006-2016	5923001- Serdang, Gunong Barat Bachok	2006-2011	2012-2016
		6021060- Rumah Pam Salor Pengkalan Kubor		
		6022001- Sg. Simpang Ampat		
Rainfall (Terengganu)	2006-2016	5131064 Sek. Men. Bkt Sawa	2006-2011	2012-2016
		5230042 Rumah Pam Pulau Musang		

		4933001 Klinik Bidan Jambu Bongkok		

Table 4.1: Calibration and Validation Year for each station

4.2 Predictors Selection

In SDSM, screening process is vital to spot the reliable predictands in order to produce reliable climate projection before calibration and validation process. In this research, several predictors were selected based on the correlation values in which five best predictors are chosen for calibration and validation.

Table 4.2 List of selected predictors

Predictors	Temperature			Rainfall Kelantan			Rainfall Terengganu		
	Max	Min	Mean	Gunong Barat Bachok (5923001)	Rmh Pam Salor. Pengkalan Kubor (6021060)	Kg. Peringat (6022001)	Sek. Men Bukit Sawa (5131064)	Rmh Pam Pulau Musang (5230042)	Klinik Bidan Jambu Bongkok (4933001)
p_u	√	√	√		√			√	
r500	√	√	√	√	√	√		√	√
r850	√	√	√	√	√	√	√	√	
p_v									√
shum									√
p_z							√	√	√
8_f					√	√			
8_u				√					
p_f							√		
5_f						√	√		√
5_u				√					
p500				√	√	√			
8_f							√	√	

The predictors were selected from a list of 26 predictors. These predictors were screened for their influence on the climate trend. For temperature, three predictors were selected from the list. Temperature in Kelantan was divided into 3 subparts, which was maximum, mean and minimum temperature. Whilst for rainfall the number of predictors used was 5 across all stations including in Terengganu. The predictors that are used widely across the rainfall stations were P_u, rhum and shum.

4.3 Calibrated and Validated Performances

4.3.1 Temperature Result

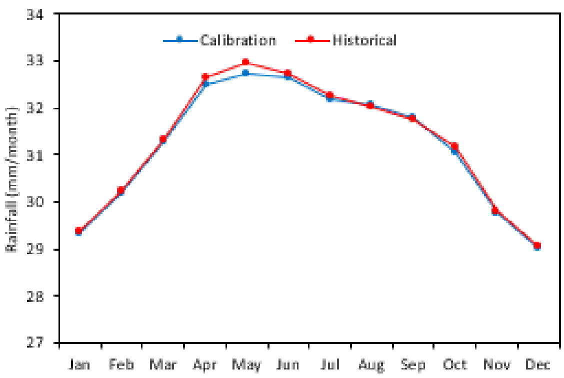
The temperature data obtained from Kelantan station which was situated in Kota Bharu has a total amount of years from 1984-2017 which has a total data of 30 years. Temperature data has three ranges, which was maximum data, minimum data and mean data. The predictors that correlates with the temperature data are surface zonal velocity (p_u), relative humidity at 850hpa (r850) and relative humidity at 500hpa (r500). All three temperature ranges used the same predictor variables as the correlation values of the graphs are near to 1 which indicates strong correlation between the calibrated & validated data against the historical data. The performances of the calibrated data (1984-1998) and the validation (1999-2013) are in the table as shown below.

Table 4.3 Temperature Calibration & Validation

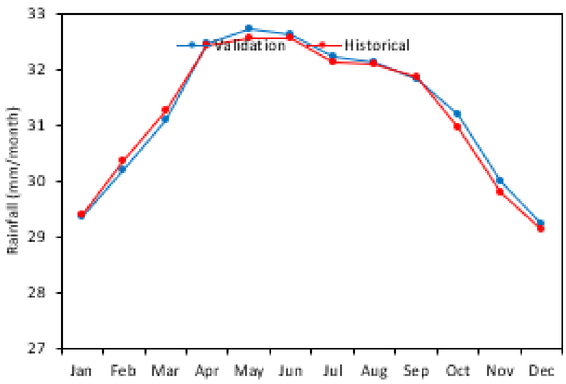
Temperature	Calibration		Validation	
	Correlation (R)	%Error	Correlation (R)	%Error
Maximum	0.99	0.16	0.99	-0.16
Minimum	0.99	-0.85	0.99	-0.96
Mean	0.96	-0.96	0.99	0.42

Based on the Table 4.3, it can be concluded that in temperature analysis, the % of Error for both calibration and validation does not exceed 20%. This step is miniscule in scale but imperative in order to obtain the best predictor which correlates towards the climate trend of a station. With the error % not exceeding more than 20%, it means that the amount of error that was present was negligible and the calibration and validation data can be used for further projection and further comparison. In the maximum range for temperature, the % of error was 0.16 percent with a correlation of 0.99 for calibration. In validation, the % of error was -0.16 with a correlation of 0.99. in minimum temperature, the % of error was -0.86 and -0.96 for calibration and validation respectively. The negative value of errors means that there was an overestimation of values in the calibration & validation graph as compared to historical graph. Both calibration and validation come with correlation values 0.99 each. The last temperature range which was mean, the % of error was -0.96% and 0.42% for calibration and validation respectively. Both readings come with a correlation of 0.96 for the former and 0.42 for the latter reading. It can be concluded that the results have a correlation of almost 1.0 which was having a perfect correlation between the historical and the calibrated/validated data.

Maximum Temperature

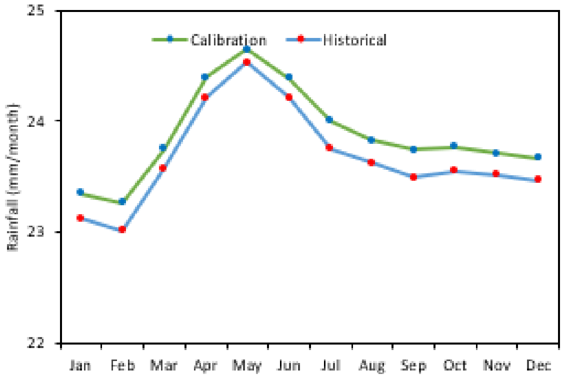


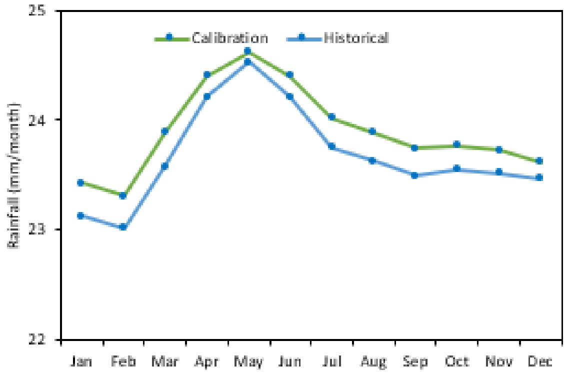
a) Calibration



b) Validation

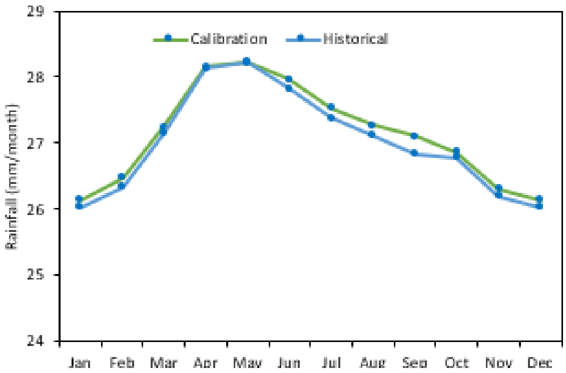
Minimum Temperature

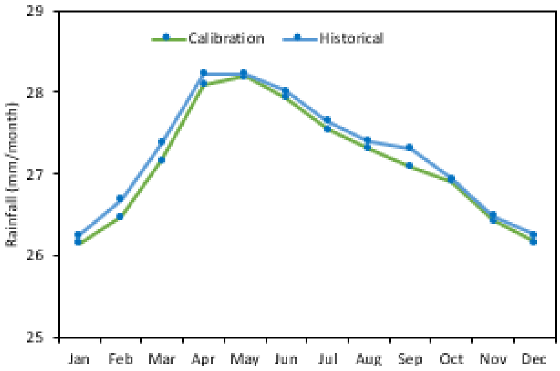




a) Calibration **b) Validation**

Mean Temperature





a) Calibration **b) Validation**

Figure 4.1 Temperature Calibration & Validation

Based on the graph above, the temperature trend for Kelantan was that the highest temperature was always during the months April and May, whilst the lowest temperature recorder was during December and January. The highest temperature recorded at Kelantan was 32.6 ˚C whilst the lowest temperature recorded in Kelantan was 23 ˚C. From the calibration results and graphs obtained, it can be concluded that the predictors selected are viable and corresponds towards the historical temperature trend without having a high percentage of error. The analysis was accepted and can be used for future projection and determination of best SRES and RCP.

4.3.2 Rainfall Result Kelantan

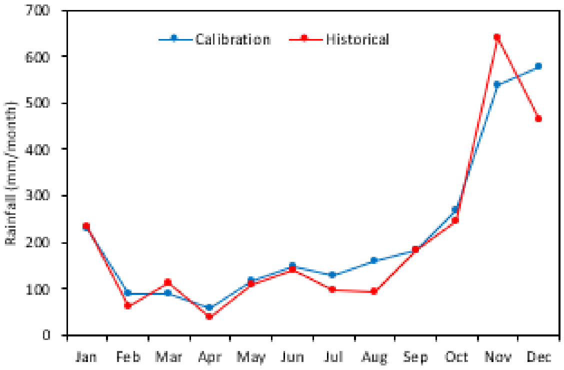
The rainfall stations in Kelantan have a total amount of three. The name of these stations are as follows, Gunung Barat Bachok which is situated in Bachok district. Rumah Pam Salor Pengkalan Kubor & Kg. Peringat. These stations have undergone processes of calibration and validation with the predictors that have been choosen through screening process. The predictors that were selected for these stations was surface zonal velocity (p_u), relative humidity at 500hpa (r500), relative humidity at 850hpa (r850), 850hpa airflow strength (8_f), 850hpa zonal velocity (8_u), 500hpa airflow strength (5_f), 500hpa zonal velocity (5_u) and 850hpa geopotential height (p500). The figure below shows the calibration and the validation results for three rainfall stations in Kelantan state.

Table 4.4 Rainfall Kelantan Calibration & Validation

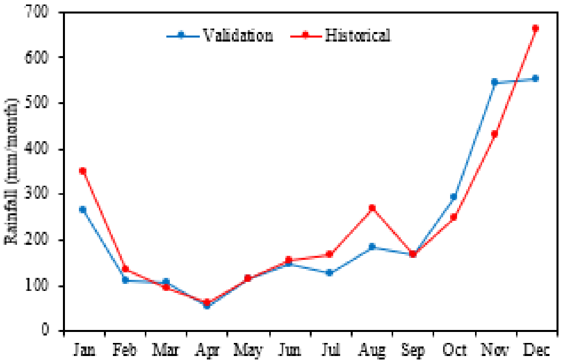
Station	Calibration		Validation	
	Correlation (R)	% Error	Correlation (R)	% Error
5923001 Gng. Brt Bachok	0.95	-6.99	0.93	6.783
6021060 Peng. Kubor	0.95	4.70	0.93	17.03
6022001 Kg. Peringat	0.96	2.72	0.95	16.79

Based on the table 4.4 above, the percentage of error for the first rainfall station which is situated at Gunong Barat Bachok, had an error of -6.99% and 6.78% for calibration and validation respectively. Meanwhile, the percentage of error in the second station in Kelantan state which is Pengkalan Kubor was 4.70% and 17.03% for calibration and validation respectively. The negative value in error percentage was an indicator of under projection of the calibrated/validated data when compare with the historical data. The positive value of the error percentage indicates over projection of calibrated/validated data when compared with the historical data. The correlation values of all stations are close to 1 meaning that the predictors selected corresponds towards the climate trend and in this case the rainfall trend of these stations. Since the data has an error percentage less than 20%, it can be concluded that the calibrated and validated data obtained can safely be used for further projection of climate since the error percentage was negligible.

Station Gunong Barat Bachok (5923001)

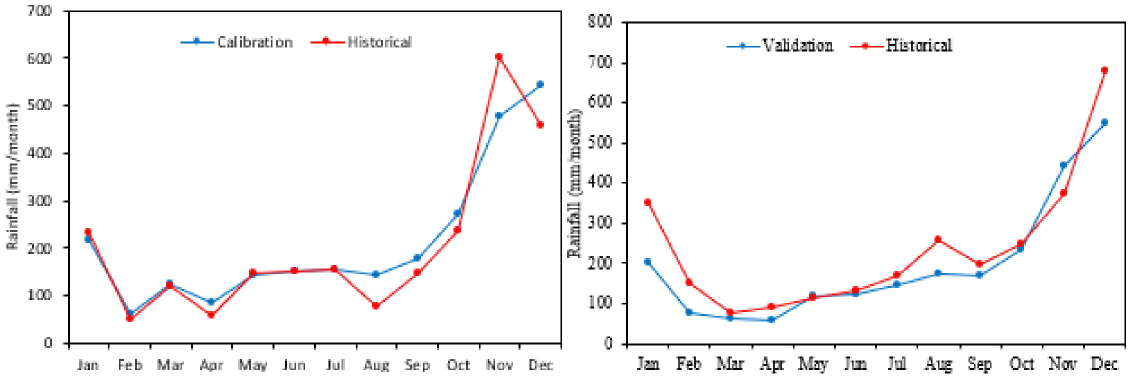


a) Calibration



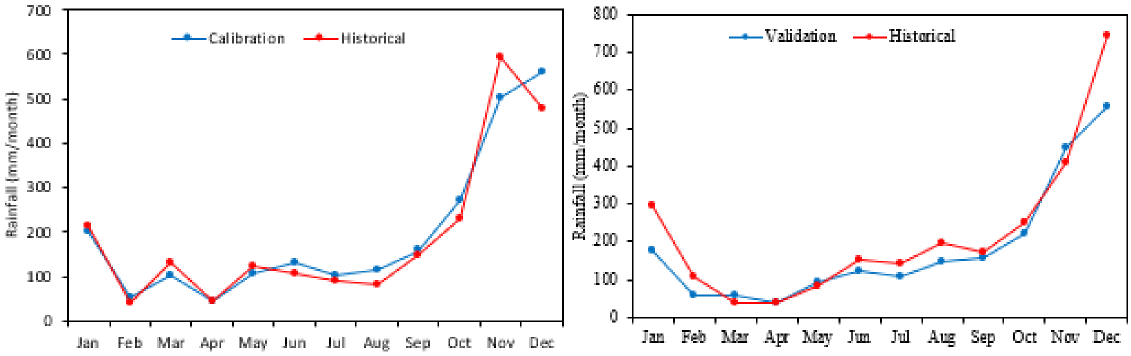
b) Validation

Station Pengkalan Kubor (6021060)



a) Calibration **b) Validation**

Station Kg Peringat 6022001



a) Calibration **b) Validation**

Figure 4.2 Kelantan Rainfall Calibration & Validation

Based on the graphs above, the highest rainfall period that was observed during the end of the year which was during months November to December for all stations. The peak rainfall amounts to more than 600mm.The rainfall trend decreases with the start of each year as we can see in January. The rainfall drops from January to February and begins a steady increment towards the end of the year for calibration. The lowest amount of rainfall in calibration amounts to no more than 100mm during February. In validation, there was no change in the rainfall trend. The highest amount of rainfall peaks at the end of year during the months November to December and then it decreases rapidly when moving to January. From February, the rainfall amount begins a steady climb until it reaches the peak during December. The highest amount recorded in validation was 700mm and the lowest amount of rainfall recorded was 100mm during the month November and February respectively.

4.3.3 Rainfall Result Terengganu

There was a total of three rainfall stations in Terengganu. The stations are Sekolah Menengah Bukit Sawa (5131046), Rumah Pam Pulau Musang (5230042), and Klinik Bidan Jambu Bongkok (4933001). These stations also have undergone processes of screening for predictors, and calibration with validation compared to the historical rainfall data of these stations. The predictors that were chosen from the screening process were surface zonal velocity (p_u), relative humidity at 500hpa (r500), relative humidity at 850hpa (r850), surface meridional velocity (p_v), surface specific humidity (shum), surface vorticity (p_z), surface airflow strength (p_f), 500hpa airflow strength (5_f) and 850hpa airflow strength (8_f).

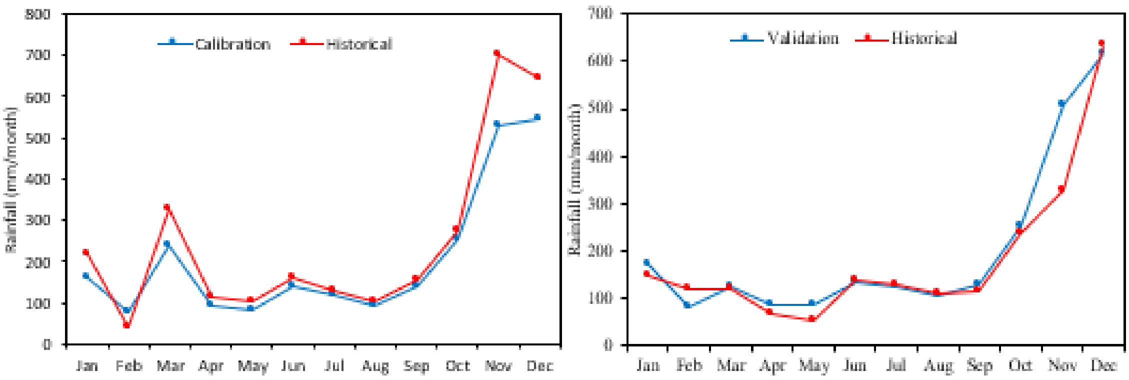
Table 4.5 Rainfall Terengganu Calibration & Validation

Station	Calibration		Validation	
	Correlation (R)	% Error	Correlation (R)	% Error
5131064 Sek. Men Bkt Sawa	0.99	16.84	0.95	-9.99
5230042	0.9	-7.60	0.9	4.8

Rmh. Pam P. Musang				
4933001 Klinik Bidan Jambu Bongkok	0.99	-10.46	0.95	-2.9

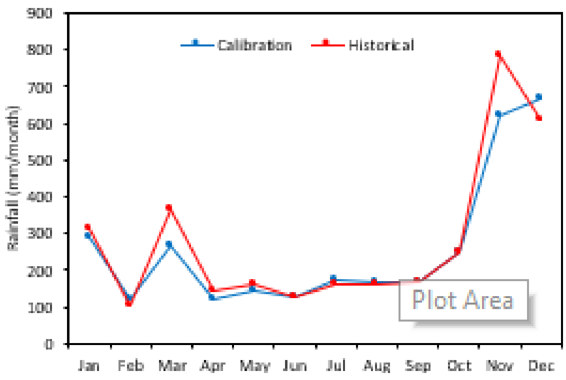
Based on the table above, the percentage of error in the first rainfall station for Terengganu state was 16.84% and -9.99% for calibration and validation respectively. The negative value of error in the table shows that the calibrated or validated graph under projected when compared with the historical data. Meaning that the historical data has more rainfall data in the specific area or month. The positive value of error shows over projection of the rainfall meaning the calibrated. The percentage of error in the second station in Terengganu state was -7.6% and 4.8% which was less than 20%. The third rainfall station in Terengganu was the Klinik Bidan Jambu Bongkok which has an error of -10.46% and -2.9% for calibration and validation respectively. The amount of errors was less than 20% which means that the predictors selected for the station corresponds with the rainfall trend of the station. The correlation value of all these stations were near 1 which signifies a high correlation between the predictors selected and the climate trend of the station. This enables for further projection of the rainfall of the state.

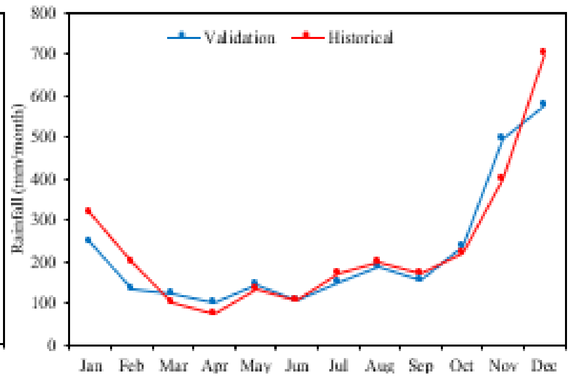
Station Sekolah Menengah Bukit Sawa (5131064)



a) Calibration **b) Validation**

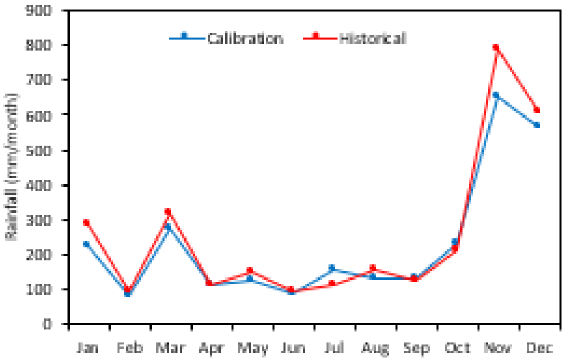
Station Rumah Pam Pulau Musang (5230042)

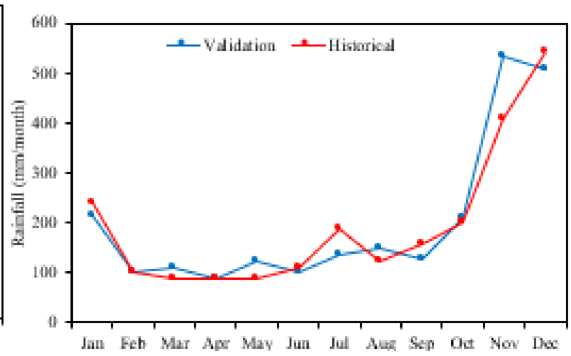




a) Calibration **b) Validation**

Station Klinik Bidan Jambu Bongkok (4933001)





a) Calibration **b) Validation**

Figure 4.3 Terengganu Rainfall Calibration & Validation

Based on the figures above, in calibration, the highest reading of rainfall that was recorded in the month November in which then declines towards December and leading to a sharp drop towards the start of the year which was during the month January. The lowest rainfall recorded in calibration was during the year February across all stations. The trend then goes a small increment towards the end of the year which was during

November. The highest amount of rainfall in calibration which was in the month November which has a reading of between 700mm to 800mm. the lowest reading of rainfall was recorded in February which has a reading of less than 100mm. for validation the highest rainfall recorded was during November whilst the lowest was during the month February. The highest reading recorded in validation was during the month November which has a reading between 600mm to 800mm. the lowest reading recorded during February which has a reading of between 100mm to 200mm.

4.4 Best RCP & SRES Analysis

4.4.1 Best RCP Analysis

The best RCP was described as a projection of scenarios that have alternative trajectories of carbon dioxide emissions and the resulting atmospheric concentration from the year 2000 to 2100. The best RCP analysis has been done to all of the stations involved in order to choose the best RCP for each station and for further projection. The RCPs that were chosen for this research were RCP2.6, RCP4.5 and RCP8.6. All of the RCPs were developed as to project the climate in the future and was developed separately as each of the RCPs has its own special characteristics. As an example, RCP2.6 was characterized by the implementation of legislative towards the emission of carbon dioxide in which reduces the carbon emission towards the future. Meaning that RCP2.6 follows a controlled environment where emission of GHG was supervised and made sure not to exceed certain quota per year. RCP8.6 was characterized by its steep curve graph which shows that there are no implementations of legislative towards the emission of carbon dioxide thus having high concentrations of GHG in the stratosphere. In RCP8.6 also, the emission was not supervised and the emission of carbon dioxide continues with the rate of emission of today and increases with time as new factories are made.

4.4.1.1 Best RCP Temperature

The temperature analysis was done by comparing the historical data from the year 2006-2013 where the historical data acts as predictands. The GCM data for each RCP scenario acts as predictors. The data for the best RCPs can be observed below with the % of Error from each corresponding RCP. The correlation between the data projected by the RCP GCM was compared with the historical data beforehand to obtain the data required to determine the accuracy of the RCP against the historical data.

Table 4.6 Temperature Best RCP Analysis

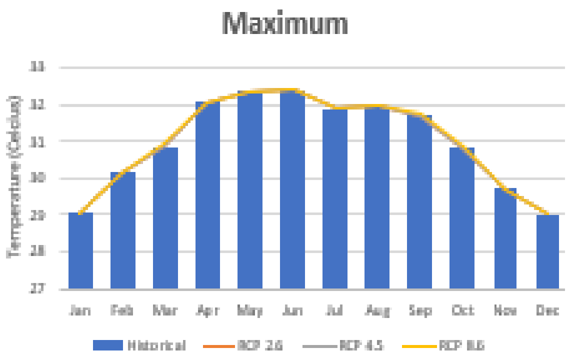
Station	RCP 2.6		RCP 4.5		RCP 8.6	
	Correlation R	% of Error	Correlation R	% of Error	Correlation R	% of Error
Maximum	0.99	0.017	0.99	**-0.0007**	0.99	-0.015
Mean	0.99	0.008	0.99	**0.0011**	0.99	-0.002
Minimum	0.99	0.004	0.99	**-0.0030**	0.99	0.004

Based on the table above, the % of error for the Maximum temperature iwas0.017% for RCP 2.6, -0.00079% for RCP 4.5, -0.015% for RCP 8.6. The negative value of the percentage of error means that the projected RCP graph was under projected and its cumulative temperature value lower than the actual historical value. If the value was positive, the graph projected was over the historical graph or over-projection. RCP 4.5 was selected as it has the lowest amount of error between the three RCPs. For correlation values, we can see that the value was the same across all RCPs for maximum temperature which was 0.99.

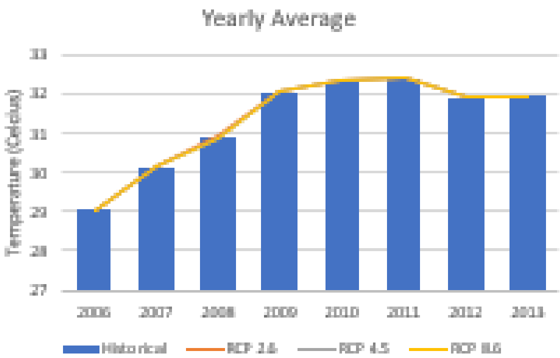
Moreover, from the table, in the mean temperature. The percentages of error also determine the best RCP for the temperature data. The percentages of error are 0.008%, 0.001% and -0.002% for RCP 2.6, RCP 4.5 and RCP 8.6 respectively. hence, the best RCP for Mean was RCP 4.5 due to having an error of 0.001 which was the lowest percentage of error amongst the RCPs. The correlation values was the same across all RCPs, which was 0.99.

The next temperature data which was minimum. In the table, the percentages of error were 0.004%, -0.003% and 0.004% for RCP 2.6, RCP 4.5 and RCP 8.6 respectively. with the error percentages compared, the best RCP for mean temperature was RCP 4.5 which has the lowest error percentage amongst the RCPs involved in the study. The correlation value of the test was the same across all RCPs which was 0.99.

Maximum Temperature

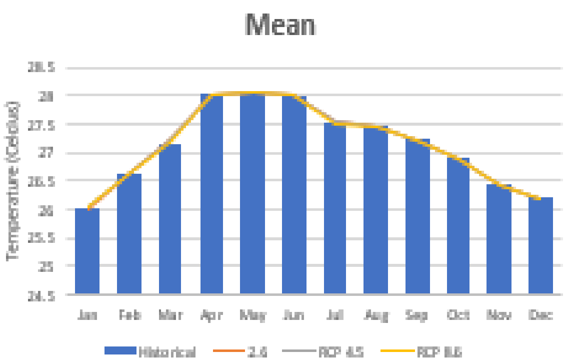


a) Maximum Temperature vs Historical

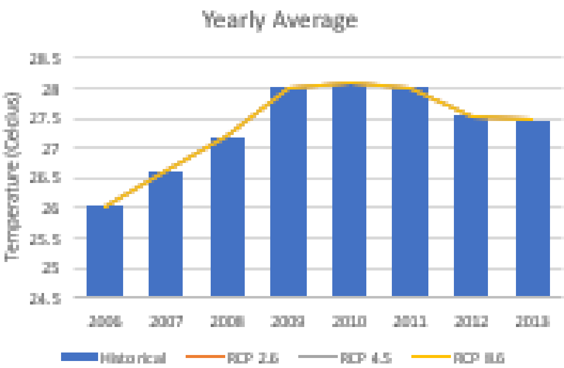


b) Yearly Average Maximum Temperature

Mean Temperature

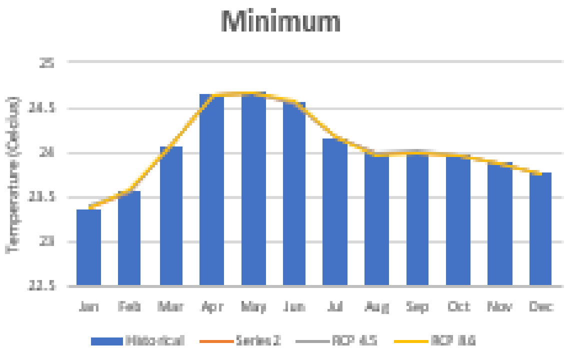


a) Mean Temperature vs Historical

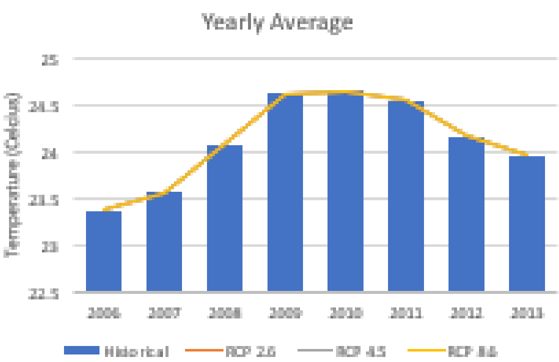


b) Yearly Average Mean Temperature

Minimum Temperature



a) Minimum Temperature vs Historical



b) Yearly Average Mean Temperature

Figure 4.4 Temperature Best RCP:- a) Temperature vs Historical. b) Yealy Average of Temperature Vs Historical

From figure above, for maximum temperature, the maximum reading for monthly average vs historical was 32.3 Celsius. This was taken during the month June. The lowest reading obtainable in the data was 29 Celsius which was in two months, January and December. The RCPs that were involved in the investigation followed closely according to the historical data thus the main way to make sure of the errors was via statistical difference. The trend of the graph follows a slow start in January with a slight increase over the next few months until the peak temperature which was during the month June. After June the temperature dropped at a steady pace, returning to the first temperature recorded in January for December reading. In the yearly average maximum temperature graph, the highest temperature recorded was 32.3 Celsius during the year 2011. The Temperature has a slight increase from the starting of the period of study which was the year 2006 until its highest point which was during the year 2011. After the peak temperature, the readings drop slightly and maintained through the final 2 years of the period.

In Mean temperature's graph of monthly average vs historical data, we can see that the highest data available was 27.5 Celsius which spans out for three months from

April to June the temperature was the lowest during January, which has a reading if 26 Celsius. The trend of the graph was that from January, the graph began as constant increase of temperature until the peak temperature which was the month April and then it plateau’s until June. After having the highest temperature for 3 months, the readings slowly decline for the next couple of months until the end of the year. In the yearly average graph of mean temperature, the maximum reading was obtained during the years 2009-2011. The RCPs that were involved in the study followed closely with the historical data obtained. The minimum data obtained from the yearly average graph was during the year 2006 which had a reading of 26 Celsius. The trend of the graph was that it fluctuates as during the early years of the period of study, the graph has increments until the maximum reading obtained which was from the years 2009-2011. After three years of maximum reading for mean temperature, the data obtained plummeted slightly in the year 2011 and 2012.

For Minimum temperature’s graph of average monthly vs historical, the data fluctuates in terms of having the maximum temperature at 26.6 Celsius during the month April and May. The minimum data obtained for this graph was 25.45 Celsius during the month January. The RCPs that are involved in the study follows the historical graph closely thus making the only way to identify the best RCP for the station via statistical means. The temperature trend of the station was that it starts slow with January having the lowest reading of temperature, slightly increasing toward the first quarter of the year, peaking at April and May. After reaching the maximum temperature, the reading decreases slightly throughout the year until December. In the yearly average of minimum temperature, it was observed to have a minimum data of 22.8 Celsius and 26.8 for the year 2006 and 2011 respectively. the trend of the temperature was that it starts with the lowest temperature throughout the period of study, increasing annually until peaking at the year 2011-2012 and then decreasing towards the end of the research period.

4.4.1.2 Best RCP Rainfall Kelantan

The number of stations picked for the rainfall in Kelantan state was 3. The data assessed in rainfall was during the years 2006-2016 The rainfall stations also undergo the same procedure whereas the historical data would be used as the predictand and the

GCMs would be as the predictors of the station. The process also includes having the predictand data projected with climate agent AR5 to project the rainfall scenario according to different RCP. From here on, the best RCP was picked by comparison of the historical graph and the data projected via different RCPs, and calculating the differences between the historical data and the projected data. For this, the percentage of error was calculated to account for all small but not negligible numbers.

Table 4.7 Kelantan Rainfall Best RCP Analysis

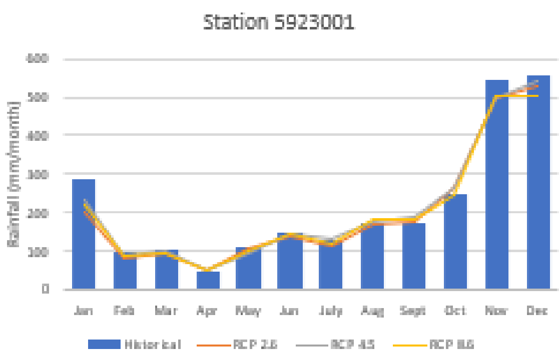
Station	RCP 2.6		RCP 4.5		RCP 8.6	
	Correlation R	% of Error	Correlation R	% of Error	Correlation R	% of Error
5923001 Gng. Brt Bachok	0.98	6.91	0.99	**3.86**	0.99	6.89
6021060 Peng. Kubor	0.98	6.99	0.99	9.31	0.98	**6.60**
6022001 Kg. Peringat	6.91	7.44	0.99	**6.21**	0.99	7.29

From the table above, for station Gunong Barat Bachok which was the first station for rainfall Kelantan, the RCP with the lowest percentage of error was RCP 4.5 which has an error percentage of 3.86%. Other RCP readings of error percentages are larger than RCP 4.5 up to 7%.

In the second rainfall station of Kelantan, which was Pengkalan Kubor, the RCP with the lowest error percentage was RCP 8.6 which has a reading of 6.60%. In other RCPs, the error readings were 6.99% for RCP 2.6 and 9.31% for RCP 4.5.

For the last rainfall station in Kelantan, the lowest percentage of error was RCP 4.5 which has a reading of 6.21%. the highest error percentage was RCP 2.6 which has an error of 7.44%. The correlation values of all RCPs towards their own respective stations was close to 1. Which indicates a strong relationship between the predictors and the historical data.

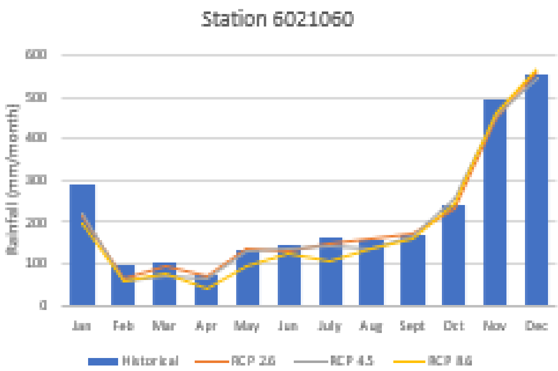
Station: Gunong Barat Bachok 5923001



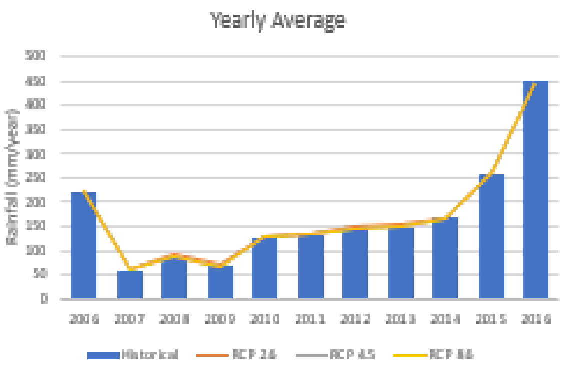
a) Monthly Average vs Historical

b) Yearly Average vs Historical

Station: Pengkalan Kubor 6021060

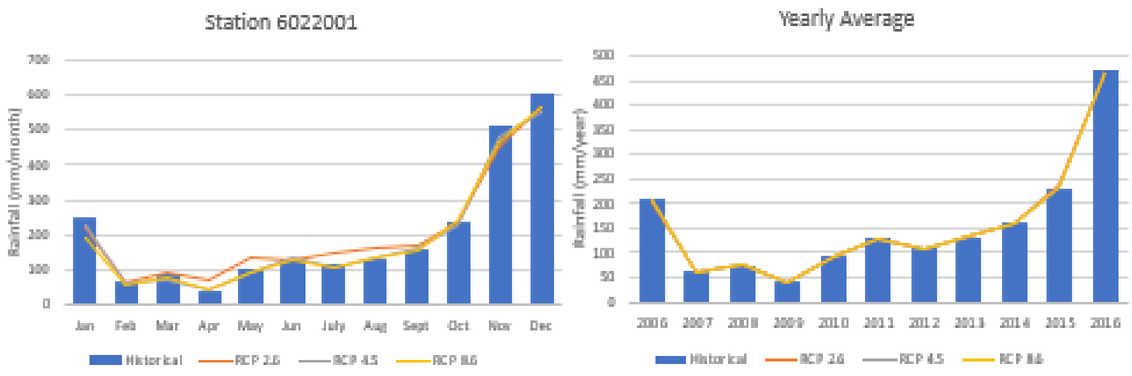


a) Monthly Average vs Historical



b) Yearly Average vs Historical

Station: Kg. Peringat 6021060



a) Monthly Average vs Historical b) Yearly Average vs Historical

Figure 4.5 Kelantan Rainfall best RCP:- a) Rainfall Monthly Average vs Historical. b) Yealy Average of Rainfall Vs Historical

From the figure above, in the first station which was station Gunong Barat Bachok, the highest rainfall reading for historical was during December which has a reading of 550mm of rainfall. All RCPs for that month also rose but not as high as historical data obtained. The lowest data obtained for the rainfall station was during April, which has a reading not more than 100mm. the trend of the rainfall fluctuates throughout the months. Beginning from January which has an intermediate reading of 290mm then decreasing towards the lowest point which was April. Then steadily increasing until the month December. In the yearly average graph, the data obtained from the RCP graphs was not consistent with the historical data, meaning that the incremental of rainfall on a yearly average does not tally towards the RCP yearly average reading. This was due to multiple causes such as the period of rainfalls that were frequent during the years 2008-2014. This made the reading differ from what the RCP projected.

In the second station which was Pengkalan Kubor, the highest data obtained was during the month December in which has a data of 550mm of rainfall. The RCPs for the station rose to the same level as the historical December data but were lacking similarities in the early months of the year. The rainfall for this station also fluctuates such that the reading starts at 300mm for January which was an intermediate for the rainfall data obtained. The trend fluctuates towards the month April with having decremental of rainfall during the months February and April but having increments of rainfall during the month march. After April, the rainfall rose slightly to November and then rose significantly towards the end of the year.in the yearly average graph, the highest data was during the year 2016 with 2007 having the lowest data. The RCPs of the station follows the climate trend of the station closely having decremental during the year 2007 and 2009 before rising slightly towards the year 20014 and then slightly increase dramatically towards the end of the period of yearly average.

For the third rainfall station which was Kg Peringat, in the monthly average graph, the reading peaks at the month December which has a reading of 610mm and having the lowest rainfall reading in April. The RCP of the station follows the historical graph closely with having differences of reading in the month May and June. The climate trend of the station was that the rainfall starts at an intermediate amount for January which was 240mm. the rainfall data drops during February and increases slightly during march before dropping to its lowest point in April. Then the rainfall. Increases toward June in which it decreases slightly before a steady increase toward the year October. After that the rainfall data rose significantly towards its highest point which was in December. In the Yearly Average data, the graph was highest during the last year of the period for the research which was the year 2016. The graph starts intermediately at the year 2006 having a reading of 200mm for yearly average which fluctuates until its lowest year which was year 2009. After that the reading increases slightly before a small decline in rainfall reading during the year 2013 before a steady increase towards the end of the period.

4.4.1.3 Best RCP Rainfall Terengganu

The number of stations picked for the rainfall in Terengganu state was 3. The data assessed in rainfall was during the years 2006-2016. The rainfall stations also undergo the same procedure whereas the historical data would act as the predictand and the GCMs would be used as the predictors of the station. The process also includes having the predictand data projected with climate agent AR5 to project the rainfall scenario according to different RCP. From here on, the best RCP was picked by comparison of the historical graph and the data projected via different RCPs, and calculating the differences between the historical data and the projected data. For this, the percentage of error was calculated to account for all small but not negligible numbers.

Table 4.8 Terengganu Rainfall Best RCP Analysis

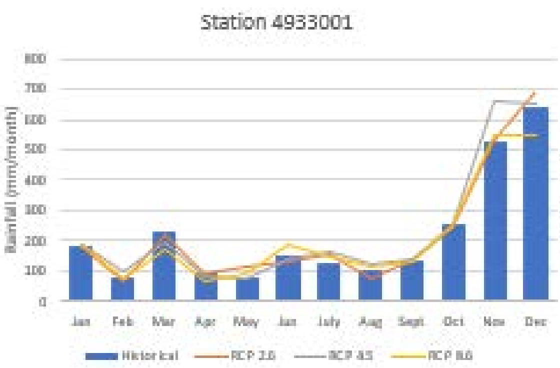
Station	RCP 2.6		RCP 4.5		RCP 8.6	
	Correlation R	% of Error	Correlation R	% of Error	Correlation R	% of Error
5131064 Sek. Men Bkt Sawa	0.99	**-0.76**	0.98	-5.47	0.9	3.2
5230042 Rmh. Pam P. Musang	0.99	**5.37**	0.99	5.97	0.9	5.79
4933001 Klinik Bidan Jambu Bongkok	0.99	5.0	0.98	1.7	0.98	**-1.67**

From the table above, in the first rainfall station for Terengganu state which was situated at Sekolah Menengah Bukit Sawa, the percentage of error across all RCPs was -0.76%, -5.47% and 3.29% for RCP 2.6, RCP 4.5 and RCP 8.6 respectively, thus the best RCP for this station was RCP 2.6 with having the least percentage of error amongst all other RCPs involved in the research. The correlation value between the difference RCPs are close to 1, meaning that there exists a strong relationship between the historical data and the projected data.

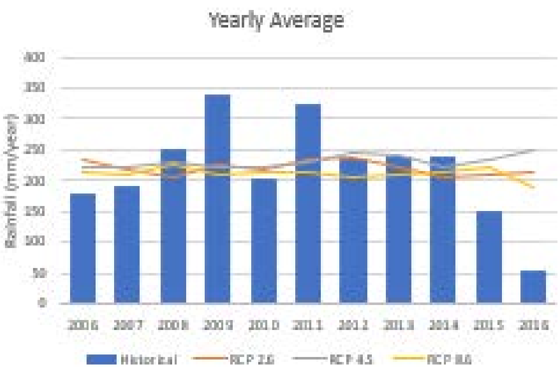
For the second station in Terengganu state which was Rumah Pam Pulau Musang, the percentage of error recorded was 5.37%. 5.97% and 5.79% for RCP 2.6, RCP 4.5 and RCP 8.6 respectively. The best RCP for this station was RCP 2.6 which has an error of 5.37% which was the lowest amongst all the RCPs involved in the research.

For the last station in Terengganu state which was situated at Klinik Bidan Jambu Bongkok, the reading for RCP's error percentage was 5.04%, 1.77% and -1.67% for RCP 2.6, RCP 4.5 and RCP 8.6 respectively. Thus, by having the least percentage of error, RCP 8.6 was the best RCP for this station. The correlation values for this station was near to 1 for all RCP, indicating a strong relationship between the historical data and the projected data.

Station Sekolah Menengah Bukit Sawa 4933001

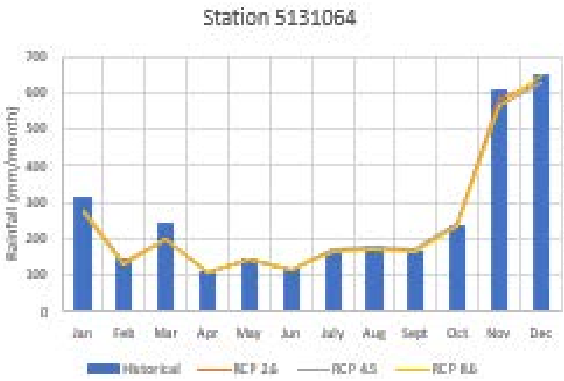


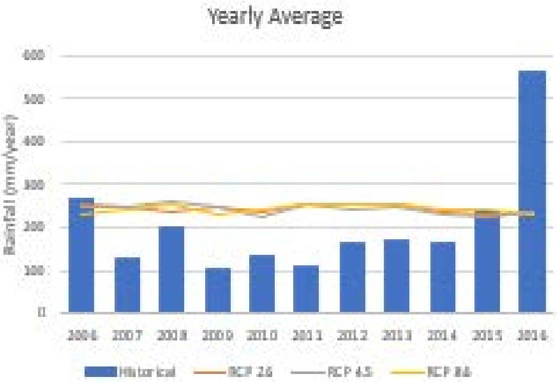
a) Monthly Average vs Historical



b) Yearly Average vs Historical

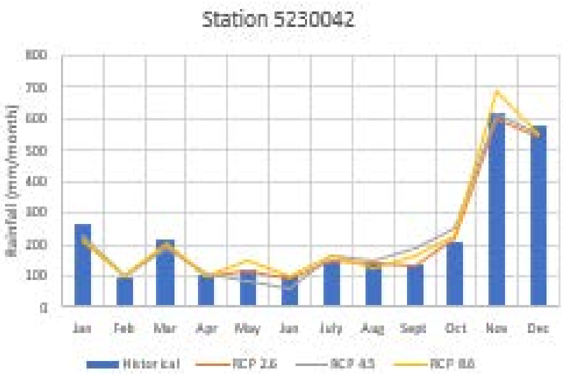
Station Rumah Pam Pulau Musang 5131064

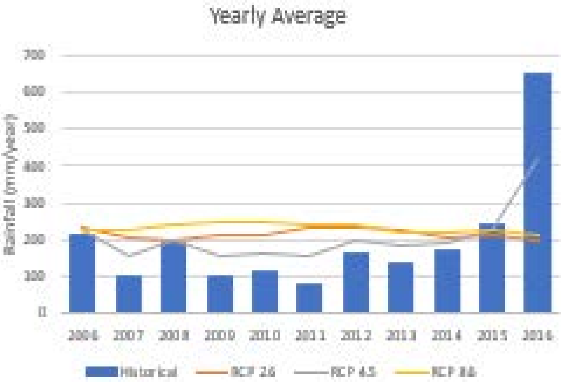




a) Monthly Average vs Historical b) Yearly Average vs Historical

Station Klinik Bidan Jambu Bongkok 4933001





a) Monthly Average vs Historical b) Yearly Average vs Historical

Figure 4.6 Terengganu Rainfall Best RCP: - a) Rainfall Monthly Average vs Historical. b) Yealy Average of Rainfall Vs Historical

From the figure above, in the first rainfall station for Terengganu which was station Sekolah Menengah Bukit Sawa which was situated in Kuala Terengganu. The monthly average vs historical graph shows a maximum reading of 610mm which was on the month November. The lowest reading can be obtained from the month February which has a reading of 90mm for the month. The graph fluctuates as it starts intermediately in January and decreases towards the pit of the graph in February and rise back to 210mm in March. The fluctuations occur until the month September where from there, the graph starts a climb to October. From October, there was a sharp increase towards November, which was where the peak of the graph is. After reaching the peak of the graph, it experiences a decrement of rainfall towards the end of the year which was December. The RCPs involved in the study closely follow the pattern of the historical data, with having certain errors that contribute to their percentage of error. In the yearly average vs historical graph, the maximum data obtained was during the final year in the research which was the year 2014. the lowest reading obtained was during the year 2009 which has a reading of 110mm.

The second rainfall station which was station Rumah Pam Pulau Musang, in the graph of Monthly Average vs Historical graph, the highest reading of historical data obtained was 650mm which was during the month of December. The lowest reading that can be obtained during the month April which has a reading of 110mm. the trend of the graph starts intermediately in January. The graph fluctuates during the first three months, having a decrease from January towards February and an increment towards march. Then it reaches April which has the lowest amount of rainfall for the year. The graph rises towards May and decreases slightly towards June. From June. the graph rises constantly towards its peak point which was during the month December which was the peak for the rainfall data obtained. Int the graph of Yearly Average vs Historical data, the highest data obtained was during the year 2009 which was 345mm. the lowest data obtained was during the year 2016 which the data was 50mm. The trend of the graph was that it fluctuates with a slight increase during the first 4 years then a drop of the rainfall data obtained was recorded during the year 2010. The reading for the year 2011 increases up to 325mm and then the pattern of the graph drops slightly throughout the years in the research.

In the third rainfall station of Terengganu which was Klinik Bidan Jambu Bongkok, the highest rainfall data obtained for historical was 670mm. the lowest rainfall was during the month May which had a reading of 40mm. The trend of the rainfall obtained at this station was the rainfall fluctuates throughout the year. It starts off intermediate during January, and then a decrease in rainfall data for February and an increase of rainfall in March. After March, the rainfall increases and decreases slightly up until September where the rainfall data starts to climb. In October, the rainfall data starts to rose up to reach the peak of rainfall data which was during the month December. The RCPs of this graph closely follows the graph of the historical data, making it hard to notice differences of data except for certain periods in the graph where the reading of RCPs does not match the reading of the historical data. In the Yearly average rainfall data vs historical data, the highest data obtained was during the final year in the research which was the year 2016 which has a reading of 580mm of rainfall. The lowest reading obtained in the graph was during the year 2008 which has a reading of 105mm of rainfall data. The rainfall data trend also fluctuates such as in the second year has a decrement of rainfall from the first year in the research. Although it was observed that the third year in the research had increments of rainfall data, the trend continues until the year 2014 where to 2015, there was a major increment in rainfall data. From 2015 to 2016, the rainfall data rose significantly, proving that there was an abnormal amount of rainy days in the year and the rainfall data obtained was much higher compared to the other data obtained in the graph.

4.4.2 Best SRES Analysis

The Best SRES was described as a projection of scenarios that have separate storylines according to the emission of GHGs and the storyline by referring to the rate of emission of GHGs from the year 2000-2100. The Best SRES has been done to all the stations that are in the scope of the research in order to choose the best SRES scenario from two separate scenarios for further projection of the climate trend. The SRES that were chosen for this research was SRES A2 and SRES B2. All of the SRES were developed to project climate and developed separately according to the storylines that the scenarios present. Each scenario represents separate characteristic and portray separate projections of the future climate. In SRES A2, the scenario represents a non-stop emission of GHGs. In A2 the growth of the population was evident and there has been no centralization of economic growth. The growth was fragmented because of the growth was focused rurally which was different from B2 scenario. In B2 there exists centralization in which the government emphasizes environmental sustainability and focuses local solutions to economic and social problems. Moreover, since its emphasis on centralization, there have been less significant growth as compared to B2. The graphs of projected climate are plotted against historical graphs to obtain the correlation values and percentages of error value.

4.4.2.1 Best SRES Temperature

The temperature analysis was done by comparing the historical data from the year 2006-2013 where the historical data acts as predictands. The GCM data for each SRES scenario acts as predictors. The data for the best SRES can be observed below with the % of Error from each corresponding SRES. The correlation between the data projected by the SRES GCM was compared with the historical data beforehand to obtain the data required to determine the accuracy of the SRES against the historical data

Table 4.9 Temperature Best SRES Analysis

Station	SRES A2		SRES B2	
	Correlation (R)	% of Error	Correlation (R)	% of Error
Maximum	0.99	**-0.0001**	0.99	-0.008
Mean	0.99	**-0.004**	0.99	-0.009
Minimum	0.99	0.011	0.99	**0.007**

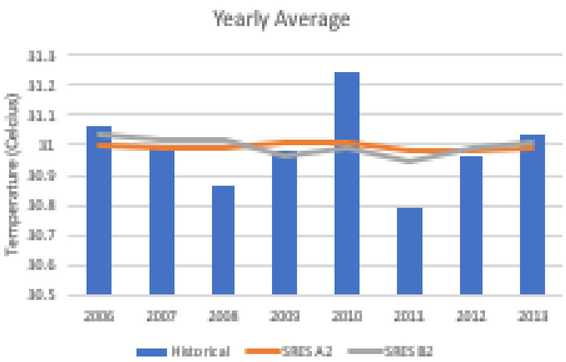
Based on the table above, in maximum temperature, the percentage of error was -0.001% in A2 whilst the error was -0.008 in B2. The negative values show under-projection which means that the projected graph was lower than the historical graph. Based on the percentages of error in the table, SRES A2 was selected as the best SRES scenario to represent the temperature trend of maximum temperature. The correlation value of the maximum temperature was 0.99 across all the scenarios in maximum temperature therefore confirming that there was a strong relationship between the projected data and the historical data.

In the table above, for mean temperature, the error percentages are -0.004% and -0.009 for SRES A2 and B2 respectively. the lowest value for the percentage of error was -0.004% which was in SRES A2, thus SRES A2 was selected as the best SRES scenario to represent the mean temperature. The correlation value of both SRES scenarios was 0.99 which means that there exists a correlation between the values of projection in comparison with the values from historical.

For minimum temperature, the error percentages that were obtained was 0.011% and 0.007% for SRES A2 and SRES B2 respectively. the positive value indicates an over-projection which means that the projected graph with the SRES predictors was higher than the historical graph. With the lowest error percentage of 0.007%, SRES B2 was selected as the best SRES to represent the climate trend of minimum temperature. The correlation values of the station are all the same across the board having values of 0.99 each. This proves that there was a strong relation between the projected graph and the historical graph when compared.

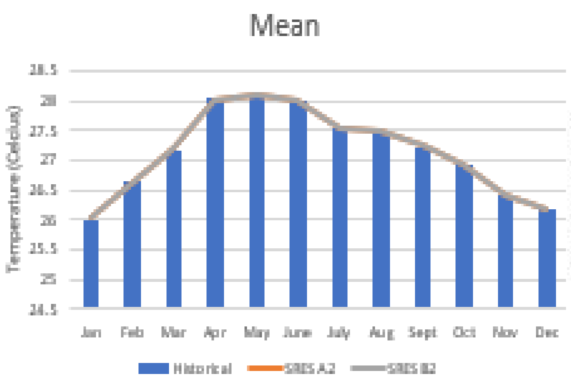
Maximum Temperature

a) Monthly Average vs Historical



b) Yearly Average vs Historical

Mean Temperature

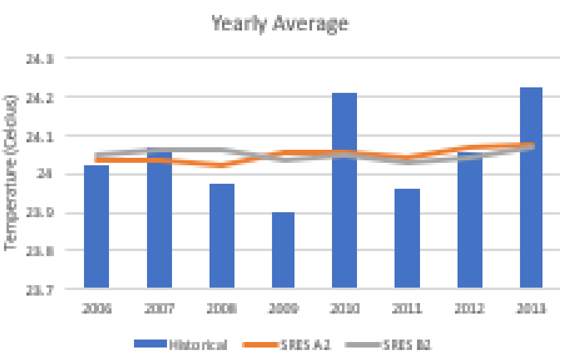


a) Monthly Average vs Historical

b) Yearly Average vs Historical

Minimum Temperature

a) Monthly Average vs Historical



b) Yearly Average vs Historical

Figure 4.7 Temperature Best SRES:- a) Temperature vs Historical. b) Yealy Average of Temperature Vs Historical

Based on the figure above, in the maximum temperature, the highest value obtained for temperature was 32.3 Celsius whereas the lowest value obtained for the temperature was 29 Celsius for the month June and December respectively. the trend of the temperature of the station was it started slow in January with slight incremental towards the peak of temperature which was around June. After June, the temperature slowly descends towards the lowest temperature which was recorded in December. For yearly average Graph vs Historical graph, the highest temperature for maximum was during the year 2010 having a reading of 31.25 Celsius. The temperature trend of the station was that it fluctuates with having 2011 as the year with the lowest temperature.

In Mean Temperature, following the figure above in the graph mean temperature vs historical, the highest temperature recorded was during the month may which has a reading of 28 Celsius. The lowest value of temperature obtained was in January which has a reading of 26 Celsius. The trend of the graph starts with the lowest data in the graph which was in January. Then the graph increases till it reaches the peak value which was on May. After reaching the peak value, the graph declines slightly month by month till the end of the year. For the yearly average mean temperature, the highest reading of temperature recorded was in the year 2010. The lowest temperature reading recorded was in the year after it which was 2011. The graph fluctuates as the reading of the temperature increases and decreases until the peak of the temperature recorded, then decreasing to its lowest point in 2011 with a slight increase in the years after that.

In Minimum temperature, for the Minimum Temperature vs Historical graph, the maximum value was founded to be on May which has a reading of 24.6 Celsius. The trend of the graph starts off with the pit of the temperature obtained which was in the month January with the reading 23.4 Celsius and gradually increasing until the peak of the temperature which was on May. After May, the temperature subsided slightly every month till the end of the year. In the graph of Yearly Average Minimum Temperature, the highest reading was founded to be on the final year of the research which was on 2016 with the reading of 24.23 Celsius. The graph fluctuates with having the year 2009 as the year with the lowest temperature reading amongst all years involved in the study. The graph increases from 2006 to 2007, decreases until it reaches the minimum reading of temperature during 2009 and rose back in 2010, falls to a lower position in 2011 and a steady increment of temperature until the peak of temperature which was on the year 2013.

4.4.2.2 Best SRES Rainfall Kelantan

The number of stations picked for the rainfall in Kelantan state was 3. The data assessed in rainfall was during the years 2006-2016 The rainfall stations also undergo the same procedure whereas the historical data would act as the predictand and the GCMs would be used as the predictors of the station. The process also includes having the predictand data projected with climate agent AR5 to project the rainfall scenario according to different RCP. From here on, the best RCP was selected by comparison of the historical graph and the data projected via different RCPs, and calculating the differences between the historical data and the projected data. For this, the percentage of error was calculated to account for all small but not negligible numbers.

Table 4.10 Kelantan Rainfall Best SRES Analysis

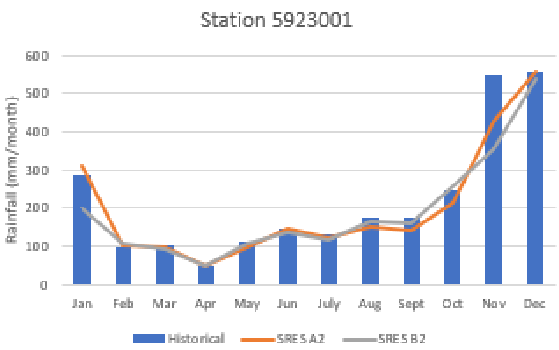
Station	SRES A2		SRES B2	
	Correlation (R)	% of Error	Correlation (R)	% of Error
5923001 Gng. Brt Bachok	0.97	**8.11**	0.95	12.82
6021060 Peng. Kubor	0.98	7.41	0.98	**7.22**
6022001 Kg. Peringat	0.99	**9.69**	0.98	12.87

From the table above, the first rainfall station in Kelantan which was Gunong Barat Bachok has an error percentage of 8.11% and 12.82% for SRES A2 and B2 respectively. The percentages of error determine the best SRES to represent the climate trend of the station. In this case, SRES A2 was selected as the best SRES to represent the station by having a percentage of error of 8.11% which was significantly lower than B2. Thus, SRES A2 more suited to represent the station in climate trend analysis. The correlation values in the table are near to 1 which indicates a strong relationship between the projected graphs with SRES predictors against historical graphs.

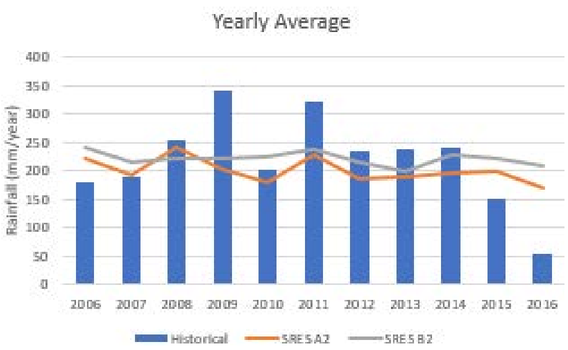
In the next station which was station Pengkalan Kubor situated in Kelantan, the error values are 7.41% and 7.22% for SRES A2 and B2 respectively. With SRES B2 having the lowest percentage of error, SRES B2 was the most suitable SRES to represent the climate trend of the station. The correlation values of the statin are 0.98 across both SRES, indicating a strong relationship between the projected climate data with the historical data.

The last rainfall station in Kelantan which was Kg. Peringat, has an error of 9.69% and 12.87%. for both SRES respectively. the best SRES to represent the station was SRES A2 in which the percentage of error in A2 was lower than the percentage of error in B2. the correlation value was 0.99 for A2 and 0.98 for B2. The correlation values also indicate strong relationship between the projected climate data with SRES predictors against historical data. If the value was higher such that in this case, A2 has a higher correlation value than B2, meaning that A2 correlates more with the historical data than B2 was.

Station: Gunong Barat Bachok 5923001

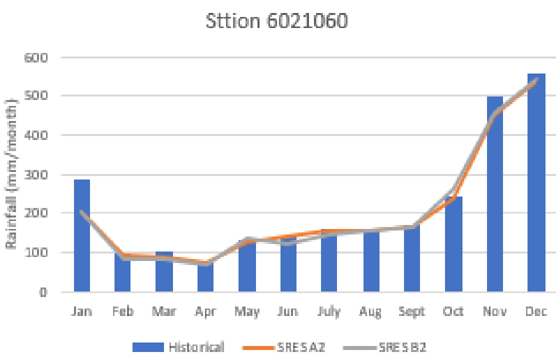


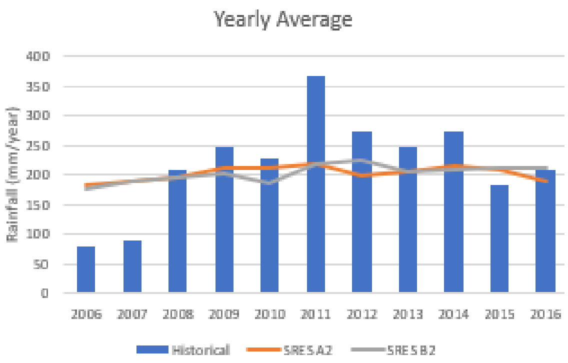
a) Monthly Average vs Historical



b) Yearly Average vs Historical

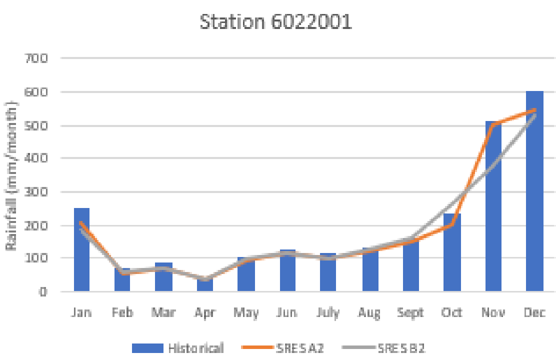
Station: Pengkalan Kubor 6021060

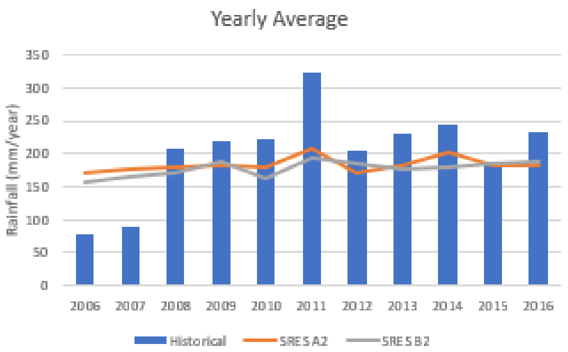




a) Monthly Average vs Historical b) Yearly Average vs Historical

Station: Kg. Peringat 6021060





a) Monthly Average vs Historical b) Yearly Average vs Historical

Figure 4.8 Kelantan Rainfall Best SRES: - a) Rainfall Monthly Average vs Historical. b) Yealy Average of Rainfall Vs Historical

From Figure above, in the first rainfall station for Kelantan which was Gunong Barat Bachok, the maximum rainfall reading obtained was during the end of the year which was during December having a reading of 550mm of rainfall. For the minimum reading of rainfall was found to be on April with a reading of 50mm of rainfall. The trend of the graph was decreasing at the early half of the year, and then increasing towards the peak of rainfall reading obtained which was on December. In the yearly average graph, it was found that the year with the highest reading of rainfall was the year 2009 with a reading of 349mm.the graph fluctuates with having the lowest reading at the end of year 2016.

In the second station which was station Pengkalan Kubor, the highest reading of rainfall obtained in the Monthly Average vs Historical graph was during December with a reading of 550mm of rainfall. The graph’s lowest point was during the month April with a reading of 80mm. the trend of the graph fluctuates until the lowest point of the graph which was on April. After April, there was a slight increase in rainfall and from October, the amount of rainfall obtained rose significantly until reaching the peak of the graph which was on December. In the yearly average graph, the highest point was on the year 2011. The lowest point in the graph was the starting year of the study which was 2006. The trend of the rainfall for the first half of the period was increments of rainfall annually until the highest point of the graph which was on the year 2011. After 2011, the graph fluctuates until the end of the period.

For station Kg. Peringat, in the monthly average vs historical graph, the highest data obtained was on the month of December with a reading of 600mm. the lowest reading of rainfall obtained was during the month April. The trend of the graph decreases at the first4 months of the year and then continues to have increment s of rainfall till the peak of the rainfall data which was on December. For yearly average vs historical graph, the highest reading obtained was during the year 2011 in which it was 310mm of rainfall. The lowest reading obtained was the first year within the study period which was 2006 with a reading of 75mm. the graph has increments of rainfall for the first half of the study period which was between the year 2006 until 2011. After 2011 there was a sharp drop and the trend of the rainfall fluctuates.

4.4.2.3 Best SRES Rainfall Terengganu

The number of stations picked for the rainfall in Terengganu state was 3. The data assessed in rainfall was during the years 2006-2016. The rainfall stations also undergo the same procedure whereas the historical data would act as the predictand and the GCMs would be used as the predictors of the station. The process also includes having the predictand data projected with climate agent AR5 to project the rainfall scenario according to different RCP. From here on, the best RCP was selected by comparison of the historical graph and the data projected via different RCPs, and calculating the differences between the historical data and the projected data. For this, the percentage of error was calculated to account for all small but not negligible numbers.

Table 4.11 Terengganu Rainfall Best SRES Analysis

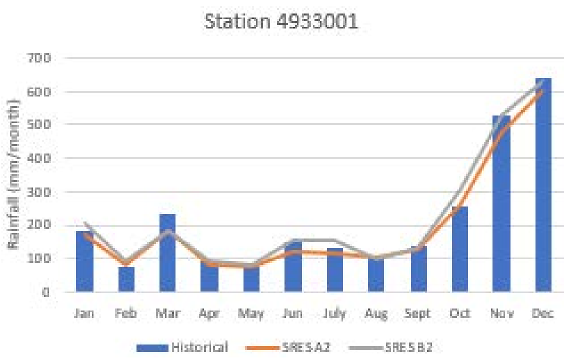
Station	SRES A2		SRES B2	
	Correlation (R)	% of Error	Correlation (R)	% of Error
5131064 Sek. Men Bkt Sawa	0.99	8.25	0.99	**-1.41**
5230042 Rmh. Pam P. Musang	0.99	6.09	0.99	**5.64**
4933001 Klinik Bidan Jambu Bongkok	0.99	**9.97**	0.99	10.84

Based on the table above, in the first rainfall station, which was Sekolah Menengah Bukit Sawa has an error percentage of 8.25% and -1.41% for SRES A2 and B2 respectively. the negative amount of error represents under-projection or the projected graph with the SRES predictors total value was lesser than the historical graph amount. Whilst the positive values indicate over-projection in which the values of projected graph were higher than the historical graph. With the percentage of error of -1.41%, SRES B2 was selected as the best SRES to represent the station.

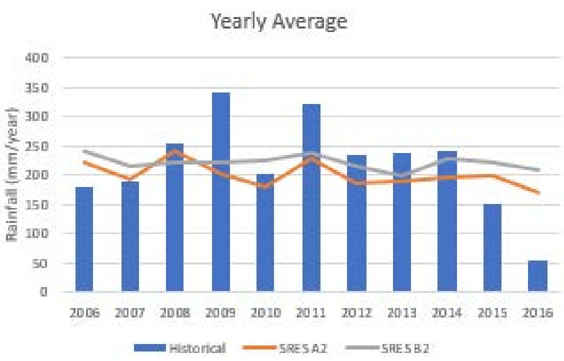
For the second station, which was station Rumah Pam Pulau Musang, the percentages of error were 6.09% and 5.64% for SRES A2 and B2 respectively. With an error percentage of 5.64%, SRES B2 was selected as the best SRES to represent the station in projection of climate trend. For correlation value, the value was the same which was 0.99 which indicates a strong relationship between the historical data and the data projected with the SRES predictors.

For the third station, which was station Klinik Bidan Jambu Bongkok in Terengganu state, the station has an error percentage of 9.97% and 10.84% for SRES A2 and B2 respectively. With an error of 9.97% in SRES A2. It was decided that SRES A2 was the best SRES to represent the station in projection of the climate future trend. For the correlation value based from the table, the values were the same which was 0.99. this indicates a strong relationship between the projected data with the historical data.

Station Sekolah Menengah Bukit Sawa 4933001



a) Monthly Average vs Historical



b) Yearly Average vs Historical

Station Sekolah Menengah Bukit Sawa 4933001

a) Monthly Average vs Historical b) Yearly Average vs Historical

Station Klinik Bidan Jambu Bongkok 4933001

a) Monthly Average vs Historical b) Yearly Average vs Historical

Figure 4.9 Terengganu Rainfall Best SRES: - a) Rainfall Monthly Average vs Historical. b) Yealy Average of Rainfall Vs Historical

From the figure above, in Terengganu's first rainfall station, which was Sekolah Menengah Bukit Sawa. From the monthly average vs historical graph, the highest reading obtained was during December having 610mm. the lowest reading obtainable from the graph was during February with a reading of 70mm. the trend of the rainfall fluctuates most of the months in the study. After September, the trend shows a significant increase in the rainfall reading towards the peak of the rainfall reading which was on December.

In the yearly average vs historical graph for the first station, the highest reading was on the year 2009 which was 345mm. the lowest reading of rainfall recorded was during the year 2016 with a reading of 50mm. the trend of the graph fluctuates most of the time until the end of the period of study where it was evident that there was a sharp drop in rainfall.

The second station for rainfall Terengganu was station Rumah Pam Pulau Musang. In the graph of monthly average vs historical graph, the highest rainfall reading obtainable was during December which was 650mm. The lowest reading obtainable in the graph was during the month April with a reading of 100mm. the graph fluctuates during the first 4 months of the year. After April, the trend increases until October where there was a significant rise in rainfall amount collected. In the yearly average, the maximum data obtained was during the year 2009 and the minimum data obtained was during the year 2016 with a reading o 80mm of rainfall the graph of the rainfall fluctuates with time but the last 4 years of the study period, the rainfall dropped significantly.

The final station for rainfall Terengganu, which was Klinik Bidan jambu Bongkok. In the graph of monthly average vs historical, the maximum rainfall obtained was 540mm in December. The minimum rainfall data obtained was during the moth February with a reading of 80mm. the graph fluctuates for the first three months in the graph. After April, there was a steady increment of rainfall data towards the end of the year which was the peak of the rainfall data obtained at the station. For the yearly average vs historical data, the maximum data obtained was during the year 2009. The minimum data obtained was during the year 2016. The trend of the graph was fluctuating but the first four years of the study showed an increment of rainfall data obtained. The data dropped in the fifth year and rose towards the sixth year in the study. After 2011, there was a decrement of rainfall towards the end of the period.

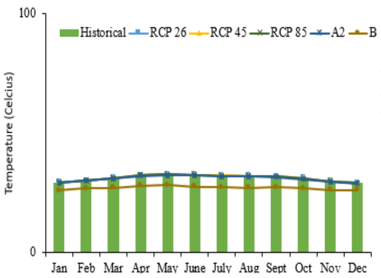
4.5 Generation of Future Climate Trends of Kelantan & Terengganu using predictors AR4 & AR5

The generation of future climate trends was used to project the future climate trends of the station whether it was rainfall of temperature. The predictor selection was important in this aspect because the error of predictor selection could lead to a different projection in the scenarios of RCP and SRES. The generation of future climate trends was done at a 30-year interval from the year 2010 until 2099, with having the first 30-year period as 2010-2039, the second period being 2040-2069 and the third period being 2070-2099. The projection was done across all stations involved with the study. Thus, the total number of stations involved in projection was 9 stations including temperature.

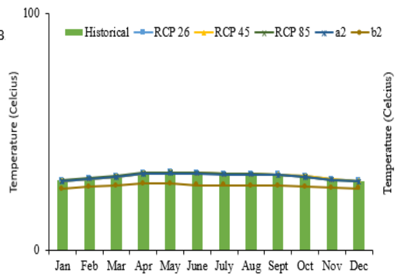
4.5.1 Temperature

The temperature data was projected at spans of 30 years interval. The first 30-year interval was during the year 2010-2039, the second interval was during the years 2040-2069 and the third interval being 2070-2099. The data was projected and plotted in graphs with the historical data and compared the differences between the projected data and the historical data. The figures below showed the average projected temperature against historical data of temperature.

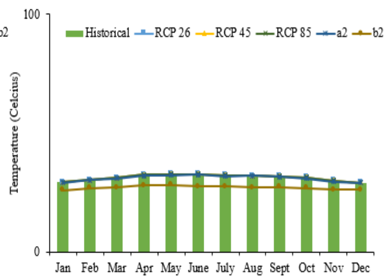
Maximum Temperature



2010-2039

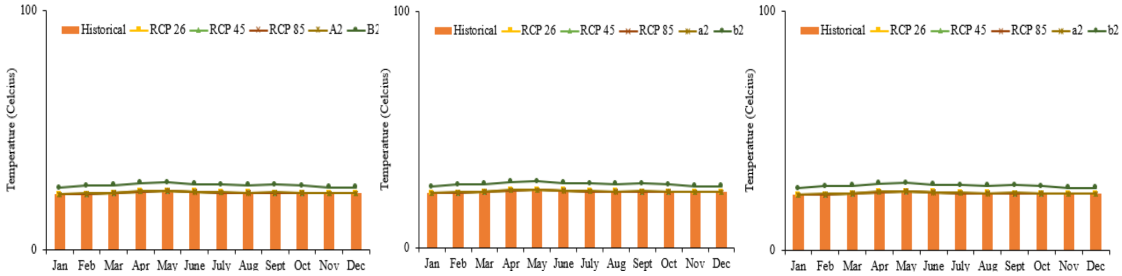


2040-2069



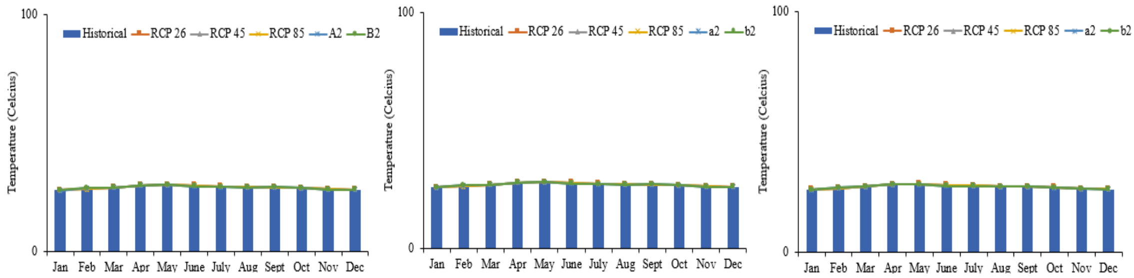
2070-2099

Minimum Temperature



2010-2039 2040-2069 2070-2099

Mean Temperature



2010-2039 2040-2069 2070-2099

Figure 4.10 Temperature Projection over 30-year intervals

From the figure above, the projection in temperature of Kelantan had no severe differences across all the RCPs and SRES. In the maximum temperature graphs, it was evident that the SRES projections were lower than RCP projections. The difference might be miniscule on paper but the graph plots of the average temperature reading vs historical reading shows differences between the projected RCP and projected SRES when plotting with the historical data. From the graphs, it was evident that the SRES has lower maximum temperature data as compared to the historical data and SRES. The trend of the maximum temperature has fluctuations of small degrees whereas the most significant change in temperature whether it was decrement or increment was only by a difference few Celsius.

In Minimum temperature graphs, the projections of average minimum temperature data against historical data has SRES over-projecting the minimum data. Again, the differences between the data were a few Celsius away from the historical data. The historical data has a maximum data of 24 Celsius whilst the SRES has a maximum temperature of 28 Celsius in the minimum average monthly graph against historical. The SRES over-projection portrays that SRES has a higher minimum reading compared to the historical data and RCP. The trend of the graph also fluctuates with having increments and decrements throughout the year.

In Mean temperature graphs of monthly average mean temperature data against historical data, both the RCPs and SRES were on the same page by having the same reading of temperature only a difference of 0.1± Celsius. This shows that the SRES and RCP have no over-projection or under-projection of the data of temperature. The trend of the graph also with a few fluctuations with having the maximum data of 26 Celsius and a minimum data of 25 Celsius.

Table 4.12 Temperature Projection

Station	Period	RCP			SRES	
		2.6	4.5	8.6	A2	B2
Maximum	2010-2039	0.0022	0.0007	-0.0013	0.80669	13.3933
	2040-2069	0.0019	-0.0003	-0.0007	0.80259	13.3933
	2070-2099	0.0010	0.0046	0.0012	0.8007	13.3933

Minimum	2010-2039	23.5436	23.5437	23.5412	23.1177	13.3933
	2040-2069	23.5413	23.5425	23.5409	23.1172	13.3933
	2070-2099	23.5420	23.5380	23.5413	23.1195	13.3933
Mean	2010-2039	13.1941	13.1875	13.1915	13.3925	13.3933
	2040-2069	13.1908	13.1903	13.1877	13.3933	13.3933
	2070-2099	13.1948	13.1901	13.1921	13.3934	13.3933

From the analysis done on previous chapters, it was concluded that the best RCP for Temperature was RCP 4.5 and the best SRES for temperature was SRES A2. In the table above were the values obtained for all of the scenarios in the study. The differences between the best RCP and the best SRES for temperature was 0.79% increment of temperature in maximum category. In minimum category, the differences in projection between RCP and SRES was 0.43% of temperature data. In mean temperature, the differences of projection of temperature was 0.2% of temperature data.

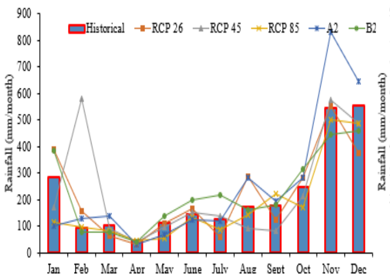
4.5.2 Rainfall

The rainfall data was also projected at intervals of 30 years in 3 periods of time the first period being 2010-2039, the second period being 2040-2069 and he third period being 2070-2099. For rainfall, the graphs of rainfall data were summed to compare against the historical data. The data was projected and plotted in lines to compare against the historical data and to obtain the differences between the projection of SRES and RCP with the historical data.

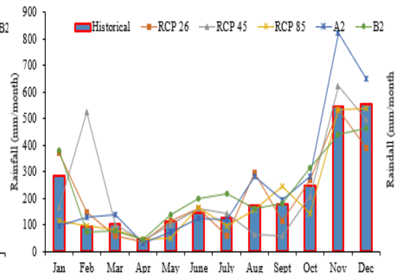
4.5.2.1 Kelantan State

In Kelantan, there were three stations that have their rainfall data projected in 3 intervals of 30 years. The stations that were projected have had their rainfall data simulated with the predictors of SRES and RCP in order to project their rainfall. The data below was the projected rainfall of the three stations of rainfall in Kelantan.

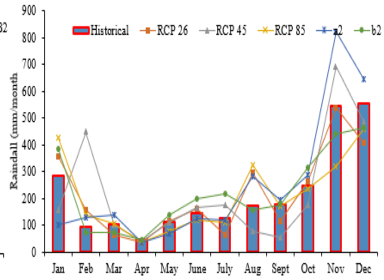
Station: Gunong Barat Bachok (5923001)



2010-2039

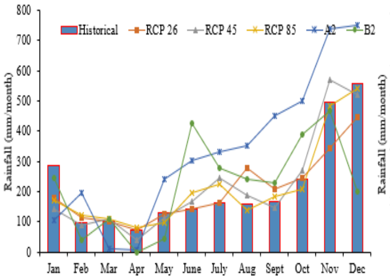


2040-2069

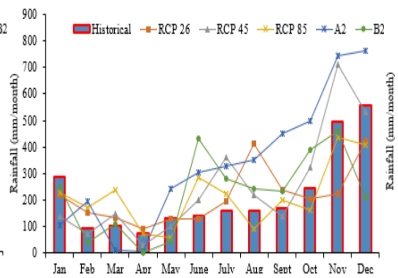


2070-2099

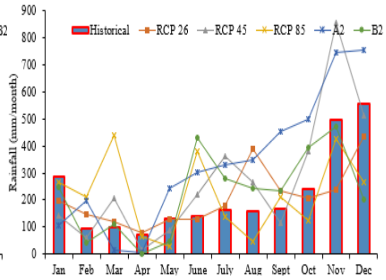
Station: Pengkalan Kubor (6021060)



2010-2039

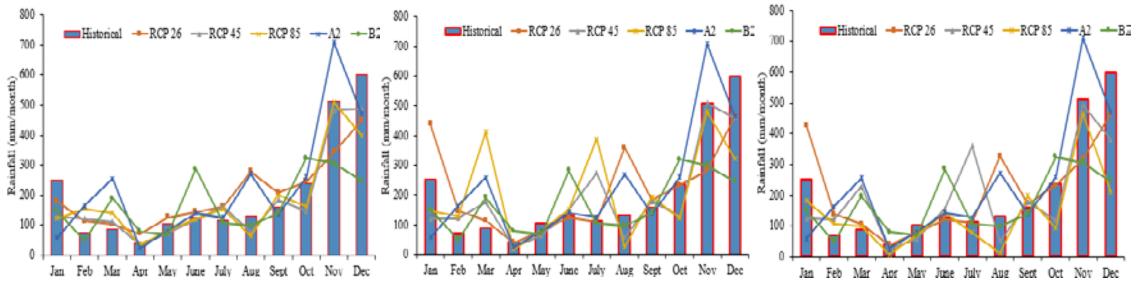


2040-2069



2070-2099

Station: Kg Peringat (6022001)



2010-2039 2040-2069 2070-2099

Figure 4.11 Kelantan Rainfall Projection over 30-year intervals

From the figure above, in the first rainfall station in Kelantan which was station Gunong Barat Bachok, the projection of the rainfall vs the historical data showed different results all across the board with each scenario including RCP and SRES having different projections. The trend for the graph was that it starts intermediately which quickly experiences decrement towards April which has the lowest data of rainfall for the station. After April, there were slight fluctuations in rainfall data in which consists of increment and decrement. From October onwards, the graph increases sharply towards the end of the year.

From the second rainfall station in Kelantan which was station Pengkalan Kubor, the projection of rainfall vs the historical data showed different results across all the scenarios. We can see that from all of the graphs of the station showed SRES A2 having a higher rainfall data than the historical data at the peak of rainfall data accumulated which was on December. The trend of the graph was fluctuating in the first four months in the graph which was from January to April. After April, which was the lowest data in the station the rainfall data begins a slight climb monthly towards October. From October onwards, the graph skyrockets till its peak data obtained which was on December.

The third rainfall station which was Kg Peringat, the projections of both SRES and RCP are different from the historical data. This can be referred to the graph in the figure above. The highest rainfall projection for the station was SRES A2 which has a peak data on November instead of December which was the historical highest data obtained. The trend of the graph in the station was fluctuations in the 7 months from January, reaching the lowest point during April. After July, the data began a climb towards the end of the year. After October, the data rose sharply towards November and December which has the highest historical data.

Table 4.13 Kelantan Rainfall Projection

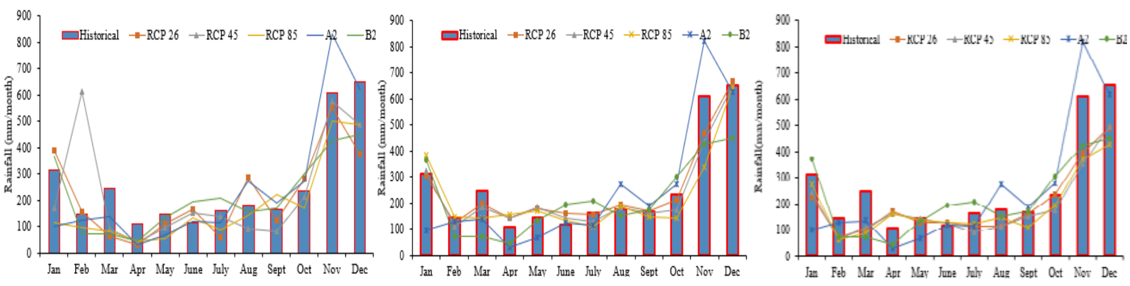
Station	Period	RCP			SRES	
		2.6	4.5	8.6	A2	B2
5923001 Gunong Barat Bachok	2010-2039	0.5667	-4.3407	18.1005	-12.7868	-2.7340
	2040-2069	2.2744	-2.7392	13.1576	-12.6433	-2.6013
	2070-2099	1.5618	-2.6477	3.4410	-12.4248	-2.6297
6021060 Pengkalan Kubor	2010-2039	7.6152	0.7698	2.4602	-52.4038	-2.3253
	2040-2069	2.2824	-13.79	-12.9705	-52.8367	-2.7873
	2070-2099	5.2405	-23.4087	0.6133	-52.7708	-3.2229

6022001 Kg Peringat	2010-2039	0.8811	12.8780	12.1299	-10.4249	16.2683
	2040-2069	-5.513	6.94780	-1.38336	-10.2217	16.7399
	2070-2099	-3.4394	6.1960	-33.4621	-10.6876	16.1120

From previous chapters, the best RCP for rainfall Kelantan was RCP 4.5 whilst for SRES, the best SRES representing rainfall Kelantan was SRES A2. The difference in rainfall projection in the first rainfall station which was station Gunong Barat Bachok, the difference of projection in rainfall amount was 9.37%. furthermore, in the second station of rainfall in Kelantan which was Pengkalan Kubor has an difference percentage of 5.04% in the projection of rainfall between RCP and SRES. In the final station of rainfall Kelantan which was Kg. Peringat, the difference of projection of rainfall between RCP and SRES was 9.11%.

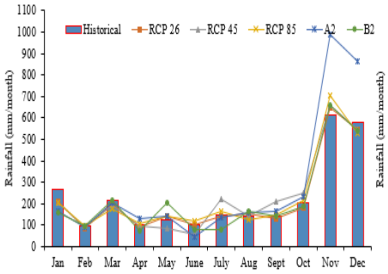
4.5.2.2 Terengganu State

Station: Sekolah Menengah Bukit Sawa (5131064)

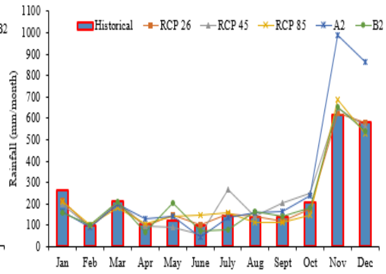


2010-2039 2040-2069 2070-2099

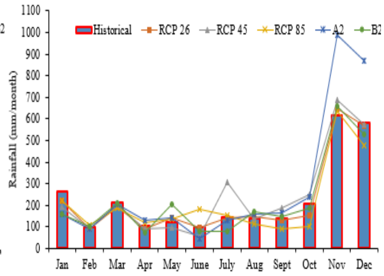
Station: Rumah Pam Pulau Musang (5230042)



2010-2039

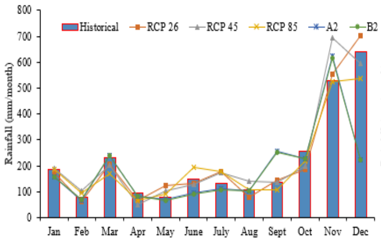


2040-2069

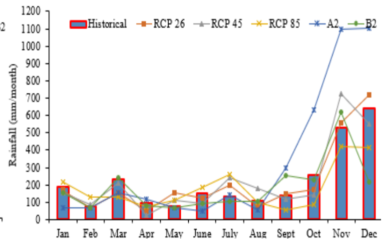


2070-2099

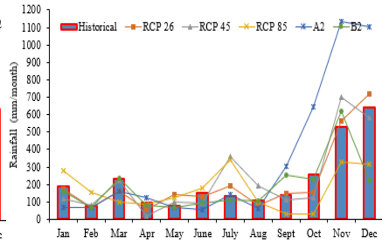
Station: Klinik Bidan Jambu Bongkok (4933001)



2010-2039



2040-2069



2070-2099

Figure 4.12 Terengganu Rainfall Projection over 30-year intervals

Based on the figure above, the first rainfall station in Terengganu which was station Sekolah Menengah Bukit Sawa, most of the scenarios in RCP and SRES follow the flow of the graph as in having incremental and decremental at the same month. However, this was not true for SRES A2 as having a maximum data during November whilst the historical data's maximum rainfall obtained was during December. This was true for all three graphs of the station. The trend of the station was fluctuations from the start of the year until October in which the graph rises sharply to attain the peak rainfall which was on December.

In the second rainfall station of Terengganu, which was station Rumah Pam Pulau Musang, the projections of the scenarios in comparison to the historical data differs as in A2, the value for the highest rainfall data obtained was up to 1000mm for the month November only. This was the same across all three graphs of the station. The trend of the graph fluctuates with having decremental and incremental of rainfall data from the month January up to June. After June, the data has a slight climb towards November where it rises sharply towards the peak of the rainfall data which was in December.

The final rainfall station in Terengganu which was Klinik Bidan Jambu Bongkok has rainfall readings that differ from the historical data of the station. The projection differs in terms of there was a high reading in SRES A2 where in turn at the end of the month has a higher reading that the historical reading. The trend of the graph fluctuates from January till August where from August onwards, the reading starts to have incremental of rainfall where it reaches the peak of the rainfall data in December.

Table 4.14 Terengganu Rainfall Projection

Station	Period	RCP			SRES	
		2.6	4.5	8.6	A2	B2
5131064 Sekolah Menengah Bukit Sawa	2010-2039	5.9962	7.0883	5.3605	-20.7690	2.0614
	2040-2069	6.7622	7.5802	7.6114	-20.3468	2.4710
	2070-2099	6.8795	7.4815	11.6222	-20.4686	1.8953
5230042	2010-2039	3.8189	-0.4099	0.3325	-21.3045	5.0843

Rumah Pam Pulau Musang	2040-2069	3.4494	-2.8979	3.2214	-21.3608	5.3799
	2070-2099	3.9881	-4.7457	7.6342	-21.4564	5.3137
4933001 Klinik Bidan Jambu Bongkok	2010-2039	0.6022	-3.4596	5.4287	14.1290	14.6152
	2040-2069	0.8549	-0.6777	16.2323	-46.9716	14.3783
	2070-2099	1.3846	-2.8412	21.6881	-50.0533	14.5376

Based on the previous chapters in study, the best RCP for the rainfall station in Terengganu was RCP 2.6 and the best SRES for rainfall Terengganu was SRES B2. In the first rainfall station of Terengganu which is Sekolah Menengah Bukit Sawa, the difference of projection between the best RCP and the best SRES was 4.43%. in the second station, which was station Pulau Musang, the difference of rainfall projection between the best RCP and best SRES was 1.5%. In the finbal rainfall station in Terengganu which was station Klinik Bidan Jambu Bongkok, the differences of rainfall projection between the best RCP and the best SRES was 42.07%.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The study has contributed towards the projection of climate trend by comparing two models back to back and deciding which model suits the most in AR4 & AR5. The models help in turn to project future climate when required and can be used as a guideline for projection of climate in the future. With the application of SDSM in the study, it was apparent that the software was vital in terms of downscaling the global-grid data and to simulate and project the future climate of the study area. Global Circulation Models (GCMs) were used to project climate trend which considered the estimated emission level in the future year. The results were used as input for data in hydrological models in the study area. In general, the differences of the Assessment Reports (AR) prove to have varying levels of interpretation in which from the basic principle of the mechanism used to take into effect the climate trend such as emission of GHGs and the radioactive forcing of the components. Therefore, without the breakthroughs in technology and the reinterpretation of the mechanisms used in the Assessment Reports, there would be problems in anticipating and planning a mitigation plan for the future.

This chapter presents the conclusions from the discussions in the chapters it superseded. The conclusion drawn was: -

5.1.1 Best RCP & SRES for Terengganu & Kelantan

a) The best RCP for Temperature data was RCP 4.5 which was evident across all temperature data in the study with an average error of 0.002% with R-value 0.99.

b) The best SRES for temperature was SRES A2 which was obtained from maximum and mean temperature. With an average error of 0.0009% and R-value 0.99.

c) The Best RCP for Kelantan rainfall is RCP 4.5 which is portrayed in stations Gunong Barat Bachok & Kg. Peringat with an average error of 5.56% with R-value 0.99.

d) The best SRES for Kelantan rainfall is SRES A2 which is obtained from the same stations as the RCP with an average error of 8.34% and R-value 0.99.

e) For rainfall Terengganu, the best RCP is RCP 2.6 which is obtained from stations Sekolah Menengah Bukit Sawa & Rumah Pam Pulau Musang with an error percentage of 6.3% and R-value 0.99.

f) The best SRES for Terengganu rainfall is SRES B2 which is also obtained from the corresponding stations in Terengganu with an error percentage of 1.91% and R-value of 0.99.

5.1.2 Performance difference between SRES and RCP

a) In maximum temperature, there was a 0.001% increase in temperature for RCP and a 0.80% increase in temperature for SRES. The difference in the readings were by 0.79%.

b) In Minimum temperature, the increase in RCP was by 23.54% whilst for SRES the increase was 23.11%. The differences between these two reading was 0.43%.

c) For Mean temperature, RCP had an increment of 13.19% whilst for SRES there was 13.39% increment. The differences for both temperature readings was 0.2%.

d) In rainfall Kelantan’s first station, for RCP there was a decrement of 3.24% of rainfall whilst SRES’s projection had 12.61% of decrement of temperature. The differences between these two readings was 9.37%.

e) In the second rainfall station of Kelantan, there was a decrement of 3.29% of rainfall for RCP whilst SRES experienced 8.33% of rainfall decrement. The differences between the readings were 5.04%.

f) In the final rainfall station of Kelantan, the RCP projection had an increment of 8.67% of rainfall whilst for SRES had a decrement of -0.44% of rainfall. The differences of these two readings was 9.11%.

g) For rainfall Terengganu, in the first station, there was an increment of 6.54% for RCP's projection whilst for SRES there was a decrement of 2.14% of data. Between these two readings, the differences were 4.43%.

h) In Terengganu's second station, the rainfall projection produced a 3.75% increment of rainfall and the SRES produced an increment of 5.25%. There was a 1.5% difference between the readings.

i) In rainfall Terengganu's final station, there was an increment of 14.44% of rainfall projection of RCP whilst SRES has a decrement of 27.63% of rainfall data. The differences were 42.07% of rainfall data.

j) For temperature, the lowest data obtained was during the month of December whilst the highest temperature data obtained was during the month May.

k) In Rainfall Kelantan, the lowest rainfall data obtained was during April. The highest data was obtained during December.

l) In Terengganu's rainfall data, the lowest data obtained was during the month April whilst the highest data obtained was during the month December.

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