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PREDICTION OF FUTURE CLIMATE TREND USING STOCHASTIC WEATHER GENERATOR

AHMAD SAIFUDDIN BIN OTHMAN

Report submitted in fulfilment of the requirements
for the award of the degree of
B.Eng. (Hons.) Civil Engineering

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Dedicated to

Parents

Encik Othman Bin Bidin

Puan Zunaidah Binti Hussin

Supervisor

Dr. Nurul Nadrah Aqilah Binti Tukimat

Others

Team Members

Friends & all related parties

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ABSTRACT

The issue of climate change and its effects on various aspects of the environment has become more challenges for society. It is desirable to analyse and predict the changes of critical climatic variables, such as rainfall, temperature and potential evapotranspiration affect in the content of global climate change. This change is also affected by the increment of gas carbon dioxide (CO2) and other gases GHGs emissions. This study is focus of analyse the prediction patterns of rainfall, temperature and potential evapotranspiration of Pahang state. The rainfall pattern can be estimate the future climate change, general circulation models (GCMs) are applied. Therefore, Long Ashton Research Station Weather Generator (LARS-WG), which utilized the Stochastic Weather Generators approach, is applied in order to convert the coarse spatial resolution of the GCMs output into a fine resolution. The result show that the changes in rainfall, temperature and potential evapotranspiration can be consider is state to the trend of change in the respective by years. Therefore, the quantity of annual rainfall decreases had reached above 64%, while the distribution of temperature can increases had reached above 10% and potential evapotranspiration raise had reached above 44% increases of the end of century. In this study, have seen different results from the PRECIS and LARS-WG models though we have used the same GCMs (HadCM3) and emission scenario, which reveals the uncertainties due to the downscaling method. The LARS-WG result shows difference with PRECIS for rainfall and temperature. However the monthly rainfall prediction by LARS-WG is performed well closer to the history compare to the PRECIS. The annually LARS-WG is performance well closer with 1.19% to the history compare to the PRECIS with 32.86%.

ABSTRAK

Perubahan iklim serta kesannya terhadap alam sekitar merupakan suatu isu yang telah menjadikan masyarakat terdedah dengan lebih banyak cabaran. Kajian yang dijalankan adalah bersesuian untuk menganalisis dan meramalkan perubahan bentuk iklim yang kritikal seperti hujan, suhu dan potensi evapotranspirasi yang mampu menjejaskan keadaan perubahan iklim global. Perubahan ini juga dipengaruhi oleh kenaikan gas karbon dioksida (CO2) dan gas-gas pelepasan GHG yang lain. Kajian ini lebih memfokuskan dalam menganalisis corak ramalan hujan, suhu dan potensi evapotranspirasi bagi keseluruhan Negeri Pahang. Perubahan iklim masa depan seperti corak keadaan hujan boleh dianggarkan menggunakan Model Edaran Umum (GCMs). Oleh itu, Stesen Penyelidikan Cuaca Long Ashton Generator (LARS-WG) yang menggunakan penjanaan cuaca secara stokastik, penjanaan ini digunakan untuk menukarkan keputusan resolusi spatial GCMs secara umum ke dalam resolusi halus. Keputusan kajian menunjukkan bahawa perubahan keadaan hujan, suhu dan potensi evapotranspirasi boleh dipertimbangkan mengikut lokasi daerah-daerah dalam Negeri Pahang bagi menentukan corak perubahan mengikut tahun. Oleh itu, kandungan kuantiti hujan telah menurun sebanyak 64%, manakala agihan suhu mampu meningkat mencecah melebihi 10% dan kenaikan potensi evapotranspirasi mencapai sebanyak 44% pada akhir abad yang akan datang. Dalam kajian ini juga melibatkan keputusan berbeza diantara model PRECIS dan LARS-WG dengan menggunakan GCMs yang sekata iaitu (HadCM3) dan juga senario pelepasan telah mendedahkan keadaan tidak menentu kerana kaedah penskalaan yang agak rendah. Hasil LARS-WG menunjukkan perbezaan dengan PRECIS untuk keadaan hujan dan suhu. Ramalan hujan bulanan yang dijalankan menggunakan model LARS-WG menunjukan prestasi yang baik apabila corak ramalan lebih menghampiri dengan corak data sebenar berbanding dengan corak daripada model PRECIS. Prestasi bagi setiap tahun model LARS-WG adalah lebih dekat hanya perbezaan 1.19% dengan data sebenar berbanding dengan model PRECIS iaitu perbezaan 32.86%.

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LIST OF SYMBOLS

°C	Celsius
mm	Millimetre
%	Percentage
N3º54’	North Coordinate
E103º08’	South Coordinate
km	Kilometre
km^2	Square Kilometre
Emp	Semi-Empirical Distribution
a_0, a_1, h_i	Histogram With Intervals
ft	Feet
m	Metres
ɳ	Mean
X_i, Y_i, i-th	Observation and Simulated Data
2.5° × 3.75°	Spatial Resolution
CO2	Carbon Dioxide

LIST OF ABBREVIATIONS

GCMs	General Circulation Model
PRECIS	Providing Regional Climate for Impacts Studies
RCMs	Regional Climate Models
LARS-WG	Long Ashton Research Station Weather Generator
MMD	Malaysia Meteorological Department
DID	Department of Irrigation and Drainage Malaysia
IPCC	Intergovernmental Panel on Climate Change
ID No	Station Number
T-max	maximum temperature
T-min	minimum temperature
R	Coefficient of Correlation
MAE	mean absolute error
RMSE	root mean square error
HadCM3	Hadley Centre Coupled Model (version 3)
A2	Scenario
KS	Kolmogorov Smirnov

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Today, Malaysia is heading towards as a developing country. The various development programmes have been introduced to improve the standard of living of the population. However, the rapid development with improper planning will brings negative effects such as extreme weather and climate change. The change of climate is caused by the changes of micro climate pattern. The potentially an extreme climate event.

In addition, Malaysia's position is on the equator line area provide the rainfall throughout the year, hot and wet climate. For annual temperature difference is highlighted in within less than 2ºC. The east coast of peninsular Malaysia, the reading average temperatures slightly different as a result of a surge effect is influenced by cold wind from Siberia during the monsoon. The condition of the sky is also rare to have a direct cloudless sky, although in season of severe drought. Malaysia is also rarely have a period of a few days with no direct sunlight except the northeast monsoons (Sulong, 1985). The climate change is an average long-term change of the trend climate within decades to millions of years. This change can refer to changes in environmental conditions such as the level of rainfall quantities. The rainfall greatly affects the process of natural ecosystems. It includes any seasonal changes in patterns of long-term average temperature maximum and minimum, radiation of sunlight, wind and season.

In Malaysia, an extreme rainfall is occurred in anything at anywhere. The rainfall intensity is expected higher during northeast monsoons compared to the rainfall amount during transition monsoon. The eastern part of the peninsula is the most affected by the rain to convection contribute more areas in the western of the peninsula.

The long term pattern of future rainfall is estimating using variables from the general circulation model (GCMs). GCMs are a computer based-model of the Earth system and are used mathematically to simulate the present and the project future climate, which is reinforced by greenhouse gases and aerosols. However, the GCMs output are not able have to use directly for the hydrological assessment because these variables coarse spatial resolution (Karamouz, 2009). Therefore, the Long Ashton Research Station Weather of Generator (LARS-WG), one of the Stochastic Weather Generators approach, is applied in order to convert the coarse spatial resolution of the GCMs output into a fine resolution.

In Malaysia, the Providing Regional Climate for Impacts Studies (PRECIS) is one of the regional climate model to generate the long term climate pattern is widely used. The PRECIS can be applied to any area of the globe to generate detailed climate change projections. This model takes into account the dynamic flow factors, atmospheric sulphur cycle, rain and cloud, radiation processes, the surface and deep soil are all described. The current limit of boundary is required to provide model domain meteorological forcing for the RCM. The information about all the elements of climate change through generating high resolution climate change scenarios using PRECIS are represented in the model produced.

1.2 Problem Statement

Lately, Malaysia enacted extreme climate change, some among them had never seen before. With countries located in the equator, Malaysia has already prevalent in a tropical climate. However, Malaysia saw a variety of weather phenomenon which is considered quite unusual. This includes the hot weather that is too hot blazing up to reach 41°C, rainfall with the sum too high during monsoon northeast to occur a major flood, cold temperatures like happened in Kelantan until decreased 19°C in the early years and the occurrence of a tornado often occurs at the end of 2014, the El-Nino phenomenon resulting in more floods, droughts, and heat waves.

The rainfall patterns are very important role in the determination of future climate conditions. Therefore, various initiatives have been undertaken to overcome the problems associated with rain due to a variety of possibilities will happen if not done vigorous. In addition, increasing the temperature at maximum and minimum readings will also affect all activities that made the study area.

The problem of natural occurrence of disasters related to rainfall also occurs such as flash floods and floods would recommend residents and urban areas. This is because excessive water will damage public property and claimed human lives (Arakawa, 1969). Furthermore, the increase in population for the two districts each year has brought in the existence of the increased water demand, not only from the aspect of public water supply only in activities agriculture and industry (Watung, 2004).

However, there are a variety of modern and sophisticated equipment used in hydrology for the researchers. However, not all problems can be overcome but it can reduce the problems. Consequently, each study and analysis is done not so accurate and precise. It is because of the accuracy of an analysis very depending on the perfection in work and consumption data.

Therefore, it is important to review and interpret the data from the analysis conducted, it was determined that a systematic method of regulating the state-condition (Sarjon, 2000). If the required data is not complete and there are many defects, this situation will cause problems for researchers in the field of hydrology. For there is not enough data for a specific problem, then arise circumstances difficult for members of hydrology.

In addition, the watershed is a place of the research centres discovered soil and water conservation in Malaysia. The conservation of water catchment areas used to water storage for the domestic using of the population. The storage area is a fundamental and has an influence on the actual rate of evaporation, groundwater recharge and runoff. The impacts of climate change on these deposits are directly or indirectly affect the hydrologic cycle differently. Due to the uncertainties in climate change, this projection can function under various climate change scenarios. This is a great way to improve the life and welfare of the population exposed to a variety of climate change.

Therefore, the proposed study is based on various climate change scenarios present. This study provides information that helps all public people and policy makers to develop an innovative idea in storage and productivity in response to climate change risks and make decisions accordingly.

1.3 Objective of Study

The objective of this study is:

i. To generate the current and future trend is rainfall and temperature at Pahang state using LARS-WG.

ii. To evaluate the performance of the climate projection between LARS-WG and PRECIS model with the historical data.

1.4 Scope of Study

The study focused on the projection of the future pattern and trend of climate at Pahang state using LARS-WG model. The historical daily rainfall provided by Malaysia Meteorological Department (MMD) and temperature data provided by Department of Irrigation and Drainage Malaysia (DID). The A2 scenario is used to represent the level of the state development due to the efficiency of the climate projection result. The contrast performance between LARS-WG and PRECIS models are compared based on statistical characteristic. The latest 30 year rainfall and temperature started 2014 until 1984, was conducted in Pahang area. This study focuses on climate change using the rainfall data base on the districts in Pahang. The study will look at the effectiveness and accuracy of data on precipitation and temperature analysed the influence of climate change in the area.

1.5 Significant of Study

This important study is to determine the pattern and trend of long term of rainfall and temperature in Pahang state affected by the climate change. The application and performance of LARS-WG as a weather stochastic model for Pahang state can be measured with comparing the climate result produced by MMD Malaysia using PRECIS model. Thus, the effectiveness of this data proved through the analysis made based on the values of average monthly and total annual rainfall, duration of cleaning (dry period) and duration of wet (wet periods) and the values of maximum and minimum temperature can would recommend the reviews. The importance of this study is as correctly identify the data distribution of rainfall and temperature in the area under study and correlate between data for rainfall and temperature are analysed in the influence of climate change in the area. Therefore, indirectly aware of the background environment and hydrological characteristics in the area and able to anticipate climate change the distribution of the quantity of rain will occur in the future at area of study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, climate is considered to be a critical global challenge to the world. Several of climate studies have been explored including the relationship between durability and capacity of the earth with the climate change. The main problem comes from the global warming issues. Climate change and global warming phenomenon should be taken serious action because it will cause damage and loss of life. The Prime Minister said, the rainfall pattern has changed and Malaysia experienced extreme drought that led to water crisis in some state early and in the middle of last year. At the end of last year, prolonged heavy rainfall causing extensive damage to property and lives lost due to flooding (Bernama, 2015). The climatic conditions will persist over the world if greenhouse gas scattered at the present stage, in the middle of this century, global temperature will rise by about 2 degrees Celsius compared to the temperature of the years 1986 to 2005. Then, the end of this century, global temperature will rise until approximately 3.7°C (Rahmat, 2014).

The weather is a combination of atmospheric and climatic event. The global warming is the study of the field of meteorology and climate research. The study and observation reveals a pattern of increased carbon dioxide that is so significant and this situation certainly raises concerns among experts study the weather. However, a small of scientists argue global warming is happening today much to the influence of solar activity on the sun, where the astrologer to detect an increase in hot spot on the surface of the sun over the past few decades.

The global climate phenomenon can cause a hot and dry climate, where human activity affects the current weather conditions. Meanwhile, the climate is generally calculated as the weather condition in a certain long period time, in minimum at least 30 years (Semenov, 1999). The climate whether has strong relationship supported by the modern technology. Nowadays, the data of temperature and rain in each every day, monthly or yearly differences can be obtained.

The change of climate has big potential to affect the human health, either directly or indirectly. A live, human health is influenced by changes in weather patterns such as temperature, rainfall, rising sea water and increased frequency of extreme weather. As a result, the changing in weather patterns affecting the growth of the virus and immunity bacteria and human until able to affect human health. Affected by the climate change makes the mechanism of atmospheric circulation may changes in quantity of rainfall, rainwater, air and soil humidity, ozone, water resources and the losses of ecosystem (Arakawa, 1969).

The most significant potential consequences of change in climate can potentially to changes the hydrological cycle of the region and subsequent changes in river flow. These any changes need to be constantly monitored in order to increase the productive capacity the area to face unexpected climate. The reserve of water is an important area that needs to be maintained so as not to damage the natural ecosystem (Amsran, 2007).

The different rainfall condition is different climate areas. Among the elements of weather and climate are most clearly effective in influencing the rate of natural rainfall is sunlight, temperature and wind. The influence of sunlight can be explained based on the intensity of extreme weather. The period time sunlight for certain area can generate the difference rate of solar radiation. The radiation of sunlight affects directly to solar radiation period rate. Many of the least sunlight also can determine whether temperature influences can become high or low.

The rainfall is the most important element affecting of the life and nature cycles. This is because rainfall is able to balance the influence of the water supply, water catchment and natural drainage. The influence of rainfall pattern in determines place area depending on the total quantity of rain received in the area and the duration of the rain either daily or throughout the year. The condition of the influence of terrain at each area such highland, hills or slopes is so difference because movement of water, runoff and exposure to sunlight as well as the processes natural ecology and weathering. This indirectly affects the environment.

The height of the earth surface at place determines the variation in climate differences as well as the elements such as sunlight, temperature and rainfall rate. The differences in the characteristics of this climate will affect humidity conditions in term of rainfall quantities (Christensen, 2004). Another factor that may influence the rainfall quantity is the altitude of the rainfall rate. For example the mountainous tropical area where the humidity is higher than land area has various climate characteristic at difference level of altitudes. The rainfall is an important component of human life and productivity. Currently, over billions of people do not have enough access for information and knowledge about what can be happen the surrounding condition (Bravo, 2009). However, the condition of the rain at each place availability vary according to environmental conditions, especially involving human activities because these activities affecting the rate of greenhouse gas content.

This problem is become critical due to the increase in industrial demand caused by economic and population growth. However, climate changes become exacerbate of rainfall patterns and trend. It can cause the frequency and volume of the uneven distribution of rainfall in some places. The tropical areas such as the equator with Malaysia, its forest condition was thick, compact, many species, height or large and able to protect the surface of the earth. The duration of sunshine is able to influence the rate of moisture to keep the land and air downturn. Thus, the forests condition in difference layers at every stage. The influence of climate and weather is temperature. The change of temperatures may influence the warm condition and the pattern of environment condition at this area.

Malaysia has huge water resources due to insufficient annual rainfall of 1500 mm to 3000 mm per year with an average of 2400 mm (DID, 2013). However, Malaysia often hit by various disasters water resources such as droughts, floods, acid rain and water pollution. Thus, the main reason for the occurrence of water disaster was attributable to uneven rainfall distribution, in terms of space and time. In Malaysia, DID and MMD are the organizations who are responsible to monitor and control these issues. According to the (IPCC, 2007) report stated that the increment of the evidence shows an increase in the average temperature of the world over the past 50 years is the result of the increase in greenhouse gases, especially carbon dioxide gas resulting from the combustion of fossil fuels. Malaysia is one of the countries that expose to receive higher rate increment of temperature (Fredolin, 2008).

During year 2014, heavy rainfall stemmed from southeast monsoon blows across the South China Sea that causing the sea is warmer than usual. Scientists have been predicting that more climate change worsen, the heavy rainfall patterns are becoming increasingly uncertain. The encounter of 2 phenomenon’s there one full moon phenomenon and the northeast monsoon that blows across the South China Sea as a result of flood disaster at the most area of Malaysia. The rivers overflowed due to non-stop rainfall at the upstream. These conditions become worse. Pahang is one of the states in Malaysia that were affected when by the sea. In year 2013, Kuantan is the worst district that was affected by flood event. The main factor contribute to this situation is the non-stop rainfall days due to northeast monsoon that raise the water level of river flow. The heaviest rainfall is focused on the land area of Bukit Rangin and Rangin Isap. In addition, the increment of population at several as a result of increment of surface runoff generated that may contribute to the flood event.

The heavy rain event occurred on an on-going basis up to four to seven days. In December 2013, the monthly rainfall was recorded to achieve 1130 mm/month. The water levels at four major rivers in Pahang had crossed the danger level there are Tembeling river in Kuala Tahan at 75.35 metres (hazard level 68.00 metres), Pahang river in Sungai Yap at 54.93 metres (hazard level 52.00 meters), Kuantan river in Pasir Kemudi at 8.79 metres (the level of danger of 8.20 metres) and Kuantan Bypass river at 5.27 metres (hazard level 3.5 metres) (DID, 2013).

2.2 The Description of Hydrological Cycle

Hydrological cycle is a natural cycle process of nature. The cycle is able to produce sufficient water resources and process surface water for the normal demand. The water can move in all circumstances as atmospheric such as in the air, on the earth's surface and in the ground of the earth. The movement of the water is always constantly moving and changing shape as liquid to steam, liquid to ice and back again in the original form, namely liquid. Since billions of years ago, the water cycle has happened and all that life is this earth needs water as a part of life. The water cycle is a cycle that occurs on an on-going basis. It begins at place and water retention areas such as the oceans.

The sun rays are expediting process of the water cycle. The sunshine will evaporate the water surface turn to water vapours. Then, the steam-water vapour will rise by air currents push. The cold temperatures will make the water vapours gather and become a cloud. The flow of wind will push the cloud movement. The cloud droplet wills encounter between each other to make growing big. Once larger, it will fall to the ground that well known as a rainfall. A portion of rainfall seeps into the ground and can be collected as groundwater and the rest will flows on the land surface as water runoff.

Some of the water runoff will be absorbed by the plant roots system for the growth process and then released to small pores on the underside of lanes so called as transpiration process. The excess water on the land surface will be absorbed into the soil and keep in the aquifers space (sub-surface rocks). This aquifer is formed and is able to store large quantities of water storage in long period. However, the water storage is still move due to the natural earth gravity and flow naturally to the lower altitude areas such as the ocean. All these processes will be continuing as a part of nature cycle.

The hydrological cycle will also move hydrosphere which is the area that contains the quantity all of air, water and the ground surface. This cycle is a process of the water movement through hydrosphere. This makes the whole process easier to move water. This process easier is divided into 5 sections it is condensation, infiltration, runoff, evaporation and precipitates. The cycle will start with the condensation process. During condensation process, the water vapour condenses to the liquid water when contact with the cloud condensation within the atmosphere to form a cloud. The condition is supported by the temperature at difference layer and the earth's surface. As a result of this temperature difference, water is expected to change in shapes and properties. It caused by the unstable temperature conditions and the changes of temperature level. When the surrounding air consistently in cold, the water vapour will condensate to the cloud formation.

When the cloud began to form, wind movement also will start moving across the globe and causes the water vapour will be cluttered. The contents of the cloud will also achieve a level no longer able to accommodate the rate of water moisture, then this will change water vapour and will produce recognized is known as distribution of rainfall. When rainfall occurs, there is the process of infiltration, flow and evaporation will start. These processes can occur simultaneously. The infiltration process will occur when water was seeping into the ground.

This process is closely related to the permeability of the ground conditions. The structural properties of soil permeability to be measured by flow speed pass through to the soil layer. The more permeable properties of the soil surface, the more moisture it will absorb water into the soil. The infiltration process is faster from surface runoff flows caused by the permeability of the soil. Then, the surface runoff flows will move above the ground and will flow to lower areas. The part of the flow of runoff water will flow like a river channel. The river flows are gathered in the reservoir water places more known as the lake and sea. Furthermore, the flow of water in the basement will also move also simultaneously and will flow into rivers and eventually return to those areas.

Evaporation is also may occur due to the sunshine radiation and the surface area that exposed to the sunshine. The evaporation or gaseous state is the process of element or compound transitions from liquid water to the water vapour. The sunshine radiation will make temperature measurements will be the growing liquid water as temperatures because ocean or lake will also be on the rise. When the water temperature is rising, the water molecules can evaporate into the air. Therefore, the hot air will start to rise higher into the atmosphere and started to change turns into water vapour, water vapour will slowly cause condensation process.

The water resource is very important to the earth life such as plants, humans and animals. Therefore sustainable of the hydrological cycle must be maintained to ensure the continuous storage of water resources for the earth life. Based on researched, 100 billion gallons of water a year are expected to be filtered and recycled through the process to ensure the quality of water before it can supply to society. The insufficient water supply may cause of diseases and intimidation for the human life. Viessman, (1977) also classified the hydrology as a soil science includes all movements of hydrology, occurrence, distribution and features in this world and relation with nature. The hydrological related fields are as geology, the study of weather and climate, meteorology and study marine scientific research. The basic components of the hydrological cycle include the groundwater flow, stream flow, runoff, infiltration, evapotranspiration, evaporation and precipitation. The flow of water movement through several phases in will process hydrological cycle was in terms of time and space (Bedient, 1988).

The movement of the water cycle process is started from the oceans into the atmosphere and then end up being part of the rainfall distribution over the surface of the earth. The water is formed and accumulated into the river or lake area and then will flow naturally to the ocean. During these processes, it involves with 3 layers of properties there are solid, liquid and gas. It as a prove that the quantity of rainfall amount of rainfall. The hydrological cycles can be summarized in the Figure 2.1.

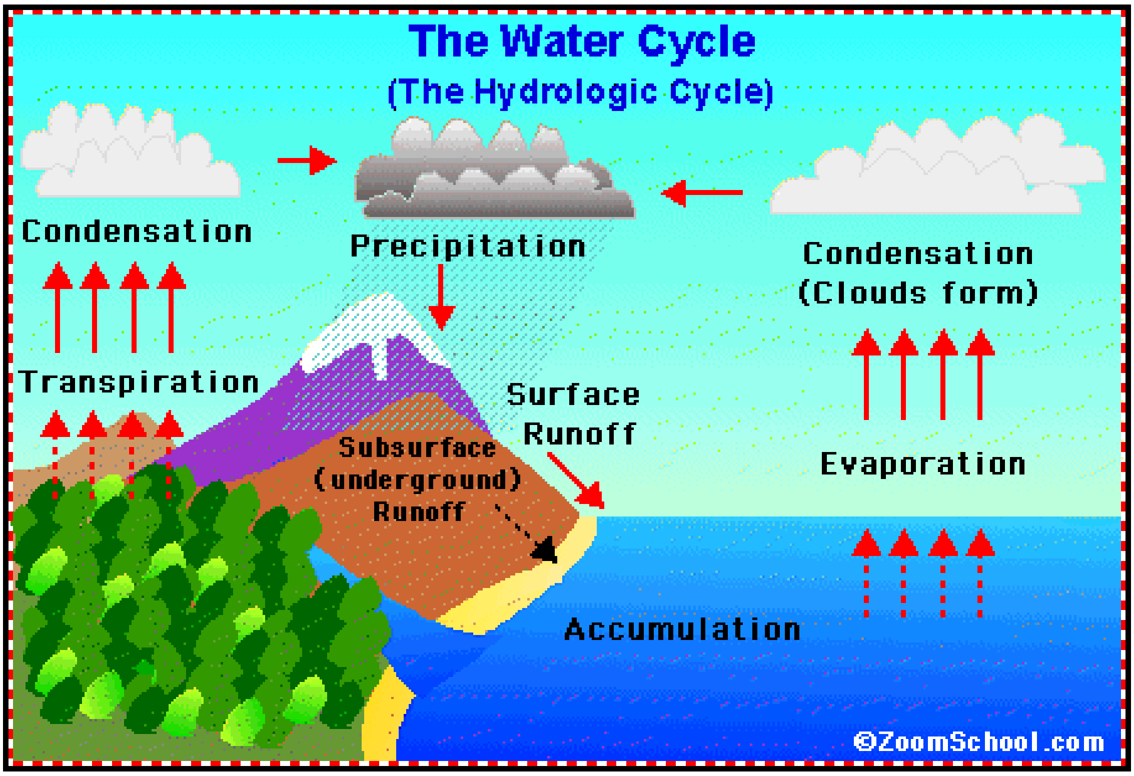

Figure 2.1: The hydrological cycle
(Source: MSMA 1)

2.3 The Climates Pattern of Malaysia

Normally, the rainfall trend in Malaysia influenced by the monsoon there are northeast monsoon, southwest monsoon and inter-monsoon seasons. The northeast monsoon season is classified as a humid condition. At the end of the season, most areas start experiencing with dry condition. This condition is influenced by the topography and land distance from the sea that influences the rainfall pattern. At the urban area, the residential and industrial activity is also the changes of rainfall pattern. The climate pattern at the equatorial area such as Malaysia is experience with hot and damp conditions through a year. Several factors that influence this trend there are terrain, lower temperature at high altitudes area, sunshine duration, the distance of the mainland from the sea that may cause wind surface during southwest monsoon and northeast monsoon that potentially to connive heavy rainfall and moderate temperatures could turn around.

Therefore, this situation will cause sluggish conditions and give the damp ground surface as well as the movement of a cool wind from the sea. The countries all over the world that is located at the equator line between 50^0 to 100^0 north and south will experience with the equatorial climate. The min annual temperature is between 26ºC to 27ºC. Malaysia receives heavy rain through a year and the humidity is archiving. The daytime temperatures may rising up to 33ºC and reduce to 21ºC during night.

At Pahang state, the temperature is relatively uniform temperature of 21°C to 32°C throughout the year with humidity 80% and annual rainfall 2650mm. The wind blows is generally quite weak. Moreover, the location of Pahang state is in the equatorial doldrums where rarely to have a direct clear sky even in the dry season. The climate trend is dominated by two monsoon cycles. There are northeast monsoon (November to February) and southwest monsoon (May to August) and two inter-monsoon seasons during March to April and September to October. During inter monsoon, these seasons bring higher rainfall intensity.

The wind patterns with the properties of the local topography seasonal determining rainfall patterns in Malaysia. During the northeast monsoon season, exposed areas such as coastal areas and sloping area is experiencing a period of high rainfall quantity distribution. Conversely, the rural areas or protected area by mountain ranges is relatively free from this influence. In addition, the pattern of uneven rainfall up to shape its own rain is very important to be studied and understood. The properties of this rainfall affects mainly against tangible source of clean water supply and agriculture. In fact, knowledge of the nature and pattern of rainfall is also important especially for engineers in the design of irrigation structures in order to avoid the problem of city soil erosion, land and landslides. The rainfall pattern should be always measured according to season.

In November, December and January is a month that has a maximum rainfall while in June and July is driest month. The rainfall pattern shows there are two maximum rain periods with separated by two periods of minimal rainfall. The maximum rainfall usually occurs in a primary in October until November. The secondary maximum rainfall occurred in April until May. This Southeast Asia country received heavy rain, namely around between 2000 to 3000 mm a year. Most of the rainfall distribution is convection and rainfall.

The average total annual rainfall quantity distribution recorded in Peninsular Malaysia is between ranged from 1500 mm to 4500 mm. Meanwhile, the humid areas region was the average total quantity of rainfall ranged between 3500mm per year were recorded. In addition, for relatively dry areas also recording an average quantity of rainfall distribution is relatively low less than 2000mm per year. This condition in pattern and trend of rainfall happened to Peninsular Malaysia very associated with the monsoon season that had picked on certain months. Thoroughly, this rainfall pattern differences can be seen rainfall rates according to the monthly rainfall quantities. The state that is location at east coast of peninsular Malaysia custom to receive an average amount of rainfall that quite a lot during the beginning of the event up to the middle of the northeast monsoon. While in November, December and January is 3 months with the average amount of rainfall that has recorded relatively high and maximum. In turn during the February to March, which is the northeast monsoon end period, East Coast states and also North West states turn out to be moved to a drier weather and hot condition.

The condition of rainfall pattern that happens by most areas especially in the states are west peninsular Malaysia shows that were two periods of maximum rainfall conditions separated by two periods of minimal rainfall. The situation during this period were the maximum rain period two will normally be occurring during the transition period from monsoon incident in October to November and also in April to May. During the creation of benchmarking of the southwest monsoon around June, July and August, most of the area which is located in state of peninsular Malaysia will be the weather relatively dry and hot condition. In Malaysia, the common types of rainfalls can be classified in three categories there are relief, frontal and convectional.

2.3.1 Relief Rainfall

This rainfall happens when the northeast monsoon and southwest monsoon blows that are coming. This will because rains formed down the hill will be heavy in the mountains and high hills. The flow of the wind blowing from the sea covered by high land, the wind will move on quickly. Meanwhile, the air in the wind in turn become increasingly cool and is a condensation and rain cloud builds. This will be the higher the clouds, the cloud into a raindrop that descend with high quantities of heavy in the presence of high land which are heading towards the sea. The rain flows downhill on the slopes of the hill overlooking the moist wind from flow South China Sea and the Straits of Malacca Sea.

The wind in damp conditions forced up into the atmosphere because there are obstacles hills. The process of condensation will occur resulting in the formation of the cloud. Water vapour is going down as rainfall in the hill slopes facing the wind. Whereas, for sheltered slopes will receive the wind. The area behind the mountain will be the rain cover and the area received little rainfall because water vapour has been lowered in front of the mountain. The rain was named rain hill.

Furthermore, figure 2.2 this rainfall occurs in the hills overlooking the sea or the ocean. Humid air from blowing ashore had to rise to the top because there are obstacles mount or Hill. The higher the rise, air conditioning is becoming increasingly cold. Up until the dew point, which when they point where conditioning cannot be cooled again, the air will condense to be dew. Drops of water will eventually come down as rain. The rain came down heavily on the hill slope overlooking the wind and the slope with their backs to the wind called the rain shadow.

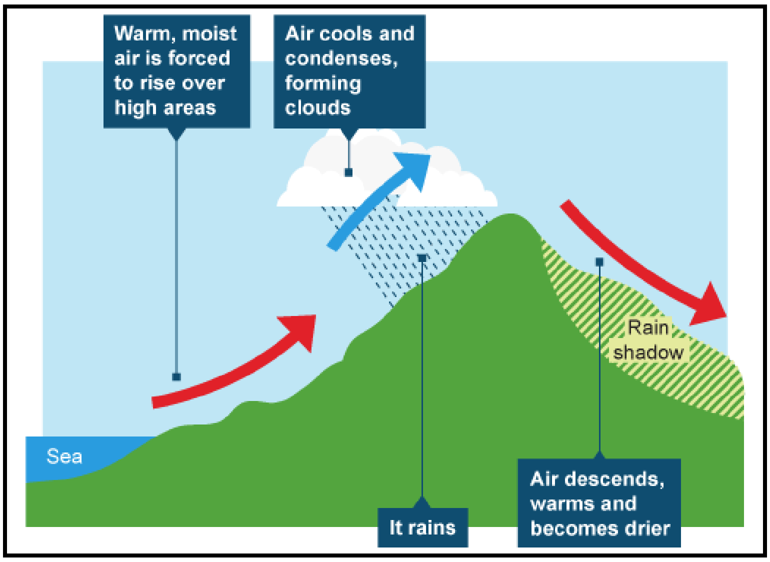

Figure 2.2: The Flow of Relief Rainfall

2.3.2 Convection Rainfall

Convection occurs when rain earth's surface is heated by the sun rays in the morning. The earth's surface that absorbs the sunlight also produces heat. The heat produced will heat the air near the Earth's surface. The heated air rises in the will inflate and convection because air is lighter than the air around it. This air will continue to go up and cooled in adiabatic air ride gets bigger the high cool. Up until the dew point, till the extent of air will condense forming drops of water and accumulate forming clouds cumulonimbus that brought heavy rain in the evenings accompanied thunder and lightning.

Furthermore, figure 2.3 the sun warms the air in the ground surface from morning till evening. Hot air expands and rises to the top because the air is lighter than the air around it. This event is called convection. The air is going up to thousand metres above and be a condensation, which is conditioning becomes cloud. A cloud formed was named cumulonimbus. The cloud will eventually turn into heavy rain. This often happens on a rainy afternoon with lightning and lightning. It fell in an area less than 50km square and in less than 6 hours. This is called convection rain.

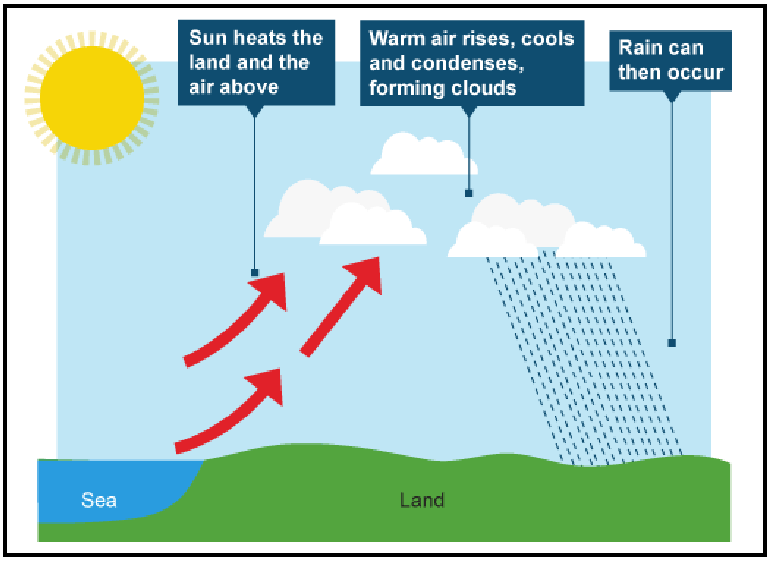

Figure 2.3: The Flow of Convection Rainfall

2.3.3 Frontal Rainfall

It occurs when there is a clash of two groups, namely air conditioning cold and hot air. This usually encounter two conditioning occurs in areas where a member is simple and tropical gardens. Cold air is denser then the air will always be close to the surface of the earth. The air hotter it lightly and will move up in the top layer of cooler air. During this hot air rises, the pressure decreases and air cleaner since expands and cools until reaching the dew point. Finally the process of condensation occurs and is followed by rain. This is also known as cyclones rain.

Furthermore, figure 2.4 the cyclonic rainfall occurs when air is very big clash with different temperature and humidity. Firstly, cyclonic hot air meets with cyclonic cold air. Then, hot air mixes with cold air. Afterwards, when the two meet, the cyclonic is cooled and hot air condensing water vapour. Finally, cloud formed and precipitation occurs.

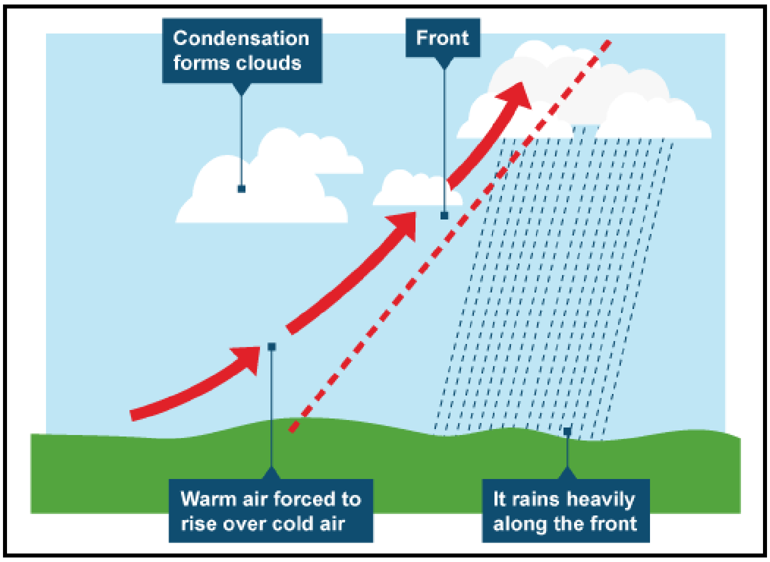

Figure 2.4: The Flow of Frontal Rainfall

2.4 Monsoon

Malaysia has a unique climate because of position is nearest to the equator range. Generally, Malaysia has 2 general monsoons. There are southwest monsoon during end of May to September and the northeast monsoon during November and March. The northeast monsoon brings heavy rain especially to the east coast states of peninsular Malaysia and western Sarawak state. The southwest monsoon has drier conditions weather. The transition period between the two monsoons is known as inter-monsoon period. Monsoon is describing with a pattern of alternating wind blowing and continuous moving system from the northeast during the winter the north and from the opposite direction namely the southwest during the northern summer. Monsoon occurs because there is a temperature difference with ground and ocean due to heating by solar radiation. In the winter at the Asian mainland area, cool down quickly resulting in a very low temperature would recommend central Asia. This condition causes the temperature to drops, atmospheric pressure upward and the situation is becoming increasingly high pressure system (anticyclone) develop over Siberia. Then cold air will move out of Siberia as northwester lies. This situation turned out to be northeaster lies of up to move through the coastal waters of China before heading to the country located in southeast Asia.

There is a strong outbursts of cold air with referred to as monsoon surges. This situation is interacted with atmospheric low pressure systems and cyclonic vortices formed near equator. This condition will cause the movement of winds and high seas in the South China Sea and heavy rain quantity to the east coast states of Peninsular Malaysia and also on the west coast of Sarawak in east Malaysia. In the summer, strong solar heating will make the temperature level on the Asian mainland east area. The pressure hot air expands and rises above while low pressure area develops semi-permanent. The southeaster lies damp who hails from the southern Indian ocean and the region Indonesia-Australia. This condition will doom the movement crossed the equator area and southwester lies on flowing across southeast Asia before converges towards Indochina, China and Northwest Pacific.

2.4.1 Northeast Monsoon

The northeast monsoon is the wind blows normally in from November to March and it able to bring large quantities of very heavy rain. Due to wind through the vast South China Sea, it brings the wind slows down that will bring down the heavy rain to the east coast states resulting in a huge flood. This season flow rate is usually the wind is blowing at 10 to 20 knots (Capslock, 2013). The average temperature during the monsoon reached 27°C. In the night the temperature recorded is not more than 24°C. The average humidity in monsoon is 88%. It could be up to almost 100% (McDonald, 2004).

In November to March, the conditions of motion of the northeast monsoon winds are blowing at the time of the northern hemisphere are experiencing winter conditions. The northeast monsoon is also known as cool monsoon winds. At that time, the condition of the northern hemisphere are experiencing a winter where temperatures become locked-in value too cool until able to achieve very significant temperature reduction up to under the level of 0^0C. This situation happens during November to April.

In addition, the condition of the atmosphere around the Interior of Asia covers such as the Tibet of Plateau area, Siberia and Mongolia will happen to atmospheric air pressure in high. At the same time, a condition of southern hemisphere is experiencing summer conditions and temperatures will rise up to be able to access more than 30^0C. This condition occurs resulting in the condition of high temperature atmospheric air pressure is become low. This condition usually occurs in the vicinity of the Australia continent and its surrounding ocean. As a result of the air pressure differences that occur between the two continents will result in the occurrence of the situation the formed slopes of pressure coming from the direction of the interior Asia move towards until towards the continent of Australia and surrounding ocean.

There will be happens the movement of air flow pattern of the interior of Asia's going to move towards the area of the Australian continent. When the condition of the air began to move out of high pressure in the interior of Asia, will air this will occur is refracted to the right by coriolis force. This process will result in producing northeast monsoon wind. The monsoon will then starts moving happen refracted again move to the left after crossing an area of the earth's equator line. These wind flows moves will begin to enter the southern hemisphere area due from the actions of the coriolis process and would later become northwest monsoon. The condition of this northeast monsoon will cause affect the temperature of the area travelled during the movement of the wind. In general, this wind conditions which have originated from the interior of the continent is in the wind conditions.

Thus most areas travelled by the wind, especially national countries area include India, Pakistan, Bangladesh, Myanmar, Thailand, Vietnam, Cambodia and Laos will experience an atmosphere around the summer conditions are very severe. However, in areas where the wind movements across the ocean area before reaching the place. The wind conditions would bring the state distribution the quantity of heavy rainfall. These areas include peninsula of Thailand and the east coast of peninsular in Malaysia which began to receive large quantities of rainfall up to reach more than 1500mm due to the wind conditions across the Gulf of Siam Sea and the South China Sea. The northeast monsoon can be summarized in the Figure 2.5.

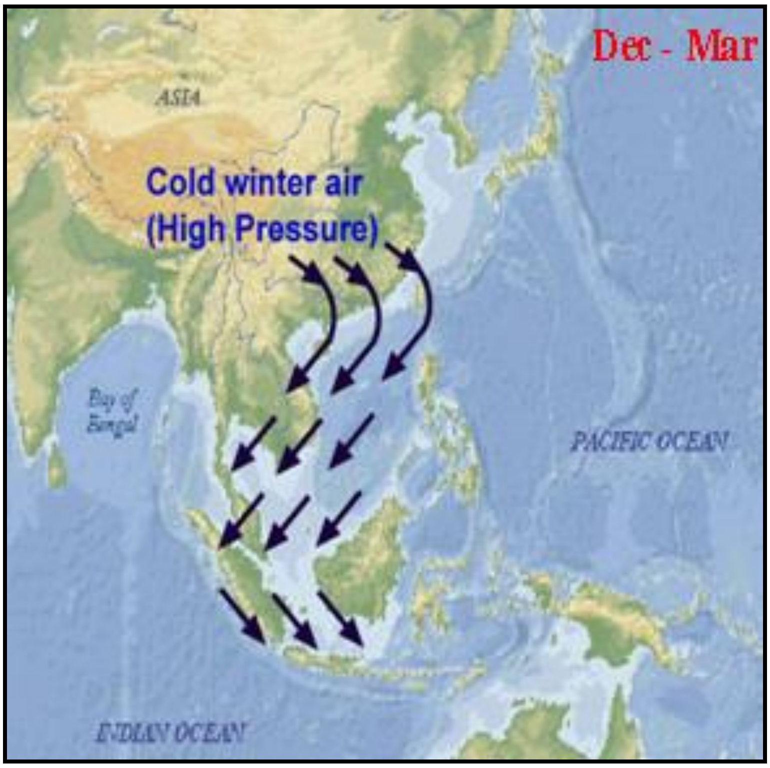

Figure 2.5: Northeast monsoon mapping

2.4.2 Southwest Monsoon

Southwest monsoon is the dry season in all states except Sabah in east Malaysia. The rainfall conditions in most states had monthly minimum rainfall. This season is relatively stable atmospheric conditions in the equatorial region. This season flow average is usually the wind is blowing at 15 knots (Capslock, 2013). The rate temperature during the monsoon reached 30°C to 35°C. In the night the temperature rate is 28°C to 29°C. The average humidity in monsoon is 72% (Capslock, 2013). In May to September, the condition of the atmosphere of the southwest monsoon will start blowing during the northern hemisphere are experiencing summer conditions. At the interior Asia will happen under which the air pressure from a condition with low. However, at the same time also the situation at the Australian continent and the ocean area around is going to be in a condition of high air pressure.

This situation occurs because of circumstances with temperature readings at low levels. This situation makes the difference in pressure between the two places will give rise to the existence of a slope between the two points of pressure. The Australian continent and the oceans around it would in the circumstances of cool air. The cold air will begin to move out toward the low air pressure area and would recommend the interior of Asia. The wind conditions originally a southeast monsoon wind system as refracted to the left by the Coriolis force. The wind will start to move towards the equator line. When the movement of the wind across the equator, this will be deflected to the wind right again by the same coriolis force, which is the same hemisphere north. This wind is known as the southwest monsoon. This situation will take considerably less wind bringing rain. This wind will through towards the west coast of peninsular Malaysia. This happens because the wind blowing is blocked by the mountain ranges on the island of Sumatra. The southwest monsoon can be summarized in the Figure 2.6.

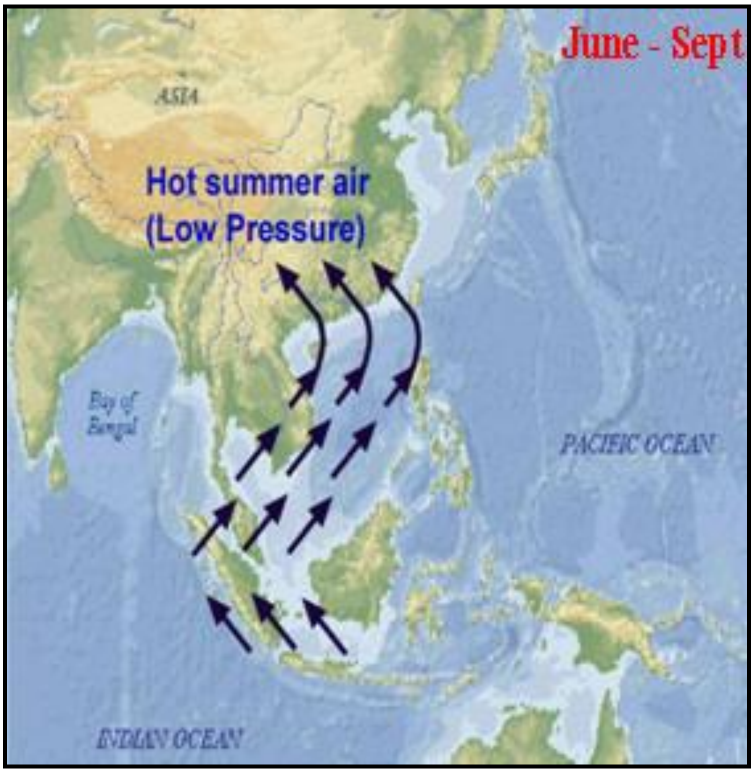

Figure 2.6: Southwest monsoon mapping

2.5 Projection of Climate Trend

The global warming will continue to increase as a result of greenhouse gas emissions on an on-going basis and would lead to more changes in the world climate system during the 21st century. This phenomenon is most likely going to be more serious than the situation during the 20th century. Warming the earth's climate system is in danger. This situation has proven to be from the results of observation through the increase in average global air, ocean temperature, rainfall and rising global mean sea level (IPCC, 2007). In 1990, MMD has recorded 31 of the 36 meteorological stations maximum temperature highest reading increased by 0.7 – 1.1 °C from the previous year's reading. For mean temperature readings the same result also showed an increase 0.6 – 1.2 °C, minimum temperature increase of 1.1 – 2.0 °C every half century (MMD, 2015). The future trends in the condition of the rain to Malaysia have shown an increase in the diversity and scale of the time cycle for the climate now and future. The condition of this trend also includes changes in the characteristics of the diversity of the monsoon. Based on the results of dynamic scaling under the influence of emission scenario A1B (medium) greenhouse gases, an increase in the number of days of extreme rainfall during the 21st century on the peninsula. However, statistical and dynamic scaling of A2 scenario emissions (medium high) consistently showed a reduction in rainfall in peninsular at the end of the 21st century (Seng, 2012).

The HadCM3 does not require additional flux adjustments with artificial heat and freshwater flux on the surface of the ocean to produce a simulation model. The HadCM3 allows higher ocean resolution in the simulation process. Besides, the components of the atmosphere and ocean mixing scheme were blended in a good relationship (Gent, 2011). This model has also been developing to produce a simulation for a distance longer period up to reach over a thousand years by showing little drift in the surface climate. The weather model HadCM3, abbreviation for Hadley Centre Coupled Model, version 3. This model has been fitted atmosphere ocean general circulation model (AOGCM) and developed at the Hadley Centre in the United Kingdom. This model is the main models used in the IPCC Third assessment report in 2001.

The HadCM3 has two important components, there are atmospheric model HadAM3 and ocean model HadOM3. The HadOM3 also includes sea ice model. The first HadCM3 component is the HadAM3 for a mapping for a grid point model has a horizontal resolution of 3.75 × 2.5 degrees in latitude × longitude. This grid model in relation to the spacing between point of approximately 300 km and is roughly comparable with T42 truncation in a spectral model (Hortal, 1991). There are 96 × 73 grid points on scalar grid. This scale grid involving factors such as pressure, moisture and temperature. For vector grid which includes wind velocity factor offset by 1/2 grid box from Arakawa B-grid (Arakawa and Lamb, 1977). This situation covers there are 19 levels. This type of vertical level in use hybrid such as sigma and pressure to the coordinates system.

The 30-minute time step is with three reading sub-time steps per time step in the dynamic. Near the pole, the field of the fourier-filtered to avoid instability due to the criteria of the CFL criterion (Courant, Friedrichs, & Lewy, 1967). This model requires be atmospheric components for distributed computing projects prediction software. The second HadCM3 component is the HadOM3 for this ocean model has a resolution of 1.25 × 1.25 degrees, 20 levels and time step of one hour. There are six ocean grid points for each atmosphere. For ease of coupling the two models of this grid is in line and the ocean coastline had to be adjusted to the atmospheric grid.

The atmospheric model is to be carried out over a period of a day. While the flux includes heat, moisture and momentum which for collect at the atmosphere ocean interface. Then, for the ocean model are also made during a day, with the flux inverted accumulated. This process will then run through the length of the repeated. Before the use of the HadCM3 model, for the use of programmed as HadCM2 very difficult there is no need for flux correction of climate models is still stable and not drift significantly. The lack of the flux correction model HadCM2 has prompted modifications of software and creation of HadCM3 model (IPCC, 1996). The ocean model will also combine forms of thermodynamic models and dynamic sea ice model with primitive dynamic of ocean fairly.

2.5.1 Long Ashton Research Station Weather Generator (LARS-WG)

The LARS-WG is a Stochastic Weather Generator developed by Dr. Mikhail A. Semenov of Rothamsted Research, UK. The model uses statistical equation based stochastic weather that able to simulate daily weather data. LARS-WG can be used for the simulation of weather data at a single site (Racsko P, 1991) (Semenov, 1998) under current and future climate condition. The LARS-WG is able to generate and process a series of long periods of weather data. This software requires data such as rainfall (mm), maximum and minimum temperatures (^{0}C) and solar radiation (MJm^{-2}day^{-1}). All this data is needed to be able to evaluate and prediction for the assessment of any risk of weather conditions more effectively.

This model is also able to communicate with the data processing to create simulated weather data on site who would like to be reviewed. The important data through observations should be made and recorded for using to input in software. This software is also able to function as a computationally that allows researchers to produce local climate through data resolution change scenario conditions. The condition of typical model is model able to combine changes in diversity and climate changes in mean climate.

The simulate of current climate on earth has been carried out continuously. This model such as a General Circulation Model (GCM). This model is also able to predict future climate change (XU, 1999). The climate forecasts based on various scenarios. The scenario will represent circumstances that result in greenhouse gas emissions. This scenario is also taken the factors which affect the production and control of these gases. Among the results of the two models that have been compared to down-scaling of SDSM and LARS-WG, the results showed better performance LARS-WG model in the study region (Rajabi, 2010). Using LARS-WG model and scenario A2 to predict rainfall, minimum temperature and maximum temperature in Sudan and South Sudan. The results showed good performance model in predicting outcome of the results (Chen, 2013).

2.5.2 Providing Regional Climates for Impacts Studies (PRECIS)

PRESIS is one of the regional climate modelling system that been develop by Met Office Hadley Centre. This software was developed in order to help generate high-resolution climate change information for as many regions of the world as possible. The large-scale projections of a global general circulation model can be added to fine scale (high resolution) information using a regional climate model (RCM). This model can be run with horizontal scales of 300km and resolve features down to 50km or less. There are several limitation and ability in the RCM appendix.

The main function of this model is to give important information about high resolution of depending on the climate change scenarios location of site study. The projection of the climate trend can be very important information in managing water resources for the long term period. The PRESIS model is user friendly that can conducted the modelling quickly and easily. The PRECIS has been designed to enable researchers in the focus area that would like to be reviewed by constructing high resolution in climate change scenarios. The any scenarios can be used in vulnerability, adaptation research and impact weaknesses and to assist in the preparation of National Communications (UNFCCC, 2009).

General Climate Models (GCM) are known to simulate projections of the future global climate conditions (Daly, 2008). According to IPCC (2011), climate change refers to a statistical variability in the state of the climate measured through changes in the mean and/or the variability of its properties. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2011). The simulated PRECIS RCM precipitation and temperature data are compared with on a monthly basis. (Mitchell, 2005). This leads to the rise in temperature of the Earth’s surface and lower atmosphere resulting to damages in the ecosystem attributed to difficulty in adaptation (IPCC, 2011).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The phases of work of study are determined. The temperature and rainfall data were used to develop the future rainfall pattern in Pahang state. The methodology was constructed to achieve the objectives of the study. In this study, two models were used there are the LARS-WG and PRECIS. These models were classified as a stochastic weather generator, to downscale the resolution that these models were classified as a more focused on the site study. This research focus area studies of Pahang state to determine climate change scenarios on a daily, monthly and yearly. The certain period times and under the climate change scenario projections using rainfall and the maximum, mean and minimum temperature output from selected Global Climate Models selected (GCMs).

Figure 3.1 shows a methodological project which involved with 2 stages in achieving the objectives of study.

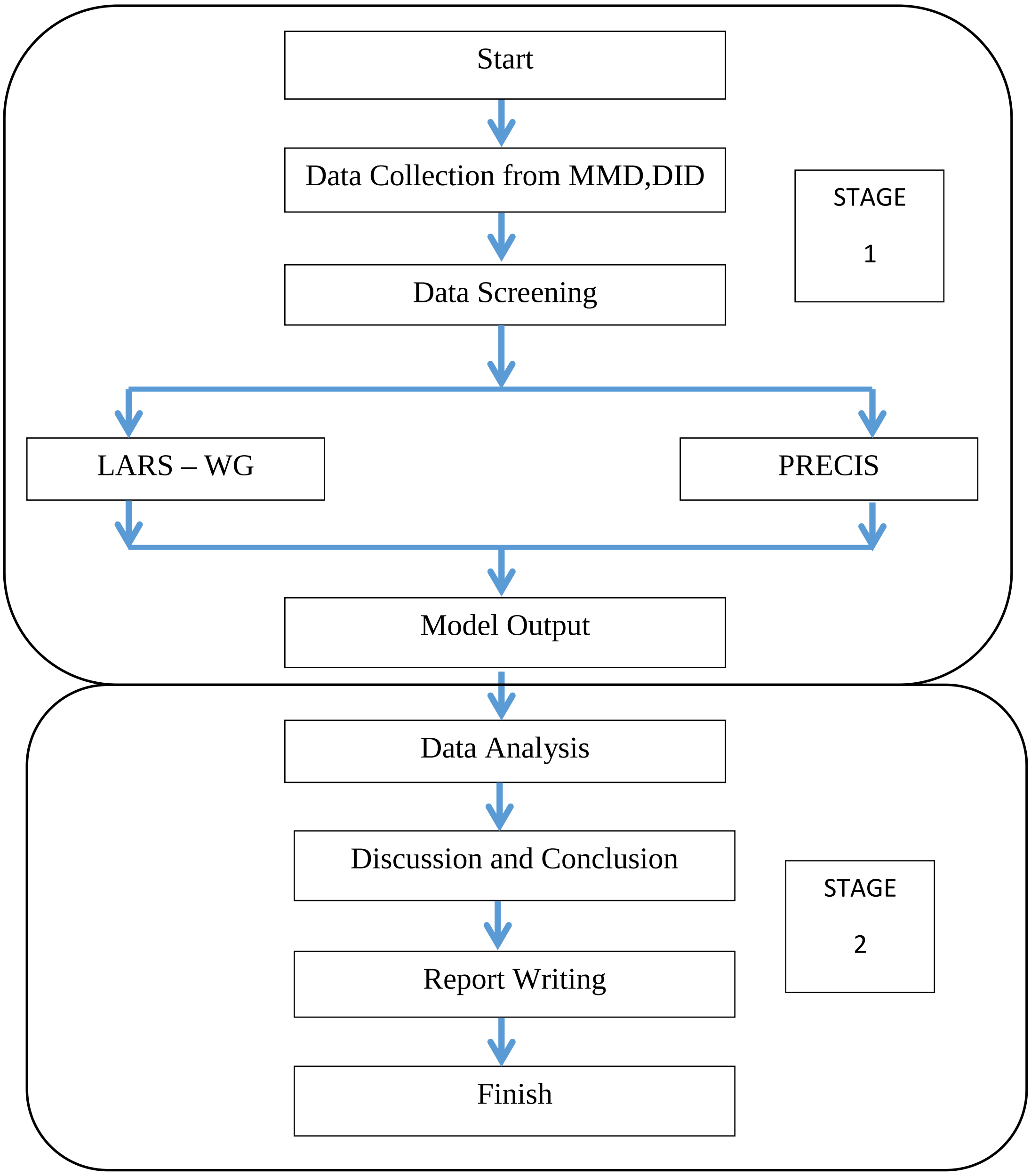

Figure 3.1: Flow Chart of Research Methodology

This study has a two stage. There are uses two climate models were there are LARS-WG model and PRECIS model to investigate the nature of distribution of rainfall in the future for the Pahang state. This level is required the data will be obtained. An important data in this study is the rainfall data for the Pahang state. This data must be obtained by the responsible agencies. This is because the agency will keep the original data and in accordance with the study. The MMD and DID is responsible for agency review, store information and data about the distribution of rainfall.

The study also needs some other data and information to support the study in order to be processed smoothly and accurately. Among the important data required such as minimum, mean and maximum temperature. After receiving the data, these data should be checked in advance. This is to ensure that data can be filtered and analysed in advance so that any defect data is inevitable. Data that has been refined to be used as input to ensure that each model is able to process weather data with accurately and efficiently. Each input is entered into the model must be correct to ensure that the results obtained in range. This is to avoid incorrect results and ensure that results obtained can minimize disability. The data should be reviewed so as to ensure that the results which will be obtained more precise and accurate.

The data has been processed will be analysed. This is to ensure that the results obtained can be presented in a more simple and convenient. These data will be evaluated with the previous data so that the accuracy of the readings can be obtained. In addition, this analysis process is important to ensure that the results to achieve the goal of the research objective of the study. The results should be in line with the study.

After satisfactory results, these data will be compiled in a more organized and structured. The discussions should be achieved with the results. This is because the conclusions of this study can be made so that this research is beneficial for general use. The report in full should be updated to reference by the authorities and can be useful for benefits in the future.

3.2 Step of the LARS-WG Model

The LARS-WG is based on the series of weather generator described in (Racsko P, 1991). It uses a semi-empirical distribution for long series of wet and dry days, rainfall and solar radiation every day. The semi-empirical distribution, Emp = {a_0, a_i; hi : i=1, … 10} is a histogram with ten intervals, [a_i–1, a_i], where the a_i–1 < a_i, and h_i mark the number of events from the data observed in the i-th interval. Random values from the semi-empirical distribution selected by first selecting partial one of the intervals with using part of the events in each interval as a probability of selection and then select a value in the range from a uniform distribution. Such a distribution is flexible and can estimate a variety of shapes by adjusting the interval [a_i–1, a_i]. The cost of this flexibility, it is that the distribution requires 21 parameters with 11 values that mark the boundaries of the intervals and 10 values that indicate the number of events in each interval to be compared with.

The interval [a_i–1, a_i] are selected based on the characteristics expected of variable weather. For solar radiation, the interval [a_i–1, a_i] equally distance between minimum and maximum values observed data for the month, while for long series of dry and wet and rainfall, the size of the interval to gradually improve as i increases. In both cases, there is usually a lot of small values but also a very large number of one and this option is preventing resolution of the interval structure used for small value. The rainfall event simulation modelling in alternate of wet and dry series, where wet day is defined as days with rainfall less 0.0 mm. The length of each series of randomly selected from the distribution of wet or dry semi-empirical for the month where the series began. In determining the distribution, observed series is also assigned to the month in which they started. For wet days, rainfall values resulting from the semi-empirical distribution of rainfall for months certain of the length with wet series or the amount of rainfall the previous day. The minimum per day and maximum temperature is considered to be the daily stochastic process and daily standard deviation on the wet or dry status of the day.

The technique used to simulate this process is almost the same as that set out (Racsko P, 1991). The cycle of seasons mean and standard deviation were modeled by finite Fourier series for 3 and the residuals are estimated by the normal distribution. The residue observed, obtained by removing the mean value from data observed, used to analyze autocorrelation time to minimum and maximum temperatures. To facilitate both is considered constant through the rest of the year for both dry and wet days with using the average value from data observed. The minimum and maximum temperature residuals have pre-set cross-correlation of 0.6. The minimum temperature simulation is greater than the maximum temperature simulation, where the program is replacing the minimum temperature with maximum less 0.1.

The daily solar radiation analysis more site shows that normal distribution of solar radiation on a daily basis, typically used in other weather generator, not suitable for particular climates (Hutchinson, 1995). The distribution of solar radiation also differs significantly in the days of wet and dry. The separate semi-empirical distribution has been used to describe the solar radiation on the daily is wet and dry. An autocorrelation coefficient also counted for the solar radiation and is considered to be constant throughout the year. The solar sunshine modelled independently of temperature. LARS-WG receives hours of sunshine as an alternative to solar radiation data. If solar radiation data is not available, then the hour of sunshine can be used, automatically converted to solar radiation using the approach described (Rietveld, 1978).

3.3 Step of the PRECIS Model

PRECIS is a flexible, the RCM designed to provide detailed climate scenarios. The human and computational resources using model is not insignificant, especially in developing countries where it is intended. PRECIS will not be adopted by all countries. In the standard PRECIS set-ups, there is a resolution of 25 km and maximum implied with the country or region that is smaller than this will not be resolved. There is always a choice to specify the area of land for approaching this scale (Wilson, 2004).

In order to check at the local level that the PRECIS model provides realistic information, it is desirable to have a good observation related to the climate of the region or the application in which the PRECIS is being used. The basic computing resources of one or more computers that fast, it is useful to have a reliable power supply and need to have the expertise to maintain the hardware and support systems. Running the model, and interpret and disseminate the results of the experiment will require the time of PRECIS, as provided from the people who have relevant experience.

The dynamic scaling techniques, using limited areas, high resolution models such as regional climate model driven by the State border from the GCM, used to obtain knowledge that small. The RCMs generally include domain 106-107 km^2 and a resolution of 20 to 60 km (Anderson, 2008). The model is called PRECIS that were used in this study using these downscaling techniques.

A regional climate model (RCM) is a high resolution climate model that covers a limited area of the globe, typically 5,000 km x 5,000 km, with a typical horizontal resolution of 50 km. RCMs are based on physical laws represented by mathematical equations that are solved using a three-dimensional grid.

Hence RCMs are comprehensive physical models, usually including the atmosphere and land surface components of the climate system, and containing representations of the important processes within the climate system. Many of these physical processes take place on much smaller spatial scales than the model grid and cannot be modelled and resolved explicitly. Their effects are taken into account using parameterizations, by which the process is represented by relationships between the areas or time averaged effect of such sub-grid scale processes and the large scale flow.

3.4 Study Area

This study is focused on Pahang state, the third largest state in Malaysia, after Sarawak and Sabah. The land area is covered about 35,965 km^2 and occupies a huge river basin. The Pahang state can be summarized in the Figure 3.2.

Figure 3.2: Pahang State Mapping

Source: National Geographic Map (ArcGIS)

Pahang has 11 districts. There are Temerloh, Bera, Rompin, Pekan, Raub, Maran, Kuantan, Lipis, Jerantut, Bentong and Cameron Highland. The area fraction for each district in Pahang state is: Temerloh (2,250 km^2), Bera (2,228 km^2), Rompin (5,296 km^2), Pekan (3,805 km^2), Raub (2,269 km^2), Maran (1,995 km^2), Kuantan (2,960 km^2), Lipis (5,198 km^2), Jerantut (7,561 km^2), Bentong (1,831 km^2) and Cameron Highland (721 km^2).

The topographic and condition for each district in Pahang state is Temerloh district is the second largest town in Pahang. It is located at the intersection of Sungai Pahang and Sungai Semantan. Temerloh experience a temperature range between 23 ° C and 34 ° C each year and the average rain down about 390 mm/monthly. Bera is especially important in the agricultural sector. The Bera Lake is a freshwater lake and surrounding wetlands. Bera experience a temperature range between 24 ° C and 33 ° C each year and the average rain down about 425 mm/monthly.

The location of Rompin district is the South-Eastern Pahang state. This district is located 130 kilometres from Kuantan, capital of Pahang. It is bordered to the North by Pekan, on the West by Bera, Johor, in the South and in the East by the South China Sea. Rompin experience a temperature range between 23 ° C and 33 ° C each year and the average rain down about 790 mm/monthly. Pekan district location, near the banks of Pahang River 50 km southern from Kuantan. Pekan experience a temperature range between 24 ° C and 36 ° C each year and the average rain down about 50 mm/monthly.

Raub is situated 265 km from the capital of Pahang, Kuantan. Raub district is located in West Pahang and between two networks, Titiwangsa Range and Benom Mountain Range. Raub experience a temperature range between 20 ° C and 30 ° C each year and the average rain down about 200 mm/monthly. Maran has agricultural products and farming. Maran experience a temperature range between 23 ° C and 33 ° C each year and the average rain down about 275 mm/monthly.

Kuantan is near the mouth of Sungai Kuantan and facing the South China Sea. The distance measure is along the East coast of Peninsular Malaysia. Kuantan experience a temperature range between 23 ° C and 33 ° C each year and the average rain down about 780 mm/monthly. Lipis is a district located in the North-West of Pahang state. This district is bordered by Cameron Highlands. Lipis experience a temperature range between 23 ° C and 34 ° C each year and the average rain down about 412 mm/monthly.

Jerantut is a major town in the centre of Pahang. It is the largest district in Pahang. Tembeling River, the main river in the district. The merger of the Tembeling and Jelai River forms the Pahang River where it flows right through the South China Sea. Jerantut experience a temperature range between 23 ° C and 33 ° C each year and the average rain down about 450 mm/monthly. Bentong district covers the area opposite the main range, Titiwangsa Mountains. Bentong experience a temperature range between 23 ° C and 34 ° C each year and the average rain down about 400 mm/monthly.

Cameron Highlands is one of Malaysia's most extensive Hill station. It is located at the North-West of Pahang, 221 miles from Kuantan. It is the smallest constituency in Pahang. The average height of land in between 1,100 metres (3,600 ft) to 1,600 metres (5,200 ft) above sea level. Cameron Highlands experience a temperature range between 23 ° C and 31 ° C each year and the average rain down about 208 mm/monthly. The each district of Pahang state can be summarized in the Figure 3.3.

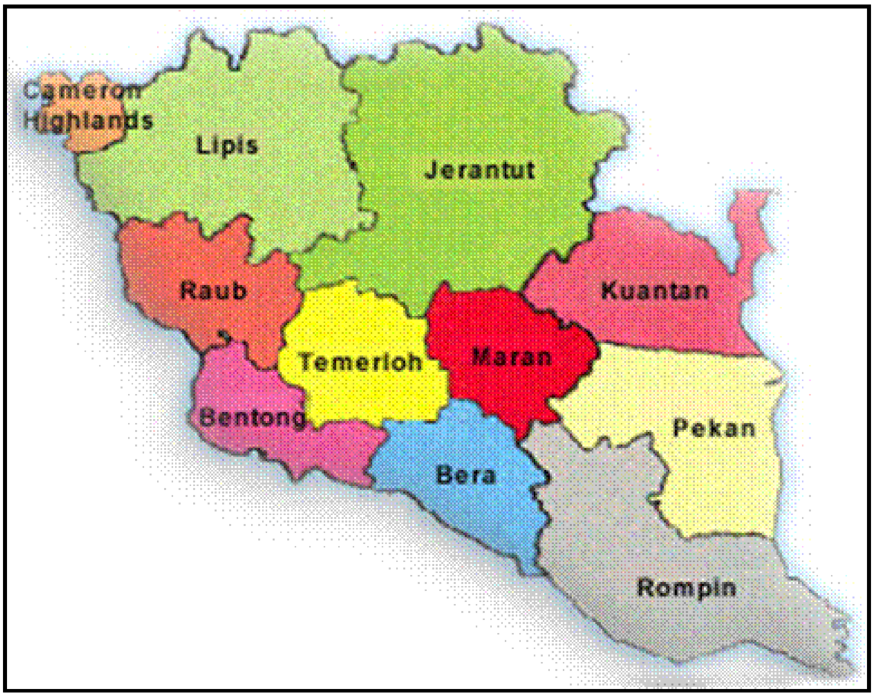

Figure 3.3: Location of the District in Pahang State

As a country surrounded by the sea and close to the equator, Malaysia naturally has abundant sunshine and thus solar radiation. However, there is rarely a day with completely clear sky even in periods of drought. Cloud cover can reduce the content of sunshine and thus solar radiation. On average, Pahang receives about 5 hours of sunlight per day (MMD, 2015). There are differences according to the season and the amount of sunlight received. The sun is closely related to the duration of sunshine. During the northeast monsoon, the average monthly hours of sunshine in November until March is 5 hours and the southwest monsoon season from May until September is 7 hours (Dorado, 2015).

Malaysia terrain is uneven country, a variety of different types and has different characteristics because the area includes mountains, lowland and mountain, rocks. This may affect physical properties because of the rain to bar mountain rain from spreading to a wider area. The lowland area consists of floodplains, delta river and the river valleys that slope is very flat and sloping almost. Rainfall in this area had similar the same depth (Sharifah, 2003).

The catchment area chosen for the study was made against him is an area with data of sufficient rainfall and temperature. In this study, the selected station will rain every area of the land area around Pahang. In Figure 3.4 shows the position and location of the stations that are chosen rain. The aspects of concern in the selection of the catchment area is dependent on the shape of the terrain or topography is whether the area is hilly, silt or development areas. In this study, analysis of rainfall data and temperature data is very important because it is used both as the impact of climate change. In Pahang state, total rainfall station that are 136 station with cover all area in Pahang. The rainfall station that using the data for this study is 11 station, selection 1 station represent for 1 distrit. It is enough to cover all area Pahang state. The Pahang map with rainfall station were from the Department of Irrigation and Drainage Malaysia (DID).

Table 3.1: The stations are selected

Station			Coordinate
Location	**ID No.**	**Station Name**	**Lat. / Lon.**
KUANTAN	3931014	KUALAREMAN	N3°54’, E103°08’
KUALA LIPIS	4122067	KERETAPIKRAMBIT	N4°07’, E102°12’
	4320066	KECHAU	N4°21’, E102°04’
BERA	3325086	KUALABERA	N3°23’, E102°32’
PEKAN	3431099	KGSERAMBI	N3°29’, E103°08’
	3429096	KGSALONG	N3°29’, E102°56’
	3532101	KGTEMAIHILIR	N3°32’, E103°14’
BENTONG	3122142	KGJAWI	N3°10’, E102°14’
	3318127	JANDABAIK	N3°19’, E101°51’
	3221001	KGMANCHIS	N3°12’, E102°09’
CAMERON	4514032	PALAS	N4°31’, E101°25’
HIGHLAND	4414038	BHGSELATAN	N4°26’, E101°27’

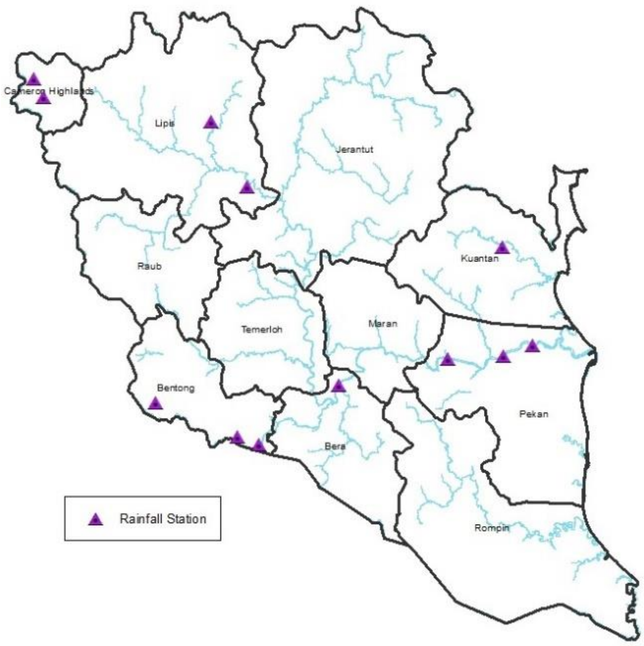

Figure 3.4: Location of the river and rainfall station in Pahang State

Source: Department of Irrigation and Drainage Malaysia (DID)

3.5 LARS-WG Model

The LARS-WG is a weather generator. This model is used for simulating weather data at a single site under both the current situation and the future (Racsko P, 1991). The first version of the model was revising by Semenov in 1998. In addition, first model introduce in 1990 in Budapest, Hungary. The model is using statistical distributions to model complex climate variables. The LARS-WG can use daily weather data for the observed and given to calculate a set of probability distribution parameters for the variables of weather as well as the relationship between them, which is used for generating synthetic time series of arbitrary length weather by selecting random values from the appropriate distribution. The first step in the production of synthetic data is a model series of today is wet and dry. This model uses a semi-empirical distribution to simulate wet and dry days, daily rainfall and solar radiation. This distribution is defined as cumulative probability distribution function.

$$EPM = (a_0, a_1, h_i, i = 0, \ldots 10)$$ (Equation 3.1)

EMP is a histogram of the distribution of 10 different intervals (ai-1, ai) where ai-1 < ai (Semenov, 2002). The number of intervals used in semi-empirical distribution in a new version of the model was 23 as compared with the previous version used 10, shows a more accurate representation of the distribution of observations (Chen, 2013). In a semi-empirical distribution of radiation, the distance between the radiation minimum and maximum monthly radiation are equally divided.

Thus, the day of wet, dry and rainfall period can increase. Maximum and minimum temperature modelling daily run by a random process with min per day and standard deviation depends on whether day is dry or wet. The radiation modelling is independent of temperature. Three order Fourier series are used to simulate the mean seasonal temperature and standard deviation. The remaining value is obtained by subtracting the mean of the value of observations used in analysis time correlation between the maximum and minimum data (Semenov, 2002). In LARS-WG, weather data generation process can be divided into three synthetic steps are different, which is described briefly as follows.

3.5.1 Calibration and Validation Model

In LARS-WG model, the data has been calibrated from 1984 to 2013 year obtain the interrelationship between variables. The observed weather data such as rainfall, maximum, mean and minimum temperature and radiation used as a data input to determine the characteristics of the statistical relationship. The parameter files obtained from weather data observed during the process of calibration model used to validate the synthetic weather data to ensure the accuracy and the reliability of the result to analyse and compare the characteristics of the observed weather data statistics and to assess the ability of synthetic weather data of LARS-WG to simulated rainfall, T-max and T-min in selected sites to determine whether or not it is suitable for use in the study (Chen, 2013).

Calibration was aimed to determine the statistical characteristics of the observed weather data with 30 years (1984-2014) of daily rainfall data was used and divided into two period times, which are 1984 -1998 for calibration period and 1999-2014 for validation period. Once the model had been well calibrated, then it needed to be validated by using independent daily rainfall data, which was not being used during calibration. It is a process to determine how well the model performs. Performance during the calibration and the validation was checked by using the statistical parameters which are mean daily rainfall, variance, average dry-spell length and average wet-spell length for all months of the year. The performance was also checked by using coefficient of correlation (R), which is defined as:

$$R^2 = \frac{\left[\sum_{i=1}^{n}(X_i - u_x)(Y_i - u_y)\right]^2}{\left[\sum_{i=1}^{n}(X_i - u_x)\right]^2 \left[\sum_{i=1}^{n}(Y_i - u_y)\right]^2}$$

(Equation 3.2)

In the above equations X_i and Y_i are i-th observation and simulated data by the model. Respectively, u_x and u_y are the average of all data of X_i and Y_i in the study population and n is the number of all samples to be tested.

In the present study, to evaluate the performance of LARS-WG model and to ensure its ability to predict climate variables of temperature and precipitation, in addition to statistical tests (t-test, F-test and Chi-square) taking place in the model in the validation phase, performance indicators, coefficient of determination (R2), mean absolute error (MAE) and root mean square error (RMSE) are also used. Coefficient of determination is a dimensionless measure of which the best value is one. The model mean error and root mean square error represent the model error rate of which the best value is equal to zero (Khalili, 2012).

$$MAE = \frac{\sum_{i=1}^{n}[X_i - Y_i]}{n}$$ (Equation 3.3)

$$RMSE = \sqrt{\frac{\sum_{N=1}^{n}[X_i - Y_i]^2}{n}}$$ (Equation 3.4)

3.5.2 Generation of Synthetic Weather Data

The parameter files obtained from the observed weather data during the calibration process model can also be used to generate synthetic data correspond to the particular climate scenario simulated by GCMS (Chen, 2013). To predict the weather data on a local, large-scale projection data simulated by general circulation model was required. In the latest version of LARS-WG model, 15 General Circulation Model (GCM), all derived from the fourth IPCC report (AR4) (Chen, 2013). From this case, the prediction of rainfall and temperature data output is carried out using HadCM3 model under A2 scenario. The HadCM3 model the most renowned atmospheric general circulation models develop at the Research Centre UKMHC7 in England with spatial resolution of 2.5 ° × 3.75 ° (Khadka, 2014). The general circulation model based prediction on scenario. The scenario is based on different assumptions about driving forces including social and economic emission scenarios, technology, and demographic developments referred to as emissions scenarios. The IPCC show a new set of emission scenarios SRES special report called in 1996 (IPCC, 2011).

HadCM3 with A2 scenario has been used as a general circulation models (GCMs). This model is a coupled atmosphere-ocean GCMs which has been developed at the Hadley Centre of the United Kingdom's National Meteorological Service. The GCMs contain a complex model of land surface processes, includes 23 land cover classifications, four layers of soil where temperature, freezing and melting are tracked, and a detailed evapotranspiration function that depends on temperature, vapour pressure, vegetation type and ambient carbon dioxide concentrations (Mohammed, 2009). HadCM3 was chosen because this model is widely used in many climate-change impact studies. Furthermore, it has the ability to simulate for a period of thousand years and it shows a little drift in its surface climate (McCarthy, 2001). The A2 scenario is considered as among the worst case scenarios, projecting high emissions for the future and the case study identified in this scenario.

The scenario for this study using in LARS-WG model is A2 mean the separated world. This scenario is cultural identities separate the different regions, making the world more heterogeneous and international cooperation less likely. The 'family values', local traditions and high population growth (0.83% yr–1) are emphasised. Less focus on economic growth (1.65% yr–1) and material wealth (IPCC, 2007).

3.6 PRECIS Model

The PRECIS model is a very similar for scientific reasoning and HadAM3P PRECIS regional model, a model that provides the default side of the boundary conditions (LBCs). Both are based on the atmospheric component of the climate model coupled Met Office Hadley Centre HadCM3. The HadAM3P is the only global model with a resolution of the order of 150km, forced by surface boundary conditions (sea-surface temperature and sea-ice fragments) from HadCM3 and observation. The PRESIS model running time to experiment regular grid covering the domain 100-by-100 and included representatives of the atmospheric sulphur cycle, running on 1 core. The PRECIS model is a primitive equation model, the grid point hydrostatic contains 19 levels reflected in the hybrid vertical coordinate (Simmons, 1981).

The scenario for this study using in PRESIS model is A1B mean the rich world. This scenario is characterised by very rapid economic growth (3% yr–1), low population growth (0.27% yr–1) and rapid introduction of new and more efficient technology. The globally there is economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income (IPCC, 2007).

Due to the detailed climate change scenarios are very important in developing countries, where the economic pressure is expected to increase exposure to the potentially damaging effects of climate change. In an effort to help address the needs of the United Kingdom Hadley Centre have developed a model PRECIS, which regional climate modelling system which run on cheap, easily available personal computers. In this procedure, the data observed at specific sites that are considered as site representative of that (Islam, 2006).

The aim of PRECIS model is to enable developing countries, or groups of developing countries, to generate their own national scenarios of climate change for use in impact studies. This will allow the transfer of technology and greater ownership resulting in transmit quickly and effectively expertise and awareness than if the decisions are only distributed from the models in developed countries. For application PRECIS to the effects of climate change, it is important to determine the appropriate method of calibration. With this in mind, the analysis was conducted in point-to-point (Islam, 2006).

The countries that use PRECIS model are in the better models using the position to confirm their own observations. An important aspect of PRECIS is the availability of training and training materials to explain its role in making use of and how the best from it. For one of the main ingredients is a technical manual discusses the steps necessary to install, configure and use of PRECIS. It is designed both to guide the user PRECIS and as a resource for training PRECIS.

CHAPTER 4

DISCUSSION AND ANALYSIS

4.1 Introduction

The analysis was conducted on monthly and annual rainfall for 12 rainfall stations located at surrounding area of Pahang state. About 12 rainfall stations have been selested as representing every district in Pahang state to obtain the pattern of temperature and rainfall in term of month, annual and decade. The total rainfall data for a period of 25 years starting from the year 1984 to 2008 for the whole of the districts. Subsequently, analysis of daily temperature is only focused on Kuantan station. The data were provided by Department of Irrigation and Drainage Malaysia (DID) and Malaysia Meteorological Department (MMD).

In this study all the missing data was treated using Theissen method to ensure the accuracy and reliability of projected result. The Theissen method was selected because it consider the nearest located of rainfall station. This is another graphical technique which calculates station data based on the relative areas of each measurement station in the Thiessen polygon network. The individual data are multiplied by the station observation and the values are summed to obtain the areal average rainfall.

4.2 Downscaling Model Description and Setup

4.2.1 Calibration Process of LARS-WG Model

The calibration of the LARS-WG model is based on the derivation of statistical parameters using the observed historical data. The data on daily precipitation of 12 stations minimum and maximum temperatures is started from 1984 to 1995 (12 years) used to perform the site analysis the period of calibration process. The LARS-WG produces monthly means and standard deviations of precipitation, minimum and maximum temperature using semi empirical distributions of dry and wet series.

The statistical significance of the result was analysed by forcing the model to generate synthetic series of data for future years. The LARS-WG will be able to simulate artificial weather data based on as little as a single year of observed weather data. However, since the simulated weather data will be based on these observed data, then the more data used the closer is LARS-WG likely to be able to match the true climate for the site in question. The use of at least 20-30 years of daily weather data is recommended (Racsko P, 1991). In order to be able to capture some of the less frequent climate events such as droughts, as long an observed record as possible should be used.

The performance of the calibration was based on p-value and KS (Kolmogorov Smirnov) results. Figure 4.1 to 4.3 show the performance of LARS-WG for the generation of mean rainfall, minimum temperature and maximum temperature with an acceptable confidence values more than 90% at all stations. The difference between the historical data and calibration with below 5% error. The higher error at the Rompin district because have a limited temperature data collected.

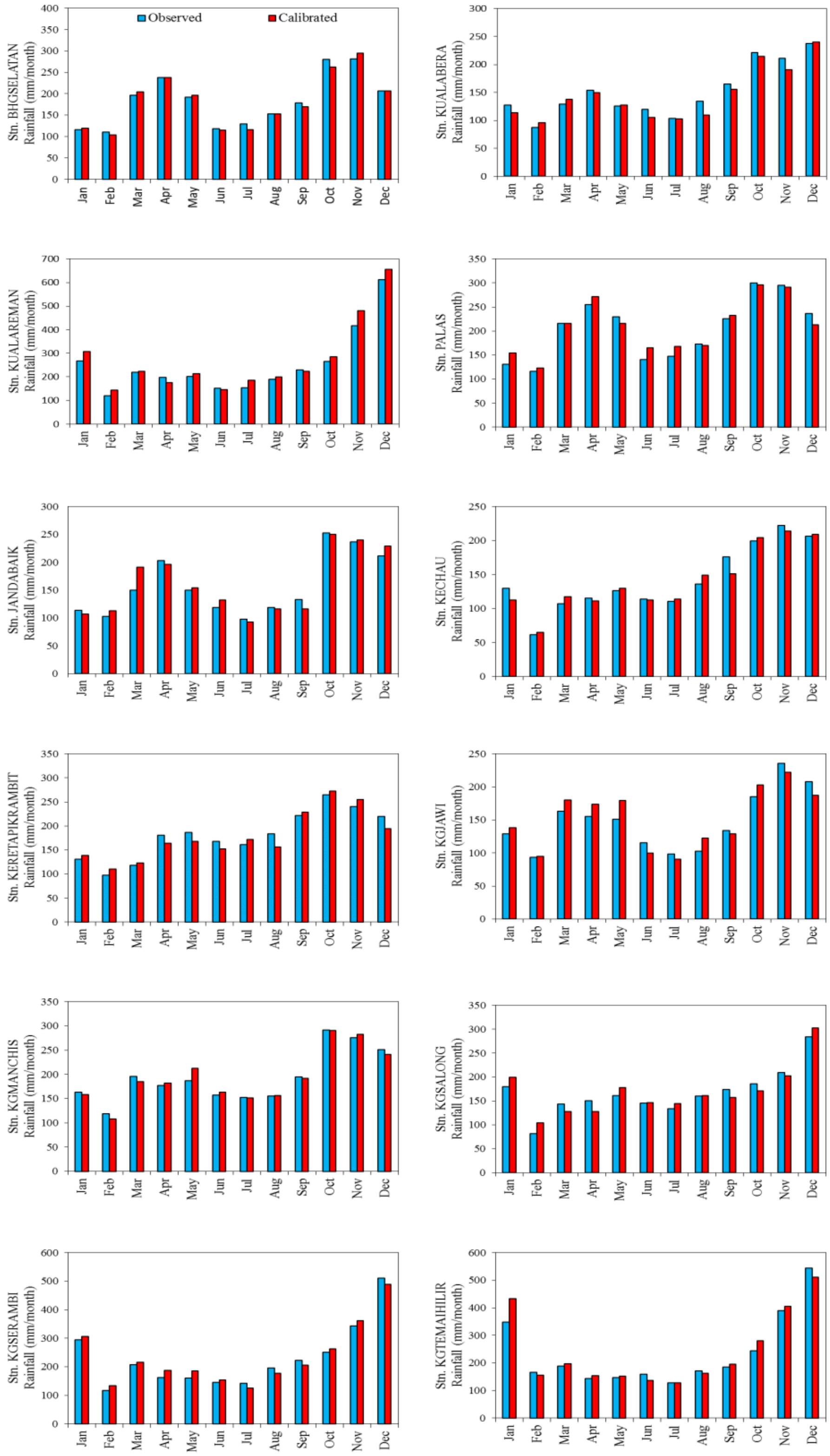

Figure 4.1: Comparison between observed and calibrated results for 12 rainfall stations during year 1984-1995

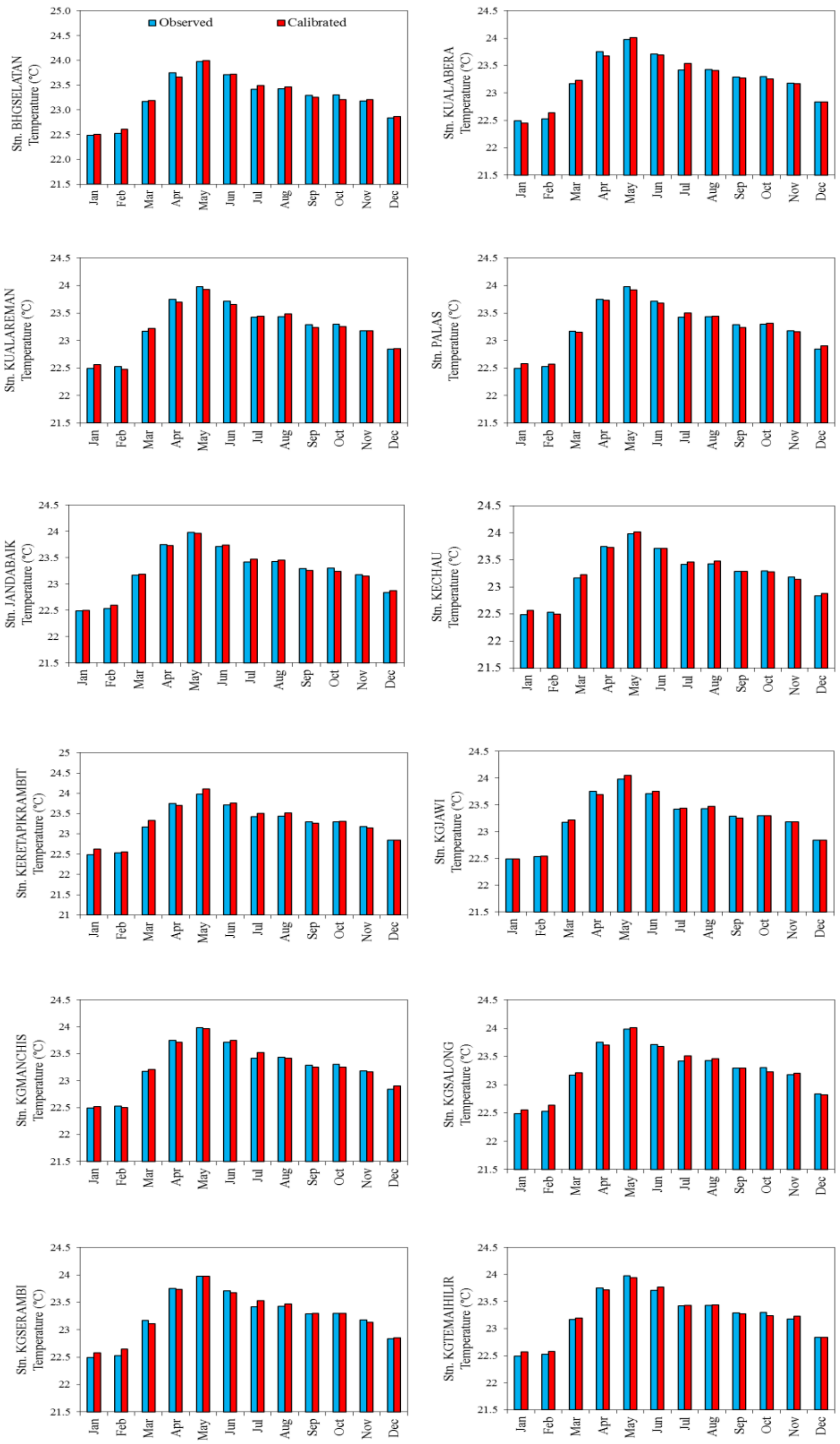

Figure 4.2: Comparison between observed and calibrated results for 12 minimum temperature stations during year 1984-1995

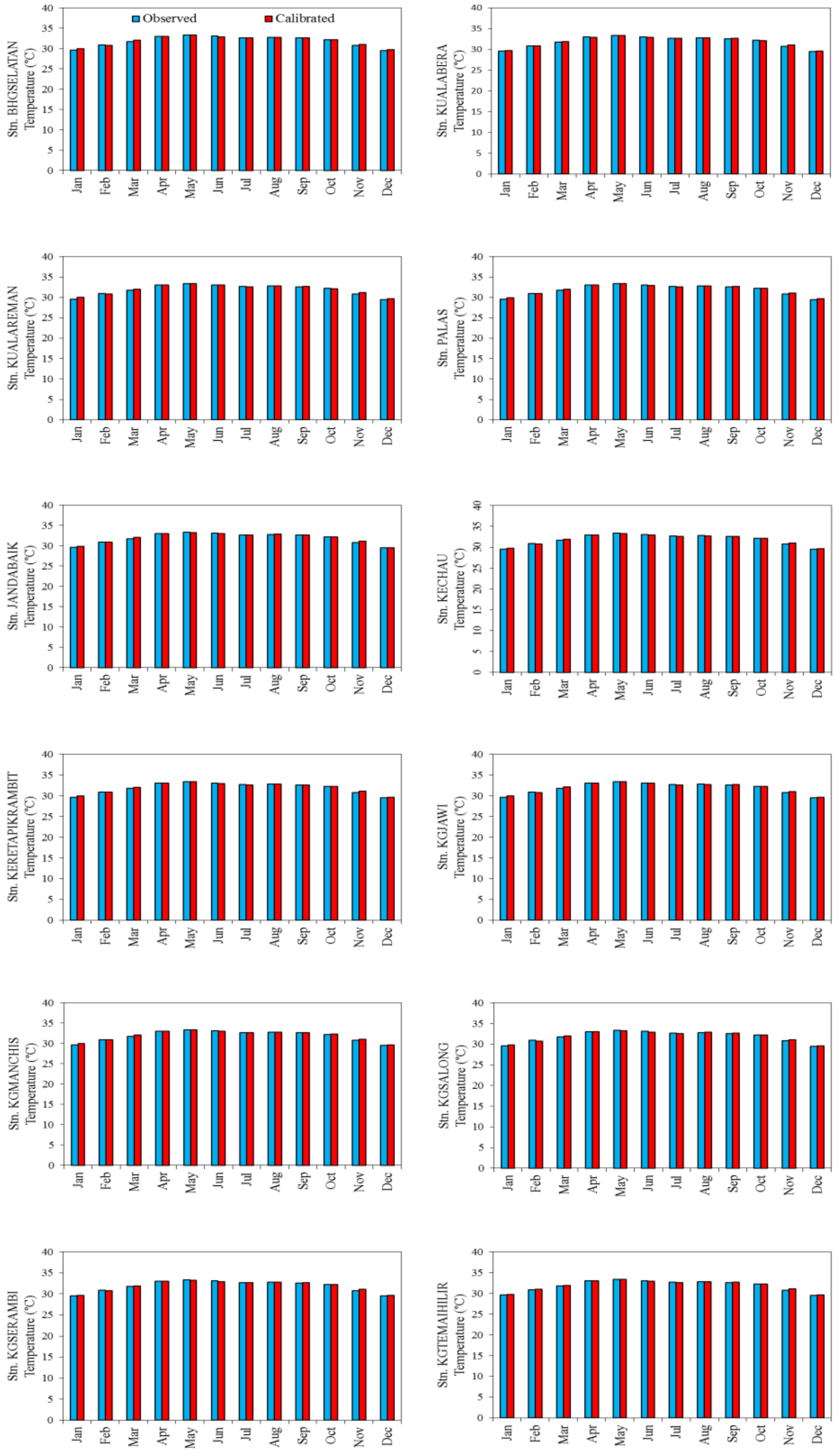

Figure 4.3: Comparison between observed and calibrated results for 12 maximum temperature stations during year 1984-1995

4.2.2 Validation Process of LARS-WG Model

To validation the result, the data sets were generated for the period of 1996–2008 for every stations. In this stage the constant statistical characteristics during calibration have been use to analyse and compare the statistical characteristics of the observed and synthetic weather data to assess the ability of LARS-WG to simulate the rainfall and temperature at the chosen sites in order to determine whether or not it is suitable for use.

The validation process involved analysing and comparing the statistical characteristics of the observed and synthetic weather data to test the capability of LARS-WG to simulate the rainfall, Tmax and Tmin at the selected site in order to determine whether or not it is suitable for use. The LARS-WG facilitated the validation procedure by employing the Q-test option to determine simulated the observed data.

Figure 4.4 to 4.6 show the performances of validation process for the generation of mean rainfall, minimum temperature and maximum temperature. The results show the performance of LARS-WG for the generation of mean rainfall, minimum temperature and maximum temperature with an acceptable confidence values more than 85% at all stations. The difference between the historical data and calibration was less than 7% error. The highest was estimated error at Rompin district due to the insufficiened data record. The maximum temperature is similar pattern below 35°C for all station. The maximum temperature result is slightly difference from all station. The difference error with below 2% error. The minimum temperature pattern is below 24°C for all station. The difference error with below 3% error. The high minimum temperature is around April to June.

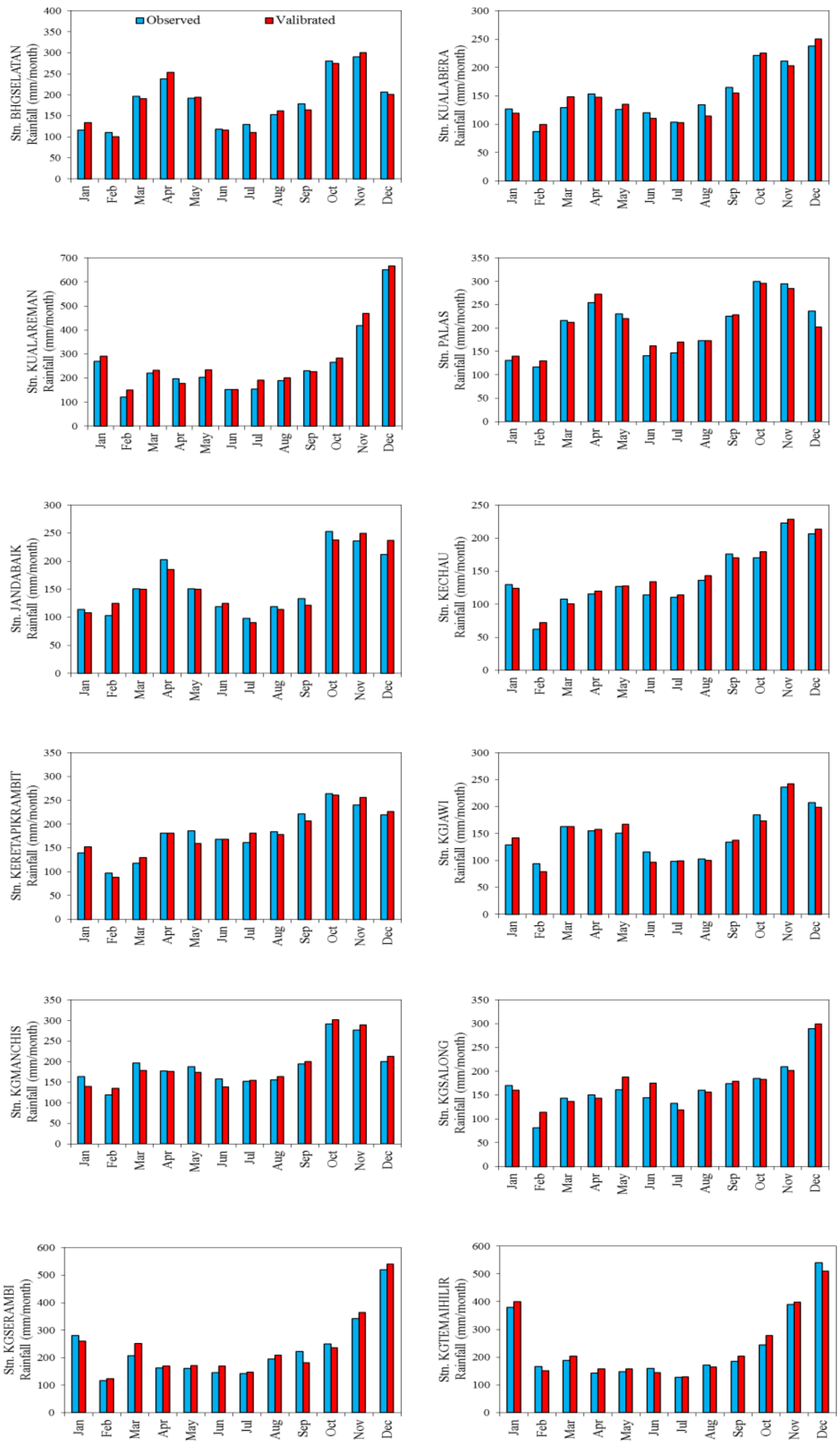

Figure 4.4: Comparison between observed and validation results for 12 rainfall stations during year 1996-2008

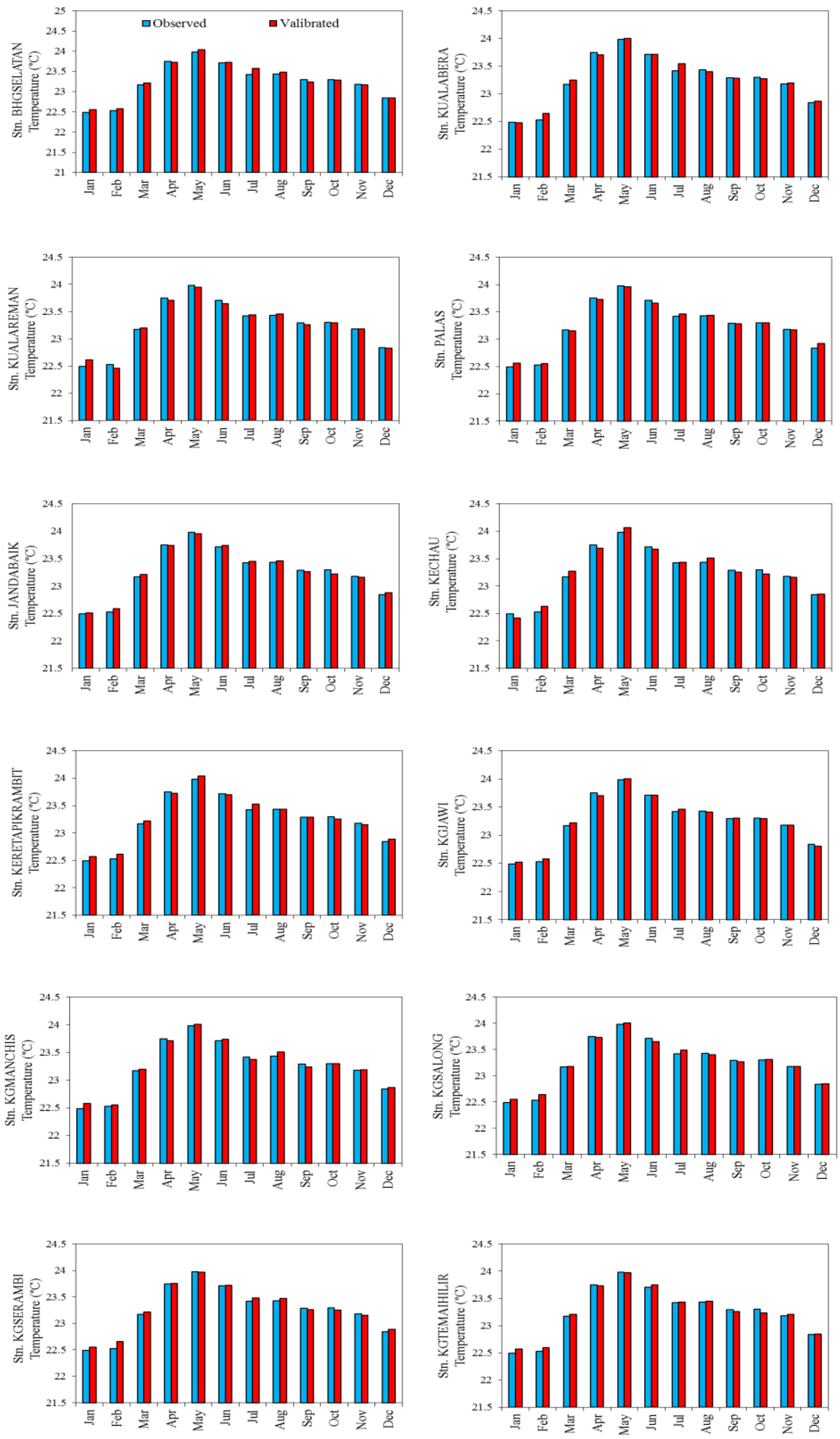

Figure 4.5: Comparison between observed and validation results for 12 minimum temperature stations during year 1996-2008

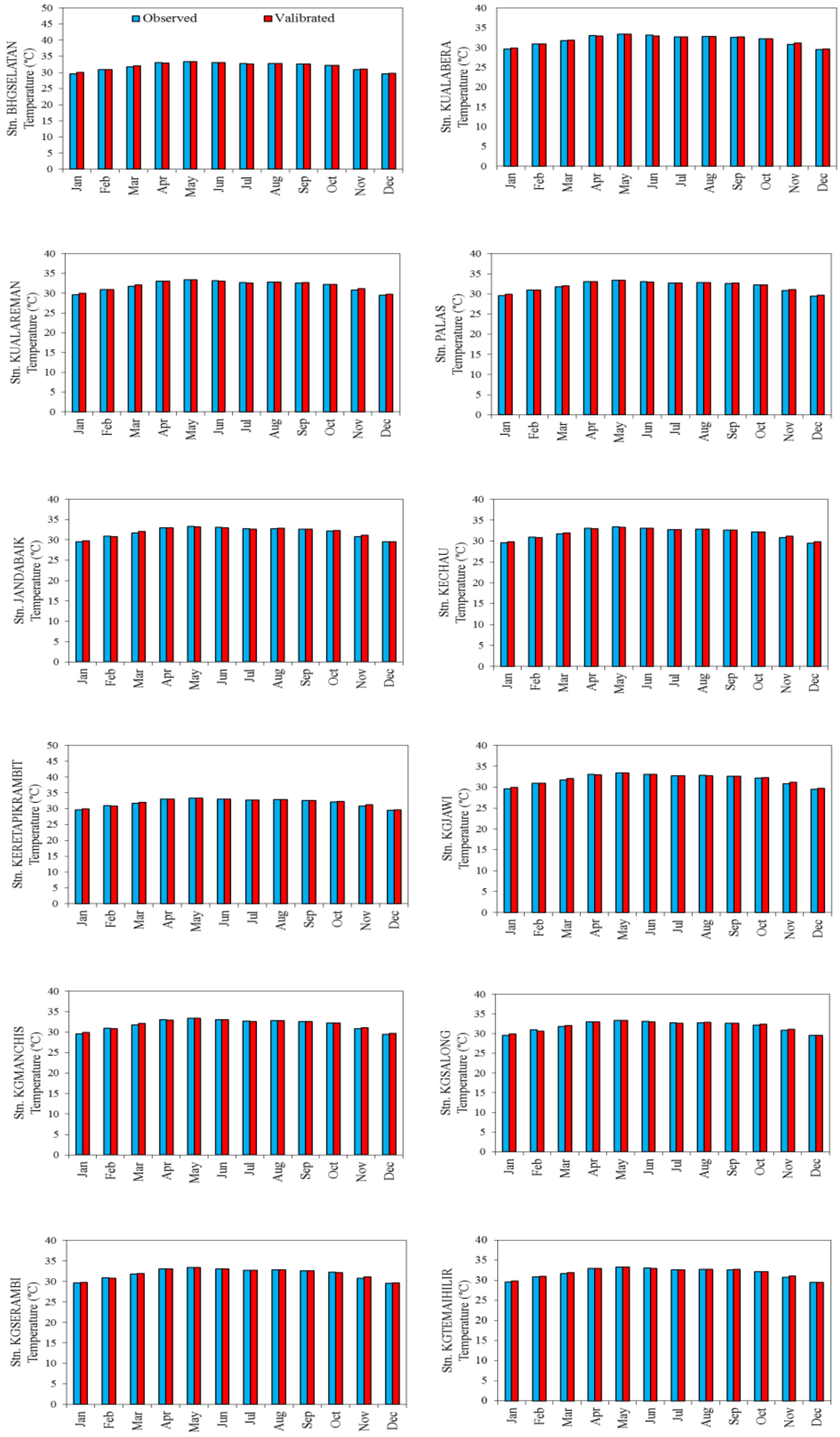

Figure 4.6: Comparison between observed and validation results for 12 maximum temperature stations during year 1996-2008

4.2.3 The Performance of Simulated Result Based on KS test and P-value

The daily rainfall data for Pahang state with the period 1984-2008 (25 years) has been used to calibrate during year 1984 to 1995 and validate during year 1996 to 2008 the model for the region. The assess ability of LARS-WG, in addition to the comparison chart, some statistical tests were also carried out. The Kolmogorov-Smirnov (K-S) test performed on the seasonal distribution of the test series of wet and dry (W Series) and daily rainfall calculated from the observed data. The significant differences between the observed data and model simulations may arise from smoothing the observed data, errors in the observed data, random changes in the observed data, and unusual climatic phenomenon in a climate station to create a climate something very different this year.

This test calculates of p-value, which is used to accept or reject the hypothesis that the two sets of data can come from the same distribution such as when there is no difference between observed and simulated climate for that variable. The p-value is similar or near to one and KS value is low-value to one meaningful climate simulation is possible with the observed climate, it should therefore be accepted.

Table 4.1 to 4.3 show the statistical analysis of the results of the simulation model performance observed seasonal data and shows the performance of the model to simulate rainfall and temperature of every month. This result shows the statistical analysis of calibration and validation. The KS value for rainfall is less than 1.0 with in range 0.072 to 0.1. Besides that, the KS value for minimum and maximum temperature in range 0.062 to 0.075. The calibration and validation of p-value for rainfall is approximately to 1.0 which are in range 0.954 to 1.0. The p-value for minimum and maximum tempeature are in range 0.992 to 0.999. The performance model for all station with calibration result have a satisfactory value with percentage error less than 0.5% and performance with validation result has also satisfactory value with percantage error less than 0.3%.

Table 4.1: KS test and p-value result for rainfall

Station		Rainfall				Assessment
		Calibration		Validation		
Location	Station Name	KS statistic	p-value	KS statistic	p-value	
KUANTAN	KUALAREMAN	0.074	0.999	0.074	0.999	Satisfactory
KUALA LIPIS	KERETAPIKRAMBIT	0.095	0.985	0.084	0.996	Satisfactory
	KECHAU	0.097	0.986	0.101	0.995	Satisfactory
BERA	KUALABERA	0.096	0.990	0.091	0.994	Satisfactory
PEKAN	KGSERAMBI	0.089	0.995	0.096	0.991	Satisfactory
	KGSALONG	0.076	1.000	0.093	0.992	Satisfactory
	KGTEMAIHILIR	0.082	0.996	0.081	0.995	Satisfactory
BENTONG	KGJAWI	0.083	0.979	0.087	0.995	Satisfactory
	JANDABAIK	0.091	0.987	0.102	0.985	Satisfactory
	KGMANCHIS	0.072	1.000	0.085	0.995	Satisfactory
CAMERON HIGHLAND	PALAS	0.103	0.982	0.102	0.982	Satisfactory
	BHGSELATAN	0.086	0.995	0.099	0.954	Satisfactory

Table 4.2: KS test and p-value result for minimum temperature

Station		Minimum Temperature				Assessment
		Calibration		Validation		
Location	Station Name	KS statistic	p-value	KS statistic	p-value	
KUANTAN	KUALAREMAN	0.071	0.999	0.075	0.999	Satisfactory
KUALA LIPIS	KERETAPIKRAMBIT	0.062	0.999	0.066	0.999	Satisfactory
	KECHAU	0.071	0.999	0.066	0.999	Satisfactory
BERA	KUALABERA	0.066	0.999	0.066	0.999	Satisfactory
PEKAN	KGSERAMBI	0.062	0.999	0.066	0.999	Satisfactory
	KGSALONG	0.062	0.999	0.071	0.999	Satisfactory
	KGTEMAIHILIR	0.071	0.999	0.066	0.999	Satisfactory
BENTONG	KGJAWI	0.062	0.999	0.071	0.999	Satisfactory
	JANDABAIK	0.079	0.999	0.079	0.999	Satisfactory
	KGMANCHIS	0.071	0.999	0.064	0.999	Satisfactory
CAMERON HIGHLAND	PALAS	0.075	0.999	0.071	0.999	Satisfactory
	BHGSELATAN	0.075	0.992	0.062	0.999	Satisfactory

Table 4.3: KS test and p-value result for maximum temperature

Station		Maximum Temperature				Assessment
		Calibration		Validation		
Location	Station Name	KS statistic	p-value	KS statistic	p-value	
KUANTAN	KUALAREMAN	0.062	0.999	0.071	0.999	Satisfactory
KUALA LIPIS	KERETAPIKRAMBIT	0.071	0.999	0.062	0.999	Satisfactory
	KECHAU	0.066	0.999	0.071	0.993	Satisfactory
BERA	KUALABERA	0.066	0.999	0.071	0.999	Satisfactory
PEKAN	KGSERAMBI	0.069	0.999	0.062	0.999	Satisfactory
	KGSALONG	0.079	0.992	0.071	0.992	Satisfactory
	KGTEMAIHILIR	0.062	0.999	0.062	0.999	Satisfactory
BENTONG	KGJAWI	0.071	0.999	0.062	0.999	Satisfactory
	JANDABAIK	0.071	0.999	0.071	0.999	Satisfactory
	KGMANCHIS	0.066	0.999	0.062	0.999	Satisfactory
CAMERON HIGHLAND	PALAS	0.074	0.999	0.066	0.999	Satisfactory
	BHGSELATAN	0.075	0.999	0.071	0.999	Satisfactory

4.3 Performances Evaluation of Climate Prediction by LARS-WG with Current Weather

The daily rainfall data was screening and refined to minimize data loss. The election observation rainfall data in year 2011 was made because this year all the selected station with daily rainfall data are sufficient and have the least data loss. The temperature data contributing to the year 2011 has been compared with the data of temperatures were predicted using the LARS-WG model to observe clearly the accuracy of such data. Normally, the incident monsoun was started in November, December and January recorded a reading of the rain rather than months earlier. The total rainfall was picked up from November and continues to decline by January the following year. The rainfall patern recorded start low by early February.

Figure 4.7 and 4.8 shows the current state of each station showed range rainfall for the year is lower than 4000 mm/year except KGMANCHIS station at Bentong distrit. In year 2011, the reading level of very high rainfall resulted in flash floods occurred in Sg. Bentong. The situation which increases rainfall starting in 2008 and continuing increase in the level of the river water in Sg. Bentong. This became clear when the occurrence of erosion the banks as a result of swift currents that occur during flash floods. The range rainfall is above 6000 mm/year. This reading is very highest compare with the normal rainfall in Pahang state with 2650 mm/year.

Table 4.4 reverted the percantage error between rainfall prediction from LARS-WG with actual weather in year 2011. Normally, the highest amount of rainfall occurred on November and declined in January of the following year. The rainfall is recorded at beginning of February. The review results show show at all station rainfall caused a decrease percantages levels except at PALAS and BHGSELATAN stations. It stations show the percentage difference quite high around reduction achieved by 64%. The distrit at Kuantan, Kuala Lipis, Pekan and Bentong drop in regular between 0.07% to 25%. The forecast reduction is based on an analysis of rainfall data preceding not without undetermine conditions such as floods.

Throughly, Figure 4.9 to 4.10 show the comparison of temperature pattern at Kuantan distrit between projected by LARS-WG with actual temperature in year 2011. It is expected to receive high temperature on May at 24.1°C in minimum temperature and 33.4°C in maximum temperature. As a result of the prediction of the LARS-WG also shows that May is also the month of the most dry and warm up to 24.6°C in minimum temperature and 33.7°C in maximum temperature. The percantage error is very small with below 0.9%. From the actual weather record the lowest temperature in December at 28.7°C. The prediction result in December at 30°C. The percantage error between prediction with 7.0%.

Figure 4.9 to 4.10 show, the analysis at Kuantan distrit has increased temperature is relatively high. The climate factors such as sunlight, topography and urbanization the main factors influencing the temperature. Kuantan district is located near ocean of South China Sea. This condition affects the condition as a resulting from the movement of the wind and breeze process on a daily basis. The intensity of the climate elements is difference base on location.

4.3.1 Rainfall

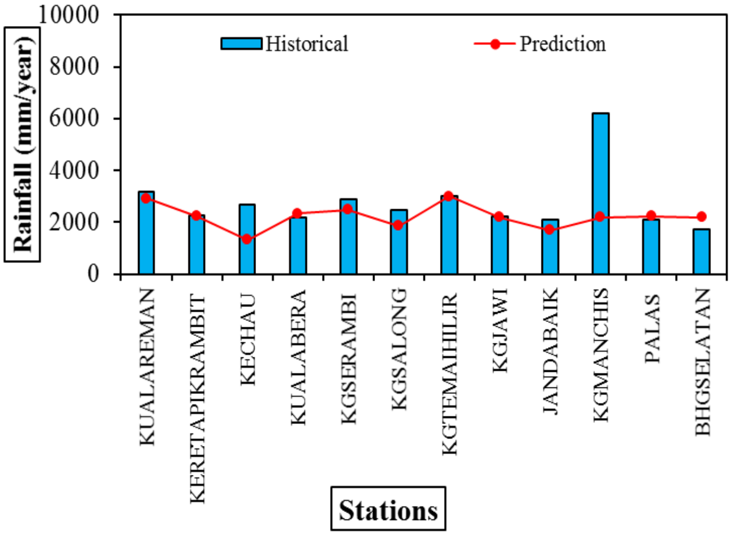

Figure 4.7: Comparison of current and prediction data with rainfall at year 2011

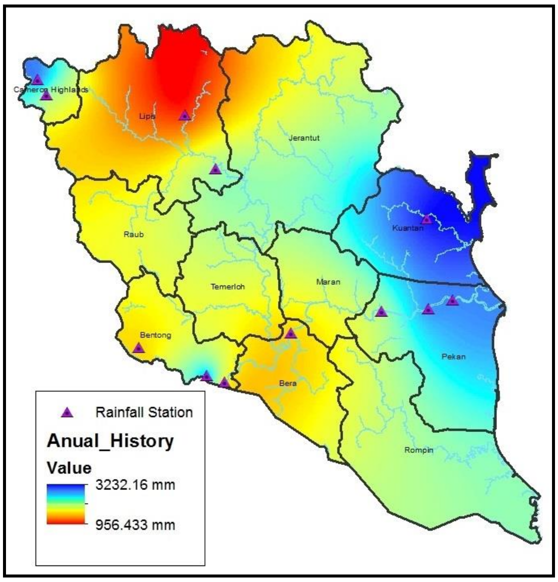

Figure 4.8: Annual historical rainfall at year 2011

4.3.2 Min Temperature

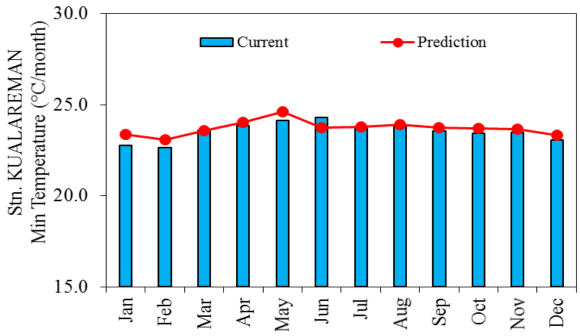

Figure 4.9: Comparison of current and prediction data with minimum temperature at year 2011

4.3.3 Max Temperature

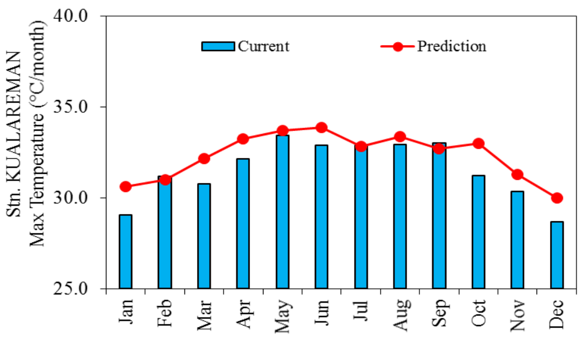

Figure 4.10: Comparison of current and prediction data with maximum temperature at year 2011

Table 4.4: The summery of comparison of current and prediction data with rainfall at year 2011 for each stations

STATION		RAINFALL		
Location	Station Name	Year 2011		
		Current (mm)	Prediction (mm)	Percentage Difference (%)
KUANTAN	KUALAREMAN	3190.5	2927.9	-8.2
KUALA LIPIS	KERETAPIKRAMBIT	2289	2233.6	-2.4
	KECHAU	2670.5	1325.4	-50.3
BERA	KUALABERA	6223	2334.9	-62.4
PEKAN	KGSERAMBI	2911	2478.2	-14.8
	KGSALONG	2495.5	1860.7	-25.4
	KGTEMAIHILIR	3014	3011.8	-0.07
BENTONG	KGJAWI	2222.5	2190	-1.4
	JANDABAIK	2091	1707.7	-18.3
	KGMANCHIS	6223	2200.1	-64.6
CAMERON HIGHLAND	PALAS	2104.8	2230	5.9
	BHGSELATAN	1748.5	2194.1	25.4

4.4 The Future Trend of Rainfall for Pahang State

Figure 4.11 to 4.13 is show available station for the future prediction of rainfall. The PALAS station and BHGSELATAN station is cover in Cameron Highland district can record the high rainfall reading at October and November of range 300 mm/month and above. Total rainfall was found to begin to increase from August and continued to fall in early December with achieve range 160 to 320 mm/month. The lowest rainfall recorded in February a reading of less than 100 mm/month. Table 4.5 show the PALAS and BHGSELATAN stations can increase amount of rainfall for the future. The PALAS station can increase with range 12% to 20% amount for after 90 year later from current condition. The BHGSELATAN station can increase with achieve 4.8% amount for after 90 year later from current condition. Through the pattern shown in figure can be said that Cameron Highland District area affected by the end of the rainy season from November to December and the dry season in February.

Figure 4.11 to 4.13 is show the KUALAREMAN station is show highest amount of rainfall is in December, exceeding 590 mm/month. The total rainfall was started to rise from June to December and declined gradually by January. Figure 4.11 to 4.13 show range with 150 mm/month to 610 mm/month from June to December and average 200 mm/month at January. The lowest rainfall is recorded in February, with rainfall amount of 150 mm/month. Table 4.5 show the KUALAREMAN station can decrease amount of rainfall for the future. The KUALAREMAN station can decrease with range 1.6% to 4.3% amount for after 90 year later from current condition. Figure 4.11 to 4.13 is show highest amount rainfall of KUALABERA station is in October, exceeding 320 mm/month. The amount can started to rise from July to October with range 150 mm/month to 320 mm/month and start to decline slowly by December with 200 mm/month. The lowest rainfall recorded in February, which is a low 120 mm/month. Table 4.5 show the KUALABERA station can drastic drop amount of rainfall for the future. The KUALABERA station can decrease with range 61% to 63% amount for after 90 year later from current condition.

Figure 4.11 to 4.13 is show highest amount of rainfall is in October, exceeding 220 mm/month at KERETAPIKRAMBIT and KECHAU statio. This stations are cover in Kuala Lipis area show the total rainfall was picked up from June until October and start to decline slowly by December with range 180 mm/month to 280 mm/month. The lowest rainfall recorded in February, which is 80 mm/month lower. Table 4.5 show the KERETAPIKRAMBIT and KECHAU stations can decrease amount of rainfall for the future. The KERETAPIKRAMBIT station can decrease with range 3% to 9% amount for after 90 year later from current condition. The KECHAU station can decrease with achieve 36% amount for after 90 year later from current condition. Through the pattern shown in figure can be said that the area affected by the Kuala Lipis district during the inter-monsoon seasons, winds are generally light and choppy (Sharifah, 2003).

The Pekan district is a near the sea. This district location is a direct effect from wheather changes such as monsoon and available amount of high monthly rainfall is in December, Figure 4.11 to 4.13 are show exceeding 500 mm/month. The KGSERAMBI, KGSALONG and KGTEMAIHILIR stations is cover at Pekan district. The total rainfall was found to begin to increase from August to December and start declining gradually by January. Figure 4.11 to 4.13 show lowest rainfall recorded in February, 120 mm/month. Table 4.5 show the Pekan district can decrease amount of rainfall for the future. The amount can decrease with range 3% to 16% amount for after 90 year later from current condition.

The JANDABAIK, KGJAWI and KGMANCHIS stations show the trend of rainfall patterns is approximately equal for each others. Figure 4.11 to 4.13 stations available amount of monthly rainfall is high in November, exceeding 320 mm/month. The total rainfall was started to rise from July to November and start descending slowly by December. Figure 4.11 to 4.13 show lowest rainfall recorded in February, 90 mm/month. Table 4.5 show the Bentong district can drastic drop amount of rainfall for the future. The amount can decrease with range 15% to 61% amount for after 90 year later from current condition.

Table 4.5: The percentage trend of rainfall (%) as simulated with year ∆2020, ∆2055 and ∆2090 base on current rainfall

STATION		**RAINFALL**		
Location	**Station Name**	**Increment or Decrement (%)**		
		YEAR		
		∆2020	**∆2055**	**∆2090**
KUANTAN	**KUALAREMAN**	-1.0	-4.3	-1.6
KUALA LIPIS	**KERETAPIKRAMBIT**	-4.8	-9.2	-3.9
	KECHAU	-35.7	-39.0	-35.7
BERA	**KUALABERA**	-63.3	-64.4	-61.8
PEKAN	**KGSERAMBI**	-3.7	-9.1	-6.0
	KGSALONG	-17.9	-21.2	-16.6
	KGTEMAIHILIR	-5.1	-10.6	-10.1
BENTONG	**KGJAWI**	-20.7	-23.3	-17.9
	JANDABAIK	-15.8	-12.3	-22.4
	KGMANCHIS	-63.3	-64.4	-61.8
CAMERON HIGHLAND	**PALAS**	17.7	12.4	20.7
	BHGSELATAN	0.004	4.8	1.7

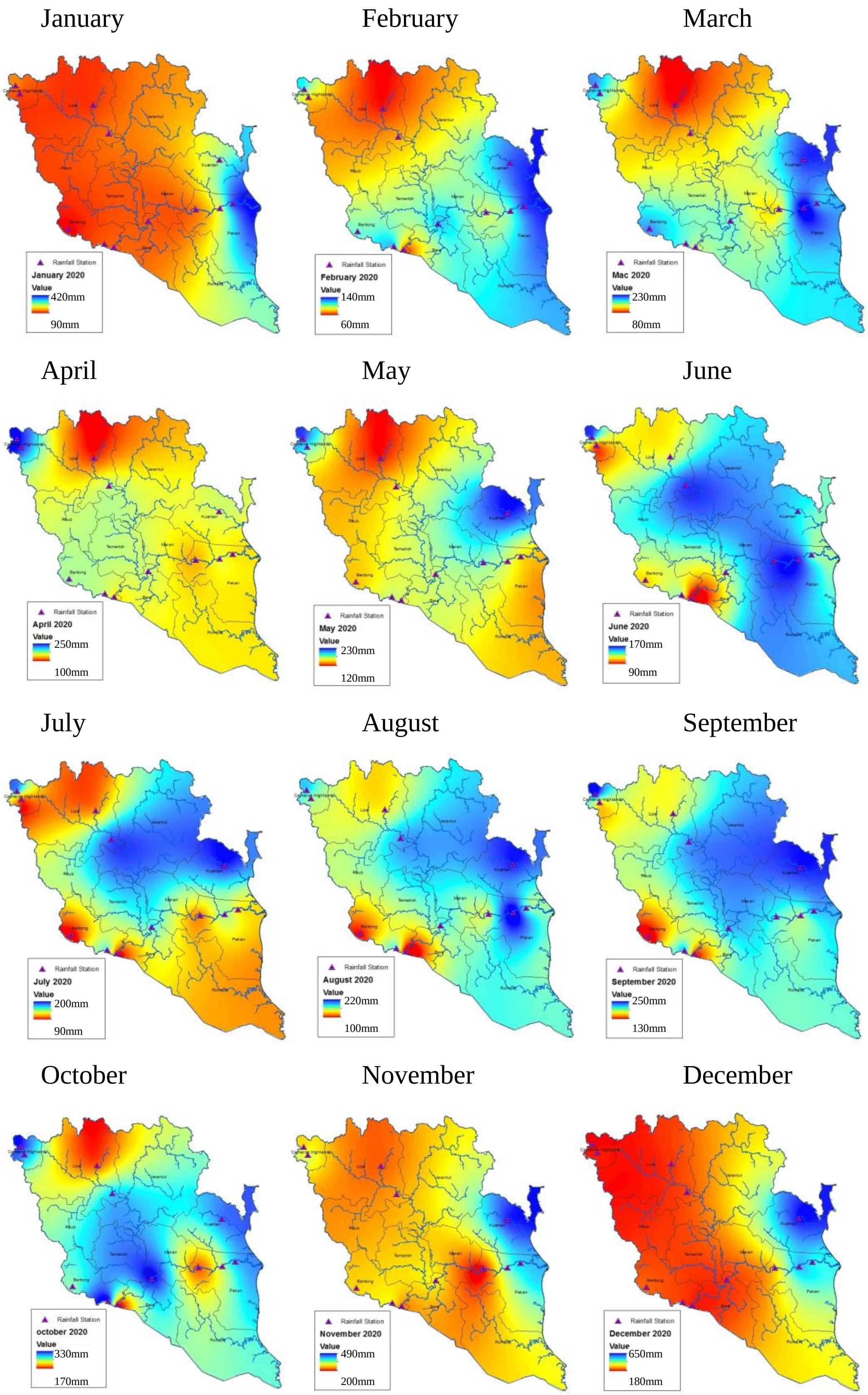

Figure 4.11: Average annual rainfall year Δ2020

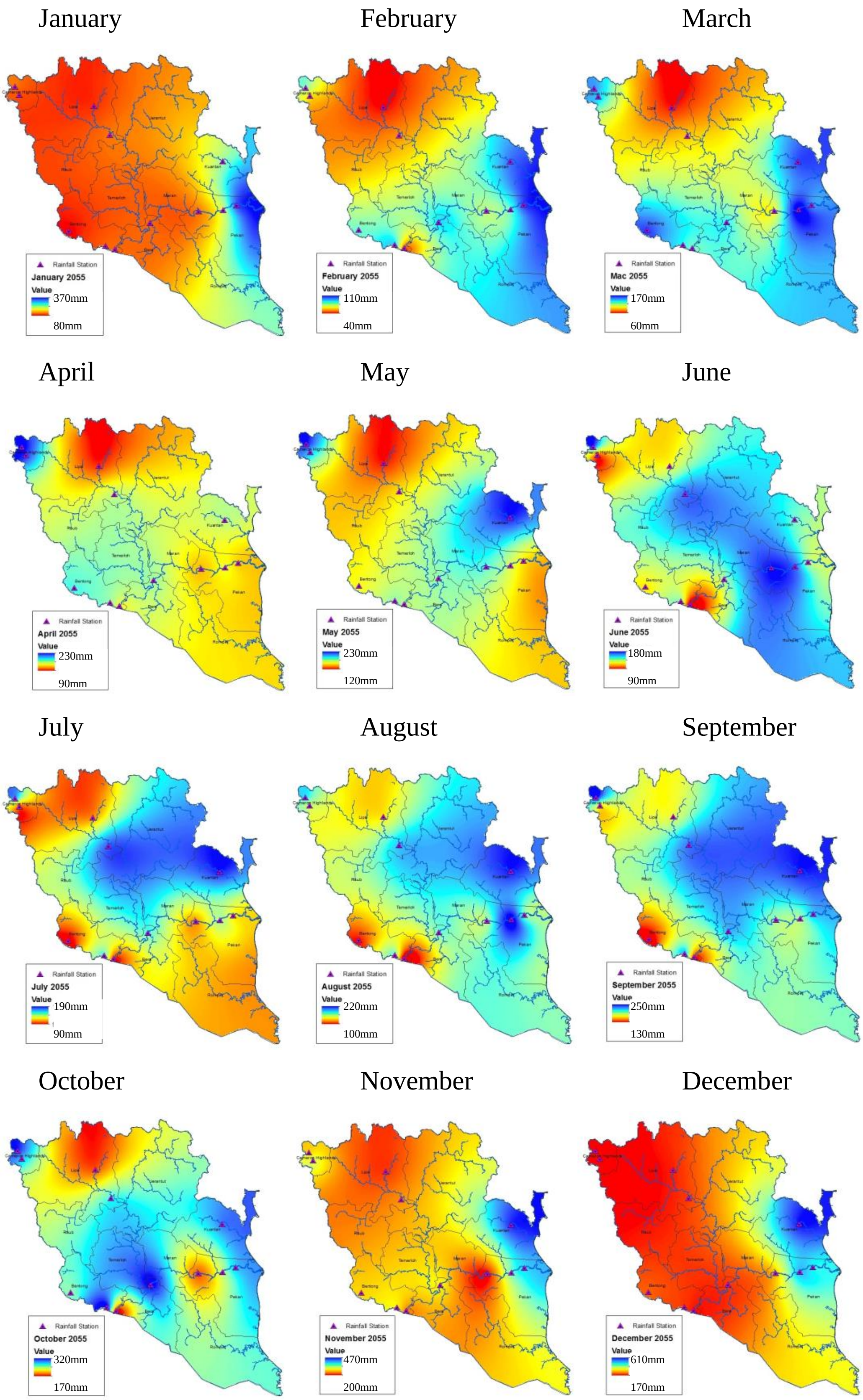

Figure 4.12: Average annual rainfall year Δ2055

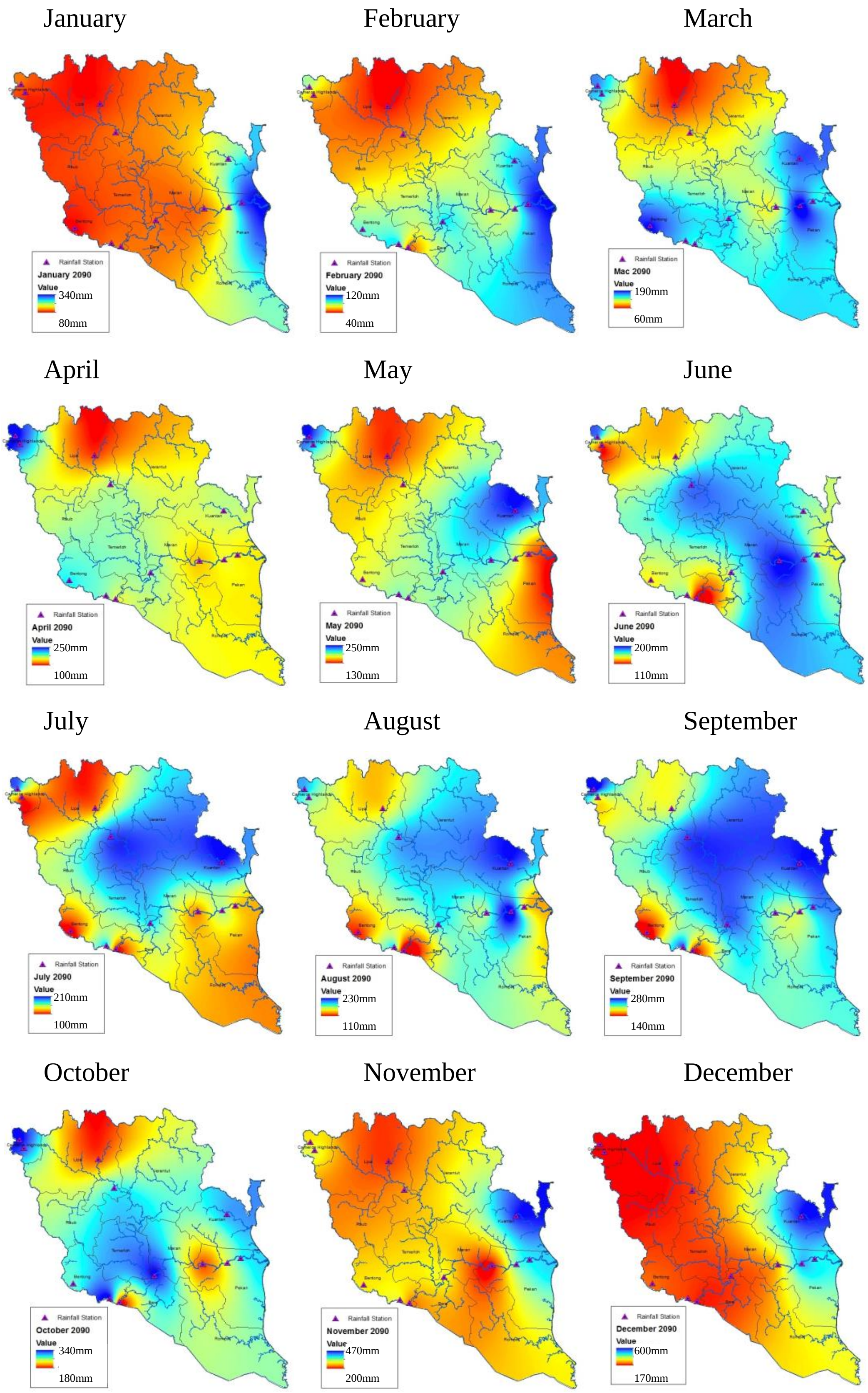

Figure 4.13: Average annual rainfall year Δ2090

4.5 The Future Changes of Minimum Temperature Trend

As a country located at the equator, Malaysia has uniform temperature throughout the year. The annual change in the temperature difference is less than 3°C (Rahmat, 2014). The predicted of temperature at all district are only based on the pattern of temperature change at Kuantan station only. This temperature forecast made only takes into account based on the factors rainfall at each station selected without consider the topography, land development and ghg emissions. Therefore the temperature prediction result using LARS-WG many unreliable at each district except at Kuantan district. But, the performance of the result at Kuantan district with 2.4% error. This model performance for temperature prediction is very satisfactory.

Figure 4.14 to 4.16 shows the pattern of minimum temperature from year Δ2020, Δ2055 and Δ2090. Figure 4.14 to 4.16 shows the an annual pattern of temperature changes according to generally based on the basic method of interpolation to get an overview of the overall pattern of changes of Pahang state. Figure 4.14 to 4.16 obtained, the pattern of this temperature increase can be seen starting from February to May with a reading of 20°C to 24°C. Commencing from June to January, the relatively and uniform temperature patterns are quite regular at 23°C. The temperature conditions relatively is also due to the factor monsoon changes occur regularly in Malaysia. The temperature conditions at a rate of 23°C, it is the normal minimum temperature. Table 4.6 show about percentege trend of minimum temperature (%) as simulated with year Δ2020, Δ2055 and Δ2090 base on current minimum temperature. Table 4.6, the analysis result show the increase minimum temperature pattern. The average can increase with average 4.9% annually for each year after 90 year later from current condition. The temperature increment for year Δ2020 is in average 0.5%. The first 30 year later is not many difference temperature change compare the current temperature. Meanwhile, the temperature increment for year Δ2055 is average at 4.4%. The pattern is estimated to slowly increase after 60 years later. The increase temperature for year Δ2090 is average at 11.2%. The pattern is become high increase after 90 year later.

Table 4.6: The percentage trend of minimum temperature (%) as simulated with year ∆2020, ∆2055 and ∆2090 base on current minimum temperature

STATION		**MINIMUM TEMPERATURE**		
Location	**Station Name**	**Increment or Decrement (%)**		
		YEAR		
		∆2020	**∆2055**	**∆2090**
KUANTAN	**KUALAREMAN**	0.6	3.3	9.5
KUALA LIPIS	**KERETAPIKRAMBIT**	0.4	4.6	11.4
	KECHAU	0.5	4.5	11.4
BERA	**KUALABERA**	0.4	4.8	11.5
PEKAN	**KGSERAMBI**	0.5	4.1	10.3
	KGSALONG	0.5	4.4	10.9
	KGTEMAIHILIR	0.6	4.0	10.3
BENTONG	**KGJAWI**	0.4	4.7	11.4
	JANDABAIK	0.3	5.1	12.1
	KGMANCHIS	0.4	4.8	11.5
CAMERON HIGHLAND	**PALAS**	1.3	4.3	11.6
	BHGSELATAN	1.0	5.1	12.4

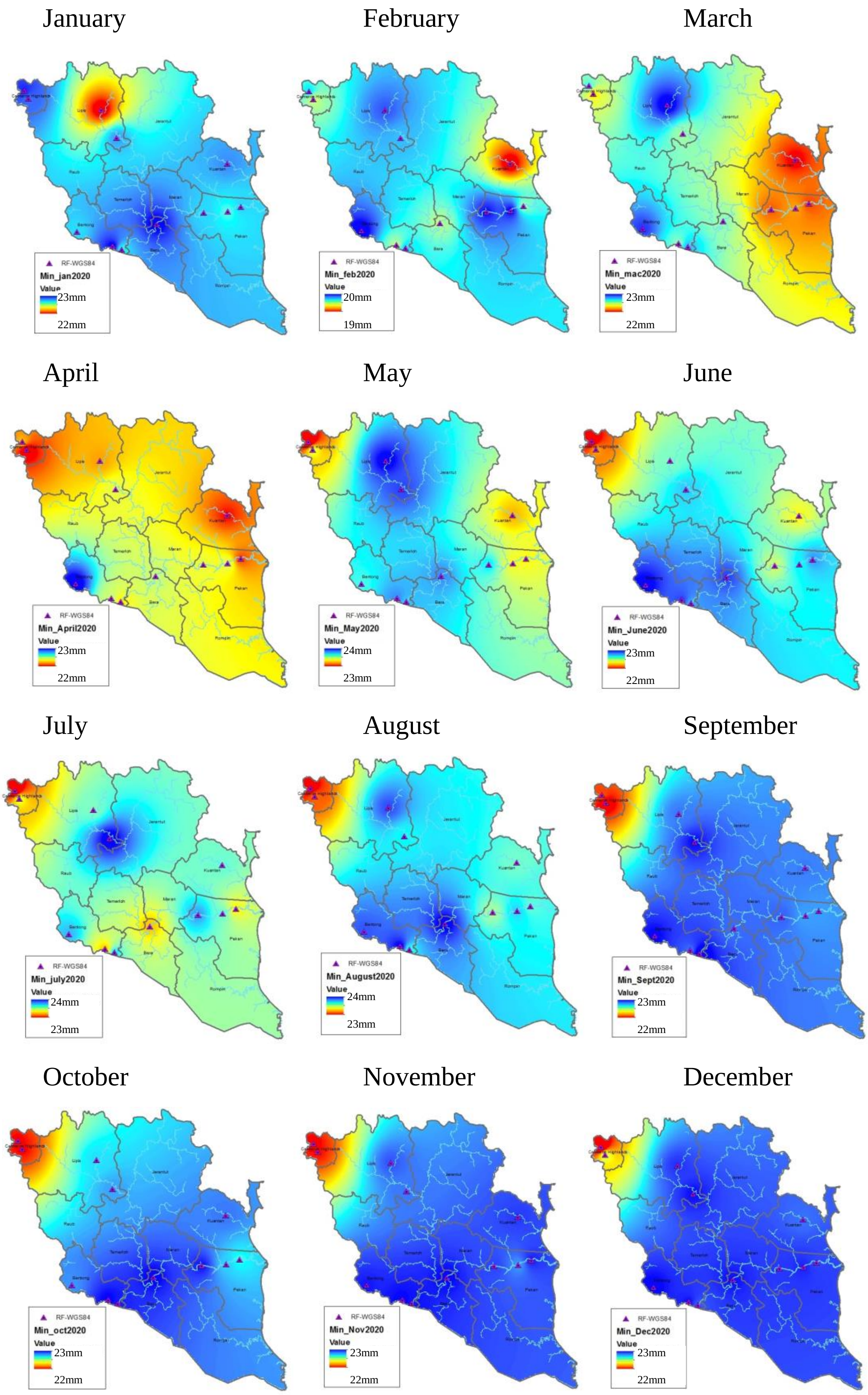

Figure 4.14: Average annual minimum temperature year Δ2020

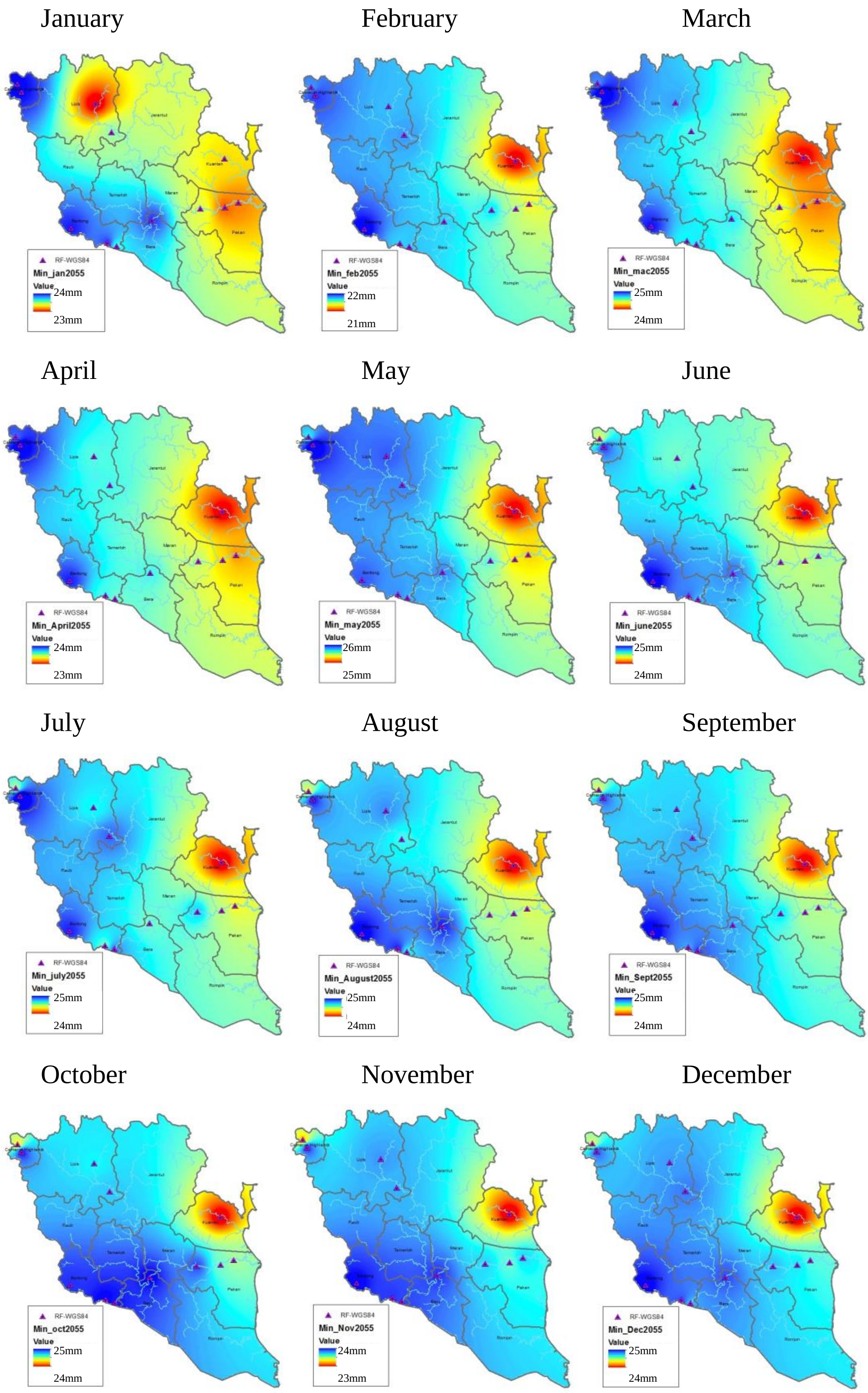

Figure 4.15: Average annual minimum temperature year Δ2055

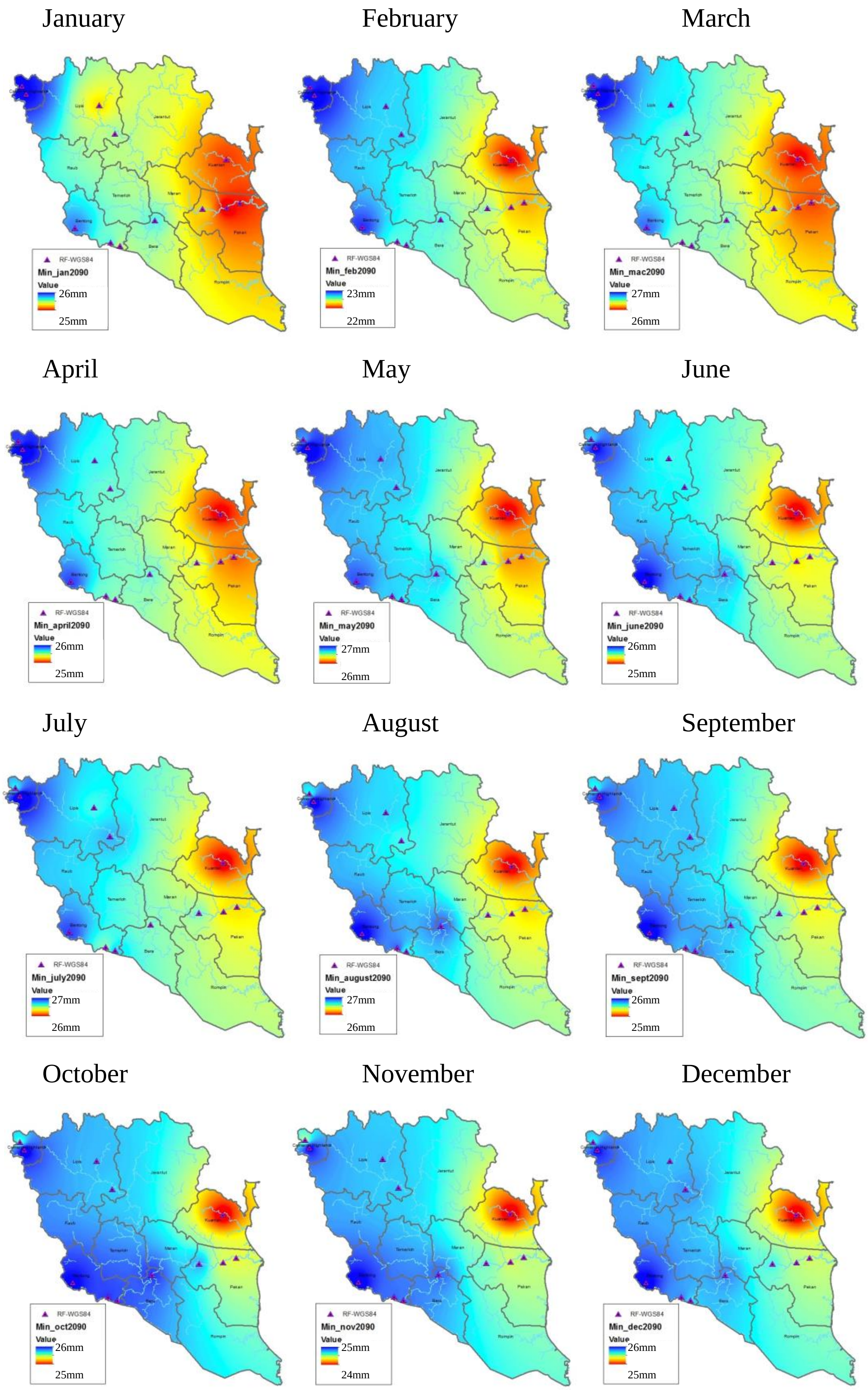

Figure 4.16: Average annual minimum temperature year Δ2090

4.6 The Future Changes of Maximum Temperature Trend

Figure 4.17 to 4.19 shows the pattern of maximum temperature year ∆2020, ∆2055 and ∆2090. Figure 4.17 to 4.19 shows the using same method of interpolation to get an overview of the overall pattern of changes of Pahang state. Figure 4.17 to 4.19 obtained, the pattern of this temperature increase can be seen starting from January to May with a reading of 29°C to 33°C. Commencing from June to August, the relatively and uniform temperature patterns are quite regular at 32°C. Start from September to December, the temperature conditions is nonuniform with range 28°C to 32°C.

Table 4.7 show about percentege trend of maximum temperature (%) as simulated with year ∆2020, ∆2055 and ∆2090 base on current maximum temperature. Table 4.7, the analysis result show the increase maximum temperature pattern. The average can increase with average 4.9% annually for each year after 90 year later from current condition. The increase temperature for 2020 is average at 0.8%. The first 30 year later is not many difference temperature change compare the current temperature. The increase temperature for year ∆2055 is average at 4.2%. The pattern is slowly increase after 60 year later. The increase temperature for year ∆2090 is average at 9.5%. The pattern is become increase after 90 year later.

Table 4.7: The maximum temperature change (in %) in future year ∆2020, ∆2055 and ∆2090 compare to the historical data

STATION		**MAXIMUM TEMPERATURE**		
		Increment or Decrement (%)		
Location	**Station Name**	**YEAR**		
		∆2020	**∆2055**	**∆2090**
KUANTAN	**KUALAREMAN**	0.6	4.1	8.8
KUALA LIPIS	**KERETAPIKRAMBIT**	0.6	4.5	9.5
	KECHAU	0.6	4.4	9.6
BERA	**KUALABERA**	0.7	4.6	9.7
PEKAN	**KGSERAMBI**	0.5	4.0	8.7
	KGSALONG	0.6	4.3	9.1
	KGTEMAIHILIR	0.5	4.1	8.7
BENTONG	**KGJAWI**	0.7	4.6	9.7
	JANDABAIK	0.7	4.8	10.1
	KGMANCHIS	0.7	4.6	9.7
CAMERON HIGHLAND	**PALAS**	0.7	4.8	10.3
	BHGSELATAN	2.7	2.7	10.2

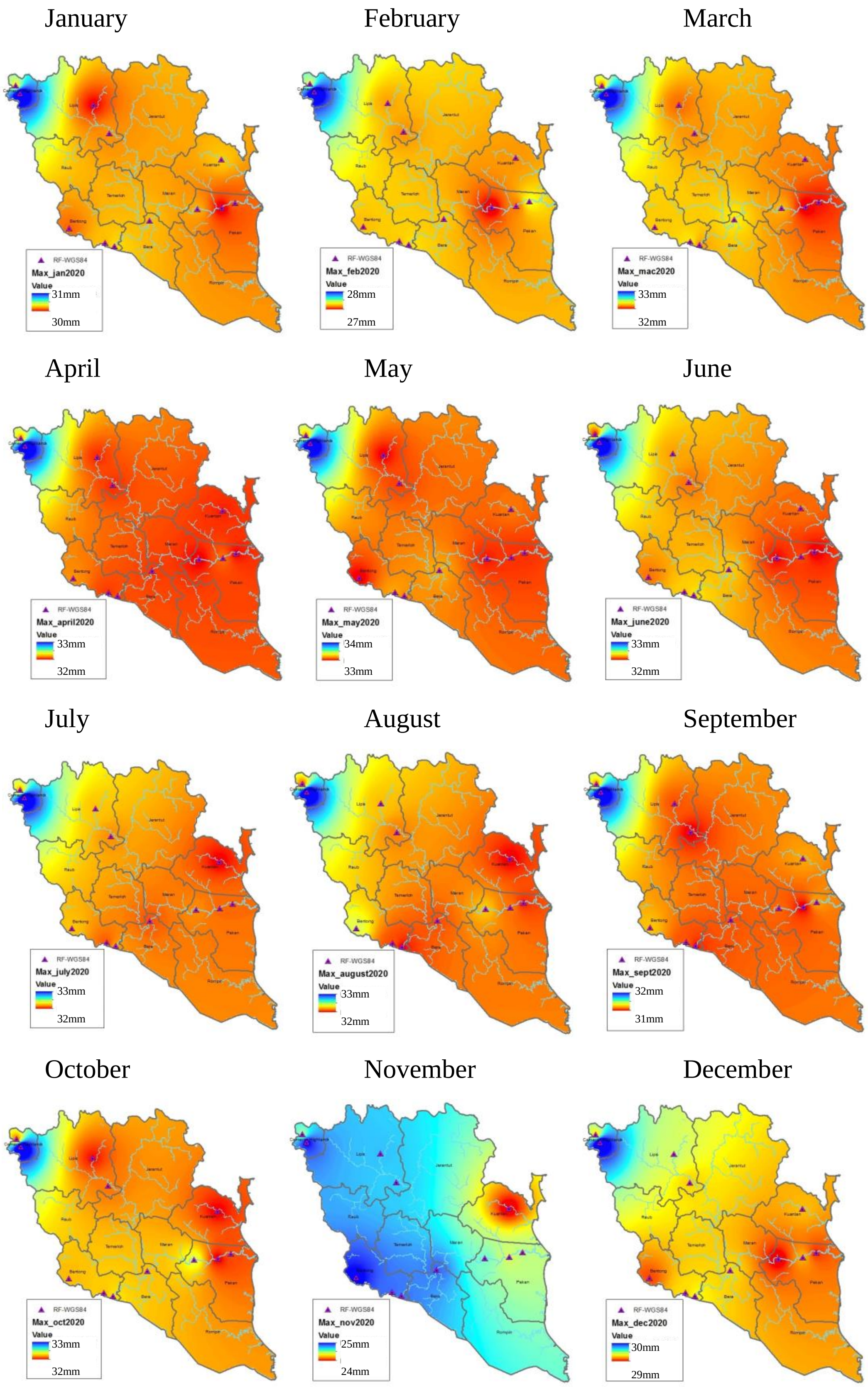

Figure 4.17: Average annual maximum temperature year Δ2020

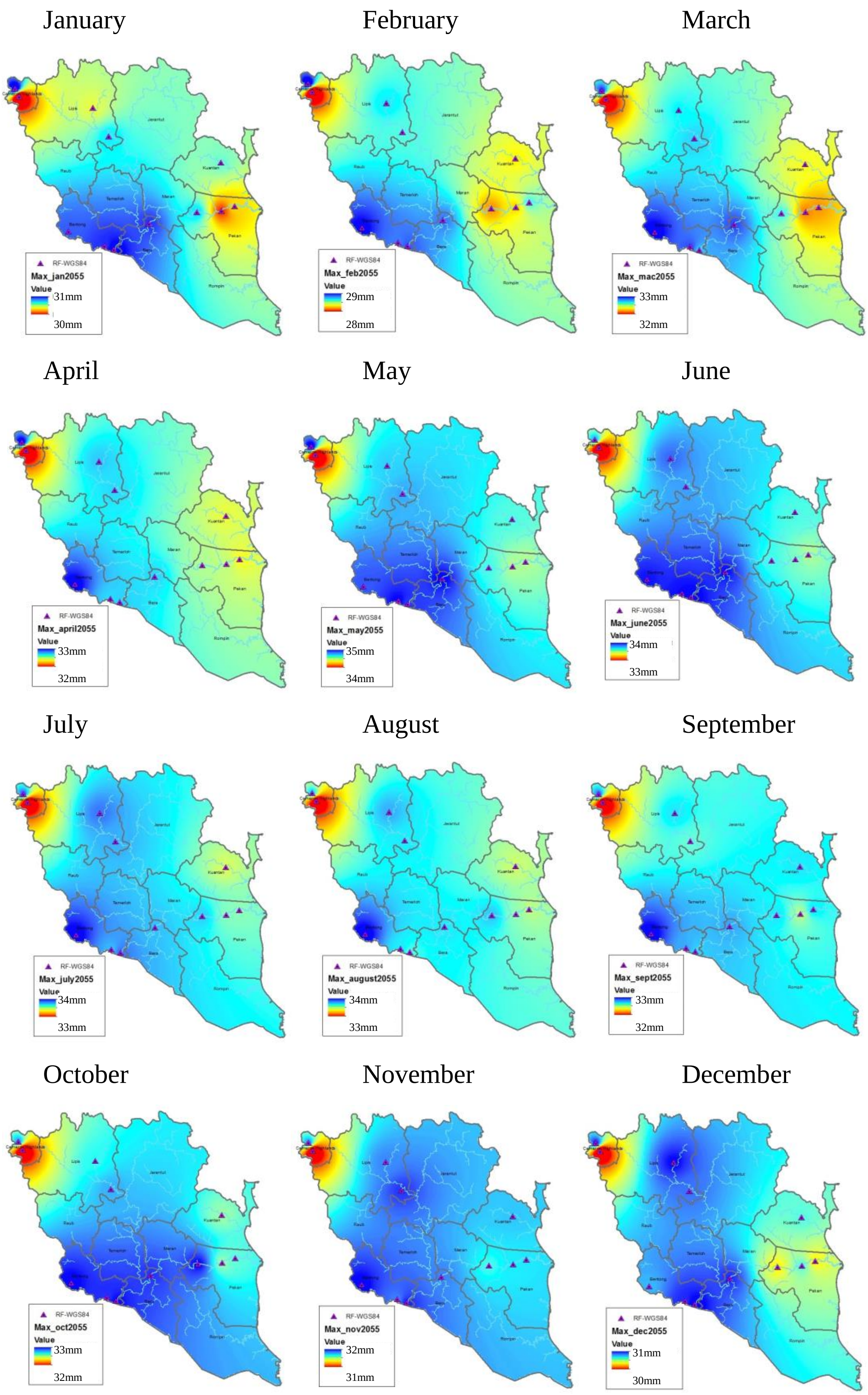

Figure 4.18: Average annual maximum temperature year Δ2055

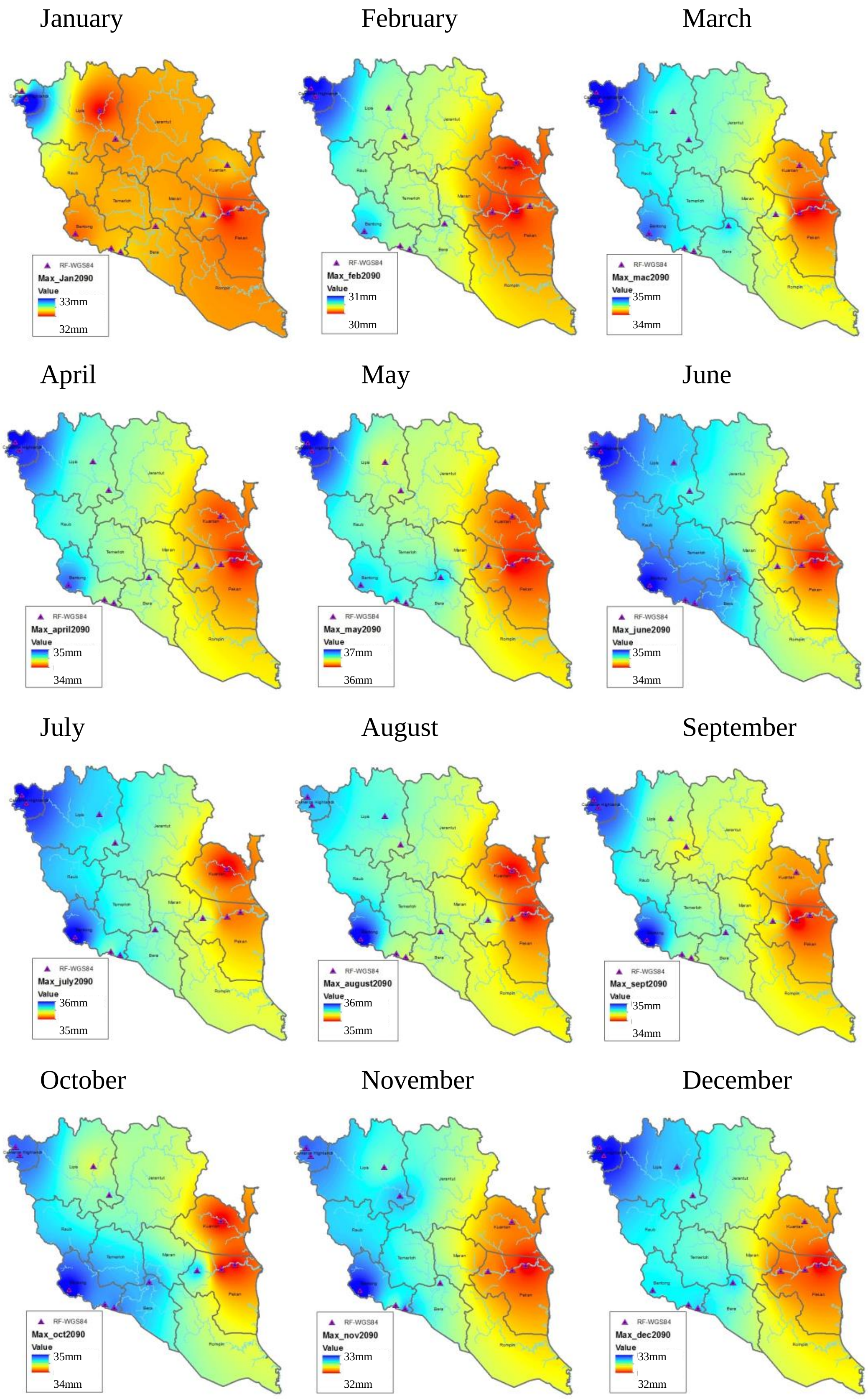

Figure 4.19: Average annual maximum temperature year Δ2090

4.7 The Future Changes of Potential Evapotranspiration Trend

In general, evapotranspiration is the sum of evaporation and transpiration from the Earth's land and ocean surface to the atmosphere. The amount of water needed or used plants depends of environmental factors such as climate and land. The plant have a process of type, growth and development phase. The water loss through surface water (evaporation) and through plant surfaces (transpiration) is an evapotrasnpirasi. The evapotranspiration is the total loss of water (water consumption) for an evapotrasi of surface area through soil or water and transpiration from the plant surface. The potential evapotranspiration is determined only by elements of climate, while actual evapotranspiration also determined by the nature of the soil conditions. The selected component of the water balance can divided into two components to evaporation and transpiration.

In this study, the Kuantan is position of the station is near at sea location, the KUALAREMAN station from Figure 4.20 show reading of average evapotranspiration is below 4.4 mm/month. Figure 4.20 show, the maximum and minimum monthly evapotranspiration is 5.1 mm/month in March and 3.1 mm/month in November. Table 4.8 show drastic increase of percentage evapotranspiration with range 35% to 43% for future trend after 90 year. The increasing is very high compare the current trend. The trend inrease with 0.5% annually. This improvement will continue up to 90 years.

The data for Bera district is taken from the KUALABERA station. Figure 4.20 show reading of average evapotranspiration is estimate to achieve 4.5 mm/month. Figure 4.20 show, the maximum and minimum monthly evapotranspiration is 6.4 mm/month in September and 2.8 mm/month in December. Table 4.8 show increase of percentage evapotranspiration with range 7% to 14% for future trend after 90 year.

The data is taken from the station 2 stations namely BHGSELATAN and PALAS stations. The reading of evapotranspiration is constant year round in Cameron Highland district. Therefore, Figure 4.20 show of the evapotranspiration difference is small for the two stations. Figure 4.20 show maximum and minimum monthly evapotranspiration is 5.4 mm/month in March and 3.1 mm/month in November. Table 4.8 show increase of percentage evapotranspiration with range 7% to 20% for future trend after 90 year. The future trend can become increasing compare the current trend. The trend inrease with 0.1% annually. This improvement will continue up to 90 years.

The data is taken from the station 2 stations namely KERETAPIKRAMBIT and KECHAU stations. The reading of evapotranspiration is constant year round in Kuala Lipis district. Figure 4.20 show maximum and minimum monthly evapotranspiration is 5.3 mm/month in March and 3.1 mm/month in November. Table 4.8 show increase of percentage evapotranspiration with range 7.5% to 17% for future trend after 90 year. The trend become increase for each year with 0.15% annually. This improvement will continue up to 90 years.

The data is taken from the station 3 stations namely KGTEMAIHILIR, KGSALONG and KGSERAMBI stations. The reading of evapotranspiration is constant year round in Pekan district. Figure 4.20 show maximum and minimum monthly evapotranspiration is 6.5 mm/month in July and 3.4 mm/month in Disember. Table 4.8 show increase of percentage evapotranspiration with range for future trend after 90 year. Table 4.8 show the increasing at year ∆2020 with 35%, at year ∆2055 with 40% and year ∆2090 with 44%. The data is taken from the station 3 stations namely KGJAWI, JANDABAIK and KGMANCHIS stations. The reading of evapotranspiration is constant year round in Bentong district. Figure 4.20 show maximum and minimum monthly evapotranspiration is 5.1 mm/month in March and 3.1 mm/month in November. Table 4.8 show increase of percentage evapotranspiration with range 7% to 16% for future trend after 90 year. The trend become increase for each year with 0.14% annually. This improvement will continue up to 90 years.

Table 4.8: The potential evapotranspiration change (in %) in future year Δ2020, Δ2055 and Δ2090 compare to the historical data

STATION		**POTENTIAL EVAPOTRANSPIRATION**		
Location	**Station Name**	**Increment or Decrement (%)**		
		YEAR		
		Δ2020	**Δ2055**	**Δ2090**
KUANTAN	**KUALAREMAN**	35.1	40.7	43.4
KUALA LIPIS	**KERETAPIKRAMBIT**	7.5	13.5	17.4
	KECHAU	7.6	13.8	17.9
BERA	**KUALABERA**	7.4	12.7	14.9
PEKAN	**KGSERAMBI**	35.0	40.4	42.8
	KGSALONG	35.2	41.4	44.0
	KGTEMAIHILIR	35.0	40.4	42.7
BENTONG	**KGJAWI**	7.3	12.6	14.8
	JANDABAIK	7.6	13.5	16.2
	KGMANCHIS	7.4	12.7	14.9
CAMERON HIGHLAND	**PALAS**	7.9	15.1	20.1
	BHGSELATAN	11.5	11.5	19.9

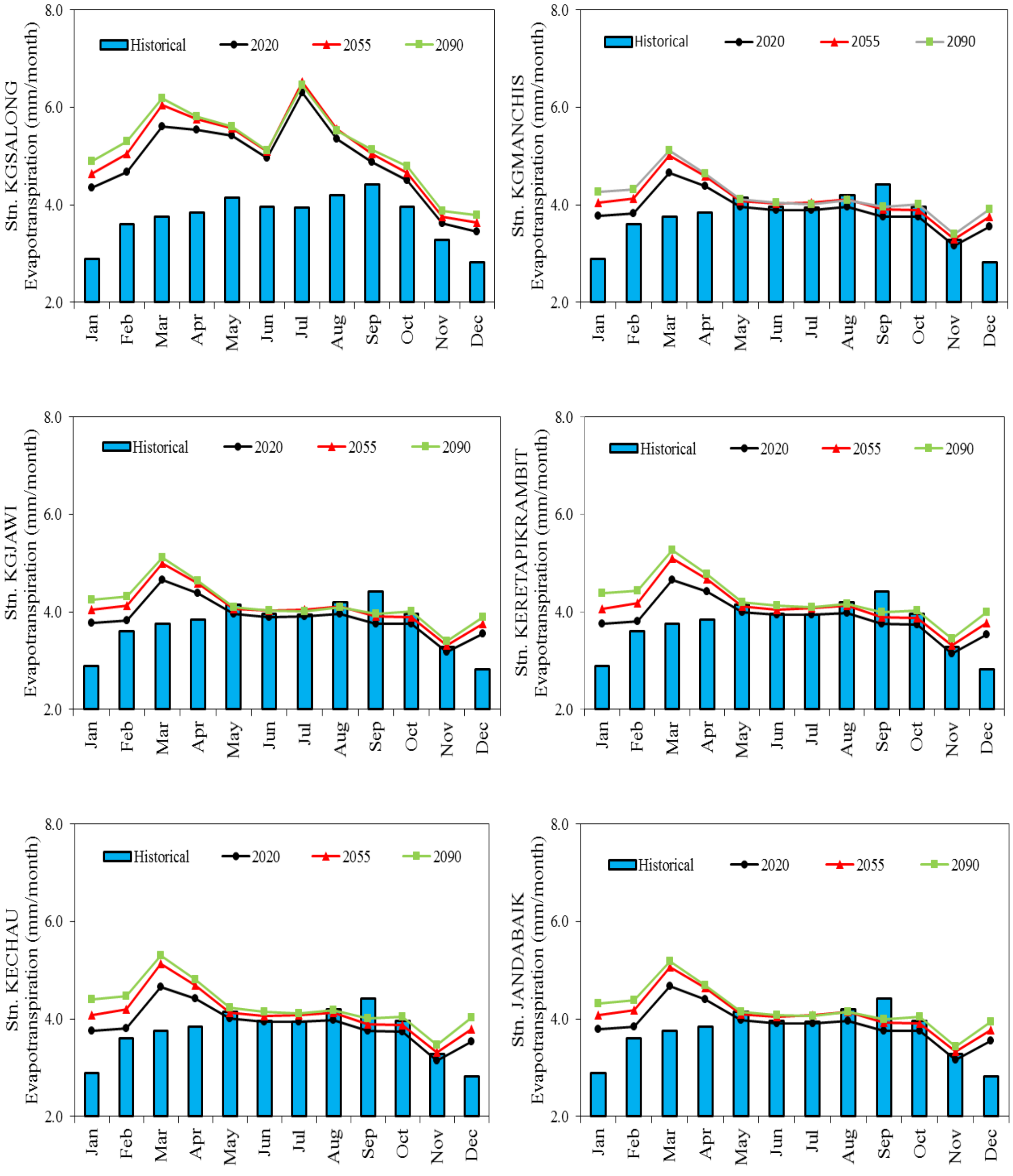

Figure 4.20: Average annual potential evapotranspiration at year (Δ2010, Δ2055, Δ2090) against historical (2011-2013) (continue)

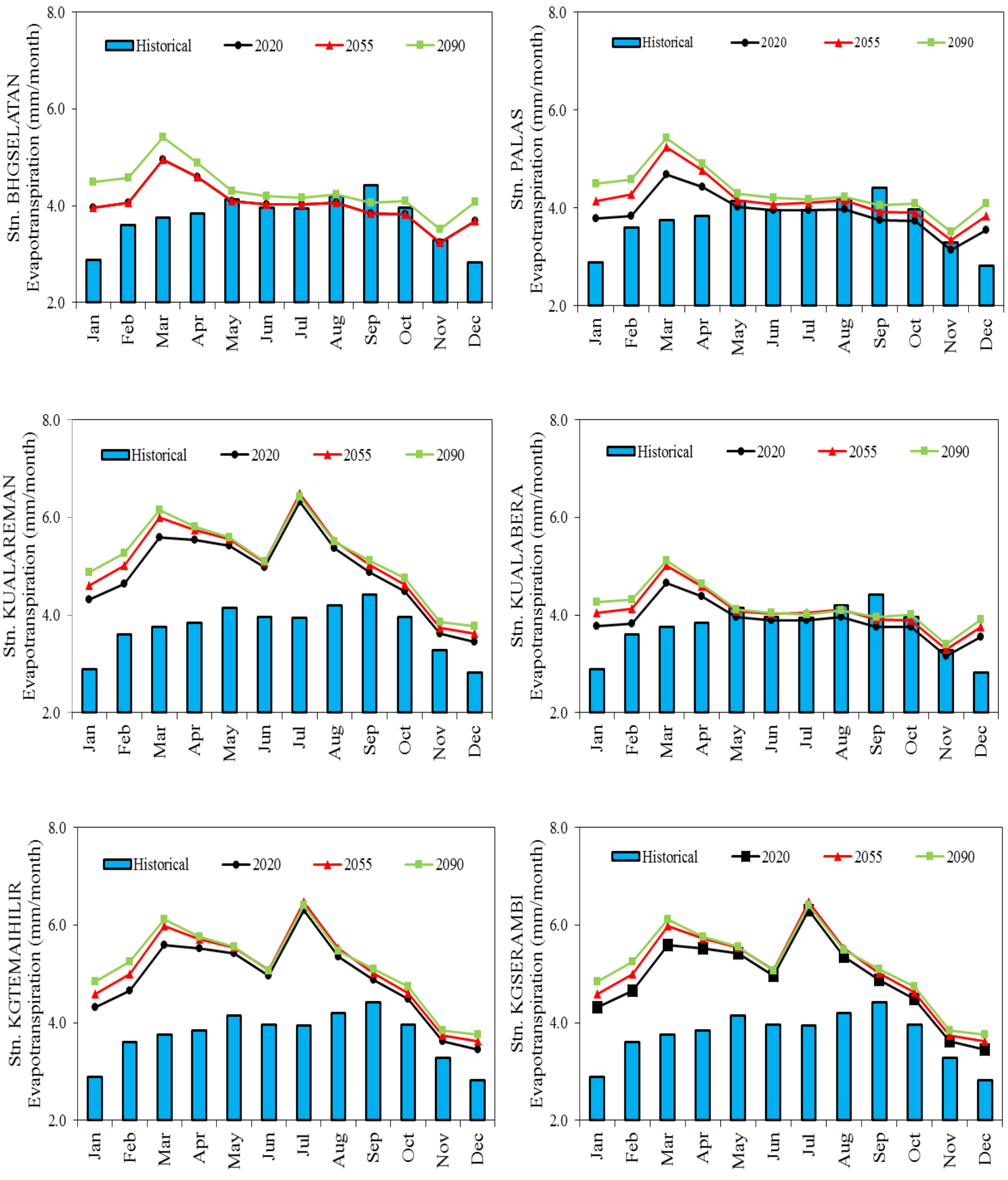

Figure 4.20: Average annual potential evapotranspiration at year (Δ2010, Δ2055, Δ2090) against historical (2011-2013)

4.8 Comparisons Of Annual Monthly Total Rainfall In Pahang State

According to Figure 4.21, is available against the annual rainfall in the state of Pahang showed that rainfall patterns are not uniform for each month. This is based on the slope of a line graph that has been obtained from three methods. This methods is namely through historical rainfall data recorded, prediction data using LARS-WG model and prediction data from the PRECIS model.

From historical rainfall data, Figure 4.21 is available against the annual rainfall in the Pahang state for historical with 25 year average staring from year 1984 to 2008. The rainfall data was record decreases in February and June. This is based on the slope of the line that had been obtained. Based on the line of march and July to November, a positive gradient indicates the occurrence of the rainfall increases, while a negative gradient means the occurrence of drought. In addition, the decrease in the total quantity of annual precipitation can be proved again in February and June as a result of climate change from monsoon. Thereby, it is correct to say the quantity of rainfall trend changes in the state of Pahang affected by the current climate as the monsoon season. Referring to Figure 4.21 show that the maximum amount of precipitation occurs in November, which recorded 234.48 mm and the minimum amount of rain was recorded in February by 87.40 mm.

The daily rainfall data using LARS-WG method is used to determine the peroid annual montly is 90 years start from year 2010 until 2099. Based on the Figure 4.21, the line of series in February and July, indicating the occurrence of the negative slope of the decrease of rainfall was recorded, while a positive gradient means the occurrence of the rainfall increases. Table 4.9 show in February and July have percentage error with decrease 19% and 4.7%. The increase in the total quantity of annual rainfall can be proved again in March and August to November. The percentages error is decrease 23% at March and increase range 4% to 11% at August to November .

Thereby, it is correct to say the quantity of rainfall trend changes in the state of Pahang is growing by the month. Figure 4.21 show that the maximum amount of rain was recorded in November of 252.13 mm and the minimum amount of rain was recorded in February by 70.25 mm. Figure 4.21 is available annual rainfall versus time of the PRECIS model data is quite different. The PRECIC data recorded that have lowest with historical data. The data is from year 2010 to 2099 with 90 year average times. Figure 4.21 show that rainfall decreased in June and Table 4.9 is show that percentage error at decrease 47%. This is based on the slope of the line that had been obtained. Based on the line in Figure 4.21, March and July to October, a positive gradient indicates the occurrence of the rainfall increases. The percentage error on Table 4.9 with decrease 25% at March and range decrease 12% to 36% at July to October. The negative slope was recorded in November until February with the error in range decrease 32% to 62%. Thereby, it is correct to say the quantity of rainfall trend changes in the state of Pahang affected by the current climate. Referring to Figure 4.21 show that the maximum amount of rainfall occurs in October, which recorded 167.43 mm and the minimum amount of rain was recorded in February by 58.77 mm.

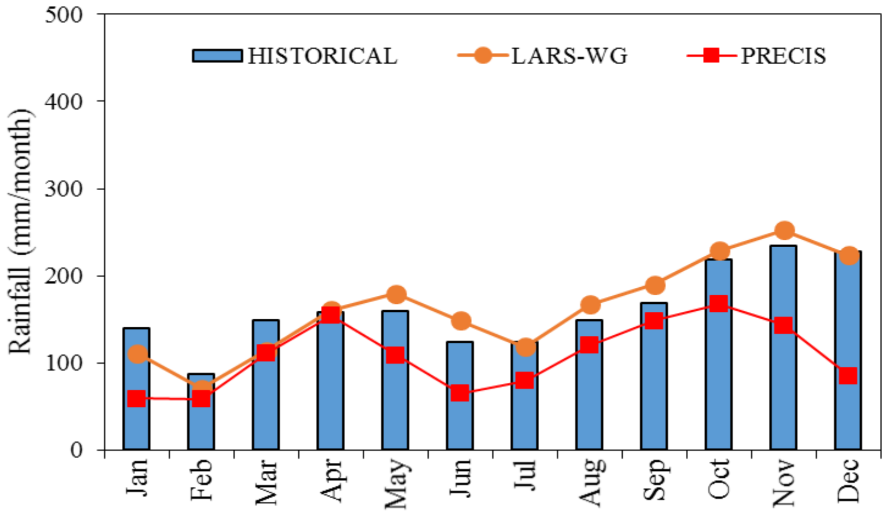

Figure 4.21: Comparison of annual monthly total rainfall (mm) for using LARS-WG model (year 2010-2099), PRECIS model (year 2010-2099) and Historical data (year 1964-2008)

Table 4.9: The summery of comparison of percentage annual monthly total rainfall (%) for LARS-WG model and PRECIS model based on Historical data

MONTH	PERCENTAGE (%)	
	LARS-WG	PRECIS
January	-20.4	-57.3
February	-19.6	-32.7
March	-23.3	-25.2
April	1.1	-2.5
May	12.7	-31.3
June	20.1	-47.4
July	-4.7	-36.1
August	11.9	-19.4
September	12.1	-12.1
October	4.9	-23.2
November	7.5	-38.8
December	-1.9	-62.5

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A study of the trend of rainfall quantity, temperature and potential evapotranspiration will be reduced by annual to covering areas of all district in the Pahang state. The monthly and annual climate patterns shown are influenced by topography and climate conditions during covering these districts areas. This phenomenon can be seen in terms of an increase and decrease the data of climate conditions annually.

5.2 Prediction of Future for Pahang State

Based on the results :

a) The KS and P-value of calibration and validation at all stations are satisfactory.

b) The LARS-WG has good performance in predicting annual rainfall for year 2011 with percentage error less than 18% except at KGMANCHIS.

c) The rainfall is predicted to be reduce 16% annually. The highest rainfall focused on Kuantan and Pekan achieving 3250 mm/year. The lowest rainfall is estimate happened at with less than 1500 mm/year.

d) In general, monthly and annual rainfall received in each area is heavily influenced by the monsoon. The influence of monsoon rain cycle-based forms the northeast monsoon, southwest monsoon and the transition period between the two monsoons is known as inter-monsoon period.

e) In almost districts with Pahang state such as Kuantan, Bera, Bentong, Pekan and Kuala Lipis are expected to drastically decrement of rainfall amount during year 2020 to 2055 in 1470 mm/year with decrease 23% compare to the historical.

f) The rainfall is prediction to rise start from year 2090 with 25% achieve 1500 mm/year.

g) The least amount of rainfall are expected in February with 90 mm/month.

h) Meanwhile November is the month that expected to receive highest amount of rainfall with 300 mm/month.

i) The predicted temperature pattern is to be gradually increase 4.9% annually until next 90 years.

j) The highest of temperature to be achieve 34°C with increasing 4.5%.

k) The potential evapotranspiration is predicted to be increase achieving 21.7% annually. The highest PET focused on Kuantan and Pekan achieving 5.2mm/day.

l) The highest of potential evapotranspiration periods for all regions are found in the early 2090 with above 14% increasing level from the current situasion.

m) The monthly rainfall prediction by LARS-WG is performed well closer to the history compare to the PRECIS. The annually LARS-WG is performance well closer with 1.19% to the history compare to the PRECIS with 32.86%.

5.3 Recommendations

Several recommendations are provided in enhancing for study purpose :

a) The LARS-WG method is recommended in order to determine the pattern of rainfall and temperature in other state.

b) The methodology of this study is suggested to be tested at several locations of temperature stations for each district in Pahang state.

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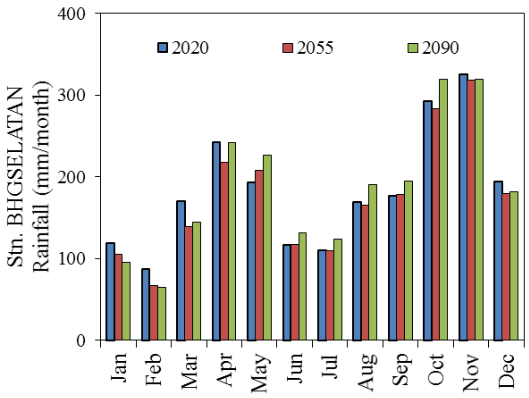
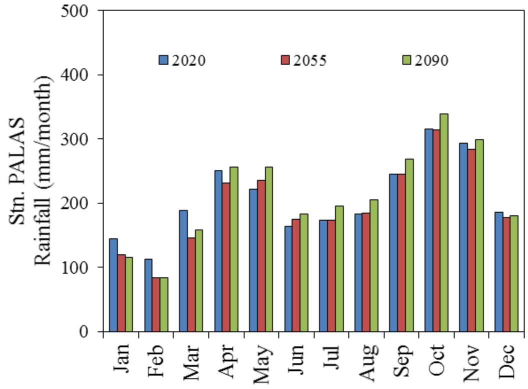
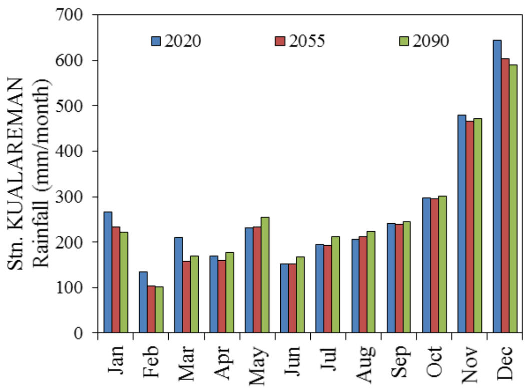
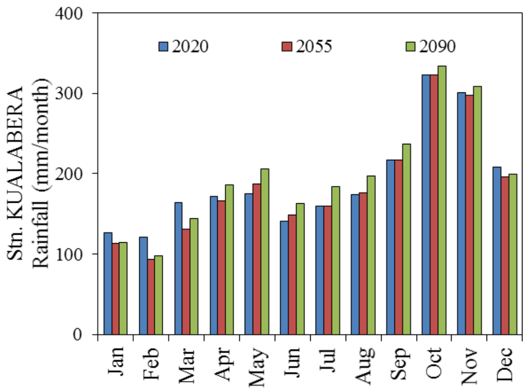
APPENDIX A

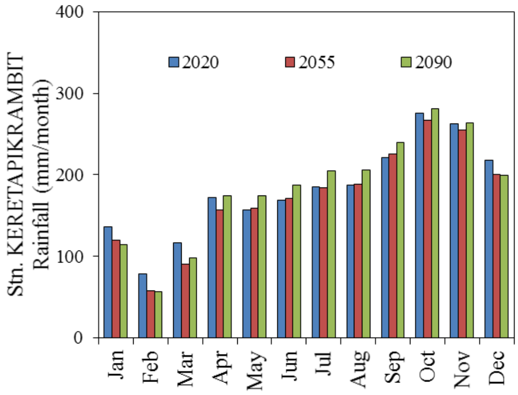
Average annual rainfall at year (2010-2099) against time (months)

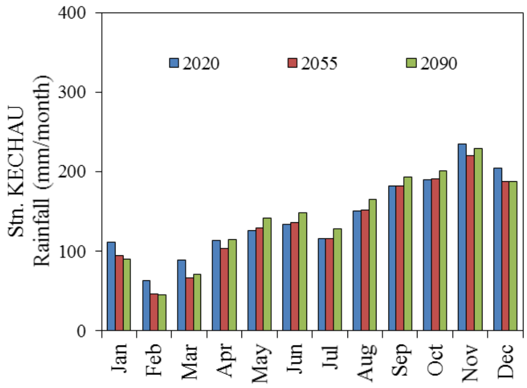


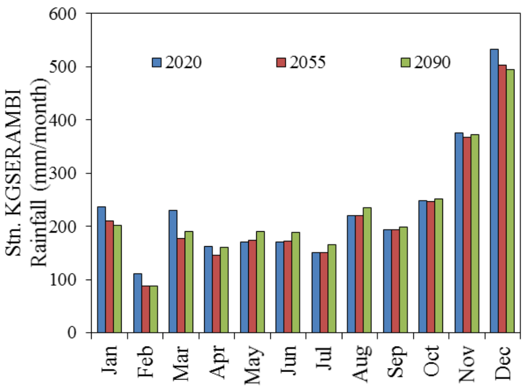











Stn. KGSERAMBI
Rainfall (mm/month)
2020
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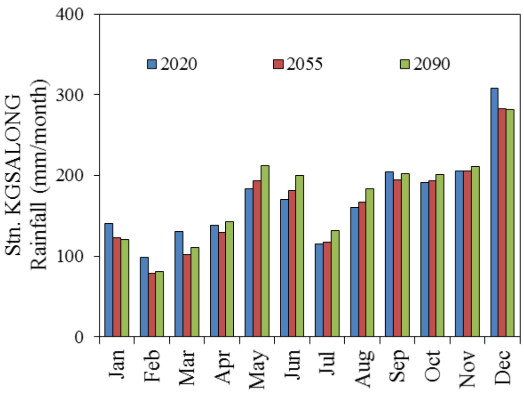
Stn. KGSALONG
Rainfall (mm/month)
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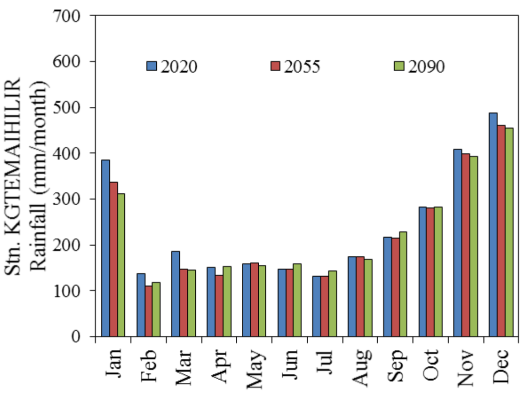
Stn. KGTEMAIHILIR
Rainfall (mm/month)
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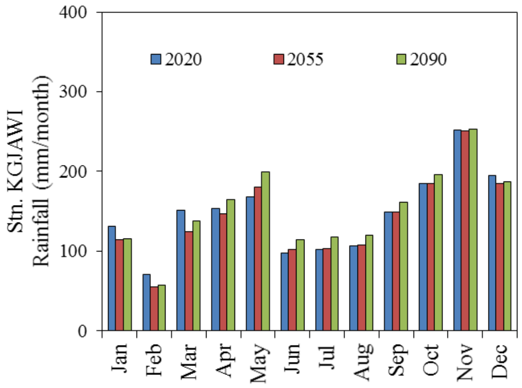
Stn. KGJAWI
Rainfall (mm/month)
2020
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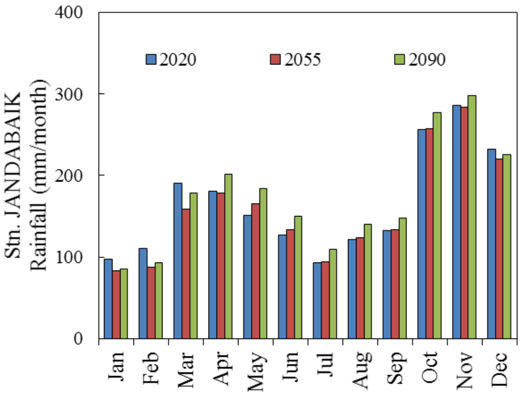
Stn. JANDABAIK
Rainfall (mm/month)
2020
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100
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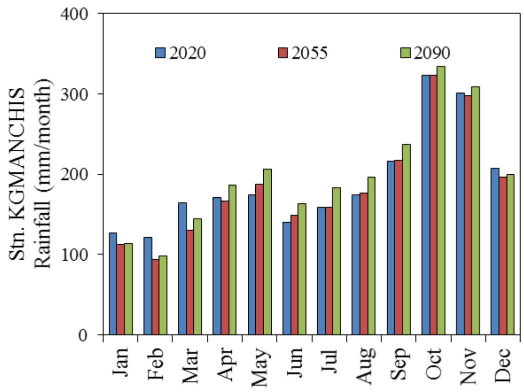
Stn. KGMANCHIS
Rainfall (mm/month)
2020
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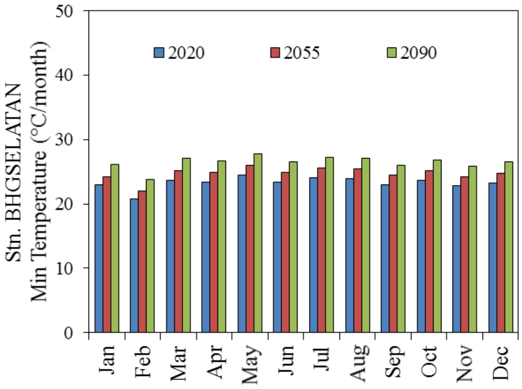
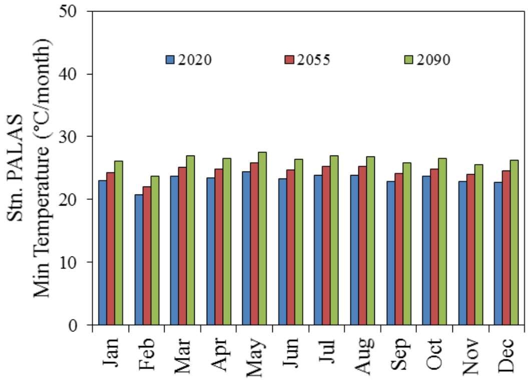
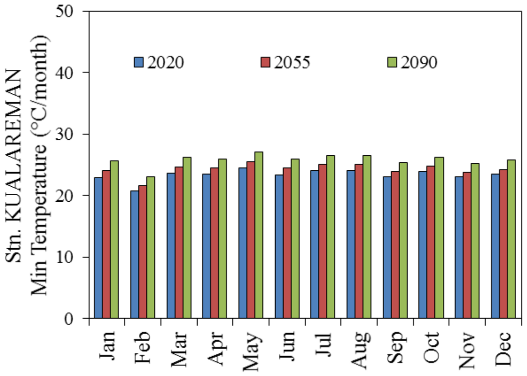
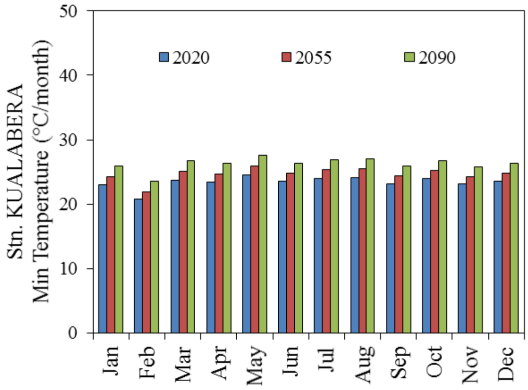
APPENDIX B

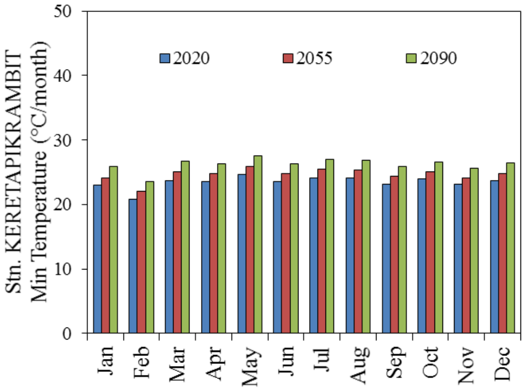
Average annual minimum temperature at year (2010-2099) against time (months)

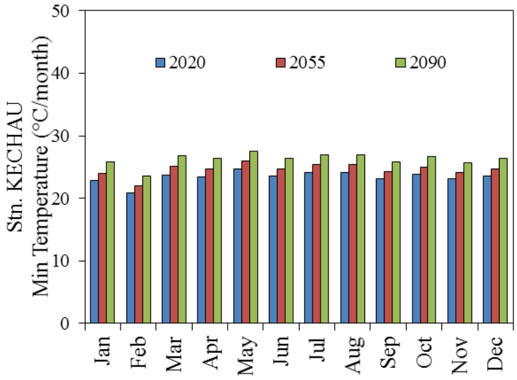


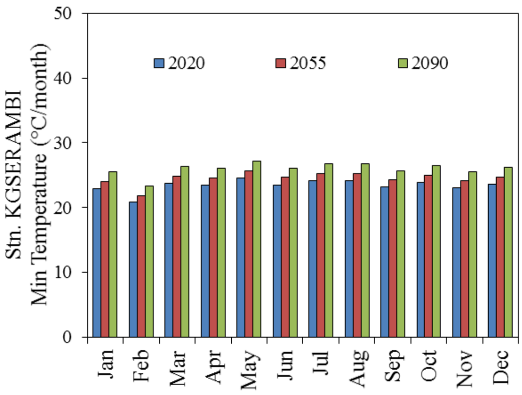











Stn. KGSERAMBI
Min Temperature (°C/month)
2020
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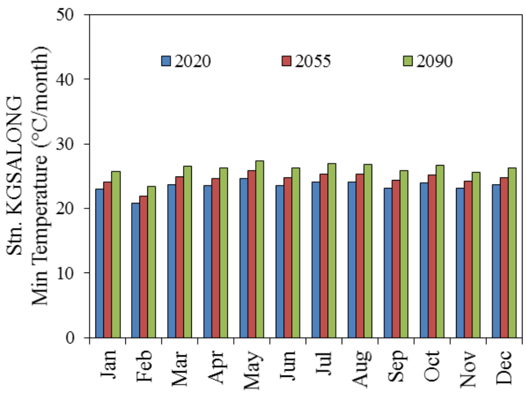
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Stn. KGSALONG
Min Temperature (°C/month)
2020
2055
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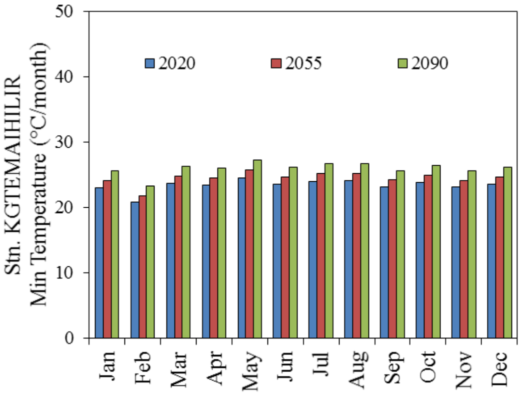
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Stn. KGTEMAIHILIR
Min Temperature (°C/month)
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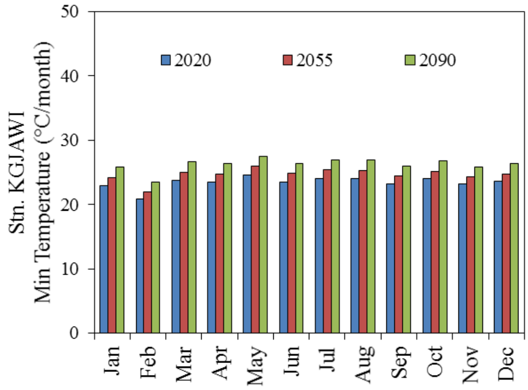
Stn. KGJAWI
Min Temperature (°C/month)
2020
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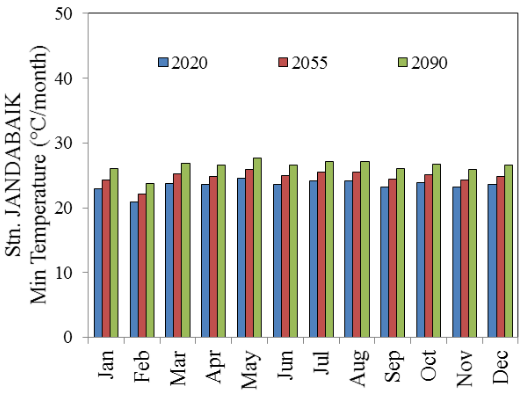
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Stn. JANDABAIK
Min Temperature (°C/month)
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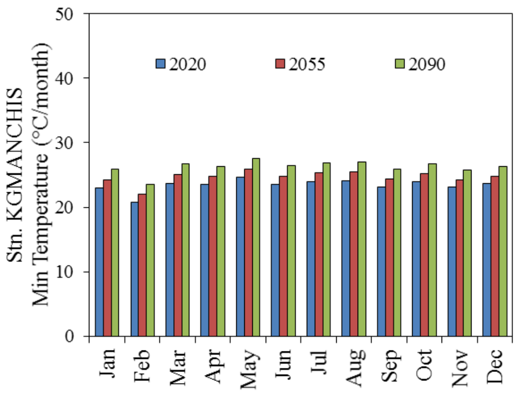
Stn. KGMANCHIS
Min Temperature (°C/month)
2020
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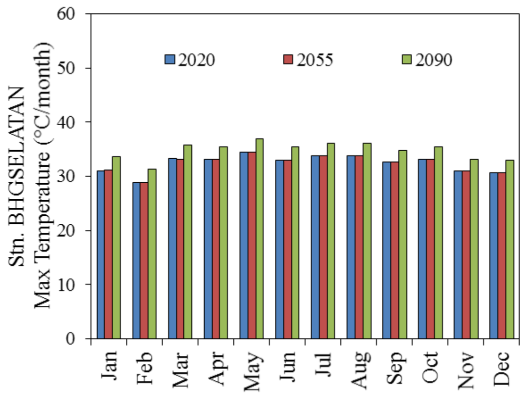
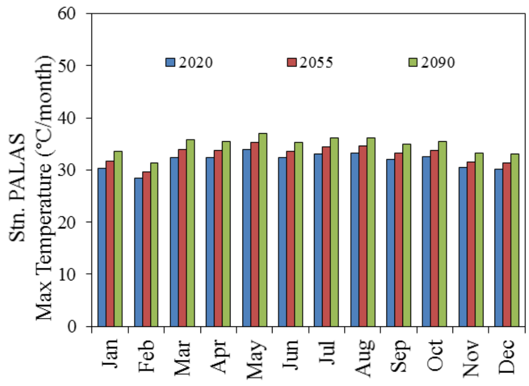
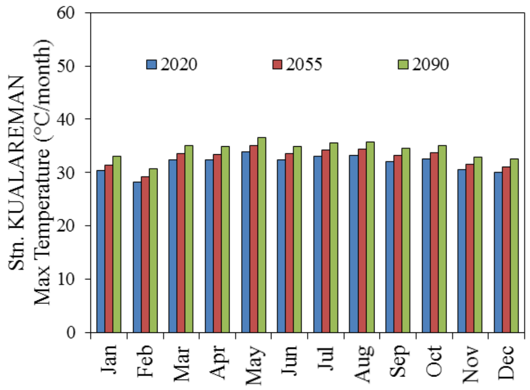
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

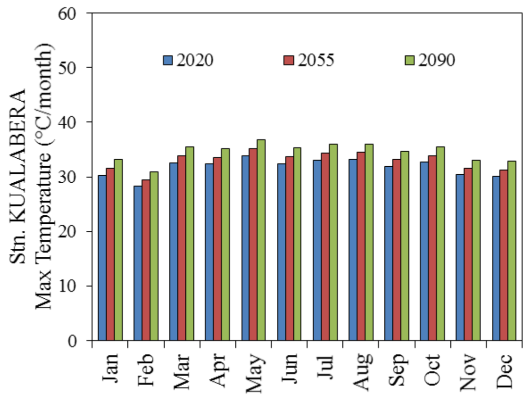
APPENDIX C

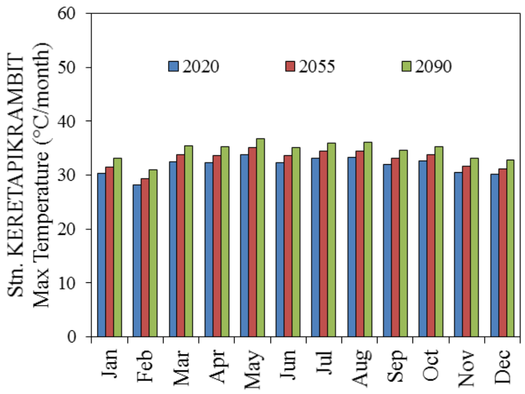
Average annual minimum temperature at year (2010-2099) against time (months)

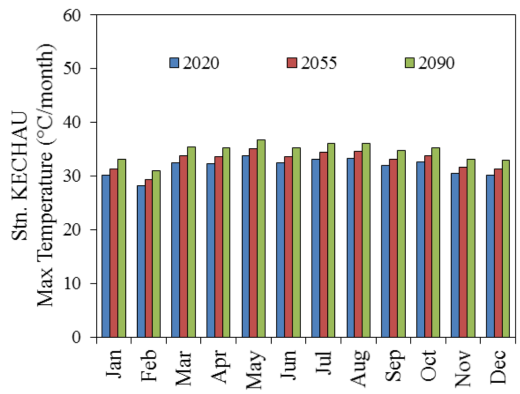


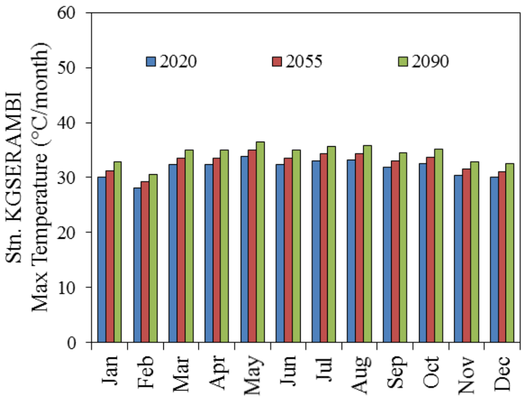











Stn. KGSERAMBI
Max Temperature (°C/month)
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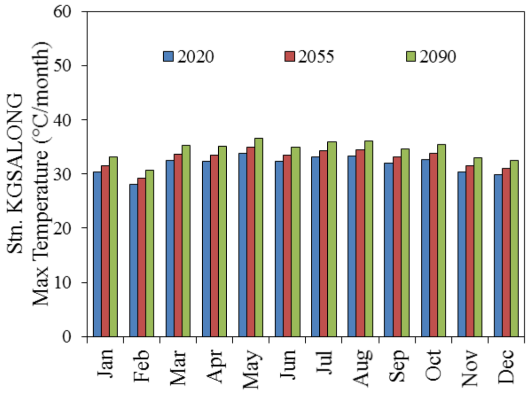
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Max Temperature (°C/month)
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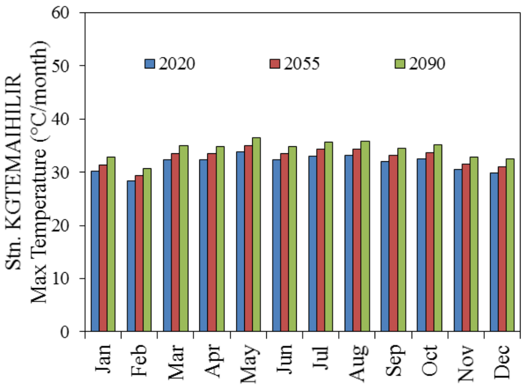
Stn. KGTEMAIHILIR
Max Temperature (°C/month)
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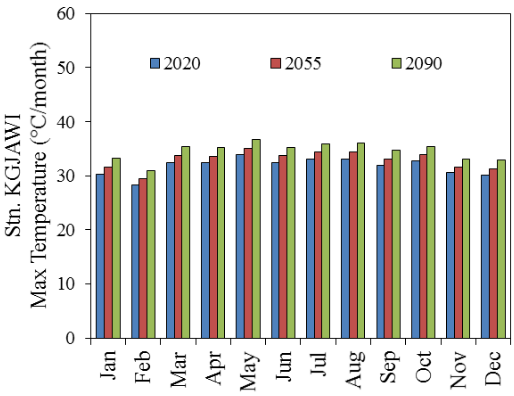
Stn. KGJAWI
Max Temperature (°C/month)
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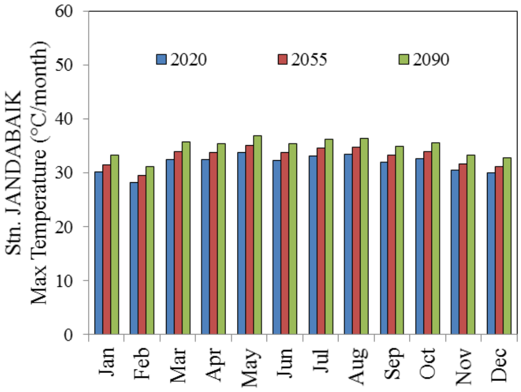
Stn. JANDABAIK
Max Temperature (°C/month)
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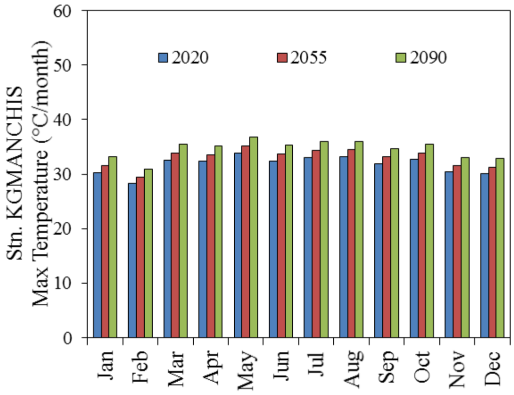
Stn. KGMANCHIS
Max Temperature (°C/month)
2020
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