# SIMULATION OF FUTURE CLIMATE VARIATIONS USING GLOBAL CIRCULATION MODEL AND DOWNSCALING MODEL

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**Dedication**

**Dedicated to my family and my friends**

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In preparing this thesis, I was in contact with many people, researchers, and academicians. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Assoc. Professor Dr. Sobri Harun, for his encouragement, guidance, critics and enthusiastic effort and friendship. Without his continued support and interest, this thesis would not have been same as presented here. My sincere appreciation also extends to all my family and my friends who have provided assistance at various occasions. Their views and tips are useful indeed. Allah blesses you all.

# ABSTRACT

Precipitation is the main cause of variability in the water balance over space and time on the earth surface, and changes in precipitation have important implications for hydrology and water resources. Precipitation varies in space and time as result of the general circulation patterns of atmospheric circulation and local factors. This study proposes the application Statistical Downscaling Model (SDSM) using three sets of data to investigate the climate variations. The data are the observed daily data of large-scale predictor variables, National Centre for Environmental Prediction (NCEP) and Global Circulation Model (GCM) simulations from Hadley Centre 3$^{rd}$ generation (HadCM3). The records of daily precipitation data (1961-1990) are from five stations namely, Ldg. Allagor, Pusat Kesihatan Kecil, Stn. Petak, Ldg. Gedong and Ldg. Gula. Those stations are located in Perak, Malaysia. The HadCM3 data starts from 1961 to 2099 were extracted for 30-year time slices. The results of SDSM downscaling model on precipitation have shown that the differences exist between current observed data and future periods (2020's, 2050's and 2080's) for the five stations. The observed parameters are mean daily precipitation, wet days percentage, wet spell and dry spell with the future simulated climate data for the periods 2020's, 2050's and 2080's. The differences can be recognized between the observed and simulated mean daily precipitation for the future periods 2020's. The SDSM model is generally feasible and reliable for use in downscaling of precipitation in Perak, Malaysia.

# ABSTRAK

Curahan adalah punca utama kepada perubahan dalam kesimbangan air dalam ruang dan masa di atas permukaan bumi, dan perubahan dalam curahan mempunyai implikasi terhadap hidrologi dan sumber air. Variasi curahan dalam ruang dan masa adalah akibat corak kitaran dalam atmosfera dan faktor lokal. Kajian ini mencadangkan aplikasi Model Statistik Penskalaan Bawahan (SDSM) menggunakan tiga set data untuk mengkaji variasi iklim. Data tersebut ialah data cerapan harian, pembolehubah peramal berskala besar Pusat Peramalan Persekitaran Kebangsaan (NCEP), dan Model Kitaran Alam (GCM) daripada generasi ke 3 Pusat Hadley (HadCM3). Rekod data curahan harian (1961-1990) adalah daripada lima stesen iaitu; Ldg. Allagor, Pusat Kesihatan Kecil, Stn. Petak, Ldg. Gedong and Ldg. Gula. Lokasi stesen-stesen tersebut ialah di Perak, Malaysia. Data HadCM3 bermula dari tahun 1961 hingga 2099 yang dibahagikan sela keratan masa 30 tahun. Keputusan model penskalaan bawahan SDSM menunjukkan terdapat perbezaan antara data dicerap semasa dengan waktu masa depan (2020an, 2050an dan 2080an) untuk lima stesen tersebut. Parameter yang dicerap adalah curahan harian min, peratus hari basah, hari basah dan hari kering dengan data iklim masa depan disimulasi bagi tahun 2020an, 2050an dan 2080an. Perbezaan dapat dikenalpasti antara min harian curahan dicerap dan disimulasi untuk waktu masa depan 2020. Model SDSM secara amnya adalah sesuai dan boleh dipercaya untuk digunakan dalam penskalaan bawahan curahan dalam kawasan Perak, Malaysia.

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| | | |
|---|---|---|
| SDSM | - | Statistical Downscaling Model |
| GCM | - | Regional Climate Model |
| HadCM3 | - | Hadley Centre 3rd generation |
| SD | - | Statistical Downscaling |
| NCEP | - | National Centre for Environmental Prediction |
| IPCC | - | Intergovernmental Panel on Climate Change |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Precipitation is the main cause of variability in the water balance over space and time on the earth surface, and changes in precipitation have important implications for hydrology and water resources. Precipitation varies in space and time as result of the general circulation pattern of atmospheric circulation and local factors. Therefore in this study, Statistical Downscaling Model (SDSM) was applied using three set of data (Harun *et al*., 2008)

Daily precipitation data for the period 1961-1990 corresponding to Ldg.Allagor at Trong rainfall (Station no.4507036), Pusat Kesihatan Kecil at Batu Kurau (Station no. 4908018), Stn. Petak Ujian at Selinsing rainfall (Station no. 4906022), Ldg. Gedong at Krian (Station no. 4905023) and Ldg. Gula (Station no. 4904026) located in Perak at the North West region of Peninsular Malaysia. The observed daily data of large-scale predictor variables representing the current climate condition is derived from the National Centre for Environmental Prediction (NCEP) and GCM simulations from Hadley Centre 3rd generation (HadCM3) coupled oceanic-atmospheric general circulation model (Harun *et al*.,2008).

The HadCM3 data starts from 1961 to 2099 were extracted for 30-year time slices. GCM simulations from Hadley Centre namely HadCM3 A2 and B2 scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Emission scenarios, are considered as A2 (Medium–High Emissions and B2 Medium–Low Emissions scenarios) of the IPCC Special Report on Emission Scenarios (SRES). These scenarios cover a range of future socioeconomic, demographic and technological storylines (Harun *et al*., 2008).

## 1.2 Problem Statement

Climate change impact assessment refers to research and investigations designed to find out what parameters or factors effects on future changes in climate could have on human activities and the natural world. Climate change impact assessment is also frequently coupled with the identification and assessment of possible adaptive responses to a changing climate.

Over the past four decades, since 1970 or even earlier, the scientific evidence for human induced climate change has become steadily stronger. By 1995 the international scientific community of atmospheric and related scientists, organised in the Intergovernmental Panel on Climate Change (IPCC), was able to conclude in a cautiously worded statement that "the balance of evidence suggests that there is a discernible human influence on the climate" (IPCC, 1996).

Information about climate impacts is needed both to help decide upon both the urgency and the desirability of mitigation and adaptation measures, actions, and policies, and their appropriate combinations. Since climate change is a global problem, decisions with respect to both mitigation and adaptation involve actions or choices at all levels of decision-making, from the most local and community level (including families and individuals) to the broadest international levels, involving all national governments and many transnational bodies as well. The intended target audience or client for impact studies therefore is also very wide ranging, and this will affect the design if the study in many ways.

Needless to say, this calls for a heavier pressure on the agricultural sector to not only become productive, but also globally competitive and capable. Taken lightly, this may likely pose a greater risk to the natural resources. So there should be more attention towards studying climatic changes and the effects it may have on water management schemes and also irrigation and agricultural activities.

## 1.3 Objectives of Study

i. To inspect the application of downscaling methods on the daily precipitation at local scale directly from large scale atmospheric variables.

ii. To explore and evaluate effectiveness of downscaling model in the simulation of daily precipitation series of different stations.

iii. To perform scenarios development with using downscaling method.

## 1.4 Scope of Study

This study comprises of a series of precipitation analysis. Five stations precipitation at period 1961-1990 was used as a predictands. This study also cover Statistical Downscaling Method (SDSM) is used to simulate Mean Daily Precipitation, Wet days, Wet Spell Length and Dry Spell Length for five precipitation stations, Daily time series precipitation for the period 1961-2099 corresponding to five rainfall stations.

GCMs simulations used for this study are coupled with Hadley Center 3rd Generation (HadCM3) and Oceanic-atmospheric General Circulation Model (Wilby *et al*., 2001). The daily time series data (1961-2099) were separated into 30-year period which each year's only considered as 360 days so the period 1961-1990 as current and 2010-2039, 2040-2069 and 2070-2099 as future periods.

## 1.5 Importance of Study

Precipitation is the most important source for water for agriculture and human resources. The probability of precipitation is any time series will be useful for understanding potential of draught scenarios of this study area. Among many of drought indices, Statistical Downscaling Model (SDSM) has been widely used for simulate future scenarios all around the world. And this would be one of the advantages of SDSM which has ability to describe in short, long-term or both drought impacts through different observed and future time periods of precipitation.

## 1.6 Outline of the thesis

This thesis consists of five main chapters. Chapter 1 begins with an introduction, as well as provides an outline of the study background, problem statement, objectives and scope of research. Chapter 2 describes, general climate models, downscaling techniques and applications and case study of similar research. Chapter 3, descriptions of study area and data collection are presented in this chapter and discusses the overall methodological framework of this study; this chapter review different Statistical Downscaling Techniques and SDSM elaborates the methods that were applied in this study. Results are discussed in Chapter 4. Conclusion and recommendation remarks are provided in Chapter 5.

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