STATISTICAL PRECIPITATION VARIABILITY CHANGES UNDER CLIMATE CHANGE SCENARIOS SIMULATIONS USING A STATISTICAL DOWNSCALING MODEL (SDSM)

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Dedication

Dedicated to my Family and my Friends

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ABSTRACT

The climate impact studies in hydrology often rely on climate change information at fine spatial resolution. However, General Circulation Models (GCMs), which are among the most advanced tools for estimating future climate change scenarios, operate on a coarse scale. Therefore the output from a GCM has to be downscaled to obtain the information relevant to hydrologic studies. The results presented in this thesis have indicated that it is feasible to link large-scale atmospheric variables by GCM simulations from Hadley Centre 3rd generation (HadCM3) outputs with daily precipitation at a local site. Statistical Downscaling Model (SDSM) was applied using three set of data; daily precipitation data for the period 1961-1990 corresponding to Endau rainfall (Station no. 2536168) and Muar (Station no. 2228016) located in Johor at the Southern region of Peninsular Malaysia; The observed daily data of large-scale predictor variables derived from the National Centre for Environmental Prediction (NCEP) and GCM simulations from Hadley Centre 3rd generation (HadCM3). The HadCM3 data from 1961 to 2099 were extracted for 30-year time slices. The result clearly shows increasing increment of daily mean precipitation of most of the months within a year in comparison to current 1961-1990 to future projections 2020's, 2050's and 2080's considering SRES A2 and B2 scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Frequency analysis techniques were carried out using the observed annual daily maximum precipitation for period 1961-1990 and downscaled future periods 2020's, 2050's and 2080's. Therefore, it does appear that SDSM can be considered as a bench mark model to interpret the impact of climate change.

ABSTRAK

Kajian-kajian kesan iklim dalam hidrologi selalu bergantung pada maklumat perubahan iklim di resolusi ruang yang baik. Bagaimanapun, General Circulation Models (GCMs) yang wujud di kalangan paling maju peralatan menganggarkan akan datang senario-senario perubahan iklim, menjalankan pembedahan terhadap satu skala yang kasar. Oleh itu, keluaran daripada GCM perlu dikecilkan untuk mendapatkan maklumat yang relevan untuk kajian-kajian hidrologi. Hasil-hasil tesis ini telah menunjukkan adalah munasabah untuk menghubungkan pembolehubah atmosferik berskala besar oleh simulasi GCM daripada Hadley Centre 3rd Generation (HadCM3) pengeluaran dengan presipitasi tempatan. Statistical Downscaling Model (SDSM) digunakan 3 set data ; presipitasi harian dari 1961 – 1990 merujuk kepada curahan hujan Endau (No. Stesen 2536168) dan Muar (No. Stesen 2228016) yang terletak di Johor, Selatan Semenanjung Malaysia ; Diperhatikan data harian yang di cerap daripada peramal skala besar dari National Centre for Enviromental Prediction (NCEP) dan simulasi GCM dari Hadley Centre 3rd Generation (HadCM3). Data HadCM3 daripada tahun 1961 untuk 2099 adalah di ekstrak untuk 30 kepingan masa. Hasil menunjukkan dengan jelas pertambahan presipitasi purata harian bagi kebanyakkan bulan dalam tahun semasa dijangkakan teknik analisis frekuensi dijalankan digunakan presipitasi cerapan harian tahun maksimum bagi jangka masa 1961-1990 dan diunjurkan masa depan 2020’s, 2050’s, 2080’s. Oleh itu, di dapati SDSM boleh dipertimbangkan sebagai model tanda aras untuk menilai impak perubahan cuaca.

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GCM	-	General Climate Model
RCM	-	Regional Climate Model
HadCM3	-	Hadley Centre 3rd generation
SD	-	Statistical Downscaling

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Precipitation is a key component of the hydrological cycle and one of the most important parameters for a range of natural, water resources management, and agriculture and flood protection. The study of consequences of global climate change on these systems requires scenarios of future precipitation change as input to climate impact models.

General Circulation Models (GCM's), based on mathematical representations of atmosphere, ocean, and land surface processes, are considered to be the only credible tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. Direct application of output from General Circulation Models (GCMs) is often inadequate because of the limited representation of meso-scale atmospheric processes, topography and land-sea distribution in GCMs (e.g. Cohen, 1990; Storch et al., 1999).

Techniques have been developed to downscale information from GCMs to regional scales. These can be categorized into two approaches: "Dynamical downscaling" uses Regional Climate Models (RCMs) to simulate finer-scale physical

processes consistent with the large-scale weather evolution prescribed from a GCM (Giorgi et al., 2001; Mearns et al., 2004). “Statistical downscaling”, adopts statistical relationships between the regional climate and carefully selected large-scale parameters (Storch et al., 1993; Wilby et al., 2004; Goodess et al., 2005). Dynamical downscaling methods are extremely computationally intensive and have data requirements which may not be easily available.

The methods dealt with in this thesis are statistical downscaling. The main strength of statistical downscaling are computationally cheap and only requires very few parameters compare to dynamical downscaling (Fowler et al., 2005).

Statistical Downscaling Model (SDSM) which is regression-based method developed by (Wilby et al. 1999) was used as the basic model to present the initial view of how significant the projections of climate change scenarios will affect the precipitation variability for the sites under study. SDSM is well documented and has been successfully tested in numerous studies (Wilby et al., 2003; Nguyen et al., 2005; Diaz-Nieto and Wilby, 2005; Haylock et al., 2006; Khan et al., 2006). The model permits the spatial downscaling of daily predictor-predictand relationships using multiple linear regression techniques and generates “synthetic predictand” that represents the generated local climate scenario.

1.2 Study Background

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 thesis, Statistical Downscaling Model (SDSM) was applied using three set of data. Daily precipitation data for the period 1961-1990 corresponding to Endau rainfall (Station no. 2536168) and Muar (Station no.

2228016) located in Johor at the Southern 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.

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.

1.3 Problem Statement

According to Intergovernmental Panel on Climate change assessment report (IPCC, 2001), global climate changes is expected to alter precipitation and run-off patterns, exerting significant pressure on water resources on a regional and global scale. Thus potential impacts of climate change on hydrologic extremes, like floods, in small and medium sized watersheds, have not received significant attention. Consequently, there is lack of sufficient development and application of suitable water resources design techniques in the context of climate change.

The specific regional projections about the impact of climate change are hampered by the limited spatial resolution of global circulation models. The spatial resolution of GCMs remains quite coarse, in the order of (250 km x 250 km), and at that scale, the regional and local details of the climate are lost. GCMs are therefore unable to provide local climate information. Alternatively, Statistical Downscaling Model is used to simulate the climate impacts on smaller scale.

1.4 Objectives of this Study

The main objectives of this thesis were to investigate the feasible to link large-scale atmospheric variables from Hadley Centre 3rd generation (HadCM3) outputs with daily precipitation at a local site. The more specific goals of the study are given below:

i. To investigate the possibility of linking daily precipitation at a local scale, directly with large scale atmospheric variables using statistical downscaling method.
ii. To evaluate and investigate the performance of statistical downscaling model in the simulation of daily precipitation series of single station.
iii. To perform scenarios development analysis using accurate statistical downscaling method.
iv. To carry out Frequency analysis of extreme values using the daily annual maximum observed precipitation and downscaled GCMs precipitation.

1.5 Scope of this Study

This study comprises of a series of precipitation analysis. Daily Precipitation for period 1961-1990 was used. This study covers:

i. Daily time series for the period 1961 to 1990 corresponding to two rainfall stations namely Endau (Station no. 2526168) and Muar (Station no. 2228016) situated in Johor state at the Southern region of Peninsular Malaysia. For each station, thirty years (1961 to 1990) high reliable daily precipitation records have been used as predicatnds.
ii. Gridded atmospheric variables were obtained from the NCEP (National Centre for Environmental Prediction reanalysis project

(Kalnay et al., 1996). Reanalysis data are outputs from a high resolution atmospheric mode that known as Numerical Weather Prediction model. The model has been run using data assimilated from surface observation stations, upper-air stations, and satellite-observing platforms and the data kept unchanged over the analysis period and constrained by observations.

iii. GCM simulations used for this thesis are from Hadley Centre 3rd generation (HadCM3) coupled oceanic-atmospheric general circulation model (Wilby et al., 2001). The Hadley circulation provides a useful framework for understanding the nature of large scale flow, the actual circulation in the tropics involves substantial zonal and regional variations (Manton and Bonell, 1995). The HadCM3 data from 1961 to 2099 were extracted for 30-year time slices. For consistency description the scenarios data will be named as follow; the baseline period, 1961-1990 (current), 2010 to 2039 (the 2020s), 2040 to 2069 (the 2050's) and 2070 to 2099 (the 2080's).

1.6 Outline of the Thesis

This thesis consists of six 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 discusses the overall methodological framework of this study; this chapter is divided into two main parts. Section one reviews different Statistical Downscaling Techniques. Section two reviews SDSM and elaborates the methods that were applied in this study. Descriptions of study area and data collection are presented in Chapter 4. Results are discussed in Chapter 5. Conclusion and recommendation remarks are provided in Chapter 6.

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