MULTIVARIATE DISAGGREGATION OF DAILY TO HOURLY RAINFALL SERIES

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To my beloved family, thank you for your love and support.

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ABSTRACT

This study focuses on a method to disaggregate daily rainfall into hourly precipitation. This method uses the multivariate technique in generating a small scale data from a larger scale data. In this method, the lower-level synthetic series must be consistent with the higher-level series. Hence, this method would involve a spatial-temporal rainfall modeling that combines several univariate and multivariate rainfall models operating at different timescales, in a disaggregation framework that can appropriately modify outputs of finer timescale models so as to become consistent with given coarser timescale series. The methodology can be applied to derive spatially consistent hourly rainfall series in rain gauge where only daily data are available. The simulation framework provides a way to take simulations of multivariate daily rainfall and generate multivariate fields at fine temporal resolution. In this study, rainfall stations with daily and hourly scale data in Johor are used. The multivariate method would emphasis on using several daily data from the nearby stations to be disaggregated to hourly scale data. According to literature this method has shown promising results in other countries. This method has the ability to preserve important properties of the hourly rainfall process such as marginal moments, temporal and spatial correlations, and proportions and lengths of dry intervals. Multivariate rainfall disaggregation models have greater potential in hydrological applications including enhancement of historical data series and generation of simulated data series.

ABSTRAK

Kajian ini menumpukan kepada kaedah untuk menghuraikan hujan skala harian ke skala jam. Kaedah ini menggunakan teknik multivariat dalam menjana data skala kecil dari data skala yang lebih besar. Dalam kaedah ini, siri sintatik tahap rendah mesti konsisten dengan siri peringkat tinggi. Oleh itu, kaedah ini akan melibatkan pemodelan ruang-temporal hujan yang menggabungkan beberapa model univariat dan multivariat hujan yang beroperasi pada skala masa yang berbeza. Dalam rangka disagregasi yang sesuai ia boleh mengubah output model skala rendah supaya menjadi konsisten dengan siri masa sekala tinggi. Metodologi ini boleh digunakan untuk memperolehi siri ruang konsisten hujan sejam dalam tolok hujan di mana hanya data harian disediakan. Rangka kerja simulasi menyediakan satu cara untuk mengambil simulasi hujan harian multivariat dan menjana bidang multivariat pada resolusi temporal yang kecil. Dalam kajian ini, data skala harian dan skala jam stesen hujan di Johor akan digunakan. Kaedah multivariat menekanan pengunaan beberapa data harian dari stesen berdekatan yang akan didisagegasikan kepada data berskala jam. Menurut hasil kajian literatur ini telah menunjukkan hasil yang memberangsangkan di negara-negara lain. Kaedah ini mempunyai keupayaan untuk mengekalkan ciri-ciri penting dalam proses taburan hujan dalam skala jam seperti detik-detik marginal, korelasi temporal dan ruang, dan bahagian dan panjang selang kering. Model hujan ini mempunyai potensi besar dalam aplikasi hidrologi termasuk peningkatan data siri sejarah dan generasi data siri simulasi.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Rainfall is one of the sources of water supply in Malaysia. Therefore the information about rainfall is crucial for human activities such as the management of water resources, hydroelectric power projects, droughts or floods warning, urban areas sewer systems and many others. Rainfall forecasting is also important for engineering applications, mainly for the design of hydroelectric power projects, because this system requires prior information about average rainfall that require the maximum/minimum rainfall, maximum intensity, duration example for a year or each month. In urban areas, rainfall also has a strong influence on traffic control, operations of sewer systems and others. Thus, we believe that precise rainfall prediction is important for practitioners who are interested to make wise policies related to this event. Rainfall mainly controls our water supplies, which are the basis for crops production. It is especially important for dry land agriculture. For example, crops use a huge amount of water and rains, to a major extent, provide this water through the soil, for the development and growth of plants.

While prioritizing the sustainable agriculture, it was found that climate change played a major role in determining crop performance. The climatic factors as expressed by the amount of rainfall, sunshine hours, temperature, relative humidity and length of the drought period result in year-to-year variability of crop production. Climate change is one of the major potential threats to national food security and

sustainable agriculture for a country. As the change of climate is a continuous and long term process, its impacts will continue for long successive years and finding out its remedy will also be a very time consuming process. The concept of climate change has both positive and negative impacts on sustainable agriculture of a country, where sustainable agriculture affect agricultural productivity, food security, technology, and environment which have different components, with varying priorities in global and regional levels. There are many empirical works to measure agricultural sustainability through use of diverse indicators, but only a few are on the impact of climate change.

In Malaysia, there are two distinct types of rainfall that are commonly experienced that is convectional rain and monsoon rain. Convectional rain is more dominant on the west coast of Peninsular Malaysia. This type of rain is very localised, could be very intense and normally lasts for about two to three hours. However, on the east coast of peninsular Malaysia and the coastal regions of Sabah and Sarawak, monsoon rains brought by the North-east Monsoon dominate. Monsoon rains are more widespread and could persist for several days to a week.

Johor is the 5th largest state by land area and 3rd most populated state in Malaysia, with a total land area of 19,210 km^2 (7,420 sq mi), and a population of 3,233,434 as of 2010. In the official census of 2000, the population of Johor was 2.75 million with 54% Malays, 35% Chinese, 7% Indians and 4% others. It is the southernmost state in Peninsular Malaysia, and is located between the 1°20"N and 2°35"N latitudes. The highest point in Johor is Gunung Ledang (1276 m). Gunung Ledang is also known as Mount Ophir. Johor also has a 400 km coastline on both the East and the West coasts. Johor has 8 large islands with numerous smaller ones, namely Pulau Aur, Pulau Besar, Pulau Dayang, Pulau Lima, Pulau Pemanggil, Pulau Rawa, Pulau Sibu, Pulau Tengah and Pulau Tinggi.

Johor has a tropical rainforest climate with monsoon rain from November until February blowing from the South China Sea. The average annual rainfall is 1778 mm with average temperatures ranging between 25.5 °C (78 °F) and 27.8 °C (82 °F). Humidity is between 82 and 86%. On 19 December 2006, a continuous heavy downpour occurred in Johor, which led to the 2006-2007 Malaysian floods.

Many towns such as Muar, Kota Tinggi and Segamat were seriously flooded with water levels as high as 10 feet (3.0 m) above ground level recorded in some areas. 15 lives were lost and many possessions destroyed, and this resulted in huge financial losses in Johor. More than 100,000 victims were evacuated to flood relief centres.

The Iskandar, Johor (also known as Iskandar Development Region and South Johor Economic Region), encompassing Johor Bahru, Johor Bahru Tengah, Kulai Jaya, Pasir Gudang and Nusajaya is a major development zone in Johor. It was named after the late Sultan Iskandar Al-Haj. At 2215 km^2, it is two-and-a-half times bigger than Singapore and 48 times the size of Putrajaya. It is intended to draw investment and business to Johor and will be among the biggest development projects in Malaysia. The state administrative capital will be moved to Nusajaya. Residential areas include Bukit Indah and Horizon Hills townships.

Prediction of rainfall has remained an unsolved problem to date. Knowledge of rainfall is of immense importance in predicting flood, flash flood and other disastrous weather. Most of the rainfall data available are measured in daily timescales. However, data of sub-daily are sparse, except in some dense urban area. Even if the data is available, the hourly rainfall data are relatively recent and generally do not exceed 10-20 years. One of the approaches used in generating the hourly data is through disaggregating the daily to hourly using a disaggregation technique. The need for hourly data for hydrological applications suggests the use of a disaggregation model to make use of the available daily information and provide user with possible realisations of hourly rainfall which aggregate up to the given daily data. This would provide a continuous simulation tool to be used for simulation studies and design.

The multivariate approach to rainfall disaggregation is of significant practical interest even in problems that are traditionally regarded as univariate. This is a common situation since detailed hydrological models often require inputs at the hourly time scale when disaggregation of historical daily rain gauges data into hourly rainfall. However, historical hourly records are not as widely and less available as daily records. An appropriate univariate disaggregation model would generate a synthetic hourly series, fully consistent with the known daily series and

simultaneously statistically consistent with the actual hourly rainfall series. However, a synthetic series obtained by such disaggregation model could not coincide with the actual one, but would be only a likely realization. The hourly rainfall data that exist at a neighbouring rain gauge mean the cross-correlation between the two rain gauges is significant, and then we could utilize the available hourly rainfall information at the neighbouring station to generate spatially and temporally consistent hourly rainfall series at the rain gauge of interest. The spatial correlation is an advantage since the available single-site hourly rainfall information will enable more realistic generation of the synthesized hyetographs. The location of a rainfall event within a day and the maximum intensity would not be arbitrary, as in the case of univariate disaggregation, but resemble their actual values.

1.2 Statement of the Problem

A particular problem in hydrological applications is the limited availability of data at appropriately fine temporal and/or spatial resolution. Most hydrological models require inputs at hourly time scale, but historical hourly series are not as widely available as daily series. If this hourly series is not available from measurements, it can be generated from daily series. Therefore, disaggregation techniques have been applied to transform daily rainfall into hourly or finer time scale. Smaller scale of time of rainfall depth provides more accurate information compared to larger scale for the researcher. The knowledge of rainfall is importance in predicting flood, flash flood and other disastrous weather in a small scale. The analysis of rainfall will make the researcher understand more and will contribute to the development of industrialization and the rapid growth of population. Shortage of water supply will cause negative impact to the daily domestics to the country. This will be used as a guide line for water resources management and planning. Due to the limited research and literature on the application of rainfall disaggregation and robustness of the disaggregation model in Malaysia, the need for a study to disaggregate daily rainfall into hourly rainfall is important.

1.3 Objective of the study

i) To estimate the model parameters in the disaggregation model used.
ii) To disaggregate daily data to hourly data.
iii) To assess the performance of the model through graph and Root Mean Square Error (RMSE).

1.4 Significance of the study

Shortage of water supply will cause negative impact to the economics and social activities of the country. Therefore water resources management and planning should be activated to minimize the loss that may occur. Natural disasters such as flood events are quite common in Johor, one of the states in Peninsular Malaysia. Therefore, any early information on the water based events is crucial and important so that the authorities may act early in avoiding harmful effect to human life's and economy. Potential hydrologic applications include enhancement of historical data series and generation of simulated data series. This include the generation of the short interval rainfall series such as hourly or minutes as these series are quite difficult to be obtained when compared with high-level series such as daily or monthly. Even if the series are available, missing data are quite a problem. Therefore, to solve this problem a model that can disaggregate the high-level series may be appropriate. Disaggregation modelling is needed when the need for level data arises. The need for hourly data for hydrological applications suggests the use of appropriate techniques to refine the available daily information and provide the user with possible realizations of hourly.

1.5 Scope of the study

This study uses four rain gauge stations from the Johor area. Ten years of hourly and daily data covering the periods from September 1996 to August 2005 will be used. Software like MATLAB, SPSS and MINITAB will be used to analyse data. Multivariate analysis will be used in modelling the rainfall process. Data was obtained from JPS Ampang.

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