CHAPTER 1

Introduction

1.1 Background and rationale

Climate change means an increasing trend in climatic temperatures. The study of global climate change has been ongoing for several decades already. The provider of the atmospheric process is the sun. The earth's surface and its atmosphere receive this energy. This energy heats the surface and warms the atmosphere. Rising global temperatures have been accompanied by changes in weather and climate. Many climate scientists have discussed and reported on the global temperature change in many ways, such as causes and effects of global warming, variations of temperatures, and the earth atmosphere system. Temperature change is an area of considerable discussion and there is much debate about the extent of apparent trends, as well as possible causes. A variety of approaches have been used to study temperature change, including computer simulation of physics models and statistical techniques. For example, multiple linear regression analysis was used by Lean and Rind (2009) to decompose monthly mean surface temperature anomalies since 1980 into four components, on a global scale. The variations in the minimum/maximum temperatures of the Antarctic region were assessed using a multiple regression model with non-Gaussian correlated errors and linear autoregressive moving average (ARMA) models (Hughes *et al.*, 2006). The extreme temperature changes in the Asia-Pacific region over the period 1961-2003 were investigated using linear regression and Pearson correlation analysis (Griffiths *et al.*, 2005).

This study uses a different novel approach to estimate temperature changes, applying statistical techniques to analyze recent patterns of global temperature change. Due to the Southeast Asia region being composed of many countries, including Thailand and being located in the tropical zone, this was our focus area. Besides climate change, the absorption of solar radiation in the atmosphere contributes global warming. Solar radiation is converted into thermal energy and heats the Earth's surface (Thompson, 1998). This causes temperature to rise in the atmosphere. We report in this thesis a study of solar absorption by clouds and other components in the atmosphere. Due to Australia having a large continental area to receive solar radiation, with the long coast line, many stations have acquired solar radiation data. The Australian Bureau of Meteorology has provided daily solar energy observations, since 1990, for over 4000 weather stations. This source of data is suitable for our study on solar radiation absorption.

1.2 Objectives for studies

The two main aims of this study were first to investigate the trends and patterns of temperature changes in a large specific region; namely Southeast Asia, from 1909 to 2008, and second to analyze the solar absorption by clouds and other components in the atmosphere using ground-based stations' observations on solar radiation in Australia from 1990 to 2012. Graphical and statistical models were applied in these studies.

1.3 Literature reviews

Various sources of literature have been reviewed, especially those applying to the statistical methods of temperature change analysis and solar radiation absorption analysis.

Temperature change

Many methodologies have been used to study temperature change, including mechanism-based computer simulation models or statistical techniques, as well as their combinations. For example, using annual averages, Jones *et al*. (1999) studied the surface air temperatures in both the southern hemisphere and the northern hemisphere, recorded over the past 150 years, considering the homogeneity of the basic data and the standard errors of estimation of the average hemispheric and global estimates. They presented global fields of surface temperature change over the two 20-year periods of greatest warming this century, 1925-1944 and 1978-1997. Over these periods, global temperatures rose by 0.37^{o}C and 0.32^{o}C, respectively.

Trends in annual mean temperatures were also studied by Hansen *et al*. (1998), who found that the average (annually and globally) surface temperature has increased approximately 0.2°C per decade in the 30-year interval 1975-2005. In Australia, trends in annual counts of extreme temperature events were examined by Collins *et al*. (2000), showing that the frequency of warm events has generally increased over the period 1957 to 1996, while the number of cool extremes has decreased. Temperature changes in Russia over the periods 1900-1949 were investigated using coefficients of correlation between the regionally averaged temperature, linear regression and time

series. Annual mean temperature rises in each region ranged from 0.2 to 0.55 C per decade (Anisimov *et al*., 2007).

Temperature change also has been studied the Asia region at a certain level. A broad range of climatological and geographic features exist within the Asia/Pacific region. All of India and Pakistan as well as much of western China are arid or semi-arid, and this central Asia has warmed by approximately 0.1-0.2^{o}C per decade over the past 100 years (Preston *et al*., 2006). Southeast Asia is characterized by tropical rainforest and monsoon climates with high and constant rainfall (Cruz *et al*., 2007), and the upward trend of winter mean temperatures between 1954 and 2001 in the eastern region of Southeast Asia is 0.34°C per decade (Gong and Ho, 2004). Moreover, subsurface temperatures which were measured in boreholes in four Asian cities have been evaluated (Taniguchi *et al*., 2007) to estimate the effects of surface warming due to urbanization and global warming, as well as the developmental stage of each city, over the periods 1991, 1992, 2003 and 2006. Mean surface warming in each city ranged from 1.8 to 2.8°C: Bangkok (1.8°C), Osaka (2.2°C), Seoul (2.5°C), and Tokyo (2.8°C).

Several studies have compared temperature change in different time periods and in different regions. For instance, temperature measurements from the past 1000 years in the Northern Hemisphere indicate an approximately 0.4°C warming between the 17th century and the mid-20th century warm period (Crowley, 2000). Parker *et al*. (1994) found seasonal global surface air temperature anomalies between two periods, 1954-1973 and 1974-1993, with a slight increase in the variance in the later period. The global surface temperature change over the two 20-year periods of greatest warming

during the twentieth century, 1925-1944 and 1978-1997 were compared (Jones *et al*.,1999). Over these periods, global temperatures rose by 0.37°C and 0.32°C, respectively. Also, in this study we have compared climate change in three different time periods in the Southeast Asia region.

Solar radiation absorption

Besides temperature change is the absorption of solar radiation in the atmosphere which occurred at the Earth's surface. This solar radiation is radiant energy in the form of electromagnetic waves spread over a very broad band of wavelengths. Data analysis and modeling shows that the amount of solar radiation reaching the top of the atmosphere is dependent on three factors: time of the year, time of day, as well as latitude which controls the obliquity of the solar beam (Thompson, 1998). It should be note that the intensity of solar radiation which is represented by the solar constant, is quite stable and has not changed substantially over many years of observations (Peixoto and Oort, 1992).

Unfortunately, there are indeed limitations on how well the radiation at different layers of the atmosphere is observed and estimated. Radiation measurement at the high levels of the atmosphere is now observed by sensors on board satellites orbiting the Earth. However, bias in the satellite-derived datasets has been identified, which may be due to the influence from aerosols (Blanksby *et al*., 2013). In terms of modelling, the kind of radiation transfer calculation is based on rigorous physical principles, complex models with large uncertainties such as simulating the cloud development processes in the atmosphere which leads to rather imprecise estimation (Ohtake *et al*., 2013). In different methods, Sun and Liu (2013) determined the direct solar irradiance, which include simple derivation from sunshine duration, radiative

transfer calculations with consideration of sky condition, parameterized global and diffuse irradiance and retrieval from back-scattered radiation data of satellite measurements (Masuda *et al*., 1995 and Polo *et al*., 2013).

Various techniques and methodologies were studied, global datasets of radiation budget and energy balance are available, such as the Earth Radiation Budget Experiment (ERBE).The goal of ERBE is to produce parameters of long wave and shortwave monthly radiation on the Earth at regional to global scales (Barkstrom 1984). The database stores energy flux monthly means measured at 1500 stations at the earth's surface. The GEBA (Global Energy Balance Archive) database is the efficient production of datasets and quality control procedures are applied to the energy flux data, the results used for the reevaluation of the energy balance at the earth's surface (Gilgen and Ohmura, 1999).

In this study, however, we have a different methodology to analyze the solar absorption by clouds and other components in the atmosphere using the observations from 144 stations in Australia. Statistical analysis is then used to analyze the spatial and temporal patterns of radiation absorption within the country.

Both studies, temperature changes and solar radiation absorption, highlight the methodology to account both times and spatial correlations by auto-regressive models and factor analysis.

1.4 Concept of study

The main concept for analysing these data for both temperature change and solar radiation energy studies which were similar as shown in Figure 1.1.

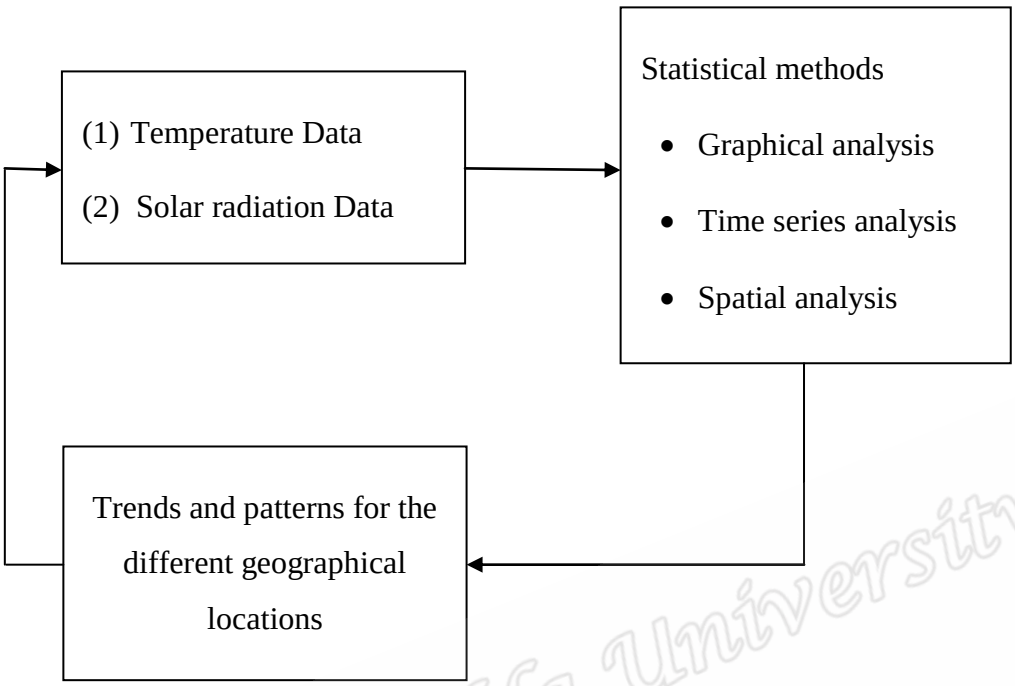

Figure 1.1 Concept of study

For this study, there are two sets of time series data. The first one is monthly temperature data in the Southeast Asia during 1909 – 2008 and the second one is daily surface global radiation data during 1990-2012. Main statistical analyses for both data were similar. Firstly, graphical method was used to plot for observed values. Secondly, time series analysis was used to describe the correlation of time and variation. Finally, spatial analysis was used to account the correlations in the study area into sub regions. The results were the estimated trends and patterns for the different geographical locations. These patterns could explain how temperatures change in Southeast Asia and clouds absorb solar radiation energy in Australia.

1.5 Road map of thesis

This thesis contains five chapters. The introductory chapter discusses the introduction, rationale and also includes a review of some relevant literature. Chapter 2 provides a description of the methodology including an overview of the statistical methods for

temperature change analysis and solar radiation absorption. Chapter 3 consists of preliminarily data analysis and the major results of published articles. Chapter 4 provides a study of solar radiation absorption in Australia. Chapter 5 concludes summarizing the main findings and discusses their implications. Suggestions for further research are also provided in this chapter.