THESIS

PROBABLE EFFECTS OF URBANIZATION AND INDUSTRIALIZATION ON HYDRO-METEOROLOGICAL CHARACTERISTICS IN THE EASTERN COAST BASIN

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THESIS

PROBABLE EFFECTS OF URBANIZATION AND INDUSTRIALIZATION ON HYDRO-METEOROLOGICAL CHARACTERISTICS IN THE EASTERN COAST BASIN

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The goals of this study are to find factors from the influences of land use change emphasizing industrialization and urbanization that alter on temperature and precipitation in Eastern Coast Basin and to predict the trend of temperature and precipitation changes caused by such alteration in the future.

Based on historical data of Urban during in 1986-2001 from the Office of Agricultural Economics, and industrial area in 1969-2005 period from the Department of Industrial Works, it was indicated that urban area trend of the Eastern Coast Basin had been increased in each year. The proportion of urban in Chanthaburi and Rayong are higher than other provinces, about 17.19 Km^2 or 34.06% and 16.36 Km^2 or 28.08%. Urban and industrial area in the Eastern Coast Basin had increased at the rate of 0.20 and 2.23 Km^2per year respectively.

The rate of changes in temperature for each month of all stations analyzed by regression and the comparison of temperature change rate between urban and rural stations (based on the available data from 1985-2005) showed that the higher rate of increase in mean monthly temperature, annual mean temperature, annual mean temperature in dry period (Nov-Apr), was found at Sattahip station (0.07 and 0.07 ˚C per year respectively). Maximum temperature in terms of mean annual maximum temperature and mean maximum temperature in dry period of urban area was higher compared to rural area. As for moving average analysis of mean rainfall in urban stations, it is seen that all stations showed a decreasing trend.

Regression analysis indicates that both parameters applied in the model (industrial and urban area) are essential influence on temperature, Industrial area plays most essential role in temperature change. It shows the most significant influence on mean temperature at Rayong station. Combination of industrial and urban areas indicate more significant influence on maximum temperature. Although the change is small influent in temperature, it implies some interesting impact on the change of temperature. Regression analysis results also should that aerosols in terms of SO_2 and NO_2 have significant influence in decreasing cloud cover in wet period. At Sriracha station, the mean SO_2 and NO_2 decreased cloud cover while the maximum SO_2 and NO_2 caused decreasing cloud cover at Chonburi station. In addition industrial area and urban area are sources releasing aerosols particular SO_2 and NO_2 which subsequently should decrease rainfall in every stations both annual and wet period. However, the PM 10 should uncertainly change of rainfall in this region.

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Student’s signature Thesis Advisor’s signature

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PROBABLE EFFECTS OF URBANIZATION AND INDUSTRIALIZATION ON HYDRO-METEOROLOGICAL CHARACTERISTICS IN THE EASTERN COAST BASIN

INTRODUCTION

The human activities such as the industrialization and technology advance have affected our world. What most people do not know is that human activities have impacted our world climate. The human-related impacts to climate have been happening particularly for the last 150 years. Several human activities that have caused climate trends include the urbanization industrialization, the rise of technology, and the increase in greenhouse gases. One important impact of climate change is land use change. Scientists believe that land use change may have a greater impact on climate change than pollution that leads to global warming (Shepherd, 2001).

Land use, or land cover change involves human activities that change land usage or affect the amount of carbon or biomass existing in forest or soil stocks. Land use changes the atmospheric concentration of carbon dioxide and increases the emissions of the greenhouse gases, which can trap heat in the lower atmosphere. Land use change can also change the energy balance of the earth’s surface and cause climate disruptions such as changing the local rainfall pattern. Land use change particularly urbanization and industrialization release aerosols and change cloud cover as a result of increasing or decreasing temperature and rainfall.

Since, the Eastern Coast Basin are among four regions of Thailand rapidly extended in industrial area and urbanization. It was thus selected to be study area for determining its change on aerosols and its probable effects on hydro-meteorological characteristics emphasizing on temperature and rainfall alteration within this region.

OBJECTIVES

1. To study trend of land use change in the Eastern Coast Basin emphasizing on urbanization and industrialization.

2. To study aerosols and cloud cover variability in the Eastern Coast Basin

3. To study rainfall variability and trend of temperature change in the Eastern Coast Basin.

3. To investigate relation among urbanization /industrialization and Hydro-meteorological characteristics in the Eastern Coast Basin.

SCOPE OF STUDY

This study is limited by the date of land-use changes in terms of urbanization during 1986-2001 and industrialization during 1985-2005 and determining probable effects of the mentioned land use change only on temperature and rainfall characteristics of the Eastern Coast Basin.

LITERATURE REVIEW

1. Urbanization and Industrialization

Urbanization is the development of land into residential, commercial, and industrial properties. Urban and suburban developments cause profound changes to natural watershed conditions by altering the terrain, modifying the vegetation and soil characteristics, and introducing pavement, buildings, drainage, and flood control infrastructure. Hydrologic and geomorphic impacts are closely associated with an increase of impervious area resulting from urban development. Reported impacts have included: increased frequency of flooding and peak flow volumes, decreased base flow, increased sediment loadings, changes in stream morphology, increased organic and inorganic loadings, increased stream temperature, and loss of aquatic/riparian habitat.

Urbanization (Wikipedia, 2006) is the expansion of metropolitan area, namely the proportion of total population or area in urban localities or areas (cities and towns), or the increase of this proportion over time. It can thus represent a level of urban population relative to total population of the area, or the rate at which the urban proportion is increasing. For instance, the or United Kingdom have a far higher urbanization level than China, India or Nigeria, but a far slower annual Urbanization rate, since much less of the population is living in a rural area while in the process of moving to the city.

The rate of urbanization over time is distinct from the rate of urban growth, which is the rate at which the urban population or area increases in a given period relative to its own size at the start of that period. The urbanization rate represents the increase in the proportion of the urban population over the period.

In terms of a place, urbanization means increased spatial scale and/or density of settlement and/or business and other activities in the area over time.

Industrialization (or industrialisation) or an industrial revolution (in general, with lowercase letters) (Wikipedia, 2006) is a process of social and economic change whereby a human society is transformed from a pre-industrial (an economy where the amount of capital accumulated is low) to an industrial state. This social and economic change is closely intertwined with technological innovation, particularly the development of large-scale energy production and metallurgy.

Rapid industrial development and urbanization transfer more and more land away from agricultural area and natural forests. This paper interests only urbanization and industrialization in land use / land cover change term.

2. The cause and factors effects on Climate.

The main conclusion that researchers found was that urban climates are cloudier and experience more precipitation than in rural areas (Burian, 2003). Urban impact on Hydro-meteorological Characteristics is caused by a combination of these four factors (Burian, 2003).

2.1 Urban Heat Islands.

As stated before, urban heat island are causes the higher temperatures in urban areas than in rural areas. The high temperatures increase evaporation and condensation, leading to precipitation. The peak time that rainfall occurs in urban areas is from noon to midnight, when the temperatures are at the maximum (Burian, 2003)

2.2 Increased Roughness caused by Tall Buildings.

As previousely mentioned with thermal capacity influencing temperature, building structures conduct more heat than vegetated areas. The main details behind the increased roughness are asphalt, brick, concrete, and other characteristics of urban structures. These characteristics increase airflow. The convection currents that form with these airflows can enhance the formation of clouds (Gow, 1996).

2.3 Change in Atmospheric Moisture.

The main ingredient behind the atmospheric moisture is also one of the main factors that influences temperature : air pollution. The increase air pollution concentration enhances evaporation and condensation in the atmosphere (Gow,1996).

2.4 Atmospheric Aerosols caused by Traffic and Industry.

The particles in fossil fuel burning and the aerosols wasted by factories, refineries, and cars in traffic acts as a condensation nuclei for cloud droplet formation (Gow, 1996)

2.4.1 Atmospheric Aerosols

Aerosols are minute particles suspended in the atmosphere. When these particles are sufficiently large, we notice their presence as they scatter and absorb sunlight. Their scattering of sunlight can reduce visibility (haze) and redden sunrises and sunsets.

Aerosols interact both directly and indirectly with the Earth's radiation budget and climate. As a direct effect, the aerosols scatter sunlight directly back into space. As an indirect effect, aerosols in the lower atmosphere can modify the size of cloud particles, changing how the clouds reflect and absorb sunlight, thereby affecting the Earth's energy budget.

Aerosols also can act as sites for chemical reactions to take place (heterogeneous chemistry). The most significant of these reactions are those that lead to the destruction of stratospheric ozone. During winter in the polar regions, aerosols grow to form polar stratospheric clouds. The large surface areas of these cloud particles provide sites for chemical reactions to take place. These reactions lead to the formation of large amounts of reactive chlorine and, ultimately, to the destruction of ozone in the stratosphere. Evidence now exists that shows similar changes in stratospheric ozone concentrations occur after major volcanic eruptions, like Mt.

Pinatubo in 1991, where tons of volcanic aerosols are blown into the atmosphere (Figure 1).

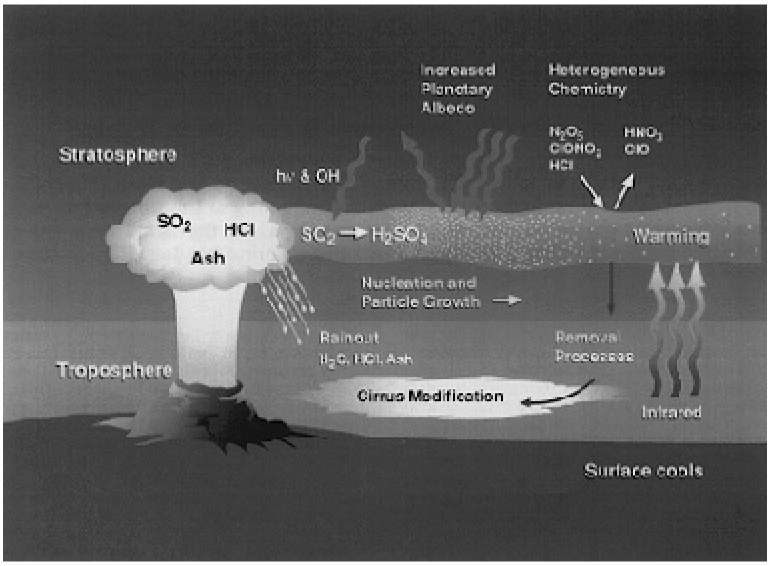


Figure 1 The dispersal of volcanic aerosols has a drastic effect on the Earth's atmosphere.

Source: NASA Langley Research Center Office of Public Affairs (1996)

Figure 1 The dispersal of volcanic aerosols has a drastic effect on the Earth's atmosphere. Following an eruption, large amounts of sulphur dioxide (SO_2), hydrochloric acid (HCL) and ash are spewed into the Earth's stratosphere. Hydrochloric acid, in most cases, condenses with water vapor and is rained out of the volcanic cloud formation. Sulphur dioxide from the cloud is transformed into sulphuric acid (H_2SO_4). The sulphuric acid quickly condenses, producing aerosol particles which linger in the atmosphere for long periods of time. The interaction of chemicals on the surface of aerosols, known as heterogeneous chemistry, and the tendency of aerosols to increase levels of chlorine which can react with nitrogen in the stratosphere, is a prime contributor to stratospheric ozone destruction.

Aerosols are tiny particles suspended in the air. Some occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels and the alteration of natural surface cover, also generate aerosols. Averaged over the globe, aerosols made by human activities currently account for about 10 percent of the total amount of aerosols in our atmosphere. Most of that 10 percent is concentrated in the Northern Hemisphere, especially downwind of industrial sites, slash-and-burn agricultural regions, and overgrazed grasslands. (Mary, 2003)

Mary said that have much to learn about the way aerosols affect regional and global climate. He have yet to accurately quantify the relative impacts on climate of natural aerosols and those of human origin. Moreover, he does not know in what regions of the planet the amount of atmospheric aerosol is increasing, is diminishing, and is remaining roughly constant. Overall, he is even unsure whether aerosols are warming or cooling our planet. The possible sources of aerosol creation are shown in Figure 2.

Aerosols tend to cause cooling of the Earth's surface immediately below them. Because most aerosols reflect sunlight back into space, they have a "direct" cooling effect by reducing the amount of solar radiation that reaches the surface. The magnitude of this cooling effect depends on the size and composition of the aerosol particles, as well as the reflective properties of the underlying surface. It is thought that aerosol cooling may partially offset expected global warming that is attributed to increases in the amount of carbon dioxide from human activity.

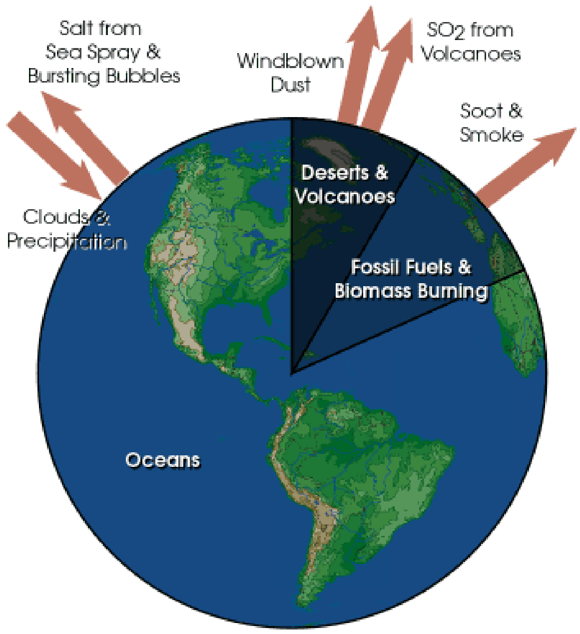
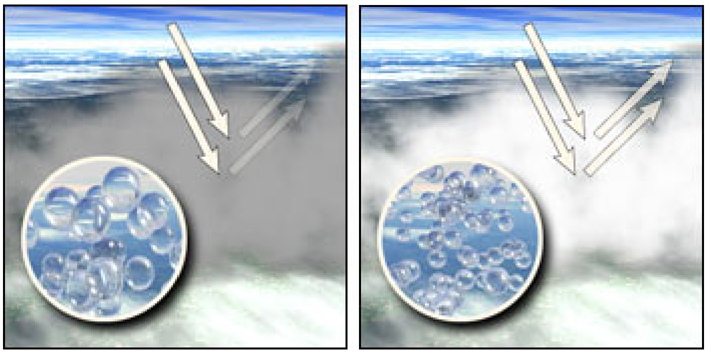


Figure 2 Sources of aerosol particles

Source : Mary Hardin and Ralph Kahn (2003)

Aerosols are also believed to have an "indirect" effect on climate by changing properties of clouds. Indeed, if there were no aerosols in the atmosphere, there would be no clouds. It is very difficult to form clouds without small aerosol particles acting as "seeds" to start the formation of cloud droplets. As aerosol concentration increases within a cloud, the water in the cloud gets spread over many more particles, each of which is correspondingly smaller. Smaller particles fall more slowly in the atmosphere and decrease the amount of rainfall. In this way, changing aerosols in the atmosphere can change the frequency of cloud occurrences, cloud thickness, and rainfall amounts.



(a) (b)

Figure 3 (a) Clouds with low aerosol concentration and a few large droplets do not scatter light well, and allow much of the Sun's light to pass through and reach the surface. (b) The high aerosol concentrations in these clouds provide the nucleation points necessary for the formation of many small liquid water droplets. Up to 90% of visible radiation (light) is reflected back to space by such clouds without reaching Earth's surface.

Source : Mary Hardin and Ralph Kahn (2003)

2.4.2 Human-Made Aerosol

The third type of aerosol comes from human activities (i.e., the burning tropical forests, the burning of coal and oil and the start of the industrial revolution). While a large fraction of human-made aerosols come in the form of smoke from burning tropical forests, the major component comes in the form of sulfate aerosols created by the burning of coal and oil. The concentration of human-made sulfate aerosols in the atmosphere has grown rapidly since the start of the industrial revolution. At current production levels, human-made sulfate aerosols are thought to outweigh the naturally produced sulfate aerosols. The concentration of aerosols is highest in the northern hemisphere where industrial activity is centered. The sulfate aerosols absorb no sunlight but they reflect it, thereby reducing the amount of sunlight reaching the Earth's surface. Sulfate aerosols are believed to survive in the atmosphere for about 3-5 days.

The sulfate aerosols also enter clouds where they cause the number of cloud droplets to increase but make the droplet sizes smaller. The net effect is to make the clouds reflect more sunlight than they would without the presence of the sulfate aerosols. Pollution from the stacks of ships at sea has been seen to modify the low-lying clouds above them. These changes in the cloud droplets, due to the sulfate aerosols from the ships, have been seen in pictures from weather satellites as a track through a layer of clouds. In addition to making the clouds more reflective, it is also believed that the additional aerosols cause polluted clouds to last longer and reflect more sunlight than non-polluted clouds.

2.4.3 Climatic Effects of Aerosols

The additional reflection caused by pollution aerosols is expected to have an effect on the climate comparable in magnitude to that of increasing concentrations of atmospheric gases. The effect of the aerosols, however, will be opposite to the effect of the increasing atmospheric trace gases - cooling instead of warming the atmosphere.

The warming effect of the greenhouse gases is expected to take place everywhere, but the cooling effect of the pollution aerosols will be somewhat regionally dependent, near and downwind of industrial areas. No one knows what the outcome will be of atmospheric warming in some regions and cooling in others. Climate models are still too primitive to provide reliable insight into the possible outcome. Current observations of the buildup are available only for a few locations around the globe and these observations are fragmentary.

Pollution and smoke aerosols can increase or decrease the cloud cover. (Yoram, 2006) This duality in the aerosol effects forms one of the largest uncertainties in climate research. Using solar measurements from AERONET sites around the globe, he show an increase in the cloud cover with an increase in the aerosol column concentration and an inverse dependence on the aerosol absorption of sunlight. The emerging rule appears to be independent of the geographical location or aerosol type, thus increasing our confidence in the understanding of these aerosol effects on the clouds and climate. Preliminary estimates suggest an increase of 5% in cloud cover.

A RECENT study at the Scripps Institution of Oceanography, USA , claims that the combined effect of air pollution (aerosols/particulate matter) and greenhouse gases may induce greater variability in the Indian monsoon heightening its intensity or weakening it.(RITU, 2006)

Chung and Ramanathan (2004) found that less-than-expected temperatures in the northern part of the ocean have weakened wind circulation and monsoon conditions in the region, causing a 5 to 8 per cent fall in rainfall over India since the 1950s and increasing rainfall over the Sahel, south of the Sahara in Africa.

Explaining the weakening of the Indian monsoon, the authors say it is probably an effect of the high aerosol concentration over the Indian subcontinent, which masks the heating up of the part of Indian Ocean close to the land mass. In other words, the northern Indian Ocean is not warming up as quickly as the rest of it. This causes low pressure areas to move away from the subcontinent, weakening monsoon-laden winds and causing drought conditions that could affect more than two billion people in south Asia.

The scientists warn of a possible reverse effect (more rainfall as well): “Greenhouse gases by themselves lead to large positive anomalies in the simulated Indian rainfall, which leads to the speculation that, when the South Asian aerosol pollution is cut down significantly, India may witness a large increase (10-20 per cent) in monsoon rainfall, but this is also related to a large surface warming due to the greenhouse gases.” The scientists say that some years the aerosol effect may dominate, while sometimes it may be the greenhouse effect. “So we are concerned that in coming decades the variability between the two will become large and it will be difficult to cope with rapid changes from year to year,” says Ramanathan (2004).

Chung believes continuous, year-round aerosol observations are necessary to augment satellite data to further help researchers understand the highly variable seasonal and yearly nature of aerosol effects in Asia and elsewhere. Dust particles from Africa, which play a significant but not fully understood role in climate systems, also require further investigation and analysis.

Some experts disagree. “This is a study using a climate model. I have serious reservations about making any conclusions from a climate model study, that too, on a cloudy issue. These models are well known for not even simulating mean Indian monsoon rainfall realistically. Therefore, this study is academic,” says M Rajeevan of the India Meteorological Department, Pune.

(Lowry, 1998) Major reviews of urban effects on local climate, extending from Kratzer in 1937 through to Landsberg in 1981, have dealt primarily with radiation, temperature, wind, and air quality. To a much lesser extent they have examined moisture-related elements including humidity, cloud, precipitation, and storminess. Selecting air temperature to represent the former group and precipitation amount to represent the latter, the author asserts that, because of the intrinsic physical differences between them, there are necessarily important differences in the methods to be used for their proper observation, analysis, presentation, and interpretation pertaining to urban effects. The principal differences are based in the fact that temperature is continuous in both time and space, whereas precipitation is continuous in neither. The author maintains that because of these differences, urban climatologists have had much greater success in specifying and explaining urban effects on temperature than on precipitation amount. Further, he makes the case that, lack of recognition that methods used for the study of urban effects on temperature are too often inappropriate for study of urban effects on precipitation amount, has led to a state of affairs where there remains basic uncertainty about the specification of urban effects on precipitation amount, and even greater uncertainty about their explanation. In making that case, the author includes 1) an historical perspective, 2) a critical evaluation of methods, 3) an overview of the status of urban precipitation climatology, and 4) recommendations concerning future research.

A regional coupled climate–chemistry–aerosol model is developed to examine the impacts of anthropogenic aerosols on surface temperature and precipitation over East Asia. Besides their direct and indirect reduction of short-wave solar radiation, the increased cloudiness and cloud liquid water generate a substantial downward positive long-wave surface forcing; consequently, nighttime temperature in winter increases by 0.7°C, and the diurnal temperature range decreases by 0.7°C averaged over the industrialized parts of China. Confidence in the simulated results is limited by uncertainties in model cloud physics. However, they are broadly consistent with the observed diurnal temperature range decrease as reported in China, suggesting that changes in downward long wave radiation at the surface are important in understanding temperature changes from aerosols.(Yan, 2005)

But, Alaka (2005) said that climatic change is one of the most important issues of present times. Unlike the greenhouse gases, which have a predominantly warming effect, atmospheric aerosols could either warm or cool the atmosphere depending upon the size, distribution and optical properties. Of all the climatic elements, temperature plays a major role in detecting climatic change brought about by urbanization and industrialization. Therefore, he attempts to study temporal variation in temperature over Pune city, India, during the period 1901–2000. The long-term change in temperature has been evaluated by Mann–Kendall rank statistics and linear trend. The analysis reveals significant decrease in mean annual and mean maximum temperature. This decrease in temperature is more pronounced during the winter season, which can be ascribed to a significant increase in the amount of suspended particulate matter (SPM) in the ambient air during the last decade. On the contrary, monsoon season shows warming. This warming can be attributed to a significant increase in the low cloud amount.

3. Effects of Urbanization and Industrialization on Hydro-meteorological Characteristics

3.1 Effects of Urbanization and Industrialization on Rainfall

In the early 1970s, researchers doing study during the Metropolitan Meteorological Experiment (METROMEX), discover alterations in rainfall in St. Louis. The study revealed a 58 % localized rain increase in the summers from 1971 – 1975 (Changon Jr, 1985) Most of the rainfall fell during the afternoon and evening hours. The rainfall was more intense in the urban area around downtown St. Louis and in East St. Louis, Illinois than in the rural areas (Changon Jr,1985).

Khemani (1972) report that the rainfall data, for the period 1901–69, of three stations in the region downwind of the urban industrial complex at Bombay and of two stations in the nearby non-urban region, have been analyzed. The study has indicated that, with respect to the non-urban region, the region downwind of the urban industrial complex recorded an increase of rainfall by about 15%, significant at less than the 1% level, during 1941–69 which is the period of increased industrialization.

The rainfall data, for the period 1927- 1976, at nine towns in Hokkaido, Japan have been analyzed. At Muroran, a non-urban steel-producing town, an increase of thunder days and rainfall in the warm season was found during the period l957-1976 when an increase of steel production is reported. It seems to suggest the effects of industrial activities on weather. An increase of thunder days was also found at the non-industrial commercial city Sapporo with a population of some 1.2 million, about eight times that in 1927. However the increase is not statistically significant at the 5 % level.(Akira, 1980)

In the late 1990s. data from the Tropical Rainfall Measuring Mission (TRIMM) satellite's precipitation radar (PR) showed that there was a 28% increase in monthly rainfall rates in southern U.S. cities such as Atlanta, Montgomery, Nashville, and San Antonio. In the metropolis areas there was a modest increase of 5.6%

(Stepherd, 2001). These two experiments gives us proof that urban areas have a significant influence on the precipitation rate.

Data from 19 rain gauges located within and nearby Houston were analyzed to quantify the impact of urbanization of the Houston metropolitan area on the local diurnal rainfall pattern. The average annual and warm-season diurnal rainfall patterns were determined for one time period when Houston was relatively small and likely would not have had a significant effect on meteorological processes (1940–58) and for a second, more recent, time period after Houston had become a major metropolitan area (1984–99). The diurnal rainfall patterns within the hypothesized urban-affected region and an upwind control region were compared for the pre- and post-urban time periods. Results indicated that the diurnal rainfall distribution in the urban area is much different than that found for the upwind and downwind adjacent regions for the 1984 to 1999 time period. For an average warm season from 1984 to 1999, the urban area and downwind urban-impacted region registered 59% and 30% respectively greater rainfall amounts from noon to midnight than an upwind control region. Moreover, the urban area had approximately 80% more recorded rainfall occurrences between noon and midnight during the warm season than surrounding areas. Comparison of the pre- and post-urban rainfall patterns indicated that the diurnal rainfall distribution has changed in southeast Texas. The changes are most significant in the urban area, especially for the afternoon time increments during the warm season. The average warm season rainfall amount registered in the urban area increased by 25% from the pre- to the post-urban time period, while the amount in the upwind control region decreased by 8%. The majority of the increase was observed for the noon to 4 p.m. and 4 p.m. to 8 p.m. time increments. (Burian, 2005)

3.2 Effects of Urbanization and Industrialization on Urban heat Island

Urban heat islands (UHIs) are defined as the warmth produced by the cities, as compared to the heat released by rural areas surrounding them (Fig.3). Urban heat island (UHI) effect is one of the most typical phenomena of urban climate, for which the temperature of the central urban locations are several degrees higher than those of nearby rural areas of similar elevation (Chou, 1985). The main contributing factors of it are urbanization and anthropogenic activity, since they induce changes in the physical characteristics of the surface (albedo, thermal capacity, heat conductivity, moisture) and changes in radiative fluxes and the near surface flow. Especially, the simultaneous removal of natural land cover and the introduction of urban materials (e.g., concrete, asphalt, metal) alter the surface energy balance, with a consequent increase in land surface temperature, then the increase in sensible heat flux at the expense of latent heat flux, finally air temperature. As a result, UHI effect would forces the development of meteorological events such as increased precipitation, boosts energy demands, poses threats to environmental quality and long-term sustainability of localities, and potentially contributes to global warming and vegetation greener.

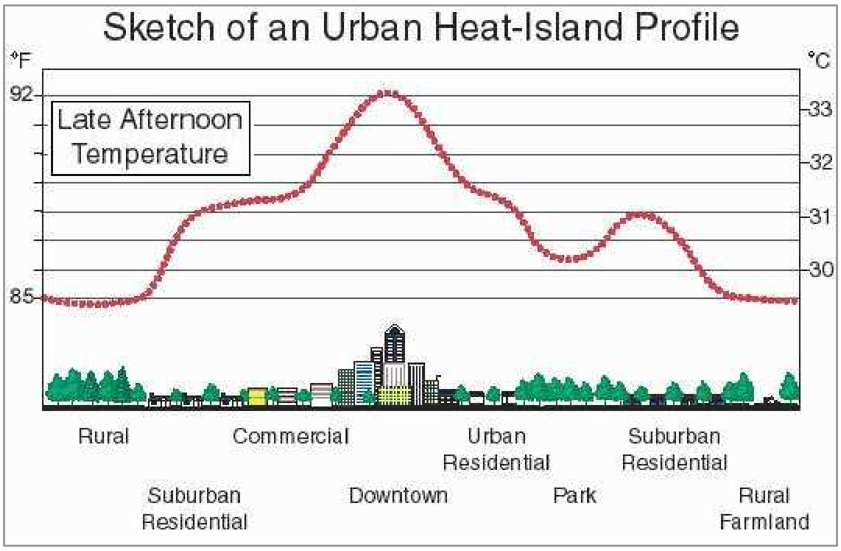


Figure 4 Show Urban Heat Island Profile, the temperature of downtown is higher than rural areas surrounding them.

Source : Chou (1985)

Traditionally, UHI studies are conducted for isolated locations and with in situ measurements of air temperatures or ground meteorological data (Streutker, 2002; Weng, 2004). Though in situ measured data takes precedence in temporal resolution, its spatial resolution is poor. Moreover, it is limited to describe the response rather than the physical processes and the forcing of repartitioned surface energy fluxes over urbanized surfaces (Owen, 1998). By contraries, in virtue of high spatial resolution, satellite remote sensing can monitor urban heat island on all scales, predominantly on regional or continental scales, and provide quantitative physical data, present heterogeneous distributed land surface characteristics, all of which could greatly facilitate our understanding of urban/suburban environment and its relationship with urbanization.

In past several decades, numerous UHI studies utilizing remote sensing technique have been done all over the world. Originally, the leading approach of urban heat island analysis is to establish certain models by regression analysis using some observational samples, then transform digital number (DN) recorded by sensor (later instead by remote sensing retrieved brightness temperature) into air temperature. Along with the stepwise advancement of land surface temperature's retrieval method, people recently prefer to use the actual temperature of land surface to describe UHI, which is believed to correspond more closely with near-ground air temperature (e.g., Streutker, 2002; Liu, 2003; Weng, 2004; Nichol,2004), achieving more accurate results. However, many people still keep on using radiation temperature or radiant flux density to analyze urban thermal environment in respect of its simplicity (e.g., Lo, 1997;Chen, 2002). Another key point is that more and more research are focusing on the relationship between LST and normalized difference vegetation index (NDVI) as well as vegetation abundance(eg., Owen, 1998; Xiao, 2002; Weng, 2004), making a great deal contributions to estimate UHI magnitude and urban sprawl.

3.3 Effects of Urbanization and Industrialization on Temperature

The warming of near-surface air over non-urban areas of the planet during the past one to two centuries is believed to have been less than 1°C. Warming in many growing cities, on the other hand, may have been a full order of magnitude greater. Thus, since nearly all near-surface air temperature records of this period have been obtained from sensors located in population centers that have experienced significant growth, it is absolutely essential that *urbanization*-induced warming be removed from all original temperature records when attempting to accurately assess what has truly happened in the natural non-urban environment.

The first study we cite in this regard only provides a *hint* of an urbanization effect. In it, Hasanean (2001) investigated surface air temperature trends with data obtained from meteorological stations located in eight Eastern Mediterranean cities: Malta, Athens, Tripoli, Alexandria, Amman, Beirut, Jerusalem and Latakia. Hasanean reports that the latter warming was *"not uniform, continuous or of the same order"* as the warming that began about 1910, nor was it evident at all of the stations. One interpretation of this non-uniformity of temperature behavior in the 1970s is that it may have been the result of temporal differences in city urbanization histories that were accentuated about that time, which could have resulted in significantly different urban heat island trajectories at the several sites over the latter portions of their records.

In a more direct study of the urban heat island effect that was conducted in South Korea, Choi et al. (2003) compared the mean station temperatures of three groupings of cities (large urban stations, smaller urban stations and rural stations) over the period 1968-1999. This analysis revealed, in their words, that the *"temperatures of large urban stations exhibit higher urban bias than those of smaller urban stations and that the magnitude of urban bias has increased since the late 1980s."* Specifically, they note that *"estimates of the annual mean magnitude of urban bias range from 0.35°C for smaller urban stations to 0.50ºC for large urban stations."* In addition, they indicate that "none of the rural stations used for this study can represent a true non-urbanized environment." Hence, they correctly conclude that their results are underestimates of the true urban effect, and that "urban growth biases are very serious in South Korea and must be taken into account when assessing the reliability of temperature trends."

Yet a third study of South Korea was conducted by Chung et al. (2004b), who evaluated temperature changes at ten urban and rural Korean stations over the period 1974-2002. As a result of this exercise, they found that "the annual temperature increase in large urban areas was higher than that observed at rural and marine stations*." Specifically, they note that "during the last 29 years, the increase in annual mean temperature was 1.5°C for Seoul and 0.6°C for the rural and seashore stations,"* while increases in mean January temperatures ranged from 0.8 to 2.4°C for the ten stations. In addition, they state that *"rapid industrialization of the Korean Peninsula occurred during the late 1970s and late 1980s,"* and that when plotted on a map, *"the remarkable industrialization and expansion ... correlate with the distribution of increases in temperature."* Consequently, as in the study of Chung et al. (2004a), Chung et al. (2004b) found that over the past several decades, much (and in many cases most) of the warming experienced in the urban areas of Korea was the result of local urban influences that were not indicative of regional background warming.

In Shanghai, Chen et al. (2003) evaluated several characteristics of that city's urban heat island, including its likely cause, based on analyses of monthly meteorological data from 1961 to 1997 at 16 stations in and around this hub of economic activity that is one of the most flourishing urban areas in all of China. Commenting on this finding, Chen et al. say *"the main factor causing the intensity of the heat island in Shanghai is associated with the increasing energy consumption due to economic development,"* noting that in 1995 the Environment Research Center of Peking University determined that the annual heating intensity due to energy consumption by human activities was approximately 25 Wm^{-2} in the urban area of Shanghai but only 0.5 Wm^{-2} in its suburbs. In addition, they point out that the 0.5°C/decade intensification of Shanghai's urban heat island is an order of magnitude greater than the 0.05°C/decade global warming of the earth over the past century, which is indicative of the fact that ongoing intensification of even strong urban heat islands cannot be discounted.

Simultaneously, Kalnay and Cai (2003) used differences between trends in directly observed surface air temperature and trends determined from the NCEP-NCAR 50-year Reanalysis (NNR) project (based on atmospheric vertical soundings derived from satellites and balloons) to estimate the impact of land-use changes on surface warming. Over undisturbed rural areas of the United States, they found that the surface- and reanalysis-derived air temperature data yielded essentially identical trends, implying that differences between the two approaches over urban areas would represent urban heat island effects. Consequently, Zhou et al. (2004) applied the same technique over southeast China, using an improved version of reanalysis that includes newer physics, observed soil moisture forcing, and a more accurate characterization of clouds.

Frauenfeld et al. report that over the period 1958-2000, *"time series based on aggregating all station data on the TP show a statistically significant positive trend of 0.16°C per decade," as has also been reported by Liu and Chen (2000). However, they say that "no trends are evident in the ERA-40 data for the plateau as a whole."*

In discussing this discrepancy, the three scientists suggest that *"a potential explanation for the difference between reanalysis and station trends is the extensive local and regional land use change that has occurred across the TP over the last 50 years." They note, for example, that "over the last 30 years, livestock numbers across the TP have increased more than 200% due to inappropriate land management practices and are now at levels that far exceed the carrying capacity of the region (Du et al., 2004)."* The resultant overgrazing, in their words, "has caused land degradation and desertification at an alarming rate (Zhu and Li, 2000; Zeng et al., 2003)," and they note that "in other parts of the world, land degradation due to overgrazing has been shown to cause significant local temperature increases (e.g., Balling et al., 1998)."

In concluding their analysis of the situation, Frauenfeld et al. contend that *"these local changes are reflected in station temperature records."* We agree; and we note that when the surface-generated anomalies are removed, as in the case of the ERA-40 reanalysis results they present, it is clear there has been no warming of the Tibetan Plateau since at least 1958. Likewise, we submit that the other results reported in this Summary imply much the same about other parts of China and greater

Asia. Hence, we feel certain that the dramatic surface-generated late-20th-century warming of the world that is claimed by the IPCC, Mann et al. (1998, 1999) and Mann and Jones (2003) to represent mean global background conditions is significantly biased towards warming over the last 30 years and is therefore not a true representation of earth's recent thermal history.

3.4 Effects of Urbanization and Industrialization on Streamflow (Quantity)

With regard to the hydrologic regime, impacts on surface water resources and groundwater resources can be distinguished. Urbanization creates a new hydrological environment. There has been a flip-flop between infiltration, important prior to urbanization, and afterward runoff and its flooding. Asphalt and concrete, and rooftops replace forest trees and soil. Storm-water sewers replace stream channels. All increase runoff, and the important flood peaks that cause stream channel erosion and destruction of channels, property, and lives. Sprawling cities and suburbs with their transportation systems, reduce infiltration

1) Mean surface runoff

The impact of land use on the mean runoff is a function of many variables, the most important being the water regime of the plant cover in terms of evapotranspiration (ET), the ability of the soil to hold water (infiltration capacity), and the ability of the plant cover to intercept moisture.

A change of land cover from lower to higher ET will lead to a decrease in annual stream flow. From a review of 94 catchments experiments, Bosch and Hewlett (1982) concluded that the establishment of forest cover on sparsely vegetated land decreases water yield. Coniferous forest, deciduous hardwood have a decreasing influence on water yield of the source areas in which the covers are manipulated. Conversely, a change from higher-ET plants to lower-ET plants will increase the mean surface runoff: reduction in forest cover increases water yield (Bosch and Hewlett, 1982; Calder, 1992). The impact, however, depends very much of the management practices and the alternative land uses. Careful, selective harvesting of timber has no or little effect on stream flow. Stream flow after maturation of the new plant cover may be higher, the same or lower than original value, depending on vegetation (Bruijnzeel, 1990) The infiltration rate is zero on pavement but unlimited on undisturbed forest floors. However it can be compacted, and "10 to 20% of the vegetated floor is commonly seriously compacted when it is logged." "Undisturbed forest floors and soils ranging from 2 to 5" deep", and when dry, can retain 4 to 10 inches of water. For example on a California 10-year stream flow record which showed the runoff increased 2.3 times as an open non-forested watershed became urbanized. In Austin, Texas runoff increased 1.9, 2.1 and 2.4 times for watersheds with 21%, 27% and 38% impervious cover, respectively. In an area in New Jersey prior to urbanization evapotranspiration was 23" and runoff 24", and when half impervious with urban surfaces, these values were estimated to change to 11.5" with 35.5" running off. (E.A. Ritzenthaler, 2002)

2) Peak flow

The increased height of flood peaks, or peak discharge, during heavy storms occurs when precipitation infiltration into the soil is reduced due to impervious surfaces. Overland flow, or the amount of water that runs into the stream channel without being infiltrated, increases and there is a reduction of recharge to the groundwater body, which decreases the base flow contribution to stream channels. Assuming that major population increases result in urbanization of an area and an increased amount of impervious surfaces, it is expected to see higher events of peak discharge events in streams in the affected area.(Stephanie Marchbanks, 2000)

Peak flows can increase as a result of the urbanization and building of roads and infrastructure. Studies in the north-western USA have shown that the construction of forest roads can intensify peak runoff from forested areas significantly (Kiersch, 2000). Consolidation of smaller plots to large fields can lead to higher runoff rates, due to drainage systems and asphalt access roads (Falkenmark and Chapin, 1989). In larger basins, effects of urbanization on peak flow are offset due to time lag between different tributaries, different land use and variations in rainfall. In larger watersheds, this de-synchronization effect can lead to a reduction in peak discharge, although overall storm flow increases due to land urbanization in individual sub watersheds (Brooks et al., 1991). If the impervious area in the basin is doubled, the peak flows may increase by about 20 percent (Pouraghniaei, M.,2001, Marsalek, J.,1989)

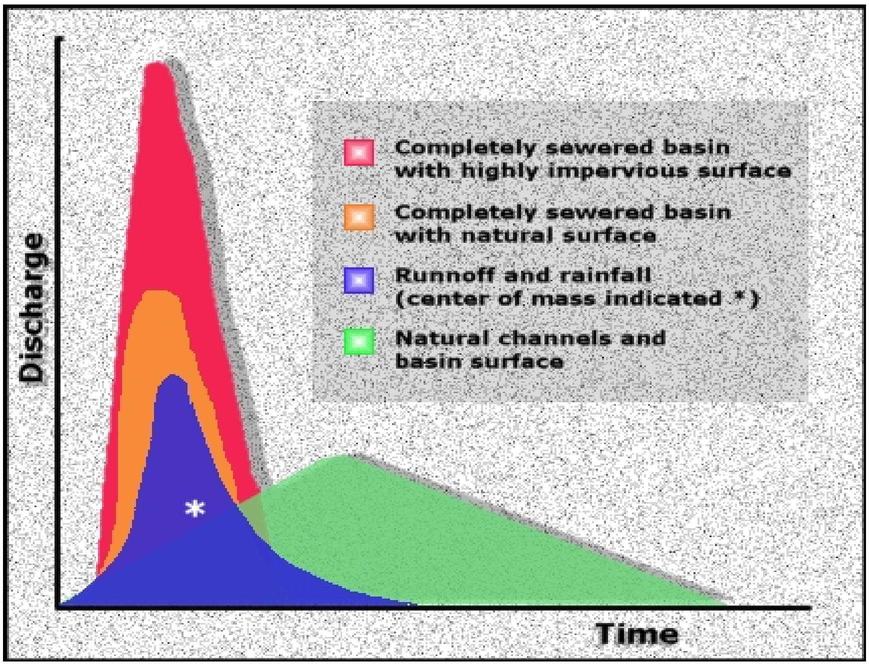


Figure 5 Comparison of discharge in urban and natural areas that difference surfaces.

Source: Pouraghniaei, M. (2001), Marsalek, J. (1989)

3) Lag time and time-to-peak

Urbanization decreases the lag time and time-to-peak. Surface detention by lawns in the urban basin is apparently an important factor in the determination of the total runoff. For example the unit hydrograph peak for the rural basin, expressed in cfs per square mi, was only 49 percent of the urban peak which indicates the effects of the large impervious area. Between 1970 and 1995, the Cobb County population increased by 167 percent. The 1970 to 1980 interval of averaged annual peak discharges was 2,800 cfs, which rose to 3,138.6 cfs during the 1980-1990 interval, and then elevated to 4,581.7 cfs between 1990 and 1995 (R. G. Feddes ,et, al,1970).

Evapotranspiration means rain that is intercepted and evaporates without even hitting the ground, plus the transpiration of vegetation roots in picking up soil moisture and transpiring it up and out of their leaves. Pavements we know do evaporate too, but when the rainfall is substantial, it soon begins to run off.

STUDY AREA

The Eastern Coast Basin covering 13,030 Km^2 located in The Eastern of Thailand, was chosen as the area of study (Figure 6). With over 1,364 villages and there are population live in basin over 2 million , this basin has more land use/ land cover change from forest to agricultural area, urban and industrial area. This basin, consist of 6 sub basins : they are Khlong Tanot, Mae Nam Prasae, Khong Yai, Mae Nam Chanthaburi, Mae Nam Muang Trat. The East Coast Gulf that situated in 5 province namely : Chonburi, Rayong, Chachoengsao, Chanthaburi and Trat.

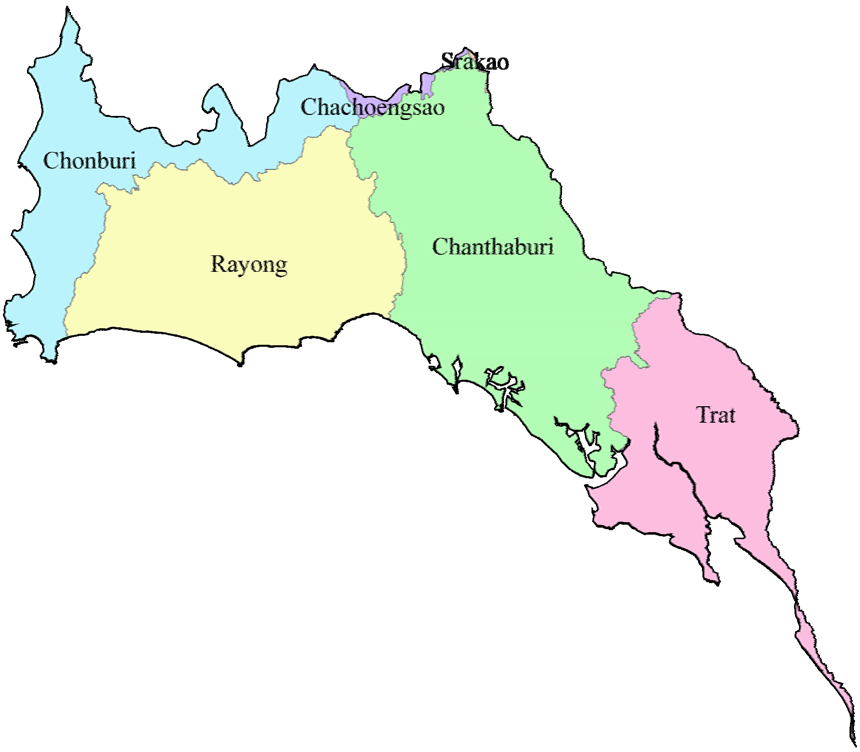


Figure 6 The Eastern Coast Basin**,** the study area.

The Eastern Coast Basin extend eastwards and situation between longitudes at 11° 21′ N to13° 55′ N and longitudes at 100° 50′ E to 102° 55′ E . In the North adjoin Bang Prakong basin, Southern and Western adjoin the Gulf of Thailand and Eastern adjoin Cambodia.

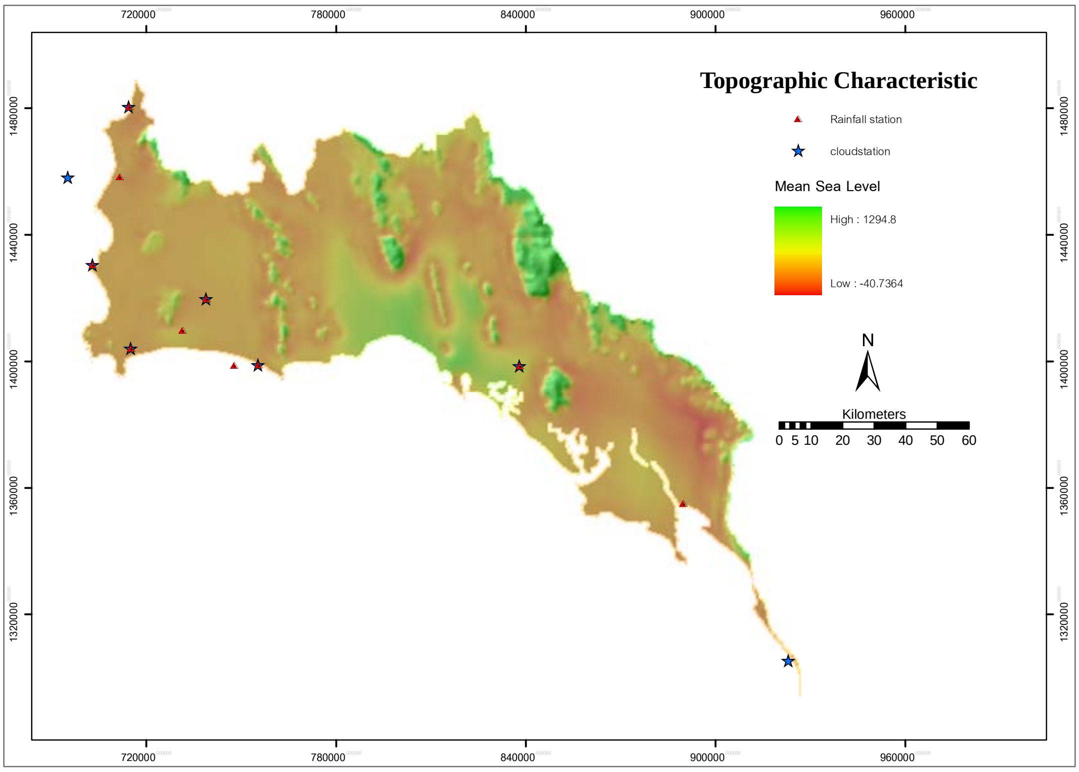


Figure 7 The topographical characteristics of The Eastern Coast Basin

Topographic characteristic of The Eastern Coast Basin, the mountain range lie southwards alternate with the plain and lie along the east coast of basin. In eastern part of basin at Chonburi province and the upper of Rayong has the plain and hills before will reach mountain of east border. (Figure 7)

An occupation in this majority part is garden plants and crops, sometime the fishery. The important garden plants is for example rambutan , crop such as sugarcane cassava and the pineapple. The fishery generally does at shore and have feeding shrimp in provinces that do rice farming. The besides an aforementioned occupation in Chanthaburi province and Trat, the present gem raw amount more decrease but Chanthaburi province is still the important center of cutting gem by import gem from foreign country. The economic is most progressing because building port of deep water in Lamchabang that present have a large factory refines oil. At the same time there are colony industry for export produces to foreign countries and Maptaput in

Rayong emphasize the Petrochemical industry by lead the natural gas that found in the Gulf of Thailand transmute is a substance plastic and PVC. There are attraction beach which near Bangkok having more the growth of the tourism and the industry. So that there are greatly build residence the whole house and the condominium (Figure 8 to 9).

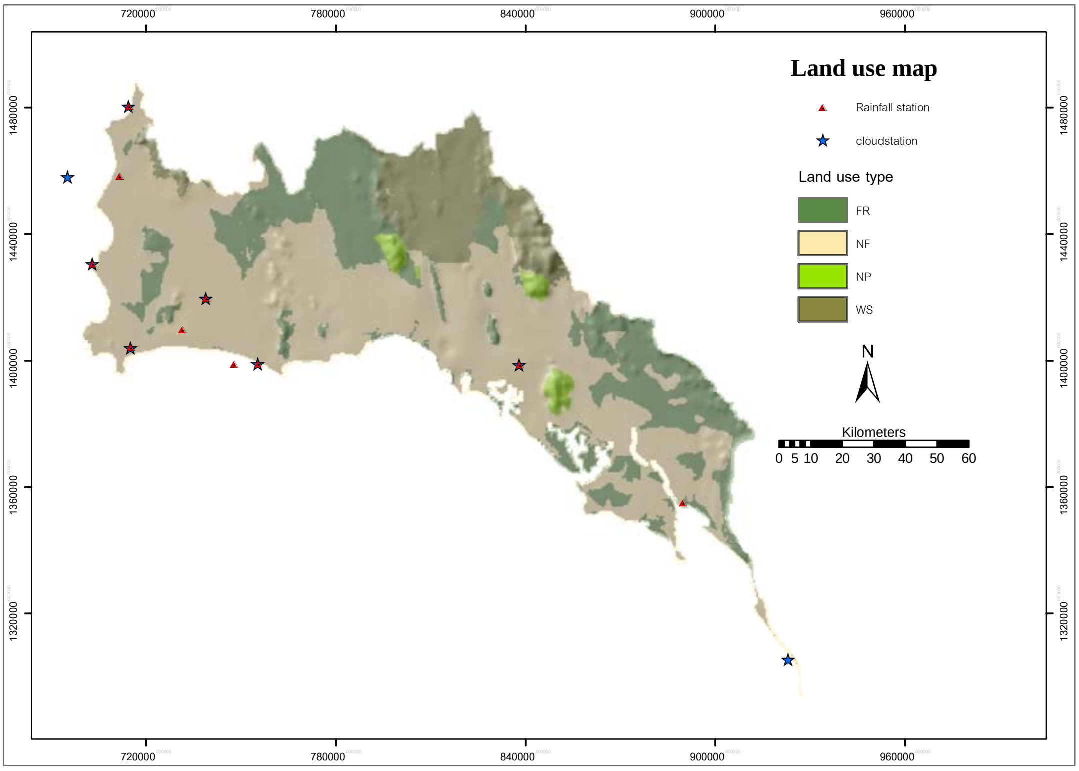


Figure 8 Forest area in The Eastern Coast Basin

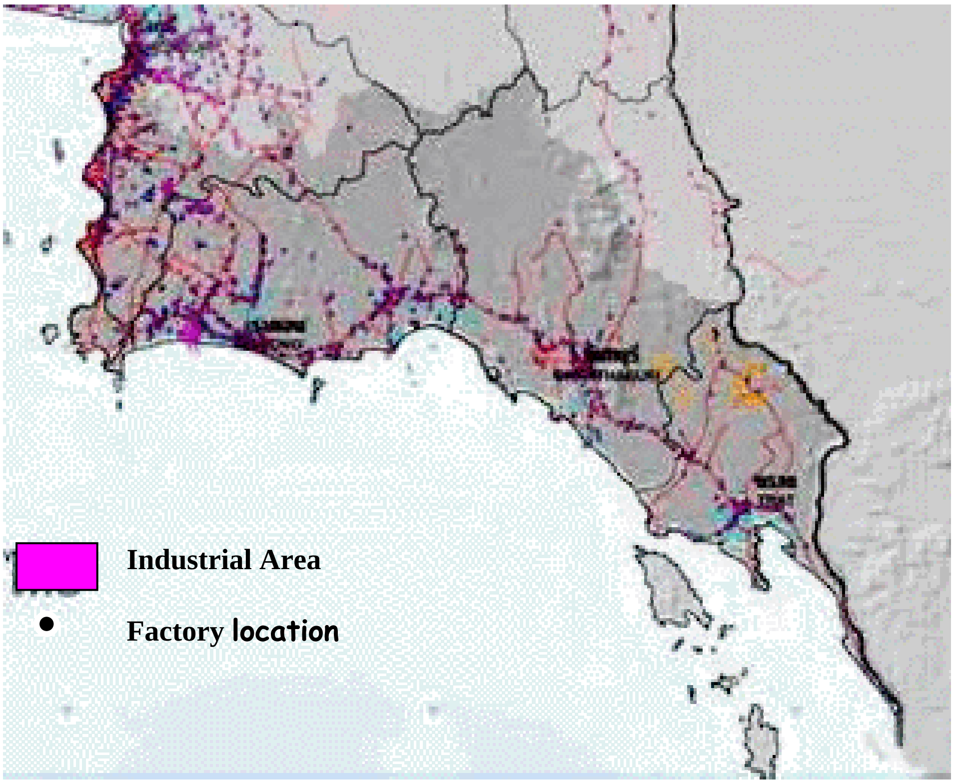


Figure 9 Industrial area in The Eastern Coast Basin

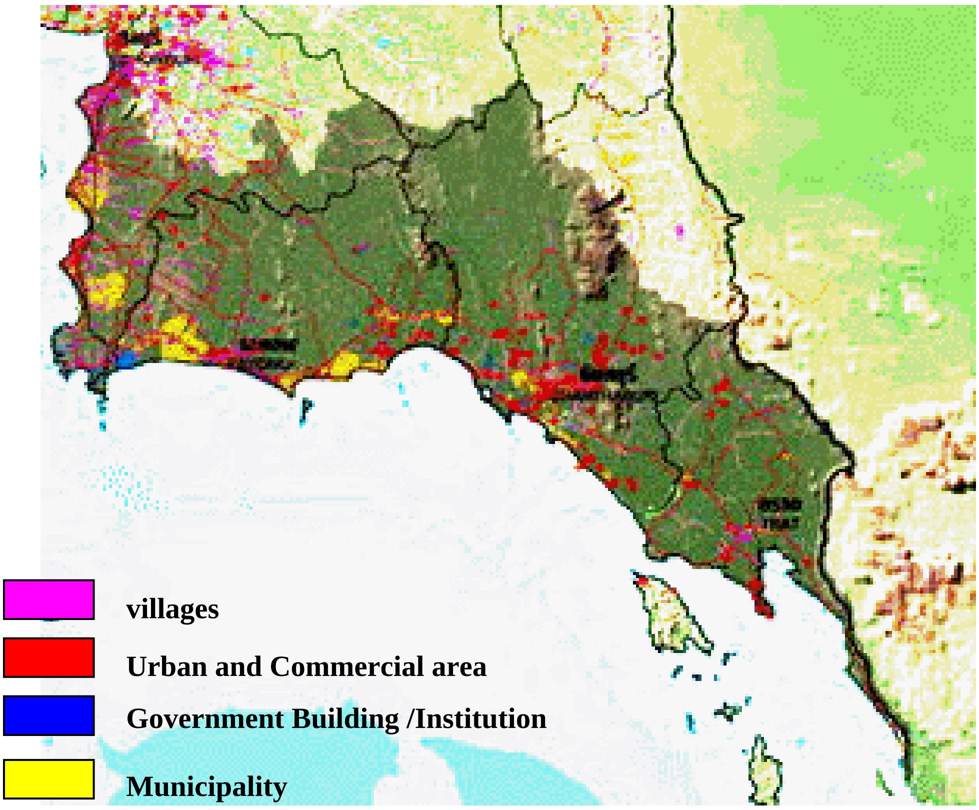


Figure 10 Urban area in The Eastern Coast Basin

MATERIALS AND METHODS

Materials

1) Computer Laptop and printer
2) Software for Hydrological and Meteorological analysis
3) Software for Geographic Information System analysis
4) Software for Remote Sensing analysis
5) Daily Hydro-meteorological data from 1985 to 2005 in the Eastern Coast Basin Station
6) Annual air quality data from 1985 to 2005

Methods

1. Detection land use change particularly urbanization and industrialization in the Eastern Coast Basin.

1) Collecting Land use data particularly urban and industrial area of the Eastern Coast Basin. Urban area data in 1986-2001 period from the Office of Agricultural Economics., and the industrial area data in 1985-2005 period from the Department of Industrial Works.

Urban area data in terns of housing, Municipality, Urban and Commercial area and Government Building /Institution and Industrial area data in term of factory location and industrial area record by provinces (Chonburi, Rayong, Chanthaburi and Trat) are employed to determine their changes overtime.

2) Performing land-use and land-cover change trend was carried out by using the statistical analysis in order to analyze the proportion, trend of land use change particularly urban and industrial areas.

2. Determining rainfall variability in the Eastern Coast Basin

1) Collecting daily rainfall and cloud data for stations in the Eastern Coast Basin with the most available period records from the Department of Meteorology. The name of stations and available data for this region are presented in table 1.

Table 1 The meteorology stations in the Eastern Coast Basin, continuous rainfall data records base on 1985 – 2005 observe data

Station No.	Station Name	Province	Period
459002	Si Racha	ChonBuri	1985-2005
459201	ChonBuri	ChonBuri	1985-2003
459203	Phatthaya	ChonBuri	1985-2003
459204	Sattahip	ChonBuri	1985-2003
478001	Rayong	Rayong	1985-2004
478007	Rayong Self-Help Settlement	Rayong	1985-2005
478201	Rayong	Rayong	1985-2003
478301	Huai Pong Agromet	Rayong	1985-2005
480201	Chanthaburi	Chanthaburi	1985-2003
501001	Trat	Trat	1985-2005

Source : Department of Meteorology (2005)

There are 27 Meteorological stations in the Eastern Coast Basin. However, only 10 of these stations have a continuous long term observation history of rainfall data (Table 1). Therefore, these 10 stations were chosen for the study of urbanization and industrialization effects, which are located in urban and industrial area and considered reflecting the urban characteristics in many respects.

3) Determining the changing trends of rainfall data in monthly seasonal and annual averages terms, using regression analysis and moving average in 3, 5, 10 and 15 year.

4) Comparing rainfall trend between each stations in annual, seasonal and monthly terms and discussion the reason of the change.

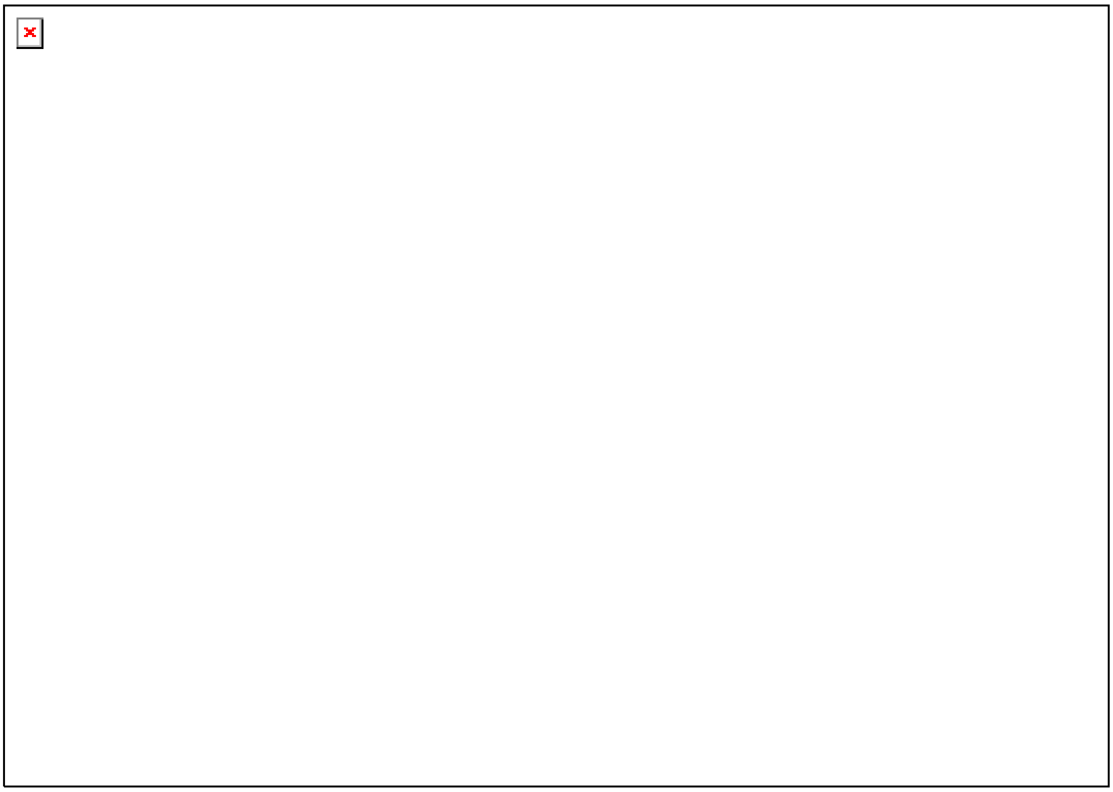


Figure 11 Location of rainfall stations in this study

3. Determination of temperature variability in the Eastern Coast Basin

1) Collecting daily temperature data for stations in the Eastern Coast Basin with the most available period records from the Department of Meteorology, as shown in Table 2.

There are only 7 stations of all stations in the Eastern Coast Basin have a continuous long term observation history of temperature data (Table 2) also in mean, maximum and minimum terms. Therefore, these 7 stations were chosen for the study of urbanization and industrialization effects, which are located in urban and industrial area and considered reflecting the urban area in many respects.

Table 2 The meteorology stations in the Eastern Coast Basin, continuous temperature data records base on 1985 – 2003 observe data

Station No.	Station Name	Province	Period	Mean Temp	Min Temp	Max Temp
459201	Chon Buri	ChonBuri	1985-2005	✓	✓	✓
459202	Ko Sichang	ChonBuri	1985-2005	✓	✓	✓
459203	Phatthaya	ChonBuri	1985-2005	✓	✓	✓
459204	Sattahip	ChonBuri	1985-2005	✓	✓	✓
478201	Rayong	Rayong	1985-2005	✓	✓	✓
480201	Chanthaburi	Chanthaburi	1985-2005	✓	✓	✓
501201	Khlong Yai	Trat	1985-2005	✓	✓	✓

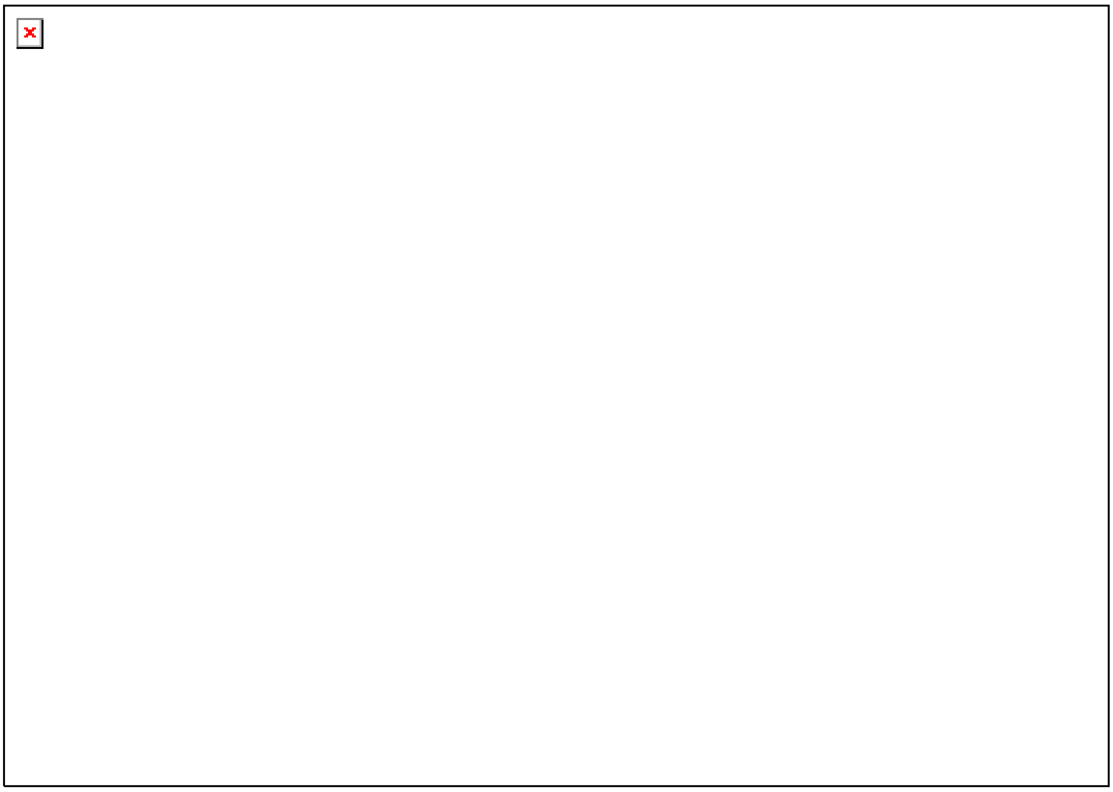


Figure 12 Location of temperature stations in this study

3) Computing an annual average seasonal average and monthly average for maximum temperature, minimum temperature and mean temperature using moving

average and regression analysis, based on 1985 to 2005. The mean indices calculated for each year were:

Tmin – the minimum temperature;

Tdmin – the minimum temperature in dry period;

Twmin – the minimum temperature in wet period;

Tmax – the maximum temperature;

Tdmax – the maximum temperature in dry period;

Twmax – the maximum temperature in wet period;

Tmean – the mean of temperature;

Tdmean – the mean of temperature dry period;

Twmean – the mean of temperature in wet period;

4) Comparing trend of the mean, minimum and maximum temperature using bar chart in each station. Thereafter, analyze variability trend of the mean, minimum and maximum temperature in each stations.

4. Determination of cloudiness variability in the Eastern Coast Basin

1) Collecting daily cloudiness data for stations in the Eastern Coast Basin with the most available period records from the Department of Meteorology, as shown in Table 3.

There are only 8 stations of all stations in the Eastern Coast Basin have a continuous long term observation history of cloudiness data (Table 3) also in mean, maximum and minimum terms. Therefore, these 8 stations were chosen for the study of urbanization and industrialization effects, which are located in urban and industrial area and considered reflecting the urban area in many respects.

3) Determining the trends of cloudiness data in monthly seasonal and annual averages terms, using linear regression analysis and moving average in 3, 5, 10 and 15 year.

4) Comparing cloudiness trend between each stations in annual, seasonal and monthly terms and discussion the reason of the change.

Table 3 The meteorology stations in the Eastern Coast Basin, continuous cloudiness data records base on 1985 – 2005 observe data

Station No.	Station Name	Province	Period
459201	Chon Buri	ChonBuri	1985-2005
459202	Ko Sichang	ChonBuri	1985-2003
459203	Phatthaya	ChonBuri	1985-2003
459204	Sattahip	ChonBuri	1985-2003
478007	Rayong Self-Help Settlement	Rayong	1985-2004
478201	Rayong	Rayong	1985-2005
480201	Chanthaburi	Chanthaburi	1985-2003
501201	Khlong Yai	Trat	1985-2005

Source : Department of Meteorology (2005)

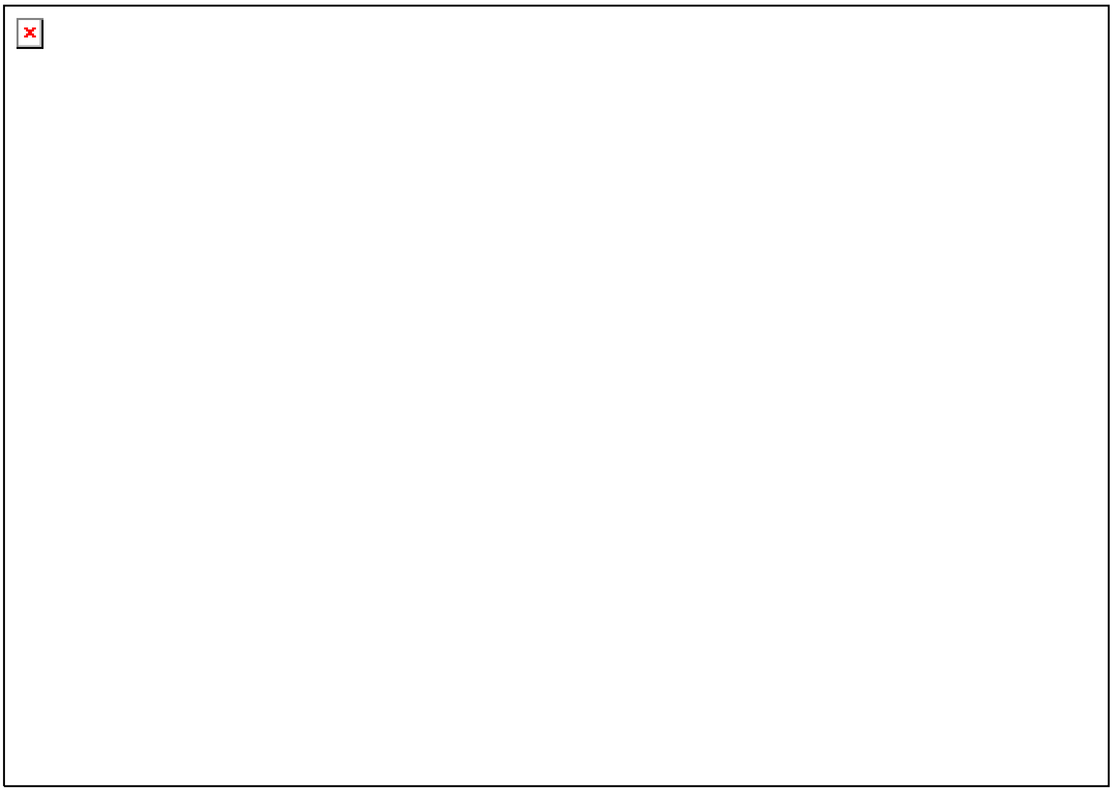


Figure 13 Location of cloudiness stations in this study

5. Determination of Aerosols in the Eastern Coast Basin.

1) Collecting air quality data from Air Quality and Noise Management Bureau, Pollution Control Department in the Eastern Coast Basin with data base on 1996 to 2006(Table 4). The locations and station names including period of record are shown in table 3 and Figure 14.

Table 4 Air Quality Station Name in the Eastern Coast Basin

ID	Air Quality Station Name	Province	Period
28T	Tasit Subdistrict Administrative Organization, T.Pluak Dang	Rayong	1996-2006
29T	Map Ta Put Health Center, A.Muang	Rayong	1996-2006
30T	Rayong Telephone Services Center, A.Muang	Rayong	1996-2006
31T	Rayong Field Crops Research Center, A. Muang	Rayong	1996-2006
32T	LamChabang-District Administration Stadium, A.Sriracha	Chonburi	1996-2006
33T	The Sriracha Juvenile Center, A.Sriracha	Chonburi	1996-2006
34T	Chonburi General Education Office, A.Sriracha	Chonburi	1996-2006

Source : Air Quality and Noise Management Bureau, Pollution Control Department, 2006

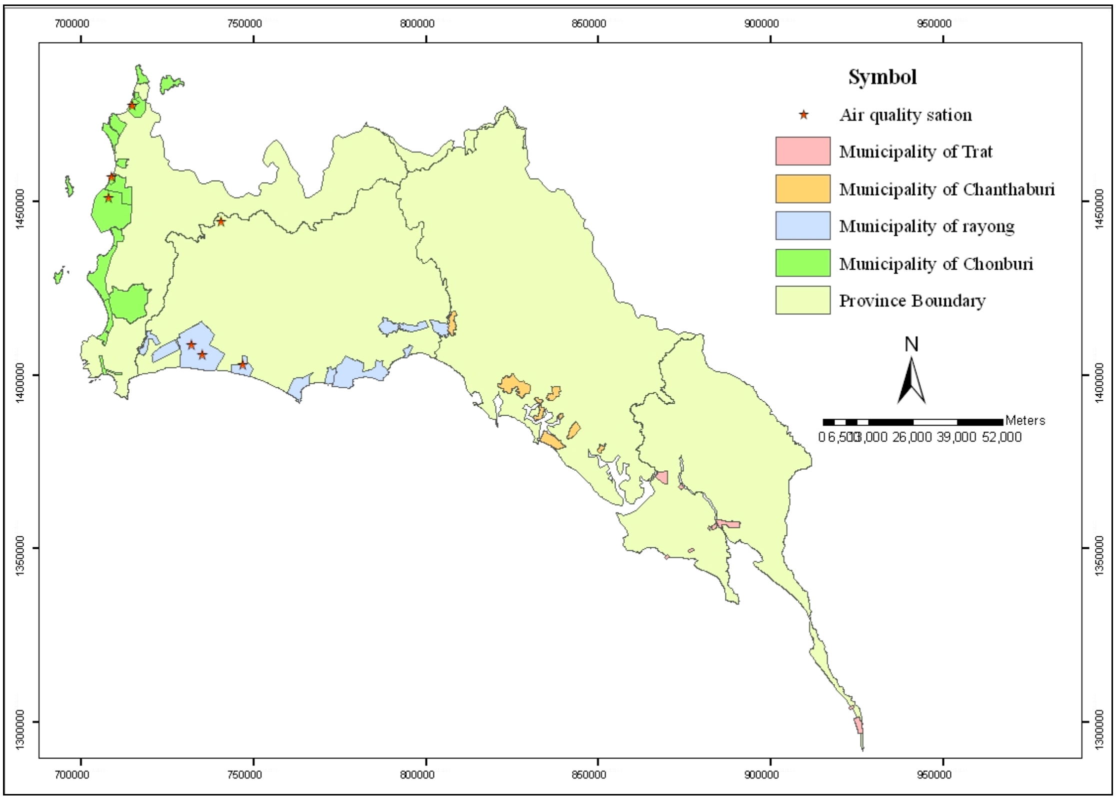


Figure 14 Location of Air Quality Station in the Eastern Coast Basin

Figure 15 Air Quality Station in the Eastern Coast Basin installed by the Pollution Control Department

2) Determining the trends of air quality data such as SO_2, NO_2, CO_2 , O_3 and Particular Matter less than 10 microns (PM10) using the regression analysis and moving average.

3) Comparing air quality data in each stations using profile graph and analyze reason of variability.

6. Analysis of relation between urbanization/ industrialization and Hydro-meteorological characteristics variability

To analyze relation between urbanization/industrialization and rainfall, temperature include other factors (Cloud and Aerosols), the multiple regression and correlation analysis more applied in this study four parameters, concerning urbanization and industrialization (i.e., urban area, industrial area, cloud and aerosols) more applied to predict the future hydro-meteorological characteristics, rainfall, and three parameters (i.e., urban area, industrial area and cloud) were employed to predict temperature. Predicted values from multiple regression are linear combinations of the predictor variables. Therefore, the general form of a prediction equation from multiple regression is:

$$Y' = A + b_1X_1 + b_2X_2 + ... + b_4X_4$$

where Y' is the predicted numerical values (rainfall and temperature),

X_1 is the numerical values on the first predictor variable (industrial area),

X_2 is the numerical values on the second (urban area)

X_3 is the numerical values on the third (cloud cover)

X_4 is the numerical values on the forth (aerosol: SO_2, NO_2, CO_2 , O_3 and Particular Matter less than 10 microns (PM10))

RESULTS AND DISCUSSION

Results

1. The changing trend of urbanization and industrialization in the Eastern Coast Basin

1.1 Change in urban area :

Using Urban area data in 1986-2001 period reported by the Office of Agricultural Economics of the Eastern Coast Basin, the proportion of urban area in 2001 for each province compare to total urban area in this basin (182.65 Km^2) indicate that Chanthaburi and Rayong has higher proportion than the other provinces (Chonburi and Trat), i.e., about 58.25 Km^2 or 37% and 56.08 Km^2 or 35% respectively (Figure 16). In the overall, urban area for particular province has increased uninterruptedly in 1986-2001 period (Figure 17, Table 5)**.**

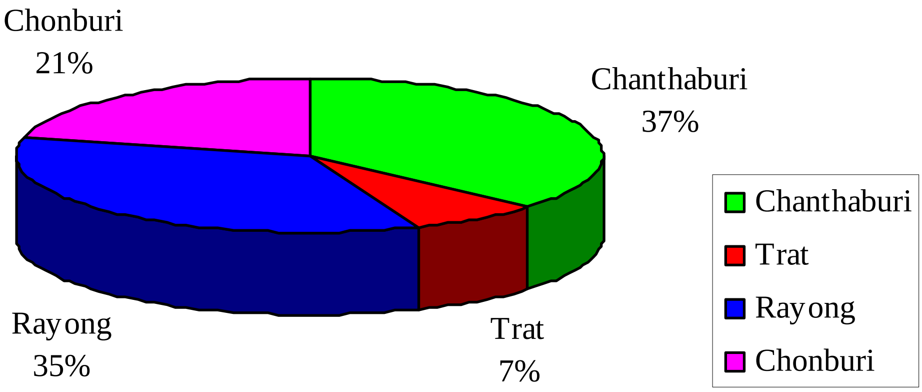


Figure 16 The proportion of urban area in 2001

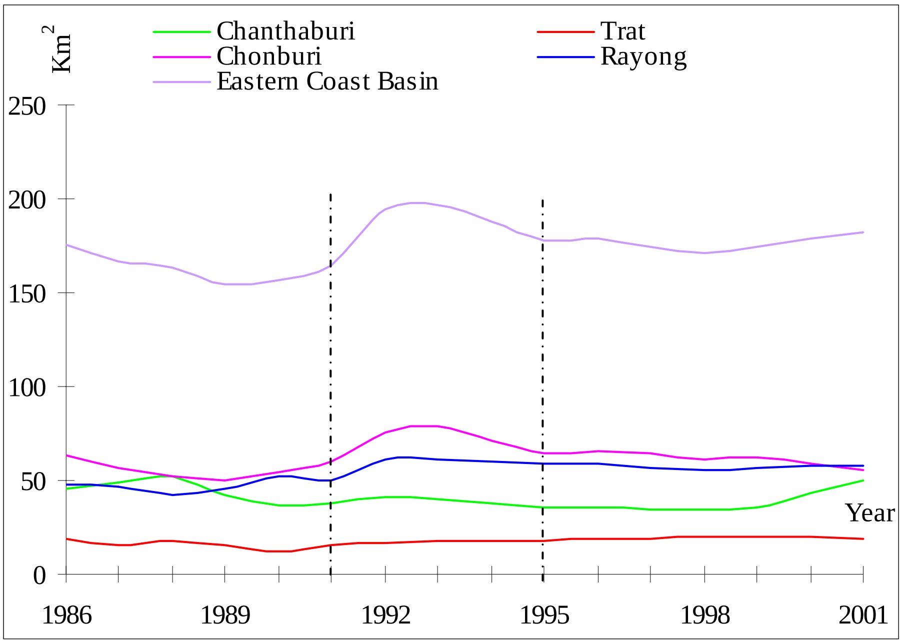


Figure 17 Urban area trends in 1986 to 2001 period

The up and down changing trend of Chonburi and Rayong province (Figure 17) are caused by provincial boundary adjustment by Ministry of Interior. The Other two provinces, i.e, Chantaburi and Trat showed smoothly increasing trend due to no provincial boundary adjustment. The criteria for identifying land use type made by Office of Agricultural Economics are also uncertainty in land use delineation.

Based on the changing trends (Table 5) and regression analysis for each district periods in Figure 18, the following rate of changes in urban area can be described :

In Chonburi province, 3 decreasing rate can be distinctive (a), i.e., 4.44 Km^2/year in the first period (1986-1993), 7.85 Km^2/year in the second period (1989-1993) and 2.28 Km^2/year in the third period (1993-2001).

In Trat (b), a slightly decreasing trend (1.09 Km^2/year) was observed in first period (1986-1990), and in 1990-2001 it increased at about 0.49 Km^2/year.

In Chanthaburi (c), during 1986-1988, it increased about 3.06 Km^2/year, and then decreased at about 2.72 Km^2/year in 1988-1992 and continued to decrease at about 1.16 Km^2/year until 1998. The rate of change in last period during 1998 to 2001 (5.316 Km^2/year).

Trend of change in Rayong (d) imitate Chonburi, urban area trend decreased in 1996-1988 at about 3.13 Km^2/year, followed by increasing at about 3.97 Km^2/year in 1988-1993. The decreasing trend of about 0.49 Km^2/year was however appeared in 1993-2001.

In overall of the Eastern Coast Basin (e), urban area trend decreased in 1996-1989 at about 5.06 Km^2/year. Subsequently, the increasing trend of about 15.10 Km^2/year in 1989-1993 was reported, perhaps due to the obligation the act of legislation concern with residential allocation in 1992. The decreasing trend of 1.61 Km^2/year was however existed in 1993-2001.

Table 5 Urban Area in the Eastern Coast Basin since 1986-2001

Year	Urban Area (KM^2)				
	Chonburi	Rayong	Chanthaburi	Trat	Eastern Coast Basin
1986	63.10	48.12	45.81	18.43	175.46
1987	56.43	46.37	49.20	15.12	167.11
1988	52.17	41.85	51.93	17.28	163.24
1989	49.71	45.82	42.77	15.68	153.97
1990	54.64	52.37	37.01	12.70	156.72
1991	60.10	50.17	37.75	15.88	163.90
1992	75.77	60.66	40.83	17.21	194.47
1993	78.37	61.19	40.08	17.24	196.88
1994	71.42	60.54	37.86	17.89	187.71
1995	64.32	59.37	35.69	18.28	177.66
1996	66.04	58.39	35.37	18.94	178.74
1997	63.95	56.94	34.66	19.40	174.94
1998	60.86	55.49	34.44	19.98	170.77
1999	61.91	56.76	35.72	20.34	174.73
2000	58.92	57.47	43.21	19.48	179.09
2001	56.08	58.25	49.66	18.66	182.65

Sources : Office of Agricultural Economics (2001)

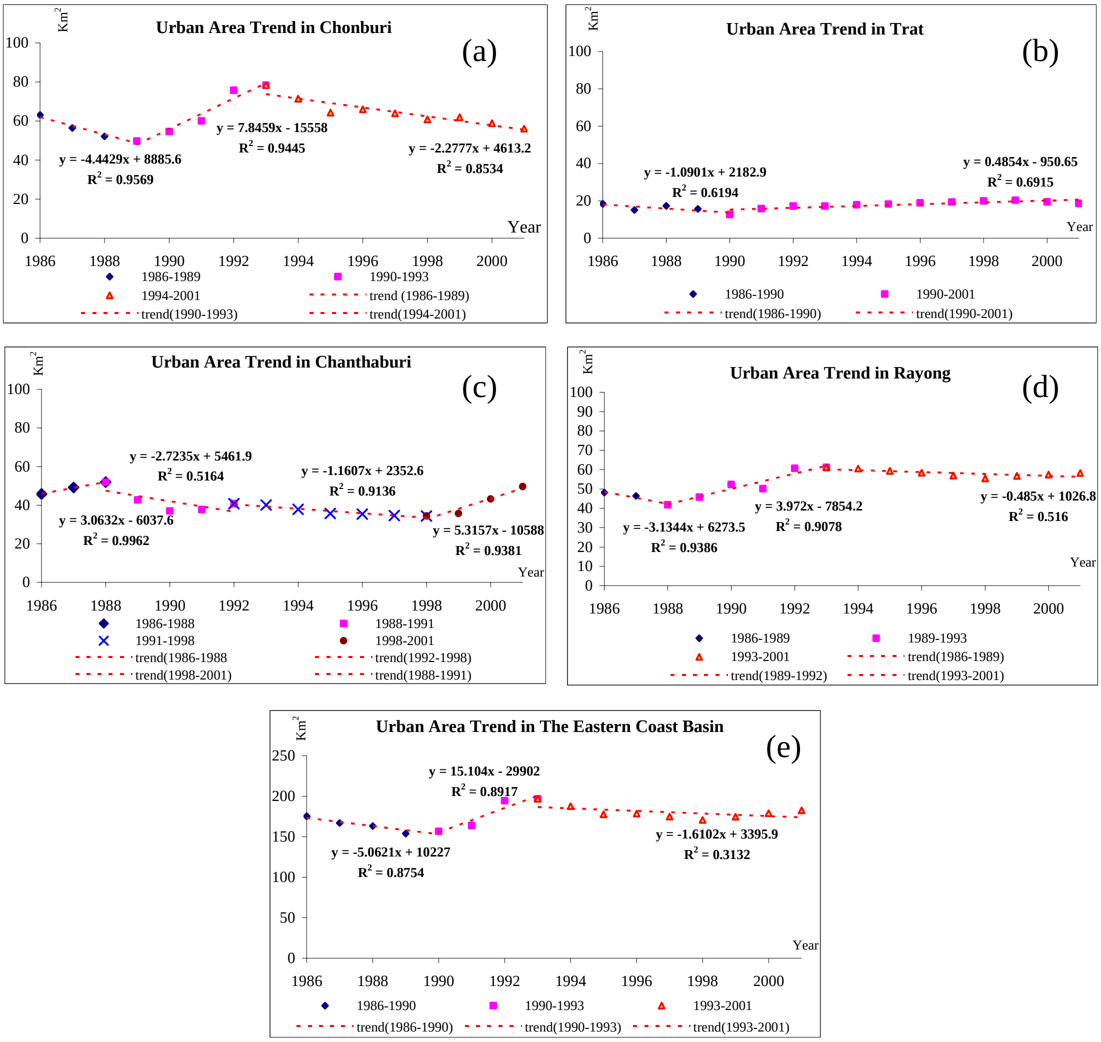


Figure 18 Change overtime of urban area in each provinces 1986 to 2001 period

1.2 Changes in industrial area :

According to the changing trend reported by Department of Industrial Works (2005), industrial area in every province in this region gradually increased from 1985 to 2002 and abruptly increased after 2003 to 2005 excepted in Chantaburi and Trat provinces (Table 6 and Figure 20). By the end of year 2005, industrial area proportion among provinces in Eastern Coast Basin are 42, 42, 15 and 1 percent for Rayong, Chonburi, Chantaburi and Trat respectively (Figure 19)

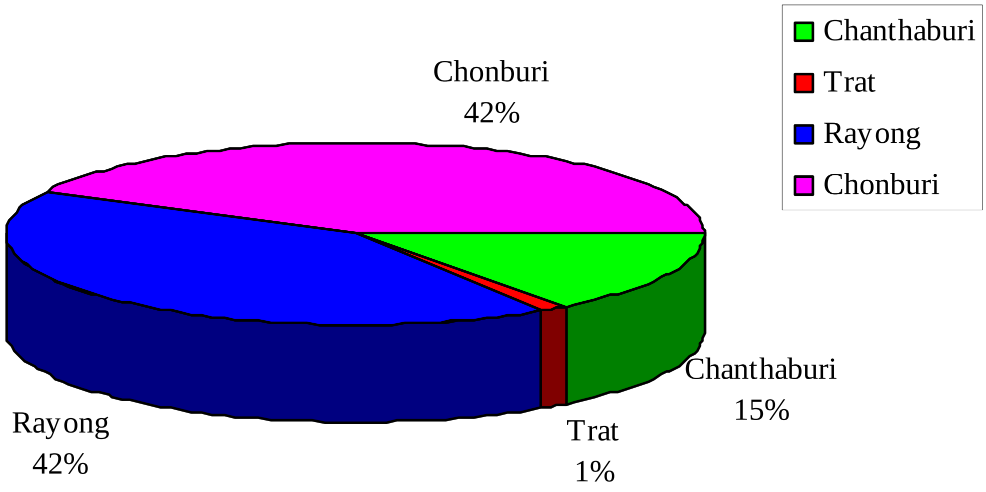


Figure 19 The proportion of industrial area in 2004

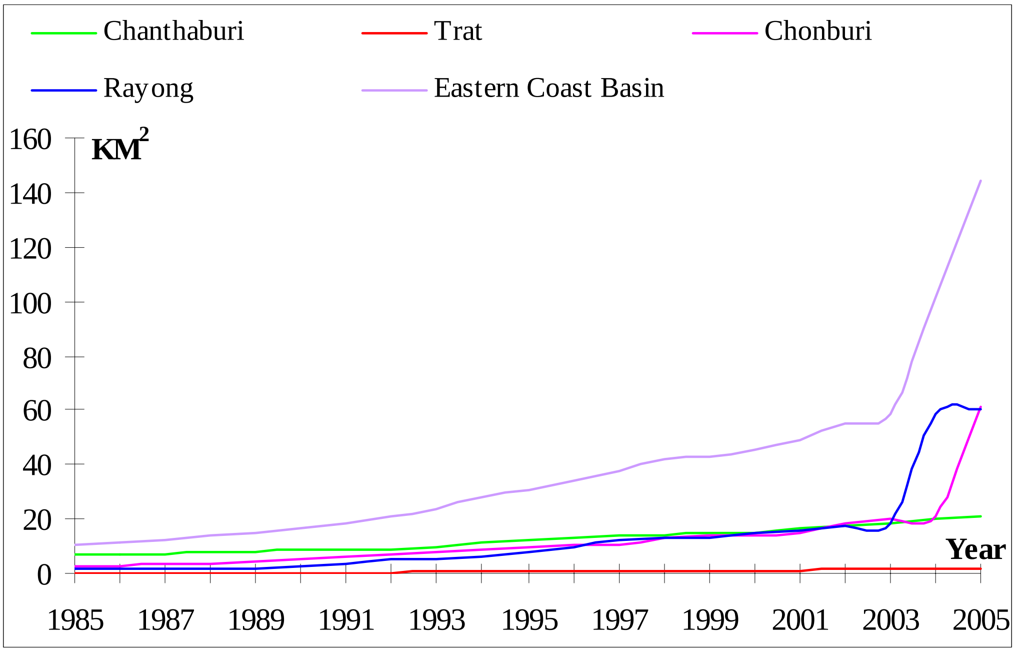


Figure 20 Industrial area trends in 1985 to 2005 period

Table 6 Industrial area in the Eastern Coast Basin since 1985-2005

Year	Industrial Area (Km^2)				
	Chonburi	Rayong	Chanthaburi	Trat	Eastern Coast Basin
1985	2.38	1.53	6.59	0.16	10.66
1986	2.99	1.58	6.80	0.17	11.54
1987	3.75	1.68	7.04	0.18	12.65
1988	3.90	1.94	7.63	0.19	13.66
1989	4.64	2.09	7.97	0.20	14.90
1990	5.04	2.62	8.44	0.20	16.30
1991	5.72	3.90	8.62	0.22	18.47
1992	7.29	4.82	8.85	0.23	21.18
1993	8.01	5.53	9.54	0.48	23.55
1994	8.94	6.44	11.69	0.48	27.55
1995	9.69	8.02	12.25	0.59	30.55
1996	10.43	9.93	13.09	0.71	34.15
1997	10.85	11.93	13.75	0.88	37.41
1998	13.14	13.29	14.42	0.95	41.80
1999	13.67	13.47	14.97	1.01	43.12
2000	14.37	14.74	15.25	1.23	45.60
2001	14.91	15.69	16.80	1.26	48.68
2002	18.08	17.75	17.43	1.45	54.74
2003	19.76	18.38	18.57	1.72	58.47
2004	20.62	58.82	20.45	1.83	101.78
2005	61.17	60.04	21.23	2.08	144.58

Sources: the Department of Industrial Works (2005)

In Figure 21, the change overtime of industrial area in the Chonburi (a) imitate Rayong (b), i.e., in the first period, trend gradually increased but abruptly increased after 2003. In 1985-2004,the rate of change in Chonburi gradually increased about 0.94 Km^2/year but abruptly increased in 2004-2005 at about 40.55 Km^2/year. Trend of change in Rayong (b), steadily increases in 1985-2003 at about 1.04 Km^2/year, but abruptly increased about 20.83 Km^2/year in 2003-2005. Chanthaburi (c) is smoothly change, during 1986-1988 with an increase of about 0.74 Km^2/year. Trat Province shown almost no change during 1985-1992(d) with a little increased in last period (1992-2005) at about 0.13 Km^2/year.

In overall of the Eastern Coast Basin (e), industrial area trend gradually increased during 1985-2003 at about 2.724 Km^2/year, and abruptly increased at about 15.10 Km^2/year in 2003-2005.

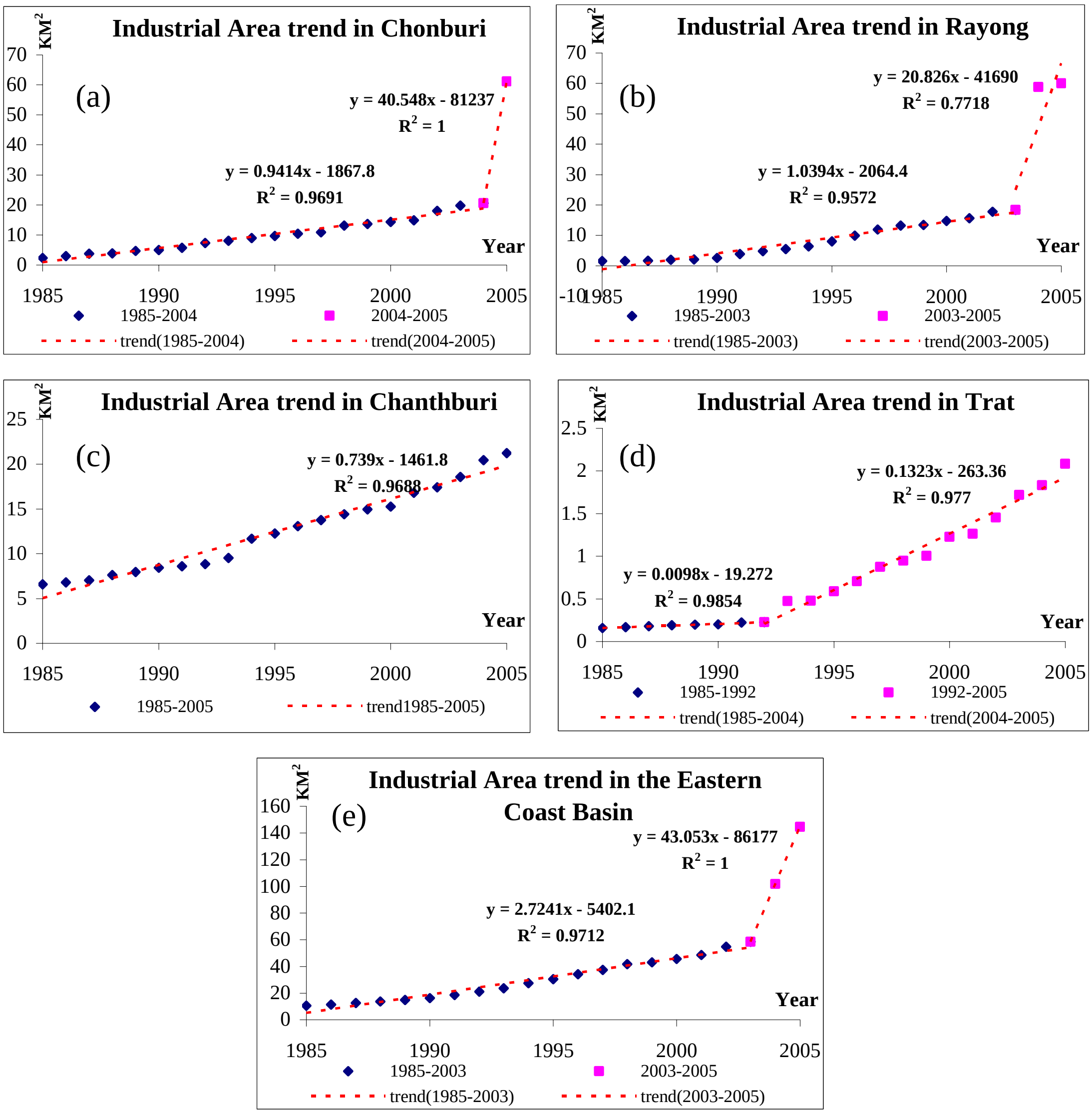


Figure 21 Change overtime of industrial area in each province 1985 to 2005 period

2. Rainfall variability in the Eastern Coast Basin

From rainfall data in 10 stations of the Eastern Coast Basin with the most available period records from the Department of Meteorology, the rate of change in a monthly averages, seasonal and annual rainfall using regression analysis and moving average in different stations based on 1985 to 2003 are thus determined in Figure 22 to 23 and Table 7-8, the rate of changes can be described as follows :

Figure 22 demonstrates the change of the annual rainfall available stations during 1995 to 2003, The average annual rainfall at Trat station was't the highest compared to other station (3,275.10 mm). The minimal one was observed at Sriracha station (945.90 mm). At Rayong station, the average annual rainfall has decreased at about 238.40 mm and continue decreasing until 1994.

At Chanthaburi station and Trat station, there have decreased rate of change. At the begining of 2001, there have been abruptly changed in industrial area is found that annual rainfall almost every station have increasing of change especially Chonburi station and station in Rayong province (Rayong, Rayong Self-Help Settlement, Huay Pong, Rayong*). Noticeable that the percent covers of cloud in Sattahip station has the most of amount average cloudiness about 69.6 %, but annual rainfall amount has not much when compare with other stations in around.

From table 7, it is found that monthly mean rainfall are highest decreased rate in Trat station is high decreased rate, 90.60 mm/ year and Chonburi station is lowest decreased rate, 13.68 mm/ year respectively, which are located in urban and industrial area.

Besides, it is found that cloud cover at Satthahip station are more than other stations but rainfall are less than other because this station is near to the coast in which that influence from the sea breeze approximate 30 m.

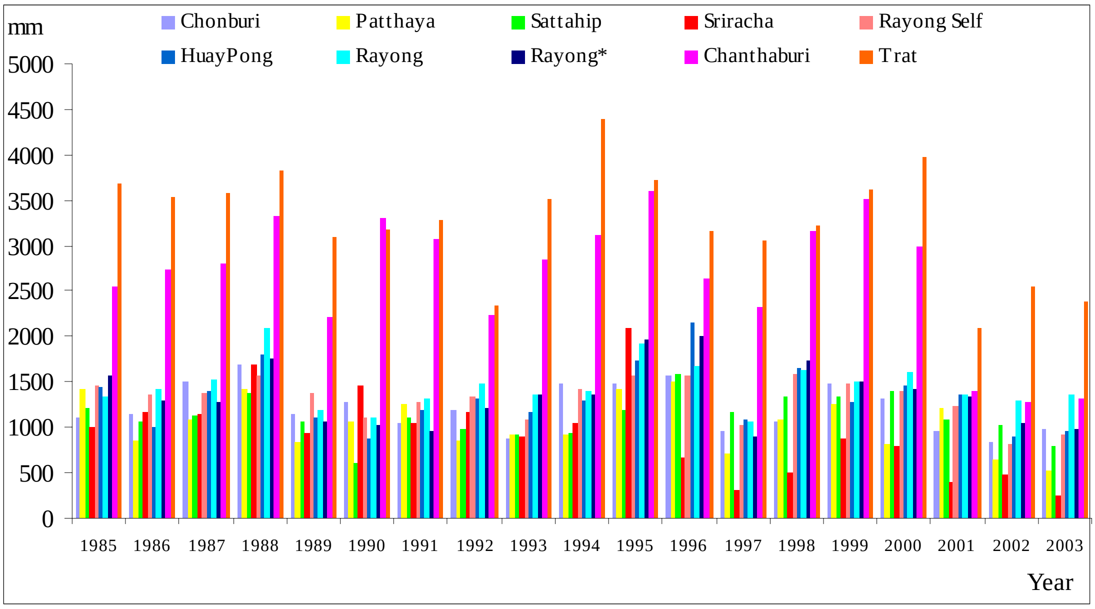


Figure 22 Temporal change of mean annual rainfall in 1985 to 2003 at different stations

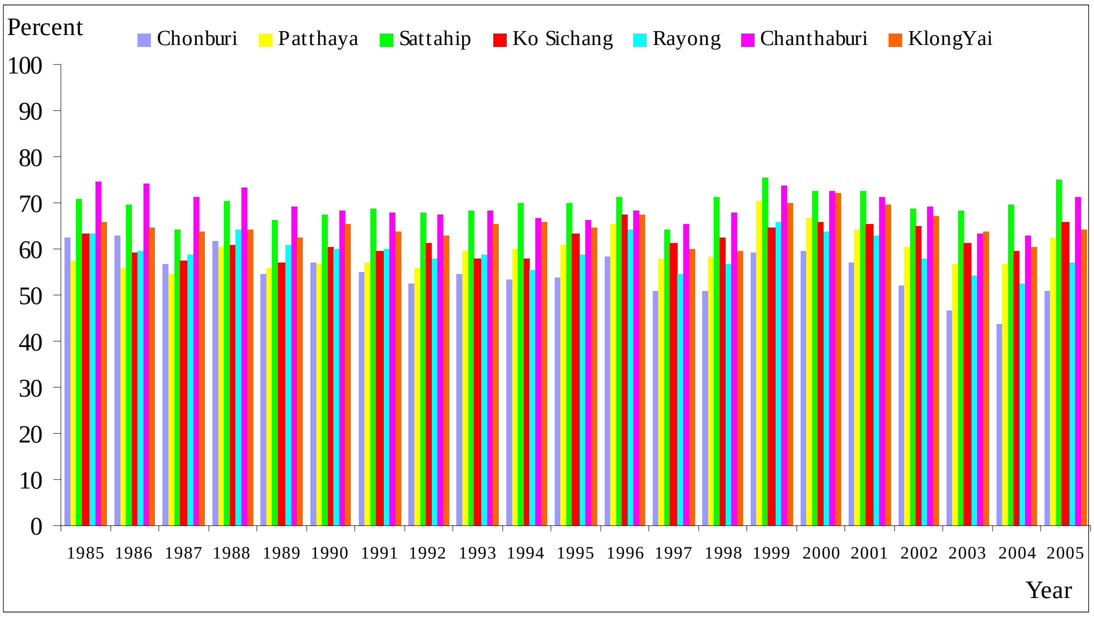


Figure 23 Variability of mean cloudiness in 1985 to 2005

Table 7 Ten year moving average of change in monthly rainfall at different station located in the Eastern Coast basin base on data 1985-2003

Name Station	Monthly rainfall increased(+) or decrease(-) rate, (mm)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1 Si Racha	0.14	0.07	0.78	-5.23	-7.58	-2.93	-5.20	-6.84	-11.24	-13.22	-2.14	0.33
2 ChonBuri	0.09	0.32	5.13	-1.96	0.18	1.41	-3.38	1.05	-3.38	-7.37	-3.38	0.45
3 Sattahip	0.51	-1.41	4.81	1.77	-7.40	-0.37	-1.17	2.00	-4.14	-5.19	-2.29	1.17
4 Phatthaya	-0.69	-0.17	3.35	-7.44	0.43	-2.50	-0.72	-5.96	-1.96	-0.72	-5.96	-1.96
5 Rayong	0.56	-0.39	3.84	-2.63	2.55	-0.15	-2.52	-2.46	-0.83	-2.52	-2.46	-0.83
6 Rayong Self-Help Settlement	0.57	-0.62	2.58	-0.51	-8.04	-1.51	-7.51	0.23	-2.36	0.35	-0.94	1.07
7 Rayong*	0.87	-1.49	5.01	0.08	-5.78	3.46	-2.65	1.46	-0.64	-3.80	-0.61	0.41
8 Huai Pong Agromet	0.44	-0.50	8.39	-0.20	-7.55	1.76	-5.55	0.90	-1.15	-0.28	-1.10	1.13
9 Chanthaburi	0.48	-0.26	1.30	-0.60	-9.80	-22.37	-7.13	-7.70	0.39	-8.45	-1.91	0.90
10 Trat	1.55	0.77	2.59	-5.66	-13.19	-38.38	-21.86	0.55	-4.17	-13.35	-0.75	1.31

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: (y = a + bx) ; implying monthly mean increase or decrease rate of rainfall for each station.

Based on Table 8, it could be described that in rainy season, it is found that almost every rainfall station has decrease rate. The highest decrease rate (-90.40 mm/year) at Trat station and the lowest at the Rayong* station (-7.27 mm/year) but at Satahip station, increases at 4.55 mm/year because during wet period still see the change is not clear concern the influence of storm crisis from Gulf of Thailand and Pacific Ocean where is influential cause the rain at this time. Annual average rainfall has resemble trend in wet period.

In dry period, at Sattahip station, it shows the highest decrease rate (-11.71 mm/year) and the least decrease rate (-0.09 mm/year) at Chanthaburi station but station in Rayong province (Rayong, Rayong Self-Help Settlement, Huay Pong and Rayong*) increase trend because extend of industrial area.The moving averages of annual rainfall at 3, 5, 10 and 15 year-period indicates all the decreasing trend in almost all station excepted at Rayong station and Huay Pong station.

Table 8 Rate of change in seasonal and annual rainfall for different stations determined by regression and time series analysis with 4 periodic moving average based on data 1985-2003

		Seasonal		Moving Average of Annual				
	Name Station	Wet	Dry	Annual	3 Yr	5Yr	10Yr	15Yr
1	Si Racha	-47.01	-6.05	-53.06	-58.86	-60.59	-63.77	-55.02
2	ChonBuri	-14.34	0.65	-13.68	-14.86	-8.24	-9.54	-22.94
3	Sattahip	4.55	-11.71	-16.26	-2.82	6.19	7.51	-23.29
4	Phatthaya	-14.50	-3.52	-18.02	-9.63	-5.68	-6.20	-19.89
5	Rayong	-6.14	4.19	-1.95	-1.92	2.94	3.85	-11.12
6	Rayong Self-Help Settlement	-17.38	2.15	-15.24	-8.68	-2.22	-2.79	-23.03
7	Rayong*	-7.27	4.27	-3.00	6.53	15.46	17.55	-13.74
8	Huai Pong Agromet	-11.37	8.15	-3.22	3.96	11.28	14.13	-13.95
9	Chanthaburi	-51.73	-0.09	-51.82	-42.57	-24.92	-28.15	-69.27
10	Trat	-90.40	-0.19	-90.60	-84.89	-67.62	-73.49	-98.87

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: y = a + bx ; implying seasonal (wet/dry) and annual mean increase or decrease rate of in rainfall for each station.

Note : Wet = Wet season (May-Oct)

Dry = Dry season (Nov-April)

3. Temperature variability in the Eastern Coast Basin

Based on the available data from 1985-2005, the rate of changes in temperature for each month of all stations analyzed by regression was shown in table 9 to 14. Trends of annual indices calculated using linear regression for each station, using data on 1985 to 2005, can be described as fallows:

From table 9 to 11, it could be observed that higher rate of increase in mean monthly temperature, annual mean temperature, annual mean temperature in dry period (Nov-Apr), was found at Sattahip station (0.072 and 0.074 ˚C per year respectively) and at Phatthaya station (0.016 and 0.017 ˚C per year respectively). As for rural stations group, It is found that Klong Yai station showed the high increasing rate, at 0.044 and 0.056 ˚C per year respectively.

From table 12, it could be observed that maximum temperature in terms of mean annual maximum temperature and mean maximum temperature in dry period of urban area was higher compared to the near by rural area. The highest increasing rate of the mentioned maximum temperature occurred at Rayong station (0.099 and 0.105 ˚C per year respectively) and at Sattahip station (0.094 and 0.085 ˚C per year respectively).

For extreme temperature in terms of mean annual maximum and mean maximum temperature in dry period (Table 11), it could be observed that at Chonburi station and Sri Racha station show the increasing trend but decreasing trend at the Klong Yai station.

Table 9 Variability of changing rate of monthly mean temperature in different stations located in the Eastern Coast basin based on data 1985-2005

Name Station	Monthly mean temperature increased(+) or decrease(-) rate, celsius(˚C)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Ko Sichang	0.014	0.011	-0.008	0.013	0.011	0.006	0.016	0.004	0.015	0.031	0.024	0.051
Rayong	0.054	0.035	0.023	0.042	0.031	0.016	0.030	0.030	0.019	0.040	0.041	0.069
Khlong Yai	0.048	0.025	0.015	0.048	0.013	0.017	0.025	0.021	0.028	0.006	0.051	0.056
Phatthaya	0.008	0.013	0.003	0.014	0.019	-0.002	0.005	0.003	0.030	0.030	0.042	0.048
ChonBuri	0.043	0.031	0.010	0.024	0.043	0.025	0.042	0.032	0.025	0.061	0.063	0.080
Sattahip	0.070	0.058	0.054	0.073	0.073	0.073	0.079	0.051	0.057	0.077	0.090	0.117
Chanthaburi	0.026	0.025	0.023	0.015	0.019	0.016	0.016	0.023	0.014	0.049	0.036	0.051

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: (y = a + bx) ; implying monthly mean increase or decrease rate of mean temperature for each station.

Table 10 Variability of changing rate of monthly maximum temperature in different stations located in the Eastern Coast basin based on data 1985- 2005

Name Station	Monthly maximum temperature increased(+) or decrease(-) rate, celsius(˚C)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Ko Sichang	0.017	0.001	0.001	-0.003	-0.009	0.005	-0.006	-0.016	0.003	0.038	0.044	0.048
Rayong	0.102	0.116	0.097	0.127	0.108	0.098	0.090	0.068	0.086	0.129	0.086	0.083
Sattahip	0.093	0.108	0.081	0.076	0.075	0.082	0.080	0.077	0.079	0.119	0.110	0.112
ChonBuri	-0.010	-0.008	-0.039	-0.007	0.025	0.013	0.017	0.014	0.019	0.060	0.057	0.018
Chanthaburi	0.005	0.027	0.027	0.033	0.023	0.035	0.026	0.031	0.017	0.069	0.077	0.048
Khlong Yai	0.001	0.000	-0.002	0.002	-0.019	0.022	-0.011	0.007	0.024	0.058	0.041	0.011

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: (y = a + bx) ; implying monthly mean increase or decrease rate of maximum temperature for each station.

Table 11 Variability of changing rate of monthly minimum temperature in different stations located in the Eastern Coast basin based on data 1985-2005

	Monthly minimum temperature increased(+) or decrease(-) rate, celsius(˚C)											
Name Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rayong	0.095	0.039	0.004	0.019	0.022	-0.002	0.032	0.028	0.007	0.015	0.039	0.116
Khlong Yai	0.027	-0.010	-0.023	-0.032	-0.031	-0.033	-0.030	-0.024	-0.029	-0.003	0.017	0.049
Sattahip	0.030	0.015	0.012	0.013	0.020	0.004	0.034	0.016	0.015	0.016	0.033	0.080
ChonBuri	0.123	0.068	0.048	0.047	0.061	0.031	0.063	0.062	0.054	0.064	0.077	0.156
Chanthaburi	0.053	0.036	0.025	-0.001	0.009	-0.003	0.006	0.011	-0.001	0.017	0.008	0.079
Ko Sichang	-0.001	-0.027	-0.0656	-0.622	-0.062	-0.077	-0.0747	-0.011	-0.0239	-0.0296	-0.042	0.0452

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: (y = a + bx) ; implying monthly mean increase or decrease rate of minimum temperature for each station.

Table 12 Moving average of mean seasonal (wet/dry) and annual temperature with different station based on data 1985-2005

	Seasonal			**Moving average of annual**			
Name Station	**Wet**	**Dry**	**Annual**	**3 Yr**	**5Yr**	**10Yr**	**15Yr**
Ko Sichang	0.014	0.016	0.016	0.013	0.009	0.009	0.016
Rayong	0.026	0.045	0.035	0.039	0.044	0.049	0.034
Khlong Yai	0.051	0.056	0.044	0.029	0.029	0.033	0.027
Phatthaya	0.010	0.017	0.016	0.013	0.010	0.012	0.015
ChonBuri	0.038	0.038	0.040	0.037	0.040	0.038	0.042
Sattahip	0.067	0.074	0.072	0.069	0.069	0.071	0.067
Chanthaburi	0.026	0.026	0.026	0.024	0.022	0.023	0.026

Table 13 Moving average of maximum seasonal (wet/dry) and annual temperature with different station based on data 1985-2005

	Seasonal			**Moving average of annual**			
Name Station	**Wet**	**Dry**	**Annual**	**3 Yr**	**5Yr**	**10Yr**	**15Yr**
Ko Sichang	0.007	0.003	0.006	0.001	-0.007	-0.007	0.007
Rayong	0.096	0.105	0.099	0.122	0.148	0.161	0.103
Sattahip	0.091	0.085	0.094	0.093	0.091	0.092	0.092
ChonBuri	0.025	-0.009	0.013	0.011	0.004	0.001	0.018
Chanthaburi	0.033	0.028	0.035	0.034	0.030	0.031	0.037
Khlong Yai	0.014	0.003	0.011	0.011	0.005	0.006	0.015

Table 14 Moving average of minimum seasonal (wet/dry) and annual temperature with different station based on data 1985-2005

	Seasonal			**Moving average of annual**			
Name Station	**Wet**	**Dry**	**Annual**	**3 Yr**	**5Yr**	**10Yr**	**15Yr**
Rayong	0.017	0.055	0.034	0.030	0.026	0.024	0.035
Khlong Yai	-0.025	0.002	-0.010	-0.017	-0.018	-0.025	-0.008
Sattahip	0.018	0.030	0.024	0.016	0.013	0.011	0.021
ChonBuri	0.056	0.088	0.071	0.061	0.060	0.063	0.063
Chanthaburi	0.006	0.039	0.020	0.018	0.019	0.022	0.018
Ko Sichang	-0.045	-0.022	-0.036	-0.0458	-0.0344	-0.0332	-0.0467

Moving average analysis of mean temperature but not for the maximum temperature. The minimum temperature are less increased trend, almost all stations except Klong Yai station which is decreased trend.

In the part of profile graph (Figure 24-26), it could be observed that at Sattahip station and Rayong station demonstate the increasing trend of temperature at higher value than other stations, perhaps due to extention of urban and industrial areas which is known as“Urban Heat Island”, so that temperature is higher than that of surrounding area. The black material in urban and industrial areas normally release heat into atmosphere. Besides, industrial area also releases aerosols and greenhouse gases into atmosphere (Chou, 1985).

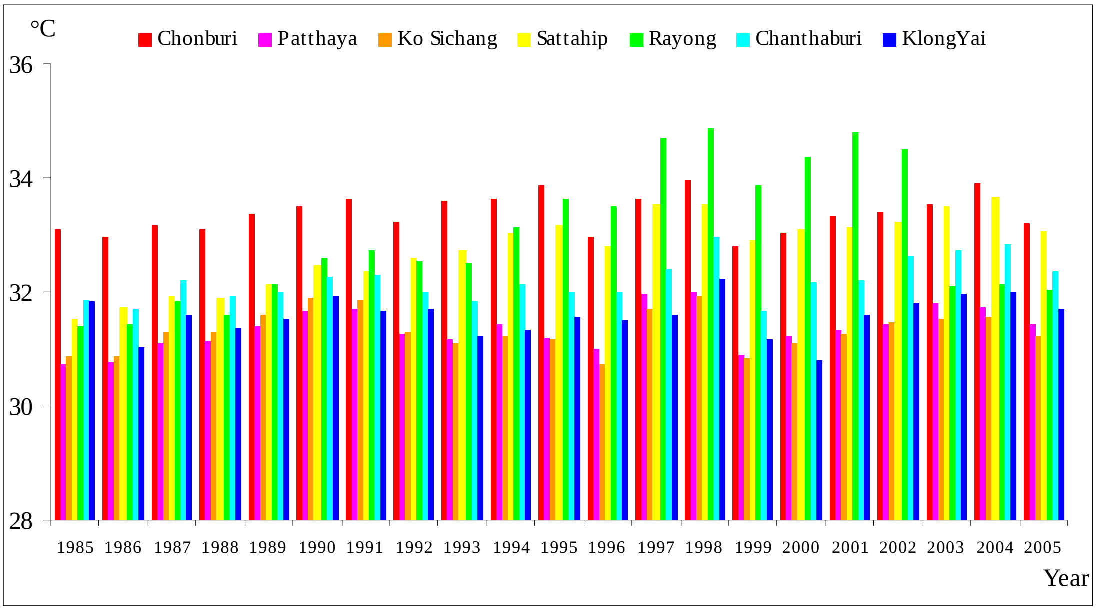


Figure 24 Temporal change of annual maximum temperature in 1985 to 2005.

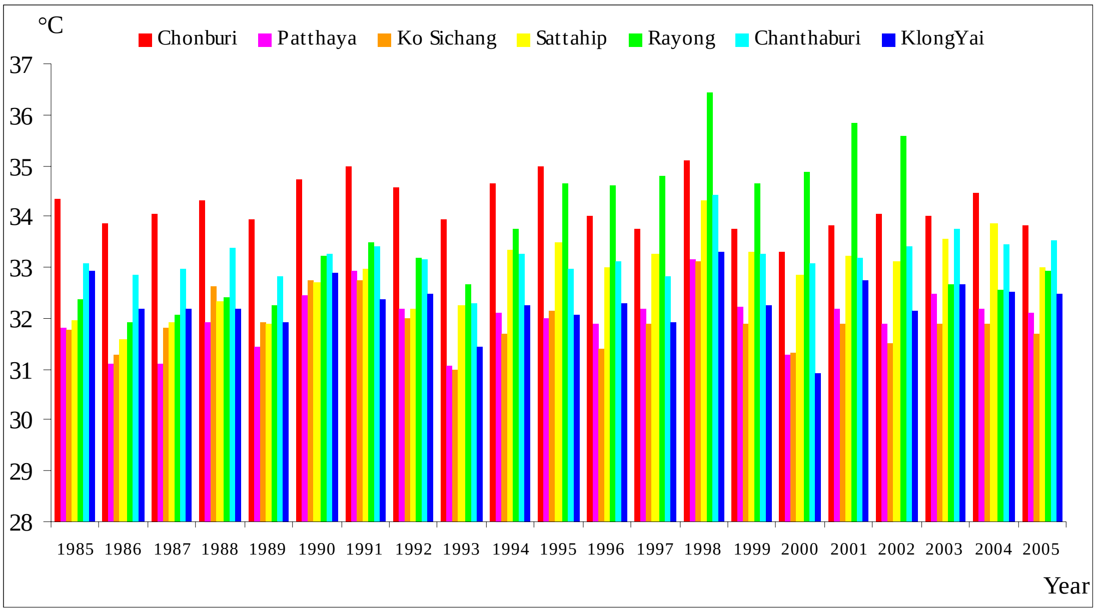


Figure 25 Temporal change of annual maximum temperature in summer (February to April) 1985-2005

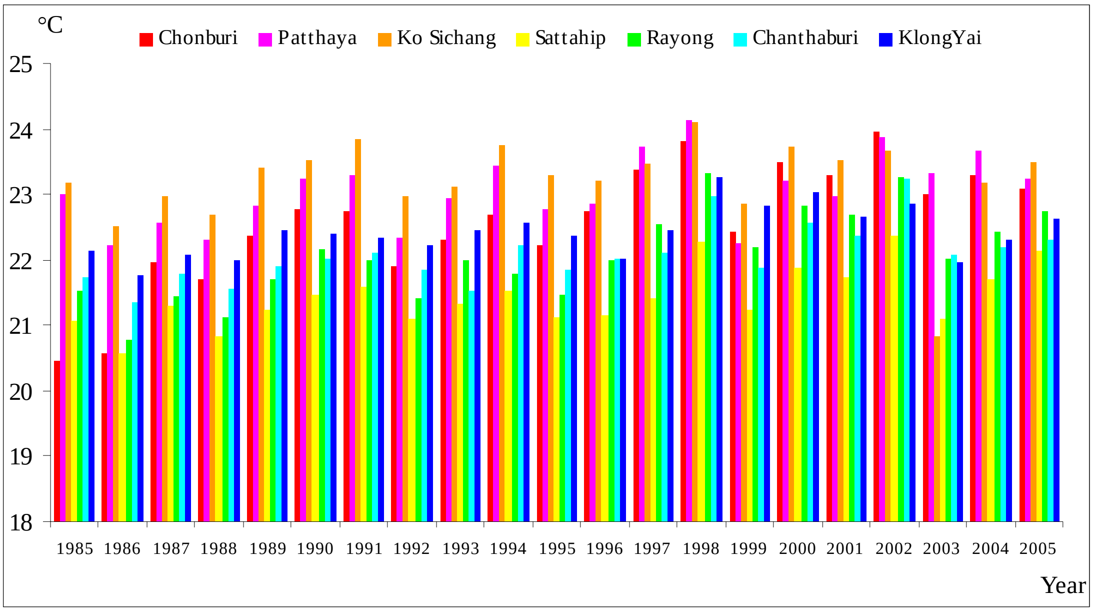


Figure 26 Temporal change of annual minimum temperature in winter (November to January) 1985-2005

4. Aerosols variability in the Eastern Coast Basin

Air quality and aerosol data including SO_2, NO_2, CO_2, O_3 and PM10 (particular matter less than 10 microns) in the Eastern Coast basin collected from six stations as shown in Figure 27 (in method and material section) were plotted and analyzed to determine the trend of change over time using regression and time series analyzes. The trend of change in SO_2, NO_2, CO_2, O_3 and PM10 during 1996 to 2006 for different stations are illustrated in Figure 22, 23, 24, 25 and 26 respectively. The maximum 1 hr averaged and annual mean of the mentioned air quality parameter during 1996-2006 are also presented in Table 15 and 16 respectively.

1) Map Ta Put Health Center, A.Muang, Rayong (MT)
2) Rayong Telephone Services Center, A.Muang, Rayong (TC)
3) Rayong Field Crops Research Center, A. Muang, Rayong (FC)
4) Udom bay fire station, LamChabang, Chonburi (US)
5) The Sriracha Juvenile Center, A.Sriracha, Chonburi (JC)
6) Chonburi General Education Office, A.Sriracha, Chonburi (GO)

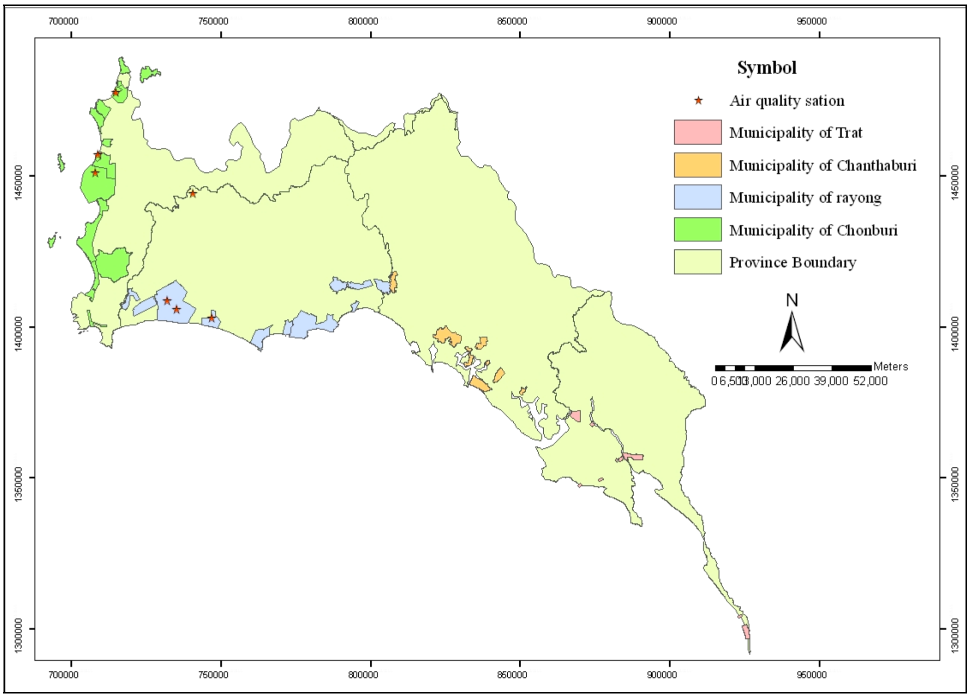


Figure 27 Location of air quality station in the Eastern Coast Basin.

4.1 Sulfur dioxide (SO_2)

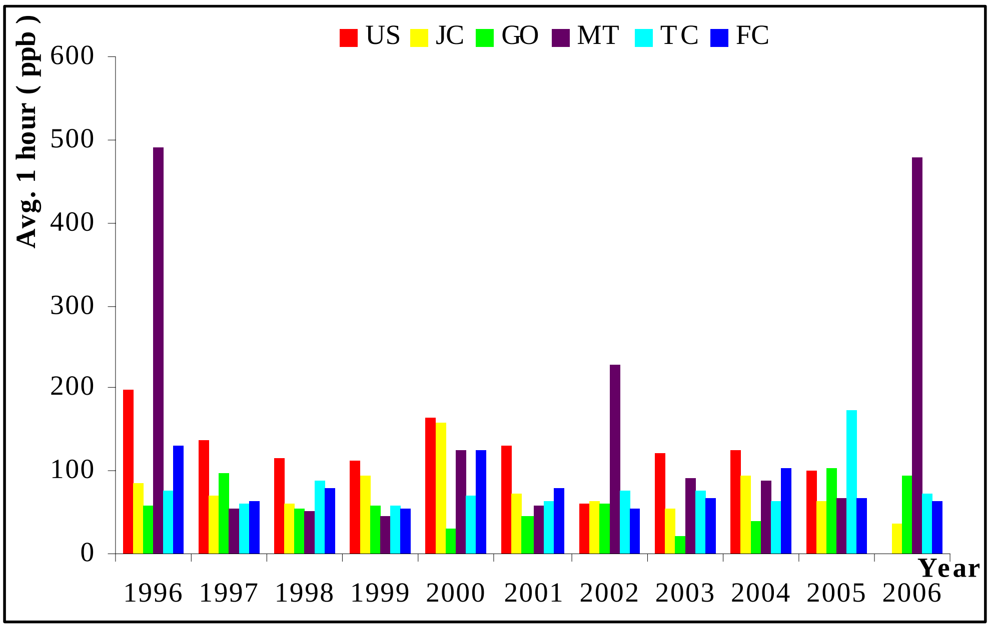


Figure 28 Temporal change of Sulfur dioxide (SO_2)

Note:	US	=	Udom bay fire station
	JC	=	The Sriracha Juvenile Center
	GO	=	Chonburi General Education Office
	MT	=	Map Ta Put Health Center
	TC	=	Rayong Telephone Services Center
	FC	=	Rayong Field Crops Research Center

Location of all stations near the sea could influence on variability of air quality. At Map Ta Put Health Center station, higher SO_2 and NO_2 than other stations since 2001 was observed because the abrupt change of industrial area (Figure 28-32). Besides, the maximum of Nitrogen dioxide at Map Ta Put Health Center and Udom bay fire station are higher than other stations because surrounding area are community and agriculture that could produced NO_2. The principal source of NO_2 is mainly NO_x from motor vehicles of all types and energy production in some places (Chou, 1985) (e.g., power plants, domestic heating).

4.2 Nitrogen dioxide (NO_2)

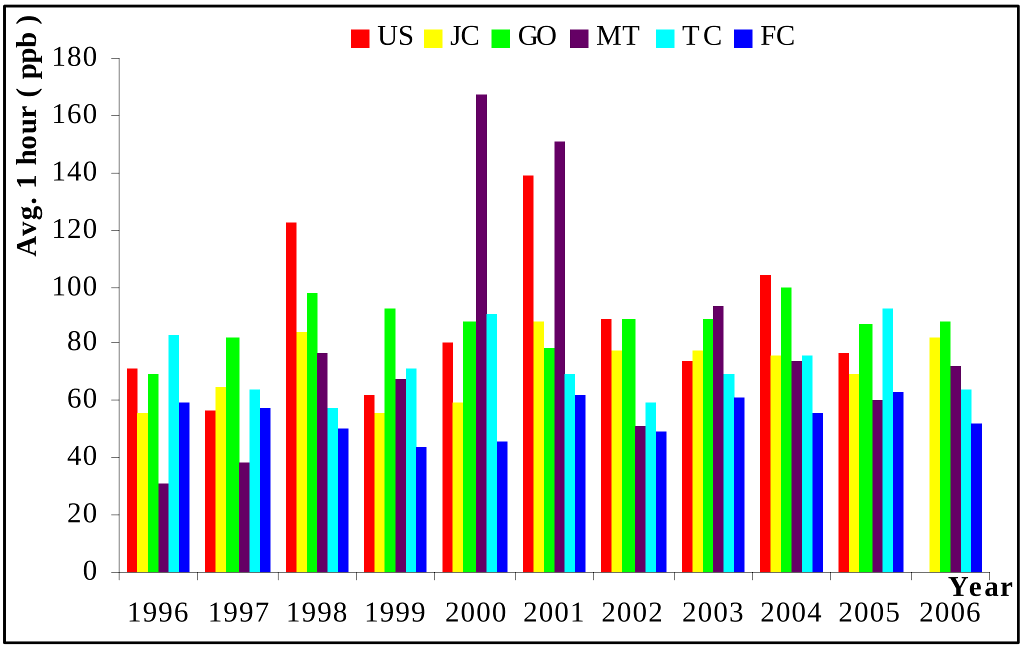


Figure 29 Temporal change of Nitrogen dioxide (NO_2)

4.3 Cabonmonoxide (CO)

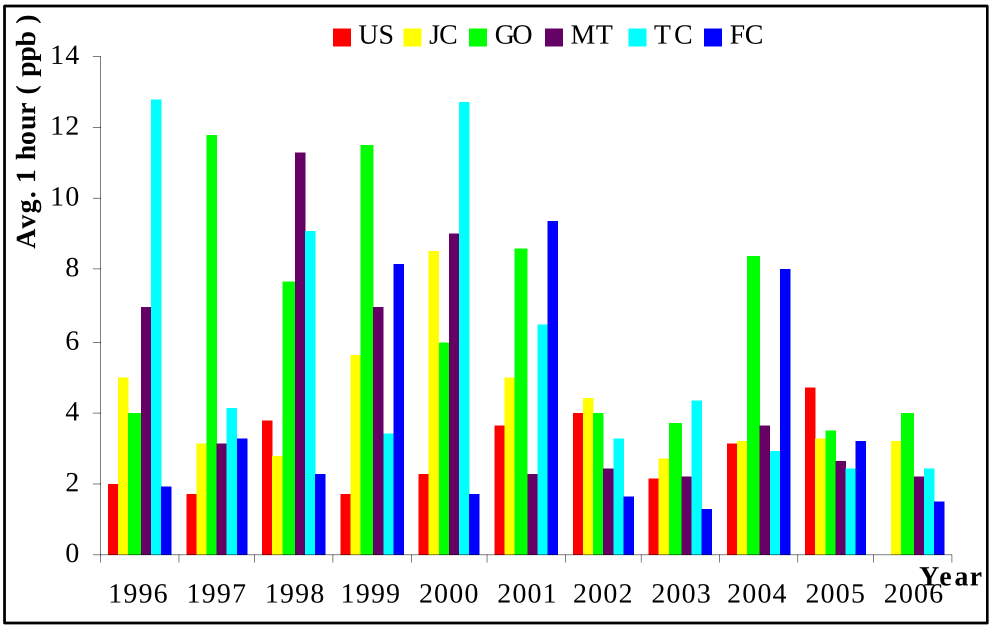


Figure 30 Temporal change of Cabonmonoxide (CO)

4.4 Ozone (O_3)

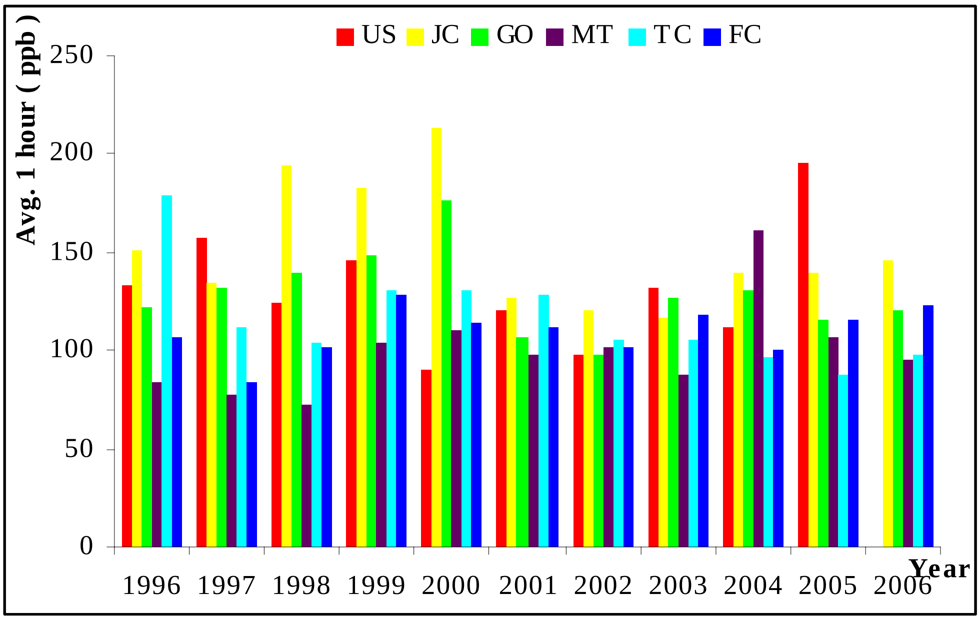


Figure 31 Temporal change of Ozone (O_3)

4.5 Particular Matter less than 10 microns (PM10)

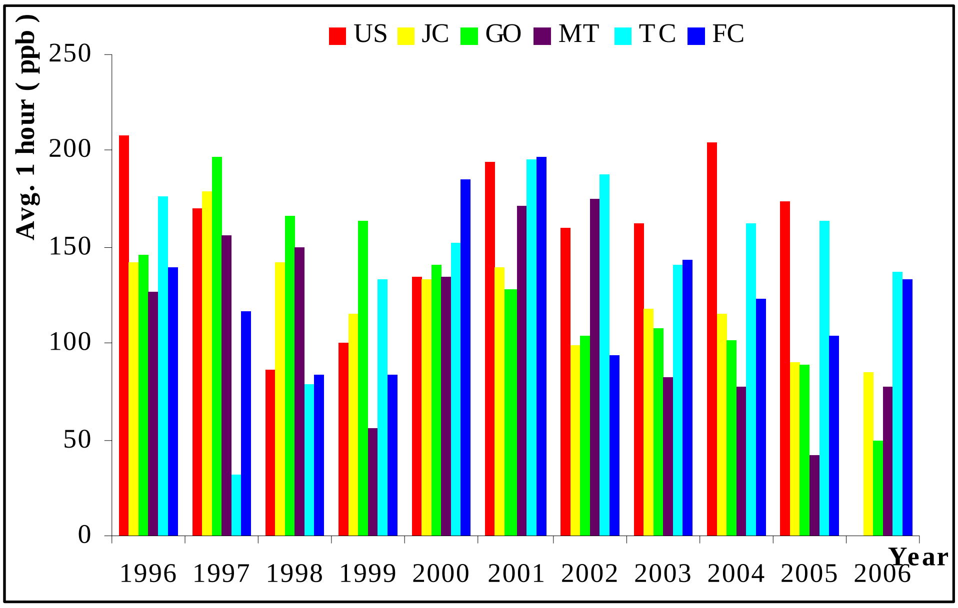


Figure 32 Temporal change of Particular Matter less than 10 microns (PM10)

Table 15 Maximal 1 hr averaged values of air quality monitored at 6 stations during 1996-2006

	Maximum SO_2						Maximum NO_2						Maximum CO						Maximum O_3						Maximum PM10					
Year	**US**	**JC**	**GO**	**MT**	**TC**	**FC**	**US**	**JC**	**GO**	**MT**	**TC**	**FC**	**US**	**JC**	**GO**	**MT**	**TC**	**FC**	**US**	**JC**	**GO**	**MT**	**TC**	**FC**	**US**	**JC**	**GO**	**MT**	**TC**	**FC**
1996	197.1	84.0	58.0	489.0	76.0	131.0	71.0	56.0	69.0	31.0	83.0	59.0	2.0	5.0	4.0	7.0	12.8	1.9	133.0	151.0	122.0	84.2	179.0	107.0	208.4	142.6	146.2	126.9	176.5	139.6
1997	135.7	69.0	97.0	54.5	62.0	65.0	57.0	65.0	82.0	38.8	64.0	58.0	1.7	3.1	11.8	3.1	4.1	3.3	157.0	135.0	132.0	77.8	112.0	84.0	169.9	179.2	196.3	155.7	31.9	116.4
1998	115.0	60.0	55.0	53.2	89.0	79.0	122.0	84.0	98.0	77.2	58.0	50.0	3.8	2.8	7.7	11.3	9.1	2.3	125.0	194.0	140.0	72.0	104.0	101.0	86.8	141.5	165.9	149.9	79.0	83.8
1999	114.0	94.0	58.0	46.0	57.0	54.0	62.0	56.0	92.0	68.0	71.0	44.0	1.7	5.6	11.5	7.0	3.4	8.2	146.0	183.0	148.0	104.2	131.0	128.0	100.0	115.2	163.9	55.4	133.7	83.6
2000	165.0	157.0	30.0	125.0	71.0	125.0	80.0	59.0	88.0	167.0	90.0	46.0	2.3	8.5	6.0	9.0	12.7	1.7	90.0	213.0	177.0	110.0	131.0	114.0	134.3	133.0	140.6	134.8	151.8	184.8
2001	131.0	74.0	45.0	58.0	63.0	80.0	139.0	88.0	79.0	151.0	69.0	62.0	3.6	5.0	8.6	2.3	6.5	9.4	121.0	127.0	107.0	98.0	128.0	112.0	194.1	140.2	128.0	171.7	195.2	196.8
2002	60.0	65.0	60.0	227.0	75.0	54.0	89.0	78.0	89.0	51.0	59.0	49.0	4.0	4.4	4.0	2.4	3.3	1.6	98.0	121.0	98.0	101.0	105.0	101.0	160.0	98.5	104.1	174.8	188.4	94.3
2003	123.0	56.0	22.0	92.0	77.0	67.0	74.0	78.0	89.0	93.0	69.0	61.0	2.1	2.7	3.7	2.2	4.3	1.3	131.6	117.0	127.0	88.0	105.0	118.0	162.1	117.9	108.2	82.8	141.2	143.1
2004	125.0	94.0	39.0	89.0	65.0	104.0	104.0	76.0	100.0	74.0	76.0	56.0	3.1	3.2	8.4	3.6	2.9	8.0	112.0	139.0	131.0	161.0	96.0	100.0	204.3	116.0	101.8	77.3	162.4	123.2
2005	102.0	65.0	104.0	67.0	175.0	66.0	77.0	69.0	87.0	60.0	92.0	63.0	4.7	3.3	3.5	2.6	2.4	3.2	195.0	139.0	116.0	107.0	88.0	116.0	173.3	89.7	88.6	42.0	163.2	103.7
2006		36.0	93.0	478.0	73.0	63.0		82.0	88.0	72.0	64.0	52.0		3.2	4.0	2.2	2.4	1.5		146.0	120.0	95.0	98.0	123.0		85.0	49.8	77.9	137.0	133.6

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: (y = a + bx) ; implying monthly mean increase or decrease rate of Maximal air quality monitored for each station.

Note :
US = Udom bay fire station
JC = The Sriracha Juvenile Center
GO = Chonburi General Education Office
MT = Map Ta Put Health Center
TC = Rayong Telephone Services Center
FC = Rayong Field Crops Research Center

Table 16 Mean 1 hr averaged values of air quality monitored at 6 stations during 1996-2006

Year	Maximum SO_2						Maximum NO_2						Maximum CO						Maximum O_3						Maximum PM10					
	US	JC	GO	MT	TC	FC	US	JC	GO	MT	TC	FC	US	JC	GO	MT	TC	FC	US	JC	GO	MT	TC	FC	US	JC	GO	MT	TC	FC
1996	3.4	4.2	4.4	5.0	4.1	5.7	12.0	11.5	17.8	5.0	11.3	9.0	0.4	0.7	0.6	0.7	0.6	0.4	14.6	17.6	12.5	10.3	15.1	15.6	64.0	63.5	67.9	44.3	54.9	41.0
1997	5.4	4.3	4.4	4.6	5.7	7.0	12.1	11.3	15.2	4.7	10.9	10.4	0.4	0.5	0.6	0.3	0.8	0.5	19.6	19.0	15.0	9.1	18.4	17.1	48.7	53.2	66.4	52.6	14.4	32.1
1998	3.8	5.5	3.2	3.1	3.5	4.0	11.7	11.2	13.6	10.1	10.5	7.5	0.2	0.3	0.7	0.4	0.4	0.5	20.2	21.0	17.6	13.1	17.6	14.4	43.3	49.0	58.9	51.1	32.1	25.4
1999	4.0	6.1	3.5	5.5	2.5	4.3	10.7	9.9	13.8	6.0	10.7	7.9	0.2	0.6	0.6	0.8	0.5	0.4	16.5	21.3	18.7	12.1	14.6	25.3	46.0	47.9	51.7	24.0	41.8	36.1
2000	4.3	4.4	3.7	3.3	4.3	5.9	13.7	11.4	15.4	16.3	11.4	7.3	0.3	0.7	0.7	0.3	0.5	0.3	12.2	19.9	17.7	13.7	17.7	16.8	50.0	43.6	53.8	43.5	44.2	62.2
2001	4.5	3.5	3.7	4.5	4.4	3.5	13.6	11.8	14.0	12.0	10.7	8.9	0.5	0.6	0.7	0.4	0.8	0.4	17.4	17.5	15.8	15.1	20.1	16.8	56.3	38.9	42.9	49.7	60.6	53.5
2002	4.7	3.5	3.4	6.1	3.2	3.4	15.0	11.4	15.6	10.1	10.2	8.6	0.5	0.6	0.8	0.3	0.6	0.3	16.2	17.5	16.8	14.8	15.8	16.1	65.9	43.8	37.3	39.9	70.4	29.0
2003	5.0	3.6	3.1	5.7	2.6	3.5	14.7	11.6	16.5	11.1	10.3	9.0	0.4	0.5	0.5	0.4	0.6	0.3	18.3	17.1	16.5	13.1	16.8	19.3	65.9	37.4	36.8	28.0	43.9	37.5
2004	4.9	3.5	3.4	6.7	3.4	2.4	14.6	12.3	15.5	12.2	11.5	8.4	0.4	0.5	0.5	0.4	0.6	0.3	16.5	20.0	16.4	13.7	17.1	19.4	72.0	40.5	38.3	28.1	44.7	39.3
2005	5.2	3.6	4.2	5.6	3.3	4.1	15.6	13.0	11.7	9.6	10.3	7.0	0.4	0.7	0.5	0.5	0.5	0.3	17.7	21.2	17.5	19.3	16.0	17.2	59.7	33.6	32.2	15.4	44.1	30.7
2006		3.0	3.3	7.6	2.9	3.9		12.3	13.1	14.3	9.4	10.6		0.5	0.5	0.5	0.5	0.3		20.2	17.7	16.9	17.1	18.8		32.6	19.2	26.7	38.9	50.9

Remarks: a plus (+) or minus (-) value is coefficient (b) in regression model: (y = a + bx) ; implying monthly mean increase or decrease rate of mean air quality monitored for each station.

Note :
US = Udom bay fire station
JC = The Sriracha Juvenile Center
GO = Chonburi General Education Office
MT = Map Ta Put Health Center
TC = Rayong Telephone Services Center
FC = Rayong Field Crops Research Center

5. Probable effect of urbanization/ industrialization on Temperature.

To determine relation between urbanization/industrialization and rainfall, temperature, the multiple correlation and regression analysis were applied. The stepwise variable selection was employed in order to determine which variable is being included in the regression equation.

Relationships between monthly temperature (˚C) and urban area (U, Km^2) with industrial area (I, Km^2) expressed as regression equations shown in Table 17-19.

From table 16, regression analysis indicates that industrial area are most significant factor influencing on mean temperature at Rayong station. It could be said that for every 1 Km^2 of increasing industrial area, mean temperature were increased 0.052 ˚C. It was found that industrial area has more influence on mean temperature of than urban area. The mean temperature in dry period increase 0.097 ˚C, if industrial area increase 1 Km^2 and if urban area increase 1 Km^2 mean temperature in dry period decrease 0.1 ˚C.

In the Eastern Coast Basin, industrial area plays more role on mean temperature in dry period (Nov-Apr) than mean temperature over year, but it has influence on maximum temperature. Specially, industrial area in Rayong and Sattahip station showed more influence on maximum temperature and maximum temperature in dry period.

Table 17 Relationships between mean temperature (Tmean) and urban area with industrial area (I) base on data during 1985-2001

Station	Regression equation		R^2
Annual Mean Temperature			
Rayong	Tmean =	27.911+0.052 I	0.438**
ChonBuri	Tmean =	28.147+0.046 I	0.253**
the Eastern Coast Basin	Tmean =	27.558 + 0.014 I	0.297**
Mean temperature in dry period			
Rayong	TDmean =	28.690+0.097 I-0.100U	0.452**
ChonBuri	TDmean =	28.436+0.062 I-0.067 U	0.218**
the Eastern Coast Basin	TDmean =	30.184+0.026 I-0.071 U	0.421**

Remark: 1) Tmean = mean temperature
2) TDmean = mean temperature in dry period (Nov-Apr)
3) ** = statistical significant

In Table 18 indicates that industrial and urban area significantly increase the maximum temperature (Tmax) at Rayong station (0.204˚C and 0.043 ˚C per Km^2 respectively) and Sattahip station (0.117˚C and 0.075 ˚C per Km^2 respectively). Regarding maximum temperature in dry period industrial and urban areas showed the higher degrees of temperature increasing than annual maximum temperature (TDmax) at Rayong station (0.223˚C and 0.021 ˚C per Km^2 respectively) and at Sattahip station (0.136˚C and 0.012 ˚C per Km^2 respectively). In Chonburi and Chanthaburi where I and U are relatively smaller proportion of total provincial area, less degree of maximum temperature changes was found. There was, however, no significantly effect of I and U on Tmin. In addition industrial area and urban area was not influent on minimum temperature.

Table 18 Relationships between maximum temperature (Tmax) and urban area with industrial area base on 1985-2001

Station	Location of Station	Regression equation		R^2
Annual maximum temperature				
Rayong	Urban	Tmax =	30.986+0.204I+0.043U	0.901**
ChonBuri	Urban	Tmax =	32.905+0.004I+0.038U	0.03
Sattahip	Urban	Tmax =	30.867+0.117I+0.075U	0.784**
Chanthaburi	Urban	Tmax =	32.306+0.020I+0.030U	0.118
the Eastern Coast Basin		Tmax =	33.556+0.028I-0.041U	0.606**
Maximum temperature in dry period				
Rayong	Urban	TDmax =	31.318+0.223I+0.021U	0.843**
ChonBuri	Urban	TDmax =	33.658-0.015I+0.004U	0.017
Sattahip	Urban	TDmax =	31.225+0.136I+0.012U	0.648**
Chanthaburi	Urban	TDmax =	32.760+0.031I-0.032U	0.087
the Eastern Coast Basin		TDmax =	34.760+0.032I+0.068U	0.493**

Remark: 1) Tmax = maximum temperature
2) TDmax = maximum temperature in dry period (Nov-Apr)
3) ** = statistical significant

Regression analysis indicated that both parameters applied in the model, industrial area plays most essential role in temperature change. Although, there is change small change on temperature, it implied some interesting impact on the change of temperature due to industrialization and urbanization.

Table 19 Relationships between minimum temperature and urban area with industrial area base on 1985-2001

Station		Regression equation	R^2
Annual minimum temperature			
Rayong	Tmin =	24.928+0.022I-0.011U	0.103
Khlong Yai	Tmin =	25.147+0.116I-0.510U	0.414
ChonBuri	Tmin =	24.990+0.079I-0.069U	0.516
Chanthaburi	Tmin =	23.437+0.026I+0.003U	0.107
the Eastern Coast Basin	Tmin =	25.421+0.025I-0.058U	0.31
Minimum temperature in dry period			
Rayong	TDmin =	23.575+0.051I+0.005U	0.167
Khlong Yai	TDmin =	24.180+0.477I-0.391U	0.079
ChonBuri	TDmin =	24.337+0.124I+0.119U	0.442
Chanthaburi	TDmin =	21.851+0.077I+0.014U	0.269
the Eastern Coast Basin	TDmin =	25.433+0.10I-0.032U	0.271

Remark: 1) Tmin = minimum temperature
2) TDmin = minimum temperature in dry period (Nov-Apr)
3) ** = statistical significant

6. Probable effect of urbanization/ industrialization on Cloud Cover and Rainfall.

In order to determine whether the air quality and aerosols play any role on rainfall amount and distribution relationships between annual cloud cover (AnnCl) and combined factors including urban area (U), industrial area (I), Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), and Particular Matter less than 10 microns (PM10) were analyzed basing on regression analysis. The results for location which the mentioned parameters have been observed are shown in Table 20.

Table 20 Relationships between annual cloud cover (AnnCl) and aerosol parameters base on data during 1985-2001

	$Y = a + bX_1 + cX_2 \ldots + d\,X_n$	R^2	Sig
	Sriracha station		
AnnCl =	58.161 - 0.010 Smax + 0.025 Nmax + 0.037 Amax	0.410	0.711
AnnCl =	123.448 - 3.561 Smean + 0.029 Amean - 3.986 Nmean	0.825	0.037
	Chonburi station		
AnnCl =	75.680 + 0.041 Amax - 0.277 Nmax - 0.061 Smax	0.657	0.239
AnnCl =	37.068 - 0.456 Smean + 0.104 Amean + 0.872 Nmean	0.491	0.560
	Rayong station		
AnnCl =	48.670 + 0.003 Amax + 0.61 Amax + 0.035 Nmax	0.611	0.071
AnnCl =	44.132 + 0.480 Smean + 0.267 Amean + 0.243 Nmean	0.456	0.210

Remark:
AnnCl = Annual cloud cover
Smax = Maximum SO_2
Smean = Mean SO_2
Nmax = Maximum NO_2
Nmean = Mean NO_2
Amax = Maximum Particular Matter less than 10 microns
Amean = Mean Particular Matter less than 10 microns

Table 20 to 21 indicate that mean SO_2, NO_2, PM10 increase the annual cloud cover at Rayong station (0.48 %, 0.243 % and 0.267 % per Km^2 respectively) but Sriracha station and Chonburi station, mean SO_2 decrease cloud cover (3.561 % and 0.456 % per Km^2 respectively). As for aerosols are more influence on cloud cover in wet period especially Sriracha station that mean SO_2 and NO_2 decrease cloud cover (2.517 % and 1.003 % per Km^2 respectively) and Chonburi station that max SO_2 and NO_2 decrease cloud cover (0.043 % and 0.297 % per Km^2 respectively). In addition industrial area and urban area as source release aerosols particular SO_2 and NO_2.

Table 21 Relationships between wet period cloud cover (WetCl) and aerosol parameters base on 1985-2001

	$Y = a + bX_1 + cX_2 \dots + d X_n$	R^2	Sig
	Sriracha station		
WetCl =	72.349 - 0.001 Smax + 0.016 Nmax + 0.047 Amax	0.567	0.41
WetCl =	93.084 - 2.517 Smean + 0.185 Amean - 1.003 Nmean	0.819	0.04
	Chonburi station		
WetCl =	94.851 - 0.043 Smax + 0.034 Amax - 0.297 Nmax	0.768	0.085
WetCl =	42.806 + 2.255 Smean + 0.052 Amean + 1.165 Nmean	0.700	0.171
	Rayong station		
WetCl =	68.450 + 0.003 Smax + 0.051 Amax - 0.012 Nmax	0.42	0.255
WetCl =	64.638 + 0.555 Smean + 0.221Amean - 0.199 Nmean	0.465	0.198

Remark: WetCl = Wet period cloud cover
Smax = Maximum SO_2
Smean = Mean SO_2
Nmax = Maximum NO_2
Nmean = Mean NO_2
Amax = Maximum Particular Matter less than 10 microns
Amean = Mean Particular Matter less than 10 microns

Table 22 Relationships between annual rainfall (AnnR) and aerosol parameters base on 1985-2001

	$Y = a + bX_1 + cX_2 \dots + d X_n$	R^2	Sig
	Sriracha station		
AnnR =	852.071 - 311.683 Smean + 59.711 Amean - 138.805 Nmean	0.657	0.12
AnnR =	2174.064 - 348.637 Smean + 60.197 Amean - 180.990 Nmean - 11.019 Cl	0.658	0.27
AnnR =	1159.252 - 1.606 Smax - 24.777 Nmax + 5.530 Amax + 11.194 Cl	0.355	0.71
	Chonburi station		
AnnR =	705.189 + 19.512 Cl - 0.954 Smax + 3.973 Amax - 12.413 Nmax	0.849	0.19
AnnR =	- 1175.134 + 417.117 Smean + 3.027 Amean - 19.821 Nmean + 18.237 Cl	0.949	0.027
	Rayong station		
AnnR =	-3.295.257 + 93.631 Cl + 0.520 Smax - 4.369 Amax - 4.811 Nmax	0.648	0.284
AnnR =	- 855.500 -101.929 Smean - 14.131 Amean - 92.293 Nmean + 71.061 Cl	0.827	0.079
AnnR =	2208.694 - 50.285 Smean + 3.885 Amean - 70.977 Nmean	0.450	0.355

Remark: AnnR = Annual Rainfall
Smax = Maximum SO_2
Smean = Mean SO_2
Nmax = Maximum NO_2
Nmean = Mean NO_2
Amax = Maximum Particular Matter less than 10 microns
Amean = Mean Particular Matter less than 10 microns

Table 23 Relationships between wet period rainfall (WetR) and aerosol parameters base on 1985-2001

	$Y = a + bX_1 + cX_2 \dots + d X_n$	R^2	Sig
	Sriracha station		
WetR =	1355.637 - 0.263 Smax + 5.168 Amax - 20.613 Nmax	0.358	0.492
WetR =	-6769.892 - 0.605 Smax - 21.872 Nmax - 0.537 Amax + 113.004 Cl	0.569	0.396
WetR =	-4638.828 - 113.977 Smean + 43.839 Amean - 26.205 Nmean + 49.483 Cl	0.663	0.264
WetR =	-412.914 - 222.885 Smean + 51.869 Amean - 43.180 Nmean	0.644	0.133
	Chonburi station		
WetR =	- 902.719 - 10.012 Nmax - 2.409 Smax + 5.839 Amax + 28.999 Cl	0.930	0.050
WetR =	-1007.190 + 9.317Cl + 456.385 Smean + 4.487 Amean - 36.512 Nmean	0.961	0.016
	Rayong station		
WetR =	-3735.074 + 0.192 Smax - 3.114 Amax - 2.060 Nmax + 72.562 Cl	0.512	0.483
WetR =	1290.340 + 0.848 Smax - 0.545 Amax - 2.441Nmax	0.241	0.682
WetR =	- 1673.896 - 102.536 Smean - 14.869 Amean - 76.858 Nmean + 62.542 Cl	0.808	0.097
WetR =	2059.408 - 30.409 Smean + 0.765 Amean - 82.825 Nmean	0.597	0.177

Remark: AnnR = Annual Rainfall
Smax = Maximum SO_2
Smean = Mean SO_2
Nmax = Maximum NO_2
Nmean = Mean NO_2
Amax = Maximum Particular Matter less than 10 microns
Amean = Mean Particular Matter less than 10 microns

In Table 22 to 23 indicate that mean SO_2 and NO_2 decrease rainfall in every stations both annual and wet period. The part of PM 10 that influence on rainfall uncertainly change because it originated from many source such as agriculture, forest fire, factory and sea.

Discussion

Regression analysis indicated that among parameters applied in the model, industrial area plays most essential role in temperature change. Although the small influence on temperature, it implies some interesting impact on the change of temperature.

The results also imply that Urbanization and industrialization in the Eastern Coast Basin influence on temperature and rainfall around urban and industrial areas. Because of the building and the waste of produce process release heat and greenhouse gas to atmosphere.

Aerosols are more influent on cloud cover in wet period especially SO_2 and NO_2 decrease cloud cover affect on rainfall because aerosols cloud contains eight times as many droplets of half the size, twice the surface area, twice the optical depth, and higher reflectivity than the natural cloud. There are several mechanisms by which aerosols can suppress rainfall. Warm rain occurs when liquid cloud droplets fall into each other and coalesce to form much larger droplets. A typical cloud droplet grown from the vapor is about 10 mm in radius. Such particles fall a few centimeters per second and can travel only a few centimeters in dry air before evaporating, which is why we observe clouds suspended in our atmosphere (Owen, 2000). In contrast, a typical raindrop is a few millimeters in size, falls several meters per second, and can fall many kilometers through dry air before evaporating. About 106 cloud droplets must collide and coalesce in order to make a precipitation-sized drop. The rate at which a falling drop sweeps up other drops depends on the fall velocity, cross sectional area, and likelihood that falling particles actually touch and coalesce. Each of these processes varies approximately as the square of the radius for cloud drop-sized particles. In the example shown in the figure on the previous page, the droplets in the unperturbed cloud sweep up about 64 times the volume of air containing other droplets as the ones in the polluted cloud. Consequently, the polluted cloud would be much less likely to rain.

Effects of aerosols on rainfall on the one hand, aerosols are important for cloud formation; on the other hand, aerosols decrease cloud rainfall efficiency (Owen, 2000). Aerosol particles from factories and power plants increase the number of droplets in clouds they pollute, causing clouds to retain their water and not produce rain.

CONCLUSION AND RECOMENDATION

Conclusion

From the results and discussion of this study, the conclusion can be drawn as follow:

1. Urban and industrial area in the Eastern Coast Basin has increased at the rate of 0.1953 and 2.2324 Km^2per year respectively. The proportion of urban in Chanthaburi and Rayong are higher than other provinces

2. Maximum temperature in terms of mean annual maximum temperature and mean maximum temperature in dry period of urban area was higher compared to rural area. As for moving average analysis of mean rainfall in urban stations, it is seen that all station are decreasing trend.

3. Industrial and urban area showed more significant influence5 on maximum temperature and maximum temperature in dry period at Rayong and Sattahip. Because of more induatrialization and urbanization in Rayong and Sattahip. Although the change of small influence on temperature, it implied some interesting impact on the change of temperature.

4. Aerosols are more influent on cloud cover in wet period especially Sriracha station that mean SO_2 and NO_2 decrease cloud cover and Chonburi station that max SO_2 and NO_2 decrease cloud cover. In addition industrial area and urban area as source release aerosols particular SO_2 and NO_2.

5. Mean SO_2 and NO_2 decrease rainfall in every stations both annual and wet period. The part of PM 10 that influent on rainfall uncertainly change because it come from many source such as agriculture, forest fire, factory and sea.

Recommendation

1. The study concerning effect of urbanization and industrialization on hydro-meteorological characteristics require long-term observed data (rainfall, temperature and cloud) in industrial area and other data such as wind direction that pollution (aerosols) spread for in order to obtain ascertain effect of aerosols.

2. Since the data on urban area and industrial area obtained from Office of Agricultural Economics uncertainty. It is thus difficult to study about spatial effect of urbanization and industrialization on temperature and cloudiness. The satellite data is therefore recommended further study.

3. In order to obtain more reasonable relationships among aerosols, urban and industrial areas and hydro-meteorological characteristics (rainfall, temperature, cloudiness, etc.) more hydro-meteorological data and air quality station should be established and distributed to all land-use types.

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APPENDIX

Appendix table 1 Air Quality of Udom Gulf fire station in Lam Cha Bung, Chonburi based on 1996 to 2005.

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			Nitrogendioxide (NO_2) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 8 hour (ppm)			Ozone (O_3) Avg. 1 hour (ppb)			Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	197.1	3.4	0	71	12	0	2	0.4	0	1.4	0.4	0	133	14.6	0	208.4	64	1.2
1997	135.7	5.4	0	57	12.1	0	1.7	0.4	0	1.4	0.4	0	157	19.6	0	169.9	48.7	14
1998	115	3.8	0	122	11.7	0	3.8	0.2	0	1	0.2	0	125	20.2	0	86.8	43.3	15.1
1999	114	4	0	62	10.7	0	1.7	0.2	0	1.2	0.2	0	146	16.5	0	100	46	10.1
2000	165	4.3	0	80	13.7	0	2.3	0.3	0	2.2	0.3	0	90	12.2	0	134.3	50	9.9
2001	131	4.5	0	139	13.6	0	3.6	0.5	0	2.9	0.5	0	121	17.4	0	194.1	56.3	19.6
2002	60	4.7	0	89	15	0	4	0.5	0	1.8	0.5	0	98	16.2	0	160	65.9	17.6
2003	123	5	0	74	14.7	0	2.1	0.4	0	1.7	0.4	0	131.6	18.3	0	162.1	65.9	23.6
2004	125	4.9	0	104	14.6	0	3.1	0.4	0	2	0.4	0	112	16.5	0	204.3	72	16.2
2005	102	5.2	0	77	15.6	0	4.7	0.4	0	2.6	0.4	0	195	17.7	0	173.3	59.7	23.2

Appendix table 2 Air Quality of Municipal youth center station in Srirahchah, Chonburi based on 1996 to 2005.

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			Nitrogendioxide (NO_2) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 8 hour (ppm)			Ozone (O_3) Avg. 1 hour (ppb)			Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	84	4.2	0	56	11.5	0	5	0.7	0	4.8	0.7	0	151	17.6	0	142.6	63.5	25.6
1997	69	4.3	0	65	11.3	0	3.1	0.5	0	2.3	0.5	0	135	19	0	179.2	53.2	21.1
1998	60	5.5	0	84	11.2	0	2.8	0.3	0	1.6	0.3	0	194	21	0	141.5	49	21.3
1999	94	6.1	0	56	9.9	0	5.6	0.6	0	2	0.6	0	183	21.3	0	115.2	47.9	11.2
2000	157	4.4	0	59	11.4	0	8.5	0.7	0	3.1	0.7	0	213	19.9	0	133	43.6	14.4
2001	74	3.5	0	88	11.8	0	5	0.6	0	2	0.6	0	127	17.5	0	140.2	38.9	19.1
2002	65	3.5	0	78	11.4	0	4.4	0.6	0	2.2	0.6	0	121	17.5	0	98.5	43.8	15.7
2003	56	3.6	0	78	11.6	0	2.7	0.5	0	1.9	0.5	0.1	117	17.1	0	117.9	37.4	15.2
2004	94	3.5	0	76	12.3	0	3.2	0.5	0	1.8	0.5	0	139	20	0	116	40.5	13.8
2005	65	3.6	0	69	13	0	3.3	0.7	0	2	0.7	0	139	21.2	0	89.7	33.6	11.5
2006	36	3	0	82	12.3	0	3.2	0.5	0	1.7	0.5	0	146	20.2	0	85	32.6	13.9

Appendix table 3 Air Quality of Elementary Education Bureau station based on 1996 to 2005

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			Nitrogendioxide (NO_2) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 8 hour (ppm)			Ozone (O_3) Avg. 1 hour (ppb)			Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	58	4.4	0	69	17.8	1	4	0.6	0	1.9	0.6	0	122	12.5	0	146.2	67.9	21.9
1997	97	4.4	0	82	15.2	0	11.8	0.6	0	3.1	0.6	0	132	15	0	196.3	66.4	20.7
1998	55	3.2	0	98	13.6	0	7.7	0.7	0	6.1	0.7	0	140	17.6	0	165.9	58.9	24.4
1999	58	3.5	0	92	13.8	0	11.5	0.6	0	4.7	0.6	0	148	18.7	0	163.9	51.7	16.2
2000	30	3.7	0	88	15.4	0	6	0.7	0	5.2	0.7	0	177	17.7	0	140.6	53.8	24.4
2001	45	3.7	0	79	14	0	8.6	0.7	0	2.9	0.7	0	107	15.8	0	128	42.9	19.1
2002	60	3.4	0	89	15.6	0	4	0.8	0	2.5	0.8	0	98	16.8	0	104.1	37.3	14.8
2003	22	3.1	0	89	16.5	0	3.7	0.5	0	2.3	0.5	0	127	16.5	0	108.2	36.8	12.1
2004	39	3.4	0	100	15.5	0	8.4	0.5	0	3.1	0.5	0	131	16.4	0	101.8	38.3	13
2005	104	4.2	0	87	11.7	0	3.5	0.5	0	1.8	0.5	0	116	17.5	0	88.6	32.2	12.8
2006	93	3.3	0	88	13.1	0	4	0.5	0	2.3	0.5	0	120	17.7	0	49.8	19.2	8.8

Appendix table 4 Air Quality of Marbtapud Sanitation in Murng, Rayong based on 1996 to 2005.

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			Nitrogendioxide (NO_2) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 8 hour (ppm)			Ozone (O_3) Avg. 1 hour (ppb)			Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	489	5	0	31	5	0	7	0.7	0	4.5	0.7	0	84.2	10.3	0	126.9	44.3	2.9
1997	54.5	4.6	0	38.8	4.7	0	3.1	0.3	0	3	0.3	0	77.8	9.1	0	155.7	52.6	19.4
1998	53.2	3.1	0	77.2	10.1	0	11.3	0.4	0	10.9	0.4	0	72	13.1	0	149.9	51.1	9.3
1999	46	5.5	0	68	6	0	7	0.8	0	3.2	0.8	0	104.2	12.1	0	55.4	24	10.2
2000	125	3.3	0	167	16.3	0	9	0.3	0	2.3	0.3	0	110	13.7	0	134.8	43.5	11.3
2001	58	4.5	0	151	12	0	2.3	0.4	0	1.8	0.4	0	98	15.1	0	171.7	49.7	12
2002	227	6.1	0	51	10.1	0	2.4	0.3	0	1.5	0.3	0	101	14.8	0	174.8	39.9	14.1
2003	92	5.7	0	93	11.1	0	2.2	0.4	0	1.5	0.4	0	88	13.1	0	82.8	28	13.3
2004	89	6.7	0	74	12.2	0	3.6	0.4	0	1.5	0.4	0	161	13.7	0	77.3	28.1	10
2005	67	5.6	0	60	9.6	0	2.6	0.5	0	1.6	0.5	0	107	19.3	0	42	15.4	8.5
2006	478	7.6	0	72	14.3	1	2.2	0.5	0	1.5	0.5	0	95	16.9	0	77.9	26.7	9.9

Appendix table 5 Air Quality of Telephone Center in Murng, Rayong based on 1996 to 2005.

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			**Nitrogendioxide (NO_2) Avg. 1 hour (ppb)**			**Cabonmonoxide (CO) Avg. 1 hour (ppb)**			**Cabonmonoxide (CO) Avg. 8 hour (ppm)**			**Ozone (O_3) Avg. 1 hour (ppb)**			**Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)**		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	76	4.1	0	83	11.3	0	12.8	0.6	0	9.4	0.6	0	179	15.1	0	176.5	54.9	4
1997	62	5.7	0	64	10.9	0	4.1	0.8	0	2.7	0.8	0	112	18.4	0	31.9	14.4	7.3
1998	89	3.5	0	58	10.5	0	9.1	0.4	0	4.2	0.4	0	104	17.6	0	79	32.1	14.5
1999	57	2.5	0	71	10.7	0	3.4	0.5	0	2	0.5	0	131	14.6	0	133.7	41.8	8.4
2000	71	4.3	0	90	11.4	0	12.7	0.5	0	4.4	0.5	0	131	17.7	0	151.8	44.2	13.7
2001	63	4.4	0	69	10.7	0	6.5	0.8	0	4.7	0.8	0	128	20.1	0	195.2	60.6	14.2
2002	75	3.2	0	59	10.2	0	3.3	0.6	0	1.7	0.6	0	105	15.8	0	188.4	70.4	27.5
2003	77	2.6	0	69	10.3	0	4.3	0.6	0	4	0.6	0	105	16.8	0	141.2	43.9	14.1
2004	65	3.4	0	76	11.5	0	2.9	0.6	0	2	0.6	0	96	17.1	0	162.4	44.7	10.3
2005	175	3.3	0	92	10.3	0	2.4	0.5	0	1.6	0.5	0	88	16	0	163.2	44.1	17.2
2006	73	2.9	0	64	9.4	0	2.4	0.5	0	2.3	0.5	0	98	17.1	0	137	38.9	13.4

Appendix table 5 Air Quality of Telephone Center in Murng, Rayong based on 1996 to 2005.

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			Nitrogendioxide (NO_2) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 8 hour (ppm)			Ozone (O_3) Avg. 1 hour (ppb)			Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	76	4.1	0	83	11.3	0	12.8	0.6	0	9.4	0.6	0	179	15.1	0	176.5	54.9	4
1997	62	5.7	0	64	10.9	0	4.1	0.8	0	2.7	0.8	0	112	18.4	0	31.9	14.4	7.3
1998	89	3.5	0	58	10.5	0	9.1	0.4	0	4.2	0.4	0	104	17.6	0	79	32.1	14.5
1999	57	2.5	0	71	10.7	0	3.4	0.5	0	2	0.5	0	131	14.6	0	133.7	41.8	8.4
2000	71	4.3	0	90	11.4	0	12.7	0.5	0	4.4	0.5	0	131	17.7	0	151.8	44.2	13.7
2001	63	4.4	0	69	10.7	0	6.5	0.8	0	4.7	0.8	0	128	20.1	0	195.2	60.6	14.2
2002	75	3.2	0	59	10.2	0	3.3	0.6	0	1.7	0.6	0	105	15.8	0	188.4	70.4	27.5
2003	77	2.6	0	69	10.3	0	4.3	0.6	0	4	0.6	0	105	16.8	0	141.2	43.9	14.1
2004	65	3.4	0	76	11.5	0	2.9	0.6	0	2	0.6	0	96	17.1	0	162.4	44.7	10.3
2005	175	3.3	0	92	10.3	0	2.4	0.5	0	1.6	0.5	0	88	16	0	163.2	44.1	17.2
2006	73	2.9	0	64	9.4	0	2.4	0.5	0	2.3	0.5	0	98	17.1	0	137	38.9	13.4

Appendix table 6 Air Quality of Corp Research Center in Murng, Rayong based on 1996 to 2005.

	Sulfurdioxide (SO_2) Avg. 1 hour (ppb)			Nitrogendioxide (NO_2) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 1 hour (ppb)			Cabonmonoxide (CO) Avg. 8 hour (ppm)			Ozone (O_3) Avg. 1 hour (ppb)			Minute Dust 10 micron (PM10) Avg. 24 hour (ug/m^3)		
Year	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
1996	131	5.7	0	59	9	0	1.9	0.4	0	1.8	0.4	0	107	15.6	0	139.6	41	11.8
1997	65	7	0	58	10.4	0	3.3	0.5	0	1.8	0.5	0	84	17.1	0	116.4	32.1	10.7
1998	79	4	0	50	7.5	0	2.3	0.5	0	1.6	0.5	0	101	14.4	0	83.8	25.4	11.9
1999	54	4.3	0	44	7.9	0	8.2	0.4	0	2.7	0.4	0	128	25.3	0	83.6	36.1	12.2
2000	125	5.9	0	46	7.3	0	1.7	0.3	0	2.2	0.3	0	114	16.8	0	184.8	62.2	15
2001	80	3.5	0	62	8.9	0	9.4	0.4	0	3.2	0.4	0	112	16.8	0	196.8	53.5	13.3
2002	54	3.4	0	49	8.6	0	1.6	0.3	0	0.9	0.3	0	101	16.1	0	94.3	29	13
2003	67	3.5	0	61	9	0	1.3	0.3	0	1.3	0.3	0	118	19.3	0	143.1	37.5	13.9
2004	104	2.4	0	56	8.4	0	8	0.3	0	1.6	0.3	0	100	19.4	0	123.2	39.3	12.1
2005	66	4.1	0	63	7	0	3.2	0.3	0	1.8	0.3	0	116	17.2	0	103.7	30.7	12.5
2006	63	3.9	0	52	10.6	0	1.5	0.3	0	1.3	0.3	0	123	18.8	0	133.6	50.9	14