HEALTH AND ENVIRONMENTAL IMPACTS FROM THE 1997 ASEAN HAZE IN SOUTHERN THAILAND

Edited by
KANCHANASAK PHONBOON

Environment and Health Program

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HEALTH SYSTEMS RESEARCH INSTITUTE

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FORWARD

Widespread uncontrolled forest fires, which originated from agricultural land clearing, occurred since July 1997 in several major islands of Indonesia, under the abnormally dry conditions from the 1997-98 El Niño/Southern Oscillation (ENSO) episode. The fires sent thick smoke haze across the sky of most countries in the region–Malaysia, Indonesia, Singapore, Brunei, southern Thailand and parts of the Philippines in September 1997. Indonesia and Malaysia had to declare a state of national emergency in the same month.

An increase in number of sick people who required clinic (outpatient) visits or hospital admission was reported from Malaysia, Singapore, and Thailand. The haze was responsible not only for health problems, but visibility as well. Poor visibility was implicated as a factor in the crash of a commercial aircraft in Sumatra, and was blamed for a series of fatal ship collisions in that period.

This report is the results of a multidisciplinary retrospective research to assess the environment and public health impacts from the 1997 haze in the southern provinces of Thailand. The study has been carried out since early 1998. The main objectives aim to evaluate what were occurring in terms of changes in meteorology and air quality conditions, health effects, and their relationship in order to better understand and prepare mitigation measures in the future. Its contents and findings will be of interest and useful at both the policy and action levels for preparedness of control and preventive measures in the future haze.

Environment and Health Program
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1 INTRODUCTION

KANCHANASAK PHONBOON

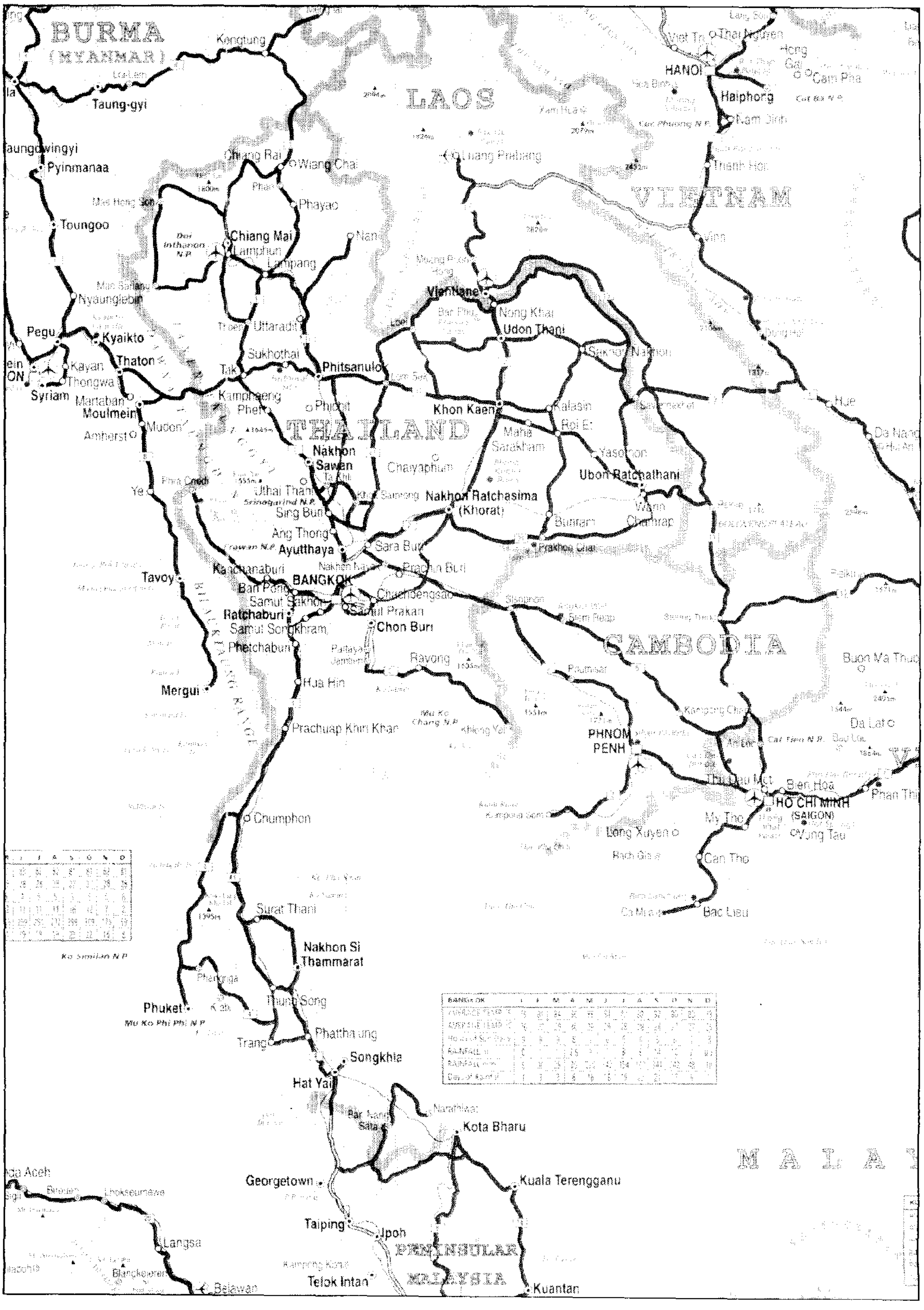
The 1997 Haze

With abnormally dry conditions from the 1997-98 El Niño/Southern Oscillation (ENSO) episode, widespread uncontrolled forest fires (originally as part of land clearing operations) occurred since June 1997 in Irian Jaya, Kalimantan (Borneo), Sulawesi, and Sumatra islands of Indonesia, a country in South-East Asia region (UNECE 1998). Approximate one million hectares were ablaze when most of the fires subsided in November, three months later. From September, the thick haze due to fine particles suspended in the air from smoke and soot had darkened skies across the region-Malaysia, Indonesia, Singapore, Brunei, southern Thailand and parts of the Philippines. Indonesia declared a state of national emergency in September 1997. Malaysia Government declared a state of emergency in Sarawak on Borneo Island on 19 September, and had all private and public offices and schools closed as well as advised people to stay indoors.

The spreading of the smoke to the Malayan peninsular, including the southern Thailand, was helped by the prevailing synoptic scale winds, as indicated by the low-level southerly wind circulation in that period. Transboundary transport of smoke, causing the haze effects to the Malayan peninsular in 1997 was not the first occurrence of this type of episode. Similar phenomenon occurred sporadically in the past (Singapore Meteorological Service 1995).

An increase in number of sick people who required clinic (outpatient) visits or hospital admission was reported from Malaysia, Singapore, and Thailand. More than 20,000 cases were reported from Malaysia, while a surge of 20 percent was found in Singapore, and several thousands cases were estimated to have occurred in Thailand. Most came with upper respiratory symptoms, bronchitis, asthma, conjunctivitis, and eczema. The haze was responsible not only for health problems, but visibility as well, making airlines canceling flights to several airports in the region. Poor visibility was implicated as a factor in the crash of a commercial aircraft in Sumatra on 26 September 1997, that killed all 234 people aboard, and was blamed for a series of fatal

Figure 1-1. Map of Thailand



ship collisions in that period.

Southern Thailand background

Thailand is located in the heart of South-East Asia mainland, covering an area of 513,115 square kilometers (sq km), with the current population of 60.6 million (Figure 1-1) (Office of the Prime Minister 1995, Ministry of Interior 1997). The country consists of 4 natural regions: the North, the Central Plain, the Northeast, and the South or Southern Peninsula. Thailand is a warm and rather humid tropical country. Its climate is monsoonal, marked by a pronounced rainy season lasting from May to September and a relatively dry season for the remainder of the year.

The Southern region occupies the area of 70,715 sq km and 8.6 million populations. Rainfall generally continues until November or December, resulting in higher average annual rainfall (2741 mm with 176 rainy days and 1697 mm with 147 rainy days in the west coast and east coast, respectively), higher relative humidity (80%), and lower average temperature (27.5 C) than the rest of the country. Administratively, the region is divided into 14 provinces; each has its own governor appointed by the central government. Densely populated areas (>200 per sq km) concentrate in the east coast on the gulf of Thailand, in Nakhon Si Thammarat, Songkhla, Pattani, and Narathiwat, except Phuket-a small island province in the west.

Biomass air pollution and health impacts - a worldwide perspective

Body of knowledge on biomass air pollution and health effects comes mainly from researchers in developed countries (Brauer 1998). Extensive studies on wood combustion and wood smoke emission and health impacts were carried out in North America during the 1980s, as the use of wood had become popular for home heating (Larson and Koenig 1994). Several investigators have studied particle composition and size distribution from forest fires in western nations and the Amazon Basin, as well as exposures to biomass air pollution encountered by forest firefighters (Andrae et al 1988, Reinhardt and Ottmar 1997, Rogge et al 1998, Sandberg and Martin 1975, Ward and Hardy 1991). Studies of exposures to biomass emissions during cooking and heating by individuals in developing countries have begun only recently (Brauer et al 1996, Ellegard 1996, Smith and Liu 1993).

Biomass smoke contains a large and diverse number of chemicals, many of which have been associated with adverse health impacts. These include both particulates and gaseous compounds such as carbon monoxide, formaldehyde, acrolein, benzene, nitrogen dioxide, and ozone (Brauer 1998). The transport of biomass burning emissions or haze layers with elevated concentrations gaseous components have been observed. During transport, many of the gaseous species are converted to other gases or into particles. Studies by several investigators indicate that nearly all particles are smaller than 1 μm, with a peak in the distribution between 0.15 and 0.4 μm. These size ranges are consistent with particle formation via condensation (gas to particle) (Larson and Koenig 1994), therefore they can be transported over long distances. Approximately 5-20 percent of wood smoke particulate mass is elemental carbon, but the composition of the organic carbon fraction varies dramatically. Detailed analyses of organic wood smoke aerosol were conducted recently, and nearly 200 distinct organic compounds were measured, including the polycyclic aromtic hydrocarbons (PAHs) (Rogge et al 1998). Inorganic particle composition was studied inside biomass fire plumes from Amazonian forest and African and Brazilian savannas. Particles from savanna fires were enriched in K, P, Cl, Zn, and Br, while tropical forest fire emissions were enriched in Si and Ca (Echalar et al 1995).

Exposure to biomass pollution occurs in many settings (Brauer 1998). The highest concentrations of particles have been measured in forest fires themselves and in indoor air in developing countries where wood and other biomass is used as cooking and heating fuel. In terms of exposure, domestic cooking and heating with biomass clearly presents the highest exposures since individuals are exposed to high levels of smoke on a daily basis for many years. Perez-Padilla and colleagues developed an index of hour-years, analogous to pack-years for smoking history, and the mean hour-years for rural Mexican women who cooked with biomass was 102 (Perez-Padilla et al 1996). Daytime respirable particulate (approximately $PM_{3.5}$) measurements in China were 2,600 $\mu g/m^3$ (Smith and Liu 1993). In Kenya and the Gambia 24-hour respirable particulate measurements were 1,400 and 2,100 $\mu g/m^3$ respectively (Armstrong and Campbell 1991, Wafula et al 1990), while in Guatemala 24-hour PM_{10} measurements were 850 $\mu g/m^3$ (Smith 1993). In rural Mexican homes, Brauer and colleagues found mean PM_{10} levels at 768 $\mu g/m^3$. During cooking periods, the mean $PM_{2.5}$ level was 887 $\mu g/m^3$, while peak (5 minutes) $PM_{2.5}$ concentrations reached 2,000 $\mu g/m^3$ or higher in most of the homes cooking with biomass (Brauer et al 1996). Ellegard reported different levels of particulate exposures during cooking with different fuels, ranging from 1,200 $\mu g/m^3$ for wood users and 540 $\mu g/m^3$ for charcoal users to 200-380 $\mu g/m^3$ for LPG and electricity users in Mozambique. For comparison, the wood exposure group had 69 hour-years of exposure (Ellegard 1996). In North America, communities with wood smoke as a major particulate source had PM_{10} and $PM_{2.5}$ levels as high as 150 $\mu g/m^3$ and 86 $\mu g/m^3$ respectively (Larson and Koenig 1994).

Wildland (forest) firefighters comprise an occupational group with high exposure to biomass smoke. It must be noted that firefighters are normally among the most physically fit in the entire population and do not normally suffer from any pre-existing health conditions (Brauer 1998). Measurements of carboxyhemoglobin in the bush firefighters indicated that health impacts of CO exposure were unlikely to occur (Brotherhood et al 1990). Materna and colleagues measured exposures of firefighters over a three-year period. Mean respirable particulate, CO, and formaldehyde exposures were 1,400 $\mu g/m^3$, 14 ppm, and 0.13 ppm, respectively. Of the 12 specific PAHs detected, all were found at low levels with mean exposures <100 ng/m^3 (Materna et al 1992). Reh and colleagues conducted extensive exposure assessment in combination with a medical evaluation. Respirable particulate levels were 600-1,700 $\mu g/m^3$ and sampling for acid gases detected low levels (Reh et al 1994). Another exposure measurements using personal sampling was conducted on 37 firefighters and found peak (15 minutes) exposures averaged 2,080 $\mu g/m^3$, 14 ppm, 0.018 ppm, 0.117 ppm, and 0.035 ppm for respirable particulates, CO, acrolein, formaldehyde, and benzene, respectively (Reinhardt 1995).

Knowledge of acute and chronic health impacts comes from 3 main sources: experimental and animal toxilology studies, epidemiological studies of non-cancer health risks, and studies of cancer risks (Brauer 1998). This section will focus on health effects in population groups which are exposed to high levels of biomass air pollution-forest firefighters and developing countries exposures. A study in 78 southern California forest firefighters found the mean cross season changes for lung function as follows: -0.5% FEV_1 (force expiratory volume), 0.2% FVC (force vital capacity), and -0.5% FEV_1/FVC ratio. No significant increase in the prevalence of respiratory symptoms was noted cross seasonally (Letts et al 1991). Another study of cross-seasonal changes in pulmonary function and respiratory symptoms in 52 wildland firefighters in northern California observed decline in FEV_1 (-1.2%) and FVC (-0.3%), and a significant increase in most respiratory symptoms evaluated (Rothman et al 1991). In a study of lung function and airway responsiveness of 63 wildland firefighters during a 5-month season of active fire fighting, Liu and colleagues found significant mean individual declines in post-season lung function, compared with preseason values. There was also a significant increase in airway responsiveness (Liu et al 1992). In an attempt to evaluate chronic impacts of firefighting exposure, a recent study compared lung function of wildland firefighters in Sardinia with a control group of policemen. The firefighters (who on average worked during 4-month fire season for 16 years) had significantly lower levels of lung function, after controlling for age, height and smoking (Serra et al 1996). Betchley and colleagues evaluated cross-shift and cross-season respiratory effects among 76 firefighters in the US Pacific Northwest. They found no significant change in respiratory symptoms. However, significant mean individual declines in lung function were observed, although annual lung function changes for a small subset (n=10) indicated reversibility of effect (Betchley et al 1997). These studies clearly indicate an association between forest-fire emissions exposure and acute effects on respiratory health.

A case-control study conducted in Zimbabwe found a significant association between lower respiratory disease and exposure to atmospheric wood smoke pollution in young children. Air sampling within the kitchen of 40 children indicated very high concentrations of respirable particulates, 546-1,998 $\mu g/m^3$. Blood carboxyhemoglobin was determined for 170 of out 244 children confirming that they did experience smoke inhalation (Collings et al 1990). In a study in Colombia, univariate analysis showed that tobacco use (odds ratio, OR=2.22, $p<0.01$), wood use for cooking (OR=3.43, $p<0.001$), and passive smoking (OR=2.05, $p=0.01$) were associated with obstructive airways disease. The adjusted odds ratio for obstructive airways disease and wood use was 3.92 (controlling for smoking, gasoline and passive smoke exposure, age and hospital) (Dennis et al 1996). In the study in Mozambique, Ellegard found wood users who exposed to higher levels of particulate pollution had significantly more cough symptoms than other groups. There was no difference in cough symptoms between charcoal users and users of modern fuels (Ellegard 1996). A recent case-control study of Mexican women reported an increased risk of chronic bronchitis and obstructive airways disease associated with cooking with wood. Crude odds ratio for chronic bronchitis and obstructive airways disease with wood smoke exposure were 3.9 and 9.7, respectively. Adjusted odds ratio ranged from 1.6-8.3 for chronic bronchitis and 1.1-2.0 for obstructive airways disease (Perez-Padilla et al 1996). During the 1994 haze episode in South-East Asia, Chew and colleagues studied emergency room visits for asthma in Singapore. They found an association between PM_{10}, which was 20 percent higher than the annual average, and visits for childhood asthma (Chew et al 1995). These studies in developing countries indicate that biomass smoke exposure is associated with both acute respiratory illness in children and the development of chronic lung disease in adults (Brauer 1998).

Extensive epidemiologic studies of health effects from wood and other biomass smoke have been carried out in developed countries, especially in North America. Several early studies focused on the presence of a wood burning stove in the home as a risk factor (Brauer 1998, Larson and Koenig 1994). In a review of respiratory effects of exposure to wood smoke by Larson and Koenig covering 10 studies from 1984-1993, they found a coherence of data reporting increased respiratory symptoms, lower respiratory infection, and decreased pulmonary function as a result of exposure to wood smoke. Duclos and colleagues evaluated the impact of a number of large forest fires in California on emergency room visits. PM_{10} concentrations as high as 237 $\mu g/m^3$ were measured. During the approximately 2 1/2 week period of the fires, asthma and chronic obstructive pulmonary disease visits increased by 40 and 30 percent, respectively (Duclos et al 1990). Two studies have been conducted regarding asthma emergency room visits and PM_{10} levels associated with the 1994 bushfires in Sydney, Australia (Copper et al 1994, Smith et al 1996). Neither detected any association during this 1994 episode in Sydney, where PM_{10} levels were elevated for a 7-day period with maximum hourly values of approximately 250 $\mu g/m^3$. In the only study to date to evaluate impacts of wood burning on adult asthma, Ostro and colleagues measured symptoms in a panel of 164 asthmatics. Exposure to indoor combustion sources, including wood stoves was associated with increased asthma exacerbation (Ostro et al 1994). A case-control study conducted among Navajo children evaluated the association between wood smoke exposure and acute lower respiratory illness (ALRI). Matched pair analysis revealed an increase risk of ALRI for children living in households that cooked with any wood or had indoor particle concentrations 65 $\mu g/m^3$ (Robin et al 1996). Two time-series studies have been conducted in Santa Clara County, California, an area in which wood smoke is the single largest contributor to winter PM_{10}, accounting for approximately 45 percent of total. The first study indicated an association between relatively low PM_{10} levels and increased daily mortality (Fairley 1990). A recent study of asthma emergency room visits in Santa Clara County and winter PM_{10} found a consistent relationship, a 10 $\mu g/m^3$ increase in PM_{10} was associated with a 2-6 percent increase in asthma emergency room visits (Lipsett et al 1997). In another recent study, 428 moderate to severe airways obstruction subjects were surveyed for their respiratory symptoms during a 2-week period of exposure to combustion products of agricultural burning (straw and stubble). During the exposure period, 24-hour average PM_{10} levels increased from 15-40 to 80-110 $\mu g/m^3$. While 37 percent of subjects were not bother by smoke at all, 42 percent reported that symptoms developed or became worse due to the air pollution episode, and 20 percent reported that they had breathing trouble. Subjects with asthma and chronic bronchitis were also more likely affected (Long et al 1998). These epidemiologic studies of indoor and community exposure to biomass smoke indicates a consistent relationship between exposure and increased respiratory symptoms, increased risk of respiratory illness and decreased lung function.

Background on air pollution and health research in Thailand

Air pollution and health research in Thailand using modern study design and methodology has just begun in the last few years under the support of the World Bank (Hagler Bailly 1997, Radian International 1997). These researches are intended to assist policy-makers in setting priorities among many competing environmental and public health issues. Specifically, they try to answer whether particulate matter health effects are occurring in Thailand as have been observed in other cities worldwide, as well as to present options for the government's action plan in reducing air pollution from particulate matter in Bangkok.

Although confronting with data problems and limitations, the Hagler Bailly study is the first attempt to quantitatively evaluate health effects and characterize certain exposure aspects to particulate matter of Bangkok population. The indoor-outdoor relationships results suggest that indoor PM_{10} concentrations where there is no air conditioning and where some indoor sources, such as cigarette smoke of charcoal, are present are as high or higher than those measured outdoors. In locations where there is some air conditioning and no notable indoor sources, indoor concentrations are between 50% and 100% of outdoors (Table 1-1). Its time-series study of mortality suggests that a 30 $\mu g/m^3$ increase in PM_{10} in Bangkok is associated with a 3% increase in daily mortality, or between 1,000 to 2,000 premature deaths each year. Its similar study for hospital admissions indicates a 30 $\mu g/m^3$ change in PM_{10} is associated with 18% and 11% increase in respiratory admissions for elderly and all-age patients, respectively. In addition, a diary study of acute daily respiratory symptoms shows an association of a 30 $\mu g/m^3$ increase in PM_{10} with a 19% increase in lower respiratory symptoms in adult with higher exposures (Table 1-2).

Table 1-1. Indoor-outdoor relationships of $PM_{2.5}/PM_{10}$ levels in no-air conditioning and air-conditioning locations

	Indoors	
	no-air conditioning	air-conditioning
Outdoor	100% or higher	50-100%

Table 1-2. Percent change in mortality and morbidity per 30 $\mu g/m^3$ increase in PM_{10}

(a) Mortality

	Natural	**Respiratory**	**Cardiovascular**	**Elderly**
Bangkok, Thailand	3.0	16.4	4.3	3.3
Philadelphia, USA	3.6	10.2	5.2	5.2
Santiago, Chile	3.0	3.9	2.4	2.7

(b) Daily admissions

	All-age respiratory	**Elderly respiratory**	**All-age cardiovascular**	**Elderly cardiovascular**
Bangkok, Thailand	11.0	17.6	5.3	7.6
Detroit, USA	-	4.7	-	2.1
Toronto, Canada	13.2	-	1.1	1.1

Table 1-2. (cont.)

(c) Daily symptoms

	Adult upper respiratory	Adult lower respiratory	Children upper respiratory	Children lower respiratory
Bangkok, Thailand	26	19	12	13
Los Angeles, USA	NS	23	-	-
Provo, USA	-	-	11	16

Based on the chemical analysis of ambient and source samples and chemical mass balance receptor model, the Radian International study indicates that mobile source emissions and reentrained road dust account for majority of PM_{10} levels in Bangkok (Table 1-3). The source samples cover construction site, power plants, steel mills, road dust, motorcycles, light-duty diesel vehicles, and heavy-duty diesel vehicles (Table 1-4). The study has developed and compiled comprehensive emission and activity factors for the major emissions sources in the area. Then, air dispersion modeling is employed in the process of evaluating alternative control measures for their effectiveness in improving air quality. Finally, it has recommended several cost-effective control measures for each major source category. For example, a complete changeover from 2-stroke to 4-stroke motorcycles, improving fuel quality such as use of natural gas for all city buses, effective inspection and maintenance program, truck bed covers, chemical spray on unpaved and construction areas, and vacuum street sweeping are suggested (Table 1-5).

Table 1-3. Particulate matter emissions inventory for Bangkok (tons per year)

Source	1996		2000		2005	
	TSP	PM_{10}	TSP	PM_{10}	TSP	PM_{10}
Power plants	9,888	7,191	9,888	7,191	9,888	7,191
Industrial/ commercial boilers	21,064	18,115	21,064	18,115	21,064	18,115
Reentrainment	106,012	20,387	98,649	18,971	80,267	15,436
Construction	9,129	1,756	9,881	1,900	10,696	2,057
Mobile sources	14,043	14,043	13,319	13,319	10,145	10,145
Total	141,178	61,492	152,801	59,497	132,060	52,944

Table 1-4. Chemical analysis of particulate matter from selected sites in Bangkok

Parameter	Steel mill	EGAT North Power Plant	Construction zone soil Rama IV	Road dust Odean Circle
Carbon (mg/gm)				
Elemental	44	NM [1]	5	17
Organic	51	NM	87	126
Total	95	NM	92	153
Ionic Species (g/gm)				
Ammonium	1,560	177	6	16
Chloride	13,250	452	467	1,640
Nitrate	6,280	<25	69	<2
Sulfate	22,400	353,000	2,390	2,490
Elements (g/gm)				
Aluminum	4,700	253	107,000	75,800
Arsenic	ND [2]	39	41	33
Barium	333	146	314	369
Bromine	114	ND	6	17
Calcium	31,300	617	162,000	217,000
Chlorine	8,150	ND	625	3,750
Chromium	431	95	116	171
Copper	1,060	18	117	530
Iron	157,000	1,230	43,700	39,900
Lead	4,480	9	72	356
Manganese	6,060	27	1,000	790
Nickel	332	5,480	29	34
Phosphorus	16	ND	528	1,190
Potassium	4,530	96	15,600	16,800
Silicon	19,200	1,040	258,000	207,000
Sulfur	1,980	29,200	2,880	5,290
Titanium	795	3	3,520	3,130
Vanadium	68	10,700	143	102
Zinc	39,100	31	252	1,560

[1] NM = Not measured (concentration of oil residues on the filter from the oil-fired power plant stack exceeded the range of carbon analyzer)
[2] ND = Not detected

Table 1-5. Maximum control scenario and hot-spot impacts (PM_{10} in $\mu g/m^3$) for Bangkok, 1996-2005

Category	Annual 1996	Ambient 2000	level 2005	24-hour 1996	ambient 2000	level 2005
Power plants	<1	<1	<1	<1	<1	<1
Industrial boilers	0.2	0.2	0.2	0.3	0.3	0.3
Reentrainment	21.6	20.1	16.4	64.4	60.0	48.8
Construction	6.9	7.5	8.1	20.7	22.4	24.2
Mobile	28.6	17.2	11.2	85.2	51.2	33.5
Total	57.3	45.0	35.9	170.8	133.9	106.9

Research on health and environmental impacts from the 1997 Haze

A multidisciplinary retrospective research to assess the environment and public health impacts from the 1997 haze in the southern provinces of Thailand has been carried out since early 1998. The main objectives aim to evaluate what were occurring in terms of changes in meteorology and air quality conditions, health effects, and their relationship in order to better understand and prepare mitigation and preventive measures in the future. This preliminary project is expected to be groundwork for more thorough study of health effects and other aspects in the future.

For the purpose of health and environmental impacts study, three types of data in 14 southern provinces during 1996-1997 were collected and analyzed: meteorology including visibility, air quality, and illness and death or morbidity and mortality. The focus is on the identification of changes in air quality and meteorological conditions, and the related impacts on morbidity and mortality during the haze event.

The scope of this book

After this introduction, the following chapters will describe related information on forest fires and forest management in Thailand, the findings on health and environmental impacts from the 1997 haze in southern Thailand, and activities carried out in response to the 1997 haze event and after.

The haze from Indonesian forest fires has provided a good impetus for us to look back at our own forest situation and the potential to cause similar problems from this source. Chapter 2 discusses the current status of forest resources in Thailand, the problems of forest fires and their impacts, and both national and local attempts to prevent and control of forest fires in the context of sound forest management.

In the following chapters, we describe the findings from the retrospective study on health and environmental impacts from the 1997 haze in southern Thailand. Data collection and analyses involved local meteorological conditions, air quality monitoring, and health data in terms of out-patient visits and admissions, that have been recorded in southern provinces of Thailand. In Chapter 3 we provide background on meteorological observation network in the area and discuss the changes in meteorological conditions during the haze, compared with background data during the past 2 years. Chapter 4 discusses air quality monitoring network in the south and describes changes observed during the haze, compared with rather clean background levels during the past 2 years. In Chapter 5 we describe, using simple statistical models, health impacts and observed health effects from the 1997 haze episode in southern Thailand.

In the final section, Chapter 6 reviews situation and activities carried out in response to the haze event in Thailand during late September-October 1997 and after. Looking back, we can learn much from the past experience and mistakes in the haze event. Chapter 7 summarizes the book and discusses various actions and policy issues and questions that are raised by the data presented in earlier chapters.

2 FOREST FIRES AND FOREST MANAGEMENT IN THAILAND

NIPON TANGTHAM

Introduction

Forest fire has been recognized as a part of driving factor effecting ecological change in all types of forest in Thailand. It has been reported that forest fires in Thailand occur annually during the dry season from December to May and peaking in March. So far it is considered as a part of abiotic factor and a major one in maintaining dry-dipterocarp forest condition. It recently damages, however, not only ecosystem function of the forest and living condition of the people farming and living nearby but also wildlife and fauna in soil. This chapter intends to provide a brief information on (1) type of forests, extent, diversity and their distribution in Thailand, (2) trends and causes of deforestation, (3) rate of reforestation and afforestation, (4) forest fires in Thailand and its impact, and (5) prevention and control of forest fire in the context of sound forest management.

Types of forests, extent, diversity and distribution

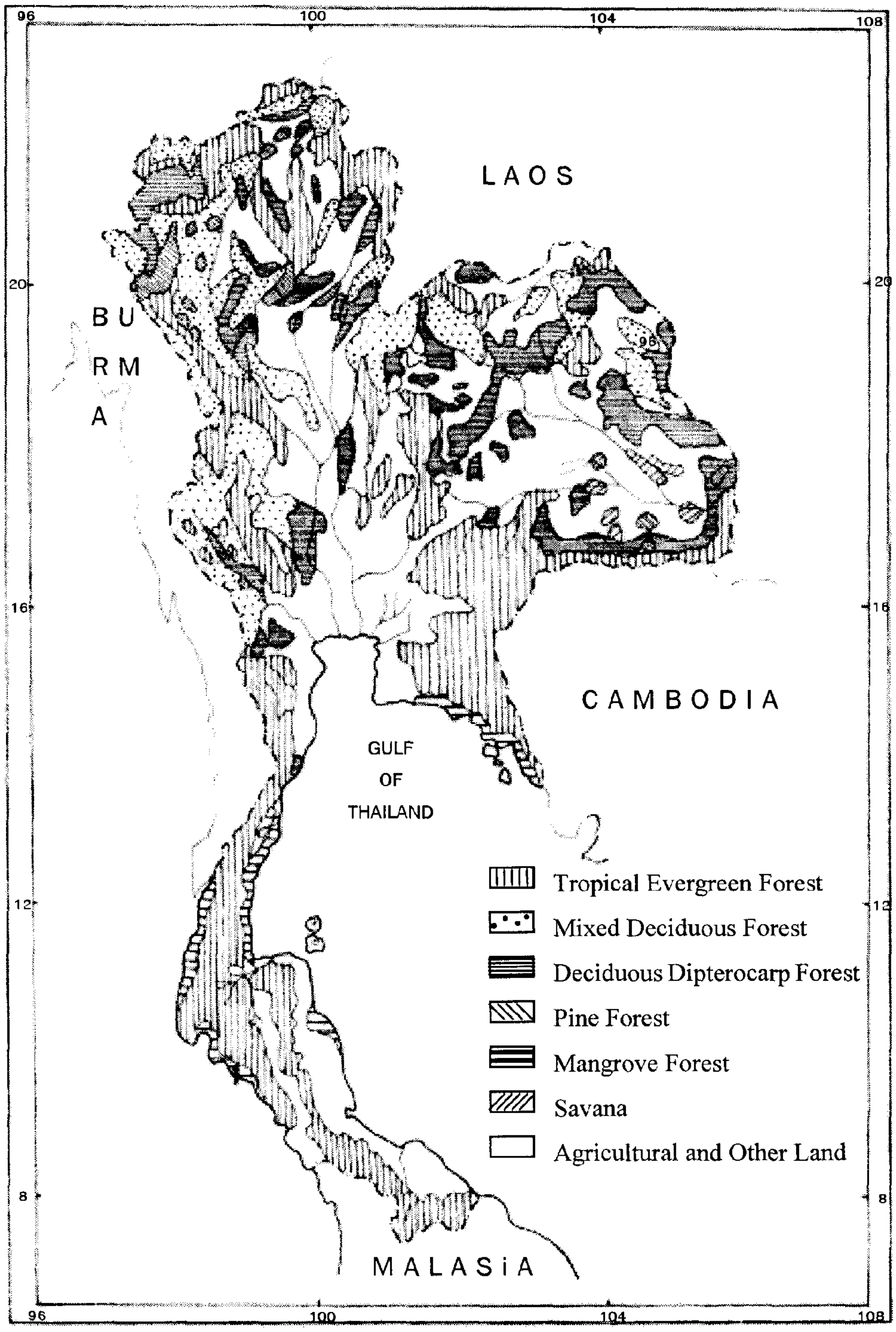
According to Smitinand (1997) and Munkorndin and Eadkeo (1998), the forest in Thailand can be defined into two main categories, the *Evergreen* and the *Deciduous*. Distribution of some important types are shown in Figure 2-1.

The Evergreen Forest

The Evergreen forests forms about 60 percent of the total forest areas. It can be subdivided into four types: the Tropical Evergreen, the Coniferous, the Swamp, and the Beach forest.

1) Tropical Evergreen Forests. This type of forests occurs along the wet belt of the country, where high amount of rainfall, 1500 millimeters (mm) and up, is prevailing; and is affected by the monsoon. They are scattered all over the country either on the peneplains or the mountains. The Tropical

Figure 2-1. Forest types and distribution of Thailand.



Source: FAC (1972)

Evergreen forest is further divided into three categories as follows:

a. Tropical Rain forests.
b. Dry or *Semi-evergreen forest.*
c. Hill or *Lower Montane forests.*

The *Tropical Rain forest* prevails in the Chanthaburi or Southeastern and Peninsular regions where contact to the monsoon is direct; the precipitation is very high (2500 mm and up). The principal trees in the lower zone, up to 600 meter (m) altitude, are mostly of *Dipterocarps*, while the upper zone, 600-900 m altitude, is mainly of oaks and chestnuts.

The *Dry* or *Semi-evergreen forest* is scattered all over the country along the depressions on the peneplain, along the valleys of low hill ranges of about 500 m elevation, or forming galleries along streams and rivulets. The annual precipitation is between 1000-2000 mm. Principal trees of this type are, for examples, *Anisoptera, Dipterocarpus, Hopea, Tetrameles, Afzelia,* and *Lagerstroemia* spp.

The *Hill Evergreen forest* confines in the upper elevation from 1000 m upwards and scatters all over the country with larger percentage in the Northwestern Highland. This type of forest is known under other names such as *Temperate Evergreen forest* or *Lower Montane* by some authors. The dominant tree species are members of the oaks and chestnuts.

2) The Coniferous Forest. This type of forests is scattered in small pockets in the Northwest Highland and the Korat Plateau of about 200-1300 m elevation, poor acid soil occurs. The annual rainfall is about 1000-1500 mm. The composition of the forest consists of only few tree species, which pines *(Pinus kesiya* and *P. merkusii)* are predominant.

3) The Swamp Forest. The estuaries and the muddy seashores form a unique type of forest. The Swamp Forest is more or less subject to occasional inundation, and is scattered in the wet region of the country where the annual precipitation is high (2000 mm up). The forest can be further physiographically classified into two kinds: the *Fresh Water Swamp* forest and the *Mangrove Swamp* forest. The Fresh Water Swamp forest is composed of trees in *Dyera, Palaquium, Melanorrhoea and Scaphium* spp. The Mangrove Swamp forest is found where soils are deep alluvial deposit with high content of salinity and usually predominated by *Rhizophora* S1DP.

4) The Beach Forest. Small strips or patches of Beach forests occur on the sand dunes, rocky seashores and elevated seacoasts along the coastlines. *Casuarina-equisetifolia* is predominant on sand dunes, forming a pure stand.

The Deciduous Forest

Along the dry belt of the country, where precipitation is low (under 1000 mm) the climate is more seasonal, and the soil is either sandy or gravely loam and sometimes lateritic, the vegetation of these regions are classified as deciduous formation. The species of this type shed their leaves during the dry season and tend to develop growth or annual rings but usually false rings due to variations of rainfall almost all year round. Deciduous forests can be subdivided into three main categories: the *Mixed Deciduous*, the *Dry Deciduous Dipterocarp* and the *Savanna* forests.

1) Mixed Deciduous Forest. The composition of this type of forest is composed of all deciduous species in a good proportion; but in certain localities a species may become predominant such as teak (*Tectona grandis*) and is generally called a teak forest for convenience. The Mixed Deciduous forest can be further classified into three kinds, based on the terrain and climatic factors: the *Moist Upper Mixed Deciduous*, the *Dry Upper Mixed Deciduous*, and the *Lower Mixed Deciduous*.

The Moist Upper Mixed Deciduous forest occurs between the elevations of 300-600 m altitude. The soil bearing this type of forest is usually loamy, either calcareous or granitic. The important tree species are, for example, *Tectona grandis, Laqerstroemia, Terminalia, Afzelia, Xylia, Pterocarpus,* and *Dalbergia* spp., most of which are high value commercial species.

Along the ridges at the elevations of 300-500 m altitude, the forest type changes into a more open nature-due to the evaporation, surface erosion and leaching of organic components of the soil-to the Dry Upper Mixed Deciduous forest. Species occurring in the former type are also present but become rather stunted and crooked, also more pronounced deciduous species such as *Shorea, Pentacme,* and *Dipterocarpus* are scattered all over.

On the low-lying country at the elevation of 50-300 altitude in the dry zone, where the soil is colluvial of either sandy loam or lateritic, the Lower Mixed deciduous forest is thrived. The absence of teak from the upper storey is a distinct characteristic and serving as a criterion to differentiate from the Upper Mixed Deciduous.

2) The Dry Deciduous Dipterocarp Forest. This type of forest occurs on the undulating peneplain and ridged, where the soil is either sandy or lateritic, and subject to extremely leaching, erosion, and annual burning. Some important trees consist of *Dipterocarpus, Shorea* and *Pentacme* spp.

3) The Savanna Forest. Savanna can be regarded as the extreme form of deciduous types, and has been originated by subsequent burning. It is more frequent in the Northeastern region where cultivation has been practiced from time immemorial. Precipitation is relatively low (50-500 mm). The Savanna forest is in essence, a grassland where trees of medium height sparsely grow, forming a very open stand with some thorny shrubs, and *Bambusa arundinacea* are interspersing.

Distribution of forest area

The distribution of forest area by type and region in 1982 was recently reported by Data Center (1997) (Table 2-1). Table 2-2 is presented in Thai Forestry Sector Master Plan (TFSMP Core Team, 1993b) where the figures are results of an RFD study and were determined study form a forest type map, which was drawn by overlaying the 1982 forest type on the 1988 forest cover map. Adjustment were made by TFSMP on the original area calculation to obtain the total forest cover by region as reported in Table 2-1.

The distribution show in Figure 2-1 is drawn based on geographic, soil, climatic and altitude factors favored by each type of forest. Up to 1988, information from RFD (TFSMP core Team, 1993a) implies that about 43.6, 21.8, 31.2, 1.4, 1.4 and 0.6 percent existed as tropical evergreen forest, mixed deciduous forest, dry dipterocarp forest, mangrove forest, pine forest, scrub forest respectively. The most recent figures for each type of forest are not made available yet.

Table 2-1. Forest Area of Thailand by Type and Region in 1982

Type of Forest	Region										Total	
	North		North-east		East		Central		South			
	sq.km.	%	sq.km.	%	sq.km	%	sq.km.	%	sq.km.	%	sq.km.	%
1. Tropical evergreen forest	25,568	29.14	9,305	35.95	6,216	77.70	12,449	67.23	14,323	87.11	67,861	43.33
2. Mixed deciduous forest	25,006	28.49	2,618	10.11	1,113	13.91	5,192	28.04	0	0.00	33,929	21.67
3. Dry dipterocarp forest	34,318	39.11	13,819	53.38	253	3.16	540	2.92	0	0.00	48,930	31.25
4. Mangrove forest	0	0.00	0	0.00	418	5.23	335	1.81	2119	12.89	2,872	1.83
5. Pine forest	2,018	2.30	144	0.56	0	0.00	0	0.00	0	0.00	2,162	1.38
6. Scrub forest	846	0.96	0	0.000	0	0.00	0	0.00	0	0.00	846	0.54
7. Para-rubber plantation area	0		0		(650)		0		(15,200)		(15,850)	-
Total	87,756	56.04	25,886	16.53	8,000	5.11	18,516	11.82	16,442	10.50	156,160	100

Note: Excluding the Para-rubber plantation area

Source: Data Center (1997)

Table 2-2. Area by forest type, stand volume, * and stand density, in 1988

	North	Northeast	Central	South	Thailand	%
Forest type	**50.25**	**14.81**	**15.67**	**9.14**	**89.88**	**100**
Tropical evergreen	14.34	5.34	11.45	8.09	39.22	43.60
Mixed deciduous	13.95	1.73	3.94	0.00	19.62	21.80
Dry dipterocarp	20.33	7.61	0.11	0.00	28.05	31.20
Pine	1.13	0.12	0.00	0.00	1.25	1.40
Mangrove	0.00	0.00	0.17	1.05	1.22	1.40
Scrub	0.50	0.00	0.00	0.00	0.50	0.60
Stand volume. '000 m^3						
Hoppus volume	249.6	48.3	40.0	73.2	411.1	
Stem volume	549.2	106.2	88.0	161.0	904.4	
Density. m^3/rai						
Hoppus volume	5.0	3.3	2.6	8.0	4.6	
Stem volume	10.9	7.2	5.6	17.6	10.1	
Density. m^3/ha						
Hoppus volume	31.0	20.4	15.9	50.0	28.6	
Stem volume	68.3	44.8	35.1	110.1	62.9	

"Hoppus volume" and "stand volume". See text and endnootes.

Source: TFSMP Core Team (1993a)

Deforestation in Thailand

Based on the Thai Forestry Sector Master Plan (TFSMP Core Team, 1993a), history of deforestation in Thailand can be summarized as follows.

Historical perspectives of forest exploitation and conservation

Thai forestry has undergone three stages of exploitation and a young stage of conservation :

1) ***Early exploitation stage.*** This stage lasted from the mid-1890 to the early 1930s. Logging for commercial purposed started before establishing the Royal Forest Department in 1896 and continued until the third stage.

2) ***Forest exploitation and management stage.*** This period lasted from the 1930s to the early 1960s. Logging became an important economy building activity. RFD attempted to put forest exploitation under management by enacting important forestry laws. The Forest Industrial Organization (FIO) was established.

3) ***Forest exploitation peak and decline stage.*** This period could be set from 1960s to the mid 1980s. Logging peak, export-oriented agriculture expanded, and the national economic development gained momentum. Large portion of the remaining forest had been lost but a growing awareness of the

link between the forest and national well-being emerged. Desperate measures were introduced to rationalizes forest management, but were unsuccessful.

4) The dawning of conservation stage. After a long exploitation period. The country entered the fourth stage which can be characterized by the people is high developed awareness of the adverse effects of deforestation. The forest had declined to a point where the nation had to decide that what the remains of the forests must be kept for conservation rather than for further exploitation. It could be said that this period started from the late 1980s.

Decline of forest resources

In the last 30 years, the average annual deforestation rate had been about 2.85 million rai (625 rai = 1sq km, 6.25 rai = 1 hectare), and the forest was reduced by about half. Deforestation peaked in mid-1970s, when the annual loss was about 4.85 million rai. The historical pattern of deforestation was shown in Table 2-3 and Table 2-4.

Causes of deforestation

Factors contributing to deforestation in Thailand are fairly extensive and complex, extending from population growth to expanding agricultural production for export. A study of deforestation in several North-eastern provinces cited population density, price of wood, poverty in terms of real provincial GDP, road density, rice yield, and distance from the market as central factors contributing to deforestation. (Panayotou and Sungsuwan, 1989). A similar study in the same region cited poverty in terms of real GDP per capita, population growth, and the real price of cassava as the main causes. (Tongpan, et.al. 1990). Yet another study showed that the demand for agricultural land, which helps to explain the conversion of forest to agriculture, is positively related to the price of main crops and the numbers of the farm population, and negatively related to agricultural productivity and degree of industrialisation. (Panayotou and Parasuk, 1990)

Table 2-3. Decline of forest area in Thailand during 1961 to 1995

Year	Country	Remaining forest area, million rai and (%)				
		North	Northeast	East	Central & West	South
1961	171.02	72.67	44.32	13.23	22.24	18.52
	(53.33)	(68.54)	(41.94)	(57.98)	(52.92)	(41.89)
1973	138.58	70.67	31.68	9.400	14.98	11.52
	(43.21)	(66.96)	(30.01)	(41.19)	(35.56)	(26.07)
1976	124.01	63.95	25.93	7.89	13.64	12.59
	(38.67)	(60.32)	(24.57)	(34.60)	(32.38)	(28.48)
1978	109.52	59.34	19.51	6.90	12.77	11.00
	(34.15)	(55.96)	(18.49)	(30.24)	(30.31)	(24.89)
1982	97.87	54.85	16.18	5.00	11.57	10.28
	(30.52)	(51.73)	(15.33)	(21.92)	(27.47)	(23.25)
1985	94.29	52.58	15.98	4.99	11.05	9.68
	(29.04)	(49.59)	(15.15)	(21.89)	(26.24)	(21.90)
1988	89.88	50.25	14.81	4.89	10.78	9.14
	(28.03)	(47.39)	(14.03)	(21.46)	(25.59)	(20.69)
1991	86.44	48.21	13.62	4.81	10.38	8.40
	(26.64)	(45.47)	(12.91)	(21.07)	(24.65)	(19.02)
1993	83.47	47.02	13.42	4.77	10.25	8.00
	(26.03)	(44.35)	(12.72)	(20.91)	(24.34)	(18.11)
1995	82.18	46.18	13.29	4.74	10.18	7.78
	(25.62)	(43.55)	(12.59)	(20.88)	(24.17)	(17.61)

Note: 625 rai = 1 sq km or 6.25 rai = 1 hectare
Source: Charupat (1997)

Table 2-4. Rate of forest depletion in Thailand during 1961 to 1995

Period	Rate of depletion (rai)	
	Between period	Annual average
1961 - 1973 (12 yr.)	32,439,687	2,703,307.25
1973 - 1976 (3 yr.)	14,567,500	4,855,833.33
1976 - 1978 (2 yr.)	14,495,625	7,247,812.50
1978 - 1982 (4 yr.)	11,640,000	2,910,000.00
1982 - 1985 (3 yr.)	3,583,651	1,994,550.33
1985 - 1988 (3 yr.)	4,414,167	1,471,389.00
1988 - 1989 (1 yr.)	241,557	241,557.00
1989 - 1991 (2 yr.)	4,199,341	2,099,670.50
1991 - 1993 (2 yr.)	1,965,317	992,658.50
1993 - 1995 (2 yr.)	1,292,806	46,403.00
1961 - 1995 (34 yr.)	88,839,651	2,612,930.91

Source: Charuput (1997)

It was stated by TFSMP Core Team (1993a) that the two main underlying causes of deforestation in Thailand have been the increasing demand for land for agriculture to meet the needs of the growing population, and commercial logging. Demand for land depends on land prices, agricultural productivity, prices of agricultural produce, alternative sources of off-farm employment and income and population growth. The intensity of logging, whether legal or illegal, is influenced by wood demand and prices, forest accessibility, and population growth. The effects of these factors are probably as follows:

- *Land prices.* There are no proper markets or market prices for forestland since it belongs to the state, but nevertheless land speculation is common close to growth centres. The implicit price of forest land is determined by the cost of clearing and transport, which the farmer would incur as long as the marginal cost is lower than the marginal benefits obtained from both the forest and the farm produce.

- *Land productivity.* As land productivity increases, the demand for land increases as farmers try to maximise profits. However, subsistence farmers need less land to meet basic food requirements. Conversely, if land productivity decreases, subsistence farmers need more land to support themselves, while profit-oriented farmers have less incentive to invest in new land. The aggregate of land productivity therefore depends on the proportion of subsistence farmers to commercial or profit-oriented farmers.

- *Crop prices.* Higher crop prices make it profitable to clear new land, some of which may have been economically inaccessible in the past. For commercial farmers the effect of crop prices is similar to the effect of land productivity. Most of the agricultural expansion made possible by clearing forests has been aimed at increasing the production of upland cash crops.

- *Off-farm employment and income.* Industrialisation of the economy provides alternative income-earning opportunities and reduces the demand for land. In an open, diversified cash economy, food can always be purchased and exchanged for other goods that are being produced.

- *Forest accessibility.* The accessibility of the forest affects both logging and land clearing through the profit maximising behaviour of the logger and the farmer. The most easily accessible forest is logged or cleared first, and as time goes on, the remaining forest may simply become more and more economically inaccessible. This slows down deforestation, whereas the opening of new roads in connection with logging or infrastructure building increases the demand for new land.

- *Wood demand* and prices. High demand for tropical hardwood for industrial or indigenous consumption and high wood prices are likely causes of deforestation. However, the areas harvested officially were not large enough to explain the high rate of deforestation, even if the logged-over areas had not been properly regenerated. Logging probably had a greater effect on deforestation indirectly, by the construction of roads, which made the forest easily accessible.
- *Population growth.* Population acts as a demand shifter for new land or for more wood. In regions of high population density, one would expect the relative forest cover to be smaller, assuming the other factors to be equal.

The TFSMP study supports the earlier finding that population density and wood prices are the major contributing factors for deforestation in the Northeast, but could not find support for the hypothesis that rising real income has reduced the demand for land and thus the pressure to clear forest. The TFSMP study could find no support, either for the hypothesis that poverty affects deforestation in the case of the Northeast. The effect of agricultural productivity found in an earlier study is the opposite of that found in the TFSMP study, which shows that profit-oriented farming has a greater effect than subsistence farming. However, the effect of subsistence farming on deforestation is imbedded in the effect of population density, which has been shown to be a very important factor. Factors controlling deforestation was illustrated by TFSMP in Figure 2-2 (TFSMP Core Team, 1993a).

Reforestation/Afforestation rate

In Thailand, the new forest plantations are mainly reforested in the once exploited forest area, which is called by forester as reforestation. Since the last decades, however, afforestation-a new plantation growing in those area which have never been a forest, have been appeared in many provinces. *Casuarina equisetifolia* and *Eucalyptus camaldulensis* are examples of afforestation in the beaches, undulating paddy area and upland cultivated areas in eastern, northeastern, central and western regions of the country.

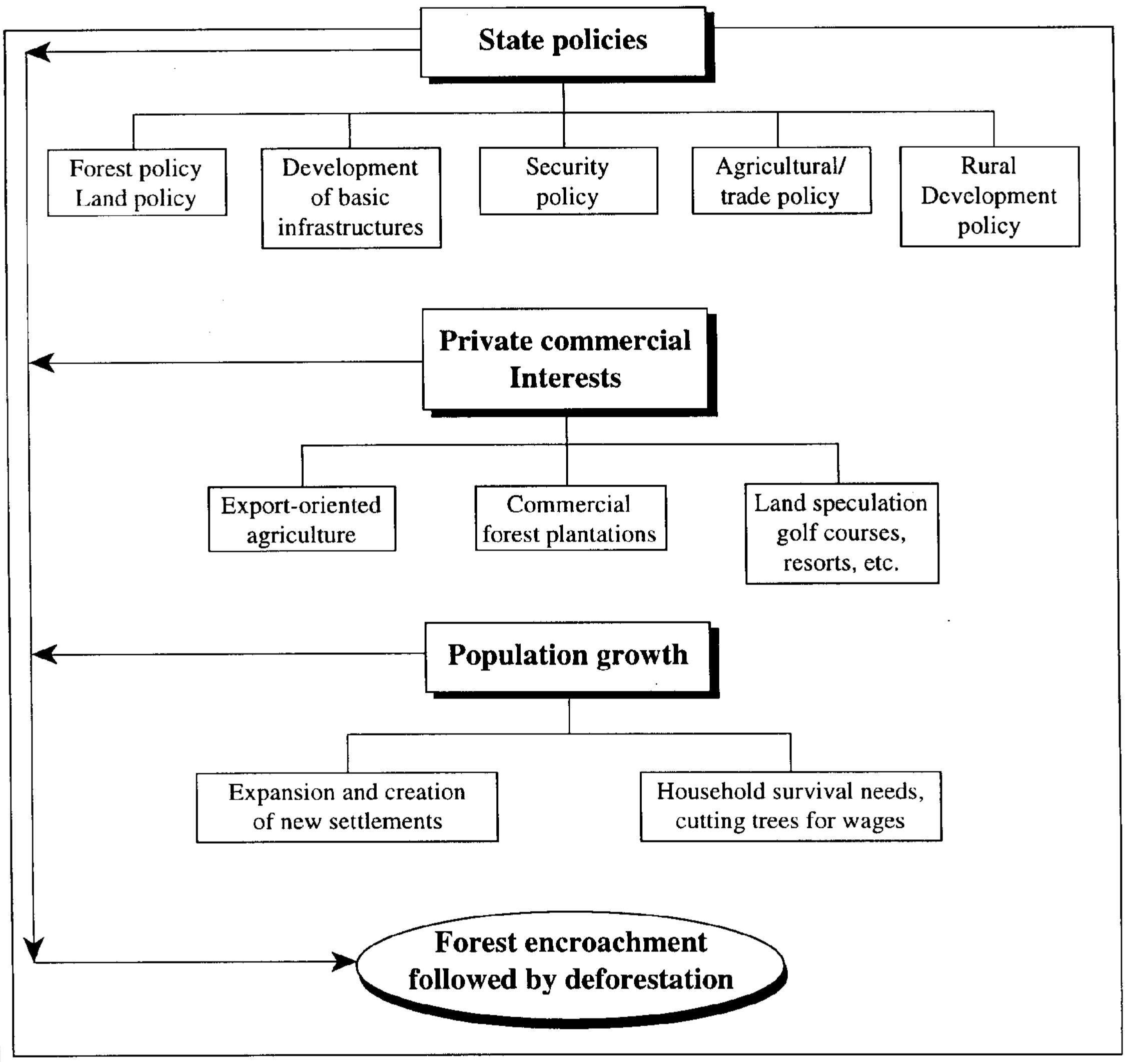
Reforestation has been made by various agencies and companies, e.g., Royal Forest Department, concessionaire, Forest Industry Organization (FIO), Thai Plywood Co., Ltd. They are mainly established on areas where once was a forest before. The main species are teak, pines and other commercial and fast growing trees. This part describes the past and present situation of reforestation constraints and possible resolution for the coming decades.

The past situation

TFSMP Core Team (1993b) reported that reforestation in Thailand dates back to 1906. Teak was then planted by foreign concessionaires. From then until 1960 small areas were planted annually. Accomplishments were very modest; only about 53,000 rai (8,500 ha) had been planted by 1960, of which 70% was teak.

The reforestation programme gradually expanded after 1961 cumulative area planted reached 4.1 million rai (663,000 ha) in 1986 (Table 2-5) and 4.5 million rai (714,000 ha) in 1990. Annual planting since 1981 has been about 462,000 rai of which about 52% were private. Reforestation was mainly in the Northern and Northeastern regions, which had 55% and 18%, respectively: of total area planted. Compared to other Southeast Asian countries, Thailand has a small area of reforestation, as well as of annual plantings. In fact, it took about a third of the time for the rubber plantation programme to cover twice the area of the reforestation program.

Figure 2-2. Three aggregate factors that control the rate of forest destruction.



Source: TFSMP Core Team (1993a)

Table 2-5. Total reforestation in 1961-1986 and annual planting since 1981

	Total in 1961-1986		**Annual since 1981**	
	Rai	**Ma**	**Rai**	**Ha**
Teak	1,000,000	160,000	100,000	16,000
Pines	544,000	87,000	37,000	6,000
Other species	2,600,000	416,000	325,000	52,000
All species	4,144,000	663,000	462,000	74,000

Note: Para rubber is not included. The figure refer to the planting done and not to the plantation successfully successfully established

Source: RFD/OPRE, 1988 and DANIDA review mission report, 1990.

Moreover, the actual area reforested is much less than the area planted since many plantations were destroyed and replanted more than once. RFD keeps no systematic records of survival rates or on areas destroyed. A 1980 FAO publication quoted a World Bank estimate of 33% survival rate. The FAO estimate for reforested area in 1987 is 2.4 million rai, or 57% of the total area planted. Losses have been blamed on farmers and on annual bush fires. The reforested area may be roughly divided into:

- Production forests, 67%.
- Watershed conservation forest, 17%
- Land reclamation forest (mine, saline soil and other), 16%

The most recent data reported by Data Center of RFD is shown in Table 2-6.

Table 2-6. Annual Reforestation by various agencies and companies from beginning to 1996

Unit : sq km

Item	From beginning to 1991	1992	1993	1994	1995	1996	Total
● Afforestation by Government Budget	5,124.47	426.53	304.83	309.78	191.49	94.27	6,451.37
● Concessionaire's Reforestation	1,437.66	17.10	8.90	4.44	1.20	1.16	1,470.46
● By Forest Industry Organization (FIO)*	323.02	6.35	6.73	4.18	1.24	**	341.52
● By Thai Plywood Co.,Ltd.*	103.64	4.09	0.62	2.43	1.46	1.38	113.62
● Reforestation According to Ministry's Regulations	107.96	8.10	2.23	0.61	1.54	5.21	125.65
● Reforestation Concessionaire Budget	92.44	60.60	10.72	6.40	18.17	8.24	196.57
Total	7,189.19	522.77	334.03	327.84	215.10	110.26	8,698.19

* Excluding Concessionaire's Reforestation
** Not available
Source: Data Center (1997)

Need for reforestation/afforestation

Based on the study of TFSMP Core Team (1993b), Thailand still needs about 11.0-12.2 million rai of forest plantations, depending on the level of self sufficiency aimed in plylogs, sawlogs, pulpwood, and other wood grades. The multipurpose forests will also need to produce fuelwood and other forest based commodities, and to help stabilise the slopes of watersheds. Table 2-7 shows the forest plantation for various scenarios proposed by TFSMP Core Team.

Table 2-7. Forest plantations to supply industrial wood; different scenarios (million rai)

	Current trends		Self-suffciency		Master Plan	
	2002	**2017**	**2002**	**2017**	**2002**	**2017**
Community forests						
Long rotation	0.00	0.00	0.16	0.46	0.16	0.46
Leasehold forest						
Medium rotation	0.00	0.00	5.67	10.17	5.67	10.17
Short rotation	0.00	0.00	2.33	1.04	0.97	0.00
Private forests						
Short rotation	0.00	0.00	0.45	0.45	0.45	0.45
Total forest plantations	0.00	0.00	8.61	12.12	7.25	11.08

Source : TFSMP Core Team (1993b)

It was also recommended by the Core Team that to meet the forest plantation requirement, about 0.8 to 1.3 million rai would be planted annually using fast-growing species for short and medium-rotation crops, and relatively slow-growing but premium species for long-rotation crops. These estimates are based on the assumption that intensive management techniques would be gradually adopted.

The alternative to forest plantations is wood importation, which is disadvantageous to the country in terms of balance of payments, utility of idle lands, creation of employment opportunities, rural development, and other related aspects.

Forest fire in Thailand

The nature of forest fire

From an ecological viewpoint, fire is considered as a non-biotic factor which, in general, works within the ecosystem to decompose, recycle, and select. As a decomposition agent, fire releases the chemical energy stored in the available fuel. Fire liberates in slightly altered forms, many of the constituent biochemicals residing in the litter. An ecosystem subjected to fire must cope with this discharge of energy and chemicals, with the eradication of some organisms and introduction of others, and with the simultaneous processes of selective destruction and selective enhancement.

It is evident that fire is not a minor factor, but a major one. Fire has always been a part of terrestrial environments. Biotic communities adapt and compensate for it, just as they do for temperature or water. Yet, as with most environmental factors, man has greatly modified its effect, increasing its influence in many cases and decreasing it in others. By careless behaviour, man has often so increased the effect of fire that a productive environment is destroyed or injured.

Extent, geographic and seasonal trend

In Thailand, forest fires occur annually during the dry season from December to May, peaking in March. Most are surface fires which take place mainly in dry dipterocarp forest, mixed deciduous forest, and forest plantations, and also to some extent in dry evergreen forest, hill evergreen forest, or even in some parts of the tropical rainforest. In extremely dry sites, double or multiple recurrence of fire in one season is common. These surface fires consume litter, and small vegetation. In recent years, a notable number of crown fires have taken place in the pine forest. Ground fire also occurs even in swamp forests in Southern Thailand, where they indicate heavy disturbance of the ecosystem.

Cause of forest fire in Thailand

The forest fire statistics of RFD indicate that nearly all fires are caused by people, particularly by those living close to the forest. In 1992 the various causes of forest fires and their relative importance were as follows:

- To facilitate collection of non-timber forest products (25%)
- Burning of agricultural debris (20%)
- Forest conversion to farmland (19%)
- To drive animals or attract them to burned areas during hunting (12%)
- Carelessness (12%)
- Other causes (12%)

The area of forest burned each year may be as much as 117 million rai (18.8 million ha), including multiple occurrences in the same area. Aerial surveys of fire affected areas showed that in 1984-1986 fire occurred on about 19.5 million rai (3.1 million ha) of forest (Table 2-8). The same study was repeated in 1992, 1993 and 1994. It was showed that in that respective years, fire occurred on about 12.7, 9.2 and 4.77 million rai of forest. The statistics of fire occurrence and forest fire control practice supplemented from the Division of Forest Fire Control are presented in Table 2-9.

Table 2-8. Occurrence of forest fire in 1984-1986 and 1992-1994, million rai per year

Region	1984-1986			1992			Burned area (million rai) in	
	Forest area	Burned area	% of forest	Forest area	Burned area	% of forest	1993*	1994*
North	52.58	12.98	24.70	48.21	9.12	18.90	4.80	2.34
Northeast	15.99	2.92	18.30	13.62	1.52	11.20	2.41	0.90
Central	16.04	2.15	13.40	15.19	1.35	8.90	1.23	1.04
South	9.68	1.43	18.60	8.41	0.69	8.20	0.68	0.44
Thailand	94.29	19.48	20.70	85.43	12.68	14.80	9.12	4.77

Note: Forest area is based on 1985 satellite imagery for 1984-1986 and 1991 imagery for 1992.
Source: TFSMP Core Team (1993a); * supplemented from Forest Fire Control Division.

Table 2-9. Statistics on forest fire control activities in Thailand during 1985 to 1997

Activities	Unit	Fiscal years												
		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Supression														
- Country forest area	hectare	14,905,286	14,905,286	14,905,286	14,905,286	14,905,286	14,905,286	13,669,792	13,669,792	13,352,100	13,352,100	13,148,506	13,148,506	13,148,506
- Country burnt area	hectare	3,535,111	3,797,289	No survey	No survey	No survey	No survey	No survey	1,940,872	1,459,617	763,648	643,805	No survey	No survey
(by aerial survey)	%	23.4	25.2						14.2	10.93	5.72	4.82	-	-
- Responded area	hectare	1,111,700	1,316,700	1,521,700	1,521,700	1,584,500	1,647,300	1,701,600	1,997,500	2,179,200	2,246,867	2,524,880	2,736,289	2,860,989
- Percentage of area in	%	7.37	8.73	10.09	10.58	11.05	11.49	12.45	14.61	16.32	16.82	19.20	20.81	21.76
- Suppression practice														
+ Number	time	2,563	3,482	4,414	3,756	3,722	3,688	4,411	4,684	4,263	4,402	5,252	5,890	7,423
+ Burnt area	hectare	7,995	8,483	8,972	11,038	11,397	11,757	12,372	15,823	12,292	30,676	23,877	18,227	24,543
+ Percentage of burnt : responded area	%	0.72	0.64	0.59	0.73	0.72	0.71	0.71	0.79	0.56	1.37	0.95	0.67	0.86
- Fire season	month							Nov-Jul	Nov-Jul	Dec-Jul	Nov-Jun	Nov-Jul	Nov-Jul	Dec-Jun
- Month of the most fire occurrence	month							February	February	February	February	February	February	February
- duration of the most fire occurrence	hour							12-14	12-14	14-16	08-10	14-16	14-16	12-14

Source: Supplemented from Forest Fire Control Division, Forest Protection office, RFD.

The peat fires

Regarding the peat fires occurring in the southern part of the country, the Pluto Daeng peat forest fire occurred in Narativas in early 1998 is the most serious one. Normally, this forest with its 1.5 to 3.0 meter depth of peat is inundated except during January-June when the water level drops to about 0.5 - 1.0 meter below the accumulative peat especially at the edge of swamp. When the peat getting dry, it is easy to be burnt by people who use the dried areas for cultivation or encroach for building their shelters. In many cases, the peat fires were caused by animal hunters and spread over in larger scale.

The peat fires which occurred on May 6, 1998 covers 4 areas as shown in Table 2.10. It can be summarized that of total area of 261,000 rai, about 13,720 rai were burned. It could be said that it had been controlled since the end of May 1996. Of the burned area, about 10 percent was prestine swamp forest, 40% was *Melaleuca leucadendra* (Pa Samed) and the rest 50% was grasses and fern forests.

Since the peat fires had occurred, agencies concerned such as RFD, Royal Irrigation Department, Land Development Department and the Royal Rain-maker Office had cooperatively operated to control fires. One helicopter was supported by the Thai Army and local administrative office joined in the suppression activities.

Table 2-10. Pluto Daeng peat forest area and area burnt in May 1998

A. Areal classification

Classification for Management	Areal distribution Rai	%	Area description
Development area	95,000	36	Completely converted, strong acidic soil, mainly irrigated
Conservation area	110,000	42	Disturbed swamp forest, not yet developed
Reserved area	56,000	22	Pristine forest, intensive protection
Total area	261,000	100	

B. Area burnt in May 1998

Location	Area burnt (Rai)	Fire control situation
Sarayo village, Ban Nam Tok, Ban Bozama, Tambon Semas, Su Ngaikoloke District	2050	Controlled by 6 May 1998
Koke Kala, Su Ngai-Padee District	11,250	Not controlled yet by 6 May 1998
Koke Yai Tambon Su Ngai Padee, Su Ngai Padee District	100	Controlled
Ban Puyo, Tambon Puyo, Su Ngai Koloke District	320	Started on 28 April, 1998 and almost controlled by 6 May 1998.
Total	13,720	

Impact of forest fire in Thailand

The effects of forest fire in Thailand have been assessed by Kaitpraneet et al (1997) as follows:

- *Effect on vegetation and wildlife.* Fire can kill plants and animals and retard their growth and development. It has been estimated that in a fire, 40% of saplings are killed and the growth of the remaining ones is reduced by 20-25%. Furthermore, about 80% of roots at or near the surface are damaged in a fire. About 20% of one to five-year old trees have been estimated to die in a plantation fire.

- *Effect on soil and water.* Surface runoff has been estimated to increase three-fold and soil erosion from three to thirty after a forest fire. As a consequence, the rate of flow suspended sediment and turgidity increase along the rivers.

Tangtham (1992) concluded based on the study of Chunkao et al (1976) that soil and water losses from teak plantation are the heaviest but moderate in the mixed deciduous forests with teak, and lowest in the deciduous dipterocarps forest. Causes are attributed to the degree of slope and next to organic matter and clay content of the soil.

In teak forest particularly, soil erosion is much higher than permissible loss for agricultural practice (12.5 ton/ha/yr), i.e., having an average in the range of 34-163 ton/ha/yr. Fire control, however, abruptly decrease soil erosion in all forest types especially in teak plantation, i.e., decreasing to 3 ton/ha/yr within 4 years and return to normal condition within 7 years.

Economically, the deterioration of soil and water as well as dredging of shallow water-ways clogged with sediment does not come cheap. It could be possibly equivalent to fertility loss at value of 400,000 to 800,000 million baht a year.

- *Effect on air quality and scenic beauty.* Smoke remains in the atmosphere for weeks or even months after forest fires. The various greenhouse gases released accumulate in the atmosphere. Smoke also contributes to reduction in light intensity, visibility, and scenic beauty. Intensive research on this matter is rather few in Thailand.

- *Economic losses.* In terms of the value of trees alone, it has been estimated that annual losses from forest fires may reach about 50 billion baht. This figure is estimated based on calculation of Pannakaphitak et al (1991) using the value of fire damage for dry dipterocarp forests, mixed deciduous forests, pine forests and reforested plantation at about 5,717, 2,460, 3,792 and 1,400 baht per rai per year respectively.

Prevention and control of forest fire in Thailand

Historical development and present state of forest fire control

Before 1971 no records were kept on the occurrence of forest fires in the Kingdom. Although the seriousness of damage from annual forest fires had been noted in various publications, and recommendations had been made to overcome the problem. Lack of funds and expertise had contributed to the apathy towards fighting forest fires. The situation improved in 1971 when the problem was given attention with the assistance of the Canadian International Development Agency. In the 1970s, forest officers were sent to Canada and the United States to train in modern forest fire control. In 1976, the Forest Fire Control Section was established under the Forest Management Division of RFD. The office was elevated to Subdivision a few years later.

A cabinet resolution in 1981 gave general directives for improving reporting and suppression of forest fires. Initial measures to implement the directives have included the development by RFD of the organization to undertake fire control activities, the establishment of forest fire control units in fire-prone areas, the sharing of responsibilities for fire prevention and suppression with the Ministry of Interior, the organization of a communication network to report occurrences of fire immediately, and provision of increased budget and essential equipment for effective fire control. Long-term measures prescribed include volunteer training for fire fighting in fire-prone areas nation-wide, a Forest Fire Control Act, obliging and training government staff in fire-prone areas to engage in fire fighting, and assessment of action on the implementing measures. However, implementation of the measures did not fully materialize. For example, the Forest Fire Control Act did not come about.

Forest fire control activities did expand quite dramatically. The declared fireprone areas under the fire control programme have been enlarged. About 13 million rai (2 million ha) have been placed under the fire control programme. Fire prevention campaigns were initiated with varying degrees of success. Modern fire suppression techniques and equipment were introduced, including the use of aeroplanes and helicopters. In late 1991, the Forest Fire Control Subdivision was upgraded into a Bureau of Forest Fire Control and Rescue.

Management activities to prevent and control.

At present, forest fire control is concerned with the following activities:

- *Collection of fire statistics.* Statistics on the number, frequency, duration, location, causes, and extent of forest fire are an essential requirement for setting up an effective fire control plan. Nationwide statistics are needed, but statistics are available only in areas covered by the fire control programme.

- *Fire research.* Fire shows different behaviour and effects on different sites. Research is needed all over the Kingdom, but is so far confined only to certain areas.

- *Fire prevention.* Since forest fires in Thailand are caused by human activities, fire prevention is the best solution to the problem. The greatest task is to change the attitude of the people towards fire. Fire prevention campaigns have been carried out. but their effectiveness is hard to assess. The main constraint his been the lack of expertise in handling, educational programmes and training courses.

- *Fire suppression.* Suppression is a laborious and costly activity. Aside from budgetary limitation current equipment and techniques have their own limitations in *terms* of effectiveness. What may work on certain types of terrain may not work on others.

- *Inter agency co-operation and co-ordination.* So far RFD has worked almost alone on forest fire control. However, in recent years, co-operation has been increasingly sought and obtained satisfactorily from other state agencies. For instance, Agriculture Aviation provides aircraft for fire suppression and the military assists in training fire-fighting volunteers.

- *Law enforcement.* There is no specific fire control law, but there are provisions on forest fire in four forestry laws. Though law enforcement is deemed necessary, the Forest Fire Control Subdivision does not have adequate manpower to enforce such laws. Also, prosecution of people is being seen as having a negative effect on the relationship between forest officers and the local people.

The forest fire prevention campaign in forms of public relation, extension, education and training, and fire suppression practiced by RFD during 1985 to 1997 are shown in Table 2-11.

It was reported by TFSMP Core Team (1993a) that the forest fire control programme has proved to be effective within its area of coverage. In 1992, only 0.5% of the area covered was burned. However, fire is still a significant problem in 88% of forest areas, which are not covered by the programme. The programme needs more resources to extend its coverage, but it appears that it has attained its budgetary limit relative to other Government programmes. Thus it cannot be replicated for total coverage. It is necessary to develop other approaches that are cost effective, but which can be extended over the entire Kingdom. One such approach is to provide the local people with vested interest in controlling forest fire. The poor attitude towards forest fire is mainly due to the fact that fire damage is limited mainly to public property. If forests are community or privately owned, the owners will collectively try to prevent fire from occurring, in case it spreads to their properties.

The most recent measures for forest protection and fire control and prevention revealed by the DG of Royal Forest Department as reported by Kanwanich (1998) implied that more serious attention will be paid by using the joint patrol units from RFD and the Thai Army. They will fence off areas that have been devastated by forest fire and will also conduct aerial surveillance during the dry season. The Army helicopters surveying the protected forest area will be equipped with night vision and global positioning systems to help locate fire at night time. The RFD itself will also upgrade its internal fire fighting plans with more personnel supported and equipment added. Officers from local administrative tambons (subdistrict), villages, and disaster relief volunteer agencies will also bc asked to help.

On a larger scale, the national master plan to combat forest fires nationwide will be drafted and agreed on by all authorities concerned such as RFD, according to officials from the Interior Ministry and the military. The Science, Technology and Environment Ministry will also support these new laws to control and end the forest fire crisis.

Table 2-11. Management activities and budget support for forest fire prevention practiced by RFD during 1985 to 1997

Activities	Unit	Fiscal years												
		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Forest fire prevention campaign														
1. Public relation														
1.1 Mobile public relation	time	613	723	833	820	880	904	1,336	2,775	2,953	3,040	5,551	7,797	7,920
1.2 Public relation vis mass media	time	125	321	517	302	559	817	365	1,306	6,236	946	924	2,551	1,583
1.3 Billboard	board	1,136	1,370	1,611	1,602	1,589	1,577	2,165	3,176	4,080	4,013	5,916	7,396	7,198
1.4 Printed material	sheet	36,230	67,731	99,248	88,488	96,231	103,975	139,228	198,711	215,388	177,094	353,233	418,108	428,105
2. Extension														
2.1 Document	copy	15,380	24,070	32,315	33,745	37,579	41,413	46,834	85,174	99,718	83,731	180,725	192,118	199,439
2.2 Exhibition	time	108	140	173	208	224	241	323	1,559	543	469	733	948	1,497
3. Education and training														
3.1 Education	time	205	275	352	388	416	443	540	1,069	1,641	961	1,962	2,839	3,169
3.2 Training	time	34	43	52	55	74	93	111	196	194	110	293	239	293
	man	1,020	1,290	1,560	1,650	2,220	2,790	3,330	5,880	5,820	3,300	8,790	7,170	8,790
3.3 Training for forest fire	time											200	202	220
prevention volunteer for	man											6,537	6,060	6,600
Royal initiation project	village											200	202	220
Forest fire suppression														
1. Preparation														
1.1 Responded area survey	rai	6,948,125	8,229,375	9,510,625	9,510,625	9,903,125	10,295,625	10,635,000	12,484,375	13,620,000	14,042,919	15,780,501	17,101,805	17,881,180
1.2 Fire crew	unit	42	54	66	69	76	84	83	100	125	134	161	205	236
	man	630	810	990	1,045	1,140	1,260	1,245	1,500	1,875	2,040	2,415	3,075	3,540
1.3 Equipment	unit	42	54	66	69	76	84	83	100	125	134	161	205	236
1.4 Transportation route	meter	84,800	74,425	64,050	63,980	66,832	69,685	99,100	146,355	165,150	172,450	151,590	266,750	306,235
1.5 Fuel management	rai	24,886	24,000	23,132	28,567	26,004	23,441	40,009	18,248	24,102	25,092	29,468	33,480	42,880
Budget	US$	data not available	data not available	856,896	867,948	982,593	1,213,263	1,269,959	2,079,715	3,272,249	3,596,248	5,723,430	11,122,015	11,223,378

Conclusion

Thailand was once the most abundance of forest resources in this region. Before 1890, larger than 60 percent of the country are was covered by various types of forests especially the so-called tropical evergreen forest. These resources have been exploited by management and conversion to agricultural purpose for longer than a century. At present, only 25 percent was left over the land of this country and sparsely distributed in all regions. Of this figure, the most critical one is the northeast where its forest area is only less than 12 percent. About 43, 21, 24 and 17 percent of the respective northeastern, eastern, central and western, and the southern regional area was monitored by satellite imageries taken in 1995.

Although a growing awareness of the adverse effect of deforestation has been recently developed among people, Thailand has lost her superlative ecosystematic function of her prestine forests. It was reported that population growth, expanding agricultural production for export, price of wood, poverty, including, extending road are blamed as central factors contributing to deforestation in Thailand. The intensity of logging in the past or even at the present, whether legal or illegal, is influenced by wood demand and prices, forest accessibility and population growth.

Besides those mentioned factors, fires which normally occurs in almost all dry seasons are also another abiotic factor causing forest depletion and destruction in Thailand. Forest fires which are mainly caused by people have damaged as much as 18.8 million ha. It has been estimated in a fire, 40% of sapling are killed and growth of the remaining is reduced by 20-25%. About 20% of one to five-year old trees have been estimated to die in a plantation fire. Forest fires increase three-fold of surface runoff and 3-30 times greater of soil erosion. The higher suspended sediment concentration and turbidity were consequently found along the rivers. Fire control abruptly decrease soil erosion to 3 ton/ha per year within 4 years and return to normal condition within 7 years if no consecutive fire occurs thereafter. Intensive research on the effect of fire on air quality and scenic beauty is few in this country. It was observed that smoke remains in the sky for weeks or even months after fires. It also contributes to reduction in light intensity and visibility in which often obstructs landing of the airplanes in the north.

It could be said that nearly all fires occur in the forests of Thailand are caused by people, particularly those living close to the forest. The main cause is to facilitate collection of non-timber forest products follows by farmland preparation and burning of agricultural debris. Driving and attracting wild animals to burned areas during hunting are another cause.

Regarding prevention and forest fire control, Forest Fire Control Section was established under RFD in 1976. The office was then elevated to Subdivision a year later. A cabinet resolution in 1981 supported to improve reporting and suppression of forest fires and led RFD to establish more forest fire units in fire-prone area in all region especially the northern. Several long-tern measures have been proposed, e.g. volunteer training for fire fighting, Forest Fire Control Act, obliging and training government staff in fire-prone area to engage in fire fighting and assessment of action on the implementing measures, they have not been, however fully implemented. So far, forest fire control is concerned with collection of fire statistics, fire research, fire prevention, fire suppression, inter-agency co-operation and co-ordination and law enforcement.

The more serious attention of forest protection and forest fire control is being and will be paid by the Royal Thai Government. The joint patrol units from RFD and the Army together with those local administrative agencies and volunteers will cooperate to combat forest fire whenever it occurs by using sophisticate tool such as helicopters with positioning systems and rehabilitating devastated areas after fire. The master plan to combat forest fire in both inland and swamp forests with new laws will be proposed and hope to be approval before the beginning of a new century.

3 METEOROLOGICAL DATA

SONGKRAN AGSORN

Introduction

The local seasonal weather of 1997 did not differ much from the previous year in which there was no evidence of the effects of the Indonesia"s smoke into the area, despite the year 1997 was one of the strongest El Niño year in decades. The spreading of the smoke to the Malayan peninsular, including the southern Thailand, was helped by the prevailing synoptic scale winds, as indicated by the low-level southerly wind circulation. Wind speed and direction are the major factors in the dynamics of dispersion of suspension of the particulate matter in the air. As the smoke is composed of the air-borne small particles originated from the incomplete combustion of the substances, the local concentration of the particles depends on the distance from the source, the concentration of the source, the wind direction and speed. Transboundary transport of smoke, causing the haze effects to the Malayan peninsular in 1997 was, in fact, not the first occurrence of this type of episode. Similar phenomenon occurred sporadically in the past (Singapore Meteorological Service 1995). Haze is one of lithometeors. It is defined as a suspension in the air of extremely small, dry particle invisible to the naked eyes and sufficiently numerous to give the air an opalescent.

Meteorological conditions in southern Thailand

While the upper Thailand's climate, having the distinct wet and dry or drought seasons, can be classified as "Tropical Savannah" by Köppen's climate classification (Griffith 1966), the southern Thailand is classified as "hot, monsoon zone" where there is a drier season but an adequate supply of rain ensures little, if any, drought. Statistically, the average annual rainfall for the whole country is 1578 mm with 130 rainy days. The annual average for the southern Thailand-west coast is approximately 2741 mm with 176 rainy days; for the southern Thailand-east coast is 1697 mm with 147 rainy days. The relative humidity for the whole country ranges from 59% to 89%

with the mean of 75%; the southern Thailand-west coast ranges from 63% to 93% with the average of 80%; the southern Thailand-east coast ranges from 63% to 92% with the mean of 79%. The annual average temperature for the whole country is 27 °C; the southern Thailand-west coast, 27.4 °C, and the southern Thailand-east coast, 27.2 °C. The evaporation annual average value for the whole country is 1688 mm; the southern Thailand-west coast, 1615 mm; and the southern Thailand-east coast, 1643 mm.

The above statistics indicate the southern Thailand is wetter and warmer than the rest of the country which is partly due to its geographic setting surrounding by the sea under the influence of the Asia monsoons. The southern Thailand is in the Malayan peninsular with the Gulf of Thailand in the east and the Andaman Sea in the west. It is part of the so called "Maritime Continent" (Ramage 1995) which includes Indonesia, Malaysia, Mindanao, the western Caroline Islands, Papua New Guinea, and the Solomon Islands. These large, high islands generate continental-like convection, while the warm surrounding ocean is an inexhaustible moisture source. It is one of the major sources of tropical thunderstorms.

The southern Thailand has the different weather patterns for its east and west coasts as influenced by the Asia monsoons: the southwest or summer monsoon and the northeast or winter monsoon. The effect of the southwest monsoon usually starts approximately in May. The northeast monsoon starts approximately in November. There is no distinct cool season as in the upper part of Thailand. The east coast region of the southern Thailand has the "equatorial" climate (Nieuwolt 1981). It is the area along the Malayan east coast, where the effects of the northeastern monsoon are strongest. The annual rainfall maximum is here during the beginning of the monsoon season. The wettest month of the year is November. The diurnal rainfall maximum shows a clear seasonal variation: during the southwest monsoon, it is early in the morning, but during the rest of the year, it comes in the afternoon or evening. On the other hand, the west coast of the southern Thailand has a tropical climate: short dry seasons and small variation in temperature. There are many local variations, caused mainly by relief, which interfere with the normal sequence of climates according to latitude.

Meteorological observation network

The Thai Meteorological Department (TMD) has an extensive network of meteorological observing stations throughout the country. A total of 77 weather stations cover all regions. For southern Thailand, 16 observing stations are located throughout the east- and west-coast sections. All stations are manned by trained meteorological personnel, and observations are made according to World Meteorological Organization's guidance, agreement or practices (WMO 1996). Regular synoptic observation stations operate 24-hour a day. Weather observations at operating airports in the region are arranged mainly for the aviation purpose. Synoptic weather elements (i.e. surface pressure, wind speed and direction, wet-dry bulb temperature, rain, cloud cover, and visibility) are observed and reported. Radiosonde soundings are made regularly at Phuket Airport (Southern West-Coast Meteorological Regional Center) and Songkhla (Southern East-Coast Metecrological Regional Center) once a day at 07 hr, local time (00 UTC). Hourly Japanese GMS-5 meteorological satellite receiving facilities are available at these two centers. The GMS-5 image resolution is about 4 km; the visible images are available only during the daytime. Three-hourly weather data from all stations in the regions and satellite images are archived at TMD's head quarter in Bangkok. Most data are available in a magnetic tape format. Data from the fourteen stations as shown in Figure 3-1 are selected for this study of smoke haze. Although there are more auxiliary weather stations in all regions, the observation schedule at such stations differs (mostly daytime) from the regular ones and the data are not well archived at this stage.

Data collection and definition

Meteorological data used in this study are from the archive of the observation data of regular synoptic stations, scattering throughout the southern Thailand. The data included weather charts, digitized data, and satellite images. Weather charts, surface and upper-air data were used in investigating the synoptic situation, especially during the critical period. Meteorological data are observed and collected on 3 hourly basis at all the fourteen stations selected for this study. The stations selected covered all but three provinces in the southern Thailand (Phatthalung, Yala and Krabi) as no regular weather stations are located there (Figure 3-1).

All data used in the study were collected from the regular manned observation stations. At such stations, meteorological observers make routine measurement at regular pre-scheduled time. Meteorological variables were observed according to WMO's guidance (WMO 1996). The 3-hourly data of pressure, wind speed and direction, temperature, relative-humidity, rainfall, and visibility were used in the analysis. The data of the years 1996 and 1997 were used in comparing meteorological variables at each station. Time series of the daily mean of each variables were plotted and used in comparing the meteorological background at the stations between 1996 and 1997.

Surface pressure is obtained from mercury barometer as given in heto-pascal (hPa) and corrected for temperature, latitude, and mean sea level. Surface wind direction and wind direction is read from a wind vane or from the records of Dine pressure-tube anemograph. Wind speed is read from either anemograph or pressure-plate or cup anemometer. Wind instrument is set at approximately 10 meters high from the ground. Upper-level winds are measured by the sounding equipment, such as a radiosonde or rawindsond. Such measurements are very few since it is very expensive to operate. Only Phuket Airport and Songkhla operate the upper-air radiosonde sounding. Wind speed is reported in 0.5 meter per second (ms^{-1}) or in knots to the nearest unit, and represents, for synoptic reports, an average over 10 minutes. Wind direction is reported in degrees to the nearest 10 degrees, and represents an average over 10 minutes. Wind direction is defined as the direction from which the wind blows, and is measured clockwise from geographic north. Wind category of "calm" is reported when the average wind speed is less than 1 knot. Relative humidity in percent (%) is obtained from wet and dry bulb thermometers. Rainfall is measured in millimeters (mm) from a cylindrical rain gauge with brass rim of 20.3 centimeters in diameter. GMS-5 Japanese geostationary meteorological satellite visible images were used in this study as a supplement in identifying the affected areas. These visible images were available only during the daytime.

According to WMO's observation guidance (WMO 1996), *meteorological visibility by day* is defined as the greatest distance at which a black object of suitable dimensions, located near the ground, can be seen and recognized when observed against a scattering back ground of fog, sky, etc. The criterion for recognizing an object, and not merely for seeing the object without recognizing what it is, is to be used in reporting a visibility value. *Meteorological visibility at night* is defined as either the greatest distance at which a black object of suitable dimensions could be seen and recognized, if the general illumination were raised to normal daylight level; or the greatest distance at which lights of moderate intensity can be seen and identified. In practice, a visibility value is obtained by visual observation with the reference to the well-marked landscape within the radius from the station. The lowest visibility within the observing circle is reported. In general, the stations at the airport are more concerned with the visibility within 10 km.

Visibility is a complex psycho-physical phenomenon, governed mainly by the atmospheric extinction coefficient associated with solid and liquid particles held in suspension in the atmosphere; the extinction is caused primarily by scattering rather than by absorption of the light. Its estimation is subject to variation in individual perception and interpretative ability as well as the light source characteristics and the transmission factor. Thus, any visual estimate of visibility is subjective. Unless mountains or hills are within the visual range of the observing station, or the station itself is at high level, the observer will not usually be able to obtain direct observation beyond 15 km. In practice, a report of the visibility of 10 km or greater is considered as "good visibility" (WMO 1996). Visibility observed at a weather synoptic station is usually reported at 3 hour intervals. Visibility at a station at an airport is reported at 1 hour interval or more frequent if needed.

Results

Southern Thailand weather in 1997 as compared to 1996

The synoptic weather of the southern Thailand in 1997 and 1996 did not differ much from each other. The effects of the 1997 El Niño phenomenon to the weather pattern in the southern Thailand, as well as the other parts of the country in 1997 were not very distinctive from other normal dry years.

Monthly means of meteorological elements (Figures 3-2 to 3-15) reported from all stations indicated that most 1997 meteorological variables, except pressure, were not different from the 30-year mean or the 1996 values. Rainfall pattern for the year 1997 did not indicated a large deviation from the 30-year mean and the year 1996 values. Although, the monsoon onset or the beginning of the rainy season in 1997 was about one week later than normal as compared to a week faster of the summer monsoon beginning in the year 1996. Temperature as well as relative humidity did not show much difference between the two years. However, local surface pressure had higher pressure values in the year 1997 above the normal (30-year mean) and the year 1996. For all stations in the southern Thailand, it was noticeable that their surface pressure values in 1997 were markedly higher than the 30-year mean and the 1996 values starting from September until the end of the year. The monthly means of temperature, relative humidity, and rainfall for the southern Thailand in 1997 and the 30-year mean are shown in Table 3-1.

All monthly mean visibility (Figures 3-2 to 3-15) reported at the stations in the southern Thailand, except Chumphon, indicated markedly poor visibility in September 1997 as compared to the values in 1996 and the 30-year mean. This pattern coincided with the reports of other air-quality parameters. It was noted that Pattani reported the most frequent of low visibility in that month. Most of these stations reported the average monthly visibility 6 km or less for September 1997, when the smoke haze situation was considered to be worse.

The mean wind speed and direction in 1997 and 1996 were relatively similar. Description of the wind rose diagram used in this chapter is displayed in Figure 3-16. Monthly wind rose analysis from most stations (Figures 3-17 to 3-44) showed the same pattern for wind direction, which reflected the influence of the southwest and northeast monsoon. Winds blew from the southwest sectors from May until October. A large number of calm winds (speed less than 1 knot) were reported at all stations.

Event of smoke haze during late September to early October 1997

Daily means of meteorological variables during September and October 1997 (Figures 3-45 to 3-58) indicated some of the synoptic weather patterns that could favor the spreading of the smoke haze from the area south of Thailand. From the 20th of September 1997, the general synoptic weather over Thailand was under the influence of the active low-pressure trough over the central Thailand with the quite active low pressure cell off the coast of Vietnam at approximately 15 °N and 100 °E. This active low-pressure cell later transformed into a tropical depression then tropical storm "Fritz" (9722) on the 23rd of September 1997. The presence of the low pressure cell or tropical storms near the coast of Vietnam often causes the cross-equator flows in the direction of feeding into the center of the storm. In this case on the low-level flows (i.e. at 600 meter high) during that time stations in Malaysia reported more southerly wind. Wind's direction changed into more southwest and west direction into the stormís position as it passed the southern Thailand. The weak influence line could be analyzed over the southern Thailand, which might be one of the factors that reduced the spreading of the smoke haze further north. At that time, rainfall occurrence in the southern Thailand seemed to lag from the 1996 for a few days.

On the 22nd September 1997, the sounding analysis at Songkhla Station indicated the low-level inversion layer up to 850 hPa. This generally indicated the existence of a stable layer close to the ground, favorable to the building-up of smoke concentration. Later, on the 23rd September 1997, the anticyclonic circulation was found at 600 meter above the ground covering the area between Songkhla and Surat Thani (Figures 3-59 to 3-61). Again the presence of the low-level anticyclonic circulation could induce the subsidence of the air favoring the accumulation of the smoke concentration.

The surface wind speeds observed during the event were slightly weaker than those in the previous week, e.g., Songkhla: average at 4.57 knots (compared to 5.39 knots a week before); Hat Yai: 6.81 knots (7.38 knots); Narathiwat: 3.58 knots (4.0 knots) and Phuket: 4.56 knots (6.05 knots). This pattern also reflected for wind speeds in other levels higher up (e.g, 2000 ft or 850 hPa). It should, however, be noted that the surface wind speeds were, as normal, reported as "calm" for half of the time of the observations.

The 10-day wind roses indicated that during the first week of September 1997, the surface wind pattern of the stations throughout the southern Thailand had the south-southwest, west, and northwest direction (Figures 3-62 to 3-75). During the 11th to 20th of September 1997, the stations in the east coast of the southern Thailand, except Narathiwat, had the southerly or southwesterly wind components while the west coast stations had more component in southwest or west direction. Phuket stations (Downtown and

Airport) had mostly west direction. In the following week (21st -30th September 1997), the surface winds had more northerly direction, especially in Hat Yai. At most of these periods the stations in Malaysia reported calm or southerly winds. The daily wind rose for Hat Yai in September indicated the southerly wind component most of the time prior to the 21st of September when the visibility reported to be worsening (Figures 3-76 to 3-78). It should be noted again that the surface winds as shown in the wind rose diagram were mostly normally "calm" (i.e. less than 1 knot).

During the last week of September 1997, all stations south of the latitude of 10 °N reported a steep decline in visibility, followed by another decline observed in early October 1997 (Figures 3-45 to 3-58). The patterns differed significantly from the visibility reported at the same time in the previous year. Based on daily means values, the peak of the poor visibility occurred and lasted within a day or two. Stations in the east coast of the southern Thailand (e.g. Hat Yai and Pattani) reported worse visibility than the west coast (e.g. Phuket). The poor visibility peak in the east coast was a day or two after the west coast (i.e. Phuket reported declining in visibility on 23rd or 24th September 1997 while Hat Yai indicated around the 24th to 26th). Visibility was reported to be worse in all provinces in the lower south. Hat Yai, Songkhla, Pattani, Narathiwat, Satun, and Trang (6 stations) reported visibility <1 km for at least one day in that period. The remainder reported a dip in visibility in the range of 2-4 km. Only Chumphon showed a slight decline in visibility, 5-6 km.

Figures 3-79 to 3-81 show the affected areas in South-East Asia during the period of 16-30 September 1997, by the GMS-5 visible satellite images.

Table 3-1. The monthly means of temperature (T), relative humidity (RH), and rainfall (R) for the southern Thailand, 1997 and the 30-year mean

	1997			30-year		
	T (°C)	RH (%)	R (mm)	T (°C)	RH (%)	R (mm)
January	26.0	75	11.0	26.1	77	56.1
February	27.1	78	66.7	27.0	75	26.3
March	28.0	76	26.2	28.0	75	44.2
April	28.3	78	95.4	28.6	77	98.7
May	28.9	78	118.8	28.2	80	228.0
June	28.1	80	176.1	27.9	80	187.7
July	27.7	81	196.0	27.5	80	205.5
August	27.8	80	344.2	27.5	80	212.9
September	27.3	84	258.6	27.1	82	257.7
October	27.3	84	237.5	26.8	81	288.1
November	27.0	83	227.1	26.3	77	321.0
December	27.0	80	199.5	26.0	72	155.8
Annual	27.6	80	1923.6	27.3	75	2082.0

Conclusion and recommendations

The year 1997 was one of the strongest El Niño year in decades. Severe draught conditions, from the strong influence of the El Niño phenomena, made uncontrolled forest fires spread rapidly in major islands of Indonesia. Transboundary transport of the smoke into the Malayan peninsular, including southern Thailand, was helped by the prevailing synoptic scale winds during that period.

More co-ordination between international and domestic agencies concerned in meteorological data and service in the region should be accelerated. Better accessibility for data pool should be explored by educating the parties involved how the data will be used and to understand the limitation of the data used. As setting up the intensive weather data network is prohibiting expensive and technologically difficult, more research on applications of the existing non-perfect data for forecasting and predicting the haze condition is more economically viable alternative.

Figure. 3-1. Map of surface weather stations used in this study.

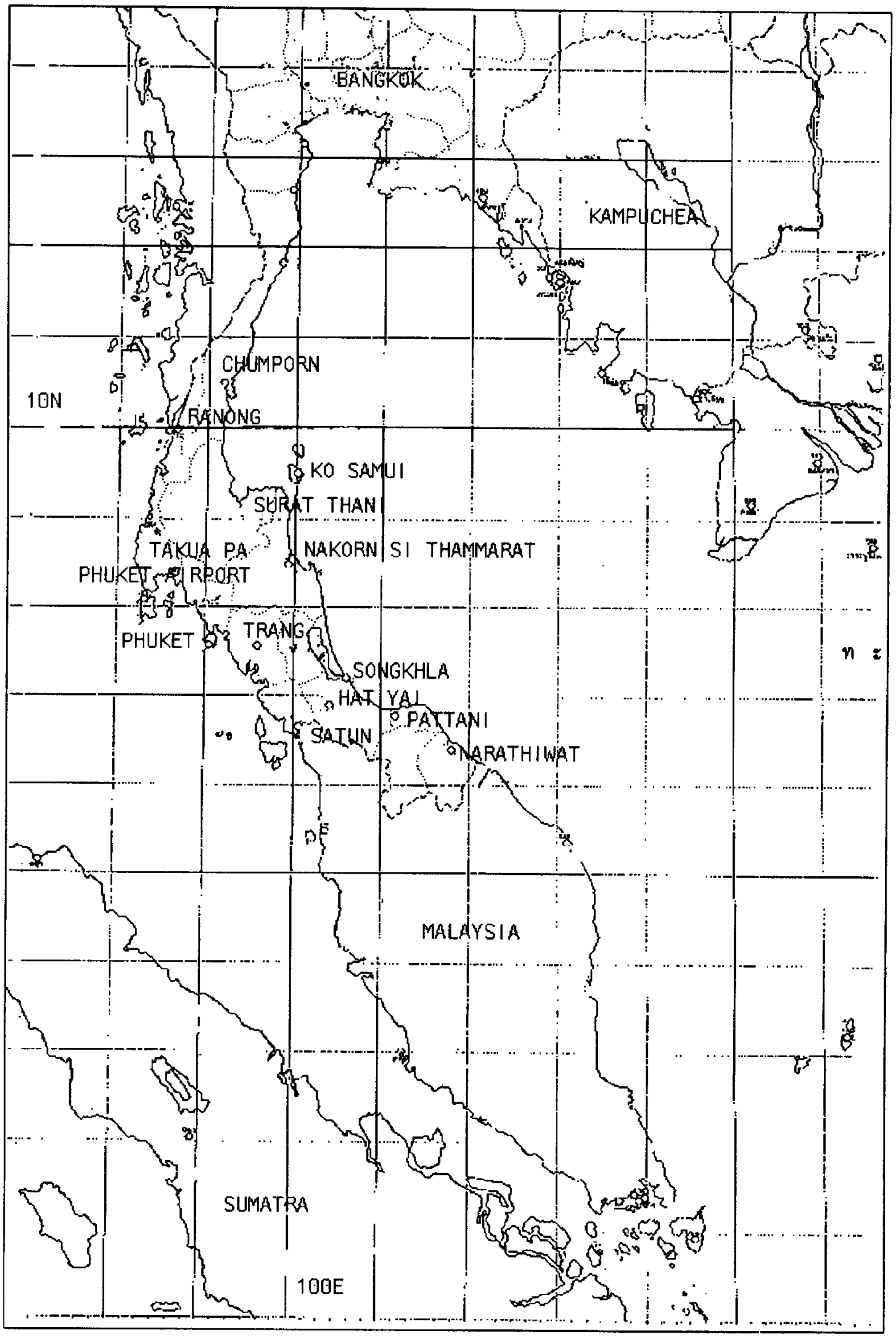


Figure. 3-2. Monthly surface meteorological observations for CHUMPHON in 1996, 1997 and 30-year mean.

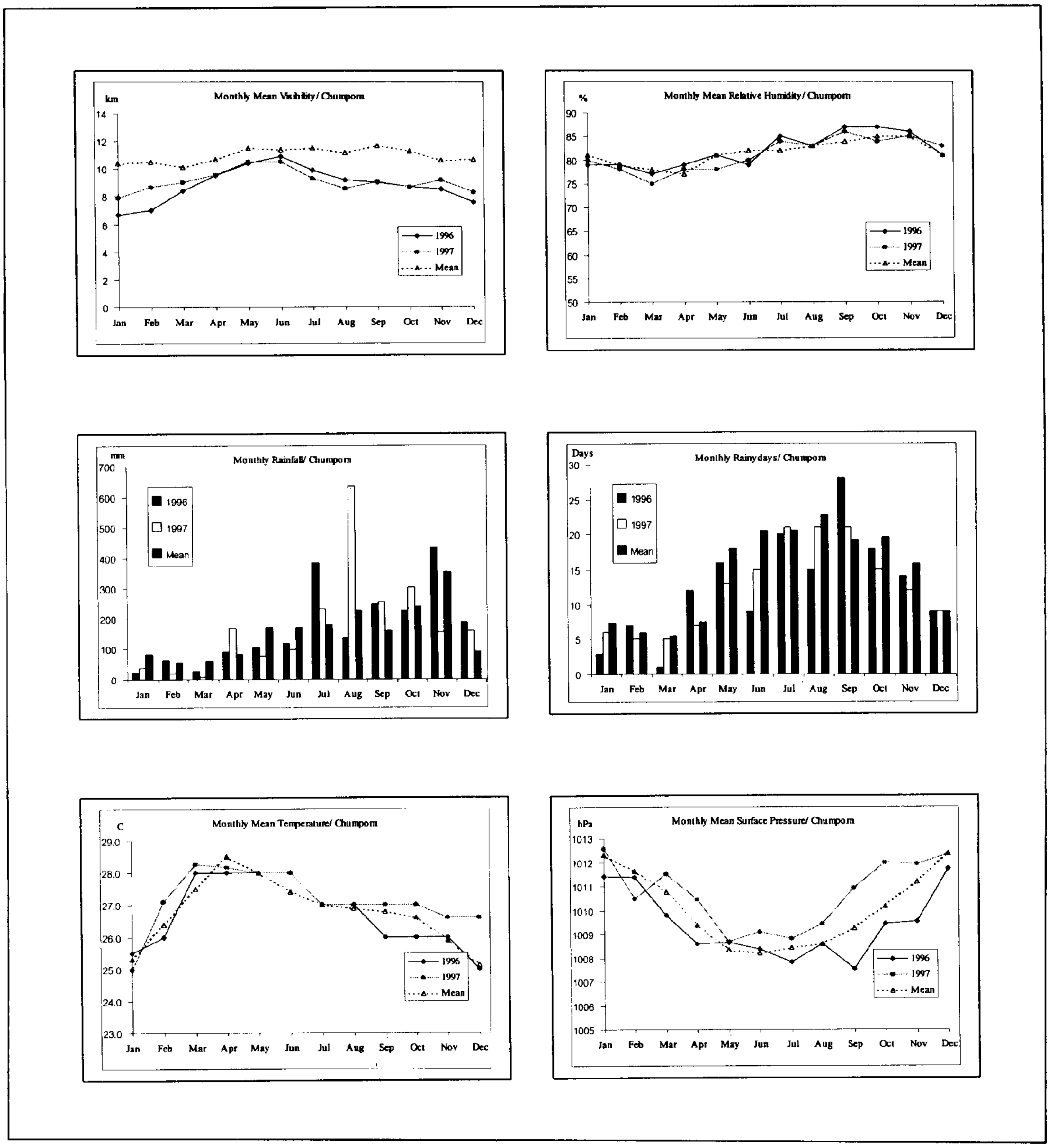


Figure. 3-3. Monthly surface meteorological observations for KO SAMUI in 1996, 1997 and 30-year mean.

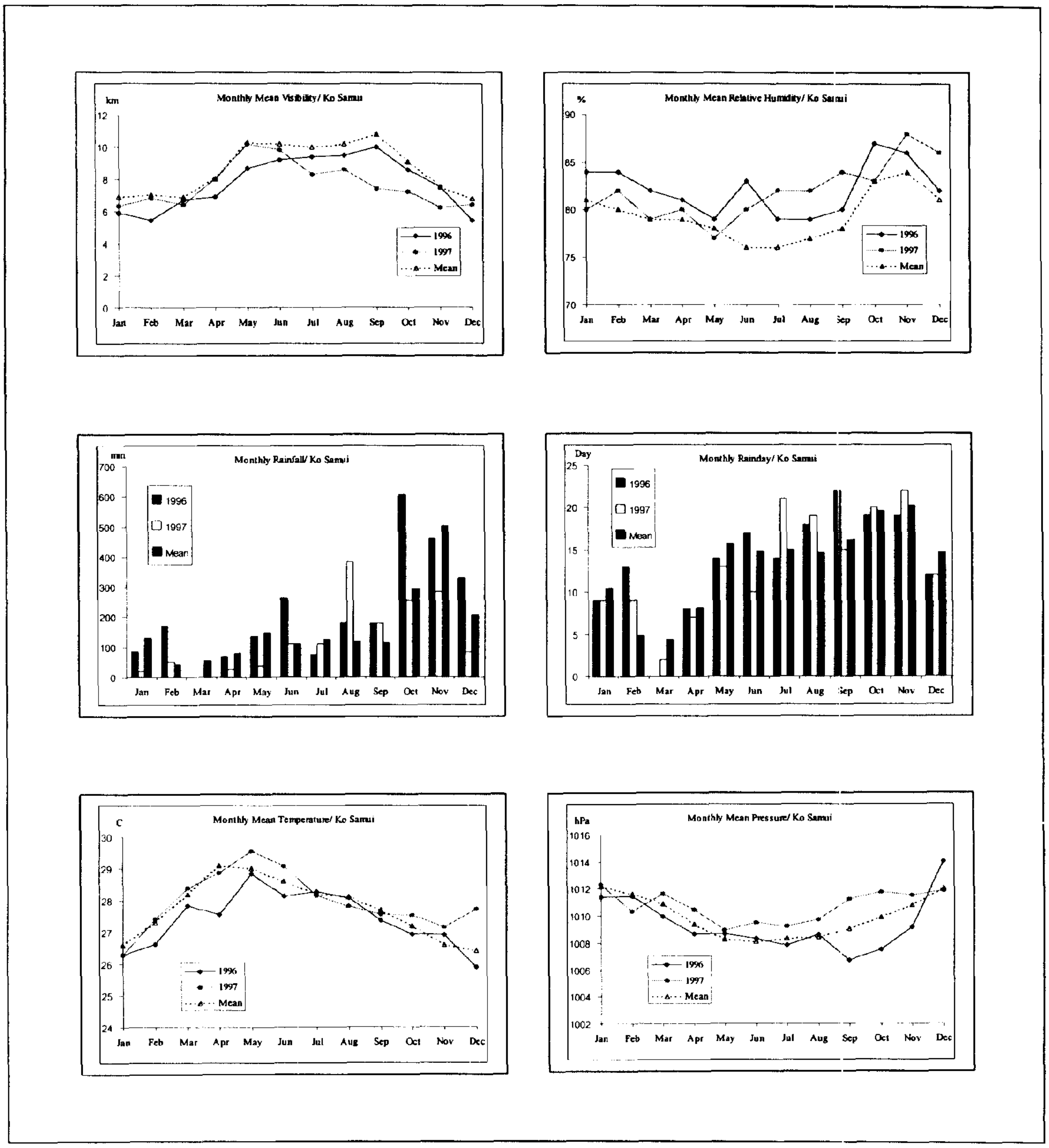


Figure. 3-4. Monthly surface meteorological observations for SURAT THANI in 1996, 1997 and 30-year mean.

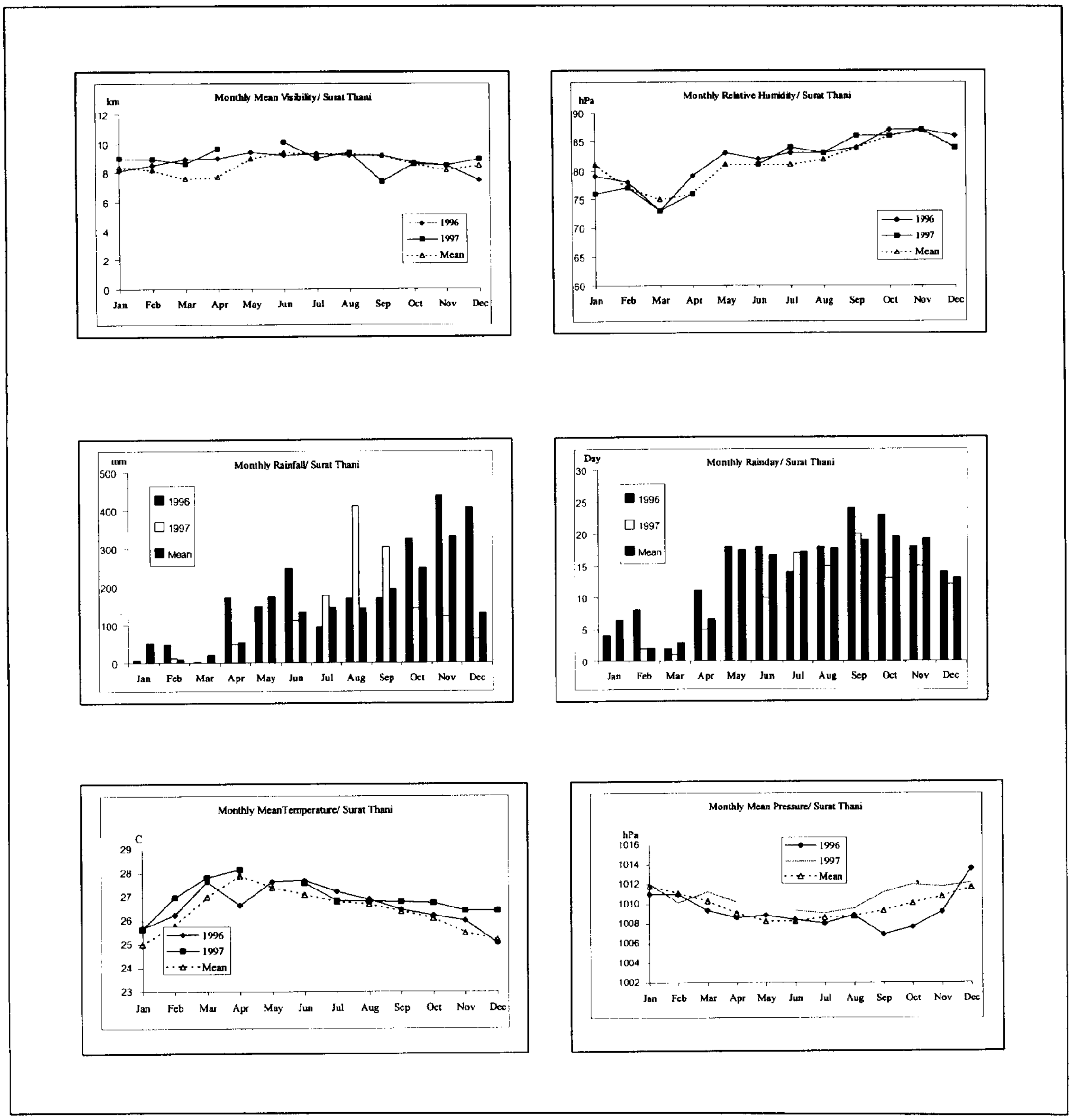


Figure. 3-5. Monthly surface meteorological observations for NAKHON SI THAMMARAT in 1996, 1997 and 30-year mean.

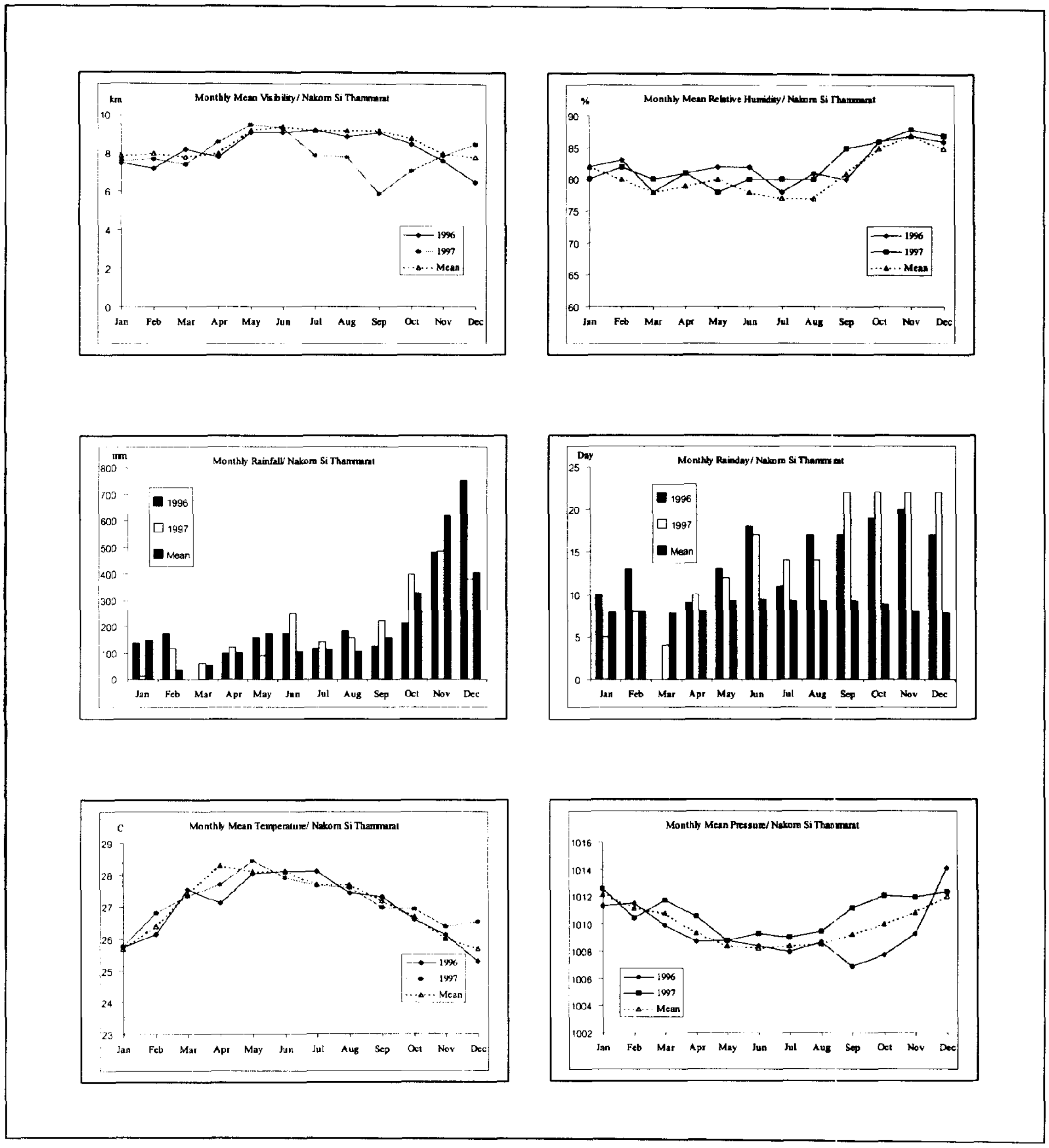


Figure. 3-6. Monthly surface meteorological observations for SONGKHLA in 1996, 1997 and 30-year mean.

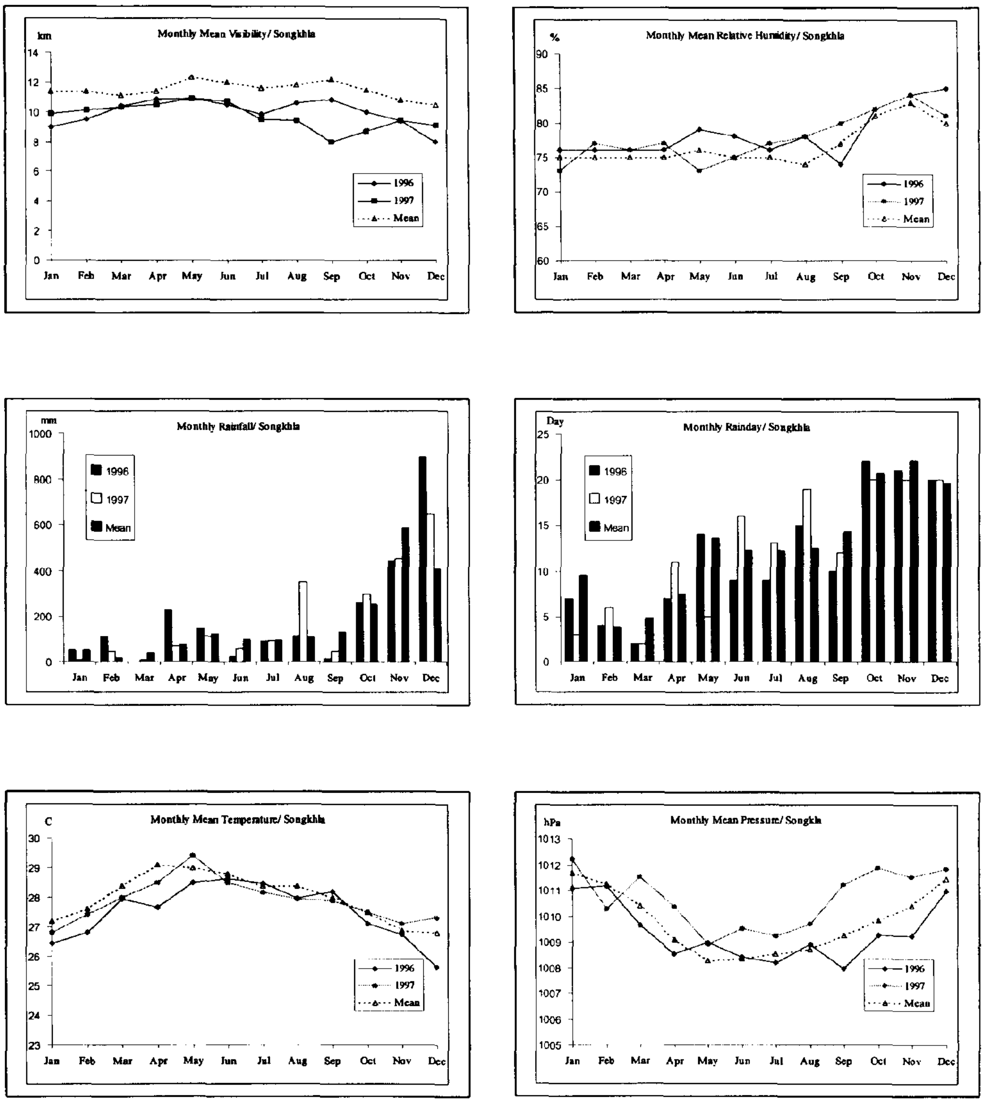


Figure. 3-7. Monthly surface meteorological observations for HAT YAI in 1996, 1997 and 30-year mean.

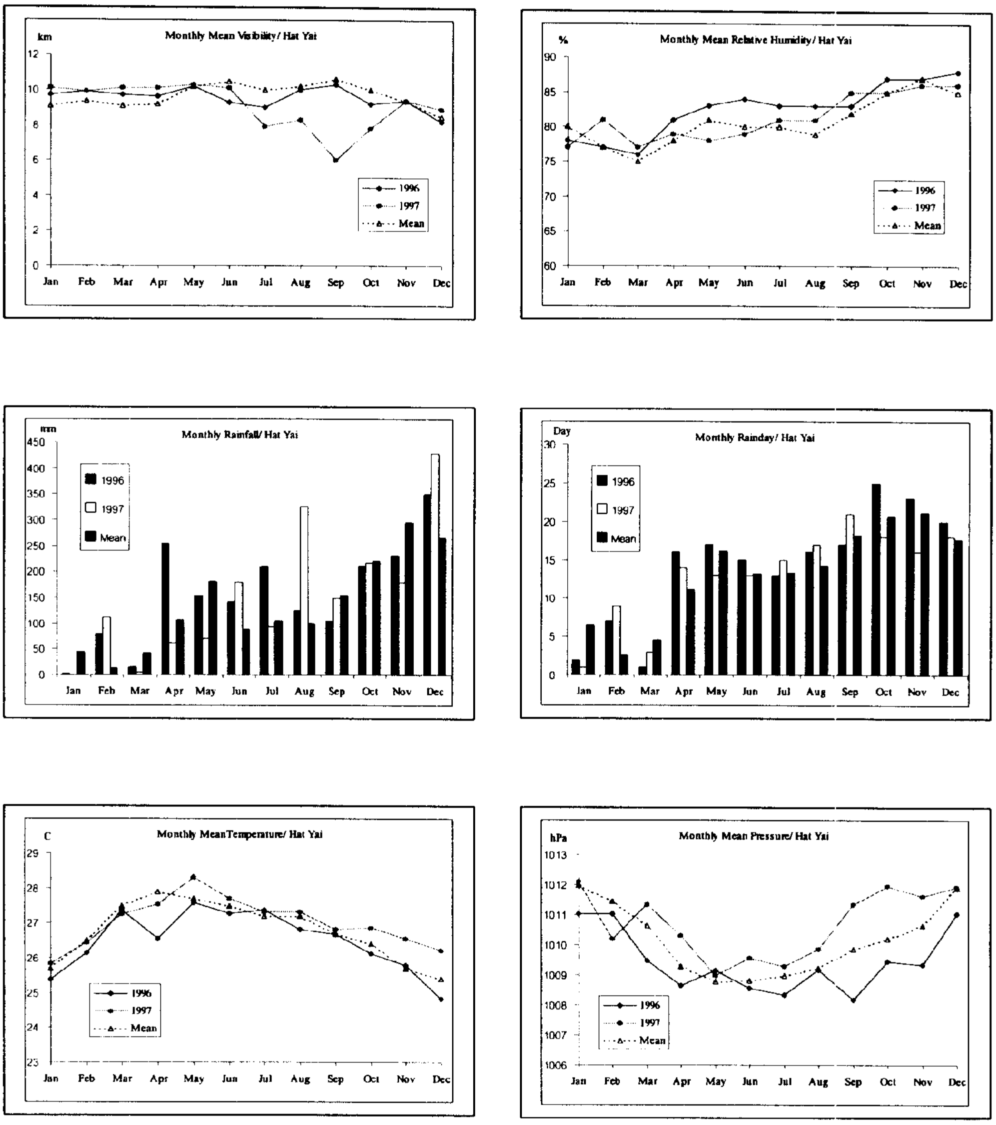


Figure. 3-8. Monthly surface meteorological observations for PATTANI in 1996, 1997 and 30-year mean.

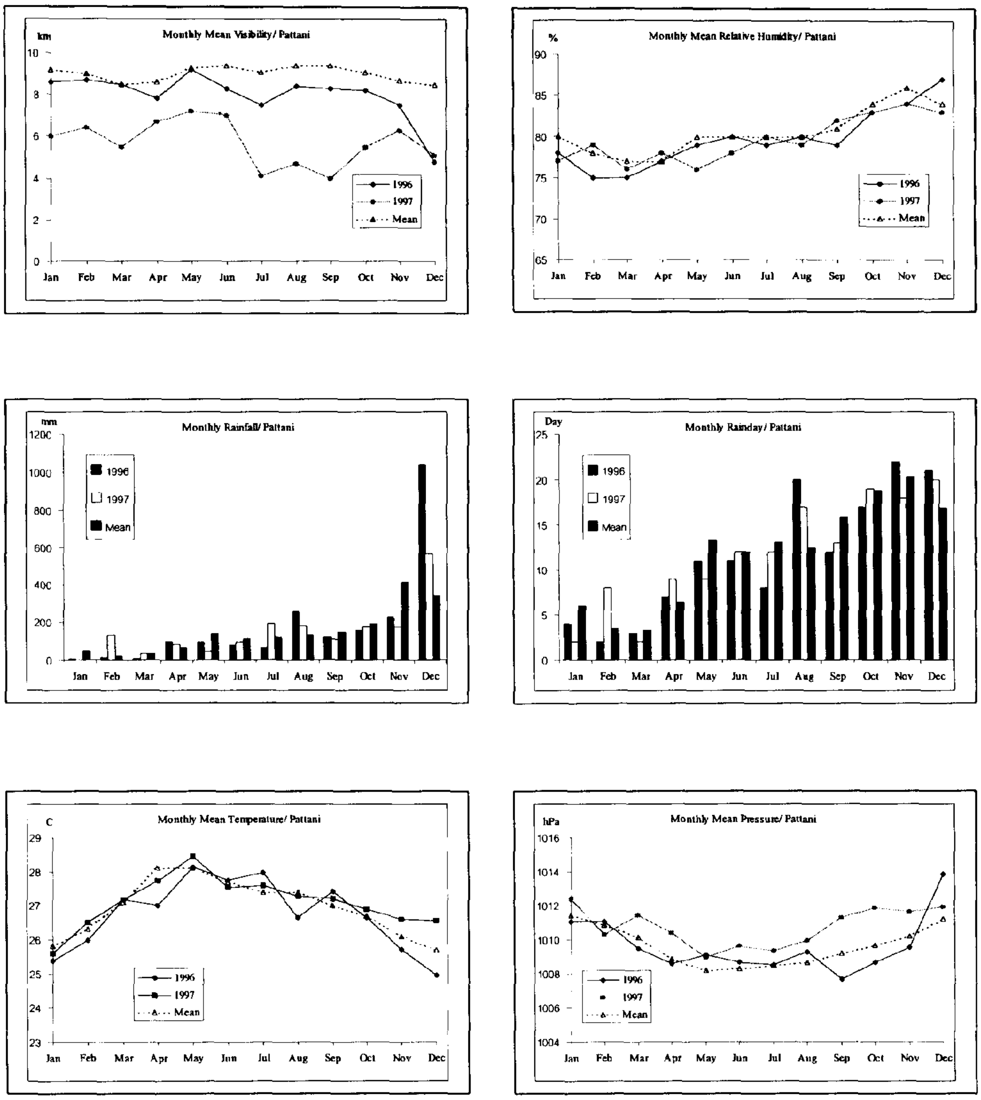


Figure. 3-9. Monthly surface meteorological observations for NARATHIWAT in 1996, 1997 and 30-year mean.

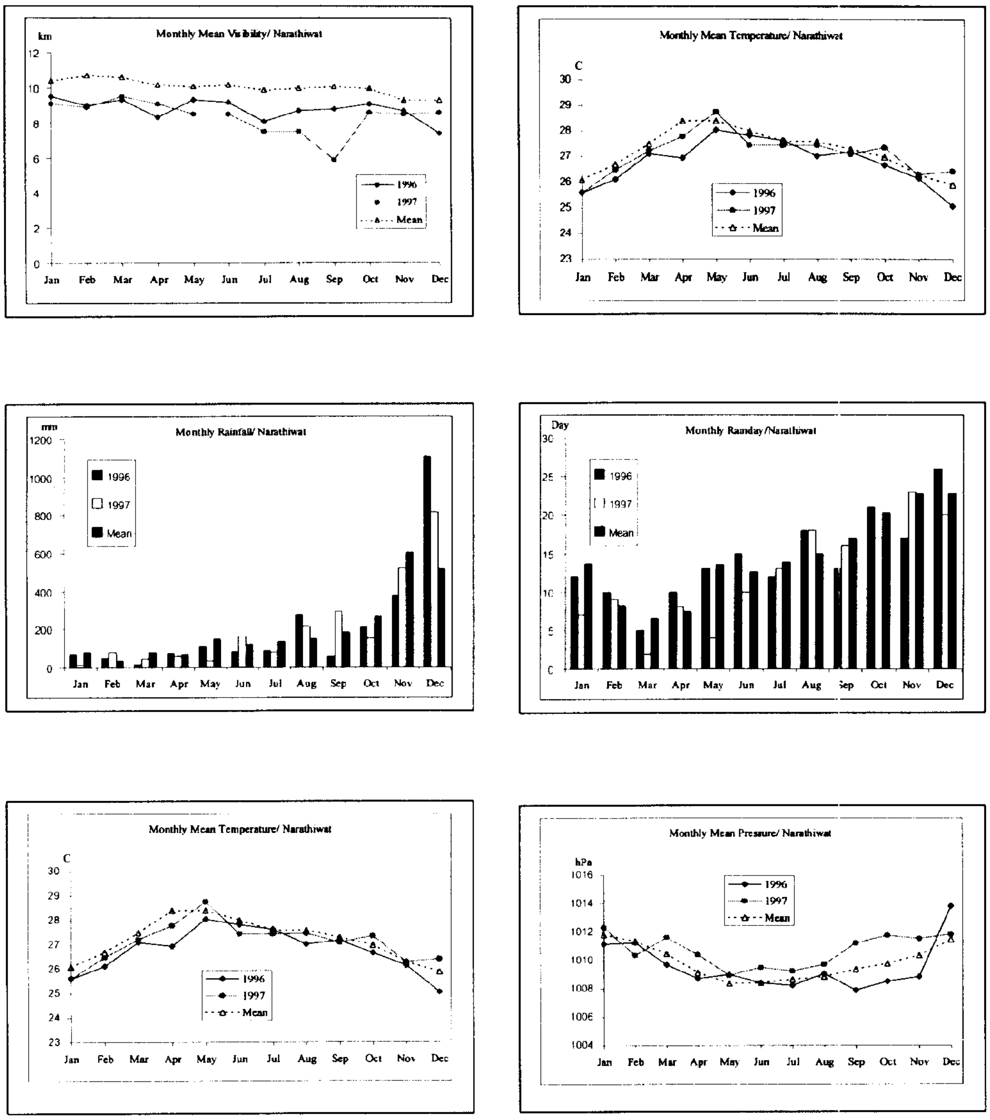


Figure. 3-10. Monthly surface meteorological observations for RANONG in 1996, 1997 and 30-year mean.

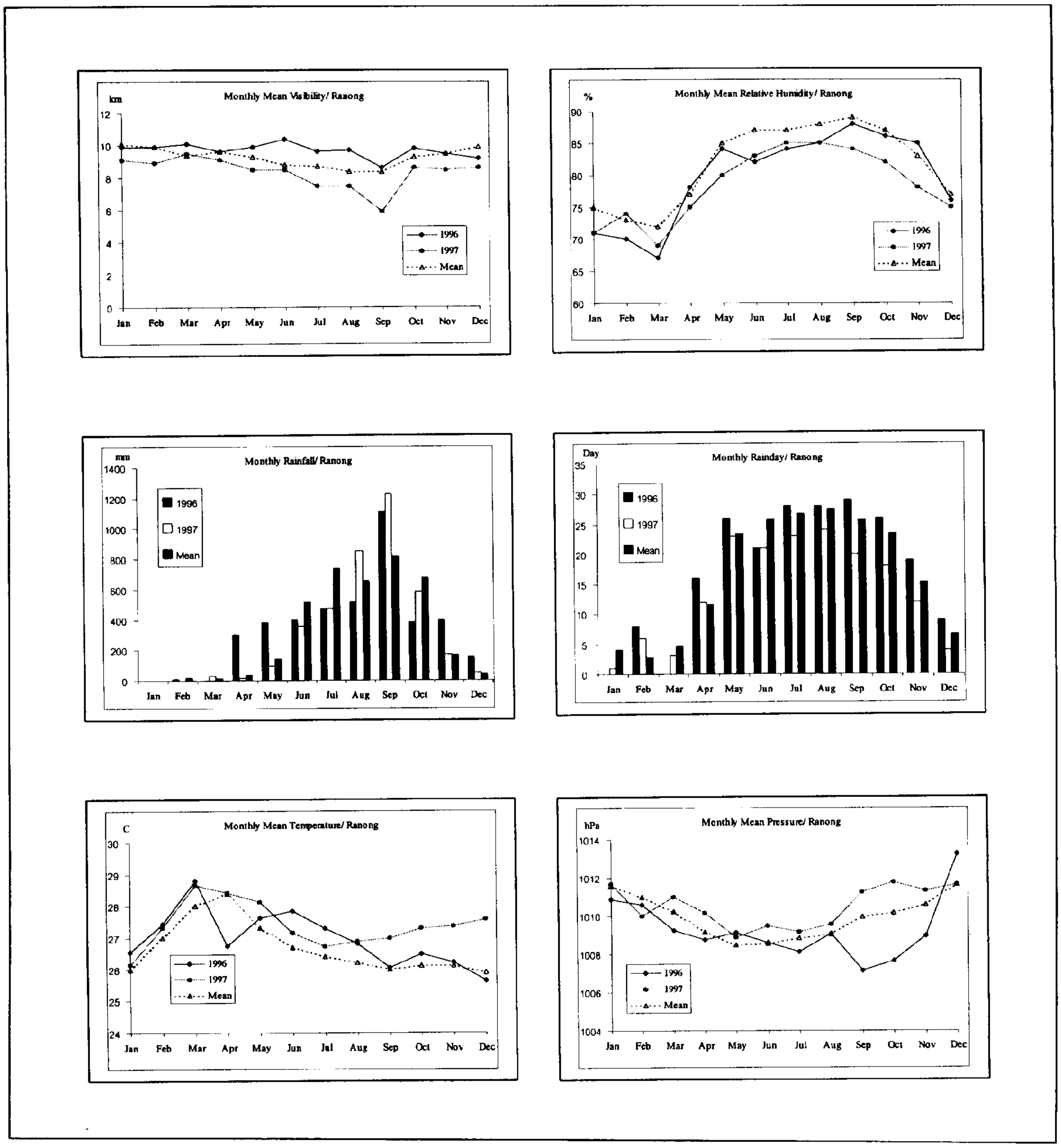


Figure. 3-11. Monthly surface meteorological observations for PHUKET AIRPORT in 1996, 1997 and 30-year mean.

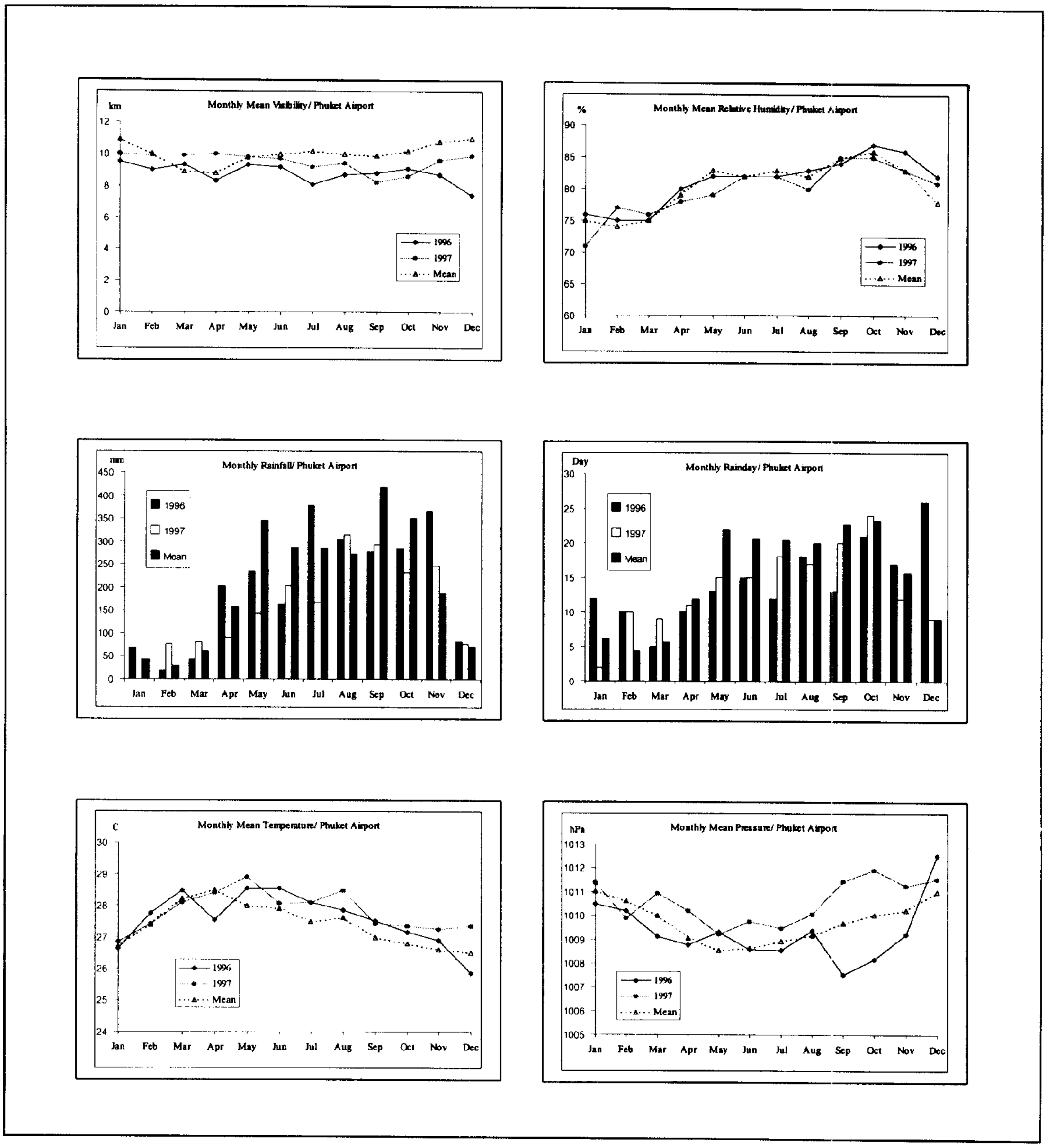


Figure. 3-12. Monthly surface meteorological observations for PHUKET (DOWNTOWN) in 1996, 1997 and 30-year mean.

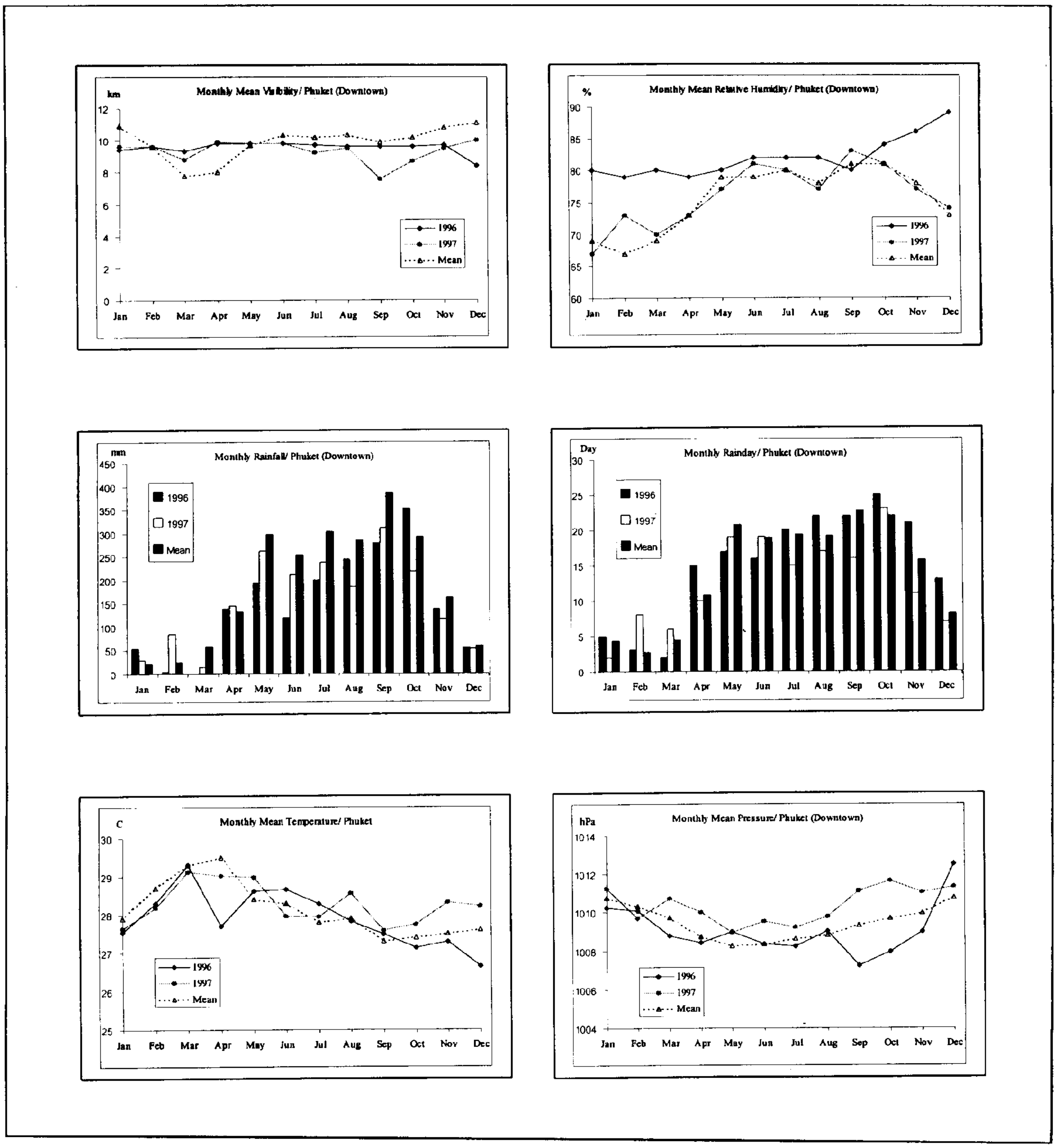


Figure. 3-13. Monthly surface meteorological observations for TAKUA PA (PHANGNGA) in 1996, 1997 and 30-year mean.

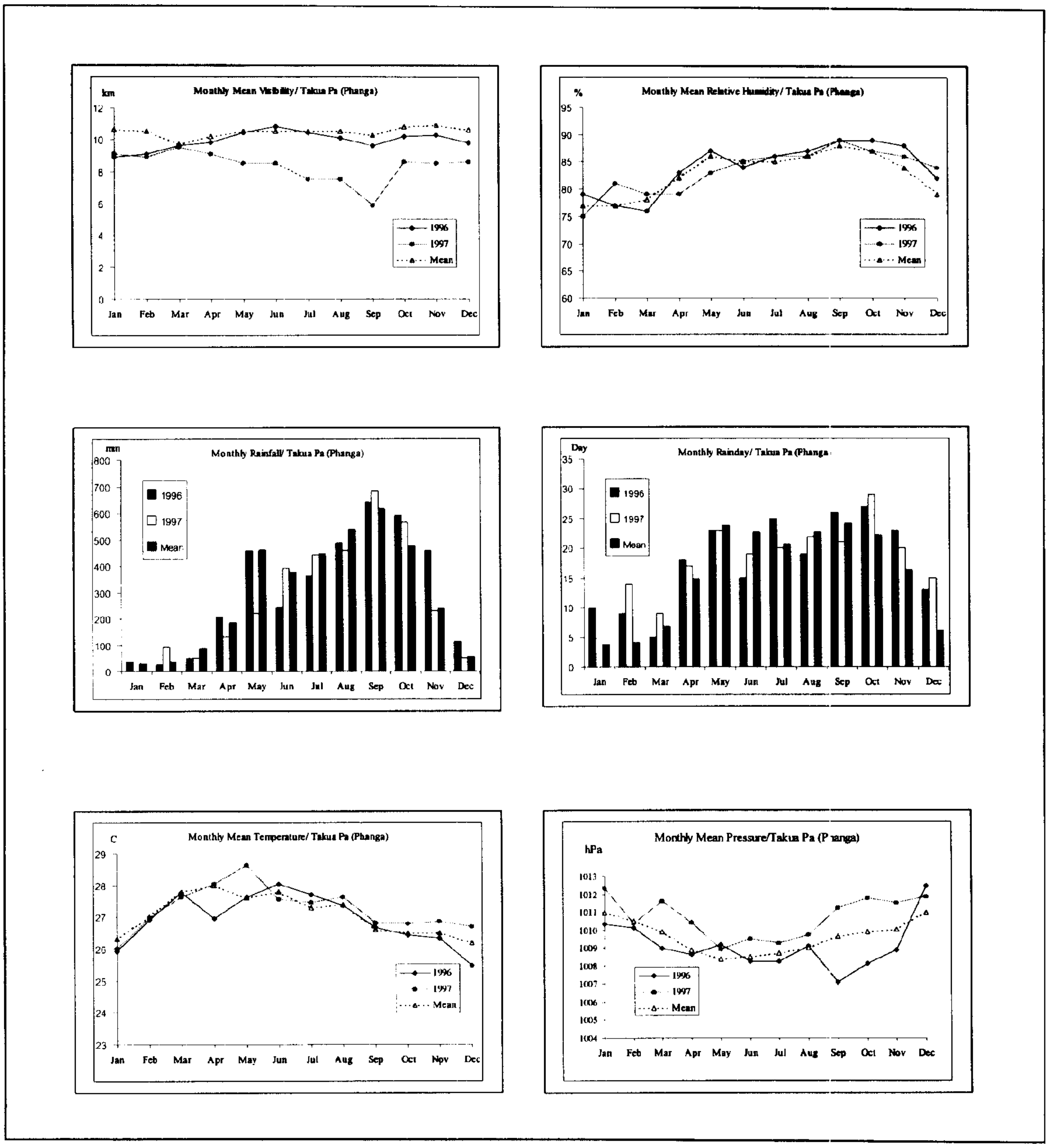


Figure. 3-14. Monthly surface meteorological observations for TRANG in 1996, 1997 and 30-year mean.

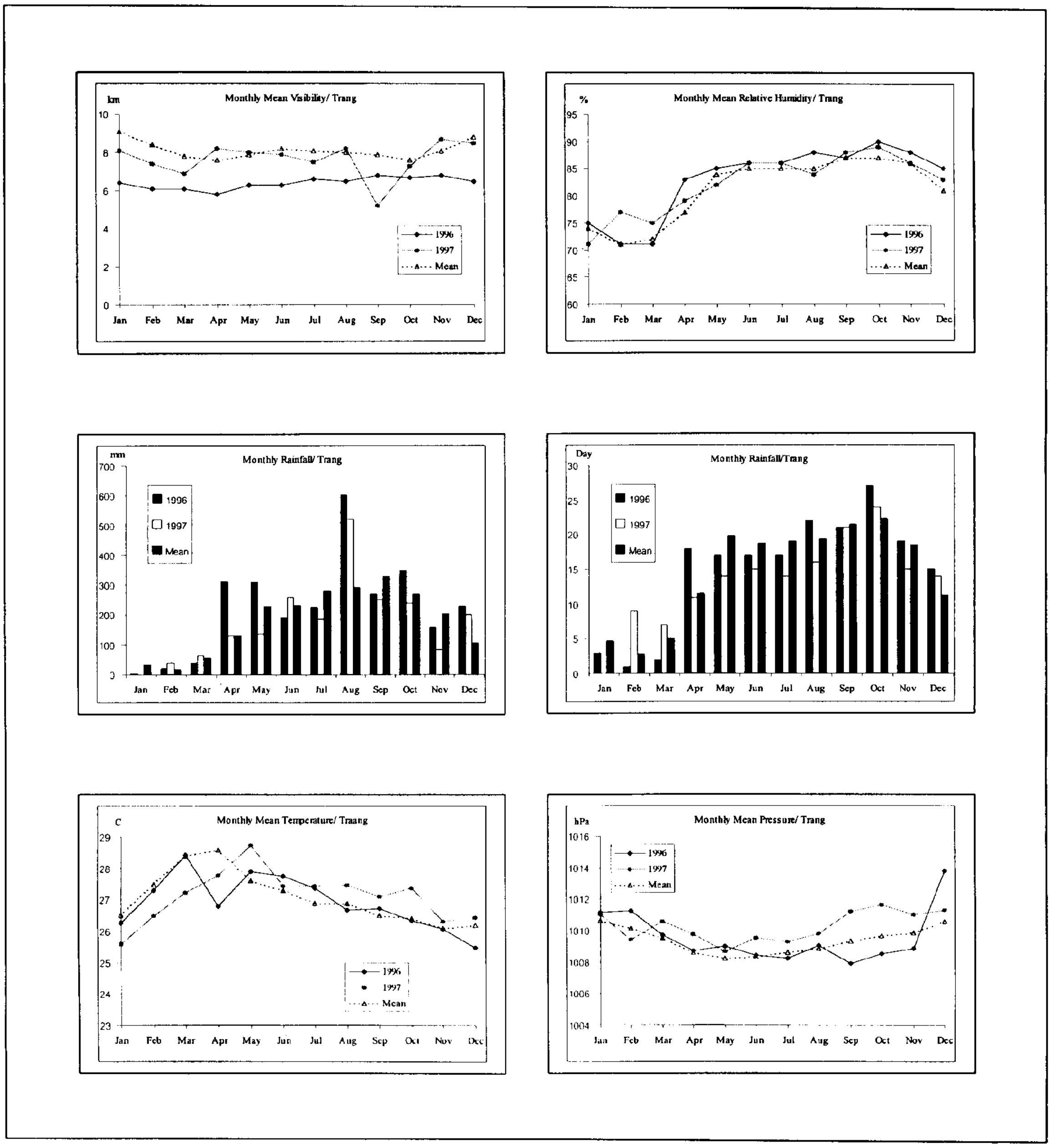


Figure. 3-15. Monthly surface meteorological observations for SATUN in 1996, 1997 and 30-year mean.

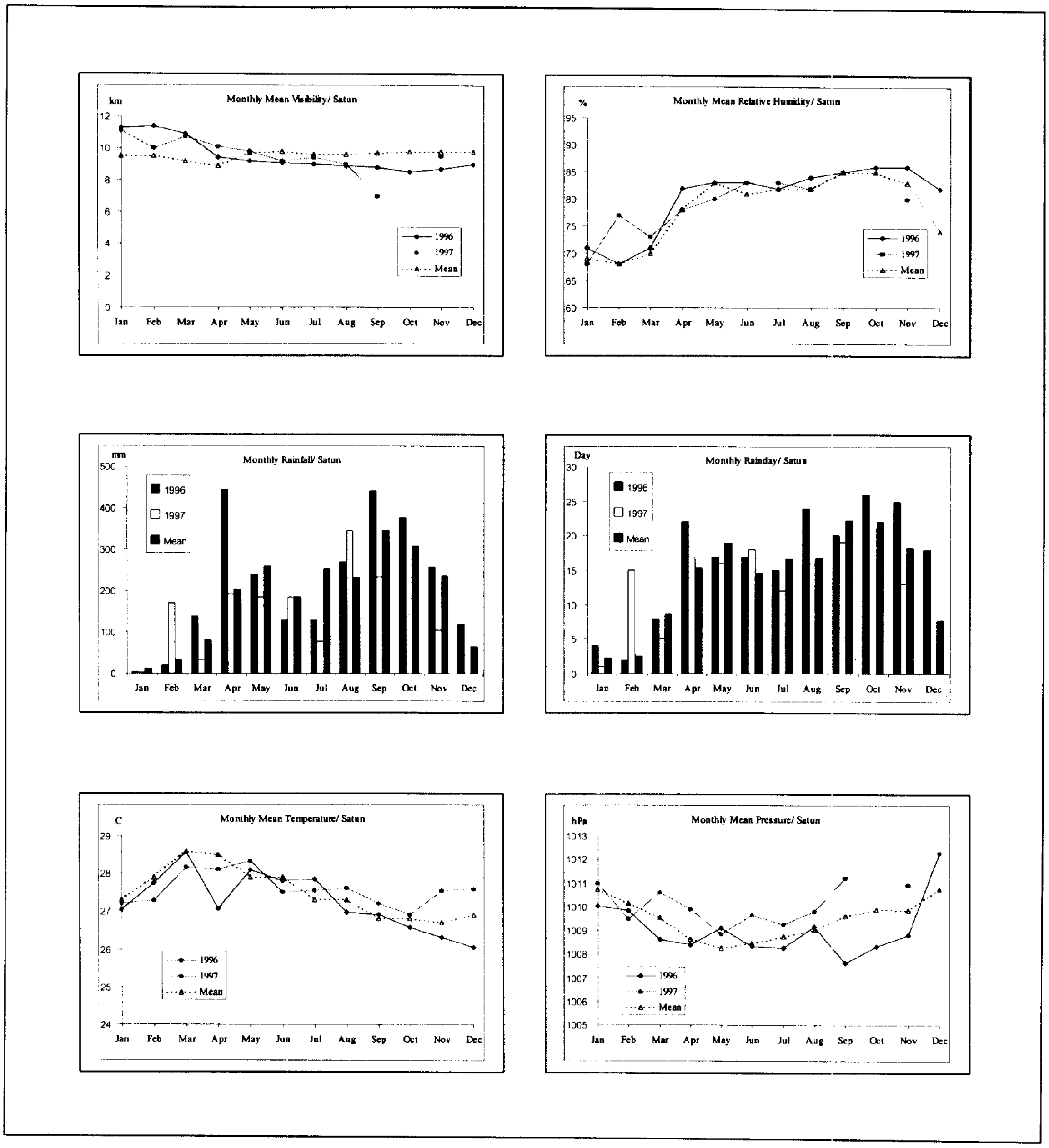


Figure. 3-16. Description of wind rose diagram used in this chapter.

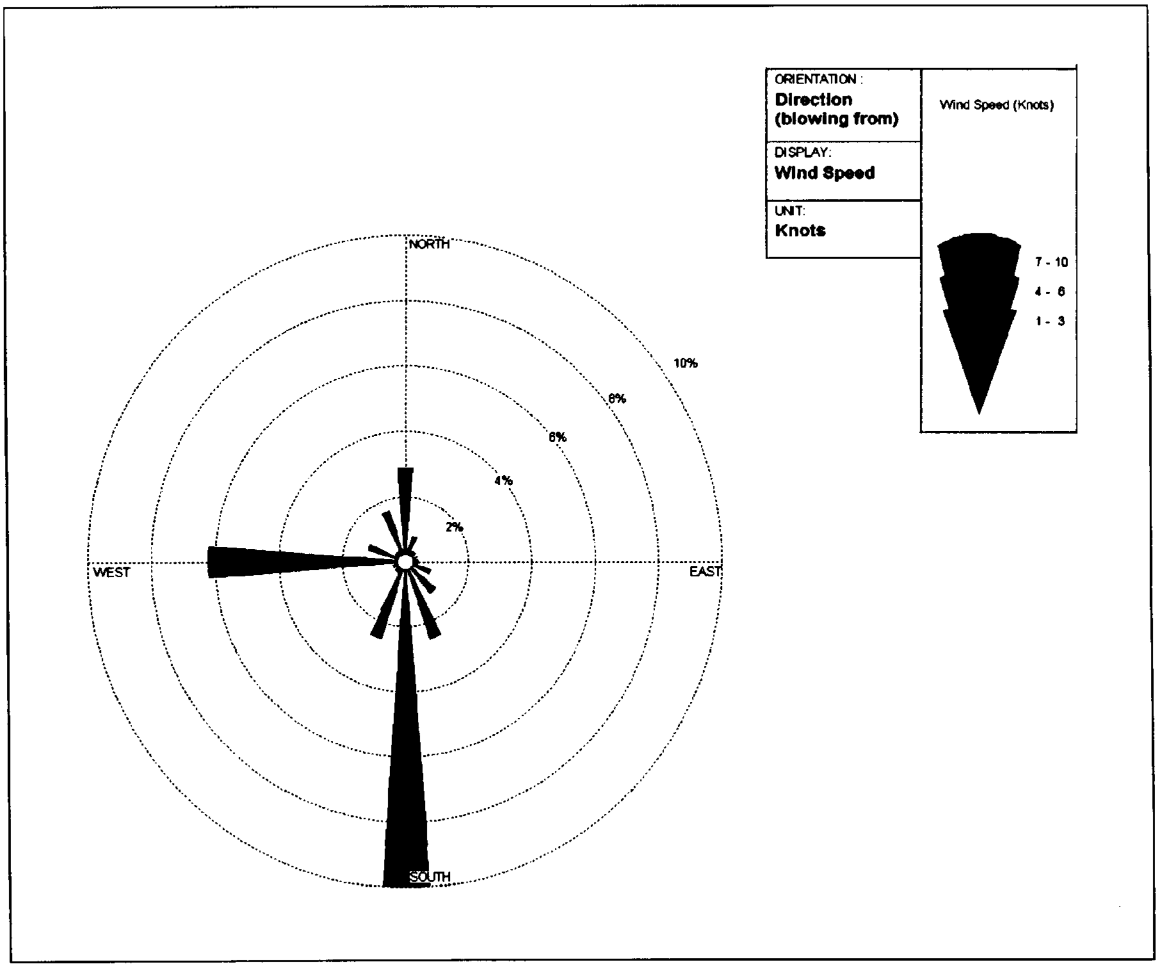


Figure. 3-17. Wind rose analysis for CHUMPHON in 1996.

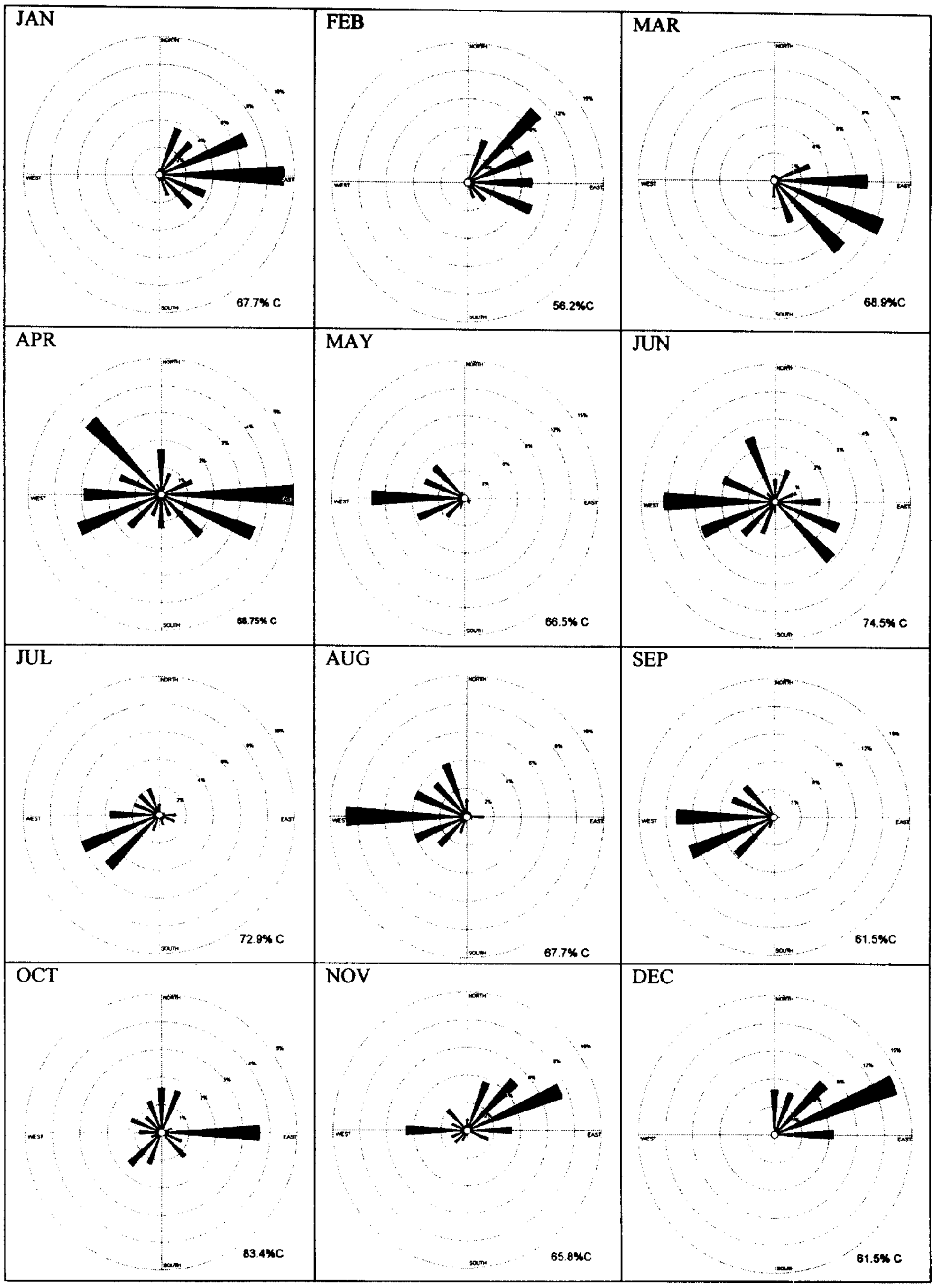


Figure. 3-18. Wind rose analysis for CHUMPHON in 1997.

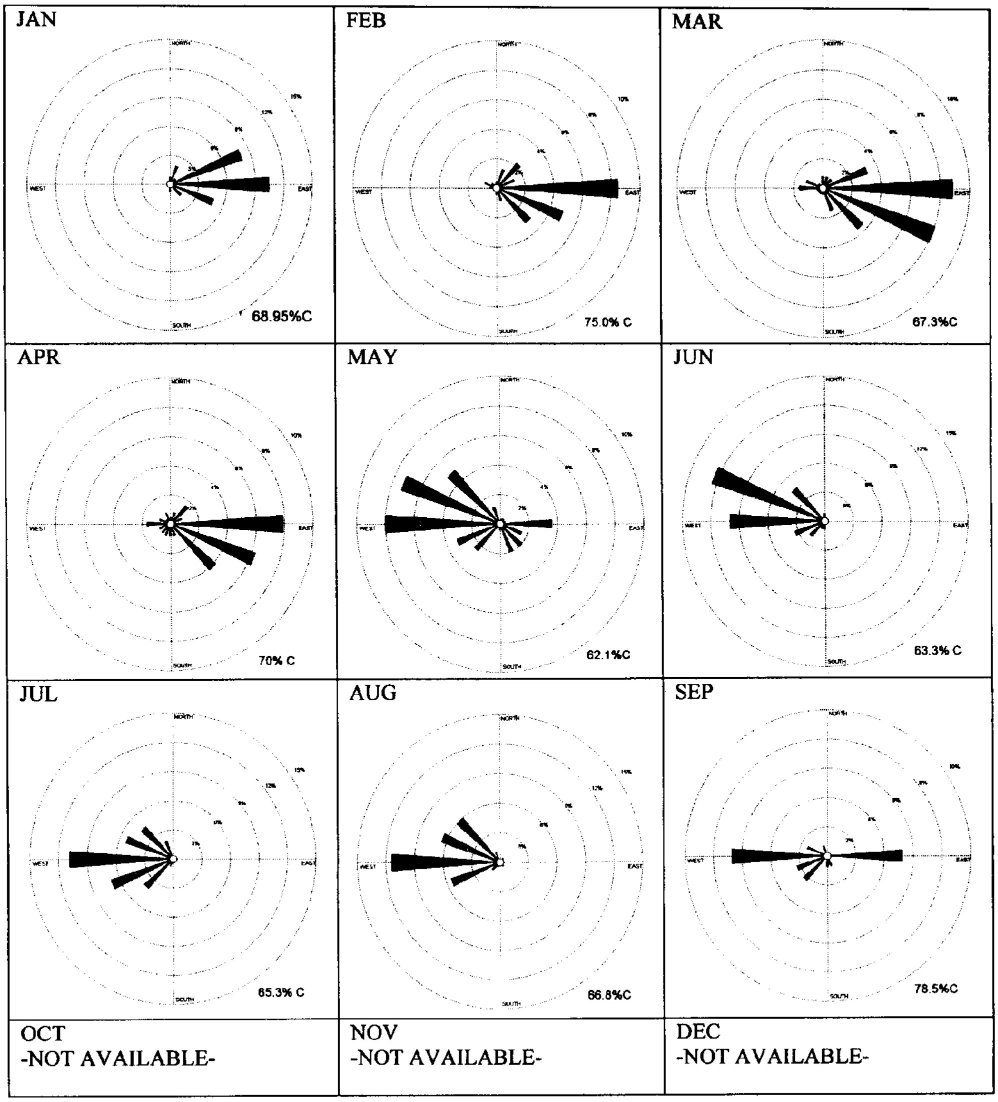


Figure. 3-19. Wind rose analysis for SURAT THANI in 1996.

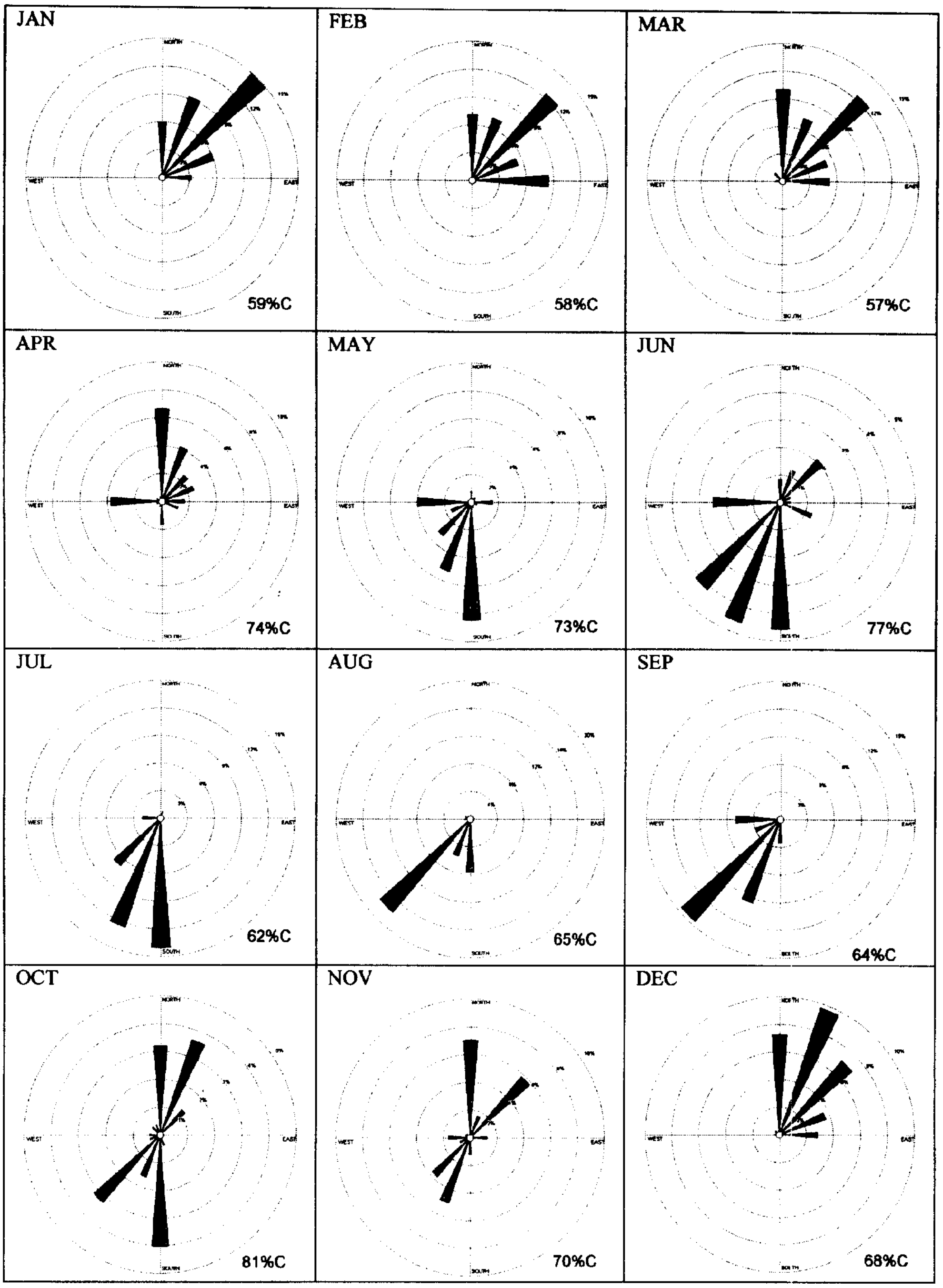


Figure. 3-20. Wind rose analysis for SURAT THANI in 1997.

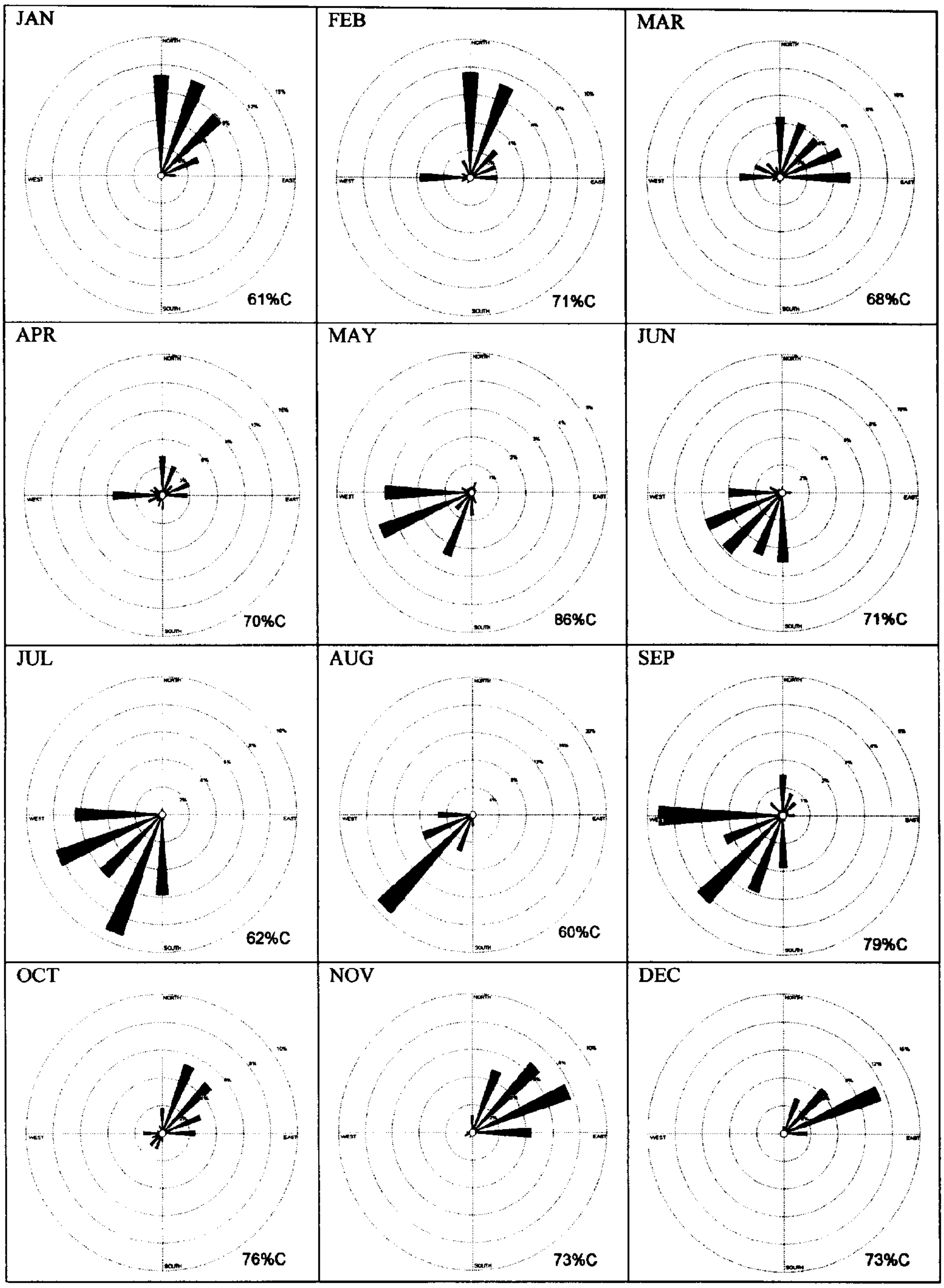


Figure. 3-21. Wind rose analysis for KO SAMUI in 1996.

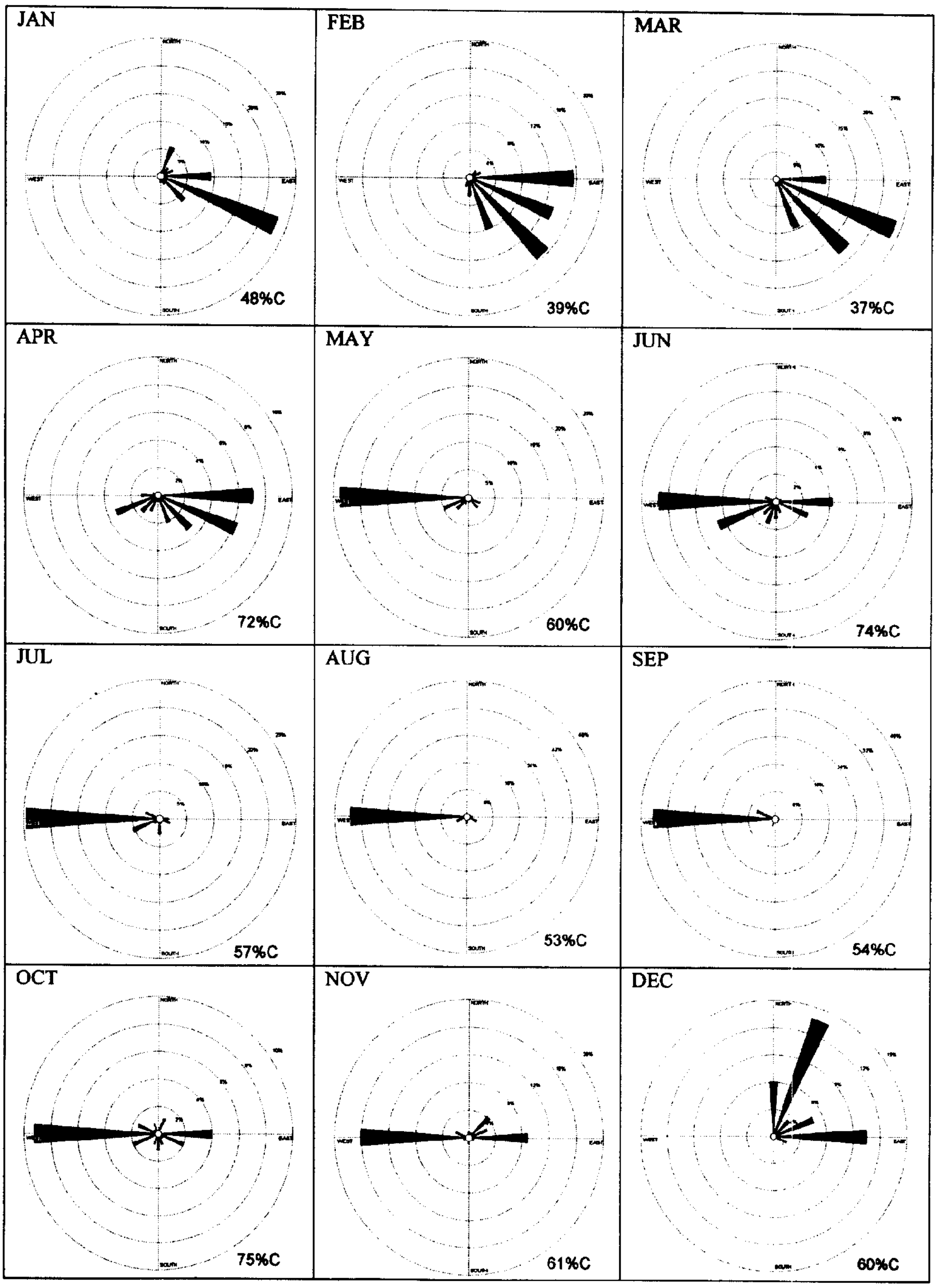


Figure. 3-22. Wind rose analysis for KO SAMUI in 1997.

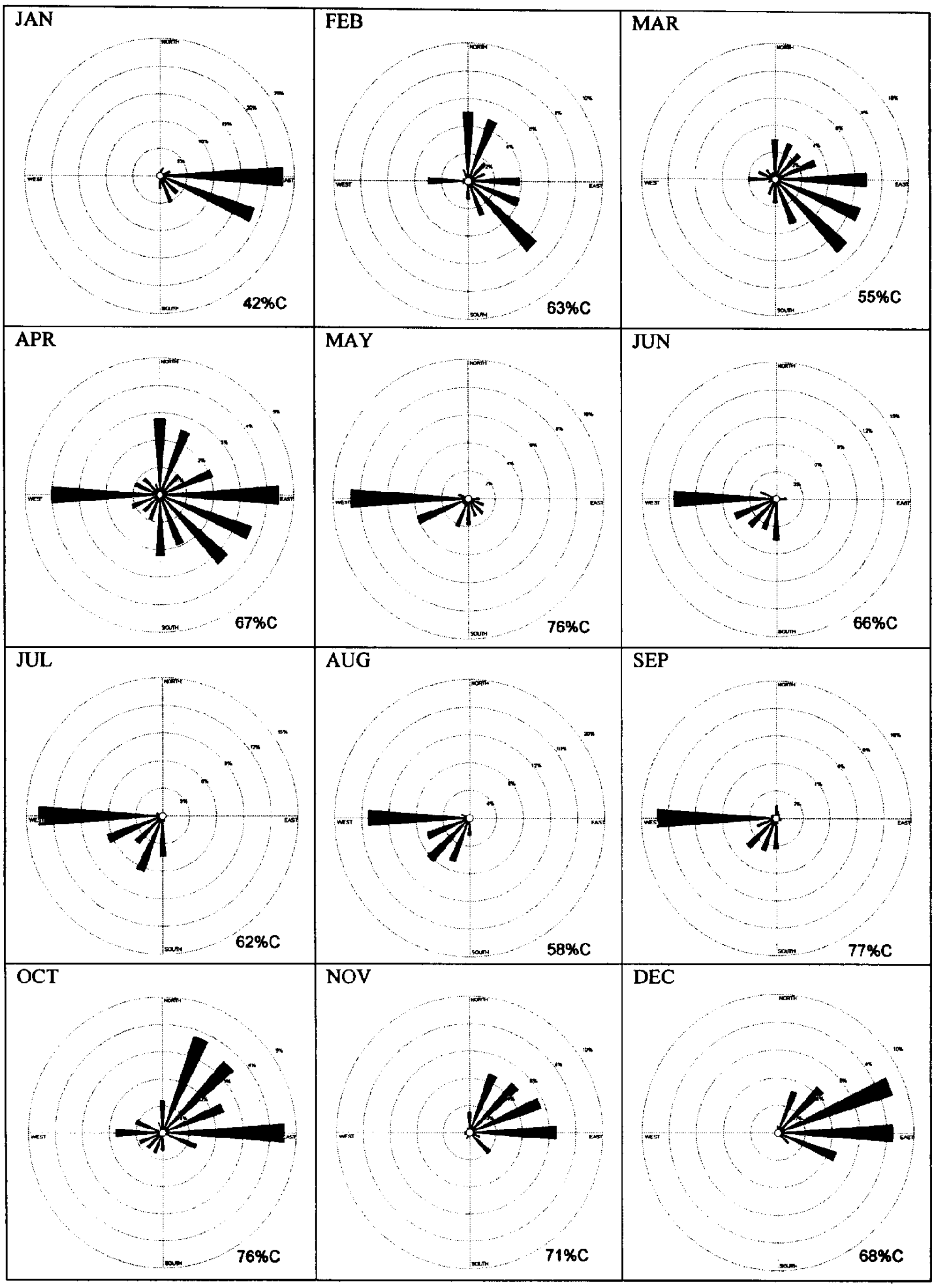


Figure. 3-23. Wind rose analysis for NAKHON SI THAMMARAT in 1996.

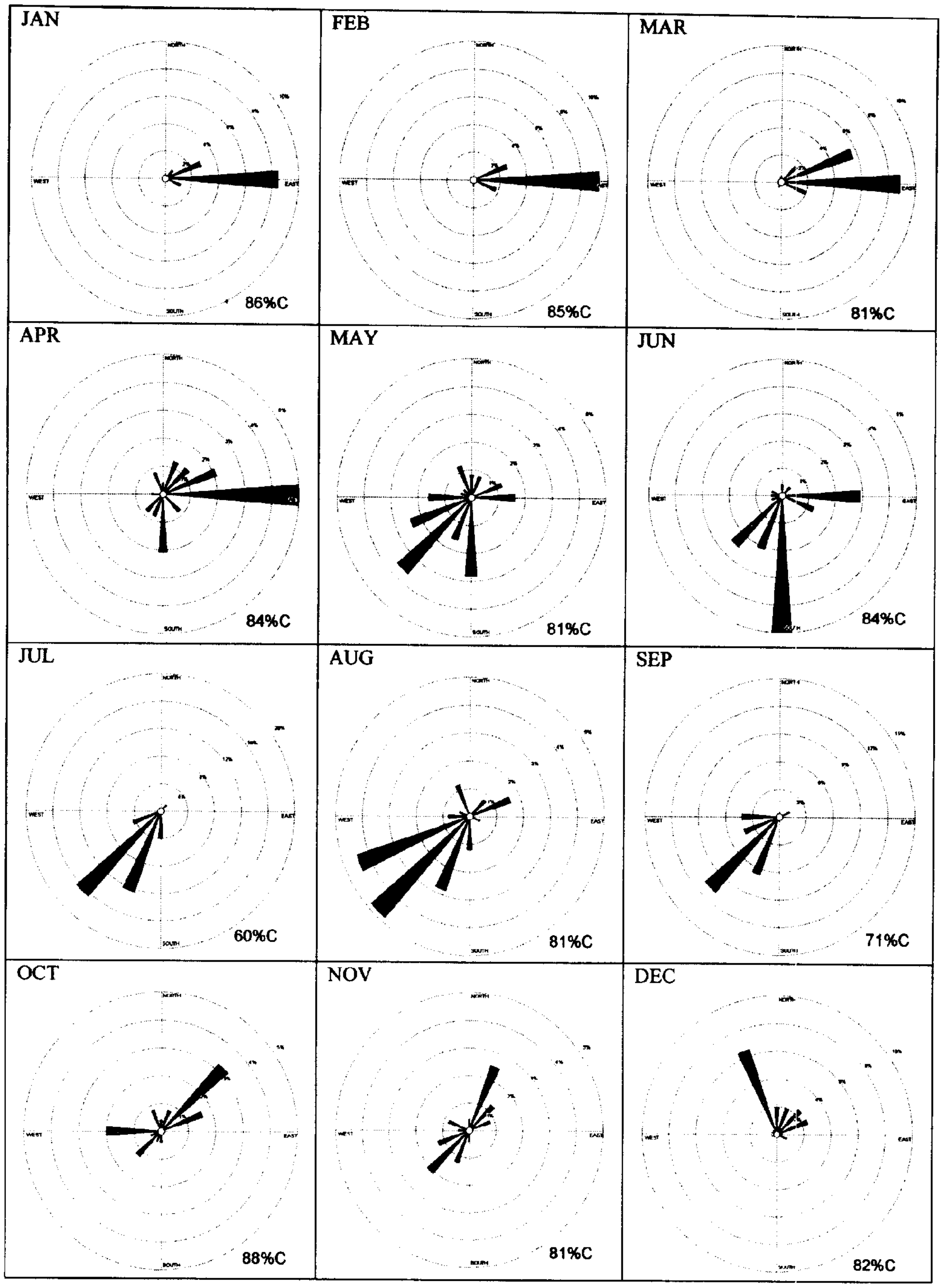


Figure. 3-24. Wind rose analysis for NAKHON SI THAMMARAT in 1997.

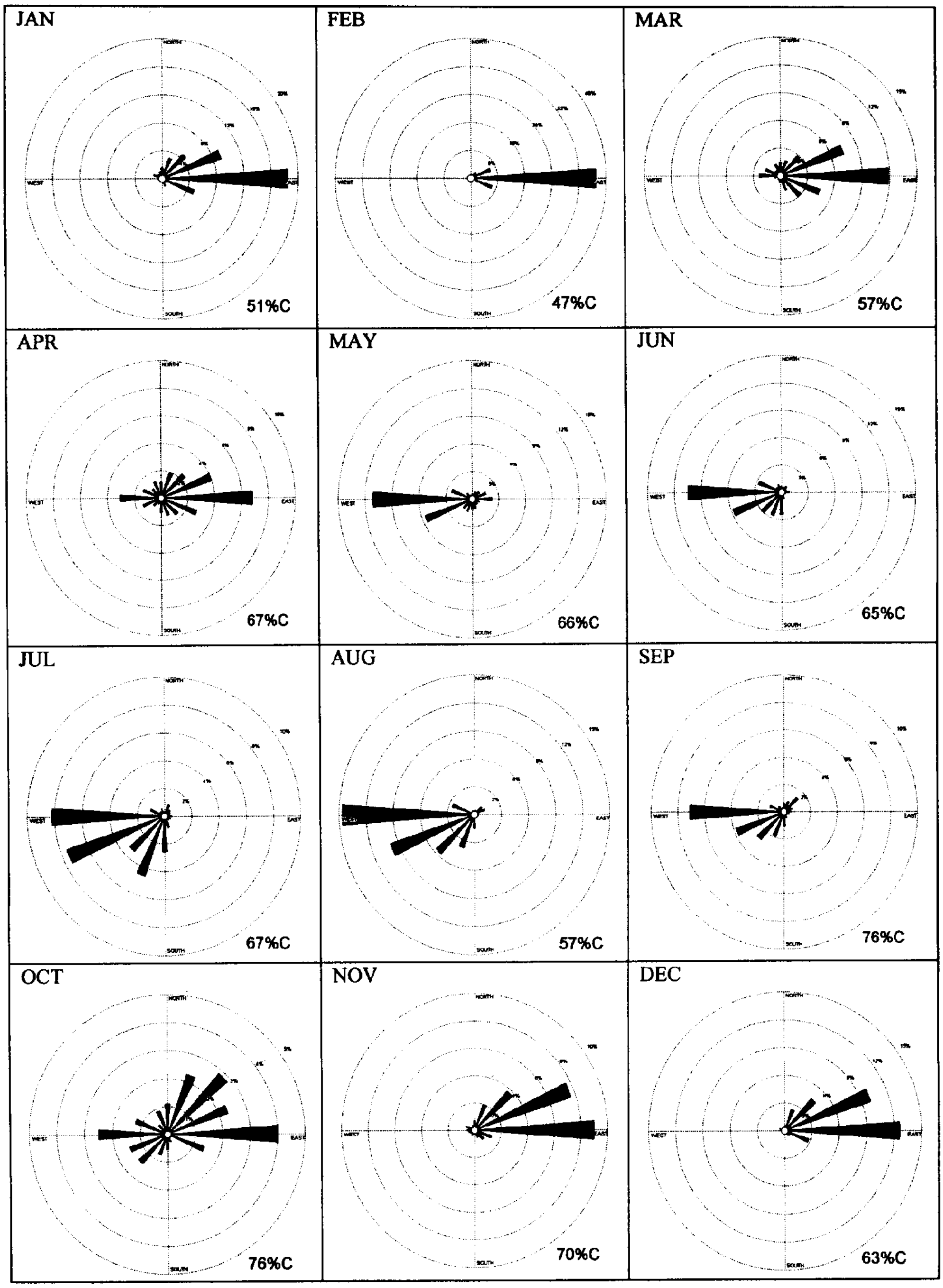


Figure. 3-25. Wind rose analysis for HAT YAI in 1996.

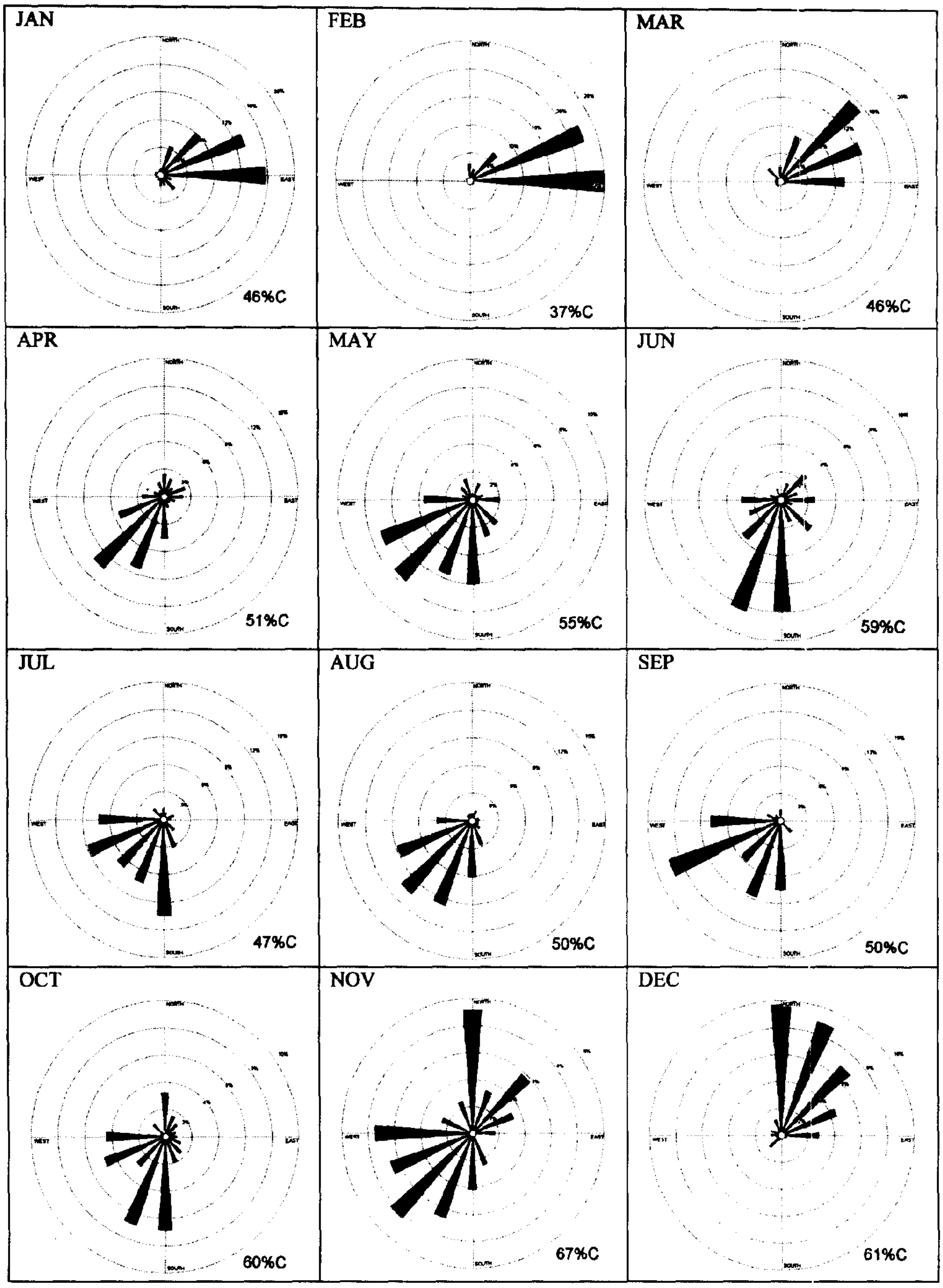


Figure. 3-26. Wind rose analysis for HAT YAI in 1997.

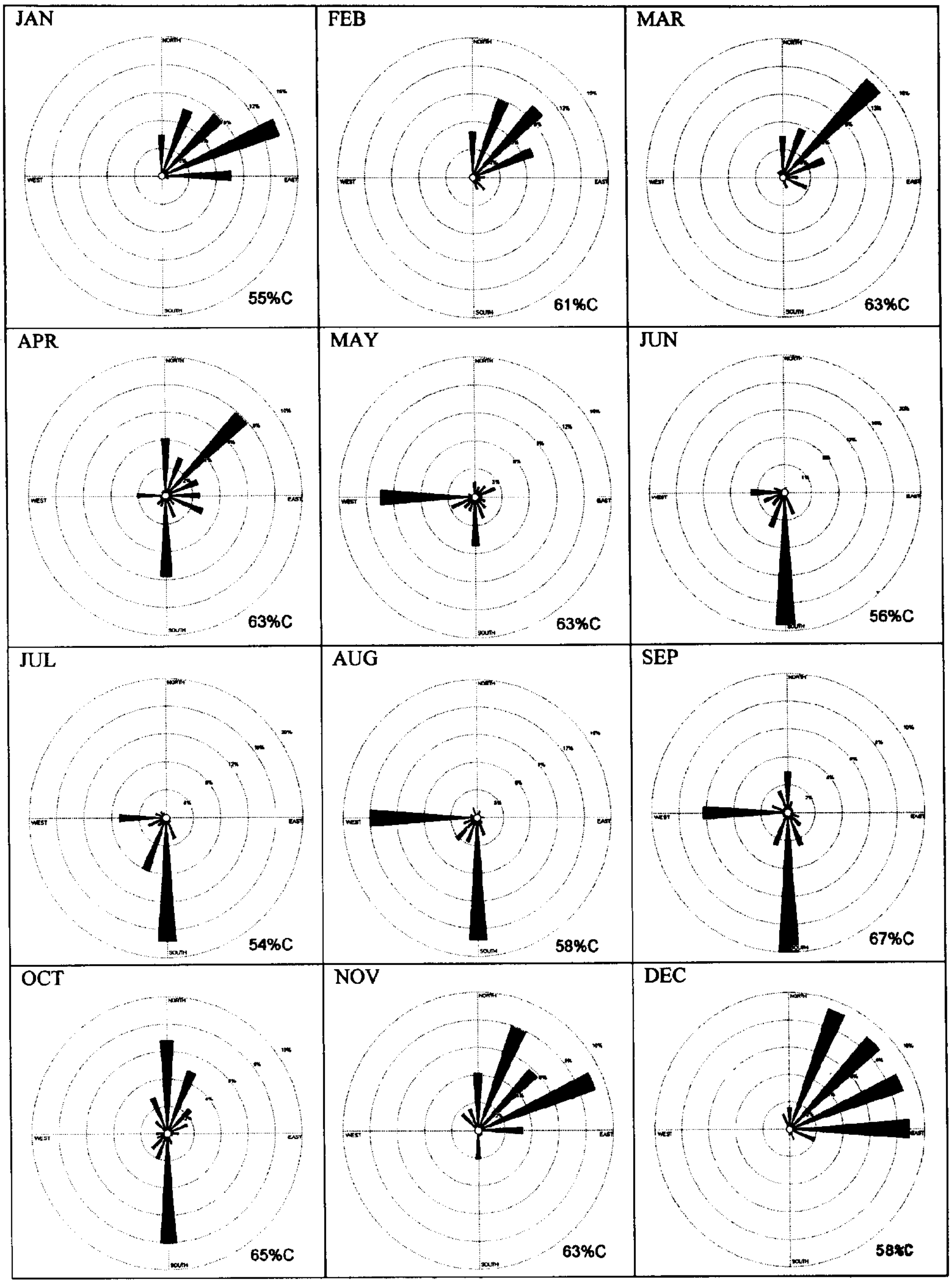


Figure. 3-27. Wind rose analysis for SONGKHLA in 1996.

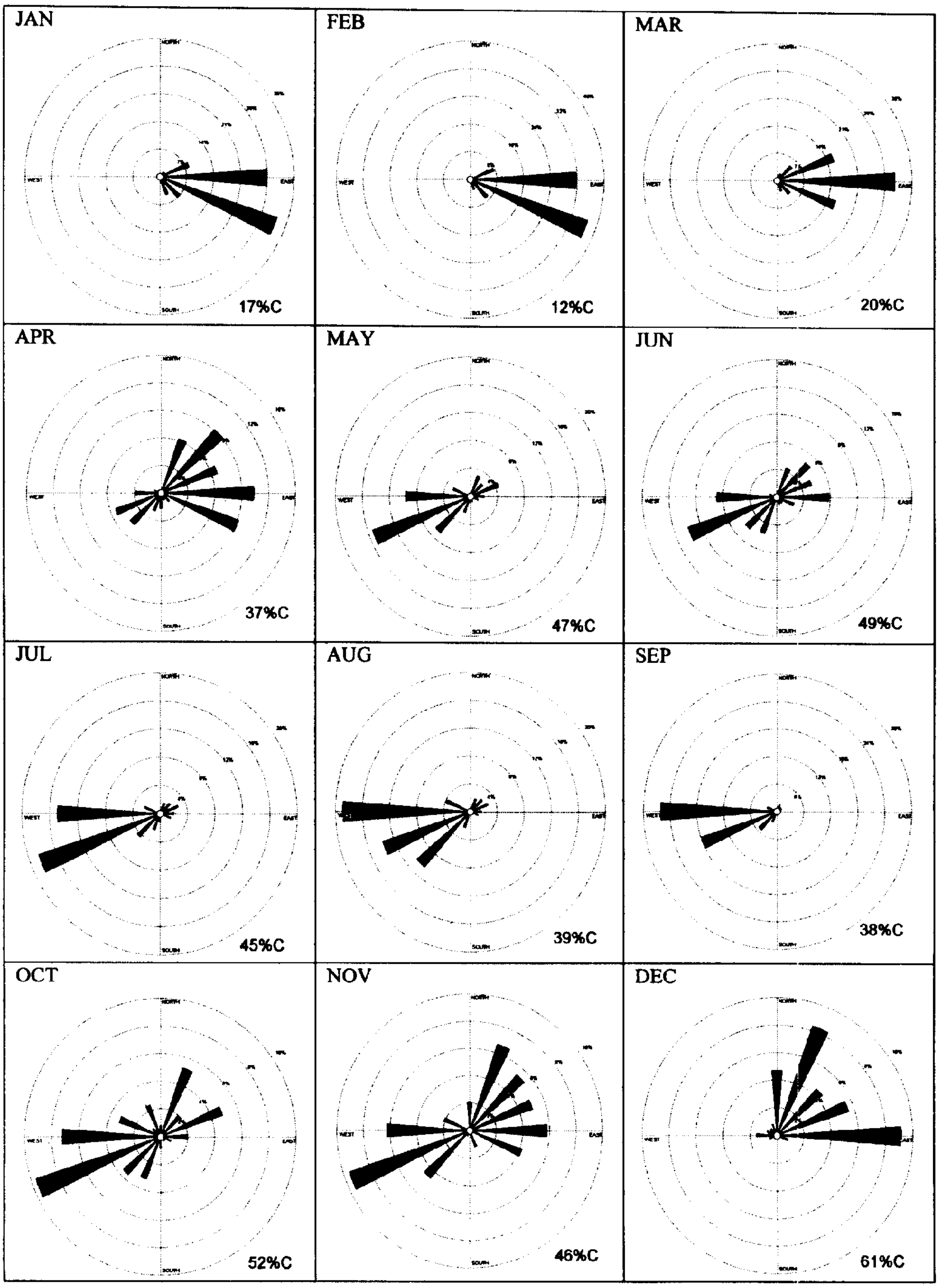


Figure. 3-28. Wind rose analysis for SONGKHLA in 1997.

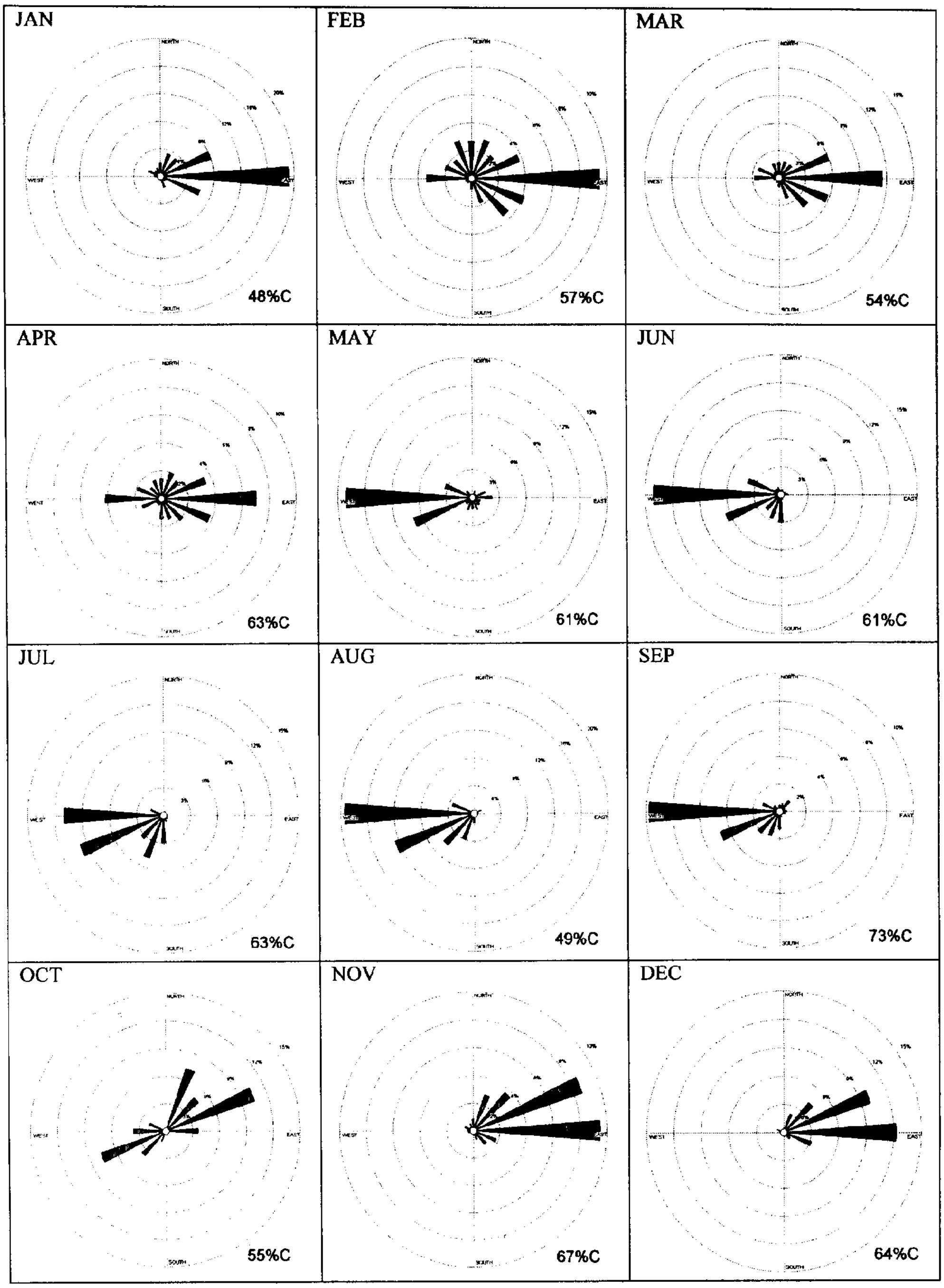


Figure. 3-29. Wind rose analysis for PATTANI in 1996.

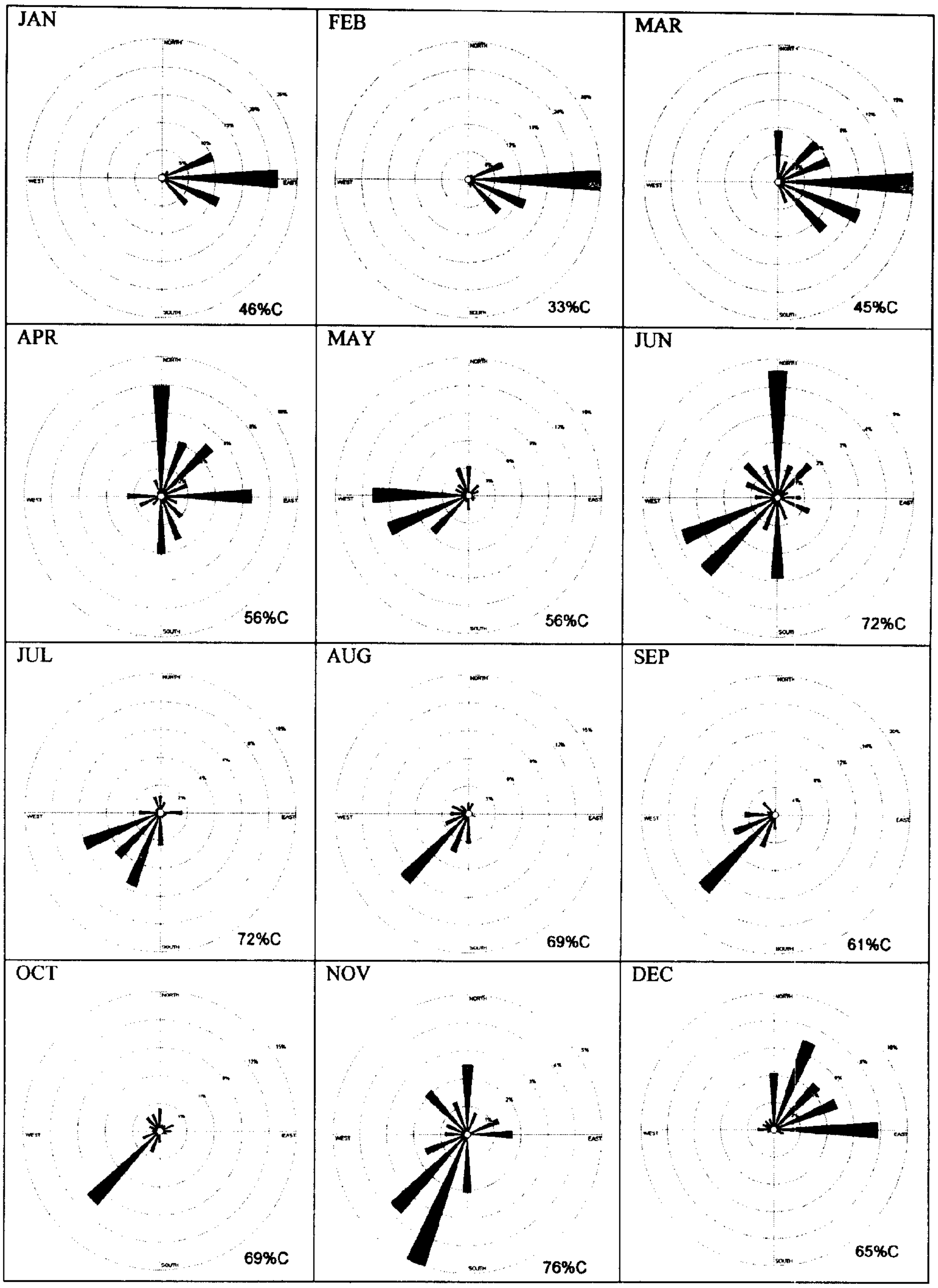


Figure. 3-30. Wind rose analysis for PATTANI in 1997.

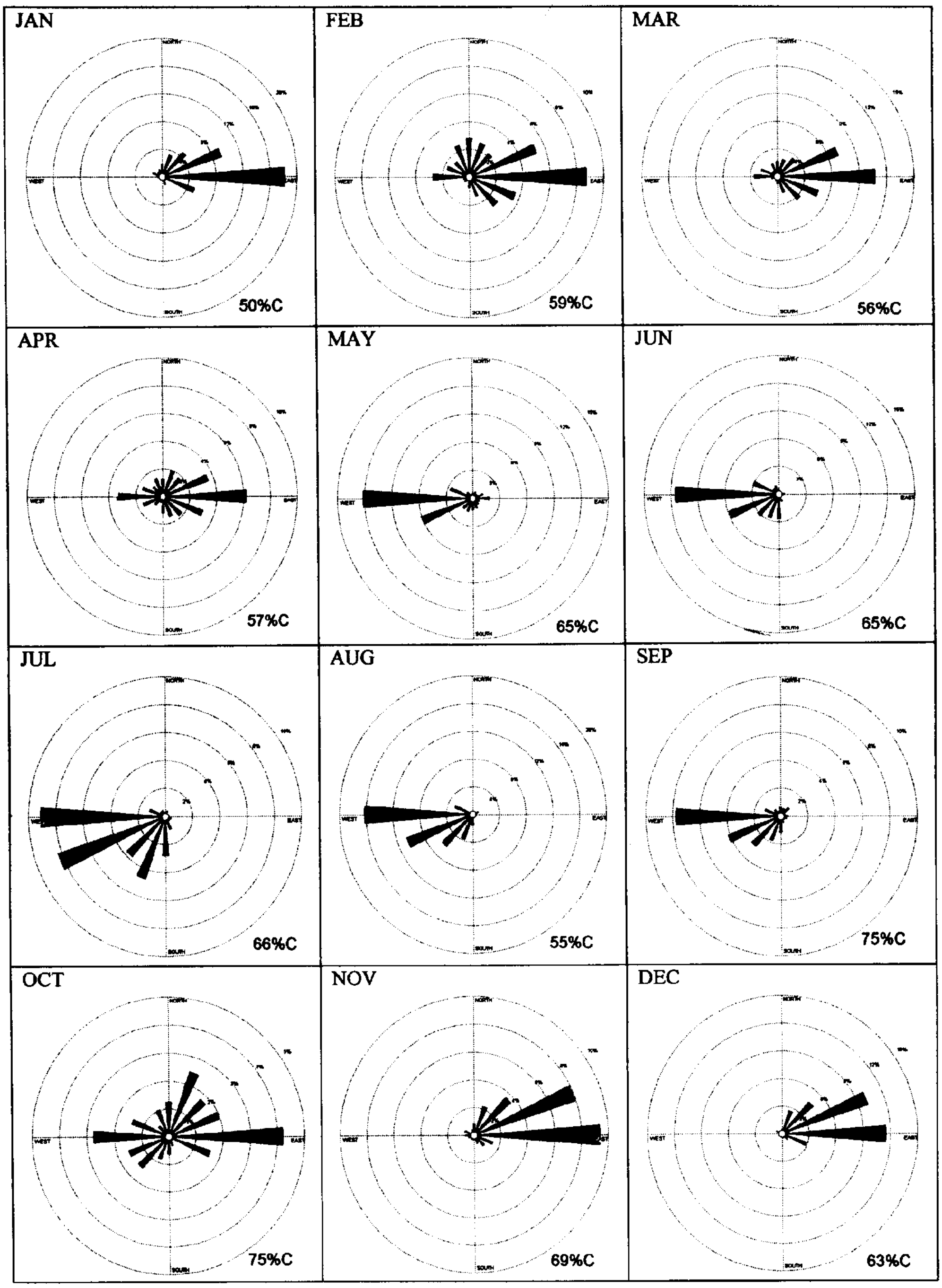


Figure. 3-31. Wind rose analysis for NARATHIWAT in 1996.

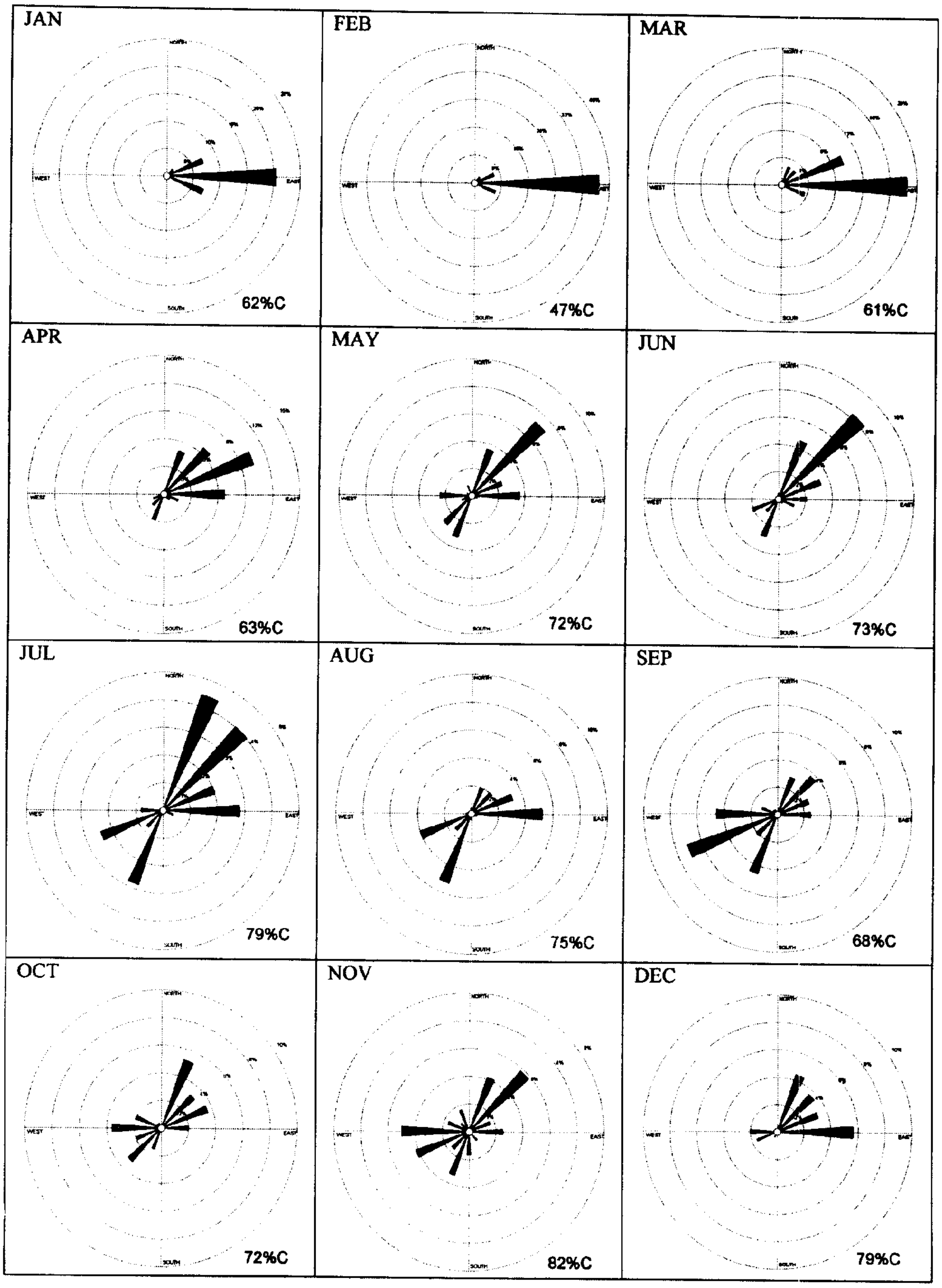


Figure. 3-32. Wind rose analysis for NARATHIWAT in 1997.

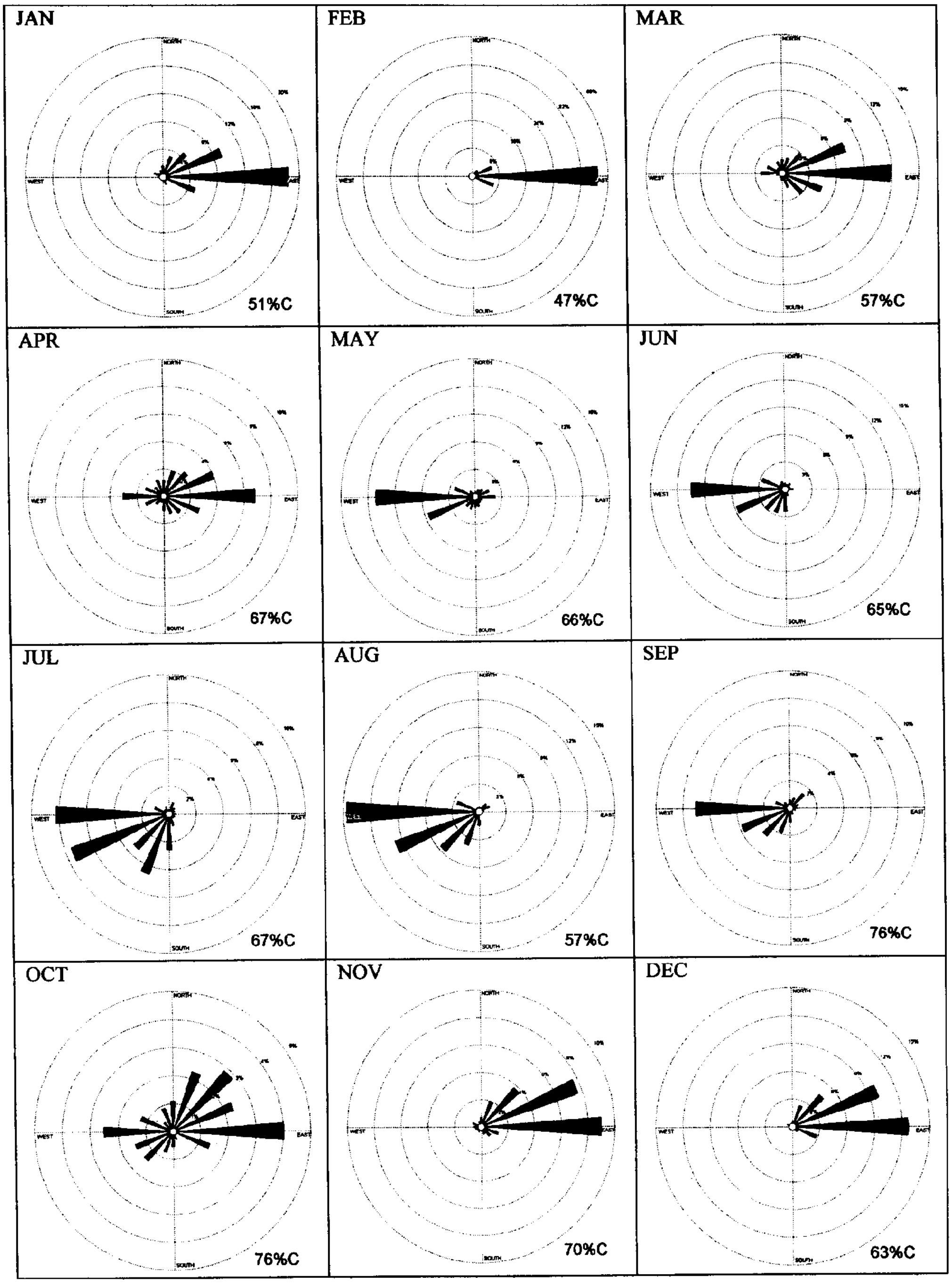


Figure. 3-33. Wind rose analysis for RANONG in 1996.

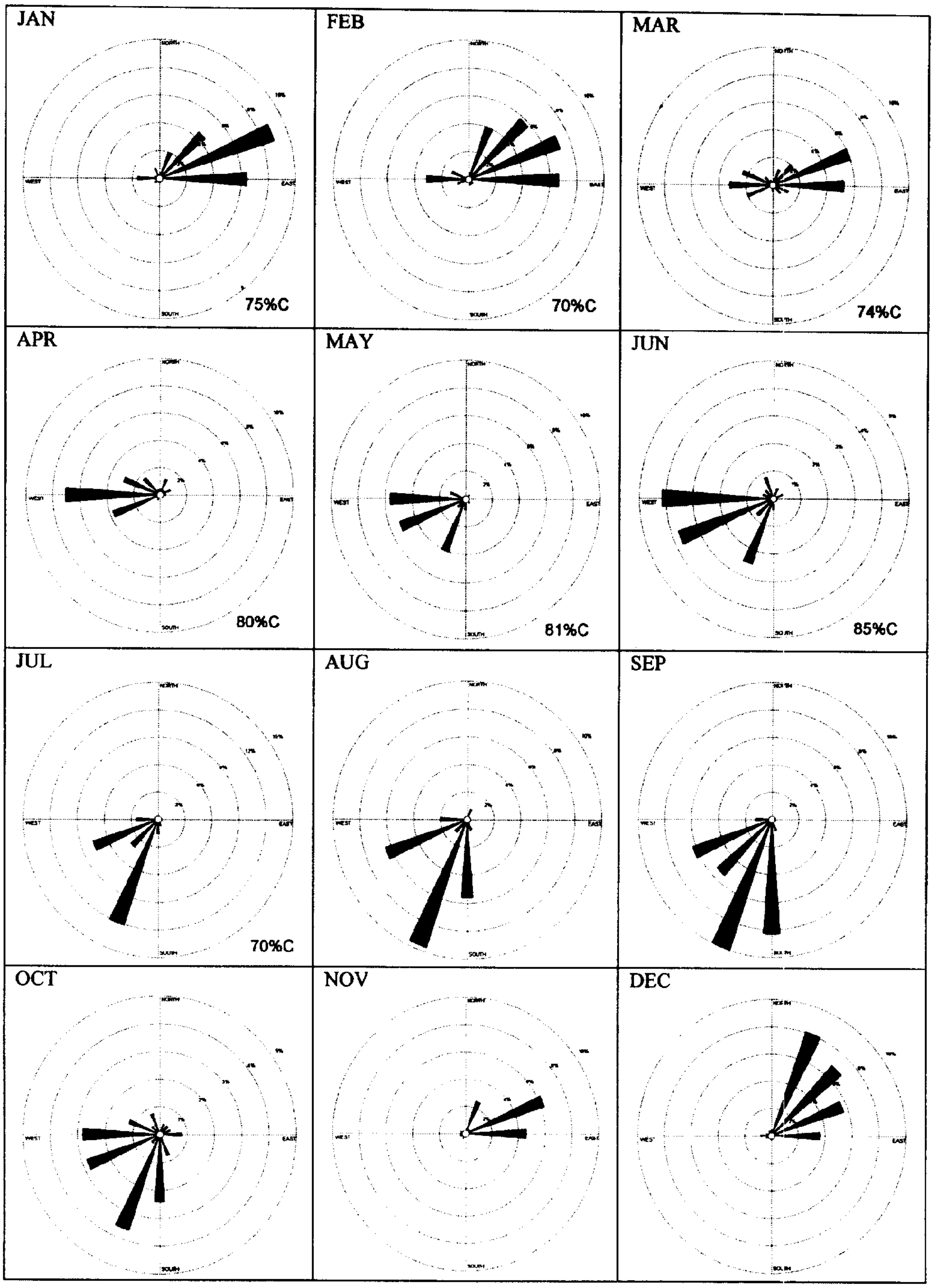


Figure. 3-34. Wind rose analysis for RANONG in 1997.

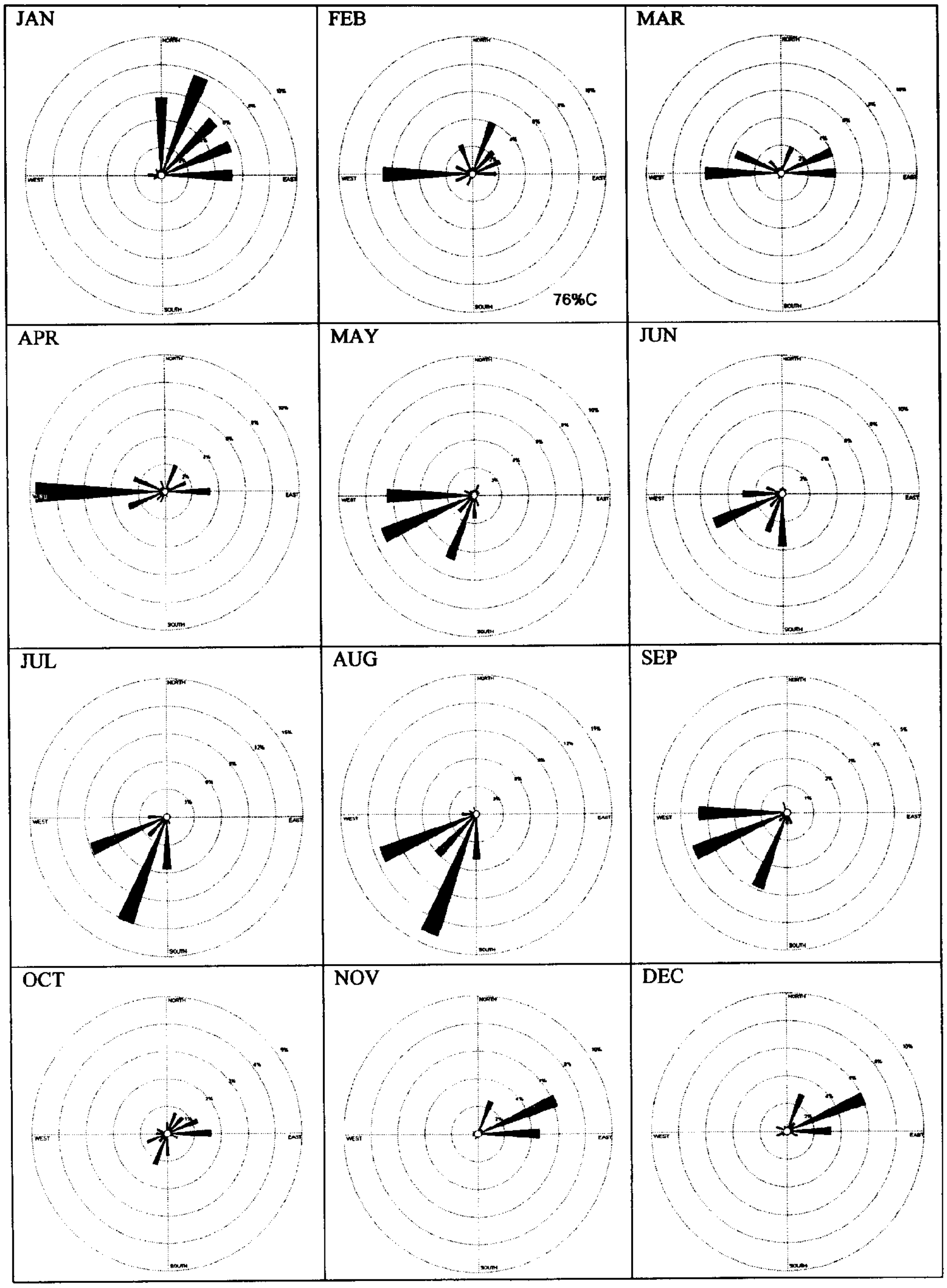


Figure. 3-35. Wind rose analysis for PHUKET AIRPORT in 1996.

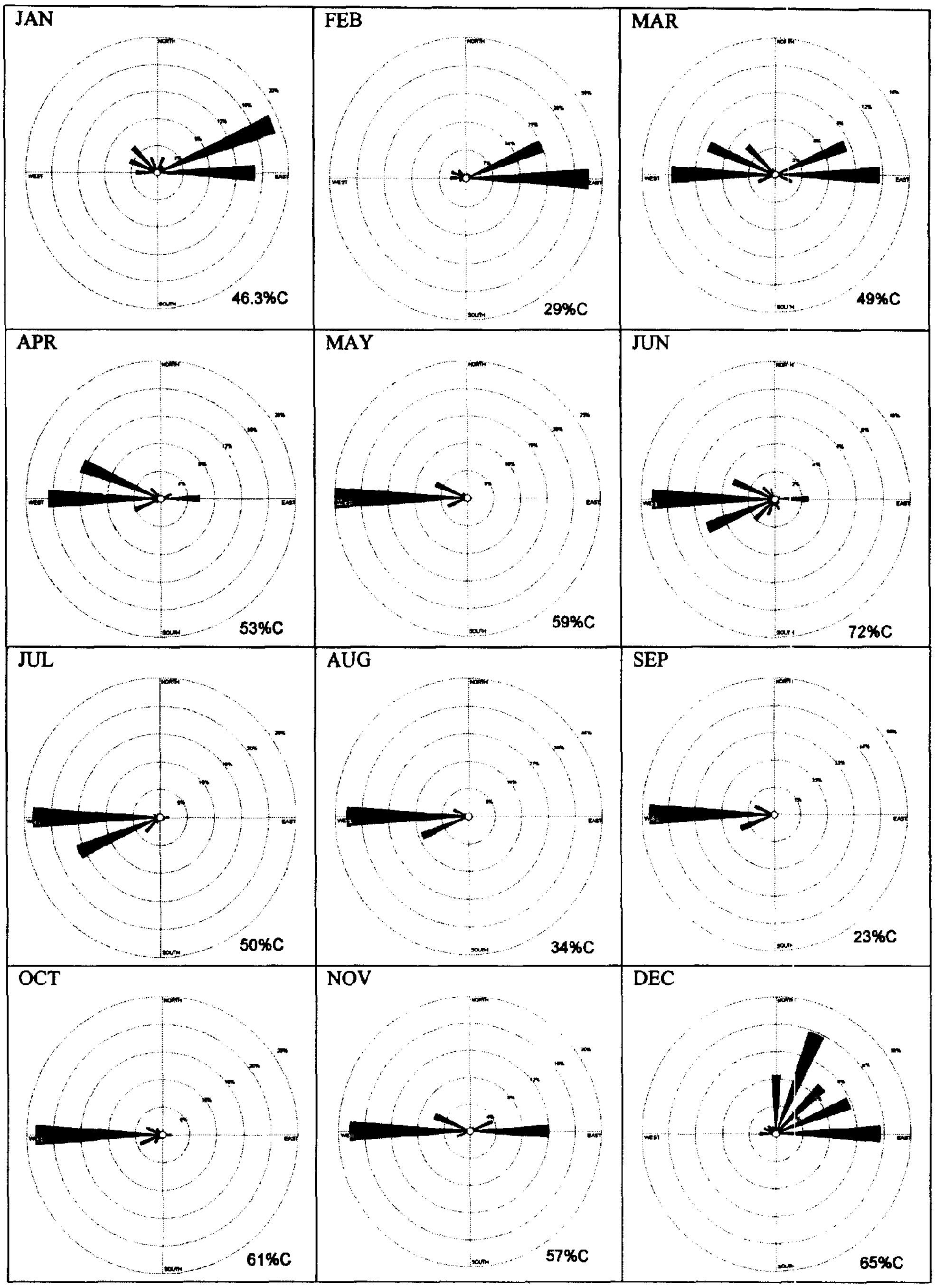


Figure. 3-36. Wind rose analysis for PHUKET AIRPORT in 1997.

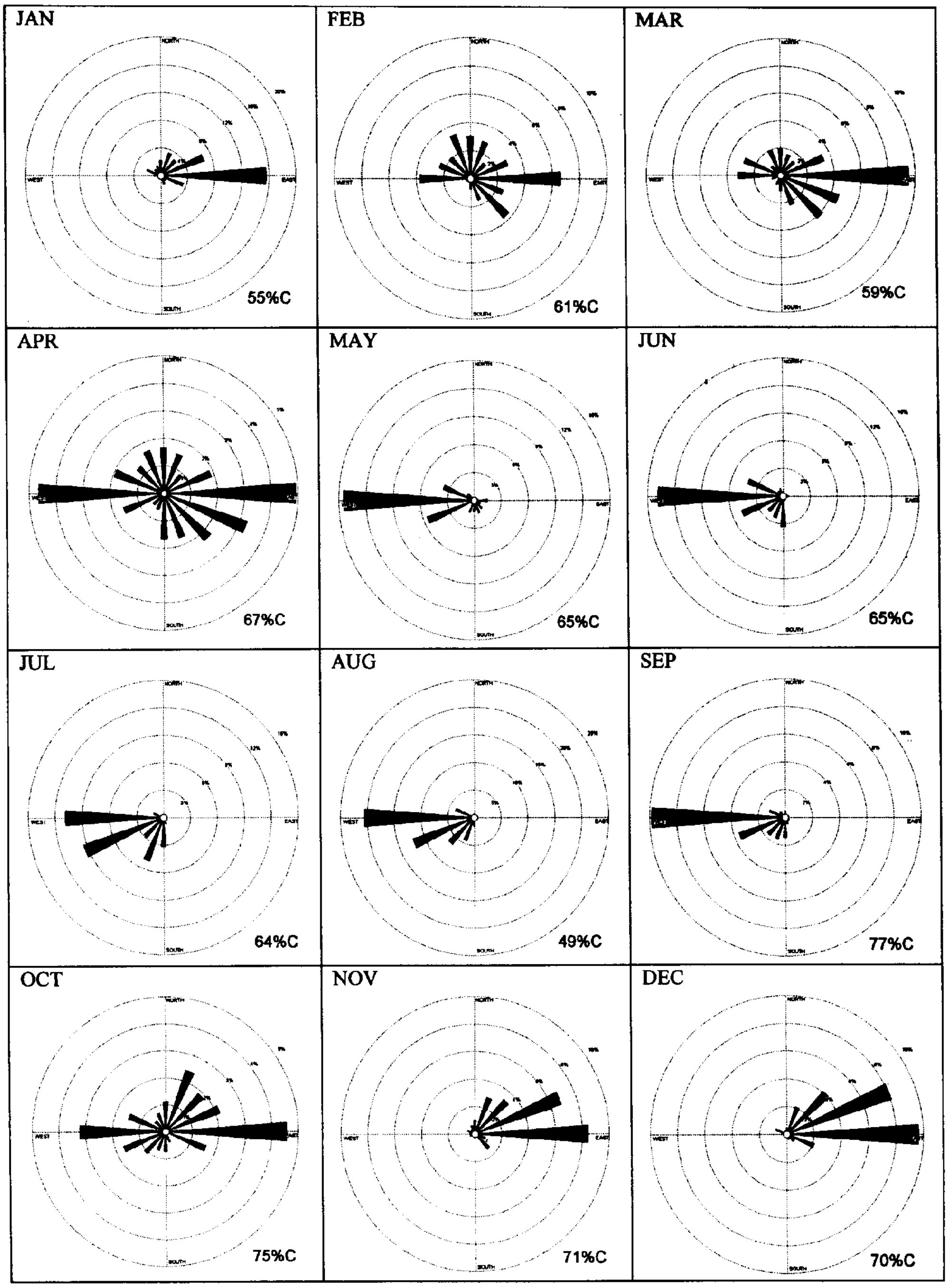


Figure. 3-37. Wind rose analysis for PHUKET (DOWNTOWN) in 1996.

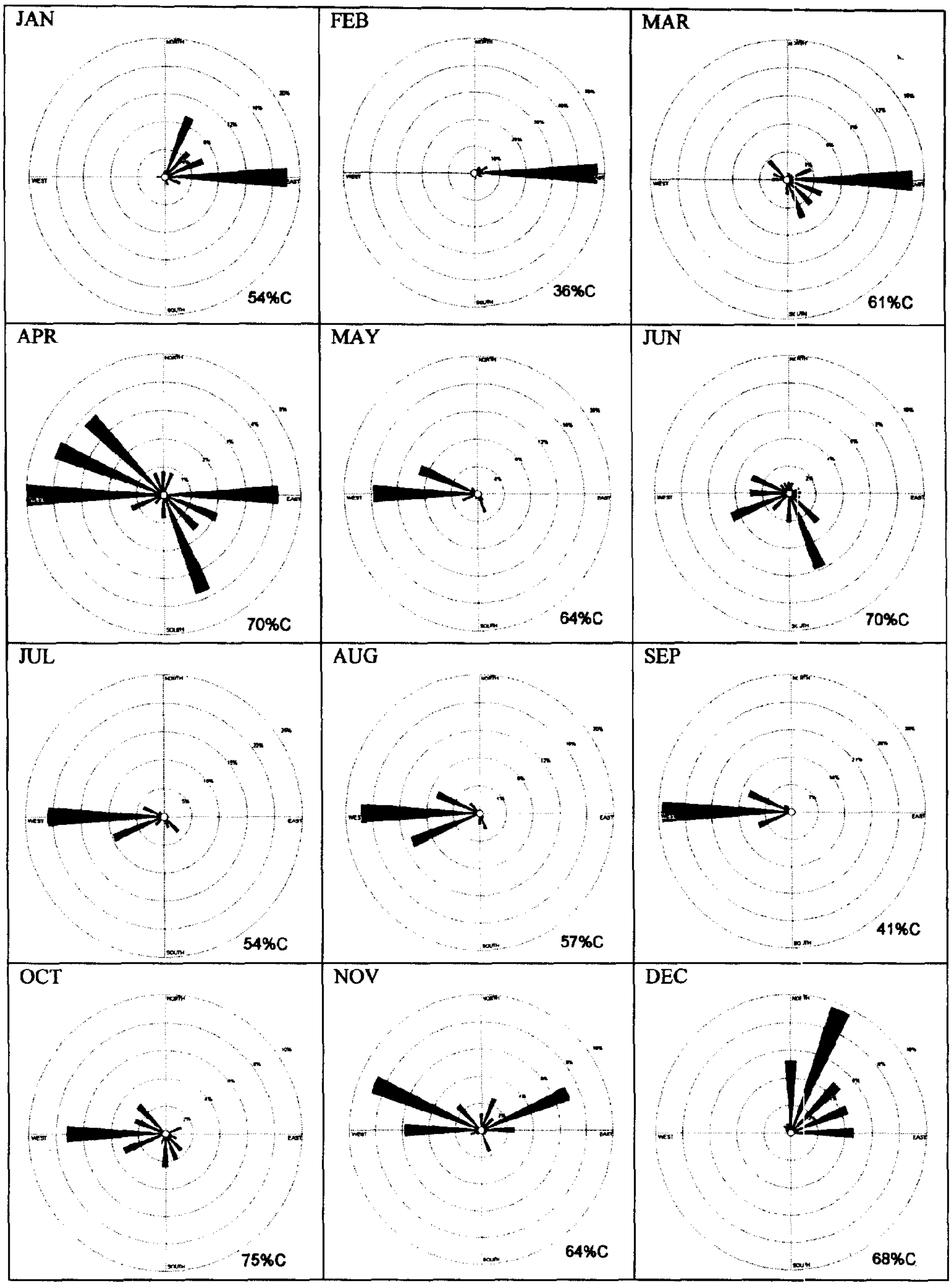


Figure. 3-38. Wind rose analysis for PHUKET (DOWNTOWN) in 1997.

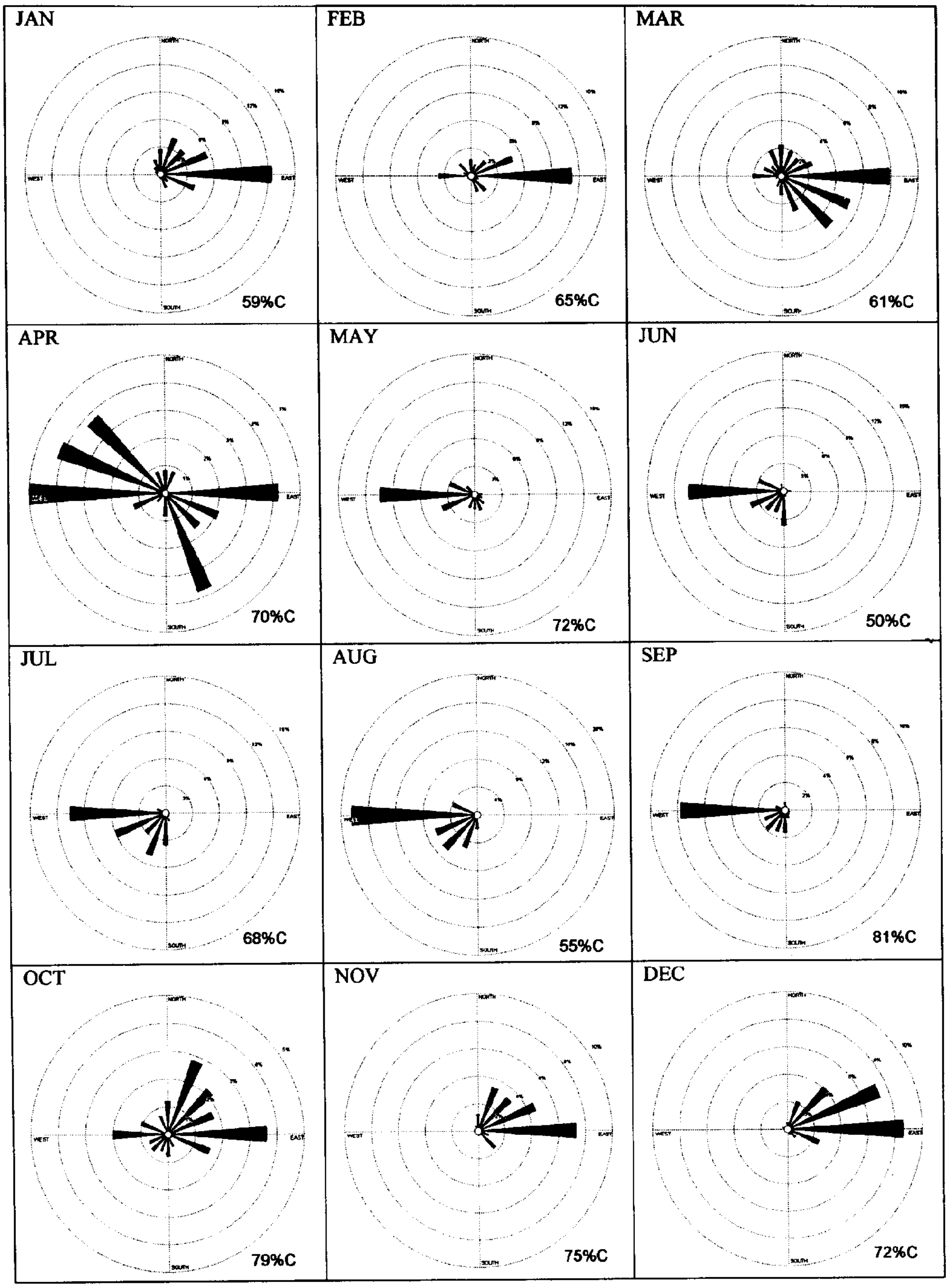


Figure. 3-39. Wind rose analysis for SATUN in 1996.

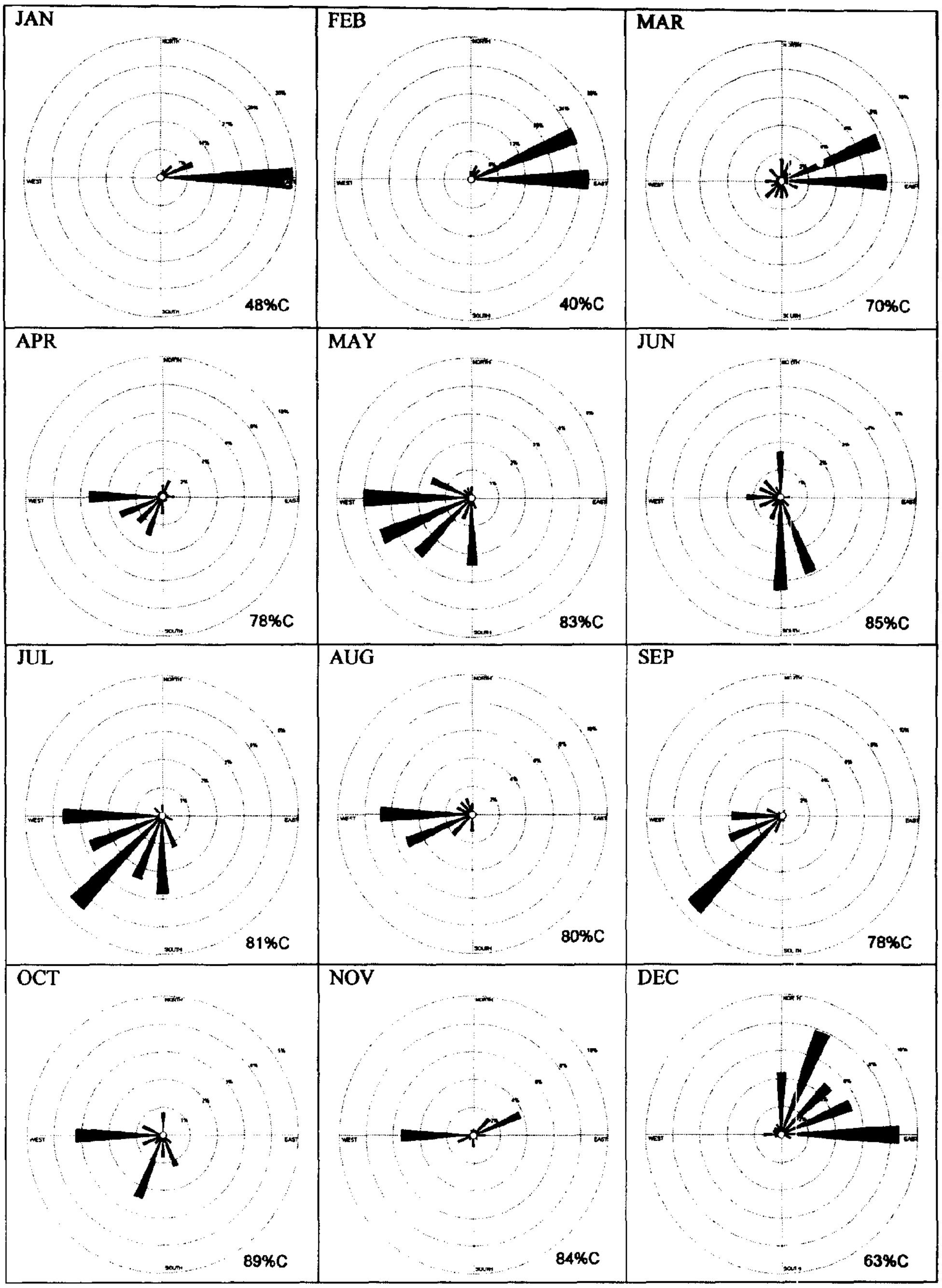


Figure. 3-40. Wind rose analysis for SATUN in 1997.

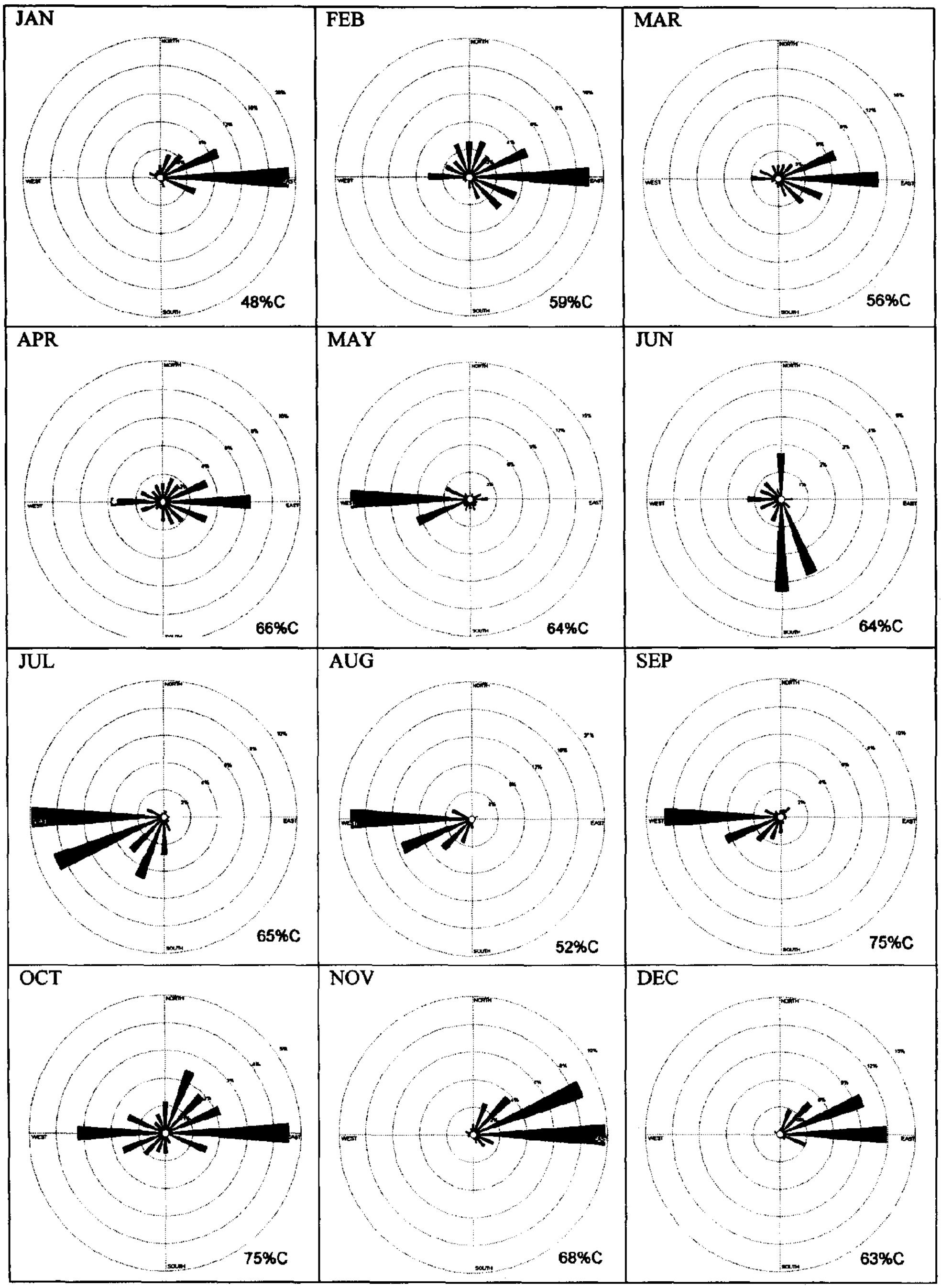


Figure. 3-41. Wind rose analysis for TRANG in 1996.

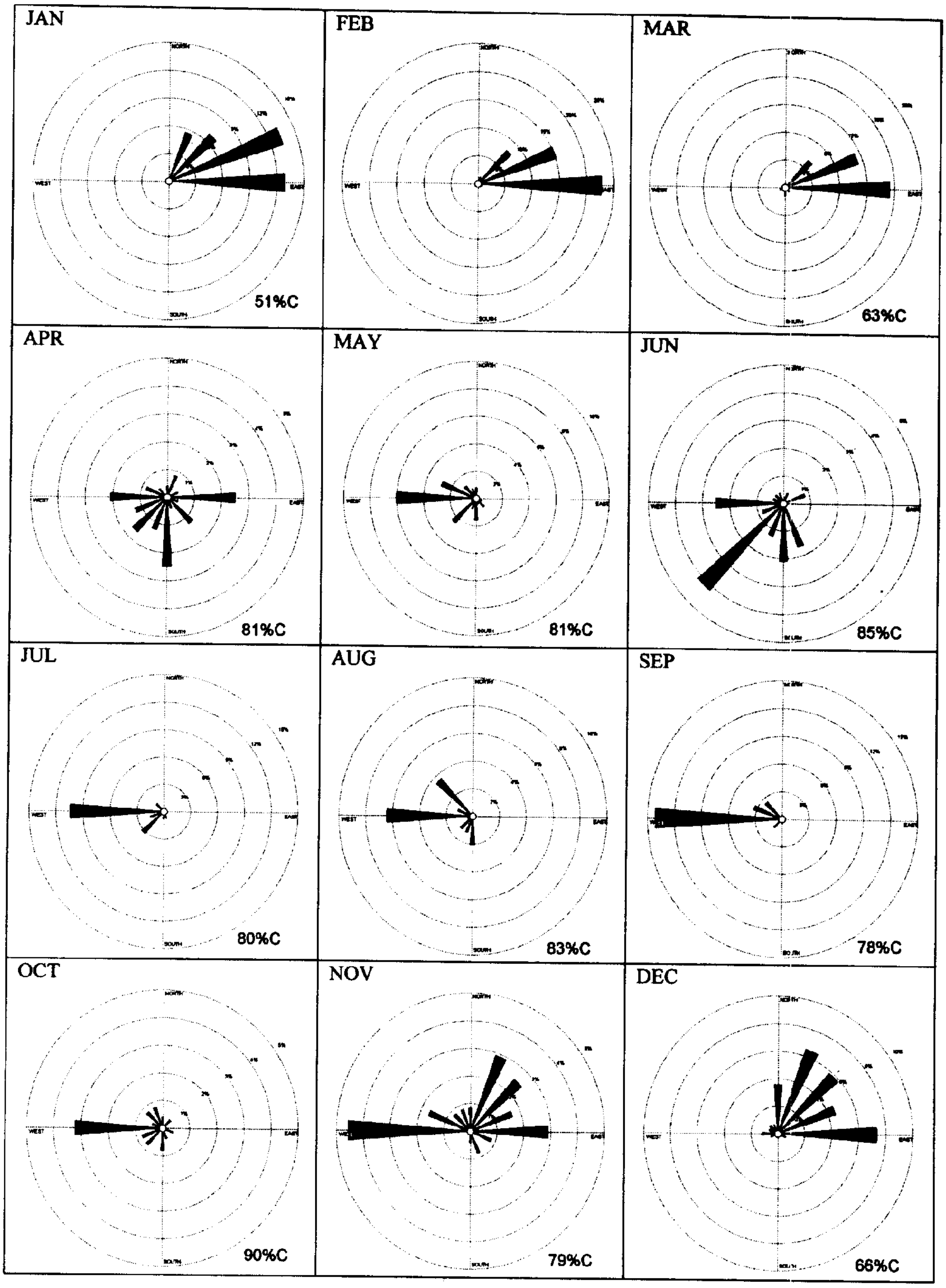


Figure. 3-42. Wind rose analysis for TRANG in 1997.

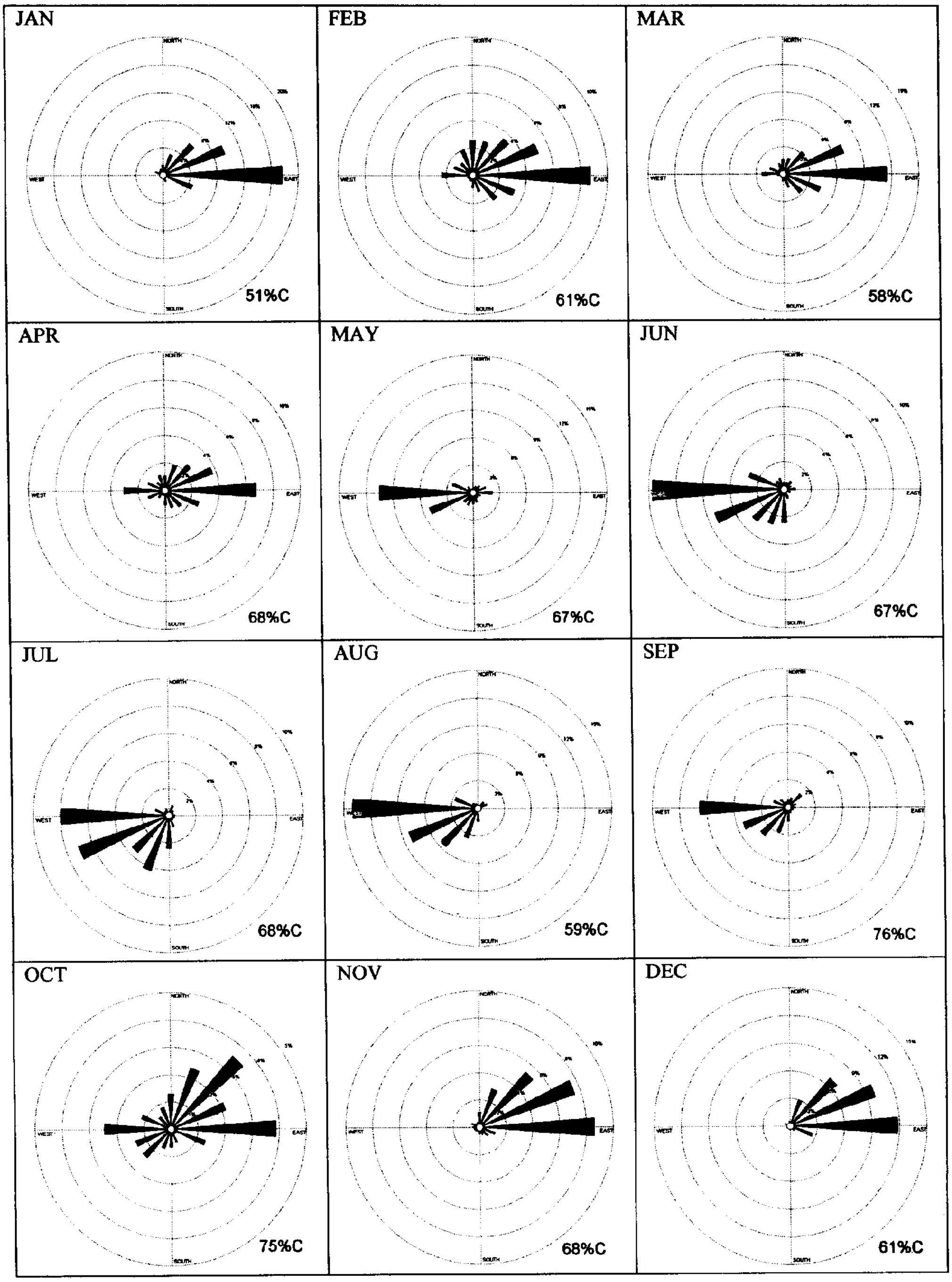


Figure. 3-43. Wind rose analysis for TAKUA PA in 1996.

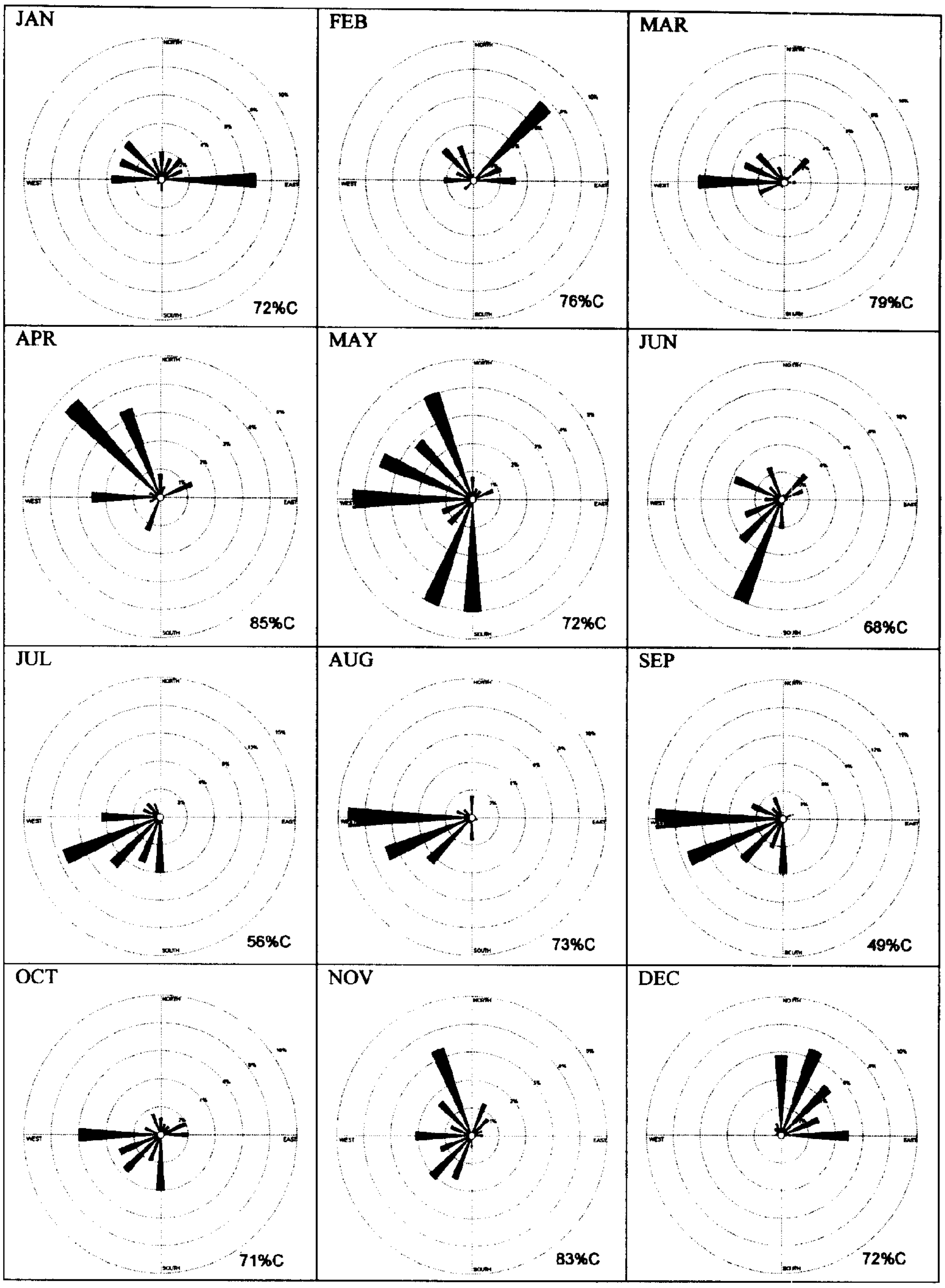


Figure. 3-44. Wind rose analysis for TAKUA PA in 1997.

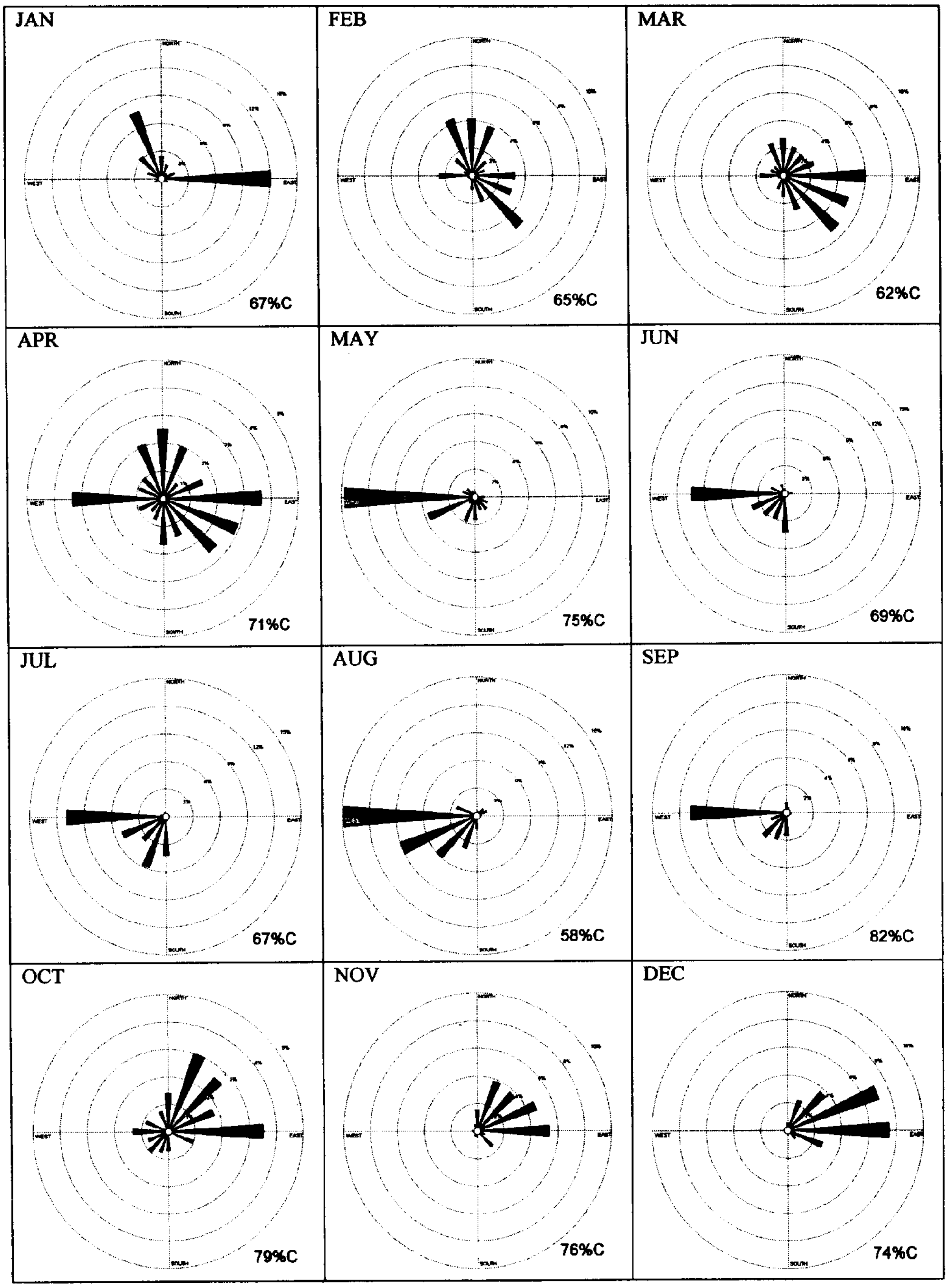


Figure. 3-45. Daily surface meteorological observations for CHUMPHON in September and October 1996 and 1997.

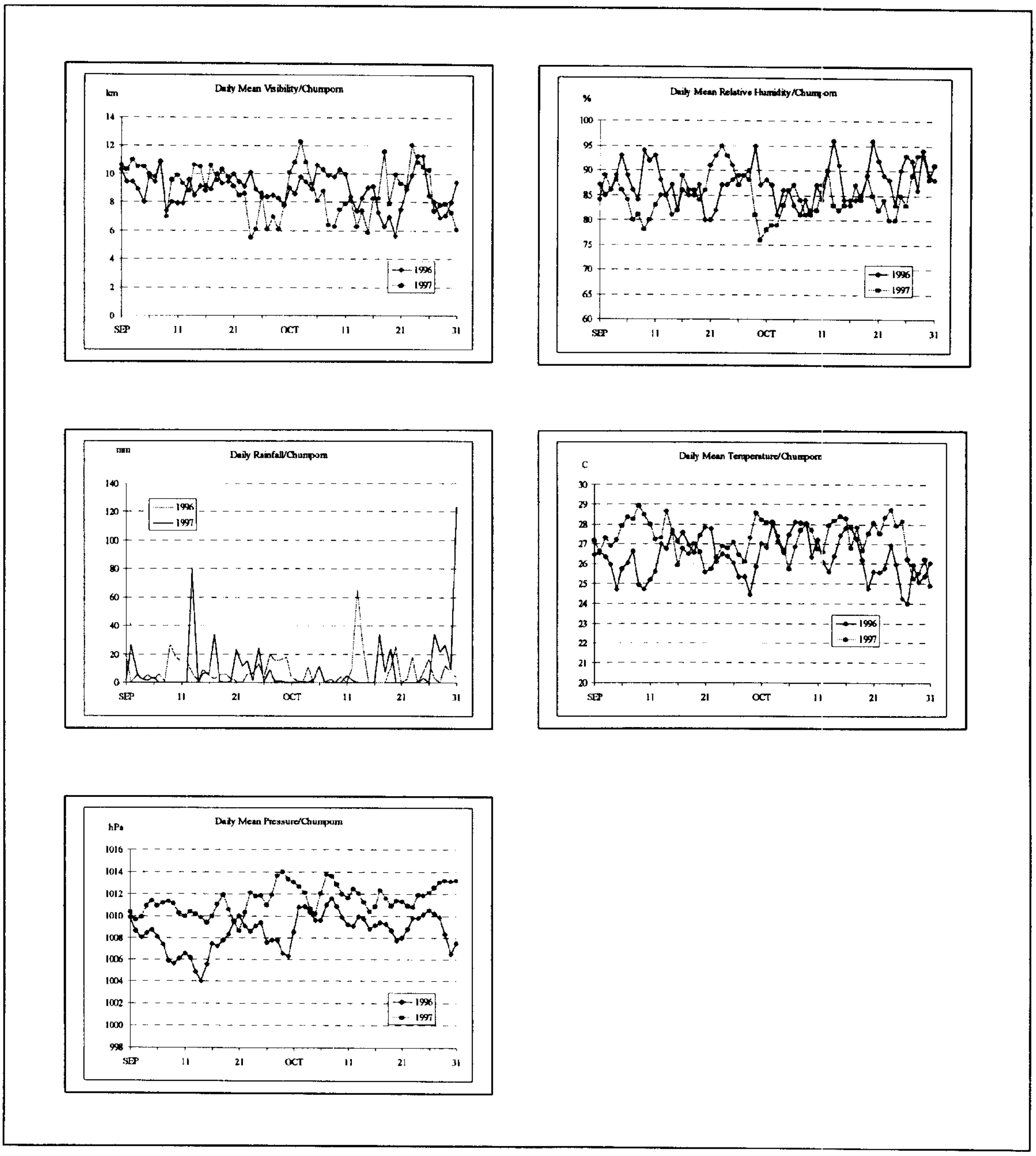


Figure. 3-46. Daily surface meteorological observations for NAKHON SI THAMMARAT in September and October 1996 and 1997.

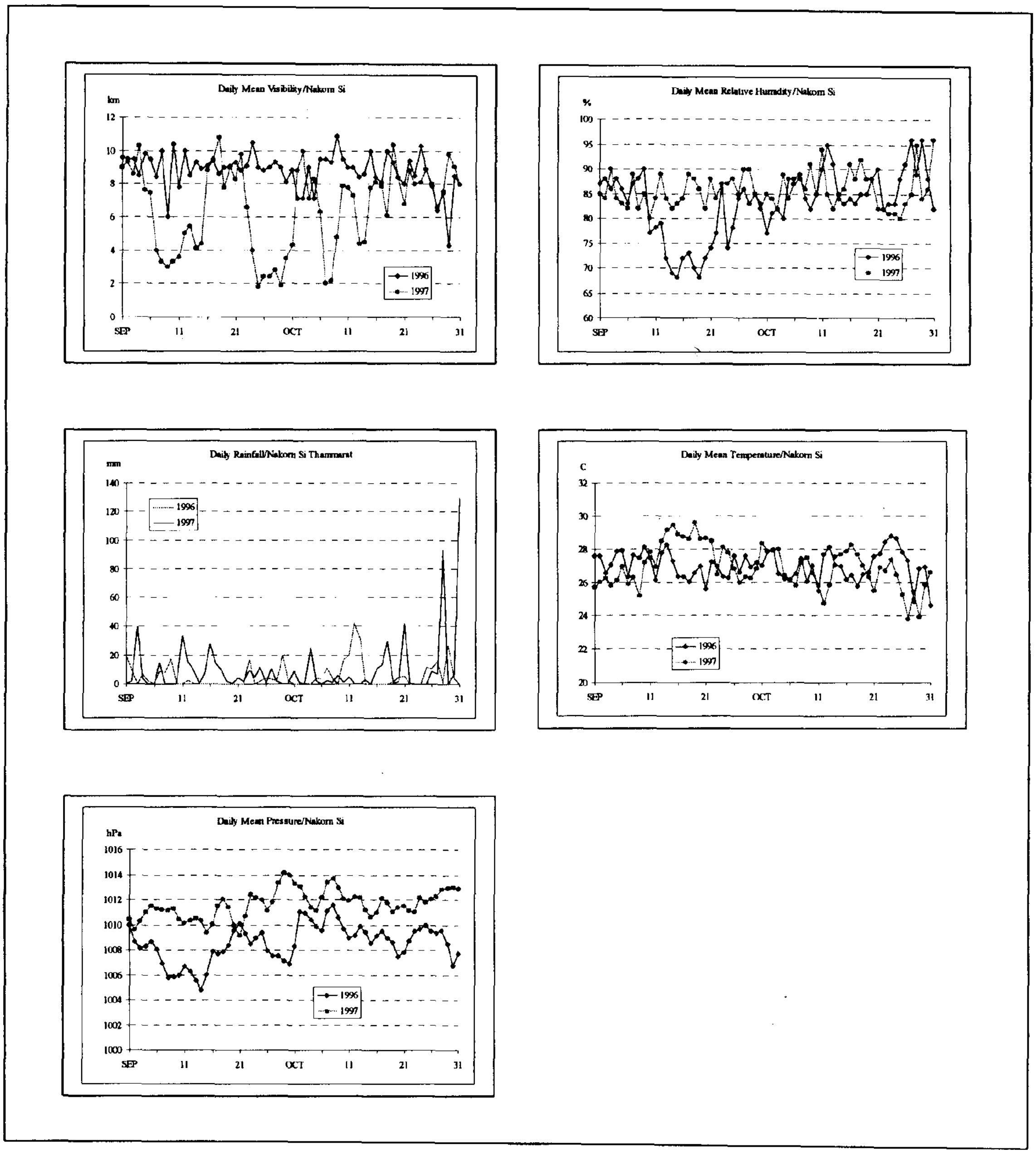


Figure. 3-47. Daily surface meteorological observations for KO SAMUI in September and October 1996 and 1997.

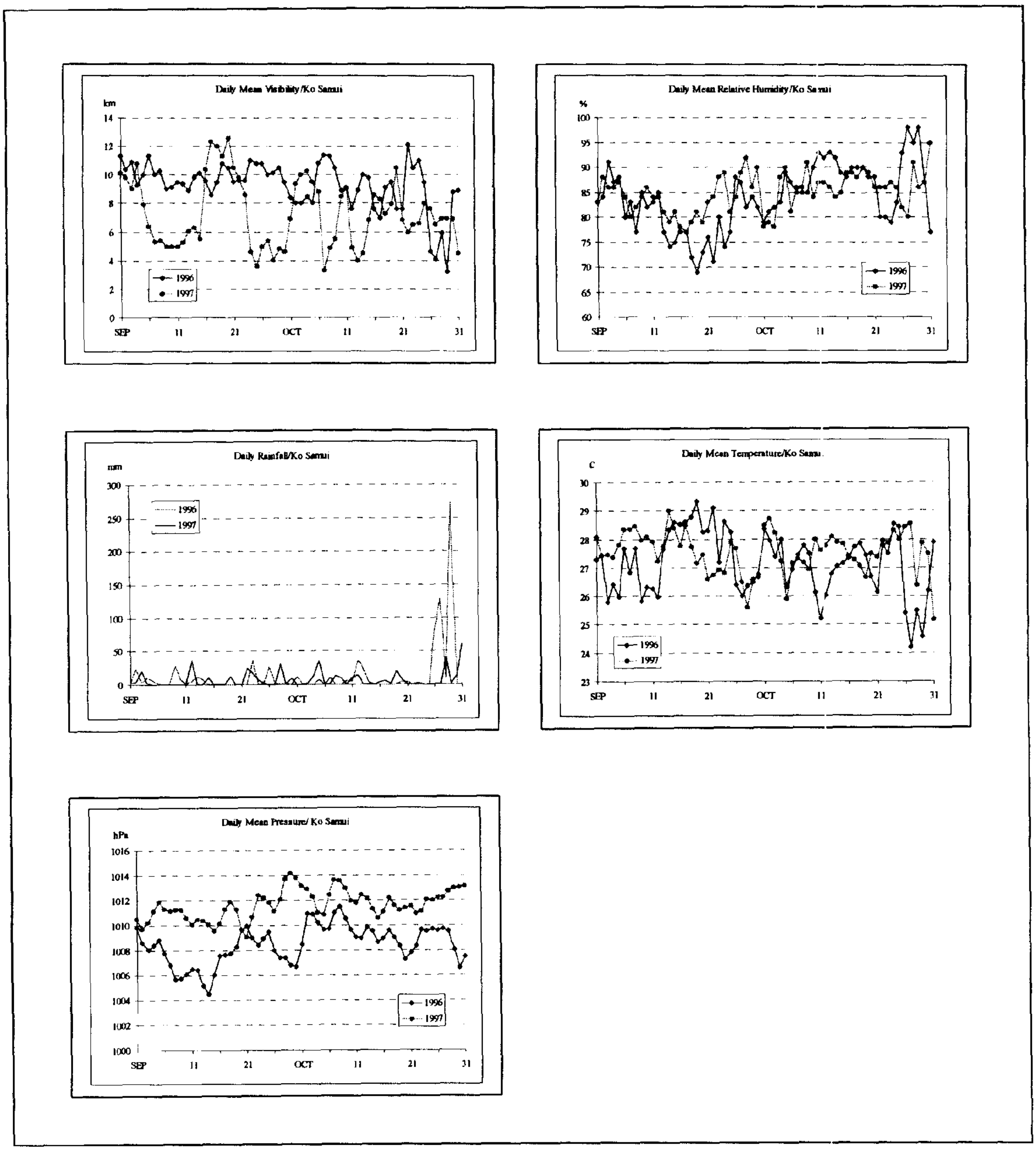


Figure. 3-48. Daily surface meteorological observations for SURAT THANI in September and October 1996 and 1997.

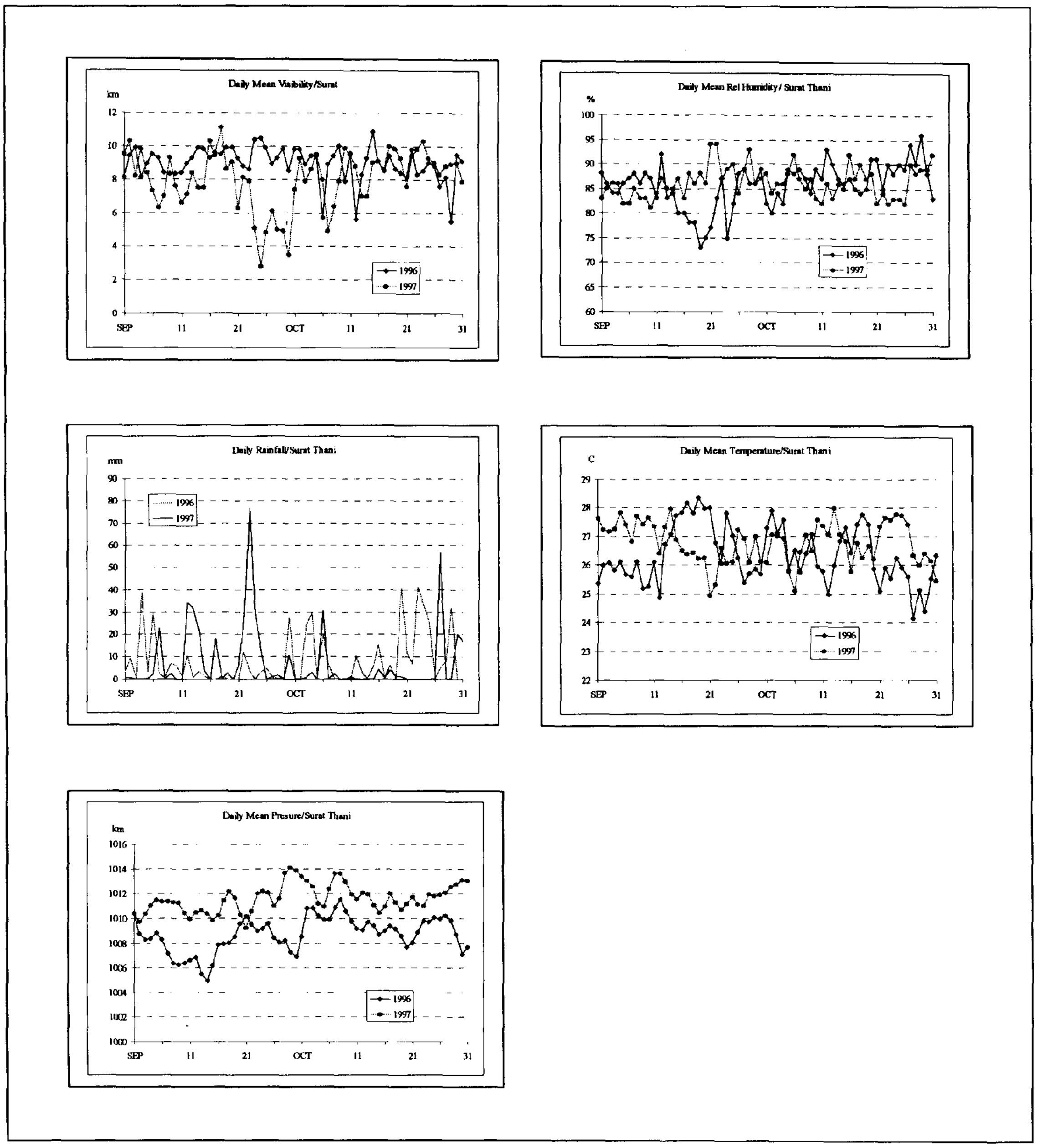


Figure. 3-49. Daily surface meteorological observations for HAT YAI in September and October 1996 and 1997.

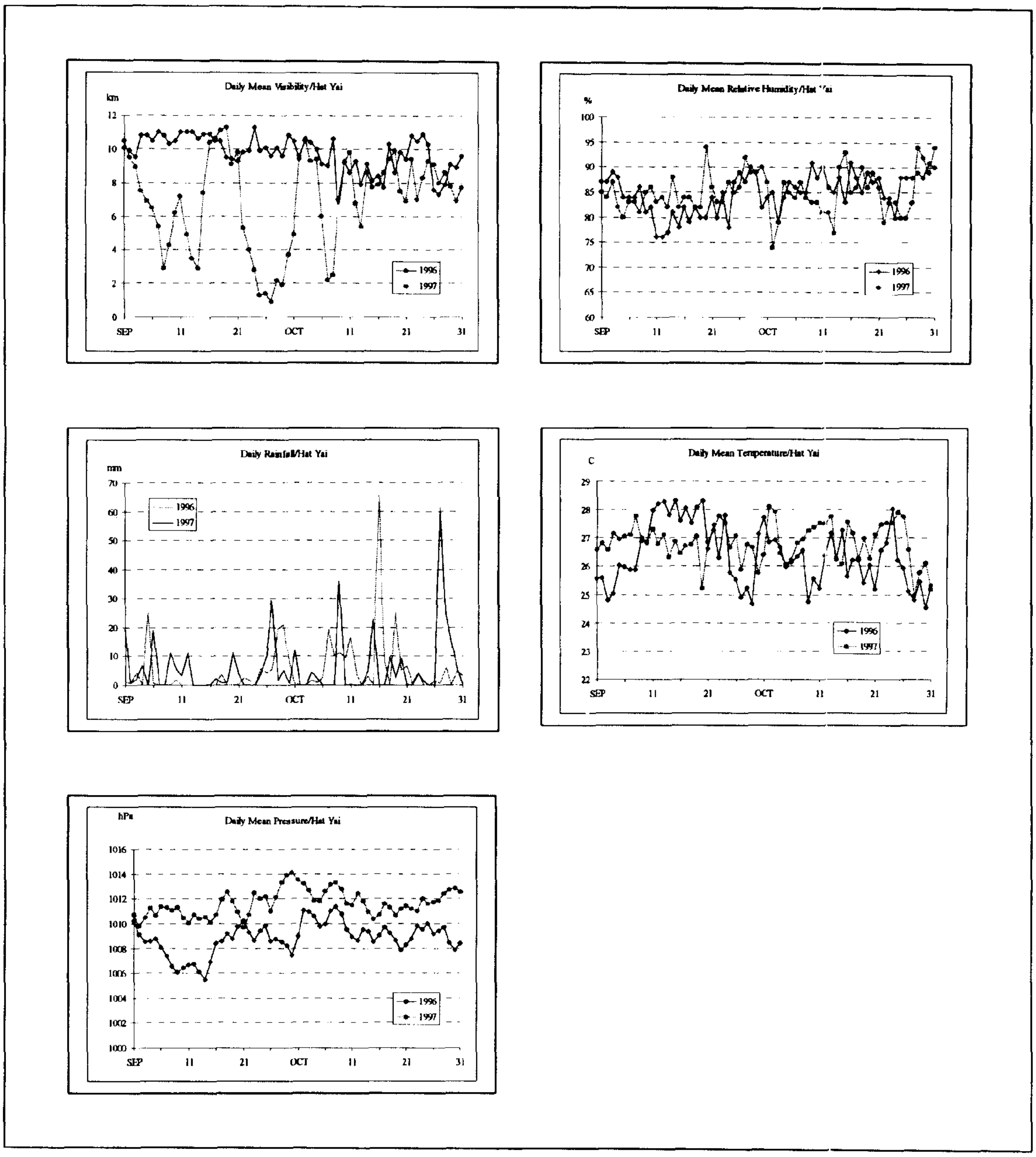


Figure. 3-50. Daily surface meteorological observations for SONGKHLA in September and October 1996 and 1997.

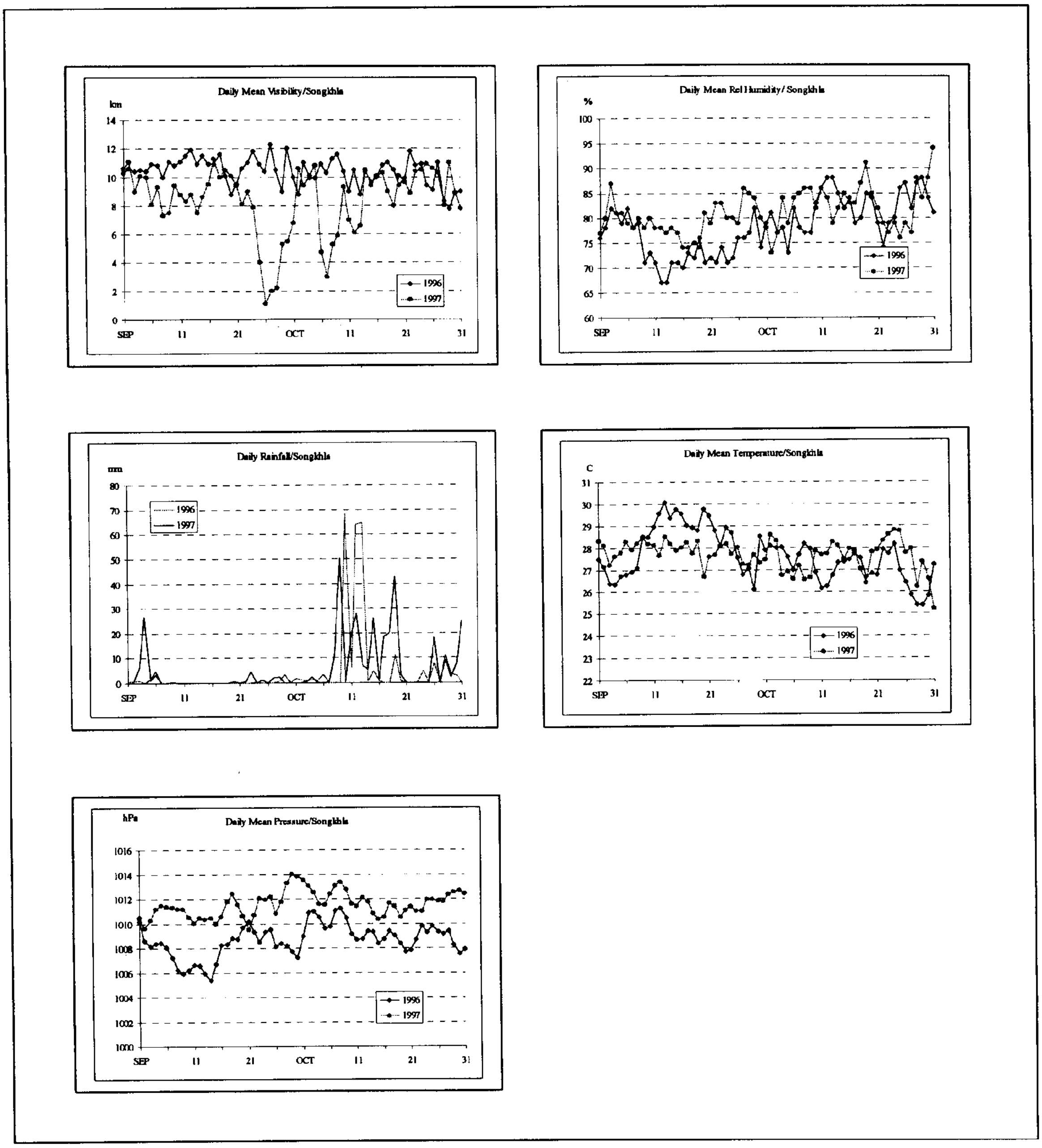


Figure. 3-51. Daily surface meteorological observations for PATTANI in September and October 1996 and 1997.

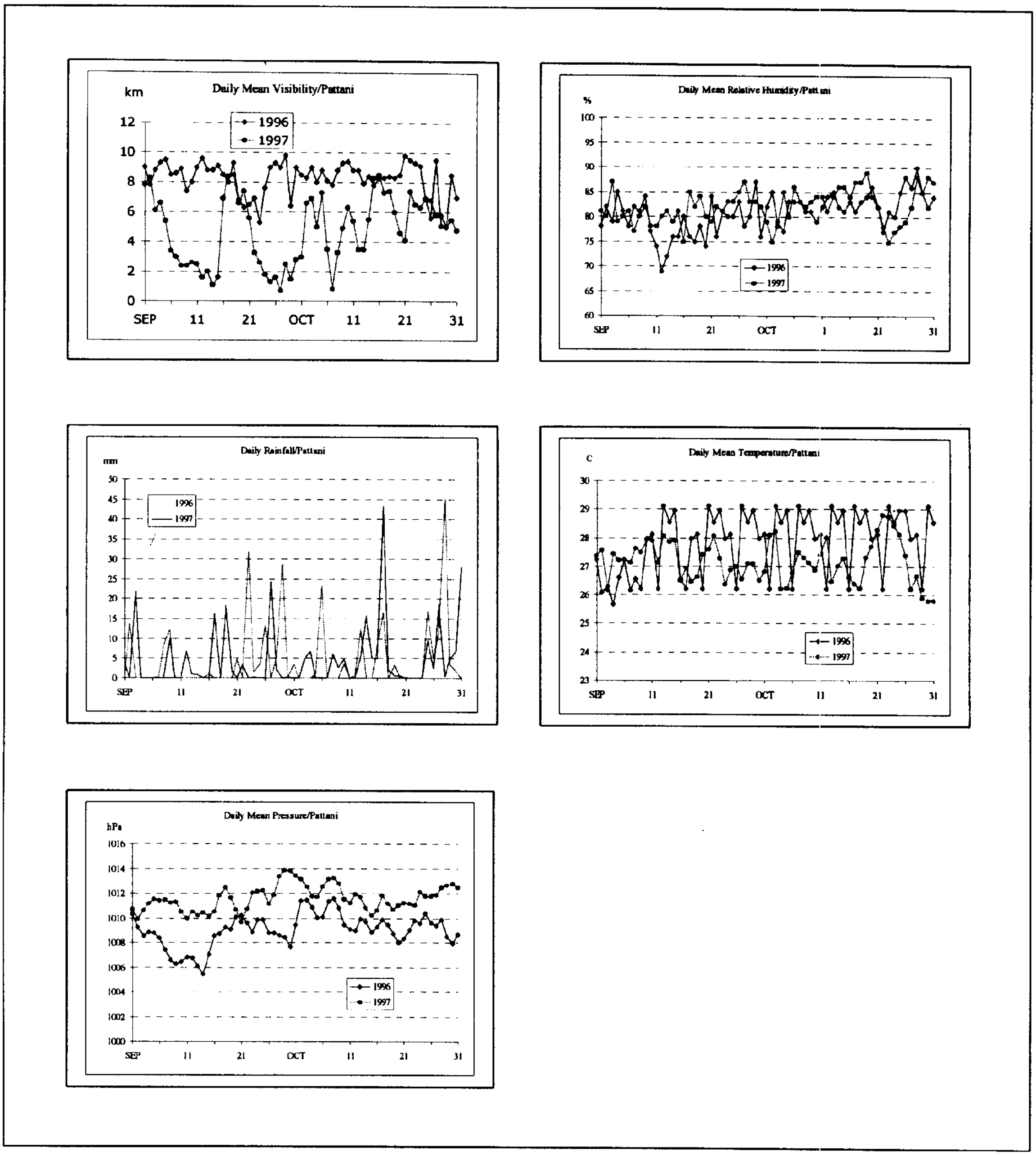


Figure. 3-52. Daily surface meteorological observations for NARATHIWAT in September and October 1996 and 1997.

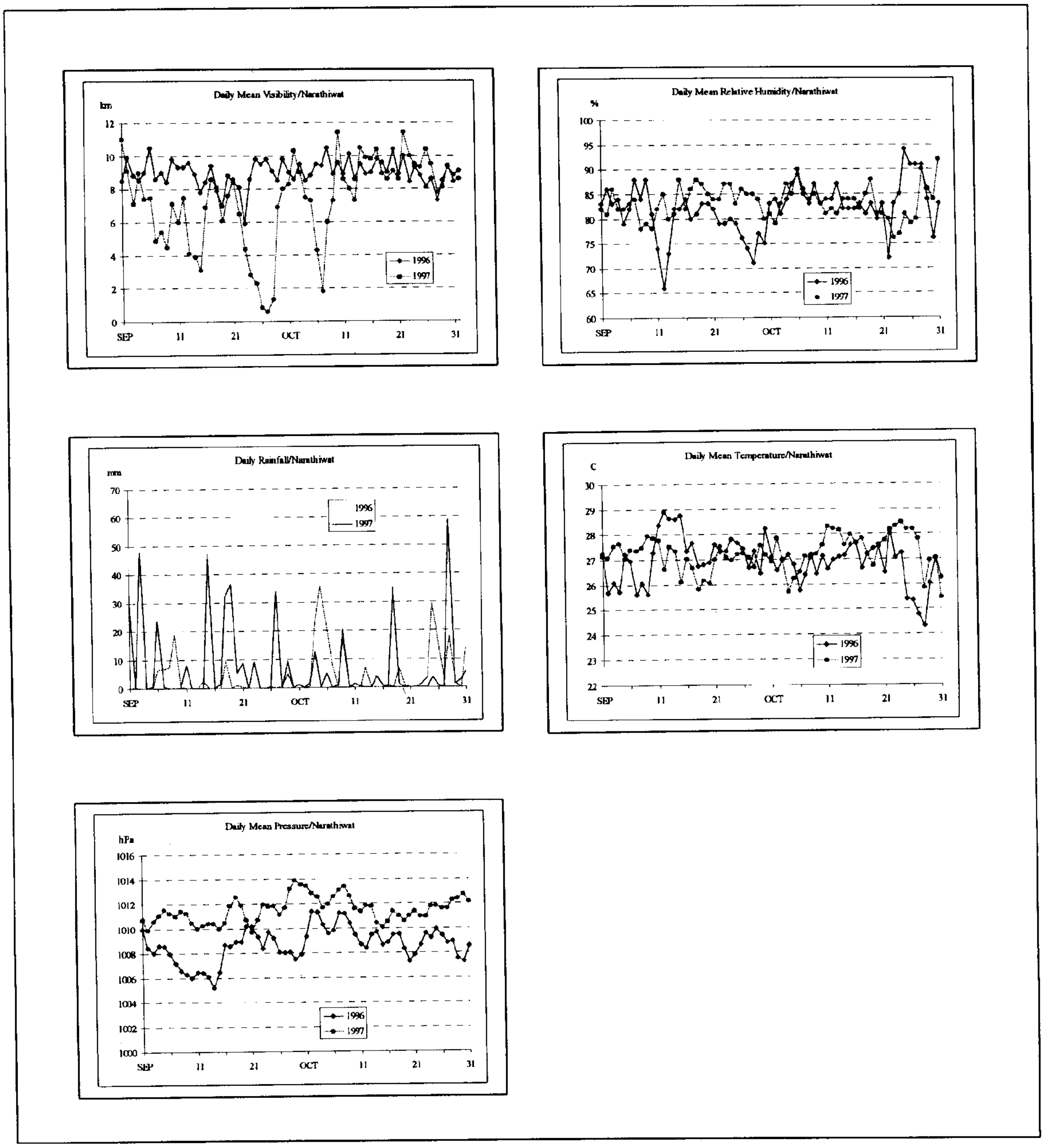


Figure. 3-53. Daily surface meteorological observations for RANONG in September and October 1996 and 1997.

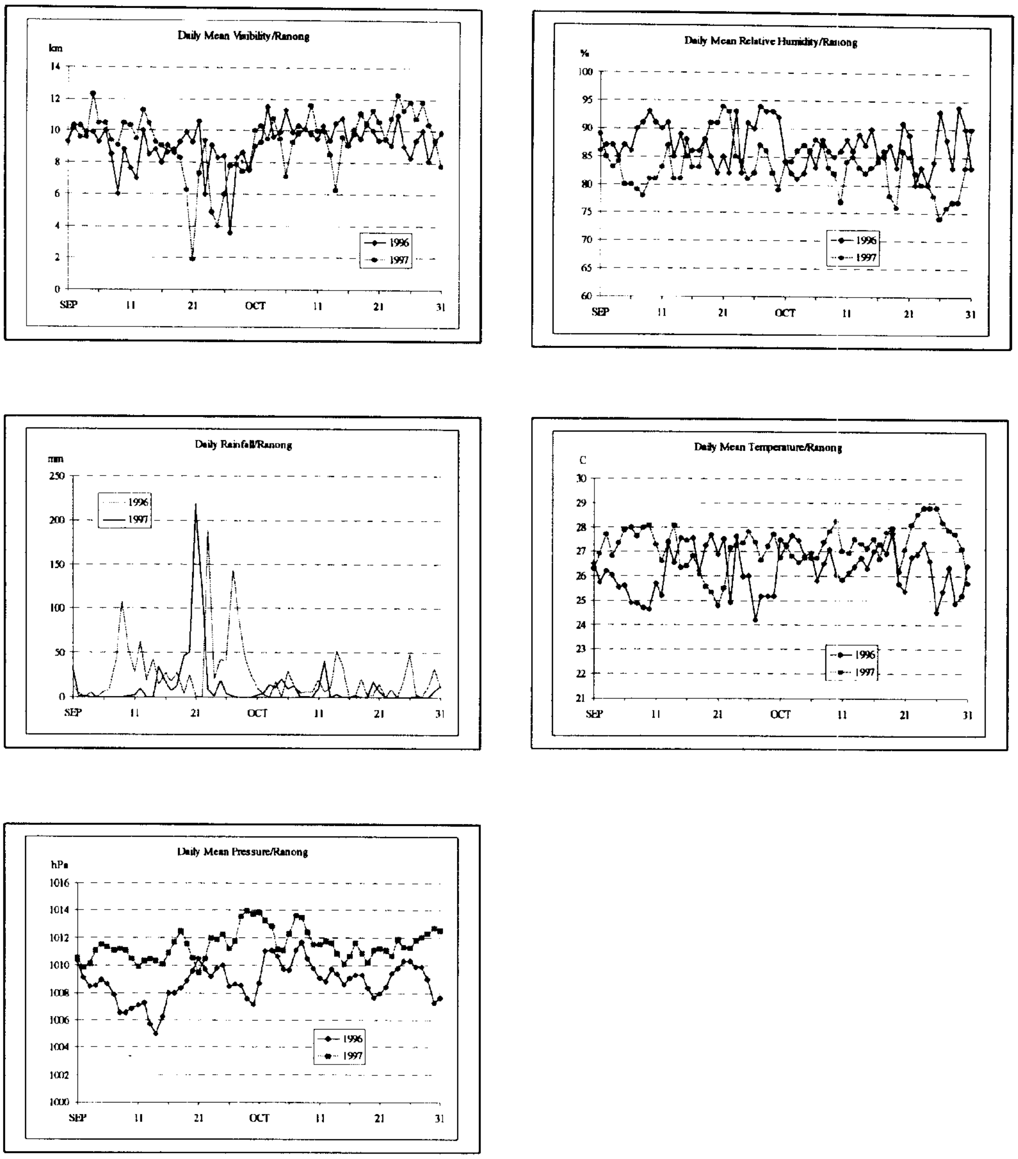


Figure. 3-54. Daily surface meteorological observations for PHUKET AIRPORT in September and October 1996 and 1997.

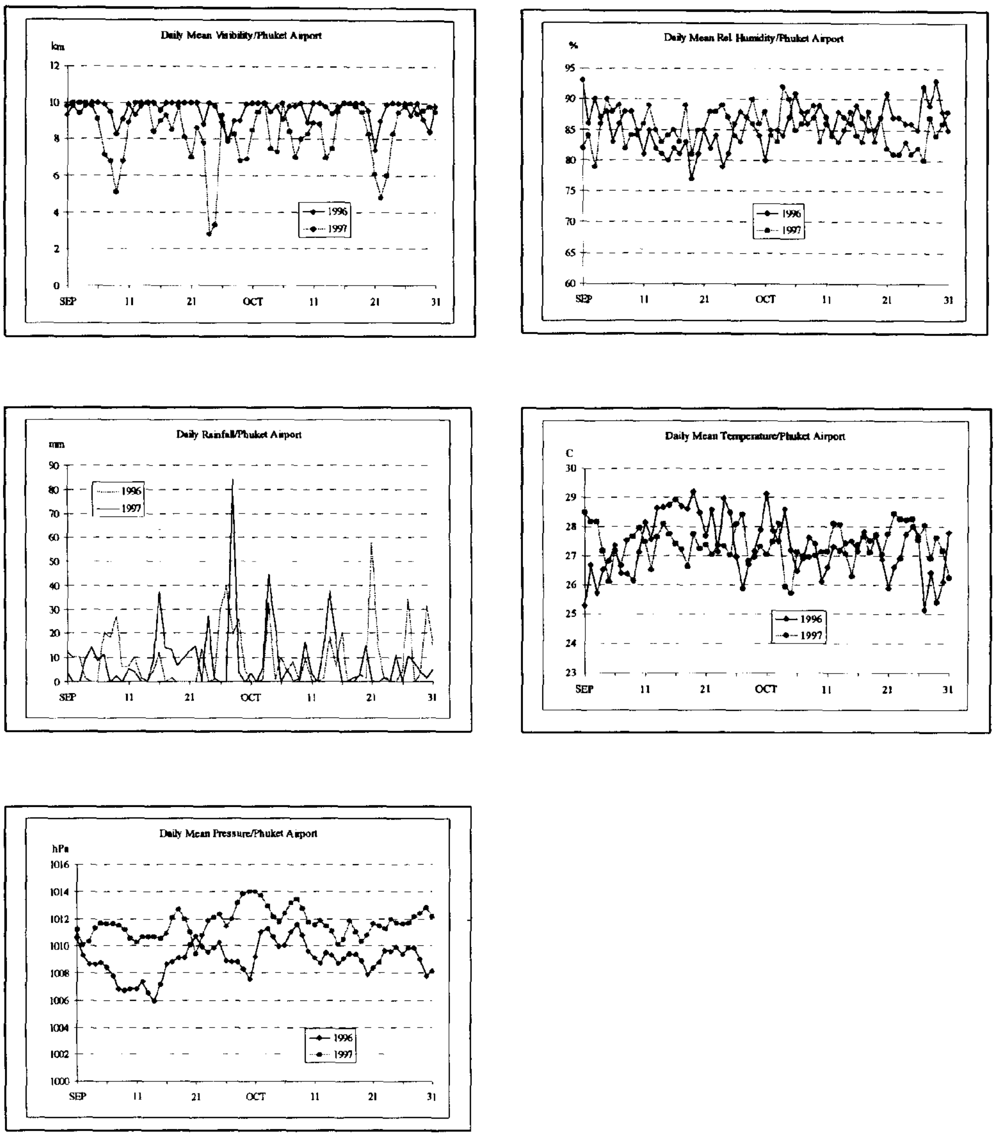


Figure. 3-55. Daily surface meteorological observations for PHUKET (DOWNTOWN) in September and October 1996 and 1997.

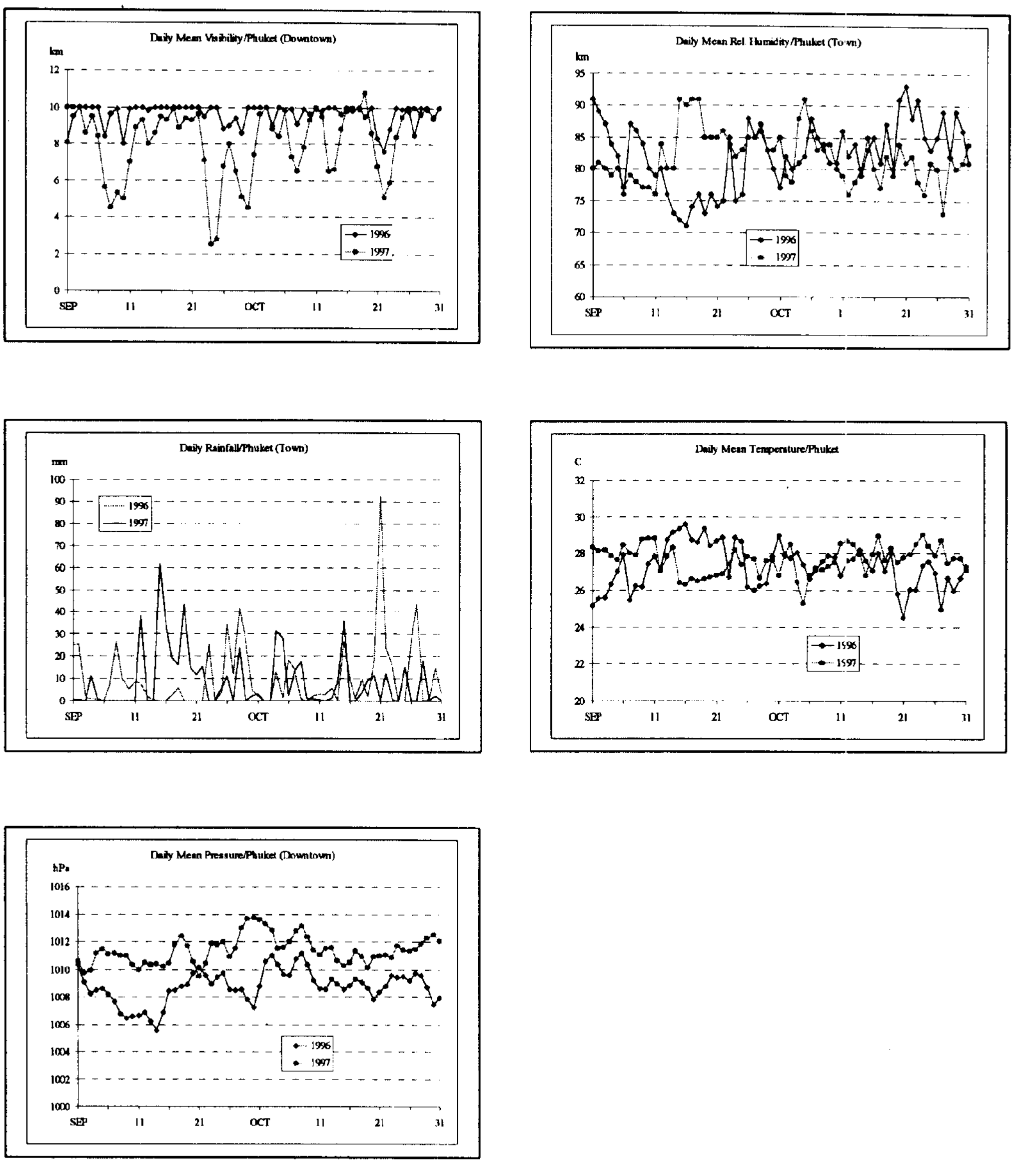


Figure. 3-56. Daily surface meteorological observations for TAKUA PA (PHANGNGA) in September and October 1996 and 1997.

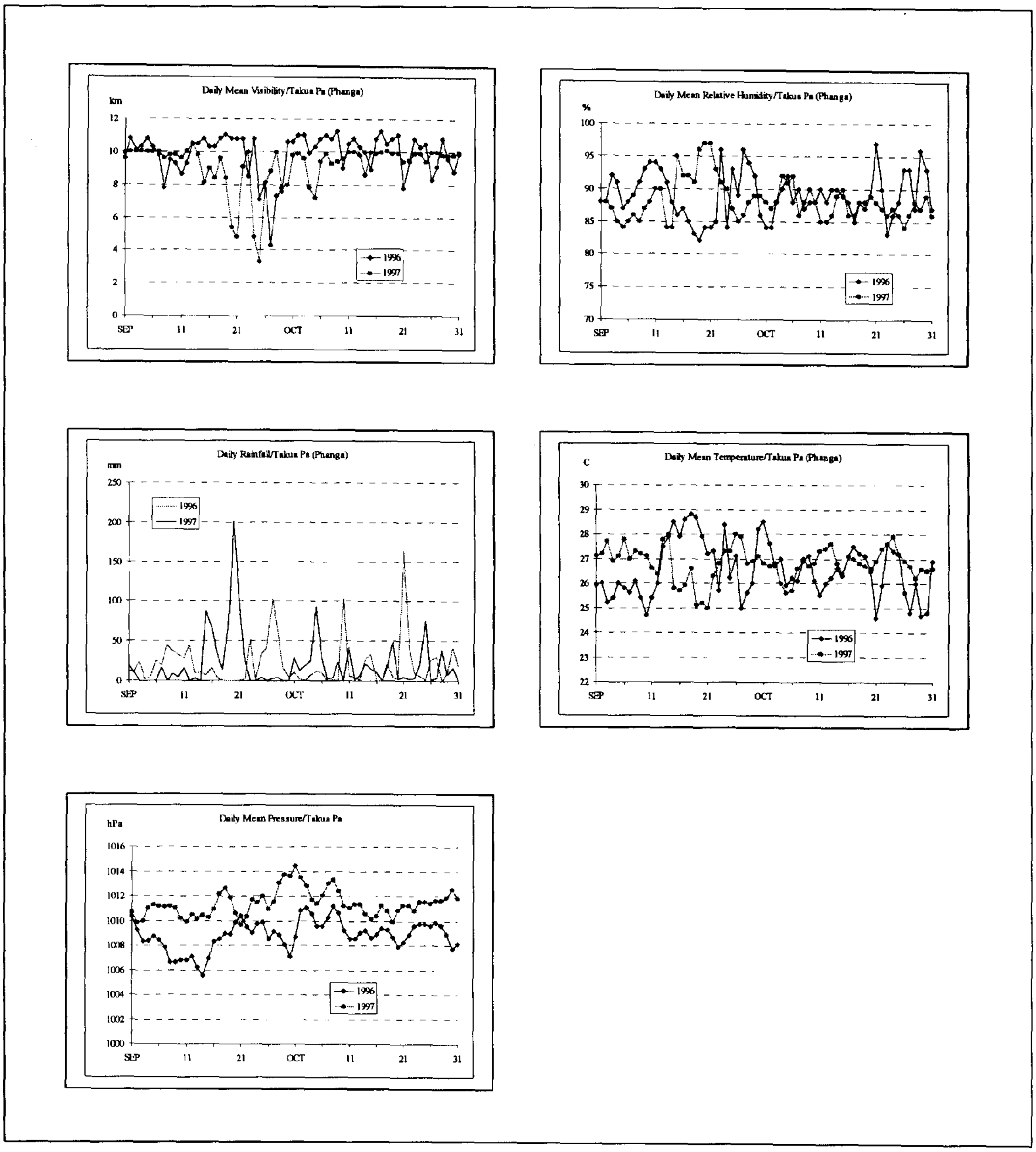


Figure. 3-57. Daily surface meteorological observations for TRANG in September and October 1996 and 1997.

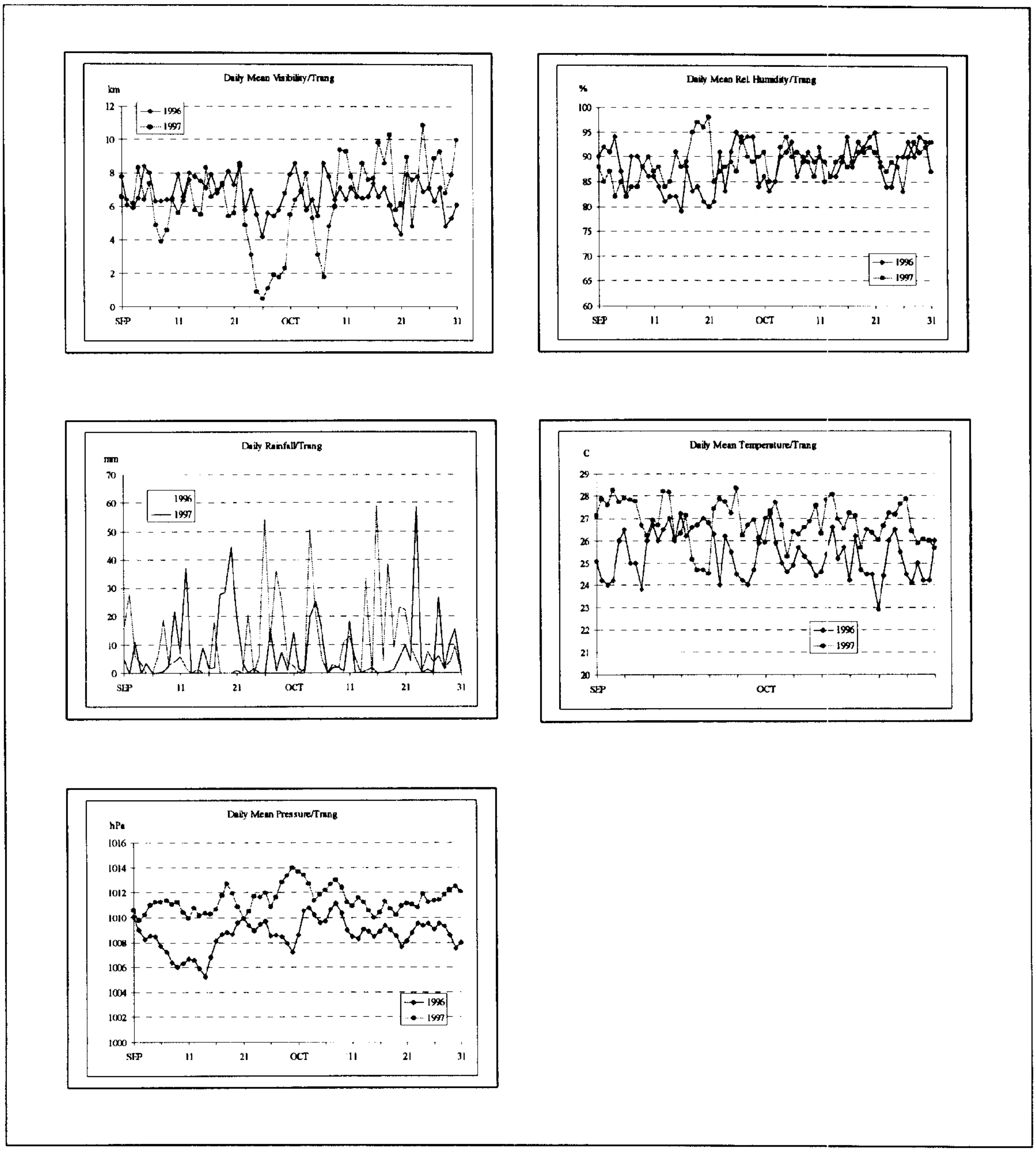


Figure. 3-58. Daily surface meteorological observations for SATUN in September and October 1996 and 1997.

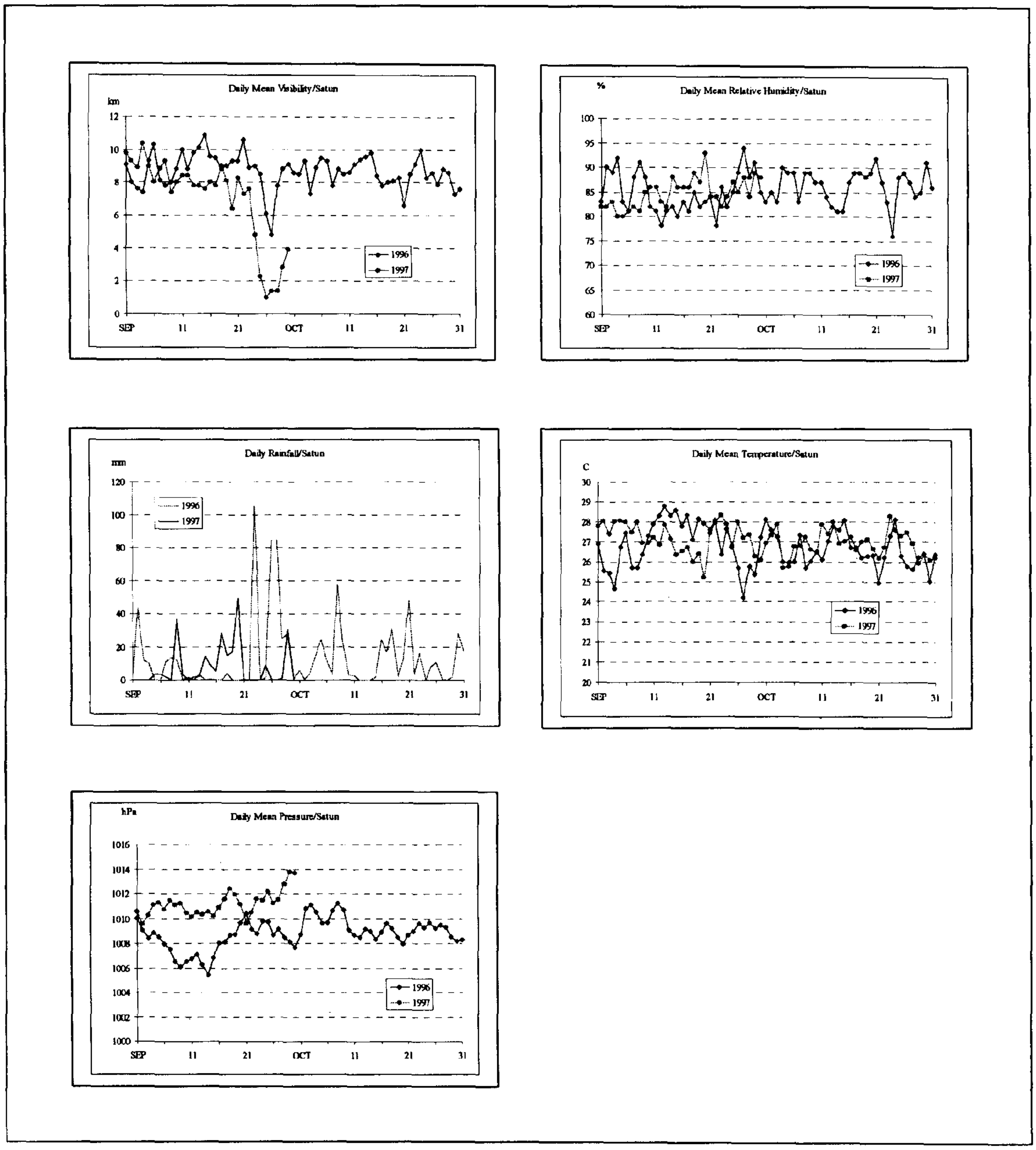


Figure. 3-59. Wind circulation at 600 meters high on 15 September 1997.

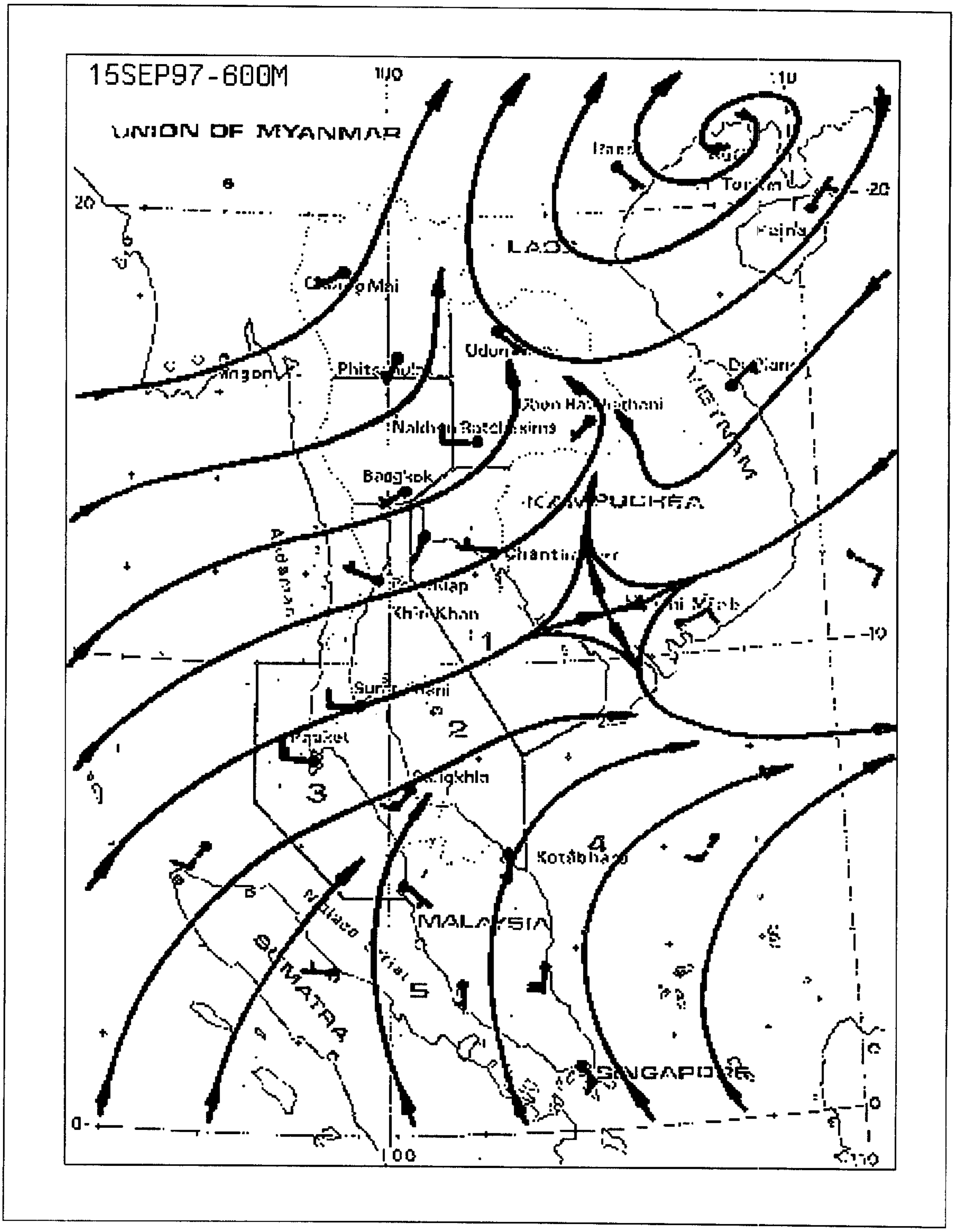


Figure. 3-60. Wind circulation at 600 m on 20 September 1997.

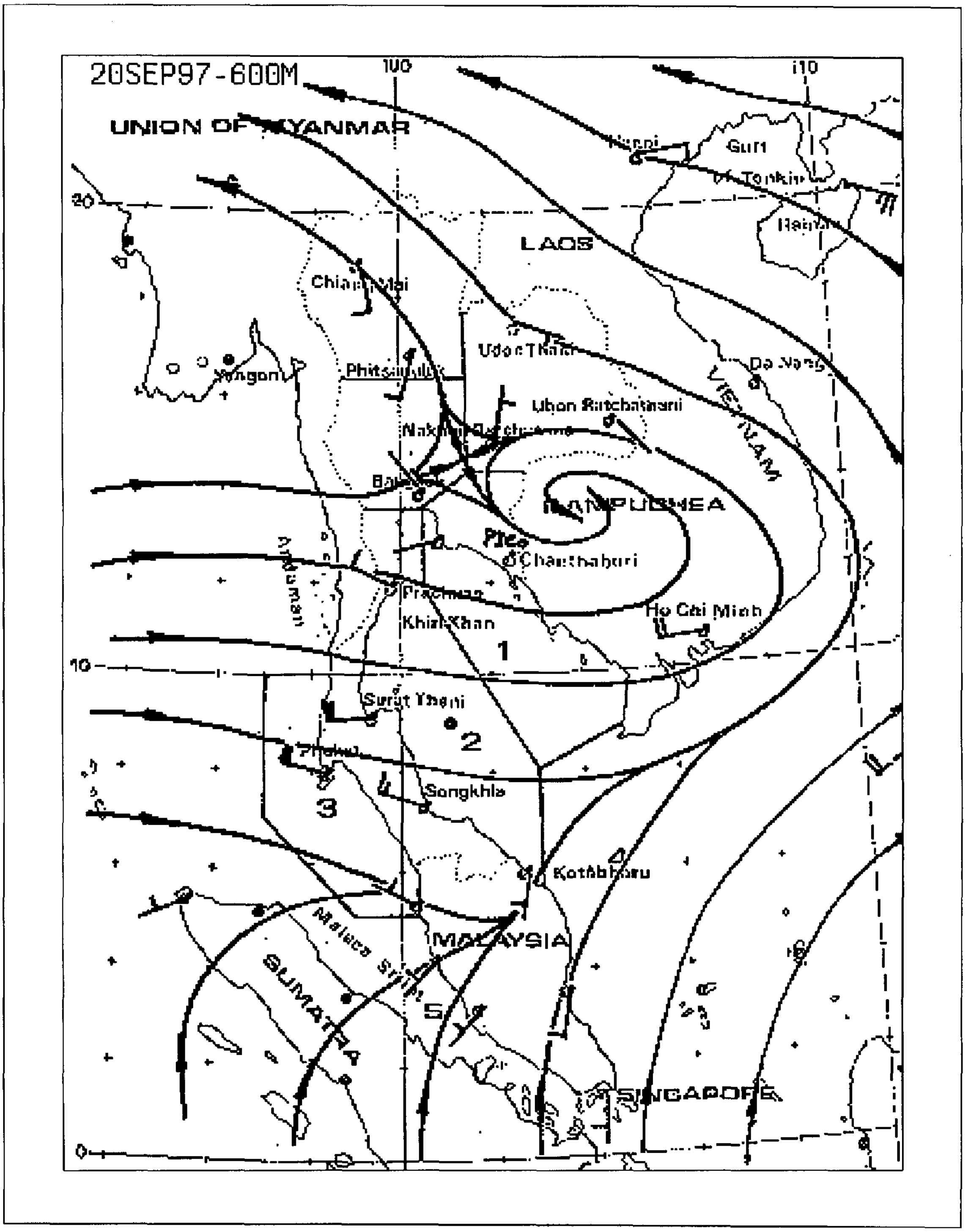


Figure. 3-61. Wind circulation at 600 m on 23 September 1997.

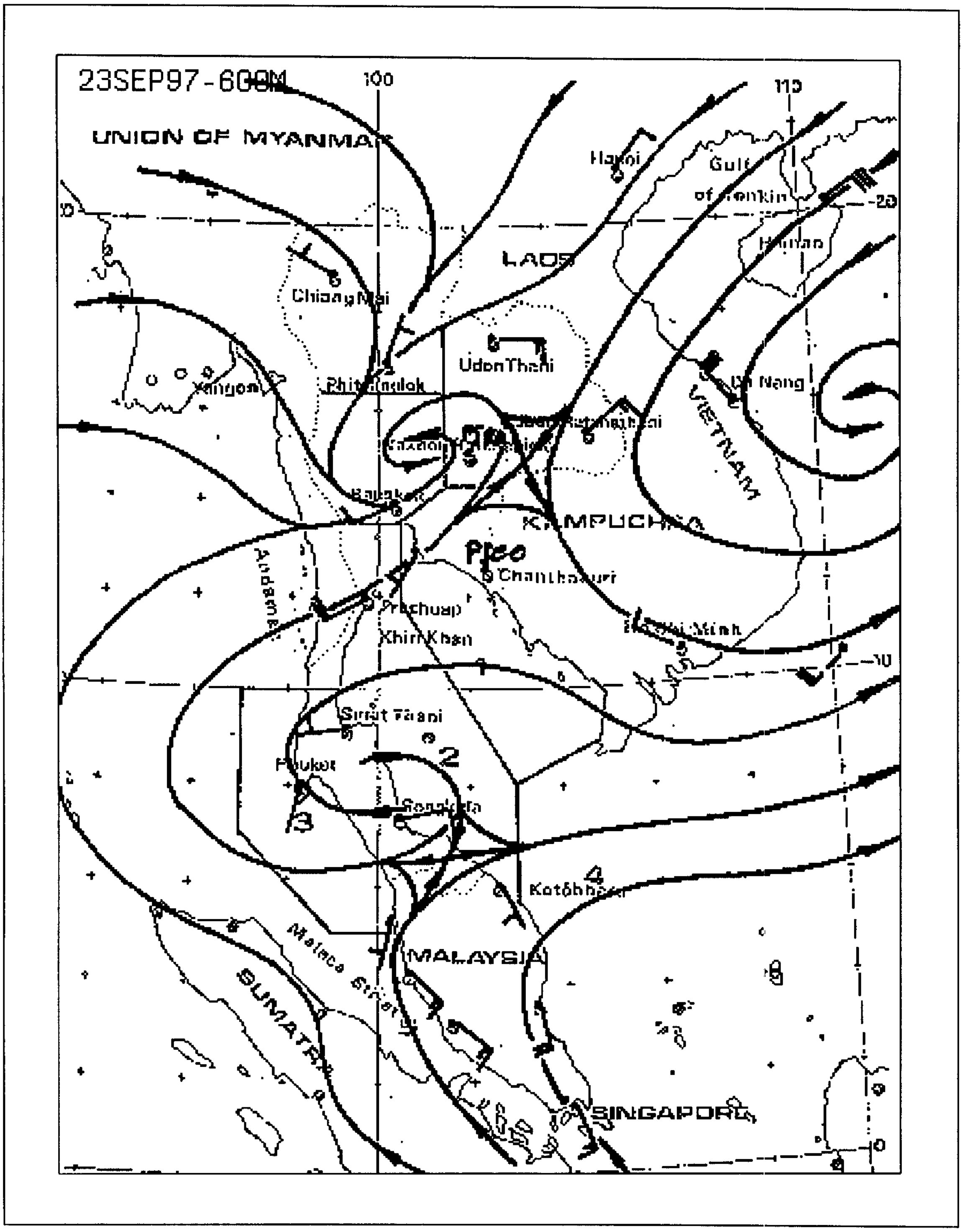


Figure. 3-62. 10-day wind rose analysis for CHUMPHON in September-October 1997.

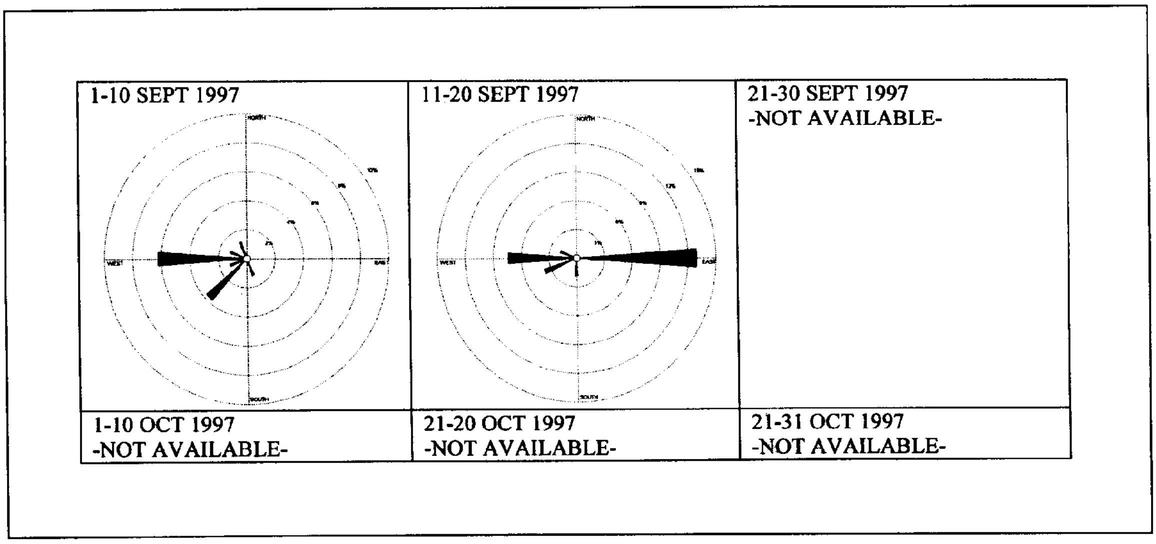


Figure. 3-63. 10-day wind rose analysis for SURAT THANI in September-October 1997.

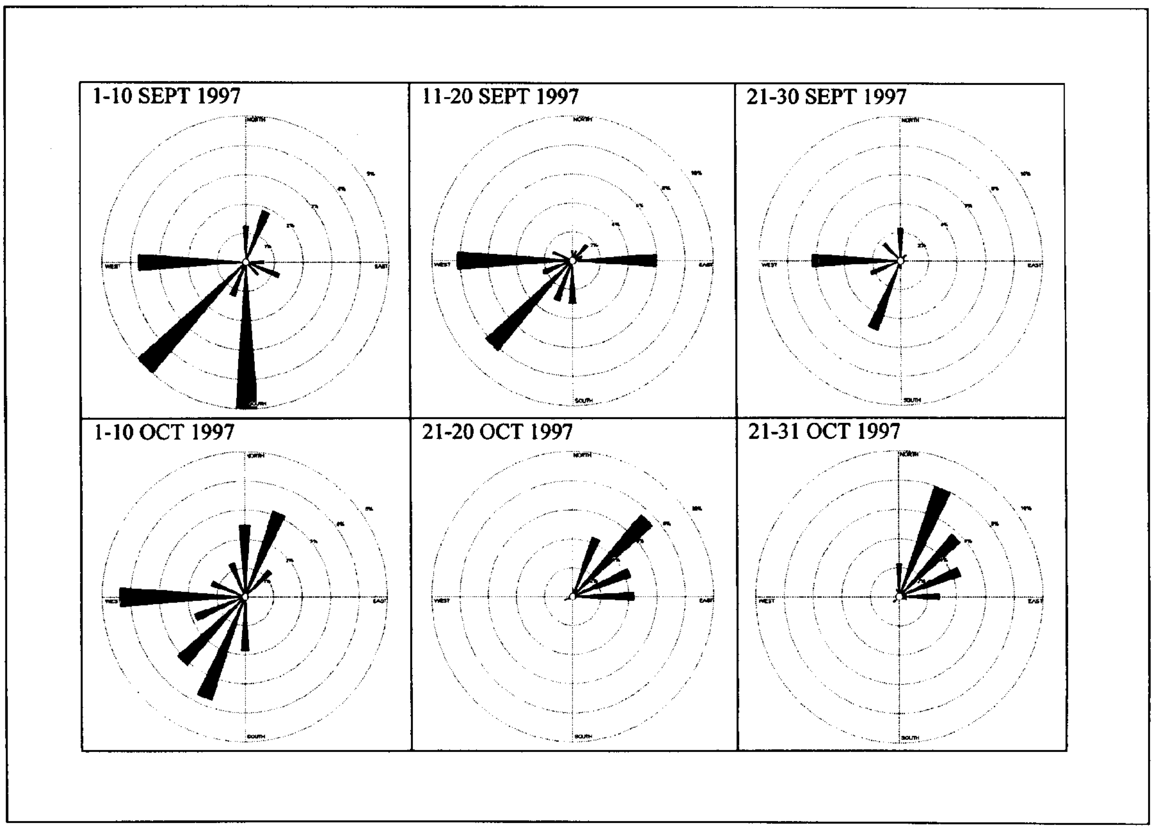


Figure. 3-64. 10-day wind rose analysis for KO SAMUI in September-October 1997.

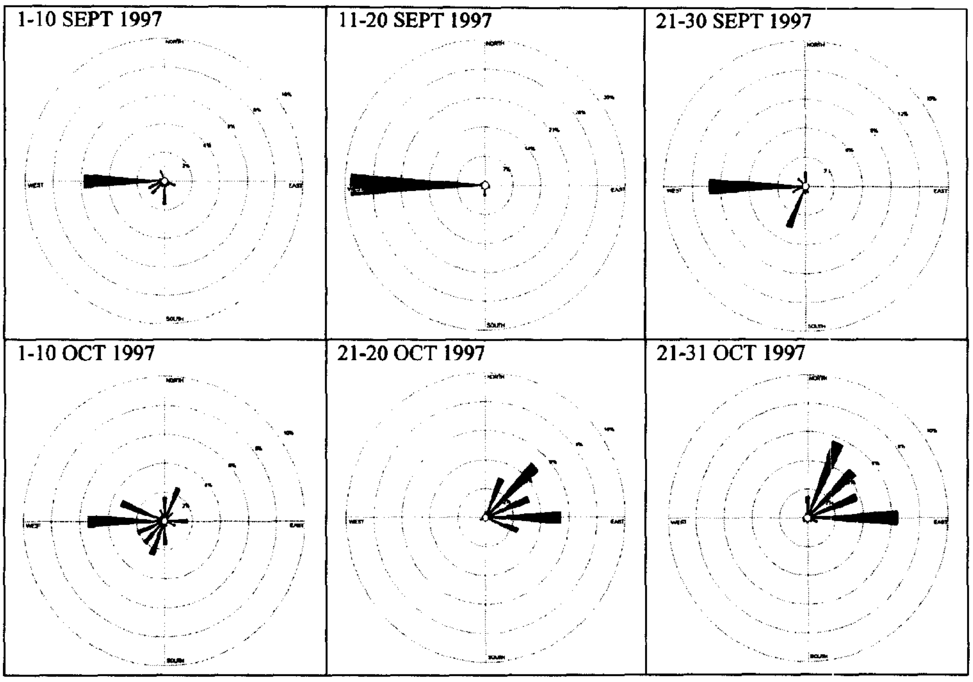


Figure. 3-65. 10-day wind rose analysis for NAKHON SI THAMMARAT in September-October 1997.

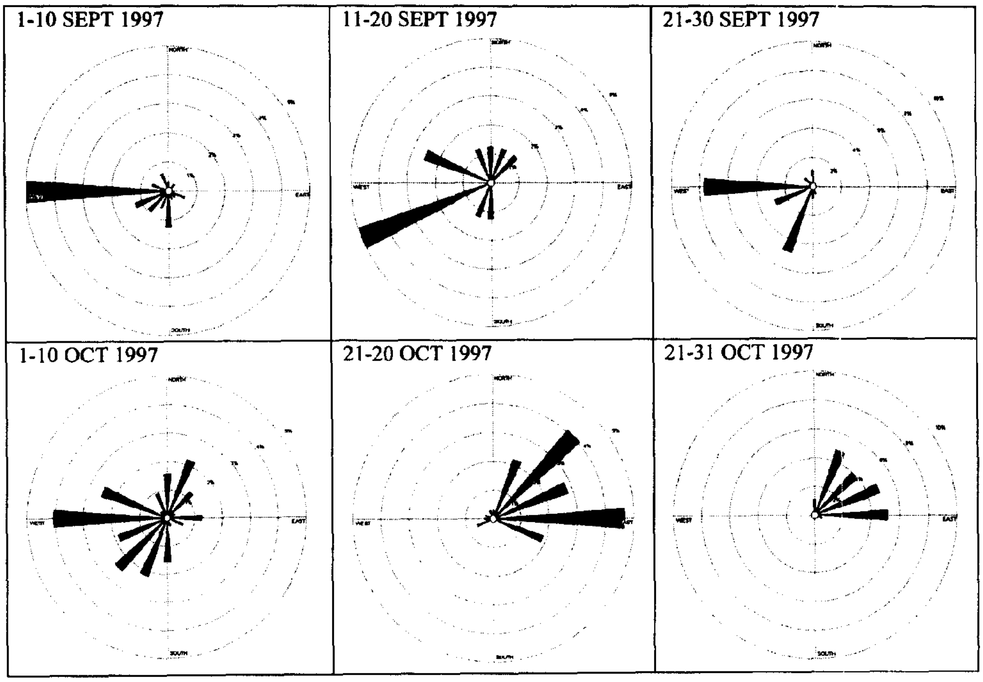


Figure. 3-66. 10-day wind rose analysis for HAT YAI in September-October 1997.

please see Figure. 3-76 - Figure. 3-78
"Daily wind rose analysis for HAT YAI"
pp. 115-117

Figure. 3-67. 10-day wind rose analysis for SONGKHLA in September-October 1997.

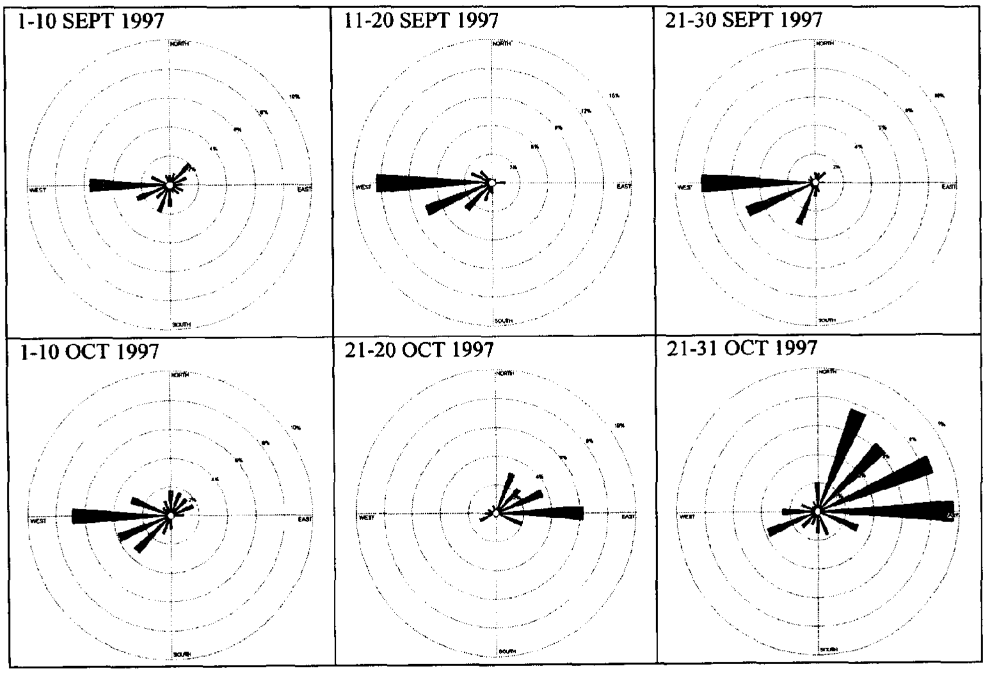


Figure. 3-68. 10-day wind rose analysis for PATTANI in September-October 1997.

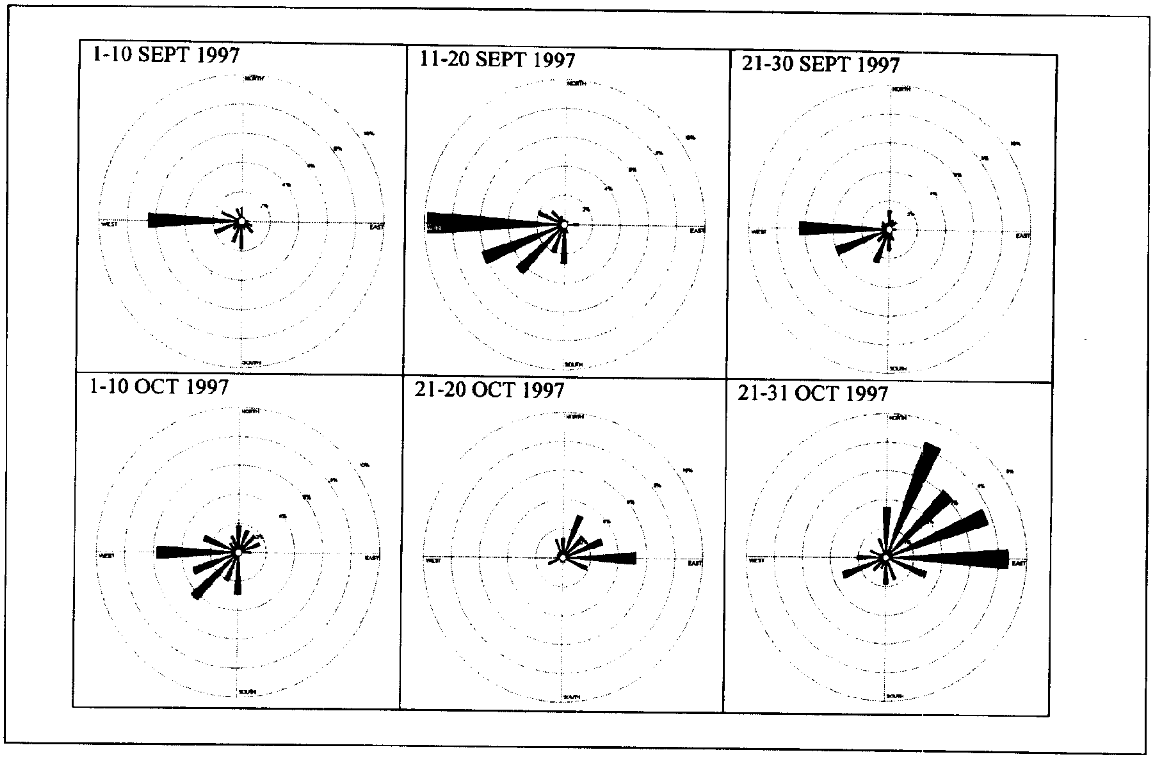


Figure. 3-69. 10-day wind rose analysis for NARATHIWAT in September-October 1997.

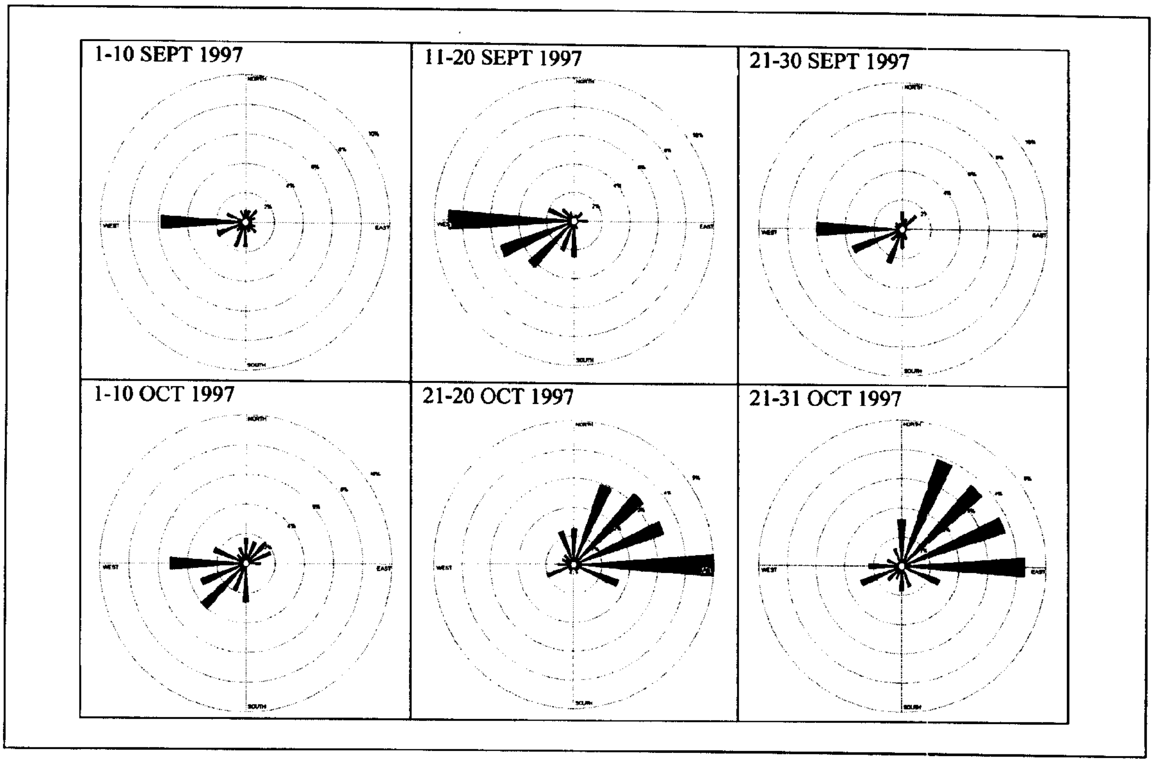


Figure. 3-70. 10-day wind rose analysis for RANONG in September-October 1997.

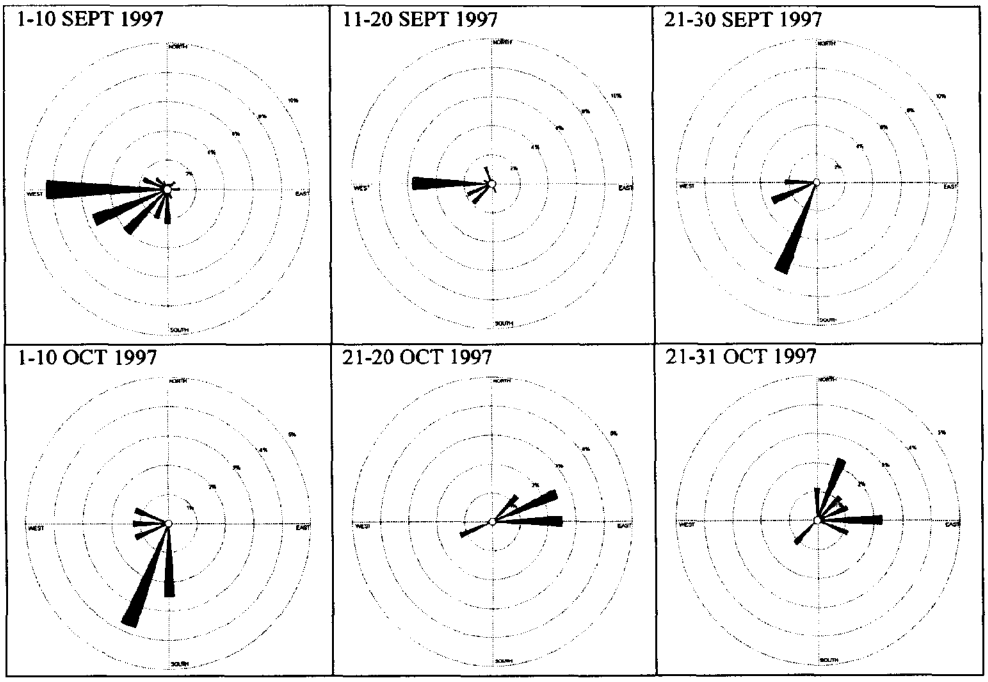


Figure. 3-71. 10-day wind rose analysis for TAKUA PA in September-October 1997.

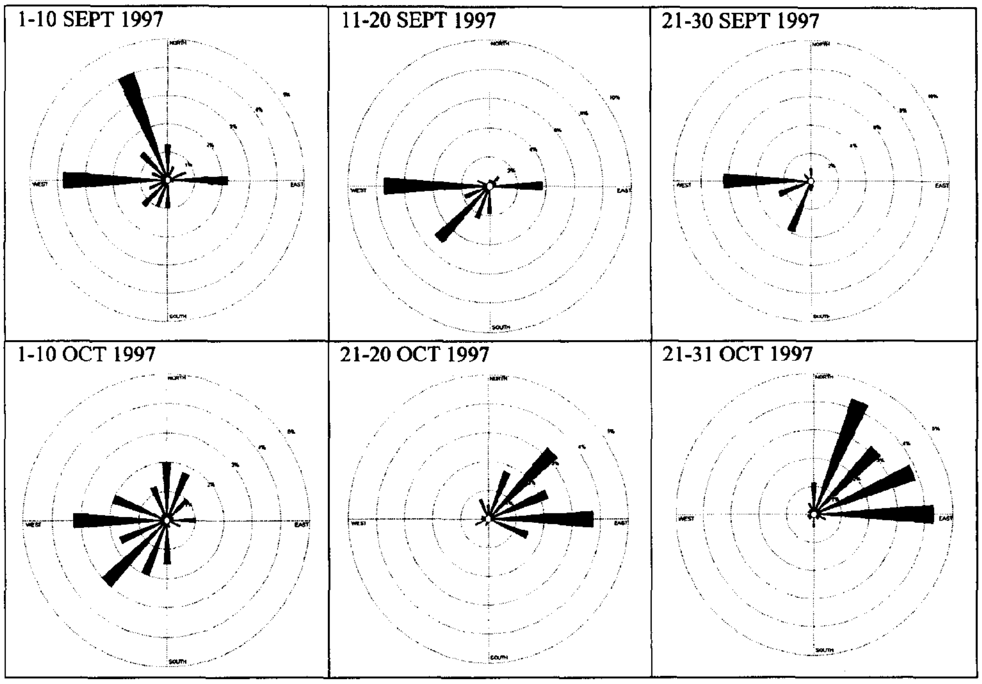


Figure. 3-72. 10-day wind rose analysis for PHUKET AIRPORT in September-October 1997.

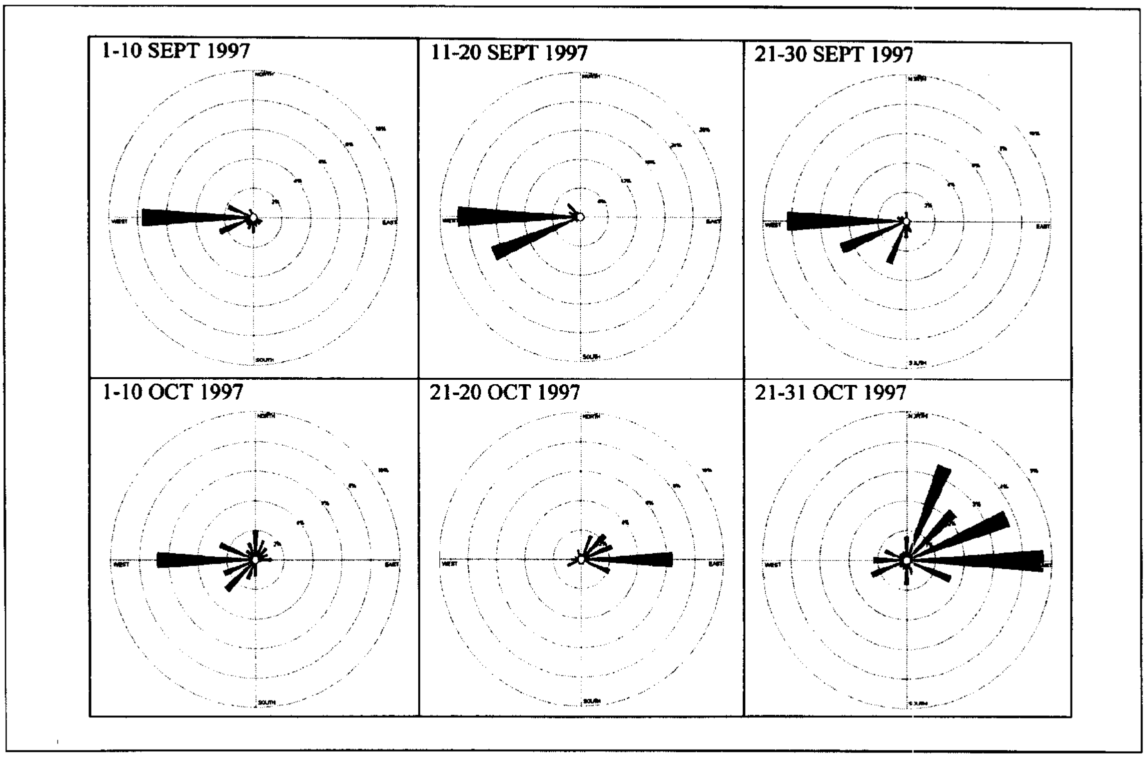


Figure. 3-73. 10-day wind rose analysis for PHUKET (DOWNTOWN) in September-October 1997.

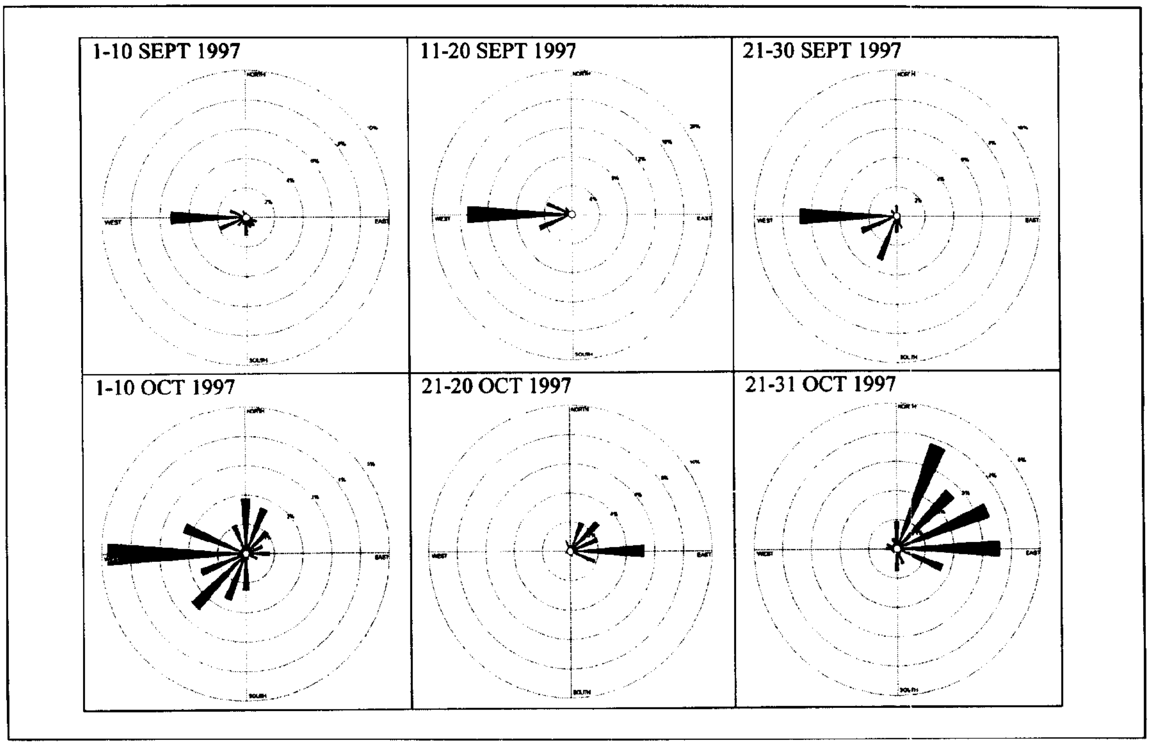


Figure. 3-74. 10-day wind rose analysis for SATUN in September-October 1997.

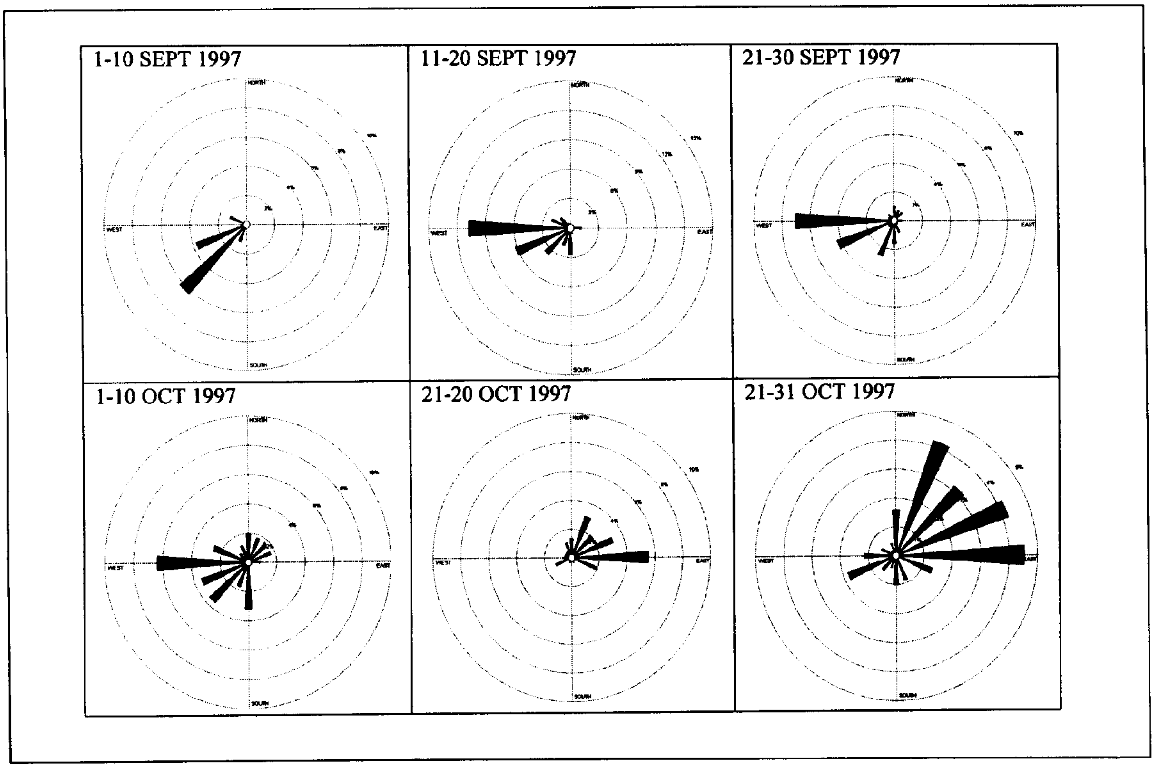


Figure. 3-75. 10-day wind rose analysis for TRANG in September-October 1997.

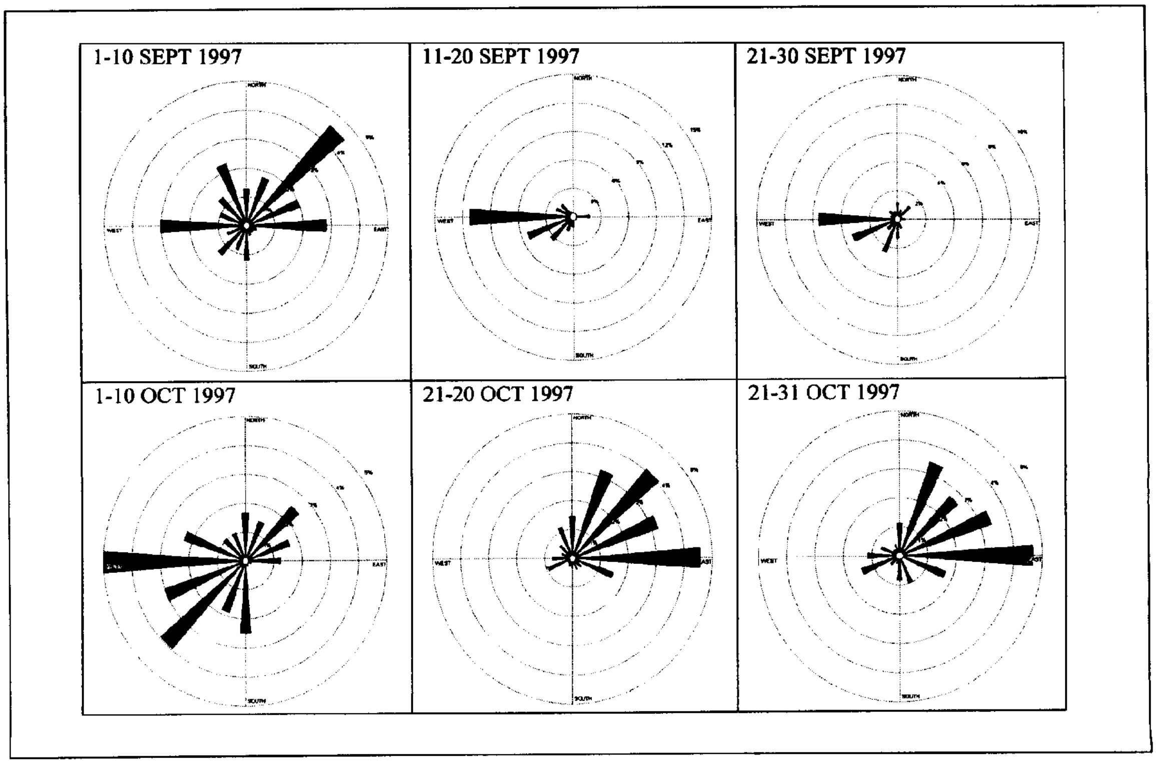


Figure. 3-76. Daily wind rose analysis for HAT YAI in September 1997.

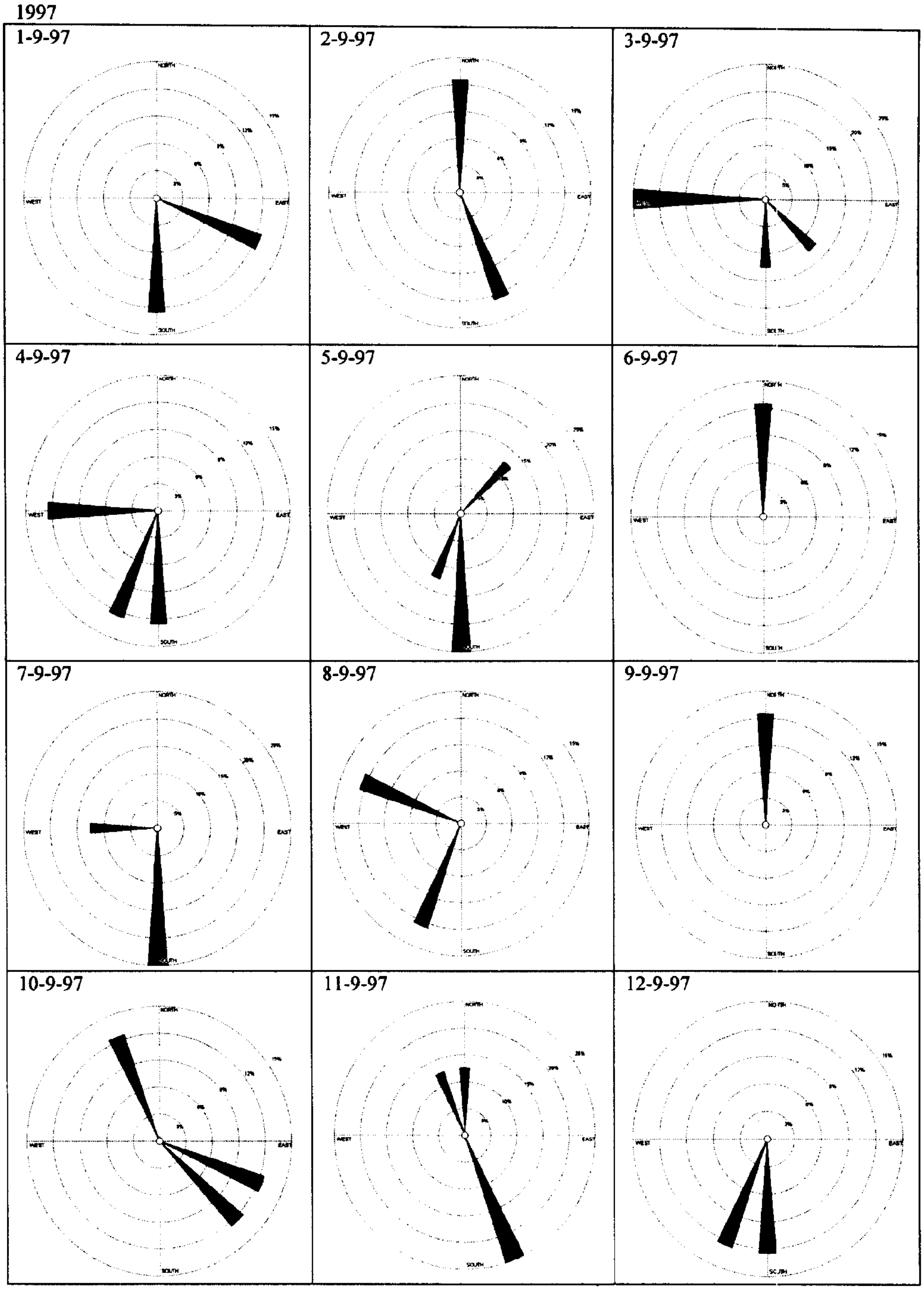


Figure. 3-77. Daily wind rose analysis for HAT YAI in September 1997.

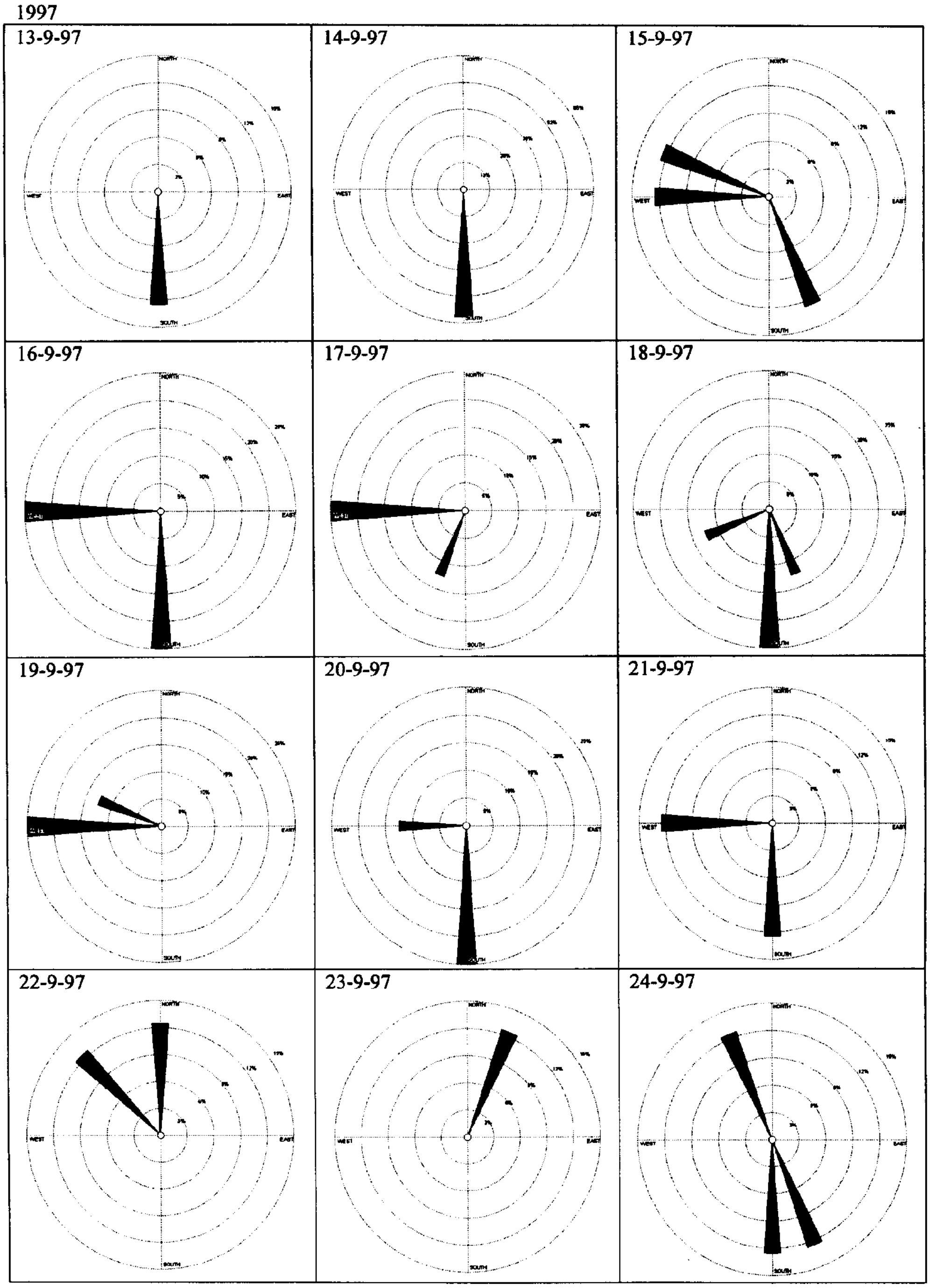


Figure. 3-78. Daily wind rose analysis for HAT YAI in September 1997.

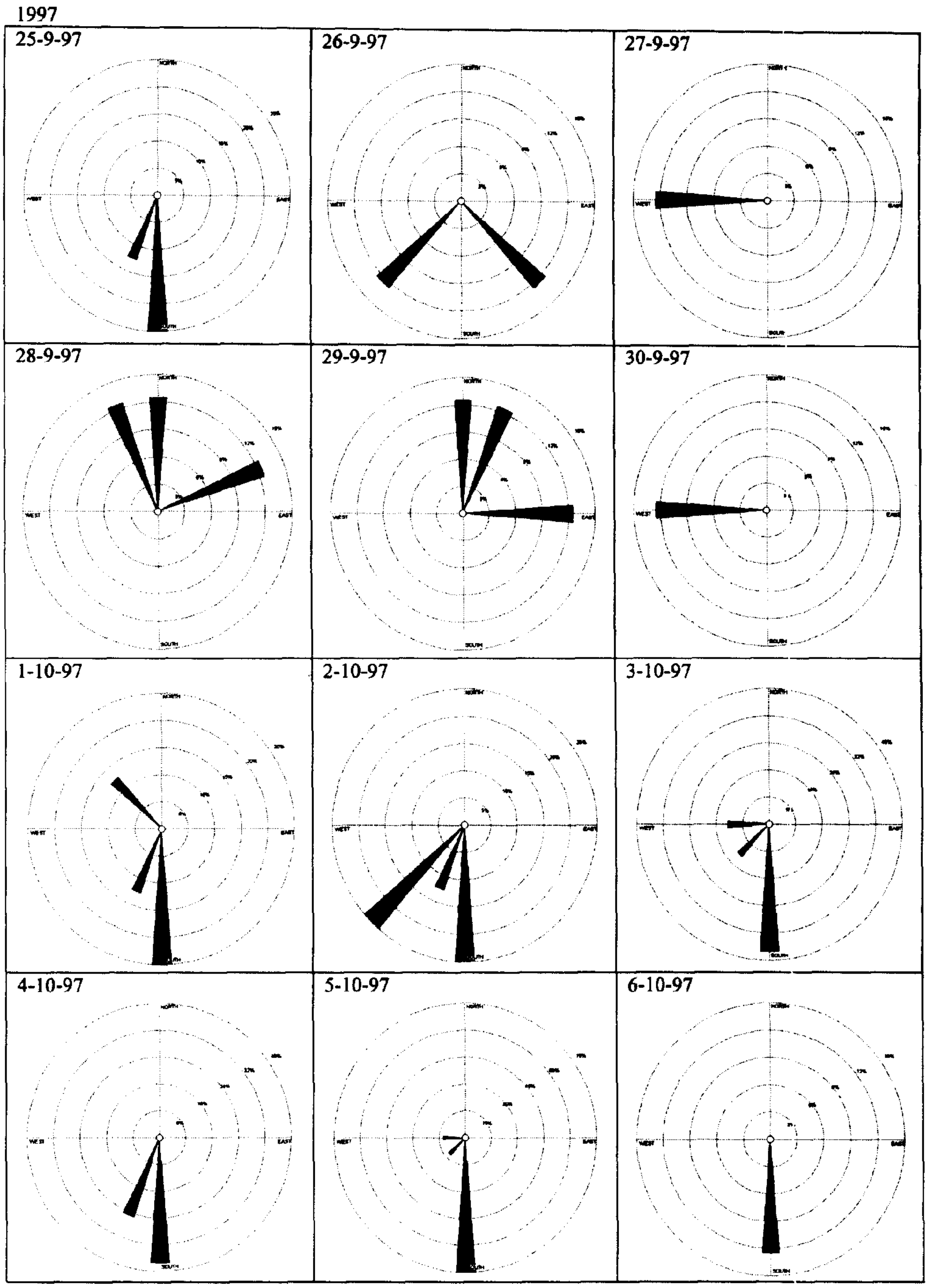


Figure. 3-79. Some of GMS-5 satellite visible images during 16th-20th September 1997.

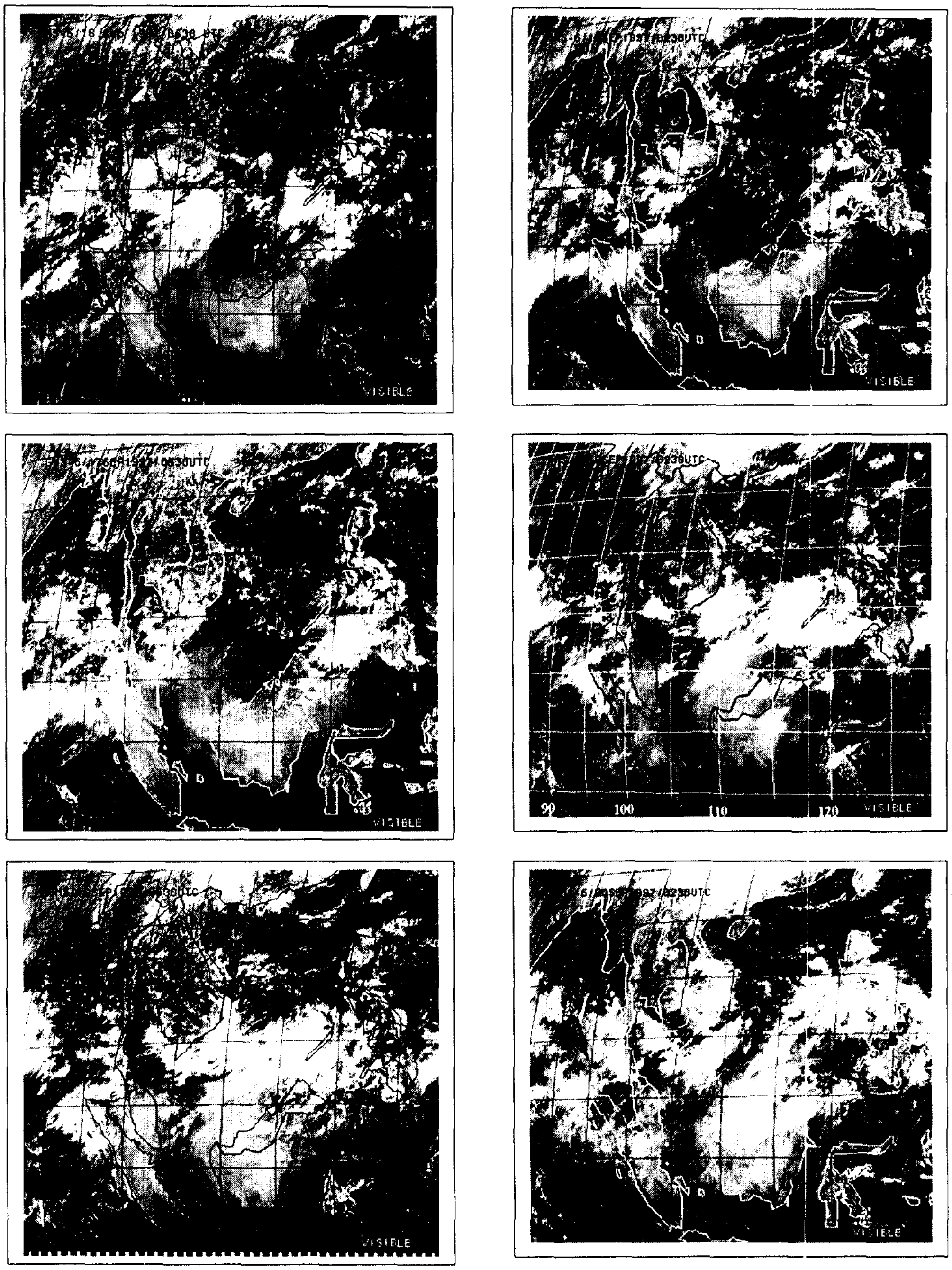


Figure. 3-80. Some of GMS-5 satellite visible images during 21st-25th September 1997.

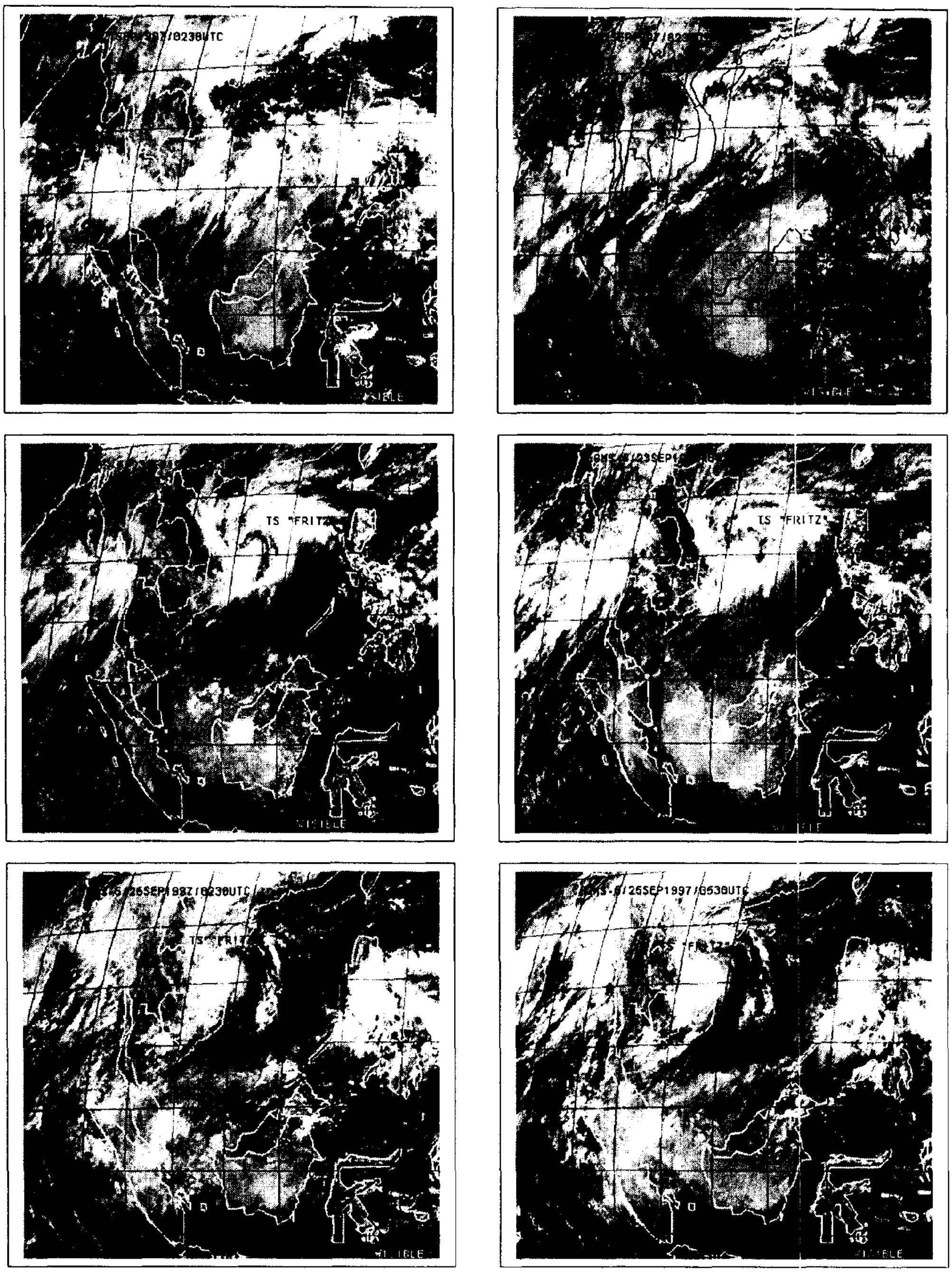
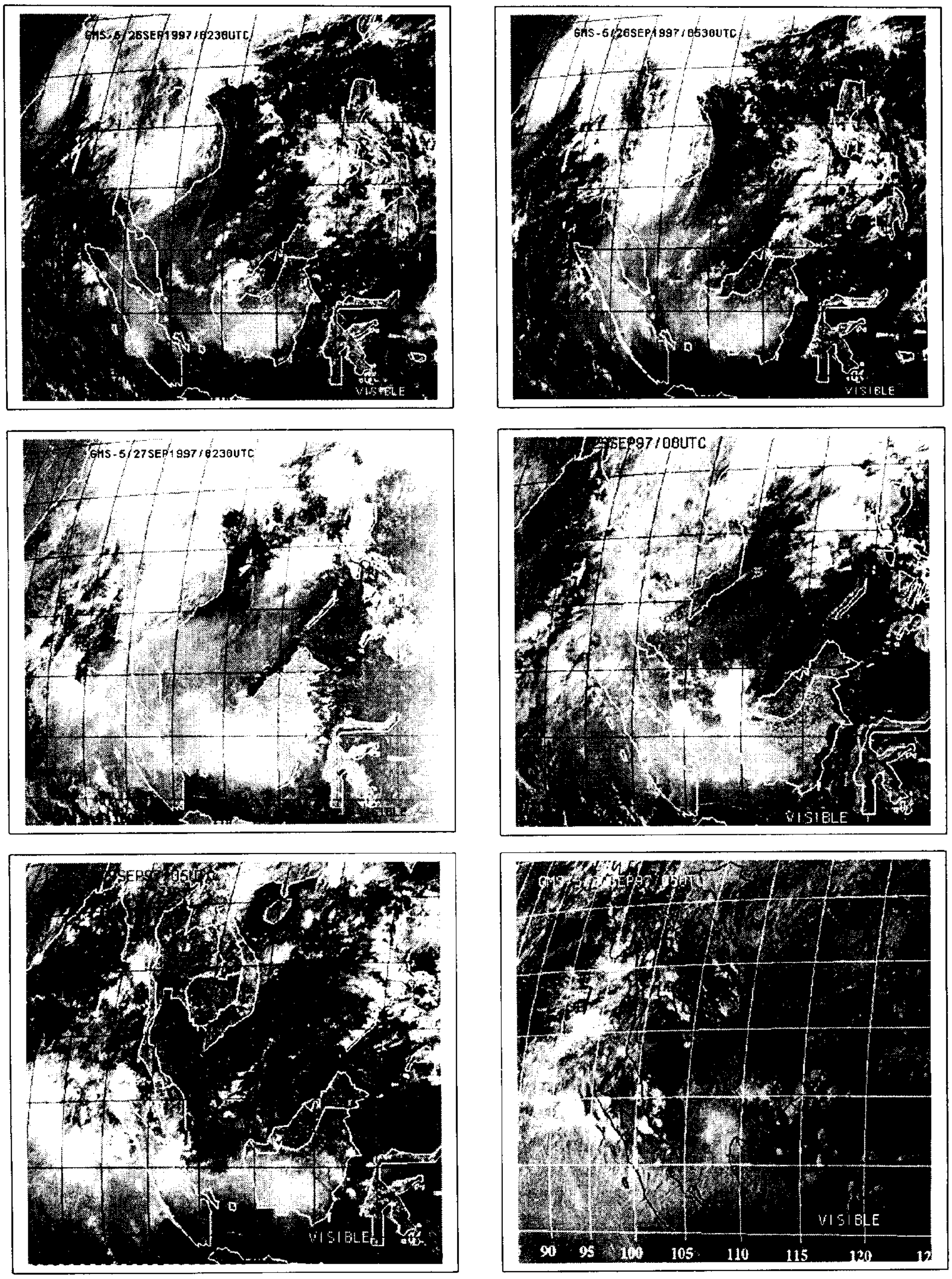


Figure. 3-81. Some of GMS-5 satellite visible images during 26th-30th September 1997.



4 AIR QUALITY DATA

ORANUT PAISARN-UCHAPONG
PROESPICHAYA KANATHARANA

Introduction

The air quality monitoring has first started in Bangkok since 1981. However, as a mean for the air quality management of the country, the Pollution Control Department (PCD) has set up a national air quality monitoring network to continuously monitor the air quality throughout the country. The network is consisted of fifty-three air quality monitoring stations, five 100-meter meteorological masts and one Wind profiler/RASS system (Table 4-1, Figure 4-1). The air quality monitoring stations monitor the air quality and the local meteorological conditions, as well. The parameters available from the stations are as shown in Table 4-2. The network has been completed and started to monitor the air quality since 1996.

Table 4-1. The national air quality monitoring network of Thailand

Region	air quality station	meteorological station
North	7	2 *
Northeast	2	1
Central (BKK)	33	1
East	7	1
South	4	1
Total	53	6

* Wind profiler / RASS system is included

Table 4-2. The parameters monitored in the station

No.	Parameters	
	ambient air quality data	**meteorological data**
1	CO	wind
2	O_3	temperature
3	SO_2	humidity
4	NO_2	solar radiation
5	NO	net radiation
6	NO_X	atmospheric pressure
7	PM_{10}	precipitation
8	Methane	
9	Non-Methane	
10	Total Hydrocarbons	

The air quality of some stations in each region are shown in Table 4-3. The data show that the major pollutants in Thailand, similar to other countries, has been the PM_{10}, and occasionally is O_3 .

Table 4-3. Maximum concentration of hourly average data in each of the region in 1996 - 1997

Region	**Station**	**PM10*** (μg/m3)		**CO** (ppm)		**SO_2** (ppb)		**NO_2** (ppb)		**O_3** (ppb)	
		1996	**1997**	**1996**	**1997**	**1996**	**1997**	**1996**	**1997**	**1996**	**1997**
North	Chiang mai [1]	215	240	28.7	2.6	50.9	42.3	146.0	62.0	119.0	113.0
Northeast	Khon Kaen	195	263	8.9	9.8	68.0	34.0	69.0	94.0	41.0	80.0
Central	Bangkok [2]	261	250	6.8	10.0	154.0	143.0	104.0	153.0	100.0	190.0
East	Rayong [3]	127	156	4.4	3.1	489.0	54.5	31.0	38.8	84.2	77.8
South	Phuket	314	197	12.7	5.0	118.0	16.7	132.8	52.5	69.0	142.8
Standard	**120**	**30**	**300**	**170**	**100**						

* 24 hr avg
[1] Government center
[2] Din Daeng
[3] Maptaput

Air Quality in Southern Thailand

There are three air quality monitoring stations in Southern Thailand, in the provinces of Surat Thani, Songkhla (Hat Yai) and Phuket, as shown in Figure 4-2. A monitoring station at Prince of Songkhla University (PSU) in Hat Yai supplemented this network. The air quality in Southern Thailand monitored during 1996 - 1997 can be summarized as follows.

Particulate Matters (PM_{10}) There were seasonal pattern for the PM_{10} level, i.e., high level during the dry season and low level during wet season. Among the three stations, Phuket had higher levels of the PM_{10} with the daily maximum of 314.1 and 196.6 microgram/cubic meter (μg/m³) respectively in May 1996 and September 1997. The PM_{10} levels monitored in Surat Thani were the lowest of the three. The information are as shown in Table 4-4.

Table 4-4. Maximum and average 24 hour-average PM_{10} (ug/ m³) of Southern Thailand

Station	Surat Thani				Songkhla (Hat Yai)				Phuket				PSU			
	1996		1997		1996		1997		1996		1997		1996		1997	
Month	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
January	67.5	51.7	145.2	58.8	177.8	77.9	115.8	59.8	63.0	22.8	78.3	55.2		—		43
February	74.5	52.9	77.6	53.6	142.8	45.3	65.3	43.1	26.4	23.3	164.2	68.9		—		43
March	84.2	60.6	105.1	71.6	184.1	72.2	80.7	48.4	219.5	64.2	127.3	58.7		—		45
April	101.8	50.8	87.7	58.4	70.0	48.9	58.1	42.9	263.9	96.3	77.7	50.3		28		45
May	55.0	33.0	76.7	41.8	57.7	44.1	75.8	51.3	314.1	161.6	67.5	42.9		34		34
June	42.2	33.3	53.5	37.7	115.5	54.2	67.8	43.0	160.5	56.6	73.7	51.3		60		60
July	43.8	29.6	74.5	34.8	115.0	53.8	121.6	59.3	72.6	47.2	96.9	60.8		—		32
August	47.6	29.1	55.9	42.5	83.9	50.6	118.2	61.8	72.7	51.1	84.0	53.8		54		—
September	26.3	21.7	106.7	47.3	96.6	53.4	159.1	73.7	139.9	51.7	196.6	74.9		48		69
October	—	—	73.4	43.8	65.9	41.2	142.8	71.9	123.3	72.9	91.8	63.7		48		38
November	—	—	83.8	48.4	66.7	41.5	185.3	75.7	156.3	86.9	60.0	33.5		41		31
December	101.0	70.7	65.5	45.8	193.6	50.0	121.6	38.0	137.1	92.6	41.8	31.1		32		28
Standard								120								

Sulfur dioxide (SO_2) The SO_2 in Southern Thailand, as high as 118 ppb in Phuket during June 1996, were still below its standard of 300 ppb (Table 4-5). Those of Surat Thani were slightly higher than the other two stations.

Table 4-5. Hourly maximum and average SO_2 (ppb) of Southern Thailand

Station	Surat Thani				Songkhla (Hat Yai)				Phuket			
	1996		1997		1996		1997		1996		1997	
Month	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
January	9.0	1.6	4.0	1.0	9.7	1.8	12.0	0.9	1.8	0.8	11.9	1.6
February	8.0	3.5	6.0	1.1	10.0	1.0	7.0	0.7	5.2	0.8	9.5	1.5
March	7.0	1.7	9.5	3.0	4.2	0.9	2.4	0.5	28.0	1.4	4.0	0.5
April	19.0	2.4	20.9	1.6	5.5	0.9	1.2	0.1	7.0	1.5	7.5	1.2
May	43.0	1.6	20.1	1.7	8.4	1.8	5.8	0.8	14.1	2.0	16.0	2.7
June	7.0	0.7	21.6	0.9	5.3	1.9	4.5	0.9	118.0	1.9	11.5	2.6
July	51.0	1.9	11.9	0.8	16.0	1.7	3.8	0.9	22.8	1.7	12.8	2.3
August	17.0	1.3	6.0	1.0	6.0	1.3	6.2	0.8	13.5	1.7	13.8	0.7
September	23.0	1.6	13.0	4.0	4.2	0.7	4.2	0.5	6.5	1.6	4.5	0.8
October	31.0	1.4	28.0	3.1	7.0	0.4	1.0	0.1	7.9	1.3	16.2	0.7
November	6.0	1.5	4.0	0.7	3.5	0.5	2.8	1.0	28.3	2.5	16.7	1.5
December	12.0	1.5	4.0	1.1	35.5	2.4	4.8	1.6	19.2	3.0	8.1	0.9
Standard							300					

Nitrogen dioxide (NO_2) None of the NO_2 data were over the standard of 170 ppb. The NO_2 levels of Southern Thailand in1996 and 1997 were quite similar even a high peak of 132.8 ppb was found in Phuket during June 1996. Of the NO_2 monitored in Southern Thailand, Phuket was the highest whereas Surat Thani was the lowest (Table 4-6).

Table 4-6. Hourly maximum and average NO_2 (ppb) of Southern Thailand

Station	Surat Thani				Songkhla (Hat Yai)				Phuket			
	1996		1997		1996		1997		1996		1997	
Month	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
January	27.0	8.9	—	—	38.0	5.9	47.8	8.3	51.0	13.7	52.5	10.4
February	25.0	7.4	10.0	3.5	42.5	5.2	47.0	8.8	29.8	11.4	40.5	10.8
March	20.0	6.9	18.0	8.4	41.2	7.2	44.0	8.0	31.5	10.8	37.5	11.7
April	29.0	8.4	26.0	5.9	45.0	10.7	35.0	10.3	27.5	11.7	30.8	10.8
May	20.0	5.4	21.0	7.6	27.0	9.3	32.8	10.1	37.5	11.4	34.5	11.5
June	19.0	5.6	24.0	10.0	34.0	9.9	41.8	11.0	132.8	11.5	30.5	11.5
July	21.0	7.4	32.0	7.2	35.0	10.0	—	—	44.0	12.0	44.2	11.6
August	23.0	5.0	15.0	6.0	31.2	8.8	—	—	50.0	12.8	42.5	11.2
September	16.0	3.2	19.0	5.1	46.0	8.5	—	—	33.0	11.4	44.0	13.9
October	23.0	7.2	29.0	6.3	28.8	10.4	—	—	33.5	13.6	30.5	10.9
November	43.0	7.3	41.0	10.5	29.0	8.4	—	—	34.8	11.8	37.2	8.7
December	26.0	9.7	30.0	11.6	41.5	13.4	—	—	67.5	13.1	25.2	7.6
Standard						170						

Carbonmonoxide (CO) High level of CO was found in Phuket (45.4 ppm) in 1996. However, most of the data were generally below its 1 hour standard. Those CO monitored in Southern Thailand in 1996 were slightly higher than 1997. The CO levels in Phuket were relatively higher than Hat Yai, with the lowest in Surat Thani (Table 4-7).

Table 4-7. Hourly maximum and average CO (ppm) of Southern Thailand

Station	Surat Thani				Songkhla (Hat Yai)				Phuket			
	1996		1997		1996		1997		1996		1997	
Month	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**
January	1.6	0.6	6.4	0	2.6	0.5	6.2	1.2	3.2	0.7	3.2	0.6
February	2.5	0.7	1.6	0.7	2.0	0.4	4.1	1.1	2.9	0.6	4.0	0.7
March	1.4	0.4	1.2	0.7	1.8	0.6	1.5	0.5	2.5	0.5	2.4	0.6
April	1.2	0.4	1.6	0.6	2.7	0.9	1.7	0.5	2.8	0.7	2.5	0.6
May	2.9	0.4	1.3	0.4	2.9	0.8	2.8	0.8	4.9	0.8	3.3	1.0
June	1.5	0.4	1.7	0.4	2.0	0.7	2.9	0.8	45.4	0.8	3.7	1.1
July	1.0	0.4	1.6	0.2	2.1	0.8	1.6	0.6	4.4	0.7	4.5	1.1
August	3.6	0.3	0.9	0.2	2.6	0.9	1.8	0.6	12.7	1.0	5.0	1.0
September	2.3	0.4	—	—	3.1	0.8	2.6	0.8	12.3	0.9	4.0	1.4
October	1.6	0.4	—	—	3.4	0.6	2.2	0.8	5.5	1.2	4.6	1.0
November	1.2	0.5	1.3	0.7	4.3	0.9	2.3	0.7	4.7	1.2	2.4	0.5
December	1.5	0.5	2.2	0.7	5.1	1.1	1.6	0.4	4.5	0.9	2.7	0.4
Standard						30						

Ozone (O_3) The O_3 level in Southern Thailand in 1996 were lower than 1997. None of the data of the three areas exceeded the standard of 100 ppb except some 4 hours with the highest of 142.8 ppb in Phuket during June - July of 1997. The data are shown in Table 4-8.

Table 4-8. Maximum and hourly average O_3 (ppb) of Southern Thailand

Station	Surat Thani				Songkhla (Hat Yai)				Phuket			
	1996		1997		1996		1997		1996		1997	
Month	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**
January	41.0	16.5	47.0	16.5	42.5	16.5	40.2	18.9	14.0	3.5	39.8	19.1
February	44.0	15.1	52.0	14.1	47.6	22.0	39.5	12.1	31.2	9.4	55.0	16.6
March	47.0	14.1	—	—	62.0	14.2	45.5	15.8	41.8	13.0	42.5	15.3
April	42.0	12.7	37.0	14.1	59.5	12.3	44.8	8.4	20.0	4.9	36.2	12.5
May	29.0	8.4	38.0	11.6	47.2	7.6	36.8	6.9	15.3	4.3	82.8	16.4
June	47.0	9.2	40.0	12.6	40.0	8.7	64.2	8.8	27.0	5.5	142.8	17.6
July	30.0	8.2	40.0	8.9	77.0	8.4	52.5	13.1	32.0	4.9	102.2	16.6
August	43.0	7.8	15.0	6.6	34.2	4.8	39.2	8.3	20.0	3.7	61.2	9.8
September	38.0	5.7	46.0	13.1	50.0	5.2	59.2	8.4	14.2	3.6	59.5	9.0
October	34.0	7.7	48.0	10.3	35.2	5.9	29.5	6.4	69.0	3.2	89.2	14.3
November	39.0	8.4	57.0	12.4	32.2	5.4	—	—	34.4	6.0	40.0	14.8
December	68.0	17.7	36.0	12.1	48.5	12.8	—	—	49.2	19.7	29.2	16.2
Standard						100						

Methane (CH_4) The 1996 methane levels of Surat Thani and Phuket were quite similar to 1997. However, during haze period, there was a rising peak of 5.3 ppb in Phuket. In contrast, those of Hat Yai in 1996 were higher than 1997. High peak with maximum of 10.2 ppb in Hat Yai was monitored during November 1996. It is noted that the CH_4 standard has not yet been set.

Table 4-9. Maximum and hourly average CH_4 (ppb) of Southern Thailand

Station	Surat Thani				Songkhla (Hat Yai)				Phuket			
	1996		1997		1996		1997		1996		1997	
Month	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
January	2.7	1.0	2.7	1.4	-	-	2.3	1.4	3.2	1.6	3.2	1.3
February	2.1	1.1	3.1	1.3	-	-	1.9	1.6	2.8	1.5	3.1	1.3
March	2.4	1.2	2.1	1.2	-	-	2.2	1.5	2.9	1.5	3.2	1.5
April	1.9	1.3	-	-	5.3	0.9	2.0	1.5	2.8	1.4	3.0	1.4
May	2.0	1.3	2.0	1.1	-	-	2.0	1.6	2.6	1.4	3.1	1.4
June	-	-	1.7	1.1	-	-	1.9	1.4	2.4	1.3	2.4	1.3
July	2.2	1.3	1.7	1.1	10.0	1.7	1.9	1.4	2.6	1.6	2.4	1.3
August	2.1	1.4	-	-	-	-	-	-	2.4	1.5	2.8	1.3
September	2.6	1.4	-	-	4.3	1.2	5.3	1.7	3.6	1.5	2.2	1.2
October	2.8	1.4	-	-	8.2	1.5	3.4	1.5	2.6	1.4	2.4	1.1
November	3.8	1.4	3.3	1.4	10.2	1.3	-	-	2.9	1.5	2.9	0.9
December	3.2	1.4	3.0	1.4	2.4	1.1	-	-	2.7	1.6	-	-

The levels of all other gaseous pollutants (SO_2, NOx, NO_2, CO, total hydrocarbons, methane, and non-methane hydrocarbons) monitored at the PSU station are shown in Table 4-9a for comparison.

Table 4-9a. Hourly average of SO_2, NOx, NO_2, CO, total hydrocarbons (TH), methane (M), and non-methane hydrocarbons (NM) (ppb, except CO in ppm), PSU station, 1996-1997

	SO_2		NOx		NO_2		CO		TH		M		NM	
	96	97	96	97	96	97	96	97	96	97	96	97	96	97
January	-	1.7	-	13.5	-	5.1	-	0.4	-	1.4	-	1.2	-	0.1
February	-	3.1	-	9.4	-	5	-	0.4	-	1.5	-	1.1	-	0.5
March	-	2	-	12.1	-	7.8	-	0.3	-	1.6	-	1.2	-	0.2
April	2.3	2	10	12	5.7	3	0.5	0.4	1.7	2.4	1.4	1.2	0.2	1.2
May	3.2	2	14.7	12	5	4	0.5	0.4	1.5	2.3	1.3	1.1	0.2	1.3
June	2.4	1	15	15	7	7	0.7	0.7	1.6	1.6	1.3	1.3	0.2	0.2
July	3	4	20	22	10.3	13	0.7	0.8	1.7	1.5	1.3	1.2	0.3	0.3
August	4.1	4	16.7	22	8.6	10	0.6	0.6	1.5	1.4	1.3	1.2	0.2	0.2
September	3	4	22	20	9	11	0.4	1	1.6	1.5	1.3	1.3	0.2	0.2
October	2.1	3	19	17	8	8	0.3	1	1.5	1.4	1.3	1.2	0.2	0.2
November	4	2	20	10	8	6	0.3	0.5	1.7	1.4	1.4	1.3	0.2	0.1
December	3.6	1	15.3	9	7	5	0.2	0.3	1.4	1.3	1	1.2	0.6	0.1

Haze episode of Southern Thailand during September 1997

During September 1997, haze from thousands of forest and bush fires raging across Sumatra and Kalimantan had moved into its neighboring countries and covered lower portion of Southern Thailand. The haze reduced the visibility and deteriorated air quality of all ASEAN countries, including Southern Thailand. Subsequently, it has caused massive concerns in health, transportation, social and economics. Health alert has been declared across the countries.

The air quality in Southern Thailand was impacted mainly during September 20-30, 1997, which will later be called as a haze period in this part of the report. This part of report would summarize all those data available during the period, both meteorological and air quality data.

Meteorological information

The major meteorological parameters discussed are wind, atmospheric pressure and relative humidity. The time period for the data analysis will cover September-October of 1996 and 1997, and specifically during September 20-30. The meteorological data during the haze period, in general, show that such atmospheric condition had blown the Indonesian haze into the lower portion of Southern Thailand. The additional slow dispersion of the atmosphere had also lead to the accumulation of high level of the pollutants in some of the area.

1. Wind speed and direction

The hourly wind speed and wind direction are monitored in all three stations. Specifically, 2 levels of wind observation are available in both Hat Yai and Surat thani. The wind observation levels in Hat Yai are at 10 and 30 meter whereas those in Surat thani are at 10 and 20 meter. The wind rose of the stations are shown in Figures 4-3 to 4-7.

Surat Thani During 1997, the wind pattern of the prevailing winds of both 10 and 20 meter levels during 1997 were quite similar. The prevailing winds are easterly wind and turn to southwesterly during rainy season. The information is summarized in Table 4-10. During September, wind speed at 10 meter level in 1997 were weaker than in 1996, especially during the haze period. The 1997 wind became stronger in October, as compared to 1996 (Figure 4-8, each figure describes events during September to October and also 20-30 September).

Table 4-10. Wind characteristics of Surat Thani in 1997

level (m)	month	wind characteristics
	January - March	easterly wind
	April	quite variable
10	June - August	southwesterly wind
	September	more easterly wind
	October - December	quite variable, but more easterly component
	January - March	variable but more east component
	April	quite variable
20	May - September	more southwest component
	October	quite variable with more west and northeast components
	November - December	easterly wind

Phuket During November through April (winter to summer), the northeast component wind prevailed over Phuket and turned to north to west component during rainy season (Table 4-11). In Phuket, wind speed pattern during the haze period was similar to Surat Thani, i.e., September wind speed in 1997 was generally weaker than in 1996, and became stronger in October 1997 (Figure 4-9). The wind speeds of the days with high PM_{10}, on September 24, 27 and 29, were quite weak, with the maximum wind speed of the day less than 2 meter/ second (m/s).

Table 4-11. Wind characteristics of Phuket in 1997

level (m)	month	wind characteristics
	January	more northeasterly component
10	February - April	variable but more north to east component
	May - October	variable but more north to west component
	November - December	variable but more northeast component

Hat Yai There were quite consistency of 1997 wind pattern at both levels, 10 and 30 meter levels. During winter, winds became more easterly to northeasterly. Southerly wind prevailed over the area during the haze period. Information is as shown in Table 4-12. The available 1997 wind speeds at 30 meter were distinctly weaker than 1996 throughout the period (Figure 4-10). During the day with high PM_{10} in September 1997, wind speed were very weak, no greater than 2 m/s.

Table 4-12. Wind characteristics of Hat Yai in 1997

level (m)	Month	wind characteristics
	January - March	northeasterly wind
10	April	quite variable, more northeast and south components
	June - October	southerly wind
	November - December	northeasterly wind
	January - March	northeast - east component
30	April	variable but more northeast to south component
	May - October	southerly wind
	November - December	easterly wind

2. Atmospheric pressure

Only the atmospheric pressure data of Surat Thani and Phuket were available during haze period. The data show distinct diurnal change pattern, high in the morning, low in the afternoon and turn to increase in the rest of the day. However, the 1997 atmospheric pressure in Southern Thailand during September-October was generally higher than 1996.

The atmospheric pressure available in Surat Thani during September-October of 1997 were generally higher than 1996, especially during the haze period (Figure 4-11). For Phuket, the 1997 atmospheric pressure during September was higher than 1996 (Figure 4-12).

3. Relative humidity

Variation in the relative humidity over the area were shown. However, the data show lesser moisture over Phuket during the haze period.

Surat Thani More moisture was generally found in 1996 than in 1997. However, the atmospheric moisture during the haze period of 1997 were higher than 1996 (Figure 4-13).

Phuket The 1997 atmospheric moisture was higher than in 1996. However, the atmosphere during 1997 haze period became drier than 1996, especially during the day of high PM_{10} (September 24, 27 and 29), as shown in Figure 4-14.

Hat Yai The 1997 atmospheric moisture at 2 meter was wetter than 1996, especially during the haze period (Figure 4-15).

Air Quality Information

The Indonesian forest fires had deteriorated the air quality of Southern Thailand in September 1997. The particulate level monitored from the three air quality stations showed some changes during the episode, especially during the end of the month. The air monitoring in the Southern Thailand showed that there were totally 4 days that the PM_{10} level exceeding its standard, 3 days in Phuket (24, 27 and 29 of September 1997) and 1 day in Hat Yai (25 September 1997). Slightly changes of other air pollutants in those stations were also found, but they were nonsignificant and still far below the standards.

The air quality data of Southern Thailand during the haze episode (September-October 1997) were analyzed, both spatially and temporally, for further details. In this chapter, the analyzed data were based on the daily average of PM_{10} and hourly maximum and average of other pollutants.

1. Spatially analysis

PM_{10} During the haze period, PM_{10} level increased in all 3 stations. However, only those of Phuket and Hat Yai were found to be higher than the PM_{10} standard, in September 24, 27 and 29, and September 25, respectively (Figure 4-16). Surat Thani is in the upper portion of Southern Thailand. Therefore, less influence of the Indonesian haze had impacted on the area.

SO_2 Among the three monitoring stations in Southern Thailand, Surat Thani showed the highest level whereas those of Hat Yai were the lowest. However, all the SO_2 level of the three stations still below the 1 hour standard. During the haze period, those of Surat Thani significantly showed increasing trend with the maximum of approximately 12 ppb where those of the other two stations did not show any significant change. The SO_2 level of Phuket varied slightly during the whole period (Figure 4-17).

NO_2 The 1997 NO_2 show diurnal pattern with peak in the afternoon. Of the available data series from 2 stations, the NO_2 in Phuket were generally higher than Surat Thani, with the highest of about 45 ppb. However, during the haze period, NO_2 level in Phuket declined whereas those of Surat Thani were slightly on a reverse (Figure 4-18).

CO The CO level in Phuket with its maximum of less than 5 ppm were slightly higher than Hat Yai. During September 25-October 4, the trend in Phuket and Hat Yai were generally on a decline (Figure 4-19).

O_3 The O_3 series in all three stations show the diurnal pattern of the peak during the afternoon. However, during the haze period, both Phuket and Surat Thani were about the same and higher than Hat Yai (Figure 4-20).

CH_4 The 1997 CH_4 levels in Phuket were slightly higher than Hat Yai. However, only the CH_4 level in Phuket during end of September were available. The data show higher peak of 5 ppb during late night in September 24 and 28, 1997, which were quite correspond to those high PM_{10} days (Figure 4-21). No CH_4 standard can be compared to those data.

2. Temporal analysis

The analysis covered the daily PM_{10} and hourly data for other pollutants available in each of the three stations during September and October of 1996 and 1997.

Surat Thani As Surat Thani locates in the uppermost of Southern Thailand. The impact of the Indonesian haze upon this area had been on a lesser extent. PM_{10} data during the haze period had risen to the peak of 106.7 ug/ m^3 on September 25, 1997, which was still below the standard of 120 ug/m^3 (Figure 4-22).

The other available pollutants (SO_2, CO, NO_2 and O_3), as in Figures 4-23 to 4-26, show that the levels were still below the standards. The SO_2 and O_3 in 1997 were slightly higher than 1996, especially during the haze period. The peak of O_3 was 40 ppb on September 24, 1997. The NO_2 of both 1996 and 1997 were quite the same, except during the haze period that the 1997 NO_2 was higher. In addition, only the 1996 CH_4 data available in Surat Thani were within the range of 0.5-3 ppb (Figure 4-27).

Phuket The 24 hour average PM_{10} levels in 1997 were relatively lower than 1996, except for the haze period of 1997. Three days of PM_{10} during the period were found to be higher than the standard , i.e., during 24, 27 and 29 of September 1997 (Figure 4-28). Those levels were 197, 153 and 128 ug/ m^3, respectively.

During September-October, other pollutants of SO_2 , CO, NO_2 and O_3 were still below their standards. The SO_2 in 1997 was slightly lower than 1996 (Figure 4-29). However, the 1997 peak of 4 ppb was found in September 28, 1997. The NO_2 and CO of September 1997 were higher than 1996 but those in October were on a reverse (Figures 4-30 to 4-31). The NO_2 of 40 ppb and CO of 4 ppm were monitored respectively in September 23 and 26 of 1997. The 1997 O_3 were generally higher than 1996 with the highest level of 60 ppb in September 1997 (Figure 4-32). The CH_4 during the haze period were higher than 1996, with the peaks coincided with those days of high PM_{10} (Figure 4-33).

Hat Yai The 1997 PM_{10} during the period were higher than 1996. The PM_{10} peak of 159 ug/m^3 during the haze period, which exceeded the standard, was found on September 25, 1997 (Figure 4-34).

Other pollutants were below their standards (Figures 4-35 to 4-39). The 1997 SO_2 and O_3 were generally lower than 1996, with exceptional of O_3 during the haze period that its levels close to 1996. The September CO in 1997 showed higher level than 1996, but the reverse was shown in October. The CO peak of 2.5 ppm was found in the same day of high PM_{10} on

September 25, 1997. The CH_4 in Figure 4-39 showed that the data in 1997 were lower than 1996.

Conclusion

During the haze period, the pollutant that distinctly showed the impact in the lower portion of Southern Thailand, i.e., Phuket and Hat Yai was PM_{10}. There were some small-scale changes in other pollutants monitored in those 3 stations, such as SO_2 and O_3, but they were not significant at their existing low background levels.

Figure 4-1. National air quality monitoring network of Thailand.

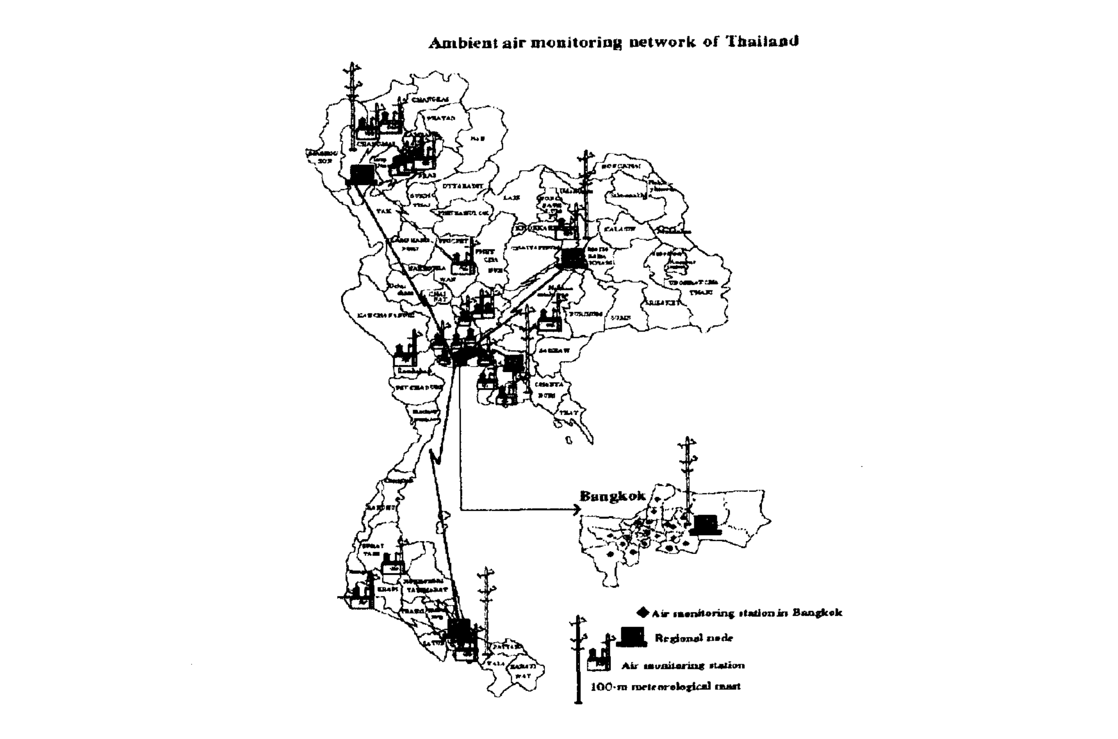


Figure 4-2. Air quality monitoring stations in Southern Thailand.

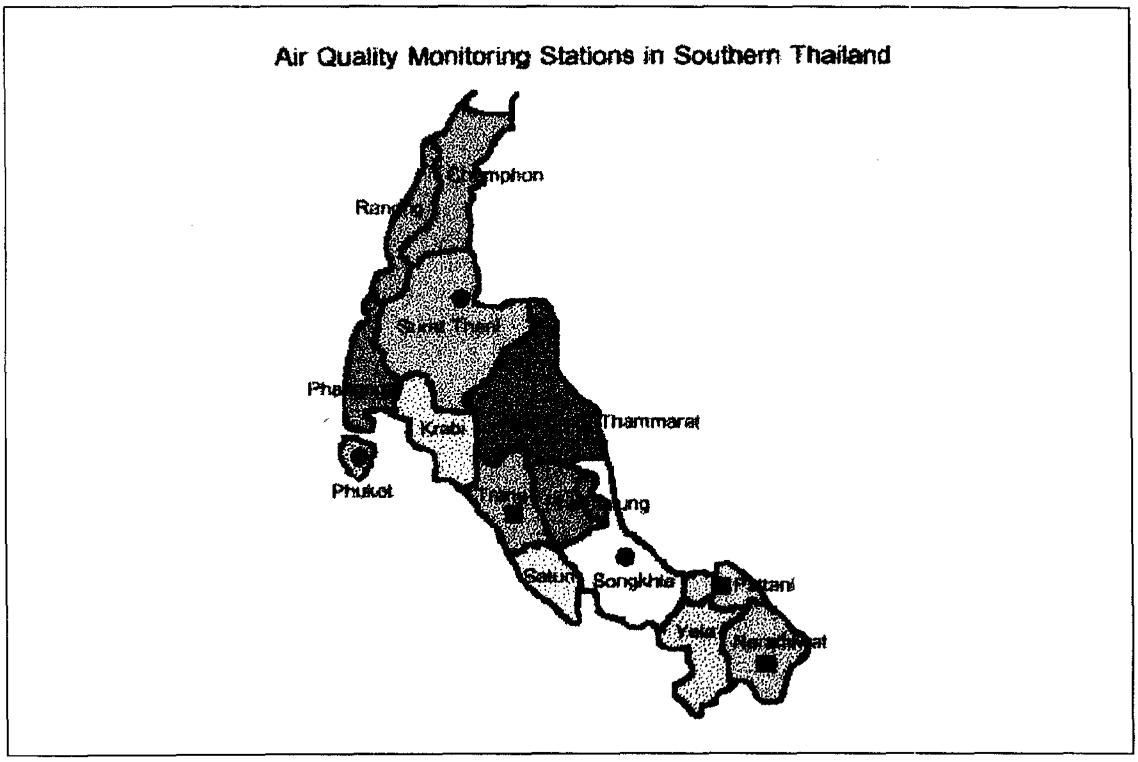


Figure 4-3. Wind rose analysis for SURAT THANI (10-meter level), 1997.

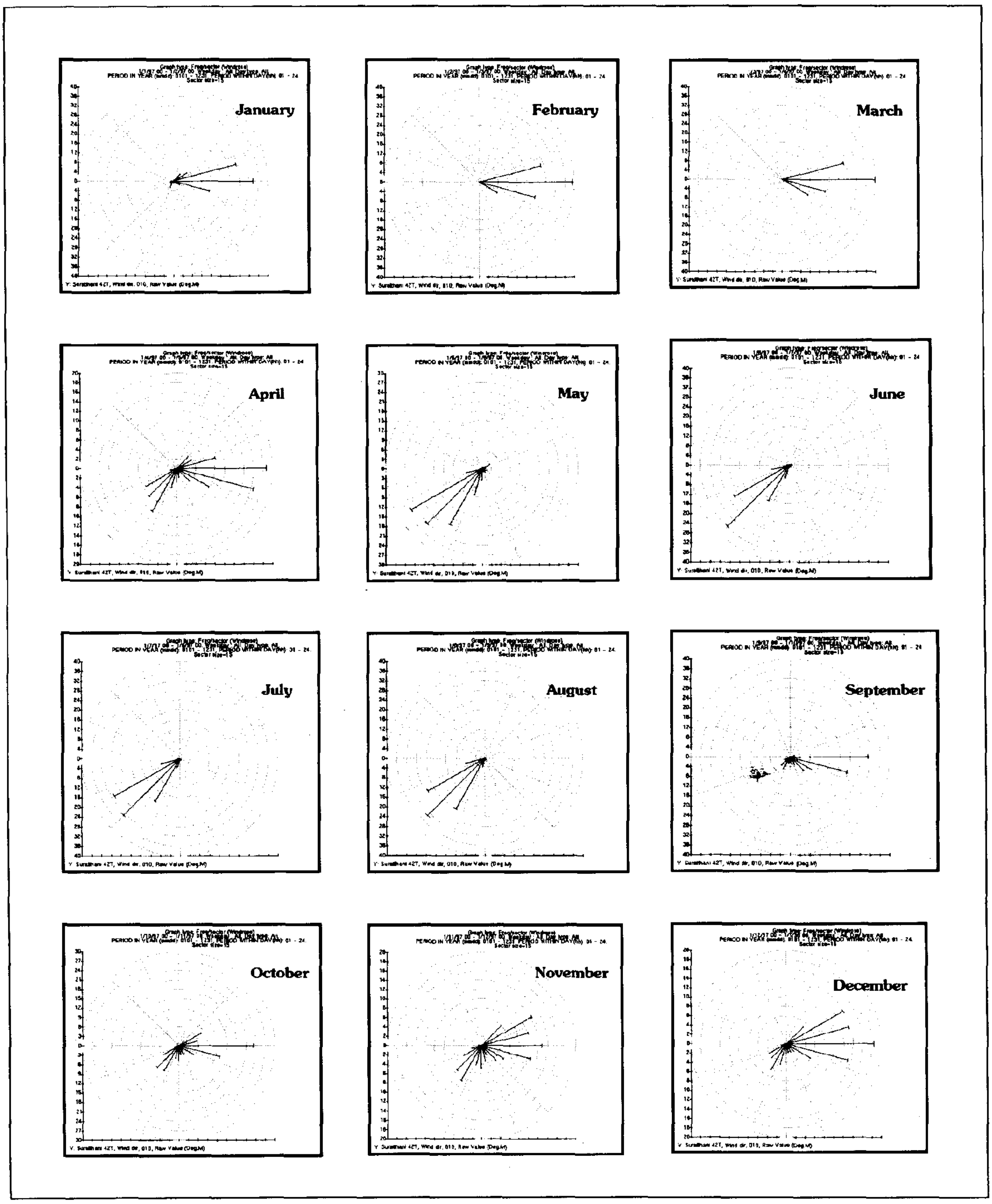


Figure 4-4. Wind rose analysis for SURAT THANI (20-meter level), 1997.

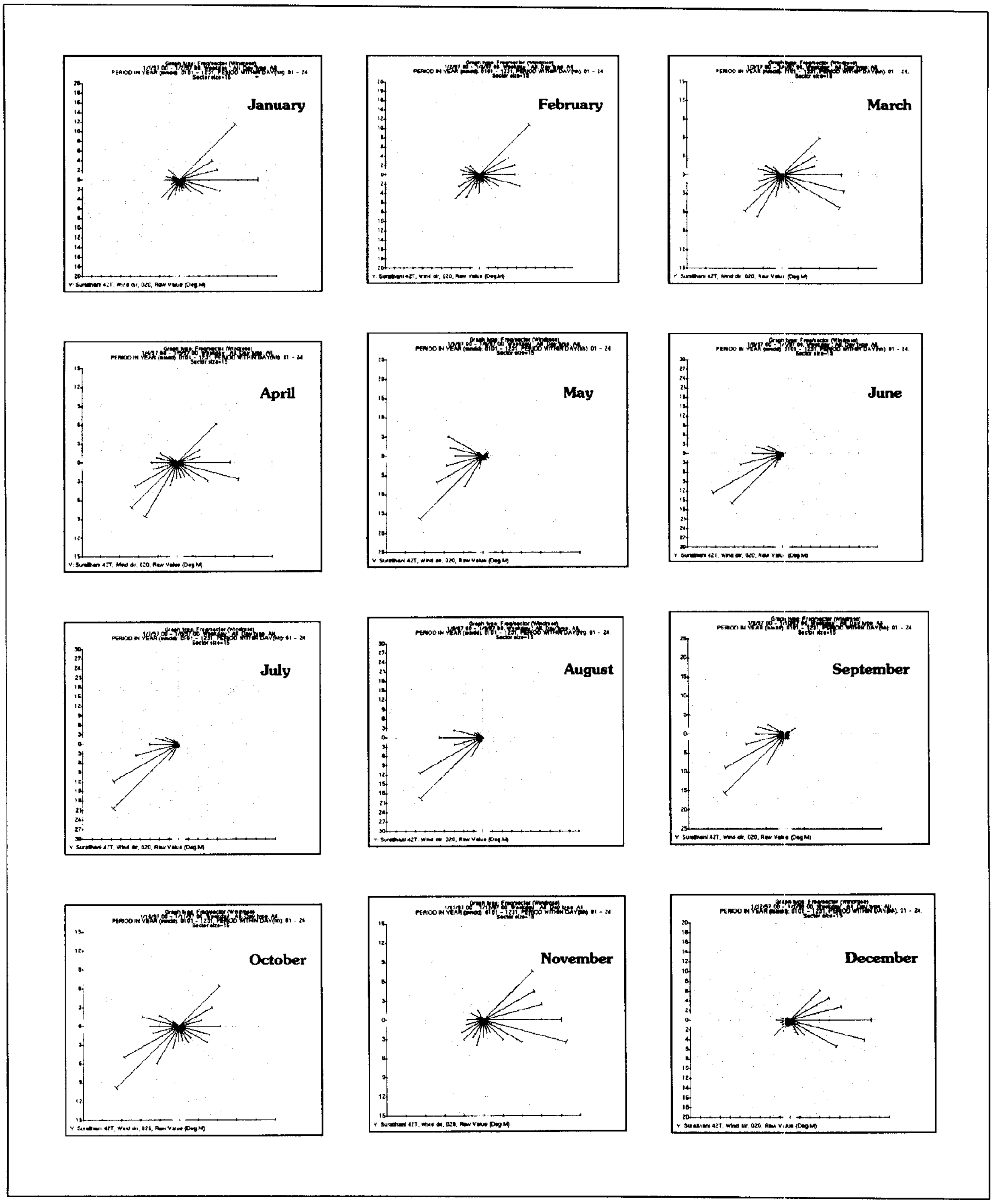


Figure 4-5. Wind rose analysis for HAT YAI (10-meter level), 1997.

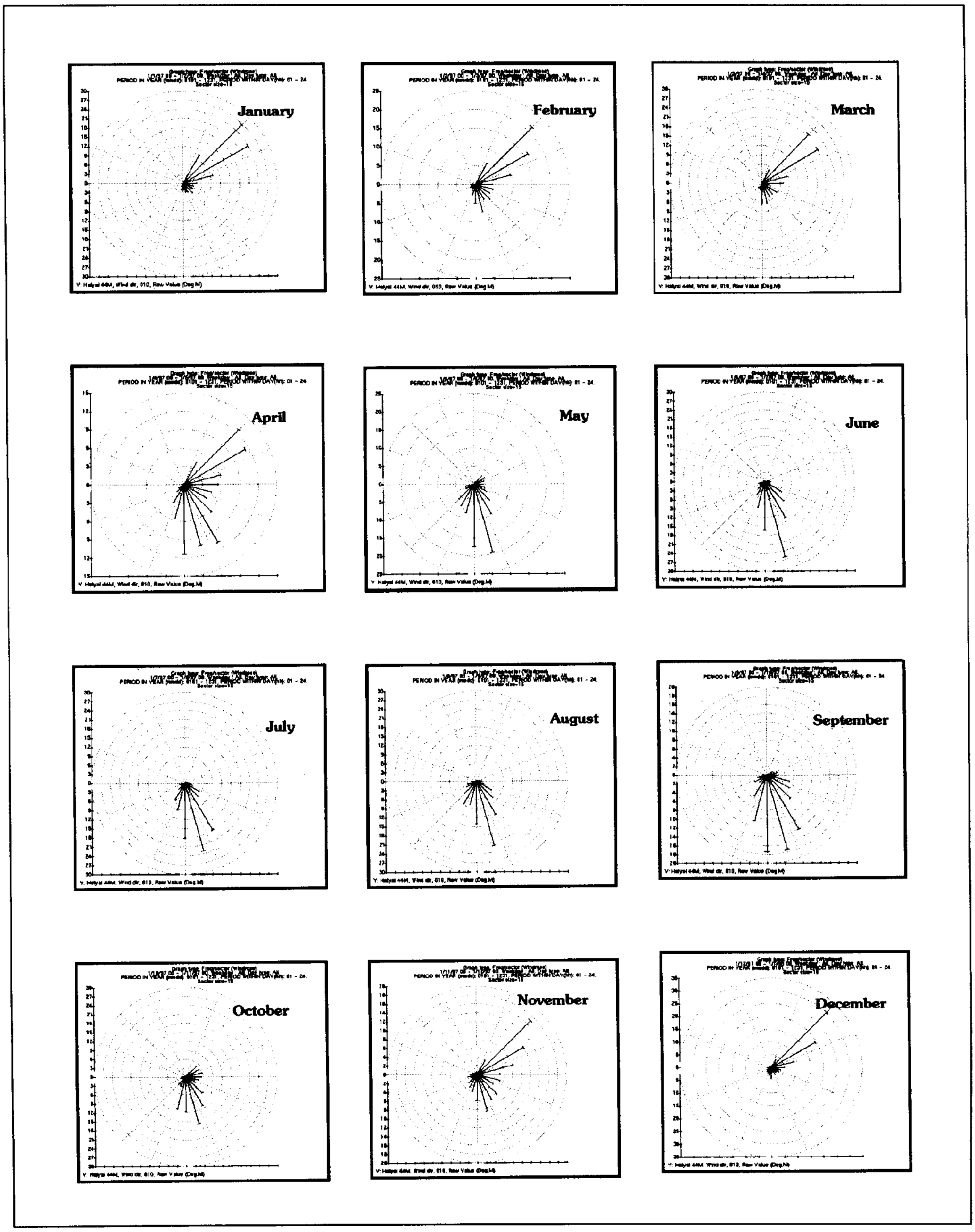


Figure 4-6. Wind rose analysis for HAT YAI (30-meter level), 1997.

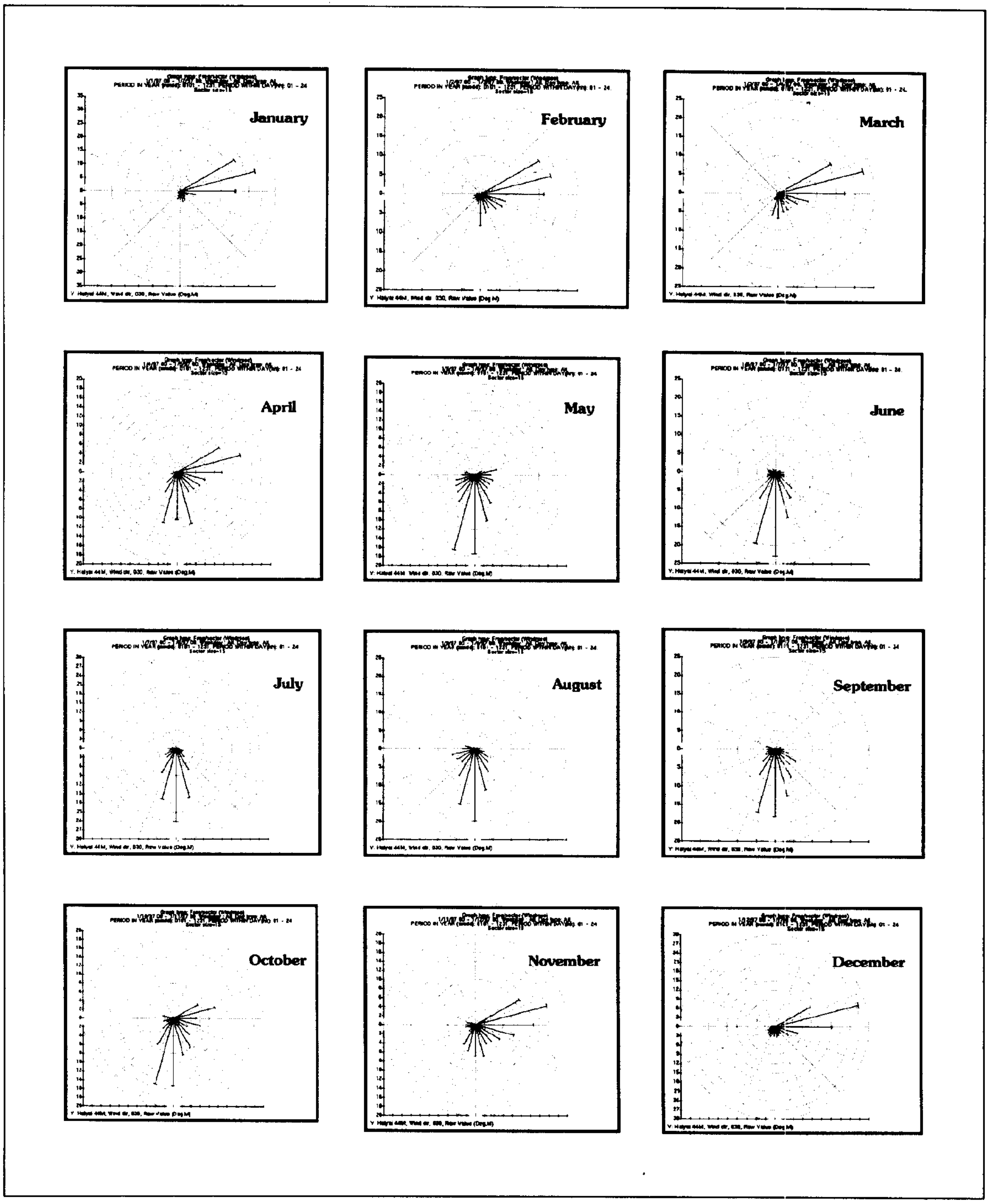


Figure 4-7. Wind rose analysis for PHUKET (10-meter level), 1997.

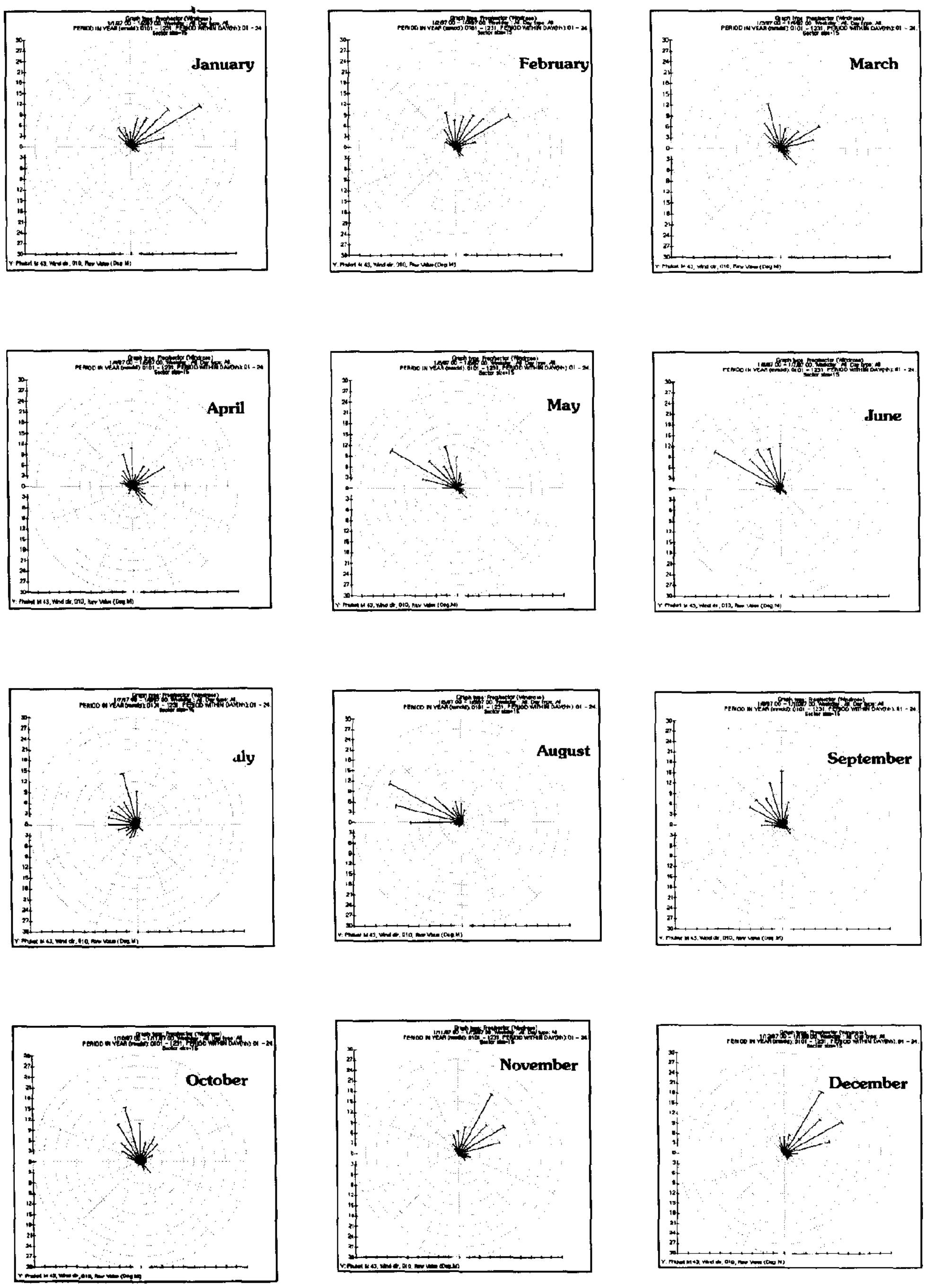


Figure 4-8. Wind speed at 10 m of SURAT THANI during Septemoer - October of 1996 and 1997.

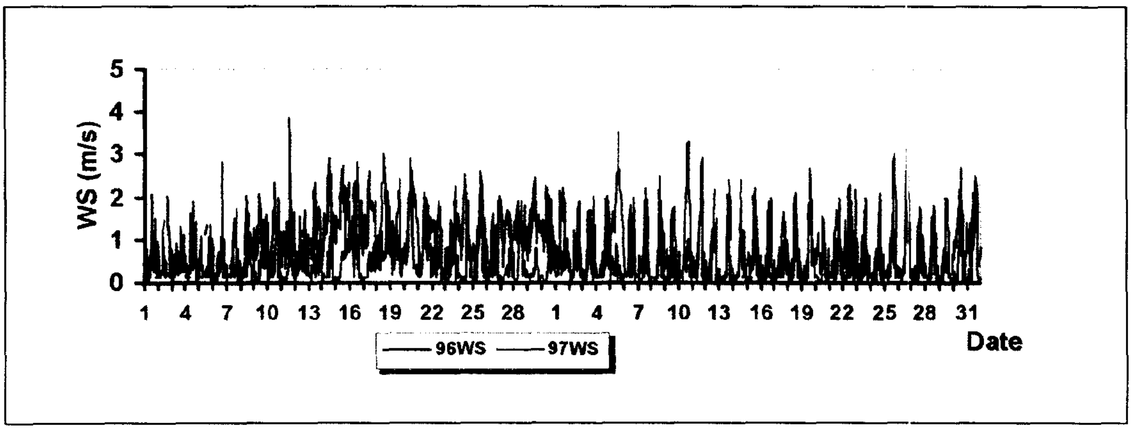


Figure 4-8a. Wind speed at 10 m of SURAT THANI during September 20 - 30 of 1996 and 1997.

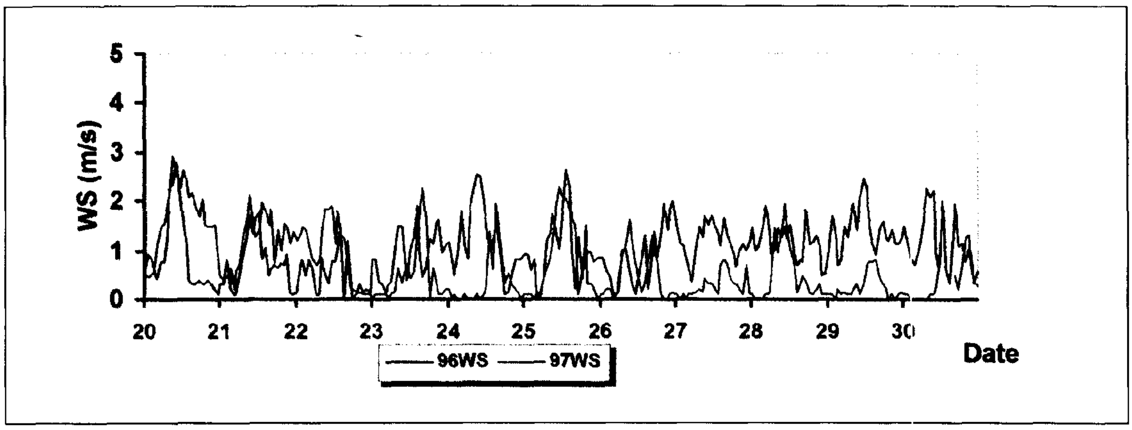


Figure 4-9. Wind speed at 10 m of PHUKET during September - October of 1996 and 1997.

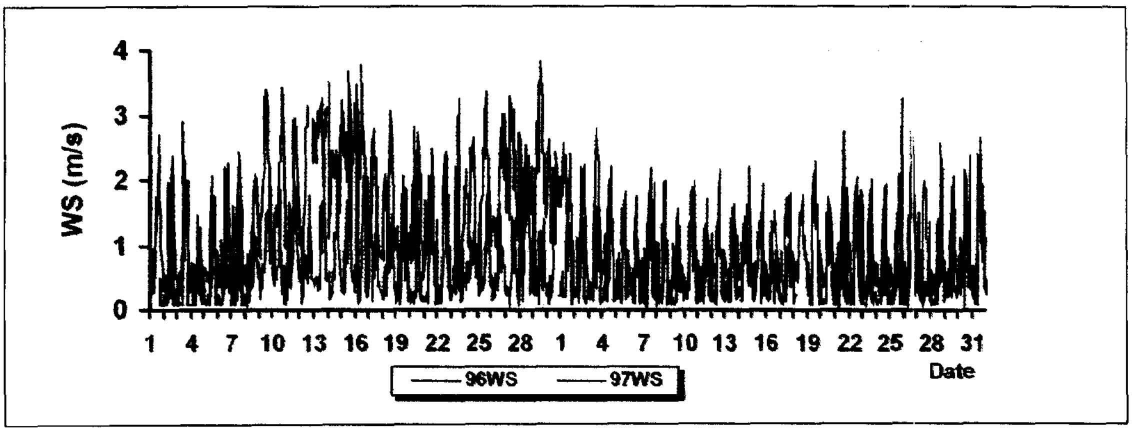


Figure 4-9a. Wind speed at 10 m of PHUKET during September 20 - 30 of 1996 and 1997.

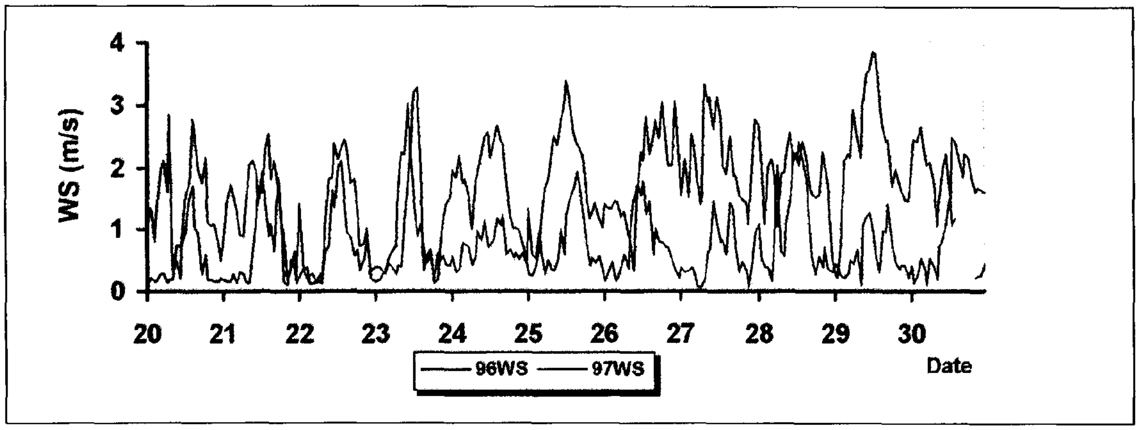


Figure 4-10. Wind speed at 30 m of HAT YAI during September - October of 1996 and 1997.

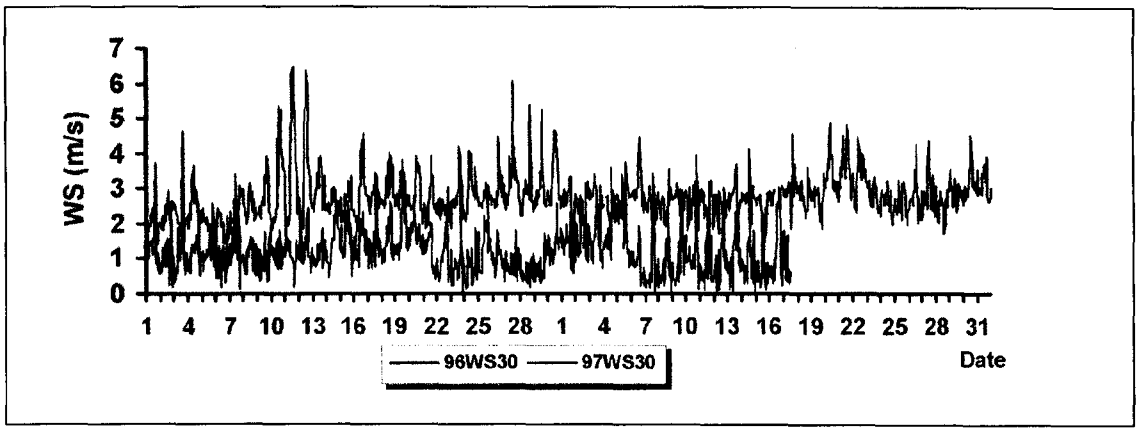


Figure 4-10a. Wind speed at 30 m of HAT YAI during September 20-30 of 1996 and 1997.

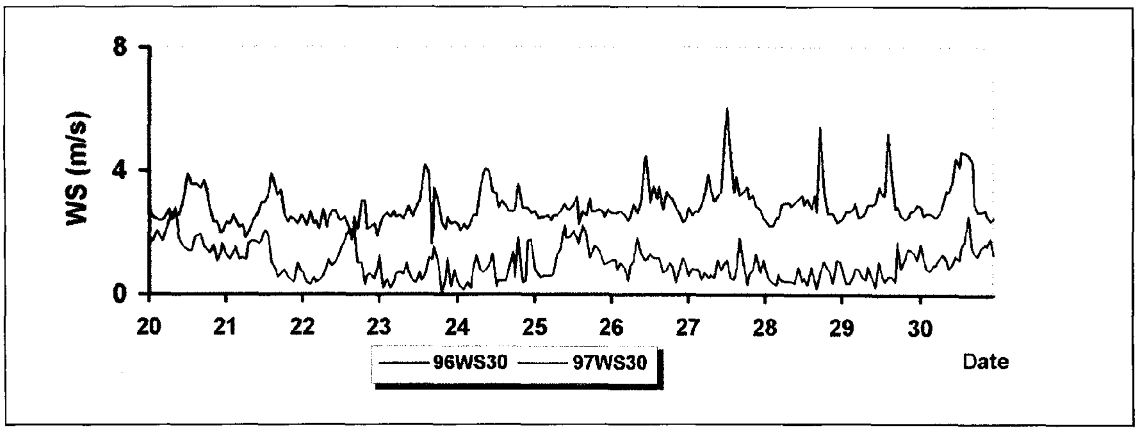


Figure 4-11. Atmospheric pressure of SURAT THANI during September - October of 1996 and 1997.

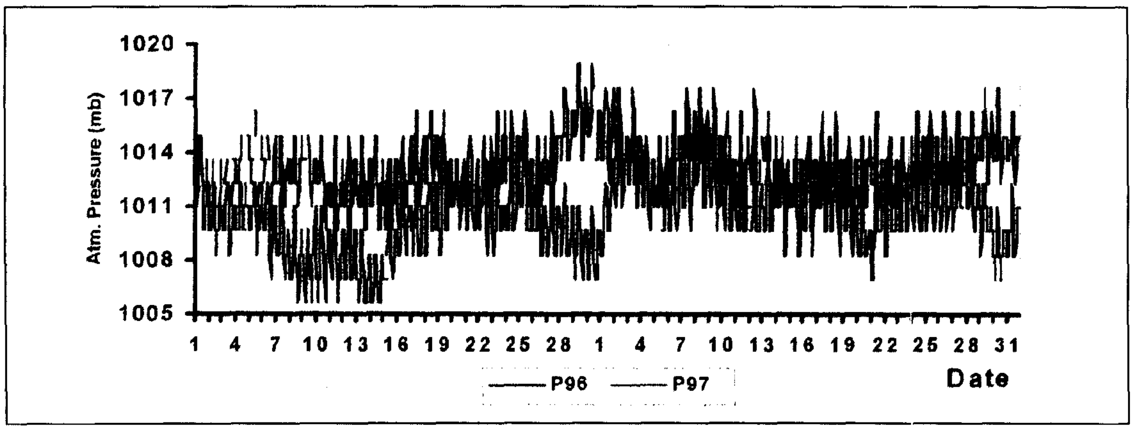


Figure 4-11a. Atmospheric pressure of SURAT THANI during September 20 - 30 of 1996 and 1997.

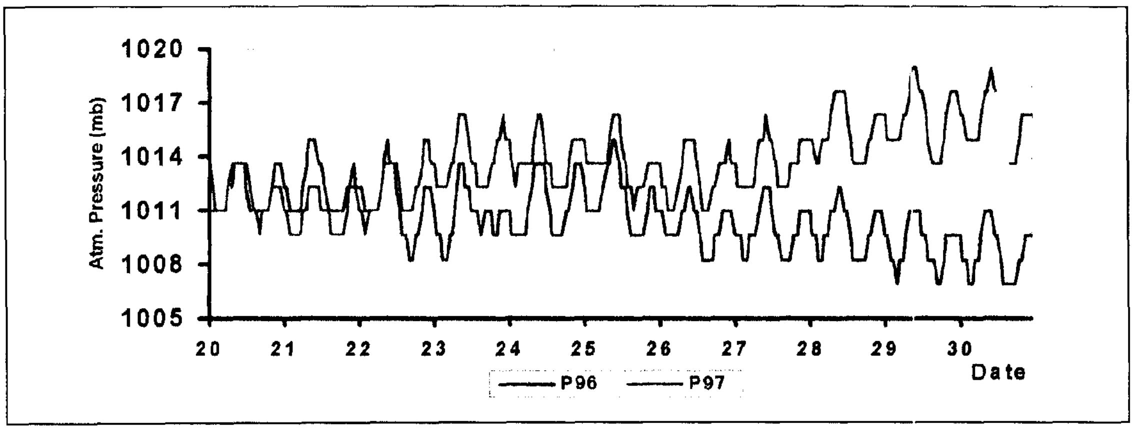


Figure 4-12. Atmospheric pressure (mb) of PHUKET during September - October of 1996 and 1997.

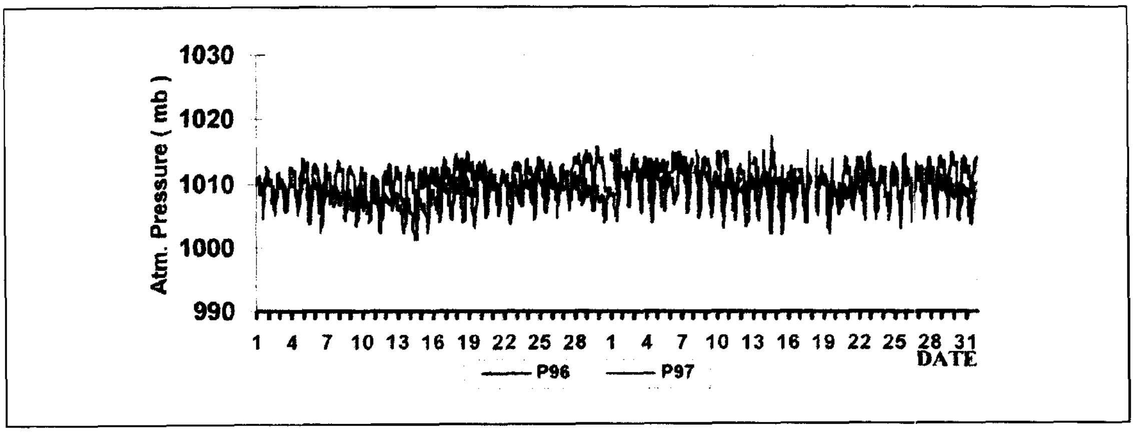


Figure 4-12a. Atmospheric pressure (mb) of PHUKET during September 20 - 30 of 1996 and 1997.

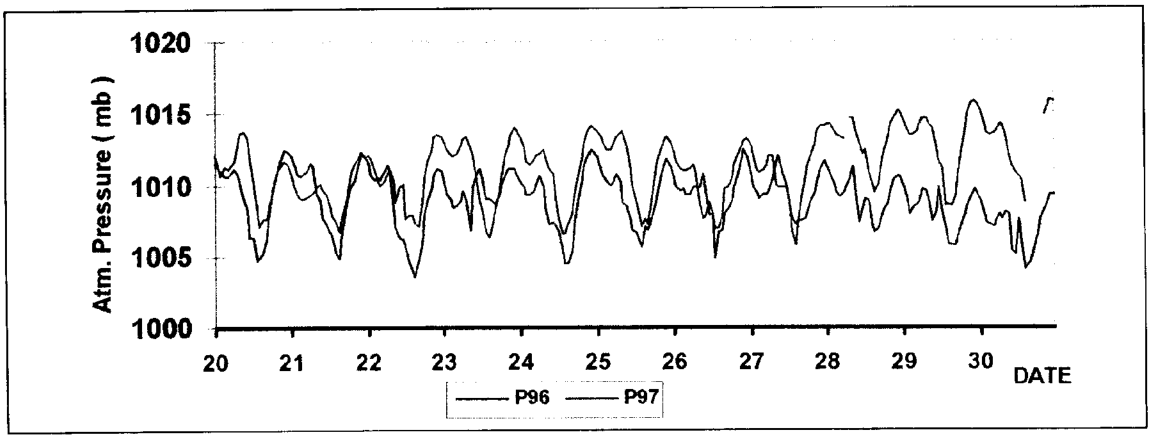


Figure 4-13. Relative humidity (%) at 2 m. of SURAT THANI during September - October of 1996 and 1997.

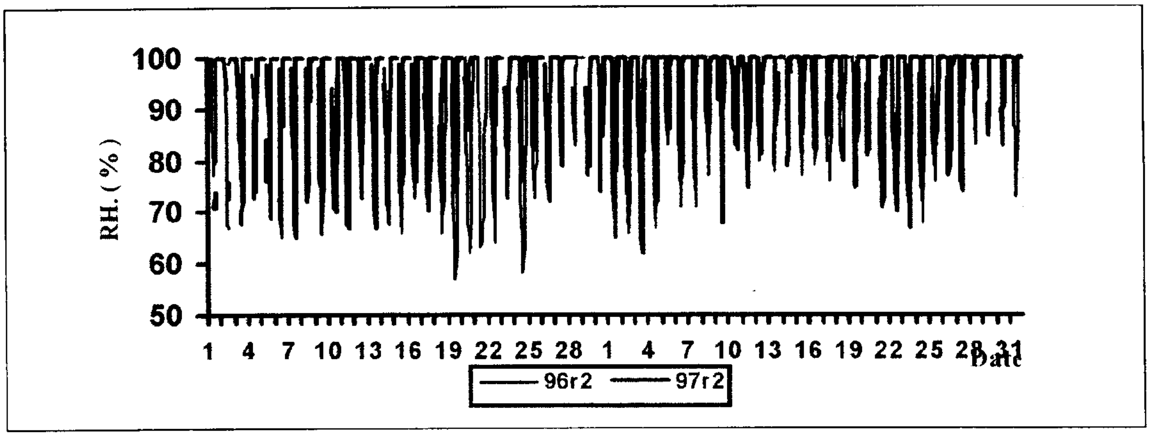


Figure 4-13a. Relative humidity (%) at 2 m. of SURAT THANI during September 20 - 30 of 1996 and 1997.

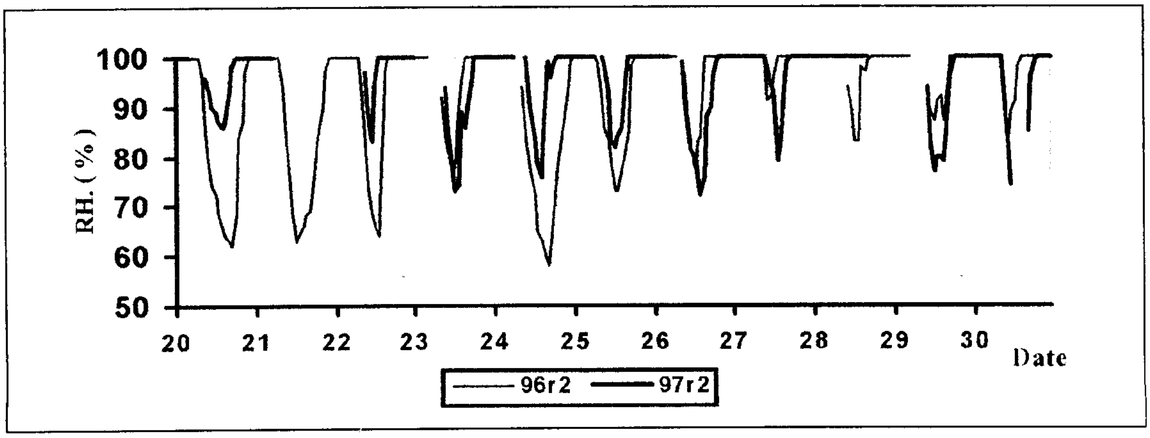


Figure 4-14. Relative humidity (%) at 2 m. of PHUKET during September - October of 1996 and 1997.

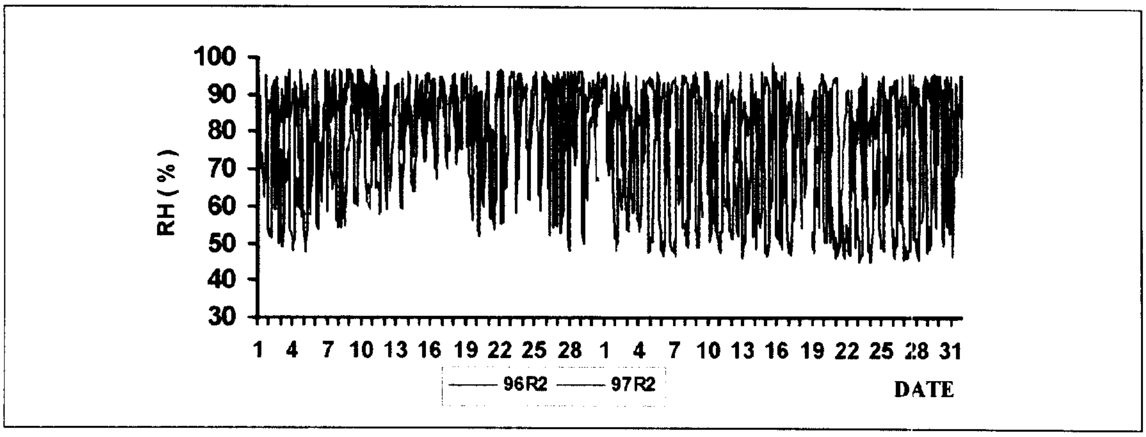


Figure 4-14a. Relative humidity (%) at 2 m. of PHUKET during September 20 - 30 of 1996 and 1997.

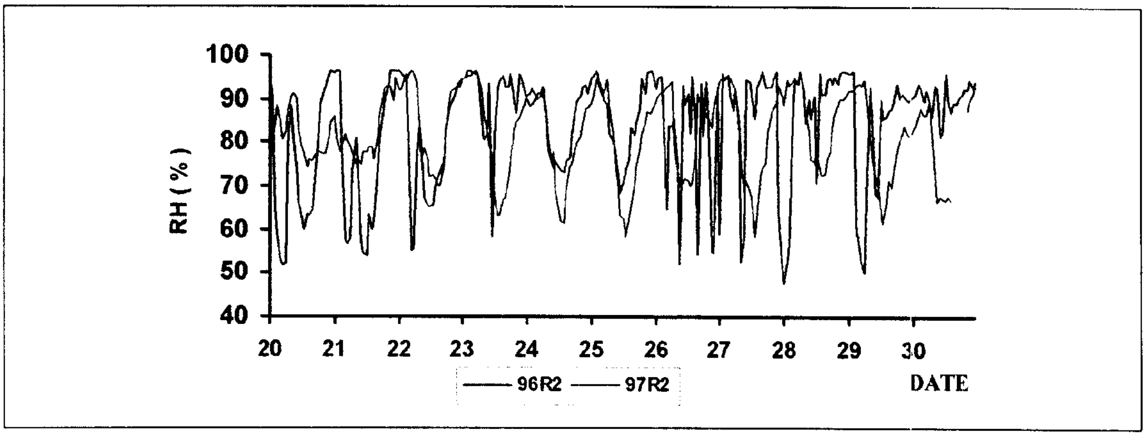


Figure 4-15. Relative humidity (%) at 2 m. of HAT YAI during September - October of 1996 and 1997.

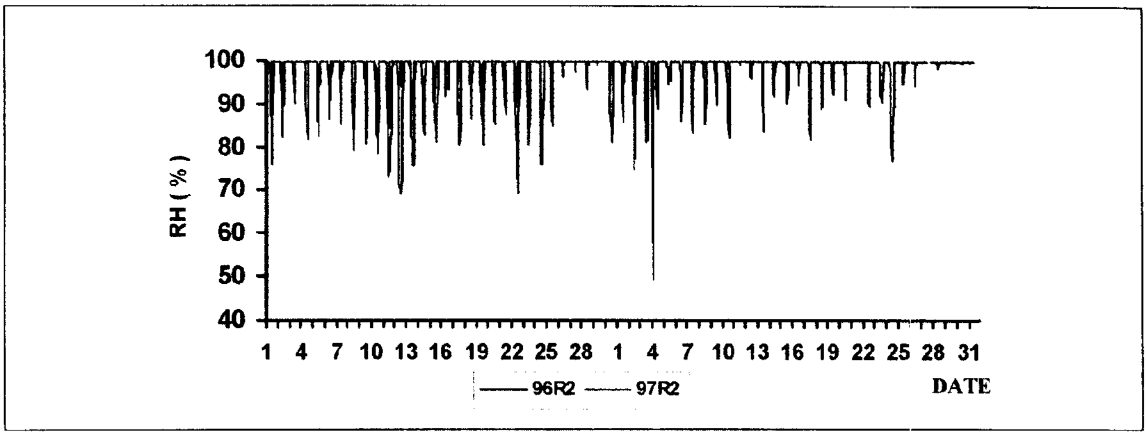


Figure 4-15a. Relative humidity (%) at 2 m. of HAT YAI during September 20 - 30 of 1996 and 1997.

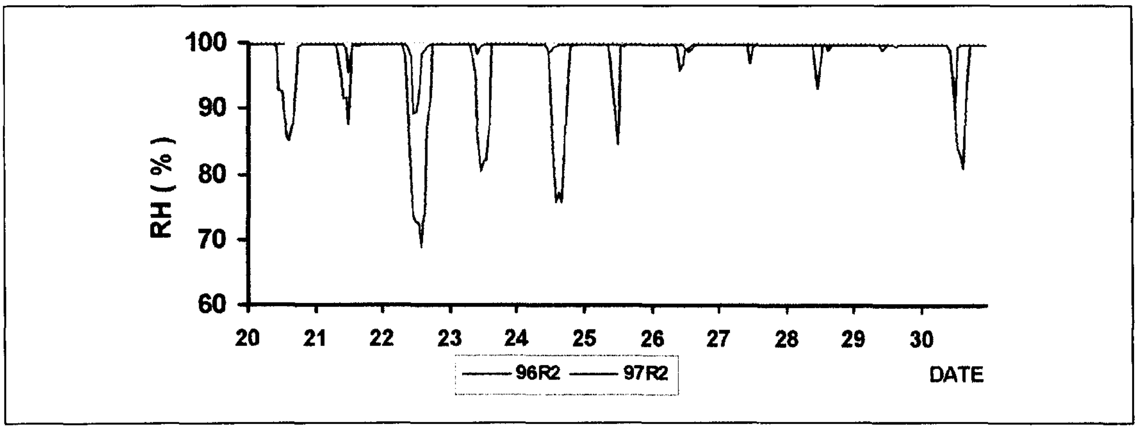


Figure 4-16. 24 hour average PM10 of SURAT THANI, PHUKET and HAT YAI during September - October of 1997.

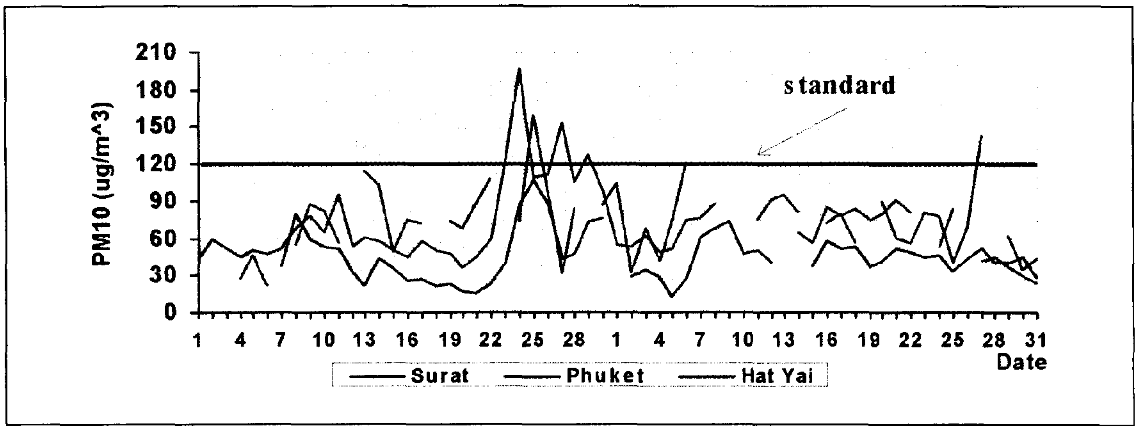


Figure 4-17. Hourly average SO_2 of SURAT THANI, PHUKET and HAT YAI during September - October of 1997.

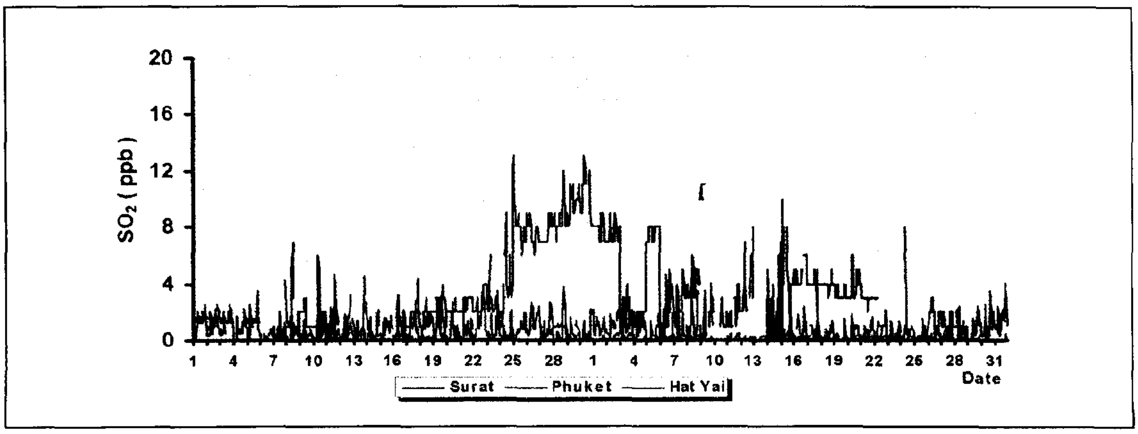


Figure 4-17a. Hourly average SO_2 of SURAT THANI, PHUKET and HAT YAI during September 20 - 30, 1997.

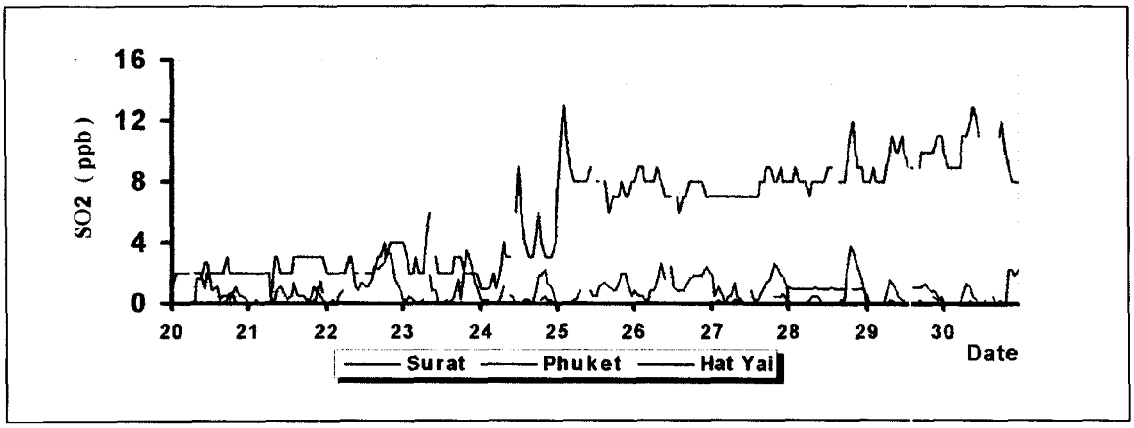


Figure 4-18. Hourly average NO_2 of SURAT THANI, PHUKET and HAT YAI during September - October of 1997.

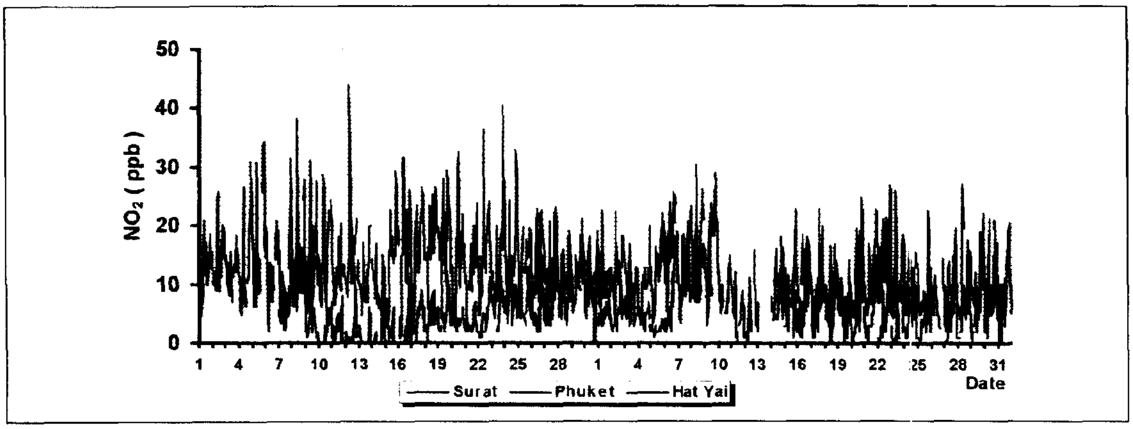


Figure 4-18a. Hourly average NO_2 of SURAT THANI, PHUKET and HAT YAI during September 20 - 30, 1970.

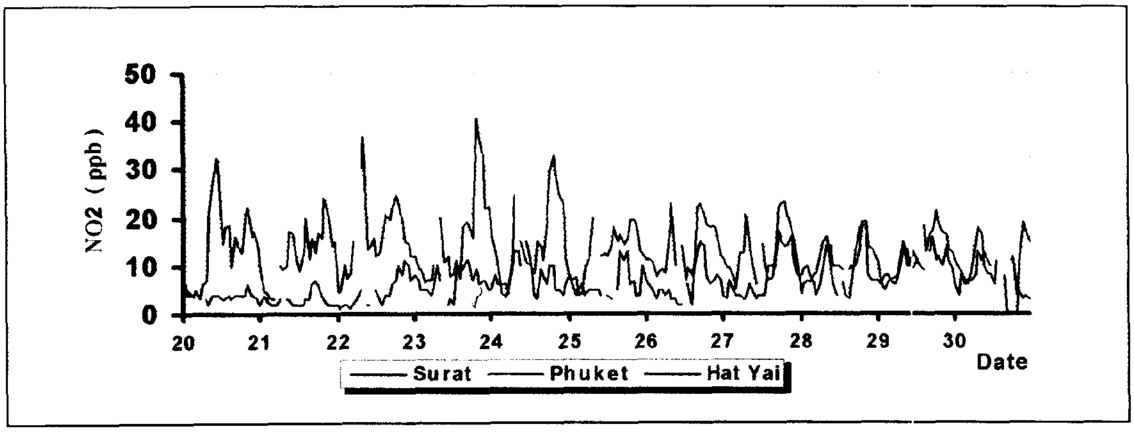


Figure 4-19. Hourly average CO of SURAT THANI, PHUKET and HAT YAI during September - October of 1997.

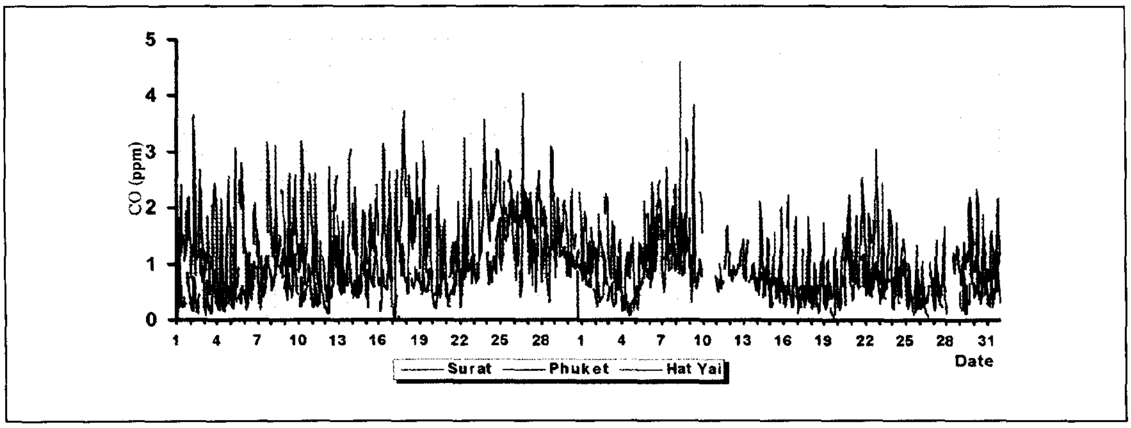


Figure 4-19a. Hourly average CO of SURAT THANI, PHUKET and HAT YAI during September 20 - 30, 1997.

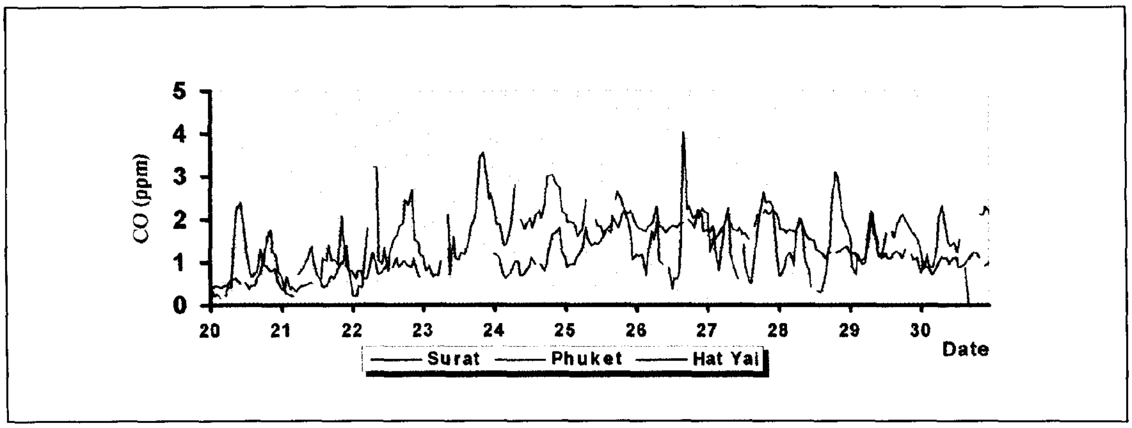


Figure 4-20. Hourly average O_3 of SURAT THANI, PHUKET and HAT YAI during September - October of 1997.

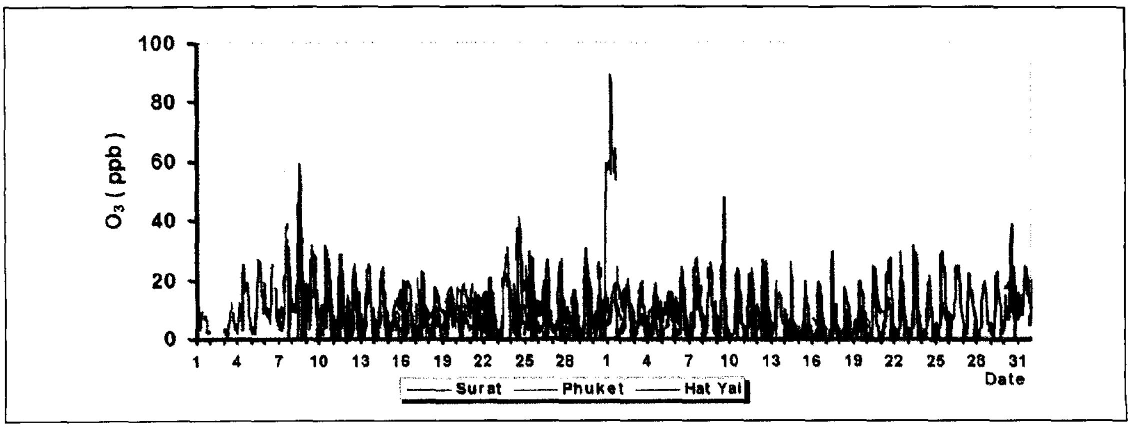


Figure 4-20a. Hourly average O_3 of SURAT THANI, PHUKET and HAT YAI during September 20 - 30, 1997.

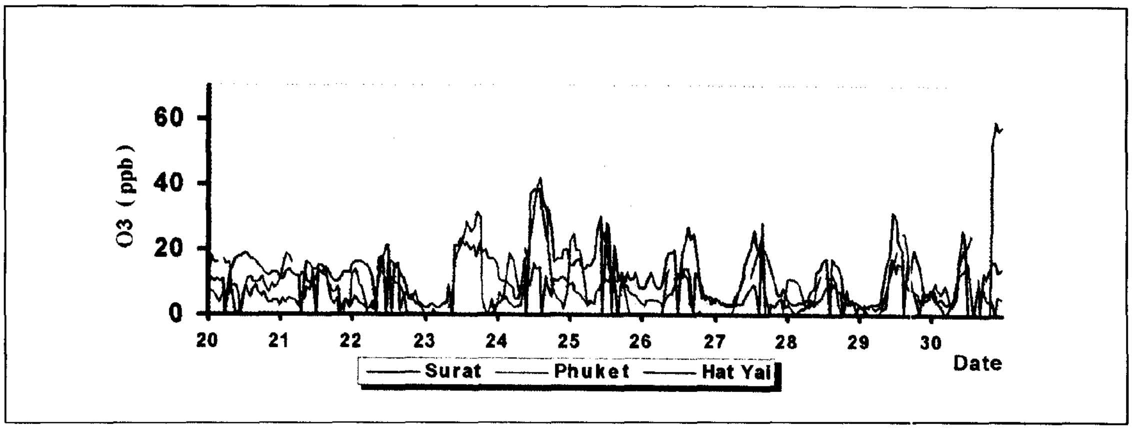


Figure 4-21. Hourly average CH_4 of SURAT THANI, PHUKET and HAT YAI during September - October of 1997.

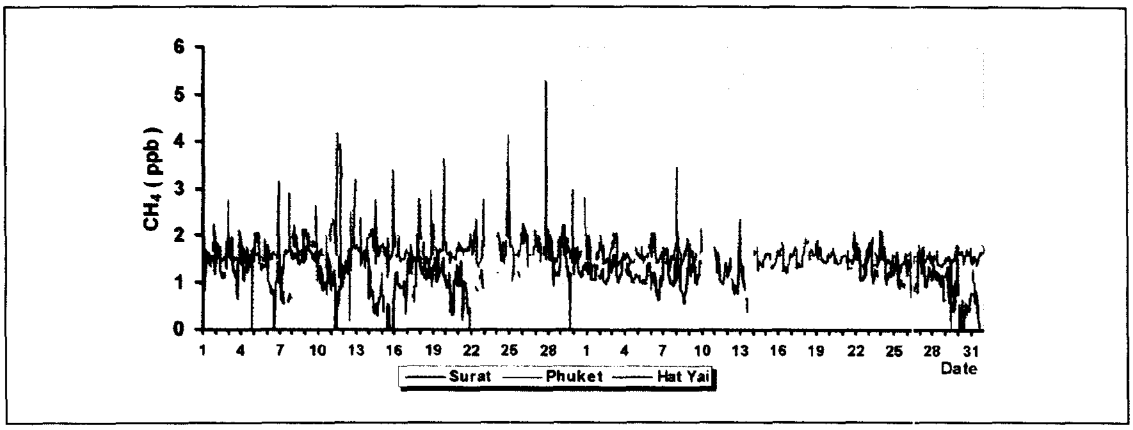


Figure 4-21a. Hourly average CH_4 of SURAT THANI, PHUKET and HAT YAI during September 20 - 30, 1997.

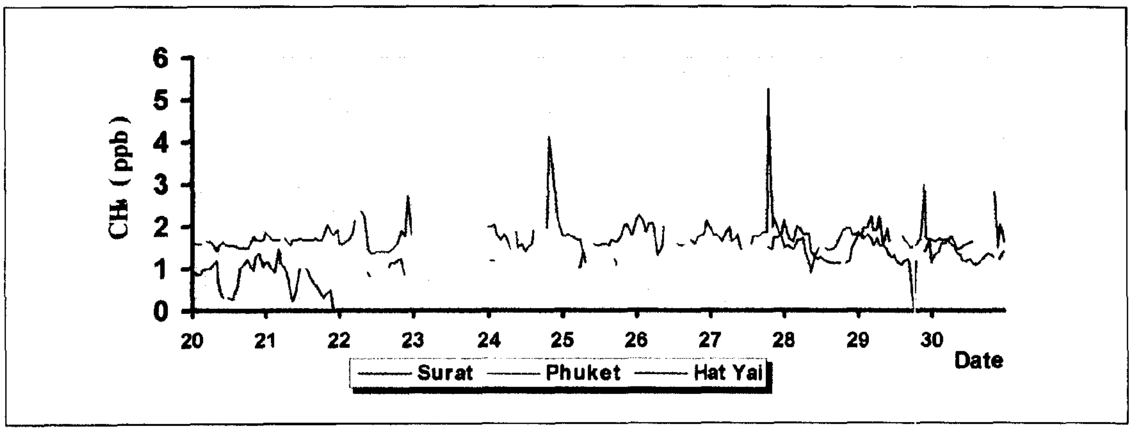


Figure 4-22. ***24 hour average PM10 of SURAT THANI during September - October of 1996 and 1997.***

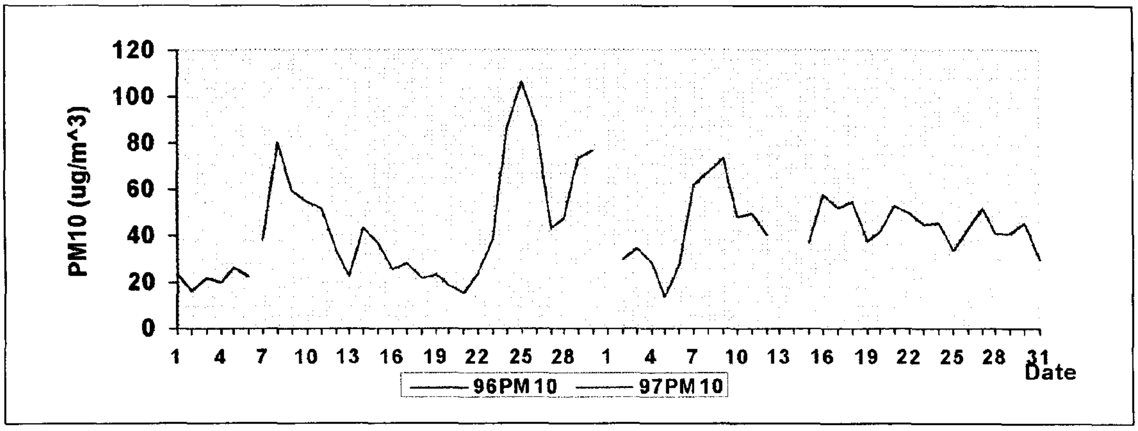


Figure 4-23. ***Hourly average SO_2 of SURAT THANI during September - October of 1996 and 1997.***

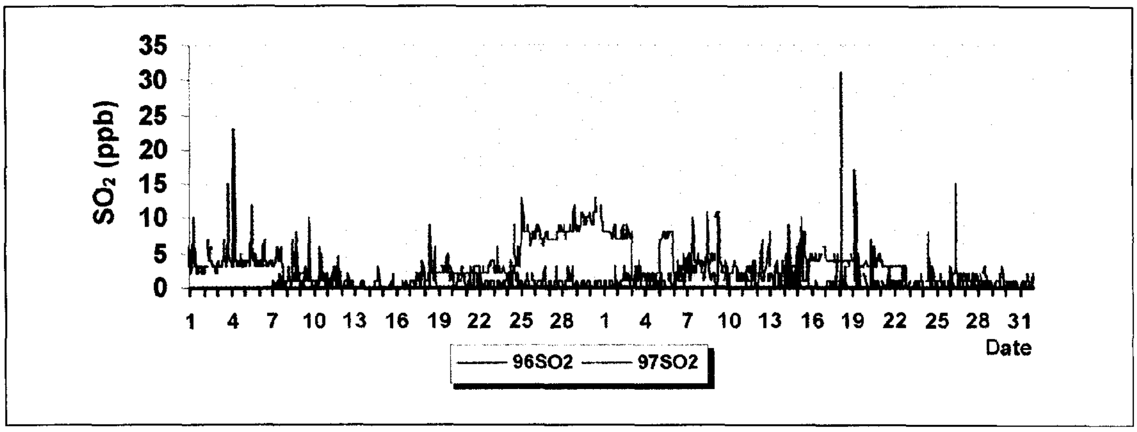


Figure 4-23a. ***Hourly average SO_2 of SURAT THANI during September 20 - 30 of 1996 and 1997.***

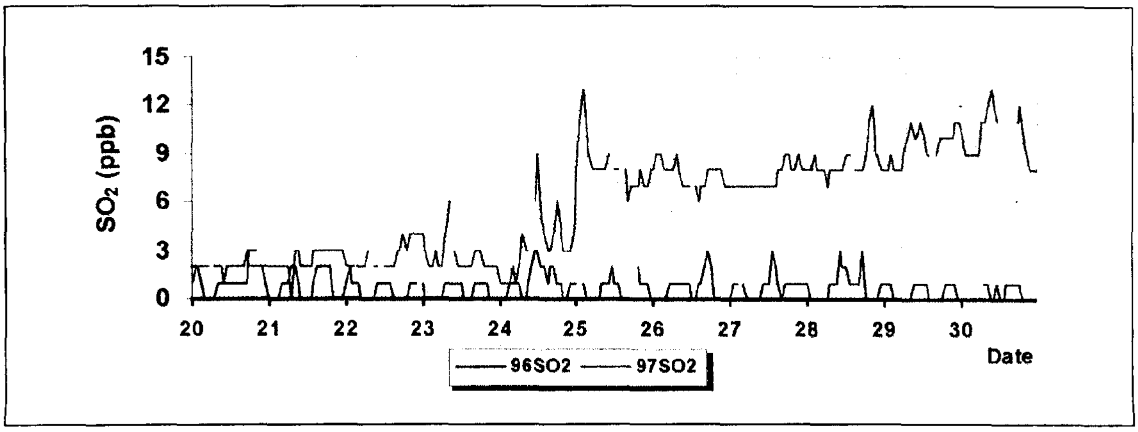


Figure 4-24. Hourly average NO_2 of SURAT THANI during September - October of 1996 and 1997.

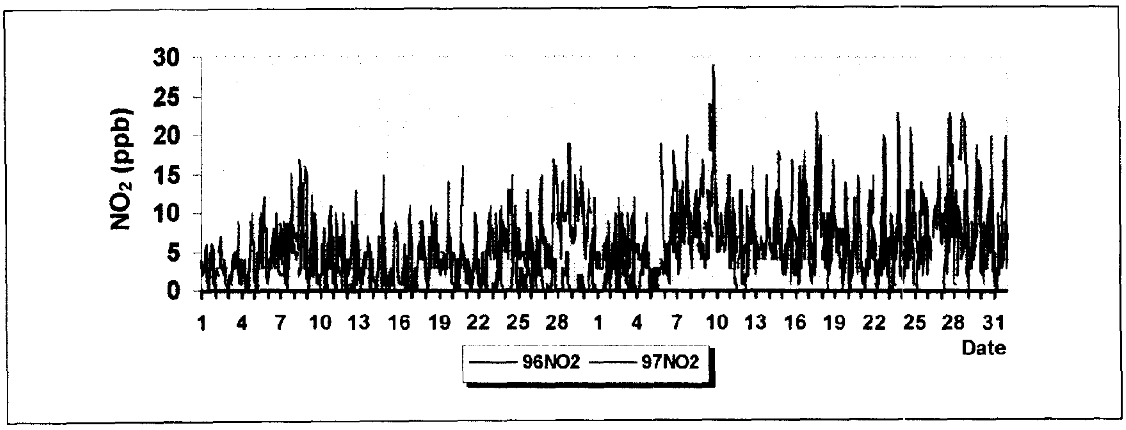


Figure 4-24a. Hourly average NO_2 of SURAT THANI during September 20 - 30 of 1996 and 1997.

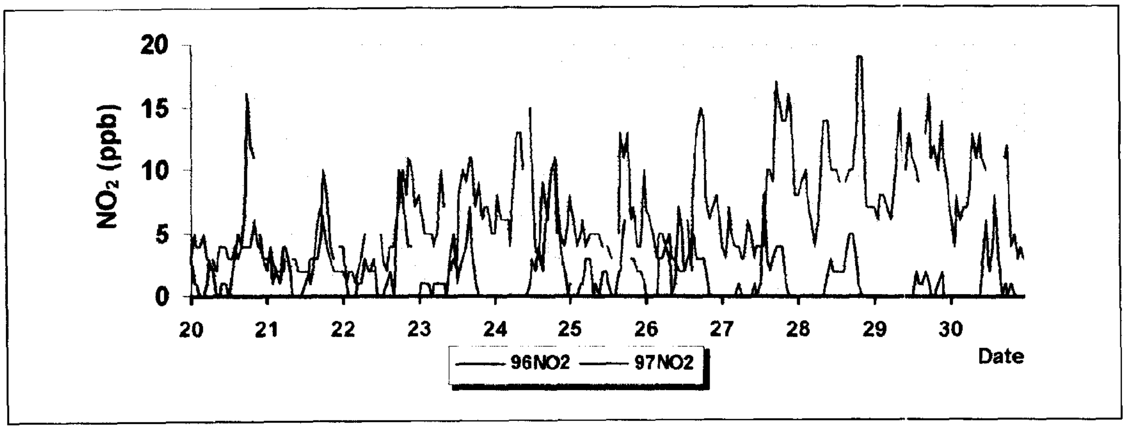


Figure 4-25. Hourly average CO of SURAT THANI during September - October of 1996 and 1997.

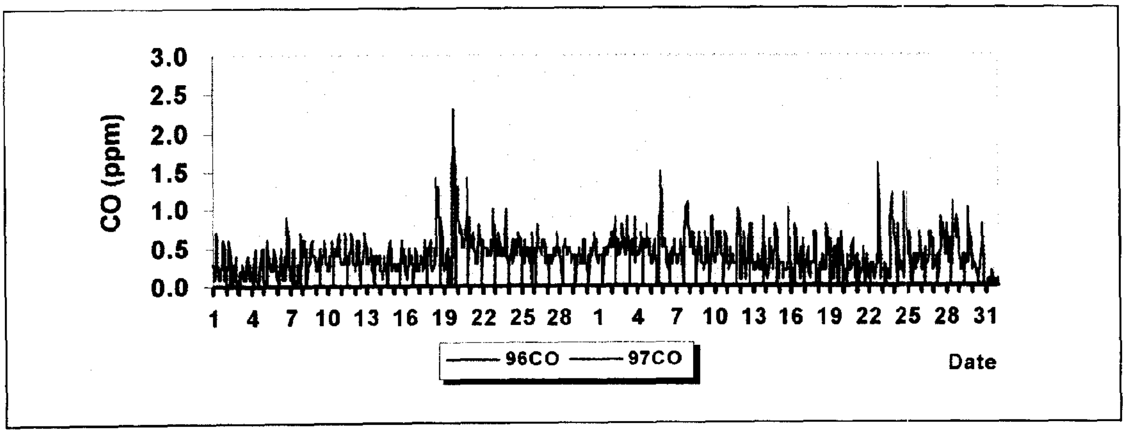


Figure 4-25a. Hourly average CO of SURAT THANI during September 20 - 30 of 1996 and 1997.

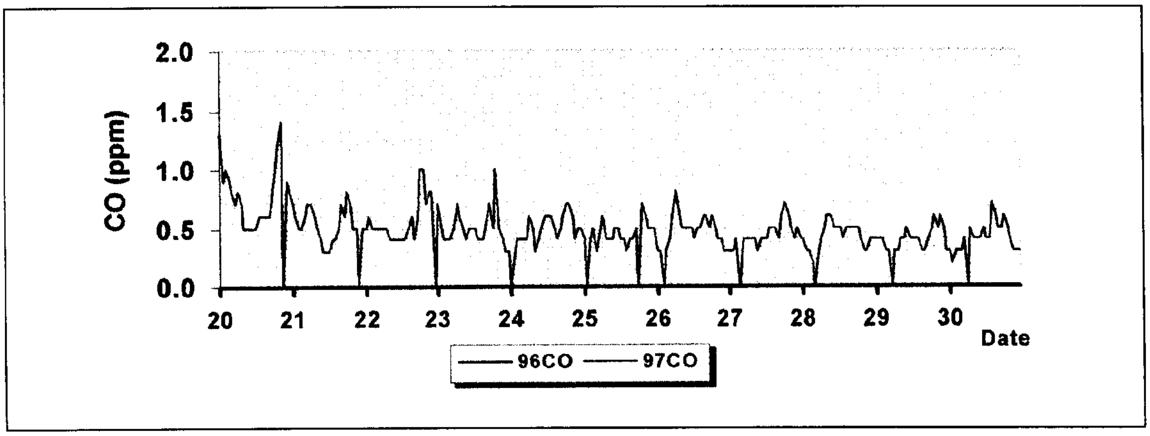


Figure 4-26. Hourly average O_3 of SURAT THANI during September - October of 1996 and 1997.

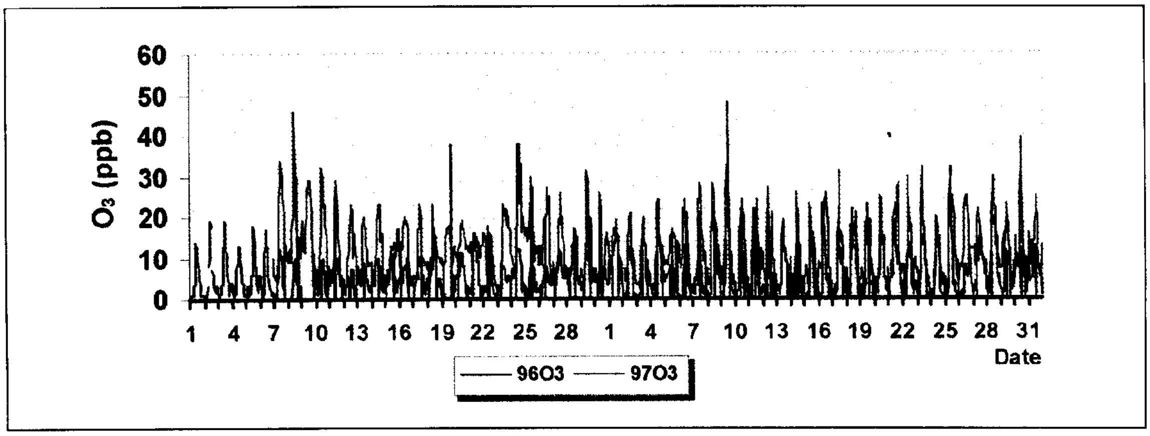


Figure 4-26a. Hourly average O_3 of SURAT THANI during September 20 - 30 of 1996 and 1997.

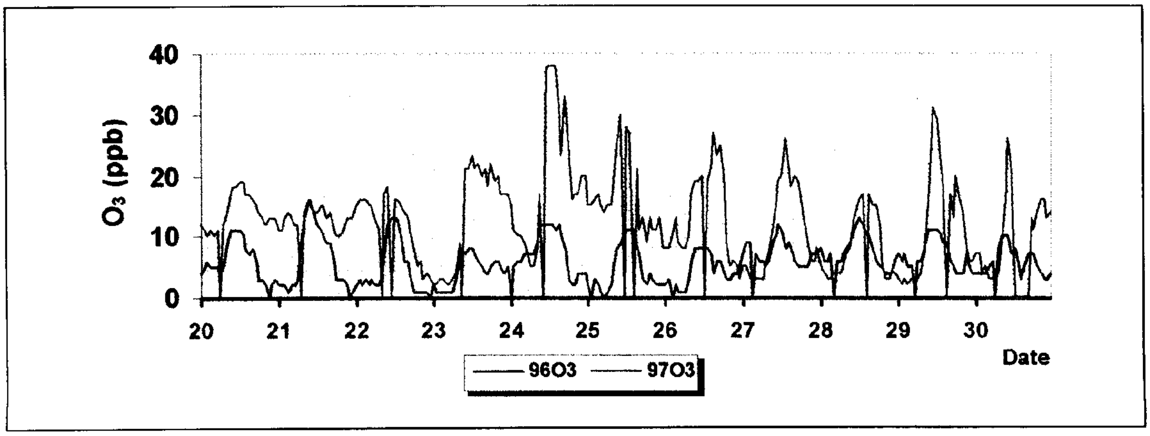


Figure 4-27. Hourly average CH4 of SURAT THANI during September - October of 1996 and 1997.

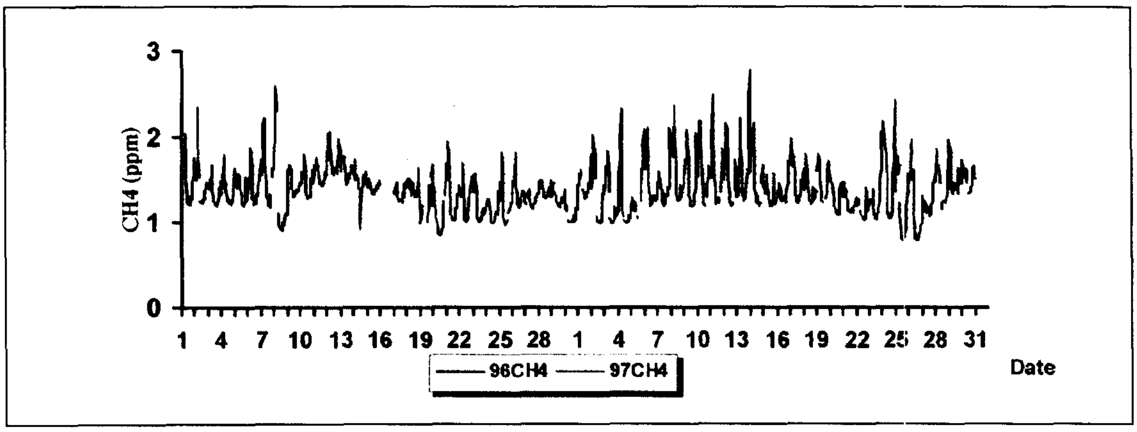


Figure 4-28. 24 hour average PM10 of PHUKET during September - October of 1996 and 1997.

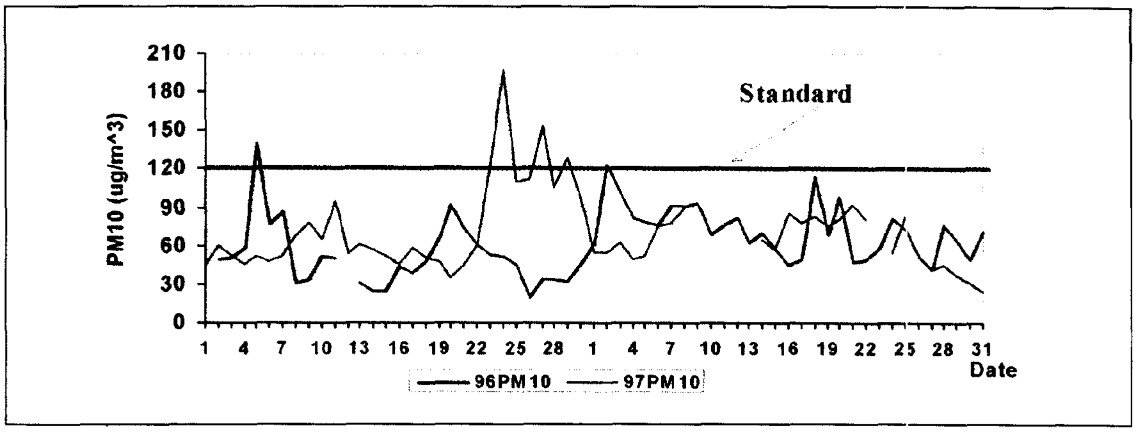


Figure 4-29. Hourly average SO_2 of PHUKET during September - October of 1996 and 1997.

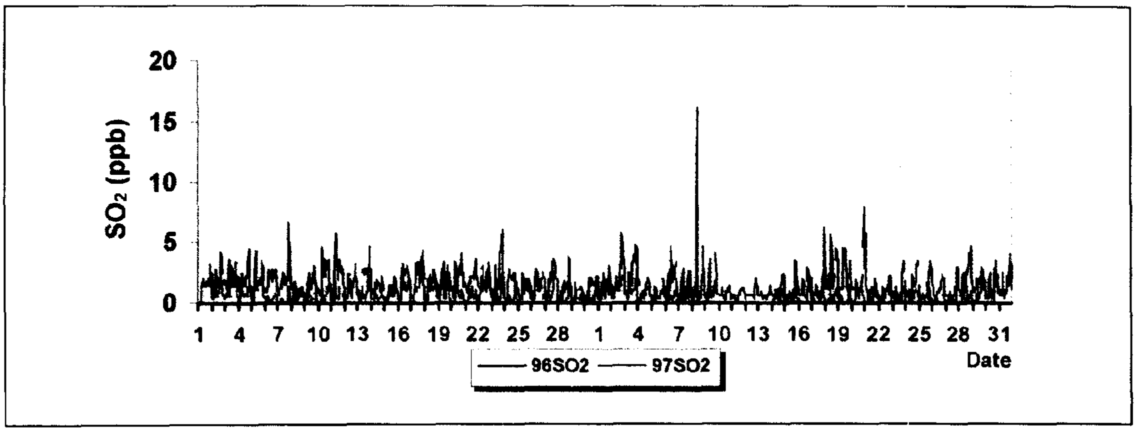


Figure 4-29a. Hourly average SO_2 of PHUKET during September 20 - 30 of 1996 and 1997.

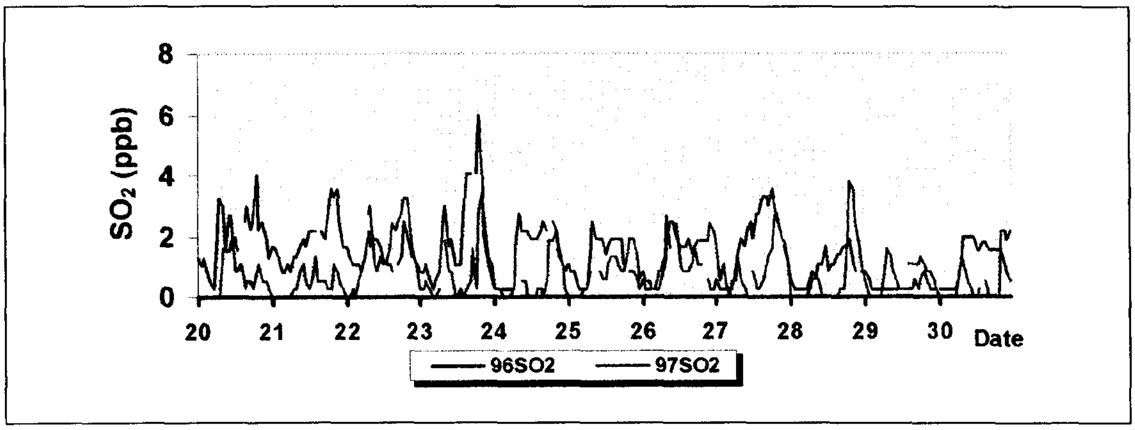


Figure 4-30. Hourly average NO_2 of PHUKET during September - October of 1996 and 1997.

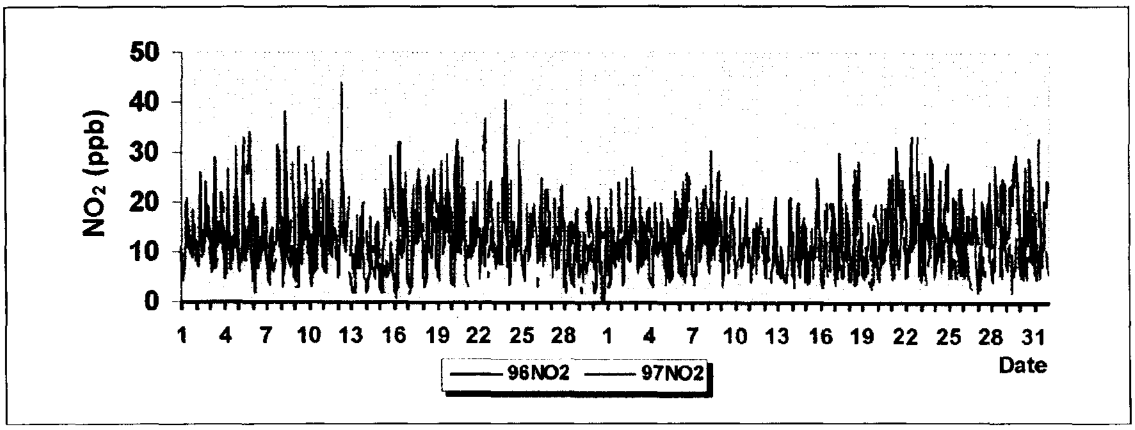


Figure 4-30a. Hourly average NO_2 of PHUKET during September 20 - 30 of 1996 and 1997.

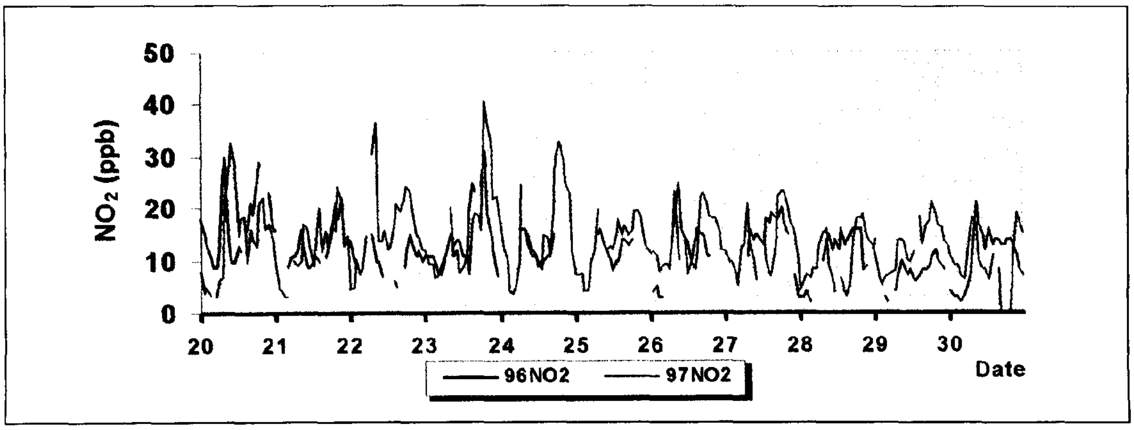


Figure 4-31. Hourly average CO of PHUKET during September - October of 1996 and 1997.

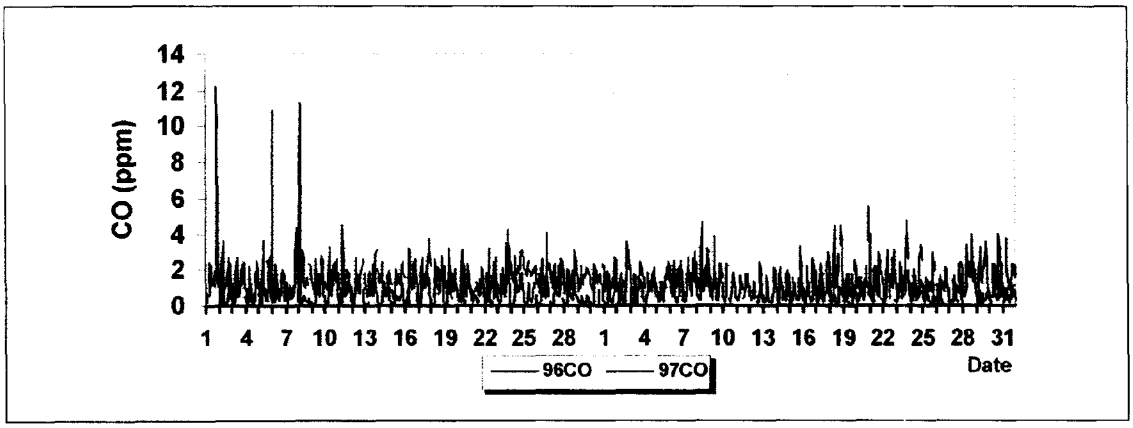


Figure 4-31a. Hourly average CO of PHUKET during September 20 - 30 of 1996 and 1997.

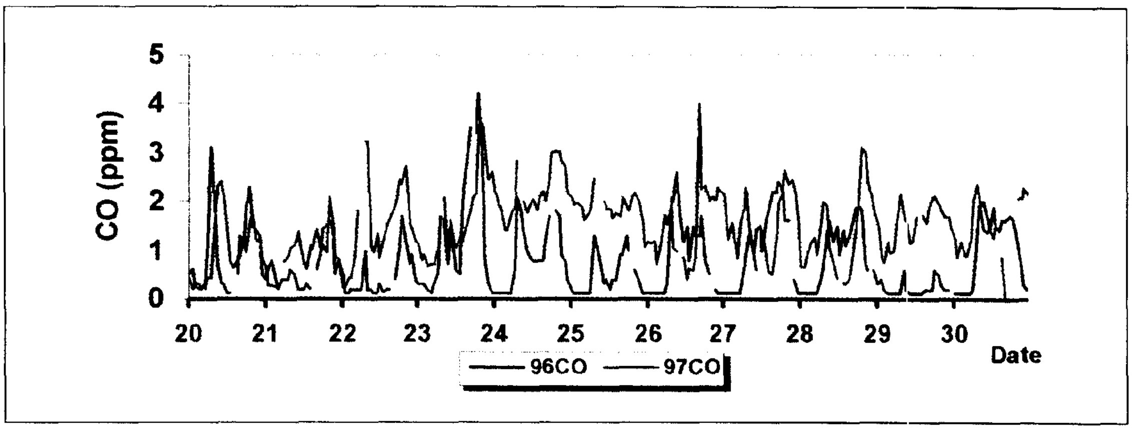


Figure 4-32. Hourly average O_3 of PHUKET during September - October of 1996 and 1997.

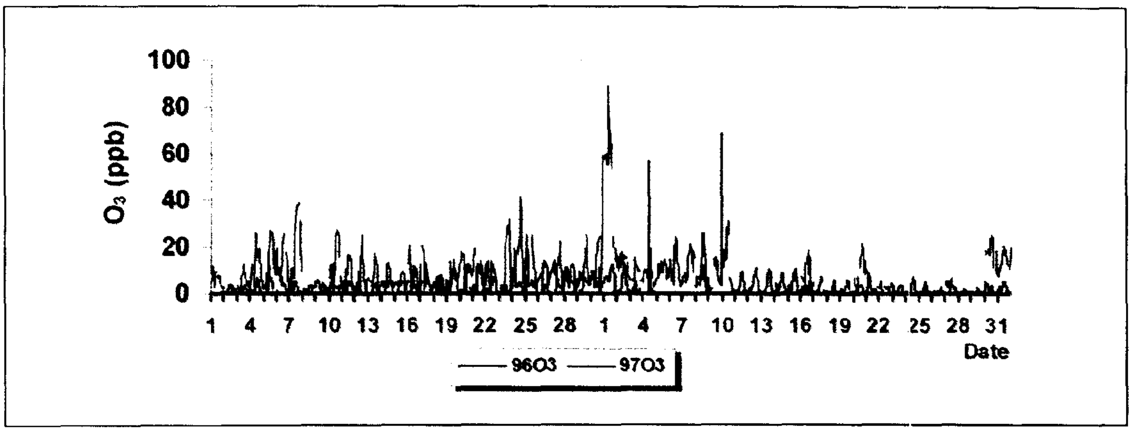


Figure 4-32a. Hourly average O_3 of PHUKET during September 20 - 30 of 1996 and 1997.

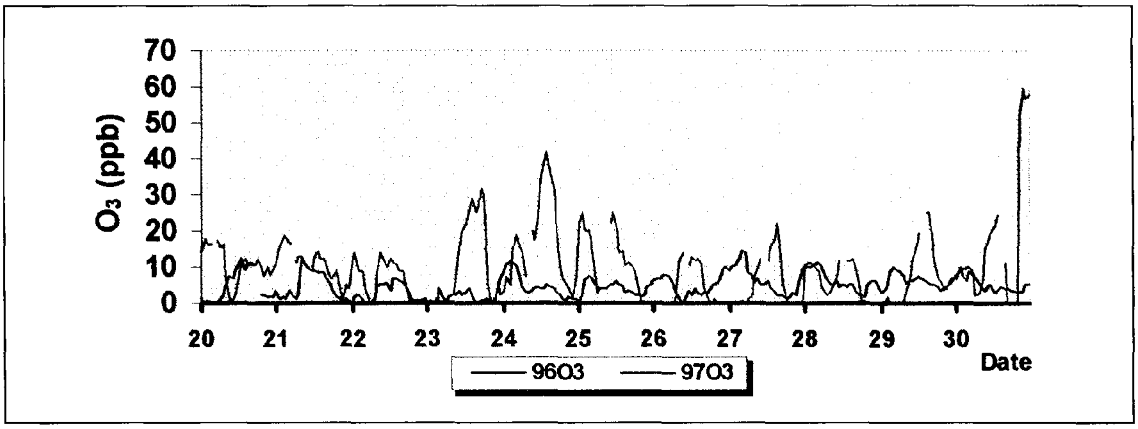


Figure 4-33. Hourly average CH4 of PHUKET during September - October of 1996 and 1997.

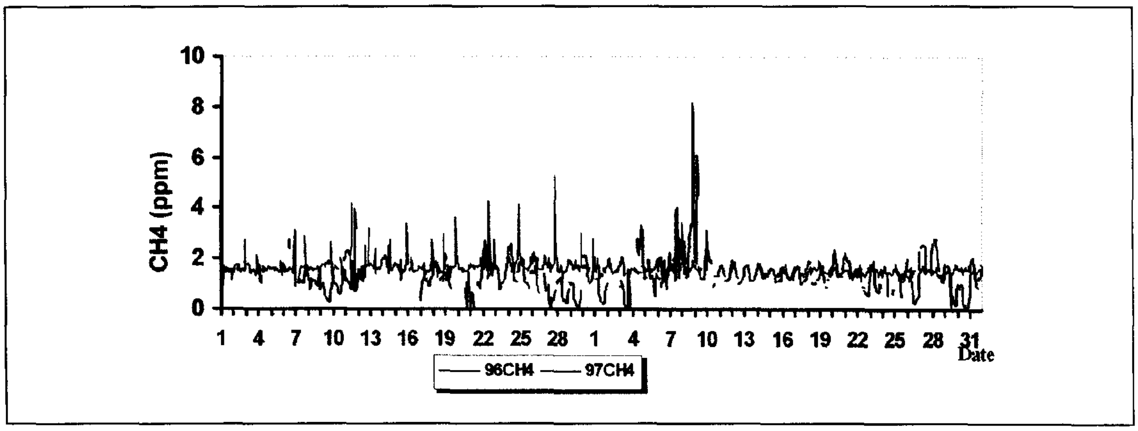


Figure 4-33a. Hourly average CH4 of PHUKET during September 20 - 30 of 1996 and 1997.

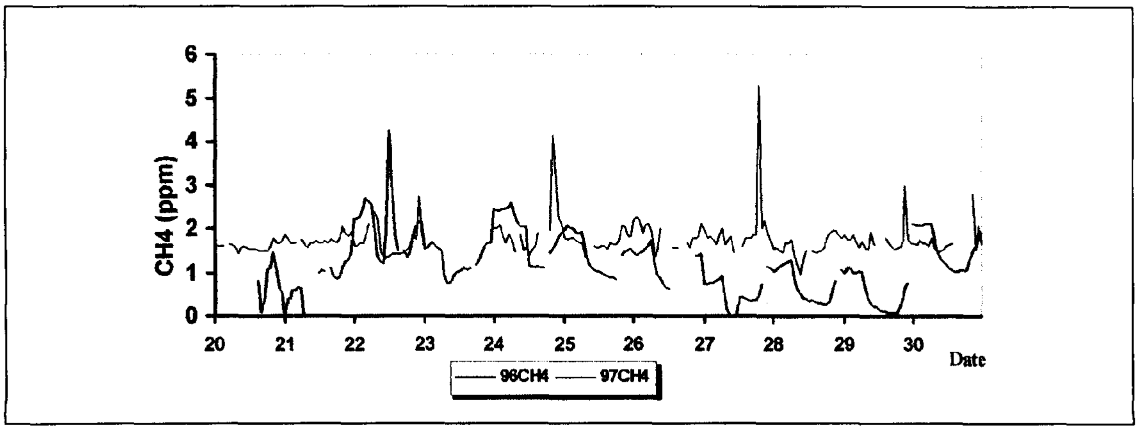


Figure 4-34. 24 hour average PM10 of HAT YAI during September - October of 1996 and 1997.

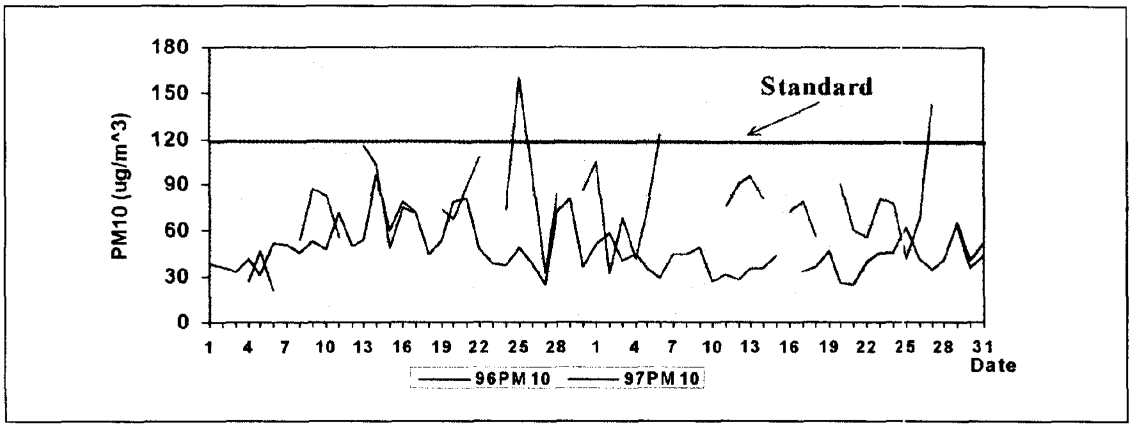


Figure 4-35. Hourly average SO_2 of HAT YAI during September - October of 1996 and 1997.

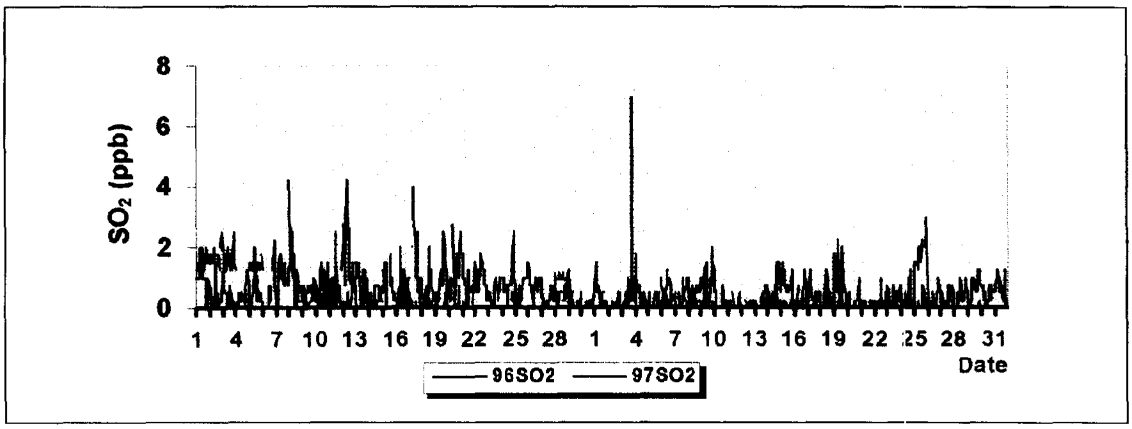


Figure 4-35a. Hourly average SO_2 of HAT YAI during September 20 - 30 of 1996 and 1997.

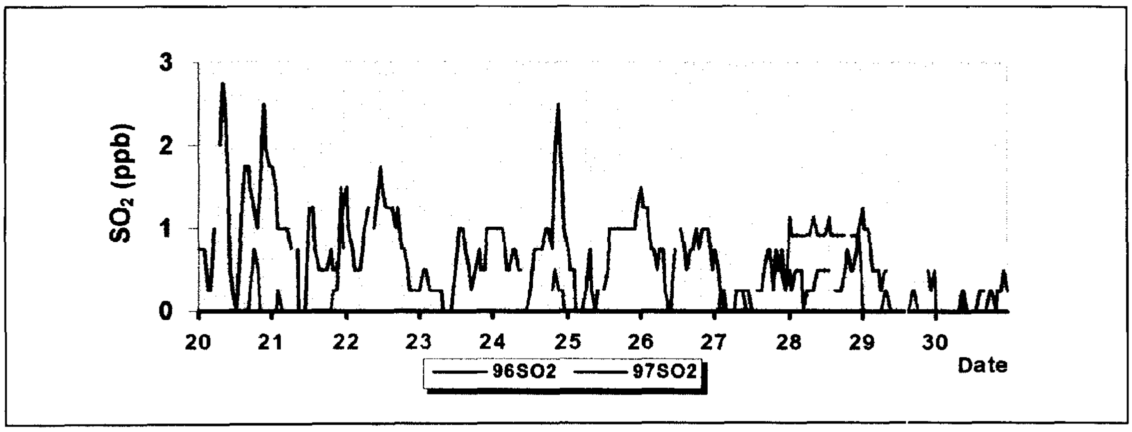


Figure 4-36. Hourly average NO_2 of HAT YAI during September - October of 1996 and 1997.

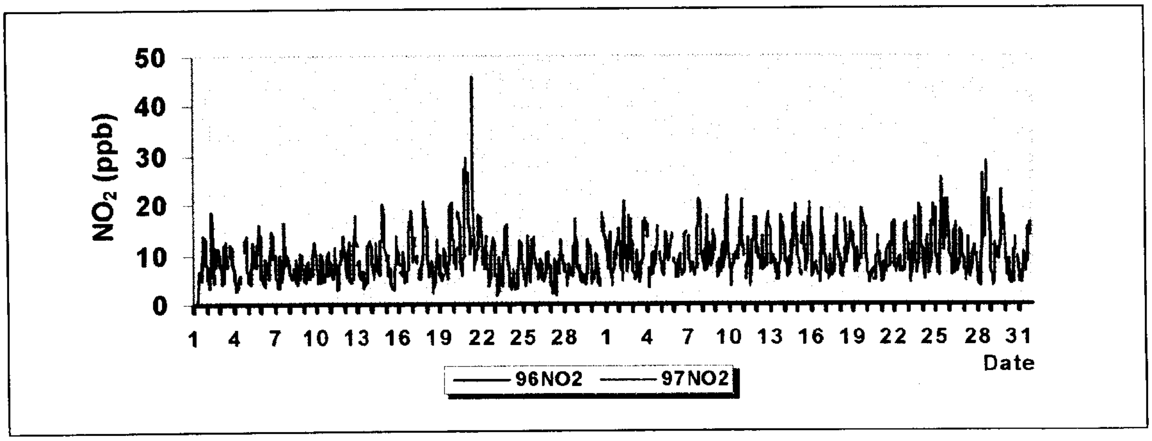


Figure 4-36a. Hourly average NO_2 of HAT YAI during September 20 - 30 of 1996 and 1997.

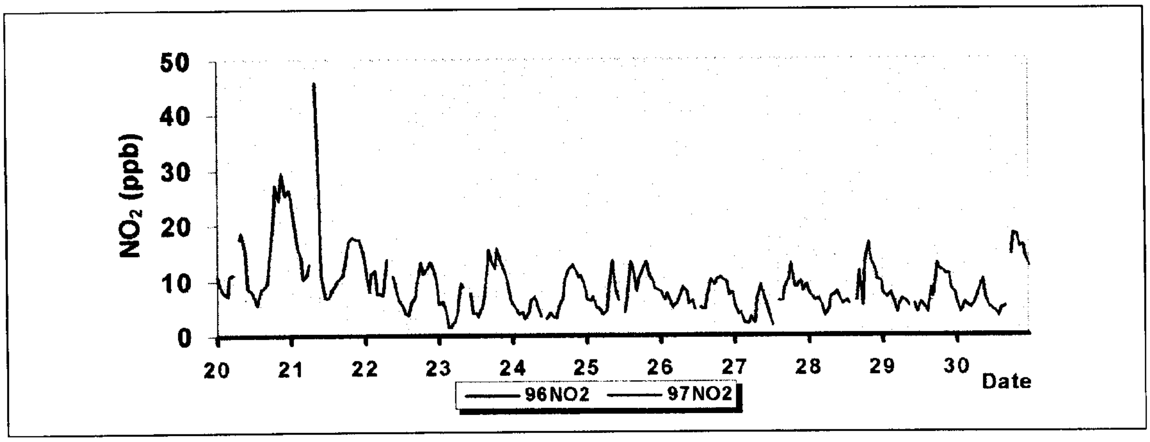


Figure 4-37. Hourly average CO of HAT YAI during September - October of 1996 and 1997.

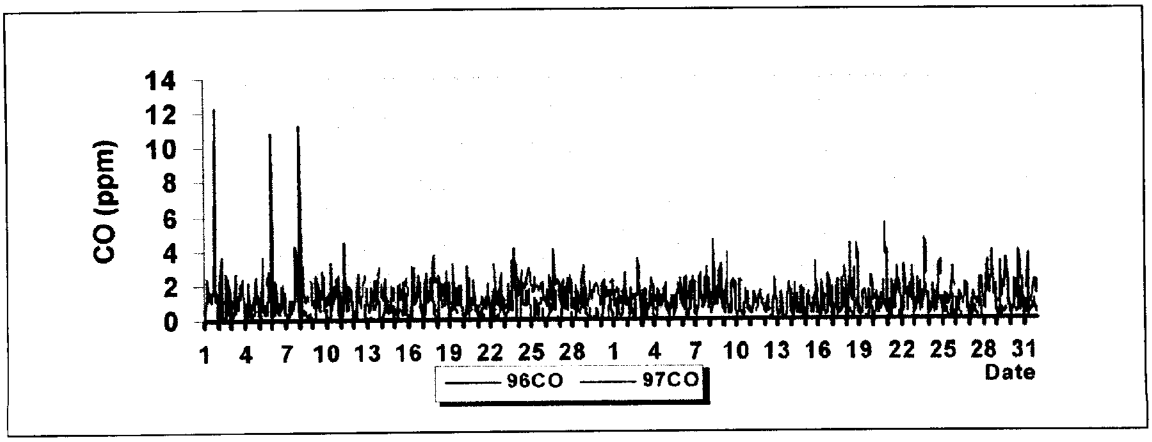


Figure 4-37a. Hourly average CO of HAT YAI during September 20 - 30 of 1996 and 1997.

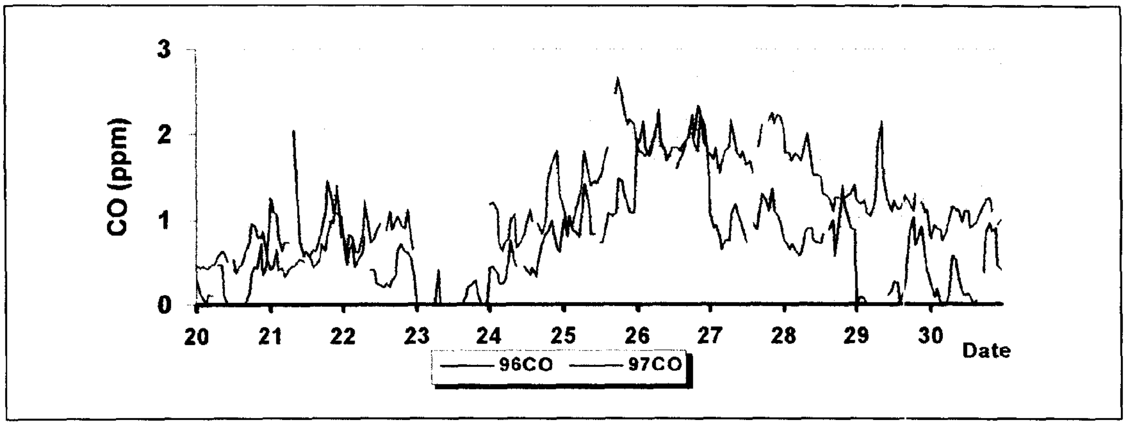


Figure 4-38. Hourly average O_3 of HAT YAI during September - October of 1996 and 1997.

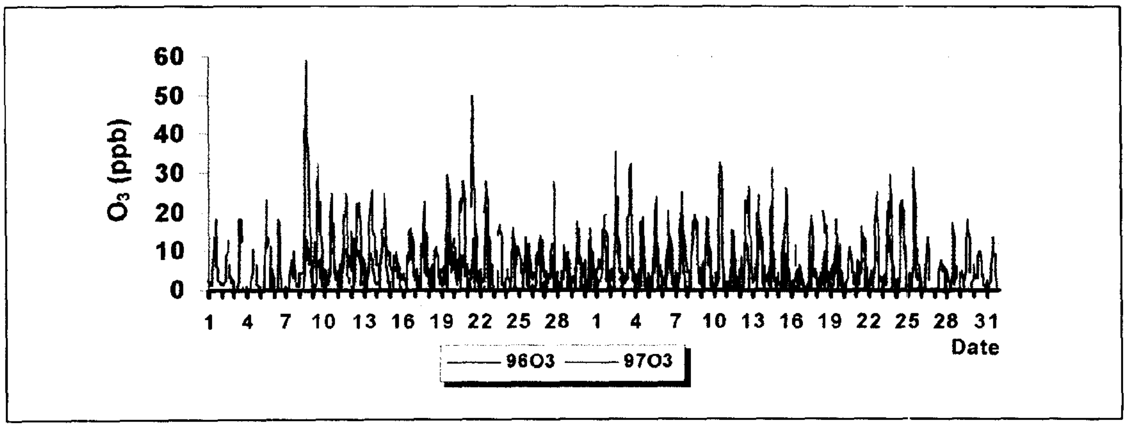


Figure 4-38a. Hourly average O_3 of HAT YAI during September 20 - 30 of 1996 and 1997.

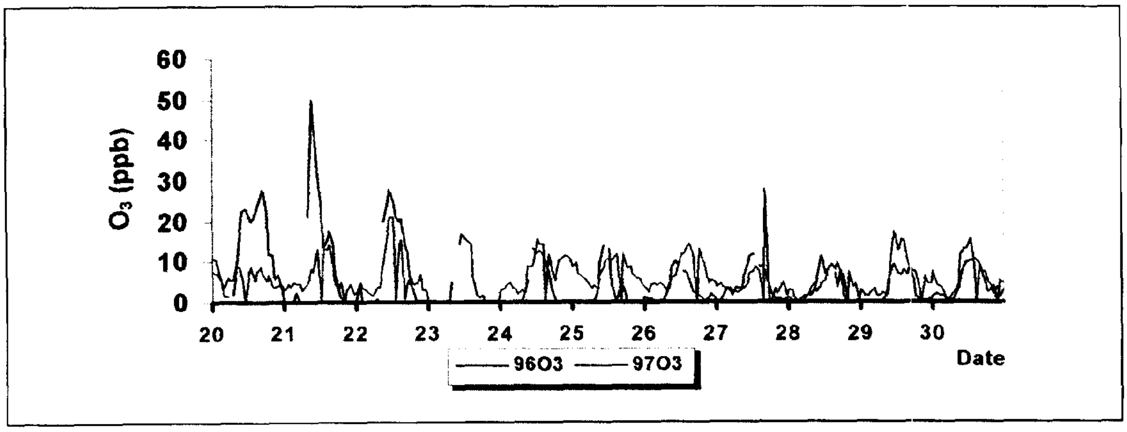


Figure 4-39. Hourly average CH4 of HAT YAI during September - October of 1996 and 1997.

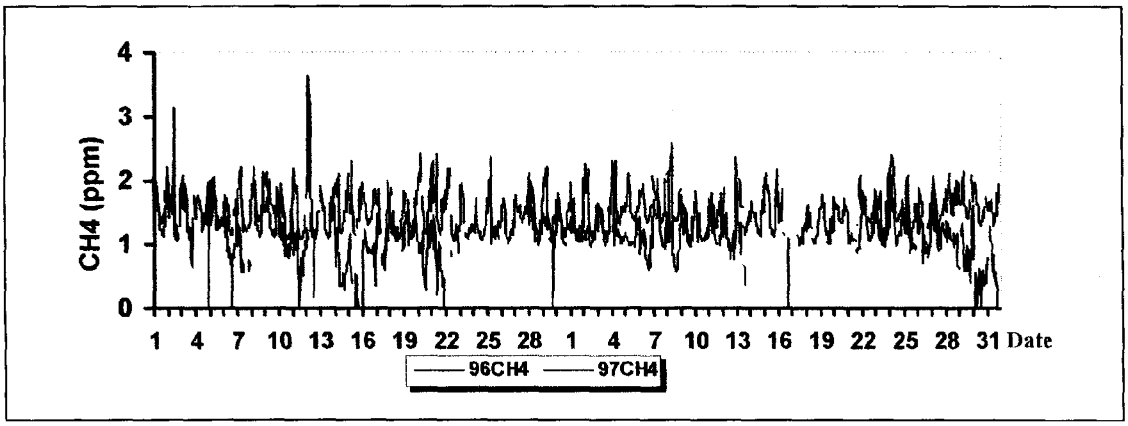
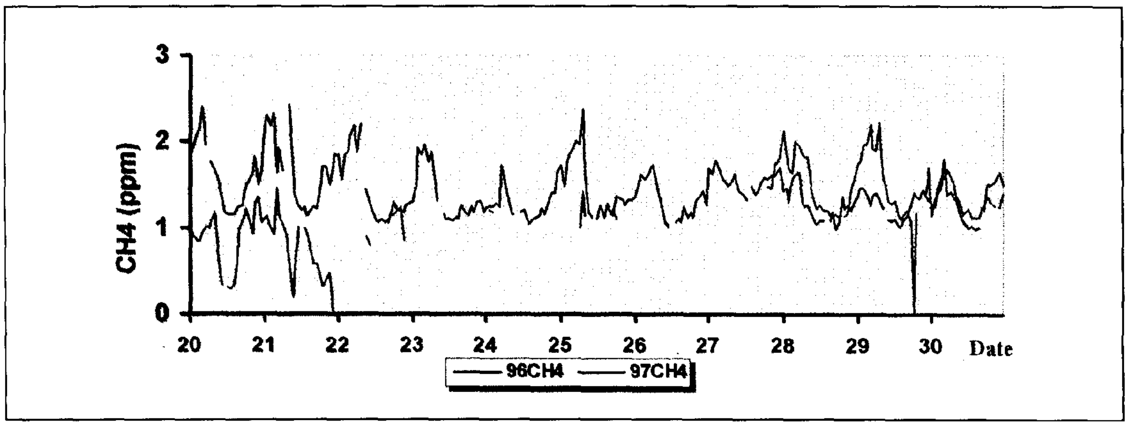


Figure 4-39a. Hourly average CH4 of HAT YAI during September 20 - 30 of 1996 and 1997.



5 HEALTH IMPACTS FROM THE 1997 HAZE

KANCHANASAK PHONBOON

Introduction

In recent human history, the public has learned about the major effects of air pollution through a number of severe incidents or episodes of air pollution (Boubel et al 1994, Wilson and Spengler 1996). The first well described episode occurred in Meuse Valley, Belgium in 1930. Mortality and morbidity increased markedly during the days of high air pollution and for several days thereafterómany cattle and 60 people died in the first week. Firket estimated that SO_2 concentrations were in the range of 25,000-100,000 µg/ m^3 (Wilson and Spengler 1996). The Donora, Pennsylvania episode occurred in 1948, with the air became so hazy that people could not see across the street. About half of the population of 14,000 became sick, 10 percent severely ill, and 20 deaths were attributed to the episode. Concentrations of SO_2 were estimated at 1,400-5,500 µg/m^3 (Wilson and Spengler 1996). A major air pollution disaster hit London in December 1952, with severe inversion trapped air pollutants for several days. When the total death rates in London were available 6 months later, a 5-fold increase was observed in the days starting just after the rise in air pollution. Smoke and SO_2 levels at that time were estimated as high as 1,500-2,000 mg/m^3, or even much higher than the Meuse episode (Ministry of Health 1954, Wilson and Spengler 1996).

During the next two decades, most western countries and the rest of the world passed their national air pollution control legislation. Air quality monitoring systems became operational throughout the world (Bouble et al 1994, UNEP/WHO 1992-95). Severe incidents or episodes of air pollution were memories of the past, however smaller episodes occurred sporadically and low level air pollution remain in most large cities worldwide, especially in developing countries (Anderson et al 1995, UNEP/WHO 1992-95, WHO 1992a, Wichmann et al 1989). Even at these lower concentrations, associations with mortality, hospital admissions, respiratory symptoms, and lung function, are still observed (Wilson and Spengler 1996).

The 1997 haze has proved once again that improper land clearing practice of human, compounded by the El Niño climatic factors, could still produce a large-scale air pollution episode. Compared to forest fires in other continents in the past, the 1997 haze from Indonesia was unique. Because of its wide coverage of densely populated area in South-East Asia region, almost 100 million population in 5 countries were exposed to the smoke. With a large number of populations at risk, its impact or health effects could be readily observed. The preliminary health impacts and observed health effects from the 1997 haze episode in southern Thailand are described in this chapter. Meteorological and air quality data indicated the 1997 haze affected the whole southern part of Thailand. Therefore, all 14 southern provinces were included in the study.

Health service in southern Thailand

The health service systems in the southern region are mainly under public sector, Ministry of Public Health, similar to other regions. All southern provinces have general hospitals (>150 beds) in large cities, community hospitals (10-150 beds) at all districts, and health centers in sub-districts. Under the Ministry of Public Health, there are 19 city hospitals, 121 community hospitals, and 1,400 health centers in the south. Services from private sector (pharmacies, clinics and hospitals) are common in urban area, however. Doctors, nurses, and hospital beds ratios to southern population are 1:5,500, 1:1,200, and 1:530 respectively (Ministry of Public Health 1997).

A provincial summary of the number of outpatients and in-patients by diagnosis group is routinely reported every month as part of activity report for health care facilities under the MOPH. There are 21 diagnosis groups for outpatient visits and 75 for admissions. Computerized data processing using the International Classification of Disease (WHO 1992b) have just been introduced into few city hospitals, and can serve only a portion of daily in-patients and outpatients. Data processing in medium/small hospitals and health centers are still done manually, resulted in limited types as well as a lag of health service data availability.

Methods and data collection

1. **The Ministry of Public Health monthly morbidity study** Morbidity changes in the south for September-October 1997, the period covering the haze episode, were analyzed and compared with the control area, the upper northern region (9 provinces with 6.2 million populations). The net health impacts from the 1997 haze were results after adjusting for equivalent changes in the control area. Changes in morbidity were assessed

by calculating changes from the same period in 1996. A regression model was applied to investigate the association between monthly morbidity and monthly PM_{10} and weather variables, by predicting monthly respiratory visits and admissions for 1997. The model included the actual monthly respiratory diseases visits and admissions, monthly PM_{10} levels (from Prince of Songkhla University station), and weather variables (monthly temperature and relative humidity) of the southern Thailand in 1997.

2. **Daily hospital morbidity and mortality study in Hat Yai** A more detailed study of morbidity and mortality from both outpatient visits and admissions was carried out in 2 large public hospitals (Hat Yai Hospital and Prince of Songkhla University Hospital) that serve Hat Yai City. Hat Yai is the largest city of the southern region with the population inside the city and its suburb of 263,000. The study focused on changes of respiratory diseases, as well as changes in mortality and age and sex distribution during the month of September-October 1997, the period covering the haze episode. The net health impacts from the 1997 haze were results after controlling for the increasing trend of service. A regression model was also applied to investigate the association between daily respiratory morbidity and daily PM_{10} and weather variables (daily temperature and relative humidity) in Hat Yai. Variations in day-of-the-week patterns of hospital data were adjusted by taking residuals from the overall average for that day.

3. **The southern death registration mortality study** Nationwide electronic data processing of death certificate is now carried out centrally at the Information Technology Center, Ministry of Interior (MOI), with some lag-time of 6 months. Currently, the 1997 death registration data set is not yet completed and available for analysis. This study is under planned in the next step.

Morbidity studies focused on the following diseases, due to the well-known effects of particulate matter towards these organs and the potential for accidents from poor visibility in that period.

1) Respiratory diseases (upper respiratory tract infection, pneumonia, asthma, bronchitis, and others, J00-J99 based on ICD-10 (WHO 1992b)).
2) Cardiovascular diseases (ischemic heart diseases and others, I00-I99).
3) Irritation and infection of eye and skin (H10-H13, and L20-L30, L50-L54).
4) Accidents (V01-V99).

Results

The Ministry of Public Health monthly morbidity study

Monthly outpatient visits (OPD) reported from all 14 southern provinces during 1996-97 were in the range of 700,000-800,000 visits, or almost 10% of the regional population. Of these nearly 1 million visits, respiratory diseases is the most common and accounted for about one third of them, followed by digestive ailments and skin plus eye diseases (Table 5-1). Monthly inpatient admissions (IPD) reported from all 14 southern provinces were between 50,000-60,000 cases, or almost 1% of the population was hospitalized each month. Respiratory diseases is the second most common at 14% of all admissions (Table 5-1). Other regions of Thailand also show similar pattern (Ministry of Public Health 1997).

Table 5-1. The 5 leading causes of OPD visits and IPD admissions in southern Thailand, 1996-97

Rank	Diagnosis group	Percent
	OPD visits	
1	Respiratory diseases	30
2	Digestive system diseases	12
3	Eye/Skin diseases	10
4	Infectious diseases	7
5	Musculoskeletal system diseases	6
	Others	35
	IPD admissions	
1	Pregnancy-related conditions	23
2	Respiratory diseases	14
3	Infectious diseases	13
4	Digestive system diseases	8
5	Accidents	6
5	Cardiovascular system diseases	6
	Others	30

Among outpatient visits, there seemed to be a seasonal trend of respiratory diseases in early rainy (June-July) and winter season (December-January) in the south (Figure 5-1a). This trend changed in 1997 with respiratory illness rose in August and peaked in September when the haze hit the area. Compared with the control area in the far north, respiratory visits showed an increase in September 1997 but peaked a month later in October (Figure 5-1b). Among IPD admissions, a similar seasonal trend of respiratory illness in early rainy season (June-July) was observed in the south (Figure 5-2a). This trend changed in 1997 with respiratory diseases went up in August and peaked in

September when the haze hit the area. In the control area in the north, IPD respiratory category showed an increase in September 1997 but continued to peak in October (Figure 5-2b).

For respiratory admissions, a seasonal trend of pneumonia can be observed during the month of September to October for both the south and the upper north (Figures 5-3a and 5-3b). Reported monthly pneumonia admissions displayed a sharp increase in September 1997 when the haze appeared in the south, followed by smaller peaks of bronchitis/chronic obstructive pulmonary disease (COPD), and asthma in the same month. While the control area in the north, which was not affected by the haze, showed smaller peaks of pneumonia and bronchitis/COPD a month later in October 1997.

This common mode of surging in respiratory diseases in both the south and the north suggested that there might be some widespread respiratory tract diseases not related to haze occurring in Thailand in that period. *Therefore, in southern Thailand, the haze event was not a sole cause but an additional cause on top for those respiratory illnesses.*

Other than respiratory diseases, reported outpatient eye and skin diseases as well as cardiovascular diseases and accidents did not show a marked increase in the south during the haze episode in September-October 1997. For inpatient cases, these diseases also did not reveal any obvious increase, all remained rather stable between the same period (Figures 5-1, 5-2, and 5-3). Consequently, the analysis of health impact from the 1997 haze focused only on respiratory effects.

During a 2-month period covering the haze episode from September-October 1997, a substantial increase in respiratory morbidity of both OPD visits and IPD admissions was observed in the study area of southern Thailand. The increases were: 26% vs. 18% (the south vs. control area) for all respiratory visits, 33% vs. 26% for all respiratory admissions, 36% vs. 18% for pneumonia admissions, 40% vs. 28% for bronchitis/COPD admissions, and 12% vs. 9% for hospitalized asthma although this category is not significant (Table 5-2). Hence, the net health impacts from the 1997 haze are 8% and 7% increases in respiratory visits and admissions, respectively. It is interesting to observe that the percentage of net haze impacts is higher in 2 specific respiratory diseases, pneumonia and bronchitis/COPD. From this finding and the monthly report of respiratory morbidity, the increase during the 1997 haze would be approximately 45,000 visits and 1,500 admissions in southern Thailand.

Table 5-2. Changes in the respiratory morbidity in the south and the upper northern Thailand and the net health impacts from 1997 haze, September-October 1997

	South	North	% net haze impacts	P-value [1]
OPD visits				
All respiratory	26	18	8	<0.01*
IPD admissions				
All respiratory	33	26	7	<0.01*
Pneumonia	36	18	18	<0.01*
Bronchitis/COPD	40	28	12	0.01*
Asthma	12	9	3	NS

[1] Chi-squre goodness of fit test, using contingency table analysis (2 x 2) for each condition

* Significant

Table 5-3. Regression analysis of monthly respiratory illness with PM_{10} levels and weather variables in southern Thailand, 1997

	R^2	Coefficient	P-value
OPD visits			
All respiratory	0.32		
PM_{10}		1372	0.21
Relative humidity		2420	0.54
Temperature		-1506	0.33
IPD admissions			
All respiratory	0.53		
PM_{10}		85	0.07
Relative humidity		305	0.08
Temperature		-76	0.90
Pneumonia	0.80		
PM_{10}		28	0.02*
Relative humidity		178	0.002*
Temperature		-96	0.54
Bronchitis/COPD	0.45		
PM_{10}		13	0.04*
Relative humidity		14	0.50
Temperature		7	0.92
Asthma	0.64		
PM_{10}		13	0.006*
Relative humidity		-7	0.60
Temperature		-25	0.64

* Significant

Regression analysis demonstrates the significant associations between all categories of monthly respiratory admissions and monthly PM_{10} levels (Table 5-3, nearly significant for all respiratory admissions). The effects of monthly PM_{10} (for each 1 $\mu g/m^3$) were about 85, 28, 13, and 13 monthly admissions for all respiratory, pneumonia, bronchitis/COPD, and asthma, respectively. Relative humidity is the only weather variable that became significant for pneumonia admissions. The effect of monthly relative humidity (for each percent) was 178 pneumonia admissions. The R^2, or the proportion of variance of illness that is accounted for by the predictor variables of the models, varied from 0.45 in bronchitis/COPD to 0.80 for pneumonia cases.

Daily hospital morbidity and mortality study in Hat Yai

Daily hospital morbidity and mortality study in Hat Yai was based on pooling data from the 2 city hospitals, Hat Yai Hospital and Prince of Songkhla University (PSU) Hospital. Respiratory diseases generally accounted for 15% of OPD visits and 12% of IPD admissions. Daily respiratory visits and admissions in Hatyai City during September-October 1997 are shown in Figure 5-4. Number of cases was higher during the weekdays, then dropped during the weekend according to the working hours. Their 7-day moving average showed different period of increase, for OPD visits in early October while for IPD cases in late September.

For respiratory visits, a rise and widening of upper respiratory tract infection (URTI) cases can be observed during the haze episode between late September to early October 1997, compared to the year before (Figure 5-5). There seemed to be no increase of other respiratory categories in OPD visits. Of respiratory admissions, some increases of pneumonia and acute bronchitis as well as bronchitis/COPD were observed during the first peak of the haze episode, although the overall numbers were small (Figure 5-6).

During the 2-month period covering the haze episode in September-October 1997, significant increases in respiratory OPD visits and bronchitis/COPD admissions were observed in Hat Yai City (Table 5-4). The increases were 11% for visits and 8% for admissions, compared with the reference of increased trend of hospital visits and admissions, 4% and 7%, resulting in the net health impacts from the 1997 haze of 7% and 1% increases in respiratory visits and admissions, respectively. These increases support results of the region-wide study in the previous section. Among OPD visits, the net increase was most pronounced in URTI (15%) and bronchitis/COPD (although not significant), while other categories showed a decrease. For hospitalization, the net haze impacts was highest for bronchitis/COPD (49%), while pneumonia cases increased slightly but asthma declined (both are not significant). Using this finding and the respiratory statistics in both hospitals, the increase in service load during the 1997 haze would be approximately

1,600 URTI visits and 40 admitted bronchitis/COPD cases in a city with 260,000 population.

Regression analysis was carried out for the category of all respiratory visits and URTI, which have significant increase in Table 5-4. The analysis showed significant associations between deviation from daily average of both all respiratory and URTI visits and daily PM_{10} levels (Table 5-5). The effect of daily PM_{10} (for each 1 $\mu g/m^3$) was 0.2 deviation from daily average for both all respiratory and URTI visits. This conclusion is based on the background of hospital utilization and practice in Hat Yai. No weather variable became significant in daily analysis. However, their R^2, or the proportion of variance of illness that is accounted for by the predictor variables of the models, are only 0.08 and 0.12.

Table 5-4. Changes in the respiratory visits and admissions in Hat Yai and the net health impacts from 1997 haze, September-October 1997

	% change	% net haze impacts	P-value [1]
OPD visits			
All respiratory	11	7	<0.01
URTI	19	15	<0.01
Pneumonia/acute bronchitis	-4	-8	<0.01
Bronchitis/COPD	12	9	NS [2]
Asthma	2	-1	NS
Reference	4		
IPD admissions			
All respiratory	8	1	NS
Pneumonia/acute bronchitis	11	4	NS
Bronchitis/COPD	56	49	0.01
Asthma	-7	-14	NS
Reference	7		

[1] Chi-squre goodness of fit test, using contingency table analysis (2 x 2) for each condition

[2] Not significant

Table 5-5. Regression analysis of daily respiratory visit with PM_{10} levels and weather variables in Hat Yai City, September-October 1997

	R^2	Coefficient	P
OPD visits			
All respiratory	0.08		
PM_{10}		0.2	0.05 *
Relative humidity		-0.5	0.66
Temperature		3.1	0.70
URTI	0.12		
PM_{10}		0.2	0.02 *
Relative humidity		-0.9	0.35
Temperature		0.3	0.96

* Significant

To identify the vulnerable groups during the haze episode, hospital utilization by age of both out- and inpatients were analyzed. For OPD visits, there was a slight increase of young age group <5 years of age (2%), but a slight decrease in older age (-2%) during the period September-October 1997 when the haze hit the area, after adjusting with increase in other months (Table 5-6). On the contrary, among IPD admissions, there was a marked decrease of young age patients (-8%), but an increase of older patients (3%) during the haze period, after adjustment with the reference period.

Table 5-6. Changes of the age distribution among hospital visits and admissions in Hat Yai during September-October 1997

	% change	% net haze impacts	P-value [1]
OPD visits			
<5 years of age	11	2	NS [2]
Reference	9		
60 years of age	7	-2	NS
Reference	9		
IPD admissions			
<5 years of age	-2	-8	0.05
Reference	6		
60 years of age	5	3	NS
Reference	2		

[1] Chi-squre goodness of fit test, using contingency table analysis (2 ¥ 2) for each condition

[2] Not significant

There were 1746 deaths in both hospitals in Hat Yai City in 1997. Monthly hospital mortality with cardiovascular and respiratory causes during 1997 and 1996 are shown in Figure 5-7. There seemed to be a pattern of higher mortality in the first half of each year. In 1997, a small rise in mortality occurred in July, September, and November. The increase in September, which was the haze episode, was due to a rise of respiratory deaths in the same month. No such increase was observed in 1996. During the 2-month September-October 1997, increases in hospital mortality were observed, although all are not statistically significant (Table 5-7). The highest increase was deaths from respiratory cause.

Table 5-7. Changes in hospital mortality in Hat Yai during September-October 1997

	% change	% net haze impacts	P-value [1]
All causes	5	5	NS [2]
Cardiovascular deaths	7	7	NS
Respiratory deaths	30	30	NS
Reference	0.1		

[1] Chi-squre goodness of fit test, using contingency table analysis (2 ¥ 2) for each condition
[2] Not significant

Conclusion

This study focused on the use of existing data at the regional and city level to determine health impacts from an air pollution episode. Certainly, in the current situation of Thailand there are limitations and weakness of these available monitoring and reporting data, such as completeness, limited type of data availability, validity, and timeliness. More complete health effects evaluation of air pollution episode in the future need better study design, better preparedness and more data collection in the field, and more resources invested in this venture.

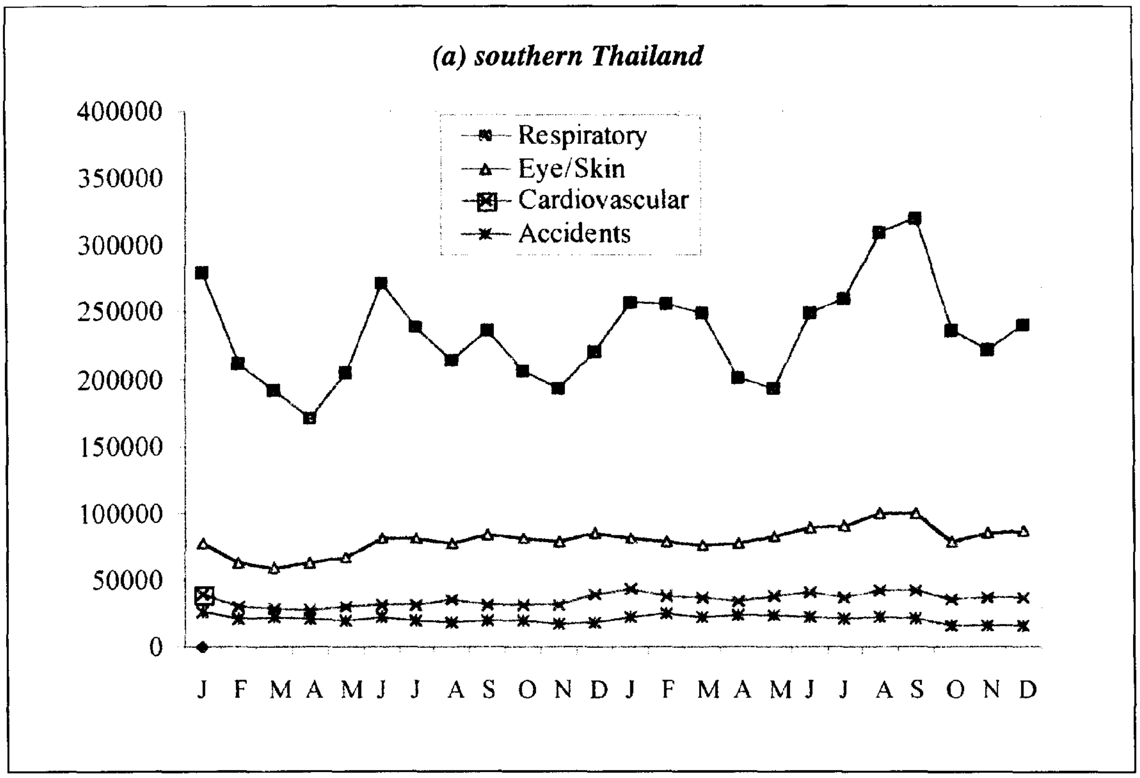
Respiratory diseases constitute ~30% and 14% of the total OPD visits and IPD admissions in the south, similar to other regions of Thailand. Seasonal trend of outpatient respiratory illness is usually in early rainy (June-July) and winter (December-January) season, while that of inpatient is in rainy season only.

During late September to early October 1997, an air pollution episode from Indonesian forest fires occurred in southern Thailand. Particulate matter was the only major air pollutant in this haze episode, with the observed maximum 24-hour average value of PM_{10} 218 mg/m^3 in late September 1997. At the regional level, a substantial increase in respiratory morbidity of both OPD visits and IPD admissions was observed in the study area of southern Thailand in the same period. While cardiovascular diseases, eye and skin diseases, and accidents did not show any obvious increase. The increases were significant for all respiratory visits and for almost all categories of respiratory admissions: pneumonia, bronchitis/COPD, and asthma. At those rises of particulate matter levels, the net health impacts from the 1997 haze are estimated as 8% and 7% increases in respiratory visits and admissions, respectively. Regression analysis demonstrates the significant associations between monthly respiratory admissions and monthly PM_{10} levels. The effects of monthly PM_{10} (for each 1 $\mu g/m^3$) were about 85, 28, 13, and 13 monthly admissions for all respiratory, pneumonia, bronchitis/COPD, and asthma, respectively.

The impact at the city level was analyzed by pooling data from the 2 city hospitals in Hat Yai City. Respiratory diseases generally accounted for 15% of OPD visits and 12% of IPD admissions. During the 2-month period covering the haze episode in September-October 1997, significant increases were observed only in the category of all respiratory OPD visits and bronchitis/COPD admissions in Hat Yai City. At those levels of rising PM_{10}, the net health impact from the 1997 haze is 7% increase in respiratory visits. These increases support results of the region-wide study in the previous section. Among OPD visits, the net increase was most pronounced in upper respiratory tract infection (URTI, 15%), and for hospitalization, the net impacts was highest for bronchitis/COPD (49%). Regression analysis showed significant associations between deviation from daily average of both all respiratory and URTI visits and daily PM_{10} levels. The effect of daily PM_{10} (for each 1 mg/m^3) was 0.2 deviation from daily average for both all respiratory and URTI visits.

The PM_{10} levels in this haze episode (200+ $\mu g/m^3$, 24-hour average) are about twice that of the national ambient air quality standards of Thailand (120 $\mu g/m^3$). This level was 4-5 times higher than normal air quality in the region. At this low to lower-moderate increase, the health effects can be clearly and readily observed in large population, as demonstrated in the regional level study. However, the effects may be less likely or more difficult to be detected in smaller area, such as characterized in the Hat Yai City study. Pooling data from several cities may be needed.

Figure 5-1. Reported monthly OPD visits, 1996-97.



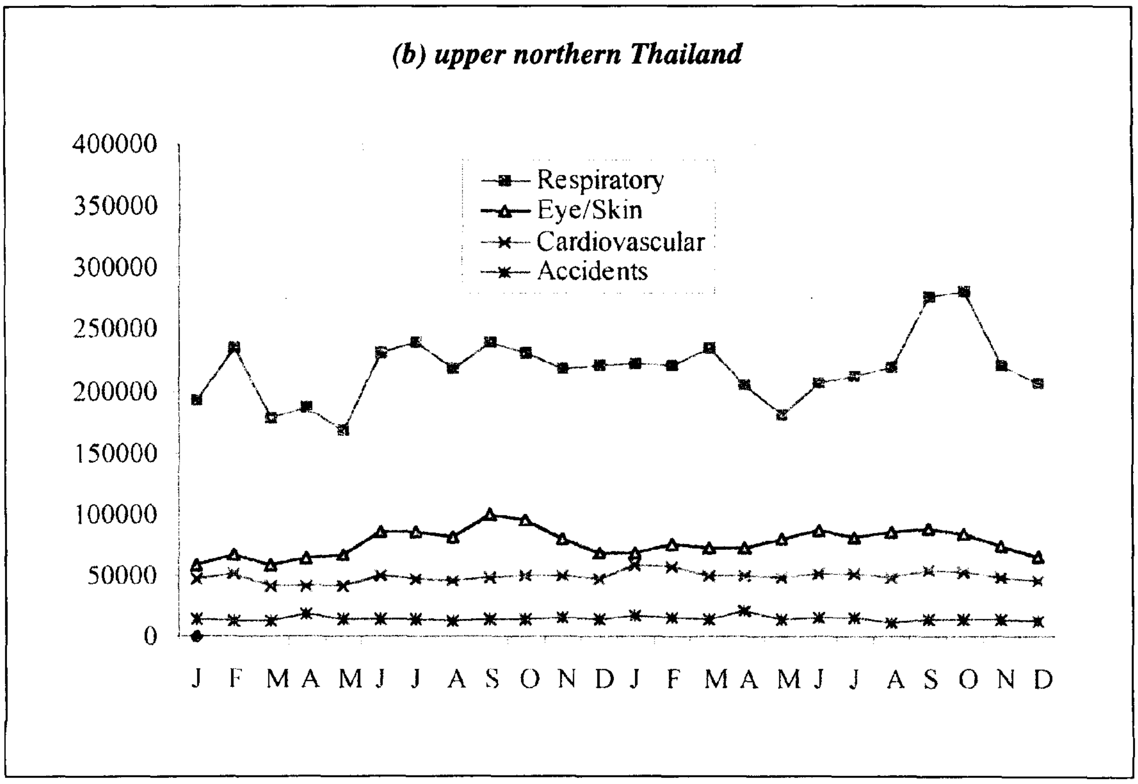
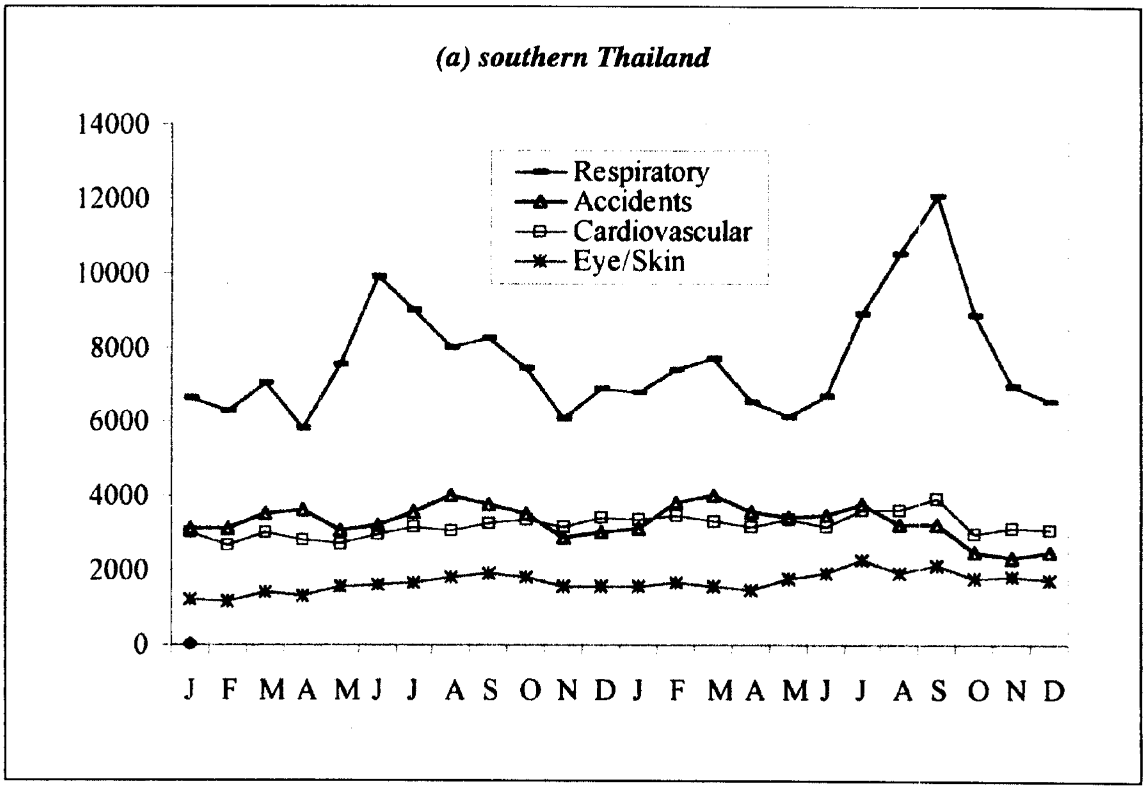


Figure 5-2. Reported monthly IPD admissions, 1996-97.



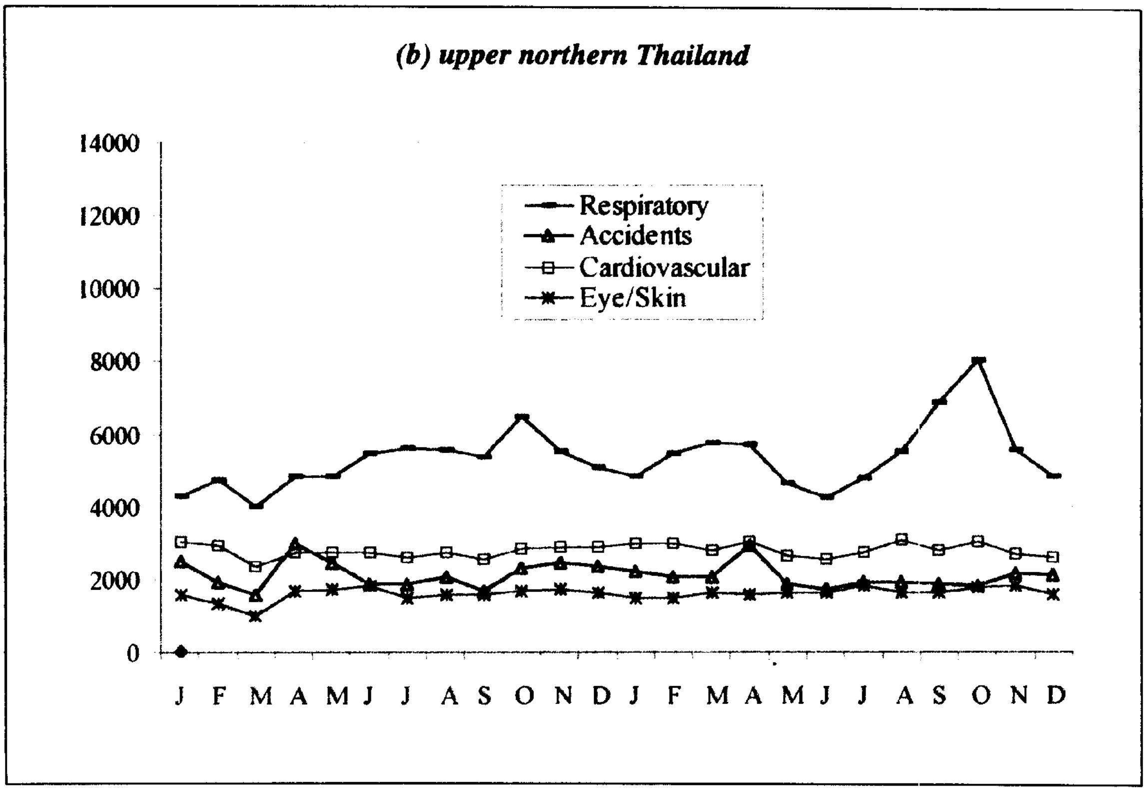
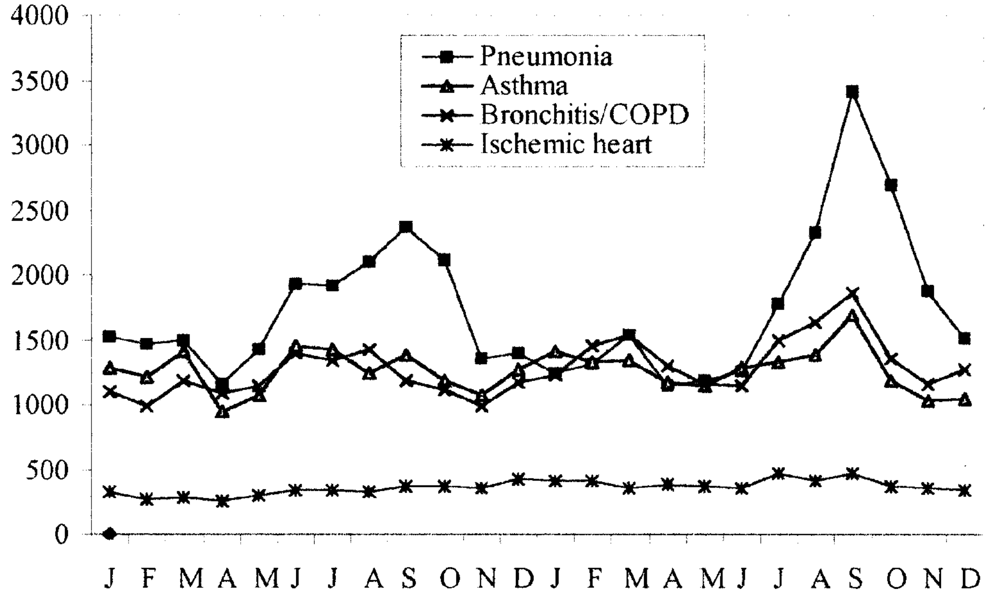


Figure 5-3. Reported monthly selected IPD admissions, 1996-97.

(a) southern Thailand



(b) upper northern Thailand

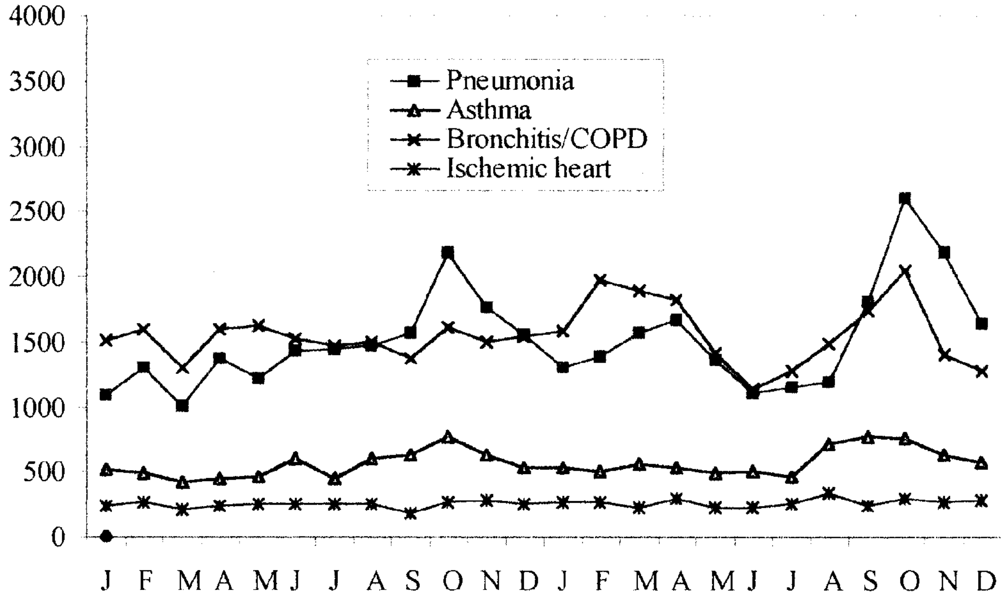
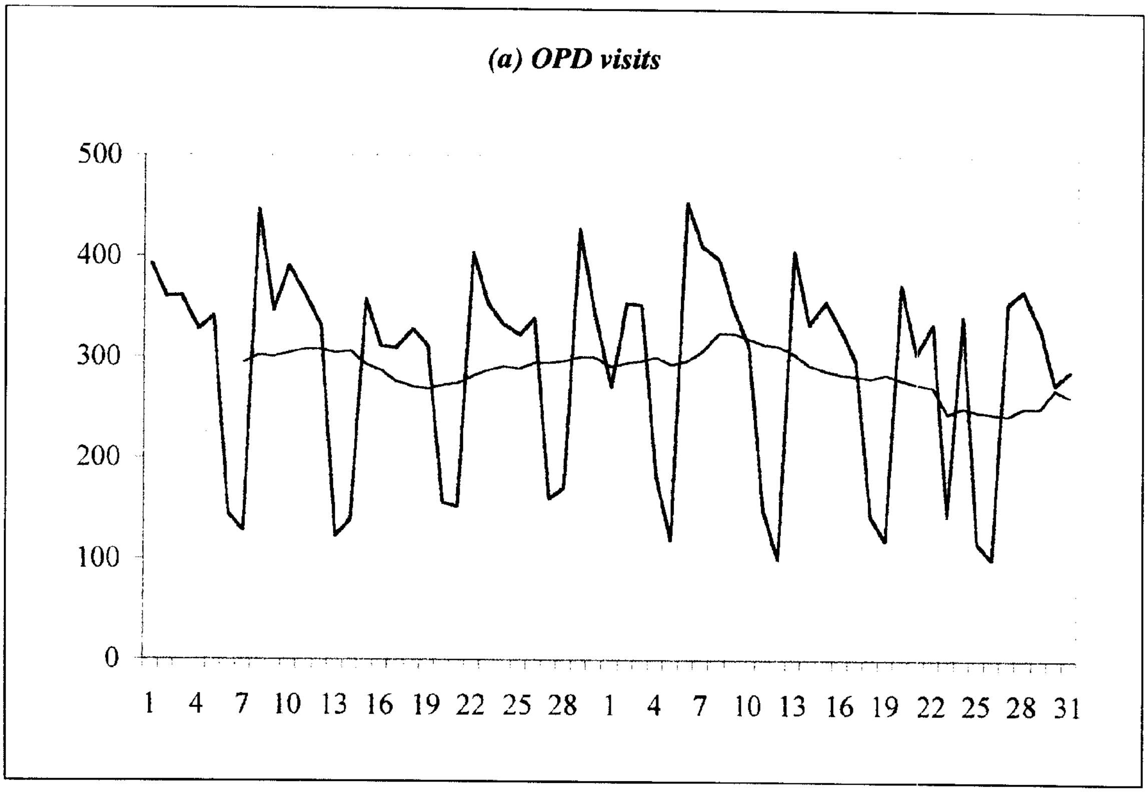


Figure 5-4. Daily respiratory OPD visits and IPD admissions and their 7-day moving average in Hat Yai City, September-Ocober 1997.



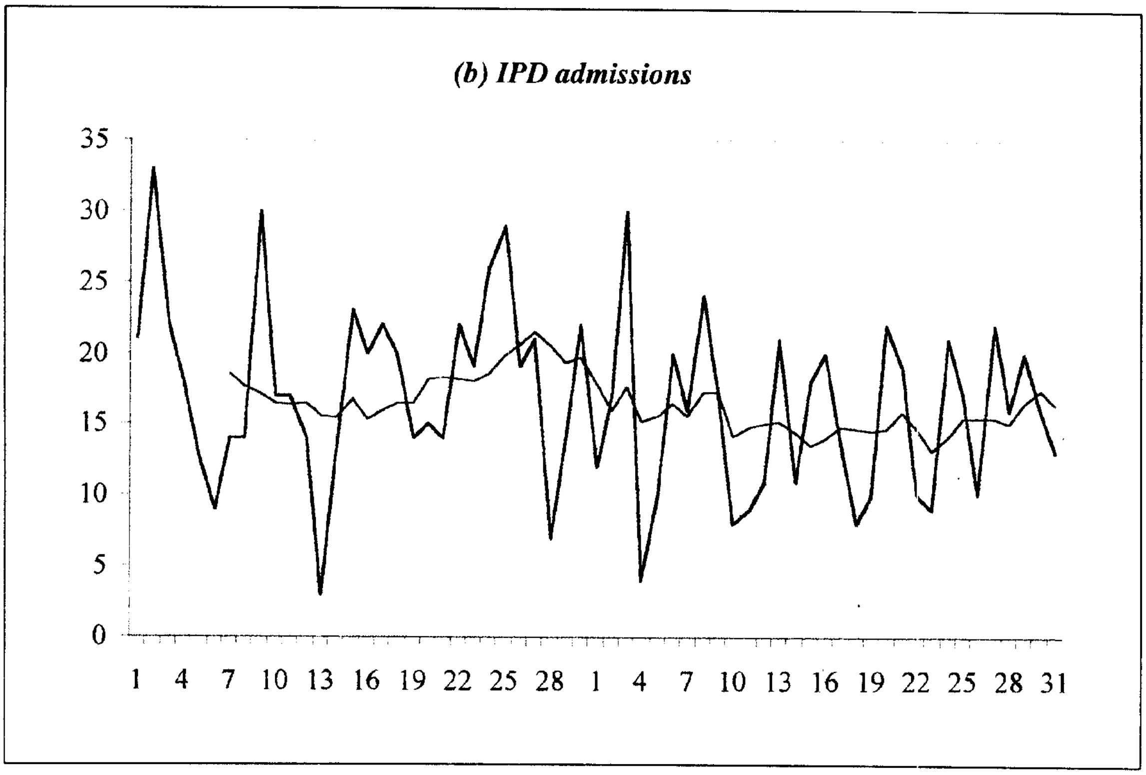
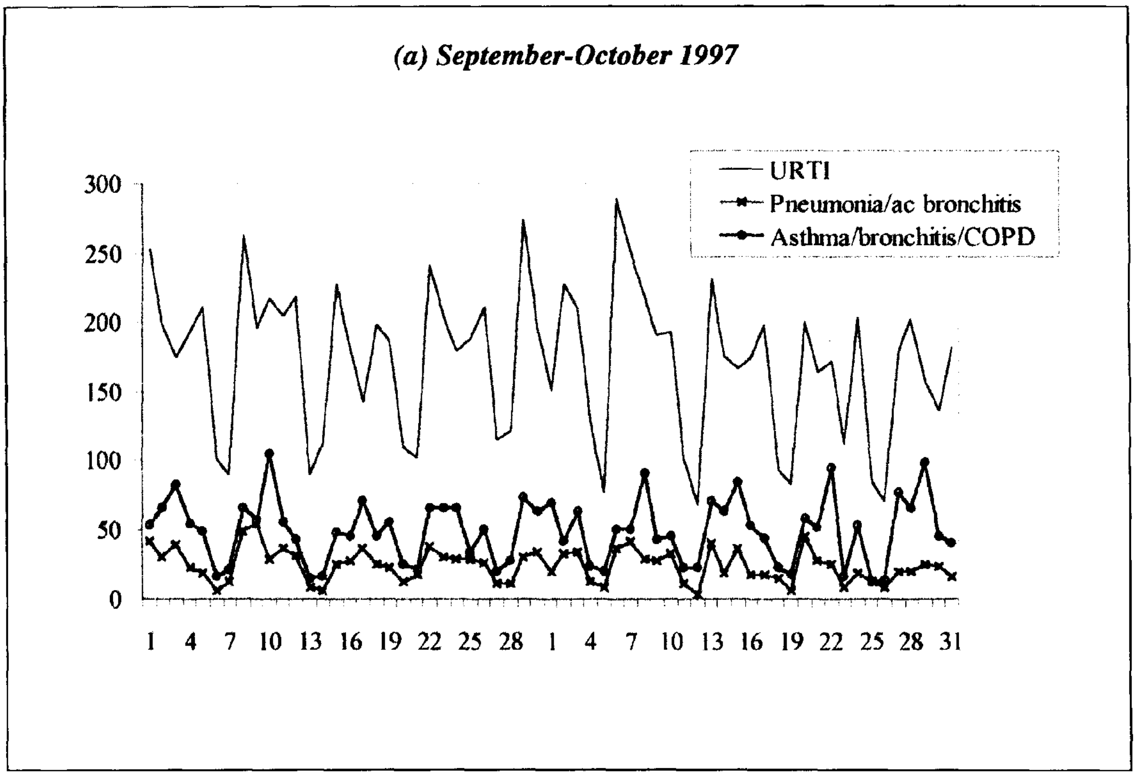


Figure 5-5. Daily selected respiratory OPD visits in Hat Yai City.



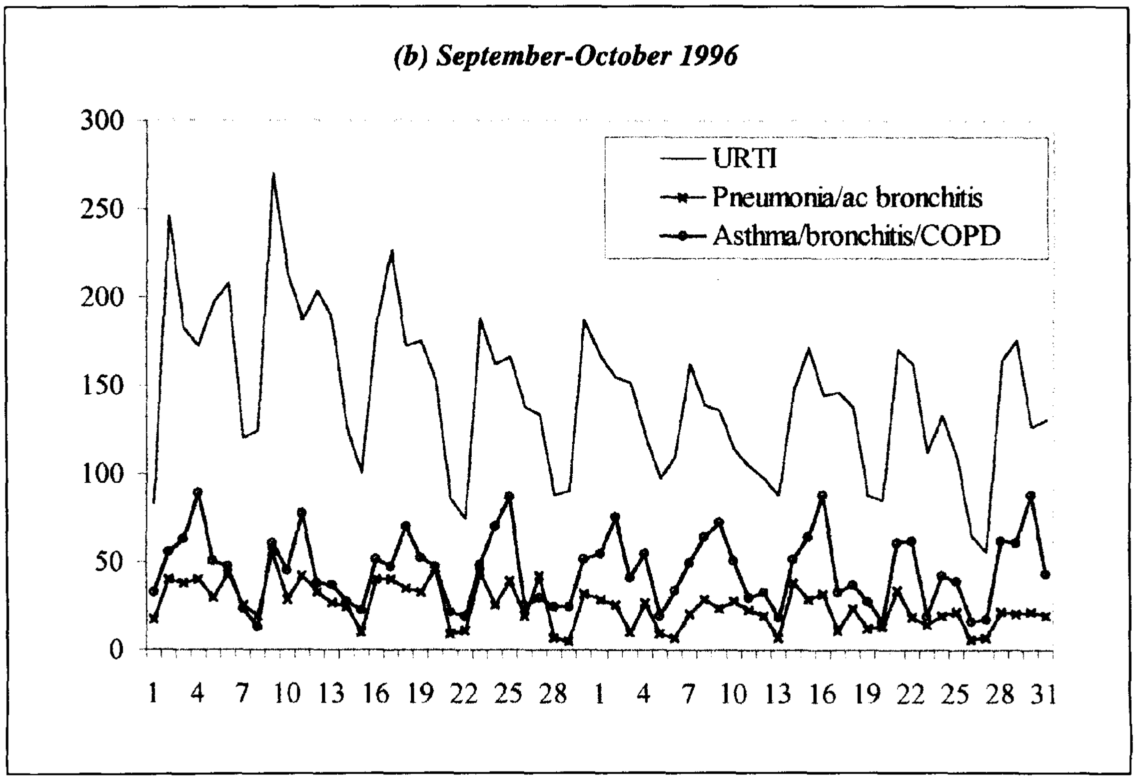
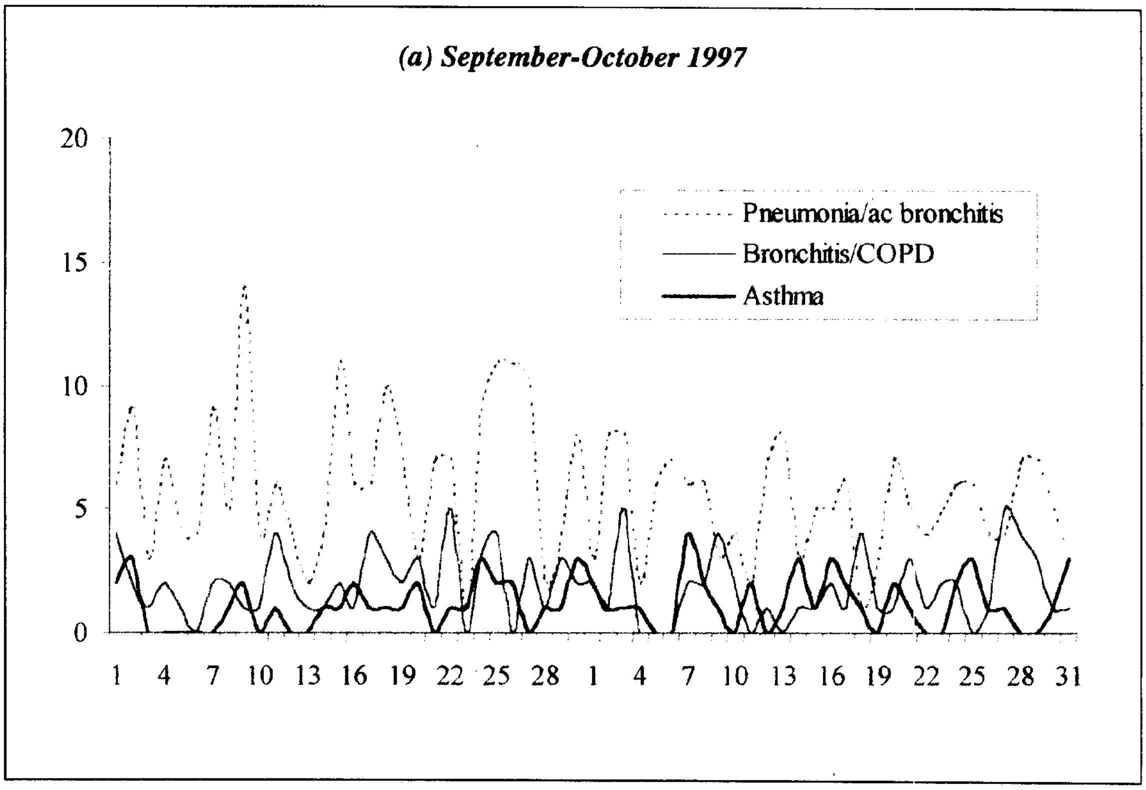


Figure 5-6. Daily selected IPD admissions in Hat Yai City.



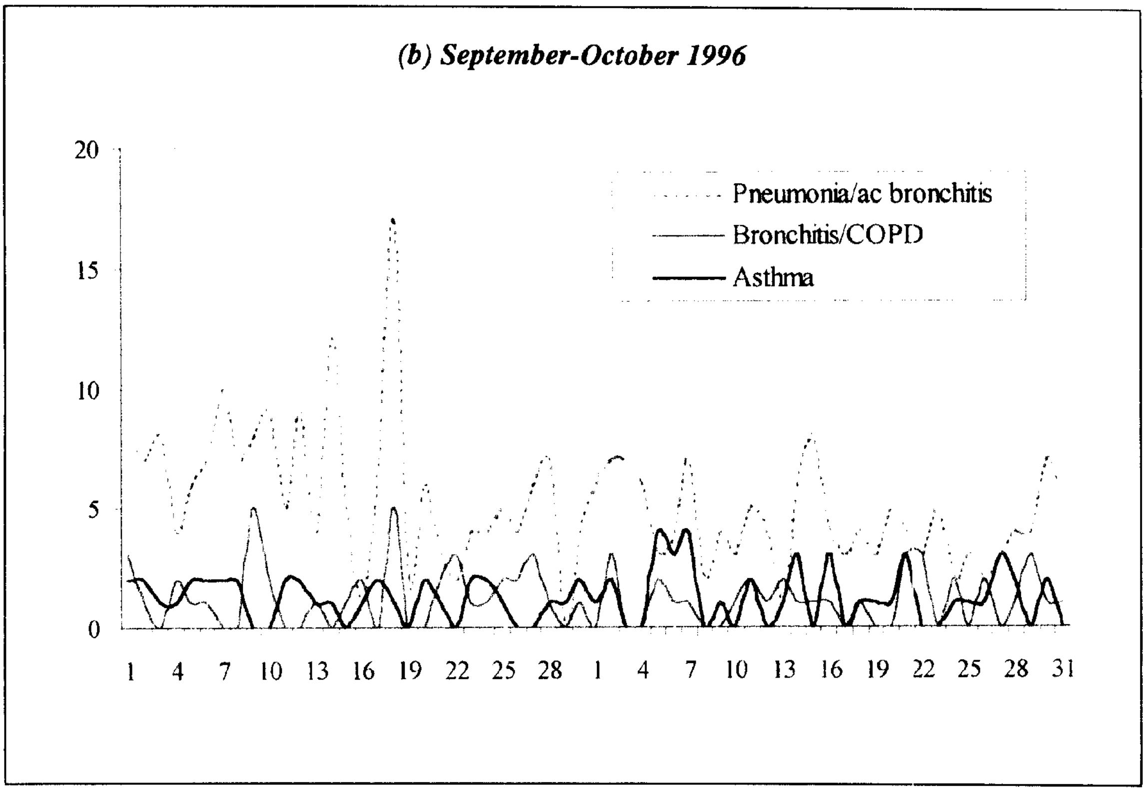
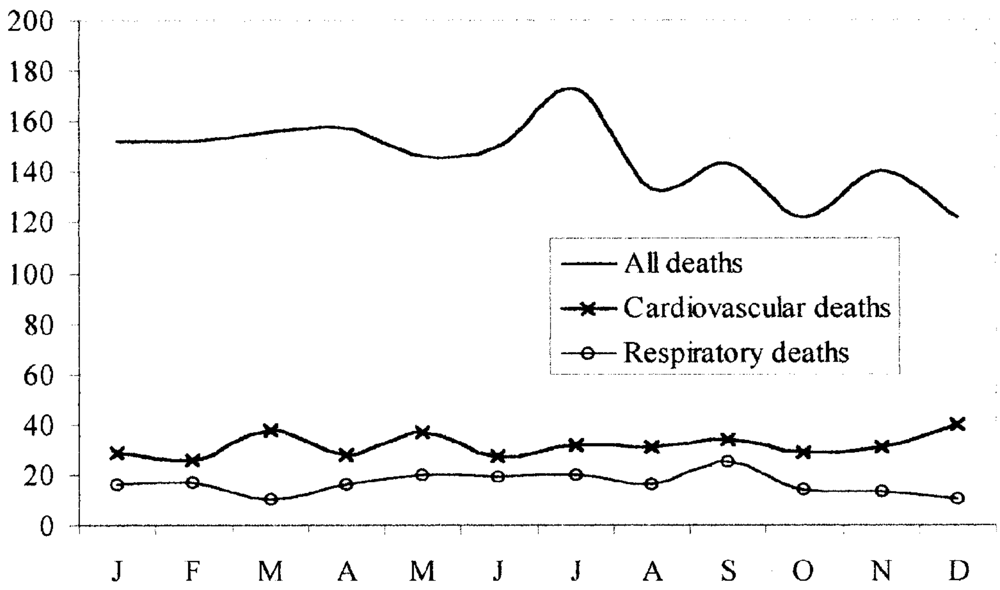
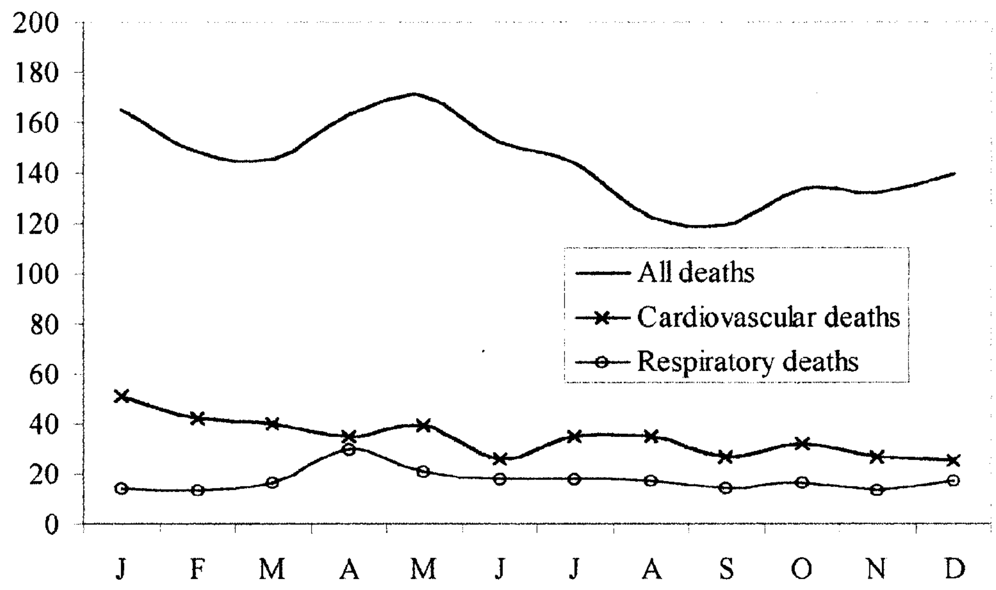


Figure 5-7. Monthly hospital mortality in Hat Yai City.

(a) 1997



(b) 1996



6 ACTIVITIES AND MITIGATION MEASURES DURING AND AFTER THE 1997 HAZE

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PROESPICHAYA KANATHARANA
SONGKRAN AGSORN

Activities of all related agencies at the local and central levels during and after the 1997 haze are described under 2 major headings: activities and mitigation measures during the event, and post-haze activities.

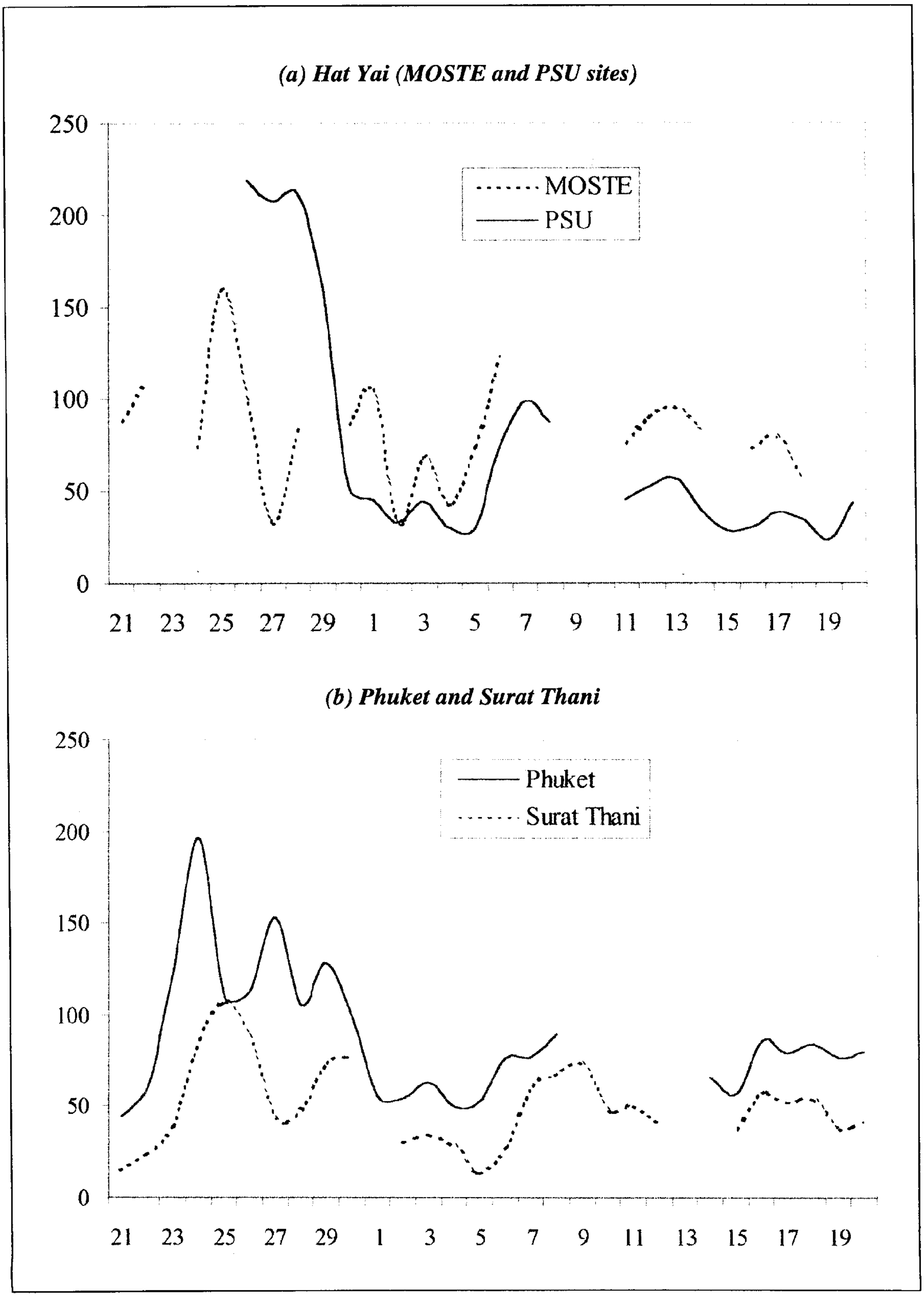
Activities and mitigation measures during the 1997 haze

After reports in international news media and warning from the Meteorological Department, the Indonesian forest fires haze was first visibly observed in southern provinces of Thailand on 22 September 1997, with a 20 $\mu g/m^3$ increase in PM_{10} from previous day in Hat Yai. The first peak of this episode occurred between 22-29 September with a maximum during 24-25 September, followed by the lower second peak during 6-8 October 1997 (Figure 6-1). However, the highest 24-hour average PM_{10} observed at Prince of Songkhla University station was 218 $\mu g/m^3$ on 26 September, with missing data of the previous 3 days. Although the forest fires in Sumatra and Borneo continued for the next several months, there is no any other transboundary haze event in Thailand after this.

Meteorological information

Thai Meteorological Department was monitoring the haze situation as it became apparently worse since August 1997. The reports from Malaysia and Singapore meteorological services as well as the meteorological satellite images, the meteorological data from the other major centers (such as Japan Meteorological Agency, European Center for Medium Range Forecast) were collected. The meteorological situations were passed on to the agencies concerned as requested. The Department was part of the committee formed

Figure 6-1. Daily PM_{10} monitoring ($\mu g/m^3$) 21 September - 20 October 1997



by the Thai government in early October 1997 to deal with the haze problem. As the situation in Malayan peninsular got worse, the Department informed the World Meteorological Organization (WMO) for information and possibly coordinating efforts. The WMO informed respecting designated Regional Specialized Meteorological Centers (RSMC) and informed that ASEAN Specialized Meteorological Center, the RSMC-Tokyo, the RSMC-Melbourne and the RSMC-Washington agreed to assist as requested. ASMC-Singapore made the Internet web-page available for haze monitoring and the results of the trajectory model runs.

Early Local and Central Response

Because of the abrupt nature of the haze and the lack of previous experience, the wave of response occurred relative late, compared to the event. Songkhla responded first with a press conference on air quality levels and health advice on 30 September, and other provinces followed suit. One consequence was a great demand on local air quality data. There was a tendency to place an emphasis on air monitoring stations (both mobile and permanent stations) rather than mitigation and prevention measures for the public or how to deal with the root cause of the problem-uncontrolled forest fires in Indonesia. Some conflicting information was generated from different agencies in this early period, for example, interpretation of air quality and rainfall acidity data. All of this book's authors joined early as well as later activities at different levels and locations. Some helped with local actions in Songkhla, while some were actively involved as focal points in their own Departments. Some contributed an article on haze and mitigation measures in a Thai newspaper.

At the central level, the Cabinet in Bangkok had ordered the Ministry of Public Health to set up a coordinating center for public assistance during the haze event and appointed its committee on 3 October 1997. The Ministry distributed 140,000 masks that are protective against particles larger than 3 microns to all 14 southern provinces in early October 1997.

Coordinating Center for Public Assistance during the Haze

Coordinating Center for Public Assistance during the Haze convened its first and only committee meeting on 3 October 1997, and appointed a subcommittee on information which also had the first meeting on the same day.

The name of the subcommittee reflected previous conflicts and confusion and the need to coordinate air quality and health risk communication as well as advice on public protection measures. The subcommittee produced guidelines for public assistance during the haze in late October 1997, and tried to setup a reporting system of respiratory diseases, which had its own problem as discussed below.

Guidelines for Public Assistance during the Haze

The guidelines contents consist of 7 chapters as follows.

1) Air quality monitoring and upper respiratory symptoms reporting during the 1997 haze.
2) Review of impacts on visibility and health.
3) Health risk communication and public advice on protective measures.
4) Role and functions of each agency in public assistance during the haze.
5) Air quality monitoring guidelines.
6) Rainwater quality monitoring guidelines.
7) Press conference and public information suggestions.

Reporting of Respiratory Diseases

An effort to set up a reporting system of respiratory diseases from southern provinces, in addition to the routine reporting system, worked partially only for the first month–September 1997. Ten of 14 provinces reported 500-800 cases of upper respiratory diseases in September. There was no any subsequent report after October. The data coming in were so crude and incomplete to draw any conclusion on health impacts of the 1997 haze. Failure of the respiratory reporting proved that it is unrealistic to expect any add-on burden, when most data processing at local levels are still carried out by hand.

Health Risk Communication and Public Advice on Protective Measures

These measures are generally similar to those of other ASEAN countries, covering suggestions for susceptible population groups (asthmatics and chronic bronchitics, elderly, infants and children, persons with underlying lung or heart disease, and smokers) and general population. They include avoiding strenuous activities and smoking, staying indoors, drinking clean water and to temporary refrain from rainwater, seeking care when having symptoms or attacks, and wearing protective masks outdoors in severe haze. Because of poor visibility during the haze event, an emphasis on traffic accident awareness and prevention is also included.

Assessment of Public Health Impacts from the 1997 Haze

To assist the Coordinating Center in producing guideline for assessing public health impacts that can be conducted locally in each province, the Health Systems Research Institute convened a technical meeting on 10 October 1997. The meeting included participants with expertise or interest in air pollution and health research, health information system and meteorology. The guidelines were produced and distributed in mid October.

Post-haze activities

Coordinating Center for Public Assistance during the Haze

The Coordinating Center's subcommittee had another meeting on 9 April 1998 to update activities and information from its members. Pollution Control Department of Ministry of Science, Technology and Environment and Meteorological Department will continue to supply the Center their air quality monitoring and meteorology data for haze warning system.

Air quality information

After the air pollution episode from the Indonesian forest fires throughout the southern Thailand, Pollution Control Department has set up the Internet homepage called Air Quality in Southern Thailand to inform the public of air quality within the region, especially from particulate matter (PM_{10}). The URLs for accessing the information are: http://www.pcd.go.th and http://www.aqnis.pcd.go.th.

Meteorological information

The Meteorological Department was involved in several committees set up by the Thai government for the Indonesia haze and other forest fires. It also took part in seminars or technical meeting concerning with the phenomenon. The department was presented at various international meteorological meetings on Indonesia haze problems and involved in established a more efficient co-ordination between meteorological services in the region.

National Haze Action Plan

The experience of the haze impacts from Indonesian forest fires in 1997 has stimulated the response of the public sector. The Prime Minister (at that time) commanded the Ministry of Science, Technology and Environment to formulate the National Haze Action Plan to prepare for and mitigate the impacts from the future forest fires in the region. The Thai Committee on ASEAN Haze Mitigatioin (TAHM) was then set up and chaired by the Deputy Permanent Secretary of the Ministry of Science, Technology and Environment. The TAHM consists of the government agencies concerned, as follows:

- Royal Thai Army, Ministry of Defence
- Royal Thai Navy, Ministry of Defence
- Royal Thai Air Force, Ministry of Defence
- Public Relations Department, Office of the Prime Minister

- Bureau of the Royal Rain Making and Agricultural Aviation Division, Ministry of Agriculture and Cooperatives
- Royal Forestry Department, Ministry of Agriculture
- Department of Health, Ministry of Public Health
- Meteorological Department, Ministry of Transport and Communications
- Ministry of Foreign Affairs
- Department of Public Welfare, Ministry of Labor, Social and Welfare
- Pollution Control Department, Ministry of Science, Technology and Environment

The role of the TAHM is to formulate the plan of immediate response and to accelerate necessary actions to mitigate/minimize impacts from the ASEAN forest fires. The National Haze Action Plan has already been prepared and currently in the process for approval from the Cabinet. Actions under the Plan are activities inside the country (local action plan) as well as the potential cooperation that can be provided to other ASEAN member countries (ASEAN coordination) in case of the occurrence of the forest fires.

Local Action Plan

The activities in this regard are prepared by concerned agencies and the plan is separated into 2 portions:

a) Before the trigger of ASEAN forest fire, and
b) At the trigger of ASEAN forest fires.

The information of the local action plan is shown in Table 6-1.

Table 6-1. The National Action Plan to mitigate the impact of ASEAN forest fires

Activity	Agency
1. Set up the National Task Force on Haze Action Plan	Ministry of Public Health
2. Continuously monitoring	
- meteorological / atmospheric condition	Meteorological Department
- air quality	Pollution Control Department
- forest fire information	Ministry of Foreign Affairs
3. Information to the public	
- current status of the haze pollution problem	Office of the Prime Minister
- health advice	Ministry of Public Health
4. Provide medical assistance, equipment and advice	Ministry of Public Health
5. Rescue, and mobilize people from the high risk area, if necessary	Ministry of Defence Ministry of Labor, Social and Welfare
6. Fortify the rain making	Ministry of Agriculture
7. Air surveillance and transportation	Ministry of Transport and Communications
8. Tourist information	Office of Prime Minister Ministry of Foreign Affairs

ASEAN Coordination

In the spirit of ASEAN, Thailand through the agencies concerned, will stand by it resources to be ready upon the request of ASEAN member countries to combat forest fires in the region (Table 6-2). However, the mobilization of these resources as well as operational activities for combating against the forest fires will certainly need financial support from the countries that make a request or from some other donor countries.

Table 6-2. Stand-by resources for combating forest fires in the region *

Organization	Equipment
Royal Thai Army	2 Chinook Helicopters including equipment and crew
Royal Thai Navy	- 2 CL215 is being repaired and will be available thereafter - willing to provide aircraft 2 NOMAD to Ministry of Agriculture's missions for Rain-making
Royal Thai Air Force	C130 from the 8th unit including crew and/or G222 from 14th unit
Bureau of the Royal Making and	- 18 Experts to employ artificial rain
Agricultural Aviation Division	- Super King Aircraft used to employ artificial rain (with 1 PC set)
Royal Forestry Department	- provide tools for suppressing surface fire (swatters, rakhoe, and backpack sprayer) - provide forest fire control experts - provide training for ASEAN crew boss and fire crew, if requested
Ministry of Health and Welfare	- medicine for respiratory and irritant problems plus diarrhea - medical team
Thai Red Cross	- medicine and equipment - medical team

* The financial support will be provided by country making a request or from other donor countries

The annual programs for the activities for both local action plan and ASEAN coordination are listed as in Tables 6-3 and 6-4. The preparation of all activities will be taken during January-May. The second half of the year is the time when the southwest monsoon prevails over Thailand and thus has higher chance to be under influence of the ASEAN forest fires. This will be the period that those activities mentioned are ready to be activated, if the fires are detected or reported.

Table 6-3. Annual program and activities for the haze-proned areas in Thailand

Activity	Triggering of ASEAN forest fire											
	Before					During						
	J	F	M	A	M	J	J	A	S	O	N	D
1. Meeting for the preparation on haze					← →			←→				
2. Public announcement of the meeting outcome					← -	- →		←—	—→			
3. Continuous monitoring												
- meteorological information	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
- air quality	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
- forest fires in ASEAN	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
4. Information to the public						←—	——	——	——	——	—→	
5. Medical assistance, equipment and advice						←—	——	——	——	——	—→	
6. National Task force on Haze						←→						
7. Rescue, and mobilize people from high risk area, if needed						←—	——	——	——	——	—→	
8. Fortify the rain making	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
9. Air surveillance for transportation	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
10. Tourist information						←—	——	——	——	——	—→	

← — → : Preparation period

←——→ : Action taken, if needed

Table 6-4. Annual program and activities for forest fire fighting support upon the request from ASEAN member countries

Activity	Triggering of ASEAN forest fire											
	Before					During						
	J	F	M	A	M	J	J	A	S	O	N	D
1. Follow up the ASEAN forest fire information	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
2. Support the assistance for forest fire fighting												
- 2 Chinook Helicopter including equipments/crew	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
- 2 CL215 be available after the 1 - 2 years	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
- 2 Nomad aircraftto support the rain-making	← -	- -	- -	- -	- →	←—	——	——	——	——	—→	
- C130 including crew and / or G222						←—	——	——	——	——	—→	
- Super King aircraft for rain-making mission						←—	——	——	——	——	—→	
- Team of 18 rain making experts						←—	——	——	——	——	—→	
- Medical team, equipments and medicine						←—	——	——	——	——	—→	
- Fire fighting training for ASEAN staff	← -	- -	- -	- -	- -	- →						
- Forest fire fighting expert, if necessary						←—	——	——	——	——	—→	
- In case of emergency, 4 forest fire suppression mobile units (60 persons) with equipments						←—	——	——	——	——	—→	

← — → : Preparation period

←——→ : Action taken, if needed

ASOEN Task Force on Transboundary Haze Polllution and ASEAN Ministerial Meeting on Haze

The regional haze events of 1991 and 1994 triggered a series of regional measures towards cooperation in fire and smoke management. In 1992 and 1995 regional workshop on Transboundary Haze Pollution were held in Indonesia and Malaysia, respectively. This was followed by the establishment of a Haze Technical Task Force during the sixth meeting of the ASEAN Senior Officials on the Environment (ASOEN) in September 1995. The task force is chaired by Indonesia and comprises senior officials from Brunei Darussalam, Indonesia, Malaysia, and Singapore. The objectives of the work of the task force is to operationalize and implement the measures recommended in the ASEAN Cooperation Plan on Transboundary Pollution relating to atmospheric pollution, including particularly the problem of fire and smoke (UNECE 1998).

In December 1996 the ASEAN Institute of Forest Management (AIFM) convened the "Conference on Transboundary Pollution and its Impacts on the Sustainability of Tropical Forests" in Kuala Lumpur. At that conference, the ASEAN Fire Forum was formed which came up with a proposal for an ASEAN-wide program in fire management and research. The Fire Forum discussed, among others, the AIFM Plan of Action Regarding Forest Fire Management. That proposal dated back to 1995 and aimed to fulfil the actions required by the ASEAN Cooperation Plan. Although Canada had offered ca. 50 percent of the total costs for preparing the action plan, the proposal was not accepted by ASEAN. The plan was based on an attempt to survey the forest fire situation in the ASEAN nations. In late 1997 a part of the original core of the AIFM Action Plan was again submitted to the ASEAN nations. The proposed Fire Danger Rating System for Indonesia: An Adaptation of the Canadian Fire Behavior Prediction System is now being prepared on a cost-share basis as a joint effort between the Canadian Forest Service and ASEAN member countries (UNECE 1998).

In response to the ASEAN Environment Minister's Jakarta Declaration on Environment and Development on 18 September 1997, the Asian Development Bank (ADB) is considering the provision of funds through a Regional Technical Assistance (RETA) grant to assist ASEAN in strengthening cooperation among fire- and smoke-affected ASEAN countries in the following areas: (i) catalyzing fire and haze prevention measures, (ii) improving fire and haze prediction and monitoring, (iii) improving fire management, (iv) human resources development, (v) economic and scientific studies, and (vi) institutional support and information management.

The first two ASOEN HTTF meetings were limited to only 4 countries: Brunei Darussalam, Indonesia, Malaysia, and Singapore. The other ASEAN members, such as Thailand or Philippines, were invited to participate in the third meeting in November 1997 in Kuala Lumpur, Malaysia, to review the steps and measures undertaken in order to deal with the haze pollution affecting the region. Singapore hosted the fourth meeting and the first ASEAN Ministerial Meeting on Haze (AMMH) during December 1997. The fourth ASOEN HTTF meeting had finalized the Regional Haze Action Plan (RHAP) and the proposal for support from the Asian Development Bank, and submitted both to the AMMH on the following day. At this meeting, the ASEAN Ministers endorsed the RHAP. The Plan mainly focused on the development of 3 programs: (1) the preventive measures (Malaysia as the focal point), (2) the establishment of operational mechanisms and monitoring measures (Singapore), and (3) the strengthening of forest fire-fighting capability and other mitigating measures (Indonesia).

The fifth ASOEN HTTF meeting was held in Indonesia during January 1998 to discuss on the progress of implementation of the 3 programs in the RHAP. The meeting also discussed the proposed scope of ADB's Regional Technical Assistance project. Malaysia hosted the sixth ASOEN HTTF meeting in Kuching on 24 February 1998, followed by the second AMMH on 25 February 1998. During the second AMMH, the progress of the RHAP and ADB's technical assistance in support of the RHAP were reported. ASEAN Specialized Meteorological Center (ASMC) has also informed the Ministers of the regional meteorological forecast activity. The seventh ASOEN HTTF meeting and the third AMMH were arranged and hosted by Brunei Darussalam during 3-4 April 1998. The latest eighth ASOEN HTTF meeting and the fourth AMMH were recently arranged in Singapore during 18-19 June 1998. The detailed outcomes of the meetings are summarized in Table 6-5.

Table 6-5. Activities of ASEAN Task Force on Transboundary Haze Pollution

	Meeting	Host country	Output of the Meeting
Nov 97	3rd ASOEN HTTF Meeting	Kuala Lumpur/ Malaysia	● Review the steps and measures undertaken to deal with the haze pollution affecting the region ● Draft RHAP was approved with amendments
Dec 97	4th ASOEN HTTF Meeting & 1st AMMH	Singapore	● RHAP was finalized and endorsed ● Revised RETA project - comprised of * short term measure (3 months) * medium-term measures (12 months) - project cost of US$1.2 million * US$1.2 million comes from ADB funds * US$200,000 in kind - the scope of work was endorsed ● Each ASEAN member countries was requested to prepare its NHAP

Table 6-5. Continued.

	Meeting	Host country	Output of the Meeting
Jan 98	5th ASOEN HTTF Meeting	Indonesia	● Discussion on - the progress of implementation of the 3 programs of the RHAP - proposed scope of RETA project ● Revised format of the NHAP
Feb 98	6th ASOEN HTTF Meeting & 2nd AMMH	Kuching / Malaysia	● Singapore informed the meeting of - ASMC workshop held in Singapore Feb 9-10, 98 - the progress of the regional meteorological forecast ● WHO representatives - on the studies being undertaken to assess health impact of haze in affected ASEAN countries ● Representative of US - to address the land and forest fires and haze problems in the region - the meeting requested for the active US assistance, particularly in strengthening the fire fighting capabilities of the region
APR 98	7th ASOEN HTTF Meeting & 3rd AMMH	Bandar Seri Begawan / Brunei Darussalam	● Review the progress of the NHAP - ASEAN Workshop on NHAP tentatively be scheduled in Indonesia during the end of April 98 - ASMC Intranet was able to be accessed by 14 users of the ASEAN members - list of additional resources for fire fighting requiring international assistance ● RETA project - Letter of agreement between ASEAN and ADB for TA be confirmed by ASEAN Secretary-General - establishment of the PMU at the Secretariat and recruitment of the project team and project implementation arrangements ● Sub-Regional Fire-fighting Set-up (RFS) ● US SAEI - allocated / earmarked 4 million US dollars funding in 4 areas - the meeting recommended that the assistance should focused on the immediate needs for strengthening fire fighting capacities of the region, in addition to the long term monitoring and modeling activities ● The meeting agreed UNEP to play a leading role in coordinating international assistance to combat and control regional fires and haze on behalf of ASEAN

Table 6-5. Continued.

	Meeting	Host country	Output of the Meeting
June 98	8th ASOEN HTTF Meeting & 4th AMMH	Singapore	

HTTF: Haze Technical Task Force
AMMH: ASEAN Ministerial Meeting on Haze
RHAP: Regional haze action Plan
NHAP: National Haze Action Plan
RETA: ADBís Regional Technical Assistance
ASMC: ASEAN Specialized Meteorological Center
PMU: Project Management Unit
US/SAEI: US State Department on a new Southeast Asian Environmental Initiative

7 Conclusions and Recommendations

Kanchanasak Phonboon

Widespread uncontrolled forest fires, which originated from agricultural land clearing, occurred since July 1997 in several major islands of Indonesia, under the abnormally dry conditions from the 1997-98 El Niño/Southern Oscillation (ENSO) episode. The fires sent thick smoke haze across the sky of most countries in the region–Malaysia, Indonesia, Singapore, Brunei, southern Thailand and parts of the Philippines in September 1997. Indonesia and Malaysia had to declare a state of national emergency in the same month.

The root cause of the problem here is **not haze** but **uncontrolled forest fires** due to shortcomings of proper forest management and practice. This phenomenon is still very common in some Southeast Asia countries, including Thailand. To effectively address this issue in the broader context of sound forest management remains really difficult. However, there is no other easy way. The 1997 haze confirmed its large-scale and huge impacts on environment, economy, health, and society, when good forest management failed.

Uncontrolled forest fires from Indonesia under favorable meteorological condition resulted in rapid air quality deterioration over South-East Asia region. The transboundary transport of smoke caused the haze effects not only in Indonesia, but also all over the Malayan peninsular in 1997. The spreading of the smoke to the peninsular, including the southern Thailand, was helped by the prevailing synoptic scale winds, as indicated by the low-level southerly wind circulation. During the day with high PM_{10} in September 1997, wind speeds were very weak and helped in accumulating high particles levels.

The 1997 haze has proved once again that improper land clearing practice of human, compounded by the El Niño climatic factors, could still produce a large-scale air pollution episode. In Thailand, the air pollution episode occurred in 2 peaks in rather short period. Fine particulate matter was the main pollutant in this event, other air pollution generally remained low. The first peak of this episode occurred between 22-29 September with a maximum during 24-25 September, followed by the lower second peak during 6-8 October 1997. The highest 24-hour average PM_{10} observed was 218 $\mu g/m^3$ on 26 September 1997 in Hat Yai. At this level, it is 4-5 times higher than normal air quality in the region.

Compared to forest fires in other continents in the past, the 1997 haze from Indonesia was unique. Because of its wide coverage of densely populated area in South-East Asia region, almost 100 million population in 5 countries were exposed to the smoke. With a large number of populations at risk, its impact on health could be readily observed. Retrospective data in the south showed elevated and widespread short-term respiratory health effects in the same period. In relatively clean areas, an air pollution episode from abrupt rising of moderate levels particles can still have major impacts upon health. At the regional level, a substantial increase in respiratory morbidity of both OPD visits and IPD admissions was observed in southern Thailand. The increases were significant for all respiratory visits and for almost all categories of respiratory admissions: pneumonia, bronchitis/COPD, and asthma. At the rising levels of fine particles, the net health impacts from the 1997 haze are estimated as 8% and 7% increases in respiratory visits and admissions, respectively. At the city level, the health impact estimate from the 1997 haze is 7% increase in respiratory OPD visits. However, the increases were significant only for all respiratory visits and bronchitis/COPD admissions. The significant effect of the haze in terms of daily PM_{10} (for each 1 $\mu g/m^3$) was 0.2 deviation from daily average for both all respiratory and URTI visits.

The PM_{10} levels in this haze episode (200+ $\mu g/m^3$, 24-hour average) are about twice that of the national ambient air quality standards of Thailand (120 $\mu g/m^3$), and 4-5 times higher than normal air quality in the region. At this low to lower-moderate increase, the health effects can be clearly and readily observed in large population, as demonstrated in the regional level. However, the effects may be less likely or more difficult to be detected in smaller area, such as characterized in Hat Yai City. Pooling data from several cities may be needed in evaluation of health impacts.

The 1997 haze is one of the great large-scale forest fires and transboundary spreading of air pollution. Activities and mitigation or prevention measures during the haze event reflect early experience of widespread forest fires for Thailand and other ASEAN countries. Looking back, we can learn much from the past experience and mistakes with the 1997 haze.

The attempt on source control proved difficult. Especially in the case of transboundary transport of haze, when the source was in Indonesia but the effects were felt in other countries. National efforts as well as international or regional cooperation and actions were too late and modest compared to the magnitude of the fires. It took almost 6 months before most of the fires subsided at the end of 1997.

Health risk communication and public advice on personal protective measures, within the framework of inter-agency coordination, were applied in most ASEAN countries including Thailand. These measures cover suggestions for susceptible population groups (asthmatics and chronic bronchitics, elderly, infants and children, persons with underlying lung or heart disease, and smokers) and general population. They include avoiding strenuous activities and smoking, staying indoors, drinking clean water and to temporary refrain from rainwater, seeking care when having symptoms or attacks, and wearing protective masks outdoors in severe haze. Because of poor visibility during the haze event, an emphasis on traffic accident awareness and prevention is also included.

Some measures taken during the haze may be inadequate or inappropriate. There are limitations and some measures recommended may not be fully justified based on the best available knowledge. As described in an earlier WHO publication (WHO 1992a) and the haze mission report (Brauer 1997), there are not yet clear answers to several prescribed mitigation/protective measures and more research is clearly needed. Who are actually the sensitive population groups? How many are they? Do asthmatics or chronic bronchitics need prophylactic medication before or during the haze event? Are protective masks for the general public really effective? Are there benefits of staying indoors? How much is the difference between indoor and outdoor pollution levels? Other appropriate measures such as the use of public shelter or public place during the haze need investigation.

Future actions and recommendations have to answer the question of how we can better prevent and prepare for future haze event. The primary focus should be on prevention. That is the integrative and region-wide approach of medium-, and long-term measures towards the real solution–sound forest management. Measures to control forest fires need to be strengthened, including regulation, incentives and enforcement, and fire control operation. Companion measures of community participation and public education on the serious health and socio-economic impacts of uncontrolled forest fires, NGOs involvement, and inter-sectoral cooperation are necessary. Regional agreement and cooperation have been initiated in ASEAN countries. It remains to be seen how these concerted efforts will help reduce this problem in South-East Asia region.

For preparedness, recommendations on immediate haze-related activities in many fronts are fully needed in order to protect health and quality of life. Rapid detection capability of uncontrolled forest fires using available and advance monitoring system needs to be established. Development of national environment and health response plans has to be set up. The plan includes establishing air quality and meteorology early warning system, stock of emergency supplies and equipment, and health surveillance based on existing data. During the haze, ongoing collection of these data is also useful activity as feedback to health risk communication and adjusting proper public measures.

REFERENCES

Anderson HR, Limb ES, et al. Health effects of air pollution episode in London, December 1991. Thorax 1995;50:1188-1193.

Andrae M, Browell E, et al. Biomass burning emissions and associated haze layers over Amazonia. J Geophysical Res 1988;93 (D2):1509-1527.

Armstrong JR, Campbell H. Indoor air pollution exposure and lower respiratory infections in young Gambian children. Int J Epidemiol 1991;20:424-429.

Betchley C, Koenig J, et al. Pulmonary function and respiratory symptoms in forest firefighters. Am J Ind Med 1997;31:503-509.

Boubel RW, Fox DL, Turner DB, Stern AC. Fundamentals of Air Pollution. 3rd ed. New York: Academic Press, 1994.

Brauer M, Bartlett K, et al. Assessment of particulate concentrations from domestic biomass combustion in rural Mexico. Environ Sci Technol 1996;30:104-109.

Brauer M. Assessment of health implications of haze in Malaysia. Mission Report. 5 November 1997. Manila: WHO Regional Office for the Western Pacific, 1997.

Brauer M. Health impacts of biomass air pollution. Report prepared for the Bi-Regional workshop on health impacts of haze-related air pollution, Kuala Lumpur, Malaysia, 1-4 June 1998. Manila: WHO Regional Office for the Western Pacific, 1998.

Brotherhood J, Budd G, et al. Fire fighters' exposure to carbon monoxide during Australian bushfires. Am J Ind Hyg Assoc 1990;51:234-240.

Charupat T. Using LANDSAT Imagery for Monitoring the Changes of Forest Area in Thailand. Forest Resources Assessment Division, Forest Research Office, Royal Forest Department. Bangkok: Royal Forest Department, 1997. (in Thai)

Chew F, Ooi B, et al. Singapore's haze and acute asthma in children. The Lancet 1995;346:1427.

Chunkao K, Kurat P, Boonyawat S, Dhammanoncha P, Panburana N. Soil and water losses from Mae-Huad Forest in Lampang. Kog-Ma WS Res Bul No.28, Faculty of Forestry. Bangkok: Kasetsart University, 1976. (in Thai with English Abstract and Tables)

Collings D, Sithole S, et al. Indoor woodsmoke pollution causing lower respiratory disease in children. Trop Doct 1990;20:151-155.

Copper C, Mira M, et al. Acute exacerbations of asthma and bushfires. The Lancet 1994;343:1509.

DANIDA. Tree improvement and seed supply in Thailand. Report prepared by a Joint Thai/DANIDA Review Mission. Copenhagen: DANIDA, 1990.

Data Center. Forestry Statistics of Thailand 1996. Information Office, Royal Forest Department. Bangkok: Royal Forest Department, 1997.

Dennis R, Maldonado D, et al. Woodsmoke exposure and risk for obstructive airways disease among women. Chest 1996;109:115-119.

Duclos P, Sanderson L, et al. The 1987 forest fire disaster in California: assessment of emergency room visits. Arch Environ Health 1990;45:53-58.

Echalar F, Gaudichet A, et al. Aerosol emission by tropical forest and savanna biomass burning: characteristics trace elements and fluxes. Geophysical Res Letters 1995;22:3039-3042.

Ellegard A. Cooking fuel smoke and respiratory symptoms among women in low-income areas in Maputo. Environ Health Perspect 1996;104:980-985.

ESCAP. State of the Environment in Asia and the Pacific 1995. ST/ESCAP/1585. Asian Development Bank and the United Nations Economic and Social Commission for Asia and the Pacific, New York, 1995

Fairley D. The relationship of daily mortality to suspended particulates in Santa Clara County, 1980-86. Environ Health Perspect 1990;89:159-168.

FAO. Present and future forest policy goal: a timber trends study 1970-2000. Report to the Government of Thailand. FAO No.TA 3156. Rome: FAO, 1972.

Griffith J. Applied Climatology: An Introduction. London: Oxford University Press, 1966.

Hagler Bailly. Draft Final Report, Health Effects of Particulate Matter Air Pollution in Bangkok. Hagler Bailly, 1997.

Kaitpraneet S, Tangtham N, Saengtongpraew S, et al. Forest fire and its effect on forest system in Thailand. Reported submitted to the National Economic and Social Development Board. Faculty of Forestry. Bangkok: Kasetsart University, 1990. (in Thai with English summary)

Kanawanich S. When the fires die down. Perspective p.1. Bangkok Post, Sunday, August 9, 1998.

Kanawanich S. Laws for the forests. Perspective p.6. Bangkok Post, Sunday, August 9, 1998.

Larson TV, Koenig JQ. Wood smoke: emissions and noncancer respiratory effects. Annu Rev Public Health 1994;15:133-156.

Letts D, Fidler A, et al. Health Hazard Evaluation Report No. HETA-91-152-2140. US Department of Interior, National Park Service, Southern California; US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, 1991.

Lipsett M, Hurley S, et al. Air pollution and emergency room visits for asthma in Santa Clara County, California. Environ Health Perspect 1997;105:216-222.

Liu D, Tager IB, et al. The effects of smoke inhalation in lung function and airway responsiveness in wildland fire fighters. Am Rev Respir Dis 1992;146:1469-1473.

Long W, Tate RB, et al. Respiratory symptoms in a susceptible population due to burning of agricultural residue. Chest 1998;113:351-357.

Materna B, Jeffrey RJ, et al. Occupational exposures in California wildland fire fighting. Am J Ind Hyg Assoc 1992;53:69-76.

Ministry of Interior. Local Administration Information. Department of Local Administration. Bangkok: Ministry of Interior, 1997.

Ministry of Health. Mortality and Morbidity during the London Fog of December 1952. Report No. 95. London: Her Majestyís Stationery Office, 1954.

Ministry of Public Health. Health in Thailand 1995-1996. Bureau of Health Policy and Plan. Bangkok: Ministry of Public Health, 1997.

Ministry of Science, Technology and Environment. Handbook for Air Quality and Noise Management Division, Pollution Control Department. Bangkok: Ministry of Science, Technology and Environment, 1995.

Ministry of Transport and Communications. Meteorological observation stations network. Meteorological Department. Bangkok: Ministry of Transport and Communications, 1997.

Mungkorndin S, Eadkeo K. Forestry in Thailand. Occasional Paper. Faculty of Forestry. Bangkok: Kasetsart University, 1978.

Nieuwolt S. Climate of South-east Asia. In: Takahashi K, Arakawa H, eds. Climates of Southern and Western Asia. London: Elsevier Science, 1981.

Office of the Prime Minister. Thailand in the 90s. Bangkok: Office of the Prime Minister, Royal Thai Government, 1995.

Ostro B, Lipsett M, et al. Indoor air pollution and asthma: results from a panel study. Am J Respir Crit Care Med 1994;149:1400-1406.

Panayotou T, Parasuk C. Land and forest. Projecting demand and managing encroachment. The TDRI Year-End Conference "Industrializing Thailand and Its Impact on the Environment". 8-9 December 1990. Bangkok: Thailand Development Research Institute, 1990.

Panayotou T, Sungsuwan S. An Economic study of the causes of tropical deforestation: the case of Northern Thailand. Development Discussion Paper No.284. Harvard Institute of Economic Development, Harvard University, 1989.

Pannakaphitak W, Maneerat B, Plodpleaw A. Estimation of economic loss of forest fires. Research Note. Forest Fire Control Section, Division of Forest Management, Royal Forest Department. Bangkok: Royal Forest Department, 1991. (in Thai)

Perez-Padilla R, Regalado J, et al. Exposure to biomass smoke and chronic airway disease in Mexican women. Am J Respir Crit Care Med 1996;154:701-706.

Radian International. Draft Final Report, PM Abatement Strategy for the Bangkok Metropolitan Area. Radian International, 1997.

Ramage CS. Forecaster's Guide to Tropical Meteorology: AWS TR240 Updated. AWS/TR-95/001. Illinois: Air Weather Service, 1995.

Reh C, Letts D, et al. Health Hazard Evaluation Report No. HETA-90-0365-2314. US Department of Interior, National Park Service, Yosemite National Park, California; US Department of Health and Human Services, Public

Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, 1994.

Reinhardt T, Ottmar R. Smoke exposure among wildland firefighters: a review and discussion of current literature. US Department of Agriculture, Forest Service. Pacific Northwest Research Station, Portland, 1997.

RFD/OPRE. National forests, plantations and tree improvement programs in Thailand. Division of Silviculture, Royal Forest Department. Bangkok: Royal Forest Department, 1988

Robin L, Less P, et al. Wood-burning stoves and lower respiratory illness in Navajo children. Pediatr Infect Dis J 1996;15:859-865.

Rogge W, Hildemann L, et al. Sources of fine organic aerosol. 9. Pine, oak, and synthetic log combustion in residential fireplaces. Environ Sci Technol 1998;32:13-22.

Rothman N, Ford D, et al. Pulmonary function and respiratory symptoms in wildland firefighters. J Occup Med 1991;33:1163-1167.

Sandberg D, Martin R. Particle sizes in slash fire smoke. US Department of Agriculture, Forest Service. Pacific Northwest Research Station, Portland, 1975.

Serra A, Mocci F, et al. Pulmonary function in Sardinian fire fighters. Am J Ind Med 1996;30:78-82.

Singapore Meteorological Service. Smoke haze over Singapore, Malaysia, and Indonesia. WMO Bulletin 1995;24:147-150.

Smith K. Fuel combustion, air pollution exposure and health: the situation in developing countries. Annu Rev Energy Environ 1993;18:529-566.

Smith K, Liu Y. Indoor air pollution in developing countries. In: Epidemiology of Lung Cancer, Samet J, ed. New York: Marcel Dekker, 1993.

Smith M, Jalaludin B, et al. Asthma presentations to emergency departments in western Sydney during the January 1994 bushfires. Int J Epidemiol 1996;25:1227-1236.

Smitinand T. Vegetation and ground cover of Thailand. Technical Paper No.1 Department of Forest Biology, Faculty of Forestry. Bangkok: Kasetsart University, 1977.

Tangtham N. Soil erosion problem in teak plantation. Proceedings of Seminar on "Fifty Year-Huay-Tak Teak Plantation" to celebrate the 60-year Queen's

Birthday Anniversary, Lampang, 5-8 August 1992. RFD/ FIO/Thai Plywood/ Faculty of Forestry/JICA. Bangkok: Royal Forest Department, 1992. (in Thai with English Abstract, Tables and Figures)

TFSMP Core Team. Thai Forestry Sector Master Plan, Vol.5: Subsectoral plan for people and forestry environment. 16H-4071-Vjpt-20, THA/88/R51. Bangkok: Royal Forest Department, 1993a.

TFSMP Core Team. Thai Forestry Sector Master Plan, Vol. 6: Subsectoral plan for production and utilization. 16H-4071-Vjpt-20, THA/88/R51. Bangkok: Royal Forest Department, 1993b.

Tongpan S, Panayotou T, Jetanavanish S, Faichampa K, Mehl C. Deforestation and poverty: Can commercial and social forestry break the vicious circle? The TDRI Year-End Conference "Industrializing Thailand and Its Impact on the Environment". 8-9 December 1990. Bangkok: Thailand Development Research Institute, 1990.

UNCEC. International Forest Fire News. No. 18 January 1998. Joint FAO/ ECE/ILO Committee on Forest Technology, Management and Training. Geneva: United Nations Economic Commission for Europe, 1998.

UNEP/WHO. City Air Quality Trends (GEMS/Air Data). Vol. 1-3. Geneva: World Health Organization, 1992-1995.

Wafula E, Onyango F, et al. Indoor air pollution in a Kenyan village. East Afr Med J 1990;67:24-32.

Ward D, Hardy C. Smoke emissions from wildland fires. Environ Int 1991;17:117-34.

WHO Regional Office for Europe. Acute Effects on Health of Smog Episodes. WHO Regional Publications, European Series No. 43. Copenhagen: WHO Regional Office for Europe, 1992a.

WHO. International Statistical Classification of Diseases and related Health Problems. ICD-10. Tenth Revision. Geneva: World Health Organization, 1992b.

Wichmann HE, Mueller W, et al. Health effects during a smog episode in West Germany in 1985. Environ Health Perspect 1989;79:89-99.

Wilson R, Spengler J, eds. Particles in Our Air. Concentrations and Health Effects. Cambridge: Harvard University Press, 1996.

WMO. Guide to Meteorological Instruments and Methods of Observation. WMO No.8, 6th ed. Geneva: World Meteorological Organization, 1996.