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Atmospheric pollutants in Chiang Mai (Thailand) over a five-year period (2005–2009), their possible sources and relation to air mass movement

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HIGHLIGHTS

- 5-year situation of atmospheric pollutants in Chiang Mai, Thailand was analyzed.
- Ammonium from agriculture and sulfate from fuel combustion were the major ions.
- Major air mass approaching Chiang Mai came from southwest direction.
- Long range transport and local emission play important role on air pollution.
- Haze phenomenon in dry season was related with open burning.

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ABSTRACT

Monitoring and analysis of the chemical composition of air pollutants were conducted over a five-year period (2005–2009) in the sub-urban area of Chiang Mai, Thailand. This study aims to determine the seasonal variation of atmospheric ion species and gases, examine their correlations, identify possible sources and assess major air-flow patterns to the receptor. The dominant gas and particulate pollutants were NH_3 (43–58%) and SO_4^{2-} (39–48%), respectively. The annual mean concentrations of NH_3 ($\mu g\ m^{-3}$) in descending order were 4.08 (2009) > 3.32 (2007) > 2.68 (2008) > 2.47 (2006) and 1.87 (2005), while those of SO_4^{2-} ($\mu g\ m^{-3}$) were 2.60 (2007) > 2.20 (2006) > 1.95 (2009) > 1.75 (2008) and 1.26 (2005). Concentrations of particulate ions were analyzed by principle component analysis to find out the possible sources of air pollutants in this area. The first component of each year had a high loading of SO_4^{2-} and NH_4^+, which probably came from fuel combustion and agricultural activity, respectively. K^+, a tracer of biomass burning, also contributed to the first or the second components of each year. Concentrations of NH_4^+ and SO_4^{2-} were well correlated ($r > 0.777$, $p < 0.01$), which lead to the conclusion that $(NH_4)_2SO_4$ was a major compound present in this area. The 3-day backward trajectories of air mass arriving at Chiang Mai from 2005 to 2009 were analyzed using the hybrid single particle langrangian integrated trajectory (HYSPLIT) model and grouped by cluster analysis. The air mass data was analyzed for the dry season ($n = 18$; 100%). The trajectory of air mass in 2005 mainly originated locally (67%). In 2006, the recorded data showed that 56% of air mass was emitted from the western continental region of Thailand. In 2007, the percent ratios from the western and eastern continental areas were equal (39%). In 2008, 67% originated from the western continental area. In 2009, the recorded air mass mainly came from the western continental area (72%). In conclusion, the major trajectories of air mass from 2006 to 2009 originated from the southwest direction of the receptor, but in 2005, the air mass appeared to be locally originated.

1. Introduction

Emissions of air pollutants in the Asian region are increasing rapidly (Higashino et al., 1997; Balasubramanian et al., 1999), resulting from large concentrated populations, rapidly growing economies, and the associated systems of energy consumption and production in the close proximity of many of the major industrial

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and urban centers (e.g. Tokyo, Seoul, Hong Kong, Bangkok, Kuala Lumpur, Singapore, and Jakarta). Biomass burning is usually composed of four types: grassland fires, forest fires, the field burning of crop residues and domestic biofuel combustion (Yan et al., 2006). In this study, only forest fires and the burning of crop residues, which are the major sources of air pollutants in Southeast Asia, were considered. These activities resulted in the haze phenomenon, which is a serious problem regularly occurring in the dry season of almost every year in this region.

Aerosol particles emitted from human activities can cause serious problem worldwide. Pyrogenic aerosols consist predominantly of carbonaceous material with a minor component of various inorganic materials (Andreae et al., 2004). The inorganic component is made up of some insoluble dust and ash material, and soluble salts, in which potassium, ammonium, sulfate and nitrate are the most important species (Fuzzi et al., 2007).

Air quality has become a major concern and has been steadily deteriorating over the past ten years in Chiang Mai, Thailand. The city of Chiang Mai covers an area of approximately 20,107 km^2 and is the country's second largest province. The geographical features of Chiang Mai City are that it is situated in a natural basin and is surrounded by high mountain ranges. Anthropogenic activities, including ever-increasing vehicle emissions, as well as wholesale biomass burning, including forest fires, are the main contributions to the critical levels of air pollutants in Chiang Mai City. Chiang Mai, as well as some provinces in the northern part of Thailand, annually faces critical levels of air pollution during the dry season. Recently, the problem has become worse than ever (Pengchai et al., 2009).

Godish (1997) reported that, without evidence to the contrary, it was widely believed that once polluted air was transported for some distance downwind, the enormity of the atmosphere and dilution processes associated with it reduced pollutants to background levels. However, elevated levels of pollutants may occur hundreds to thousands of kilometers downwind of large point sources and areas producing urban plumes. This phenomenon is known as long-range transport. Long-range transport is a significant factor in producing Arctic haze and exacerbating the problems of acidic deposition. The knowledge of possible long-range transport contribution will help shed understanding on the nature of air pollution at a given location, in order to formulate optimal abatement strategies. However, difficulties may arise when attempting to quantify this long-range transport contribution and to identify its source regions (Pongkiatkul and Kim Oanh, 2007). A simple back-trajectory model is normally applied to track the origin of air masses (Stein et al., 2000; Zeng et al., 2003). The Hybrid Single-Particle Langrangian Integrated Trajectory model Version 4 (HYSPLIT4) is a useful air trajectory model, which is widely applied for long-range transport studies (Draxler and Hess, 1997).

The aims of this study are therefore: (i) to determine seasonal variations of particulate ions and gases over a 5-year period (2005–2009), (ii) to examine the correlation of ion compositions, (iii) to identify possible sources of air pollutants in this area, and (iv) to consider the direction of air mass back-trajectories over 5 years to assess dominant flow patterns.

2. Experiment

2.1. Sampling site

The sampling site was located at the meteorological station in the area of Mae Hia Research Center, Chiang Mai University, Muang District, Chiang Mai Province, Thailand. This station was located at 98° 55′ 54.3″ E and 18° 45′ 40.3″ N. Its elevation was 334 m above sea level. The sampling site has been classified by the Acid Deposition Monitoring Network in East Asia (2000) criteria as a rural site, ever since the year 2000. However, due to the rapid rate

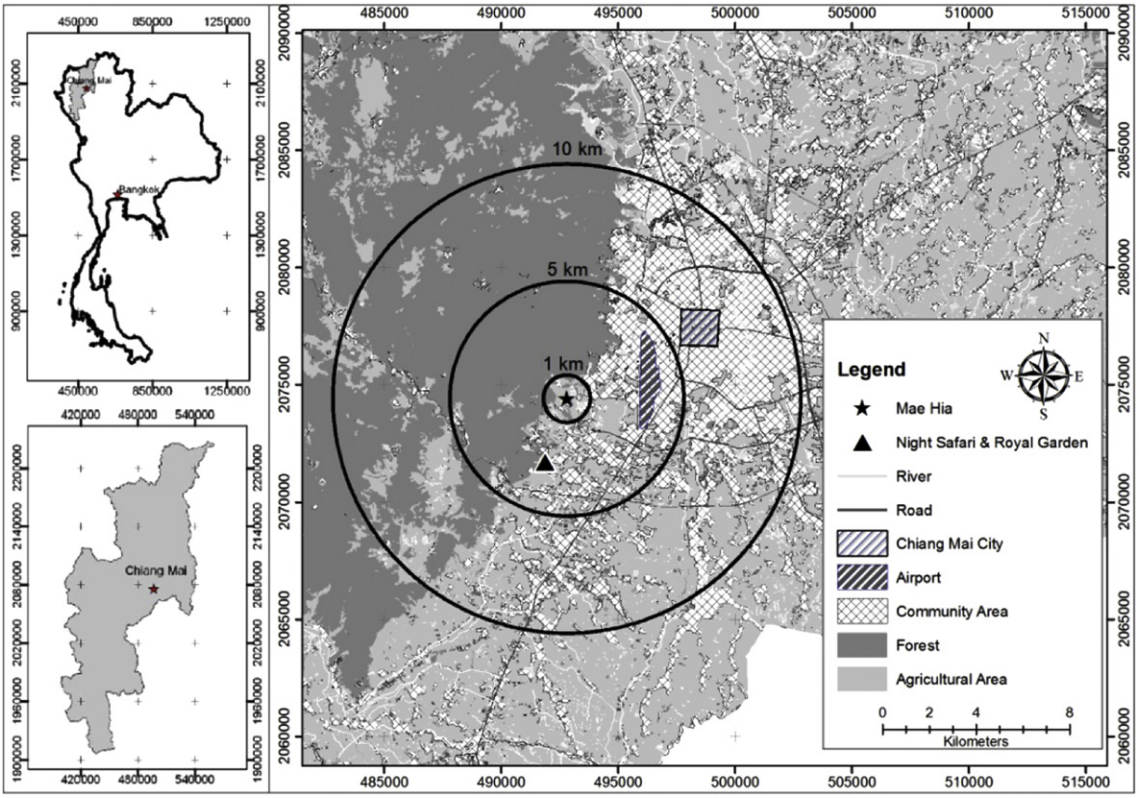

Fig. 1. Land use profile of Mae Hia Research Center, Chiang Mai City.