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Meteorological factors affecting lower tropospheric ozone mixing ratios in Bangkok, Thailand

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ABSTRACT

This paper examines the influence of meteorological conditions in ozone mixing ratio measured at the Thai Meteorological Department (TMD) in Bangkok, Thailand. In addition to surface wind speed and direction, surface ozone concentrations, ozonesondes and CALIPSO Lidar images were collected during the study period extending from 01/01/2014 to 30/04/2015. Surface ozone concentrations show a strong seasonality, with maximum in the dry months of December to April and minimum during the wet southwest (SW) monsoon period extending from May to October. High ozone concentrations are related to biomass burning in the northeast highland regions of the country and neighboring Myanmar and southern China. These precursors travel in a southerly direction towards Bangkok in a well-defined aerosol layer which may be at ground level or at elevated heights. The growth of the daytime mixed layer scavenges some of the upper level aerosols, although local maxima in ozone concentrations at 1–2 km are a frequent feature at Bangkok. There is an evidence of fumigation in the Gulf of Thailand and a return flow via the southerly sea breezes.

1. Introduction

Atmospheric ozone is an important factor in stratospheric absorption of ultraviolet radiation (IPCC, 2007), but in the troposphere it is a pollutant linked to a range of illnesses such as cardiovascular diseases, strokes and respiratory problems (Zanobetti et al., 2010). In southern Asia, a range of ozone precursors such as motor vehicle emissions, industrial emissions and biomass burning, combines to produce high levels of tropospheric ozone. Typically, the large megacity of Bangkok has levels of tropospheric ozone often exceeding the one hour standard (Zhang and Kim Oanh, 2002; CAI-ASIA, 2009; Zhu et al., 2012).

Much of the research in southern Asia focuses on the relationship between high ozone concentrations and a range of environmental factors such as solar radiation and seasonal variability (Elampari and Chithambarathanu, 2011) and the photolytic cycle (Nishanth and Kumar, 2011). Other studies use backward trajectory analysis with ozone measurements to study long-range transport of precursors released by biomass burning episodes, these having been found to affect tropospheric and boundary layer concentrations at considerable distances downstream (Sahu et al., 2013a, 2013b). Within the Bangkok Metropolitan Region (BMR), Zhang and Kim Oanh (2002) found that local emissions and photochemistry are responsible for high ozone episodes and that high ozone levels were found downstream of the city centre, assuming the northeast/east wind direction.

Despite the considerable progress made as outlined above, there is need for a better understanding of the basic wind flow and temperature structure associated with ozone concentrations. Measurements of ozone are a result of complex reactions involving photolytic source terms, as well as vertical and horizontal transport. In particular, there is need to assess the relative importance of the various precursor mechanisms which include local sources (industries, incinerator emissions, open fires), mobile sources (motor vehicles) and advective transport into the region from biomass burning episodes located at a considerable distance upstream from Bangkok. Ideally a comprehensive measurement and modelling programme would be required to accomplish these tasks, but it is beyond the scope of this study. As an alternative and as a preliminary study, we have chosen to examine measurements of ozone levels in the lower troposphere and relevant meteorological factors at the Thai Meteorological Department (TMD) located in Bangkok. In the analysis, we examine ozone, air temperature and wind speed profiles at the site as well as surface O_3, NO_2, CO and wind speed and direction. These data are also supplemented by Lidar backscatter images for the region, backward trajectory analysis and satellite data on biomass burning.

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In Section 2 of this manuscript, we describe the site characteristics, instrumentation and measurement programme. Section 3 presents seasonal variation, and Section 4 discusses factors relevant to ozone concentrations. Section 5 summarises the various meteorological factors involved in high O_3 measurements at the study site, and the conclusions are presented in Section 6.

2. Methodology

2.1. Site characteristics

The BMR encompasses Bangkok and five surrounding provinces including Samut Prakan, Nonthaburi, Pathumthani, Nakhon Pathom and Samut Sakhon (Fig. 1). It is located in the Chao Phraya River Basin with a total area of 7762 km^2 and with a population of 10.1 million (Zhu et al., 2012). The motor vehicle is a major source of air pollution, although other sources such as power plants, industries, incinerators and biomass/residue burning also contribute to frequent episodes of poor air quality. Table 1 provides a source inventory for the BMR, showing that volatile organic compound (VOC) and Nitrogen oxides (NO_x), two important ozone precursors, are mainly emitted from motor vehicles. However, sources transported into the region are not taken into account.

The climate of the region is subject to the northeast (NE) monsoon dominated by NE winds which extend from November to February and which brings dry conditions, light winds and poor air quality to these winter months. The southwest (SW) monsoon is associated with warm, humid and unstable air masses from the Indian Ocean and South China Sea from May to October. There is considerable precipitation during these months and an improvement in air quality compared to the winter months (Janjai et al., 2014, 2015).

Table 1
Estimating emissions of air pollutants for Bangkok in 1997. Source: PCD (2000), and adapted from Zhang and Kim Oanh (2002).

Pollutants	Emission loads (tons/year)			
	Point source	Mobile source	Area source	Total
NO_x	6553	164,737	6434	177,724
CO	909	249,320	4467	254,696
VOC	382	171,086	8468	179,936

In this work, the study site is located at the TMD (13° 39′ 58.57″ N, 100° 36′ 21.44″ E, 2 m msl) in southern Bangkok (Fig. 1). It is surrounded by industries to the southeast and north, and several traffic highways.

2.2. Instrumentation and data acquisition

The study encompassed the period 01/01/2014 to 30/04/2015. Data collected are shown in Table 2. All meteorological and air quality data on-site with the exception of those collected with the ozonesonde, were provided courtesy of the TMD and Pollution Control Department (PCD). The ozonesondes (Electrochemical

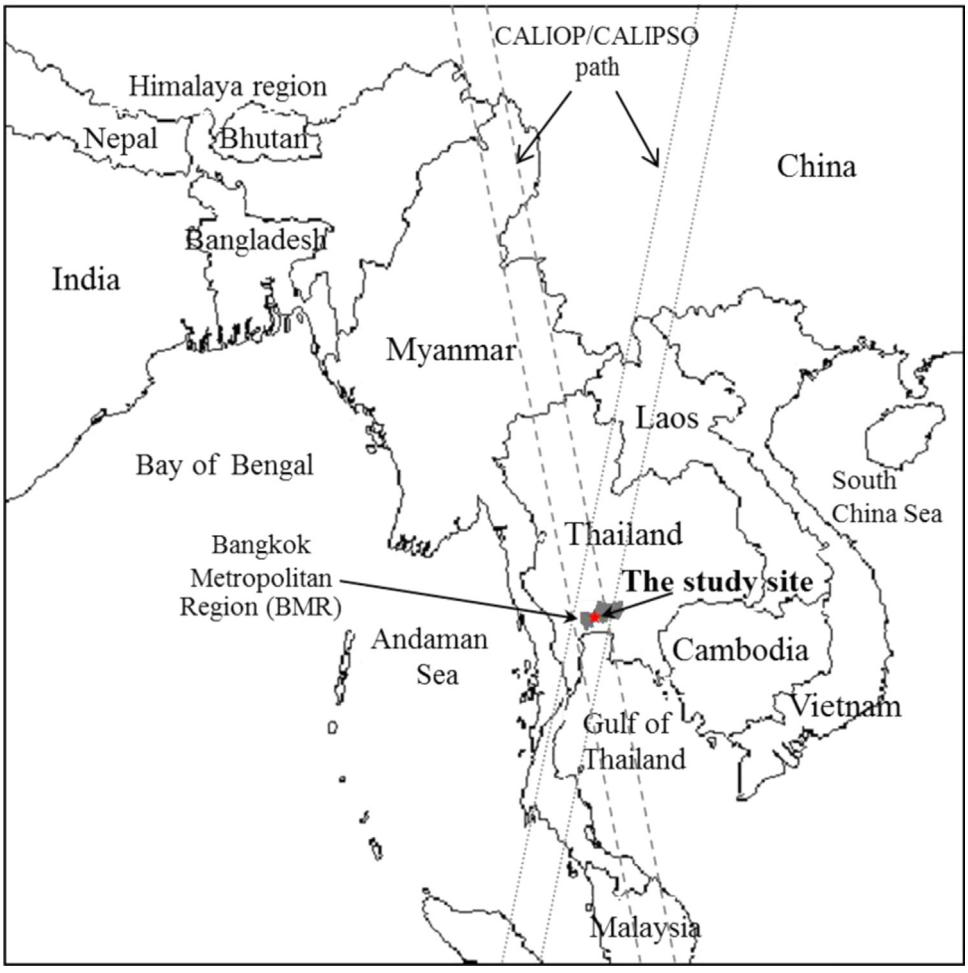

Fig. 1. Map of Thailand indicating the location of the study site which is located at the headquarter of the Thai Meteorological Department and the path of the CALIOP Lidar instrument of CALIPSO, which are marked by dash line (daytime) and dot line (nighttime).