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Assessment of acid deposition over Dhaka division using CAMx–MM5 modeling system

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ABSTRACT

This study provided an insight into the complex phenomenon of acid deposition over Dhaka division of Bangladesh. The 10– day HYSPLIT back trajectories showed that majority of air masses arriving to Bangladesh were originated from the west. The gridded emissions (0.055° or ~5.5 km) for Dhaka division was prepared for 2006 by updating a preliminary emission inventory (EI) available for 2000 and by conducting a new EI for two major source categories, brick kilns and traffic. In Dhaka division as of 2006, the brick kilns contributed the largest SO_2 emission (about 70%), while residential emissions had the highest share of CO and PM_{10} (over 60%) and substantial NMVOC (about 40%). Emission rates of SO_2 and NO_x in the dry season of 355 t/d and 183 t/d, respectively, were higher than the corresponding rates in the wet season of 60 t/d and 146 t/d, which was mainly due to the operation of brick kilns in the dry season. The acid deposition was simulated, using CAMx–MM5 model, for December and June to represent the dry and wet seasons, respectively. Model performance was reasonable considering the simulated spatial distribution of acid deposition with simulated wind and precipitation fields. The model results for SO_2 and NO_x concentrations were in the same ranges of the limited monitoring data available. However, the acid deposition simulation was still largely experimental due to the lack of acid deposition monitoring data for the model evaluation. The preliminary acid deposition simulation results suggested that the nitrogen wet deposition was the major contributor over the Dhaka division that could be the reason of exceeding the critical load for the local ecosystem. Further research is still required to refine the emission inventory and to gather the monitoring data to confirm the modeling results.

Keywords:
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1. Introduction

Once released, air pollutants, such as SO_x and NO_x, are transported over long distances. During their atmospheric residence time, they can be transformed to form new pollutants. They may be deposited from the atmosphere as dry or wet particles or as vapors causing acidifying effects on the earth surface. This phenomenon is known as acid deposition, which incorporates both wet (with precipitation) and dry deposition to the earth surface (ISU, 2006).

The impact of acid deposition on an ecosystem depends on its assimilation capacity of the excess acidity, usually caused by NO_3^- and SO_4^{2-}, which in turn, depends on the components of the ecosystem (IIASA, 1994). The level of sensitivity of an area to acid deposition is usually indicated by biotic communities (Kuylenstierna and Chadwick, 1989). An ecosystem can tolerate the acid deposition as long as it is below the critical deposition load, i.e., the level that would not cause chemical changes leading to long–term harmful effects on essential ecosystem properties (Kamari, 1989).

Bangladesh has a population of 150 millions (BBS, 2008) and an agriculture based economy. Air pollution is a serious issue of concern in the country. Multiple sources, such as vehicles, industries, open biomass burning, etc., release a large amounts of particulate matter (PM) and toxic gases into the atmosphere. In addition, the country may also receive the Long–Range Transport (LRT) air pollution that is originated in upwind countries and arrived into the country following the prevalent monsoons. Thus, acid precursor emissions from both the local and regional sources may cause the acid deposition in the country (IIASA, 1994; Hicks et al., 2008). This may affect especially central part of Bangladesh where soil is of acidic nature (SRDI, 2008) and would harm the agricultural crops, the main product of the country. However, at present there is no adequate quantitative information on the potential acid deposition and potential effects for Bangladesh.

This study attempts to analyze the potential acid deposition threat to Bangladesh using an integrated approach that combines a source emission inventory (EI), air mass trajectory analysis, and three dimensional (3D) air quality modeling system: Comprehensive Air Quality Model with Extensions (CAMx) driven by Mesoscale meteorological Model (MM5) or CAMx–MM5. Due to the current lack of monitoring data, the modeling approach appeared to be a cost–effective way to assess the acid deposition over the study domain.

2. Methodology

2.1. Study area

Bangladesh is divided into six major divisions and 64 districts administratively. Dhaka division (Figure 1), located in the centre of Bangladesh, was selected as the study area. The division has an area of 31 120 km^2 consisting of 17 districts (Banglapedia, 2008) with population of about 39 millions, i.e. about 31% of the total population of the country (BBS, 2008).

Bangladesh has a tropical monsoon climate, withhot and rainy summers (April–September) and a dry winters (November to February). Mean annual temperature of the country is about 25 °C.

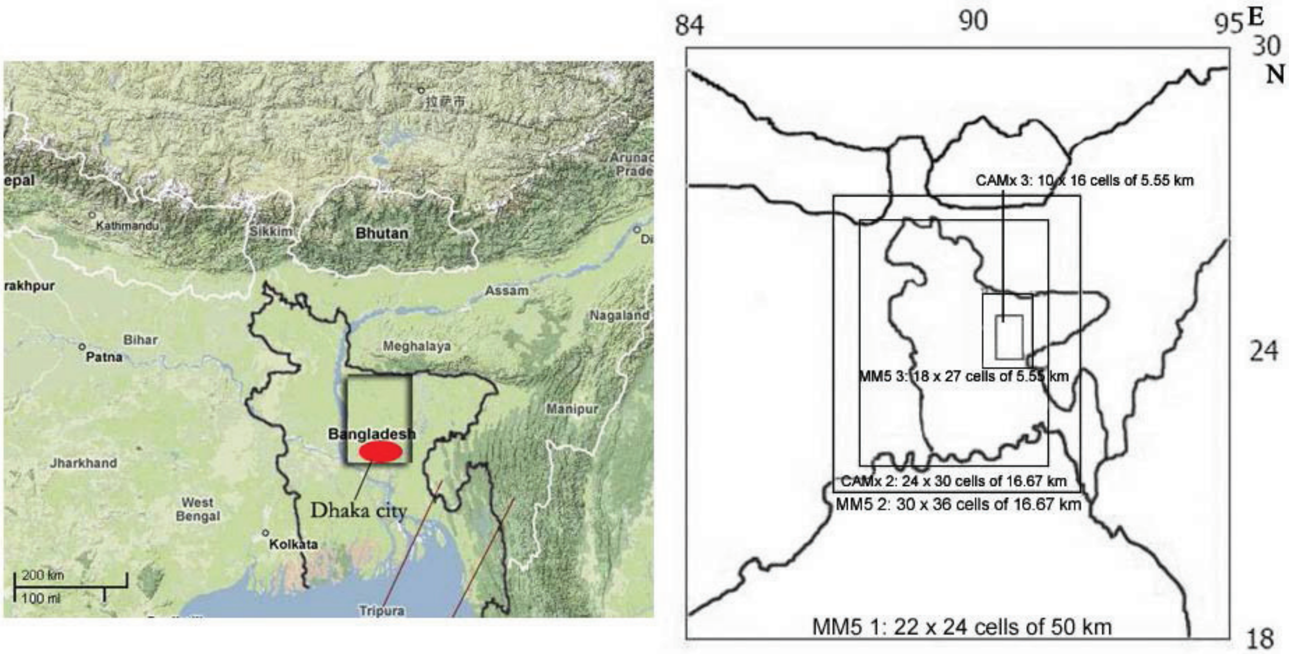

Figure 1. *Map of Bangladesh indicating its location in Asia, the modeling domain in Bangladesh and the CAMx–MM5 modeling domain structure (Dhaka city is indicated).*

April is the hottest month, when the mean temperature ranges from 27 °C in the south eastern to 31 °C in the northwestern part of the country with the country wise monthly mean of 30 °C. Average temperature in January, the coolest month, varies from 17 °C in the northwestern and northeastern parts of the country to 20 – 21 °C in the coastal areas with the country–wise mean of 18 °C. The annual minimum temperature is observed in late December or early January that may drop to as low as 3 to 4 °C in the extreme northwestern part. In the study area of Dhaka, the average January temperature is about 19 °C and the average April temperature is about 29 °C (Banglapedia, 2008; BMD, 2008).

Bangladesh is one of the wettest countries in the world. The average annual rainfall over the country is about 1 525 mm while in hilly areas the value may be as high as 5 080 mm. Most of rain occurs during the monsoon months (June–September) and little rain occurs in winter (November–February). Generally, winds are stronger in summer (ranging between 2.2 and 4.4 m/s) than in winter (ranging between 0.83 and 1.6 m/s) (Banglapedia, 2008; BMD, 2008). Figure 2 shows the meteorological conditions measured at a station in Dhaka for the year 2006.

The Dhaka division has numerous emission sources including traffic, industries of various scales ranked from traditional to advanced technologies, agricultural residue burning and residential combustion. In 2006, about 230 000 vehicles of different categories were running on the roads of the Dhaka division. Each month thousands of new vehicles were being added to the fleet. New industries are established regularly to meet the economic development, most of which are in Dhaka division to grab maximum facilities. In Dhaka division about 436 000 industries of different categories were in operation in 2006, which was increased 59% as compared to 2000 (BBS, 2008).

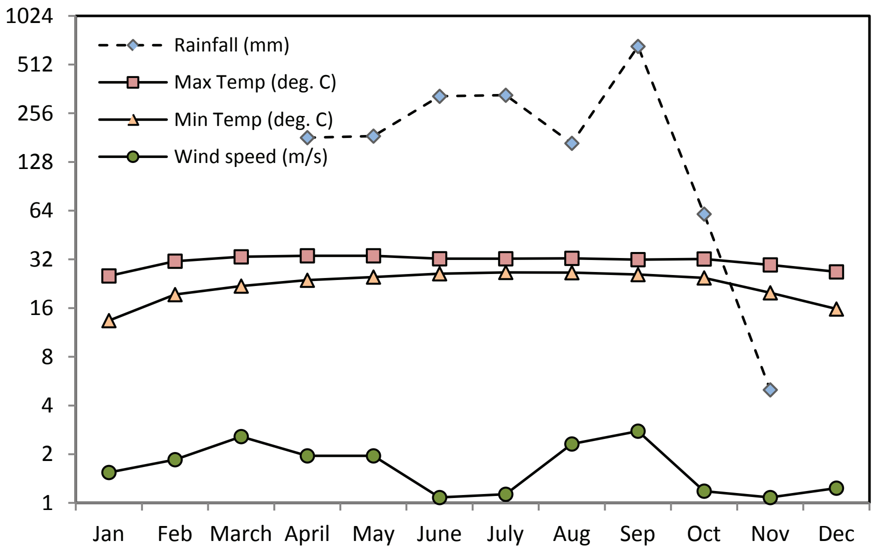

Figure 2. *Meteorological data of Dhaka station indicating monthly average maximum temperature; monthly average minimum temperature; monthly average rainfall and monthly average wind speed for 2006 (Source: BMD, 2008).*