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Dispersion of atmospheric coarse particulate matter in the San Luis Potosí, Mexico, urban area

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RESUMEN

La contaminación atmosférica en áreas urbanas de México se ha convertido en un problema grave. Por ello, el estudio de la evolución espacial y temporal de las concentraciones del material particulado es un asunto importante. En el periodo de mayo de 2003 a abril de 2004 se recolectó un total de 188 muestras diarias con un equipo de alto volumen en el área urbana de San Luis Potosí, ubicada en la parte centro-norte de México, usando filtros de fibra de cuarzo. Se realizó una serie de experimentos de modelación numérica en el mismo periodo que las mediciones, para investigar las concentraciones de material particulado (PM) en dicha área urbana. Aunque hay una considerable variabilidad anual en la circulación atmosférica, el análisis de los resultados indica patrones de circulación estacionales preferenciales: vientos del suroeste en invierno y vientos del sureste en verano. Los altos valores de concentración de material particulado estuvieron estrechamente vinculados con características locales de la circulación atmosférica. El transporte neto de la zona industrial es una de las más importantes conclusiones de la investigación.

ABSTRACT

Atmospheric pollution in urban areas of Mexico has become a serious problem. The study of spatio-temporal evolution of concentrations of particulate matter is an important issue. A total of 188 samples were randomly collected at 24-hour running time within the period from May 2003 to April 2004 for the San Luis Potosí urban area, located in the central-north part of Mexico, using quartz fiber filters. A series of numerical modeling experiments were conducted for the same period of measurements to investigate particulate matter (PM) concentrations in the above-mentioned urban area. Although there is a considerable annual variability in the atmospheric circulation, the analysis of results indicates preferential seasonal circulation patterns: southwesterly winds during winter and southeasterly during summer. High concentration values of particulate matter were closely associated to local characteristics of the atmospheric circulation. A net transport from the industrial zone into the urban area is one of most important outcomes of the investigation.

Keywords: Particulate matter, dispersion model, particle characterization, air quality.

1. Introduction

There is considerable uncertainty about the effects of atmospheric particulate matter (PM) on the global climate. Hence, it is important to know the physical and morphological characteristics of PM and to evaluate the dispersion phenomena that contribute to the presence of high concentrations of particulate matter in the atmosphere and particularly in urban areas (Campos-Ramos *et al.*, 2011). Atmospheric particles may be solid or liquid particles that are incorporated into the atmosphere by natural and anthropogenic emission sources. Atmospheric processes and multi-source origins tend to generate a complex mixture of aerosol components of different chemical and physical characteristics. The origin and transport mechanisms of particles give information about final properties, since the particles are continuously controlled by physical and chemical processes that influence composition, shape and distribution (Korhonen *et al.*, 2004). PM effects on atmospheric pollution have been documented in fields including health, physics and chemistry, which highlight the relation between the exposure to these contaminants and various health impacts, such as cardiovascular and respiratory diseases (WHO, 2002).

Previous studies on the urban area of San Luis Potosí (UASLP), Mexico, have revealed some morphological characteristics and chemical composition of particles that originate from mining-metallurgical activities (Aragón-Piña *et al.*, 2000, 2002) and from the industrial zone (Aragón-Piña *et al.*, 2006). In these studies, high concentrations of heavy metals such as lead and arsenic surrounding the metallurgical industrial zone have been reported. Additionally, high concentrations of calcium sulfate and fluorite coming from industrial wastes have been documented. Nevertheless, these studies do not consider atmospheric circulation, pollutant dynamics or the effects of the topography.

The regional circulation and wind patterns are important factors in the particles dispersion that determine their main mechanisms of transport and deposition. The final product of these processes is a heterogeneous spatial distribution (Querol *et al.*, 2004). Atmospheric circulation should be considered whenever an air quality monitoring location is selected. In this study, we applied the Mesoscale Model of fifth generation (MM5) (Grell *et al.*, 1994) and the Multiscale Climate Chemistry Model (MCCM) (Grell *et al.*, 2000) to investigate air quality aspects of an urban area in Mexico.

The UASLP comprises a population of more than one million, a large number of vehicles and an industrial zone (IZ) of around 253 factories (Fig. 1b). In the western part of the city there are several foundries with an intense melting activity. In the industrial zone, located in the southern side of the UASLP, there is an important number of companies, such as automotive assembly plants, foundries, steel and non-ferrous metal manufacturing, and chemical industries. Recently, both industrial activities and the expansion of the urban zone have increased, which stresses the importance of air quality concerns. The emission of airborne particulate matter represents a complex mixture of organic and inorganic substances. Nevertheless, there are only a few studies on air quality in the UASLP that propose strategies to control pollution problems associated with the emission of particulate matter (Leyva *et al.*, 1996). Thus, there is interest in understanding the emission, dispersion, deposition, and physicochemical characteristics of atmospheric particulate matter. There is evidence that atmospheric particle concentrations exceed the Mexican standards several times each year (Aragón-Piña *et al.*, 2006; SINAICA, 2008). In this research work, a numerical study was carried out in order to calculate the spatial distribution of atmospheric particles generated in the industrial zone from May 2003 to April 2004. Considering sources that affect and influence air quality, calculated and observed, data were compared for several points of the UASLP.

2. Experimental setup and modeling

2.1 Study area

The UASLP is located at 22.15º N and 100.98º W in the central part of Mexico (Fig. 1a), within the San Luis Potosí valley, which is surrounded by two mountain ranges that work as natural barriers channeling wind between Sierra San Miguelito on the west side of the city and Sierra de Álvarez to the east. Its climate is arid with a rainy season in the summer. The valley is approximately 1877 masl; it is topographically flat and orientated in a southwest-northeast direction (Fig. 1b) (Pineda-Martínez *et al.*, 2007).