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Development of a GIS-based decision support system for urban air quality management in the city of Istanbul

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ABSTRACT

A decision support system has been developed for urban air quality management in the metropolitan area of Istanbul. The system is based on CALMET/CALPUFF dispersion modeling system, digital maps, and related databases to estimate the emissions and spatial distribution of air pollutants with the help of a GIS software. The system estimates ambient air pollution levels at high temporal and spatial resolutions and enables mapping of emissions and air quality levels. Mapping and scenario results can be compared with air quality limits. Impact assessment of air pollution abatement measures can also be carried out.

1. Introduction

Many cities around the world, particularly in developing countries, are experiencing rapid growth. Yet, in the absence of adequate environmental policies, this growth is occurring at a considerable, and often increasing, economic and social cost. More people, more industry, and more motor vehicles cause ever-worsening air quality that poses a serious environmental threat in many cities.

Aside from its severe local effects, urban air pollution has profound regional and global impacts. Urban emissions are major contributors to the problems of ozone layer depletion and ground level ozone, global warming and climate change (Dyominov and Zadorozhny, 2005; Jenkin and Clemitshaw, 2000; Ramanathan and Feng, 2009; Alcamo et al., 2002; Jacob and Winner, 2009; Vautard and Hauglustaine, 2007; Kinney, 2008). Urban air pollution also causes respiratory diseases (Selgrade, 2000; Devalia et al., 1994; Schwartz, 1993; Lee et al., 2007; Jalaludin et al., 2004; Boezen et al., 1999). To deal with these problems at the regional level, the air quality in cities have to be monitored and managed.

An effective environmental planning and management process helps decision makers to formulate and implement realistic and effective strategies and action plans to improve air quality. These strategies and action plans have to systematically address the short and long-term causes of urban air pollution and help the city to achieve a sustainable growth pattern.

Many computer based decision support systems for urban air quality management are applied in major cities around the world. The application of decision support systems is an opportunity for improving air quality planning in large cities. Decision support systems generally include emission inventories, air quality monitoring, modeling, mapping, and air quality impact assessment of various control strategies. They support the evaluation of action plans by using information to the public about past and present air quality levels. Examples of decision support systems used by the local authorities in major European cities such as Stockholm, Lisbon, Milano, Berlin, Geneva, Vienna, Paris, Oslo and Athens are the Swedish AirViro (SMHI, 2009), the Austrian AirWare (Fedra and Haurie, 1999), the Norwegian AirQUIS (Bohler et al., 2002) and the Swedish EnviMan (Tarodo, 2003) systems. A few more decision support systems for specific air quality management studies are in operation around the world (Guerrero et al., 2008; Lim et al., 2005; Elbir, 2004; Puliafito et al., 2003; Fine and Ambrosiano, 1996; Schmidt and Schafer, 1998; Jensen et al., 2001; Lin and Lin, 2002; Finzi et al., 1991).

Available air quality decision support systems like Airviro, AirWare, AirQuis and EnviMan generally apply simple air quality dispersion models, they have low spatial resolution that does not conform with the high spatial variability of characteristics in urban areas, and they only consider simple exposure assessment if any (Jensen, 1999). Further, they are commercial systems developed to

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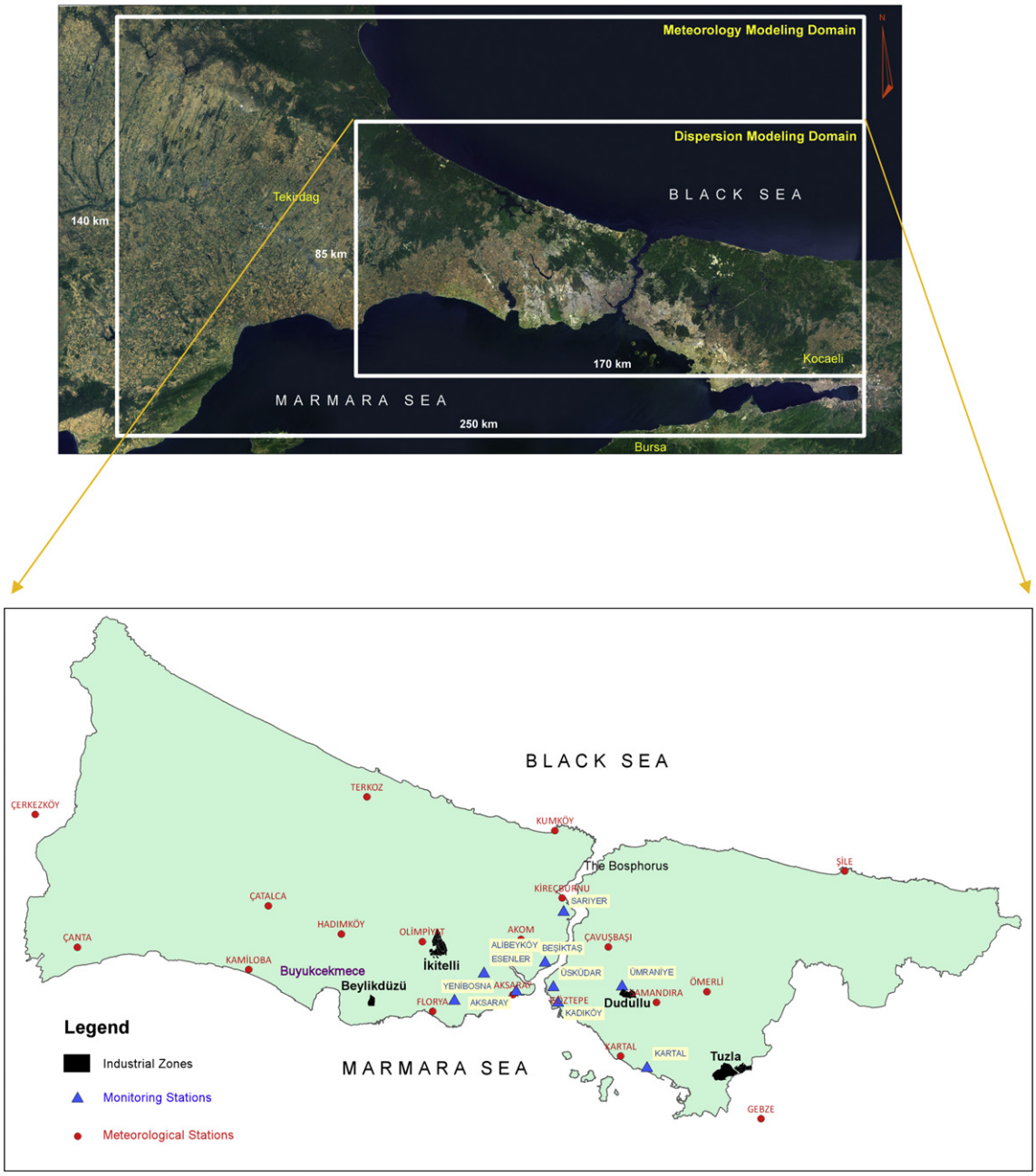

Fig. 1. Locations of industrial zones, monitoring and meteorological stations in the study area.

be marketed in many countries and they certainly do not take into consideration the local conditions (i.e., specific fuels, industrial activities, and vehicle types/ages) within their administrative databases.

Istanbul is one of the world's biggest cities with ~12 million population. Air pollution in Istanbul is one of the important problems of modern life due to rapid population growth, dense immigration, improper site selection for industry, usage of poor quality fuels, usage of old combustion technologies in industry, lack of control technologies for stack gases, and traffic emissions (Incecik, 1986; Bozyazi et al., 2000; Unal et al., 2000; Sumen et al., 2005).

To identify the causes of this problem, and to improve the air quality, a geographical information system (GIS) based decision support system has been developed for the city of Istanbul. Preparation of a comprehensive emission inventory, air quality modeling, air quality mapping by GIS, and scenario analysis for air pollution abatement were carried out as the components of this urban air quality management system.

2. Characteristics of the study area

The city of Istanbul is located in the north-west Marmara region of Turkey, in the coordinates of 28°10′ and 29°40′ East longitudes and 40°50′ and 41°30′ North latitudes (Fig. 1). The city with a surface area of 5313 km^2 (TUIK, 2008) has three neighboring provinces (i.e., Kocaeli in the east, Bursa in the south and Tekirdag in the west). Marmara Sea at south and Black Sea at north surround the city besides these provinces. The Bosphorus, connects the Black Sea with Marmara Sea and divides the city of Istanbul into two parts, and also separates the Continents of Europe and Asia.