Model Study with MM5 and CAMx in Istanbul Area during High Ozone Days

Umit Antepliogiu[1] Selahattin Incecik[2] and Sema Topcu[2]

[1] *Division of Meteorology Kandilli Observatory, Bosphorus University Cengelkoy Istanbul, Turkey*
[2] *Department of Meteorology, Istanbul Technical University 34469 Istanbul Turkey*

Development pollution control strategies relies on photo-chemical transport models. These models integrate of mesoscale meteorological models with chemical moduls. In this study, the PSU/NCAR mesoscale meteorological model with CAMx is used to investigate the temporal and spatial dynamics of the photochemical air pollution in urban atmosphere of Istanbul for selected high ozone days. The ozone climatology for the selected days and model simulations are presented.

Key words: Ozone climatology, Mesoscale model, Photochemical model, Urban air pollution

1.Introduction

The Istanbul region is one of the most densely populated areas in the world. High emissions of NOx and VOCs lead to high ozone concentrations under intense solar radiation. The history of photochemical air pollution in Istanbul is not long. In recent years, the number of motor vehicles in Istanbul increased at a very fast rate. Due to the rapid development of transportation in Istanbul ozone potential problem is growing. The high ozone levels now occur frequently in the city center.

As a consequence air quality problem in Istanbul has shifted from conventional air pollution to secondary air pollution in last five years. The goal of this study is to apply and assess the temporal and spatial distribution of photochemical air pollution in Istanbul. For this purpose our focus is to understand the relationships of ozone conducive conditions in between chemical and meteorological characteristics and the explain the realistic evolutions of flow fields on the impact of surface ozone concentrations.

Corresponding Author; Selahattin Incecik, Department of Meteorology, Istanbul Technical University, 34469 Istanbul, Turkey
Phone: + 90 212 2853143
E-mail: incecik@itu.edu.tr

2.Ozone Climatology

Istanbul with a population of approximately 12 million is one of the mega cities in the world. The city is located at about 41°N; 29°E. The Bosphorus channel separates the European part from its counterpart in Asia minor. The total area of the two parts is about 5700 km^2. The general climate characteristics of Istanbul is controlled by the Sea of Marmara, the Black Sea and the Bosphorus channel. Usually, the climate of Istanbul is Mediterranean, being warm and dry in summer and cold and wet in winter[1)]. Photochemical ozone is formed through complex, non-linear interactions between chemical reactions and meteorological parameters. A well-known general reaction mechanism for ozone at the surface boundary layer involves reacting NOx and NMHC with solar radiation. Generally weak morning surface winds, early morning stable atmospheric conditions and precursor concentrations lead to higher ozone levels.

Ozone levels as well as other pollutants are monitored in Istanbul. Surface ozone concentrations have been measured since 1998 in the city at two sites. Topcu and Incecik[2)] explained the preliminary results of the ozone levels in the city. Furthermore, NOx emissions are continuously increased depending on the increasing motor vehicles in the city. According to OECD Report[3)] NOx emissions totaled 844,000 tons in 1997 figures, almost two and half times those recorded in 1980s in Turkey.

Fig. 1 indicates a time series for the daily maximum ozone concentrations in Istanbul over Kadikoy. Usually, July peak ozone concenterations are higer than the other days. We selected a limited time period (16-18 July) for this study. Table 1 defines the local conditions for selected ozone high days.The synoptic and mesoscale meteorological factors that contributed to the 16-18 July ozone episode are discussed in Topcu and Incecik[4]. Furthermore local meteorological conditions can indicate the ozone potential over an area.

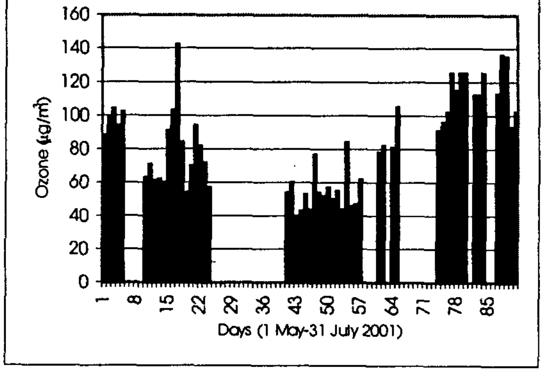

Fig.1 Peak ozone concentrations for July, 2001[4].

3.MM5 and CAMx

3.1. MM5

In this study we used the Mesoscale meteorological model MM5 version 3.5 developed by PSU/NCAR[5]. The MM5 mesoscale model is a limited area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate mesoscale atmospheric circulation. MM5 is a very robust tool with multiple applications

Table 1. A summary of the ozone climatology in İstanbul [4].

Date July	Hour. Max. O_3	Mea WD 0700	Mean WD. 1400	WSP 0700 (m/s)	WSP 1400 (m/s)	Max. Temp (°C)
16	102	W	NNW	1.3	4.3	31.7
17	125	SW	WSW	0.9	2.4	30.0
18	115	W	NNE	1.4	5.6	30.1

world wide to provide reliable meteorological information at mesoscale level[6]. The meteorological simulations were performed for the period 16-18 July with 3 km^3 km resolution with 91x 139 inner grids. Analysis nudging is used above

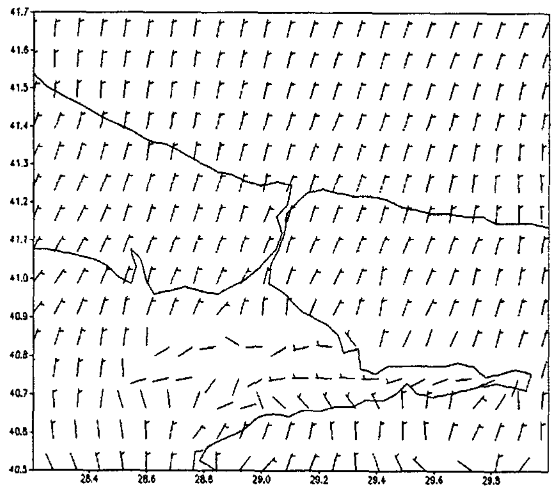

Fig.2 MM5 Surface winds for 1100 UTC July 16.

PBL for only outer most domain. A few examples of the model results are given in Figures 2 and 3.

3.2. CAMx

The Comprehensive Air Quality Model with extensions (CAMx) was used to understand the meteorological conditions and to predict the surface ozone concentrations during an episode period[7]. The chemical mechanisms supported by CAMx are based on Carbon Bond-IV mechanism. It considers 22 layers within surface and 6000 meter. Furthermore CAMx has been used with 2 km resulation and 60x60 grid. The data included were wind speed, wind direction and temperature. u and v components of the wind which were the actual wind inputs variables has been calculated. Model results are also given in Figures 4 and 5.

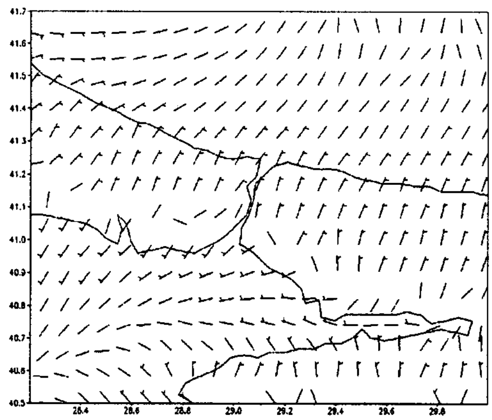

Fig. 3 MM5 surface winds for 1100 UTC July 17.

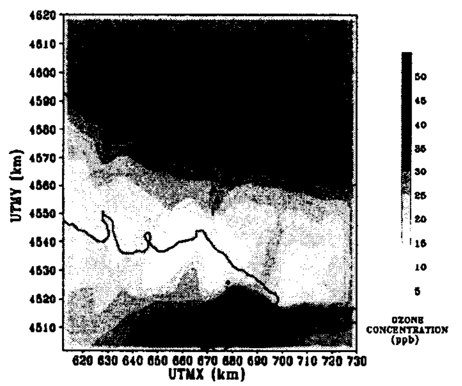

Fig. 4 Surface ozone concentrations by CAMx at 16 July 1100 UTC.

4. Results

In this study, a limited emission inventory from important high ways of the city was considered. An emission inventory with high spatial and temporal (1h) resolution was developed by the Anteplioglu[8,9]. The emission inventory adapted from the 1999 conditions to 2001 in the city considering by Carbon Bond IV mechanism. The synoptic situation between 16-18 July was governed by a stationary high pressure ridge extending from northern Africa to southern Russia.

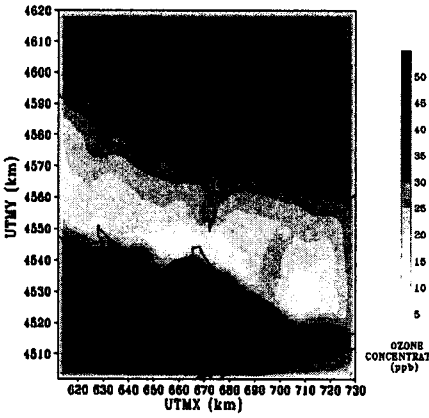

Fig. 5 Surface ozone concentrations by CAMx for 17 July 1100 UTC.

A vorticity map of the region was given in Fig.6. It was favorable conditions for the high photochemical production. The stagnant weather condition was dominated by clear sky and intense solar radiation. The temperature maxima of 31.7 °C were reported. The weather conditions lead to southerly winds in this area during the day and to northerly winds in early morning hours due to the circulations over the city. In the late afternoon hours, the city experiences the peak ozone concentrations. Vorticity variation over the region support the mesometeorological model circulation over the region. Figures 6, 7 and 8 indicates air pollution potential over Istanbul and surrounding areas with negative or weak positive vortisity field for the July 16, 17 and 18.

As a summary,

- Surface heating is an important driving force in inducing the sea/land breeze circulation. Its realistic representations by the model will influence the success of the wind field simulations.
- The circulation is clearly appearing during intense solar heating hours and then disappearing at the late afternoon hours.
- To identify which meteorological parameters are strongly associated with the fluctuations of daily maximum ozone concentrations and

to perceive the temporal variation patterns of ozone concentrations.

A limited period for both explaining and understanding of the ozone formation mechanism and to make simulations both wind field and ozone variation over Istanbul are used.

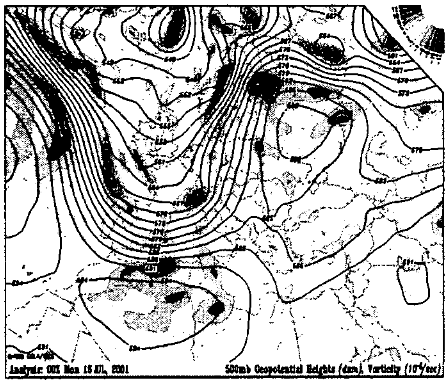

Fig.6 Vorticity map of the region for July 16.

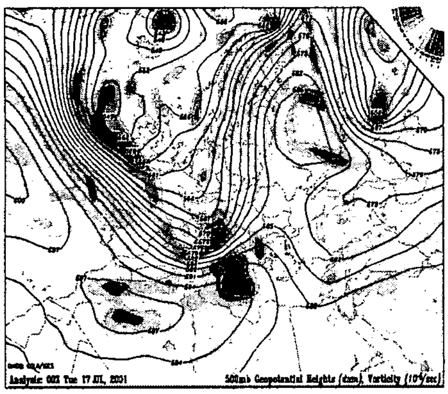

Fig.7 Vorticity map of the region for July 17.

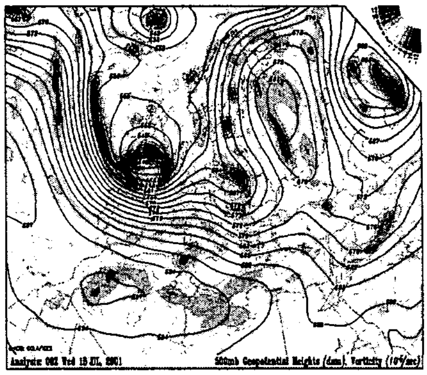

Fig.8. Vorticity map of the region for July 18.

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