Nitrogen Oxides and Ozone Concentrations and Statistical Modelling of Maximum NO_x Concentrations in the Tel Aviv Area

A contribution to subproject SATURN

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Summary

Concentrations of NO_x, NO_2 and O_3 from three automatic monitoring sites within the Tel Aviv conurbation show significant seasonal, weekly and diurnal variations; maximum daily concentrations of NO_x and O_3 vary from high levels in the winter to lower ones in the summer. On working days NO_x and NO_2 show double-peak diurnal cycles, reflecting mainly the traffic flow pattern; variations of O_3 reveal one diurnal peak. Ozone varies in the range of 40-70 ppb during the spring/summer months, decreasing to 20-30 ppb in winter. Peak ozone concentrations reached values of 100-120 ppb. Traffic emission of NO_x does not play a vital part in determining the maximum levels of O_3.

Based on ground-level meteorological data and radiosonde probing, regression equations for maximum morning and evening NOx concentrations were developed and tested. Among the model variables the vertical temperature gradient in the surface atmospheric layer is the most significant factor. Predicted NOx concentrations are in a good agreement with the observed values.

Activities and results

In the major Israeli cities, such as Jerusalem, Tel Aviv and Haifa, motor vehicle exhausts define air quality, the contribution of other sources is insignificant. Among these cities Tel Aviv is the most problematic. Three first air-quality monitoring sites were established in the center of the Tel Aviv conurbation, starting continuous measurements since 1994. These monitoring stations are situated on the roofs of buildings with the inlets for gas measurements at a height of about 15-20 m. It is clear that the street level concentrations may be higher than that measured on the rooftop. Concentrations of NO_x, NO_2 and O_3, measured at these sites during 1995-1998, are given in the paper. It should be mentioned that the Israeli Air Quality Standard incorporates 30-min average NO_x concentration Limit Values of 940 μgm^{-3} (500 ppb). The 30-min average O_3 limit level is of 230 μgm^{-3} (115 ppb).

The Tel Aviv urban area lies 10 km along the Mediterranean shoreline at the coastal plain and extends 5 km eastward without any meaningful topographic features. Mountains to the east limit the coastal plain to a width of about 20 km. The Tel Aviv climate is Mediterranean; the average daily temperature is of 25°C during the summer and 14°C during the winter; relative humidity is of 69% and 66% in summer and winter, respectively. The mean global irradiance reaches 28 MJ $m^{-2}day^{-1}$ in the summer and 13 MJ $m^{-2}day^{-1}$ in the winter (Stanhill and Ianetz, 1997). Precipitation occurs from November to March, mainly in December – February; the quantity of precipitation along the seacoast reaches of 500-600 mm per year. The summer wind rose reflects the daily sea-land breeze circulation with some influence of the summer trough (the Persian Bay trough); in winter winds caused by different pressure systems play a significant role.

Annual variations of maximum diurnal 30-min average NO_x and hourly average NO_2 are presented in Figures 1 and 2 for one of the sites (Central Bus Station site). The concentrations are averaged over 1995-1998. In general, annual distributions are similar at all monitoring sites. The dominant contribution to emission inventories is from traffic emission and it may be assumed that vehicle emissions variation during the year is small. Other significant season emission sources (fuel combustion for heating etc.) are practically absent in the Tel Aviv area. So the seasonal variations are mainly caused by the reduction of pollution dispersion in winter and its intensification in summer.

Annual variations of diurnal maximum 30-min average O_3 are given in Figure 3. Maximum concentrations oscillate near a level of 40 ppb also at all sites, rising to the level of 70 ppb in April and descending to 20-30 ppb during December-January, which are usually cloudy and rainy.

To analyze diurnal variations of NO_x, NO_2 and O_3 during the week and in the winter and summer seasons, air quality data were averaged for each of weekdays during two winter months, January-December, and two summer months, July-August, of 1995-1998. In Israel the week starts in Sunday, Friday is a short workday and Saturday is a non-working day without public transport. The Sunday- Thursday NO_x and NO_2 diurnal variations have similar shape and amplitude. Diurnal variations of NO_x and NO_2 for three days of week in winter and summer are shown in Figures 4 and 5. Diurnal O_3 variations are similar for all weekdays in the winter and for all the working days in summer. The Sunday and Saturday O_3 cycles are presented in Figure 6.

To forecast the morning and evening maximum NO_x concentrations, two multiple-linear regression models have been developed and tested. The models based on half-hour measurements of NO_x from five traffic monitoring stations of the Ministry of Environment. The stations are located in the central area of the Tel Aviv conurbation and operate since 1998. The set of input meteorological data for the model development included standard ground-level meteorological parameters and data from diurnal (11:00 GMT) and nocturnal (23:00 GMT) radiosonde launches at the Bet Dagan meteorological station near Tel Aviv. Expediency to develop two separate models for morning and evening hours follows from the double peak diurnal NO_x distribution and essential distinction in the morning and evening meteorological conditions.

For the model development one-year data set of 1999 (half-hour average NO_x concentrations, standard ground-level meteorological parameters and vertical temperature distribution) was used. Using an ordinary least squares method and stepwise regression, the set of predictor variables for each of the model was obtained (Table 1). The predictant is the maximum NO_x concentration during the morning and evening hours.

For operative forecast of NO_x concentration the meteorological parameters, predicted by the Israel Region Forecasting Model (IR/HRM), were used. The results of one-year predictions versus observed values, from May 2000 till May 2001, are presented in Figures 7 and 8. The morning model predicted correctly 96% of occurrences of the admissible NO_x concentrations (less the National Air Quality Standard level of 500 ppb) and 64% of exceeding of the limit level (> 500 ppb). The corresponding results of evening prediction are 89% and 63%, respectively.

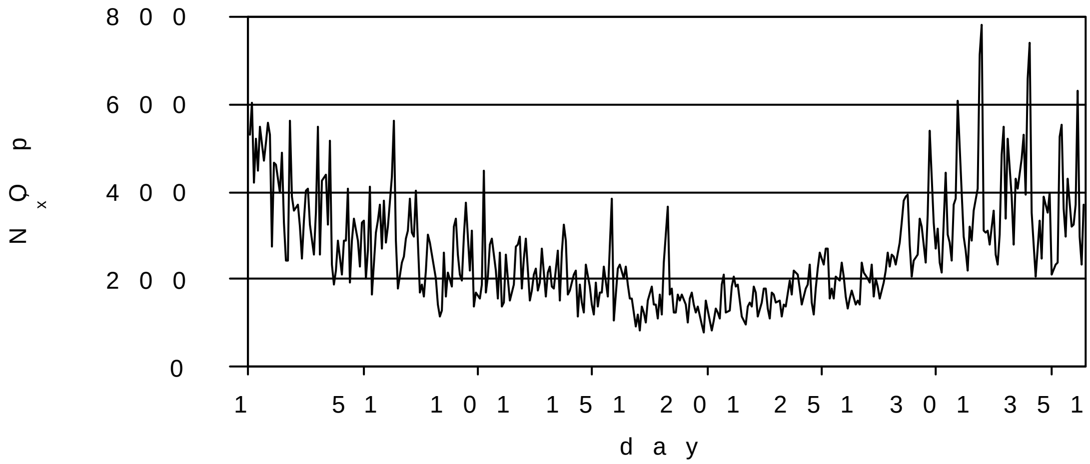

Figure 1. Annual variation of maximum 30-min average NO_x concentration during 1995-1998

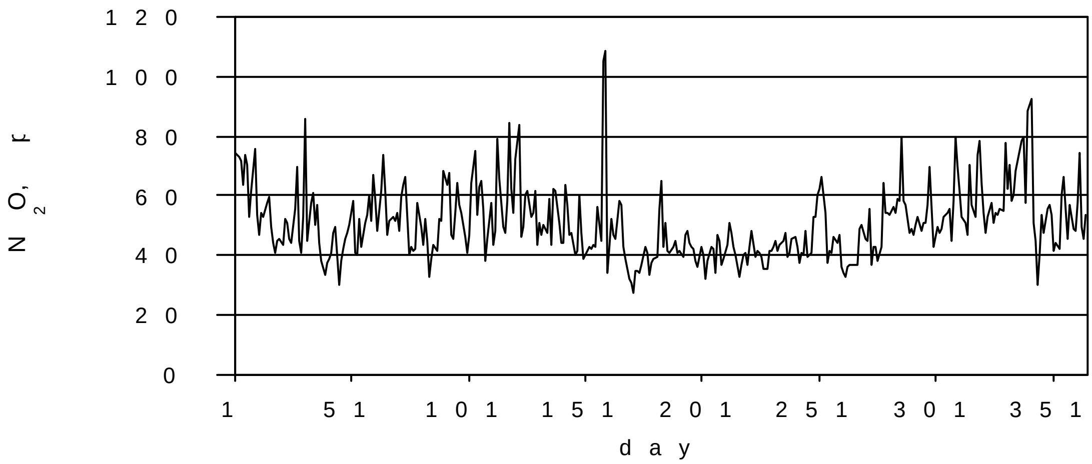

Figure 2. Annual variation of maximum hourly average NO_2 concentration during 1995-1998.

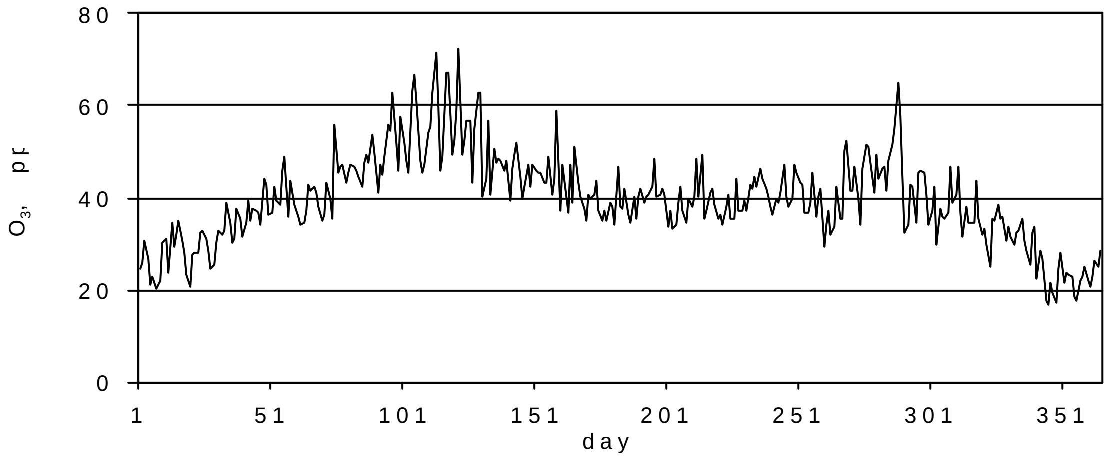

Figure 3. Annual variation of maximum 30-min average O_3 concentration during 1995-1998.

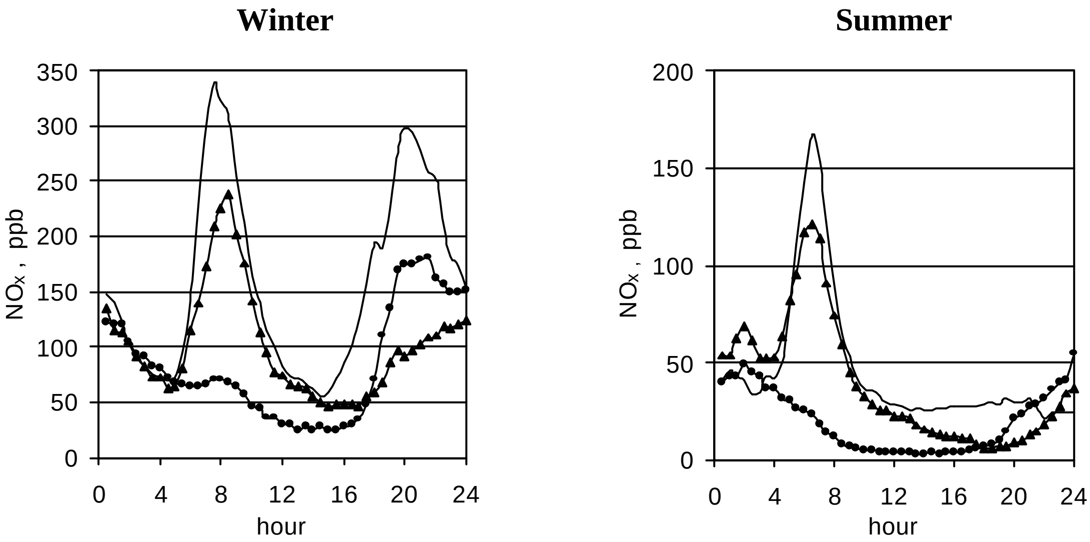

Figure 4. Diurnal variations of 30-min average NO_x concentration during winter and summer of 1995-1998 / Sunday; Friday; Saturday /.

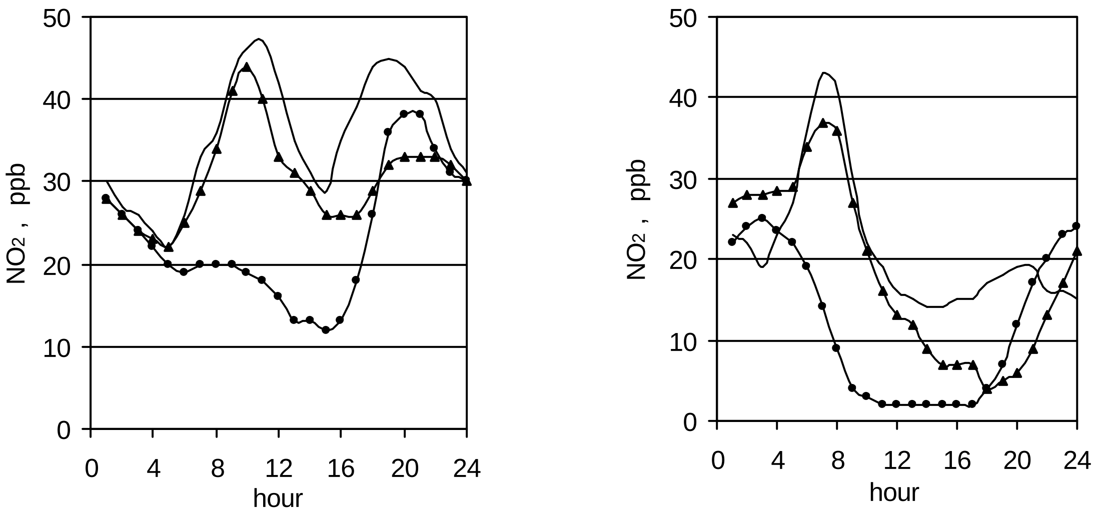

Figure 5. Diurnal variations of hourly average NO_2 concentration during winter and summer 1995-1998 / Sunday; Friday; Saturday /.

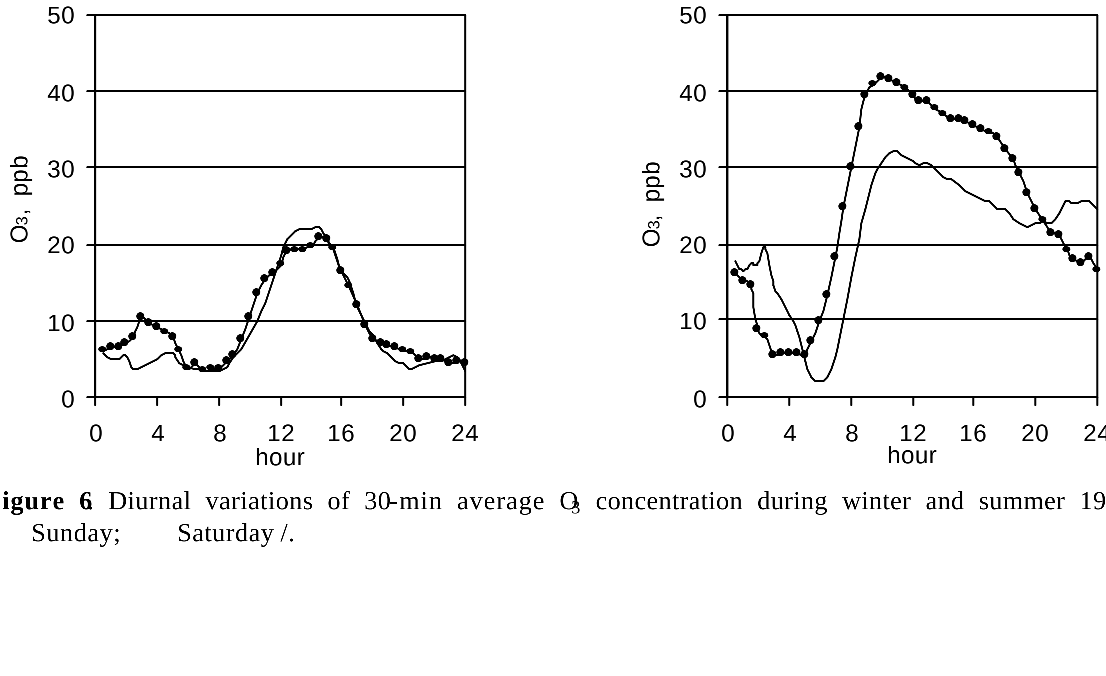

Figure 6. Diurnal variations of 30-min average O_3 concentration during winter and summer 1995-1998 / Sunday; Saturday /.

Table 1. Input parameters for the NOx forecast models

	Morning model [a]	Evening model [b]
Previous day maximum concentration, [c] ppb	+	+
Wind direction (normalized scale)	+	
Gradient of temperature in the first 100 m, C	+	+
Temperature, C		+
Temperature of dew point, C	+	+
Temperature at 850 mb level, C	+	+
Relative humidity, %	+	
Turner stability category [d]		+
Monin-Obukhov length	+	+
Friction velocity		+
Cloud cover [e]	+	+
Height of low clouds	+	+

[a] For the morning forecast (7-9 LST) the predictive nighttime (23:00GMT, 01:00 LST) meteorological data are used;
[b] For the evening forecast (19-22 LST) the predictive daytime (11:00GMT, 13:00 LST) meteorological data are used, excepting the gradient of temperature. For the gradient of temperature the following nighttime (23:00 GMT) predictive value is used;
[c] Maximum NO_x concentrations observed during morning and evening hours, respectively;
[d] Stability category, S, Monin-Obukhov length, L, and friction velocity, u*, are the calculated input parameters;
[e] Cloud cover and low clouds height used only for the definition of S, L and u*.

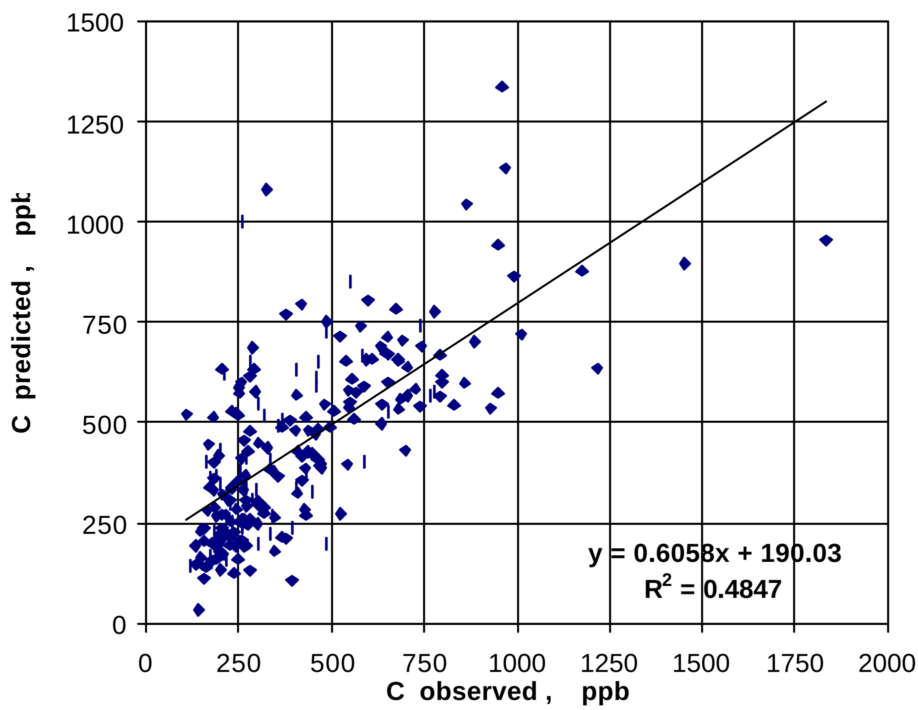

Figure 7. Maximum NO_x morning concentrations during May 2000 – April 2001.

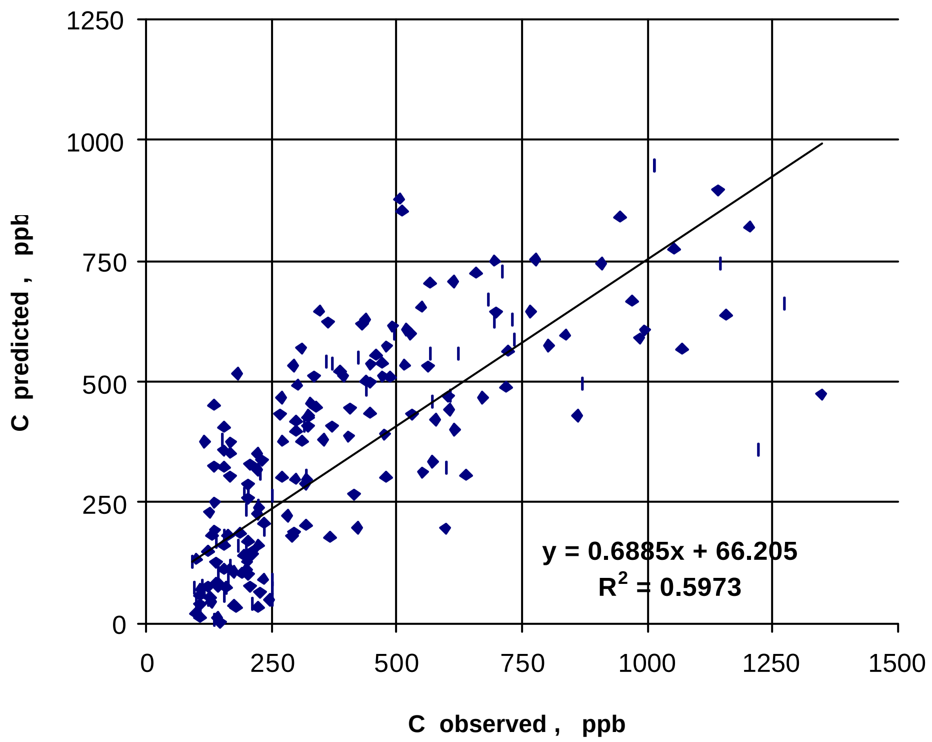

Figure 8. Maximum NO_x evening concentrations during May 2000 – April 2001.

Conclusions

Annual variations of NO_x in the Tel Aviv urban area are mainly defined by the seasonal change of meteorological conditions; winter NO_x levels are substantially higher then in summer due to the weaker atmospheric dispersion. Diurnal workday NO_x and NO_2 variations show double-peak distributions, formed by traffic flow peaks coincident with the weak atmospheric dispersion during the morning and evening hours. Annual and diurnal NO_x and NO_2 cycles found are similar at three monitoring sites.

Ozone concentrations vary diurnally within the range of 40-70 ppb in summer, decreasing to 20-30 ppb in winter. The few peaks in ozone concentrations reached values of 100-120 ppb. During the night ozone is practically reduced to zero.

Used in combination with the IR/HRM data, the developed regression models can be a useful tool for the urban air quality forecasting.

Aims for the coming year

During 2002 statistical models for the operative NO_x forecast will be validated and updated, using the meteorological parameters, predicted by the Israel Region Forecasting Model (IR/HRM) as input data (Activity 2). It is proposed that such prognostic meteorological data will be used in the future for the short-time air quality forecast.

One more set of two regression models will be developed and tested. These models will be based on the predicted by IR/HRM meteorological parameters (Model Output Statistics Method) and not on the observed data.

Reference

Stanhill G. and A. Ianetz, 1997: Long-term trends in, and the spatial variation of, global irradiance in Israel. *Tellus* **49B**, 112-122.