AIR QUALITY MESO-SCALE MODELING IN HO CHI MINH CITY EVALUATION OF SOME STRATEGIES' EFFICIENCY TO REDUCE POLLUTION

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ABSTRACT : *Ho Chi Minh City (HCMC), the largest city of Vietnam and the seventh city with the highest density of inhabitants in the world (3,300 persons by kilometer square) (HCMC Urban Drainage Company, 1998), is one of the cities in the world which are seriously influenced by pollution. The main sources of atmospheric pollution are vehicles (motorbikes), the industry and population. Numerical models are the only existing tools able to predict air quality concentrations and to determine the strategies of reduction of air pollution in HCMC, different scenarios were tested.*

The results obtained show that the wind direction is more influenced by global scale than local phenomena. The results of the simulations show that the ozone plume is 90km in length and 30 km in width at 12h00 LT. During the selected episode (8/1/2003), the zone in the South-West of HCMC is the most polluted one (180ppb at midday).

1. INTRODUCTION

The economic growth and urbanization in (Ho Chi Minh City) HCMC of Viet Nam have caused air pollution episodes of high ozone (O_3). The main sources of atmospheric pollution are vehicles (motorbikes), the industry and population. In the busy streets of HCMC, 2,305,415 motorcycles and 332,622 cars were counted at the end of 2003, for a population of 5,625 million people in an area of 2,093.7 kilometer square.

According to the HCMC's General Statistics Office, there are about 28,500 factories in the city, distributed in ten industrial zones and two exports processing zones, producing a total of 60,128 tons per year of SO_2, 15,295 tons per year of NO_2 and 1,539 tons per year of CO. In comparison with other regional cities that also experienced rapid economic growth in recent decades, the air pollution problem in HCM City is not as bad but rapidly becoming a serious problem unless some measures are taken. In HCMC, air quality is an increasing problem and it becomes important to design abatement strategies to reduce the pollution levels. Air quality studies are necessary to test the efficiency of the different strategies. For such studies, we need measurement as well as numerical model. In many countries as in Viet Nam, it is difficult to access all the data needed for the air quality simulation. In this article, we propose a methodology to simulate the air quality in a minimum of time with a minimum of input data.

2. THE AIMS OF OUR PROJECT ARE:

- To simulate air pollution to understand the atmospheric phenomena taking place at Ho Chi Minh City.
- To determine the strategies to reduce air pollution in HCMC

3. METHODS AND CONTENTS OF RESEARCH

The first methodology, based on the numerical Eulerien model FVM, was selected to simulate meso-scale wind fields, on January 8, 2003. The method "Nesting-one way" was used to obtain boundary and initial conditions.

The second methodology, based on the "Bottom–up" - COPERT III, was used to generate a traffic emission inventory, whereas the "Top-down" methodology was used for the rest of the sources.

The third methodology, based on the numerical Eulerien model TAPOM (transport and air pollution model) was used to simulate air pollution in HCMC. Lastly, to determine the strategies of reduction of air pollution in HCMC, different scenarios were tested

4. DESCRIPTION OF THE DATA AND MODEL USED FOR THE STUDY

4.1 Description of the data

4.1.1.Data used for the emission

To make an emission inventory, a very large data of many different origins and with different organizations are necessary. In a developing country, like Viet Nam, the main problems are:

- "Access" the data (data does not exist)
- Economic activities responsible of the emissions are changing very rapidly.

So that, it is necessary to use methodologies simple and easily implemented. To perform the emission calculations, we will estimate from available existing data. For industries, residence and biogenic sources, we use data of total emissions in Viet Nam, distribution of the sources of emissions for each pollutant (Projet Mics-Asia, Austrian 2000), the land use of domain calculated, the population and the area of Viet Nam, the population and the area of domain calculated. For the road traffic, we used the emission factors from China (Doste, report N°1. 2001) for calculations because the situation of the traffic in China is similar to Viet Nam.

4.1.2. Measurement data

The air quality network (fig.1) in HCMC (by DOSTE: Department of Science, Technology and Environment of Ho Chi Minh City): At the end of 1992, The network includes four ambient air-monitoring stations and three stations for roadside monitoring. In June 2000, the automatically air quality monitoring system supported by UNDP & ANIDA, including two urban background stations (monitor PM10, SO_2, NOx, CO, O_3), two roadside stations, were installed. In Nov 2002, more new five automatically air quality monitoring stations were installed by NORAD support, including three urban background stations, two roadside stations. Meteorological data was acquired from the DOST, meteorological parameters such as wind speed and direction, humidity, temperature, solar radiations and air pressure.

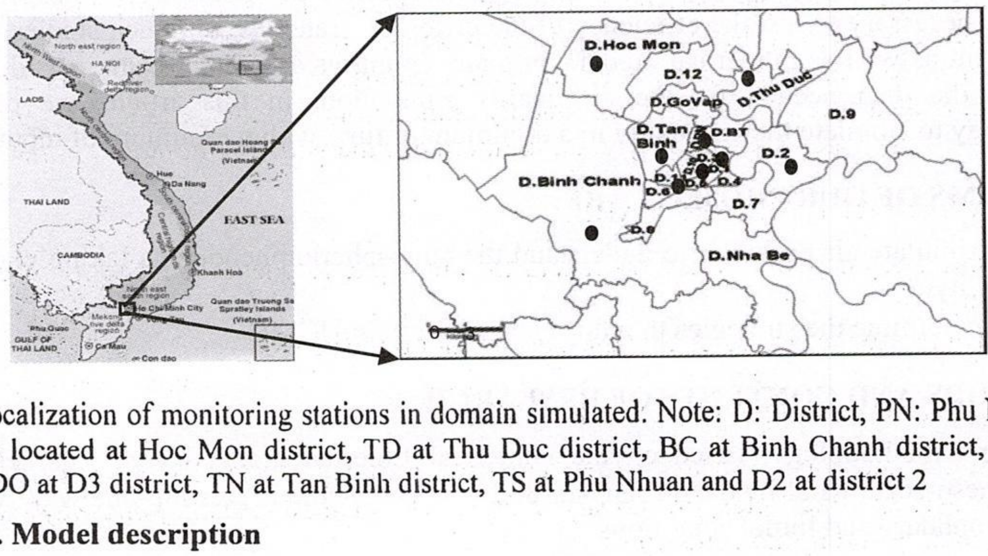


Fig.1. Localization of monitoring stations in domain simulated. Note: D: District, PN: Phu Nhuan. QT station is located at Hoc Mon district, TD at Thu Duc district, BC at Binh Chanh district, ZO at D.1 district, DO at D3 district, TN at Tan Binh district, TS at Phu Nhuan and D2 at district 2

4.2. Model description

The LPAS (Clappier et al., 1996) has developed models for air quality simulation: meteo model FVM and chemical transport model TAPOM.

4.2.1. Metrological model FVM (Finite Volume Model)

A meso scale FVM model is non-hydrostatic (Schayes et al., 1996; Thunis, 1995) and anelastic. It solves the momentum equation for the wind component, the energy equation for the potential temperature, the air humidity equation for mean absolute humidity and the Poisson equation for the pressure. The turbulence is parameterized using turbulent coefficients. In the transition layer these coefficients are derived from turbulent kinetic energy (TKE, computed prognostically), and a length scale, following the formulation of Bougeault and Lacarrere (1989). In the surface layer, in rural areas, the formulation of Louis (1979) is used. The ground temperature and moisture, in rural areas, are estimated with the soil module of Tremback and Kessler (1985). In the urban area, the effect of the buildings are simulated using the parameterization developed by Martilli et al. (2002)

4.2.2. Air quality model (TAPOM)

The TAPOM model simulates the evolution of the pollutants in the atmosphere. It takes into account different atmospheric processes: The transport by the mean wind, the diffusion by turbulence, the transformation by several chemical reactions and the dry deposition. The chemical transformations are simulated using the RACM (Stockwell et al., 1997) which considers 76 chemical species linked via 236 reactions. The transport is solved using the algorithms developed by Collella and Woodward (1984) and Clappier (1998).

The photolysis rate constants used for chemical reactions are calculated using the radiation module TUV (Madronich, 1998)

4.3 Model setup

4.3.1. Choice of the period of simulation

The choice of the period of simulation must be representative of an episode of pollution. We chose one of the worst cases of pollution in all of one year in HCMC. The climate in HCMC is divided into 2 principal seasons: the wet season (from May to November) and the dry season (from December to March of year next) (Hien et al ,2001). April is the hottest period of the year and the coldest December. **On 8 and 9 January 2003 was selected for the period of modeling because**: This period is in dry season (because the model does not contain the rain, the cloud and pollution is stronger during this season), have the high temperatures and solar radiation. After analysis we finds that solar radiation of January are highest (solar radiation is moreover 1000W/m^2 and the temperature of 38 Celsius degrees).

This period have the strongest ozone concentration, it is found that the ozone concentration passed the limiting standard during this period. At BC station (sub-urban), the highest 1h average zone concentration of 125 ppb was observed (while the 1h Viet Nam Air Quality Objective for ozone is of 102 ppb)

4.3.2. Choice of the domain of simulation

In horizontal, the simulated domain consists of 34 points in the east–west by 30 grid points in the north-south direction with a resolution of 1km x 1km covering the HCMC (D2 Fig. 2).

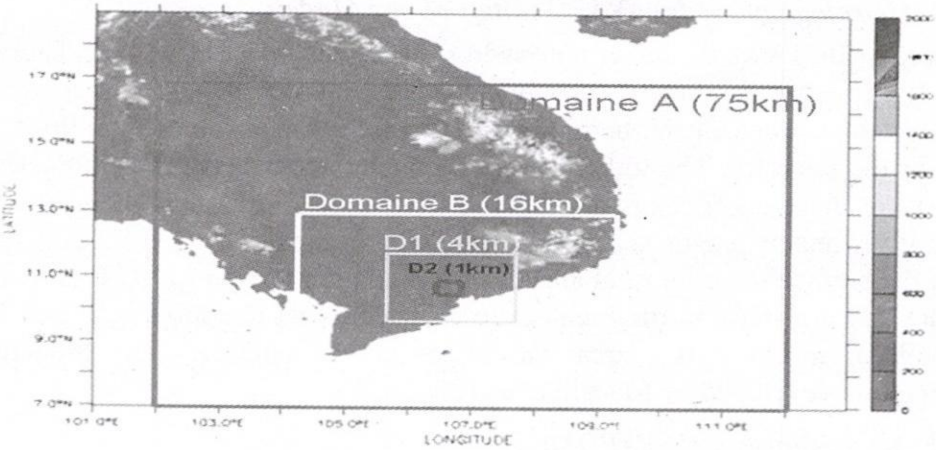


Fig.2. Topography and geographical description of simulated by FVM (DA, DB, D1, D2) domains on the HCMC peninsula

Lateral boundary conditions were externally forced from the output of larger–scale simulations performed; four additional grid cells with spacing ranging from 1 to 75km are added in order to reduce the impact of the uncertainties in the boundary conditions on the domain of interest. The vertical resolution is 40m for the first level, and then it is stretched up to the top of the domain at 1500m (Martilli et al., 2002).

4.3.3. Initial and boundary conditions

Meteorological parameters: For the largest domain, the initial and the boundary conditions are interpolated from the results of NCEP climate forecast model which are available at the NCEP. For the smaller domain, the initial and boundary conditions are obtained using the "nesting-one-way" technique.

To interpolate of a larger domain to a smaller domain, it is necessary to use a program of interpolation, "PREPROCYA".The program uses the data micro-weather of the larger domain to calculate the smaller domain like boundary conditions. Boundary conditions for photochemical simulations are based on the results of measurements of CEFINEA and DOSTE. Those show 30ppb of ozone and very low values of NO and NO_2 (0.19ppb)

4.4. Emission inventory

The calculated emissions include (CO, NOx, VOC) regularly and irregularly of pollutants (N_2O, NH_3, SO_2, NMVOC speciation...) and the fuel consumption is also calculated. In other to get high spatial, temporal resolution (respectively 1 x 1 km^2 and 1 hour) and the availability of the data, a bottom-up approach has been chosen for traffic source. COPERT III software is used to make the emission inventory for traffic source. For this domain, the data for industries, residential and biogenic sources is unavailability to make emission inventory by bottom-up approach so that a top-down approach has been chosen for these others sources.

From data of total emissions in Viet Nam and distribution of the sources of emissions for each pollutant *(Projet Mics-Asia, Austria 2000)*, we can calculate the emission for one certain hour within by year by using formula: $\mathbf{E_h = E_a * f_a * f_w * f_d / 8760}$. With: E_h, E_a are the emission for a certain hour and the annual total emissions. f_a, f_w and f_d are the emission quota for annual cycle, for weekly cycle and for diurnal cycle. 8760 is a number of hours per year (Friedrich et Reis.2004). The results obtained are divided into three types of emissions: "Hot emission", "cold start" and "evaporation" (only for COV). Hot emission is the most important emission (more than 95% of the total of the emissions)

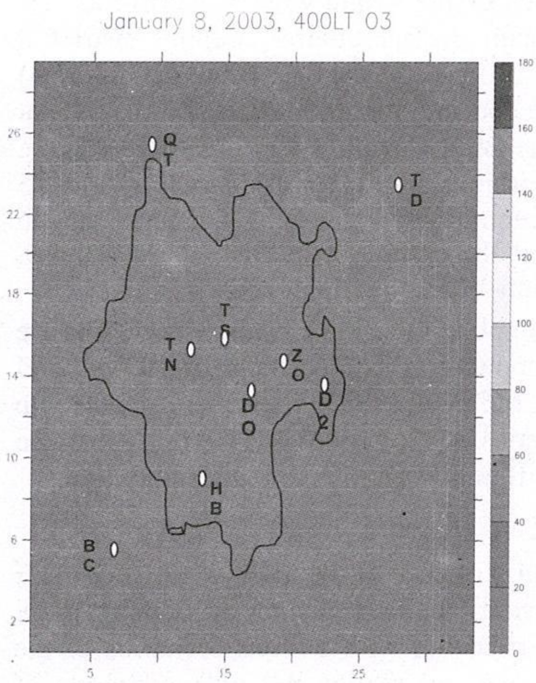
5. MODEL RESULTS COMPARED WITH MEASUREMENTS

5.1 Meteorology results

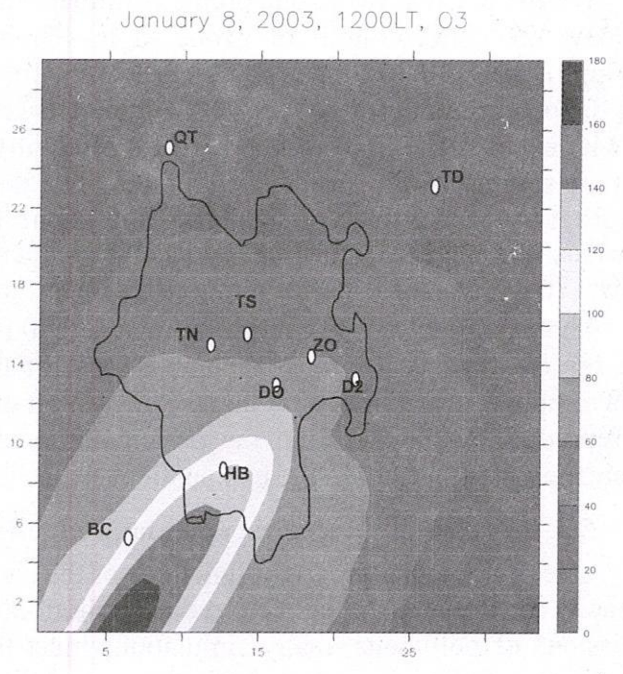
The results of wind speed of the model and measurement are similar, the wind speed is low (0.6-1.7m/s) of the morning and becomes high (1.8-2.5 m/s) at the beginning of after midday, during the evening the wind speed is similar the morning. The result of simulations shows that the wind direction was influenced very weakly by the local phenomena, which are the phenomena of slopes wind and sea breeze. At 7h00, the wind direction was influenced by the phenomenon "slopes wind" on the mountain in North-east of domain because at 7h00 of the morning on the mountain the weather is still cold, so that the wind direction is Northern- east on the zone near the mountain. In addition, at this hour the sea is still hot, so that wind direction is Northern-West on the zone near the sea "sea breeze". At 16h00, the wind direction on the mountain already changed towards the mountain (Southern-West), because at 16h00, the air on the mountain is already heated.The results of this simulation show that the passage of the wind on a large scale (forcing) with a small grid gives very similar results with measurements and in HCMC, the wind direction is more influenced by global scale than local phenomena

5.2 Air quality results: Distribution of O_3 along the plume trajectory

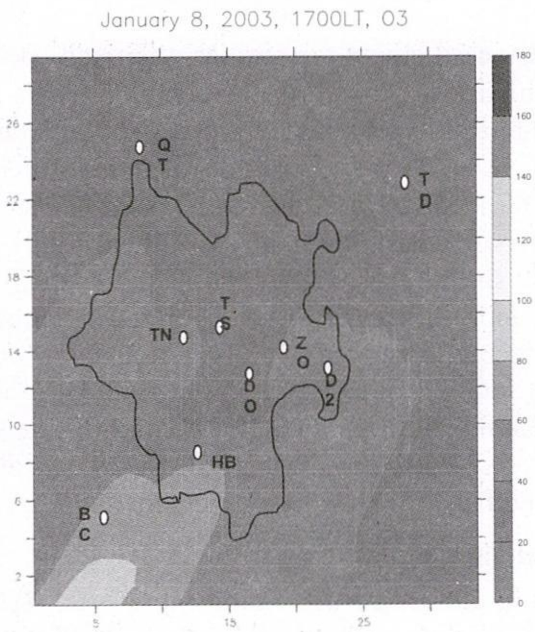
Ozone is a strong oxidant likely to react with almost all the biological tissues. At high concentrations (>60 ppb), ozone exposure irritates the mucous membranes of the respiratory tract and causes a feeling a pressure on the chest and pain when breathing deeply. Short-term effects of ozone are documented in numerous studies (Ponce de Leon et al, 1996, Jones et al., 1995) showing a correlation between hospital admissions due to asthma or pneumonia during photochemical smog episodes. Long-term exposure to ozone, exerts adverse effects on human heath. In this case, measured diminution of pulmonary function goes along with chronic infections and structural modifications of the tissues in the bronchi-pulmonary tissues and promotes premature ageing of the respiratory organs.



a)



b)



c)

Fig. 3. Simulated O_3 values within the first vertical layer (30m) at
(a) 0400LT, (b) 1200LT, and (c) 1600LT on January 8, 2003.
The contour is the zone in center of HCMC and localization of monitoring stations in domain simulated.

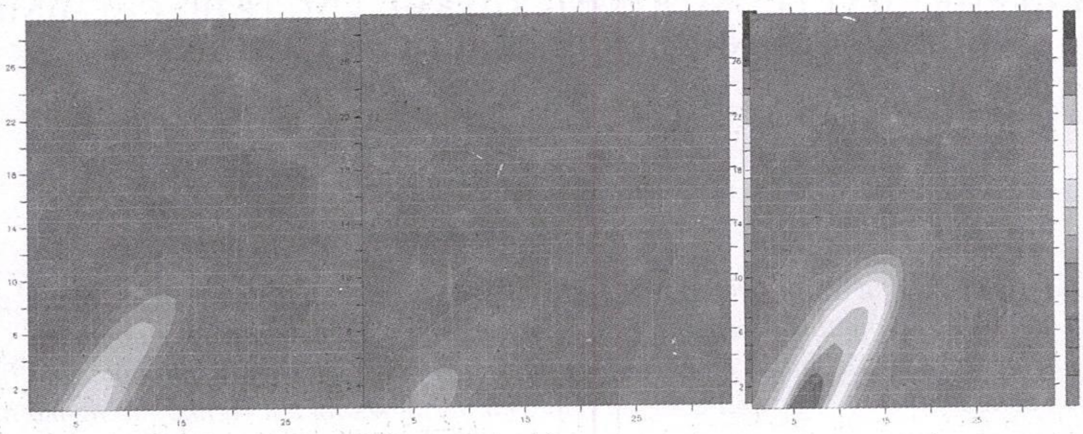
Figure 3 shows the development of the ozone plume during the day of January 8, 2003. We are observed that: during the day, the ozone plume goes down to the South-West of the city. The maximum ozone concentration is 180ppb (at midday). The plume leaves the basin of HCMC by the South-West at the beginning of evening (18h00). The ozone concentrations remain low in center HCMC (80ppb of O_3 at 17h00).

We can see that the ozone plume is influenced much by the strong wind of North-East. At midday, the concentration of ozone in the Binh Chanh district attains 180ppb, district 8 (160ppb), district 6 (140ppb), Districts 1, 3, 5, 10, 11 (100ppb), at the Tan Binh, 4, 7 (80ppb) and the other districts are lower than 60ppb. Hence, the concentration of ozone of 3 districts at HCMC exceeds the limit of the standard (102ppb). The Binh Chanh, 8 and 6 districts (figure 1.1) are seriously influenced by pollution, while the emissions are higher at districts 1, 3 and 5 (figure 1). For this reason, to reduce the ozone concentration in the Binh Chanh, 8 and 6 districts, it is necessary to find strategies of reduction of the emissions in Districts 1, 3 and 5. After 17h00, the plume leaves almost the city in the South-West direction.

The maximum ozone concentration at 17h00 is 100ppb at the Binh Chanh district. And we can see that this is the most favorable case for the population in the center of HCMC and unfavorable for the population in the South-West of HCMC. Once the models were shown able to reproduce and understand the principal characteristics of pollution in HCMC, it can be interesting to go deeper in the explanations by testing different scenarios to reduce pollution.

5.3. Abatement strategies: emission reduction scenarios

One of the most important functions of the air quality models of the meso-scale 3D is their capacity to simulate strategies to reduce pollution. To study the best manner of reducing these emissions of pollutants, many simulations must be carried out with various scenarios of the reductions of the emissions. With these models 3D, we can realize not only scenarios of reduction by sources, but also of the scenarios of reduction in the various zones of the city.



a) b) c)

Fig.4. ffect of two scenarios on O_3 concentration fields for the 8th January, 2003 at 1200LT. The figure a) represents the concentration fields for the base case, the figure b) represents the concentration fields for the scenarios of traffic and the figure c) represents the concentration fields for the scenarios of population.

We present here the impacts of two scenarios on the ozone troposphere levels. Two scenarios, the first case increases 100% the total emissions (scenarios of population) and the second case reduces in 50% the total emission from motorbikes and the total emission from buses was increased in 100% (scenarios of traffic), were evaluated on the domain of 1020km^2. For the first case, suppose that if the population of HCMC increases in 100%, the emissions also will increase 2 times and the second case means that we replace the motor bicycles by buses.

The results show that, in the first case (fig.4c), ozone concentration increases 27.76% in the centre of HCMC (maximum 200 ppb at midday), and 56.18% (maximum 300ppb at midday) in the South–West part of the city. In the second case (fig. 4b), the results show that the ozone concentration is reduced until 60ppb (12h00) in the center of the city, and until 140ppb (12h00) in the South-West of the city. In general, the ozone concentration reduces 21% and the surface influenced by the pollution of the ozone, will be reduced from 100km^2 to 28km^2.

6. CONCLUSION

The results obtained show that the meso-scale meteorological fields depend simultaneously on the local and global scale conditions; the wind direction is more influenced by global scale than local phenomena. It is necessary to use the method "Nesting-one way" to obtain more precise boundary and initial conditions.

The emissions coming from traffic are very important among them; the motorbikes produce serious emissions of pollutants in HCMC. The results of the simulations show that the ozone plume is 90km in length and 30 km in width at 12h00 LT. During the selected episode, the zone in the South - West of HCMC is the most polluted one (180ppb at midday).

Two scenarios (the first case increases 100% the total emissions, the second case reduces in 50% the total emission from motorbikes and the total emission from buses was increased in 100%) were evaluated. In the first case, ozone concentration increases 27.76% in the centre of HCMC (maximum 200 ppb at midday), and 56.18% (maximum 300ppb at midday) in the South – West part of the city. In the second case, the results show that the surface influenced by the pollution of the ozone, will be reduced from 100km^2 to 28km^2.

MÔ HÌNH HÓA CHẤT LƯỢNG KHÔNG KHÍ KHU VỰC TP.HỒ CHÍ MINH - NGHIÊN CỨU NHỮNG CHIẾN LƯỢC GIẢM THIỂU

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TÓM TẮT: *Hồ Chí Minh (HCM) là một thành phố lớn nhất của Việt Nam, là thành phố có mật độ dân số cao đứng thứ 7 trên thế giới, bị ảnh hưởng nghiêm trọng bởi sự ô nhiễm. Các nguồn ô nhiễm không khí chính ở Tp.HCM là giao thông, công nghiệp và sinh hoạt. Mô hình tóan học là công cụ duy nhất có khả năng dự báo chất lượng không khí và nhờ những mô hình này mà chúng ta tìm ra các chiến lược giảm thiểu ô nhiễm không khí cho Tp.HCM, nhiều kịch bản khác nhau đã được nghiên cứu.*

Kết quả nhận được chỉ ra rằng khí tượng tại Tp.HCM phụ thuộc vào khí tượng của thang đo toàn cầu hơn thang đo địa phương. Kết quả mô phỏng chỉ rằng chùm khói ozon có kích thước 90km chiều dài và 30 km chiều rộng. Suốt thời kỳ được chọn mô hình hoá (8/1/2003), nồng độ ozon trung bình ở trung tâm Tp.HCM lúc 12h00 là 100ppb và nồng độ ozon cao nhất ở phía Tây-Nam của Tp.HCM là 180ppb vào lúc 12h00.

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