Air Quality in Urban Areas: Traffic Induced Pollutants Concentration and Dispersion

Contribution to subproject SATURN.

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Summary

An Eulerian-Lagrangian method that was developed in 1998 and 1999 (Jicha et al., 2000) for road tunnels has been further extended and modified for pollutants dispersion in street canyons and cross roads. The method is based on CFD modelling and accounts for moving vehicles and by them induced flow and turbulence. In 2001 the team has been focusing on both theoretical advancement of the aforementioned method and onto applications to actual city areas. The theoretical development was oriented mainly to model dynamic situations of "Stop-And-Go" in intersections. The model was applied to real situations in the city intersection in the city of Brno and in the frame of an excercise also to a street structure in Hannover in Germany (Podbielski strasse). The prediction was compared with field measurements.

Aim of the research

The principal aim is to establish the influence of traffic in specific urban situations like area around road tunnel openings, street canyons and intersections and to predict the influence of different traffic and meteorological conditions on the dispersion of pollutants in microscale. Based on this work, the main goal is to complement the current methodology of the Czech Hydrometeorological Institute that is not applicable inside the canopy layer.

Activities during the year

The aforementioned Eulerian-Lagrangian method to model moving vehicles and by them induced flow and turbulence has been further developing for traffic dynamics of the type "stop and go" to model flow and concentration field when cars slow down or speed up. The method was further applied to real areas around city road tunnel in Prague for the prediction of pollutants dispersion with the aim to optimise location of the Automatic Immission Monitoring station.

Principal results

As input data for the computational modeling, the actual traffic situation from one intersection in the center of city of Brno was used. This intersection was selected among other city intersections since it has rather regular geometry with mostly 4 story buildings. Schematic view is in figure 1. Dimensions of the solution domain are 120x120x115m. In both street canyons two way traffic was set in four traffic lanes in total.

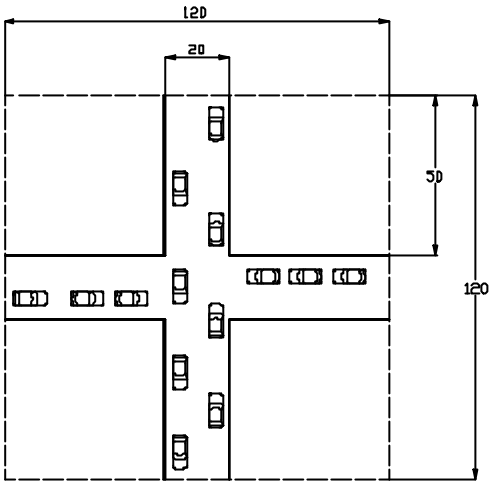

Figure1: Schematic view of the intersection

From the field measurements done in March 2001 the following data on the traffic were obtained:

- number of cars that stop in one street canyon on red light and number of cars passing in the other street canyon
- length of car line waiting on red light
- stopping distance and driving distance of cars to a terminal speed
- traffic light sequence and timing of stop-and-go of traffic lights
- fleet of vehicles

The traffic rate was set to 360 cars/hour/traffic lane, speed of traffic to 50 km/hour, stopping distance 69m, gap between cars on red light 2.5m, the average car acceleration when driving away 10m/s^2, frequency of driving away cars was set to 1 car/s. Identical conditions were assigned in both street canyons. The time intervals on traffic lights are regular and switching over the red and green lights occurs every 60 seconds. During the calculations, no wind conditions were applied to emphasize the dynamics of traffic. The flow diagram was written for the traffic dynamics in the intersection. During one cycle, the slowing down and stopping of cars in one street and in the other one the acceleration and driving out of intersection is modelled. In the time instant of 120s the whole cycle repeats. Similarly the flow diagram of transient emissions produced by cars as the function of time and location was written. As a result, the transient flow field and ground concentration of a passive scalar and NOx were predicted. In figure 2 and 3 results of predictions and measurements are presented.

Main conclusions

An Eulerian-Lagrangian method developed for traffic induced flow (Jicha at al., 2000) was applied to prediction of velocity and concentration in the model intersection equipped with traffic lights. The method was complemented with transient speed of cars and transient and locally dependent production of emissions. From the results it can be seen that the traffic dynamics namely at very low wind velocities significantly influences the flow field and thus results in a very different field of ground concentrations. The peak values of concentrations occur when cars start driving away from the intersection. Contrary, the minimal values are when cars slow down to stop. The method could be used to optimize the traffic control in city intersections. Comparison with measurements shows that the time average values are in a very good agreement. The measurements show the average value of 70 ppb NOx and

predicted value is approximately 82 ppb.The instant values are extremely dependent on wind that very rapidly changes both direction and speed in a very short time interval and can not be appropriately integrated into the modelling.

Aims for the coming year

1. Improvement of traffic dynamics algorithm
2. To continue on validation of CFD modelling against measurements. Several field measurements are planned:
   - Tangential two-lane dual carriageway in Brno
   - City road tunnel outlet and its surrounding

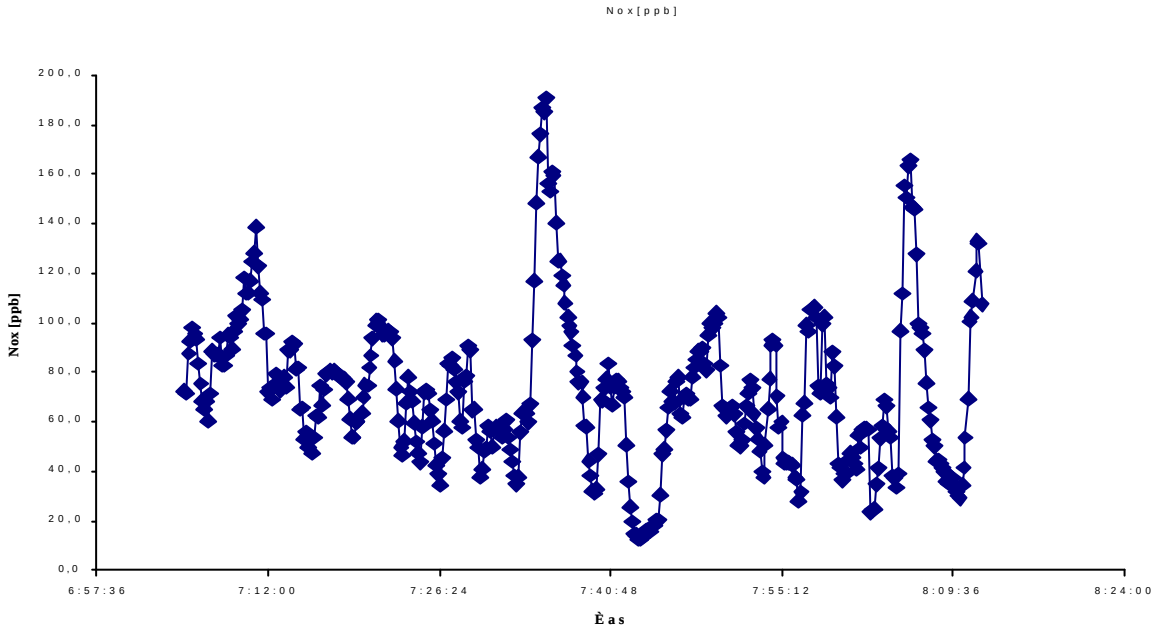

Figure 2. NOx concentration measurement

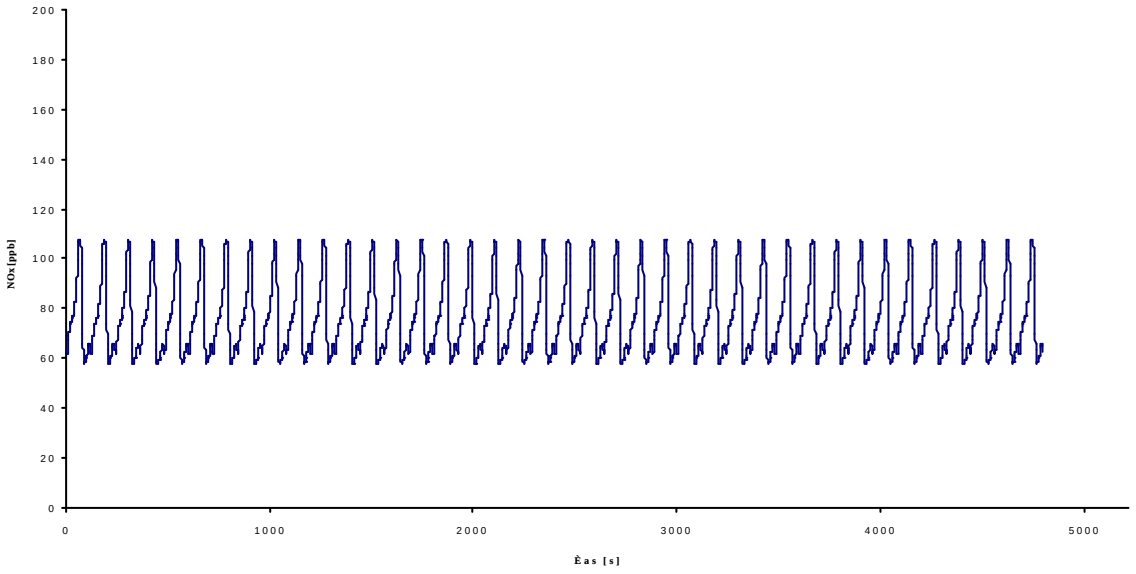

Figure 3. NOx concentration prediction

Acknowledgements

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References

Jicha, M., J. Katolicky, J. Pospisil, 2000**,** Dispersion of Pollutants in street canyon under traffic induced flow and turbulence, International J. for Environmental Monitoring and Assessment. vol. 65, 343-351