THE CONTRIBUTION OF SATURN TO A BETTER UNDERSTANDING OF URBAN AIR POLLUTION

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INTRODUCTION

The state-of-the-art in urban air pollution research was considerably improved in the frame of SATURN (cf. http://aix.meng.auth.gr/saturn/). This EUROTRAC-2 subproject aims at a better understanding of urban air pollution as a prerequisite for finding effective solutions to air quality problems and for a sustainable development in the urban environment. For this purpose, the main scientific objective of SATURN is to substantially improve our ability of establishing source-receptor relationships at the urban scale. Ensuring the validity of such relationships may also facilitate assessing the impact of urban areas to regional and global scale problems of the atmospheric environment.

The following methodology was adopted for meeting the above objective:

- Development of an appropriate model hierarchy, covering also the local scale (down to street canyon geometries) in the extent necessary to establish source-receptor relationships.
- Evaluation of individual models with suitable procedures.
- In support of such procedures, creation of proper validation data sets from observations and experimental results originating from laboratory studies and field campaigns.

The structure of SATURN is based on three different clusters, namely the Local Cluster, the Urban Cluster and the Integration Cluster. The Local Cluster deals with microscale and local-scale phenomena investigated with wind tunnel and field experiments as well as numerical models. Accordingly, the Urban Cluster tackles urban-to-regional scale matters (without resolving individual obstacles) with field experimental campaigns and numerical models. Both clusters include development and validation of models and novel modules. The Integration Cluster gives special emphasis on the integration of models in Air Quality Management Systems (AQMS) and the testing/validation of such systems with collected data. SATURN includes contributions of about 40 research groups from 16 European countries, the European Commission and Israel.

The main achievements of the research conducted in SATURN are summarised in the following. More details may be found elsewhere (*Moussiopoulos*, 2002).

EXPERIMENTAL WORK

Field experiments led to a better insight into the characteristics of polluted urban air. Special focus was given on the particulate pollution with emphasis on the smallest fractions (cf. Figure 1). Specifically, it was found that traffic is the dominating source of ultrafine particles in busy streets, but also the traffic contribution to PM_{10} is significant. The PM_{10} mass and most of the analysed species are dominated by the fine fraction. The application of averaged PM data, collected continuously, in combination with routine monitoring data and manually counted traffic rates, is a powerful tool to determine contribution and emission factors of particles from diesel and petrol vehicles from the actual car fleet under normal driving conditions. The method is useful for demonstrating the effect of air pollution abatement measures.

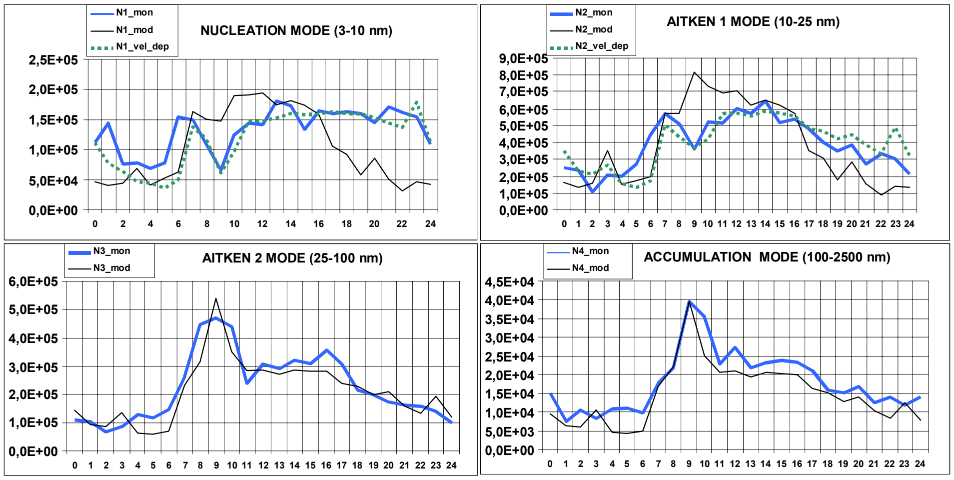

Figure 1. Particle number concentrations in Stockholm: Measured (thick line) vs. computed values (thin line: constant emission factors, dashed line: velocity dependent emission factors) for various modes. The results demonstrate the need for an emission factor correction in the case of the finer modes (Johansson, 2002).

Other local experiments concentrated on photochemical pollution especially in South Europe showing that photochemical processes lead to secondary particle generation. Regarding the chemical composition, the coarse mode (composed of sea salts and nitrates) is most important at the beginning of the event, but decreases strongly when the pollution increases, to become much lower than the accumulation mode. The latter mode is totally dominated by sulphates and ammonium and the smaller particles of this mode become progressively more important during the event. Other experiments focussed on the investigation of the thermal characteristics of the urban atmosphere and their effects on the boundary layer flows and structure.

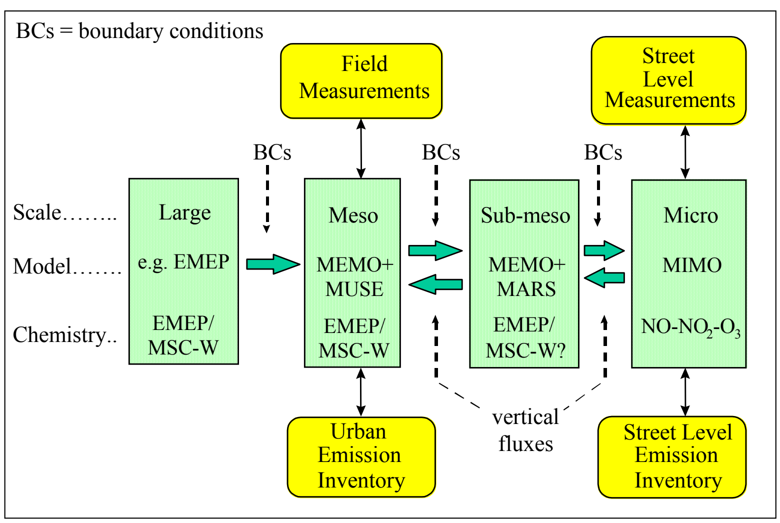

Figure 2. Schematic presentation of a multi-scale model cascade for evaluating urban air pollution levels (Moussiopoulos et al., 2000).

MODEL DEVELOPMENT

Newly developed urban scale dispersion models represent a sound basis for reliable urban air quality assessments. Efficient interfaces were developed for linking such models to suitable regional scale models (see Figure 2). In addition, improved parameterisation methods were developed and numerical techniques refined. Work included evaluating the aerosol behaviour in urban areas using detailed chemical and aerosol dynamical models. In addition, transport-chemistry models were developed for the evaluation of emission reduction strategies, for providing information to the public, and as the central part of models for calculation of human exposure and for forecasting episodes.

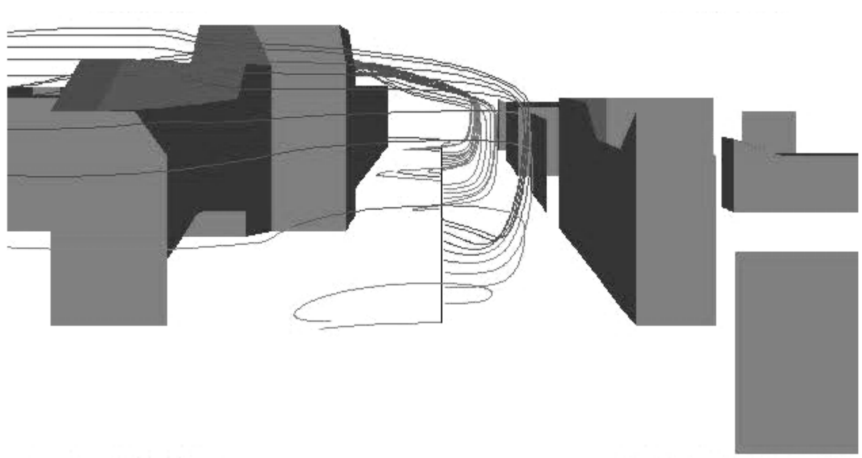

Figure 3. Simulation of a tracer experiment in an urban street canyon with MITRAS. Buildings are indicated as shaded blocks. The tracer is released at a line source in the centre of the street. Advection of the tracer is visualised by streamlines. Above the urban canopy, the wind is blowing from right to left (Schluenzen, 2002).

As far as so-called local scale models are concerned, both their concept and their application range progressed significantly in the frame of SATURN. Applications include simulations of the air motion, turbulent field and heat fluxes close to building walls as well as their effect on pollutant dispersion (cf. Figure 3). In particular, Computational Fluid Dynamics (CFD) codes, especially those applying the standard k-ε model, have been applied for predicting the airflow patterns at the local scale. The output of these codes depends, among other, on the numerical scheme used, the way boundary conditions are implemented, the model domain size and the grid resolution. The effects of such parameters on the predicted flow were analysed with detailed investigations of simple cases such as the flow within a single cavity or around a single mounted cube (cf. Figure 4). Furthermore, the models' ability in accurately simulating the flow and dispersion characteristics in real cases was successfully tested.

Within SATURN, local scale models have been also applied in simple fast-chemistry examples considering the photochemical reactions taking place within a street canyon right after pollutants have been emitted (mainly the NO-NO_2-O_3 cycle). In spite of first encouraging results, further research is necessary in order to describe more complex chemical processes that occur within a street canyon affecting the residence of pollutants in the urban canopy.

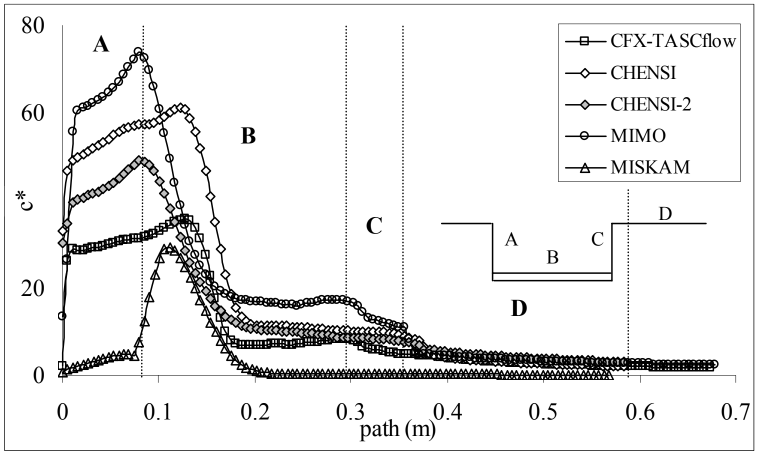

Figure 4. Comparison of the normalised concentration c along the path ABCD for the cavity with W/H=2 (A and C correspond to 75% of the cavity depth, while B and D are equal to its width) after Sahm et al. (2001).*

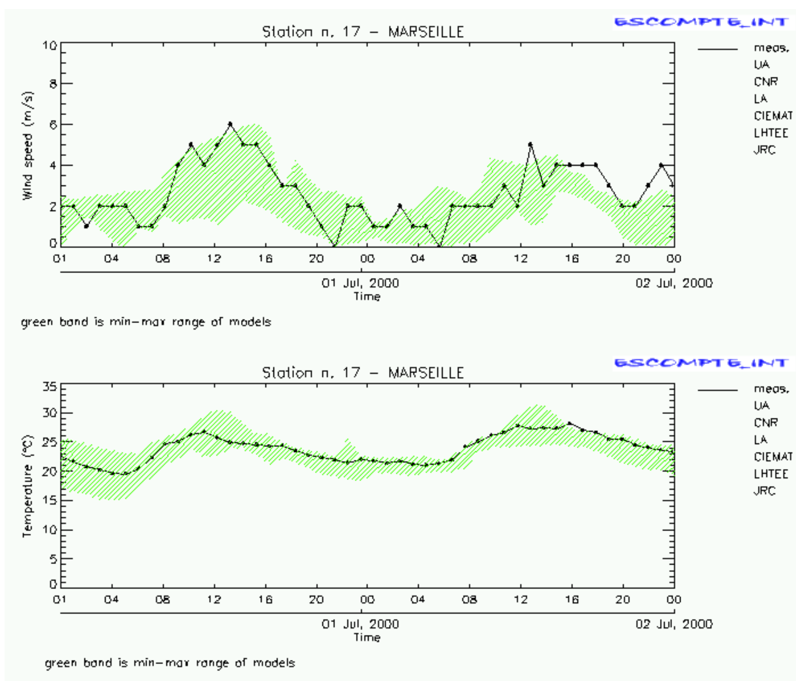

Figure 5. Range of wind speed and temperature in Marseille on 1 July 2000 resulting from simulations with six different urban scale models compared to corresponding results of the ESCOMPTE pre-campaign (cf. http://rem.jrc.cec.eu.int/escompte_int/RESULTS/).

MODEL QUALITY ASSURANCE

Valuable new knowledge regarding quality assurance of urban scale dispersion models resulted from sensitivity studies and intercomparison activities. An example for the latter category is

ESCOMPTE_INT, an exercise based on the ESCOMPTE pre-campaign data sets (cf. Figure 5). Moreover, SATURN stimulated numerous fruitful discussions between numerical model developers and experimentalists, which resulted into an improved model validation strategy. It is characteristic for the urban canopy layer that the velocity and concentration fluctuations are larger than the corresponding mean values causing a large inherent uncertainty in the data, and need to be quantified before the data can be used for validation purposes. A methodology for the quantification was developed and applied. On the other hand, wind-tunnel experiments have been carried out to quantify up to which degree numerical model results depend on domain size and geometrical resolution.

POLICY-RELEVANT APPLICATIONS

The policy relevance of the above scientific achievements is obvious, given their direct influence on the formulation of improved tools for urban air quality assessments. In the last years new methods to determine the contributions of various sources to air pollution in conurbations were developed and existing ones were improved. Such methods may be utilised by urban authorities wishing to have insight in the possibilities to reduce air pollution levels or to control anticipated increases of levels. Furthermore, methods were refined for predictions of the effect of long-term emission changes. Such methods may considerably help formulating and evaluating air pollution abatement strategies.

Knowledge and tools acquired in the framework of SATURN were integrated in order to make them directly suitable for applications related to environmental policy and to support urban air quality management. Gradually, the integrated modelling tools for modelling and predicting air pollution improve in quality and efficiency, while novel telematics techniques are being applied for informing the public on air pollution.

CONCLUDING REMARKS

The development of reliable urban and local scale flow and dispersion models is among the great challenges in Atmospheric Sciences. Physical and chemical processes that are only parameterised in larger scale models must be resolved at these scales. The practical relevance of this development is obvious. The resulting tools will contribute directly to better air quality assessments and to the quality of discussions in public hearings on planned urban projects of intense public concern. Despite the substantial scientific progress achieved in this context within SATURN, much remains to be done. The associated tasks continue to be relevant. Therefore the scientific work on urban air pollution needs to be continued.

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