# 1.33 APPLICATION OF MC2-AQ AND GEM-AQ MODELS TO LONG-TERM AIR QUALITY SIMULATION OVER EUROPECONTRIBUTION TO CITYDELTA/EURODELTA PROJECTS

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## INTRODUCTION

Over the last century there has been detected a noticeable rise in the long-term trends of photochemical oxidants, and similar trends of the emissions of precursor species. Highly sophisticated atmospheric models, can be used to establish relationships between ozone concentration and the source, transport and sink processes (*Chang et al.*, 1987; *Yamartino et al.*, 1992; *Pudykiewicz et al.*, 1997; *Memmesheimer et al.*, 1997; *Ebel et al.*, 2001).

The response to emission changes is an important output from the chemical transport models for integrated assessment strategies and policy applications. Two European projects - CityDelta and Eurodelta - focus on the ability of atmospheric dispersion models to reproduce non-linear chemical response to emission changes. The main objective of the CityDelta project is to investigate the role of spatial resolution on the impact of emission reduction scenarios. In the Eurodelta project the regional model inter-comparison aims to evaluate the performance of different regional models against observations, and quantify their performance in terms of agreed evaluation criteria.

For interpretation and inter-comparison of the results obtained with different models used in CityDelta and Eurodelta projects, the information of physical processes parameterisations should be taken into account. In the frame of CityDelta/Eurodelta projects, the limited-area model MC2-AQ has been applied to study ozone distribution in the local and regional scale over Europe. The use of an on-line model allows the study of the impact of physical processes on ozone and its precursor concentrations within the planetary boundary layer. We will present results obtained with alternative parameterisations of surface layer fluxes, turbulent diffusion coefficient profiles and dry deposition processes. Performance of the model in specific meteorological conditions will be discussed.

## MC2-AQ MODEL DESCRIPTION

The core of the modelling system is a meteorological mesoscale model MC2 (*Benoit et al.*, 1997). The MC2 is a non-hydrostatic limited-area model based on the solution methods of *Robert et al.* (1985) and *Tanguay et al.* (1990) for the compressible form of the Euler equations, coupling an implicit treatment of elastic and gravity waves with a three-dimensional semi-Lagrangian treatment of advection.

Chemical calculations are carried out concurrently with the integration of the meteorological model, and are performed on the same grid and use the same advection and diffusion algorithms as used in the host meteorological model. Also, parameterisations used in the chemical calculations are harmonised with those used in the meteorological model (*Mailhot et al.*, 1998). The vertical transfer of trace species due to subgrid-scale turbulence is parameterised using eddy diffusion for heat transfer calculated by the host meteorological model (*Benoit et al*., 1989).

The gas-phase chemistry mechanism used in the MC2-AQ model has been taken from the Acid Deposition and Oxidants Model (ADOM) (*Venkatram et al*., 1988), derived from the condensed mechanism of *Lurmann et al.* (1986). The mechanism is comprised of 47 species, 98 chemical reactions and 16 photolysis reactions.

The effects of dry and wet deposition are calculated as a loss term in the chemistry solver. Emissions of trace species are also calculated as part of the chemistry. Area emissions, defined as all anthropogenic and biogenic emissions, are assumed to be emitted at the surface and ditributed within the lowest model level. Emissions from major point sources may occur directly into model layers above the surface.

The model is highly flexible and can be adapted to different spatial scales. The full description of the model is given in *Plummer et al*. (2001) and *Kaminski at al.* (2002). The model has been evaluated against measurements in several experiments (e.g. *Yang et al*. 2003).

## CITYDELTA I – MC2-AQ MODEL CONFIGURATION

Preliminary calculation (CityDelta I emission data set, EMEP chemical boundary conditions) has been performed for the domain covering Central Europe. It has been assumed that for long term simulation transboundary transport would have significant impact on ozone distribution. Therefore the domain for CityDelta I simulation included predefined domains for three cities: Berlin, Prague and Katowice, which might influence each other. The 255 x 250 grid covered Central Europe with 3 km resolution.

Initial and boundary meteorological fields have been generated with MC2 simulation over Europe on the 171 x 171 grid with 20 km resolution. Output from the MC2 simulation on the 20 km grid was used to provide meteorological boundary conditions for a subsequent run of the MC2-AQ model at 3 km resolution. Initial and boundary conditions for chemical species have been supplied by the EMEP model. Since the EMEP model VOC speciation is different from those used in MC2-AQ model, the conversion between these parameterizations has been applied.

Emissions data have been combined from detailed emissions inventories for each city (300 km x 300 km) and EMEP emissions data, and distributed vertically according to the CityDelta guidelines.

Results of the preliminary calculation showed some problems with the diurnal variability of ozone concentration. After some corrections in the surface layer parameterization, which had influenced vertical exchange and dry deposition, the model performed correctly.

## EURODELTA

### MC2-AQ model configuration

For Eurodelta experiments the MC2-AQ domain has covered the entire European continent with 100 x 100 grid points and 50 km resolution. To minimize input data errors and to avoid emission data interpolation the EMEP grid definition has been used. Initial and boundary conditions for the chemical species have been taken from a global, tropospheric chemical transport model (*McConnell et al.*, 1995).

Initial and boundary conditions for meteorological field (temperature, pressure, humidity and wind) have been taken from the operational objective analysis (*Gauthier et al*., 1999).

Emission fields for Eurodelta model setup have been distributed vertically up to 500 m, and vertical distribution factors have been slightly changed compared with those suggested by EMEP. Total NMVOC emission has been speciated according to MC2-AQ chemical mechanism.

**Application of the global tropospheric chemistry model (GEM-AQ)**

Many areas of Europe are receiving acidifying and eutrophying deposits of air pollutants in excess of critical loads (e.g. *Tarrason and Schaug*, 2000) and a fraction has its origin outside Europe - thus cannot be controlled regionally. The amount of North American pollution advected and entrained into the planetary boundary layer over Europe and brought down to the surface is not yet determined. Recent model calculations (e.g. *Auvray and Bey*, 2003) have suggested that as much as 9 ppbv could be contributing to background ozone levels in the European boundary layer. Analysis of global model results would help to determine how often pollution plumes from North America can be observed at the surface in Europe and to what extent they contribute to exceedances of European air quality standards thus informing policy makers about the effectiveness of current EU mitigation strategies.

The Global Environmental Multiscale (GEM) (*Côté, et al*., 1998) model, developed at the Meteorological Service of Canada (MSC) coupled with tropospheric air quality modules will be run for the same periods as MC2-AQ. Research and applications of GEM-AQ are carried out by a network of Canadian universities (www.MAQNet.ca). GEM-AQ is used in the context of global multiscale three-dimensional comprehensive air quality modelling (it includes modules to calculate gas and aqueous phase chemistry, aerosol formation, dry and wet deposition, anthropogenic and biogenic emissions) and chemical data assimilation system. In this study the model will be run on a regional variable resolution grid centred over Europe.

**SUMMARY**

Applying the MC2-AQ model for CityDelta and Eurodelta calculations we have focused on the model evaluation component. The aim was to test and validate an advanced tool for studying the formation of photochemical smog on an urban and regional scale. With long term simulations, its most important 'on-line' model feature becomes disadvantageous since the model does not use pre-calculated meteorological fields but performs chemical integration simultaneously with the meteorological calculation every time-step.

We will present model results for specific periods. The objective is to reproduce with better accuracy the transport and formation of pollutants – and its dependence on meteorological conditions, which influence significantly the chemical composition of the PBL.

Comparison of MC2-AQ and GEM-AQ results for the Eurodelta calculations would help an estimation of the influence of trans-continental transport on European air quality. Since the chemical mechanism is highly uniform for both models, it can be assumed that differences in concentration fields are caused by the transport from outside of Europe.

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