

1.21 SENSITIVITY OF LONG-TERM CTM SIMULATIONS TO METEOROLOGICAL INPUT

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INTRODUCTION

The City-Delta exercise is an open model intercomparison aimed to explore the effects of changes in urban and regional emissions on urban air quality, with focus on ozone and PM10. The participating modelling groups were asked to run long-term (6 months or 1 year) simulations with 3d Chemical Transport Models (CTM), on regional (300x300 km²) domains centred on 8 European cities. Common emission inventories and boundary conditions were provided to all groups, for both the base case (present day emissions) and several emission-reduction scenarios, while the meteorological input was prepared independently by each modelling group; a common verification tool was also developed and made available by JRC. After a first stage mainly aimed to ozone analysis, the exercise has then been extended, and a second stage (City-Delta 2) is still in progress. The structure of the exercise is essentially the same as City-Delta, but new emission inventories and boundary conditions have been provided, and participants are required to focus on one-year simulations of PM10.

THE SENSITIVITY STUDY

Meteorological fields are a very important input to CTM: wind and turbulence in the PBL determines how pollutants are dispersed and transported over distance, thus affecting their surface concentrations and the production of secondary species. These fields can be produced in different ways: by interpolation of observations, by post-processing of large-scale analysis, by running an high resolution meteorological model (LAM) or by a combination of these. This study investigates the model response to the different formulations of the meteorological input.

Three different sets of meteorological data were produced, using the Calmet (*Scire J.S. et al*, 2000) pre-processor with different input data and model configurations. Only the horizontal wind field was changed, while the other parameters (temperature, surface fluxes, physiographic constants) are the same in all the datasets; it should be noticed indeed that horizontal wind also affects vertical velocity (diagnosed from topography and wind divergence) and turbulent vertical diffusion (the formulation of Kz depends on wind speed). In detail, the datasets are:

- "ECM": 50 km resolution wind analysis from ECMWF global model (www.ecmwf.int) were used as first guess; a selected set of surface observations were vertically extrapolated up to PBL top, and used to correct the first guess fields.
- "Ala": 10 km resolution fields from the French LAM "Aladin" were used without modification, except for interpolation on model grid; the first 12 hours of half-daily forecasts were used.
- "Base": Aladin data were corrected in the lowest layers by use of surface observations; differences are important in the first 400 meters.

Aladin (www.cnrm.meteo.fr/aladin/) operational forecasts were made available by Météo France, specifically for City-Delta exercise. Surface observations were collected from GTS

(Synop stations) and from the local network of the Italian Regional Environmental Agencies of Emilia Romagna, Piemonte and Lombardia: a total of 30 stations were finally selected and used in the simulations. Vertical temperature profiles from Milan radiosounding (TEMP network, 6 hourly measurements) were also used.

Two groups of simulations were performed on the City-Delta domain centred on Milan, using two different CTM:

- Calgrid (Yamartino, R. J. et al., 1991): two simulations, lasting 6 months (summer 1999); emissions and boundary conditions from City-Delta 1, meteorology from “ECMWF” and “Aladin” datasets; PM10 is not included in the model;
- CAMx (Environ Corp., 2004): three simulations, lasting 14 days (june-july 1999); emissions and boundary conditions from City-Delta 2, meteorology from the three datasets; the model includes PM10.

The output of the two models are not directly comparable, due to the different length of integration and also to the differences in emissions and BC. Nevertheless, the time period chosen for the CAMx runs includes a variety of meteorological conditions, and also the days with the highest concentrations of pollutants: it can then be considered somehow representative of the whole summer period, at least as regards model sensitivity.

ANALYSIS OF THE METEOROLOGICAL INPUT

The three wind datasets are analysed and verified, taking into account the whole 6 months period. In the upper boundary layer (1000-2000 m) the “Ala” wind shows several regional-scale structures, mostly induced by the high resolution topography, while the “ECM” fields are much smoother. Near the surface the “Ala” wind is significantly stronger than “ECM”: in Po valley the difference is of the order of 1 m/s (50% of the observed average wind speed); moreover, “Ala” wind frequently shows an organized eastern flow on Po valley, while “ECM” fields are much more irregular in time and space (Figure 1). The “Base” dataset is somehow a compromise of the two, resembling “Aladin” in upper levels and “ECMWF” near the surface.

To verify the datasets, wind at the first model level (10 meters) are compared with a set of 8 independent surface stations (not used in the production of the fields): “Ala” wind speed results overestimated, while “ECM” and “Base” (i.e. the two datasets containing local observations) have very little bias in wind speed, and also show slightly better performance in wind direction. On the whole, all the datasets look “reasonable”, with “Base” having the best scores (Table 1).

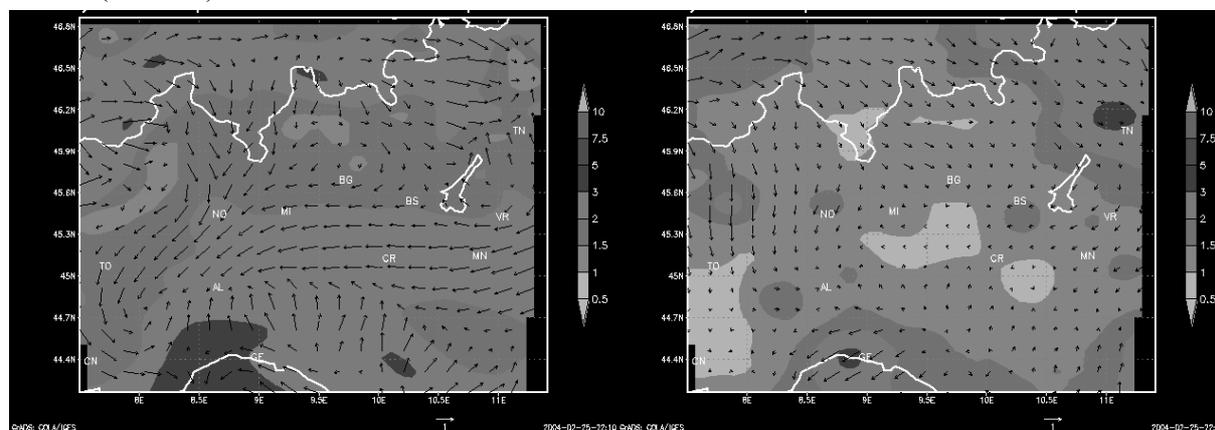


Figure 1: 6 months averaged, 10 meters wind speed (shading) and vectors of mean u and v wind components (arrows), for the “Ala” (left) and “ECM” (right) meteorology.

Table 1. scores of the three wind datasets; 6 months of data from 8 independent stations.

Wind speed (m/s)	Base	Aladin	ECMWF	Wind dir (degrees)	Base	Aladin	ECMWF
BIAS	0.0	+ 0.7	- 0.2				
RMSE	1.1	1.5	1.1	RMSE	67	79	71

MODEL RESULTS

First, average ozone concentrations for CAMx are examined, comparing the “Base” run with the other two (Figure 4, left); since the CAMx simulations all start from the same initial conditions, to make the comparison more meaningful the first 3 days of each simulation have been excluded from analysis.

Generally speaking, the spatial distribution looks rather similar in the three runs, although the mean values are not the same, and there are different behaviours in specific parts of the domain. In rural areas, “Ala” data are similar to “Base”, with an average 2 ppb difference caused by slightly lower daytime maxima in “Ala”. On the other hand, in Milan area “Ala” diurnal cycle is reduced with respect to “Base” (not shown), due to a little decrease in daytime maxima and a remarkable (up to 20 ppb) increase in night-time minima: this leads to a 5 ppb difference in daily mean, and actually seems to improve ozone scores (CAMx shows a tendency to underestimate night time ozone). This effect could be linked to the stronger surface winds in “Ala” data, which increase night time mixing and reduce the ozone removal associated with urban emissions. In “ECM” simulation, ozone concentrations are lower than in “Base” on most of Po valley: the difference is in the order of 10% (i.e. 5 ppb), and is mainly due to daytime values.

Larger differences are observed in two locations near the boundaries of the domain, namely in Ligurian Sea (south) and Garda Lake region (east): here both “Ala” and “Base” show the highest concentrations of the domain, while “ECM” values are up to 25% (15 ppb) lower. This effect could be linked with an inconsistency between Aladin wind and the wind used to generate the boundary concentrations: in City-Delta exercise, these were extracted from a continental scale, low resolution run of the EMEP CTM model (www.emep.int). The wind field used in this run is probably similar to the ECMWF wind, while in the two regions highlighted Aladin wind is stronger, and steadily directed towards the inside of the domain (Figure 1). This inconsistency may lead to a fictitious “creation” of ozone and other pollutants, therefore increasing surface concentrations downwind the boundaries.

Taking into account Calgrid simulations, differences are qualitatively similar, but quantitatively much stronger: again, differences in ozone mean concentrations are relatively homogeneous in space and “ECM” meteorology leads to lower values, but the difference now is on the order of 30-40 % (i.e. 10-15 ppb; Figure 2). The “Ala” run always overestimates ozone, but the “ECM” underestimates it, and the overall score of the two simulations is similar. This very different sensitivity is not easy to explain, and is probably linked to the characteristics of the two models; the different length of the simulations probably don’t affect very much the results (Calgrid shows the same sensitivity if the analysis is restricted to the 11 days of the CAMx runs),

In PM10 analysis, only the CAMx simulations can be used, and very few observations are available (4 stations with daily data, all in Milan area). The first thing to be noticed is that the model strongly underpredicts PM values, by an amount of 20 to 50 % (Figure 3). On the whole, “ECM” and “Base” runs have rather similar values, but in “ECM” the maximum is displaced about 40 km to the East and falls outside Milan area (Figure 4, right), leading to

lower values at the monitoring stations. On the other hand, “Ala” concentrations are notably lower in Milan area and in central Po Valley, with a reduction of about 25% with respect to “Base”. This difference is mainly due to a reduced concentrations during night hours, and can again be linked to the stronger “Ala” wind in low levels: these enhance vertical mixing, especially during night when the thermal forcing is lower, and primary emitted PM can be more effectively dispersed.

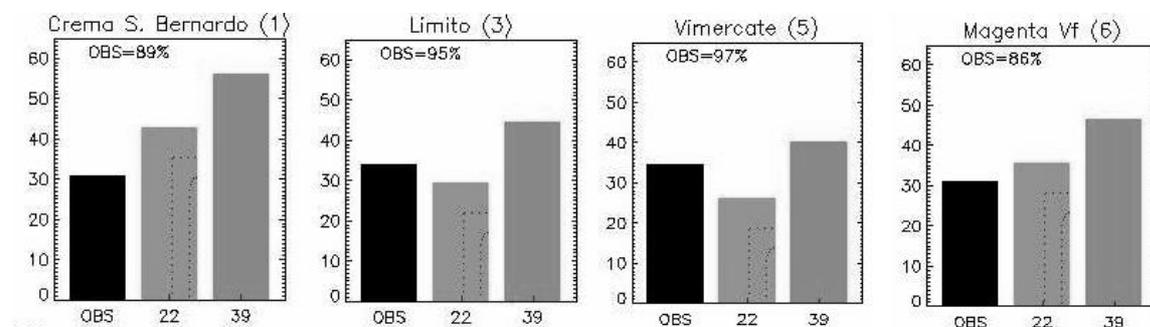


Figure 2. 6 month average ozone concentrations (ppb) at 4 monitoring stations in Milan area. Observations (OBS), Calgrid with “ECM” input (22), Calgrid with “Ala” input (39)

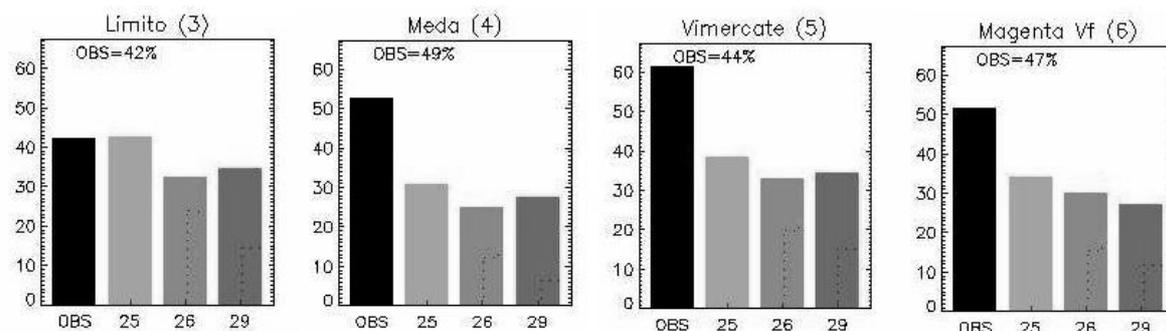


Figure 3. 11 days mean PM10 concentrations ($\mu\text{g}/\text{m}^3$) at 4 monitoring stations in Milan area. Observations (OBS) and 3 CAMx simulations: “Base” (25), “Ala” (26), “ECM” (29)

CONCLUSIONS

Sensitivity of CTM to meteorological input seems to be very model-dependent: differences in mean ozone concentrations are in the order of 10% for CAMx and 40% for Calgrid. Moreover, differences seem to affect more the mean values than the geographical distribution.

The use of low resolution wind field corrected with local observations (“ECM” dataset) produces lower concentrations of ozone and PM10, especially during daytime. On the other hand, if the direct output of a LAM (“Ala” dataset) is used, near-surface winds are stronger and more constant: this leads to an enhanced night-time mixing, which produces higher ozone and lower PM10 concentrations. Correcting the LAM wind with observations (“Base” dataset) seems beneficial to model performance.

When a regional scale CTM is nested in a larger scale model, inconsistencies in the wind used by the two models can affect pollutant concentrations; in this particular study, a significant change in ozone concentrations is observed, but it seems to affect only areas relatively close to the boundaries of the domain.

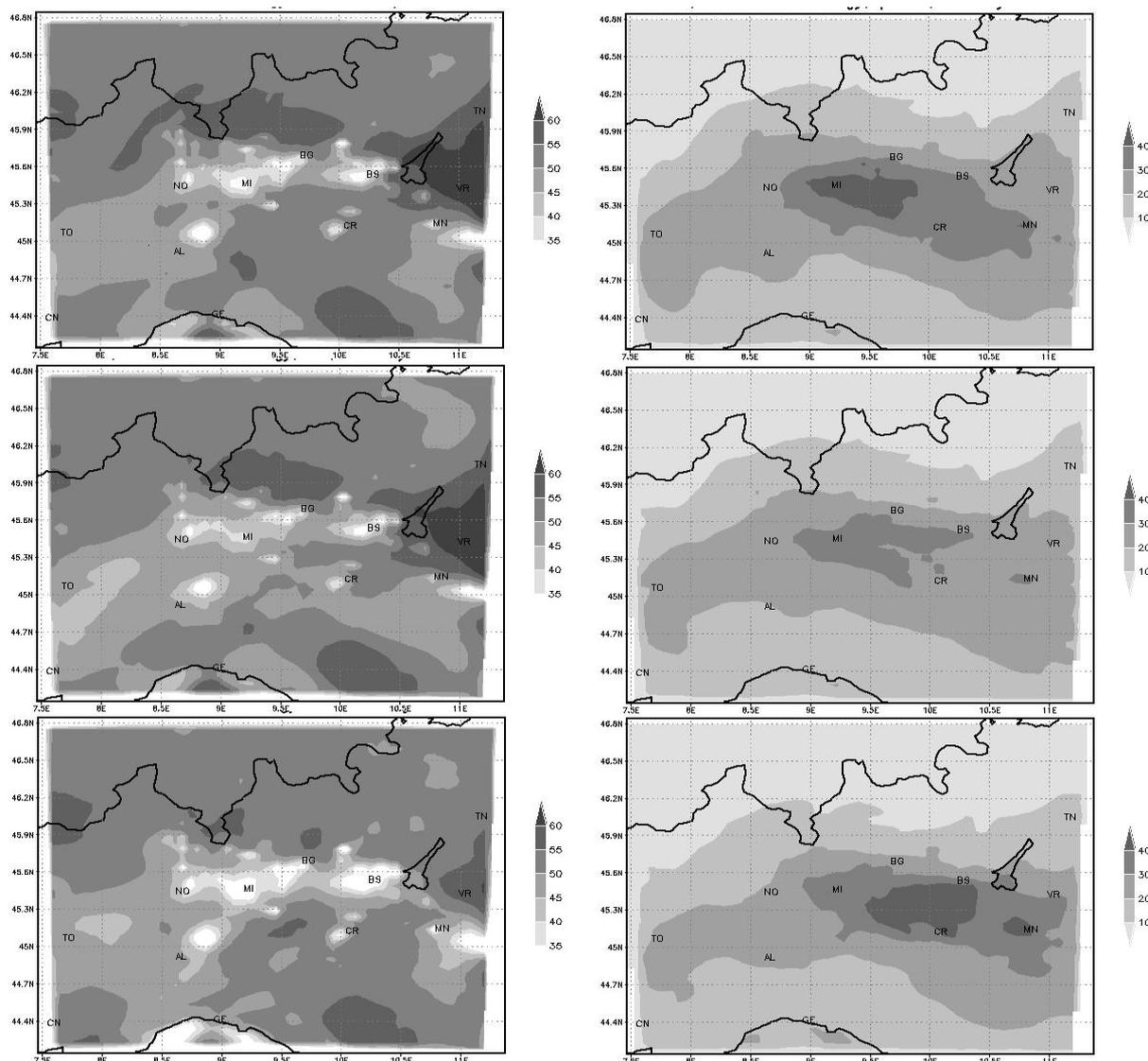


Figure 4. 11 days mean concentrations of ozone (left) and PM10 (right) in the different CAMx simulations: “Base” (top), “Ala” (middle) and “ECM” (bottom)

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