METEOROLOGICAL DATA ASSIMILATION EFFECTS ON ATMOSPHERIC DISPERSION MODELS RESULTS

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INTRODUCTION

The performance of atmospheric dispersion models (ADMs) depends crucially on the meteorological input that they receive mainly from meteorological pre-processors (MPPs). Data assimilation (DA) procedures have been developed in a MPP code in order to enable simultaneous use of meteorological measurements with Numerical Weather Prediction (NWP) data. The objective of the above activity is to exploit in an optimized way the meteorological measurements obtained at a later time than when the prognostic data have been calculated. In order to evaluate the effect such assimilation techniques have in the simulation of atmospheric dispersion, the Lagrangian particle dispersion model DIPCOT was applied using the output of the MPP code. Two applications were performed using data from the European Tracer Experiment (ETEX) with and without the use of DA procedures in the MPP code. The first application used the MPP output obtained by only the prognostic meteorological fields from the ECMWF. The second application used the MPP output obtained by applying DA of the meteorological measurements in the prognostic fields. The ADM predictions in both cases were compared between themselves and to the experimental tracer concentration data. The model performance is evaluated in both cases and the differences are analysed and discussed. The predicted concentrations were statistically and qualitatively compared with the observed ones and the analysis showed that concentration simulations are improved when the DA technique are used.

MODEL DESCRIPTION

The MPP used in this work is a diagnostic meteorological model (*Andronopoulos et al.*, 2003) that produces gridded data sets of variables such as wind velocity, temperature, mixing layer height, atmospheric stability, etc., based on routine weather prognostic data and on local measurements. These data are used as input for atmospheric dispersion calculations. The horizontal computational grid is Cartesian while the vertical is terrain-following, both non-equidistant. The meteorological variables for which observations exist are calculated on the computational grid by spatial $1/r^2$ interpolation from the observation points in the horizontal direction. For the variables without available observations, semi-empirical relations are used.

In case of emergency situations such as accidental releases from nuclear power stations, meteorological data from available prognostic models as the ECMWF are used to estimate the dispersion of the pollutant at large distances from the release point. The problem of integrating the prognostic with the observational meteorological data is known as data assimilation problem. When that problem is solved in the frames a diagnostic meteorological model the procedure is called "Three Dimensional Data Assimilation" (3DDA, i.e., not including time). The 3DDA procedures implemented in the current MPP were based on the optimal interpolation algorithm and the method of iterations to optimal solution, combined with methods for scaling the weighting coefficient between fields obtained by the measurements and those obtained by the NWP data. A detailed description of assimilation procedures used in the MPP code is given by *Kovalets et al.* (2003).

The ADM used in this study is the Lagrangian particle dispersion model DIPCOT (*Davakis et al.*, 2003, 2004). DIPCOT is a 3D air pollution model, which simulates atmospheric dispersion estimating particle trajectories based on Lagenvin equation. The trajectories of the particles are calculated assuming that the mean velocity of the particles is that of the wind field at the particular location, plus a random component to simulate turbulent diffusion. The pollutant concentration at a certain location is calculated by summing the contributions from all particles, according to a Gaussian-type density kernel.

THE EXPERIMENTAL DATA SET

The European Tracer Experiment ETEX (*Grazianni et al.*, 1998) was performed in October 1994 and involved the release of a passive non-depositing gas in western France and the subsequent dispersion over North Europe. Besides the tracer concentrations measurements, the experimental database contains ground and upper air meteorological observations and prognostic meteorological fields from the ECMWF (*Gryning et al.*, 1998, *Straume and Nodop*, 1997). Therefore it is a suitable case for the purposes of the current study.

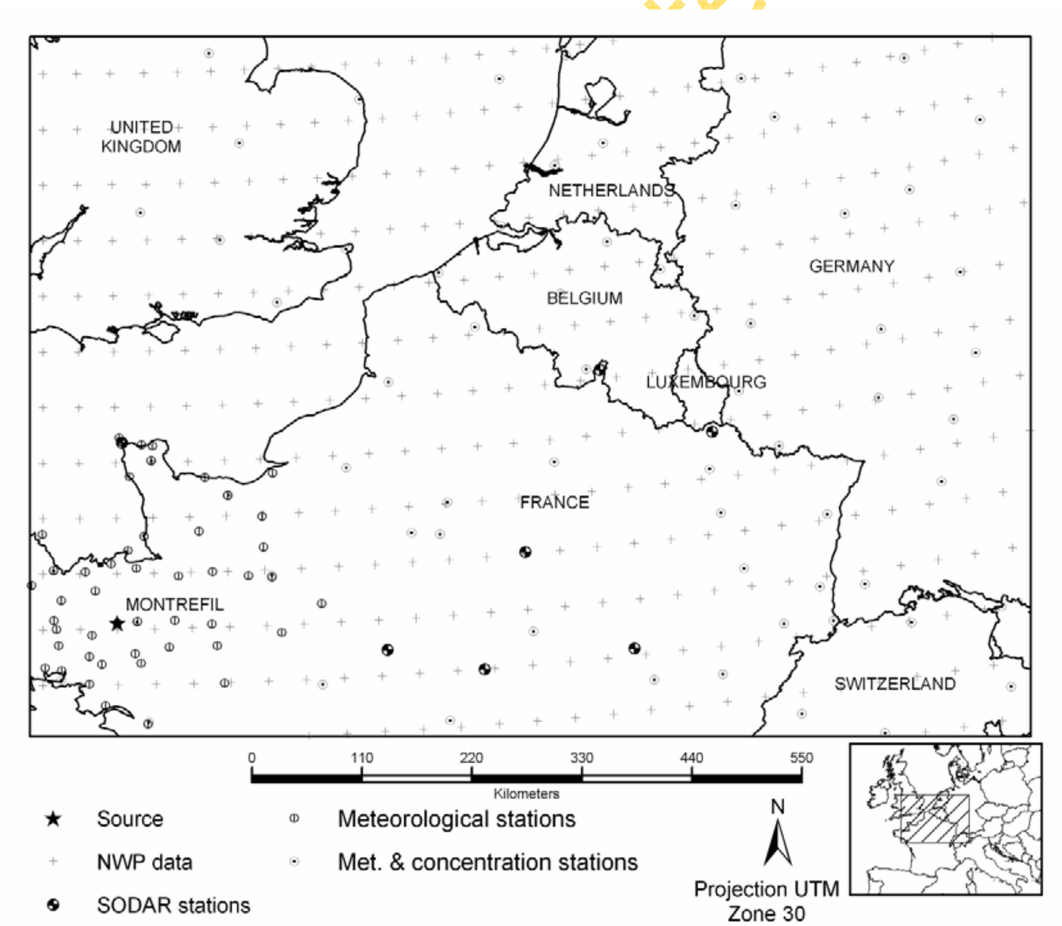

Fig. 1; Computational domain with the tracer release location, the observation point's locations from the ETEX database and the grid of the Numerical Weather Prediction model

The prognostic meteorological data supplied by the ECMWF have been processed in this work by the MPP as the meteorological model forecast. For the present simulation a computational domain of 1000 x 700 Km^2 was used. Available meteorological observations are routine synoptic weather observations and data from SODAR. The data set contains surface observations in addition to the vertical data from the SODARs. The selected computational domain with the tracer release location, the meteorological and concentration monitoring stations and the points of the Numerical Weather Prediction grid are shown in Figure 1.

The predicted concentrations were compared with concentrations from the so-called "Global analysis" data set (*Mosca et al.*, 1998, *Dubois et al.*, 2005). For evaluation reasons we used only non-zero pairs of experimental vs. predicted concentrations. Dispersion simulations where performed for 32 hrs after the release.

RESULTS

In order to examine the effect of the assimilation techniques in the calculation of the atmospheric dispersion two applications of the DICOT code were made. In the first one the ADM model was applied using the output of the MPP model produced by the use of NWP data from ECMWF. In the second application meteorological DA procedures were adopted in the MPP code and the ECMWF analysed data were "corrected" by the use of the synoptic and the SODAR measurements. The ADM model results were intercompared statistically using well-known statistical indices (e.g., *Mosca et al.*, 1998, *Hanna et al.*, 1989) such as the Fractional Bias (*FB*) and the Geometric Mean bias (*MG*) with their 95% confidence limits, the Normalized Mean Square Error (*NMSE*), the Geometric Variance (*VG*), the FACTor-of-2 (*FACT2*), the FACTor-of-5 (*FACT5*), the FACTor-of-10 (*FACT10*) and the Factor Of Exceedance (*FOEX*). The statistical analysis was carried out using the pairs of predicted and measured ground level concentrations (Figure 2a, b, c). A qualitative approach was also achieved through scatter plots (Figure 2e, f) and Quantile-Quantile graphs (Q-Q plots – i.e., plots of ranked pairs of observed vs. theoretical values, Figure 2d).

The statistical analysis showed that when DA procedures were employed in the MPP code the performance of the ADM model was improved. This is indicated by almost all the statistical indices. The value of *FB* and *MG* is closer to zero and unit respectively, which are the optimum values. The values of *FACT2*, *FACT5* are higher and the value of FOEX is closer to zero. The values of *NMSE* and *VG*, which is are measures of the deviations between the observed and the predicted concentrations, are smaller, as it can also be seen at the two scatter plots, implying better agreement with the measured concentrations.

In both cases the model exhibits a tendency towards underprediction (the values of *FB* and *MG* are greater than zero and unit). However, when DA techniques are used in the MPP code the underpredictions are reduced, especially at the higher concentrations. This is displayed in the scatter plots and indicated by the value of *FB*, which is very close to zero. The effect of the DA procedures is more pronounced for the higher concentrations, close to the source. This can be observed at the scatter graphs and especially in the Q-Q plots. The smaller concentration values are similar at the two applications and are generally underestimated. However, the values of *MG* and *VG*, which give the same weight to all the values contrary to the *FB* and *NMSE* values that are mainly affected by the higher concentrations, reveal a slightly better performance of the ADM model even for the smaller concentrations when the DA procedures are used in the MPP code.

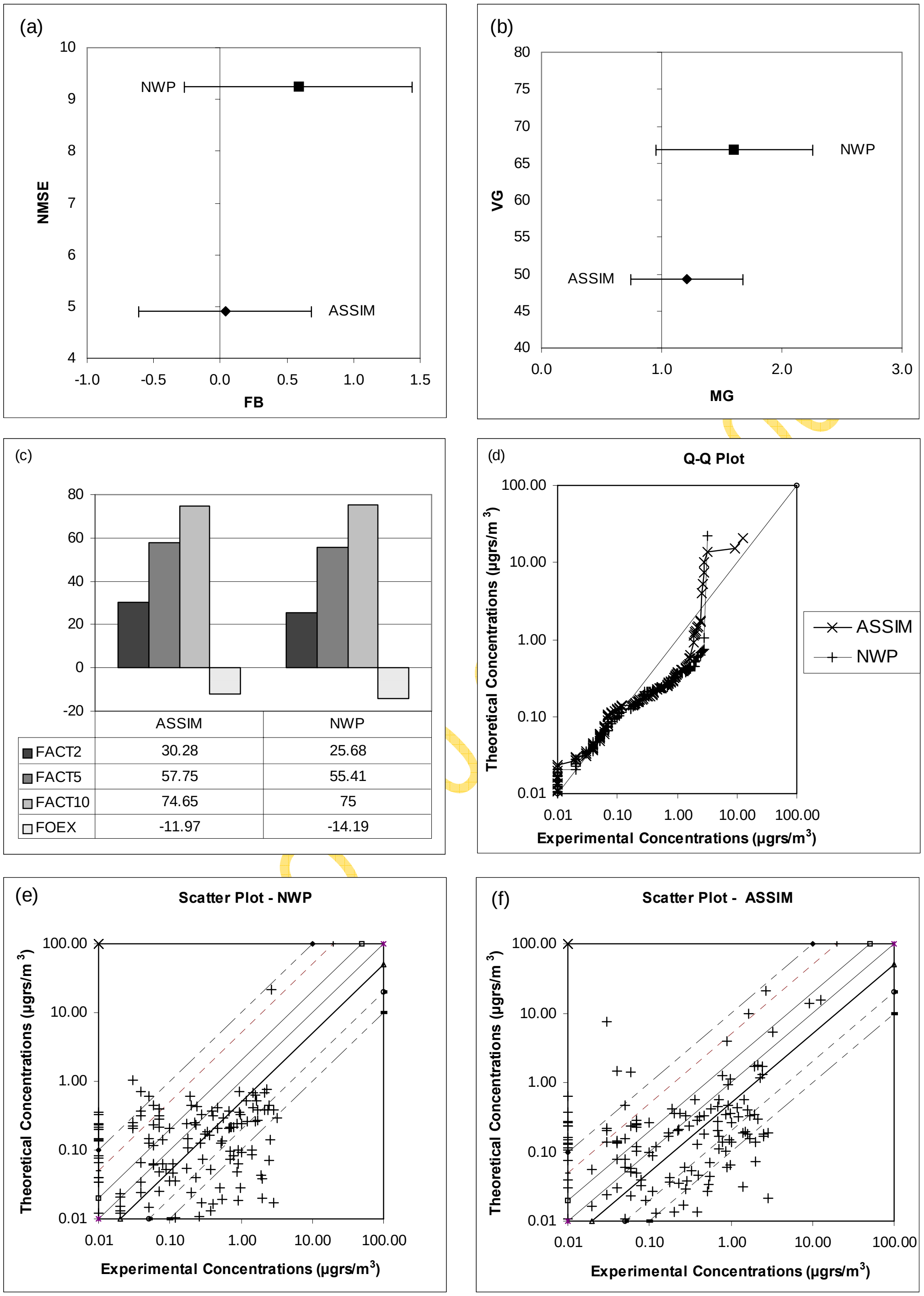

Fig. 2; Comparison between the results of the DIPCOT applications using the output of the MPP model (NWP stands for the case where only the NWP data from ECMWF are used and ASSIM represents the results when DA methods are incorporated.)

Further tests must be carried out in order to examine the effect of DA procedures in dispersion simulation using data sets with more upper air meteorological measurements. Another important issue is the computational cost of the assimilation calculations. The computational time sharply increases with the number of meteorological stations taken into account. This makes necessary the use of more efficient numerical schemes.

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