APPLICATION OF LAGRANGIAN PARTICLE DISPERSION MODELS TO AIR QUALITY ASSESSMENT IN THE TRANS-MANCHE REGION OF NORD-PAS-DE-CALAIS (FRANCE) AND KENT (GREAT BRITAIN).

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INTRODUCTION

In the framework of the cross-border EU Interreg IIIA activity, the joint Anglo-French project, ATTMA, has been commissioned to study Aerosol Transport in the atmosphere of the Cross-Channel, or "Trans-Manche" region of Nord-Pas-de-Calais (France) and Kent (Great Britain). The air quality of the region is dominated by the industrial area of Dunkerque, in addition to transportation sources linked to cross-channel traffic in Kent and Calais. The project aims to determine, through modelling pollutant dispersion patterns and identify sources responsible for episodes detected, using ground monitoring data from UK and French networks and with the assistance of satellite images.

Lagrangian Particle Dispersion (LPD) models compute trajectories of a large number of notional particles and can be used to numerically simulate the dispersion of a passive tracer in the planetary boundary layer. The project uses two widely used particle dispersion models: the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model and the model FLEXPART. Both models possess the forward tracking and inverse (or receptor-based) modes. Both models are driven by meteorological datasets output from the MM5 mesoscale model. Datasets from the ECMWF MARS archive are used to initiate the MM5 model. This paper investigates the sensitivity of these models to input data resolution and in particular the impact of mesoscale topographic effects. Previous work by the authors [Plainiotis, 2005a 2005b] concentrated on the identification of far-field sources driven by synoptic conditions.

DATA AND METHODS

A number of requirements must be met for credible air pollution modelling. The mathematical models discussed in this paper use input data (meteorological, emissions etc.) to predict pollutant concentration, or to identify pollution sources.

Particle Dispersion Model "FLEXPART"

FLEXPART is a Lagrangian Particle Dispersion (LPD) model, developed by Andreas Stohl (1998) and is widely used to calculate the transport and dispersion of non-reactive pollutants in the atmosphere [Stohl,1998]. It is an open source code (Fortran 77) project; hence it can provide a good base for the project. FLEXPART has been validated with measurement data from large-scale tracer experiments, during case-studies of stratospheric intrusions and has performed well in comparison with other similar models [Stohl, 1998]. FLEXPART is driven by synoptic data from ECMWF.

The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) V.4.7 Model.

HYSPLIT is an alternative LPD model used in comparisons. Dispersion assumes either a Gaussian or a top-hat distribution within a puff or from a fixed particle position. HYSPLIT is coded in Fortran-90 and incorporates its own Graphical User Interface and several tools to analyse and post-process the output of air concentration, trajectory, or precipitation simulations. The main difference with FLEXPART is in its characterisation of dispersion coefficients. FLEXPART has enhanced physics with vertical diffusion and convection mixing.

Meteorological Input data

Aerosol dispersion models generally use synoptic fields and emission inventories as input, and calculate time-dependent concentration fields as output, using suitable models for physical processes such as advective or convective transport, mixing by diffusion, and mass transfer through dry or wet deposition, or chemical reaction. Several sources used in this project are given below.

The European Centre for Medium-Range Weather Forecasts (ECMWF)

In this project both LPD models can be driven by meteorological data from the Mars archive of the European Centre for Medium-Range Weather Forecasts (ECMWF), encoded under the WMO FM-92 GRIdded Binary (GRIB) format. Scale resolution, 0.36 degrees, 90 vertical levels and 3 hours temporal (as of 19-08-05).

Meteorological fields of higher resolution by the Fifth-Generation NCAR / Penn State Mesoscale Model (MM5), Version 3

The Version 3 of the PSU/NCAR Mesoscale Model, nonhydrostatic, terrain-following and sigma-coordinate model, was designed to simulate or predict mesoscale and regional-scale atmospheric circulation. The model, known as MM5 V.3 is in open-source and contains contributions from users at several universities and government laboratories. It provides a good base for our simulations because of multiple-nesting capability and can output weather data of higher resolution. It is supported by several auxiliary programs, which are referred to collectively as the MM5 modelling system. Input data are required:

> *Terrain data.* MM5 model requires various terrain input data, such as elevation, vegetation/land-use, land-water mask and vegetation. High resolution terrain data of 0.3 degrees (0.925 km) is adopted for this project, available from the USGS EROS Data Centre's anonymous ftp site edcftp.cr.usgs.gov under directory: /pub/data/gtopo30/global.
> *Analysis Data.* Meteorological data from ECMWF, encoded under the GRIB format can be used to provide the initial weather fields for the MM5 V.3 model runs.
> The data, encoded under the GRIB format are then re-gridded and interpolated to create an input for MM5. The GRIB data are re-gridded and interpolated to the horizontal grid and map projection as defined by the MM5.

MM5 V.3 model output

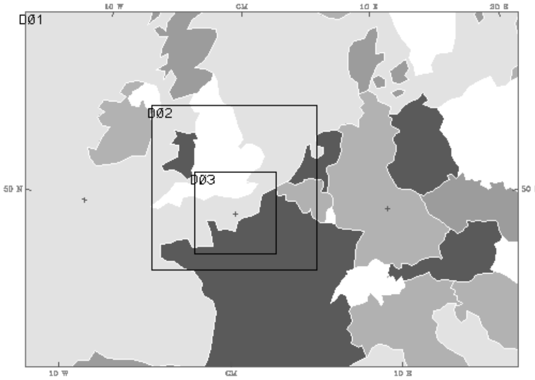
FLEXPART in its official version is driven by synoptic ECMWF data. However, modified versions of FLEXPART are available for handling the mesoscale MM5 model, based on older versions of FLEXPART (3.1) [G. Wotawa ,2000].

The MM5V3 output is first converted to the format of MM5V2, using a utility provided by NCAR. The resulting MM5V2 data is converted to ECMWF GRIB format, using the preprocessing tool provided by G. Wotawa. The resulting data use the MM5's Lambert Conformal projection instead of the ECMWF's geographical latitude-longitude system and can provide a direct input for the MM5 version of FLEXPART. In HYSPLIT, the ECMWF GRIB datasets are converted to the model's ARL native format.

Air Quality Data

The Kent Air Quality Monitoring Network

The Kent Air Quality Monitoring Network provides a co-ordinated means of monitoring air quality throughout the county. Information on levels of 6 pollutants (carbon monoxide, ozone, nitrogen dioxide, coarse particles, fine particles and sulphur dioxide) is distributed every day.



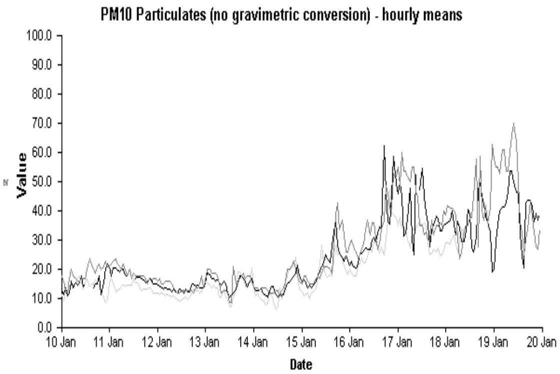


Figure 1a (left). Domain setup: D01 (resolution of 36km), D01 (12km) and D03 (4km). Figure 1b (right). PM10 Concentrations (ug/m3) at the air quality stations: Ashford Rural (light grey), Stoke Rural (grey) and Maidstone Rural (black), showing peak on the 19th (source EXPER-PF)

The "EXPER/PF database" project

EXPER/PF (Exposure of communities living in the centre of the Euro region to polluting atmospheric particles: the case of fine particulate matter) is a project under the framework of the INTERREG III programme. It provides information over air pollution by particulate matter at the regional scale (Trans-Manche, Nord–Pas de Calais, and Flanders, Belgium).

SIMULATION EXAMPLES

Two particle dispersion cases are presented here:

1 An inverse simulation of a particulate episode, observed across much of the Trans-Manche region, caused by a prolonged period of cold still weather and

2 A forward simulation of a hypothetical pollution episode in the industrial area of Dunkerque

Overview of case study 1

The prolonged period of cold still weather between the 16th and the 21st of January 2001 gave rise to elevated concentrations of pollutants such as PM10 particulates and nitrogen dioxide across the Trans-Manche Region. We performed two inverse simulations using HYSPLIT to investigate the origin of the pollutants. In both models we applied the same grid (0.03 degrees), but different weather domain input, all provided by MM5:

1) Three meteorological domains having resolutions of 36km, 12.km and 4km, (domains D01, D01 and D03 in Figure 1a).
2) A single weather domain of 36km (Domain 1 in figure 1a).

The MM5 model used 6-h ECMWF analysis as initial and boundary conditions to provide data with 1hour temporal resolution, for the 3 domains (figure 1a). Air quality information was retrieved from the EXPER-PF database for the episode period and can be seen in figure 1b in the form of PM10 concentration plots (ug/m3). A Gaussian distribution has been assumed and short range mode was adopted (Horizontal and vertical velocity variances).

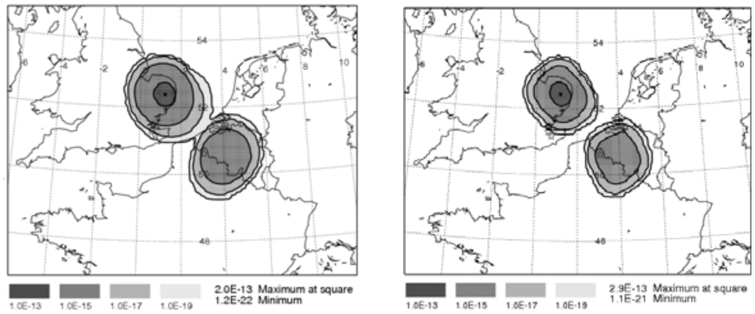


Figure 2. Receptor probability contours for PM10 release 21 hours prior to the detection, from 4 ground monitoring stations (figure 1b and Lille Faidherbe), using a) the 3 domain configuration of figure 1a (left) and b) the single input of 36km resolution (right).

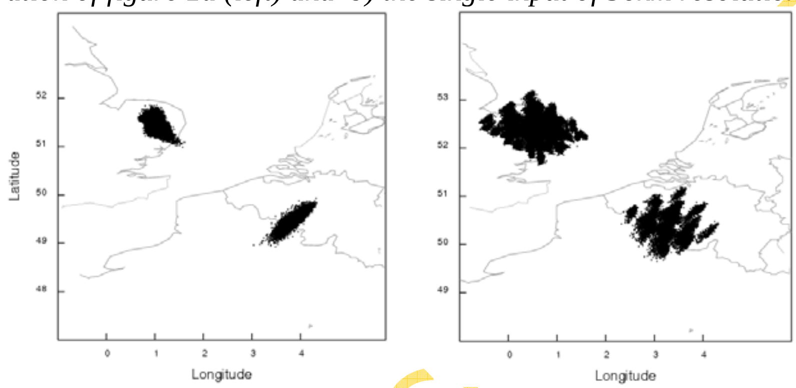


Figure 3. Horizontal distribution of particles: The LPD model produced an initially smaller plume at the release point for the model of higher resolution data (left) and a resultant narrower dispersion plume.

The results shown on Figures 2 and 3 indicate that local pollution sources are responsible for the particulate episode, due to still air conditions. Also, there is no significant difference between the results of the two models.

Overview of case study 2

In the process of evaluating and comparing the results of the model HYSPLIT, using the two meteorological domain configurations, a hypothetical simulation was set up with a positive time step (forward mode). In both setups 100000 notional particles were tracked to simulate a release of SO_2, in the industrial area of Dunkerque, France and within the area of the high (4km) resolution nested domain (D03, figure 1a). Sulphur dioxide is a particular concern in port areas due to the fuel, still used by many older ships. Prevailing weather conditions suggest (figure 4) a low pressure system creating a large scale recirculation centred in the Bay of Biscay.

In previous papers *(Plainiotis 2005a, 2005b)* FLEXPART and HYSPLIT were compared for this particular case, showing similarities but also substantial differences. This time, two HYSPLIT model runs were configured to simulate the release of SO_2, constant for duration of 1 hour, at 15:00 on the 2nd of August 2002. The model runs used the same settings but different meteorological input data, as is described in case study 1. The results are shown on figure 5 in the form of horizontal plots of particle positions. There are notable differences observed, with the fine grid showing a lower general spread and capturing a high altitude transport pattern close to the source release.

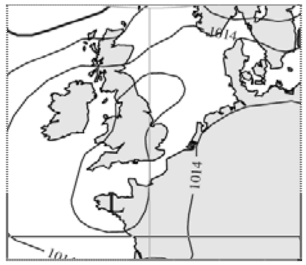


Figure 4. Sea level pressure contours for the 2-08-200 (source:ECMWF).

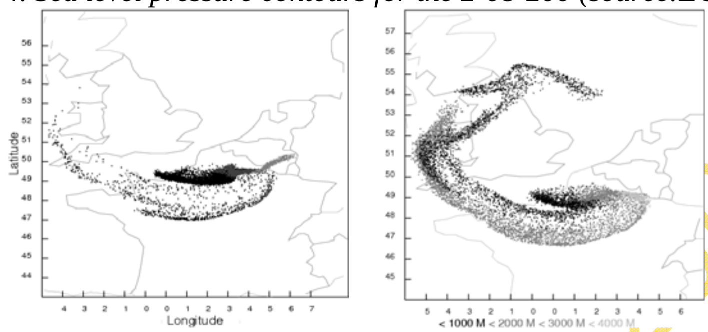


Figure 5. Particle positions 22 hours after the release, using low resolution weather data of 36km (right) and the three domain high resolution configuration of 36km-12km-4km (left).

Conclusion

The output of the simulations shows that there are notable differences between the results. Both models used the same grid and source input, but meteorological data of different resolution, suggesting that although general trends are captured, the qualitative distribution is rather sensitive in some meteorological conditions to grid resolution.

Further work is in progress trying to understand the factors affecting the differences in the model outputs obtained with different grid density. A possible reason for the differences is the applied Gaussian distribution, producing initially a smaller plume at the release point for models with higher resolution data and a corresponding narrower dispersion plume. Thus initial conditions may influence dispersion at longer distances. It is certain that some of the variation can be attributed to physical reasons, but also to model peculiarities such as the source prescription.

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