P4.16 A STUDY OF THE DISPERSION OF AN ELEVATED PLUME ON COMPLEX TERRAIN UNDER SUMMER CONDITIONS

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1. INTRODUCTION

Characterisation of atmospheric pollutant dispersion (advection+turbulent diffusion) requires a detailed description of the wind and turbulence fields, especially on complex terrain under summer conditions. The objective of this study is to describe the atmospheric dispersion in summer of the emissions from a power plant situated on very complex terrain in the Western Mediterranean Basin (WMB).

Results from the European research projects aimed at characterising the dynamics of pollutants in the WMB have documented that during the warm season diurnal cycles in the flow regime represent a typical pattern in the region (Millán et. al. 1997). The development of the Iberian Thermal Low (ITL) during the day forces the surface−winds flows to merge into several major convergence lines, which become landlocked to the main orographic features (Millán et al. 2000). Gaussian regulatory dispersion models cannot be applied under these circunstances because of the limitations they assume (Millán, 1987).The power plant selected, with a 343−meter−tall chimney, is located in the Northeast of the Iberian Peninsula and the plume is affected by the diurnal cycle of the wind flow.

By experimentation and modelling, the study attempts to characterise both the advection (through the reconstruction of 3−D wind fields) and the turbulent dispersion present during the period of analysis. Systematic SO_2 plume tracking was carried out for 3 days in summer, by means of a vehicle equipped with a COSPEC (COrrelation SPECtrometer). This passive remote sensor utilises solar radiation to obtain SO_2−concentration distribution measurements aloft and around the emission source. In addition, the study used a non−hydrostatic mesoscale meteorological model MM5 (Grell et. al. 1994) coupled to a Lagrangian Particle Dispersion (LPD) Model FLEXPART (Stohl and Seibert, 2001).

Simulated dispersion results are generally checked against measurements of tracer−pollutant surface concentrations, with the dispersion analysis limited to the impact areas. The availability of measurements aloft enables us to verify the patterns of advection and turbulent diffusion which govern atmospheric pollutant dynamics in the area as a previous step to the analysis of the cause−effect relation between the emission source and the ground−level concentration.

2. METHODOLOGY

The mesoscale model uses a nested−grid configuration with 5 domains (100x100 grids spaced at 108, 36, 12, 4 and 1.3 km, respectively) centred over the power plant. The model predicts the wind components u, v and w and the turbulence parameters. Four−dimensional data assimilation (Stauffer and Seaman 1994) was applied to the mother domain nudging toward the gridded 2.5º resolution NCEP Reanalysis (Kalnay et. al. 1996).

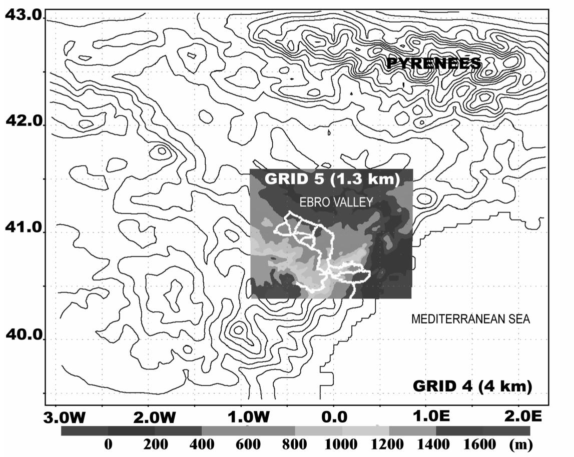

Figure 1. Topography and geographical location of domains 4 (NE Spain) and 5. The road network used to measure the plume distribution with the COSPEC is indicated by the white line in grid 5.

The LPD model takes into account wind velocity variances and Langrangian autocorrelations. The spread of the pollutant is simulated by the Langevin equation derived by Thomson for inhomogeneous and Gaussian turbulence under non−stationary conditions (McNider et al., 1988). Turbulence statistics are obtained by using the Hanna scheme with some modifications taken from Ryall and Maryon for convective conditions (Stohl and Seibert, 2001). The Gaussian turbulence assumption is not strictly

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valid under convective conditions when the vertical velocity distribution is skewed. However, the differences between a Markov process which includes wind velocity covariances and one which neglects them are likely to be very small as Uliasz (1994) showed when evaluating different LPD model simplifications over mesoscale and regional areas. The FLEXPART model incorporates a density correction term for Gaussian turbulence which takes into account the density decrease with height within the PBL (Stolh and Thomson, 1999).

The autocorrelation coefficient is assumed to be an exponential function that depends on the Lagrangian time scale. The time step used to move particles in the Markov chain model has to be variable in inhomogeneous turbulence and depends on the Lagrangian time scale (Uliasz, 1994). Well−mixed profiles can be obtained as long as the timestep is small enough to resolve the small−scale turbulence in the vicinity of the boundaries (Hurley and Physick, 1991).

In our simulations, we treated the buoyant plume of the power plant by releasing particles at an effective stack height of 700 m. The particles were released randomly within a 0.1 X 0.1 X 0.01 Km volume at the start of the test simulations.

Tracking of the SO_2 plume was performed with the use of a vehicle instrumented with a correlation spectrometer (COSPEC) and a fast−response SO_2 analyser. This equipment makes it possible to record the distribution of the pollutant aloft and on the ground.The COSPEC is a passive remote sensor that uses the sunlight dispersed in the atmosphere as its radiation source (Millán et al., 1976). Its response is proportional to the vertically−integrated SO_2 concentration (throughout the optic path between the infinitum and the instrument telescope). The pulsed fluorescence analyser is used to measure the SO_2 concentration over the roof of the vehicle. Our plume−tracking strategy consisted of making transects, as transversal as possible to the mean plume−transport direction, at different distances from the stack (Millán et al., 1976). Measurements were taken throughout the day to record any changes that might occur in the plume transport direction or in the dispersive conditions.

3. METEOROLOGICAL CONDITIONS

On the first day, the meteorological situation was conditioned by the passage of a low−pressure system over the Cantabrian Sea. On the second day, when the Low migrated to the NE, a ridge of high pressure arrives at the Iberian Peninsula. On the last day, the High was centred over the Cantabrian Sea and a Thermal Low formed in the South of the Iberian Peninsula.

Thus, the wind in the area of interest came from the SE during most of the first day until it changed to SW due to the passage of the Low to the East. On the second and third day, nocturnal drainage occured during the night and the wind flow followed the Ebro valley direction (NW) to the Sea. During daytime conditions the situation favoured the development of thermally driven mesoscale processes on both days.

4. RESULTS AND DISCUSSION

The measurement campaign took place on 25, 26 and 27 July 1995 . A short description of the main measured and simulated results is presented below:

Day 1: SE winds in the Ebro valley direction turn to the SW in the afternoon. This change in the wind direction affects the behaviour of the plume, as the COSPEC measurements show, and is also simulated by the model.

Day 2: Down−valley drainage in the early morning. With solar heating, mesoscale circulations begin to affect the behaviour of the plume which is involved in a transitory field until it turns to the SW of the power plant due to the developtment of the ITL in the evening.

Day 3: Low−speed southern nocturnal flow, as can be derived from the concentration distribution recorded by the COSPEC (very wide shape near the stack). This agrees with the scarce transport simulated during a 6−hour period by the model. At

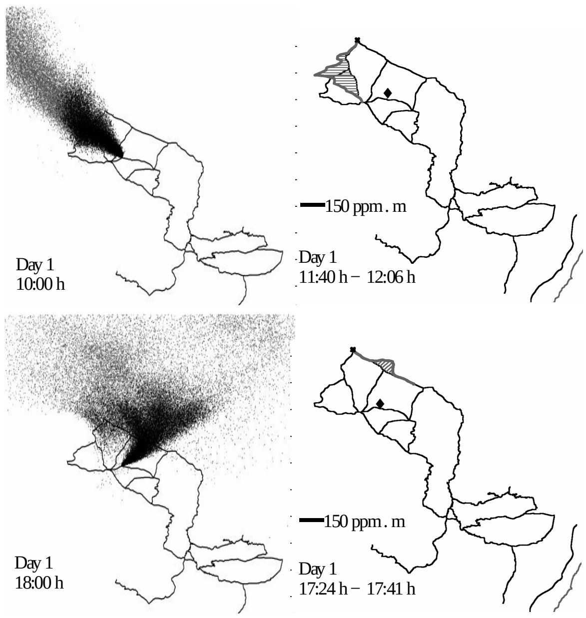

Figure 2. Sequence of the experimental and simulated distributions for day 1. Correspondence between simulated outputs and experimental measurements (vertically integrated SO_2 concentration) was determined from equivalent temporal periods. Representations are presented on the road network. Particles in gray scale (figures on the left) indicate up to 2 (darker), 4 and 6 (lighter) hours since emission.

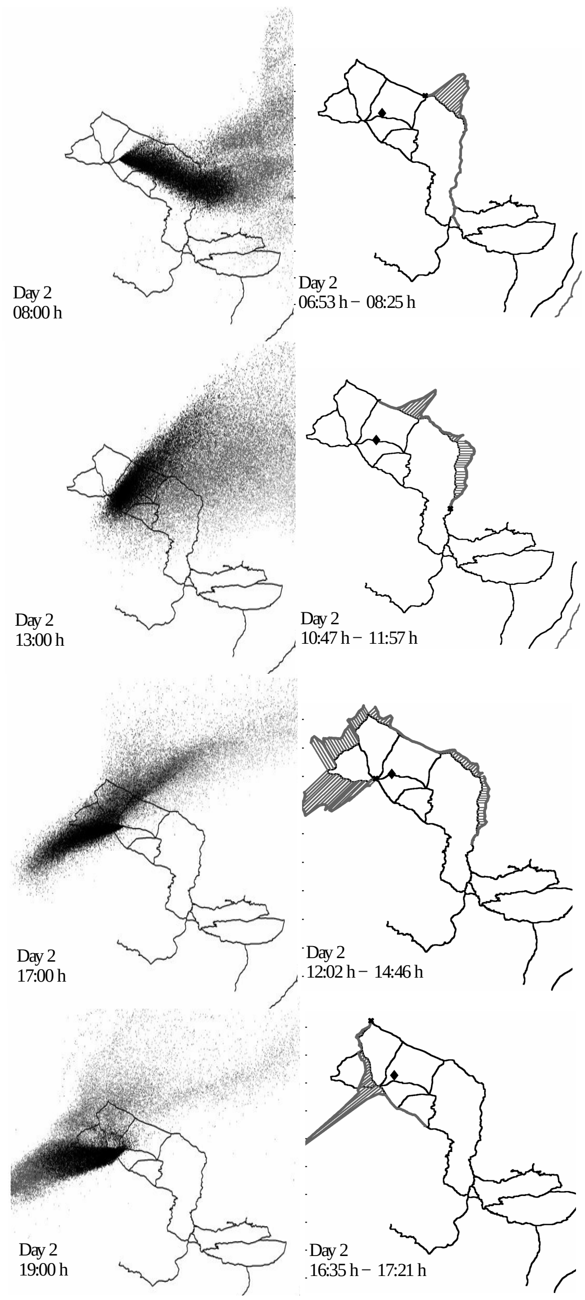

Figure 3. Equivalent to figure 2: for day 2. COSPEC scale as indicated in figure 2.

noon the direction of the plume is not well−defined, although both measured and simulated results show a slight tendency towards the SE. In the evening the plume is again conditionated by the ITL, turning towards the SW, as can be seen in the simulation and in the experimental measurements.

Comparison between measured and simulated dispersion results (Figs. 2, 3 and 4) shows that the model is able to reproduce the behaviour of the plume measured by the COSPEC. Nevertheless, the mesoscale circulation that makes the plume turn

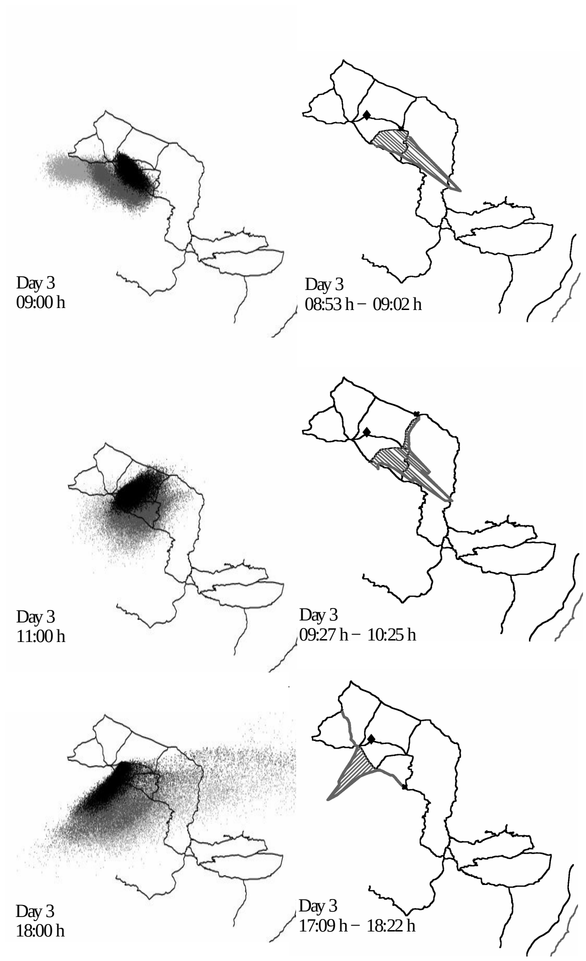

Figure 4. Equivalent to figure 2: for day 3. COSPEC scale as indicated in figure 2.

towards the SW on the second day (Fig. 3) is simulated with a significant delay.

Comparing the experimental and simulated horizontal dispersion of the plume for equivalent temporal periods (Fig. 5), three measurements, corresponding to the central hours of the day and the afternoon, present discrepancies higher than 200%. These discrepancies (bold numbers in Table 1) correspond to days characterised by dispersive scenarios showing transition periods in the wind and turbulence fields. These diurnal transition periods between dispersive scenarios are typified (in dispersive terms) by the lack of a well−defined plume axis (or mean transport direction). The consequent indetermination of the transversal plume to the preferred transport direction implies a small (or null) physical significance of the standard deviation of the concentration distribution, whether this distribution is measured with the COSPEC, simulated with a dispersion model or parametrized through different schemes and approximations implemented in some dispersion models.

Day	Start.	Finish.	Dist. (Km)	Exp. Disp. (Km)	Std. error (Km)	Sim. Disp. (Km)	Std. error (Km)
07/25	09:50	11:30	6.07	0.79	*****	1.14	0.04
07/25	16:17	16:54	15.49	0.92	0.01	2.37	0.21
07/25	17:24	17:54	15.06	1.41	0.13	3.30	0.70
07/26	07:15	08:49	9.97	1.89	*****	1.20	0.10
07/26	08:57	09:17	9.94	1.96	*****	2.15	*****
07/26	09:25	10:06	19.14	4.63	*****	4.74	*****
07/26	10:47	11:35	13.15	**1.78**	0.02	**5.70**	0.30
07/26	16:35	18:00	9.03	**2.10**	0.30	**9.10**	0.40
07/27	17:09	18:20	8.42	**1.97**	0.05	**11.00**	1.00

Table 1. Summary of the values of the dispersive results. Start.: Starting time of the measurements; Finish.:Finishing time of the measurements; Dist.: Distance to the stack; Exp. Disp.: Experimental dispersion; Std. Error: Standard error; Sim. Disp.: Simulated dispersion.

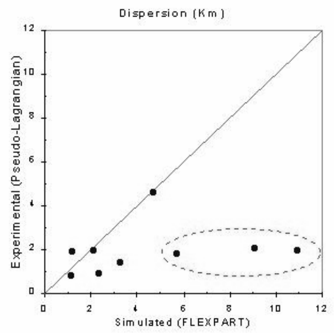

Figure 5. Comparison of experimental and simula− ted horizontal dispersion for equivalent temporal periods.

5. CONCLUSIONS

The availability of measurements aloft obtained by means of a vehicle equipped with a remote sensor enabled us to make a direct comparison between the experimental dispersion parameters and the simulated ones. This represents a clear advantage over the information provided by the fixed ground−level monitoring stations for atmospheric pollutant control.

The model was able to reproduce the typical stationary−dispersion scenarios (experimentally characterised with the COSPEC), although a significant temporal delay was detected between the simulation and the experimental measurements (Fig. 3) of the plume dispersion.

Contrary to what occurs in stationary periods, during the transition between dispersion scenarios (Figs. 3 and 4) there is a significant discrepancy between the experimental values of the plume concentration horizontal distribution (Sigma−y, defined from the transversal axis to the average transport direction) and the values obtained from the model (table 1 and Fig. 5). In these kinds of situations, with no defined transport direction and, consequently, with transitory wind and turbulence fields, classical dispersion parameters lose their physical meaning.

6. REFERENCES

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7. ACKNOWLEDGEMENTS

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