1.06 METEOROLOGICAL INPUT FOR ATMOSPHERIC DISPERSION MODELS: AN INTER-COMPARISON BETWEEN NEW GENERATION MODELS

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INTRODUCTION

The behaviour of atmospheric dispersion models is strongly influenced by meteorological input, especially as far as new generation models are concerned. More sophisticated meteorological pre-processors require more extended and more reliable data. This is true in particular when short-term simulations are performed, while in long-term modelling detailed data are less important. In Europe no meteorological standards exist about data, therefore testing and evaluating the results of new generation dispersion models is particularly important in order to obtain information on reliability of model predictions.

BRIEF DESCRIPTION OF THE MATHEMATICAL MODELS

The SAFE_AIR II modelling system consists of: i) two meteorological pre-processors, WINDS (*Ratto, C.F.,* 1996), a mass consistent model which builds a three-dimensional wind field, and ABLE, for the calculation of boundary layer parameters; ii) dispersion code P6 (e.g. *Canepa, E. et al.*, 2000; *Canepa, E. and C.F. Ratto*, 2003), which performs the dispersion calculations, using either the “Gaussian puff” or the “Gaussian segmented-plume” concepts depending on the wind speed.
The CALPUFF modelling system comprises CALMET, a meteorological model including a diagnostic wind field generator and a micrometeorological module (*Scire, J.S. et al., 1999a*), and CALPUFF, a non-steady state dispersion model that advects Gaussian “puffs” of material emitted from sources by using a Lagrangian law. It includes modules for terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal and deposition, and a simplified chemical transformation mechanism (*Scire, J.S. et al., 1999b*).
AERMOD is a steady-state Gaussian plume model designed to handle both flat and complex terrain modelling computations (*US EPA*, 1998). The AERMOD modelling system consists of two preprocessors (the meteorological preprocessor, AERMET, and the terrain preprocessor, AERMAP; the latter has not been used in this work) and the dispersion model.
ISC3 (*US EPA*, 1995) is a Gaussian code widely employed for pollutant dispersion assessment and mentioned as a ‘preferred model’ in the US EPA recommendations. This code presents two different options to calculate dispersion σ-functions; for the present study only the ‘Briggs-urban’ option has been used. ISC3 also allows calculation of gradual plume rise by Briggs formulas. Contrary to the other models used in this work, the mixing height has to be provided by the user and it is not calculated by ISC3.

CASE STUDIES

In this study several simulations have been carried out, using different meteorological input for the described codes, as shown in Tab.1. Two main periods have been chosen for the comparison between SAFE_AIR and CALPUFF. These are particularly critical with respect to diffusion conditions (calm wind conditions). The chosen periods are: 7-9 January 2002 (A) and 16-18 May 2002 (B). Since Gaussian models (AERMOD and ISC3) are not able to simulate calm wind conditions, another period has been chosen in order to compare the results of the four models. The chosen day (8 March 2002; C) presents strong wind conditions from 11 A.M. on. The point source is located in the Florence outskirts, and the domain size is 20 x 20 km^2. The two meteorological stations are located near the source (less than 4km) and both surface and upper air data are available. Upper air (U.A.) data are derived from RASS and SODAR measurements (temperature, wind speed and direction) up to an elevation of 600-700 m. Since the RASS-SODAR system is not able to sound up to 2000-3000 m, as requested by CALPUFF and AERMOD, an extrapolation of temperature and wind profiles proved to be necessary.

Table 1. Description of the performed simulations

Model-ID	**Model**	**Met. Input**	**Terrain data**	**Periods**
SA1	SAFE AIR	Surface and U.A. data (extrapolated profiles)	Orography and land-use data	A, B and C
SA 2	SAFE AIR	Surface and U.A. data	Orography and land-use data	A and B
SA 3	SAFE AIR	Surface data only	Orography and land-use data	A and B
SA 4	SAFE AIR	U.A. data only	Orography and land-use data	A and B
CP	CALPUFF	Surface and U.A. data (extrapolated profiles)	Orography and land-use data	A, B and C
AM	AERMOD	Surface and U.A. data (extrapolated profiles)	Flat terrain	C
ISC-CP	ISC 3	Surface data only. Mixing height from CP	Orography	C
ISC-SA1	ISC 3	Surface data only. Mixing height from SA1	Orography	C

RESULTS AND DISCUSSION

A comparison between results provided by meteorological pre-processors has been carried out; to be brief, only some results are reported here. The comparison has been performed based on calculated wind speed (WS), mixing height (H_{mix}), Monin-Obukhov length (MOL), friction velocity (u_*) and convective velocity scale (w_*). Some of the results are shown in tables 2, 3 and 4.

Table 2. Calculated space-averages (considered period: 8 January, 2002, 6 A.M.-5 P.M.)

Hour	*WS [m/s]*					*H_{mix} [m]*				
	CP	*SA1*	*SA2*	*SA3*	*SA4*	*CP*	*SA1*	*SA2*	*SA3*	*SA4*
6	0.102	0.032	0.048	0	0.604	28.824	19.337	19.346	19.337	17.009
7	0.192	0.058	0.054	0	0.726	29.082	19.391	19.355	19.337	15.43
8	0.219	0.038	0.037	0	0.388	29.283	19.354	19.35	19.337	19.463
9	0.237	0.061	0.056	0.042	0.307	29.404	19.338	19.337	19.337	19.382
10	0.247	0.051	0.056	0.043	0.416	81.106	19.337	19.337	19.337	19.337
11	0.436	0.431	0.459	0.454	0.74	129.681	19.334	19.337	19.388	15.351
12	0.296	0.26	0.226	0.275	0.501	166.6	23.274	22.819	32.652	73.375
13	0.342	0.339	0.34	0.35	0.291	202.834	72.019	70.317	204.619	123.904
14	0.726	0.653	0.631	0.709	0.428	237.018	129.84	126.042	269.802	155.459
15	0.79	0.716	0.693	0.757	0.165	256.158	126.476	123.06	274.866	156.94
16	0.428	0.631	0.541	0.644	0.748	199.721	23.392	24.297	35.987	32.165
17	0.233	0.199	0.191	0.223	0.217	28.957	19.337	19.337	19.337	19.338

Table 3. Calculated space-averages (considered period: 17 May, 2002, 6 A.M.-5 P.M.)

Hour	WS [m/s]					H_{mix} [m]				
	CP	SA1	SA2	SA3	SA4	CP	SA1	SA2	SA3	SA4
5	0.079	0.065	0.076	0	1.086	37.034	19.355	19.355	19.355	17.985
7	0.062	0.033	0.111	0.043	1.092	561.011	19.362	19.362	19.362	18.18
8	0.12	0.111	0.102	0.095	0.729	861.073	19.694	20.107	19.452	23.047
9	0.211	0.168	0.17	0.19	0.644	1078.745	282.114	369.479	465.326	213.134
10	0.561	0.358	0.357	0.378	0.157	1176.018	373.93	479.713	641.313	327.59
11	0.227	0.166	0.182	0.19	0.248	1324.145	497.038	633.131	832.891	497.42
12	0.519	0.443	0.439	0.472	0.222	1362.117	646.355	864.285	1035.383	769.301
13	1.113	0.993	0.977	1.039	0.625	1450.288	797.372	1084.168	1233.733	1012.907
14	1.812	1.611	1.601	1.699	0.377	1619.962	934.465	1279.7	1415.058	1221.46
15	2.614	2.333	2.31	2.455	0.598	1812.602	1050.669	1443.798	1569.389	1392.017
16	4.14	2.787	2.748	2.927	0.831	1987.246	1204.247	1570.919	1690.016	1521.521
17	3.512	3.151	3.13	3.303	1.145	2051.886	1260.488	1658.465	1773.599	1608.866

Table 4. Calculated space-averages (considered period: 8 March, 2002, 11 A.M.-11 P.M.)

Hour	WS [m/s]		H_{mix} [m]		MOL [m]		u_* [m/s]		w_* [m/s]	
	CP	SA1	CP	SA1	CP	SA1	CP	SA1	CP	SA1
11	4.96	2.207	1560.773	1307.346	-215.009	-168.263	0.653	0.266	2.565	1.213
12	5.581	4.862	1745.03	1440.303	-249.734	-555.859	0.715	0.56	2.704	1.79
13	5.077	5.077	1816.133	1507.643	-184.897	-431.199	0.661	0.591	2.774	2.063
14	5.061	4.622	1903.935	1586.065	-202.558	-291.775	0.665	0.543	2.804	2.178
15	5.966	5.007	2000.14	1661.381	-360.156	-417.469	0.76	0.581	2.806	2.133
16	7.307	5.589	2111.342	1720.829	-1022.222	-859.866	0.907	0.639	2.761	1.897
17	5.255	5.244	2068.337	1680.037	-429.425	-1129.56	0.681	0.603	2.725	1.359
18	5.749	4.873	1953.109	467.604	-2661.027	396.436	0.728	0.515	2.215	0.015
19	5.88	5.429	1140.273	540.938	1145.318	611.054	0.672	0.583	0	0
20	5.481	5.122	1081.57	488.636	954.488	511.613	0.628	0.547	0	0
21	5.685	5.414	1126.811	529.555	1070.424	585.191	0.653	0.576	0	0
22	4.134	5.447	780.346	539.36	195.764	602.216	0.456	0.583	0	0

As shown by the tables, the four SA models give different results, especially in the winter period. The SAFE_AIR calculated mixing heights are generally lower than the CALPUFF ones. In figures 1-3 are shown some concentration maps for the three considered periods.

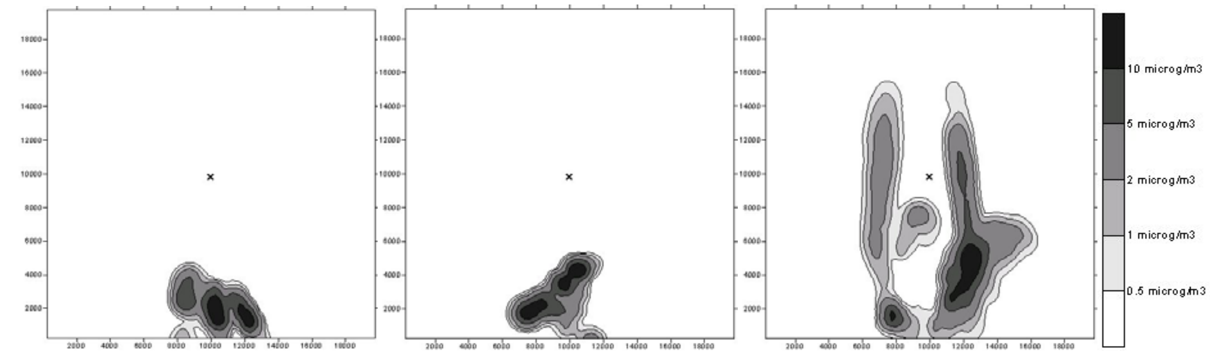

Figure 1. Ground level mean concentrations (7-9 Jan 2002). From left: SA1, SA2, SA4.

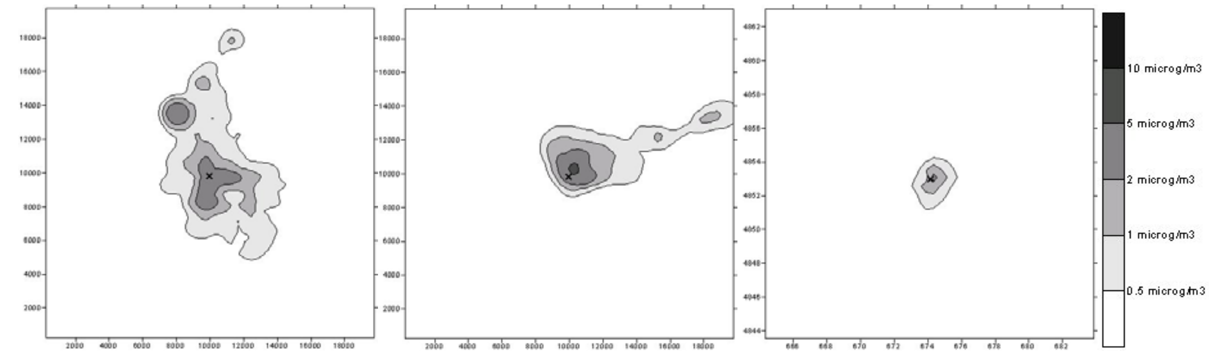

Figure 2. Ground level mean concentrations (16-19 May 2002). From left: SA1, SA3, CP.

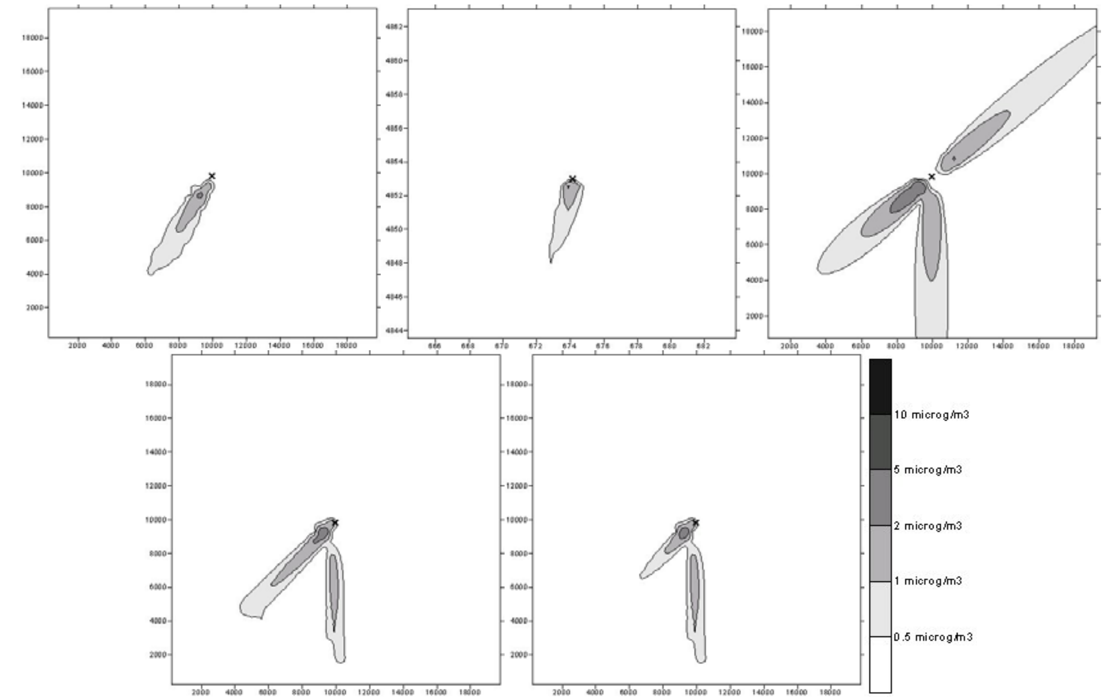

Figure 3. Ground level mean concentrations (8 Mar 2002). From top-left: SA1, CP, AM, ISC-SA1, ISC-CP.

Concentration maps confirm the criticality of the winter condition. As a matter of fact, a strong difference in the shape of the contour map can be seen, even among the SA models, for the period A. A lower difference can be seen in the other two simulation periods.

Some simple statistics concerning the mean concentrations (time averaged) have been calculated in order to better analyse the behaviour of the models. In particular: mean concentration (space averaged); standard deviation; the mean of the 100 highest concentrations; the maximum and the minimum values of the 100 highest concentrations.

Table 5. Statistics for the mean concentrations (7-9 January 2002). All values are in [$\mu g/m^3$].

Model	***Mean C***	***St. Dev. C***	***Mean C100***	***Max C100***	***Min C100***
SA1	*0.23*	*1.40*	*3.65*	*19.56*	*0.06*
SA2	*0.22*	*1.38*	*3.49*	*21.00*	*0.10*
SA3	*0.03*	*0.07*	*0.27*	*0.46*	*0.19*
SA4	*0.59*	*1.71*	*5.91*	*19.32*	*2.74*
CP	*0.11*	*0.20*	*0.67*	*3.38*	*0.38*

Table 6. Statistics for the mean concentrations (16-18 May 2002). All values are in [μg/m³].

Model	Mean C	St. Dev. C	Mean C100	Max C100	Min C100
SA1	0.20	0.45	1.54	5.11	0.80
SA2	0.15	0.48	1.41	7.61	0.53
SA3	0.12	0.41	1.27	6.41	0.52
SA4	0.19	0.27	0.98	2.57	0.58
CP	0.08	0.13	0.41	2.43	0.19

Table 7. Statistics for the mean concentrations (8 March 2002). All values are in [μg/m³].

Model	Mean C	St. Dev. C	Mean C100	Max C100	Min C100
SA1	0.04	0.16	0.49	2.75	0.22
AM	0.17	0.38	1.25	5.81	0.70
ISC-SA1	0.07	0.24	0.76	4.60	0.35
ISC-CP	0.05	0.20	0.58	4.51	0.19
CP	0.06	0.13	0.44	2.08	0.19

The highest differences can be observed in the period A; in particular the maximum concentration (72h average) varies by a factor of about 45. The differences are less marked for periods B and C. In general the CP model tends to estimate lower mean and maximum concentrations then those estimated by the other models. Another remarkable difference can be observed by comparing the behaviour of SA3 (initiated only with surface meteorological data) with respect to the other models. This difference is particularly relevant in period A.

CONCLUSIONS

A model intercomparison has been performed in order to point out the importance of meteorological input on model results, particularly when last generation models are used. The influence of meteorological input (and its treatment by the model) seems to be stronger in calm wind and stable atmospheric conditions. Moreover, mixing height proved to be another critical parameter, especially in wintertime period, when values are lower and small differences affect more dramatically modelled concentrations.

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