An Intercomparison of the AERMOD, ADMS and ISC Dispersion Models for Regulatory Applications: Dispersion over Terrain

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1 Introduction

A wide ranging intercomparison of the AERMOD, ADMS and ISC dispersion models has been carried out on behalf of the UK Environment Agency to assess any differences that would affect their application to regulatory practice (Hall et al 2000(a,b)). The development of an effective intercomparison protocol for the study was described at HARMO 6 (Hall et al 2000(c)) and the final test protocol covered the models' basic dispersion behaviour, plume rise and penetration of the boundary layer, interaction with building wakes, effects of surface roughness and terrain. Here we describe the methodology and results for the intercomparison with regard to dispersion over terrain only.

AERMOD, ADMS and ISC all treat dispersion over terrain in different ways. The AERMOD and ISC model algorithms are fully documented. Less detailed information is available on ADMS. AERMOD represents the concentration by a weighted combination of the concentration from a horizontal plume state, in which the plume can impact on the terrain, and a terrain following plume state, where the plume is carried over the terrain. The weighting factor depends on stability and a terrain dependent height scale. The concentration equations also require the effective source height and dispersion parameters are those for flat terrain. ADMS calculates a perturbed mean and turbulent velocity field using the linear wind flow model FLOWSTAR. The deflection of the mean streamline through the source can then be determined and it is this height which appears in the concentration equations. The turbulent velocity field is used to prescribe the dispersion coefficients. For ISC, terrain is used to calculate the effective plume height used in the concentration equation. The relationship of the terrain to plume height also determines the form of the equation used.

2 Model Intercomparison protocol and test methodology for terrain

The topography of the UK is largely flat, so that terrain is only expected to affect dispersion behaviour in a limited number of areas. The approach used here has been to devise a limited set of variants on a real basic terrain to cover a generic range of typical UK conditions. The terrain chosen was that of Porton Down, UK, whose meteorological and dispersion characteristics have been well studied over many years. The test procedure took the basic terrain of the central region of Porton Down and to modify it simply to generate six test cases. In each case the model domain consisted of a terrain feature located on a flat plain. This format was less site-specific, while retaining the asymmetry and local variability of the real terrain, and clearly distinguished between the plume being over the terrain or flat ground. The stack could be sited on flat terrain and the relative distance to terrain base and terrain peak more clearly defined.

The six test terrains constitute: three levels of gradient slope: 'normal' (as in the original Porton terrain), half and twice normal; three levels of terrain height: equal to, greater and less than the stack height; and three distances from the stack to the steepest part of the terrain. They are described briefly below. The neutrally buoyant discharge was from a 40m stack in all cases, placed upwind of the terrain. Figure 1 shows the plan and elevation views for cases 1, 2 and 3.

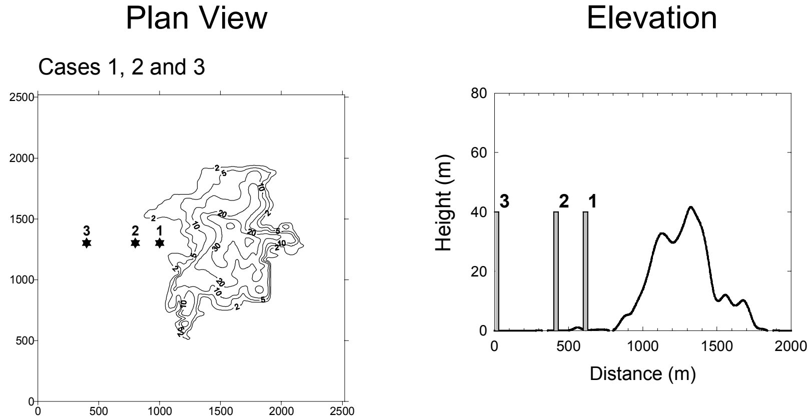

Figure 1 Plan and Elevation Views for Cases 1,2 and 3.

Case 1. Terrain and stack heights equal (at 40m), terrain slope ‘normal’ (that is, as on the Porton site). The stack was positioned upwind close to the terrain, at its rising edge, 600m from the centre of the terrain. In neutral stability the plume’s first contact with the ground would have been at around this distance in the absence of the terrain, so that the plume contacted the rising terrain.

Case 2. Terrain and stack heights as in Case 1 (40m), except that the stack was positioned further upwind, 800m from the centre of the terrain. In neutral stability the plume’s maximum concentration would have been at around this distance in the absence of terrain.

Case 3. Terrain and stack height as in Case 1 (40m) with the stack far upwind of the terrain, 1200m from its centre. At this distance the plume impacted the ground ahead of the terrain.

Case 4. Terrain height halved over Case 2, leaving the planform the same, so that the terrain slopes were halved and the height reduced to 20m. The stack height was then twice the terrain height. The stack height and position were as in Case 2, 40m height 800m upwind of the centre of the terrain. The terrain slopes were at the margin of those commonly thought to be significant to dispersion.

Case 5. Terrain height doubled over Case 2, to 80m, leaving the planform the same so that the slopes were doubled; the maximum slopes were then around 0.28 and the stack height was half the terrain height. The stack position was as in case 2, 800m upwind of the centre of the terrain.

Case 6. Terrain height and planform doubled over that of Case 2, so that the terrain slopes remained the same. The stack height was then half the terrain height. The stack was 800m upwind of the maximum of the terrain height, so it was then positioned on the terrain. The stack height was 40m above the local terrain height, which was about 17m above the ground plane.

Three single meteorological states, representative of convective, (low wind speed) neutral and stable conditions, were used as input to the models for each of the six cases. These were selected from yearly data measured at the nearest Meteorological Office site to Porton Down in 1995. The full year’s data were used in the corresponding annual calculations.

The choice of grid spacing, both for the terrain and the dispersion calculation, can affect dispersion calculations over terrain. In order that the same calculation receptor grids were used in all three models, the restrictions of the ADMS model were used to determine the receptor and hence terrain grid sizes for AERMOD and ISC. Terrain data was provided on a regular grid at 40m intervals, except for ADMS case 6 where an 80m interval was used. For cases 1 to 5, concentrations were output on a regular grid at 100m spacing and for case 6 at 200m spacing. For the annual calculations, a new 100m interval receptor grid, centred on the source, was used to include the results from all wind directions.

3 Results of intercomparison

Table 1 contains normalised maximum concentrations and corresponding distance from the source at which these occur for all six terrain cases, together with the equivalent flat terrain case, for the three models and three meteorological states. These data summarise the general trends observed in the centreline ground level concentration (glc) and lateral glc contour plots, of which only a few examples can be presented here.

Table 1 Effects of terrain on single condition releases.(Concentrations normalised as (m^{-2}) x 10^6

Scenario	Model/Ratio	Neutral		Unstable		Stable	
		Distance to Maximum (m)	Maximum Concentration (m^{-2} x 10^6)	Distance to Maximum (m)	Maximum Concentration (m^{-2} x 10^6)	Distance to Maximum (m)	Maximum Concentration (m^{-2} x 10^6)
No terrain	**AERMOD**	1000	24.4	300	38.9	1600*	4.00
	ADMS	700	24.9	200	75.3	1400	9.50
	ISC	900	47.7	300	60.1	1600*	23.2
	ADMS/AERMOD	0.7	1.0	0.7	1.9	*	*
	ISC/AERMOD	0.9	2.0	1.0	1.5	*	*
Case 1	**AERMOD**	500	58.3	300	38.7	800	64.6
	ADMS	700	39.1	200	70.2	1100	21.2
	ISC	500	301.0	400	79.1	700	255.0
	ADMS/AERMOD	1.4	0.7	0.7	1.8	1.4	0.3
	ISC/AERMOD	1.0	5.2	1.3	2.0	0.9	4.0
Case 2	**AERMOD**	700	41.7	300	38.9	900	75.6
	ADMS	900	30.3	400	70.2	1000	19.6
	ISC	700	188.0	300	61.0	900	180.0
	ADMS/AERMOD	1.3	0.7	1.3	1.8	1.1	0.3
	ISC/AERMOD	1.0	4.5	1.0	1.6	1.0	2.4
Case 3	**AERMOD**	1300	25.0	300	38.9	1300	43.4
	ADMS	1300	19.3	200	75.7	1300	15.9
	ISC	1300	86.3	100	60.1	1100	87.8
	ADMS/AERMOD	1.0	0.8	0.7	2.0	1.0	0.4
	ISC/AERMOD	1.0	3.5	0.3	1.5	0.9	2.0
Case 4	**AERMOD**	900	26.0	300	38.9	900	7.30
	ADMS	900	26.4	200	75.6	1300	14.3
	ISC	700	109.0	300	60.4	900	67.3
	ADMS/AERMOD	1.0	1.0	0.7	1.9	1.4	2.0
	ISC/AERMOD	0.8	4.2	1.0	1.6	1.0	9.2
Case 5	**AERMOD**	600	37.2	300	38.9	800	34.0
	ADMS	900	37.0	200	76.0	900	31.4
	ISC	600	198.0	300	61.6	600	106.0
	ADMS/AERMOD	1.5	1.0	0.7	2.0	1.1	0.9
	ISC/AERMOD	1.0	5.3	1.0	1.6	0.8	3.1
Case 6	**AERMOD**	300	158.9	300	31.5	300	209.3
	ADMS	700	38.9	300	68.0	700	22.2
	ISC	500	384.2	300	155.6	300	623.5
	ADMS/AERMOD	2.3	0.2	1.0	2.2	2.3	0.1
	ISC/AERMOD	1.7	2.4	1.0	4.9	1.0	3.0

3.1 Neutral Stability

For cases 1 to 5, the shape of the centreline glc profile is clearly influenced by the terrain for all three models, as can be seen from Figure 2. Under flat terrain conditions a smooth profile is obtained. Both the AERMOD and ADMS centreline glcs are greater than their flat terrain equivalents (up to 3 times for AERMOD) but the ADMS predictions are consistently lower than AERMOD's. The ISC centreline glcs are significantly greater than both the corresponding AERMOD results and the ISC results over flat terrain. AERMOD and ISC show reduced lateral spread over terrain in contrast to ADMS. For case 6, where the source is located on the upwind slope of the terrain, the proximity of the source to the terrain dominates the solution for AERMOD and ISC. The lower ADMS glc prediction is consistent with the other terrain cases for this model. The results for all three models can be explained by the different methods they use.

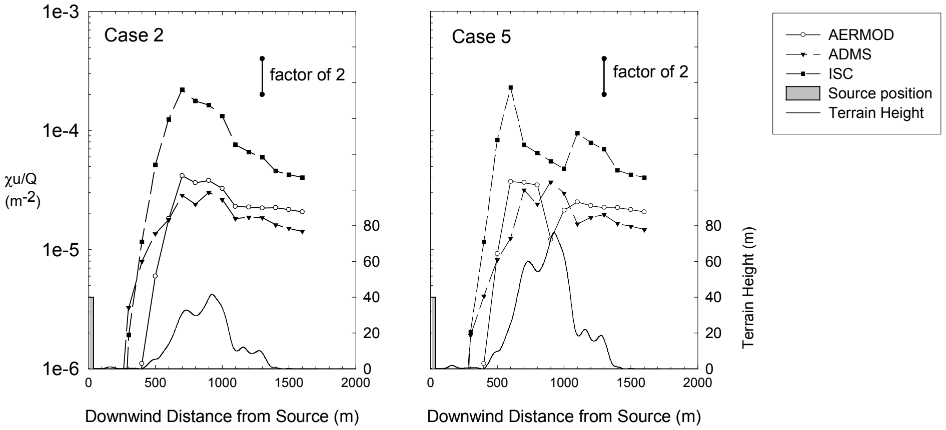

Figure 2 Effects of Terrain.
Basic Dispersion Rates for Cases 2 and 5 in Neutral Stability.

3.2 Unstable boundary layers

No significant terrain effects are seen in the glc contour plots or centreline glc profiles for cases 1 to 5. Hence, in general, the maximum glc occurs upwind of the terrain. The maximum glc predictions for AERMOD were within 1% of the flat terrain result. The ADMS maximum glcs are higher than under neutral stability, following the same trend as the result over flat terrain. The results can be explained by plume rise dominating in the concentration formulae. Figure 3(a) shows the centreline glc profiles for case 2. Terrain effects are more evident for case 6 when the initial plume rise is over the terrain, with the reduced effective plume height evident for ISC.

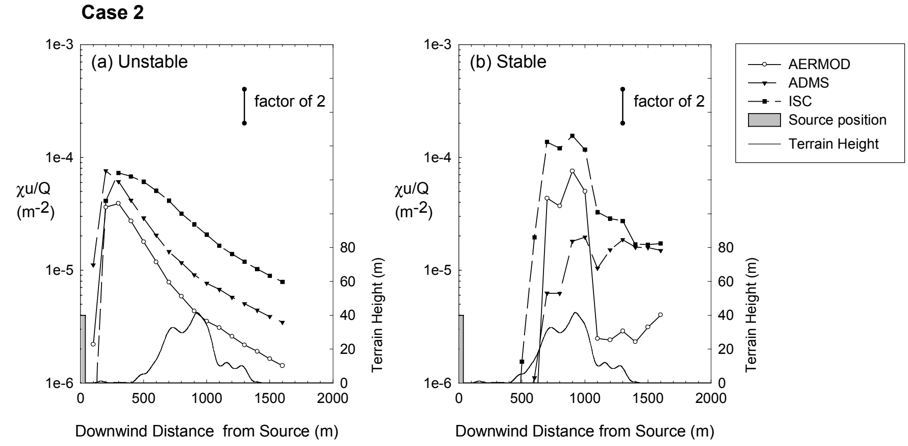

Figure 3 Effects of Terrain.
Basic Dispersion Rates for Case 2 in Unstable and Stable Boundary Layers.

3.3 Stable boundary layers

Figure 3(b) shows the centreline glc profiles for case 2 under stable conditions. The stability categorisation used in both AERMOD and ADMS means that each model applies the same approach (although different for each model) to both the neutral and stable meteorological states considered in this study. The results are therefore similar to the neutral case, allowing for effect of increased stability. The AERMOD glc predictions are significantly greater over terrain than the equivalent flat terrain case, with a particularly large maximum for case 6. The ADMS maximum glc predictions are much smaller than AERMOD's and also smaller than ADMS's corresponding results under neutral and unstable conditions. For each terrain case, the ISC predictions are again significantly greater than those for AERMOD and for the ISC flat terrain case.

3.4 Annual calculations

The maximum glc predictions are important for the annual calculations as it is these which influence the long term statistics. The case 5 99.9 percentile concentration contours are shown in Figure 4 for each model. As expected from the single state calculations, the largest values occur close to the source for ADMS and are unaffected by the terrain, whereas for AERMOD and ISC, the largest values occur over the terrain.

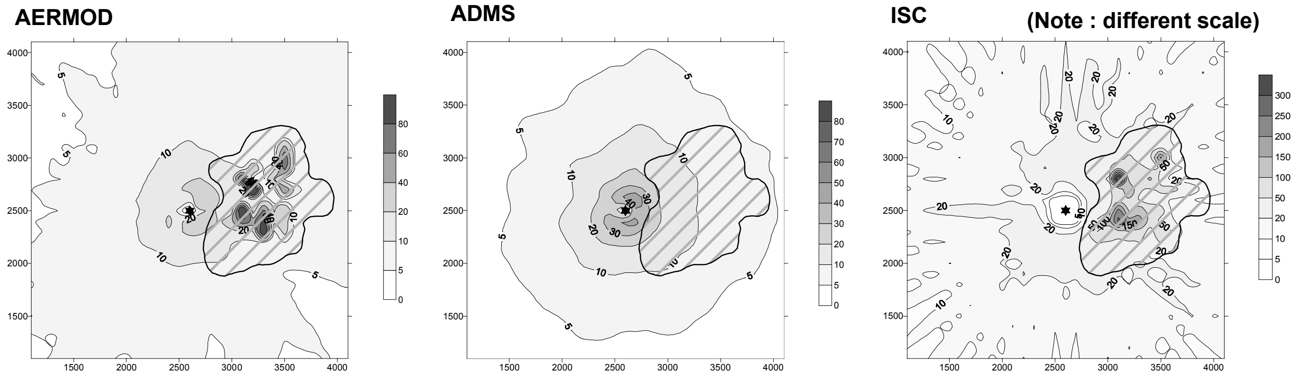

Figure 4 Effects of Terrain on Annual Calculations.
Case 5. 99.9%ile Concentration Contours.

4 Conclusions

AERMOD, ADMS and ISC use different methods to account for the effect of terrain on dispersion which generate correspondingly diverse results. Air Quality guidelines and standards are often formulated in terms of percentile statistics. The implication of the model results for regulatory purposes is that the location and value the maximum concentrations predicted by the each of the models over a given period is likely to be significantly different. This is borne out by comparative calculations for a whole single year.

References

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