Comparison of ADMS and AERMOD Meteorological Preprocessor and Dispersion Algorithms

Paper # 10

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Abstract

Comparison and validation studies have been performed by various individuals and organisations with ADMS and AERMOD dispersion models for a wide range of source types and locations in North America, Europe and Asia. In addition, there are many examples of environmental impact assessments where both models are used to calculate impacts. It is, therefore, important to understand the source of model differences. Both ADMS and AERMOD are based on broadly similar principles, e.g. characterization of the boundary layer structure using the Monin Obuhkov length and boundary layer height, a skewed Gausssian profile for convective conditions. However, the models have significant differences in detail both in the meteorological preprocessors and dispersion algorithms, which result in very different predictions of pollutant concentrations in some situations. These two sources of model differences have made it difficult to determine why calculated pollutant concentrations are different in particular cases.

In order to examine and understand these differences in detail, a hybrid model has been constructed which allows users to run combinations of the meteorological and dispersion components of the two models. Thus as well as standard uses of the models, AERMOD can be run with the ADMS met preprocessor and vice versa. The system has been used to look at the factors determining model differences for a range of source types and meteorological conditions.

Introduction

A hybrid version of ADMS[1] and AERMOD[3,4] has been constructed to allows users to run combinations of the meteorological and dispersion components of the two models. This paper describes how the meteorological data from one preprocessor are transformed into the variables required by the disperison models and describes the initial work carried out comparing typical sources of a variety of heights: near ground, 50m, 199m; with and without plume rise; for short-term met conditions representing convective, neutral and stable met conditions and long-term meteorology represented by 1 year’s data from the Clifty Creek field experiment in the US[6,7].

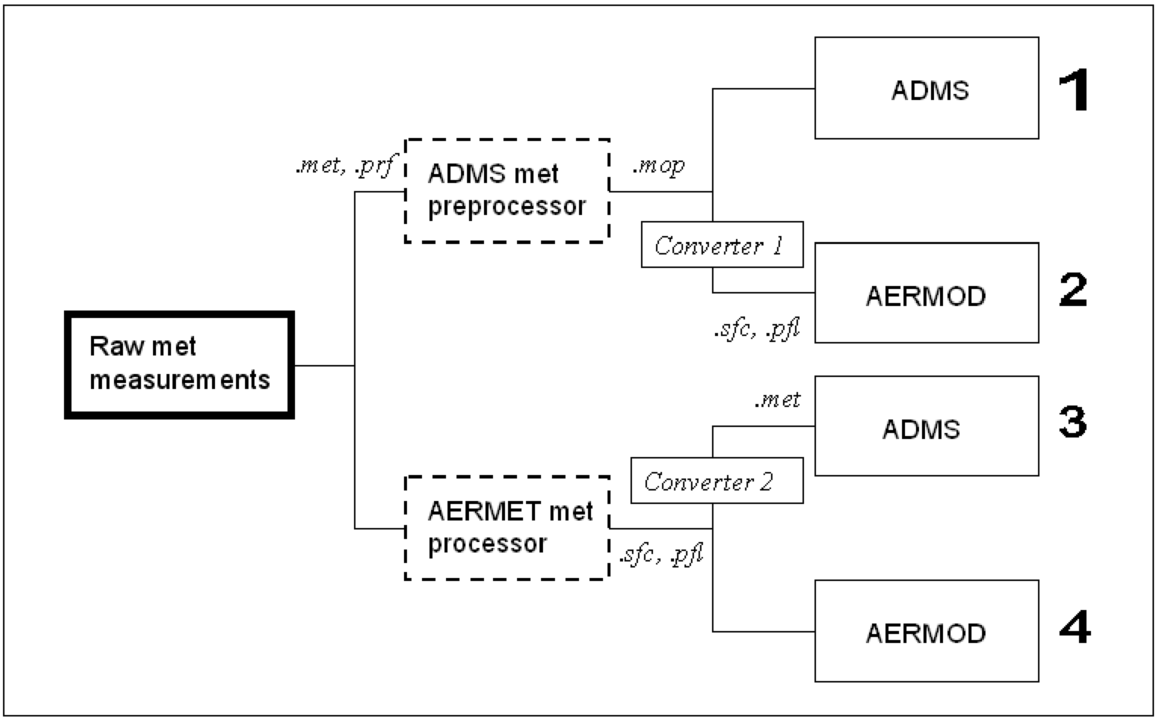
Meteorological data processing

ADMS has a built-in meteorological preprocessor[2], developed by the UK Met Office, that can take as input raw meteorological measurements such as wind speed, wind direction, cloud cover or incoming solar radiation and near-surface temperature and near-surface relative humidity, from which it calculates parameters to characterise the boundary layer such as boundary layer height, Monin Obuhkov length and the change in potential temperature across the top of the boundary layer. It can also use the derived parameters directly. The input parameters are entered in a simple comma or tab-separated format file with the extension *.met* and the processed parameters are written to an output file with extension *.mop*. ADMS can also use vertical profile data for wind speed, turbulence parameters, temperature and specific humidity that users enter via a file with the extension *.prf* , but in this comparison only the surface parameters have been entered.

AERMOD can use meteorological data from pairs of files, the file with extension *.sfc* that contains the surface data and the file with extension *.pfl* containing the data at the surface and at other heights. Both files must be present even if the *.pfl* file only contains surface data, which was the case in this study. The *.sfc* and *.pfl* files are created by the AERMET[5] meteorological processor.

Starting from raw meteorological observations, users could process their meteorological data using the ADMS meteorological processor or AERMET and then use the processed met data to calculate dispersion using ADMS or AERMOD. The choice of paths, or cases, is illustrated in Figure 1.

Figure 1. Possible combinations of meteorological processors and dispersion algorithms.



The hybrid model has been put together with the aim of investigating all of these cases. Currently, cases 1, 2 and part of 3 are implemented. Here we report on initial results using cases 1 and 2 (starting from *.met* data). Converter 1, used to convert ADMS processed meteorological parameters into AERMOD input format, is described below. Converter 2 is not described in any detail here, as it is very simple. The minimum set of parameters required to create an ADMS *.met* file are a subset of those parameters found in the *.sfc* and *.pfl* files.

Table 1 shows how the ADMS processed meteorological variables were mapped to those required by AERMOD in the *.sfc* and *.pfl* files. The limit values given in Table 2 are applied in the Converter.

Table 1. Mapping of meteorological parameters in Converter 1.

Name	**ADMS variable**	**AERMOD variable**	**Conversion**
Year	✓	✓	Convert format only
Month	x	✓	Calculate from Year and Julian day
Day of month	x	✓	Calculate from Year and Julian day
Julian day	✓	x	None required
Hour of day	✓	✓	None required
Heat flux (W/m^2)	✓	✓	None required
Surface friction velocity, u_* (m/s)	✓	✓	None required
Convective velocity scale, w_* (m/s)	✓	✓	Used if conditions are convective, otherwise set to –9.
Lapse rate above mixing height (K/m)	x Can be derived	✓	See Table footnote [1].
Convective mixing height (m)	✓	✓	None required
Mechanical mixing height (m)	✓	✓	None required
Monin-Obukhov length, L (m)	1/L is an ADMS variable	✓	Calculated from 1/L

Table 1 (cont). Mapping of meteorological parameters in Converter 1.

Name	**ADMS variable**	**AERMOD variable**	**Conversion**
Surface roughness length, z_0 (m)	✓	✓	None required
Reference wind speed (m/s)	✓	✓	None required
Reference wind direction (degrees)	✓	✓	None required
Reference height for wind (m)	From model interface	✓	Value passed from model interface
Ambient temperature (T)	✓ in Celsius	✓ in Kelvin	$T\_{AERMOD} = T\_{ADMS} + 273.15$
Reference height for temperature (m)	1.22m	✓	Set to ADMS constant value of 1.22m
Precipitation code (0-45)	x	✓	Set equal to 0
Precipitation amount (mm)	✓ (mm/hr)	✓ (mm)	None required. If wet deposition is not modelled set to 0 mm.
Relative humidity (%)	✓	✓	None required
Surface pressure	x	✓	Set equal to 1013mbar
Cloud cover (CL)	✓ in oktas	✓ in tenths	$CL\_{AERMOD} = (10/8)*CL\_{ADMS}$

Table footnote [1]. The lapse rate for AERMOD is calculated from N_u, the buoyancy frequency above the boundary layer, that is an ADMS output parameter, as follows:

$$lapse\, rate = -\frac{\partial T}{\partial z} = \frac{g}{c_p} - \frac{N_u^2 h}{R}$$

where:
g = acceleration due gravity (m/s^2)
c_p = heat capacity water vapour (J/(kg °C))
h = mixing height (m)
R = water vapour gas constant

Table 2. Limit values set by converter

Parameter	Limit value set
Temperature lapse rate above the mixing height	Minimum value of 0.005 (ºC/m) if the Monin-Obuhkov length is negative (convective conditions).
Near ground temperature	If it is lower than 220K or greater than 330K it is set to be missing data.
Friction velocity u_*	If it exceeds 1.5m/s a warning is issued to the log file and the value is set to 1.5m/s
Surface roughness z_0	If it is lower than 0.001m a warning is issued to the log file and the value is set to 0.001m/s
Convective velocity scale w_*	If it exceeds 3m/s a warning is issued to the log file and the value is set to 3m/s

Source data

The sources used in the comparison were a variety of typical industrial sources. The parameters of the sources are given in Table 3. They include sources with and without plume rise in order to separate the effect of the basic dispersion model and the modelling of plume rise.

Table 3. Source parameters.

	Source height (m)	Plume rise	Diameter (m)	Exit velocity (m/s)	Exit temperature (ºC)
Industrial source with plume rise	50	Yes	1	15	15
Industrial source without plume rise	50	No	1	0	15
Low level stack with plume rise	10	Yes	1	15	15
Ground level source without plume rise	0	No	1	0	15
Power station source with plume rise	199	Yes	13	22	135
Power station without plume rise	199	No	13	0	135

Meteorological data

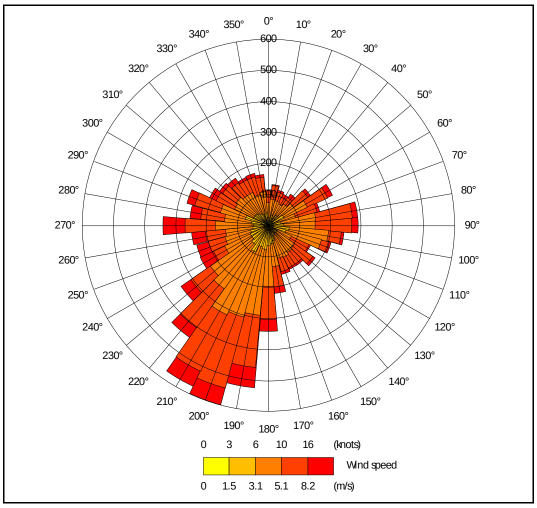
The cases were modelled using a set of short-term meteorological conditions and 1 year's meteorological data. The short-term data were a set of three hourly conditions, corresponding to convective, neutral and stable meteorological conditions, roughly representative of Pasquill Classes B, D and F, as shown in Table 4.

Table 4. Short-term meteorological parameters describing convective, neutral and stable met conditions.

	Stability class		
	B **Convective**	**D** **Neutral**	**F** **Stable**
Wind speed (m/s)	2.0	5.0	2.5
Wind direction (°)	270	270	270
Julian day	250	35	1
Local time (hours)	15	10	20
Cloud cover (oktas)	0	2	5
Boundary layer height (m)	1000	400	1200
Surface temperature (°C)	25	15	15
Surface roughness (m)	0.1	0.1	0.1

The year's meteorological data were the data accompanying the Clifty Creek field experiment[6,7]. Figure 2 shows the wind rose for the data. The wind speed and direction were measured at a height of 60m.

Figure 2. Wind rose for 1 year's meteorological data at Clifty Creek, US.



Short-term results

The six typical sources were run using the three short-term meteorological conditions. The calculated concentrations were normalised using the emissions rate to give concentration in µg/m^3/(g/s). The maximum concentration in the modelling domain was found and these are given in Table 5. The hourly average concentrations were plotted and compared. The contour plots are not all presented here.

Table 5. Maximum normalised concentration (µg/m^3/(g/s))

Source	**Stability class**	**Case 1 (ADMS/ADMS)**	**Case 2 (ADMS/AERMOD)**
Low level stack with plume rise	B	106	34
	D	59	50
	F	36	264
Ground level source **without plume rise**	B	6098	6681
	D	4018	4943
	F	14743	18833
Industrial source with plume rise	B	19	8.5
	D	6	6.5
	F	2.5	2.5
Industrial source **without plume rise**	B	30	23
	D	9	13
	F	0.9	<0.01
Power station source with plume rise	B	0.003	0.02
	D	0.00006	0.01
	F	0	<0.01
Power station **source without plume rise**	B	3.00	2.3
	D	0.63	0.95
	F	0.001	0.00

The hourly maximum concentrations are most similar in the cases without plume rise. Figure 3 shows the hourly average concentrations for neutral conditions for the three sources without plume rise. Not only are the maximum concentrations similar, the shapes of the contours are similar, except for the ground level source. This difference in shape was also seen in the convective and stable conditions for the ground level source. A difference in shape that affects most of the cases is that AERMOD predicts upwind diffusion of the source under most meteorlogical conditions whereas ADMS would only predict upwind dispersion from a point source if the calm conditions option in ADMS were used.

There is no discernable trend for either model to predict the highest hourly concentration for a particular height of source or for a particular met condition (convective, neutral or stable).

Figure 3. Hourly normalised concentrations in (μg/m^3/(g/s)) under neutral meteorlogical conditions for sources without plume rise: ground level source (top); 50m source (middle); 199m source (bottom). The ADMS dispersion results are shown on the left and the AERMOD dispersion results on the right.

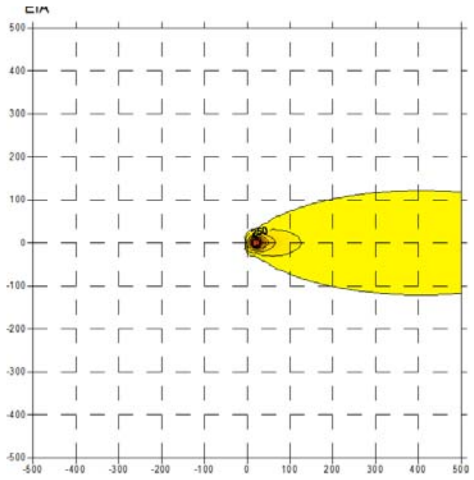
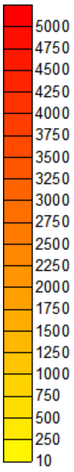
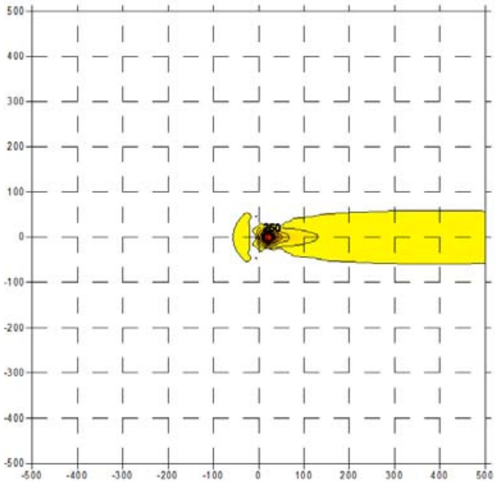
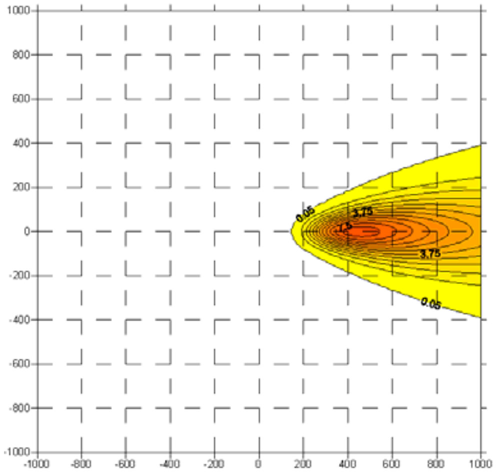
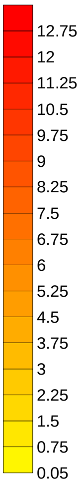
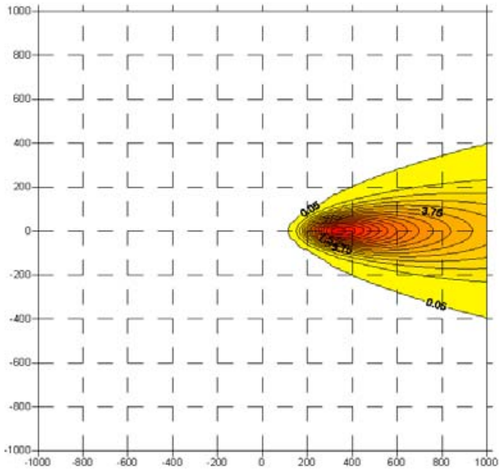
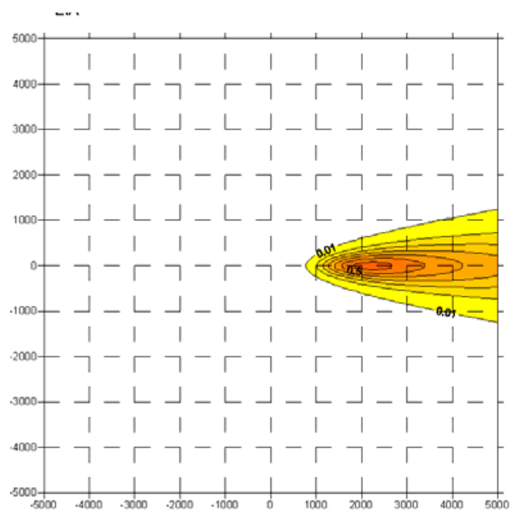
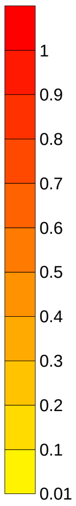
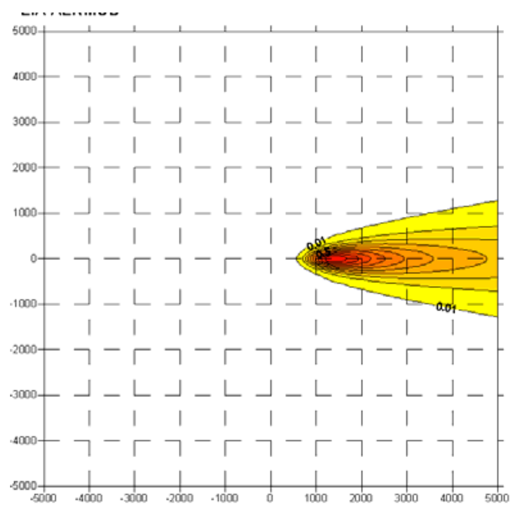
Case 1 (ADMS/ADMS)		**Case 2 (ADMS/AERMOD)**
		
		

Figure 3 (cont).

Case 1 (ADMS/ADMS)		Case 2 (ADMS/AERMOD)
		

Long-term results

The six typical sources were then run using the 1 year’s met data from Clifty Creek. The calculated concentrations were once again normalised using the emissions rate to give concentration in µg/m^3/(g/s). The maximum concentration in the modelling domain was found and these are given in Table 6. The annual average, 100th and 99th percentiles of hourly concentrations were plotted and compared.

The maximum normalised concentrations, both with and without plume rise, are in most cases quite similar. The annual mean concentration from a low level source with plume rise shows the greatest difference, Figure 4, and this must be due to near-source plume rise as annual averages for the ground level source without plume rise are very similar.

In those cases where the maximum annual average and high percentile values agree well, there is a greater difference in the pattern of the contours for the high percentiles than the annual average, as shown in Figure 5. This is to be expected as the high percentiles depend on just a few met lines of data from the year-long time series. Similar values may be predicted by ADMS and AERMOD dispersion models but arising from different hours of met data.

There is no discernable trend for either model to predict the highest concentrations for a particular height of source, with or without plume rise or for a particular statistic (annual average, 100th or 99th perecntile hourly concentration).

Table 6. Maximum normalised concentration (µg/m^3/(g/s))

Source		**Case 1 (ADMS/ADMS)**	**Case 2 (ADMS/ AERMOD)**	**Ratio Case 2 /Case 1**
Low level stack with plume rise	Annual mean	0.7	22	31.43
	100th percentile	755	800	1.06
	99.9th percentile	309	623	2.02
Ground level source **without plume rise**	Annual mean	7556	6837	0.90
	100th percentile	329258	479789	1.46
	99.9th percentile	193372	254290	1.32
Industrial source with plume rise	Annual mean	0.6	0.5	0.83
	100th percentile	51	69	1.35
	99.9th percentile	37	14	0.38
Industrial source **without plume rise**	Annual mean	1.1	1.2	1.09
	100th percentile	102	96	0.94
	99.9th percentile	70	49	0.70
Power station source with plume rise	Annual mean	0.0006	0.0017	2.83
	100th percentile	0.07	0.1	1.43
	99.9th percentile	0.04	0.07	1.75
Power station source **without plume rise**	Annual mean	0.06	0.08	1.33
	100th percentile	9.2	7.4	0.80
	99.9th percentile	6	3.4	0.57

Figure 4. Comparison of annual average normalised concentrations (µg/m^3/(g/s))from a low level (10m source) with plume rise.

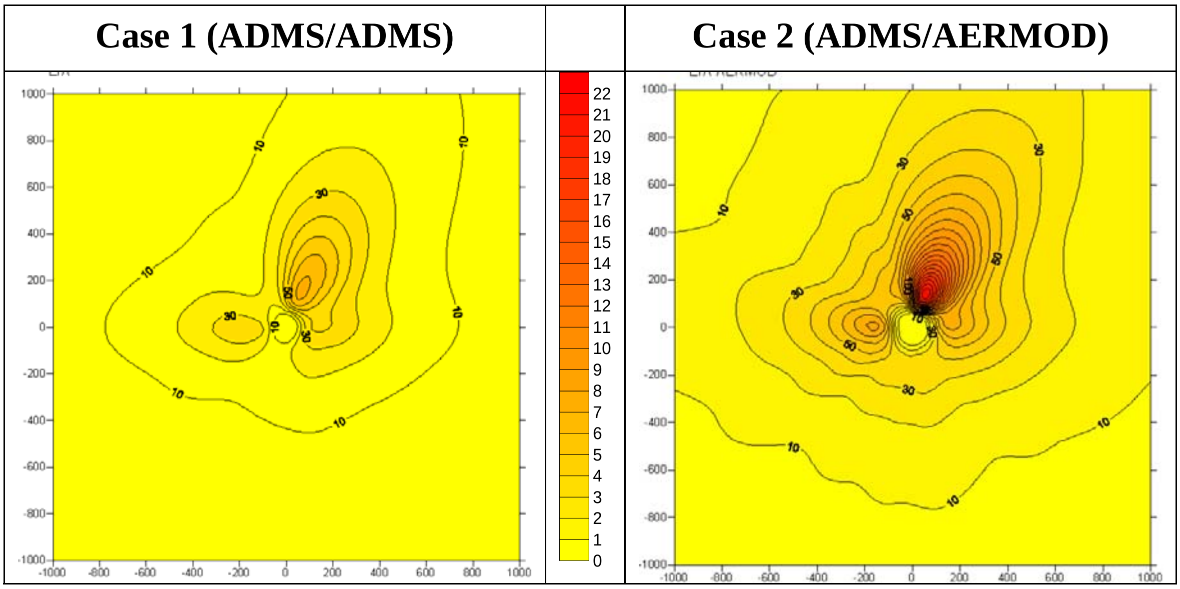
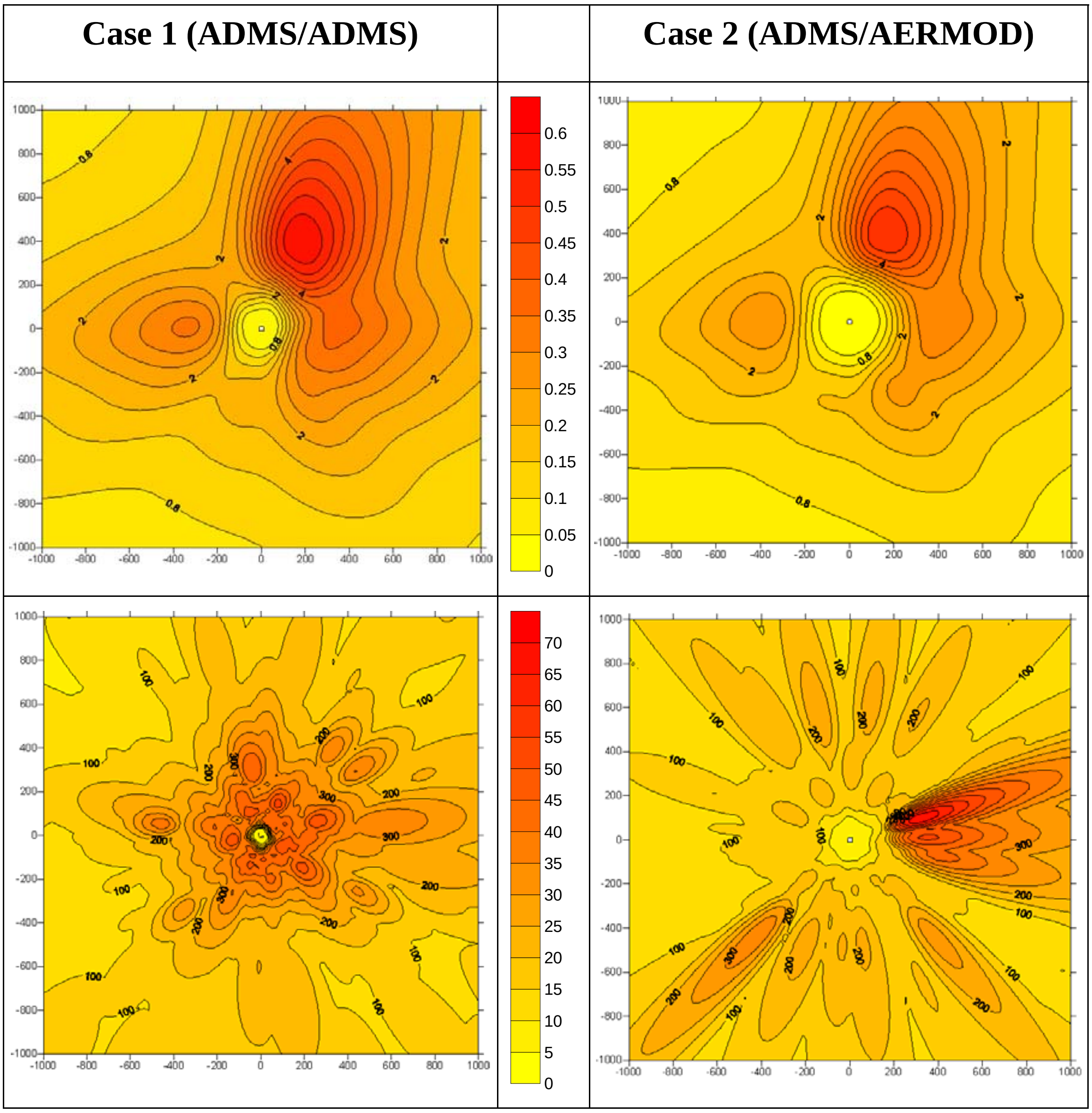


Figure 5. Normalised concentrations in (μg/m^3/(g/s)) from a 50m source with plume rise: annual average (top); 100th percentile of hourly concentrations (bottom). The ADMS results are shown on the left and the AERMOD results on the right.



Summary

A hybrid version of ADMS and AERMOD has been constructed to allow users to run combinations of the meteorological preprocessor and dispersion components of the two models. The hybrid version was used to compare maximum normalised concentrations from a variety of typical industrial sources (near ground, 50m, 199m; with and without plume rise):(i) for short-term met conditions representing convective, neutral and stable met conditions; and (ii) for long-term meteorology represented by 1 year's data from the Clifty Creek field experiement.

Comparison of maximum normalised concentrations generally, with some exceptions, shows good agreement in the cases considered, which used the ADMS meteorological preprocessor to generate data for input to both ADMS and AERMOD dispersion models.

In the short-term comparisons there was greatest agreement between the non-plume rise cases. There was no discernable trend for either model to predict the highest hourly concentration for a particular height of source or for a particular meteorological condition (convective, neutral or stable). In the long-term case differences are modest except for the annual mean concentration for the ground level and power station sources including plume rise. The difference in the plume rise modules in ADMS and AERMOD appears to be the key driver for differences between the models.

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Key words

ADMS, AERMOD, AERMET, meterological processor, plume rise, dispersion.