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REGULATORY REQUIREMENTS FOR DISPERSION MODELLING IN TAIWAN INCLUDING THE USE OF ADMS

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Abstract: The ADMS range of models (ADMS4 for industrial emissions, ADMS-Screen, ADMS-Urban and ADMS-Roads) are currently used across the world and have been widely used in Asia, e.g. Mainland China, Hong Kong, and India. This paper considers the regulatory requirements for dispersion modelling and the application of ADMS in Taiwan. Until recently ISCPrime has been the only short range dispersion model acceptable for regulatory purposes in Taiwan. For the purposes of regulatory dispersion modelling, Taiwan is divided into 16 different regions each region containing a significant urban area; for example there are areas centred on the major cities of Taipei and Kaoshung. Each region has assigned to it a particular representative meteorological dataset (hourly data for a full year) and surface conditions including surface roughness; because of the mountainous nature of Taiwan the impact of complex terrain needs to be considered in all cases. Previously as part of the regulatory requirements modelling test cases for single point sources were set up with ISCPrime for each of the regions and these datasets are available on the Taiwanese EPA website. In order for ADMS to be approved for use in Taiwan the test cases were required to be run for ADMS. Model output required included contour maps of the annual 1 h mean concentration, and 1 hour and 24 hour average percentiles and a time series of 24 hour averages at specified receptor points time. This paper presents the results of using those datasets for ADMS 4, and discusses the performances of ADMS in a Taiwan context including where appropriate comparison with ISCPrime and discussion of the impacts of complex terrain and surface roughness in the different regions.

1. INTRODUCTION

This report describes modelling studies performed as part of the submission of ADMS Carruthers et al (1993) to the Taiwanese Environmental Protection Agency (EPA) for approval for use for regulatory purposes in Taiwan. The overall requirements of the Taiwanese authorities consisted of the following:

(i) comparisons between ADMS and the current regulatory model ISC3P, in particular comparisons of the 5th, 50th and 95th percentiles of 1-hour and 24-hour averages and the correlation at a key receptor points, contours of pollutant concentrations over the modelling domain and time series of concentrations at the receptor point;
(ii) consideration and explanation of the differences between ADMS and ISC3P; there is currently a predisposition on the part of the regulatory authorities to assume that ISC3P is the model by which other models are judged. Informing the authorities about the scientific advantages of other models is an important part of enabling this situation to change.
(iii) indication of the input parameters required by ADMS including meteorological input and also parameters used to represent the surface properties at each of the sixteen areas in Taiwan (surface roughness, albedo and Taylor-Priestley parameter);
(iv) discussion of basic ADMS modelling approach and pollutant types considered by the model;
(v) discussion of the treatment of complex terrain, impacts of buildings and treatment of calm conditions;
(vi) discussion of treatment of deposition and chemical transformation;
(vii) references for model.

With regard to the modelling requirements ADMS was required to be run for sixteen different areas in Taiwan each containing a significant city. These areas were Chahwa, Chaji, Hwalein, Ilan, Inlin, Kaoshung, Keelung, Miauli, Nantou, Pintung, Shinchu, Taichung, Taidong, Tainan, Taipei and Taoyuan and are shown in Figure 1. The same locations have previously been modelled with ISC3P and thus as stated in (ii) above a key aspect of this work is to compare the pollutant concentrations calculated by the two different models.

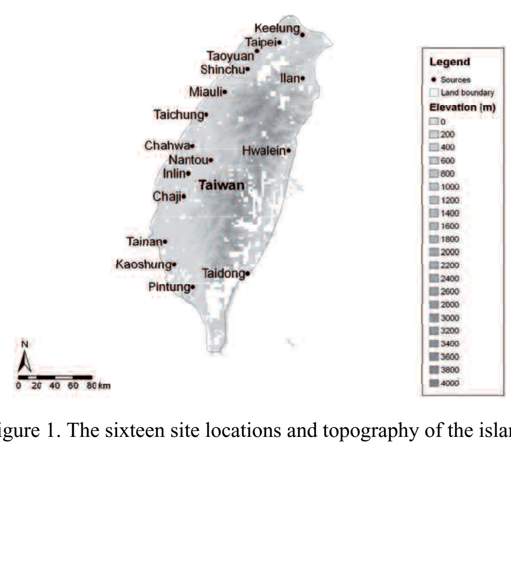

Figure 1. The sixteen site locations and topography of the island.

2. SIMULATIONS

Taiwan data were provided to CERC by the EPA in two series: (1) meteorological data for a number of sites, a topography database and data of emissions from transport, industries, etc., and (2) the input, configuration and result files of the simulations performed with ISC3P. The data provided were used to configure ADMS. In particular, the topographical data, wind measurement heights and weather station latitudes were extracted from the first series, and the source location, modelling domain and meteorological data from the second series.

Each simulation covered a 20 by 20 km^2 area with a 500-m resolution (41x41 grid points). In each case an idealized emission from a single stack was modelled with the following characteristics: height 50 m; diameter 1.6 m; continuous emission of total suspended particulates TSP of 5 gs^{-1} with an exit velocity of 24.2 ms^{-1} and at a temperature of 99.85°C. The simulations all included topography and one year of hourly sequential meteorological data. Note that the simulations for each area differ in the domain they cover (different locations), the topography (that corresponding to each site), the meteorological data (different weather stations) and the location of the receptor.

3. RESULTS

Model calculations were performed for each of the sixteen sites and the following and output as required were the following: Note that since the stack is not representative of a stack at a real site there was no option to compare modelled and measured concentrations

1) a **wind rose** of the wind directions and speeds
2) a **contour plot of the annual mean concentration** of TSP − calculated from the hourly concentration values and presented superimposed on topography, 100th percentile indicated by a dot;
3) a **time series of the daily concentration** of TSP with the **correlation** − concentrations are for a specific receptor located close to the source (within 1 km;
4) **a time series of the hourly and daily concentration percentiles** of TSP − concentrations are at the receptor located nearby the source (within 1 km);
5) a **table of the 50th and 95th percentiles of the hourly and daily concentrations** of TSP −these values may not match directly those shown in the plot of percentiles as an additional filter was applied to the data (the ISC3P values were only considered if an ADMS value was available for the corresponding hour).

Note that since the stack is not representative of a stack at a real site there was no option to compare modelled and measured concentrations.

A summary of the model results are presented in the Table whilst more detailed results for Chawa and Nantou are presented in Figures 2 and 3.

Table 1. 95th percentiles of 1-hour and 24-hour averages at receptor points in each of the sixteen Taiwan areas.

Site	1-hour average concentration				24-hour average concentration				Correlation
	ADMS	ISC3P	Difference ADMS-ISC3P		ADMS	ISC3P	Difference ADMS-ISC3P		
	(μgm^{-3})	(μgm^{-3})	(μgm^{-3})	(%)	(μgm^{-3})	(μgm^{-3})	(μgm^{-3})	(%)	
Chahwa	15.74	14.63	1.11	7.6	5.98	5.85	0.13	2.2	0.43
Chaji	14.59	14.28	0.31	2.2	6.53	5.61	0.92	16.4	0.90
Hwalein	14.18	12.24	1.94	15.8	6.24	8.05	-1.81	-22.5	-0.34
Ilan	12.41	15.67	-3.26	-20.8	4.55	4.59	-0.04	-0.9	0.71
Inlin	14.29	14.28	0.01	0.1	4.74	8.00	-3.26	-40.8	0.29
Kaoshung	14.63	12.70	1.93	15.2	3.96	5.35	-1.39	-26.0	0.81
Keelung	11.51	28.81	-17.30	-60.0	4.97	21.62	-16.65	-77.0	0.57
Miauli	11.69	23.27	-11.58	-49.8	6.71	12.45	-5.74	-46.1	0.80
Nantou	11.31	12.80	-1.49	-11.6	3.42	3.43	-0.01	-0.3	0.67
Pintung	15.42	12.94	2.48	19.2	5.16	5.42	-0.26	-4.8	0.17
Shinchu	8.45	8.26	0.19	2.3	4.01	4.64	-0.63	-13.6	0.82
Taichung	8.02	8.30	-0.28	-3.4	4.71	4.94	-0.23	-4.7	0.84
Taidong	15.81	14.66	1.15	7.8	5.56	4.76	0.80	16.8	0.15
Tainan	20.78	19.83	0.95	4.8	7.23	10.77	-3.54	-32.9	0.41
Taipei	18.48	17.00	1.48	8.7	7.61	12.22	-4.61	-37.7	0.65
Taoyuan	10.39	18.10	-7.71	-42.6	5.80	12.98	-7.18	-55.3	0.72

It is seen that the differences between the model predictions at the receptor point is relatively small at most sites, the notable exceptions being Keelung, Miauli and Taoyuan. The concentrations calculated by ISC3P at these points are likely to be unrealistically high due to the tendency of the ISC3P complex model sometimes to overpredict by large factors − in ISC3P the hilly or mountainous terrain does not affect the airflow so that the plume is transported directly into the hill or mountain side; this effect is illustrated well in the contour plots for Nantou where ISC3P shows high levels on hill top despite very little wind in the relevant directions. In reality it is well understood the air tends to flow over (neutral/convective flow) or around hilly terrain reducing ground-level concentrations relative to those predicted by ISC3P. Note that ADMS explicitly calculates the flow over complex terrain and hence the dispersion. There are of course many other factors which distinguish ADMS (a 'new generation model' taking account of the latest understanding of the physics of the atmospheric boundary layer and dispersion) from ISC3P (an 'old generation model' which is based on an outdated representation of the atmospheric boundary layer). These can of course result in differences in the predicted concentrations between the two models.

Considering the results for Chawa and Nantou in more detail, notable for Chawa is the much broader area affected by elevated annual average concentrations especially to the north of the site despite the wind generally being from the north; ADMS generally reflects the prevailing wind. Despite this the peak short term concentrations as indicated by the table 2 of 50th and 95th percentiles near the point of greatest impact are generally similar. A similar conclusion can be reached for the Nantou site with markedly different spatial pattern for the annual average but quite similar peak levels.

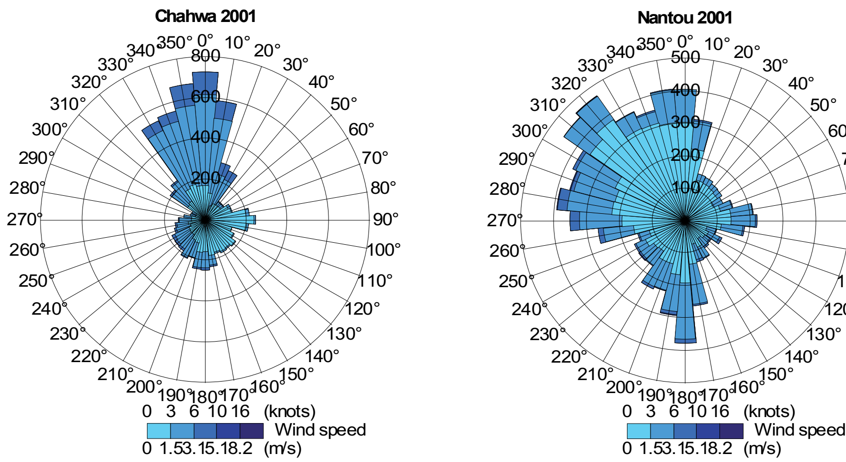

Figure 2. Wind roses of Chahwa and Nantou.

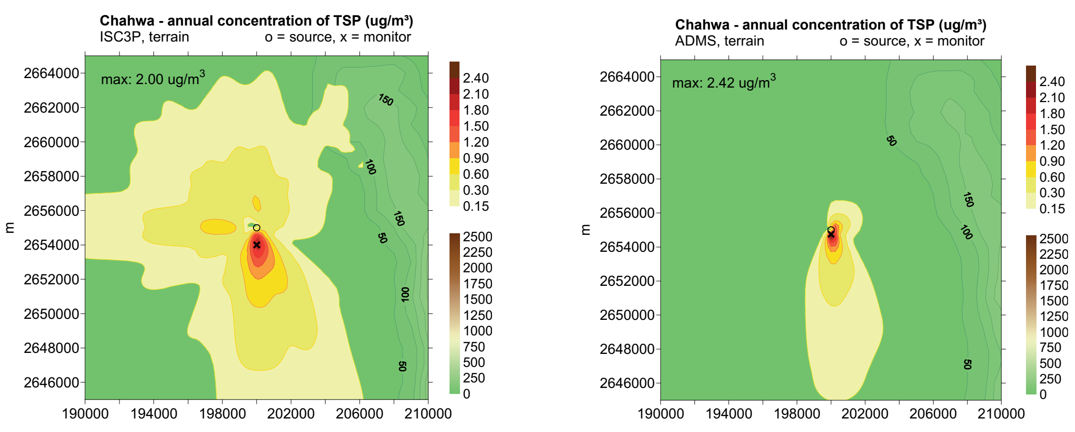

Figure 3. Annual mean concentration for Chahwa of TSP modelled by ISP3P and ADMS 4. The receptor is marked close to the source.

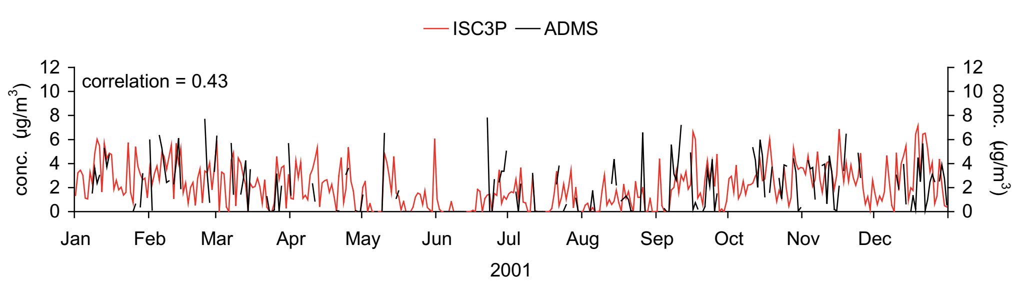

Figure 4. Chahwa; Temporal series of ISC3P and ADMS 4 model results at the receptor.

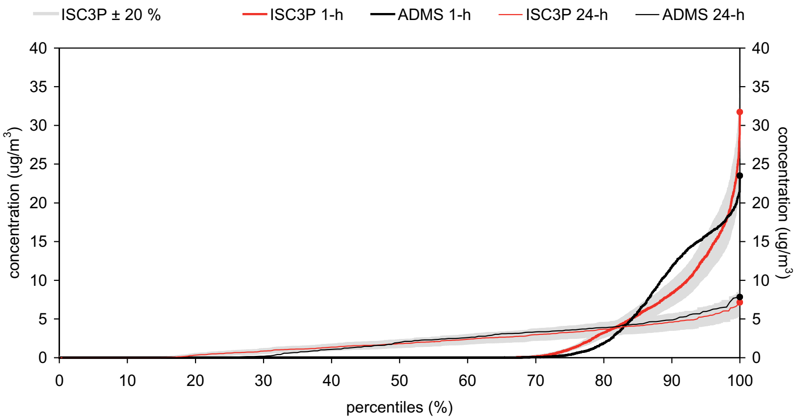

Figure 5. Percentiles plot of ISC3P and ADMS 4 model results at the receptor; for hourly and daily averages.

Table 2. ISC3P and ADMS 4 hourly and daily percentiles for Chahwa.

Data	1-hour average		24-hour average	
	ISC3P	ADMS	ISC3P	ADMS
50th percentile	0.00	0.00	2.25	2.01
95th percentile	14.63	15.74	5.85	5.98

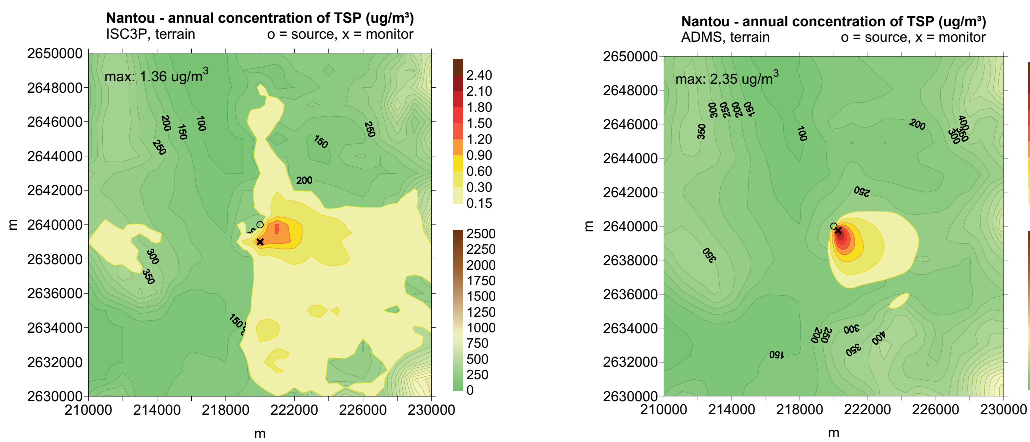

Figure 6. Annual mean concentration of TSP for Nantou modelled by ISC3P and ADMS 4 of Nantou. The receptor is marked close to the source.

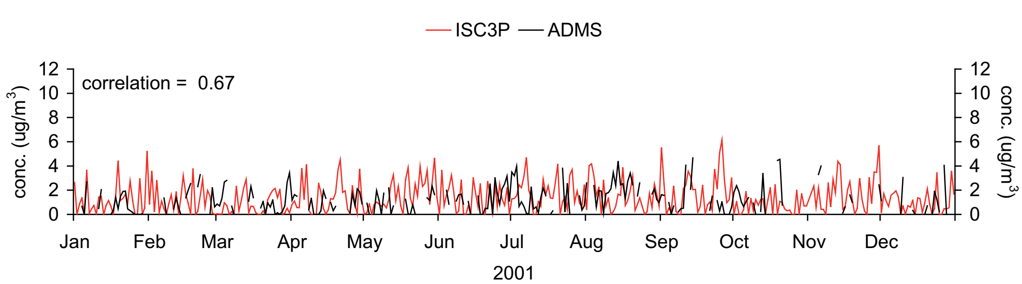

Figure 7. Temporal series of daily averages of ISC3P and ADMS 4 model results at the receptor.

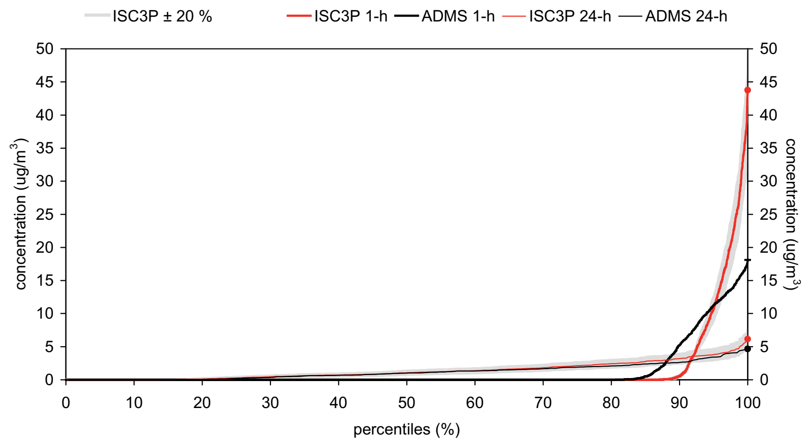

Figure 8. Percentiles of ISC3P and ADMS 4 model results at the receptor point hourly and daily averages.

Table 3. ISC3P and ADMS 4 hourly and daily percentiles for Nantou.

Data	1-hour average		24-hour average	
	ISC3P	ADMS	ISC3P	ADMS
50th percentile	0.00	0.00	1.02	1.00
95th percentile	12.80	11.31	3.43	3.42

4. CONCLUSION

The regulations in Taiwan have until recently required the sole use of ISC3P for regulatory permitting. The regulators have now accepted the principle that other models may be used subject to satisfactory compliance with submission requirements. Use of new models may provide the basis for these regulations to evolve so that ISC3P is no longer seen as the standard.

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