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COMPARING THE PERFORMANCE OF ADMS AND AERMOD USING A HYBRID MODEL AND CONDITIONAL ANALYSIS TECHNIQUES

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Abstract: The **v**alue of inter-comparisons can be limited by the difficulty of auditing model differences back to the processes that caused them. Conditional analysis methods can be used to improve this auditability. Another recent improvement is the development of a 'hybrid' model that facilitates more rapid inter-comparisons between ADMS and AERMOD. An example of using conditional analysis to compare models is given for a tall stack with receptors in the near- and far-field. Differences between the models are related to different predictions of boundary-layer height; these predictions are compared using a 'Dispersion Calendar' that shows how height differences vary for different dispersion conditions.

***Key Words:** Inter-comparison; Tall-stack; Conditional-analysis; ADMS; AERMOD*

INTRODUCTION

Inter-comparison studies of dispersion models have been a regular aspect of model development and evaluation for many years, and are central to the 'Harmonisation' initiative. Comparisons are made to identify differences between newer and older versions of a single model, e.g. ADMS 4, and to identify differences between different models, e.g. ADMS and ISCST (CERC, 2008). Inter-comparisons are important because they identify features of model behaviour that may affect model results in regulatory situations. However, given the complexity of new-generation models, it is often difficult to target comparisons on the most relevant aspect of model performance, and to determine the underlying causes of any differences. This paper describes how conditional analysis techniques can be used to identify areas of divergence between models, which can help with targeting comparisons and determining causes of difference.

BACKGROUND

Limitations of Inter-Comparisons

If inter-comparison studies are not systematic in their design it can be difficult to determine the underlying causes of differences in model output. For example, by comparing Quantile-Quantile and Scatter plots for all model output, there is a loss of the audit trail from the model results back to specific dispersion cases and model parameterisations. This limits opportunity for a more detailed examination into model differences. Similarly, if comparing single meteorological-state calculations, it is easy to carry out a large number of calculations but still be unable to interpret the results (Hall et al., 2000).

In this paper, we address 2 particular limitations: i) the ability to relate differences in model performance to model processes/inputs, and ii) the speed/ease of model of comparing between models. The following sections 2.2 and 2.3 address these limitations in more detail.

Conditional Analysis

We have previously shown how 'conditional' ways of analysing observational air-quality data can offer insight and evidence that 'un-conditional' analyses do not(e.g. Whyatt et al., 2011). Conditional methods are based on developing ensembles of results for specific groups of conditions, which can be defined in terms of 1) meteorology, e.g. wind speed, wind direction, atmospheric stability, and/or 2) source activity, e.g. time-of-day, day-of-week. These techniques have tended to be applied to observational data, for example to 'normalise' air-quality observations for the effects of meteorology, so that changes in source emissions can be identified earlier and more easily. In this paper we assess the extent to which conditional methods can be used in inter-comparison studies to identify areas of model divergence and track the causes of difference.

CERC's Hybrid Model

Inter-comparison studies between different models can be time-consuming to organise and implement, particularly when models require different input parameters. Limited access to a range of dispersion models may also restrict some users comparing results between models.

Cambridge Environmental Research Consultants (CERC)have developed a 'hybrid' model that facilitates comparisons between 2 dispersion models: ADMS (CERC, 2008) and AERMOD (Cimorelli, 2004). It offers a more user-friendly, faster and more detailed comparison by enabling users to combine the meteorological pre-processor of one model with the dispersion algorithms of the other. This means that different meteorological and dispersion components of each model can be combined to make 4 different model combinations; 2 'pure' models and 2 'hybrid' models (Fig. 1). It is therefore easier to isolate the impact on predicted concentrations of varying different components of each model.

The new 'hybrid' model should enable the modelling community to make more rapid inter-comparisons between ADMS and AERMOD. In this paper we demonstrate the hybrid model and consider how inter-comparison studies are designed and implemented. In particular, we consider if 'conditional' analysis techniques are useful for inter-comparisons as a means of organising the information and clarifying the most important differences.

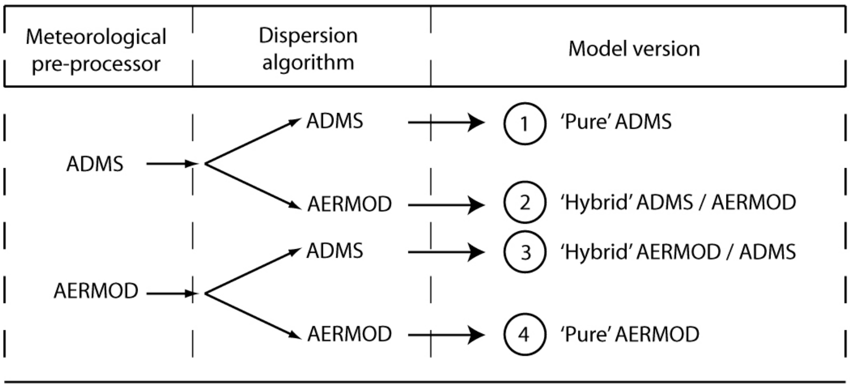


Fig. 1 The hybrid model of ADMS and AERMOD. Pathways show how users can combine meteorological and dispersion components of each model

METHODS

Experimental Set-up

Previous inter-comparison studies have shown that there are interesting differences between the meteorological pre-processor predictions of boundary-layer height in ADMS and AERMOD (Sidle, 2004). In this paper, we therefore target our analyses around modelled impacts from a tall-stack, in order to exploit the differences in the models vertical parameterisation of the atmosphere. We compare model parameters at 2 receptor distances: a near field receptor located approximately 5 effective heights from source (1.5km), and a far-field receptor located approximately 25 effective stack heights from source (7.5km). The near-field receptor will typically be associated with short-term convective/plume 'knock-down'maxima, and the far-field receptor with annual-average concentrations.

Model predictions of ambient concentration and boundary-layer height from ADMS and AERMOD are organised into atmospheric stability bins (convective, stable, neutral) using ranges of boundary-layer height/Monin-Obukhov length (H/L_{MO}).

Exploratory Analysis

We compare scatter plots and histograms of ADMS and AERMOD output as an exploratory investigation of the model differences. These plots illustrate some differences but also highlight a myriad of information within the model outputs. So thatfurther comparisons target key differences between the models more systematically, we use the exploratory plots to identify a number of important differences. Particular features of the data may be important because they represent conditions of high ambient impacts (which are of regulatory interest) or because there are substantial differences between the 2 models (which may isolate treatment of a particular dispersion process).

Dispersion Calendar Analysis

We also demonstrate how novel display techniques that have been developed alongside conditional analysis techniques, can be used in model inter-comparison studies. The Dispersion Calendar (Malby et al., 2007) is a means of mapping in 'dispersion space' the magnitude and frequency of a modelled or observed atmospheric parameter, e.g. pollutant concentration, boundary-layer height, temperature etc. The Calendar is anchored in familiar meteorology (wind speed, cloud cover, time-of-day, season), and is therefore useful for linking arithmetic differences in model performance to model processes.

PRELIMINARY RESULTS

Comparison of Near- and Far-field Impacts

Fig. 2 shows 2 scatter plots that compare predicted ambient SO_2 concentrations at 2 receptor distances (1.5km and 7.5km) and for convective conditions ($H/L_{MO}<-0.3$). It is notable that there is a tendency for AERMOD predictions to exceed ADMS predictions in the near-field (1.5km), but for ADMS predictions to exceed AERMOD predictions in the far-field (7.5km). Convective conditions are also responsible for delivering the largest ground-level impacts at each receptor distance. We will identify the specific meteorological conditions that underlie these differences, and examine them in more detail using single meteorological-state calculations.

Dispersion Calendars of Boundary-Layer Height

Fig. 3 shows sub-sections of 3 Dispersion Calendars. The sub-sections show 2 of the 4 seasonal categories (winter and spring) and 2 of the 9 time-of-day categories (0500 – 0700 and 1100 – 1500). Each of these 'temporal' categories is further divided into 'meteorological' categories (9 cloud cover and 12 wind speed bins). The calendars in Fig. 3 show mean boundary-layer height (m) as predicted by the meteorological pre-processers of ADMS (Fig. 3a) and AERMOD (Fig. 3b). Dispersion 'bins' are coloured depending on the mean boundary-layer height in order to aid the comparison between the 2 calendars. Fig. 3c shows a Calendar of the difference in boundary layer height between ADMS and AERMOD.

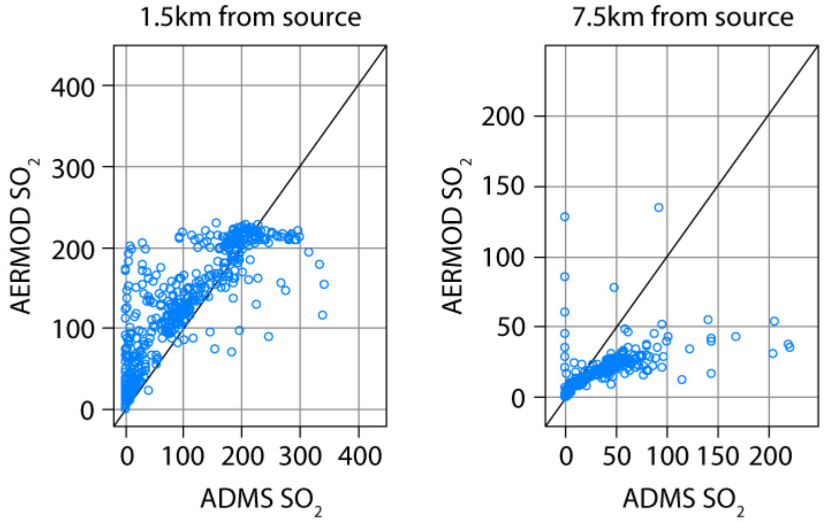
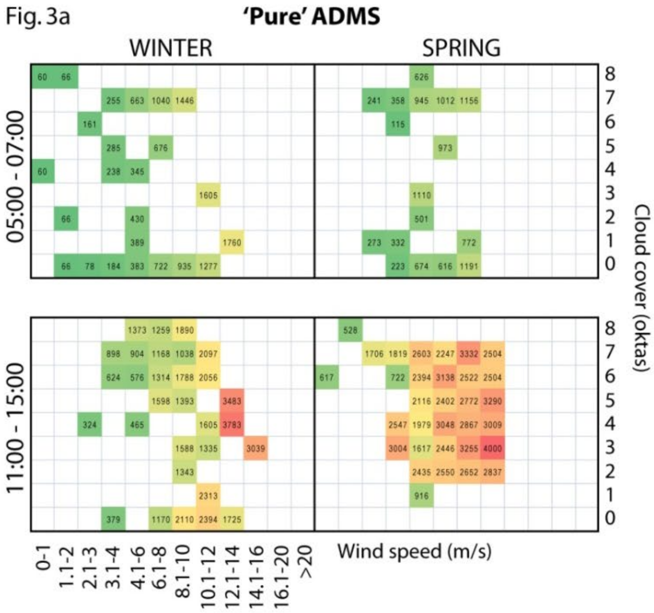
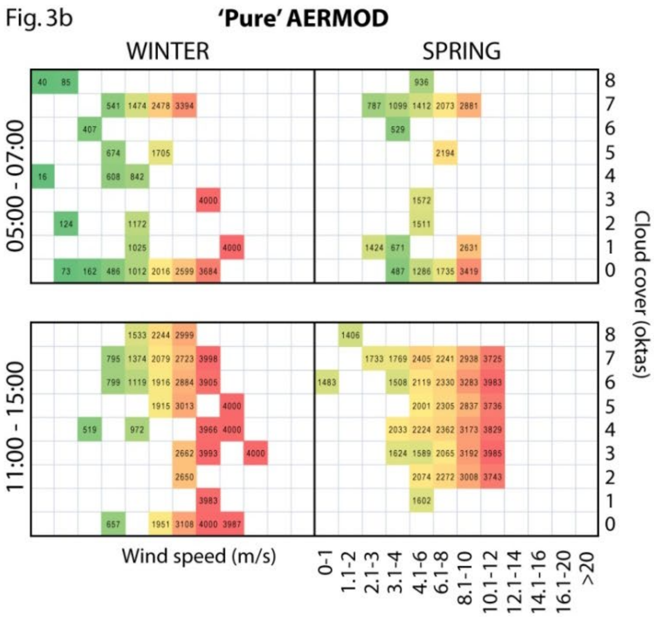


Fig. 2 A comparison of modelled SO_2 impacts from ADMS and AERMOD for near- and far-field receptors (1.5 and 7.5km) and convective conditions (H/L_{MO}< -0.3). Source modelled is a stack of height 150m and diameter 4m. SO2 is emitted at a constant rate of 1000g/s, with an exit temperature of 130 degrees C and exit velocity of 25m/s.





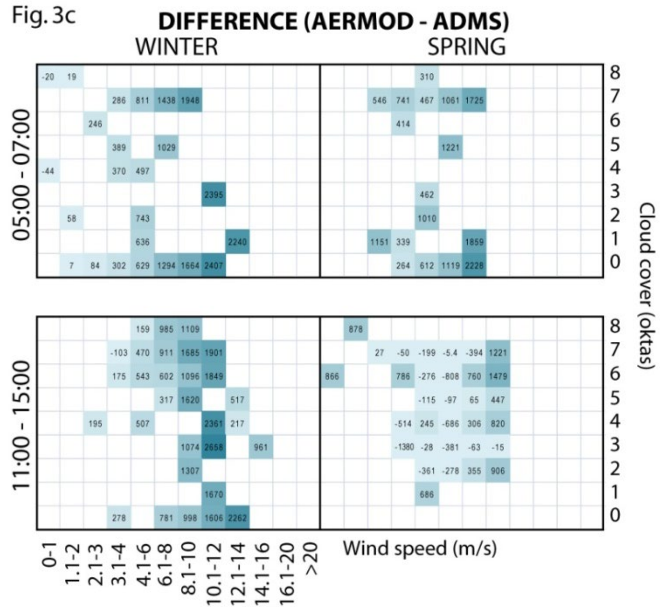


Fig. 3 Sub-sections of Dispersion Calendars showing means values of modelled boundary-layer height for ADMS (a) and AERMOD (b). The Calendar in (c) shows the difference in boundary-layer height, calculated as AERMOD (b) – ADMS (a).

A visual comparison of the Calendars confirms that AERMOD predictions of boundary-layer height tend to be higher than those of ADMS, which is consistent with previous studies (REF). There are also interesting differences between the 2 models in the distribution of high and low boundary-layer conditions. AERMOD predicts very high boundary-layer heights (up to approximately 4km) during all seasons of the year. During winter, these conditions occur within all time-of-day divisions of the Calendar. By contrast, there are substantially fewer occasions of very high boundary-layer heights in ADMS, and they tend to be focused within a narrower zone of the Calendar; specifically around midday and during the spring. The Calendar also indicates a stronger dependence of boundary layer height on wind speed in AERMOD, than in ADMS. These differences are likely to have important implications for modelled plume concentrations, particularly for conditions associated with plume penetration of the boundary layer, and winter night-time periods when some of the greatest and most consistent differences occur.

Finally, we consider the effect of incorporating upper-air data in ADMS, in order to refine calculations of buoyancy frequency above the boundary-layer. ADMS runs which include upper-air data are consistent with AERMOD's requirement for upper-air measurements. Initial analyses indicate that incorporating upper-air data into ADMS tends to increase predictions of boundary-layer height. Further analyses will explore the extent to which predictions are brought closer to those of AERMOD.

CONCLUSIONS

This paper shows that making it easier to compare between dispersion models will be essential to the future of the 'Harmonisation' initiative. It is regular challenge for dispersion modellers to link model differences back to model processes. However, it remains important so that we can identify the reasons for differences and consider their implications for model parameterisation. Conditional analysis and CERC's hybrid model take important steps towards achieving this challenge.

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