EVALUATION OF OML AND AERMOD

Helge R. Olesen, Ruwim Berkowicz and Per Løfstrøm
National Environmental Research Institute (NERI), Aarhus University, Denmark

You may visit the web page
http://www.dmu.dk/International/Air/Models/Background/OML.htm
to check whether a revised version of the present paper is available.

INTRODUCTION

The Danish OML model is a Gaussian plume model, which belongs to the same family of models as AERMOD and UK-ADMS. It is based on boundary-layer theory and not on traditional stability classification. The current standard OML model became operational for regulatory purposes in Denmark already in 1990. Recently, the model has been reviewed in order to introduce improvements where appropriate (Olesen et al., 2007a).

During this activity an extensive set of model evaluation activities have been undertaken. The model evaluation comprised the currently operational OML model ("Standard OML"), the new, improved "Research Version" of OML, and the US AERMOD model.

The present paper focuses on model evaluation activities based on the classic field experiment of Prairie Grass (Barad, 1958). Several additional data sets have also been considered. Thus, evaluation has also been undertaken with the classic field experiments of Kincaid and Copenhagen (pertaining to the Model Validation Kit). Furthermore, we have considered data from a series of experiments conducted in Denmark in the nineties – the Borex experiments. Results from all of these latter experiments are not discussed here. A brief description can be found in the report by Olesen et al. (2007a). More publications are in preparation – check the web address above (URL 1) for such information.

Finally, a series of studies on building effects have been conducted, mainly based on wind tunnel data produced by R. Thompson of the US EPA in 1990. This set of studies is described in a conference paper (Olesen et al., 2007b) and on the web (URL 1).

The present paper deals with just a small fraction of the evaluation activities. The main emphasis here will be on validation data and model evaluation – not on details of model formulation. Focus is on the Prairie Grass data set. The Prairie Grass data have been used by many groups, but there is not an official, digital version of the data available. It is relevant in a harmonisation context identify problems and potential pitfalls of the data set. The subsequent discussion also addresses such aspects.

METHODOLOGY

It is common when reporting results of model evaluation studies that results are condensed to a few statistical performance metrics, such as correlation, fractional bias, fraction within a factor of two, etc. However, a statistical performance evaluation should not stand alone as it can conceal many aspects of model behaviour and of data quality. It is widely recognised that exploratory data analysis is an important part of model evaluation.

Thus, the process of model validation can be a rigorous statistical performance evaluation, but it can also – and this is the approach taken here – be an "insightful groping for clues to model improvements". The latter is the formulation of Joe Knox (1984), who advocates the view that model evaluation can be regarded as a learning process.

During the course of our work we have pursued a very detailed approach. We have plotted model results and observations for every single hour of an experiment. The experimental data, model generated data and the plots are all collected in a single Excel file, making it easy to step through the hours of an experiment, while observing model behaviour. This approach allows us to gain insight into the data and into model behaviour. Some of our data sets are available on the web (URL 1) as well as through the Wiki on Atmospheric Dispersion (URL 2). Besides this detailed approach we have also summarised results in terms of statistical metrics based on grouped data.

Very importantly, it should be kept in mind that when results for individual experiments are presented one should be very careful about drawing conclusions. Atmospheric processes are stochastic. Deviations between observations and model results are natural. Therefore – even for a perfect model – results will deviate from observations. Only if we construct an ensemble average over a large number of closely related scenarios can we expect that a perfect model will behave like the ensemble average.

Models studied

The subsequent model validation results refer to three models:

- The "standard OML" model, which corresponds to the currently operational version of the OML model (OML-Multi 5.03 from 2003).
- The "research version" of OML, which was formulated in 2005-06. It includes a number of modifications compared to standard OML.
- The US AERMOD model, version 04300 (Cimorelli et al., 2004).

Three main differences between the standard OML model and the new research version are outlined below. Further details can be found in Olesen et al. (2007a).

In the standard OML model, the effective transport wind speed is constant regardless of the distance from the source (as long as there is no plume rise). However, this assumption – implying that effective wind speed does not change during plume transport – is quite crude, in particular for sources close to the ground, where the wind changes rapidly with height, while the plume increases its vertical extent during transport. The Research Version of OML has a more elaborate description of effective wind speed.

The standard OML model assumes a large horizontal dispersion in stable conditions for small values of u_*, in order to account for meandering. The magnitude of this effect seems exaggerated in view of the experimental data that are now available. Therefore, the parameterisation of s_y has been revised.

With modern computers it is now feasible to implement a model structure where the vertical dispersion does not follow a simple Gaussian distribution. A Gaussian distribution has long been known to be an oversimplification of reality when it comes to vertical dispersion in convective conditions. A new model formulation allows for a "vertical meandering" of the plume, combined with a Gaussian shape of the basic plume.

The Prairie Grass data set

The Prairie Grass experiment is a classic experiment conducted in July-August 1956. A release took place from a point source close to ground level (46 cm height). SO_2 was used as a tracer, and concentrations were measured on arcs at distances of 50 m, 100 m, 200 m, 400 m and 800 m. The duration of each of the 68 sampling periods was 10 minutes. The original data were published in a paper report (Barad, 1958). There is no official, digital version of the data.

The wind speed was measured at heights of 0.25, 0.5, 1, 2, 4, 8 and 16 m above the ground. Use of the velocity profile to estimate a roughness length for each run gives quite consistent results, except for 4 runs. Generally, a roughness length of approximately 6 mm is estimated. However, for runs 3, 4, 13 and 14 the estimated roughness length is considerably larger (around 10 cm). For the runs in question the wind speed profile is not well-behaved. It is characteristic for these runs that the wind speed is very low – less than 1 m/s (at a height of 1 m). Many users of the Prairie Grass data set have discarded these runs, and also we exclude them from our "standard subset" of data. However, statistical performance measures will be very much affected, depending on whether the abnormal runs are included or not, so it is worth noting that they exist.

MODEL RESULTS

In the present context we will focus on the parameter of cross-wind integrated concentration. It is less sensitive than the maximum arc-wise concentration to the problem that the models predict 1-hour averages, whereas the measurements represent 10-minute averages. Fig. 1 presents an overall picture of model performance for cross-wind integrated concentration, based on the 'standard' subset of data. The concentration values have been normalised by emission rate. Results for each arc are presented by distinct symbols. The Research Version of OML appears to be an improvement over the standard version. There is an indication of overpredictions for AERMOD.

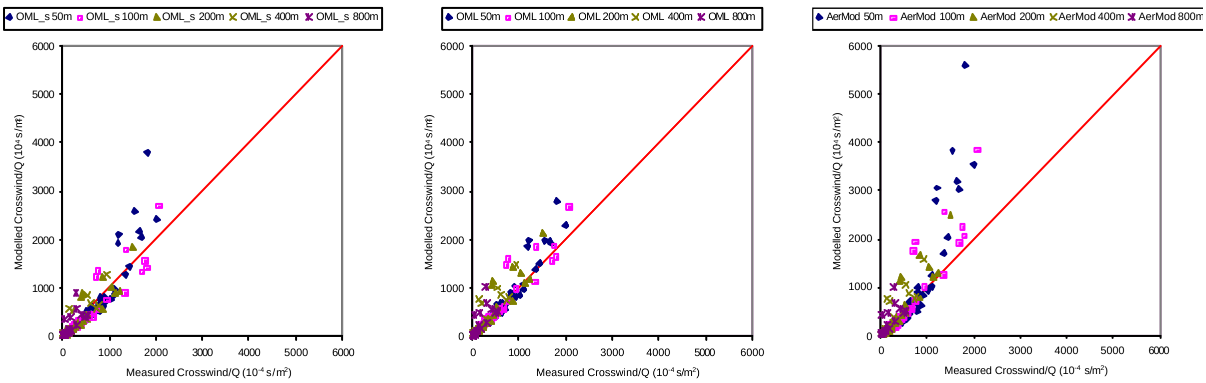

Fig. 1. Crosswind integrated concentrations for the runs in the standard subset (60 runs). From left to right: OML standard, OML Research Version, AERMOD.

However, certain features are not visible from this set of graphs. It requires additional graphs to shed light on the effect of considering different subsets of data, as well as the effect of stability.

The apparent model performance is very much affected by data selection criteria. The four abnormal runs (extremely low wind speed) result in very large predicted concentration values, especially for standard OML and AERMOD. Fig. 2 shows the result of including *all data* in the analysis. One consequence is that the scale must be changed. The immediate impression is one of severe overpredictions for standard OML and AERMOD.

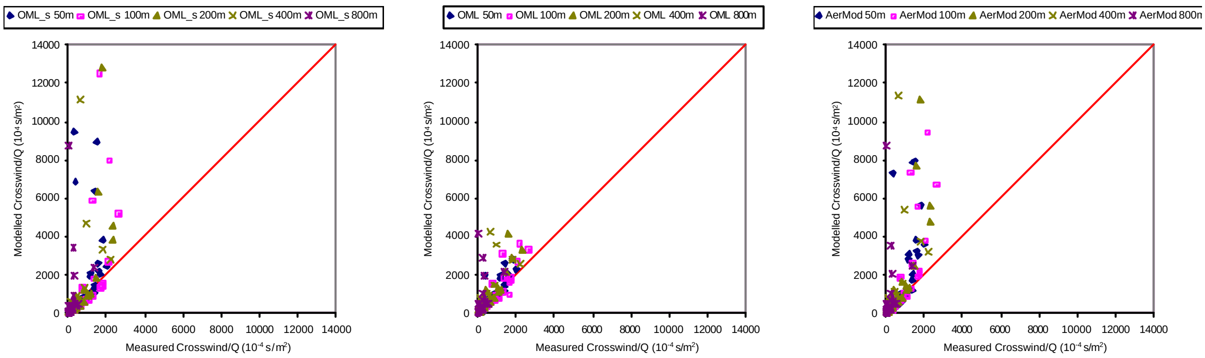

Fig. 2. As Fig. 1, but based on all data including those flagged as abnormal (runs 3, 4, 13 and 14). Note that the scale of the axis has been changed dramatically in order to accommodate these model results.

It is interesting to analyse model behaviour as a function of u_*. In Fig. 3 we have included *all* data – also the four abnormal runs – and plotted cross-wind integrated concentration at the 50 m arc as a function of u_*. It is striking that for low values of u_*, the models – especially AERMOD – tend to predict very large values. The degree of overprediction should not be taken at face value, because the meteorological input for the abnormal runs is questionable and the runs may deserve a special treatment. Nevertheless, it is a cause of concern that when very small values of u_* are used as input, modelled concentrations have a tendency to explode.

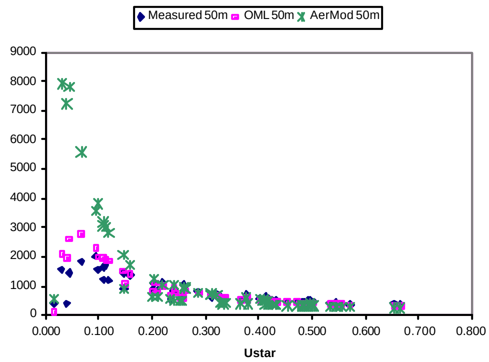

Fig. 3. Crosswind integrated concentration at the 50 m arc for all runs except the elevated (64 runs). According to measurements, OML Research Version and AERMOD

Concentration levels are very different for stable, respectively unstable conditions. The values for stable conditions are by far the largest, especially at the 50 m arc. The stable cases dominate the visual impression in Fig. 1. In order to reveal model behaviour for unstable conditions data have to be plotted separately, as shown in Fig. 4. From Fig. 4 it appears that for unstable conditions the standard OML and AERMOD have a tendency for underprediction, but that this trend is eliminated in the Research Version of OML. This is mainly due to the new parameterisation of vertical dispersion and wind speed.

CONCLUSIONS

The paper shows a few, central results from an evaluation of the three models OML standard, OML Research Version and AERMOD. Based on the Prairie Grass data set, the new OML Research Version appears superior to the other models.

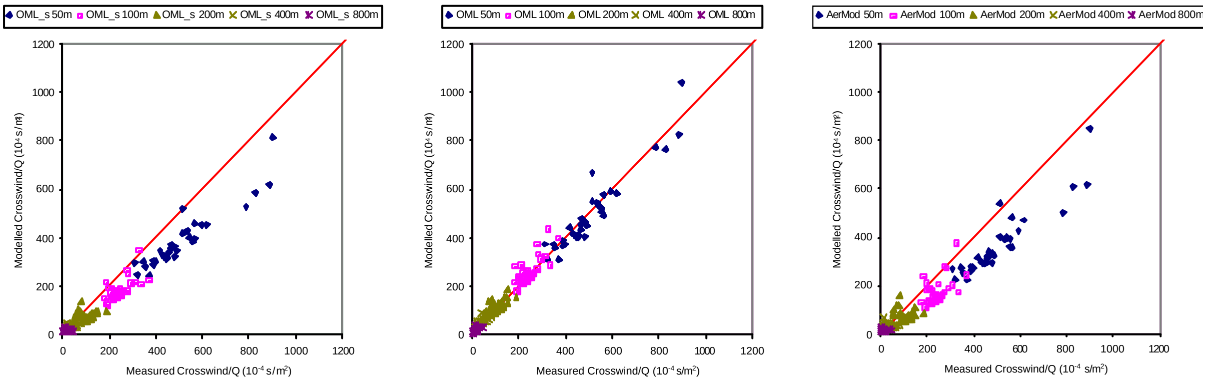

Fig. 4 Standard subset of data, but only unstable conditions (34 runs). From left to right: OML standard, OML Research Version, AERMOD.

The Model Validation Kit is a toolbox of experimental data sets and software, intended to serve as a common frame of reference for modellers. The Prairie Grass data set is not part of the Model Validation Kit at present. However, the work described here provides some of the necessary foundation so that the Prairie Grass data set can eventually be included in the Kit. Already now some useful tools for inspecting data are available on the web (URL 1). An entry to these data has also been established at the Atmospheric Dispersion Wiki (URL 2). The use of the Wiki as a central entry makes it possible for others to contribute with experiences to a common pool of information.

ACKNOWLEDGEMENT

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