VALIDATION OF THE IMPROVED AEROPOL MODEL AGAINST THE COPENHAGEN DATA SET

Marko Kaasik, Veljo Kimmel
Institute of Environmental Physics, University of Tartu. Tartu, ESTONIA

INTRODUCTION

The international agreement represented by COM (1999) sets certain criteria to which results of air pollution modelling must correspond. Usually there does not exist enough spatial information about pollution field – thus, validation of the model is complicated. International data sets for validation of models are good alternatives – they represent pollution field in different meteorological conditions and pollution patterns.

The aim of current study is to validate Gaussian-plume AEROPOL model against the Copenhagen data set and thus check its applicability in typical weather and urban conditions. The triggering reasons for this study were (1) the improvement of model and (2) the extensive use of AEROPOL for urban planning applications in Estonia.

BACKGROUND

The AEROPOL model (developed in Tartu Observatory, Estonia) is a Gaussian plume model, which includes the reflection and partial adsorption of the pollutant at the underlying surface, wet deposition, initial rise of buoyant plumes. The model is applicable for gaseous pollutants and particles from stacks, transport and area sources like domestic heating (Kaasik, 1996, Kaasik et al., 2002).

The model was earlier validated against the Lillestrøm data set (expressing predominantly very stable stratification) with relative success (Kaasik, 2000). In recent years the AEROPOL model was intensely applied for urban planning purposes in Estonia. The model was recently improved, introducing the two-level wind data (instead of 10 m wind only) and heat flux based method to determine the Pasquill stability classes (instead of earlier determination by cloud amount and solar elevation). Thus, the need for validation in more typical weather conditions became urgent.

The conditions of dispersion experiment in Copenhagen (1978 – 79, Gryning and Lyck, 1984) correspond well to the typical situation, in which the AEROPOL model is applied: urban elevated (115 m) release, mid-latitude maritime climate with quite strong winds and neutral or slightly unstable stratification. The improved AEROPOL model was validated against the Copenhagen data set (observed data: Olesen, 1994). The determination of statistics available in the data set follows formulae given by Hanna et al. (1991):

normalised mean square error $$\mathrm{NMSE} = \frac{\overline{(C_0 - C_P)^2}}{\overline{C_0 C_P}} \qquad (1)$$

fractional bias $$\mathrm{FB} = \frac{\overline{C_0} - \overline{C_P}}{0.5\left(\overline{C_0} + \overline{C_P}\right)} \qquad (2)$$

fractional standard deviation $$\mathrm{FS} = \frac{\sigma_{C_0} - \sigma_{C_P}}{0.5\left(\sigma_{C_0} - \sigma_{C_P}\right)}. \qquad (3)$$

In formulae (1 – 3) C_0 is the measured concentration, C_P is the observed one, overbar means averaging over the ensemble and σ with corresponding indexes is the standard deviation. Other applied statistics are the linear correlation coefficient (COR) and the factor of C_P/ C_0 in the diapason 0.5 – 2 (or fraction in factor 2, FA2).

VALIDATION

The summary statistics for arc-wise maximal concentrations is given in Table1 and for crosswind integrated concentrations in Table 2. Both concentrations are normalised with the source emission (mass emitted in unit time).

Table 1. Statistics for maximum arc-wise concentrations (normalised with emission, unit 10^{-9} s/m^3, 23 observations). Sigma – *standard error,* NMSE – *normalised mean square error,* COR – *linear correlation coefficient,* FA2 – *fraction in factor 2,* FB – *fractional bias,* FS – *fractional standard deviation.*

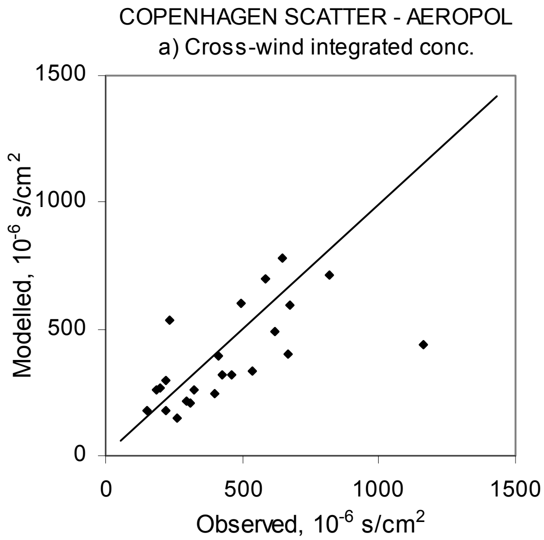
Model (country, comparison year)	Mean	Sigma	Bias	NMSE	COR	FA2	FB	FS
Observations	632.7	450.3	0.0	0.00	1.000	1.000	0.000	0.000
AEROPOL (Estonia, 2002)	573.0	448.7	59.6	0.30	0.642	0.826	0.099	0.004
HPDM (USA, 1994)	358.2	268.1	274.4	0.61	0.847	0.658	0.554	0.507
IFDM (Belgium, 1994)	551.9	345.3	80.8	0.19	0.843	0.870	0.136	0.264
INPUFF (Romania, 1994)	560.6	352.7	72.1	0.50	0.490	0.739	0.121	0.243
OML (Denmark, 1994)	283.6	251.1	349.1	1.12	0.823	0.217	0.762	0.568
UK-ADMS (UK, 1994)	177.1	138.5	455.5	2.84	0.891	0.043	0.125	1.059
UK-ADMS extra (UK, 1994)	261.8	176.9	370.8	1.37	0.913	0.348	0.829	0.872

Table 2. Statistics for cross-wind integrated concentrations (normalised with emission, unit 10^{-6} s/m^2, 23 observations). Explanations of used statistics see Table 1.

Model (country, comparison year)	Mean	Sigma	Bias	NMSE	COR	FA2	FB	FS
Observations	448.7	239.3	0.0	0.000	1.000	1.000	0.000	0.000
AEROPOL (Estonia, 2002)	386.5	183.6	62.2	0.19	0.624	0.913	0.149	0.263
HPDM (USA, 1994)	382.3	161.6	66.4	0.16	0.778	1.000	0.160	0.387
IFDM (Belgium, 1994)	443.3	193.4	5.43	0.16	0.681	0.957	0.012	0.212
INPUFF (Romania, 1994)	339.6	180.4	109.1	0.46	0.361	0.696	0.277	0.280
OML (Denmark, 1994)	249.2	131.7	199.5	0.52	0.893	0.565	0.572	0.580
UK-ADMS (UK, 1994)	207.1	110.7	241.6	0.86	0.912	0.348	0.737	0.735
UK-ADMS extra (UK, 1994)	297.0	122.5	151.6	0.34	0.856	0.783	0.407	0.646

Like the models validated earlier (Olesen, 1995), the AEROPOL model tends to underestimate slightly both concentrations (bias). Scatter of data is relatively large (moderate correlation coefficient COR), but extreme deviations from observed values are seldom (high FA2 and low NMSE). The overall scatter (Sigma) for cross-wind integrated concentrations is somewhat underestimated and for maximum arc-wise concentrations almost perfect.

Looking at the plots of modelled *versus* observed concentrations (Figure 1) we see, that both cross-wind integrated and arc-wise maximal concentrations are randomly scattered.



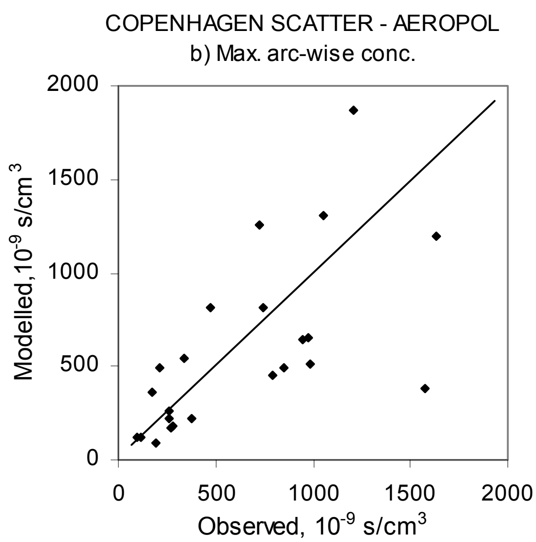


Figure 1. Plots of modelled and observed cross-wind integrated (a) and maximal arc-wise (b) concentrations. Concentrations are normalised with the source emission rate, one-to-one line is added to the graphs.

The deviations from the one-to-one line are bilateral and balanced (which is consistent with the small bias) and increase nearly in proportion with the concentration, i.e. relative error is nearly constant. The maximal arc-wise concentrations are slightly more scattered than the cross-wind integrated ones.

CONCLUSIONS

We have to conclude, that the AEROPOL model performs fairly for elevated releases in urban area during neutral or slightly unstable stratification. The systematic error of results is relatively small - significant advantage from the operational point of view. Therefore, the best performance is expected for long-term average concentrations.

Most of the models give higher correlations with observation than the AEROPOL model, but tend systematically underestimate the concentrations (especially UK-ADMS). These models, however, were validated eight years earlier and therefore the comparison does not reflect the present state of their development. Nevertheless, as these models were in operational use already in the middle of nineties during the validation at the Mol workshop, we have to conclude, that AEROPOL performs well at level with the models applied in Europe and USA during the last decade.

Assessment of air pollution levels by measurements is well determined through standard methods and procedures set by COM (1999) and later directives. Although we cannot expect that assessment of air pollution by modelling is standardised, we can expect that validation of models is somehow standardised. Intensified practice of validating models against available international data sets, and creating newer and better data sets can accelerate ongoing process of standardisation of and improve comparability and quality of air pollution modelling.

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