A COMPARISON OF THE AERMOD MODEL WITH THE POLISH REGULATORY DISPERSION MODEL

Joanna Cieślińska[1] and Lech Łobocki[2]
[1]Institute for Environmental Protection, Warsaw, Poland
[2]Warsaw University of Technology, Warsaw, Poland

INTRODUCTION

In Poland, a Gaussian climatological plume model is used for regulatory purposes since late 60's. Over the last three decades, the atmosphere protection policy has been resting mainly on permits, issued upon demonstration that a new source would not cause violation of air quality standards in the immediate vicinity. The Environment Protection Act of 2001, in compliance with the Framework directive 96/62/EC and its Daughter Directives, entered a new, broad group of tasks related to the air quality management system operation. As the climatological model could not fulfil all the new requirements, the Ministry of Environment issued guidelines, recommending the use of several newer models (Łobocki, 2003). This has led to a situation where different tools are used in policymaking and regulatory applications; hence, it is essential to find out (1) whether the modeling results differ considerably, and, if so, (2) are any systematic differences that can be identified, and (3) what could be the possible consequences of replacing the current regulatory model with a newly proposed one? The guidelines recommended four models applicable to industrial-type point sources: the AERMOD (Cimorelli *et al*., 1998), the CALPUFF (Scire *et al.*, 2000), the ADMS (Carruthers *et al*., 1995) and the AUSTAL-2000 (Ingenieurbüro Janicke, 2005). In present work, we focus on the intercomparison of AERMOD and the current Polish regulatory model.

This paper is intended as a model-to-model intercomparison study, focused on a co-called consequence analysis (estimation of possible effects of a model replacement). Hence, much effort is spent on calculating statistics required by the law. However, to get some insight into the differences, we begin with a case-by-case analysis. As one of the models (the AERMOD) has a more general formulation and incorporates effects (e.g. effect of hills, plume downwash, etc.) that are not handled by the current Polish regulatory model, we also restrict our comparison to simple terrain conditions. Here, we discuss gaseous pollutants only, postponing the issue of particulate matter to a broader publication.

THE CURRENT POLISH REGULATORY MODEL

The Polish regulatory atmospheric dispersion model (hereafter termed the GCPM, for Gaussian Climatological Plume Model) is based on a classic formulation of a Gaussian plume from a point source, under steady-state, horizontally-homogeneous conditions. The details of the model formulation are given in the Decree of the Minister of Environment of Dec. 5, 2002.

In case of gaseous pollutants, the permit procedure rests on two statistics: the annual mean concentration, and the frequency of excedance of limiting value (LV) as set for 1-hour averaging time. For sulphur dioxide, these thresholds are 30 and 350 μg m^{-3}, correspondingly, and the allowed excedance frequency is 0.274%.

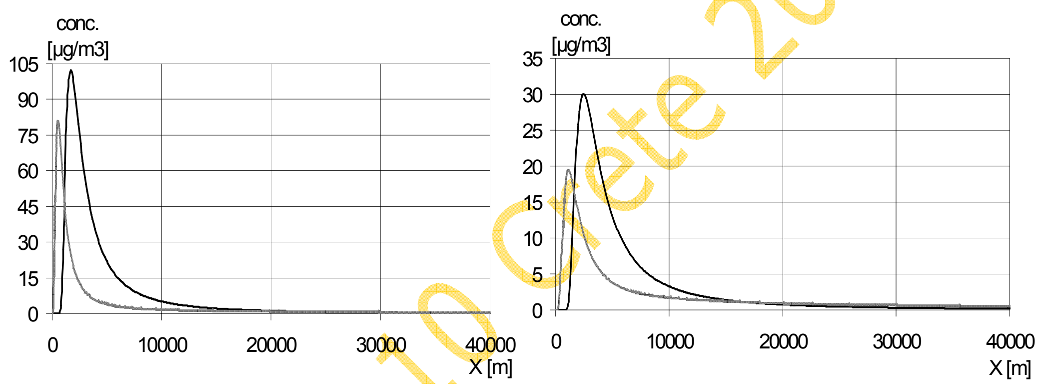
CASE STUDIES

A set of cases, comprising several characteristic boundary layer scenarios was chosen for a case-by-case analysis from a year-long series of surface and aerological observations. Calculations were made using a number of typical stack parameters. Table 1 shows parameters of emitors, selected for this presentation. Calculations were made along the plume center axis.

Table 1. Parameters of emitors used in case studies

Symbol	QS	HS	TS	VS	DS
parameter	emission rate	stack height	flue gas temperature	flue gas exit velocity	diameter
[unit]	[g/s]	[m]	[K]	[m/s]	[m]
Amount	225.9	50.0 300.0	468.7	15.2	5.1

Results presented here were obtained for three classes of stability: strongly unstable (L^{-1} = -0.149 m^{-1}), neutral (L^{-1} = 0.0002 m^{-1}) and slightly stable (L^{-1} = 0.017 m^{-1}). For all cases maximum one-hour average of concentrations was calculated. Corresponding stability classes



were determined using Golder's (1972) method. Figures 1-3 display the intercomparison of results.

Figure 1.Ground-level concentrations for stack heights 50 (left pane) and 300 (right) [m] for strongly unstable conditions and wind velocity 2 [m/s]. Horizontal axis: downwind distance from the stack, vertical – pollutant concentration. Solid line: GCPM, dotted – AERMOD.

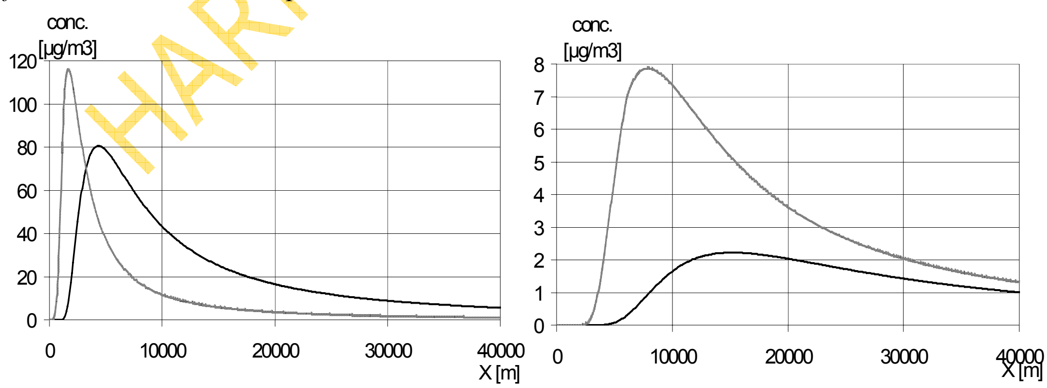
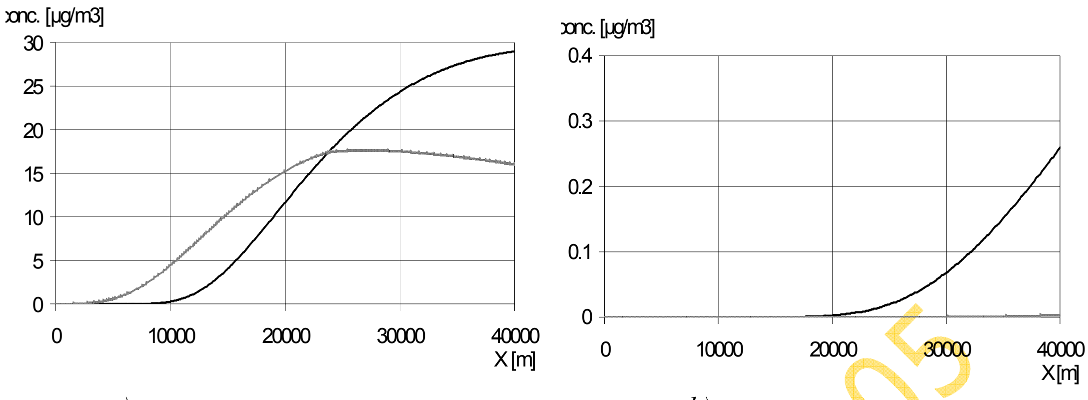


Figure 2. As Fig. 1, for neutral conditions and wind velocity 8 [m/s].



a) *b)*

Figure 3. As Fig. 1, for slightly stable conditions and wind velocity 3 [m/s]

Under unstable conditions (Fig. 1), the maximum ground-level concentration calculated by AERMOD is located much closer to the source, and has slightly smaller value than in case of GCPM. This is true for both tha tall and the low stack. In the near-neutral case (Fig. 2), the maximum calculated by AERMOD is also shifted closer to the stack location, but has a higher concentration value than GCPM. Under stable conditions (Fig. 3), for the low stack, we have again less pronounced maxima located closer to the stack in case of AERMOD. In case of a tall stack, the AERMOD does not predict noticeable values because of the inversion located below the stack, while the GCPM predicts a very distant (over 40 km), weak maximum. In all cases, the ground-level concentrations calculated by the GCPM are near-zero at the immediate vicinity of the stack (within a radius of a few hundred meters to 1 km). he emissions near emitor equal or almost equal zero. Both models predict higher ground-level concentrations for taller stacks.

CONSEQUENCE ANALYSIS

To supplement the findings of the previous section, we conducted a series of tests, using a year-long series of meteorological data (surface and 00Z soundings) from Wrocław, WMO #12424. This series was pre-processed by AERMET for its further use with AERMOD; using AERMET results (i.e. surface-layer parameters), we have also determined stability classes using the Golder's (1972) method, and constructed the wind/stability climatology as required by the GCPM. Four emitors were considered, representing mid-size to LCP-range industrial or power plant stacks; two of them – the lowest and the tallest ones are discussed here. While some typical, realistic stack parameters were used, the emission rates were arbitrarily chosen to cause excedances of the 1-hour LV, still keeping the annual means below the limit. The stack parameters used in this paper are summarized in Table 2. Calculation results are presented in Figs. 4-5.

Table 2. Parameters of emitors used in the consequence analysis

source id	stack height (m)	diameter (m)	flue gas exit velocity (m s^{-1})	flue gas temperature (K)	emission rate (g s^{-1})
1	200	7.7	26.0	388	3995.2

source id	stack height (m)	diameter (m)	flue gas exit velocity (m s^{-1})	flue gas temperature (K)	emission rate (g s^{-1})
2	100	5.8	13.4	408	1083.04

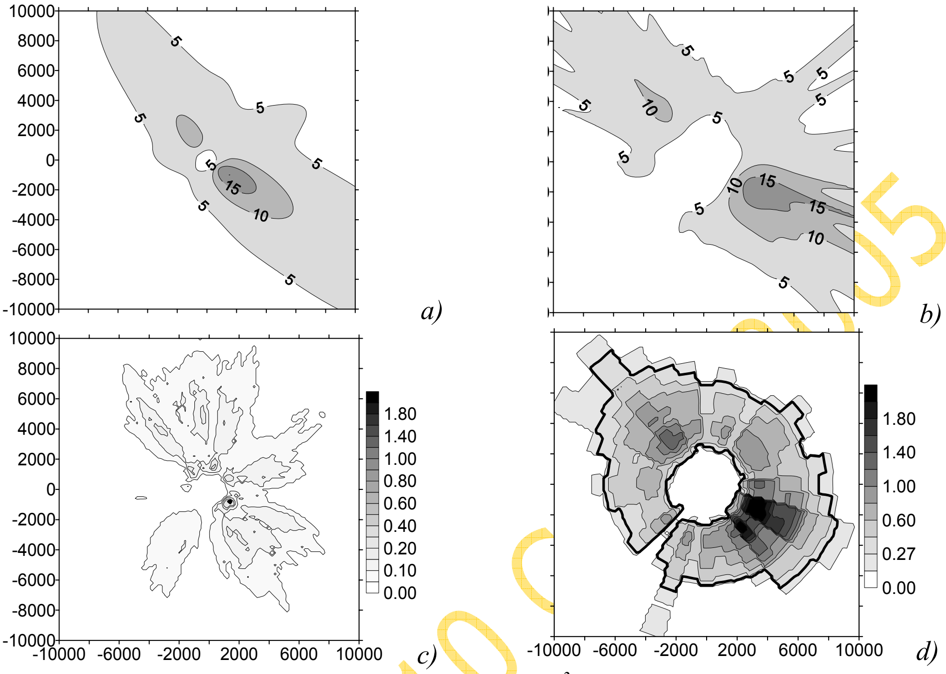


Figure 4; Annual average concentrations [Φg/m^3] (a-AERMOD, b-GCPM) and excedance frequency [%] (c-AERMOD, d-GCPM) for stack height 200 [m].

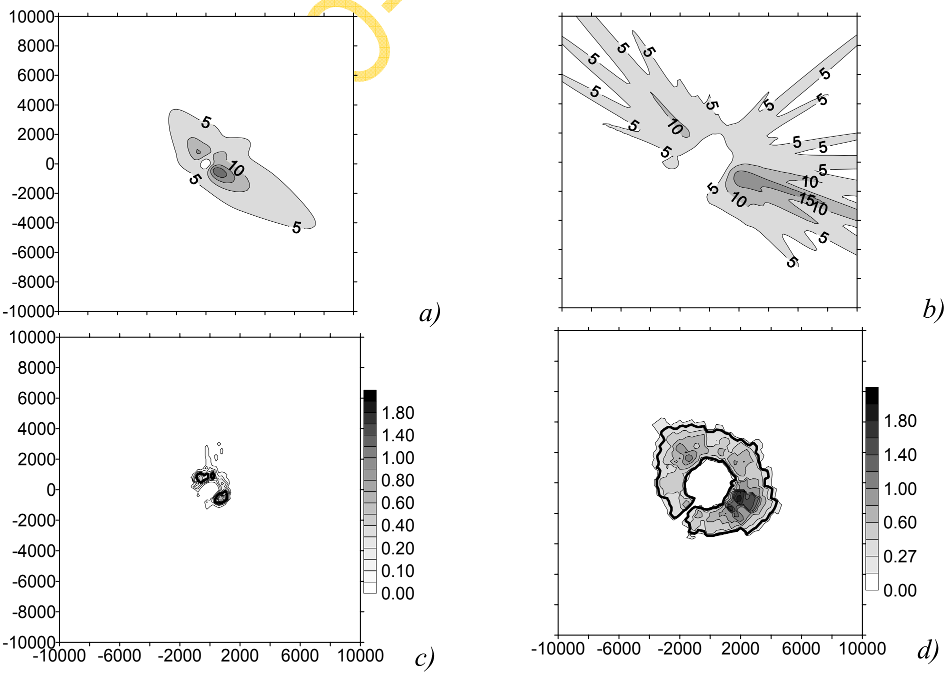


Figure 5; Annual average concentrations [Φg/m^3] (a-AERMOD, b-GCPM) and excedance frequency [%] (c-AERMOD, d-GCPM) for stack height 100 [m].

RESULTS AND CONCLUSIONS

As can be seen in Figs. 4-5, annual mean concentration fields produced by the AERMOD tend to display smaller spread then those calculated by the GCPM. Maxima are more pronounced (a few to a few tens of percent) and shifted closer towards the emission source; this feature corresponds with the findings of the case-by-case analysis of the former section. A near-zero pollutant concentration zone around the stack, which seems to be an arte fact of the GCPM, is much more narrow in AERMOD results. The 'focusing' of the annual means field is more pronounced for lower stacks.

The comparison of excedance statistics involves more complexity, and the results cannot be easily generalized. The excedance number (particularly in case of the GCPM) becomes highly sensitive to the emission rate, once the latter becomes higher that a certain value corresponding to a single excedance case. The growth is much more rapid than in case of the annual means. In the spatial variation, frequency maxima occur along rings surrounding the receptor and tend to be collocated with the maxima of annual means. Again, the radius of these rings is much smaller in case of AERMOD. The critical excedance frequency value, 0.274% (as set by the Polish law) encompasses areas that are significantly smaller in case of AERMOD for all the sources except the lowest one.

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