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THE AUSTRIAN GUIDELINE FOR SHORT SCALE DISPERSION MODELING

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Abstract: Dispersion modeling to assess the impact of emissions from small businesses, parking lots, etc. on air quality is a rather challenging task as such need to be performed with a minimum of effort. In many cases it is required to come up with results during a licensing procedure. However, there are often complex building structures or source configurations, which call for sophisticated dispersion models. In addition concentrations statistics (e.g. annual mean) have to be computed to assess compliance with air quality standards. Long computation times needed by e.g. Lagrangian particle models prevent their usage in such cases. In literature, there exist a lot of screening or simple models for specific applications, such as box models for parking lots, simple Gaussian models for small stack dispersion, etc. Often such simple types of models have not been validated or only tested against a few data sets (sometimes only wind tunnel tests). As it is desirable to have one single tool/model for a harmonised modeling approach, it was decided by a national working group on this issue, to develop a new modeling tool for such applications. It is based on dispersion simulations with the Lagrangian Particle Model GRAL, a model which was available in the working group and which is well validated (currently 26 data sets) and documented. Simulations have been performed for 34 different source configurations, such as line sources with and without accompanying buildings, area sources with different extensions and building structures in the near surroundings, and point sources with different stack configurations (varying stack heights, exit velocities, exit temperatures, building heights). The simulations are based on classified meteorological situations characterised by wind speed, wind direction and stability class. For each configuration 2D concentration data has been stored in a directory. For a given time series of such classified meteorological data, annual mean, maximum daily mean, and maximum hourly concentrations can be calculated within a few seconds/minutes. A Graphical User Interface enables a comfortable application and minimizes the possibility of false use. The tool also provides the assessment of annual odour hours for given odour emissions in [MOU/h]. The modeling tool has been validated against eight field experiments and showed for the various source configurations satisfying results. After approval by the Austrian ministry, the model will be made available free of charge for anyone interested.

***Key words:** dispersion, modelling, Lagrangian, GRAL, GRAMM*

INTRODUCTION

Dispersion modeling to assess the impact of emissions from small businesses, parking lots, etc. on air quality is a rather challenging task as such need to be performed with a minimum of effort. In many cases it is required to come up with results during a licensing procedure. However, there are often complex building structures or source configurations, which call for sophisticated dispersion models. In addition concentrations statistics (e.g. annual mean) have to be computed to assess compliance with air quality standards. Long computation times needed by e.g. Lagrangian particle models prevent their usage in such cases. In literature, there exist a lot of screening or simple models for specific applications, such as box models for parking lots, simple Gaussian models for small stack dispersion, etc. Often such simple types of models have not been validated or only tested against a few data sets (sometimes only wind tunnel tests). As it is desireable to have one single tool/model for a harmonised modeling approach, it was decided by a national working group on this issue, to develop a new modeling tool for such applications.

METHOD

In order to use only one model for the broad variety of source configurations in typical licensing procedures, we took the prognostic Eulerian wind field model GRAMM (Oettl, 2000) coupled with the Lagrangian particle model GRAL (Oettl and Uhrner, 2009). Such types of models are very flexible in contrast to other kinds of models. For instance the widely used microscale prognostic wind field model MISKAM (Eichhorn, 2008) is not designed to treat stratified boundary layers or buoyant plume rise. Currently other available models, such as AUSTAL2000 (Janicke and Janicke, 2002), or ADMS (CERC, 2007) have problems in calm wind situations, which are very frequent in many Austrian regions. A model validation performed by the national working group using experimental data from Graz in Austria (Anfossi *et al.*, 2006) showed, that all models except for GRAL have a strong tendency to underestimate concentrations (Figure 1). This is not surprising as GRAL is the only model among the ones tested, which has a specific algorithm to treat calm wind situations. In the experiment, tracer was released from a point source approximately 1.5 m above ground level. Half-hourly mean concentrations were observed in a circle around the release point at a distance of 50 m.

The models have also been tested against the field experiment Uttenweiler (Bächlin *et al.*, 2002), were tracer was released from a low stack of a pig stable during relatively high wind speeds and neutral atmospheric stratification. In this case GRAL and AUSTAL2000 were the only models with satisfying results (Figure 2).

In total GRAL has been validated against 26 field and wind tunnel experiments, which are documented in Oettl and Uhrner (2009). The data sets comprise point sources in flat and complex terrain with and without building downwash, line sources within and outside build-up areas, tunnel portals, area sources, all atmospheric stratifications and low up to high wind speeds. In the case of dispersion within built-up areas, GRAL uses 3-dimensional wind and turbulence (turbulent kinetic energy and ensemble average of dissipation rate) fields generated by GRAMM. GRAMM solves the conservation equations for momentum, enthalpy, mass, turbulent kinetic energy, and dissipation rate. The following equations are used to derive the standard deviations of the wind fluctuations in GRAL:

$$\sigma_u = \sigma_v = \sigma_w = \sqrt{\frac{k}{1.5}} \qquad (1)$$

k turbulent kinetic energy
u, v, w kartesian components of the standard deviations of the wind fluctuations

As soon as the dissipation rate computed by GRAMM is lower than the "ambient" dissipation rate computed by eq. (2) the turbulence scheme of GRAL is used in the dispersion calculations. Eq. (2) is a slight modification of the function proposed by Kaimal and Finnigan (1994).

$$\varepsilon = \frac{u_*^3}{z}\left[1 + 1.5 \cdot \left|\frac{z}{L}\right|^{0.6}\right]^{1.8} \qquad (2)$$

u_* friction velocity
z height above ground
L Monin-Obukhov length

When GRAL is coupled with GRAMM to take buildings into account and when there is a line source defined in GRAL, then GRAL sets a minimum turbulent kinetic energy of 2 m²/s² in a layer up to 5 m above street level. This enhances the dispersion in the model due to traffic induced turbulence.

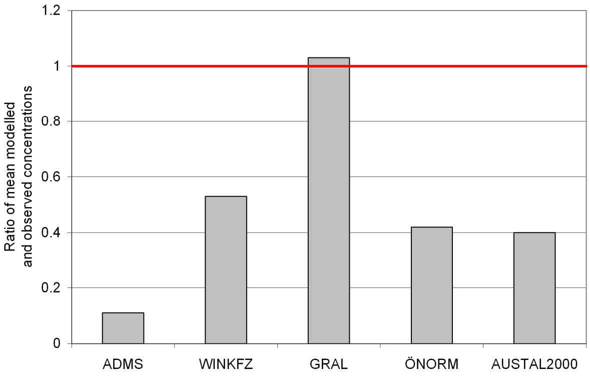


Figure 1. Comparison of mean modelled and observed concentrations for the field experiment in Graz (Austria)

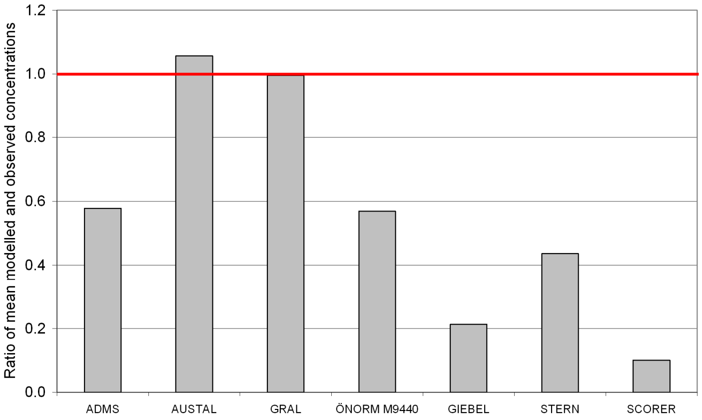
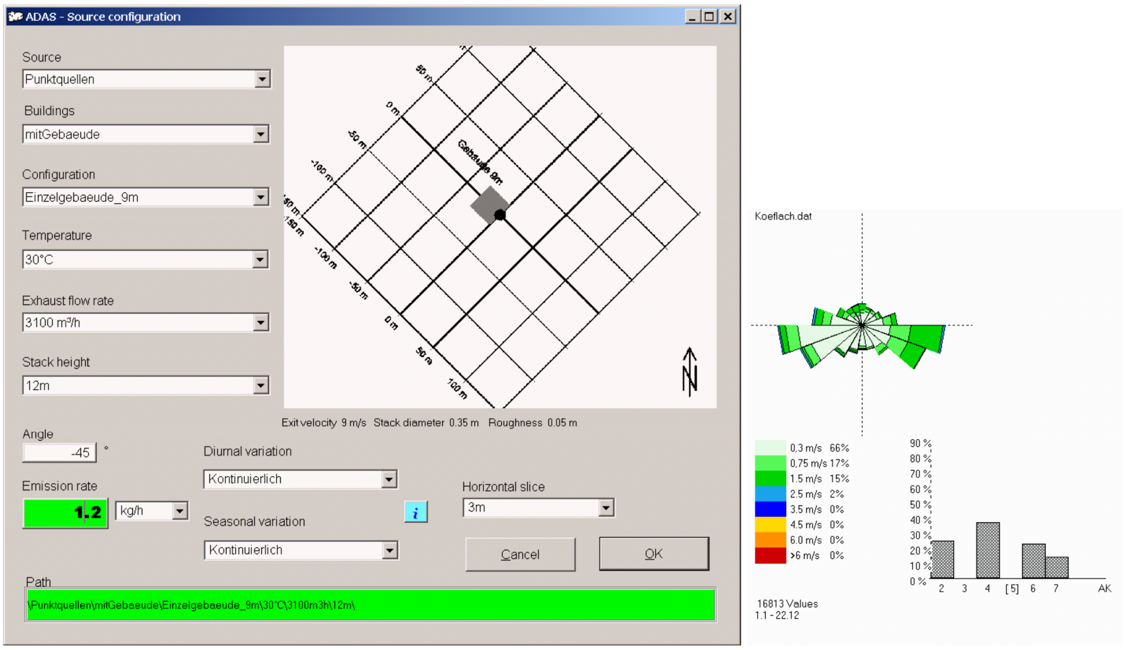


Figure 2. Comparison of mean modelled and observed concentrations for the field experiment in Uttenweiler (Germany)

As the computation times of GRAMM/GRAL are by far exceeding the time frame of a typical licensing procedure lasting typically just a few hours, the following method (ADAS = **A**ustrian **d**atabase for **a**ir quality assessment near small **s**ources) has been worked out: For predefined source configurations flow and dispersion simulations have been performed. 2-dimensional concentration fields have been stored in a library. A graphical user interface (GUI) has been developed to facilitate working with the library. All in all 18 different area sources, 3 different line sources, 6 different basement garages, and 7 different point sources have been computed. In the case of the point sources simulations have been made for a certain range of exit temperatures, exit velocities, and stack heights (all in all 136 variations). A fixed model domain of 300 x 300 m² and a horizontal resolution of 5 x 5 m² have been used. Meteorological input data has been classified in the following way:
Wind speed: 0.3, 0.75, 1.5, 2.5, 3.5, 4.5, 6.0, 8.0 m s^{-1}
Wind direction: 20 deg. Sectors: 2 (=20 deg.), 4, 6, 8, ……..,32, 34, 36
Stability classes: 2 (very convective), 3 (convective), 4 (neutral), 6 (stable), 7 (very stable)
This leads to 504 meteorological situations for which dispersion calculations for each source configuration have been made. Meteorological input data has to be provided as (half)-hourly time series of classified wind speed, -direction, and stability class over the period for which an average, a maximum, and a maximum daily mean concentration will be computed. The

computation for e.g. a one year period lasts usually about 60 seconds. If there are no meteorological data available, the ADAS only computes a maximum concentration. The whole method is very similar to the model ADIP, which is also a database for dispersion computations from exits of basement garages (Zenger and Rau, 2002).

Figure 3 depicts the GUI to select the source configuration and an example of meteorological data. Two results for different source configurations are shown in Figure . It should be noted that it is also possible to compute odour hours and to define daily and seasonal variations in emissions. In this way specific emission behaviour of e.g. a heating facility from a carpenter, which is operated only during daytime, can be handled.



ADAS - Source configuration

Source: Punktquellen

Buildings: mitGebaeude

Configuration: Einzelgebaeude_9m

Temperature: 30°C

Exhaust flow rate: 3100 m³/h

Stack height: 12m

Angle: -45 °

Emission rate: 1.2 kg/h

Diurnal variation: Kontinuierlich

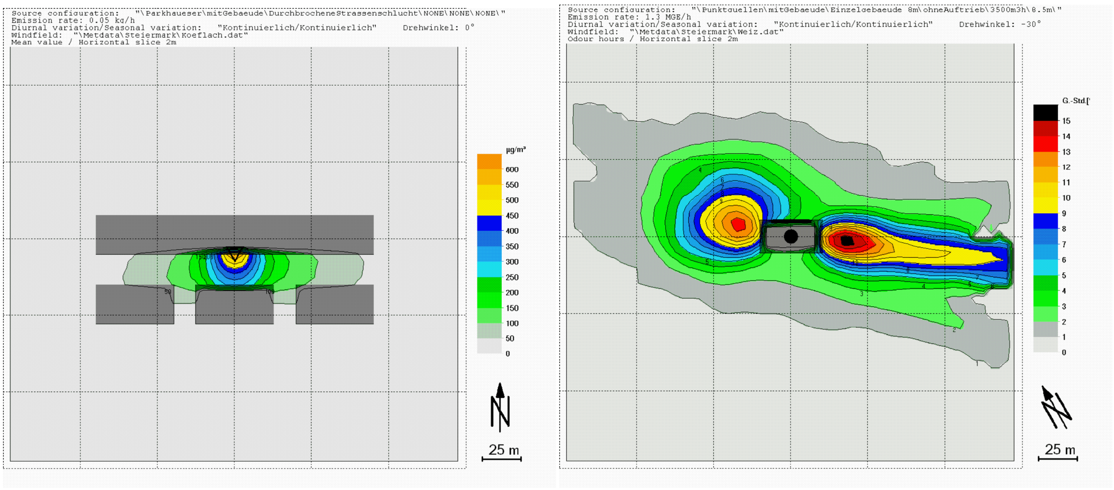
Seasonal variation: Kontinuierlich

Horizontal slice: 3m

Exit velocity 9 m/s Stack diameter 0.35 m Roughness 0.05 m

Path: \Punktquellen\mitGebaeude\Einzelgebaeude_9m\30°C\3100m3h\12m\

Figure 3. Left: Graphic user interface to select the source configuration; Right: Selected meteorology



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Source configuration:   "\Parkhaueser\mitGebaeude\DurchbrocheneStrassenschlucht\NONE\NONE\NONE\"
Emission rate: 0.05 kg/h
Diurnal variation/Seasonal variation:   "Kontinuierlich/Kontinuierlich"    Drehwinkel: 0°
Windfield:  "\Metdata\Steiermark\Koeflach.dat"
Mean value / Horizontal slice 2m
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```
Source configuration:   "\Punktquellen\mitGebaeude\Einzelgebaeude 8m\ohneAuftrieb\3500m3h\8.5m\"
Emission rate: 1.3 MGE/h
Diurnal variation/Seasonal variation:   "Kontinuierlich/Kontinuierlich"    Drehwinkel: -30°
Windfield:  "\Metdata\Steiermark\Weiz.dat"
Odour hours / Horizontal slice 2m
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Figure 4. Computed mean values for two different source configurations (left: Annual mean concentration [µg/m³] around an exit from a basement garage; right: Odour hours [%] computed for a point source with building downwash)

VALIDATION

Emphasis is laid on the validation of ADAS. While GRAL usually provides good results for the 26 data sets currently used for validation purposes, ADAS due to the limitations in selecting the correct source configuration has a larger uncertainty. Nine tracer experiments have been used to test ADAS:

Table 1. Brief description of the dispersion experiments used to test ADAS

Experiment	Description	References
Göttinger Road	Street canyons in Hannover, Stockholm, and Berlin.	Flassak (2008)
Hornsgatan Road		Moussiopoulos *et al.* (2004)
Frankfurter Allee		Moussiopoulos *et al.* (2004)
Uttenweiler	Pig stable, exit velocity : 5 m s^{-1} ; non-buoyant, low stack, neutral stratification, moderate – high wind speeds	Bächlin *et al.* (2002)
Roager	Pig stable, exit velocities : 5-25 m s^{-1} ; non-buoyant, stack heights: 6-11m, neutral stratification, moderate – high wind speeds	Ellerman and Løfstrøm (2002)
AGA	Gas compressor stacks, exit velocities 8-15 m s^{-1} ; exit temperatures >600 K; stack heights 10-24 m; mostly convective stratification; moderate – high wind speeds	U.S. EPA (2003)
CALTRANS99	4-lane highway without accompanying buildings; mostly low wind speeds; convective – stable stratifications	Benson (1984)
A2 Biedermannsdorf	4-lane highway with a noise abatement wall; moderate wind speeds, all stratifications; annual mean concentrations	Kalina *et al.* (2000)
Parking lot, Vienna	Small parking lot; moderate wind speeds, neutral stratification	Not published

Remarks regarding the validation:
In the case of the field experiments at a parking lot in Vienna, two different source configurations have been used in the simulations with ADAS. One configuration with an area source double the size of the real case and one configuration with half of the size. This has been done because it was found that concentrations at the border of the parking lot depend on the emissions density at the parking area. For comparison with observed data the average of both results has been taken.
For the point sources it is important to select exhaust flow rates as close as possible to the real flow rates in order to simulate the momentum correctly.

Table 2 lists the results of modelled vs. observed mean concentrations for all experiments. While the results for the Göttinger Road and the Hornsgatan Road are quite good, ADAS overestimates concentrations in the Frankfurter Allee by about 80 %. This might be reasoned with the width of the street canyon of 42 m, which is double as much as the best fitting configuration in ADAS. The overestimation in case of the A2 Biedermannsdorf can be expected, as the noise abatement wall probably leads to lower concentrations near the road compared with an undisturbed dispersion without such a barrier.

Table 2. Validation results with ADAS for average concentrations

Experiment	Observed [µg m^{-3}]	Modelled [µg/m^{-3}]
Göttinger Road	257	230
Hornsgatan Road	148	160
Frankfurter Allee	67	120
Uttenweiler (Exp. I-L)	8.5	8.4
Roager	73	71
AGA	116	107
CALTRANS99	208	167
A2 Biedermannsdorf	61	80
Parking lot, Vienna	1484	1144

HINTS FOR USERS

Although ADAS is rather easy to use, much knowledge is required for correct use. The following notes should be kept in mind:

- For those cases, where none of the source configurations provided by ADAS meet the real case, it might be useful to make simulations with several configurations to assess the impact on air quality.
- It is important to keep the selected exit flow rates for point sources close to the real ones to simulate the momentum of the plume correctly. The exit velocity is of minor importance.

- Caution is necessary in cases, where the roughness lengths deviate significantly from the ones used in ADAS. Note that the roughness length in ADAS is determined only for obstacles, which are not resolved. This is the reason, why rather low roughness lengths have been used. (E.g. parked cars on a parking lot correspond with a roughness length of about 0.05 m).
- Computed concentrations at the facades of buildings are quite uncertain due to the interpolation scheme applied before plotting the graphs. Concentrations should thus be assessed always a few metres in front of facades.
- A constant factor of four is applied to take odour fluctuations within one hour into account (C_{90}/mean = 4).

AVAILABILITY

ADAS will be made available via an ftp-Server. The download size is approx. 550 MB and it is free of charge. ADAS can be operated on any Windows PC. For more information please contact: dietmar.oettl@stmk.gv.at or visit the web-site: http://www.umwelt.steiermark.at/cms/ziel/2054533/DE/

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