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A comparison of separation distances against odour annoyance calculated with two models

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HIGHLIGHTS

- Austrian peak-to-mean algorithm is successfully applied to the Lagrange model LASAT.
- Atmospheric stability is deduced from ultrasonic anemometer measurements.
- Site-specific peak-to-mean ratios are obtained and discussed.
- Separation distances obtained with two models are compared and discussed.
- Use of factor 4 of a German guide line can give unrealistically large separation distances.

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ABSTRACT

Dispersion models are a common means to calculate separation distances around odour sources to protect the neighbourhood from odour nuisance. As the models usually calculate half-hourly or hourly averages of concentrations, they have to account somehow for the ability of the human nose to perceive odour within a single breath. For this purpose, the authors have developed and already published a peak-to-mean approach used with the Austrian Odour Dispersion Model (AODM), a Gaussian model adapted for the prediction of odour sensation. This approach is here used also with the Lagrangian particle diffusion model LASAT in a post-processing mode. Both models can now calculate direction-dependent separation distances for a prescribed combination of odour threshold and exceedence probability which are a function of the prevailing atmospheric stability conditions. This is demonstrated for a rural site in the Austrian flatlands east of Vienna. In addition, separation distances are also determined for an odour threshold of 0.25 (factor 4) of the German TA Luft (Technical Guideline for Clean Air) uniquely applied over all stability conditions and distances. The resulting separation distances and their implications when using these approaches with the two models are presented and discussed.

1. Introduction

Separation distances to protect the neighbourhood from odour annoyance can be obtained from dispersion models. Such models predict the ambient odour concentration on an hourly or half-hourly basis. This time series of concentration values allows a calculation of the percentage of the time in a year during which the threshold odour concentration will be exceeded. This can be compared to a tolerated exceedence probability depending on the land-use category. Usually, separation distances between an odour source and the nearby residential area are calculated depending on wind direction, e.g. in 10° increments. Combinations of threshold odour concentrations and tolerated exceedence probabilities are called odour impact criteria. An overview of various national odour impact criteria can be found in Sommer-Quabach et al. (2014).

Two pre-requisites are necessary to run this procedure: a transformation of the mean values calculated by the models to short-term concentrations relevant for human odour perception, and the appropriate meteorological input, i.e. representative wind and stability information for the site under investigation.

For Austria, to determine the short-term peak concentrations required for the assessment of odour perception, the authors developed a peak-to-mean approach depending on atmospheric stability; this algorithm is used in the Austrian Odour Dispersion

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Model (AODM), the regulatory Austrian Gauss model, and a description has been published already in Schauberger et al. (2000) and Piringer et al. (2007); in Piringer et al. (2014), the latest version is described in detail. With the German Lagrange model LASAT, a factor 4 is used independent of the distance from the source and the meteorological conditions (Janicke et al., 2004; Janicke Consulting, 2013). The discrepancy of the two concepts is discussed in Schauberger et al. (2012).

Gauss models are suited for pollutant emissions into stationary and uniform atmospheric flows. They are unable to allow for meteorological changes (direction, speed, atmospheric stability) within space and the time interval in which the concentration field is calculated so that a steady state for this period is assumed. It is accepted that over rougher surfaces these models can still be applied when clouds of pollutants disperse above the buildings or when the dimensions of the cloud are much bigger than the dimensions of the obstacles. A Lagrange dispersion model has a wider range of applicability than a Gauss model. In these models, the plume consists of individual plume parcels, and their paths are modelled on the basis of a random walk process. They need a complete mean and turbulent flow field as model input, which is usually delivered in form of 3D-gridded fields by either a diagnostic or prognostic model. Thus, shear as well as topographical effects can in principle be simulated.

The possibility to apply a Lagrange model like LASAT also in built-up areas or moderately orographic terrain stimulated the coupling of the peak-to-mean approach developed for AODM to LASAT, thus broadening the applicability of the approach. Technically, this was achieved by creating a post-processor for LASAT, in this way not changing the structure of the program code or the physics of the model.

Dispersion models need mainly wind and stability information as meteorological input data. Whereas the use of wind data, either based on measurements or from meteorological pre-processors, is often straightforward, on-site representative stability information is more difficult to obtain. An overview on methods to determine discrete stability classes can be found e.g. in Piringer et al. (2004; Section 4.6) and Piringer and Schauberger (2013). We use here stability information directly derived from three-axis ultrasonic anemometers. These instruments offer the advantage to determine atmospheric stability via only one parameter, namely the Obukhov length or its inverse, the Obukhov stability parameter. Details will be given in Section 2.2.

In this paper, the peak-to-mean approach developed for AODM is for the first time applied to the Lagrange particle diffusion model LASAT in a post-processing mode, and the resulting separation distances will be compared and discussed. The necessary stability information comes from conventional methods as well as three-axis ultrasonic anemometers. Section 2 presents a brief description of the models used, the derivation of atmospheric stability, and the model input data. The results are presented in Section 3, followed by a discussion in Section 4. Finally, Section 5 contains concluding remarks and a brief outline of intended future work.

2. Material and methods

2.1. The models

The Austrian odour dispersion model (AODM, Piringer et al., 2007, 2013; Schauberger et al., 2000, 2013, 2002) estimates mean ambient concentrations by the Austrian regulatory dispersion model (Österreichisches Normeninstitut, 1996; Kolb, 1981) and transforms these to instantaneous values depending on the stability of the atmosphere (Section 2.2). The model has been validated internationally with generally good results (Pechinger and Petz, 1995, 1997; Baumann-Stanzer and Piringer, 2011; Piringer and Baumann-Stanzer, 2009). The regulatory model is a Gaussian plume model applied for single stack emissions and distances from 100 m up to 15 km. Plume rise formulae used in the model are a combination of formulae suggested by Carson and Moses (1969) and Briggs (1975). The model uses a traditional discrete stability classification scheme with dispersion parameters developed by Reuter (1970).

The dispersion model LASAT (Janicke Consulting, 2013) simulates the dispersion and the transport of a representative sample of tracer particles utilizing a random walk process (Lagrangian simulation). It computes the transport of passive trace substances in the lower atmosphere (up to heights of about 2000 m) on a local and regional scale (up to distances of about 150 km). A number of physical processes, including time dependencies, are simulated, such as transport by the mean wind field, dispersion in the atmosphere, sedimentation of heavy aerosols, deposition on the ground (dry deposition), washout of trace substances by rain and wet deposition, first order chemical reactions. The quality of the results achievable by Lagrangian models mainly depends on the wind field they are based on. A simplified version of LASAT is offered free of charge (AUSTAL2000, http://www.austal2000.de) which is favoured by German guide lines (GOAA, 2008; TA-Luft, 2002). LASAT as well as AUSTAL2000 are usually run with the Klug-Manier stability scheme (TA-Luft, 2002). Like AODM, LASAT has been evaluated using test data sets for different applications (e.g. Hirtl et al., 2007; Hirtl and Baumann-Stanzer, 2007; Baumann-Stanzer et al., 2008; Piringer and Baumann-Stanzer, 2009; Schatzmann et al., 2010; Baumann-Stanzer et al., 2014). More references concerning LASAT model evaluation can be found at www.janicke.de.

2.2. Atmospheric stability and the peak-to-mean concept

The calculation of the peak-to-mean factors both for standard meteorological data as well as for ultrasonic anemometer data is described in detail in Piringer et al. (2007) and Piringer and Schauberger (2013); only the main features are repeated here. Both methods are applied here. When atmospheric stability is derived from three-axis ultrasonic anemometer measurements, stability classes are obtained without additional sensors or data. The estimate of atmospheric stability is obtained using the standard deviations of the three wind components and the Obukhov stability parameter (OSP, in m^{-1}). Depending on the stability scheme, different limit values are used for the attribution of OSP to a certain stability class. The scheme of Golder (1972) developed for Turner stability classes (the Reuter (1970) scheme is very similar to these) is used here for AODM (Table 1a); LASAT uses its own transformation scheme (Table 1b) based on the German Klug-Manier stability classes (TA Luft, 2002). The scheme of Golder (1972) provides OSP class limits and OSP calculation values for stability classes for roughness lengths between 0.01 and 0.5 m (Table 1a), whereas the LASAT scheme shows these values up to roughness lengths of 1.5 m (Table 1b).

Stability classes with the Reuter-Turner scheme are determined as a function of half-hourly mean wind speed and a combination of sun elevation angle, cloud base height and cloud cover; alternatively, the radiation balance (net radiation) or the vertical temperature gradient is used in combination with the mean wind speed. The details of the schemes are given in Section 4.6 of Piringer et al. (2004). In practice, within this scheme, stability classes 2 to 7 can occur in Central Europe. Stability classes 2 and 3 occur during daytime in a well-mixed boundary layer, class 3 allowing also for cases of high wind velocity and moderate cloud cover. Stability class 4 is representative for cloudy and/or windy conditions including precipitation or fog and can occur day and night. Stability classes 5