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Determining Separation Distances to Avoid Odour Annoyance With Two Models for a Site in Complex Terrain

Martin Piringer[a], Werner Knauder[a], Erwin Petz[a], Günther Schauberger[b]

[a]Central Institute for Meteorology and Geodynamics, Department of Environmental Meteorology, Hohe Warte 38, A 1190 Vienna, Austria
[b]WG Environmental Health, Department of Biomedical Sciences, University of Veterinary Medicine Vienna, Veterinärplatz 1, A-1210 Vienna, Austria
martin.piringer@zamg.ac.at

Direction-dependent separation distances to avoid odour annoyance, calculated with the Gaussian Austrian Odour Dispersion Model AODM and the Lagrange particle diffusion model LASAT for a site in complex terrain, will be analysed and compared. The relevant short-term peak odour concentrations are calculated with a stability-dependent peak-to-mean algorithm. For both models, the same emission and meteorological data, but model-specific atmospheric stability classes have been used. The estimate of atmospheric stability is obtained from three-axis ultrasonic anemometers using the standard deviations of the three wind components and the Obukhov stability parameter. 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 results are demonstrated for the Austrian village Weissbach in the narrow Saalach valley.

Meteorological data at this site are provided by a three-axis ultrasonic anemometer from which also stability information (Obukhov stability parameter, OSP) is directly deduced. Separation distances are determined for two odour impact criteria, namely exceedence probabilities of 3 and 8 %, each in combination with the odour threshold of 1 ou_E/m^3. The form of the separation distances around the fictitious odour source depends strongly on the prevailing meteorological conditions (wind and stability), on the odour impact criteria and on the peak-to-mean factors.

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. To account for the ability of the human nose to perceive odour within a single breath, 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 (Schauberger *et al.*, 2000; Piringer *et al.*, 2007; Piringer *et al.*, 2014). This approach is here used also with the Lagrangian particle diffusion model LASAT in a post-processing mode as described in Piringer *et al.* (2015). Both models can now calculate direction-dependent separation distances for a prescribed combination of odour threshold and exceedance probability which are a function of the prevailing atmospheric stability conditions. This is demonstrated for a site in complex terrain.

2. Material and methods

The Austrian odour dispersion model (AODM, Piringer *et al.*, 2007; Piringer *et al.*, 2013; Schauberger *et al.*, 2000; Schauberger *et al.*, 2013; Schauberger *et al.*, 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 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). LASAT as well as AUSTAL2000 are usually run with the Klug-Manier stability scheme (TA Luft, 2002).

The peak-to-mean approach used to transform the half-hourly model concentrations into short-term peak values as well as the scheme to transform the Obukhov stability parameter OSP [m^{-1}] to atmospheric stability classes depending on the local roughness length z_0 [m] are described in full detail in Piringer et al. (2014).

The Obukhov stability parameter and the standard deviations of the three wind components are derived from a one-year time series of ultrasonic anemometer measurements. Sonic anemometers measure the along-path velocity components from the travel time of acoustic waves between transducers separated about 10-20 cm. In addition to the three-dimensional wind vector, the sound velocity is derived, from which the so-called “sonic temperature” is calculated. The measurement of sonic temperature fluctuations is necessary to calculate the sensible heat flux. Other quantities which are derived from sonic measurements are the means, standard deviations, and co-variances of the wind components and the momentum flux, the Obukhov stability parameter, and the friction velocity. Sonic anemometers usually sample at 10 Hz, and the data are usually stored as averages over 10 minutes or half an hour.

The investigation has been carried out for Weissbach near Lofer (12.789 E, 47.498 N, at 678 m asl.), situated in the Saalach valley in the county of Salzburg which at the site stretches from SE to NW. The valley with approx. only 1 km in width is relatively narrow, flanked by steep slopes of heights of several hundred meters.

For all model runs, the same source data are used (Piringer *et al.,* 2015).

Besides using the peak-to-mean algorithm, 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.

3. Results

3.1 Meteorological conditions

Due to the topographical situation at Weissbach, the wind is channelled along the valley axis. Up-valley flow is from NW, down-valley flow from SE (Fig. 1). The down-valley flow from SE shows a larger fraction of weaker winds, but also a slightly larger amount of stronger winds than the up-valley flow. The strong southerly winds might also be associated with Foehn events.

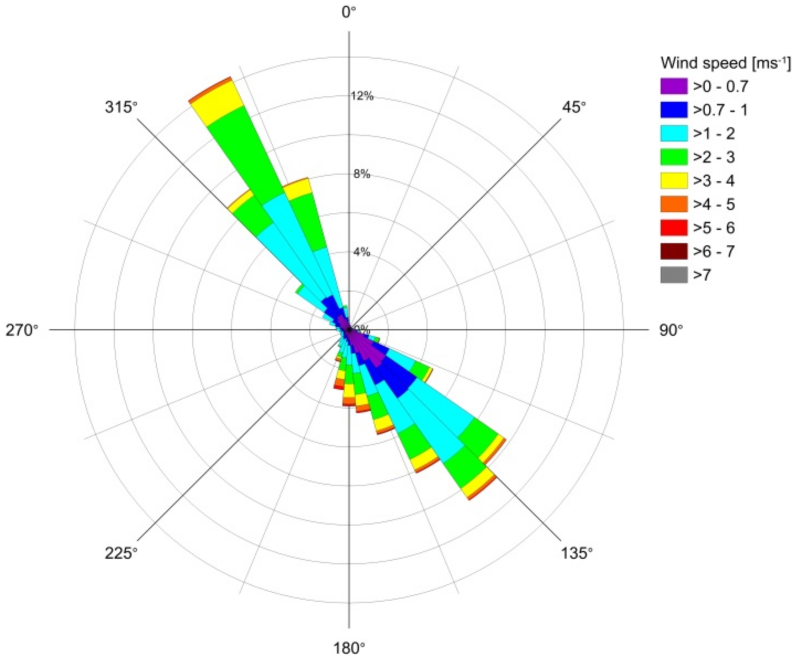

Figure 1: Wind rose for Weissbach (01.09.2010 – 31.08.2011); colour coding denotes wind speed

The frequency of stability classes is determined from the OSP with a roughness length and 0.5 m in Weissbach. From Fig. 2, the frequency distribution is roughly 30:30:40 for unstable-neutral-stable conditions. The LASAT scheme calculates slightly more stable and less unstable conditions. Neutral conditions are more frequent with the LASAT scheme. Class 5 has no appropriate counterpart in the LASAT scheme.

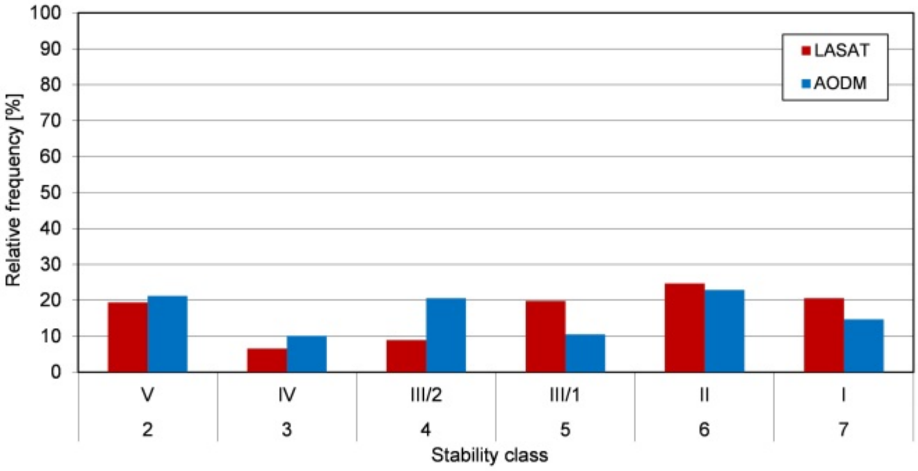

Figure 2: Relative frequency [%] of stability classes at Weissbach

3.2 Attenuation curves

Site-specific attenuation curves for each stability class obtained from the ultrasonic anemometer measurements are presented in Fig. 3. The peak-to-mean ratios depend on the models because they use different stability classification schemes. Unstable classes are most relevant at Weissbach, for both models, the peak-to-mean ratios starting at high values near the source and approaching 1 at about 200 m. All in all, the AODM and LASAT curves in Fig. 3 do not differ much.

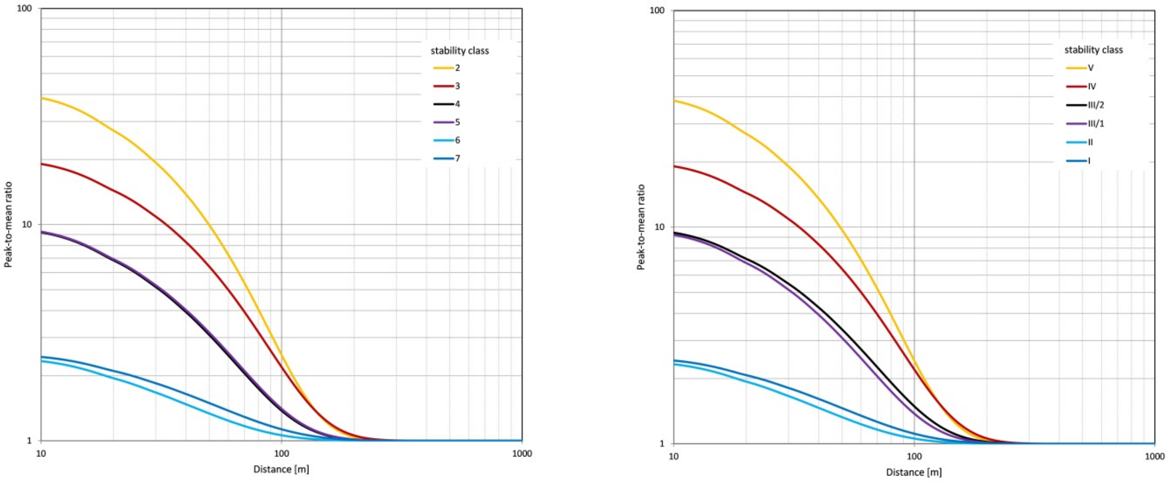

Figure 3: Peak-to-mean ratios for Weissbach derived from ultrasonic anemometer data (OSP) using the conversion to stability classes for AODM (left) and for LASAT (right)

3.3 Separation distances

Direction-dependent separation distances are calculated for two odour impact criteria used in Austria: 1 OU_E/m^3 and 3 % exceedance probability, representative for recreation areas (high odour protection), 1 OU_E/m^3 and 8 % exceedance probability, representative for residential areas mixed with commercial activity (lower odour protection). The separation distances are shown as isolines in Fig. 4, encompassing the area of exceedance of the given thresholds. The larger the area, the more unfavourable is the odour impact criterion. AODM results (left) are compared to LASAT results (right) for the same scenario.

The shape of the separation distances is strongly influenced by the wind directions in Weissbach (Fig. 1) and by atmospheric stability (Fig. 2). The peak-to-mean ratios play a minor role, as they approach 1 after 200 to 300 m (Fig. 3). An elongation along the valley axis is observed which is due to the valley wind system. Using AODM, maximum separation distances for an exceedance probability of 3 % are about 600 m towards NW and about 500 m towards SE; with 8 %, these distances are about 300 m in both directions (Fig. 6, left). The calculation with LASAT leads to a considerable increase of separation distances for an exceedance probability of 3 % (Fig. 6, right) compared to AODM. For 8 %, however, maximum separation distances calculated with LASAT only slightly increase to about 400 m in both directions, compared to the AODM results.

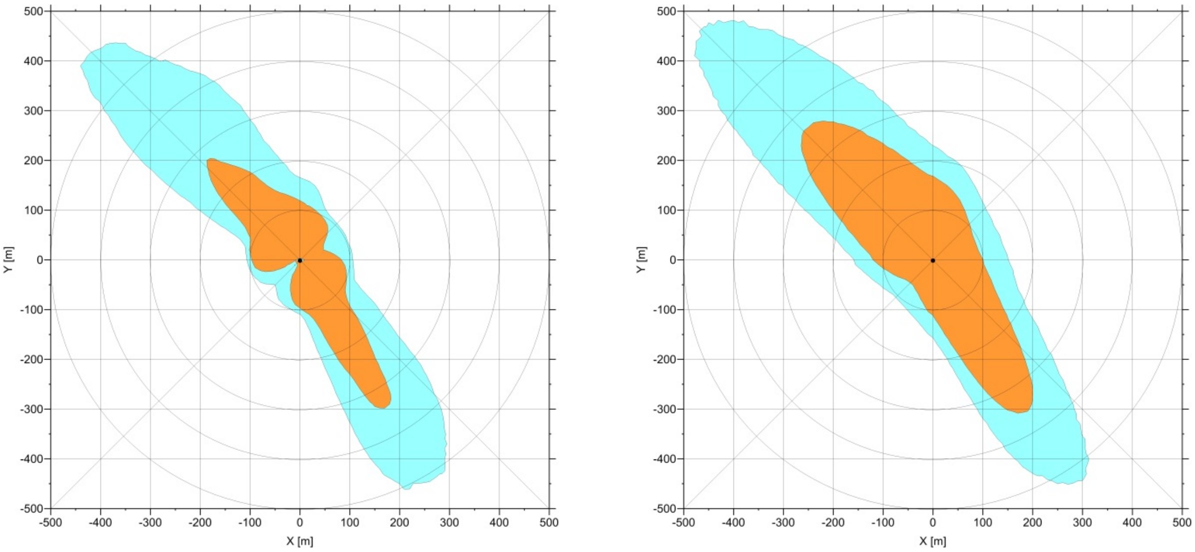

Figure 4: Direction-dependent separation distances [m] with (left) AODM and (right) LASAT for 1 OU_E/m^3 and 3 % (blue) and 8 % (orange) exceedence probability with peak-to-mean ratios derived from ultrasonic anemometer measurements at Weissbach

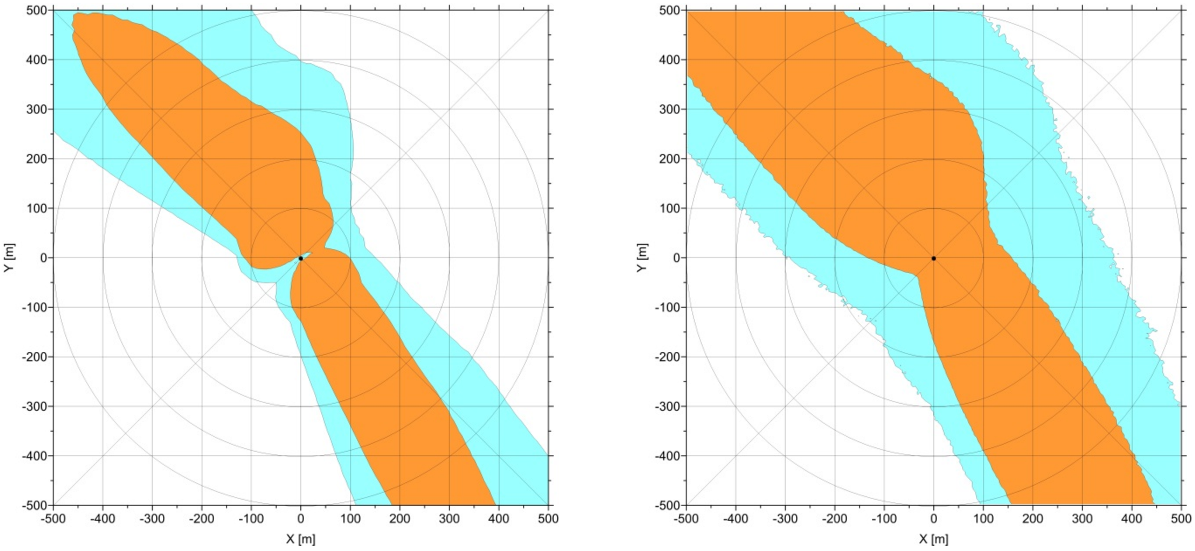

Figure 5: Direction-dependent separation distances [m] with (left) AODM and (right) LASAT for 1 OU_E/m^3 and 3 % (blue) and 8 % (orange) exceedence probability with the factor 4 of the German TA Luft (2002) for Weissbach

Using a constant factor 4 over all stability conditions and distances in combination with OSP-derived stability classes results in by far the largest separation distances for both models (Fig. 5). This is clearly a result of this factor dominating over the peak-to-mean ratios derived from ultrasonic anemometer measurements at distances over 100 m (Fig. 3). Along-valley maximum separation distances are well outside the area displayed, with the exception of the downvalley direction and 8 % exceedance probability for AODM (Fig. 5, left). Again, separation distances with LASAT are larger and comprise a bigger area than those with AODM. This is due to the fact that the stability classification scheme used with LASAT comprises more stable cases than that with AODM (Fig. 2). The largest separation distances are calculated for stable dispersion categories.
The along-valley wind directions at Weissbach are often associated with stable conditions. The channelling of the flow in combination with frequent stable conditions causes high odour concentrations and leads to enhanced separation distances at Weissbach compared to a flatland site. This enhanced frequency apparently compensates for the peak-to-mean ratios which are not relevant at Weissbach for large separation distances. While the separation distances for the peak-to-mean ratios in Fig. 3 with up to several hundred meters are within a plausible range (Fig. 4), this is certainly not the case for the large separation distances in Fig. 5 (see also the discussion in Piringer *et al*., 2015).

4. Conclusions

In this paper, direction-dependent separation distances to protect the neighbourhood from odour nuisance have been calculated with two models, the Gaussian Austrian Odour Dispersion Model AODM and the Lagrange particle diffusion model LASAT. Short-term peak odour concentrations have been calculated either with the stability-dependent peak-to-mean algorithm developed with AODM (Piringer *et al.*, 2014) or with the factor 4 – approach used with LASAT in Germany (TA Luft, 2002). The same emission and meteorological data have been used, but atmospheric stability is determined from different stability schemes used with the models. Differences in the resulting separation distances are then both due to the different peak-to-mean concepts and to the different atmospheric stability schemes. The results are demonstrated for Weissbach near Lofer, a rural site in the narrow Saalach valley in the county of Salzburg.
On-site meteorological conditions are presented in Figs. 1 and 2. The wind is channelled along the valley axis. The down-valley flow from SE shows a larger fraction of weaker winds, but also a slightly larger amount of stronger winds than the up-valley flow. The strong southerly winds might also be associated with Foehn events. The frequency distribution of stability classes is roughly 30:30:40 for unstable-neutral-stable conditions. The LASAT scheme calculates slightly more stable and less unstable conditions than the scheme used with AODM. Neutral conditions are more frequent with the LASAT scheme.
The maximum of the separation distances occurs in all cases along the main valley axis. Applying the factor 4 gives by far the largest separation distances, because this factor dominates over the peak-to-mean ratios deduced from ultrasonic anemometer data from about 100 m onwards. LASAT calculates larger separation distances than AODM. This is attributed to the fact that the Klug-Manier scheme used with LASAT shows a tendency to deliver more stable cases than the Reuter scheme used with AODM. Probably more important, LASAT, in contrast to the stationary concentration fields of AODM, calculates concentrations as long as the trajectories stay within the model domain, thus likely increasing residence times and also separation distances.

Acknowledgement

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