An operationally applicable tool for sound immission evaluation including the atmospheric excess attenuation of sound

Astrid Ziemann, Kati Balogh, Andreas Pittelkau, Klaus Arnold, Armin Raabe
Universität Leipzig, Institut für Meteorologie, D-04103 Leipzig, Germany, Email: ziemann@uni-leipzig.de

Introduction

The enhancement of methods to forecast the sound immission including atmospheric effects is an important task of the environmental protection near inhabited areas. A multiplicity of guidelines to determine a limited emission and immission of noise exists in Germany (and also in other European countries). Thereby, the calculation of outdoor sound propagation results from DIN ISO 9613-2 [1]. During such calculations the atmospheric influence plays, apart from sound absorption, only a secondary role. On the other hand models and measurements of sound propagation show deviations from the sound forecasts by the guideline. One important reason for this discrepancy is the coupled influence of vertical profiles of temperature and wind vector as well as surface properties on the sound propagation. Because of the variable coaction between vertical gradients of air temperature, wind velocity and wind direction no general statements are possible. In fact a greater number of atmospheric situations has to be investigated to estimate the atmospheric influence on sound immission around a sound source. Such investigations can only be executed using an effect-adjusted sound model with small computational requirements.

Sound propagation model SMART

In the presented study the two-dimensional sound-ray model SMART (Sound propagation model of the atmosphere using ray-tracing; [2]) is applied for this purpose. Outgoing from a sound source the way of sound rays is calculated by the model. In contrast to the common use of a refraction law for the normal of the sound wave we apply a generalized refraction law specially developed for the sound ray refraction because the directions of the normal and the sound ray itself are different in stratified moving media [3].

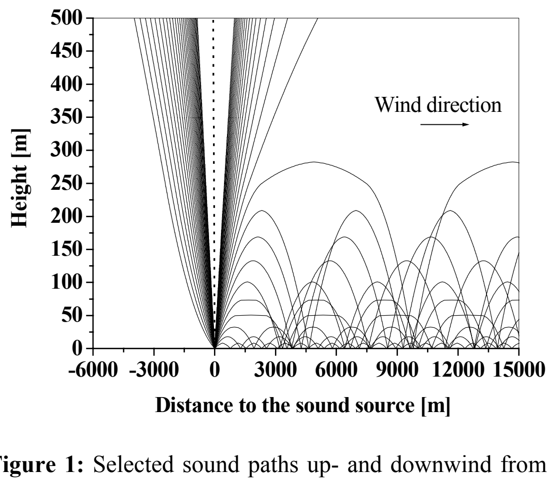

Figure 1: Selected sound paths up- and downwind from a sound source during an atmospheric situation with vertically increasing temperature and wind velocity.

During an atmospheric situation with a temperature inversion the sound signals could be detected in great distances from the sound source because of the refraction of sound rays back to the earth's surface. Especially in the downwind direction higher sound immissions must be expected. This increasing noise effect caused by positive temperature gradients is reversed in the case of a strong wind influence on the sound propagation. In that case a shadow zone occurs in the upwind direction of the sound source (see Figure 1).

The simulated sound rays could now be used to calculate an excess attenuation caused by the atmospheric refraction and sound-ray reflection at the surface [2, 3].

The change of the sound intensity level (attenuation level) at the height of noise immission is only dependent on the relation between the cross sections of the sound tube in a reference distance (here 1 m) and in another distance from the sound source [4]. This is the reason why the calculation of the excess attenuation can be carried out only using geometrical quantities from the ray tracing.

Sound immission forecast with MetaVIS

Classification of meteorological situations

The atmospheric situations were divided into different classes to calculate the sound propagation for a great number of vertical profiles of temperature and wind vector. As a result of sensitivity investigations different intervals for the gradients of meteorological quantities were specified with 7 classes for temperature, 13 classes for the wind velocity and 24 classes for the wind direction. By a convenient combination of temperature and wind profiles 1551 so-called profile classes result which should cover the spectrum of possible atmospheric states.

Program flow of MetaVIS

The operationally applicable visualization software MetaVIS (Meteorological attenuation VISualization) is operating-system independent and based on a data base of atmospheric excess attenuation maps calculated for the 1551 meteorological profile classes using the model SMART.

Input data

To determine a sound immission forecast by MetaVIS the vertical profiles of meteorological quantities air temperature, wind velocity and direction are necessary. These data can be imported into the software from an external file. Additionally it is possible to manually insert the data using an input mask. The actual profiles are now classified according to the given profile classes.

Output data

The tool MetaVIS works now with a data base of atmospheric excess attenuation maps in a range of 15 km around the sound source outgoing from the 1551 meteorological profile classes. As a result the influence of the refracting atmosphere on the sound immission ('sonic weather') can be evaluated.

The main window of MetaVIS visualizes the vertical profiles of temperature and wind vector as well as the atmospheric excess attenuation (see Figure 2).

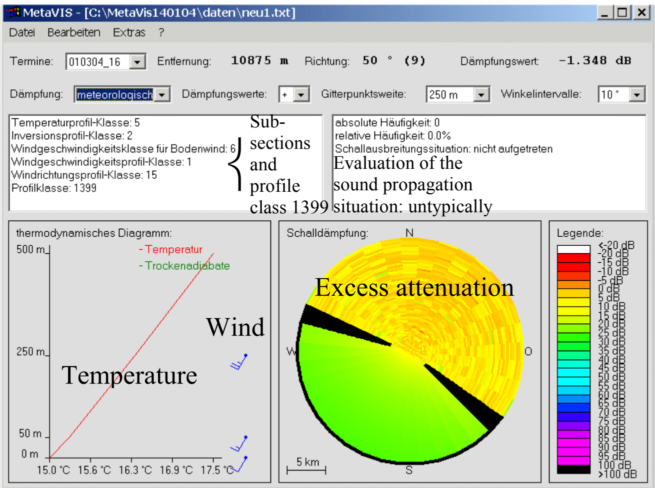

Figure 2: Main window of the visualization software MetaVIS: vertical profiles of temperature (red line) and wind vector (blue wind arrows) and atmospheric excess attenuation [dB] around a sound source up to a distance of 15 km. Red colours symbolize an additional immission of sound in comparison to a sound propagation without atmospheric and surface's influence.

In the downwind region the sound immission is increased because of refracted sound rays moving back to the earth's surface (see Figure 1). As expected the positive temperature gradient results in increasing noise impact in comparison to the undisturbed sound propagation in this area.

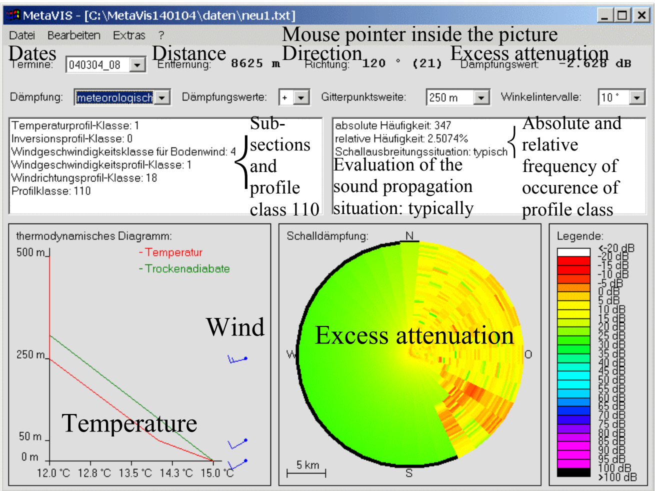

Figure 3: Same as Figure 2, but another profile.

Compared with this the sound immission forecast is changed and complicated if a turning wind vector with height is studied (see Figure 3). Even for the (surface) crosswind direction an increasing sound immission results with a near-surface decreasing temperature and a constant temperature in higher levels.

Evaluation of 'sound weather'

The validation of the actual ‚sonic weather' arises from a 'climatology' according to the occurred meteorological profiles for the area under investigation. In the presented study such a climatology was prepared for Meppen situated in the north-western part of Germany. The relative frequency of occurrence of the 1551 meteorological profile classes was calculated for radiosonde measurements over 30 years (1973-2002). Typical profiles are defined if the added up relative frequency of all profile classes (descending sorted by their frequency) reaches 75%. So the profile class 1399 (Figure 2) is untypical and the class 110 (Figure 2) is typical for the location Meppen. Furthermore, statistical investigations of meteorological data of different locations result in regionally variable evaluation of 'sound weather' (here not shown).

Summary and conclusions

The operationally applicable tool MetaVIS to estimate the additional sound immission including the atmospheric effects was presented. This method can be applied to forecast and evaluate the actual 'sonic weather' in comparison to an undisturbed sound propagation and using a 'climatology' of meteorological profile classes.

The results show the important influence of temperature, wind velocity and direction profiles on the outdoor sound propagation. Because of the coupled effects and a great variability of temperature and wind gradients no general statements to the sound immission forecast are possible. Rather the actual situation must be investigated using MetaVIS to estimate the atmospheric influence on noise impact. So this tool could be very useful for applications in advisory service and for the preparation of expert's opinions.

References

[1] DIN ISO 9613-2, 1999-10, Dämpfung des Schalls bei der Ausbreitung im Freien, Beuth, 1999 (in German)

[2] Ziemann, A.: Zum Einfluss vertikaler Gradienten meteorologischer Größen auf die Laufzeit von akustischen Signalen zwischen Schallquellen und Schallempfängern in der bodennahen Atmosphäre. Wiss. Mitt. Inst. für Meteorol. Univ. Leipzig **26** (2002), 31-42 (in German)

[3] Ostashev, V.E., Hohenwarter, D., Attenborough, K., Blanc-Benon, Ph., Juvé, D. und Goedecke, G.H.: On the refraction law for a sound ray in a moving medium. Acustica **87** (2001), 303-306

[4] Ziemann, A.: Auswirkungen unterschiedlicher Schall-ausbreitungsmodelle auf die Lärmprognose. Wiss. Mitt. Inst. für Meteorol. Univ. Leipzig **30** (2003), 61-72 (in German)

[5] Brekhovskikh, L.M. und Godin, O.A.: Acoustics of layered media II. Point sources and bounded beams. Springer Series on wave phenomena, Volume 13, Springer, Berlin, 1992