Urban Physics

7S0X0, 2020-2021 Quartile 3

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EINDHOVEN UNIVERSITY OF TECHNOLOGY

www.tue.nl/buildingacoustics

Urban Acoustics

Week 4 Effects on noise propagation

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Assignment Urban Acoustics

http://www.fss.nl/portfolio-item/gemeente-eindhoven/

Assignment Urban Acoustics

1) Analysis of the use of the outdoor space

2) Analysis of the sources in the outdoor space

3) Analysis of the aspects that influence the acoustics of the outdoor space

4) Measurement and analysis of the noise level in the space

5) How to improve this space from an urban acoustics point of view?

Assignment Urban Acoustics

Course week 4: Selection of urban space

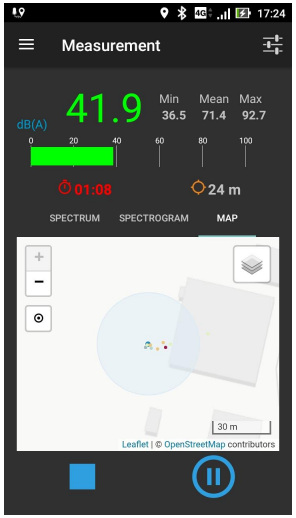
Course week 5: Visit of space and measurement

Course week 6: Design of noise reducing measures in the area

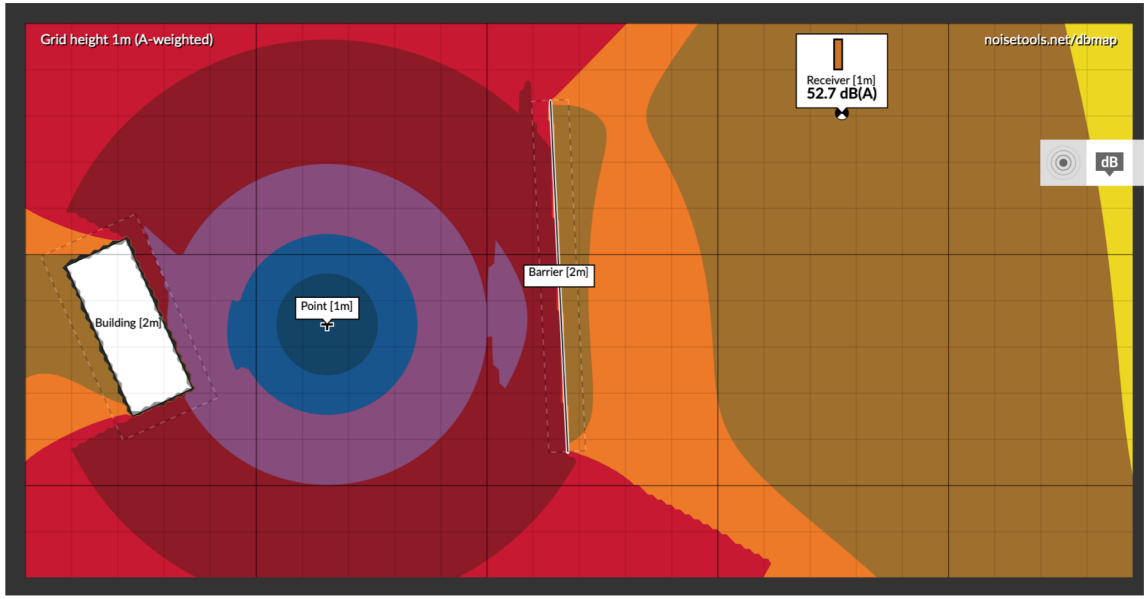
Course week 7: Writing of report, preparation of presentation

Assignment Urban Acoustics

NoiseCapture app



Calculation software

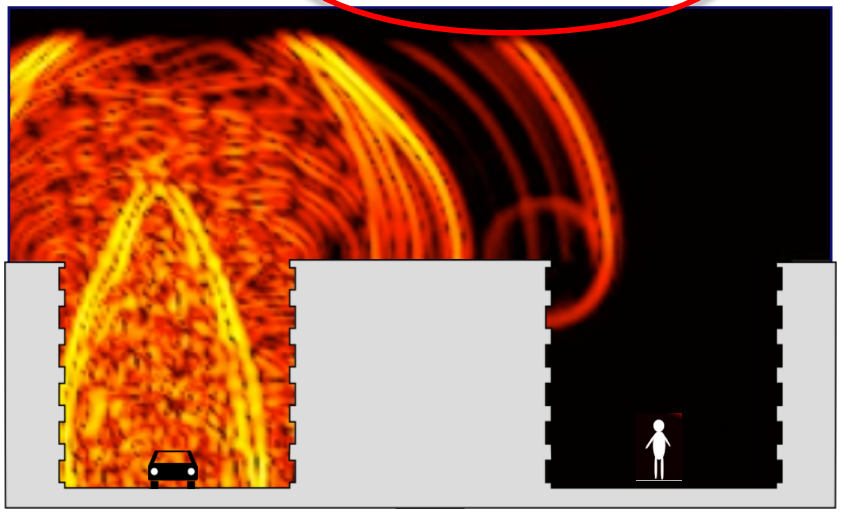


Overview Urban Acoustics

Physics/Mech.Engineering

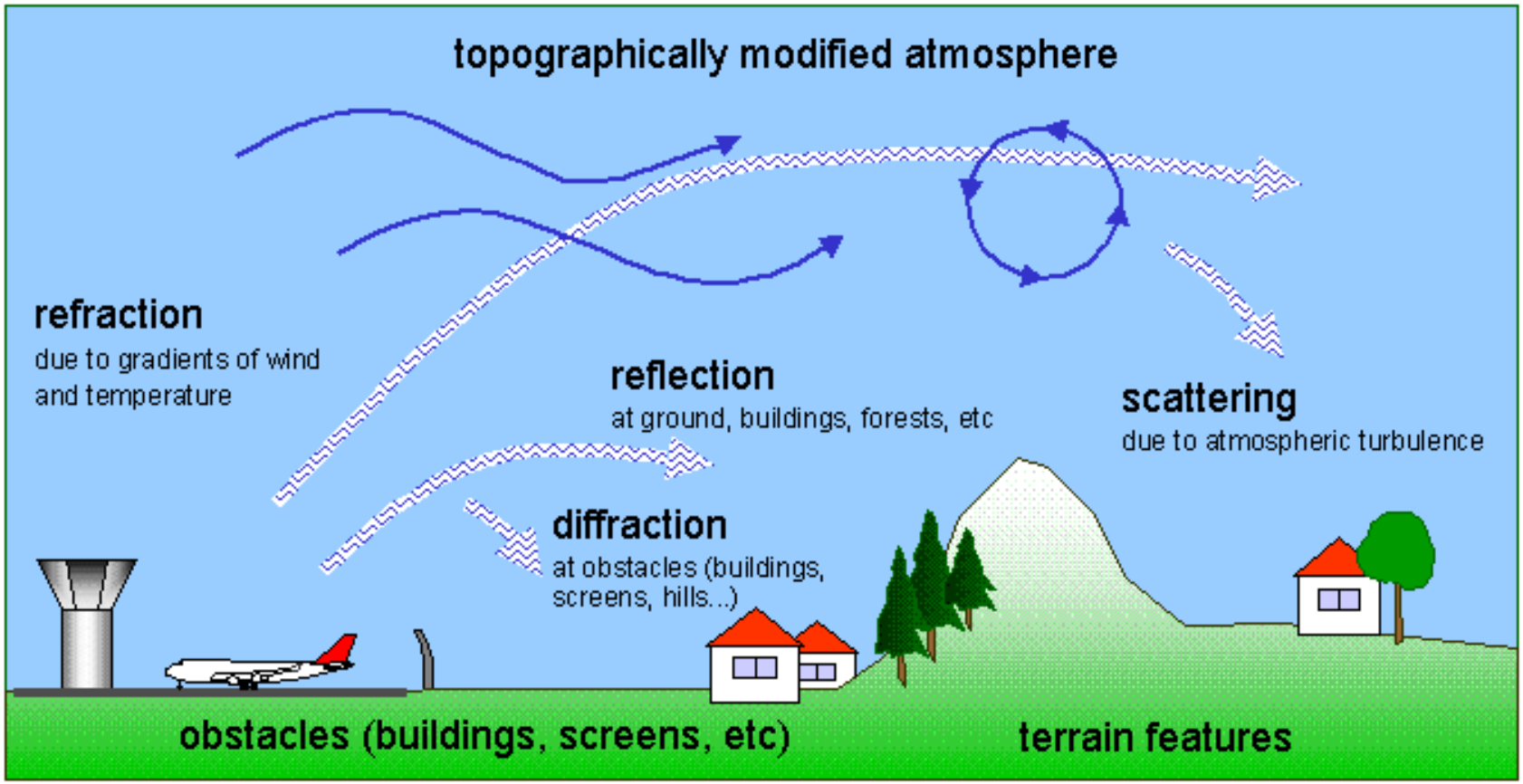
Built Environment

IE&IS / psychology



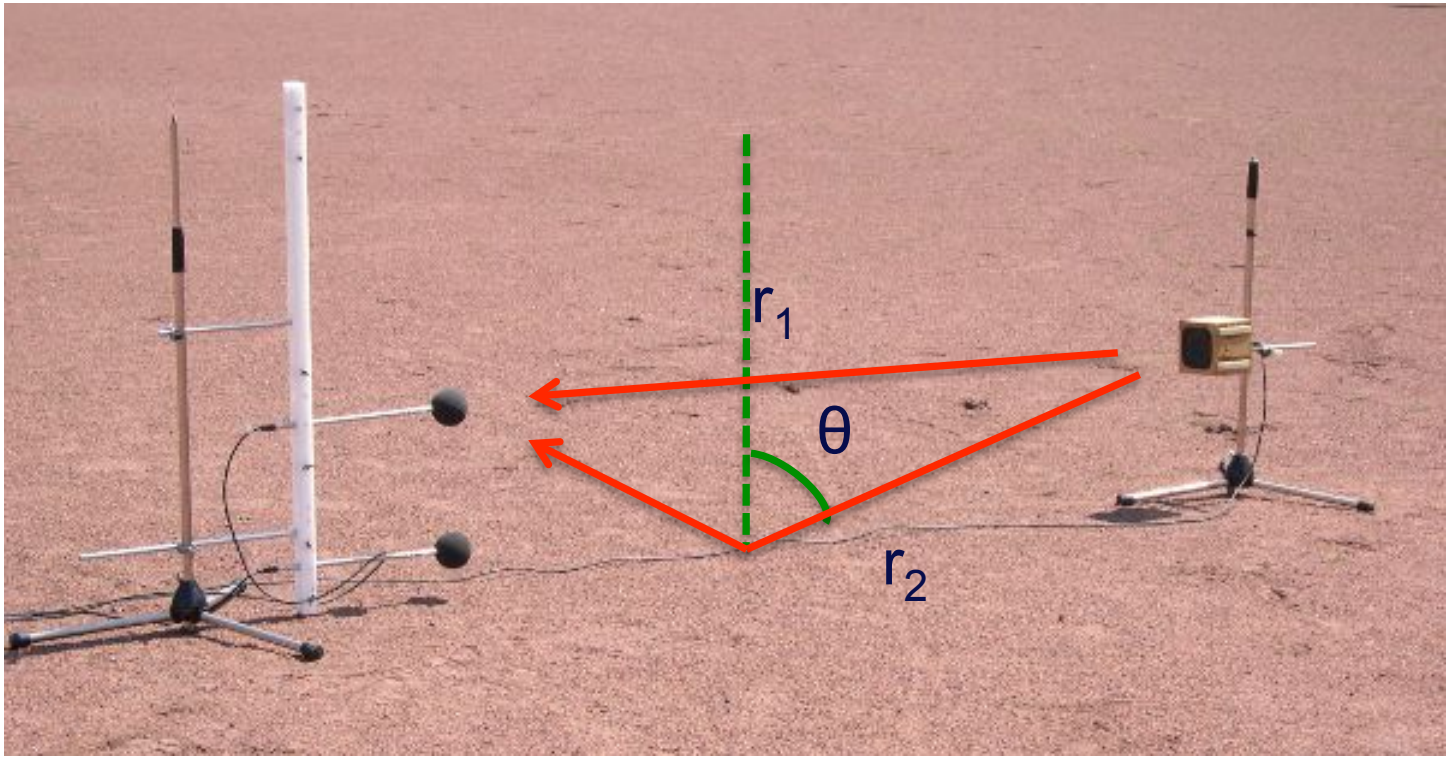
Overview Urban Acoustics

- Ground effect
- Meteorological effects
- Screening
- Urban effects



http://www.pa.op.dlr.de/acoustics/index.html

Ground effect



http://www.akustik.uni-oldenburg.de

$$p = S\frac{\cos(kr_1)}{r_1} + SR\frac{\cos(kr_2)}{r_2}$$

S = source strength
k = 2 π f / c = wavenumber
R = reflection factor

http://www.pa.op.dlr.de/acoustics/index.html

Ground effect

- Surface impedance Z_n: a measure of opposition to motion of a medium subjected to acoustic pressure (force). Depends on
  - Frequency
  - Material properties (as flow resistivity σ)
  - Thickness of the material

- Reflection factor *R*: amplitude and phase change of waves

$$R(f,\theta) = \frac{Z_n(f)\cos(\theta) - \cos(\theta')}{Z_n(f)\cos(\theta) + \cos(\theta')}$$

with

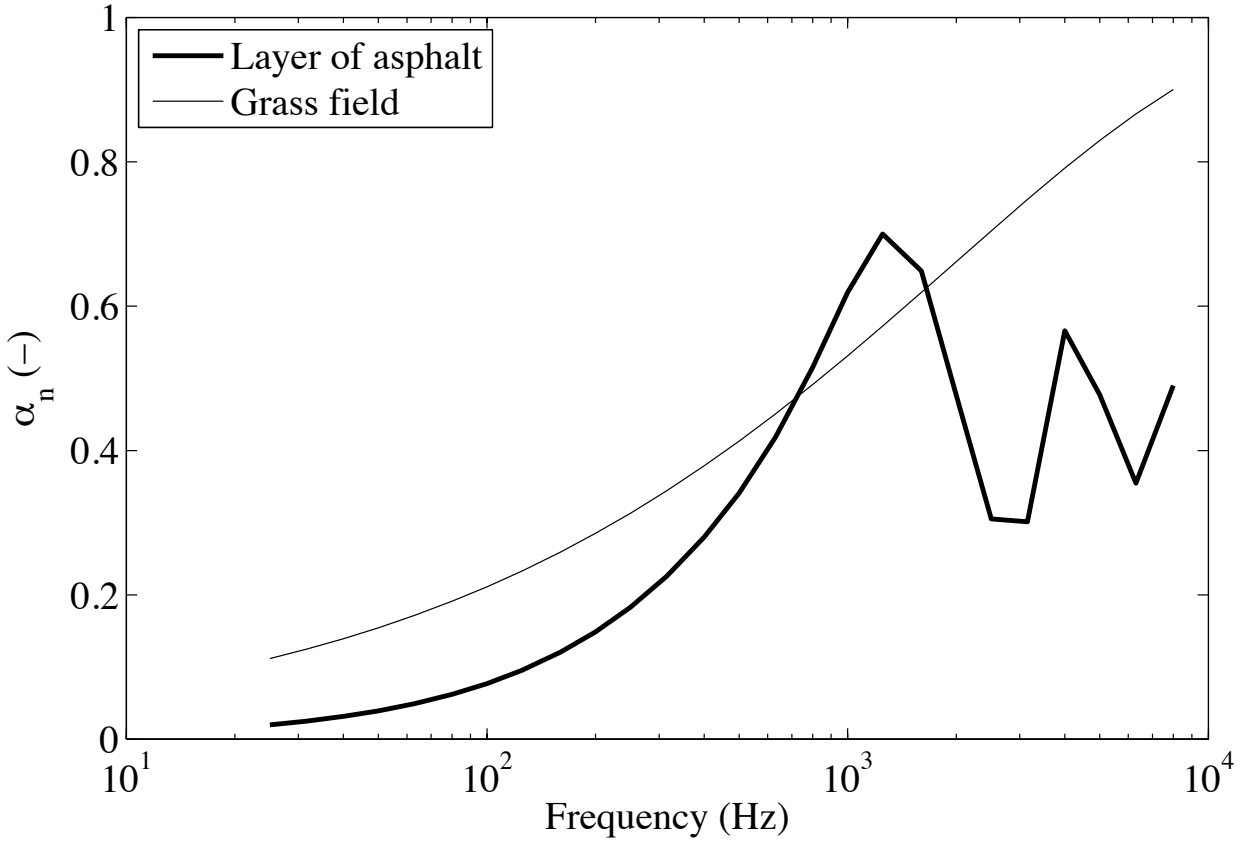
θ' = propagation angle in second medium

- Absorption coefficient

$$\alpha(f,\theta) = 1 - \left|R(f,\theta)\right|^2$$

Ground effect

- Results typical for outdoor porous surfaces



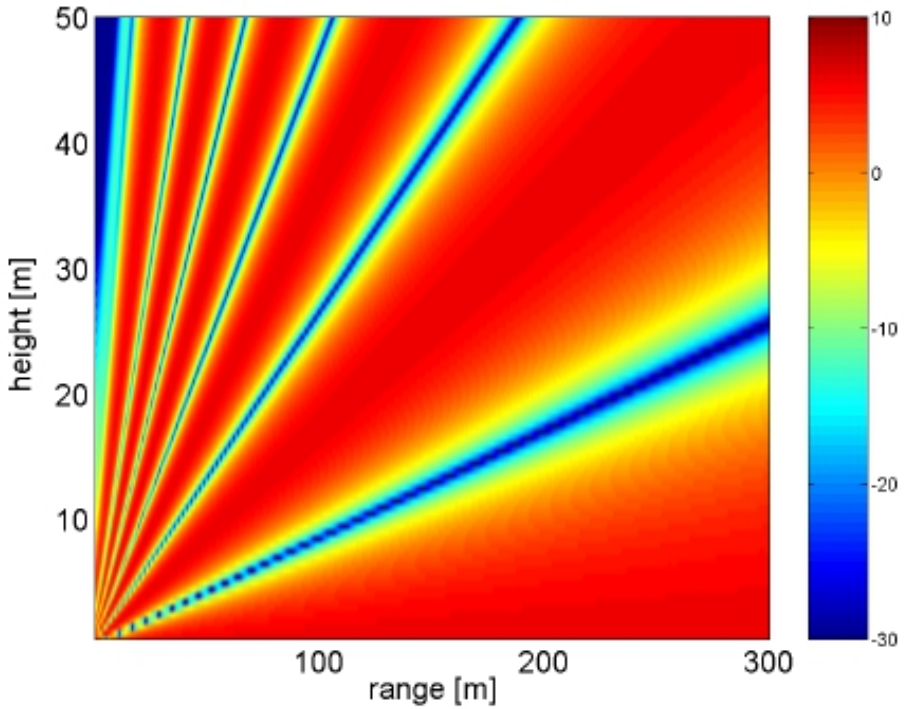
Calculation according to slit-pore model, Attenborough et al., J. Acoust. Soc. Am., **129**, 2806–2819

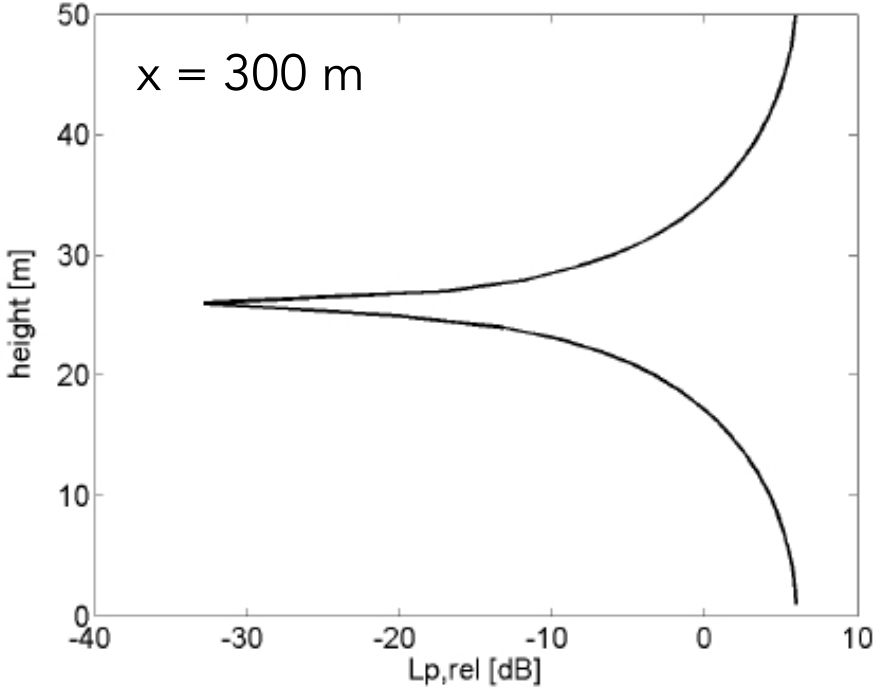
Ground effect

f = 500 Hz

z_{source} = 2 m

$$\sigma = \infty \ (Z_n = \infty)$$





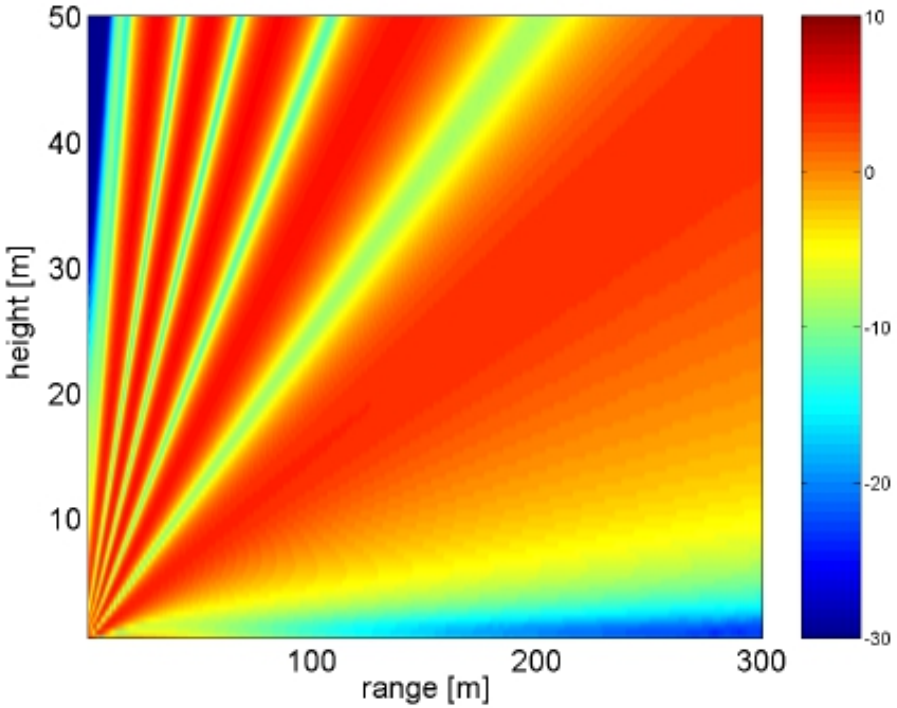
Hornikx, M. Modelling urban sound propagation in a moving medium. (2004). Master's *Thesis report 04.16.A, TU/e, The Netherlands.*

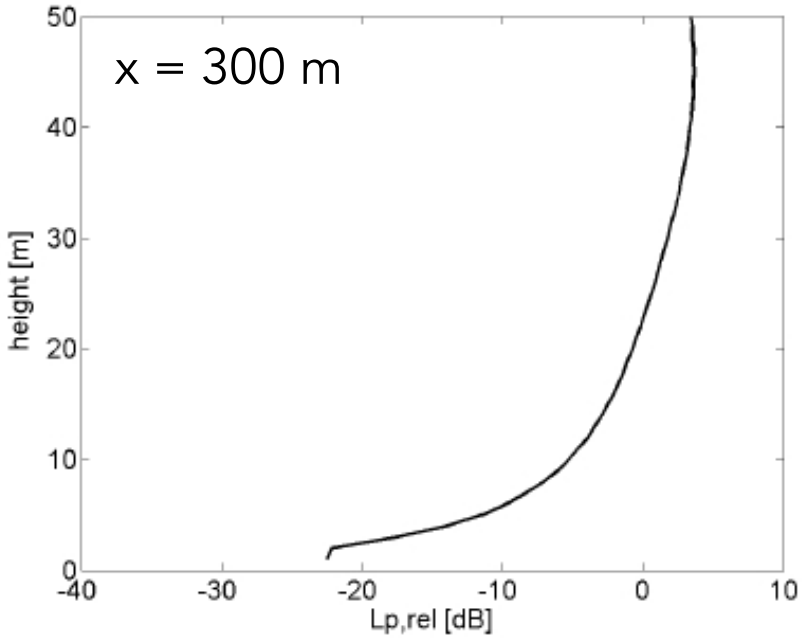
Ground effect

f = 500 Hz

z_{source} = 2 m

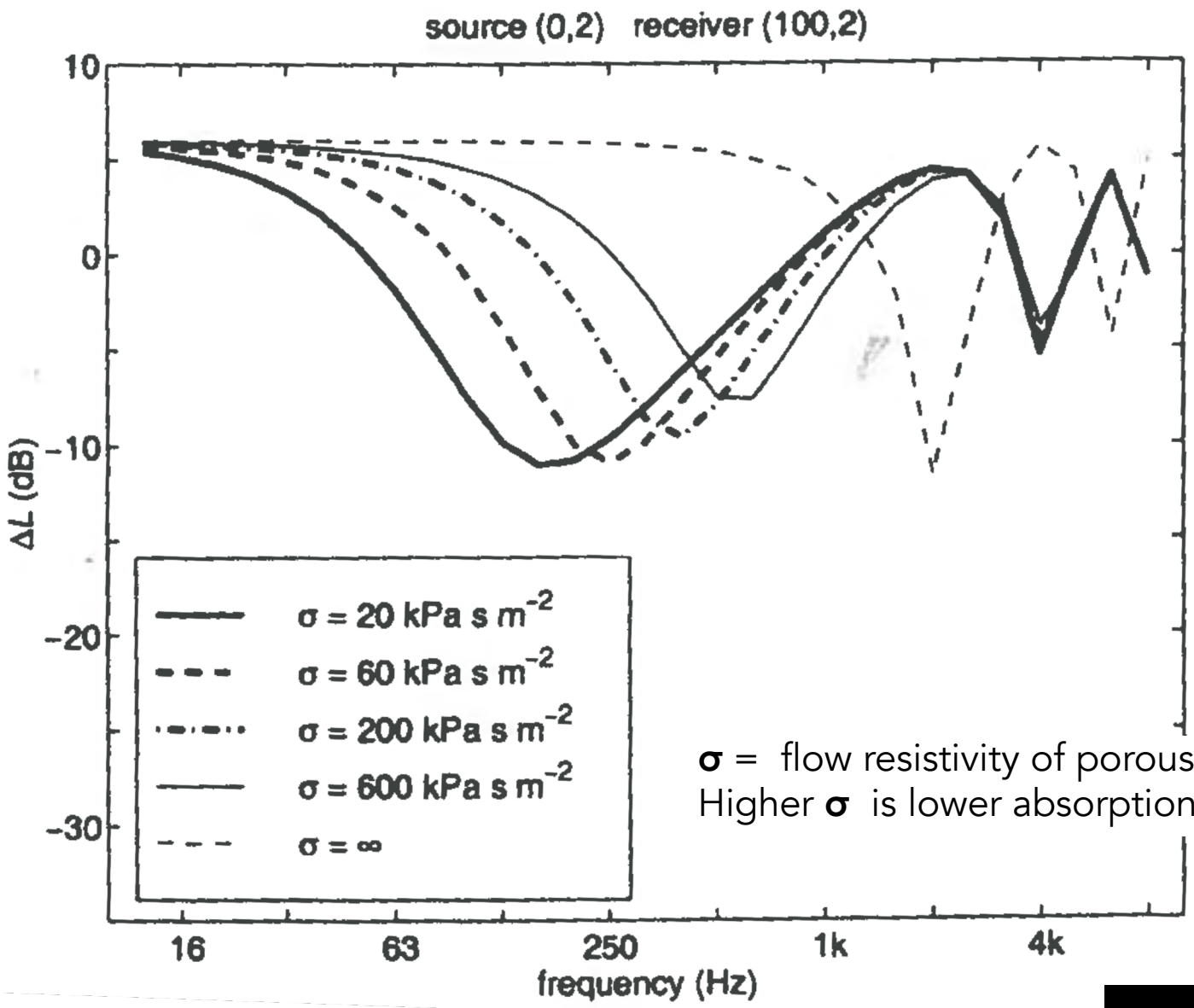
grass: σ = 300 kPa.s/m^2





Hornikx, M. Modelling urban sound propagation in a moving medium. (2004). Master's *Thesis report 04.16.A, TU/e, The Netherlands.*

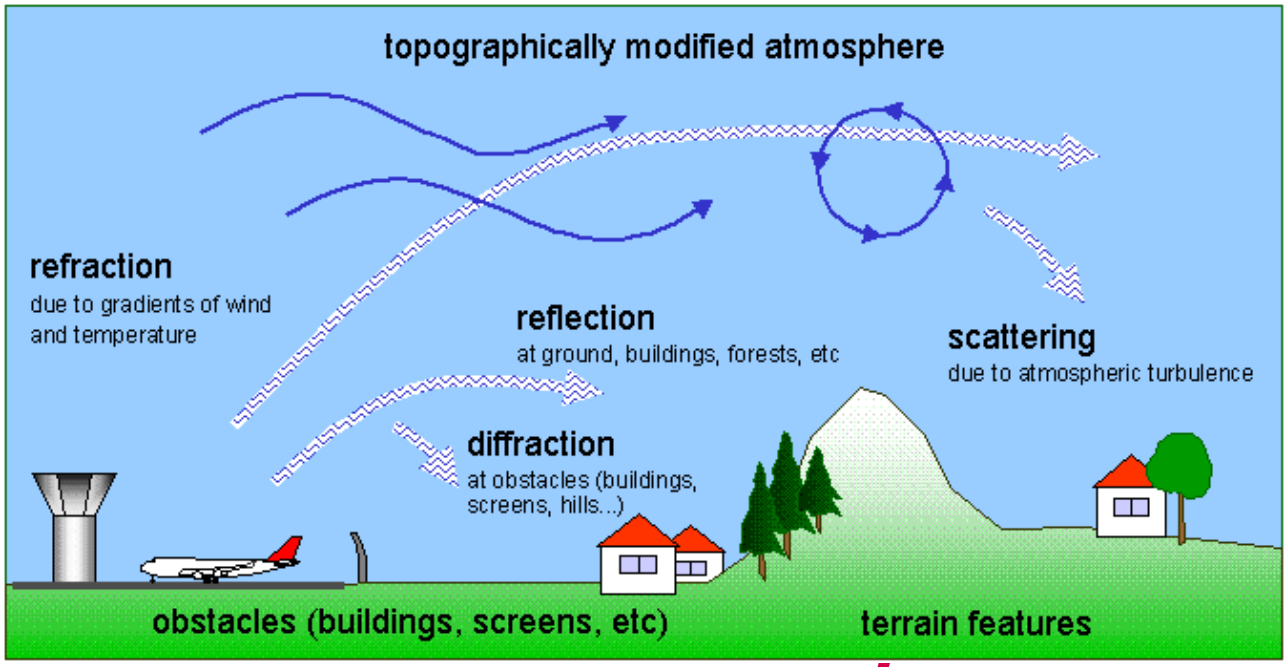
Ground effect: Level relative to case without ground



σ = flow resistivity of porous material
Higher **σ** is lower absorption coefficient

Overview Urban Acoustics

- Ground effect
- Meteorological effects
  - Air absorption
  - Refraction
  - Scattering
- Screening
- Urban effects



http://www.pa.op.dlr.de/acoustics/index.html

Meteorological effects: air absorption

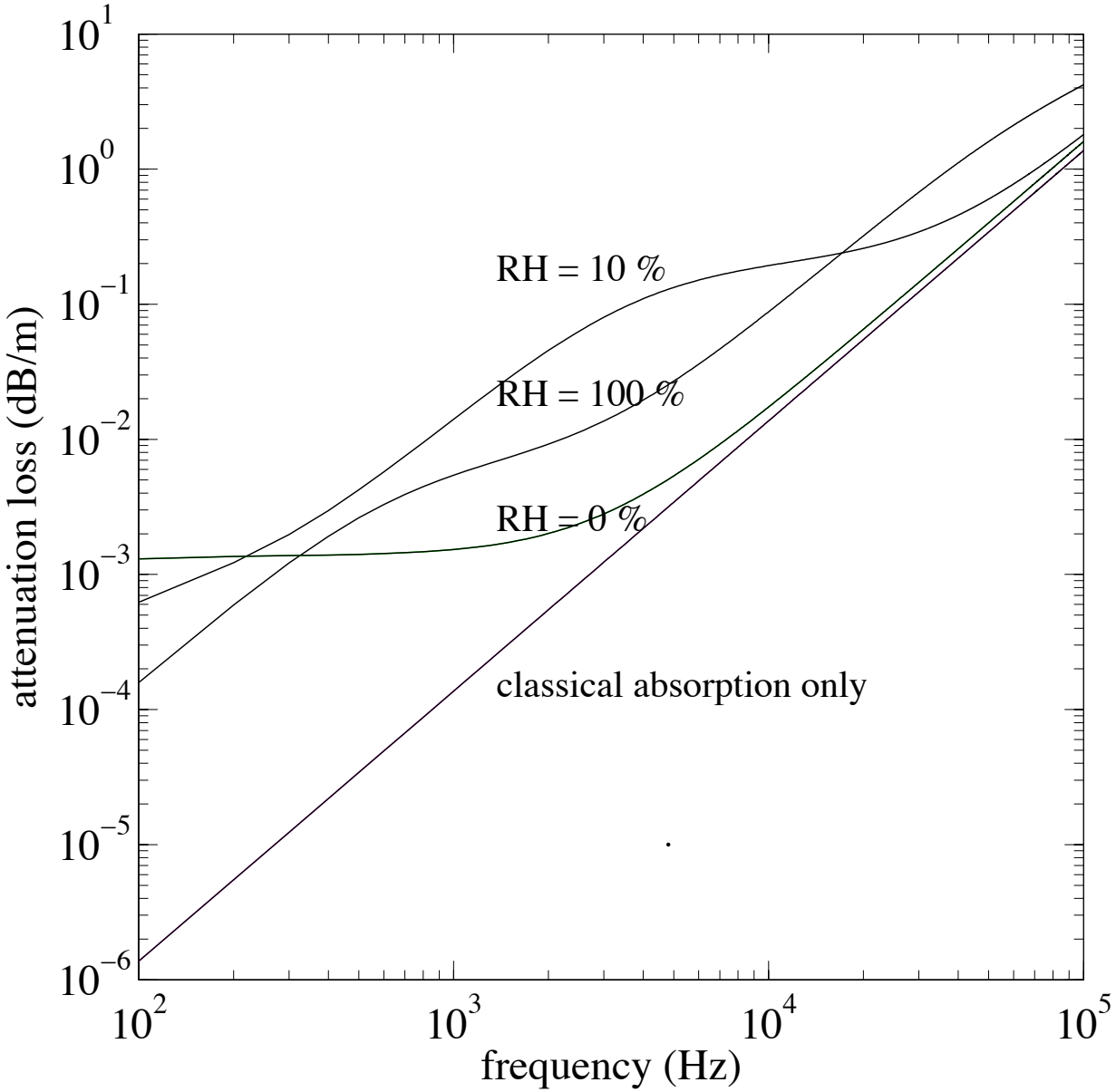
- Air absorption
  - Classical absorption: Viscous friction and thermal heat conductivity

    -> attenuation loss proportional to f^2
  - Molecular absorption: Relaxation and compression effects of nitrogen and oxygen

    -> attenuation loss non-linearly proportional to f

- Air absorption depends on
  - Frequency of the sound
  - Atmospheric temperature
  - Humidity and air pressure

Meteorological effects: air absorption



Meteorological effects: refraction

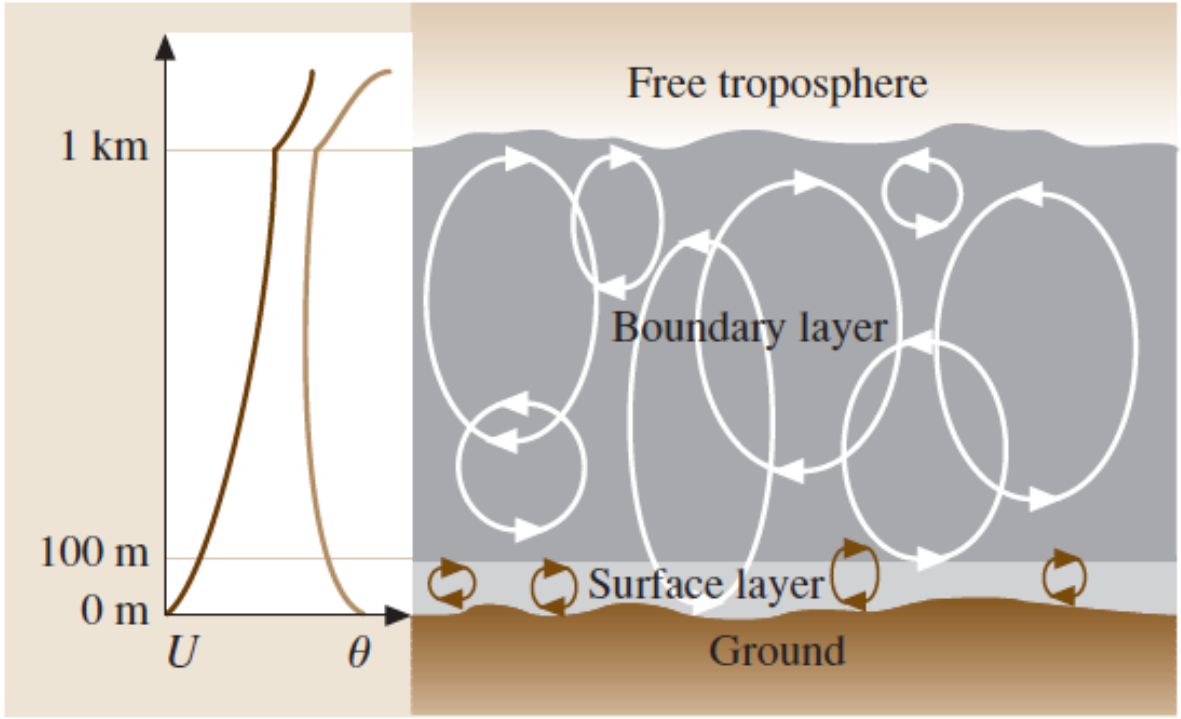


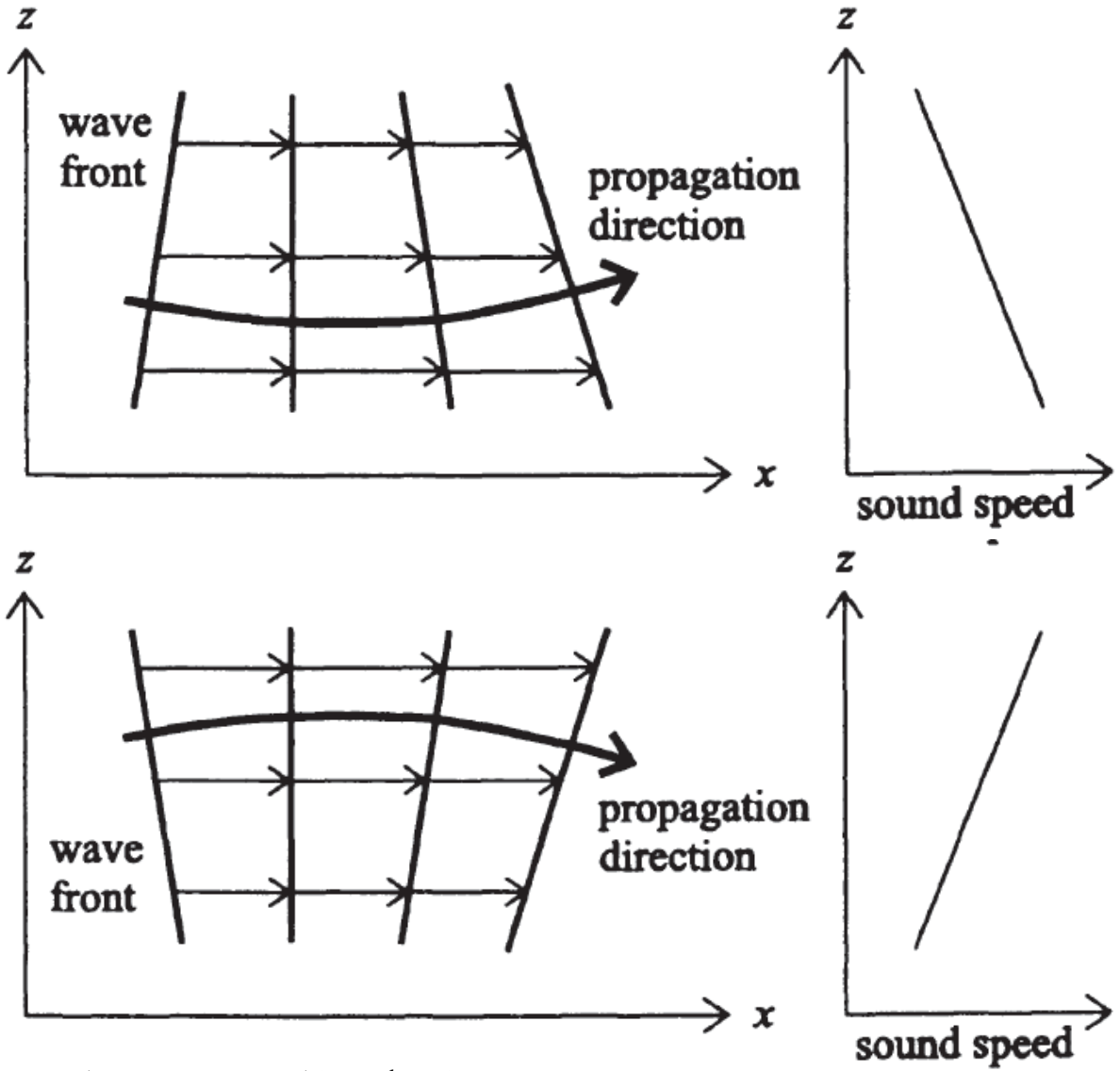
Fig. 4.14 Schematic representation of the daytime atmospheric boundary layer and turbulent eddy structures. The curve on the *left* shows the mean wind speed (U) and the potential temperature profiles ($\theta = T + \gamma_d z$, where $\gamma_d = 0.098\,°\text{C/km}$ is the dry adiabatic lapse rate, T is the temperature and z is the height)

Springer Handbook of Acoustics

Meteorological effects: refraction

Sound speed is higher for

- Higher wind velocity
- Higher temperature

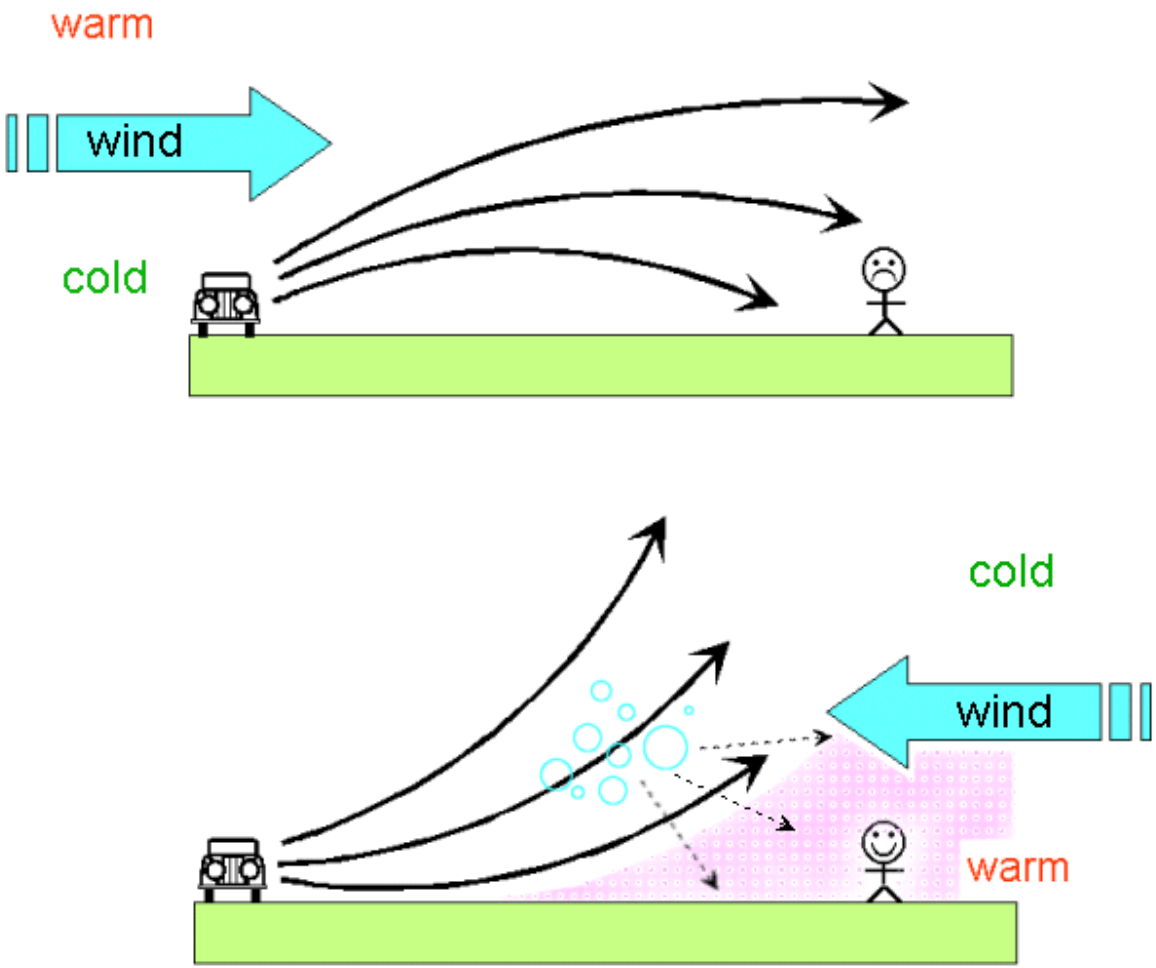


E. Salomons, Computational Atmospheric Acoustics

Meteorological effects: refraction

Refraction depends on

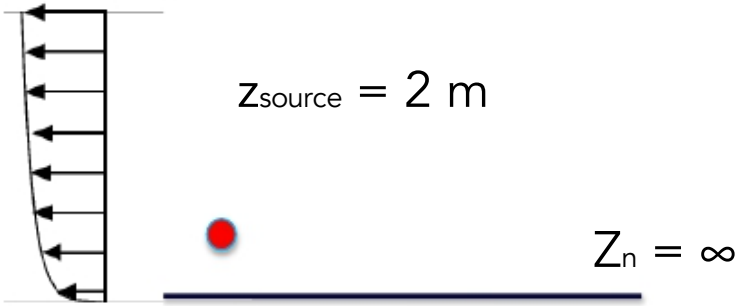
- Frequency
- Wind velocity
- Temperature
- Wind and temperature **profiles**

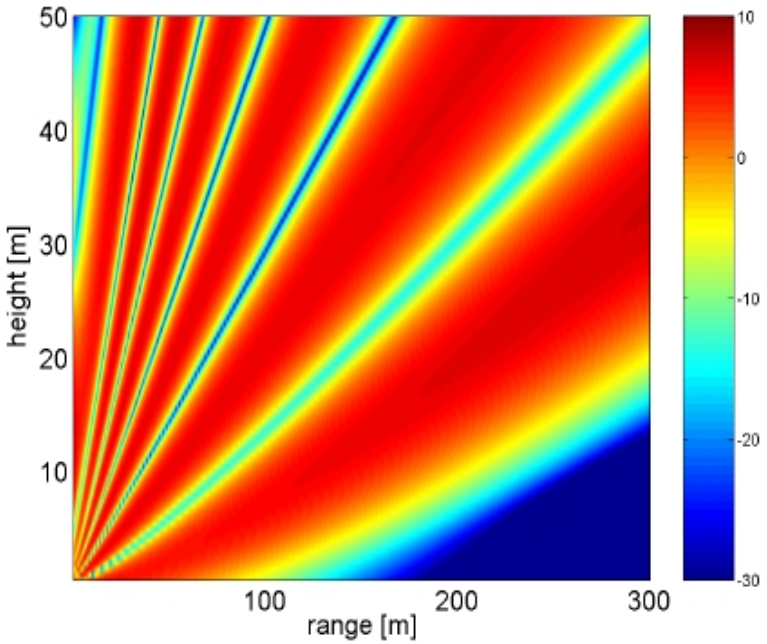


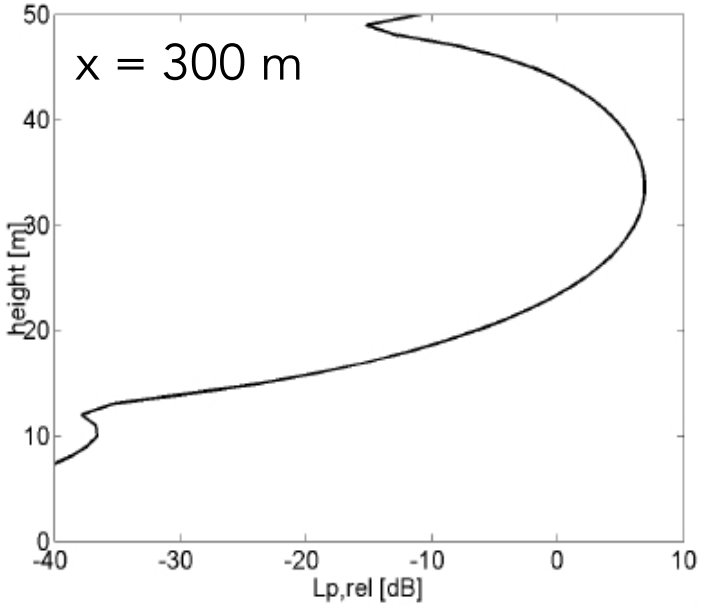
Heimann, D., (2003). Influence of meteorological parameters on outdoor noise propagation, EuroNoise Conference Naples 19-21 May 2003.

Meteorological effects: refraction

f = 500 Hz







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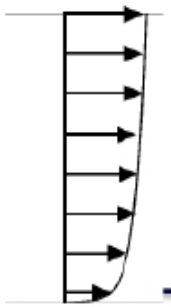
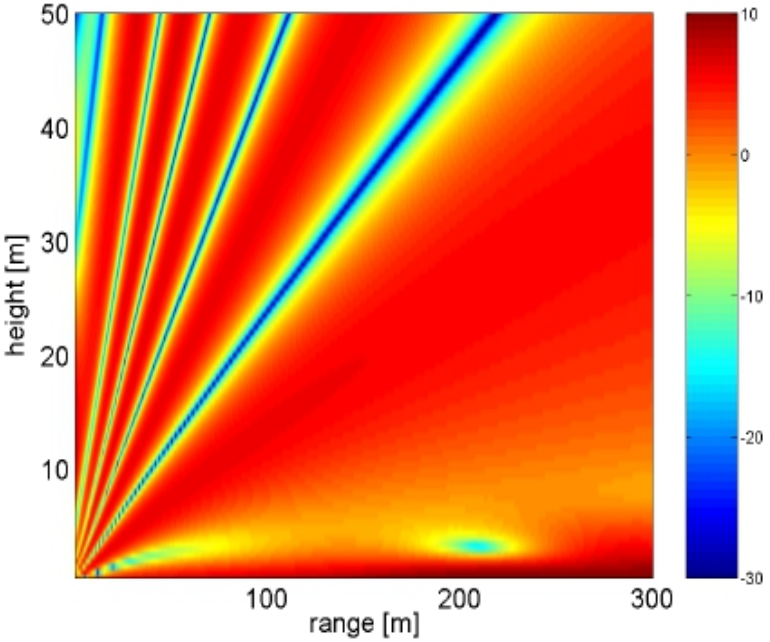
Meteorological effects: refraction

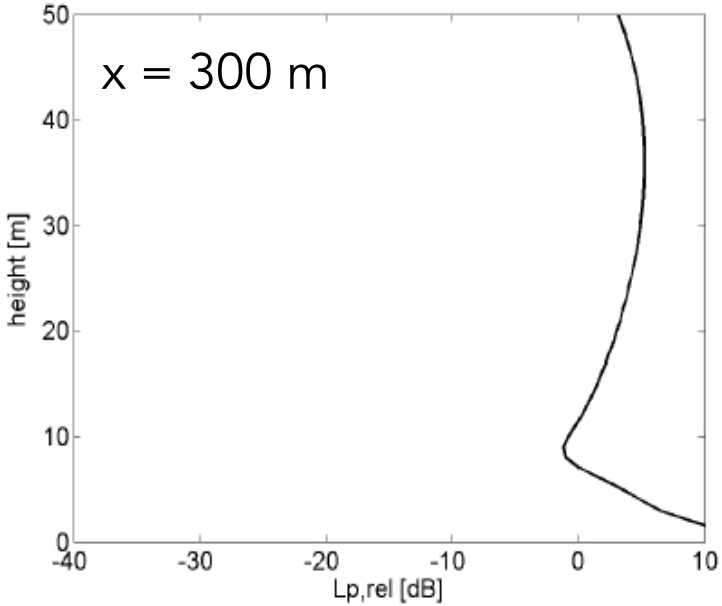
f = 500 Hz



z_{source} = 2 m

$Z_n = \infty$





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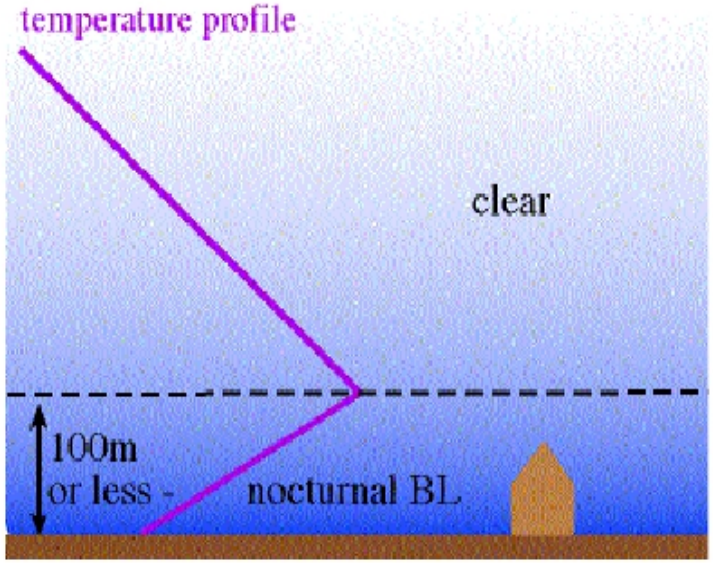
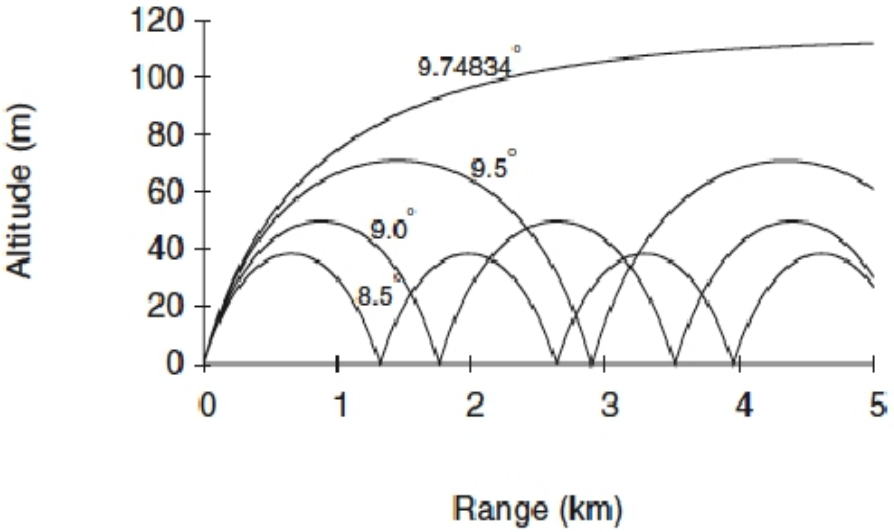
Meteorological effects: refraction

- Nocturnal boundary layer



http://apollo.lsc.vsc.edu/classes/met130/notes/chapter9/bl_evol_6am.html



Waxler et al. J. Acoust. Soc. Am., 124(5), 2008.

Meteorological effects: turbulent scattering

Atmospheric turbulence: Small scale refraction leading to

- Phase changes of sound waves
- Amplitude changes of sound waves

Turbulent scattering depends on:

- Frequency
- Strength of atmospheric turbulence
- Scales of turbulent structures

http://skullsinthestars.files.wordpress.com/2009/08/shimmer2.jpg

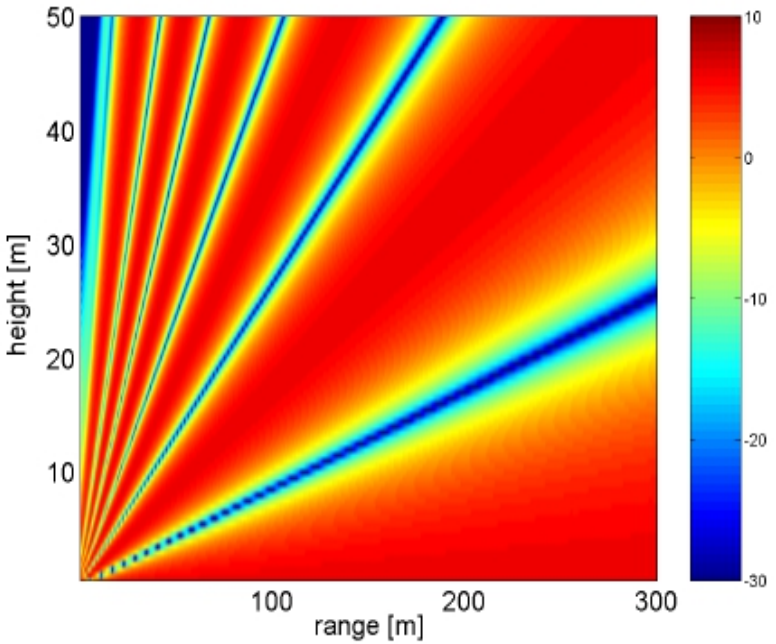
Meteorological effects: turbulent scattering

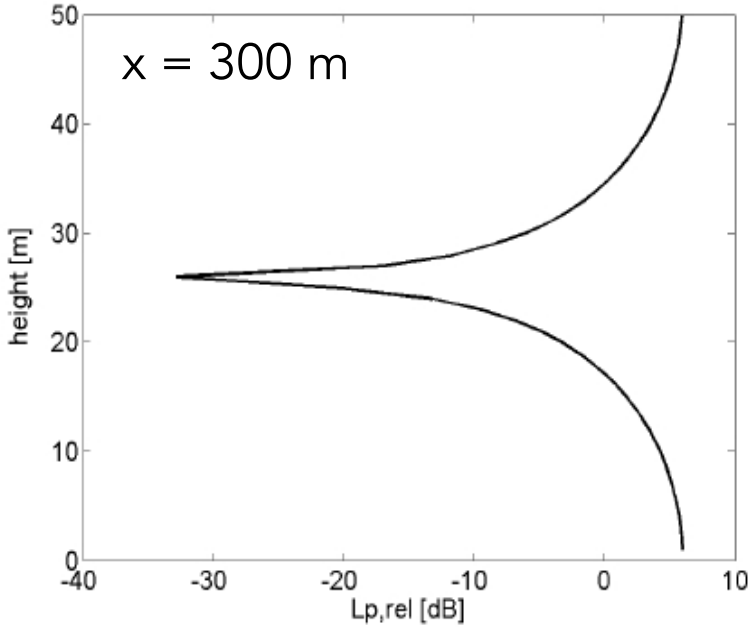
f = 500 Hz

z_{source} = 2 m

No turbulence

$Z_n = \infty$





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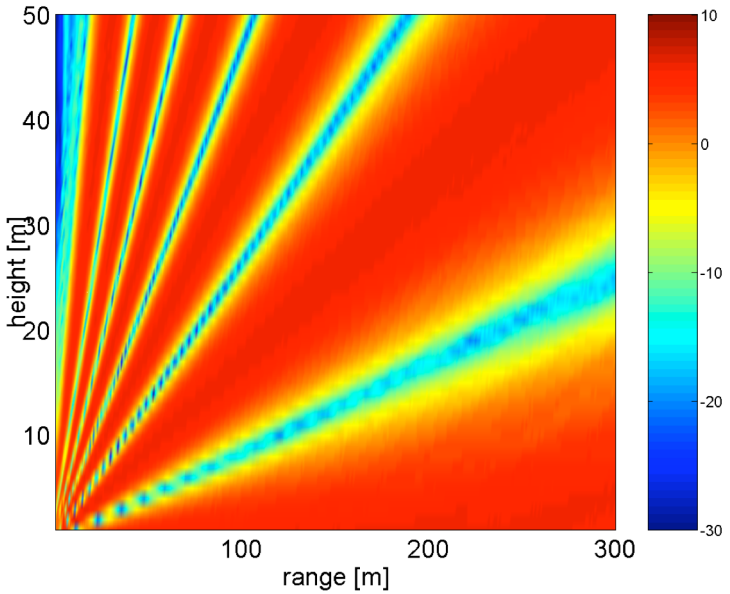
Meteorological effects: turbulent scattering

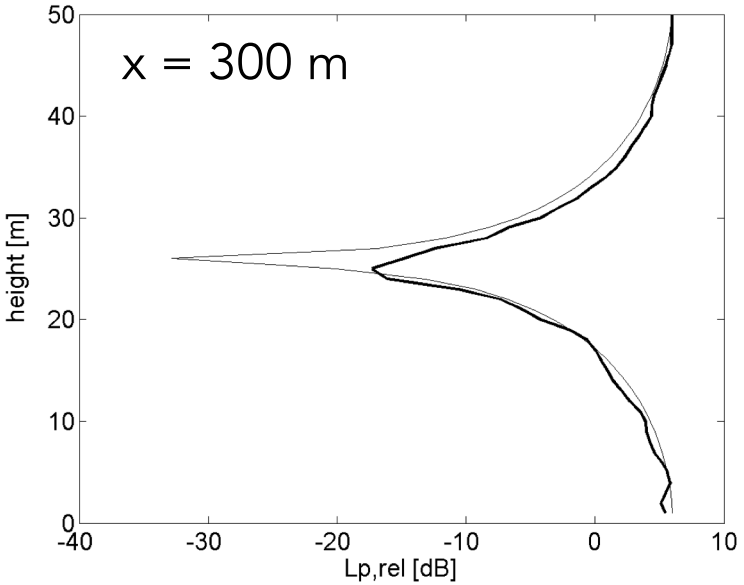
Turbulence

f = 500 Hz

z_{source} = 2 m

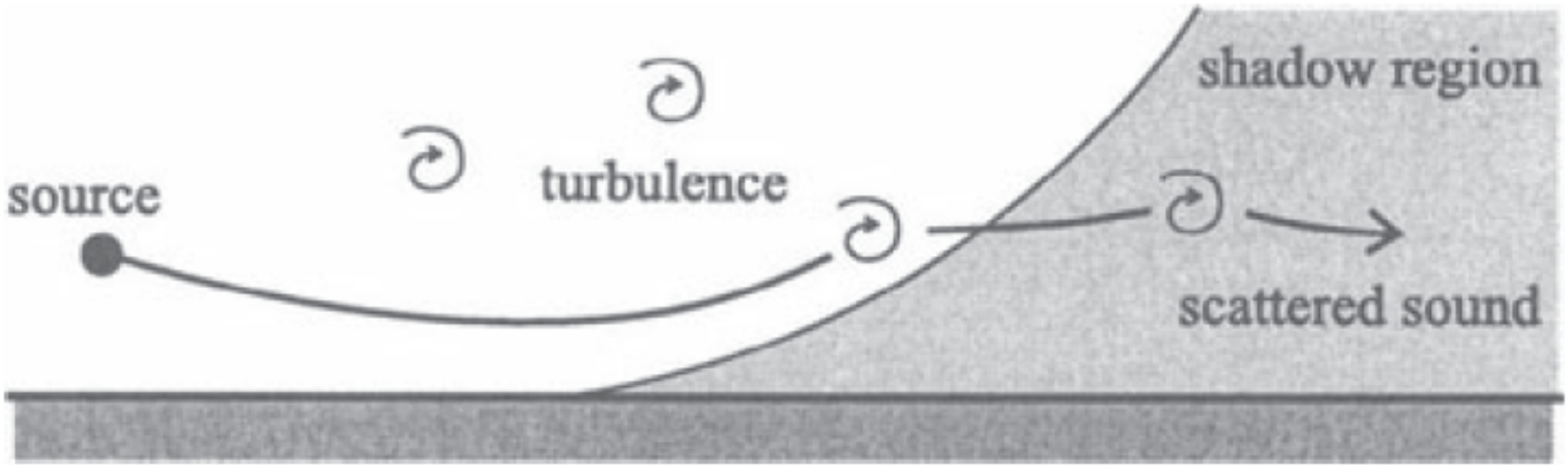
$Z_n = \infty$





Hornikx, M. Modelling urban sound propagation in a moving medium. (2004). Master's *Thesis report 04.16.A, TU/e, The Netherlands.*

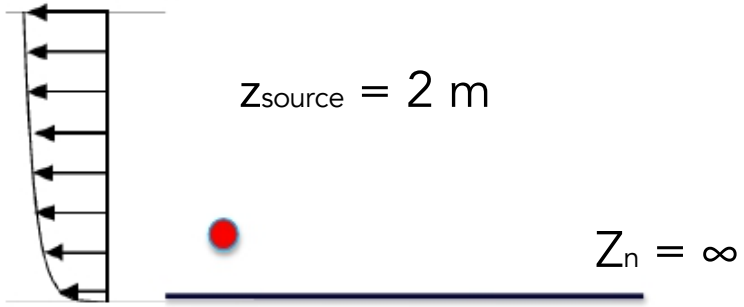
Meteorological effects: turbulent scattering

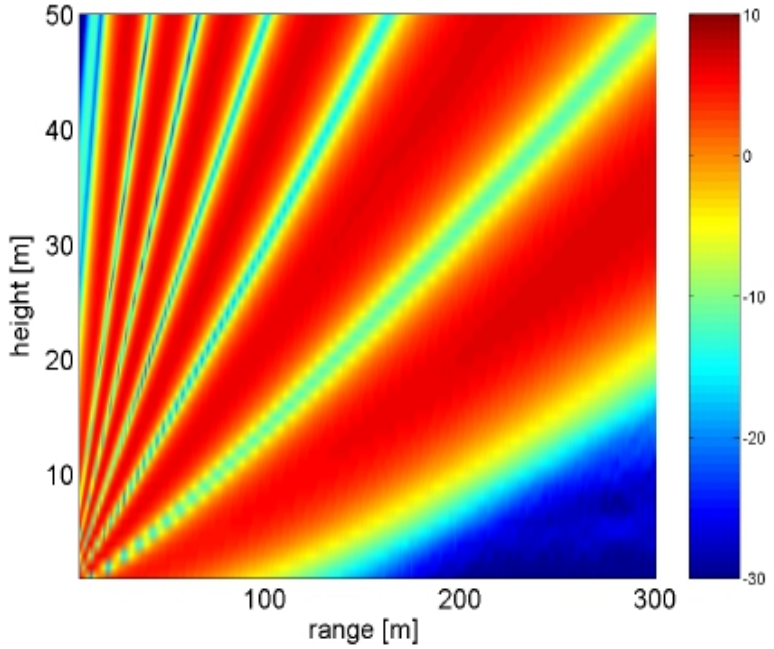


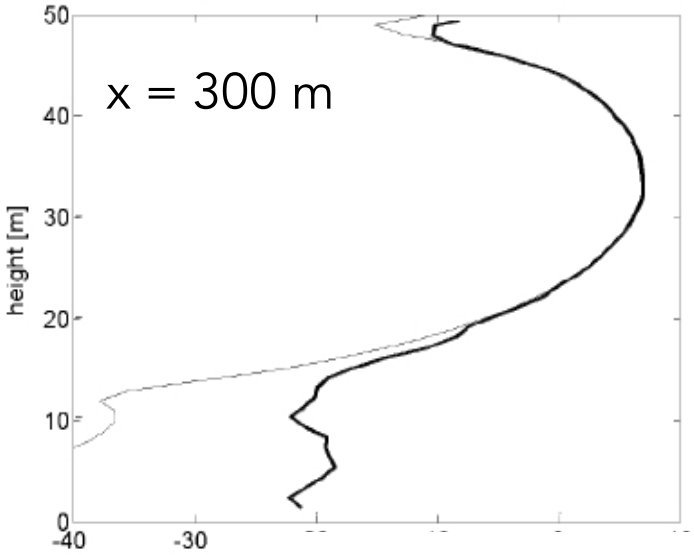
Meteorological effects: refraction

Turbulence

f = 500 Hz







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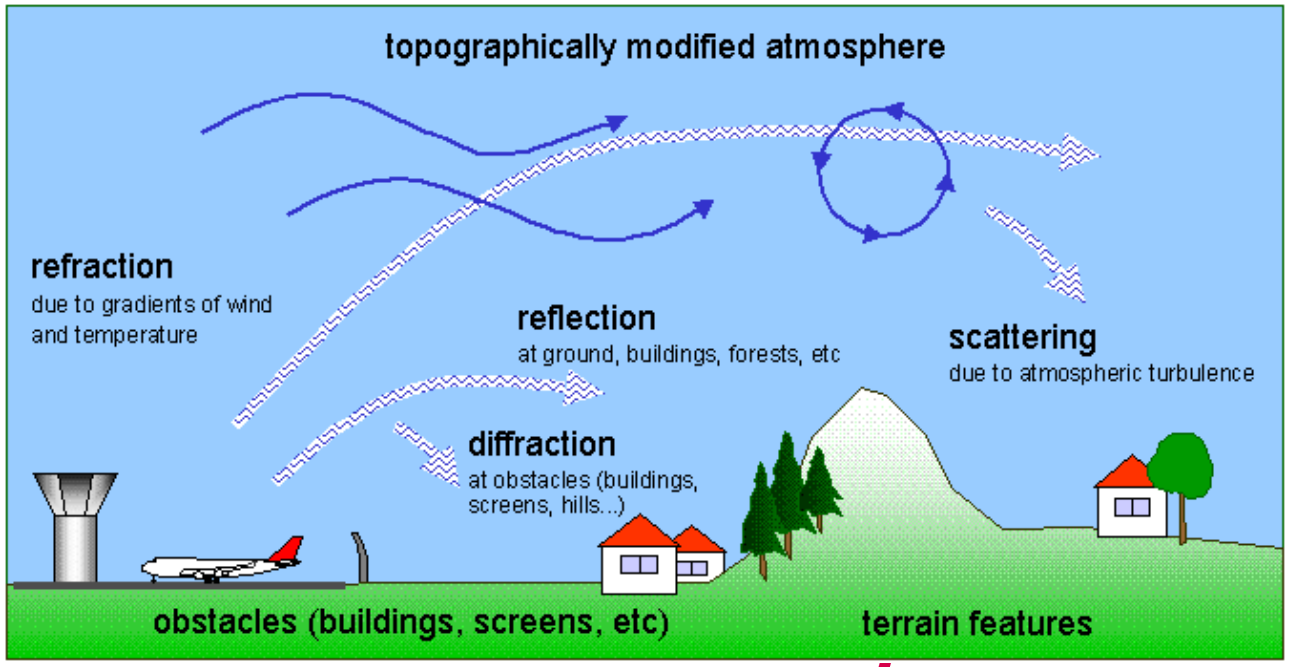
Overview Urban Acoustics

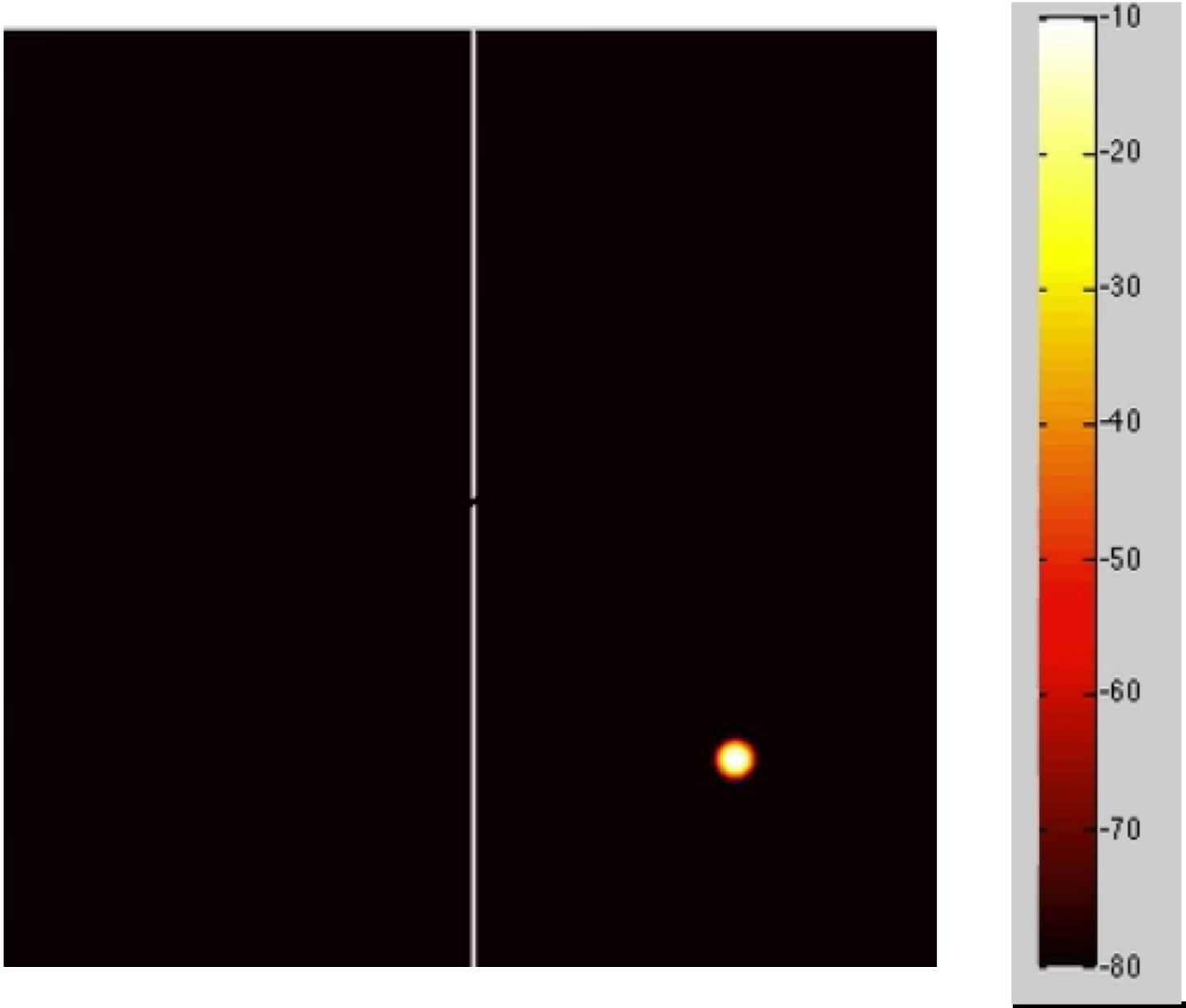
- Ground effect
- Meteorological effects
- Screening
- Urban effects



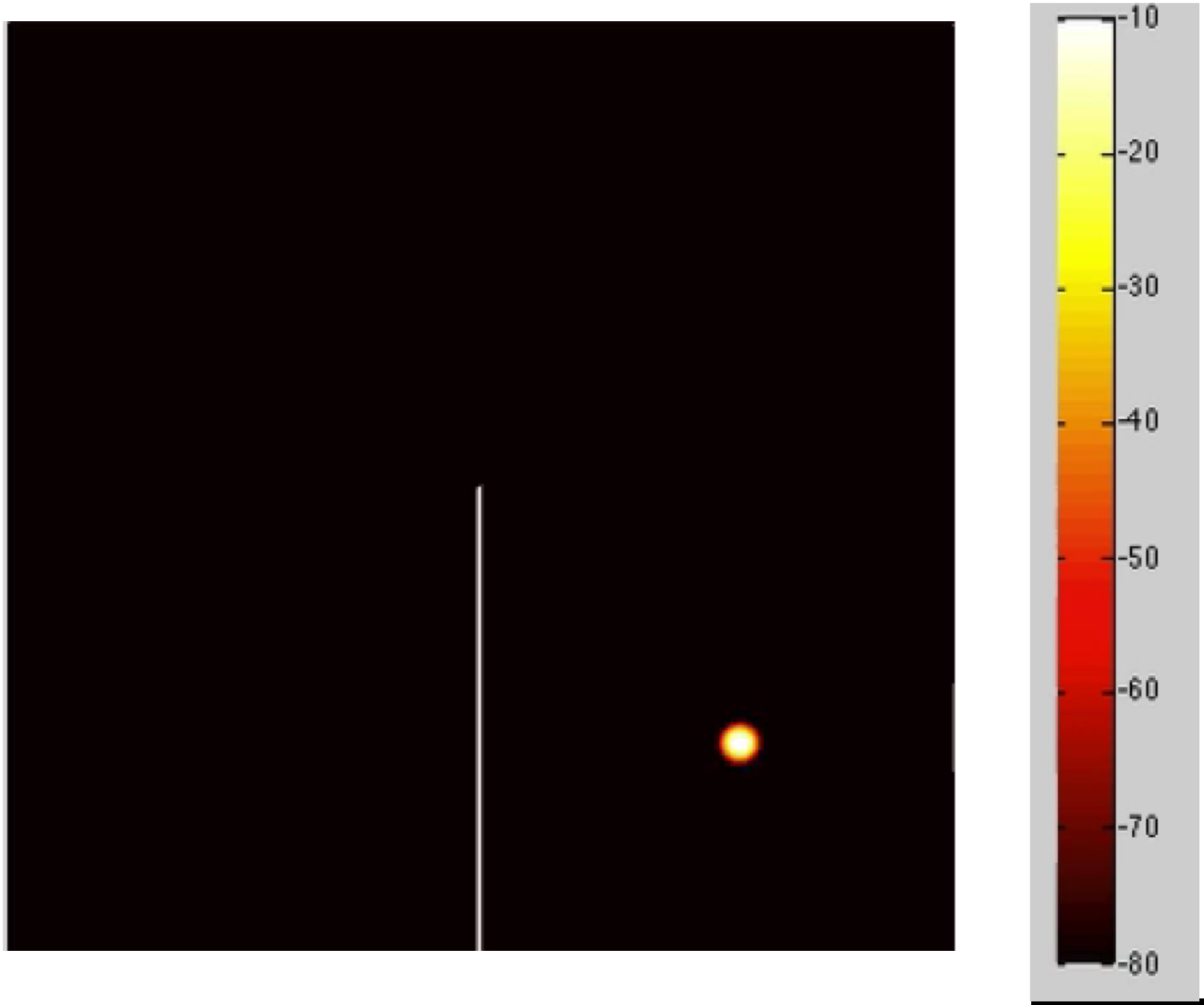
http://www.pa.op.dlr.de/acoustics/index.html

Screening

Screening

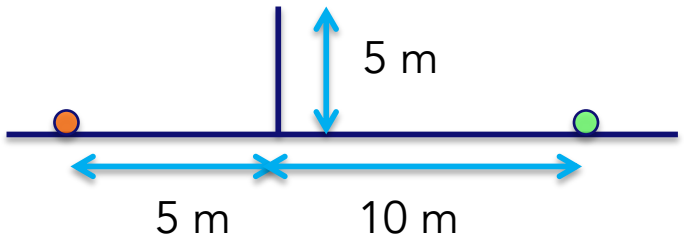


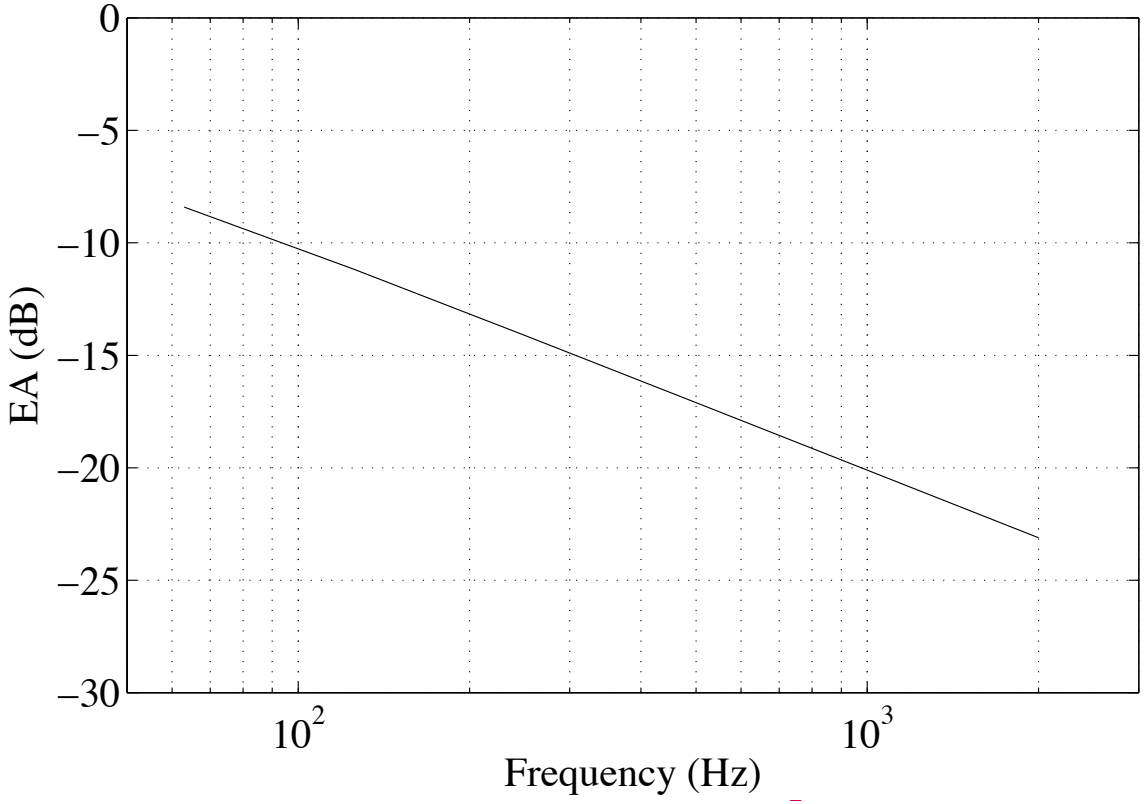
Screening



Screening

Screening depends on
- Frequency
- Angle of diffraction (higher attenuation for large diffraction angles)





Computed with the diffraction model as presented in: Hadden, J.W. and Pierce, A.D., "Sound diffraction around screens and wedges for arbitrary point source locations," J. Acoust. Soc. Am. 69, 1266-1267, (1981). Erratum; J. Acoust. Soc. Am. 71, 1290, (1982).

Overview Urban Acoustics

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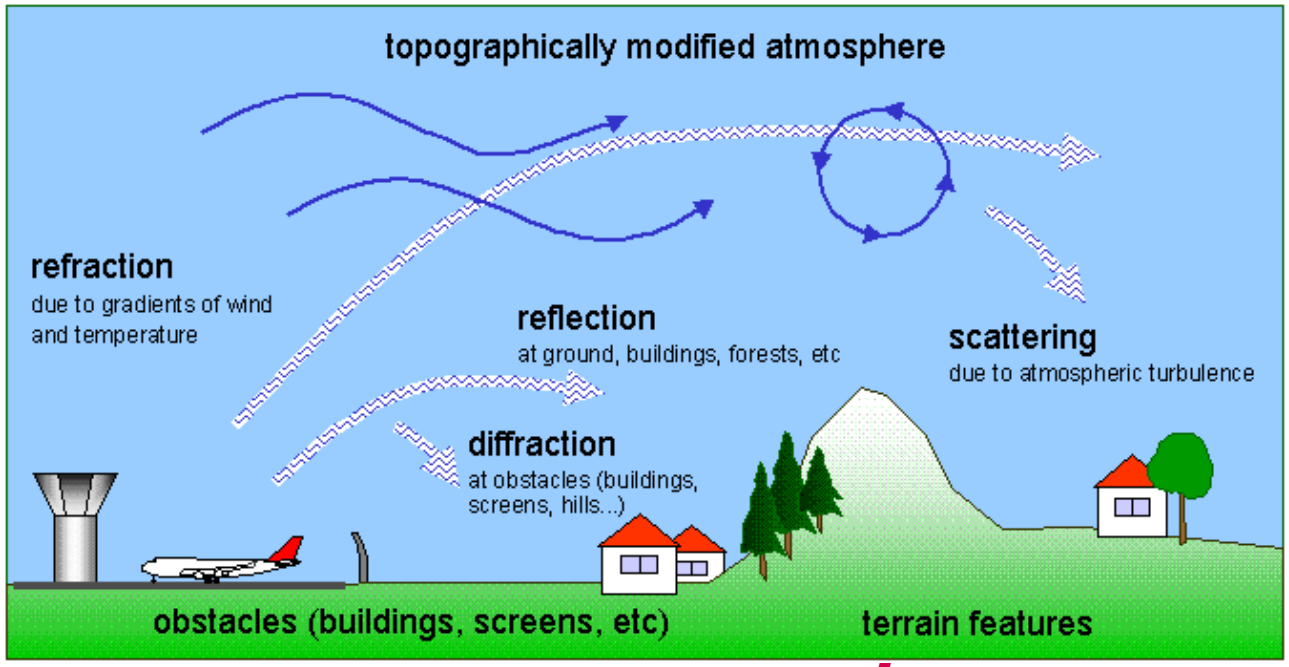
- Screening
- Urban effects



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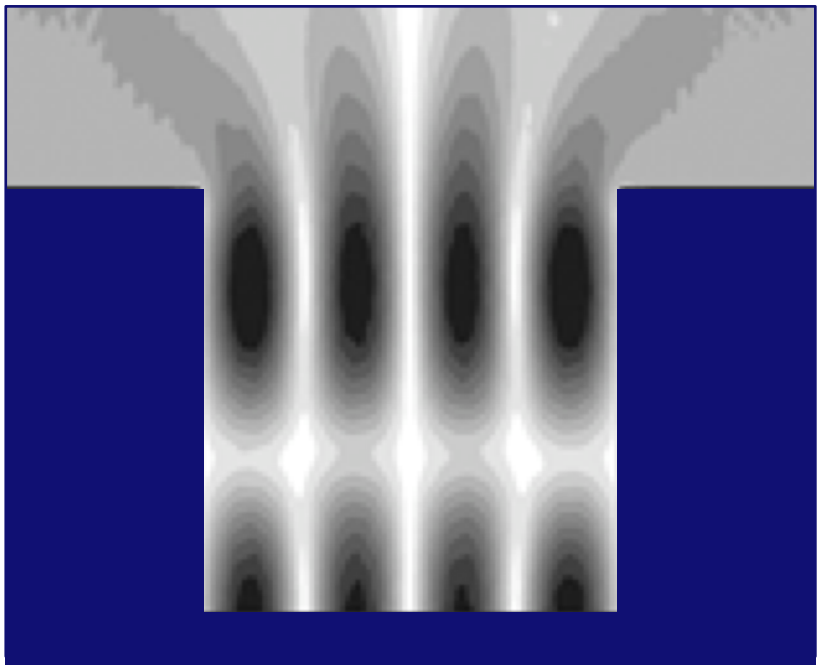
Urban effects

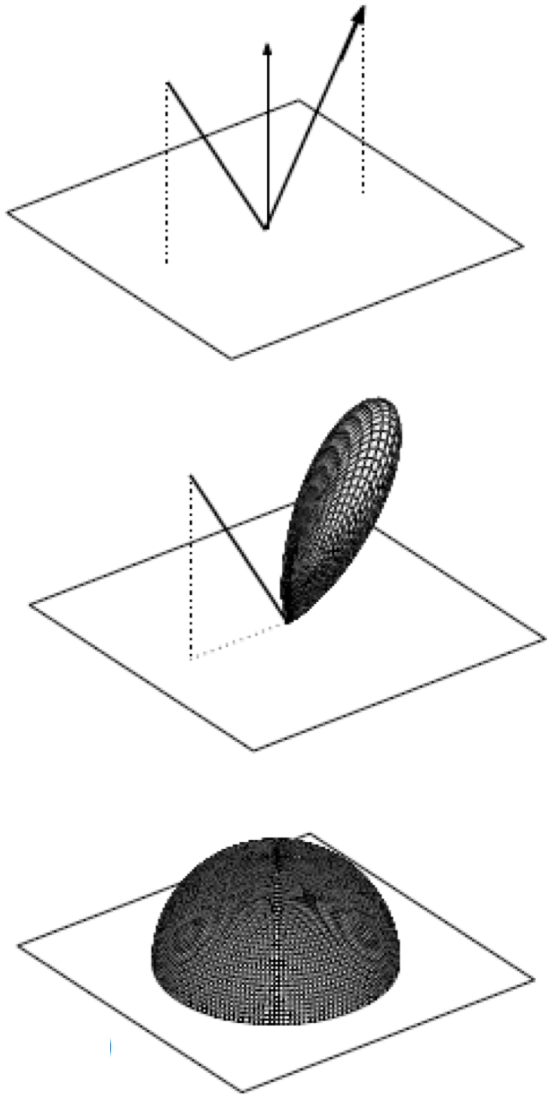
- Inner city configuration comparable with indoor environment
- Interferences may cause high levels locally



Pelat et al., J. Acoust. Soc. Am. 129 (3), 1240–1249

Urban effects

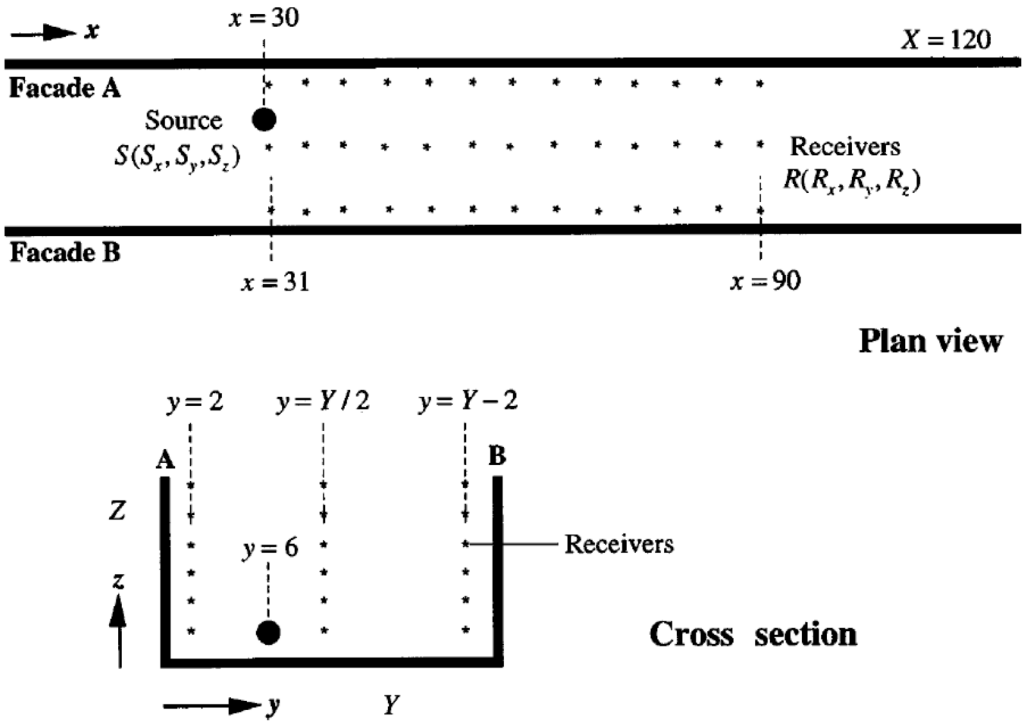
- Reflections from building facades and other surfaces
- Specular versus diffuse reflection

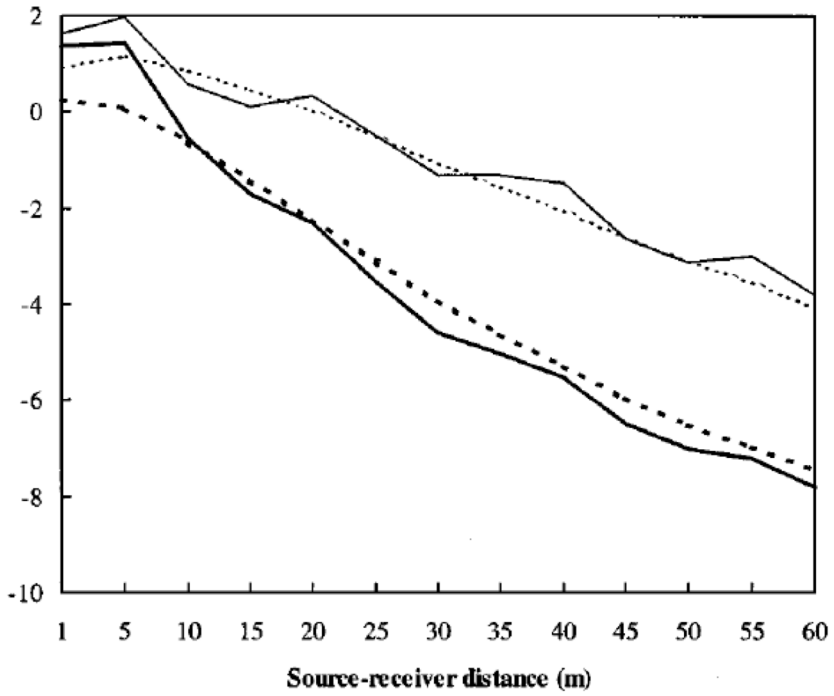


Picaut et al., Acta Acustica united with Acustica 95 (2009), 653-668

Urban effects

- Attenuation of diffuse façade reflections versus specular reflections

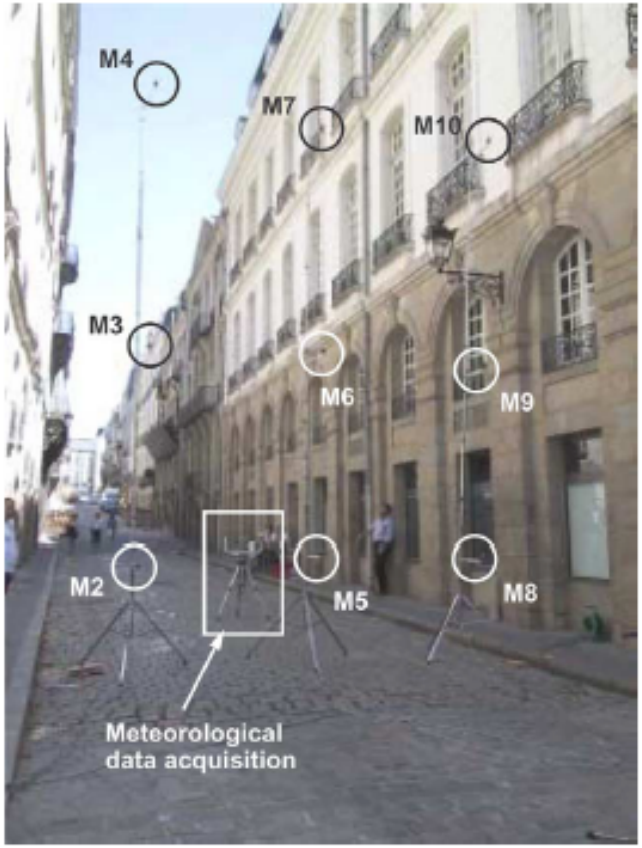


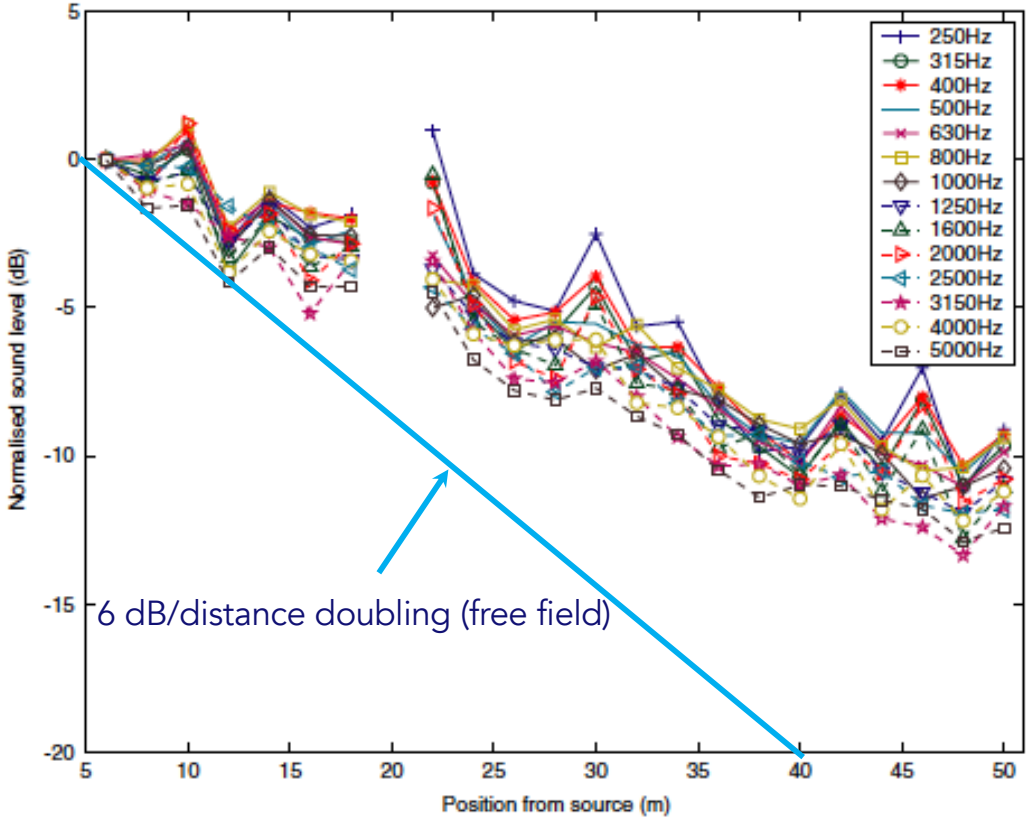


Kang, J., "Sound propagation in street canyons: Comparison between diffusely and geometrically reflecting boundaries," J. Acoust. Soc. Am. 107, 1394-1404, (2000).

Urban effects

- Attenuation in street versus free field



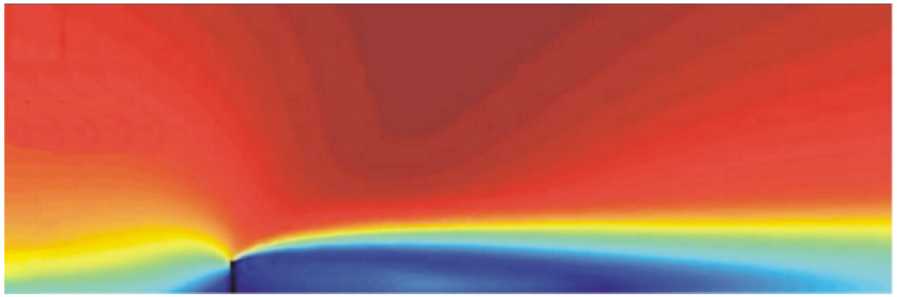


Picaut, J., Le Polles, T., L'Hermite, T., Gary, V. Experimental study of sound propagation in a street. App. Acoust. 66 (2005) 149–173.

Combined effects

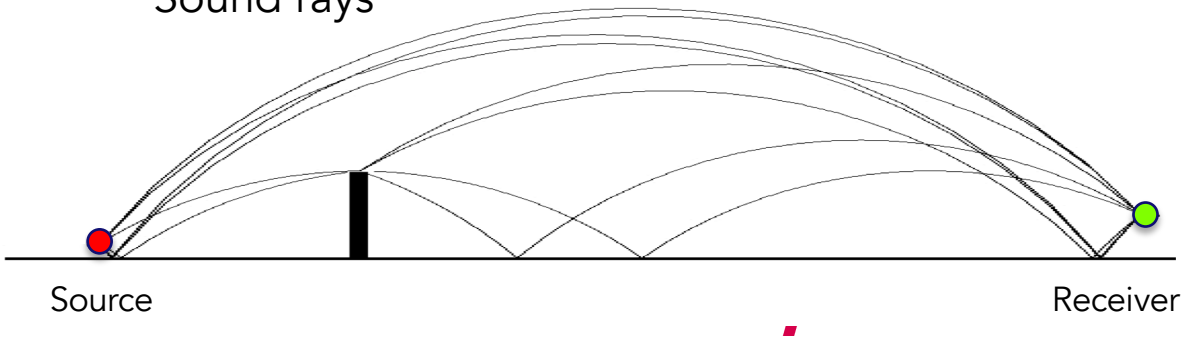
- Unfavourable effects in presence of noise barrier
  - Downward refraction (wind direction from source to receiver) due to wind or temperature gradients

Wind field



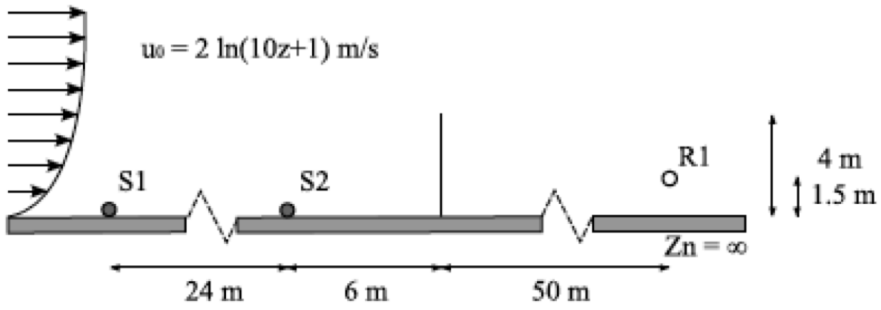
Timothy van Renterghem

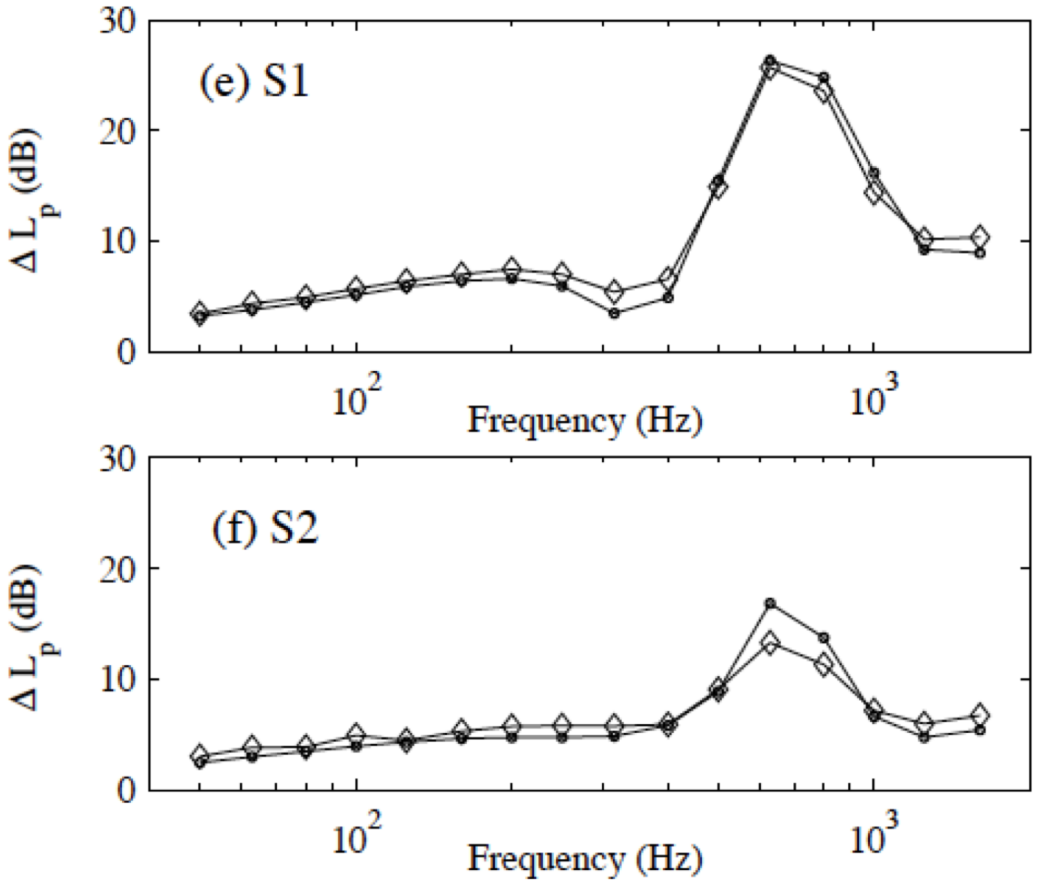
Sound rays



Combined effects

- Unfavourable effects in presence of screen
  - Downward refraction due to wind or temperature gradients
  - Level relative to situation without wind

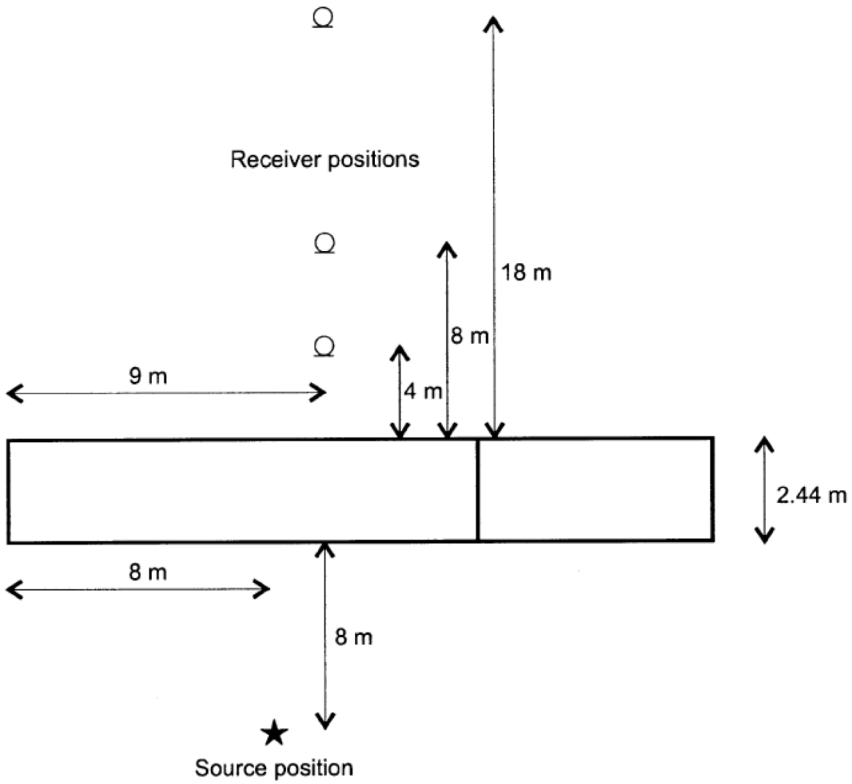




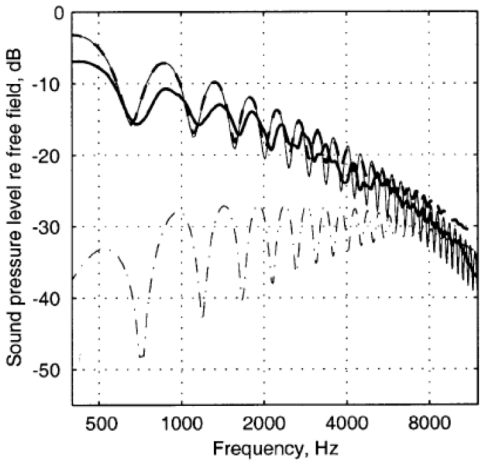
Hornikx, M., Waxler, R., Forssén, J., (2010). The extended Fourier pseudospectral time-domain method for atmospheric sound propagation, J. Acoust. Soc. Am., 128(4), 1632-1646.

Combined effects

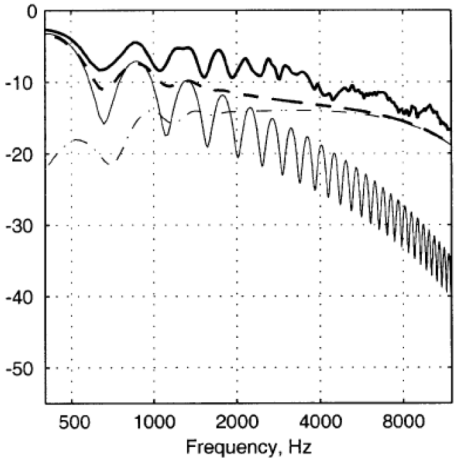
- Unfavourable effects in presence of screen
  - Scattering due to atmospheric turbulence

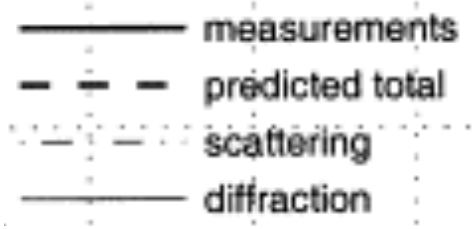


Weak turbulence



Strong turbulence

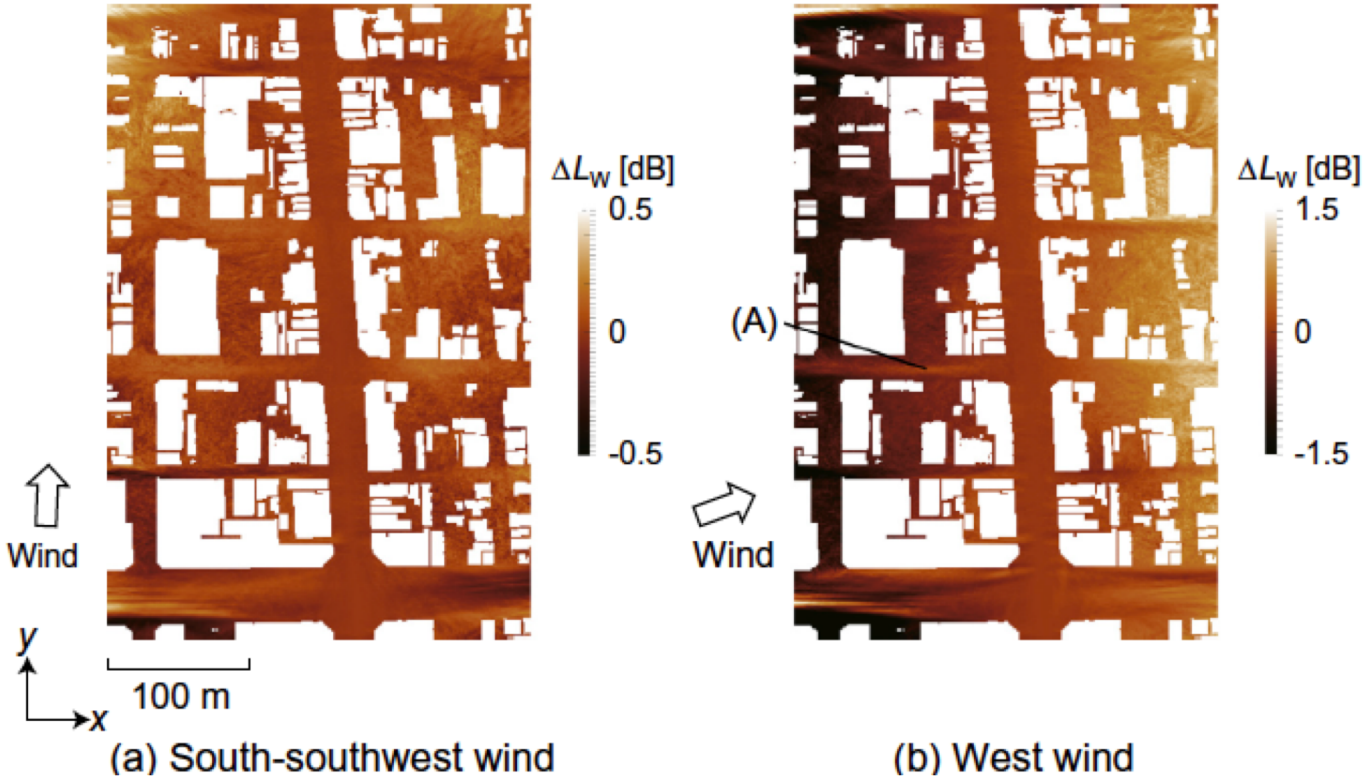




Forssén, J., Ogren, M. Thick barrier noise-reduction in the presence of atmospheric turbulence: Measurements and numerical modeling, Appl. Acoust. 63, 173–187 2002.

Combined effects

- Urban topology and wind
  - Noise level differences due to wind direction



Oshima, T., Imano, M,. Hiraguri, Y., Kamoshida, Y., (2013) Linearized Euler simulations of sound propagation with wind effects over a reconstructed urban terrain using digital geographic information. Appl. Ac., 74(12), p. 1354-1366