Einfluss der Meteorologie auf die Schallausbreitung von Bahn- und Straßenverkehr

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ACOUSTICS | NOISE CONTROL | MEDICAL PHYSICS

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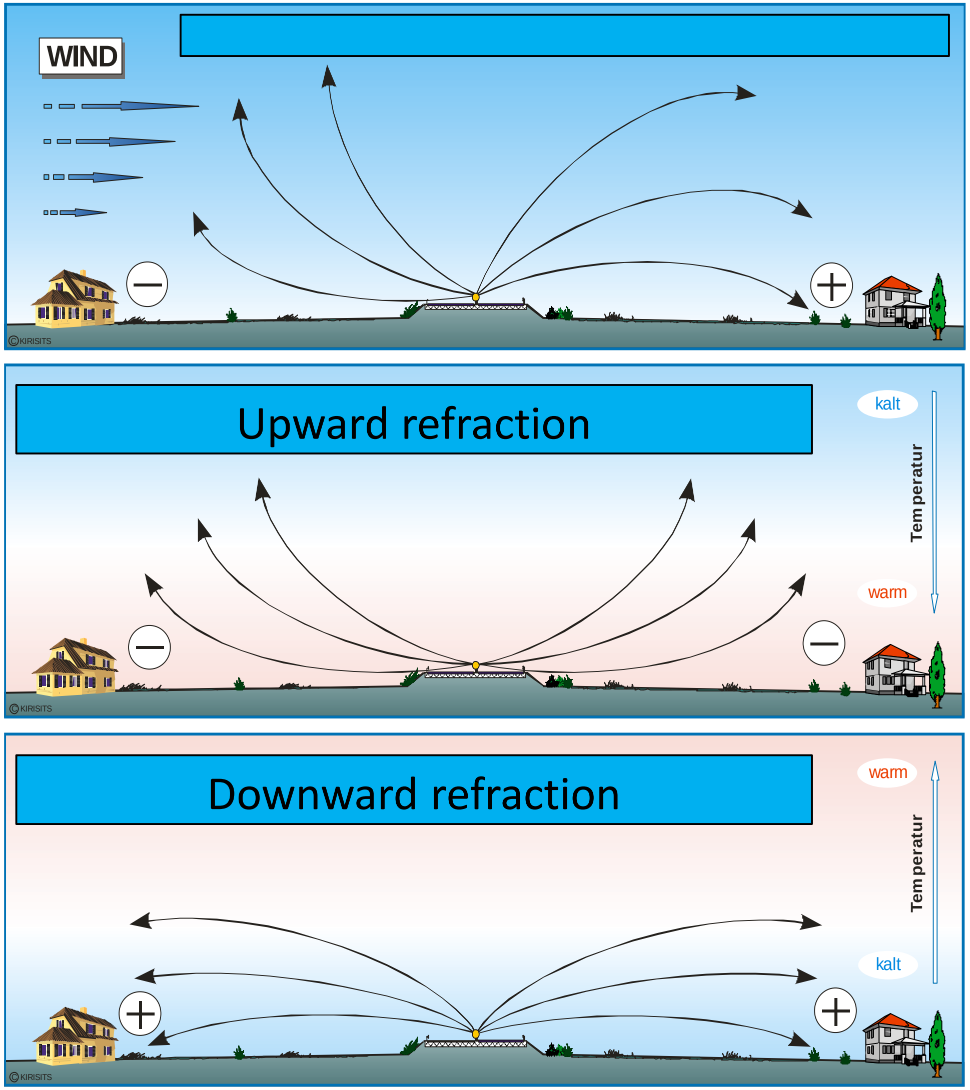
Influence of sound speed gradient



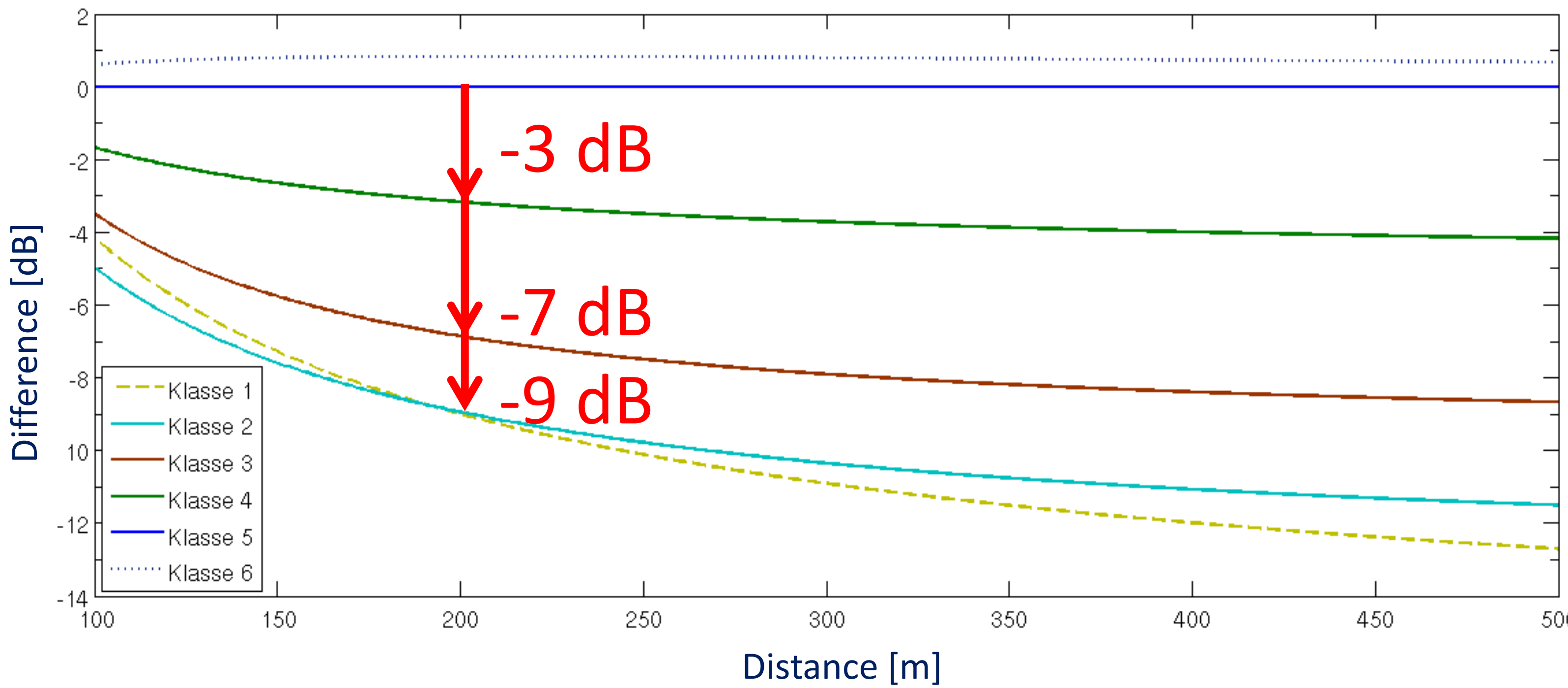
Upwind versus Downwind

e.g. Daytime with strong incoming radiation

e.g. Nighttime with clear sky

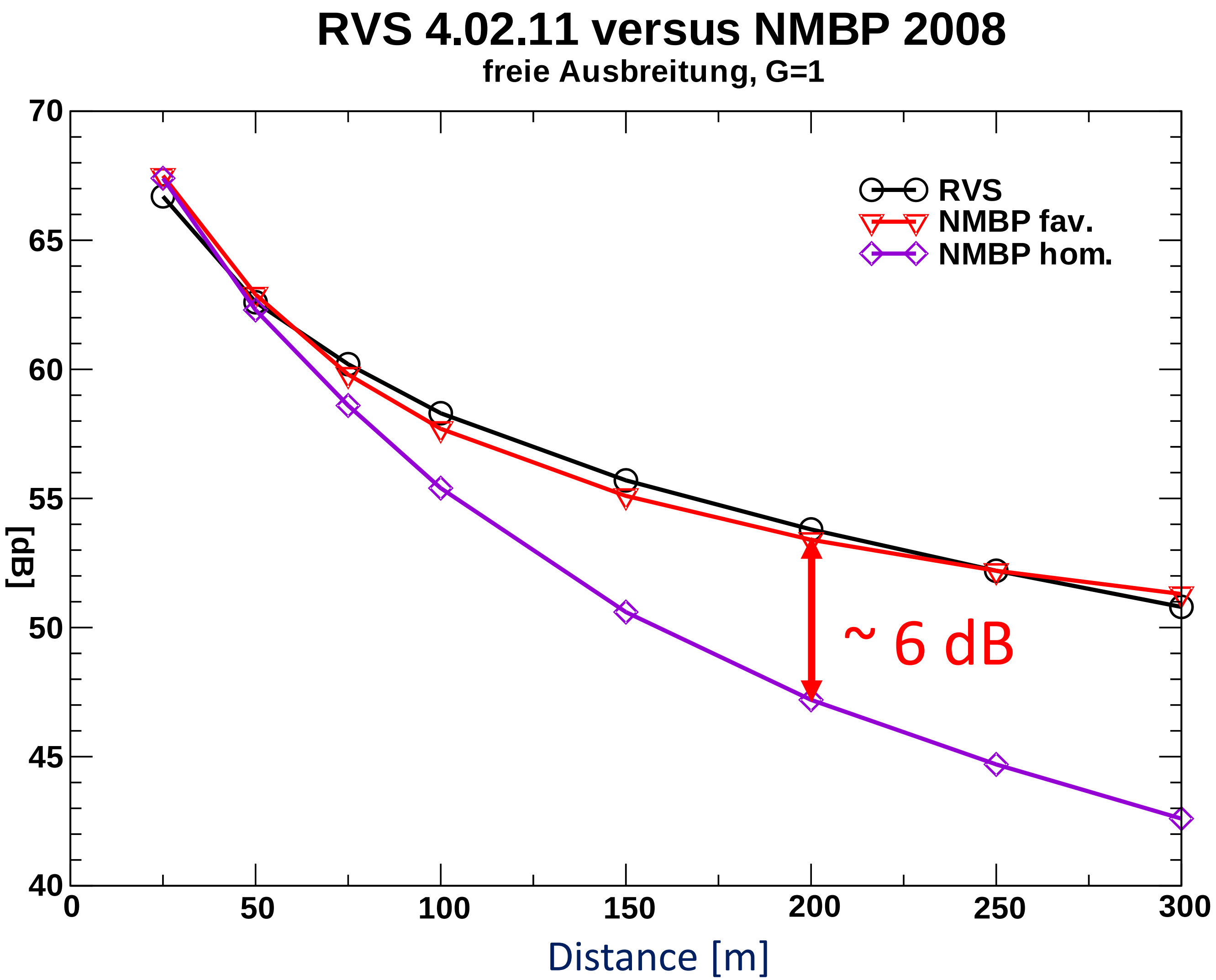
CONCAWE

Difference normalized to class 5 (favorable)



Calculated with Matlab script for a straight line source and traffic sound spectrum based on
Marsh KJ. THE CONCAWE MODEL FOR CALCULATING THE... Appl Acoust 1982; 15: 411–28.

Example for free propagation of road traffic noise over porous ground Favorable / homogenous propagation conditions



Overview of analysed concepts

- **NF S31-085**. (Characterization and measurement of road traffic noise – General measurement specifications), Norme Française (2002)
- The **CONCAWE** model for calculating the propagation of noise from open-air industrial plants, Marsh, Applied Acoustics (1982)
- **ISO 1996-2**, Description, measurement and assessment of environmental noise — Part 2: Determination of environmental noise levels (2007) *– in revision!*
- **IMAGINE** consortium, 8th draft 06-01-11 IMA32TR-040510-SP08 downloaded from http://www.imagine-project.org/ (2011)

NF S31-085

- Provides tables to classify the propagation condition in five levels: --, -, Z, +, ++
- Classification can be based on local observations and simple meteorological measurements as follows:
  - Wind speed at 2 m (new – 6 m) above ground [m/s]
  - Wind direction [°]
  - Incoming solar radiation [W/m²] / Cloud cover [%]
  - Humidity of the ground [yes/no]
- Thermal classes linked to vertical temperature gradient
- Aerodynamic class linked to wind speed and wind direction
- Both classes combined determine the propagation class.

CONCAWE

- Pasquill meteorological stability category based on:
  - Wind speed [m/s] (10 m?)
  - Incoming solar radiation [mW/cm^2] /Cloud cover [octas]
- Vector wind speed
- Combination of both defines 6 different meteorological categories. Category 4 represents the situation with assumed zero meteorological influence. Categories 5 and 6 represent favorable conditions with downward refraction.

IMAGINE

- Radius R approximating the curvature of the sound paths caused by atmospheric refraction based on friction velocity, the temperature scale and the inverse Monin-Obukhov length 1/L.
- These parameters are given in tabulated form based on
  - Wind speed at 10 m above ground [m/s]
  - Wind direction [°]
  - Day / Night
  - Cloud cover [octas]
- Source-Receiver distance D
- R/D ratio determine favorable, neutral and unfavorable conditions

Situation – Clear summer day

*Downwind on a clear day with high solar radiation (700 W/m²). The table shows the classification for different methods and downwind speed. Favorable conditions are marked with a *.*

Wind Speed [m/s] at 10 m	NF S31-85 (–,-,Z,+,++)	CONCAWE (1-6)	IMA (M1-M4)	ISO1996-2 (-,+)
0.0	-	3	M1	-
1.0	-	4	M2	-
2.0	-	4	M2	+*
3.0	-	5*	M3*	+*
4.0	-	5*	M3*	+*
5.0 and higher	+*	6*	M3*	+*

Situation – Downwind / overcast

*Downwind on an overcast day (8/8 cloud cover) with low solar radiation (30 W/m²). The table shows the classification for different methods and downwind speed. Favorable conditions are marked with a *.*

Wind Speed [m/s] at 10 m	NF S31-85 (–,-,Z,+,++)	CONCAWE (1-6)	IMA (M1-M4)	ISO1996-2 (-,+)
0.0	-	4	M2	-
1.0	-	5*	M3*	+*
2.0	Z	5*	M3*	+*
3.0	Z	6*	M4*	+*
4.0	Z	6*	M4*	+*
5.0 and higher	+*	6*	M4*	+*

Situation – Clear night

*Situation in a clear night (0/8 cloud cover). Wind direction is from source to receiver with negative wind speed values indicating upwind directions. Favorable conditions are marked with a *.*

Wind Speed [m/s] at 10 m	NF S31-85 (–,-,Z,+,++)	CONCAWE (1-6)	IMA (M1-M4)	ISO1996-2 (-,+)
-5.0	-	2	M1	N/A
-4.0	Z	2	M1	N/A
-3.0	Z	3	M1	N/A
-2.0	Z	4	M1	N/A
-1.0	+*	4	M1	N/A
0.0	+*	5*	M4*	N/A
1.0	+*	6*	M4*	N/A
2.0	++*	6*	M4*	+*
3.0	++*	6*	M4*	+*

Messungen in Österreich

- Measurement position: 25, 50, 100 and 200 m perpendicular to railway line
- Railway track ~1 m above agriculture area, microphones 4 m above ground

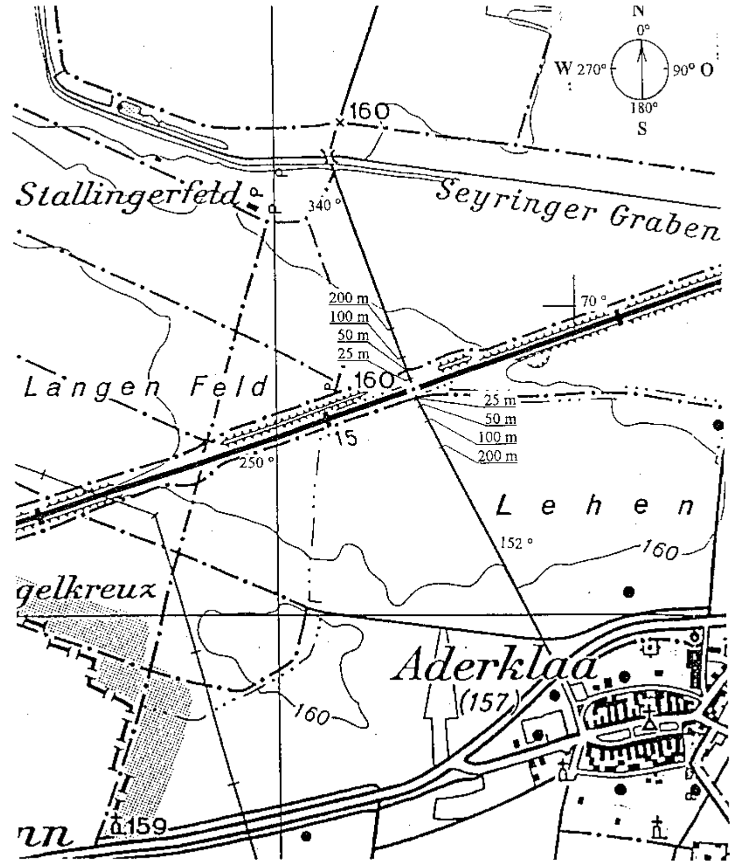


Fig.1: Measurement situation

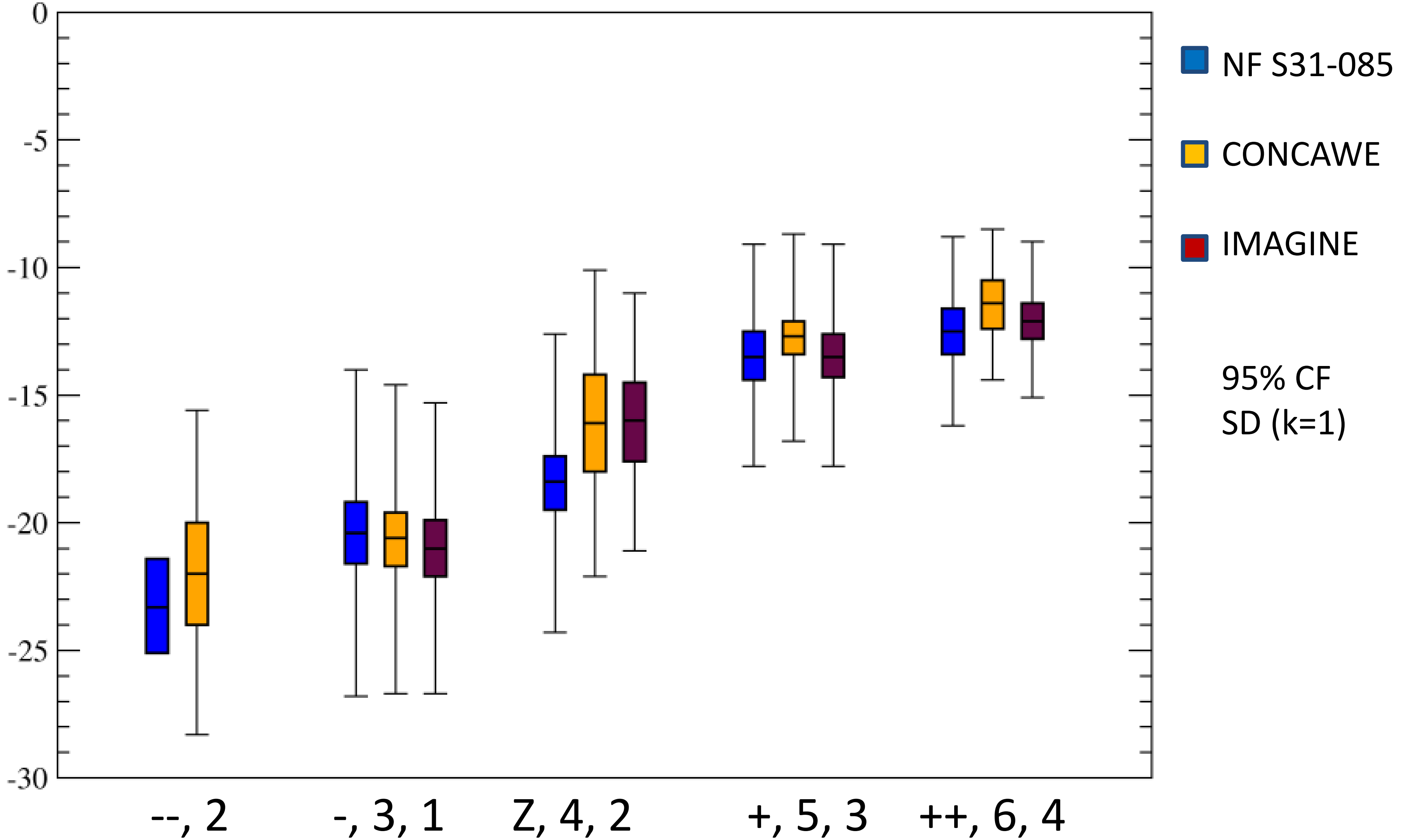
Hohenwarter D, Mursch-Radlgruber E. Nocturnal boundary layer profiles and measured frequency dependent influence on sound propagation. *Appl Acoust* 2014; **76**: 416–30.

Meteorological conditions during measurement of the sound exposure level difference $\Delta L = L_{200m} - L_{25m}$ were classified according to different methods defining meteorological classes

French NF S31-085		CONCAWE Modell		IMAGINE		ISO 1996-2	
--	-23,3	**2**	-22,0				
-	-20,4	**3**	-20,6	**1**	-21,0	**X**	-17,8
Z	-18,4	**4**	-16,1	**2**	-16,0		
+	-13,5	**5**	-12,7	**3**	-13,5	**0**	-15,6
++	-12,5	**6**	-11,4	**4**	-12,1		

Kirisits C, Hohenwarter D. Variations and uncertainties for measurements due to meteorological conditions - Existing guidelines and practical applications Classification into propagation conditions. In: Proceedings of the International Conference on Acoustics AIA-DAGA. Meran, 2013: 505–7.

Sound level difference for different meteorological classes



Verkehrsinfrastrukturforschung F&E
Dienstleistungen - 3. Ausschreibung (VIF2013)

ACUMET

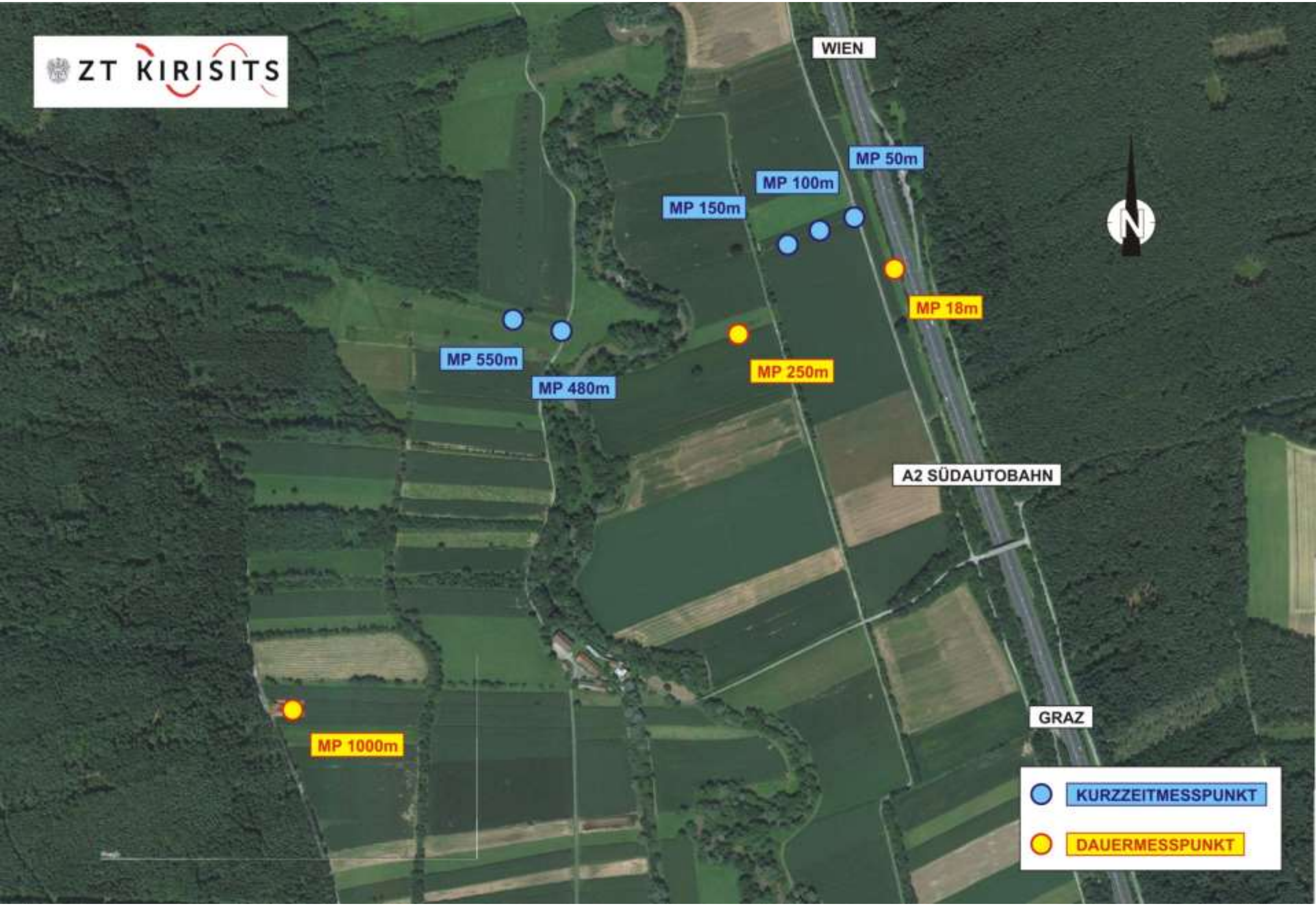
Analyse und Berücksichtigung des Einflusses der Meteorologie auf die Schallausbreitung von Bahn- und Straßenverkehrslärm

Projektpartner: ZT KIRISITS, BOKU Universität für Bodenkultur Wien

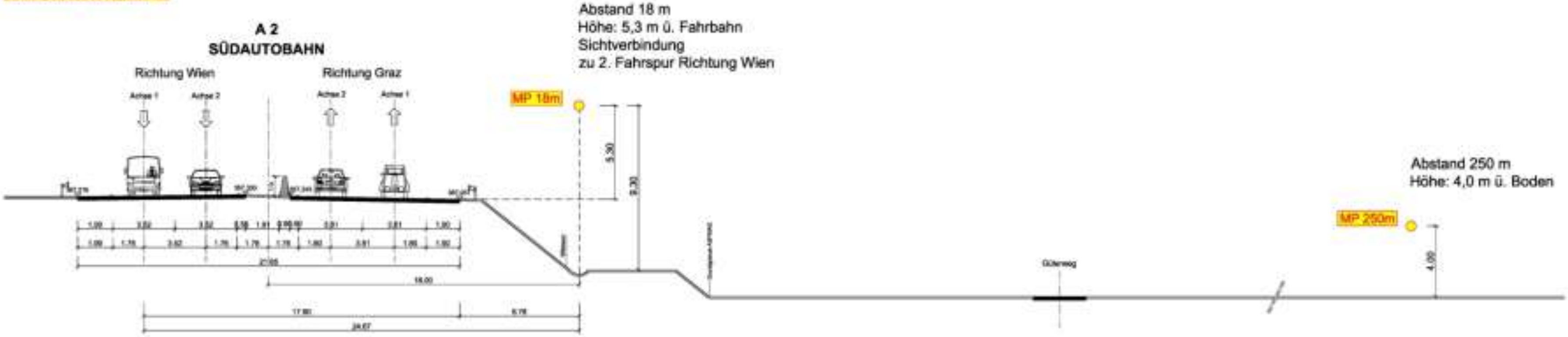
Subauftragnehmer: tgm Die Schule der Technik

Messungen

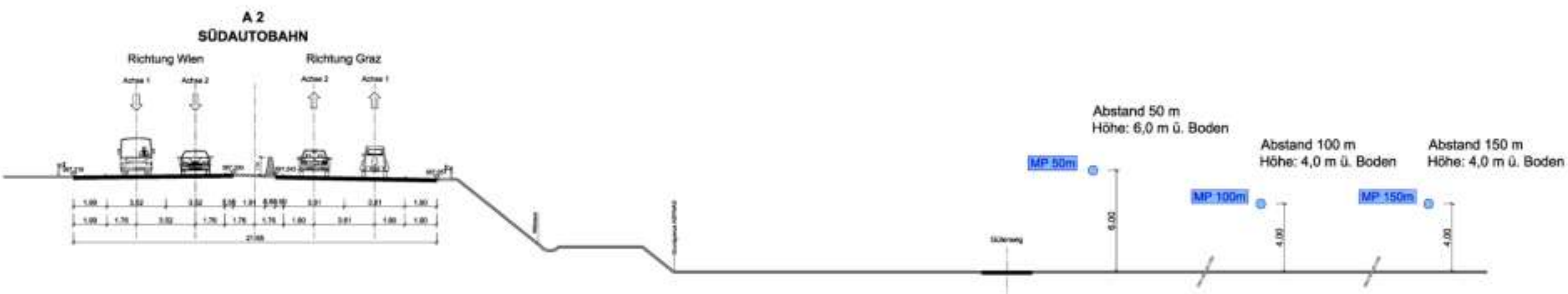
ZT KIRISITS
WIEN
MESSKORRIDOR
A2 SÜDAUTOBAHN
GRAZ
STEIERMARK
BURGENLAND
Kitzladen
Buchschachen
Buchschachner Mühlhäuser
Buchschachner Berghäuser
Wagendorf
Oberlungitz
Unterlungitz
Fersten
Trulitsch
Oberbergen
Markt Allhau
Süd Autobahn
Gemeindestraße
L446
L229
A2

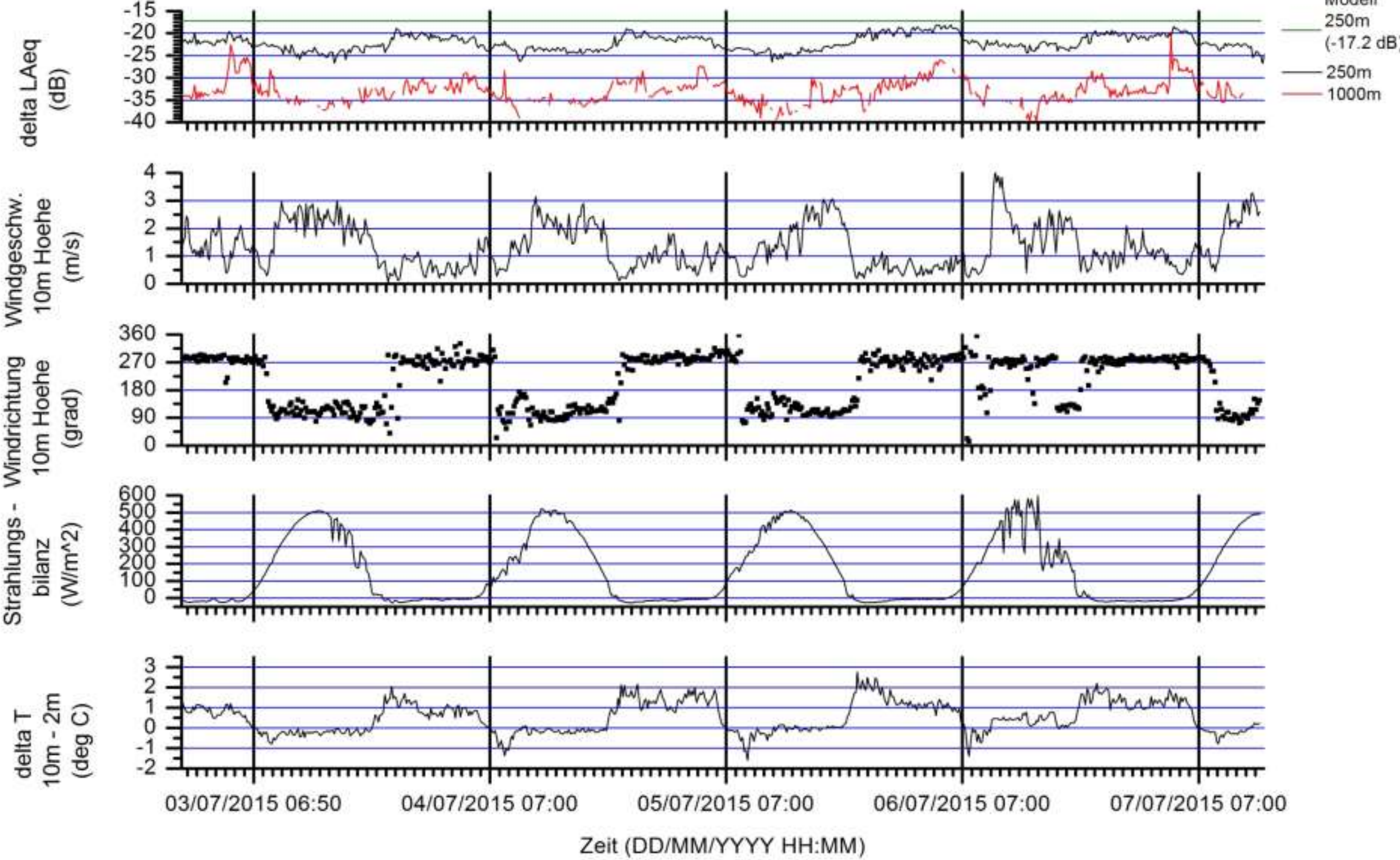

ZT KIRISITS
WIEN
MP 50m
MP 100m
MP 150m
MP 18m
MP 550m
MP 480m
MP 250m
A2 SÜDAUTOBAHN
GRAZ
MP 1000m
KURZZEITMESSPUNKT
DAUERMESSPUNKT

DAUERMESSPUNKTE



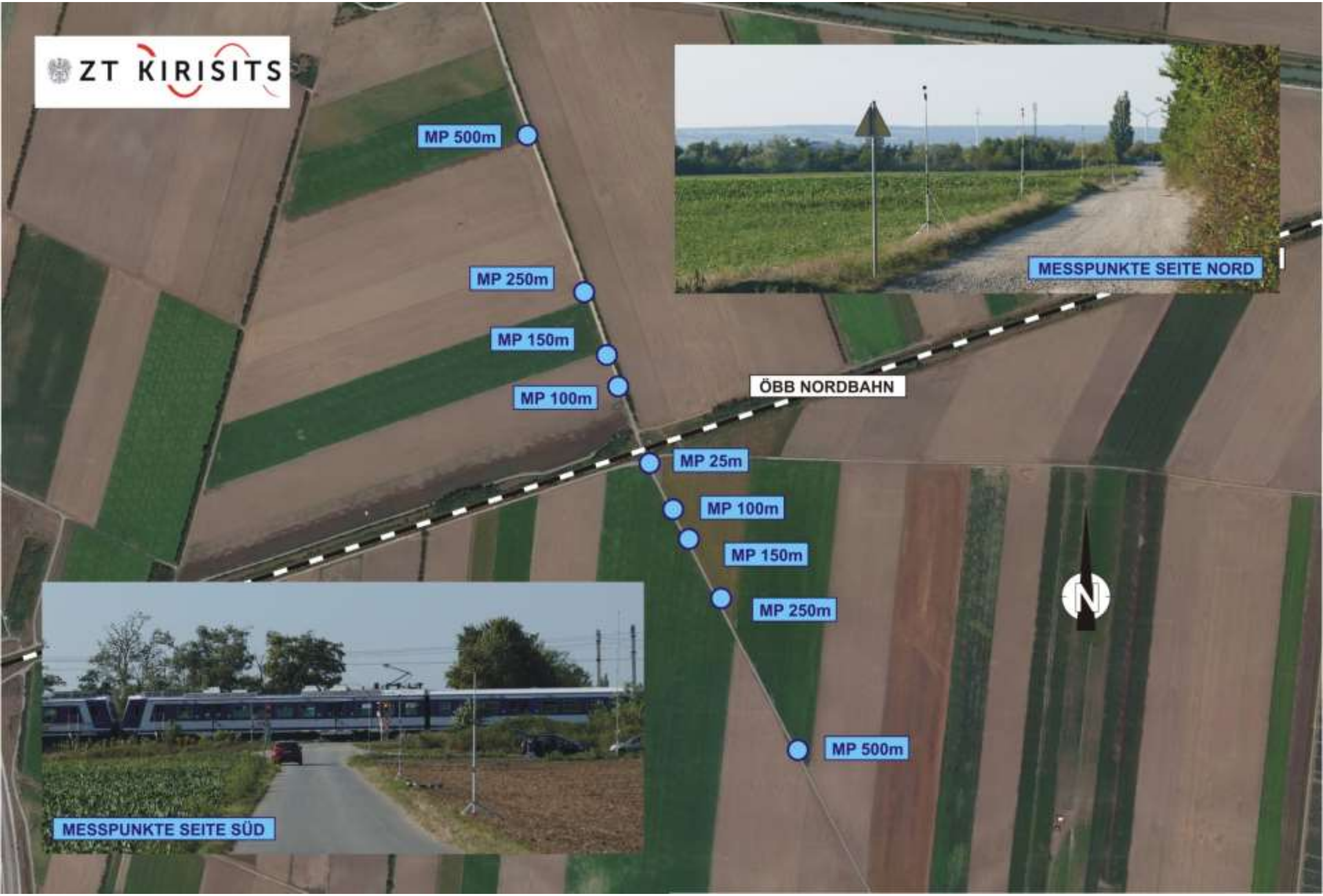
KURZZEITMESSPUNKTE





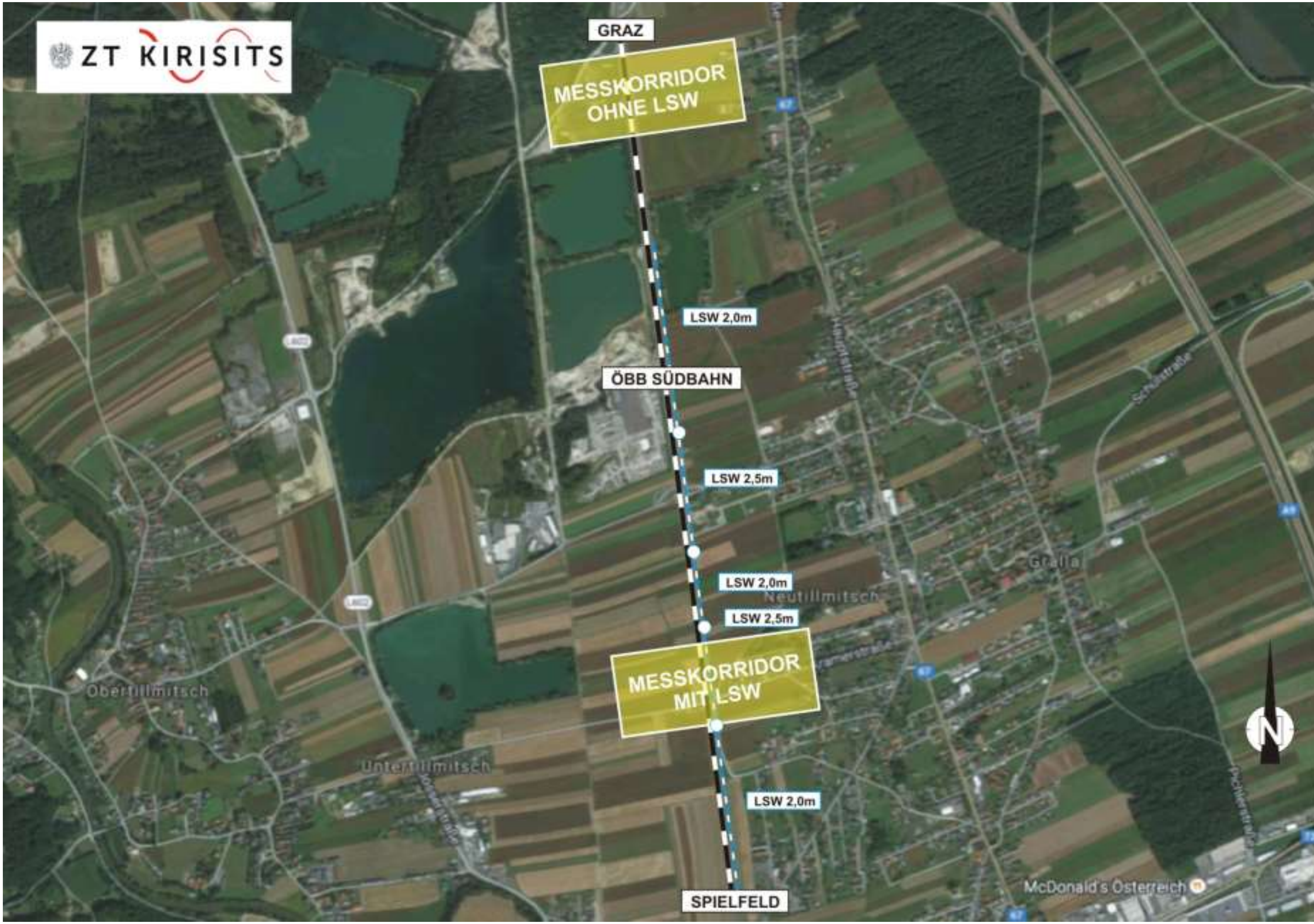
Modell
250m
(-17.2 dB)
250m
1000m
delta LAeq (dB)
Windgeschw. 10m Hoehe (m/s)
Windrichtung 10m Hoehe (grad)
Strahlungs - bilanz (W/m^2)
delta T 10m - 2m (deg C)
03/07/2015 06:50
04/07/2015 07:00
05/07/2015 07:00
06/07/2015 07:00
07/07/2015 07:00
Zeit (DD/MM/YYYY HH:MM)

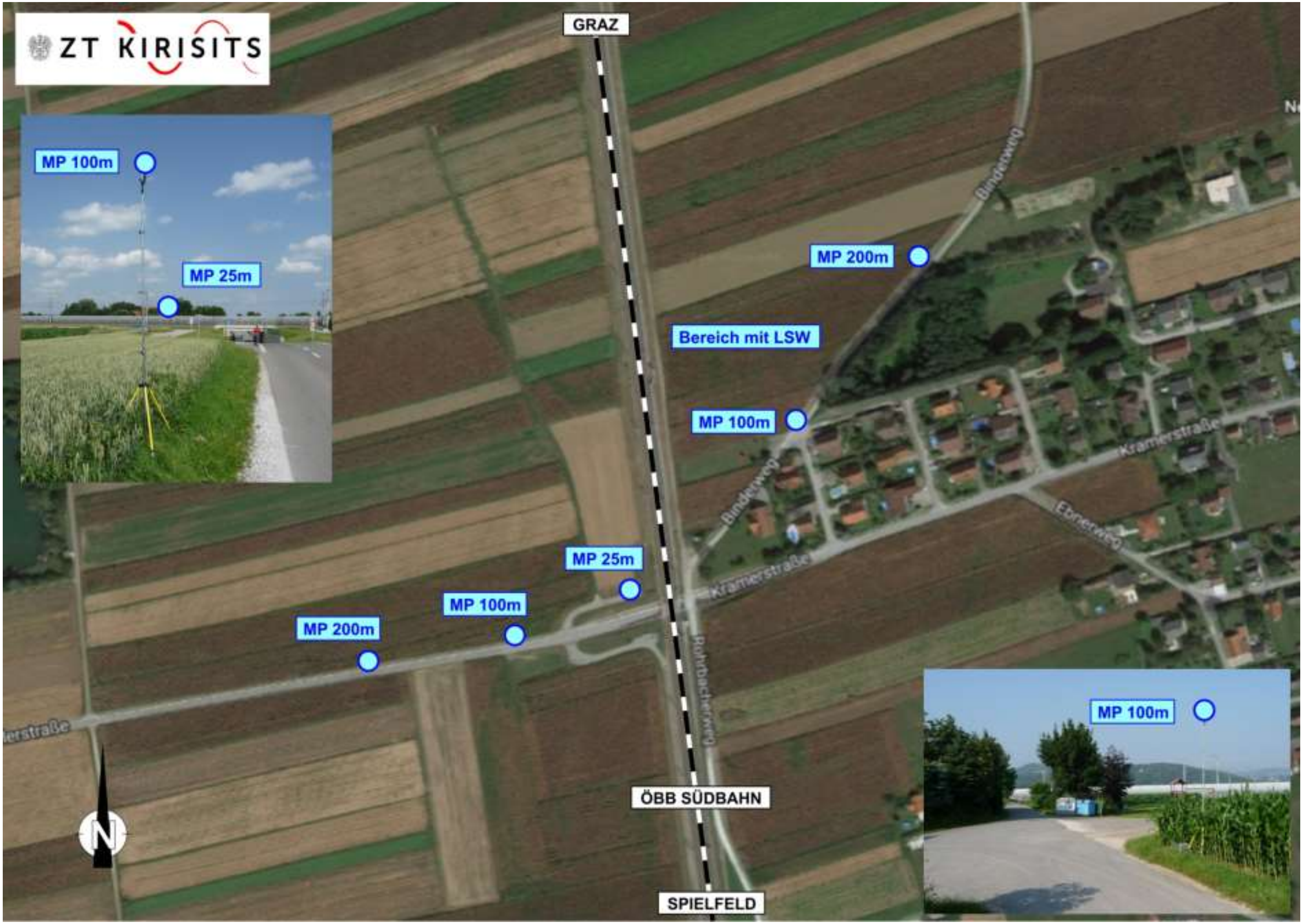

ZT KIRISITS
L6
N
BRECLAV
Abzugsgraben
SÜßENBRUNN
Deutsch-Wagram
MESSKORRIDOR
ÖBB NORDBAHN
WIEN
8
L3019
Aderklaa
Golf Club
Wien-Süßenbrunn
7
Angerner
Straße
L3023
BREITENLEE


ZT KIRISITS
MP 500m
MP 250m
MP 150m
MP 100m
ÖBB NORDBAHN
MP 25m
MP 100m
MP 150m
MP 250m
MP 500m
MESSPUNKTE SEITE NORD
MESSPUNKTE SEITE SÜD
N

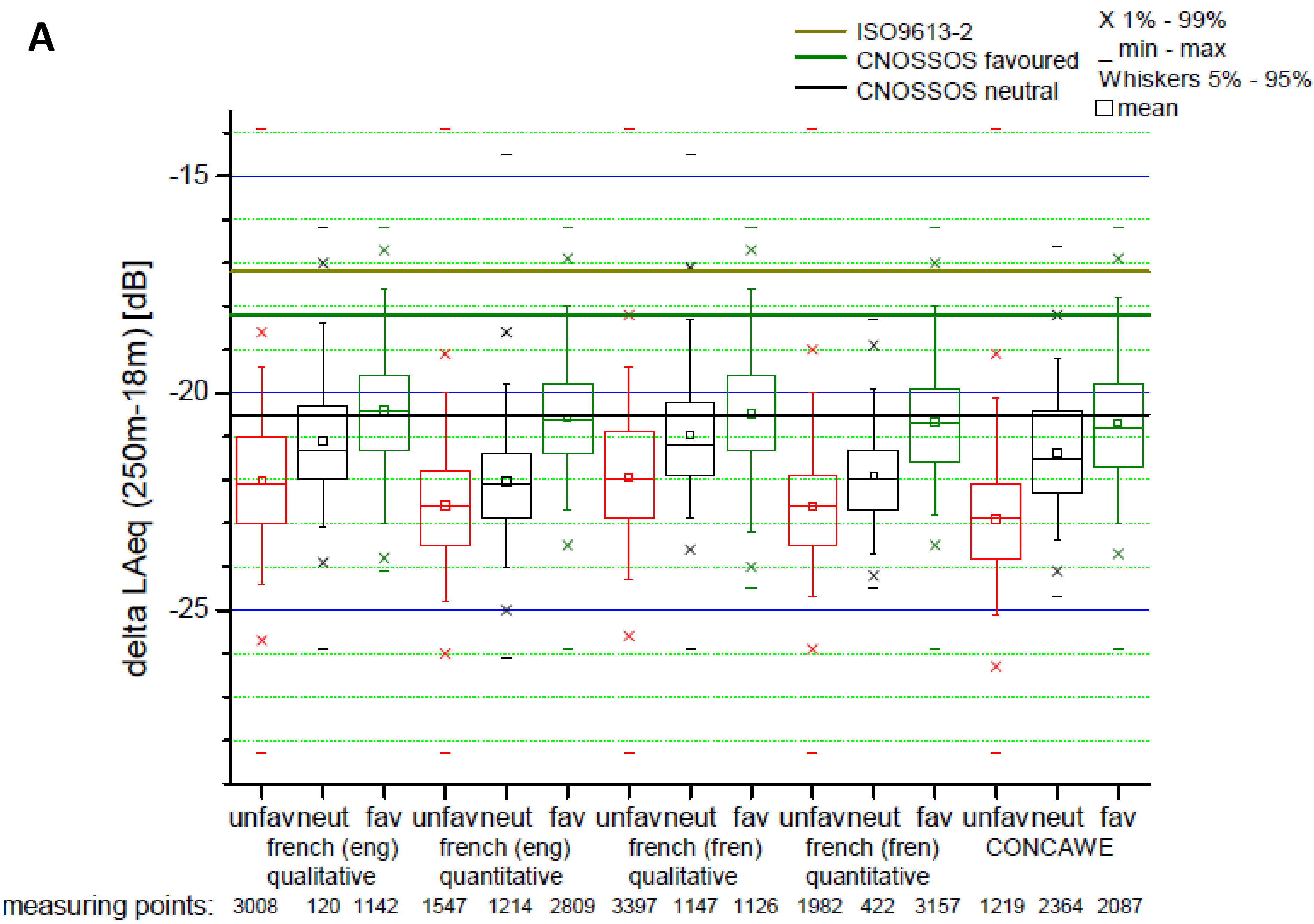

ZT KIRISITS
N
WIEN
A2 SÜDAUTOBAHN
MESSKORRIDOR
Schildbachweg
Grazer Straße
Remise
GRAZ


ZT KIRISITS
MP 200m
MP 200m
MP 34m
MP 34m
MP 34m
MP 34m
MP 200m
MP 200m
A2 SÜDAUTOBAHN
WIEN
GRAZ
A2
N

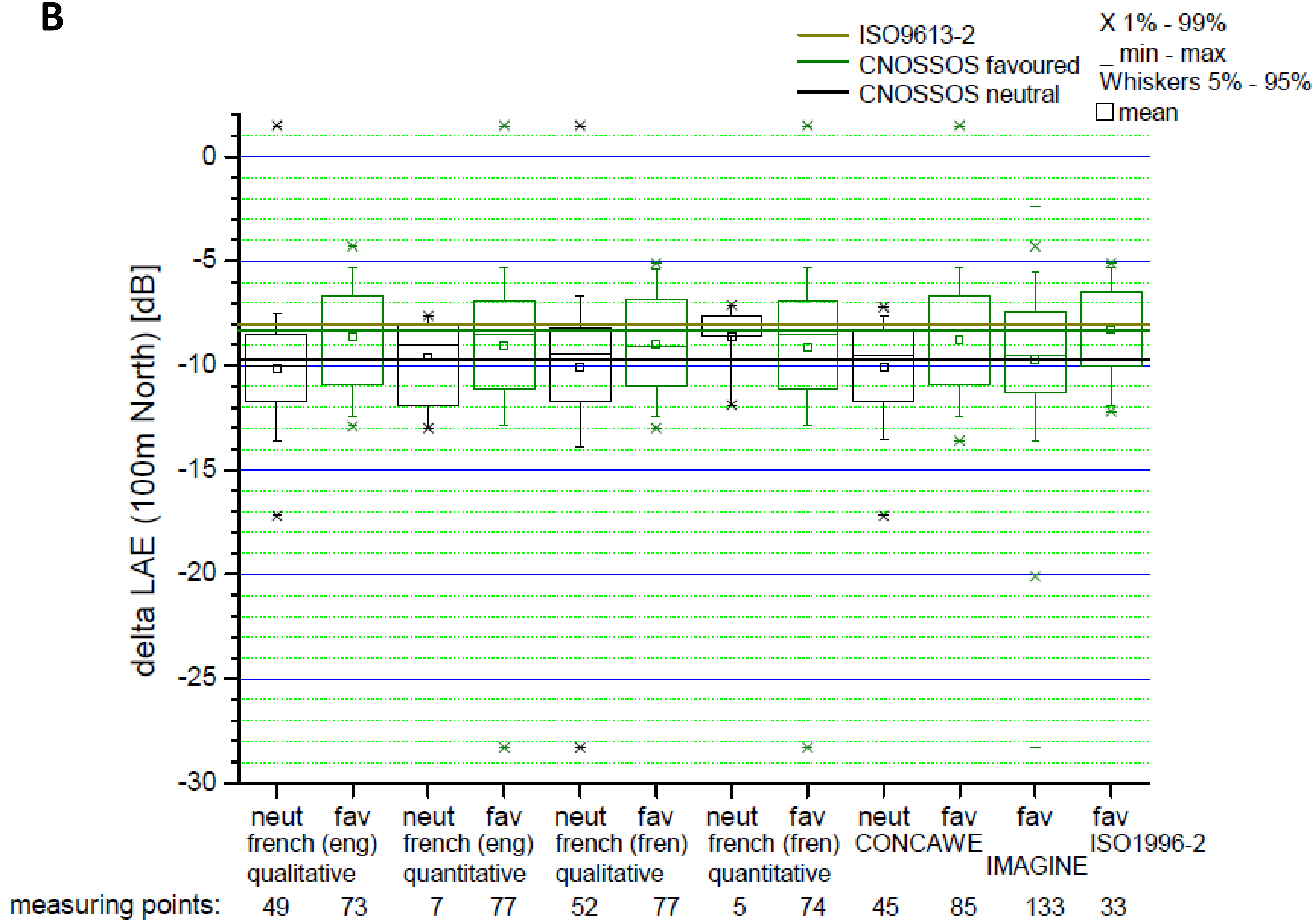

ZT KIRISITS
GRAZ
MESSKORRIDOR
OHNE LSW
LSW 2,0m
ÖBB SÜDBAHN
LSW 2,5m
LSW 2,0m
LSW 2,5m
MESSKORRIDOR
MIT LSW
LSW 2,0m
SPIELFELD
Neutillmitsch
Obertillmitsch
Untertillmitsch
Gralla
McDonald's Österreich
N


ZT KIRISITS
GRAZ
MP 100m
MP 25m
MP 200m
Bereich mit LSW
MP 100m
Kramerstraße
Ebnerweg
MP 25m
Kramerstraße
MP 100m
MP 200m
ÖBB SÜDBAHN
SPIELFELD
MP 100m
N

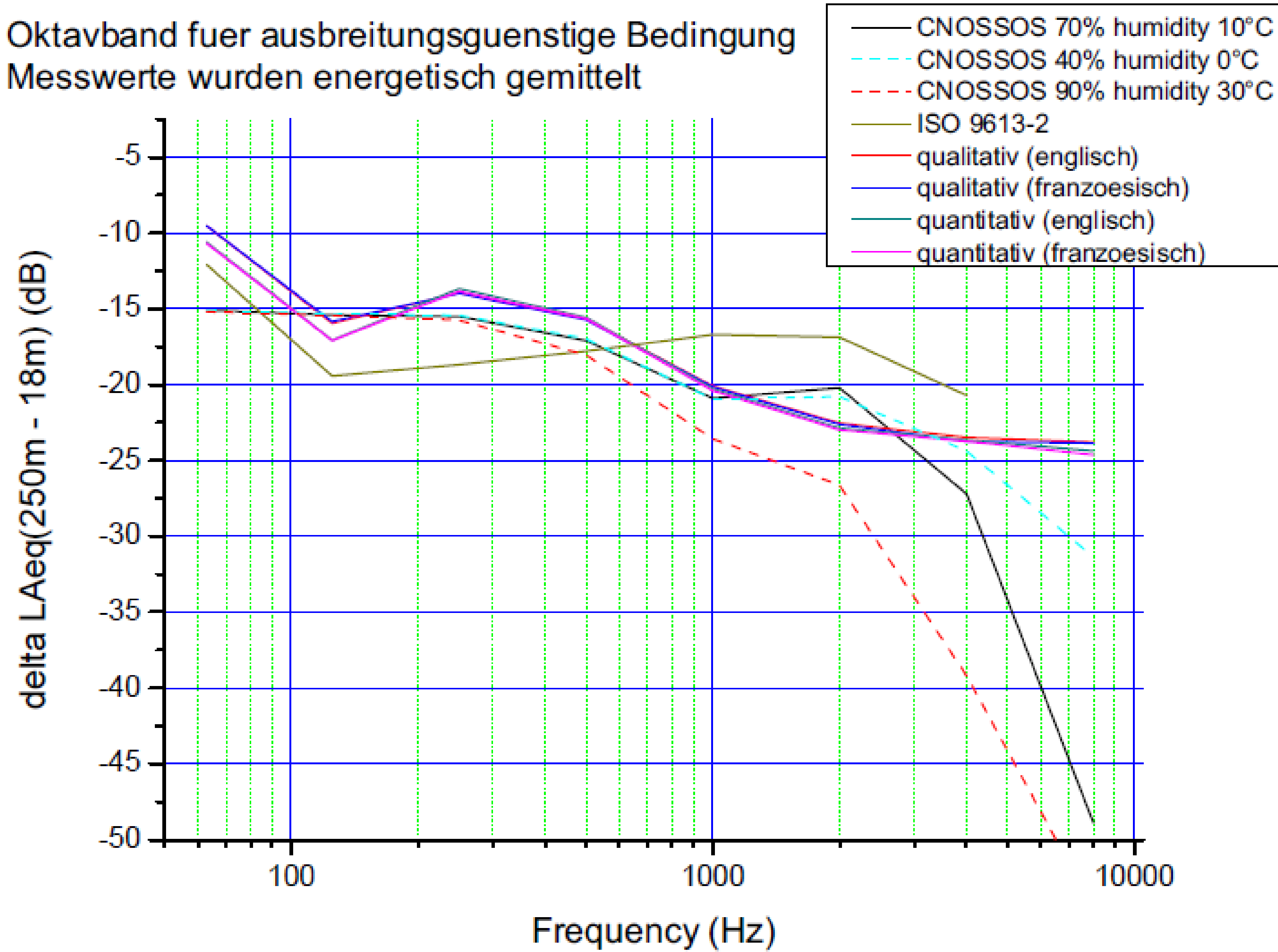
Klassifizierung


A
ISO9613-2
CNOSSOS favoured
CNOSSOS neutral
X 1% - 99%
_ min - max
Whiskers 5% - 95%
mean
delta LAeq (250m-18m) [dB]
-15
-20
-25
unfav neut fav unfav neut fav unfav neut fav unfav neut fav unfav neut fav
french (eng) qualitative
french (eng) quantitative
french (fren) qualitative
french (fren) quantitative
CONCAWE
measuring points: 3008 120 1142 1547 1214 2809 3397 1147 1126 1982 422 3157 1219 2364 2087

B



ISO9613-2
CNOSSOS favoured
CNOSSOS neutral
X 1% - 99%
_ min - max
Whiskers 5% - 95%
mean
delta LAE (100m North) [dB]
0
-5
-10
-15
-20
-25
-30
neut
fav
neut
fav
neut
fav
neut
fav
neut
fav
fav
fav
french (eng)
qualitative
french (eng)
quantitative
french (fren)
qualitative
french (fren)
quantitative
CONCAWE
IMAGINE
ISO1996-2
measuring points:
49
73
7
77
52
77
5
74
45
85
133
33


Oktavband fuer ausbreitungsguenstige Bedingung
Messwerte wurden energetisch gemittelt
CNOSSOS 70% humidity 10°C
CNOSSOS 40% humidity 0°C
CNOSSOS 90% humidity 30°C
ISO 9613-2
qualitativ (englisch)
qualitativ (franzoesisch)
quantitativ (englisch)
quantitativ (franzoesisch)
delta LAeq(250m - 18m) (dB)
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
100
1000
10000
Frequency (Hz)

Introduction of the effective sound speed gradient

Effective sound speed c_{eff} for the case of a line source:

Sound speed c: $\vec{c}_{eff}(z) = \vec{c}(z) + \vec{w}_n(z)$

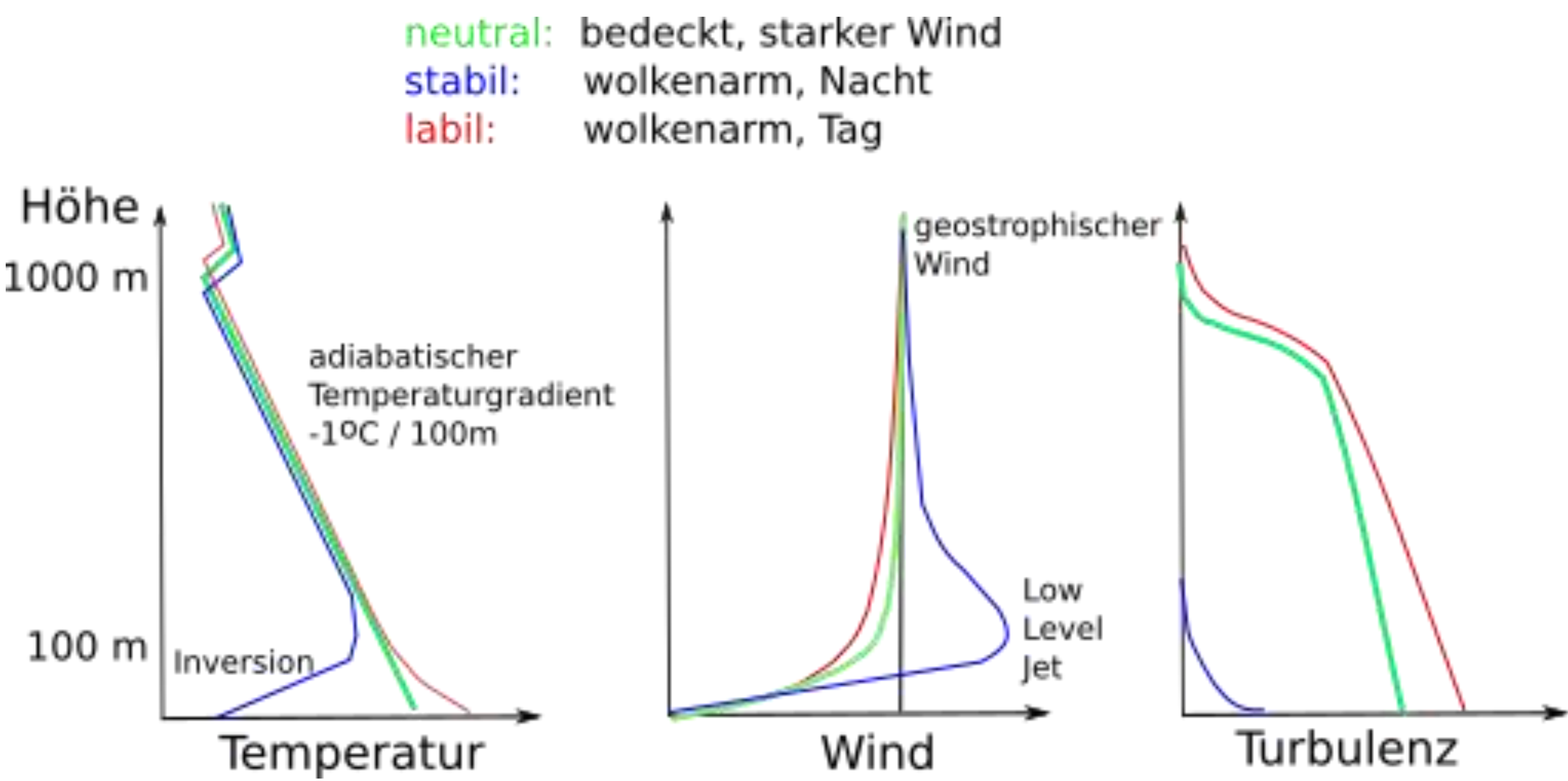
$c = \sqrt{\chi R T (1 + \eta q)}$ $\chi = c_p / c_v \approx 1{,}4$

R gas constant, T temperature (Kelvin) $T = T_0 + \Delta T$

$\eta = 0{,}511$; q=mass of vapor/mass of dry air

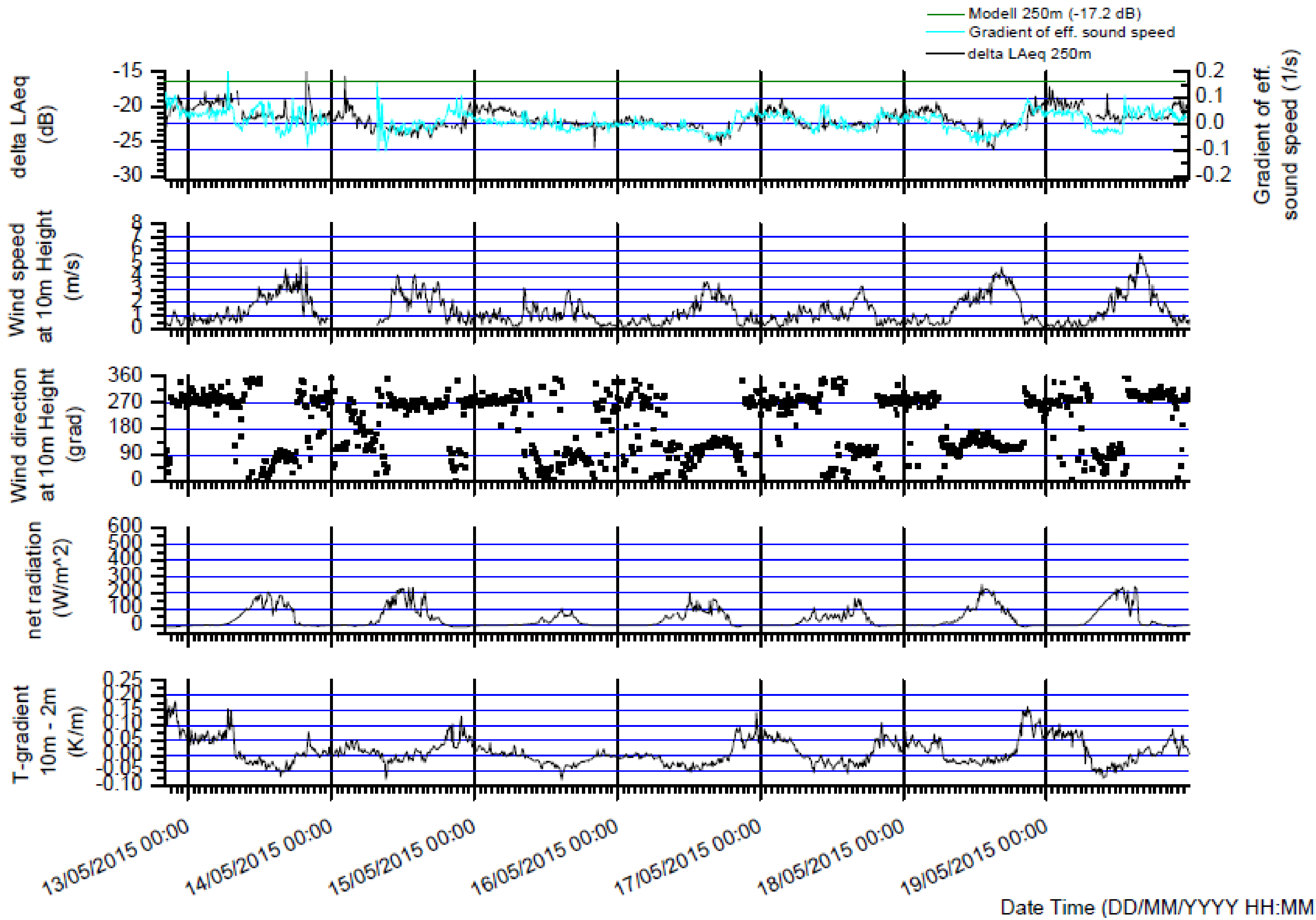
$$c = c_0 \left[1 + \frac{1}{2} \left(\frac{\Delta T}{T_0} + \eta \Delta q \right) \right] \qquad \frac{\Delta c_{eff}}{\Delta z} = \frac{c_0}{2 T_0} \frac{\Delta T}{\Delta z} + \frac{c_0 \eta}{2} \frac{\Delta q}{\Delta z} + \frac{\Delta w_n}{\Delta z}$$

D. Keith Wilson, The sound speed gradient and refraction in the near-ground atmosphere, JASA 113(2), Feb. 2003, p. 750-757



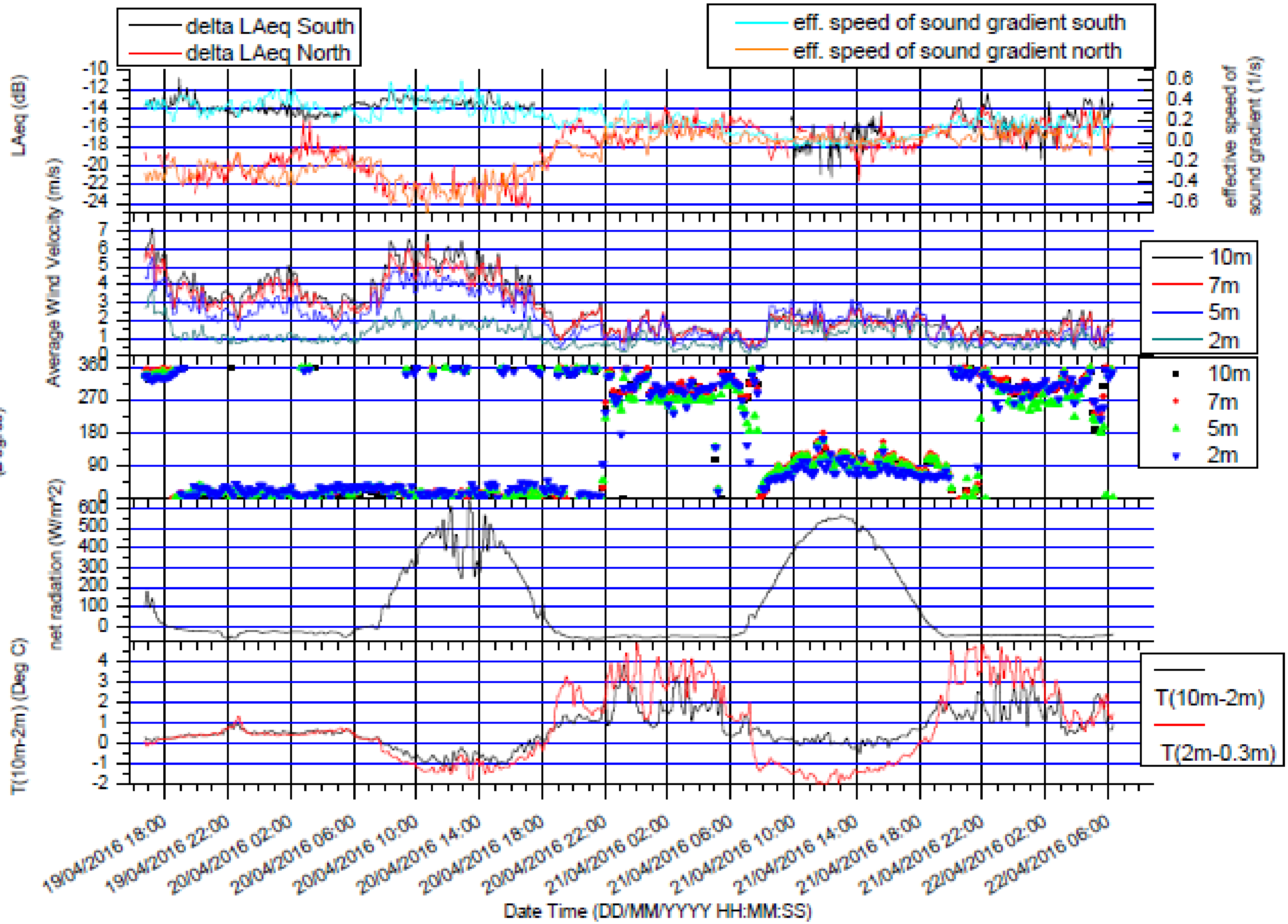
$$Grad_c = \frac{\partial \langle c(z) \rangle}{\partial z} \cong \frac{1}{2} \frac{\gamma R}{c_0} \frac{\partial \langle T(z) \rangle}{\partial z} + \frac{\partial \langle u(z) \rangle}{\partial z} \cos\theta$$

A



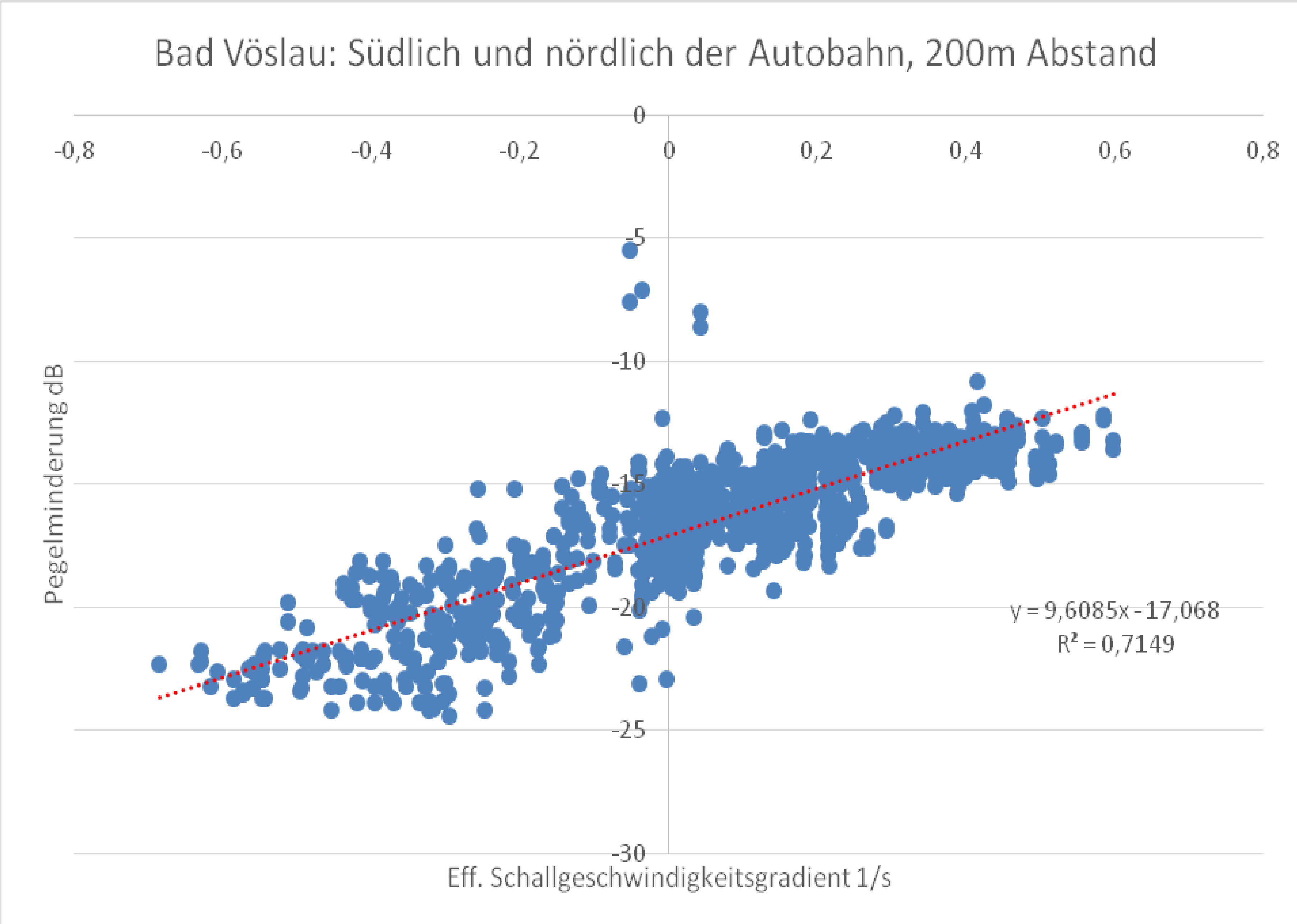
Modell 250m (-17.2 dB)
Gradient of eff. sound speed
delta LAeq 250m
delta LAeq (dB)
Gradient of eff. sound speed (1/s)
Wind speed at 10m Height (m/s)
Wind direction at 10m Height (grad)
net radiation (W/m^2)
T-gradient 10m - 2m (K/m)
13/05/2015 00:00
14/05/2015 00:00
15/05/2015 00:00
16/05/2015 00:00
17/05/2015 00:00
18/05/2015 00:00
19/05/2015 00:00
Date Time (DD/MM/YYYY HH:MM)

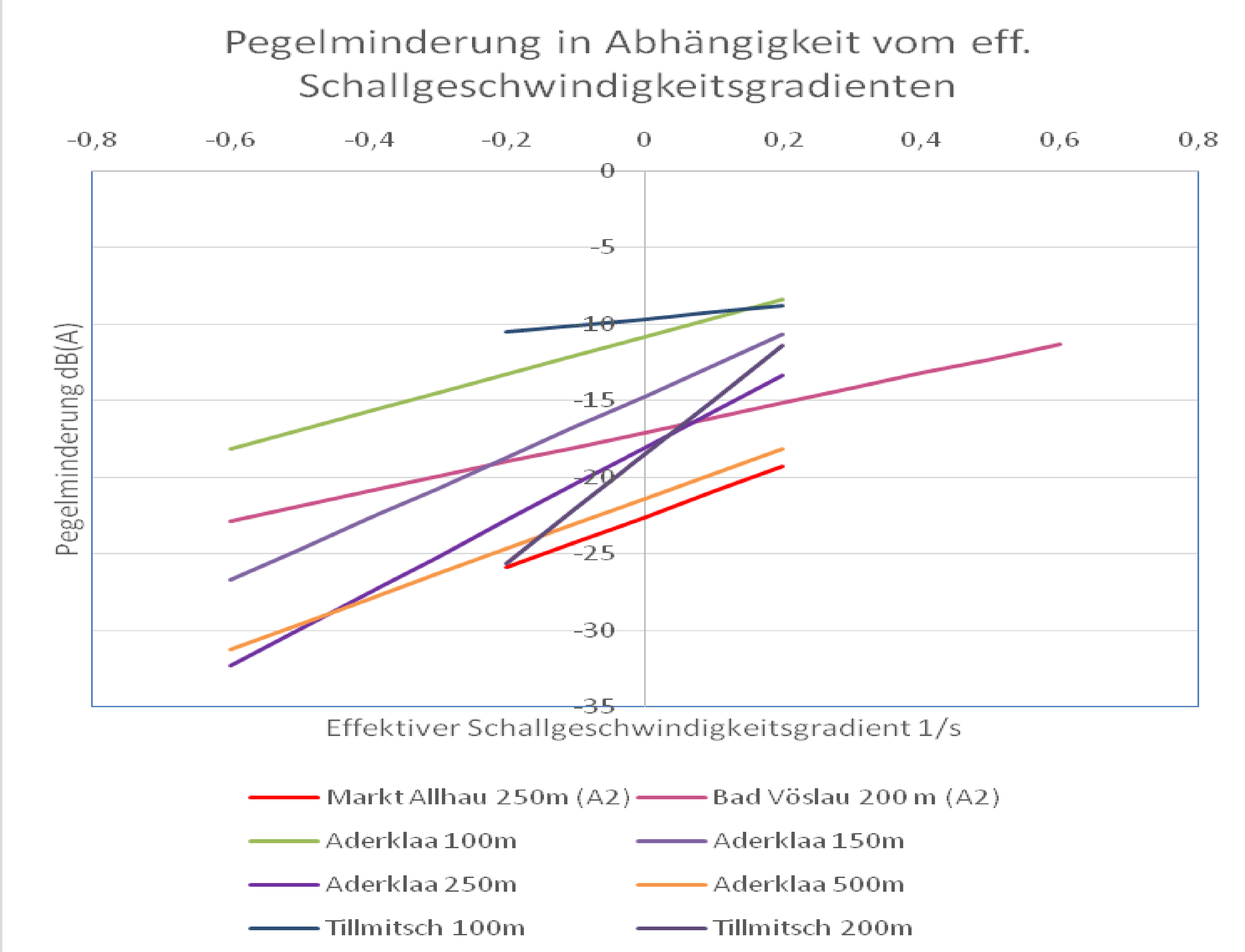
C


delta LAeq South
delta LAeq North
eff. speed of sound gradient south
eff. speed of sound gradient north
LAeq (dB)
effective speed of sound gradient (1/s)
Average Wind Velocity (m/s)
10m
7m
5m
2m
Wind direction 0° favourable for South (Degree)
net radiation (W/m^2)
T(10m-2m) (Deg C)
T(10m-2m)
T(2m-0.3m)
Date Time (DD/MM/YYYY HH:MM:SS)

c

	250 m in [dB]
Berechnete Werte nach RVS 04.02.11	- 12
Gesamt	-16,6 ± 2,9
Gradc>0	-15,1 ± 1,7
Gradc>0,1	-14,5 ± 1,4
Gradc>0,2	-14.0 ± 1,1


Bad Vöslau: Südlich und nördlich der Autobahn, 200m Abstand
0
-5
-10
-15
-20
-25
-30
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4
0,6
0,8
Pegelminderung dB
y = 9,6085x - 17,068
R² = 0,7149
Eff. Schallgeschwindigkeitsgradient 1/s


Pegelminderung in Abhängigkeit vom eff. Schallgeschwindigkeitsgradienten
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4
0,6
0,8
0
-5
-10
-15
-20
-25
-30
-35
Pegelminderung dB(A)
Effektiver Schallgeschwindigkeitsgradient 1/s
Markt Allhau 250m (A2)
Bad Vöslau 200 m (A2)
Aderklaa 100m
Aderklaa 150m
Aderklaa 250m
Aderklaa 500m
Tillmitsch 100m
Tillmitsch 200m

Vielen Dank für die Aufmerksamkeit

Besonderer Dank an die Projektpartner:

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