The verification of SBL models by mobile SODAR measurements

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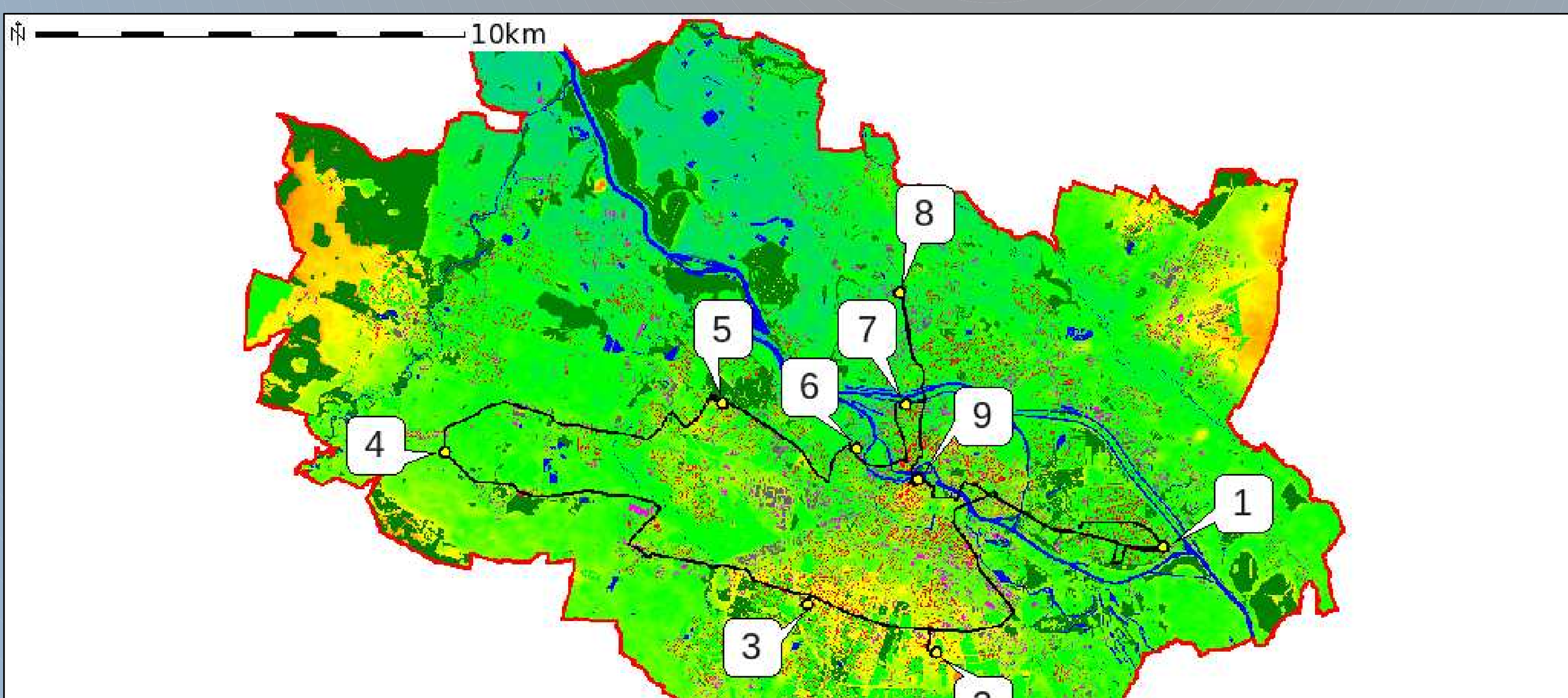
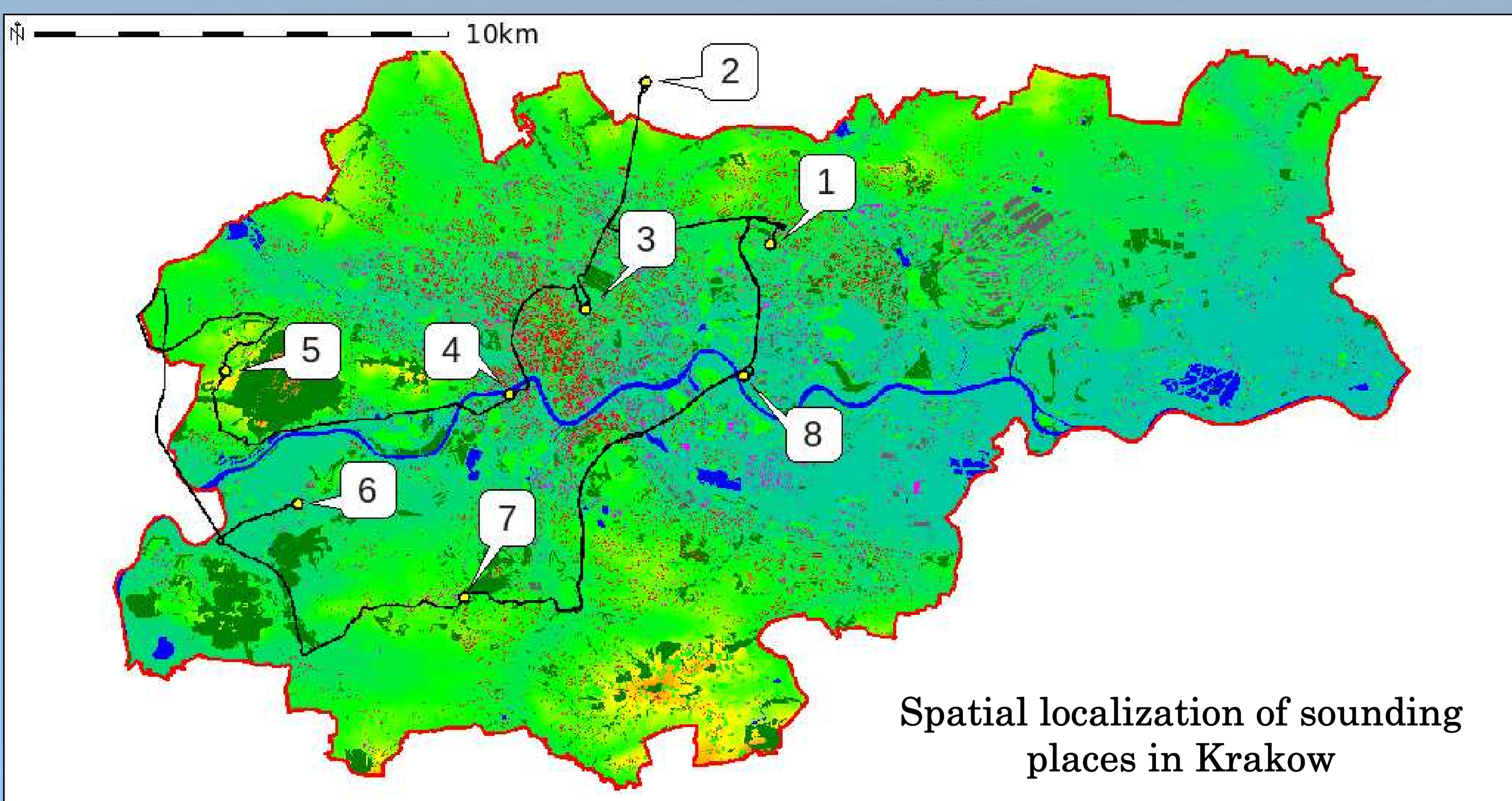
Models of atmospheric pollutant transport need information about structure of atmospheric boundary layer (ABL). The most important characteristic for such applications is parametrization of stable boundary layer (SBL) and mixing layer height (MH). Recently many different scheme was employed to calculate SBL height, but there are many problems with implication these models in environmental studies. Remote sensing of the atmospheric boundary layer using acoustic sounder provides an opportunity to asses the mixing height based on analyzing sodar echo strength. During the night, with a steady state of stable boundary layer, mixing height is associated with a range of inversion layer. In the present study, an attempt is made to assess the stable boundary layer height over urban area based on six different schemes. Furthermore, the relationship of mixing height form sodar measurement and models is examined. The data gathered during field experiment in Wroclaw and Krakow are employed for the evaluation of models The evaluation of models employing data gathered during field experiment in Wroclaw and Krakow

The data gathered during a field experiment conducted in Wrocław and Kraków were chosen for validating parametrization schemes. The measurement points were located at fixed locations throughout the cities. These points were selected in order to obtain the data for different land use categories



Spatial localization of sounding places in Wrocław



Spatial localization of sounding places in Krakow

Stable Boundary Layer models

In recent years many works have been done in parametrization of MH, on the base of direct measurements or involving different schemes (Baklanov et al., 2008) There are two main approaches: a) profile data about temperature, humidity, wind speed; b) surface turbulence variables. Several parametrization for MH during stable condition have been proposed. Many models for SBL height are semi-empirical and their university is not a priori guaranteed for different location. In these studies, six of simple models (Table 1) were examined.

Table 1. Models equations

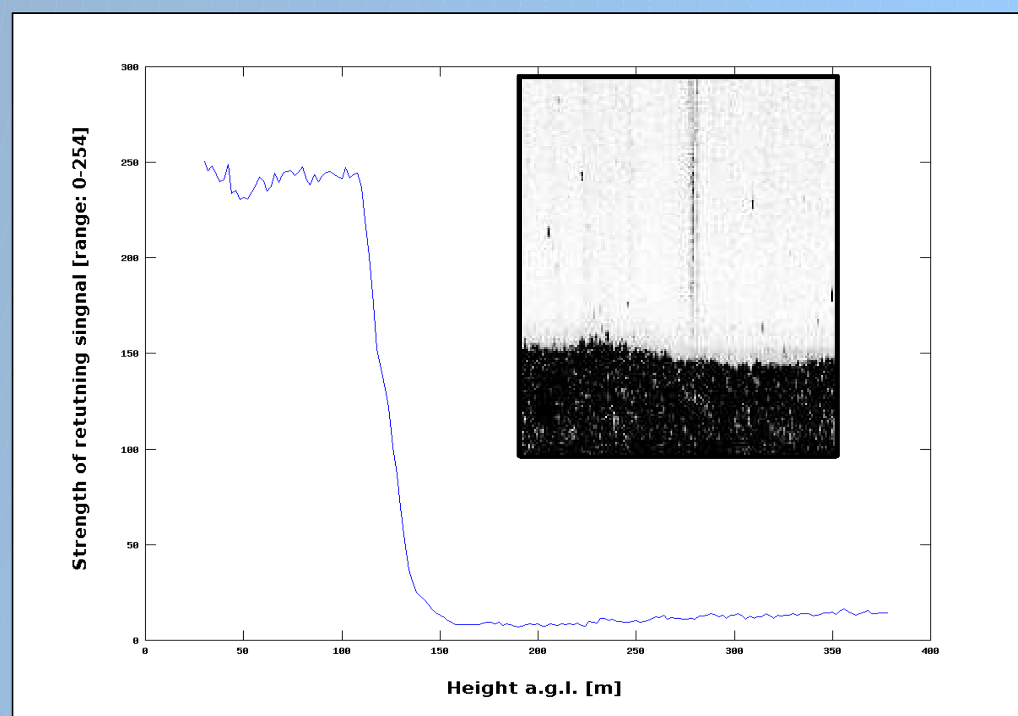
Model	Equation	Reference
Model 1	(1) $h=0.4\cdot\sqrt{\frac{u_*\cdot L}{f}}$	Zilitinkevich S., 1972
Model 2	(2) $h=2300.0\cdot u_*^{1.5}$	Venkatram A., 1980
Model 3	(3) $h=u_*\cdot\sqrt{\frac{2}{f\cdot N}}$	Ventakram A., 1980
Model 4	(4) $h=0.43\cdot\left(\frac{u_*\cdot L}{f}\right)^{0.5}+29.3$	Arya S. P. S., 1981
Model 5	(5) $h=L\cdot\frac{0.3\cdot u_*}{\lvert f\rvert\cdot L}\cdot\frac{1.0}{1.0+1.9\frac{h}{L}}$	Nieuwstadt F. T. M., 1981
Model 6	(6) $\left(\frac{f\cdot h}{0.5\cdot u_*}\right)^2+\frac{h}{10\cdot L}+\frac{N\cdot h}{20\cdot u_*}+\frac{h\lvert f\rvert^{0.5}}{(u_*\cdot L)^{0.5}}+\frac{h\lvert N\cdot f\rvert^{0.5}}{1.7\cdot u_*}=1$	Zilitinkevitch S., Mironov D., 1996
Model 7	(7) $h=\frac{0.74\cdot u_*}{\lvert f\rvert\sqrt{1+\frac{0.4^2\cdot u_*\left(1+0.25*\frac{L\cdot N}{u_*}\right)}{0.74^2\cdot\lvert f\rvert\cdot L}}}$	Zilitinkevich S. et al., 2002
where: h–mixing height , u*–friction velocity, L–Monin-Obukhov length , N– Brunt–Vaisala frequency, f – Coriolis factor.		

Mobile vertical monostatic Doppler SODAR, model 1DDS – the tool for acoustic sounding of atmospheric boundary layer.

Operating parameters of SODAR 1DDS

Weight	about 50 kg (about 200 kg with trailer)
Electric power at the speaker's input	400 W
The frequency of the sound signal emitted	4000 Hz
The maximum range of probing	380 meters above the ground
Spatial sampling resolution	2 m (175 samples in a range of 350 m)
Sampling Frequency	0.5 Hz (samples are collected every 2s)

In order to objectify and improve analyzing of SODAR records, the processing of sodar data have been automated. Removing the signal interferences and determining the height of the inversion was realized as a script in GNU Octave system (Eaton, 2002). This script reads SODAR registration records and removes the vertical noise patterns. The inversion height was calculated based on the returning signal strength curve.



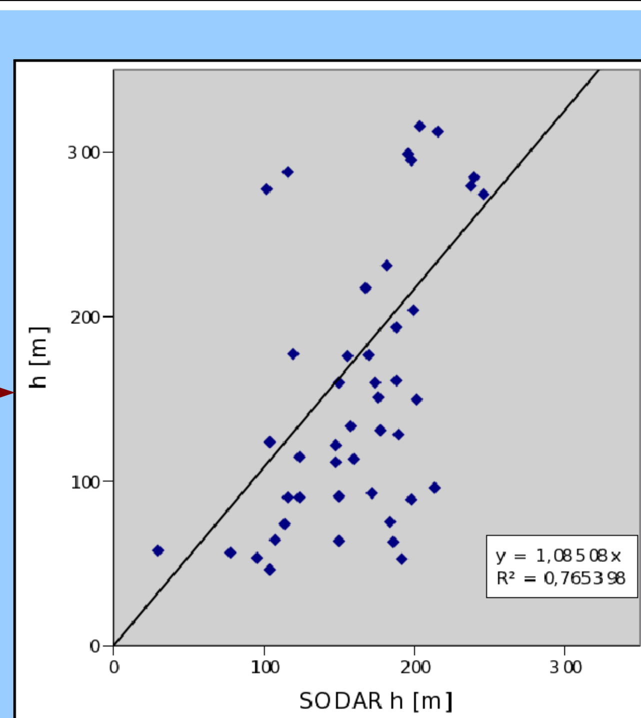
Example of raw and processed SODAR data

The results of parametrization formulas were compared with inversion height measured during mobile sodar sounding. Measurements carried out during the survey session in Wroclaw and Krakow, has produced 51 data about inversion height, which were used for further analysis. The results of the comparison are presented in table no. 2.

Table 2. The relationships between inversion height calculated and measured by sodar

Model no.	Differences (model, SODAR): minimum	maximum	average	STD	R
1	60,95	928,50	400,90	214,66	0,48524
2	−93,75	1799,78	487,24	570,69	0,53946
3	−84,16	735,74	222,15	229,37	0,55725
4	109,22	1035,98	472,35	231,07	0,48524
5	300,35	794,67	607,86	119,42	0,00724
6	−139,41	275,45	18,26	101,10	0,55624
7	4,71	1332,39	498,58	385,54	0,55907

The relationship of mixing layer height calculated from the formula 6 and obtained from the acoustic survey is shown in this figure.



SUMMARY

The stable boundary layer height was calculated using NOAA gridded data and surface measurement of temperature and wind speed. The direct measurement involving mobile mini-SODAR were used to estimate height of layers in areas with different types of land-use. The cases with well-defined stable boundary layer depth were used for detail analyses.

According to the verification of simple diagnostic models carried out with direct measurements of mixing height during stable condition, the best compliance is obtained for the model no. 6, proposed by Zilitinkevitch and Mironov (Zilitinkevitch, and Mironov, 1996). In general, other formulas performed poorly and often grossly overestimated the stable boundary layer height. The above study indicated that the inversion height was significantly different depending on the land-use cover and distance from the densely built-up areas. Therefore, using data from only a single site can provide incomplete information.

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