5.06 MEASUREMENTS AND VALIDATION OF PARAMETRIC SCHEMES. RECENT RESULTS, CRACOW EXPERIMENT / IN THE FRAMEWORK OF COST – ACTION 715.

J. Godłowska, A. M. Tomaszewska, W. Rozwoda, J. Walczewski, J. Burzyński
The Institute of the Meteorology and Water Management, Division for the Remote Sensing, Cracow, Poland

INTRODUCTION

In the framework of COST 715 two extensive measurement periods were conducted simultaneously in cities of Katowice and Cracow, Poland (20-25 08.2002 and 10-18 06.2003). The cities influence on the ABL, especially on its MH, was investigated. The measurement sites are located in the city areas. One Urban Meteorological Station is Cracow Czyżyny. This station is located in the middle of the city between two main centres of urbanisation (Old centre of Cracow and new industrial part Nowa Huta), in the green district of the city, on the terrain of the older airport of Cracow. The area is flat, surrounded by numerous trees and bushes. The nearest flat buildings are located more than 300 meters away. The set of devices consisted of two monostatic sodars with Doppler analyses of vertical wind component (30 – 1000 m, second located in Katowice), one Doppler sodar for the determination of the vertical wind profile, a dust lidar, a tethered balloon (profile of wind speed, temperature, humidity), one sonic anemometer mounted 2m above the grass covered surface, a system of three pyrranometers and a semiconductor sensor to determine the heat flux. The special dedicated meteorological automatic station was responsible for the stability class determination (6 traditional classes from A to F, based on implemented, new (2003) categorization scheme dependent on calculated values of Monin- Obukchov Length L). This station measures temperature and the wind speed on the two levels 2 and 10 m each 6 sec, for the L calculations. The measurement equipment was supplemented by standard meteorological measurements in both locations and with a network of meteorological stations in the surrounding areas (also rural representative measurement).The described extended measurements were made mainly in Cracow. The standard measurements and second monostactic sodar were deployed in Katowice.

The calculations of the sensible heat flux H schemes for given location were made with use of formulas based on the Penman- Monteith resistance method with 3 different theoretical approaches (Smith, Holtslag and Van Ulden, Berkowicz and Prahm). These formulas are widely used for the flat, non-urban terrain. The results were compared with the results of measurements made with use of a ultrasonic anemometer (30 minutes moving data for every 1 minute).

The input data for the parameterisation schemes consisted of measurement results of net radiation Rn (pyrradiometr Schenk model 8111 working in 0.3 – 60 μm range with sensors directed up and down), surface temperature and temperature, relative humidity, wind speed measurements on 2m level.

The ultrasonic anemometer (R. M. Young 81000) was working (at a height 2m) with frequency 4 Hz, collecting data set of vertical wind speeds w and sonic temperature T.

MH derived from the sodar data was compared to that derived from the vertical profiles of potential temperature by tethered balloon. The results are usually high correlated. With the improved sodar algorithm, the sodar is a valuable tool to determine MH in all conditions, except the fully developed convective boundary layer with capping inversion out of the range of the sodar. The algorithm is based on the sodarogram echoes categorization analysis (*Bielak, A. et al. 1997, Walczewski 1997, Walczewski 1998, Walczewski, J. et al. 1999*).

THE RESULTS OF THE THREE SCHEMES OF DAYTIME ESTIMATES FOR THE SENSIBLE HEAT FLUX CALCULATION IN COMPARISON WITH MEASUREMENT RESULTS OF THE SONIC ANEMOMETER

TheSmith Heat Flux Scheme

The distribution of energy between sensible heat flux and latent heat flux is proportional to the total net radiation with additional dependence on the Sun elevation φ. The sensible heat flux is calculated by the Penman –Monteith resistance method (*Monteith, J. L. and Unsworth, M. H.*, 1990) with aerodynamic resistance reverse proportional to the wind speed. The surface resistance depends on the temperature and Sun elevation (*Galinski, A. E. and Thomson*, D. J. 1995, *Smith F. B.* , 1990).

The calculations were made for the Smith's height z=3m with constant c_z=188.9, u_z values were taken as 5 minutes mean values of the wind speed from the sonic anemometer. The values u_z equal to 0.01m/s were used in the calm wind condition to eliminate infinite values of aerodynamic resistance r_a.

A scatter plot of the heat flux values from the Smith daytime scheme against observed values is given in Figure 1 and statistics are given in Table 1.

	The Smith Daytime Heat Flux Scheme
n	3340
$\bar{x}$	87.34
$\bar{y}$	91.23
s_x	64.41
s_y	54.50
$\bar{y}-\bar{x}$	3.88
rms	23.41
r	0.94

Table 1. Smith daytime (φ >10^o) heat flux statistics (n=no. of values, $\bar{x}$ = mean observed (ultrasonic anemometer) value, $\bar{y}$ = mean estimated value, s_x= standard deviation of the observed value, s_y= standard deviation of the estimated value, σ= rms error and r=correlation coefficient).

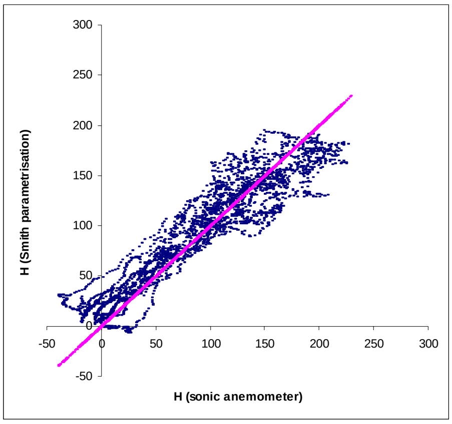


Figure 1. Scatter plot of the calculated and observed values of daytime (φ >10^o) sensible heat flux from the Smith heat flux scheme.

THE HOLTSLAG AND VAN ULDEN HEAT FLUX SCHEME

The distribution of energy between sensible heat flux and latent heat flux is made with assumption of the available energy equal to 0.9 total net radiation Rn. Sensible heat flux is taken from the Penman –Monteith resistance method with empirical parameters α and β depending on the soil moisture conditions (Holtslag, A. A. M. and Van Ulden A. P. 1983, Van Ulden, A. P. and Holtslag, A. A. M. 1985). For the moist covered surfaces $\alpha\approx1$ and $\beta\approx20W/m^2$ were found to be good estimates by Holtslag and Van Ulden. The best fit between the calculated and measured values was found with $\alpha\approx0.7$ probably because of the drought condition in Cracow in June.

A scatter plot of heat flux values from the Holtslag and Van Ulden daytime scheme against observed values is given in Figure 2 and statistics are given in Table 2.

	The Holtslag and Van Ulden Daytime Heat Flux Scheme
	α=0.7 and β=20W/m^2
n	3340
$\bar{x}$	87.34
$\bar{y}$	85.55
s_x	64.41
s_y	61.61
$\bar{y}-\bar{x}$	-1.80
rms	19.95
r	0.95

Table 2: The Holtslag and Van Ulden daytime (φ >10^o) heat flux statistics for α=0.7.

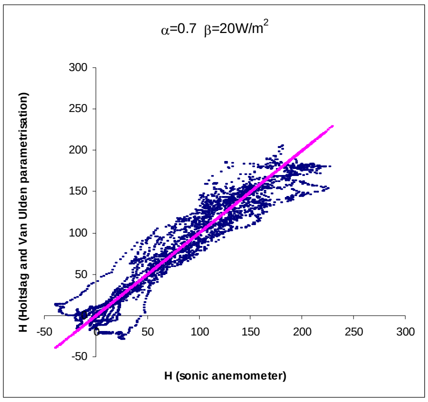


Figure 2. The scatter plot of the calculated and observed values of daytime (φ >10^o) sensible heat flux from the Holtslag and Van Ulden heat flux schemes for α=0.7

THE BERKOWICZ AND PRAHM HEAT FLUX SCHEME

The ground heat flux G is parameterized by H/3. The aerodynamic resistance used by Berkowicz and Prahm, which is based on the Monin - Obukhov similarity theory is determined by means of iteration (*Berkowicz, R. And Prahm, L. P.* 1982) Berkowicz and Prahm suggest to take the surface resistance reverse proportional to function F. This function depends on absolute net radiation values and terms A and D. These terms are determined from „integrated hourly net radiation since last recorded rainfall".

A scatter plot of heat flux values from the Berkowicz and Prahm daytime scheme against observed values is given in Figure 3 and statistics are given in Table 3.

CONCLUSIONS

The presented results show good agreement between calculated and observed values of the sensible heat flux, for all the parametrisation schemes used.

Smith parametrization method did not need any modification, while in the cases of the Holtstslag and Van Ulden method application of the values α=1 (given by authors) lead to the significant reduction of the H value. Changing of the value of parameter α (responsible for the soil moisture conditions) and application of the value α=0.7 improved the results in significant way.

It seems possible, that the too low values of the sensible heat flux, obtained by the means of Berkowicz and Prahm iteration method, are caused by the assumed values of surface resistance.

	The Berkowicz and Prahm Daytime Heat Flux Scheme
N	3340
$\bar{x}$	87.34
$\bar{y}$	62.92
s_x	64.41
s_y	48.41
$\bar{y}-\bar{x}$	-24.43
rms	33.05
r	0.96

Table 3: The Berkowicz and Prahm daytime ($\varphi > 10^o$) heat flux statistics.

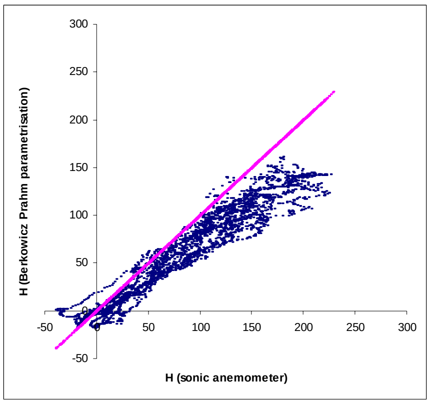


Figure 3. The scatter plot of the calculated and observed values of daytime ($\varphi > 10^o$) sensible heat flux from the Berkowicz and Prahm heat flux scheme.

COMPARISON OF THE MIXING LAYER HEIGHTS DETERMINED BY SODAR ECHOES AND BY THE VERTICAL PROFILES OF THE POTENTIAL TEMPERATURE

Two experiments were organized in Cracow, Poland, in the framework of COST-715 Action, for determination of the mixing heights with use of two different methods. The first method was the sounding of the atmosphere by tethered balloon equipped with instrumentation for measurements of wind speed, humidity, and the temperatures of dry and wet thermometers. The second method was the acoustic sounding of the atmosphere with use of the vertical sodar. This made possible to compare the mixing heights deduced from the vertical profile of the potential temperature, and from the sodar echoes (Figure 4). Data from the measurements with use of these two methods were collected at the time of each balloon sounding. In the cases in which character of data was different for the balloon ascent and descent, both cases were analysed separately. When the balloon sounding ceiling was lower than the mixing height derived from sodar data, the case was excluded from the analysis.

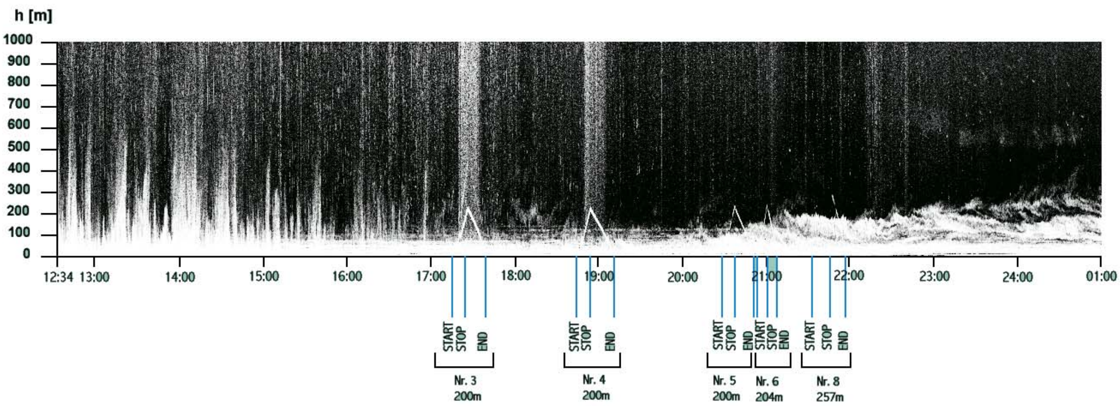
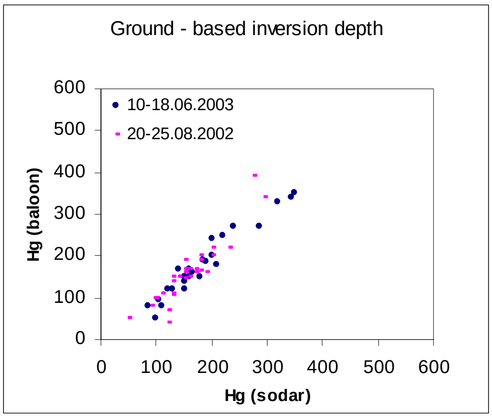
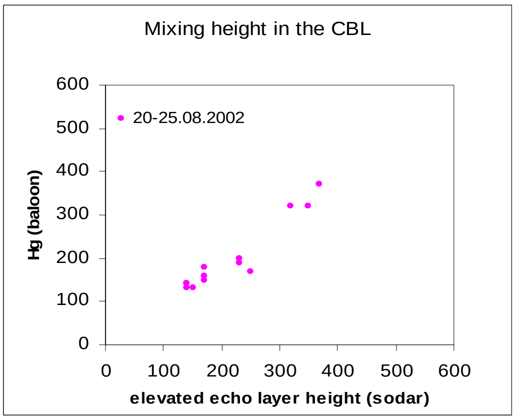


Figure 4. Sodar record for one of the experiment days, hrs 12.34 – 01.00, with marked times of the tethered balloon ascents. Convective echoes visible up to 17.00 hr, ground-bases inversion since 19.00 hr.

The results of comparison is presented on the Figure 5.



A)



B)

Figure 5. Comparison of the mixing height determined on the basis of sodar echo (Hg SODAR) and determined on the basis of the vertical profile of the potential temperature (Hg BALLOON) A) stable case, B) convective case, in the presence of capping elevated layer (morning time).

The results of the experiments are showing a reasonably good conformity between sodar indications and the tethered balloon measurements. This conformity refers to the determinations of the ground-based inversion layer heights, and to the determination of the Convective Boundary Layer height when convections are capped by an elevated inversion layer. For the periods of free convection the behaviour of convective layer is approaching the model one. The multiplication coefficient which is applied for determination of the mixing layer height (by multiplication of the convective echoes height) should be verified, yet. This verification program is planned for the period of the next experiment.

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