9.8 FIRST RESULTS FROM BUBBLE I:
PROFILES OF FLUXES IN THE URBAN ROUGHNESS SUBLAYER

Andreas Christen[(1)]*, Roland Vogt[(1)], Mathias W. Rotach[(2)], Eberhard Parlow[(1)]
[(1)] University of Basel, Institute of Meteorology, Climatology and Remote Sensing, Basel, Switzerland.
[(2)] Swiss Federal Institute of Technology, Institute for Atmospheric and Climate Science, Zurich, Switzerland.

1. INTRODUCTION

The Basel Urban Boundary Layer Experiment (BUBBLE) brings together activities in modeling, remote sensing and turbulence measurements, in order to increase the understanding of exchange processes in urban areas (Rotach, 2002). As part of the project, a field experiment is currently carried out in the city of Basel (Switzerland) with continuously operated micrometeorological surface measurements at different sites from November 2001 to July 2002. This presentation focuses on turbulence profiles, measured during the first three months of operation.

2. INSTRUMENTATION AND DATA PROCESSING

The tower *Basel-Sperrstrasse* (7°E 35' 47.8", 47°N 33' 57.2", WGS-84, 255 m a.s.l.) supports six sonics, starting at street level reaching up to two times the building height (Fig. 1, Tab. 1). Additionally, profiles with six ventilated temperature/humidity sensors, 12 cup anemometers and 10 air sampling inlets for a gas multiplexer are installed at the tower. All radiation components are measured at top (z/h=2.3) and inside the street canyon (z/h=0.2).

From the sonics, 20 Hz raw data are continuously collected. Data are filtered for spikes and acquisition errors. In this analysis, data based on 10 min block averages from Dec 1, 2001 to Feb 18, 2002 are shown. Calm situations with a mean wind speed lower than 0.25 m s^{-1} at top level and data outside the stability range $-2 < (z-d)/L < 1$ are excluded.

3. FIRST RESULTS

Because the profiles show a strong dependence on wind direction relative to the canyon alignment, two flow patterns are distinguished: (i) along canyon flow with the mean wind within ±20° of the canyon direction, and (ii) cross canyon flow with flow ±45° perpendicular to the canyon.

For cross-canyon flows the profile of mean horizontal wind speed u shows an increasing gradient towards the rooftop and an inflection point at z/h~1.5 (Fig. 2). The along canyon cases show a nearly linear wind profile due to the different drag geometry.

* *Corresponding author address:*
Andreas Christen, Institute of Meteorology, University of Basel, Spalenring 145, CH-4055 Basel, Switzerland
e-mail: andreas.christen@unibas.ch

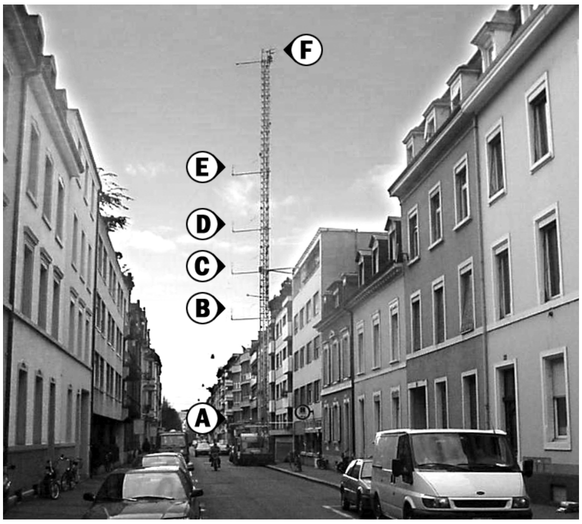

Fig. 1. The instrumented tower at *Basel-Sperrstrasse*. Labels refer to the instrumentation according Tab. 1. This typical Middle-European street canyon has a height-to-width aspect of 1. The mean building height h is ≈ 14m.

Tab. 1: Turbulence instrumentation at *Basel-Sperrstrasse*.

Level	Instrument, Serial No (Calibration)	Height z	z/h
F	Gill HS Sonic, #000046 (wind tunnel) Fast hygrometer Krypton KH2O #1448	31.7m	2.3
E	Gill R2 Sonic, #0043 (wind tunnel)	22.4m	1.6
D	Gill R2 Sonic, #0212 (wind tunnel)	17.9m	1.3
C	Gill R2 Sonic, #0160 (wind tunnel)	14.7m	1.1
B	Gill R2 Sonic, #0107 (manufacturer)	11.3m	0.8
A	Gill R2 Sonic, #0208 (manufacturer)	3.6m	0.3

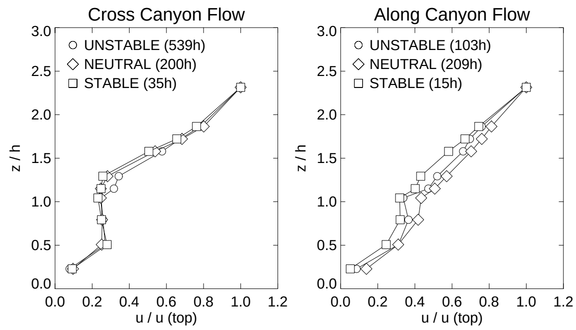

Fig. 2: Median profiles of cup wind speed u normalized by *u(top)* at z/h = 2.3 from the cup anemometers for cross canyon (left) and along canyon flow (right) for different stability classes. Note that the instruments are 2.5 m away from one building wall, in contrast to the sonic, which are operated in the centre of the canyon.

The highest momentum fluxes are observed at z/h=1.1 with u_*/u (local) values up to 0.45 in the median (Fig. 3, left). However, the cross canyon flow leads to momentum fluxes that are up to factor two higher than in along canyon flows. At 2h the ratio u_*/u schows less scatter, and is independent from wind direction, indicating that the roughness sublayer height z_* is reached. u_* was calculated by $u_*=[(\overline{u'w'})^2+(\overline{v'w'})^2]^{0.25}$.

As a result of the high drag at rooftop the normalized turbulent kinetic energy *TKE* / (0.5 M^2) shows in both flow situations its maximum in the same part of the profile (Fig. 3, right). *M* is the local mean scalar wind speed. Overall, higher turbulence is measured in the cross-canyon flow, associated with negative skewness (~ –0.6 $m^3\ s^{-3}$) probably caused by injections into the canyon. A similar shape of the normalized *TKE*-profile is observed in wind tunnel studies, but with lower absolute values (Kastner-Klein et al., 2000). At street level (z/h < 0.7) *TKE* is significantly higher in the along canyon flow.

The normalized vertical velocity standard deviations σ_w/u_* and σ_w/M (Fig. 4, both locally scaled) show extraordinary high values inside the upper canyon due to predominant vertical motions in this part. For both profiles values above the building height match well to other experiments over urban surfaces (Roth, 2000), and to the measurements of Feigenwinter et al. (1999) that were carried out within 400 m distance from the current site 1995/96 from z/h=1.5 upward.

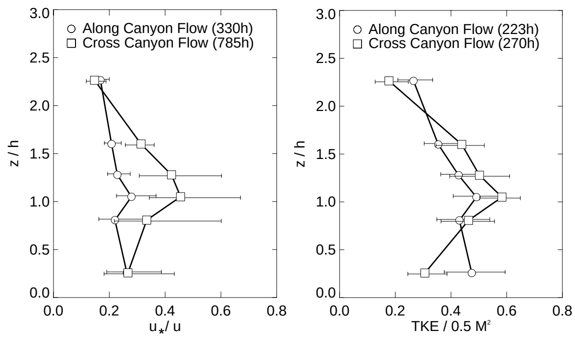

Fig. 3: Median profiles of locally scaled friction velocity u_* / *u* (left) and turbulent kinetic energy *TKE* / (0.5 M^2) (right). Data are from Dec 1, 2001 to Feb 18, 2002. Error bars indicate 50% of all values are inside bars.

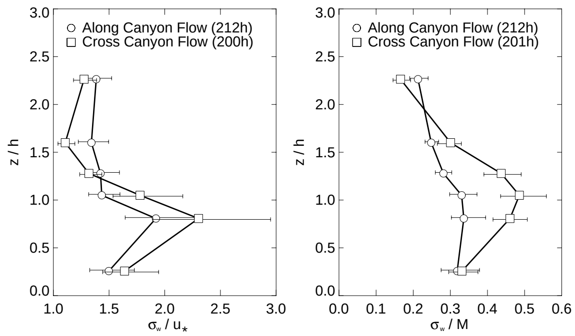

Fig. 4: Median profiles of the standard deviation of vertical wind σ_w normalized by local u_* (left) and *M* (right) for neutral cases. Data period and methods are analogous to Fig. 2.

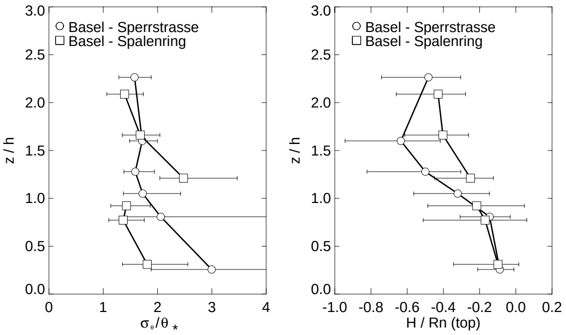

Fig. 5: Median profiles of σ_θ / θ_* (left) and *H* / *Rn* (right), at two urban sites during the same wintertime period (Dec 1, 2001 to Feb 18, 2002) *Basel-Sperrstrasse* with 800 (left) / 1800 (right) runs and *Basel-Spalenring* with 1750 / 600 runs. The error bars indicate 50% of all selected values are inside bars.

The normalized standard deviation of acoustic temperature σ_θ/θ_* is presented in Fig. 5 for two urban sites. Only periods with $\overline{w'\theta'}$ > 0.06 K m s^{-1} and u_* > 0.02 m s^{-1} are shown. With increasing height the values converge towards typical surface layer values for unstable conditions. To give an overview on future applications, vertical profiles of the sensible heat flux *H* are shown in Fig. 5. *H* is normalized by net radiation *Rn* at z/h=2.3. Only periods with *Rn* > 80 W m^{-2} are taken into statistics. The contributions to *H* are increasing up to 2h where the daytime value of ~–0.5 is reached (see Christen et al., 2002).

4. OUTLOOK

The results of the first three months of operation at this urban measurement tower have already delivered valuable and interesting data. Together with five months of oncoming data, data from other urban stations as well as with remote sensing and modeling results, the experiment will lead to more detailed insight into micrometeorological exchange processes near the urban surface and inside the street canyon. Additional turbulence and radiation instrumentation will be deployed during an IOP in June/July 2002 with international contributions.

5. REFERENCES

Project website: www.mcrlab.unibas.ch/projects/BUBBLE/

Christen, A. Vogt, R., Rotach, M. W. and E. Parlow, 2002: First results from BUBBLE II: Partitioning of turbulent heat fluxes over urban surfaces. *This conference*, P1.4.

Feigenwinter, C., Vogt, R. and E. Parlow, 1999): Vertical Structure of selected turbulence characteristics above an urban canopy. *Theor. Appl. Clim.*, **62**, p. 51-63.

Kastner-Klein, P., Rotach, M.W., Brown, M.J., Fedorovich, E. and R. E. Lawson, 2000: Spatial variability of mean flow and turbulence fields in street canyons. *3rd symposium on the urban environment*. Davis, CA, Paper 2.5, p. 13-14.

Rotach, M. W., 2002: Overview on the Basel Urban Boundary Layer Experiment—BUBBLE. *This conference*, 3.6.

Roth, M., 2000: Review of atmospheric turbulence over cities. *Q. J. R. Meteorol. Soc.* **126**, p. 941-990.