Turbulence characteristics and energy balance on urbanized area - Łódź case study

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Outline

1. Eddy covariance sites in Łódź
2. Data verification
3. Standard deviations for wind components and for scalars
4. Energy balance and its parameterisation
5. Scintillometry

Energy balance (EB) measurement points in Łódź

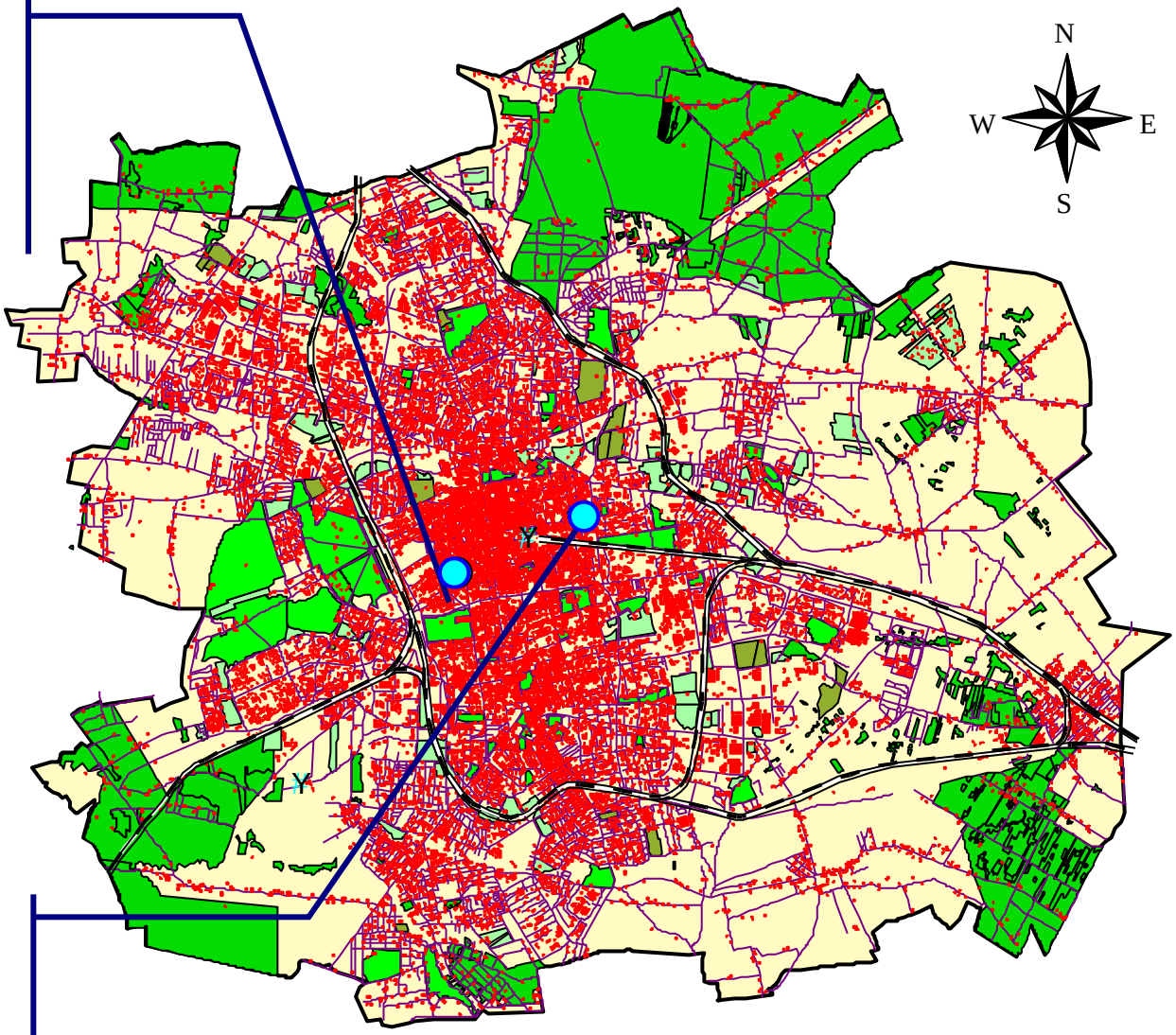
EB 1 Lipowa

(2000-2003)

Grimmond and Offerle

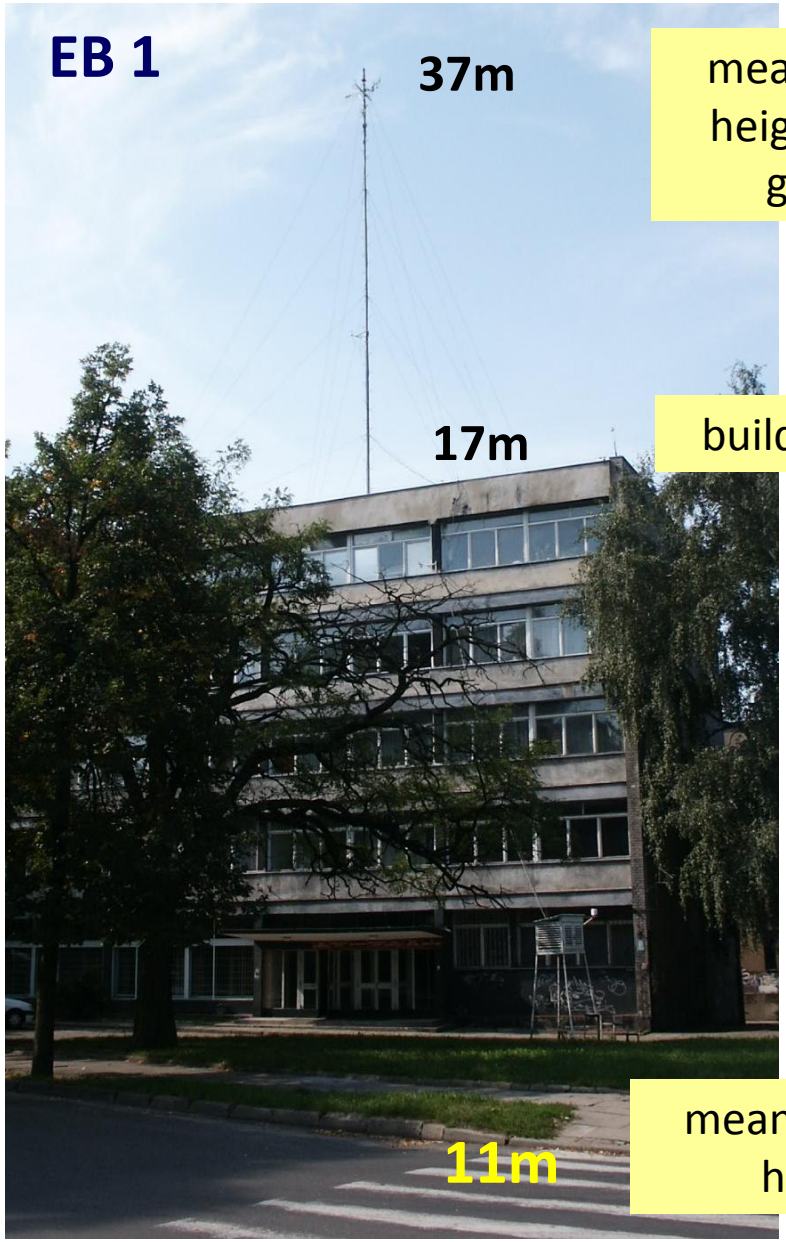
(since July 2006)

Łódź, Poland, 51°47'N, 19°28'E
population 750,000



EB 2
Narutowicza
(since June 2005)

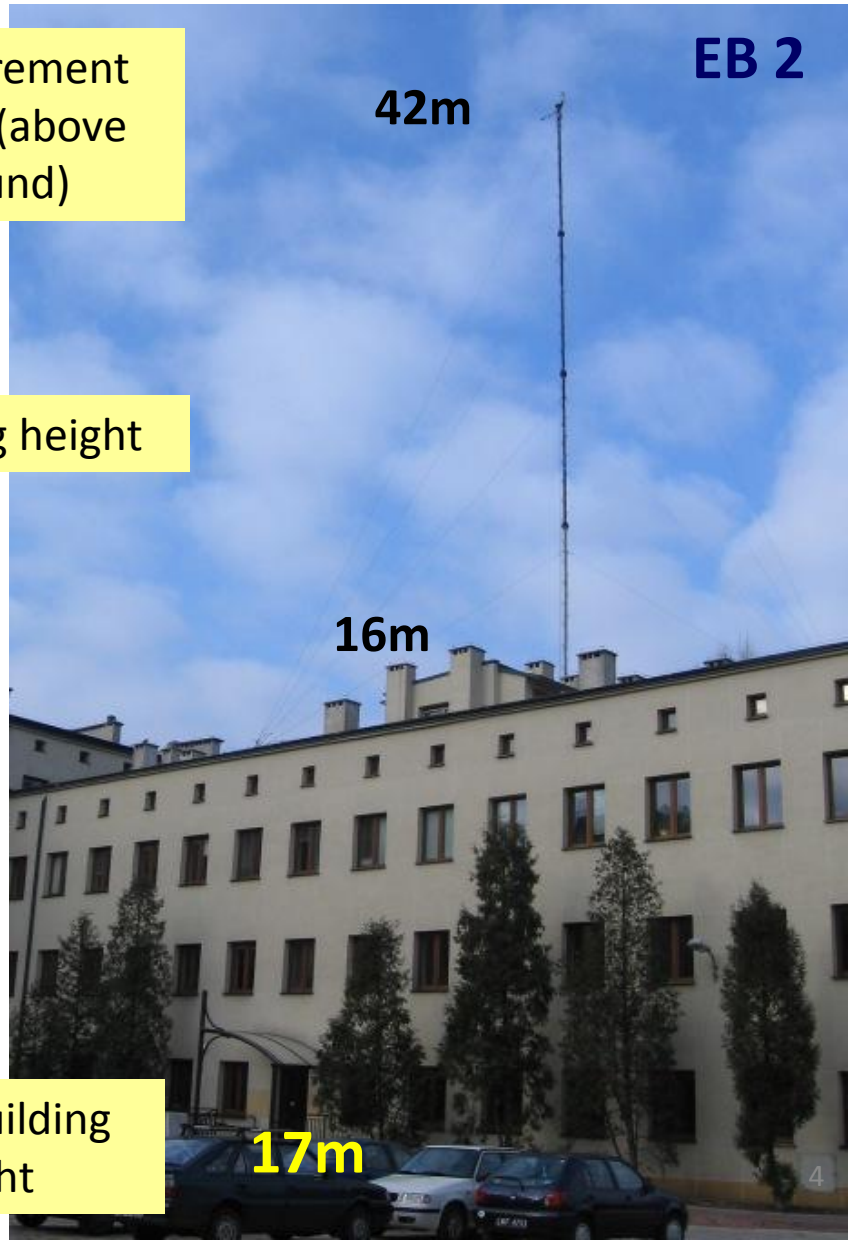
Eddy covariance towers in Łódź



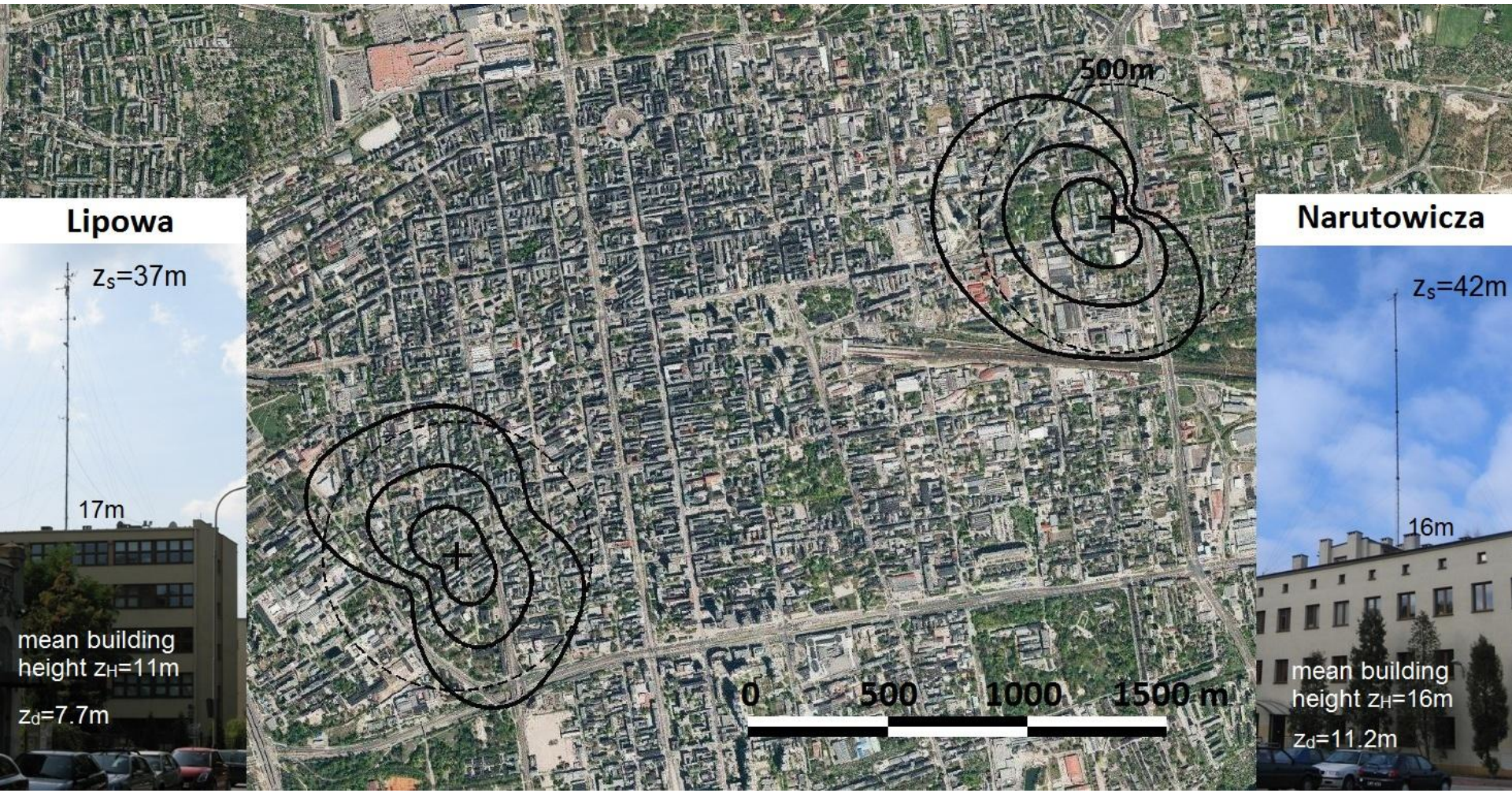
measurement height (above ground)

building height

mean building height

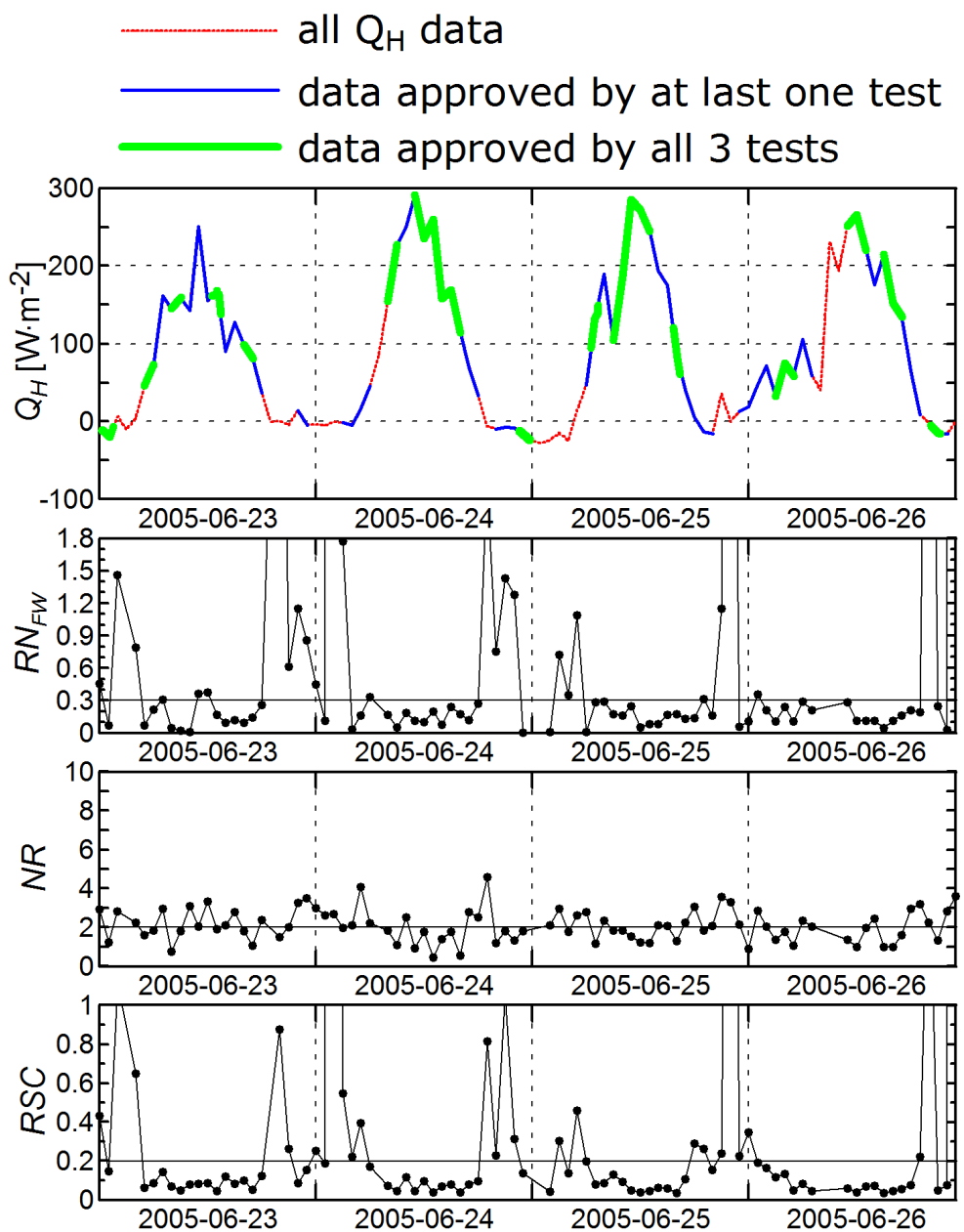


Eddy covariance towers in Łódź



Łódź city centre with location of measurement sites and views of measurement towers. Solid lines surrounding the measurement point indicates source areas at *p* = 50, 75 and 90% calculated for turbulent fluxes measured in unstable stratification.

Quality control – stationarity tests



Three stationarity tests used in post-processing data quality control:

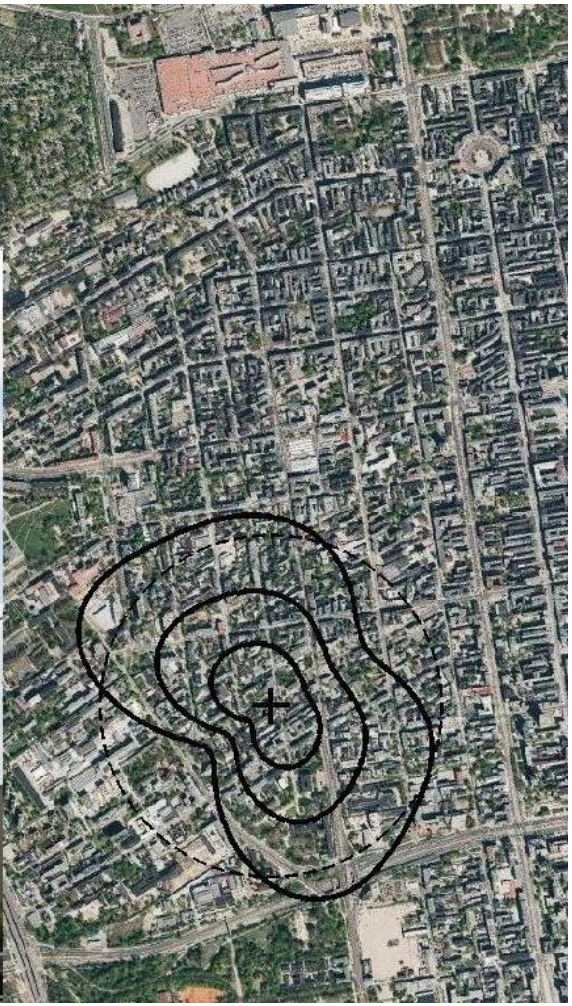
RN_{FW} – the statistic proposed by **Foken and Wichura (1996)** with critical value 0.3;

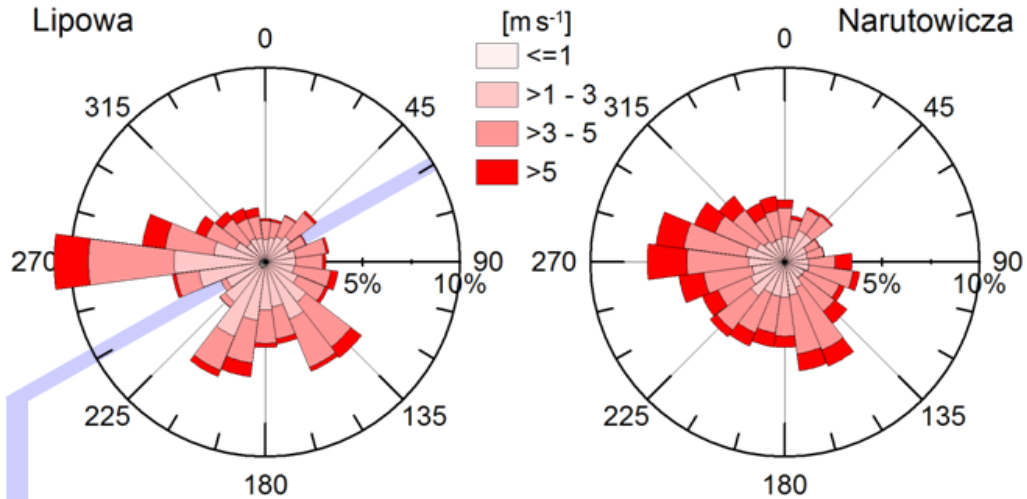
NR – the non-stationarity ratio given by **Mahrt (1998)** with critical value NR=2;

RCS – the relative covariance stationarity criterion, introduced by **Dutaur et al. (1999)** and modified by **Nemitz et al. (2002)** with critical value RCS=0.5.

Quality control – flow direction selection

Wind rose for Narutowicza is typical for central Poland. At Lipowa strong influence of tunnelling by street canyon is observed.



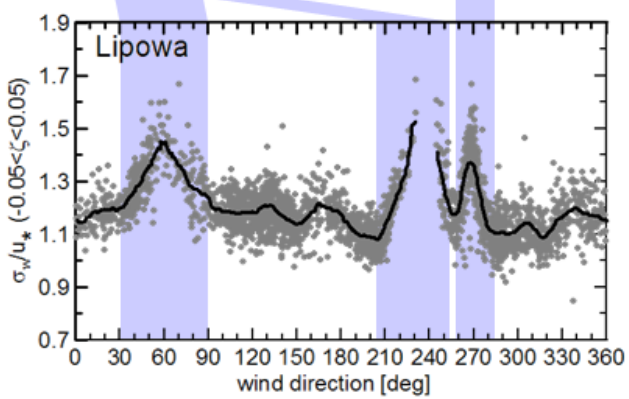


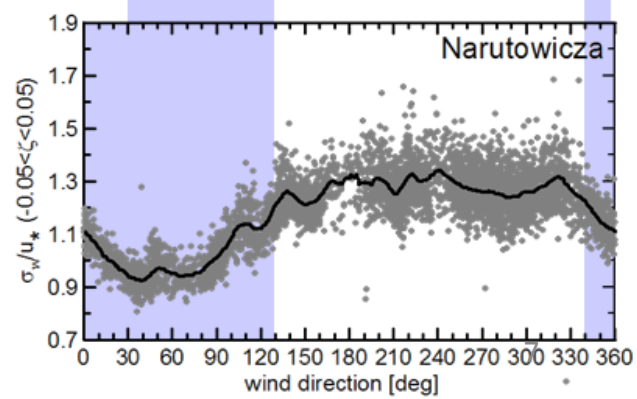
wind tunnelling by the street canyon

flow distortion by the mast

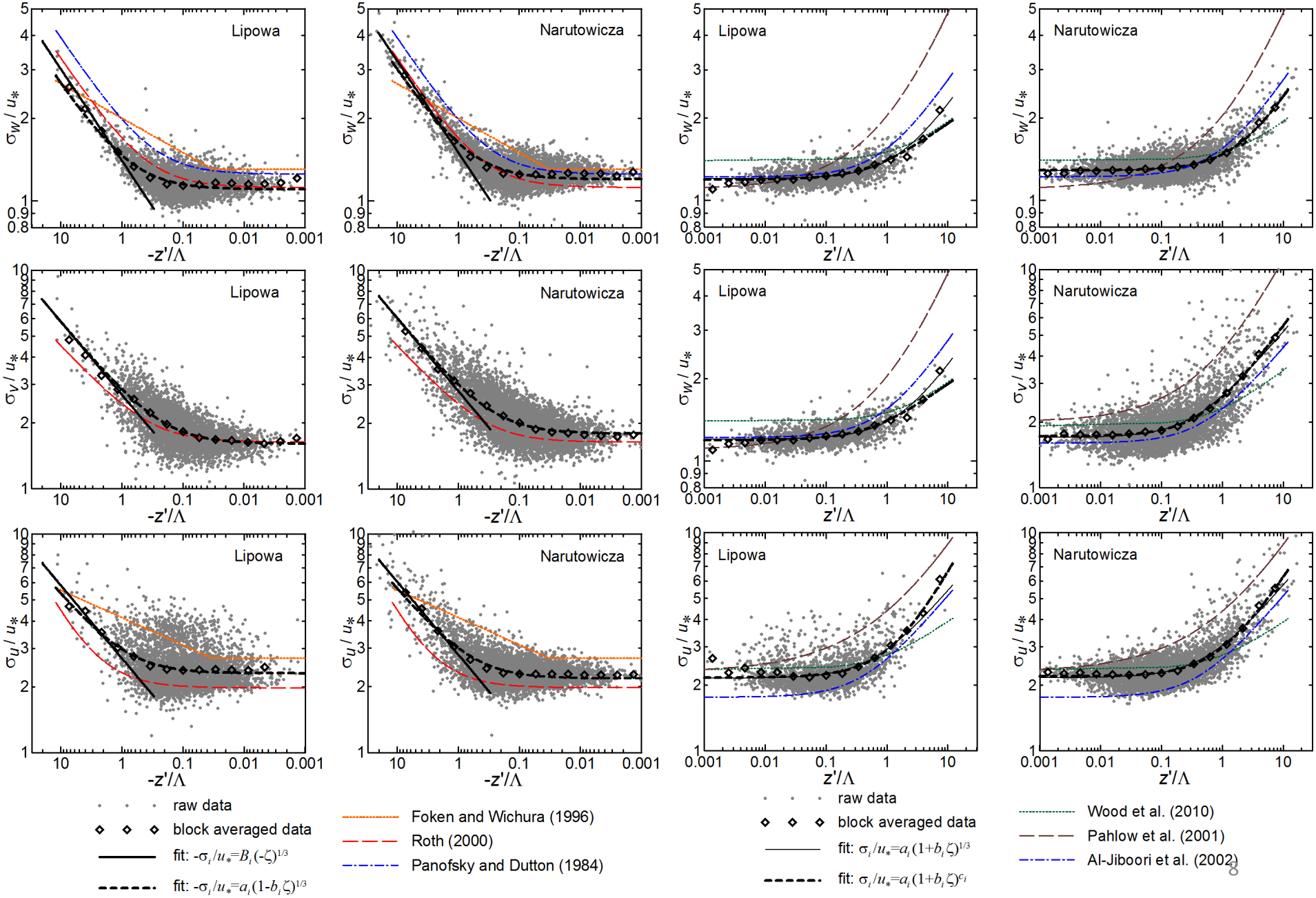
Data excluded from further analysis

strong inhomogeneity in surface cover

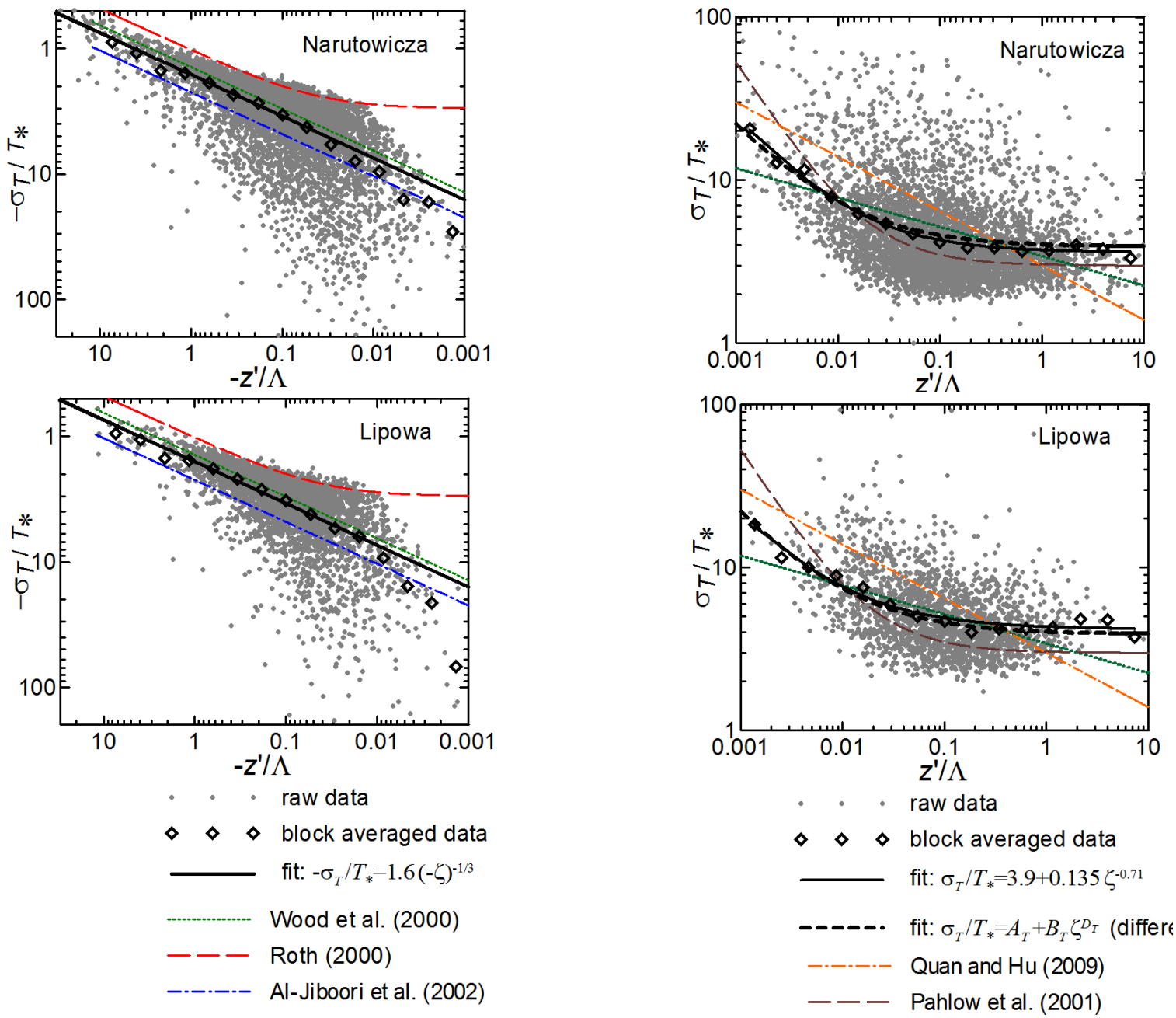




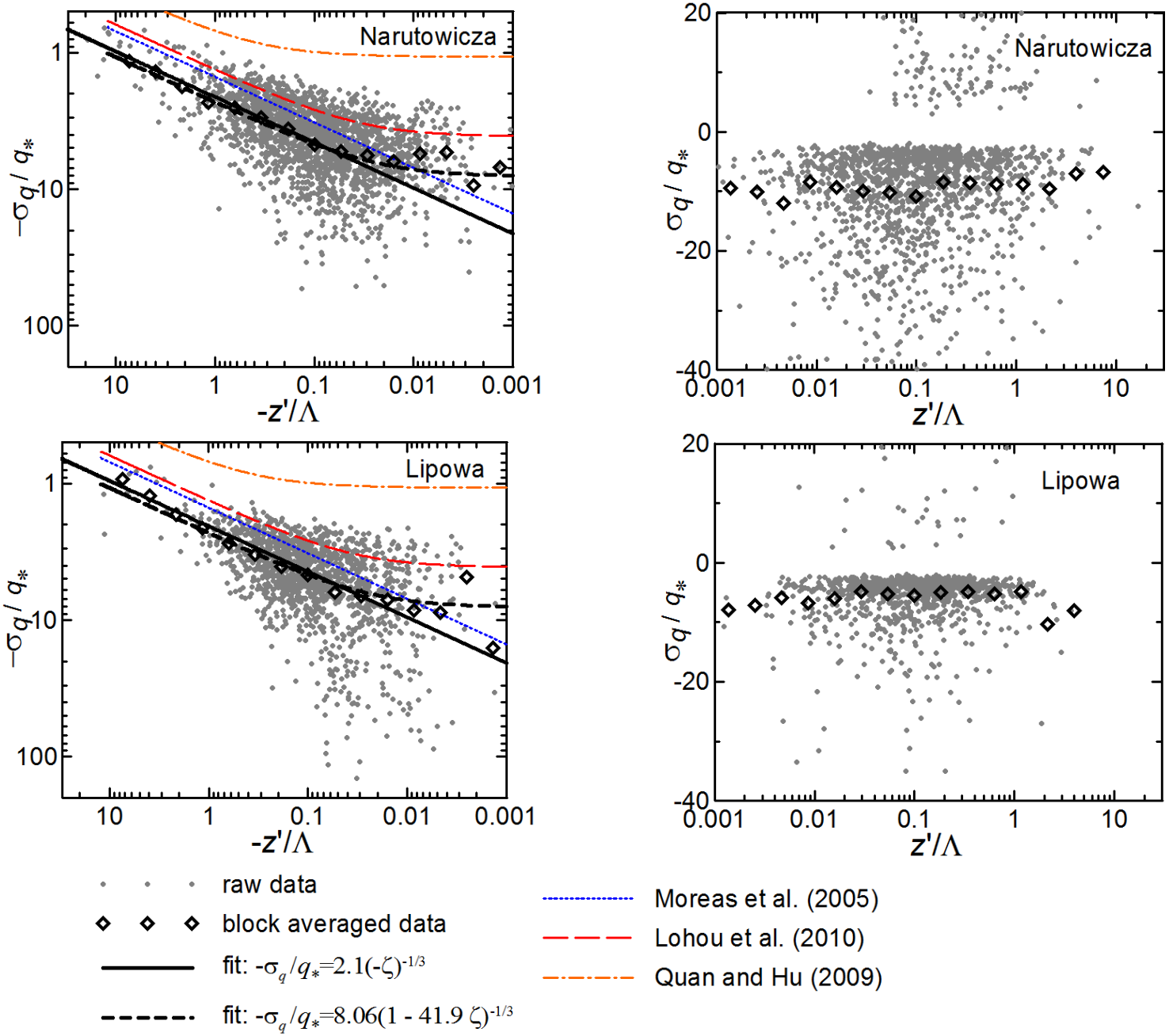
Normalised standard deviations of wind components



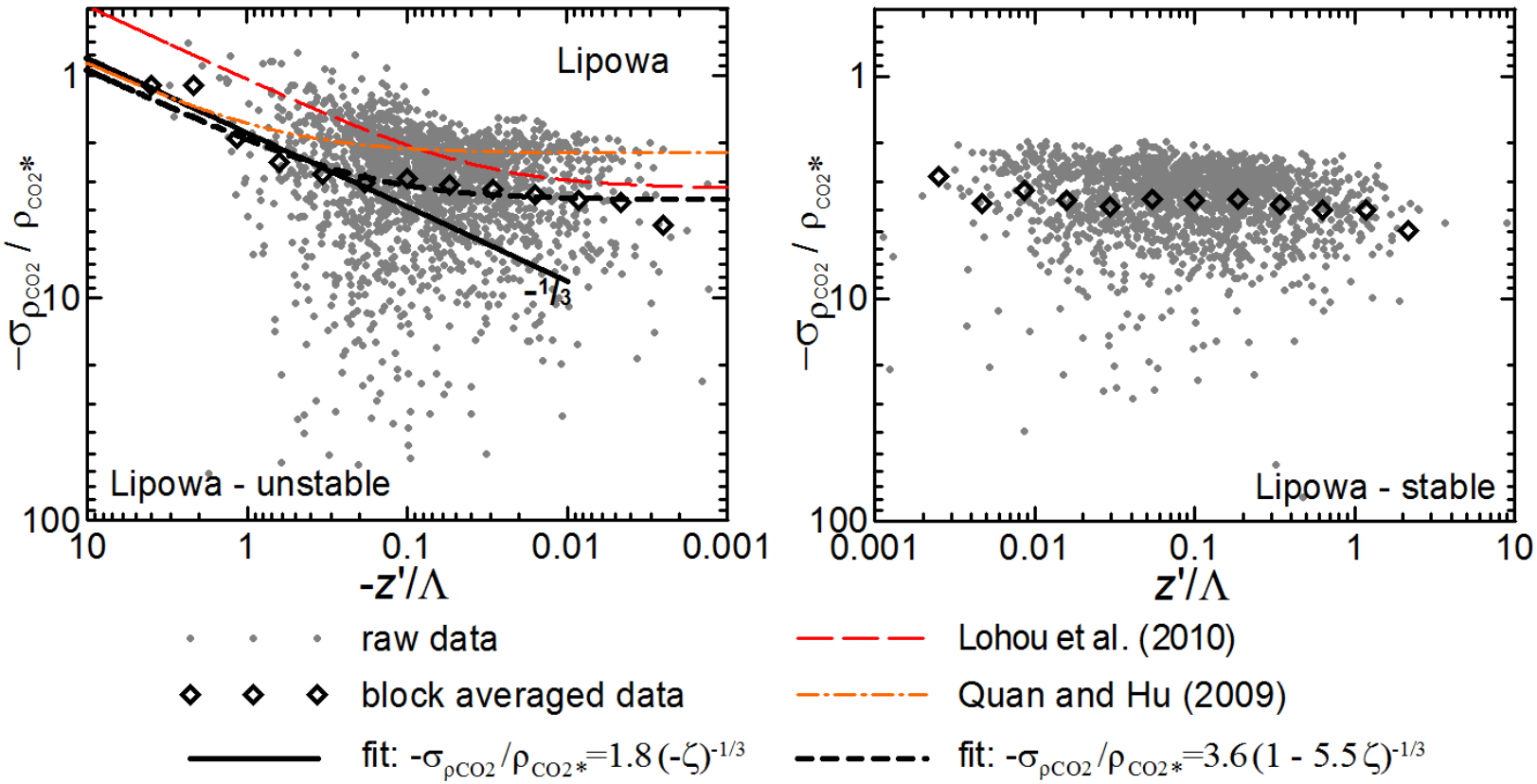
Normalised standard deviations of temperature



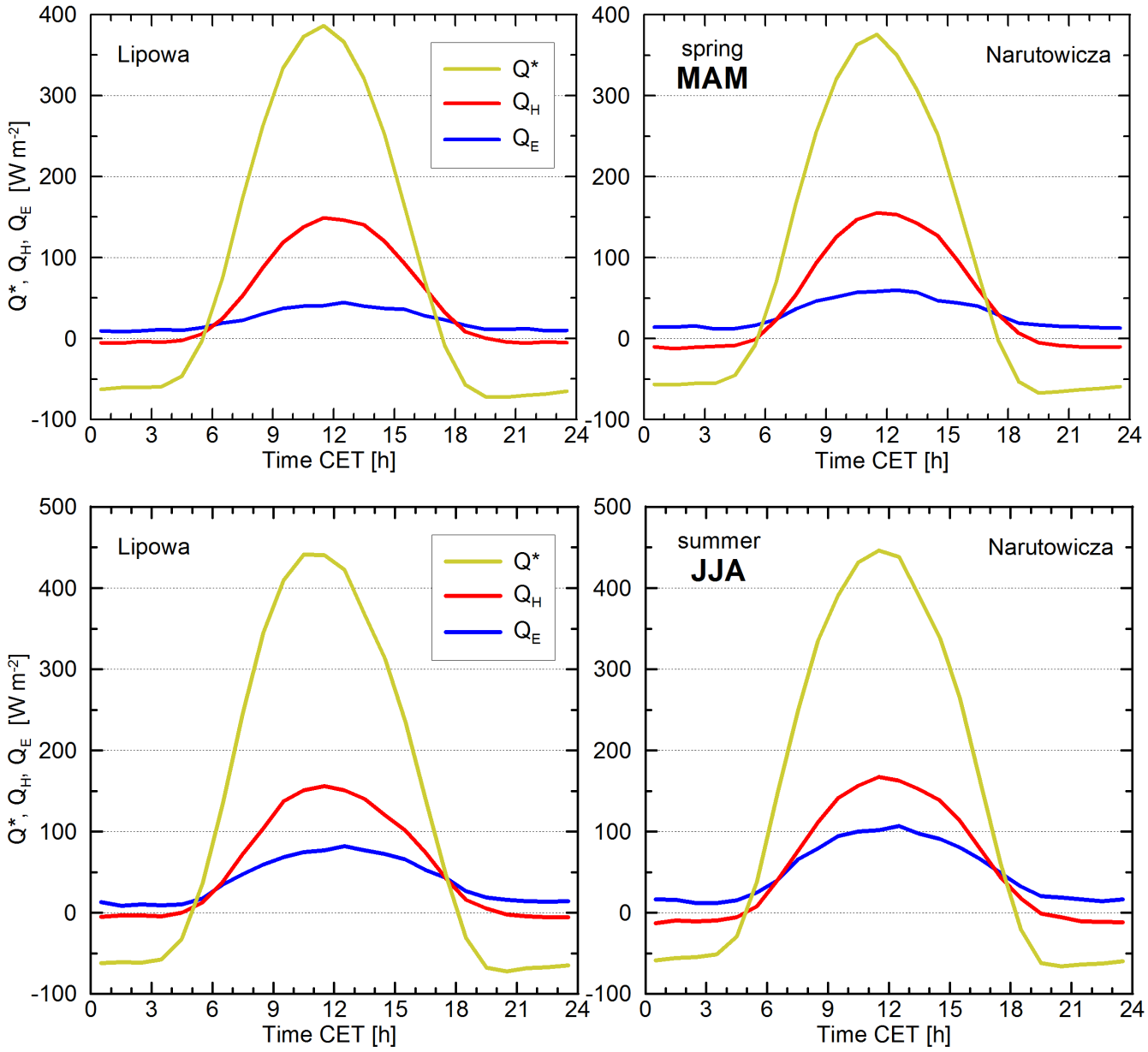
Normalised standard deviations of humidity



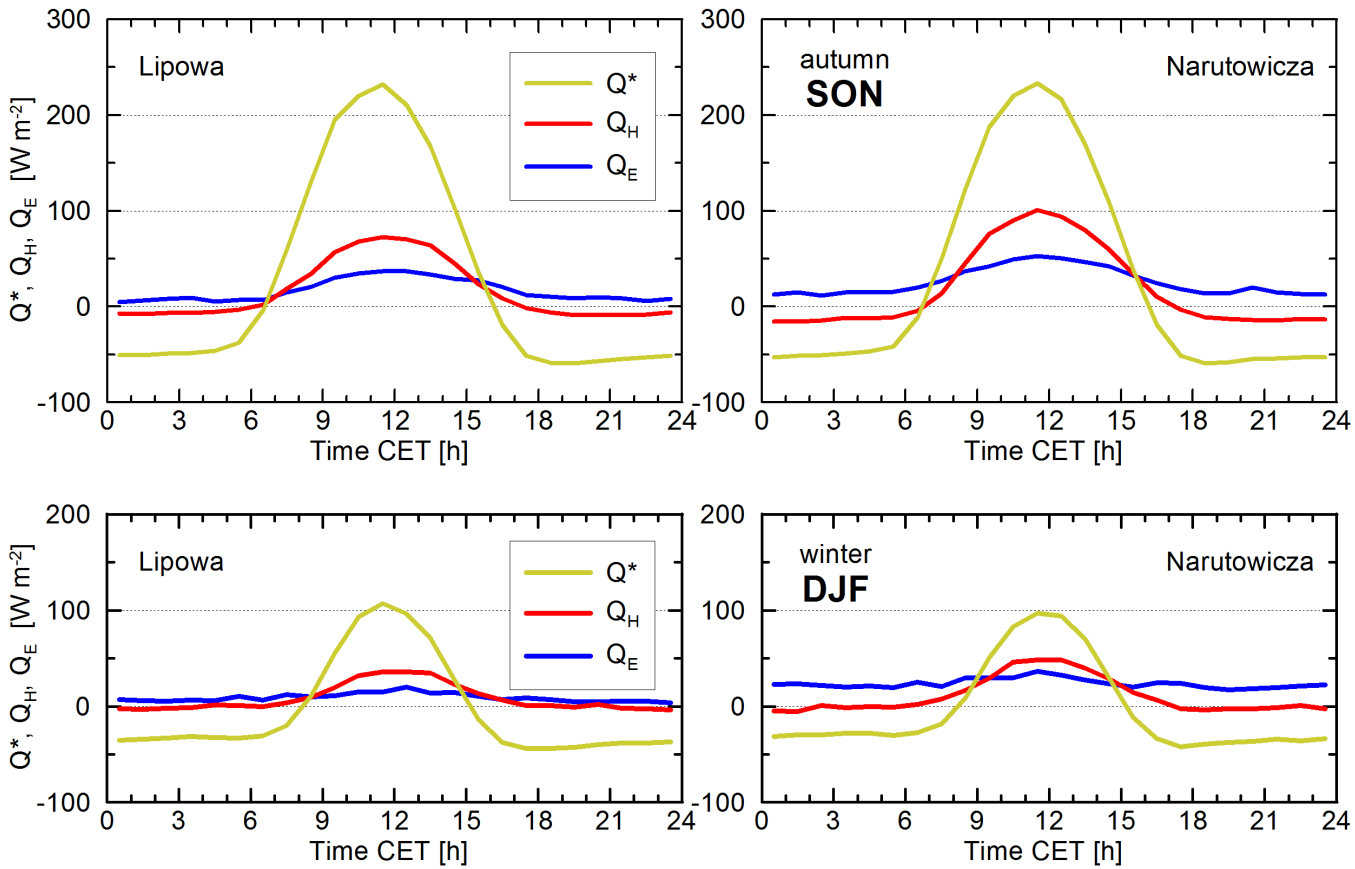
Normalised standard deviations of CO_2



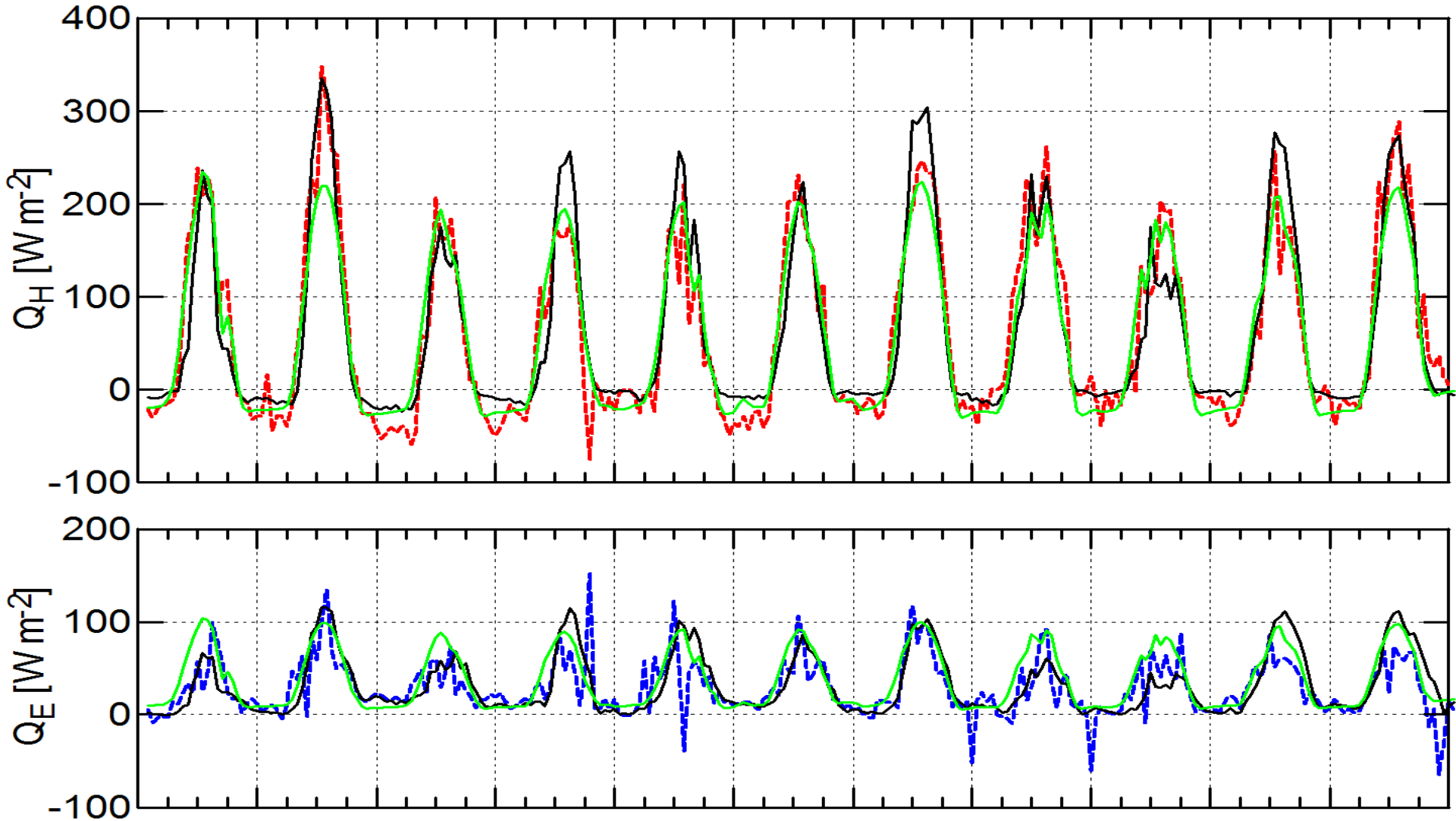
Average diurnal course of energy balance components in seasons



Average diurnal course of energy balance components in seasons

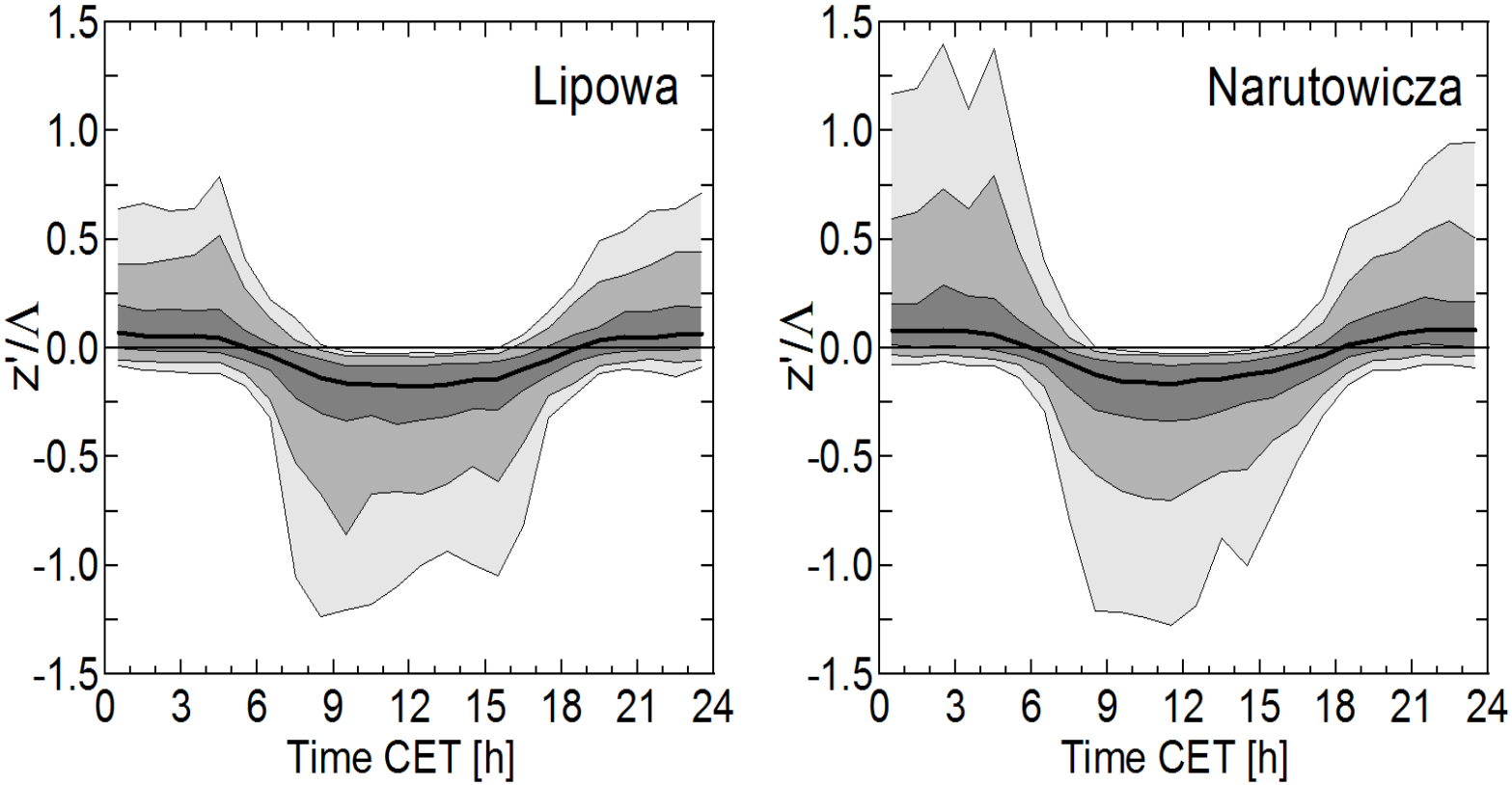


Modelled and measured turbulent fluxes



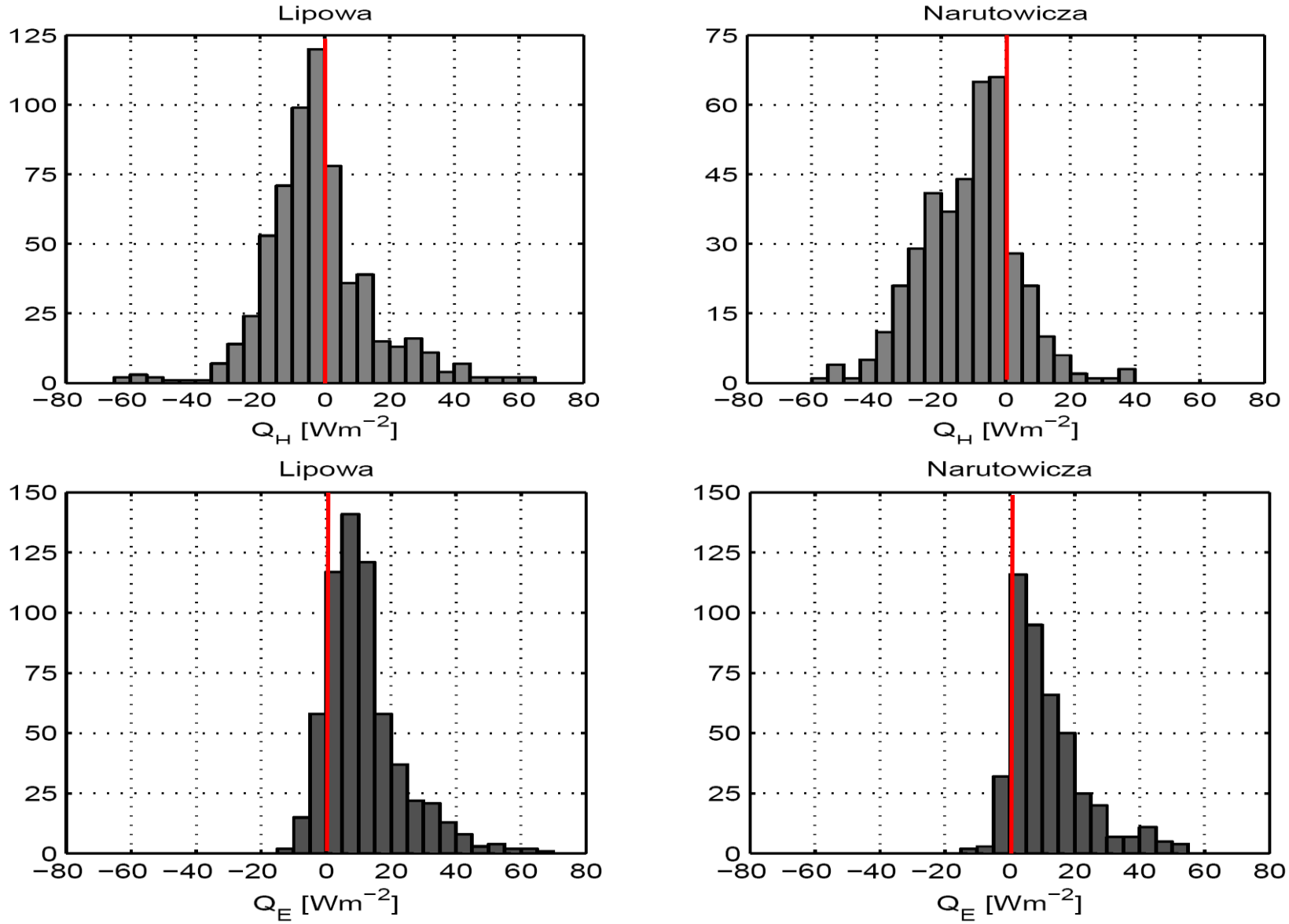
Q_H and Q_E measured at Narutowicza in the period 3-13 May 2006 (dashed lines), modelled with the aid of M-O similarity (black) and as regression versus Q* (green)

Diurnal course of the stability parameter

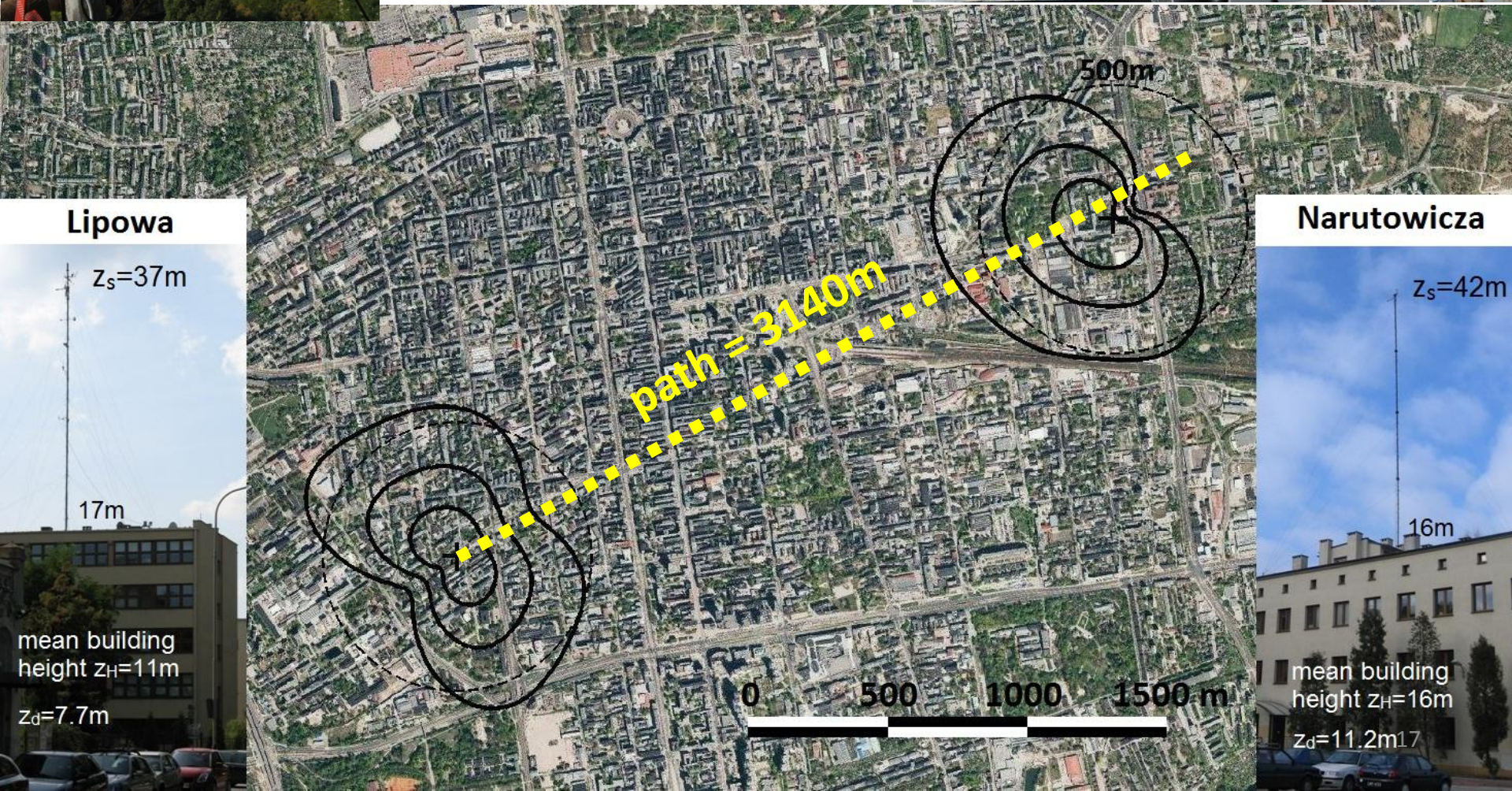


Diurnal course of the stability parameter, $\zeta = z'/\Lambda$, at Lipowa and Narutowicza sites for the entire study periods. Lines from the bottom to the top indicate 5th, 10th, 25th, 50th (median – bold line), 75th, 90th, and 95th percentiles.

Histograms of nigh-time (mean for all night hours) Q_H and Q_E



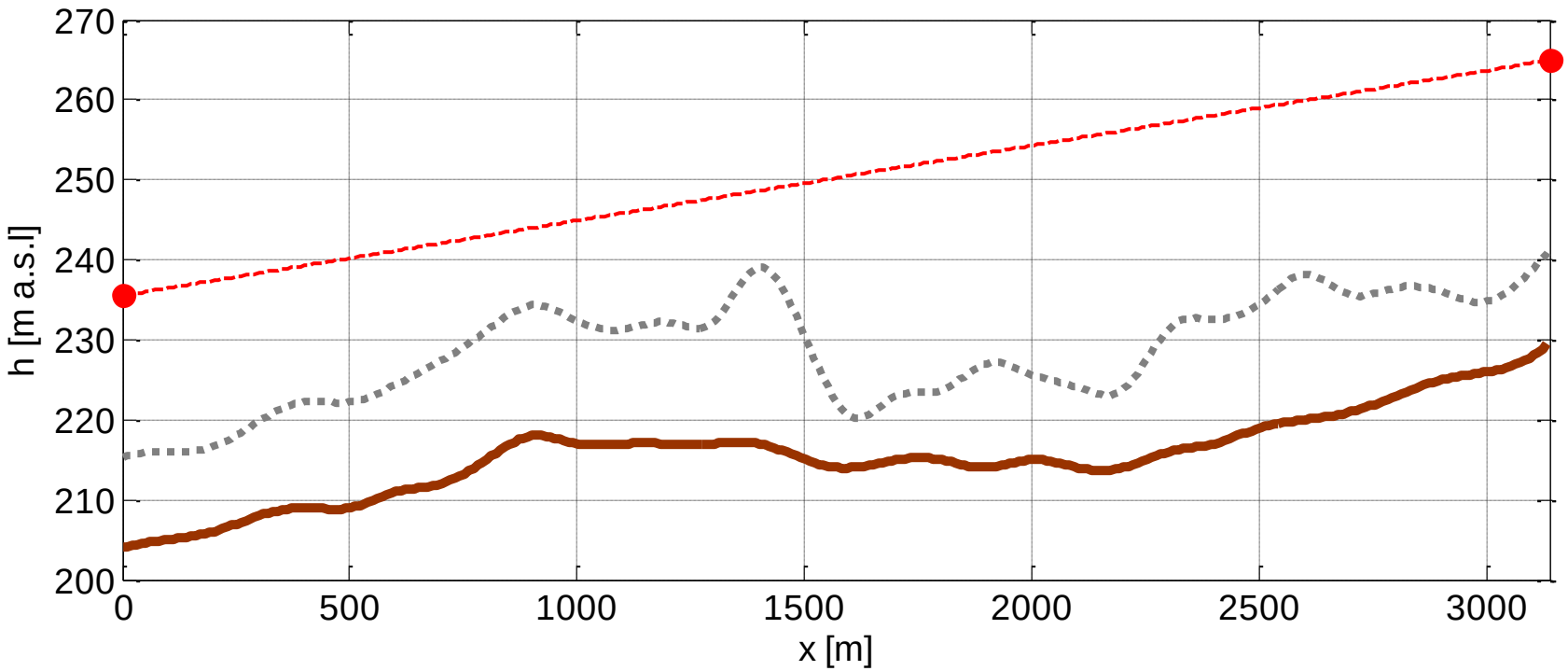
Scintillometry – BLS900



Scintillometry – BLS900

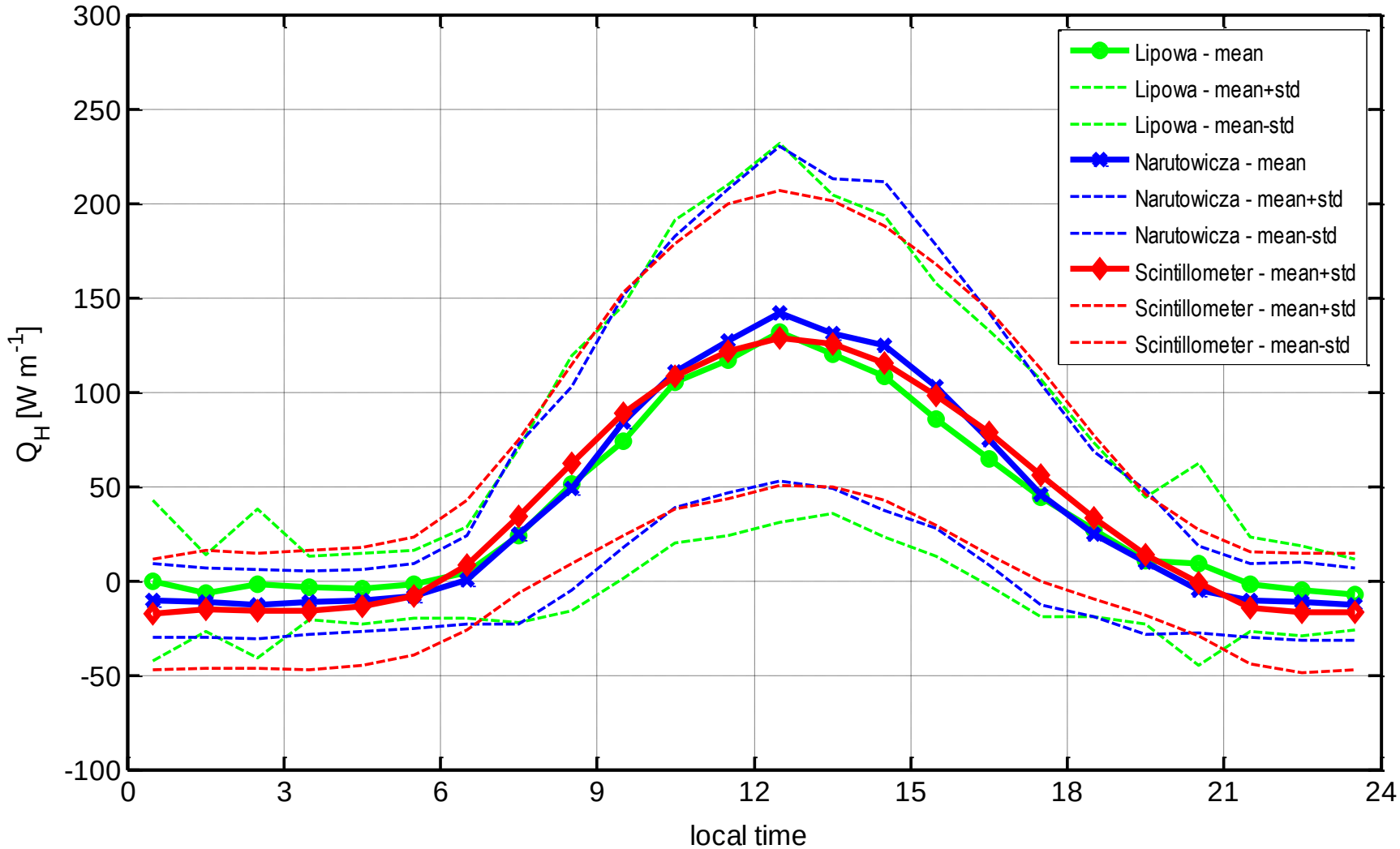
$$Q_H = b \cdot \rho \cdot c_p \cdot k \cdot z_{eff} \cdot \left(\frac{g}{T}\right)^{1/2} \cdot \left(C_T^2\right)^{3/4}$$ - free convection assumption

$$z_{eff} = \int_0^1 (z_{path} - d) \cdot W(u)\, du = 25m$$



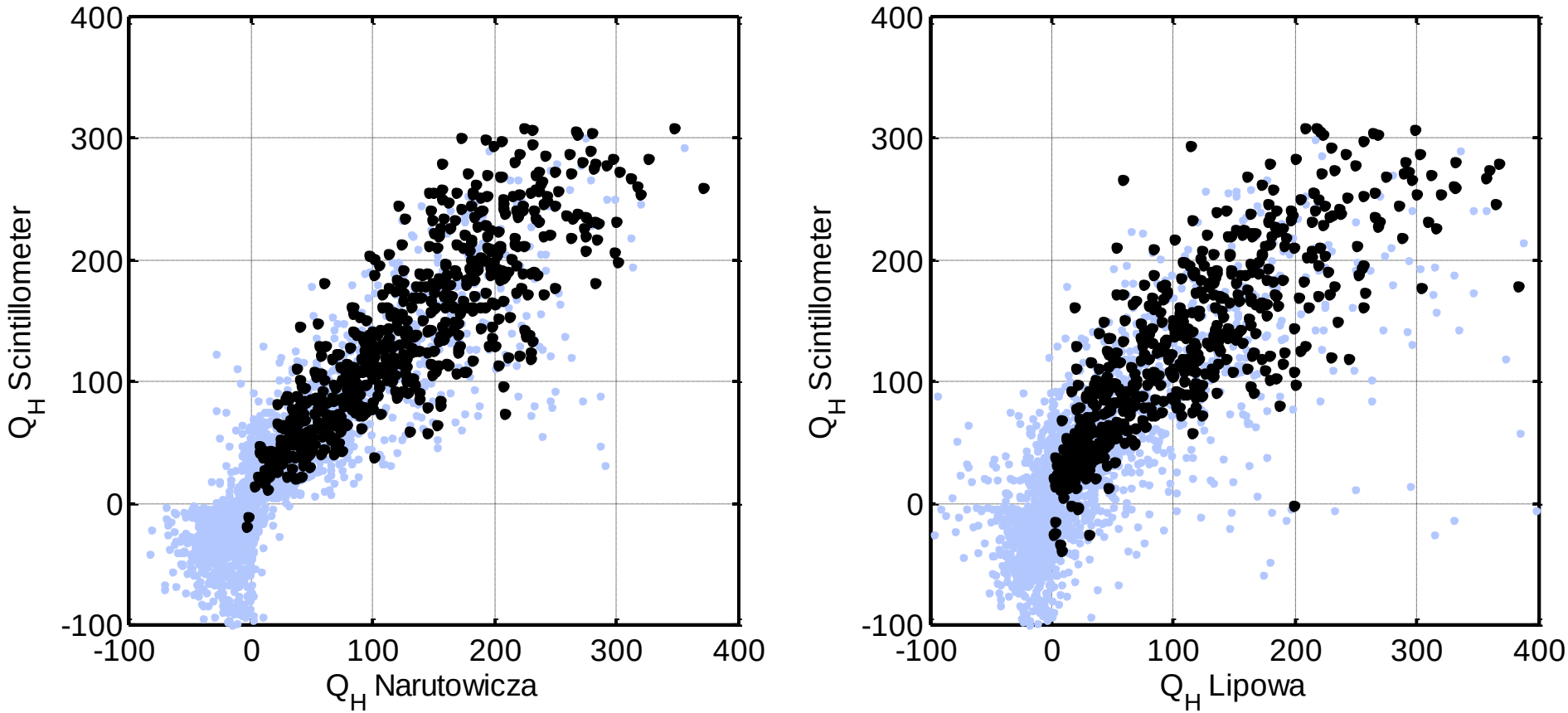
Scintillometer path height (dashed line) above topography of the ground (thick line) and topography of the built canopy(dotted line).

Scintillometry – BLS900



Mean daily course of Q_H measured by scintillometer (free convection assumption) and at two eddy covariance towers in a period 2010.06.11 – 2010.11.05 (148 days).

Scintillometry – BLS900



Q_H measured by scintillometer (free convection assumption) and at two eddy covariance towers in a period 2010.06.11 – 2010.11.05 (148 days).
All data – blue dots, data for z/L<-0.05 – black dots

Summary

1. Results from two eddy covariance points in Łódź give information on energy balance for the area of the diameter about 1 km – results are representative for central part of mid-European towns.

2. Analysis of normalised variances of wind components and scalars shows that local scaling is suitable for describing urban data with the framework of Monin-Obukhov similarity theory. Normalised standard deviations of wind components and scalars undergo power law with exponent equal ±1/3 in free convection limit.

3. Energy balance in central parts of Łódź is characterised by domination of sensible heat flux in noon hours (similar to other cities) and large frequency of stable stratification during the night (unlike to other cities).

4. Average sensible heat flux measured by scintillometer is very similar to the fluxes measured at two eddy-covariance points.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