Turbulent Flux Measurements in the Urban Boundary Layer

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Introduction

WHAT? Turbulent fluxes transport heat, mass and momentum from the surface to the atmosphere. They influence weather conditions and climate from the microscale (at street level) up to the synoptic scale. The turbulent fluxes of sensible (Q_H) and latent heat (Q_E) are key variables in the surface energy exchange.

WHY? Knowledge of their climatology in urban areas as well as their dependence on different surface characteristics is a crucial aspect to understand the urban climate. This information is integrated in studies on surface energy exchange, air pollution, thermal comfort and water resource management, which in turn provide the basis to urban planning decisions. ➡ **APPLICATIONS FOR URBAN PLANNING:**

- Urban vegetation & water resources: How do vegetation fraction, type of vegetation & water areas alter energy partitioning between sensible and latent heat flux?
- Building characteristics & roughness: How do building materials, roof height & sky view factor influence the transport of heat in the urban roughness layer?

Methods

Accurate estimation of turbulent surface fluxes in urban areas is a challenge for micrometeorological measurement techniques. All flux measurements are representative for a certain source area (Schmid et al. 1991). In order to evaluate the applicability of different approaches the turbulent fluxes are measured by two methods.

Eddy Covariance Method

- Eddy Covariance most established technique to observe turbulent surface fluxes
- Turbulent fluxes of CO_2, sensible and latent heat taken at a height above the roughness sublayer
- Mean surface characteristics of an upstream source area – dependent on atmospheric stability
- EC-system: CSAT sonic anemometer and Li7500 open path gas analyser (Fig. 1)
- Turbulent fluctuations of temperature, humidity and carbon dioxide recorded at a frequency of 10Hz
- Fluxes processed in near real time using two software packages simultaneously: *ECpack* (van Dijk et al. 2004) and *TK2* (Mauder and Foken 2004).

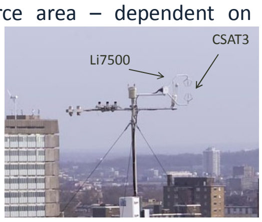


Figure 1: Eddy Covariance System

- Procedures differ in terms of corrections applied to the raw data (Fig. 2).
- Another aspect is the chosen averaging interval (Fig. 2):
  Block averaging applied to raw data acts like high pass filter – Eddies of temporal scale larger than averaging interval do not contribute to results.

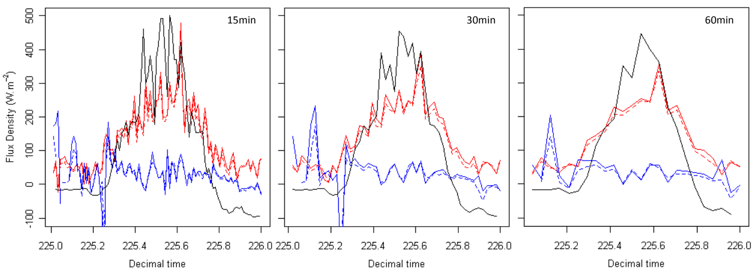
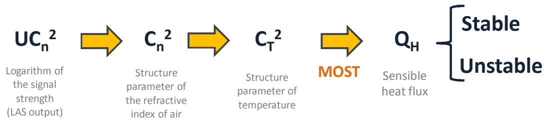


Figure 2: Observed (13/08/2009) sensible (red curves) and latent heat flux (blue curves) calculated with software packages ECpack (solid lines) and TK2 (dashed lines) for three averaging intervals, all wave net radiation from CNR1 (black curve).

Scintillometry

- New technique for measuring spatially integrated turbulent heat fluxes (scale compatible with most operational models)
- A large aperture scintillometer (LAS) is composed of a transmitter and a receiver, which can be separated from 500 m to 4.5 km.
- Measurement of intensity oscillations (termed *scintillations*) of an electromagnetic beam along the path between the two instrument parts, giving information about variations in the refractive index of the air.
- Retrieval of the sensible heat flux through an iterative process, making use of local meteorological variables and the Monin-Obukhov Similarity Theory (MOST). Methodologies by Hartogensis and de Bruin (2005) for stable and Hartogensis et al. (2003) for unstable conditions of the atmosphere.



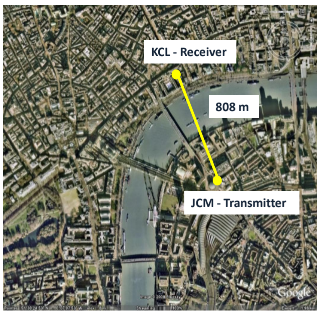


Figure 3: Measurements area in central London, showing optical path.

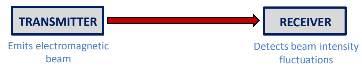


Figure 4: LAS receiver.

Results and Future Work

Results

Example of turbulent fluxes obtained by techniques described above (Fig. 5):

- Sensible heat flux (EC and LAS) shows pronounced daily cycle, latent heat flux does not
- Sensible heat flux of greater magnitude than latent heat flux as typical for urban areas
- Good agreement between LAS and EC, in this example EC gives lower night time and higher daytime values

Outlook

Comparison of flux climatology from flux tower measurements and scintillometry requires

- Optimum settings for EC-data processing, compare results from TK2 and ECpack software packages
- Identify regions influencing flux tower and LAS path by applying source area model for one location/path length
- Retrieve surface characteristics of source areas to establish a connection to the turbulent fluxes

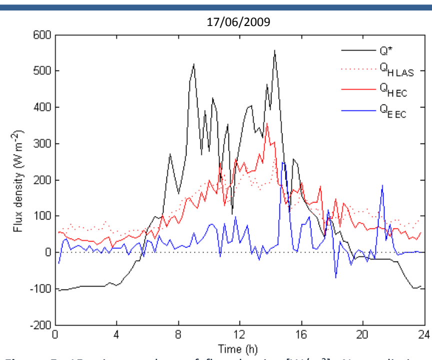


Figure 5: 15 minute values of flux density [W/m²]: Net radiation Q* (measured with CNR1), latent heat Q_E (EC), and sensible heat Q_H (EC and LAS). EC results processed with ECpack.

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