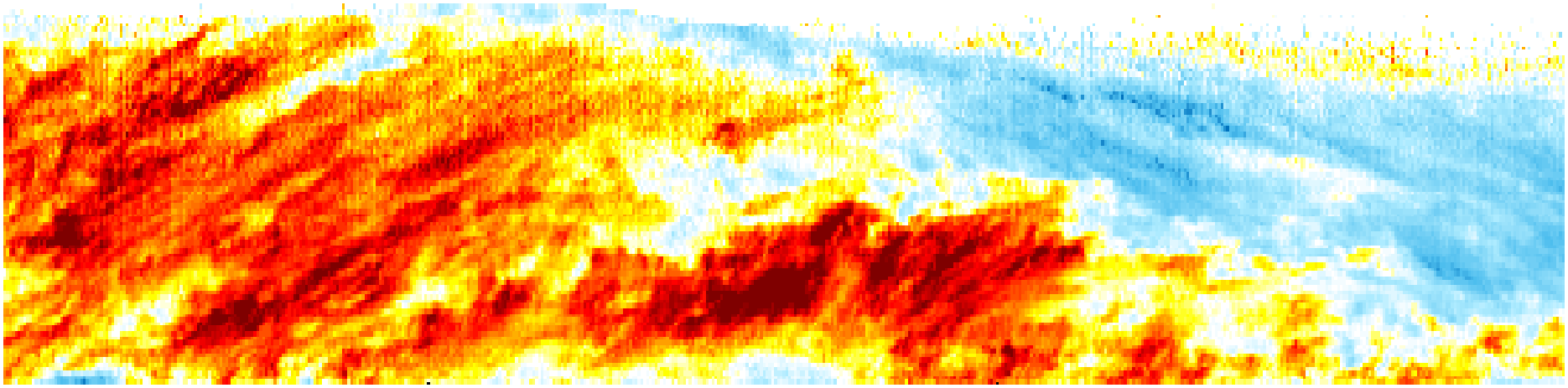
Meso-scale eddies contribute to near-surface exchange: evidence from field measurements

Fabian Eder [1,2], Marius Schmidt [3], Thomas Damian [4], Katja Träumner [4], Matthias Mauder [1,2]

[1] KIT / IMK-IFU, 82467 Garmisch-Partenkirchen, Germany
[2] KIT / IfGG, 76131 Karlsruhe, Germany
[3] FZJ / IBG-3, 52425 Jülich, Germany
[4] KIT / IMK-TRO, 76344 Eggenstein-Leopoldshafen, Germany

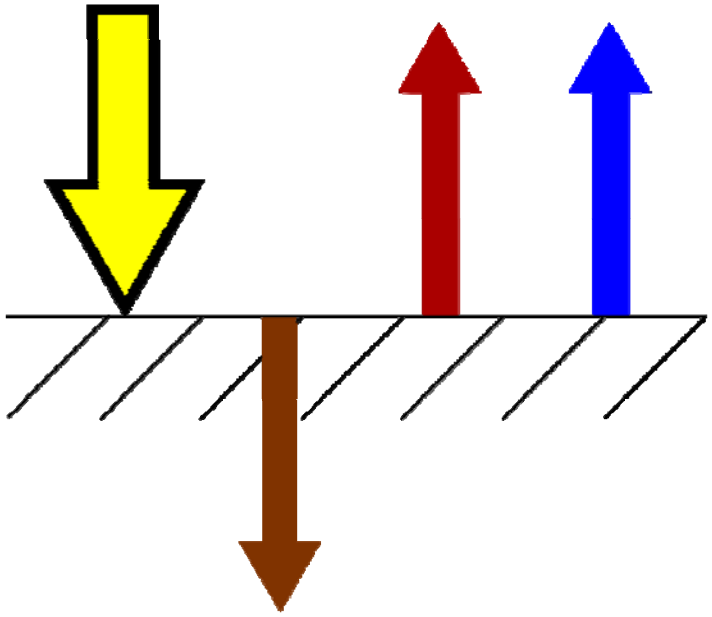
TERENO International Conference 2014 28 Sept – 2 Oct 2014, Bonn



The energy balance

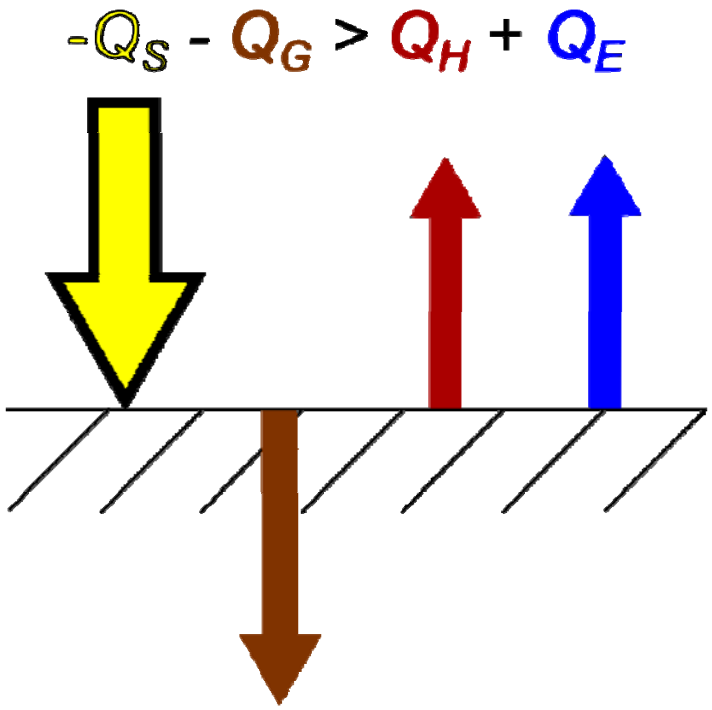
- Conservation of energy at the surface

$$-Q_S - Q_G = Q_H + Q_E$$



The energy balance closure problem

- Eddy-covariance towers **underestimate** the turbulent heat fluxes



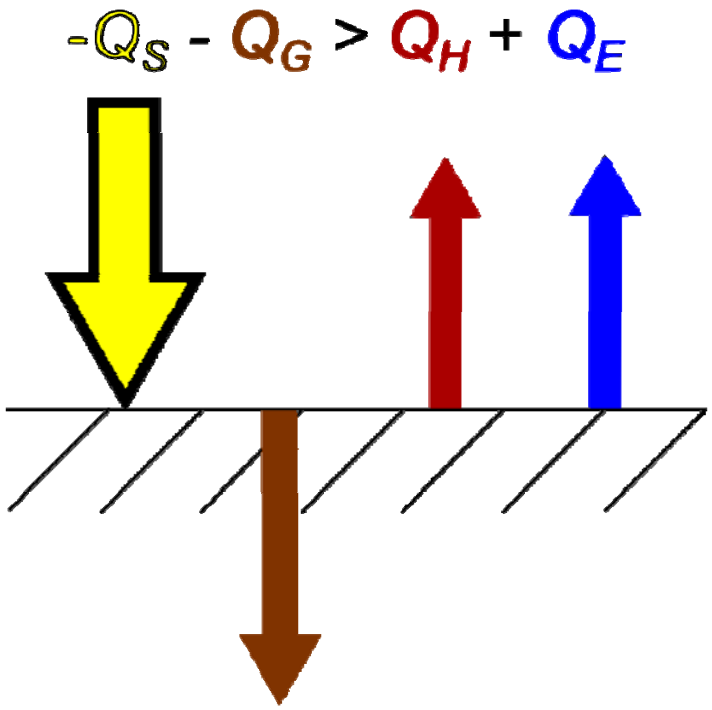
$$EBR = \frac{Q_H + Q_E}{-Q_S^* - Q_G}$$

mean *EBR* of 173 FLUXNET sites:

0.84 ± 0.20 (Stoy et al. 2013)

The energy balance closure problem

- Eddy-covariance towers **underestimate** the turbulent heat fluxes

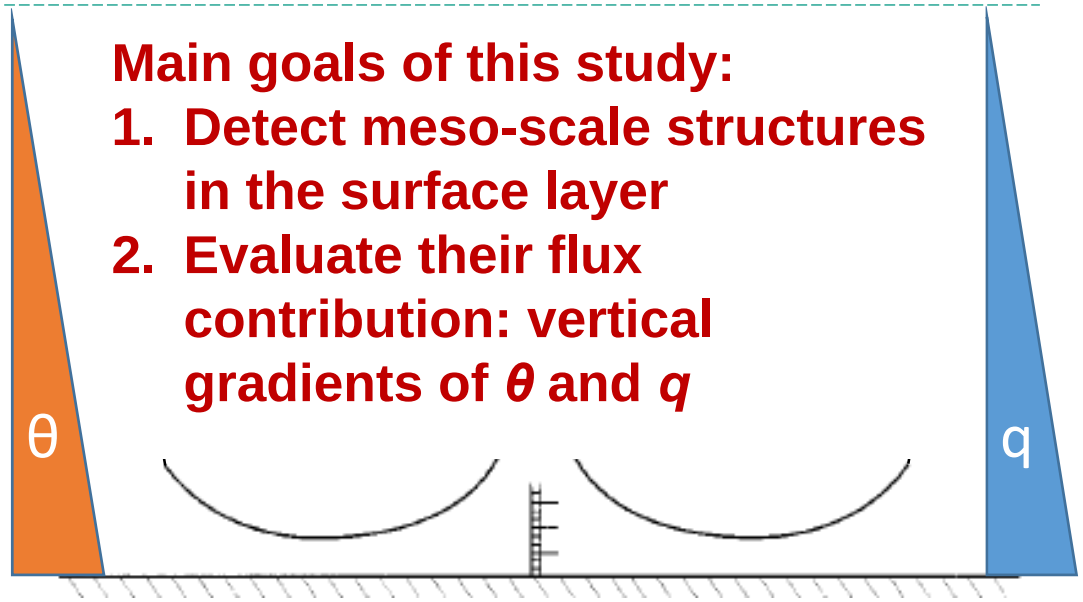


Hypothesis:

The flux contribution of meso-scale structures is ***not*** captured by eddy-covariance towers.

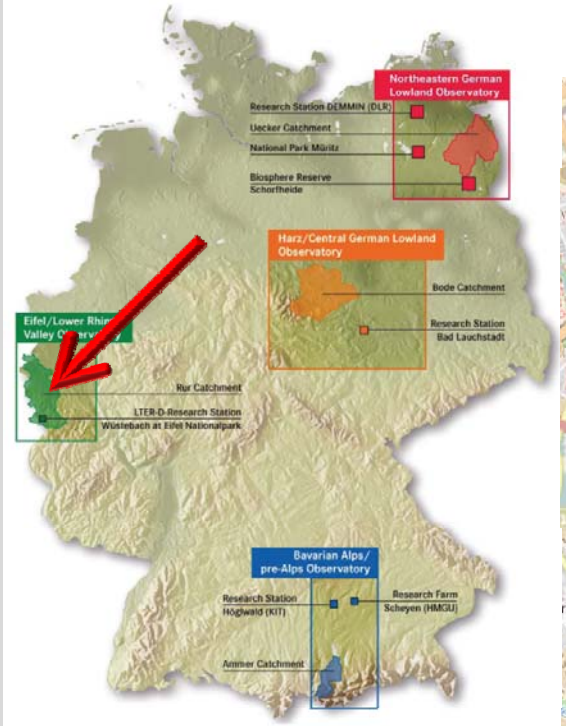
Meso-scale structures in the surface layer

- **Hypothesis:** The flux contribution of meso-scale structures is ***not*** captured by eddy-covariance towers.



modified after
Mahrt (1998): Flux sampling errors for aircraft and towers, *Journal of Atmospheric and Oceanic Technology*

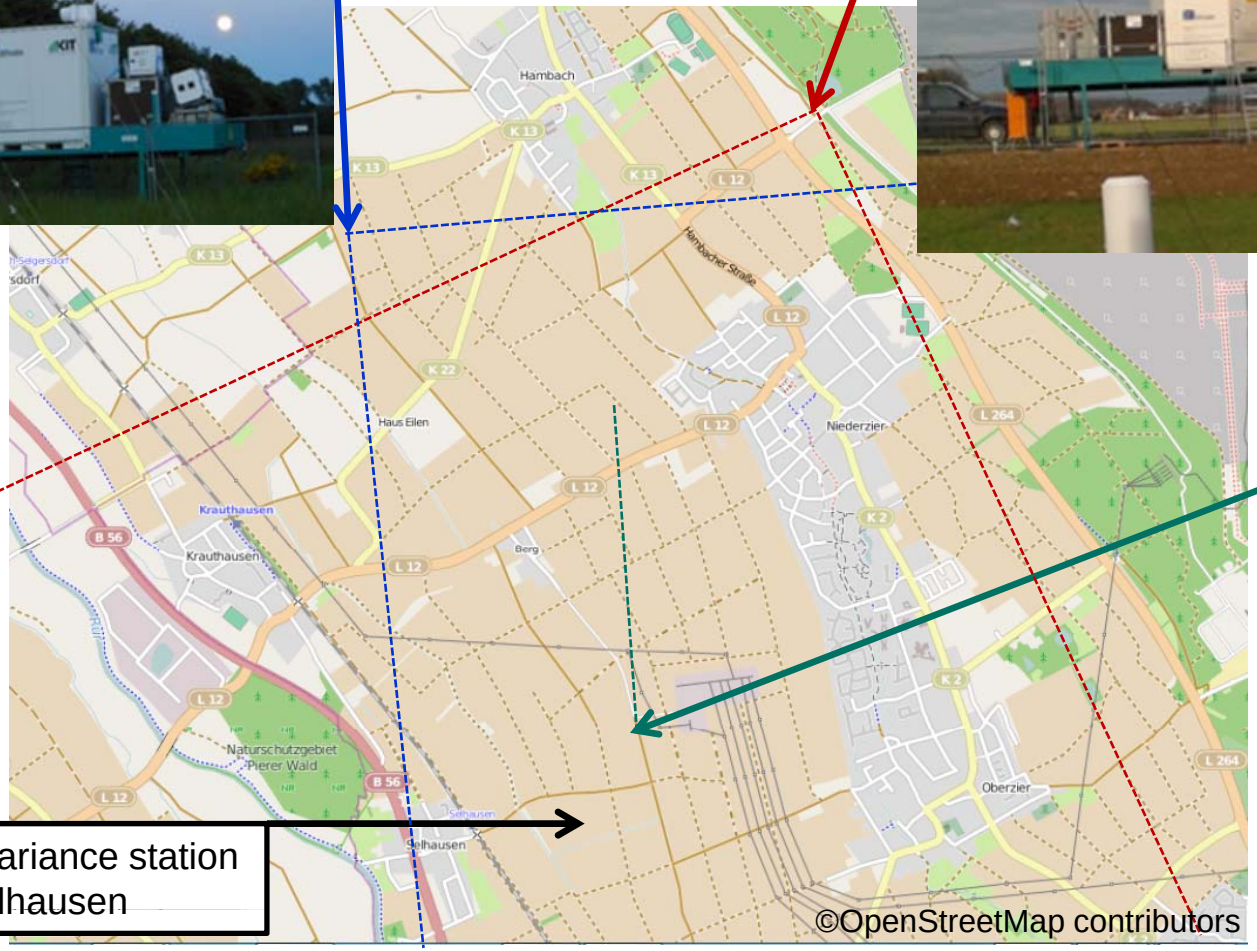
Experimental site



Experimental site

WindTracer lidar 1

WindTracer lidar 2, HATPRO radiometer



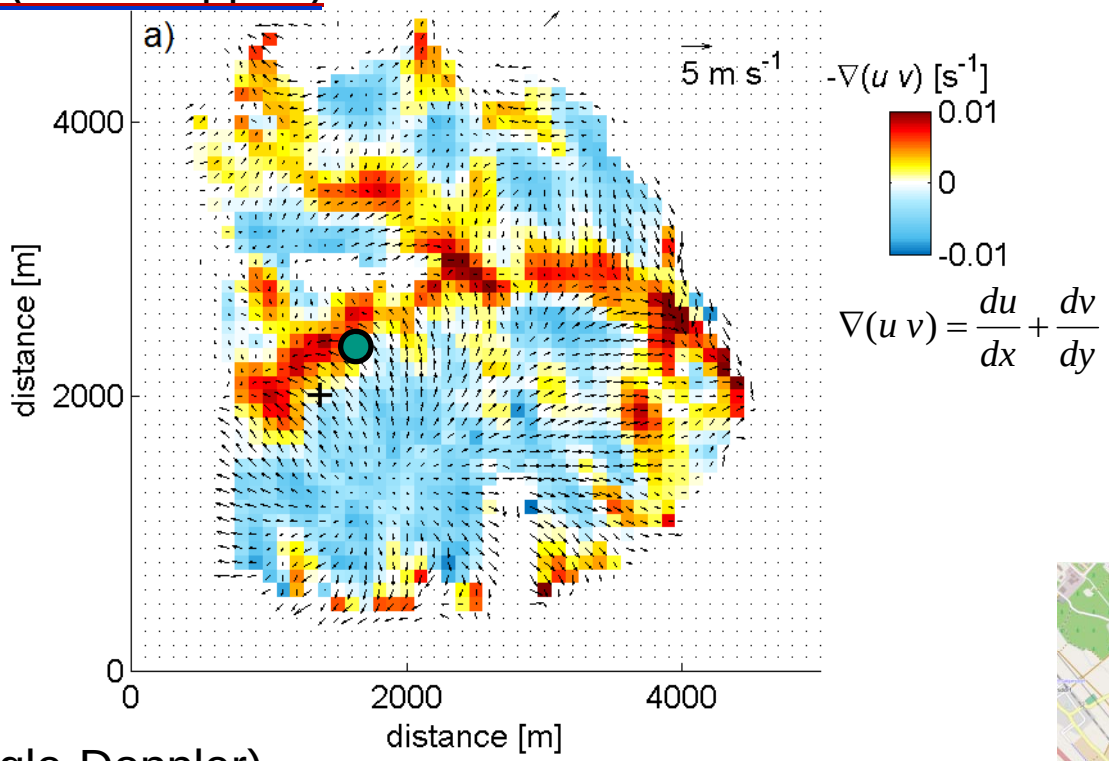
©OpenStreetMap contributors

Streamline lidar

Eddy-covariance station Selhausen

1. Detect meso-scale structures

-∇ *(u v)* (Dual-Doppler)

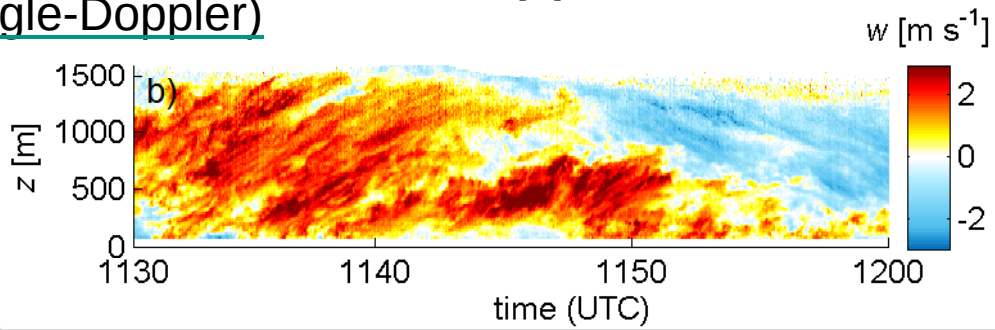


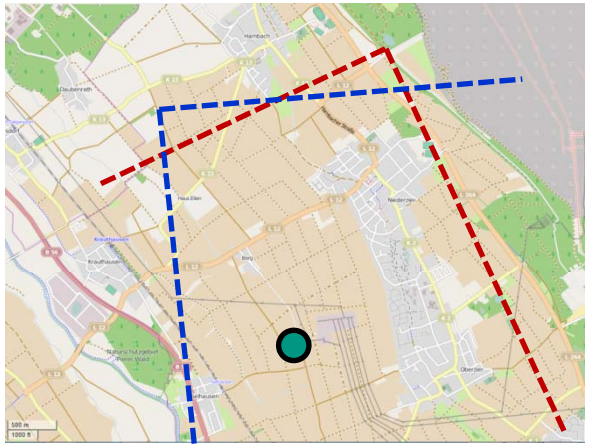
$$\nabla(u\,v) = \frac{du}{dx} + \frac{dv}{dy}$$

7 Apr 2013

u_{3m} = 0-2 m s^{-1}
EBR = 0.79

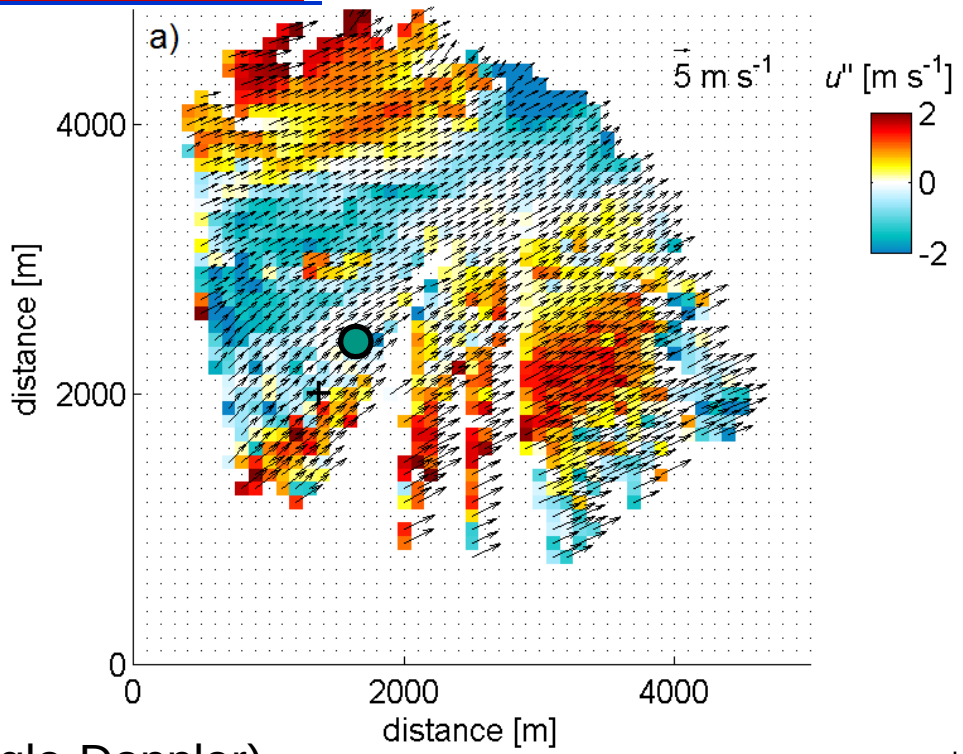
w (Single-Doppler)



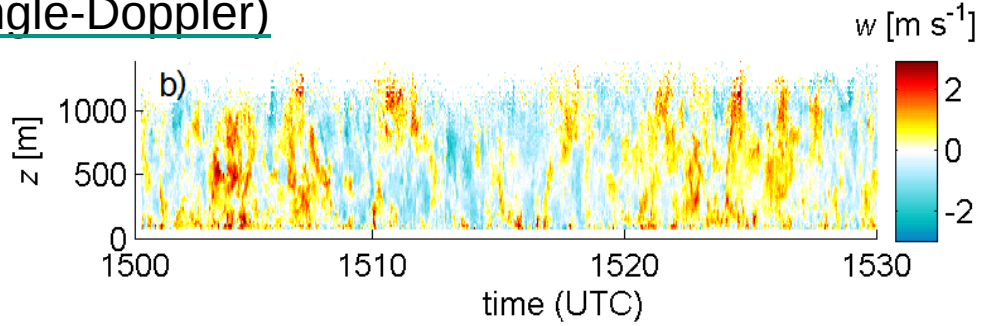


1. Detect meso-scale structures

$u - \langle u \rangle$ (Dual-Doppler)

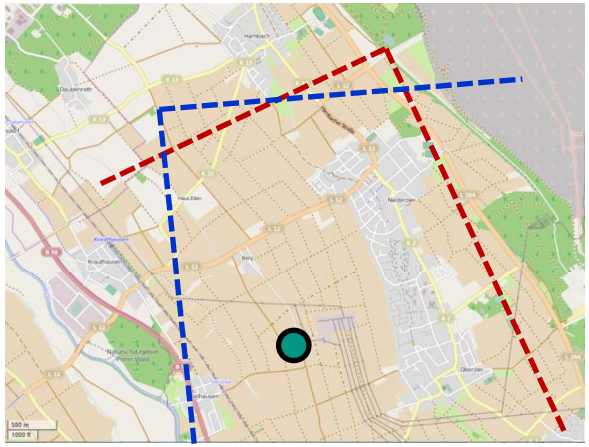


w (Single-Doppler)



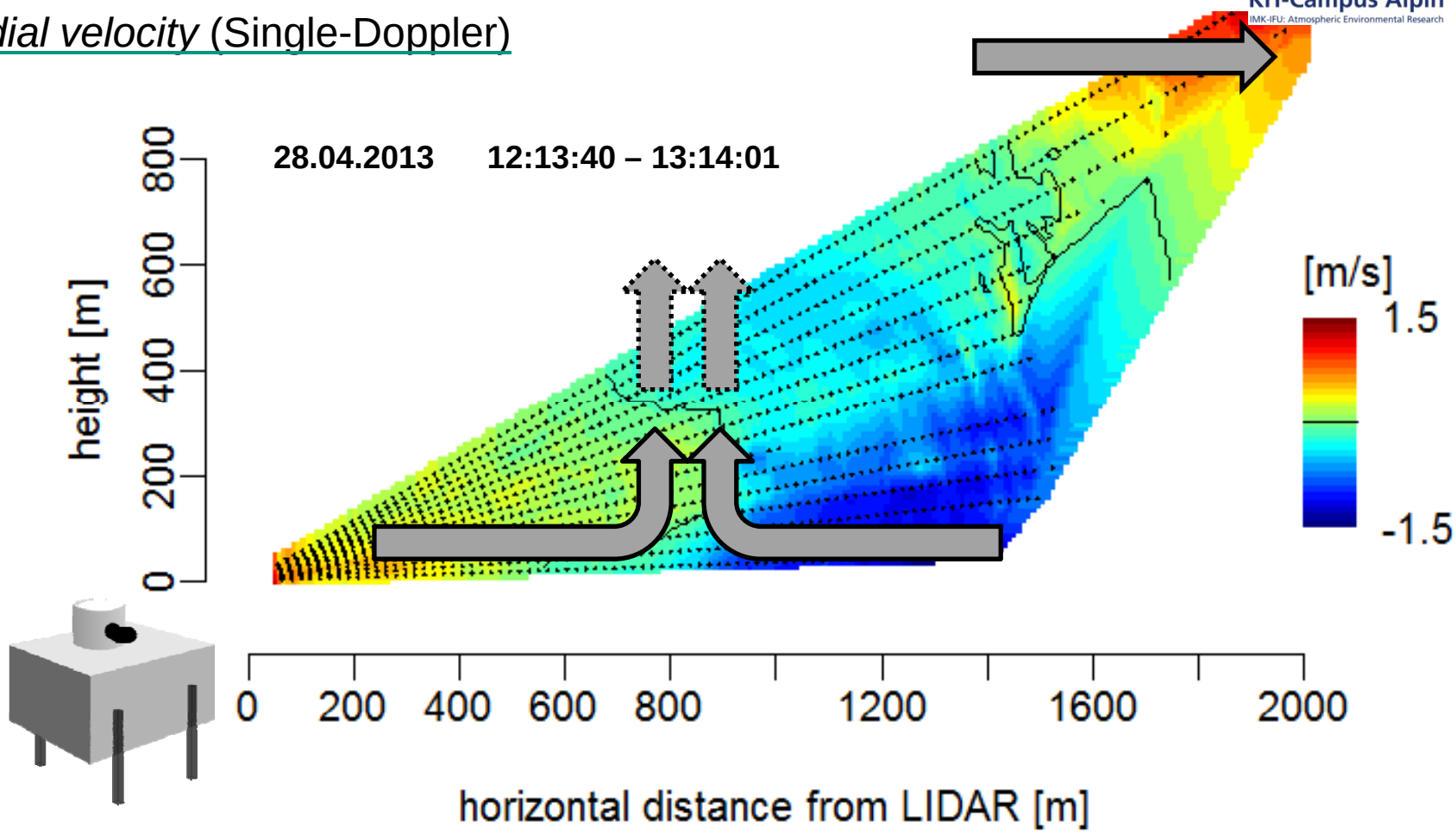
16 Apr 2013

u_{3m} = 2-4 m s^{-1}
EBR = 0.97

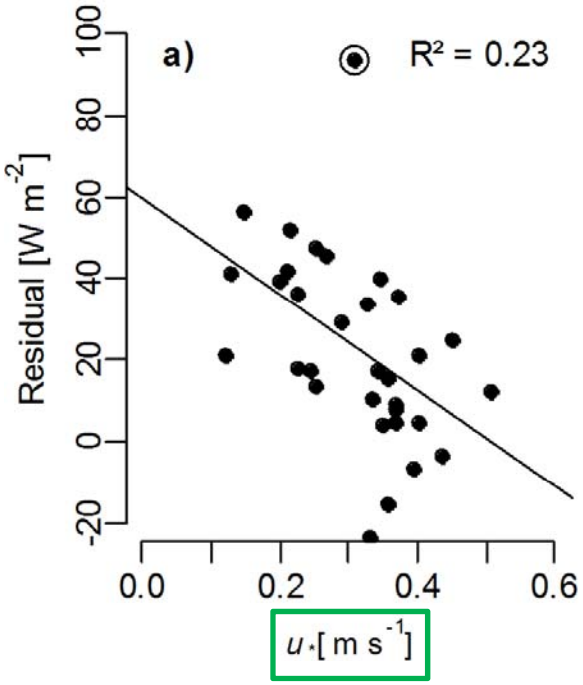


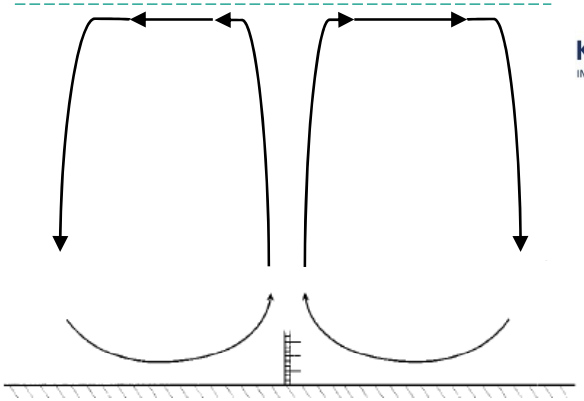
1. Detect meso-scale structures

radial velocity (Single-Doppler)



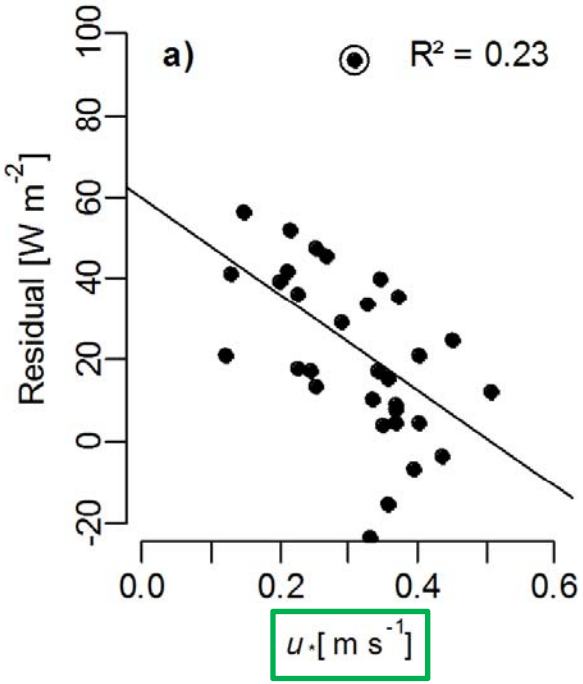
2. Flux contribution of meso-scale eddies?

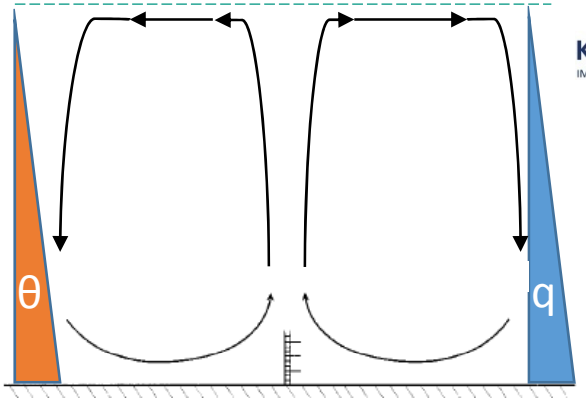


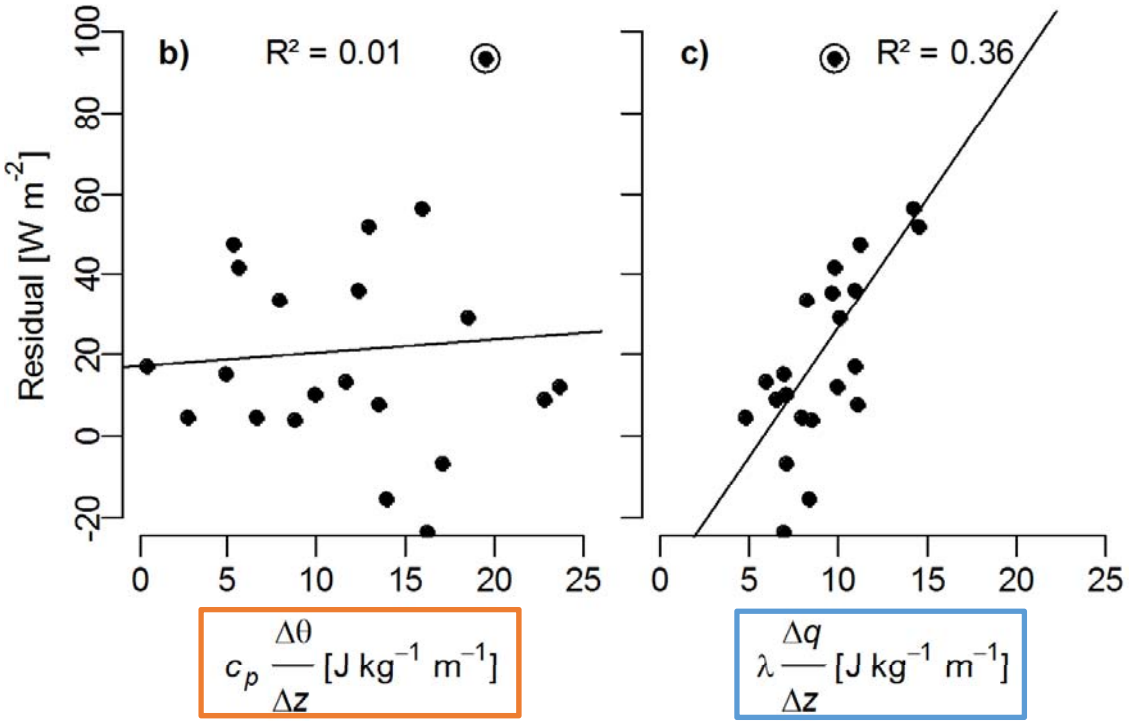


station: Selhausen
period: Apr / May 2013

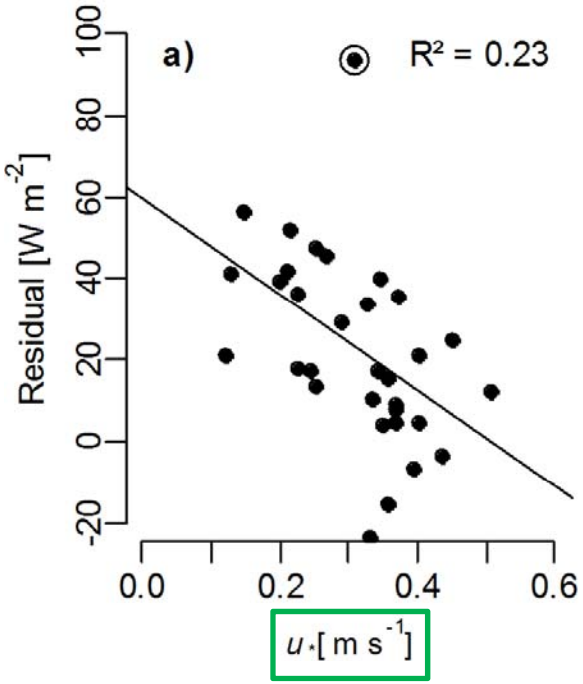
2. Flux contribution of meso-scale eddies?

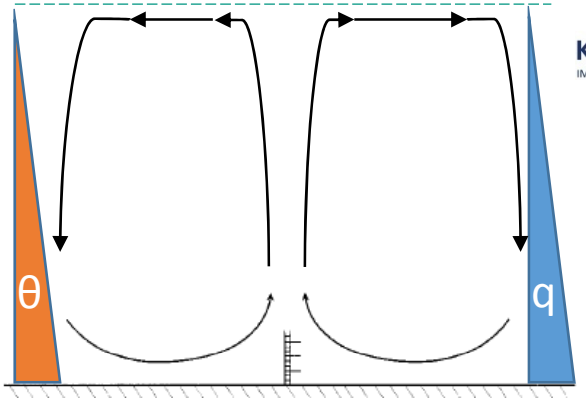


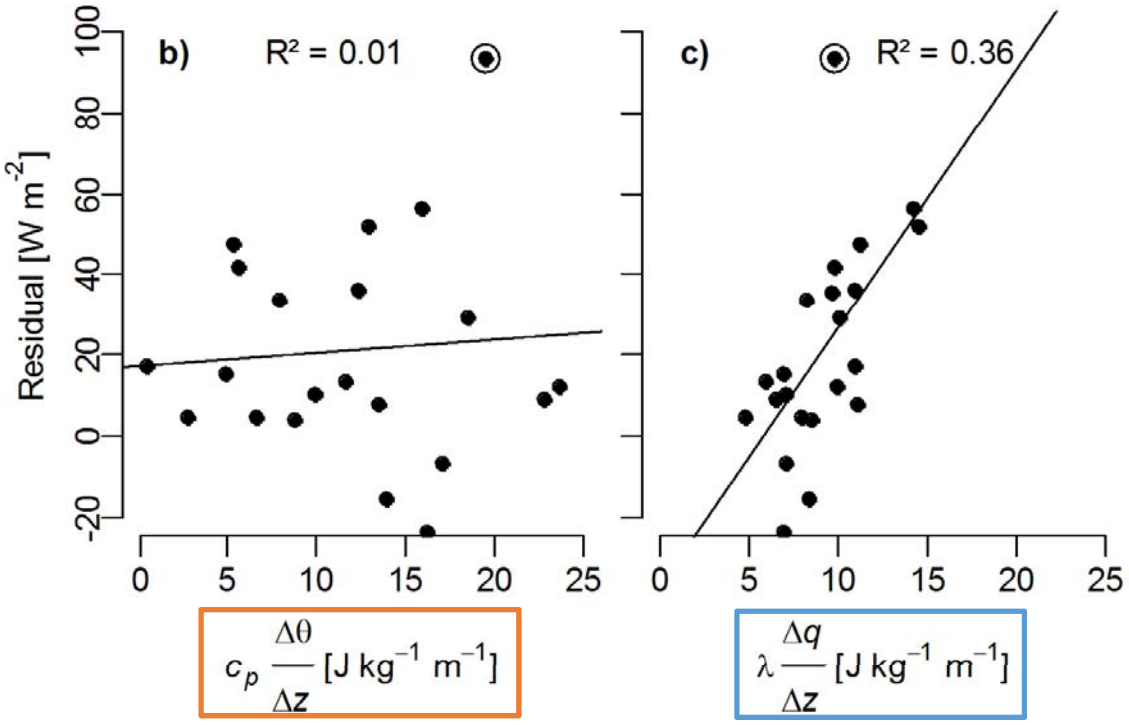




2. Flux contribution of meso-scale eddies?







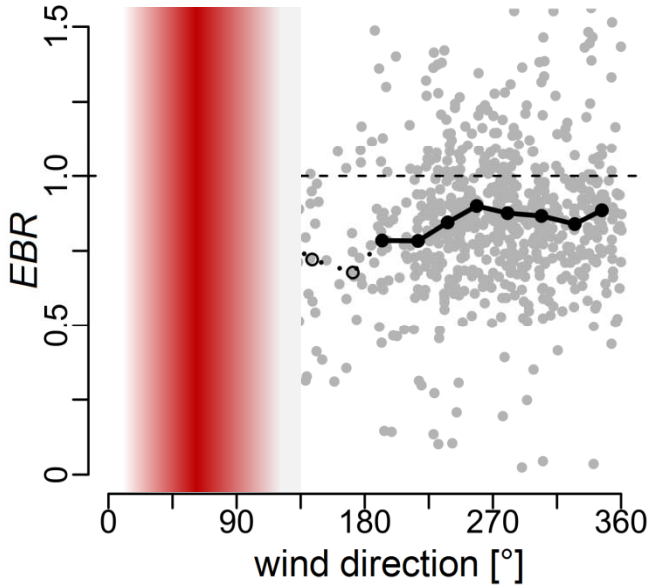
Multiple linear regression:

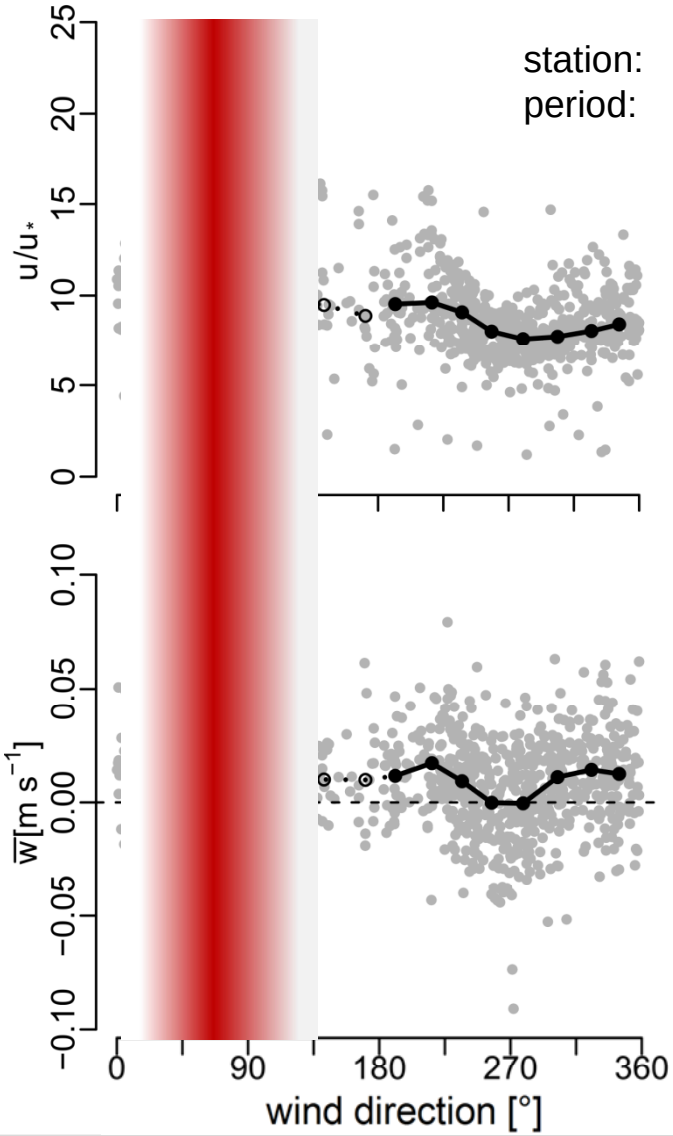
$$Residual = c_o + c_1 \frac{1}{u_*} + c_2 \lambda \frac{\Delta q}{\Delta z}$$

R^2 = 0.40 (0.60)

Other reasons for the unclosed energy balance

- anemometer backwind deficiencies
- flow distortion (tower mountings, instruments)





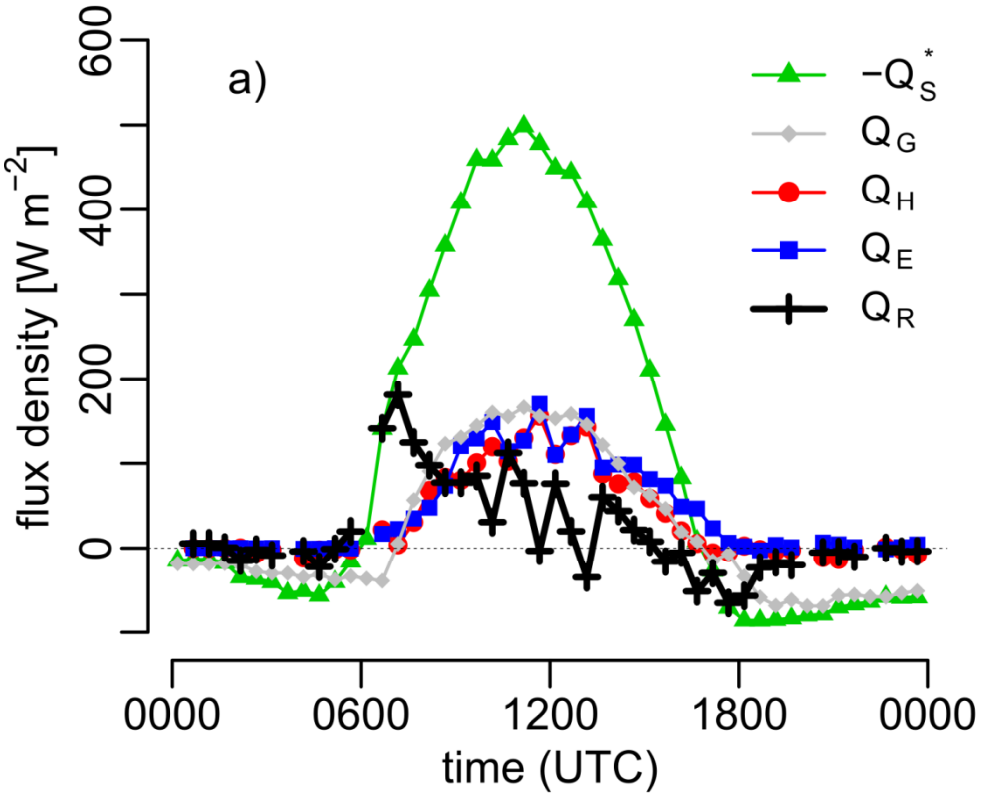
station: Selhausen
period: Apr / May 2013

daytime data
best quality flag

Other reasons for the unclosed energy balance

- heat storage in biomass of winter wheat
- melting of the white frost

station: Selhausen
day: 07 Apr 2013



Summary

Hypothesis: The flux contribution of meso-scale structures is ***not*** captured by eddy-covariance towers.

1. Detect meso-scale structures in the surface layer

- hexagonal cells, high- and low-speed regions with timescales > 30 min
- lowest measurement height (LIDAR): ≈ 15 m a.g.l.

2. Evaluate their flux contribution

- only indirect evaluation was possible
- negative correlation with u_* (relative intensity of high-freq. turbulence)
- positive correlation with vertical moisture gradient (*but: site-specific!*)

Other factors contributing to the energy imbalance:

- anemometer backwind deficiencies
- flow distortion (tower mountings, instruments)
- neglected heat storage terms