

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

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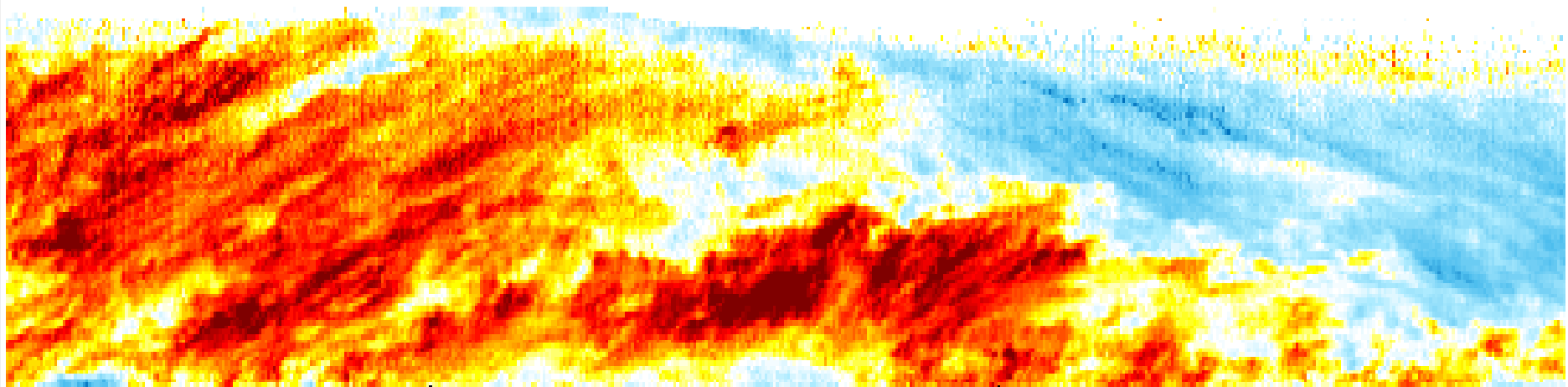
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TERENO International Conference 2014 28 Sept – 2 Oct 2014, Bonn

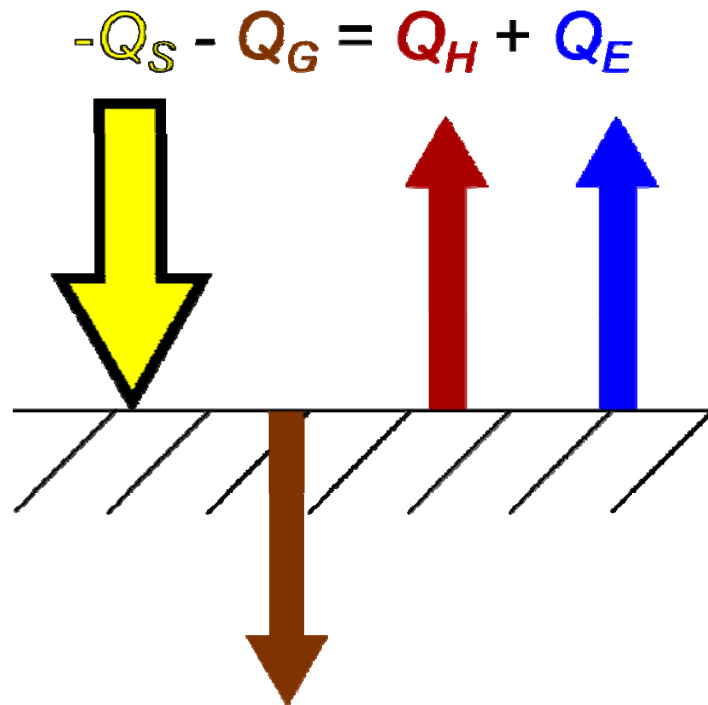


**TERENO**  
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES



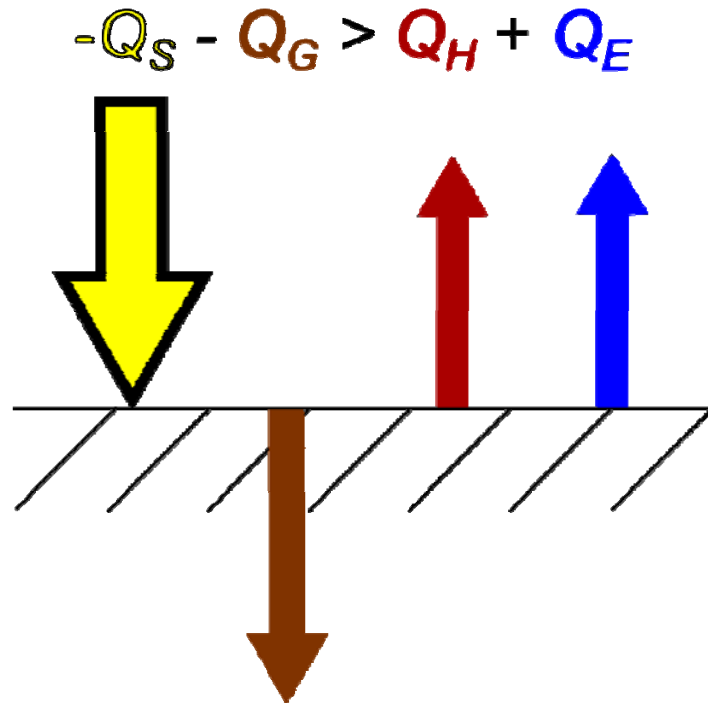
# The energy balance

- Conservation of energy at the surface



# The energy balance closure problem

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



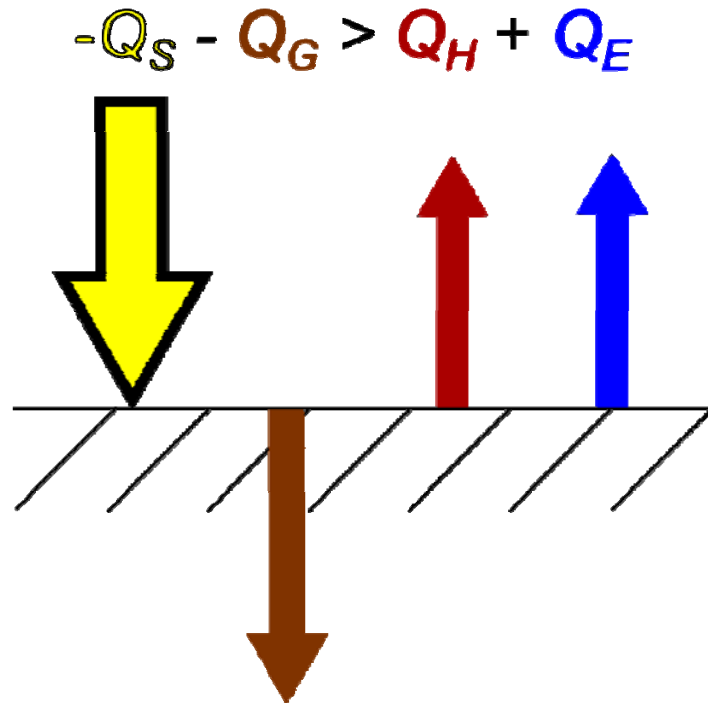
$$EBR = \frac{Q_H + Q_E}{-Q_S^* - Q_G}$$

mean *EBR* of 173 FLUXNET sites:

$0.84 \pm 0.20$  (Stoy et al. 2013)

# The energy balance closure problem

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

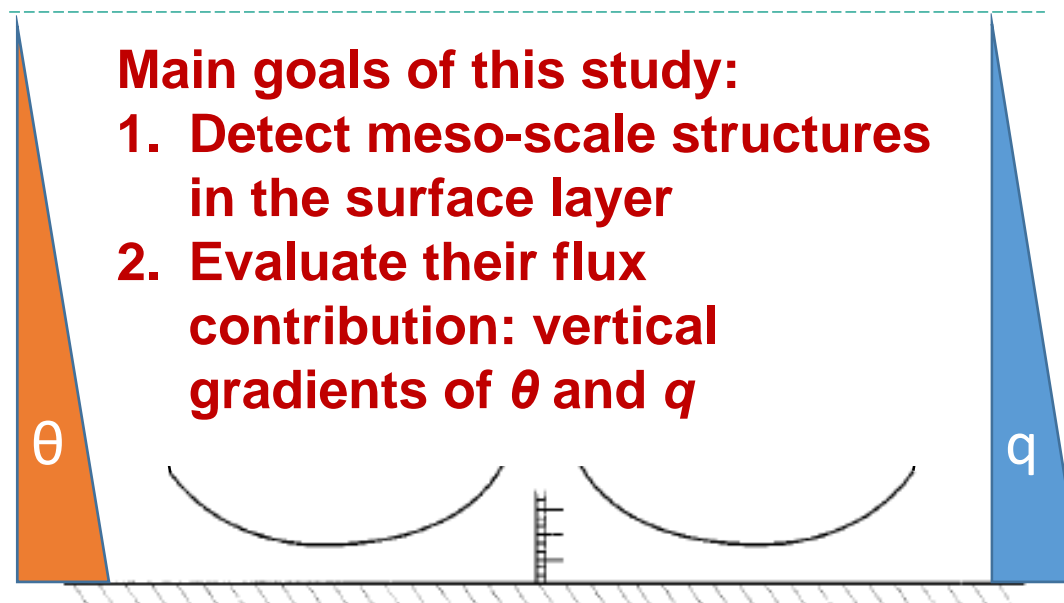


## Hypothesis:

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.



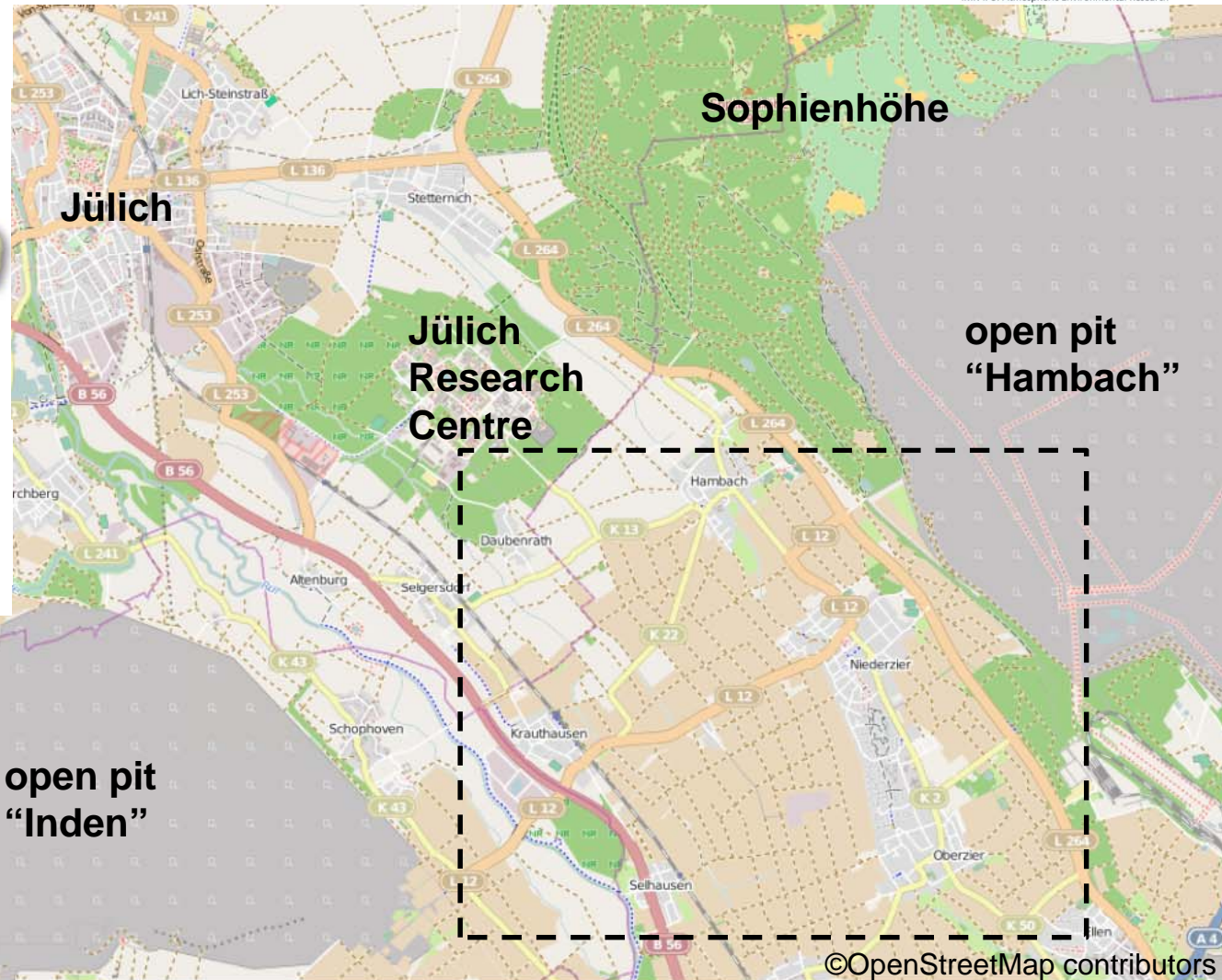
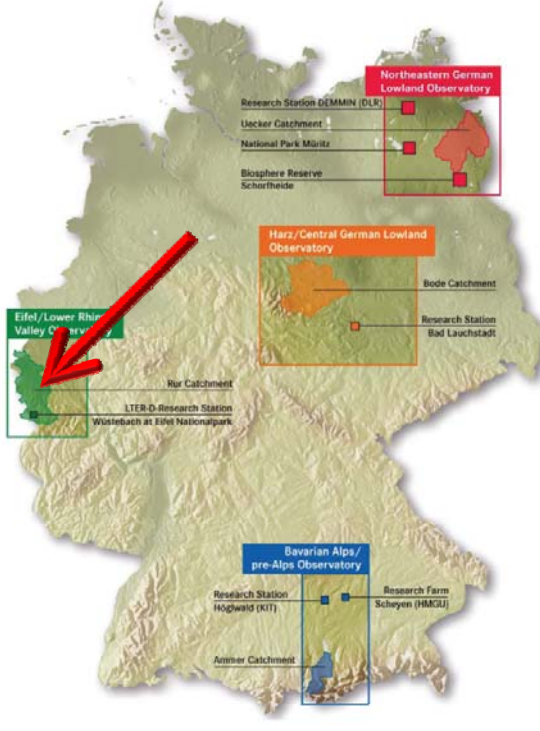
modified after

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

# Experimental site



**HD(CP)<sup>2</sup>**  
 High definition clouds and precipitation  
 for advancing climate prediction



# Experimental site



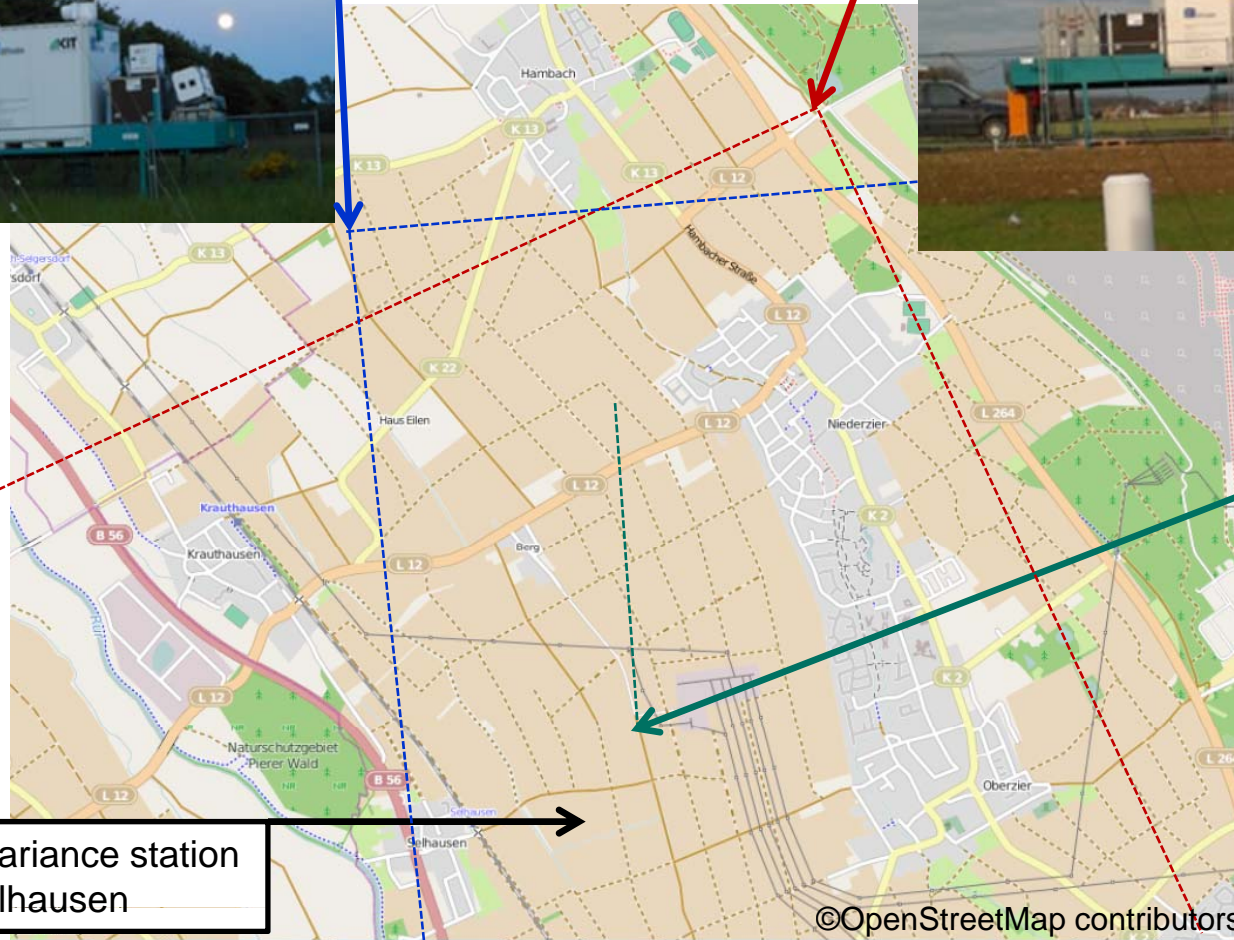
HD(CP)<sup>2</sup>



WindTracer lidar 1



WindTracer lidar 2, HATPRO radiometer



Streamline lidar

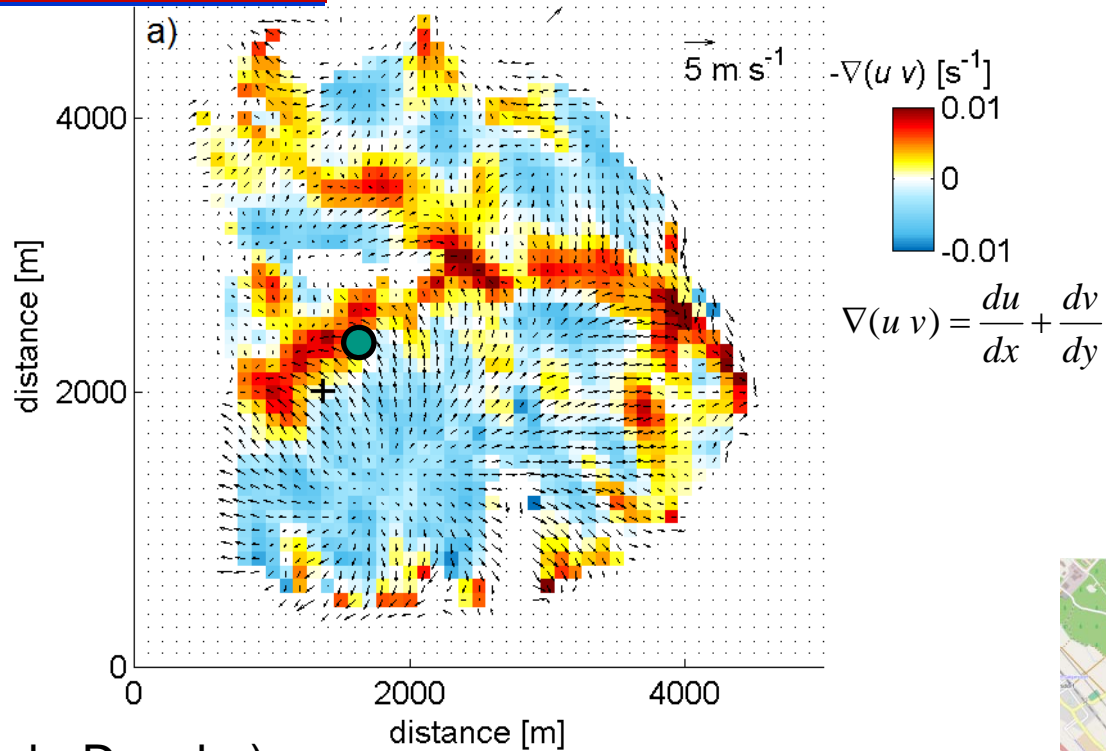


Eddy-covariance station Selhausen

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# 1. Detect meso-scale structures

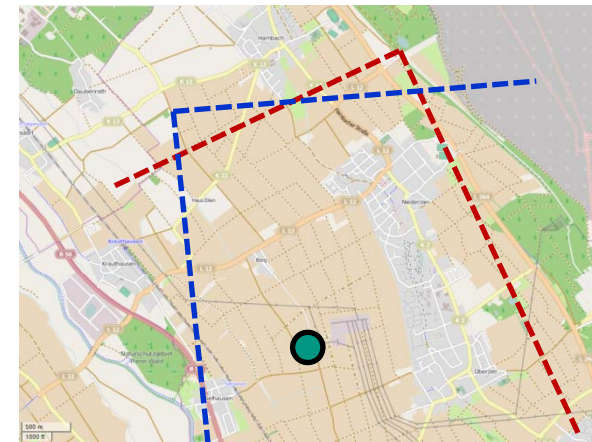
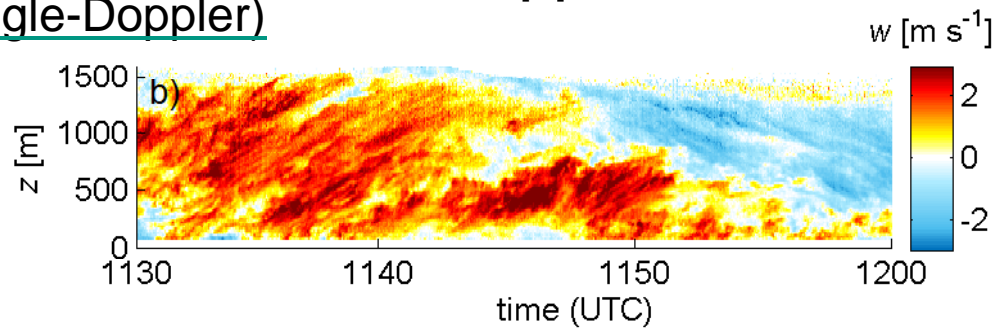
## $-\nabla(uv)$ (Dual-Doppler)



7 Apr 2013

$u_{3m} = 0-2$  m s<sup>-1</sup>  
 $EBR = 0.79$

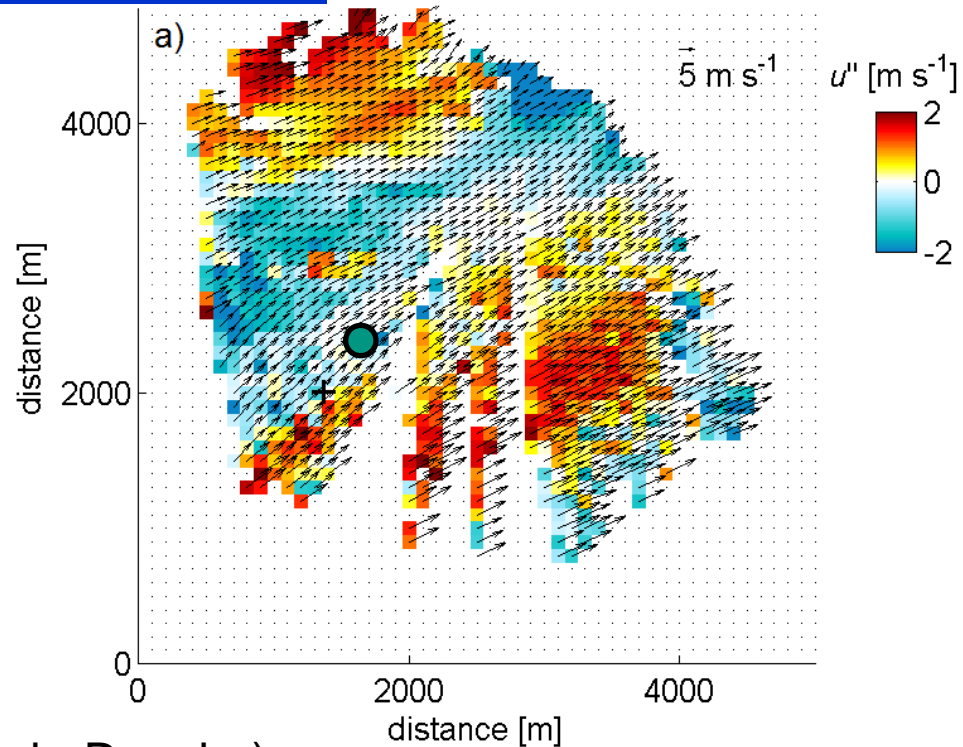
## w (Single-Doppler)





# 1. Detect meso-scale structures

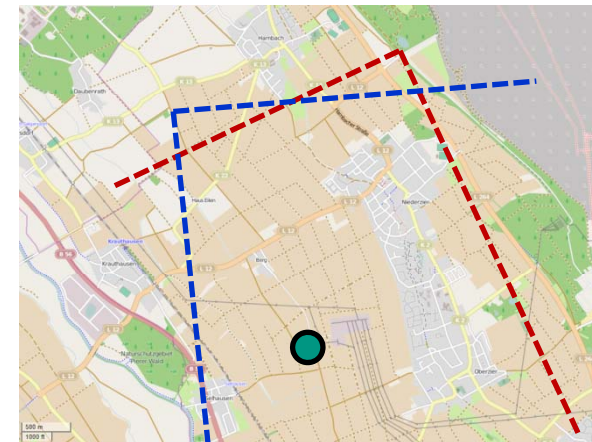
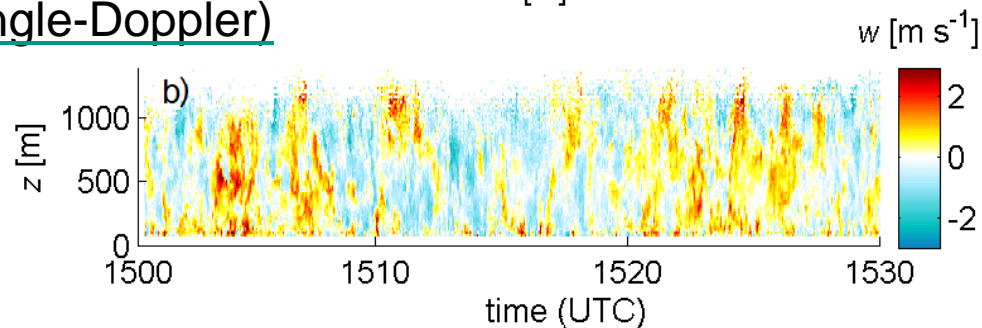
$u - \langle u \rangle$  (Dual-Doppler)



16 Apr 2013

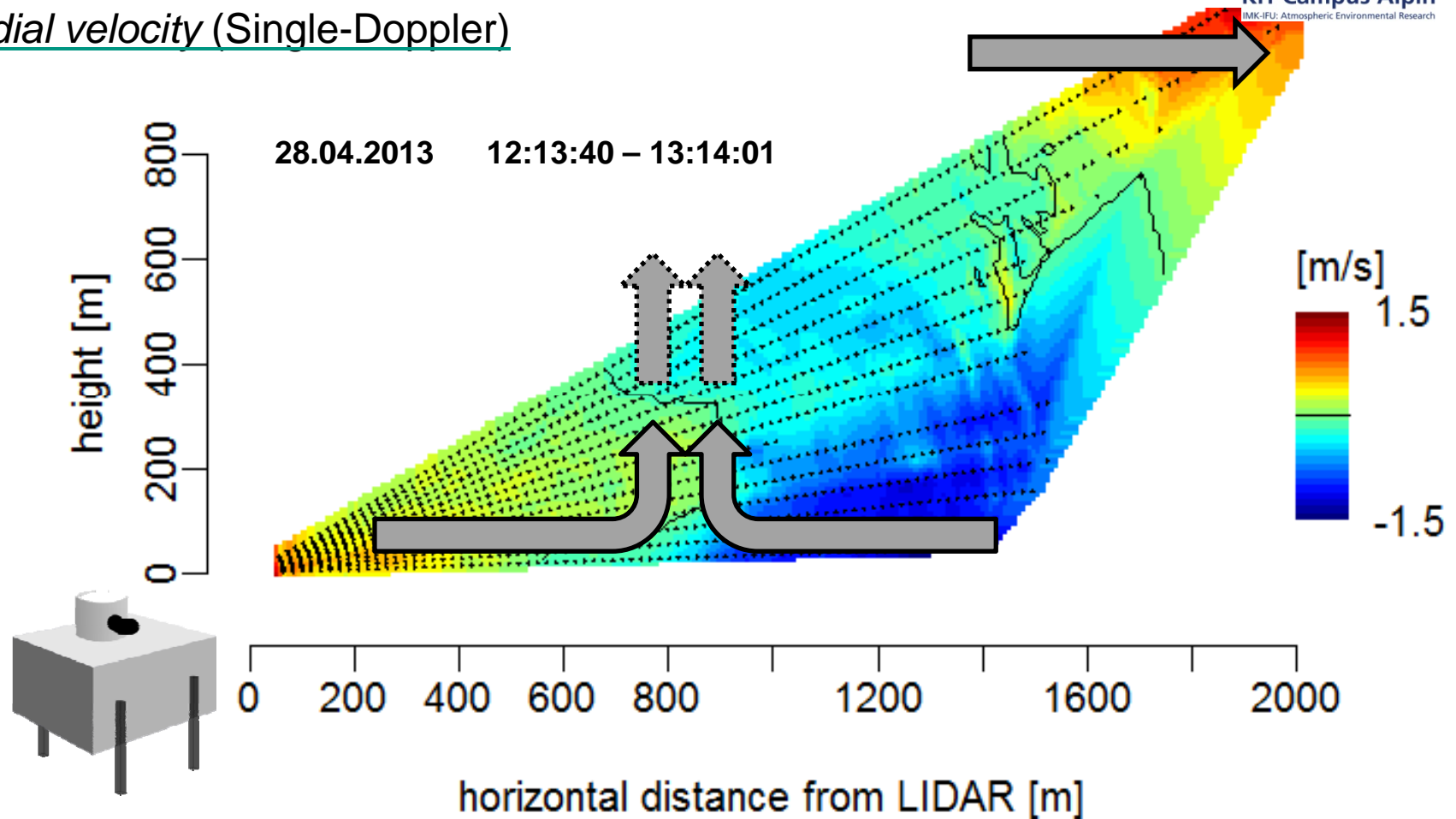
$U_{3m} = 2-4 \text{ m s}^{-1}$   
 $EBR = 0.97$

$w$  (Single-Doppler)

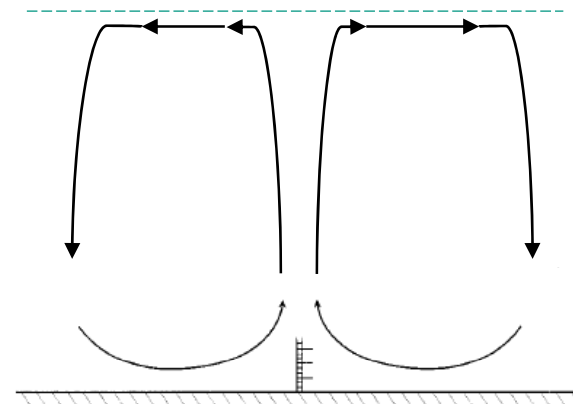
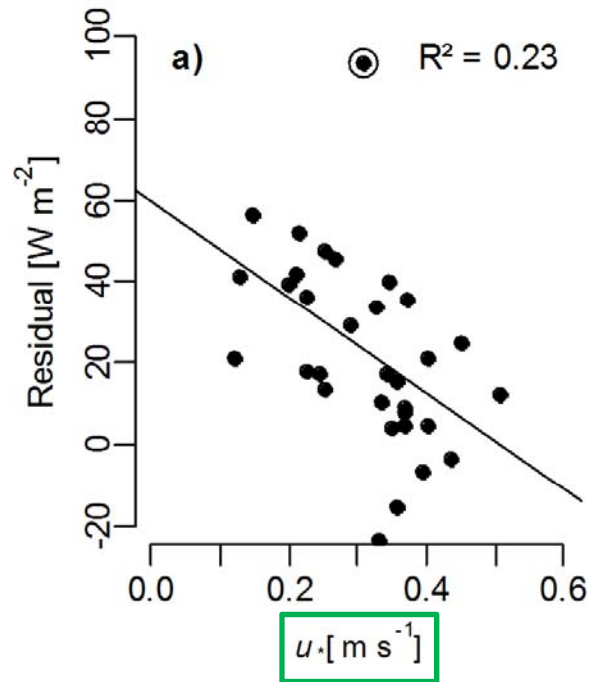


# 1. Detect meso-scale structures

radial velocity (Single-Doppler)

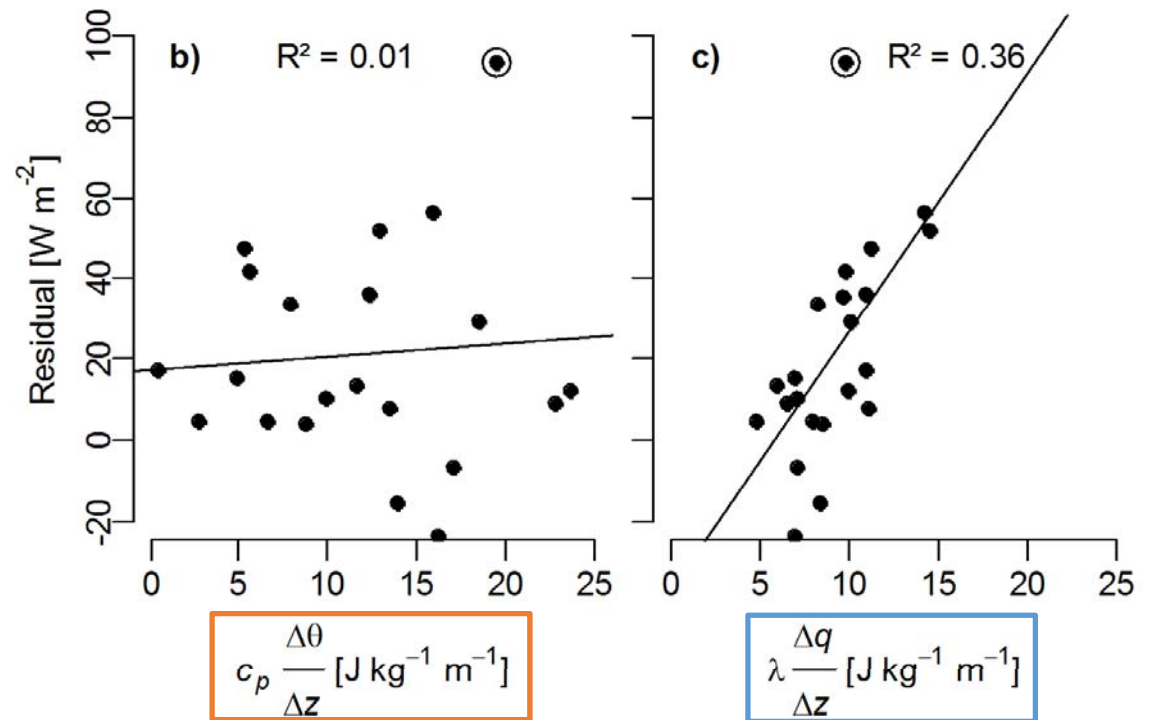
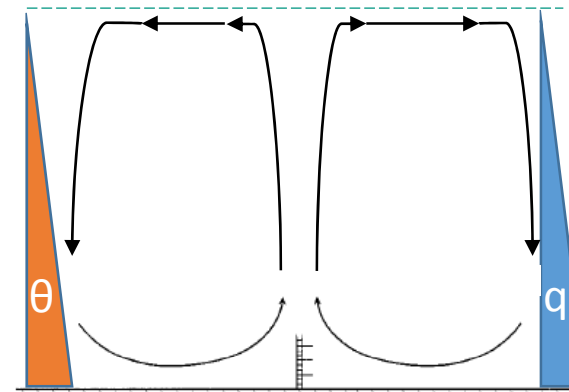
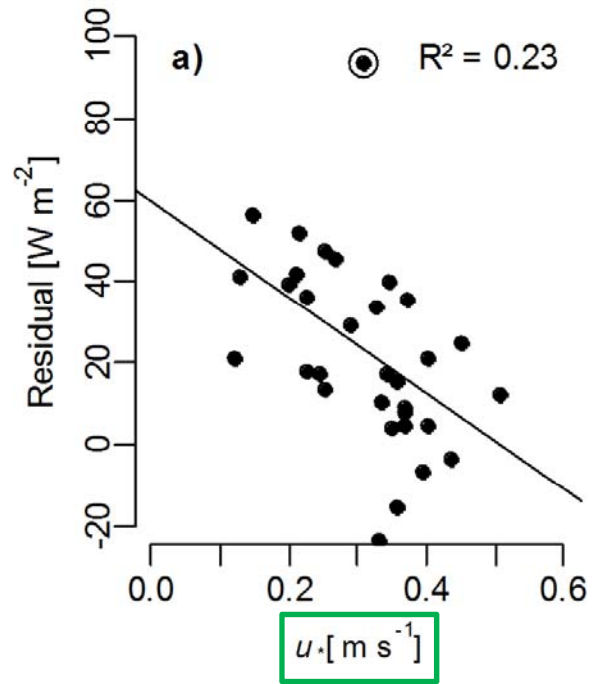


## 2. Flux contribution of meso-scale eddies?

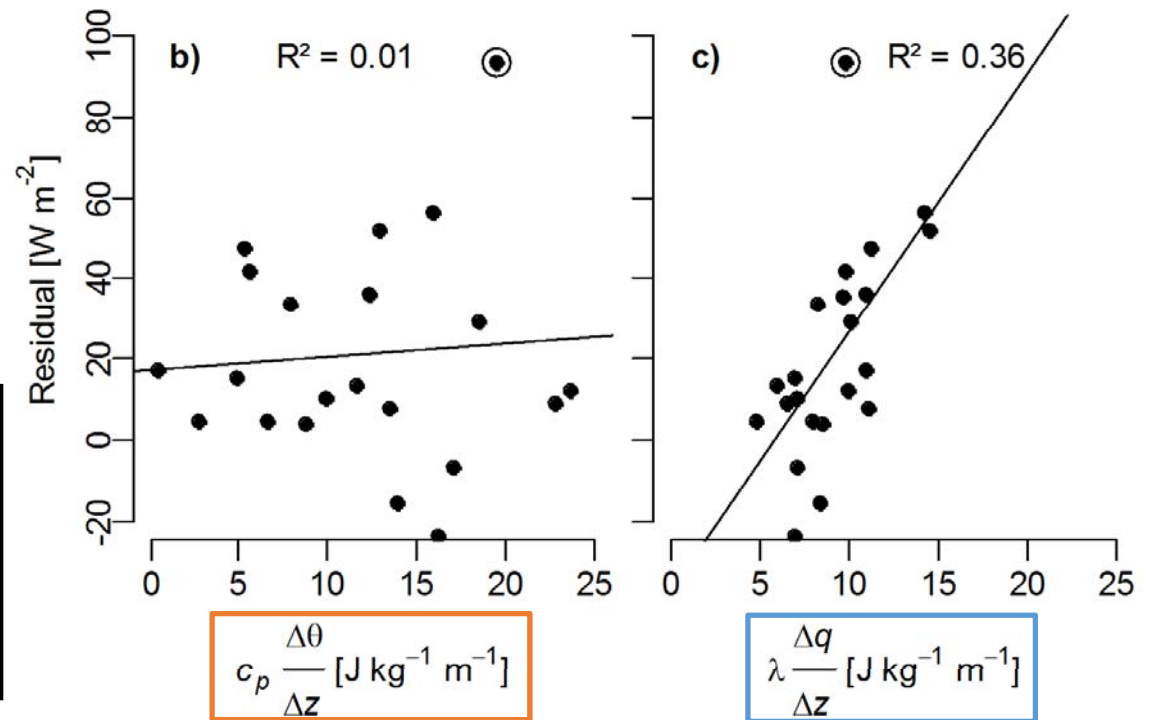
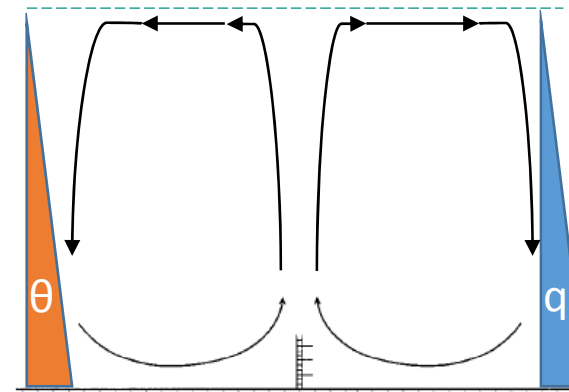
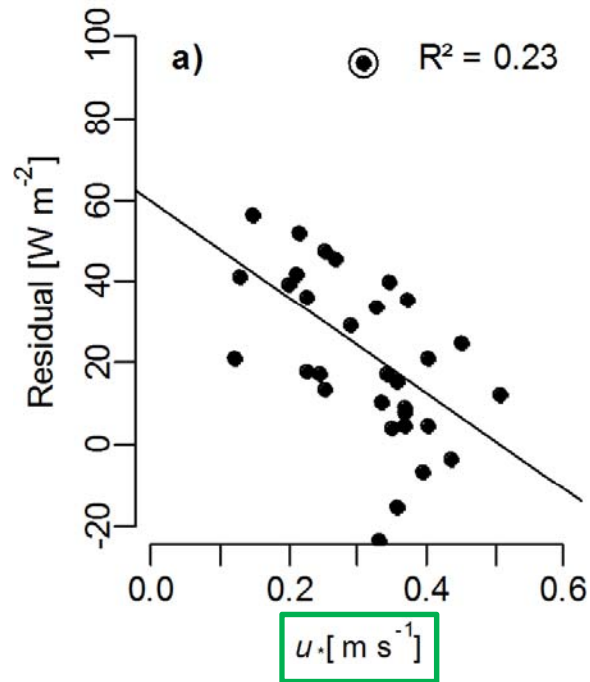


station: Selhausen  
 period: Apr / May 2013

## 2. Flux contribution of meso-scale eddies?



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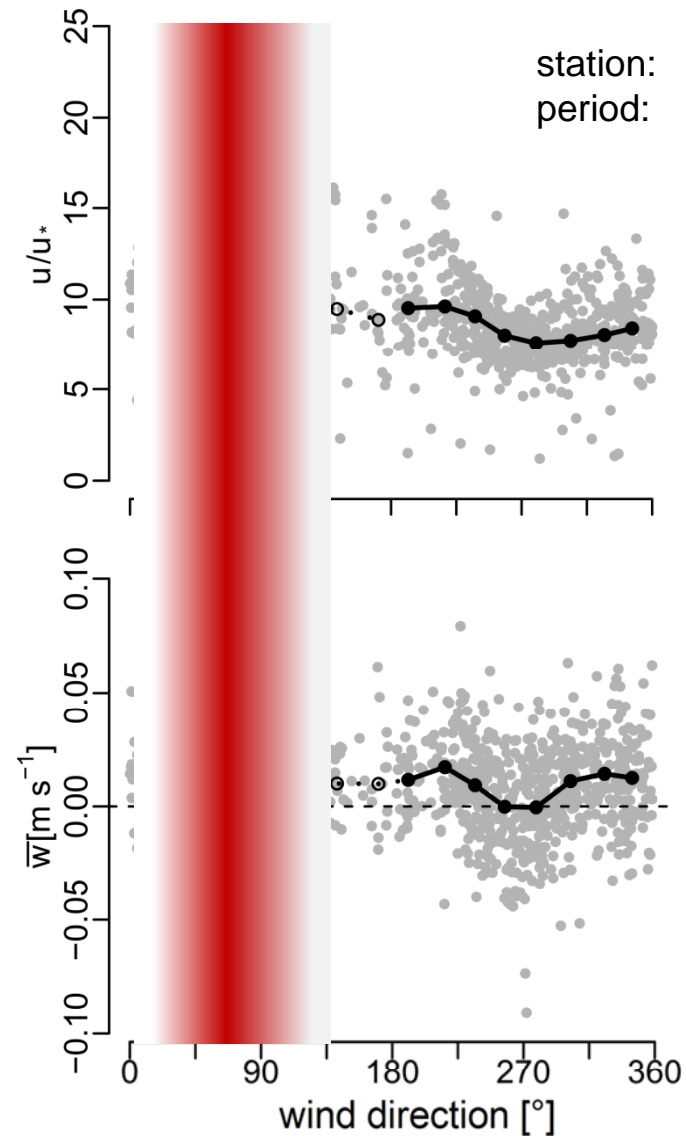
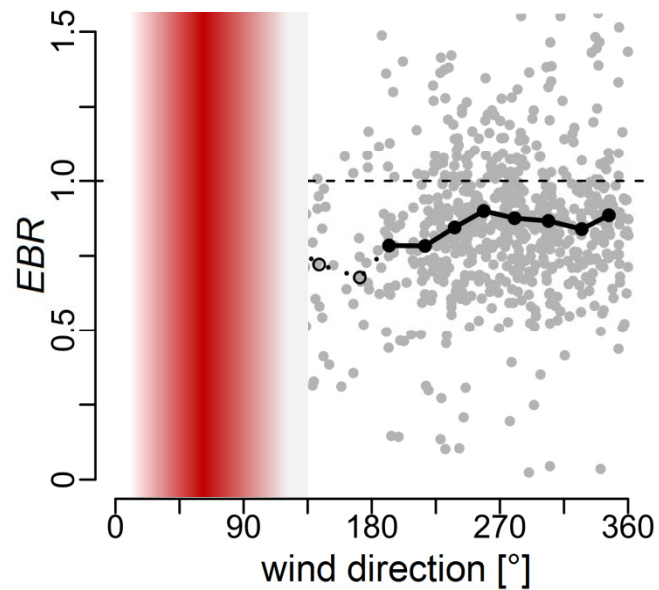
Multiple linear regression:

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

$$R^2 = 0.40 \text{ (0.60)}$$

# Other reasons for the unclosed energy balance

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

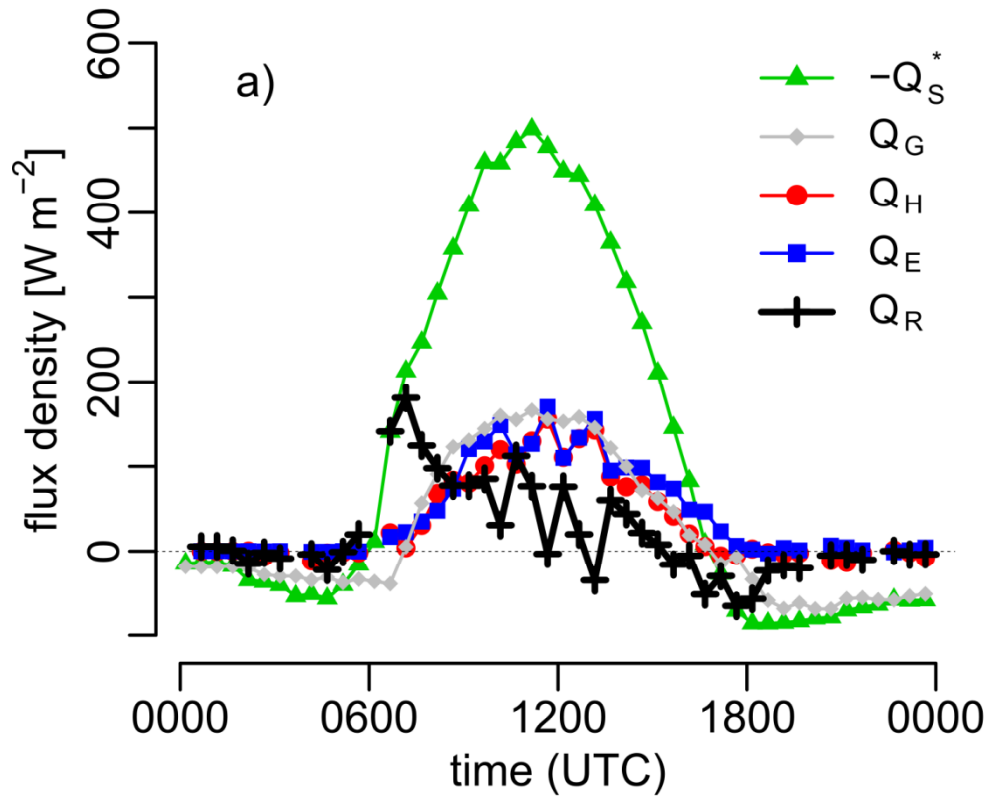


station: Selhausen  
 period: Apr / May 2013  
 daytime data  
 best quality flag

# 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):  $\approx 15$  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