Validation of two energy balance closure parameterizations using field measurements

Fabian Eder (1), Frederik De Roo (1), Katrin Kohnert (1,2), Raymond L. Desjardins (3), Thomas Foken (2), Hans Peter Schmid (1), Matthias Mauder (1)

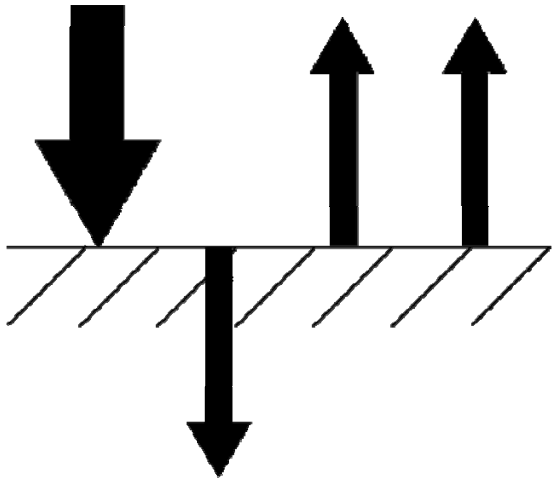
(1) Institute for Meteorology and Climate Research, Atmospheric Environmental Research (IMK-IFU), Karlsruhe Institute of Technology (KIT), Kreuzeckbahnstrasse 19, 82467 Garmisch-Partenkirchen, Germany
(2) Department of Micrometeorology, University of Bayreuth, Universitätsstrasse 30, 95444 Bayreuth, Germany
(3) Agriculture and Agri-Food Canada, 960 Carling Avenue, Ottawa, Ontario, K1A 0C6, Canada

EGU General Assembly 2013, Vienna

The energy balance

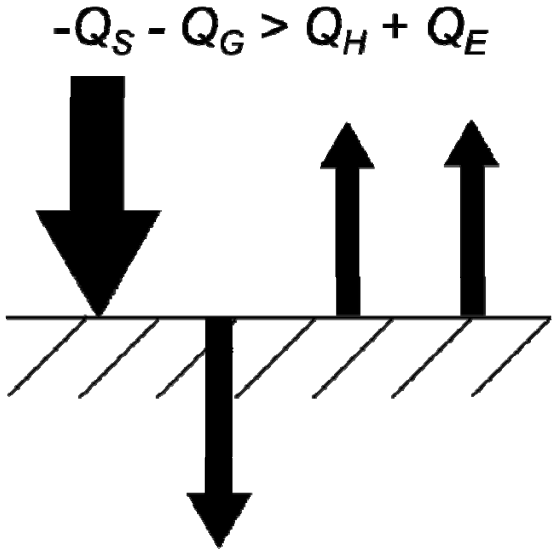
- Conservation of energy at the earth‘s surface

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



The energy balance closure problem

- Eddy-covariance towers **underestimate** surface heat fluxes: low-frequency motions, non-propagating meso-scale structures,...



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

mean *EBR* of 173 FLUXNET sites:

0.84 ± 0.20 (Stoy et al. 2013)

- **Is the *EBR* predictable for a given site / for given atmospheric conditions?**

→ need for a robust **parameterization** scheme

Parameterization of the energy balance closure

- *Huang et al. (2008)*

large-eddy simulation
homogeneous terrain
considers **atmospheric conditions**

$$I \sim f_1\left(\frac{u_*}{w_*}\right) \times f_2\left(\frac{z}{z_i}\right)$$

$$I = \frac{Q_H + Q_E}{-Q_S^* - Q_G} - 1$$

explains closure on a **30-min basis**

- *Panin and Bernhofer (2008)*

eddy-covariance measurements
surface roughness heterogeneities
considers **landscape properties**

$$k_f \sim \frac{z_{0_{eff}}}{L_{eff}}$$

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

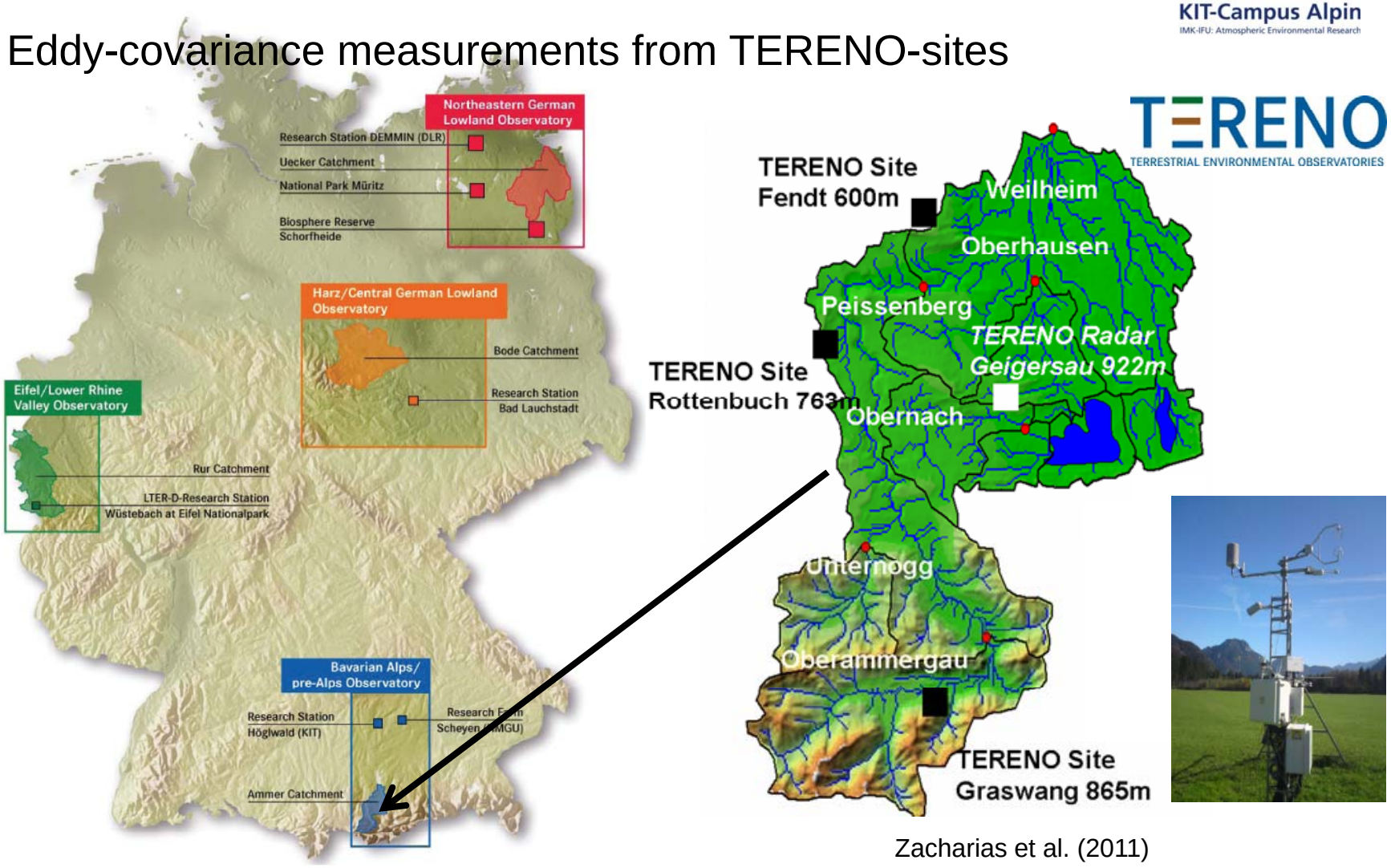
explains **mean closure** of a site

Huang J, Lee X, Patton E (2008) A modelling study of flux imbalance and the influence of entrainment in the convective boundary layer. Boundary Layer Meteorol 127:273-292

Panin GN, Bernhofer Ch (2008) Parametrization of turbulent fluxes over inhomogeneous landscapes. Izvestiya Atmos Oceanic Phys 44:701-716

Experimental data

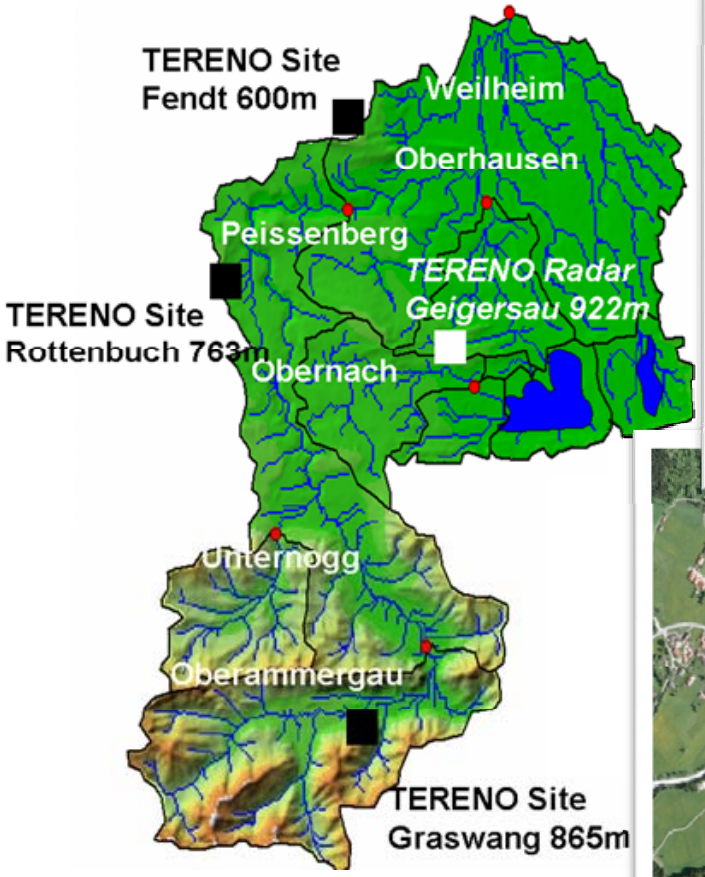
- Eddy-covariance measurements from TERENO-sites

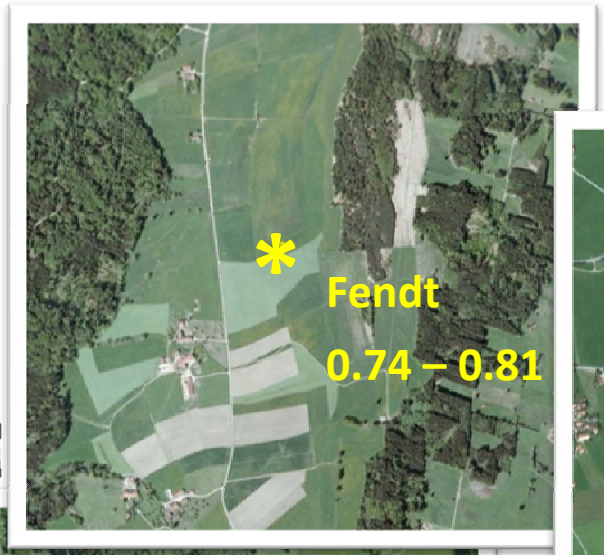


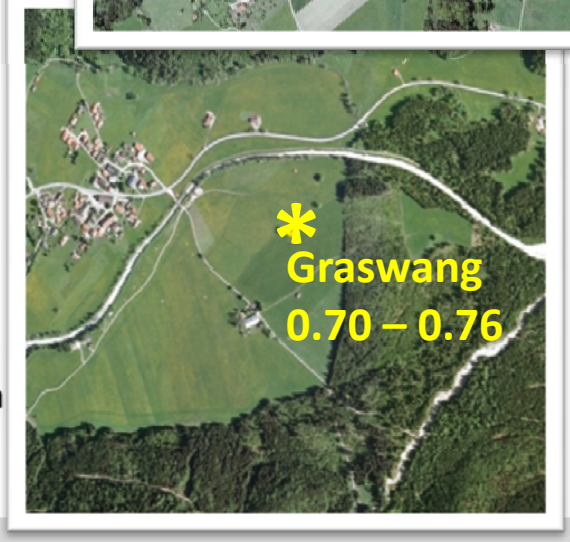
Zacharias et al. (2011)

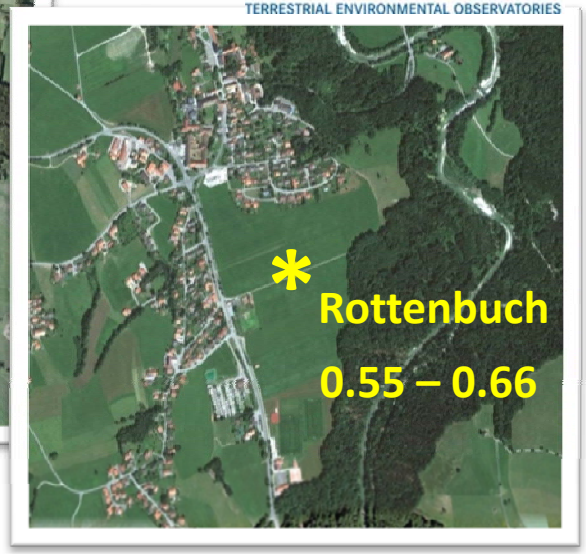
Experimental data

- Eddy-covariance measurements from TERENO-sites







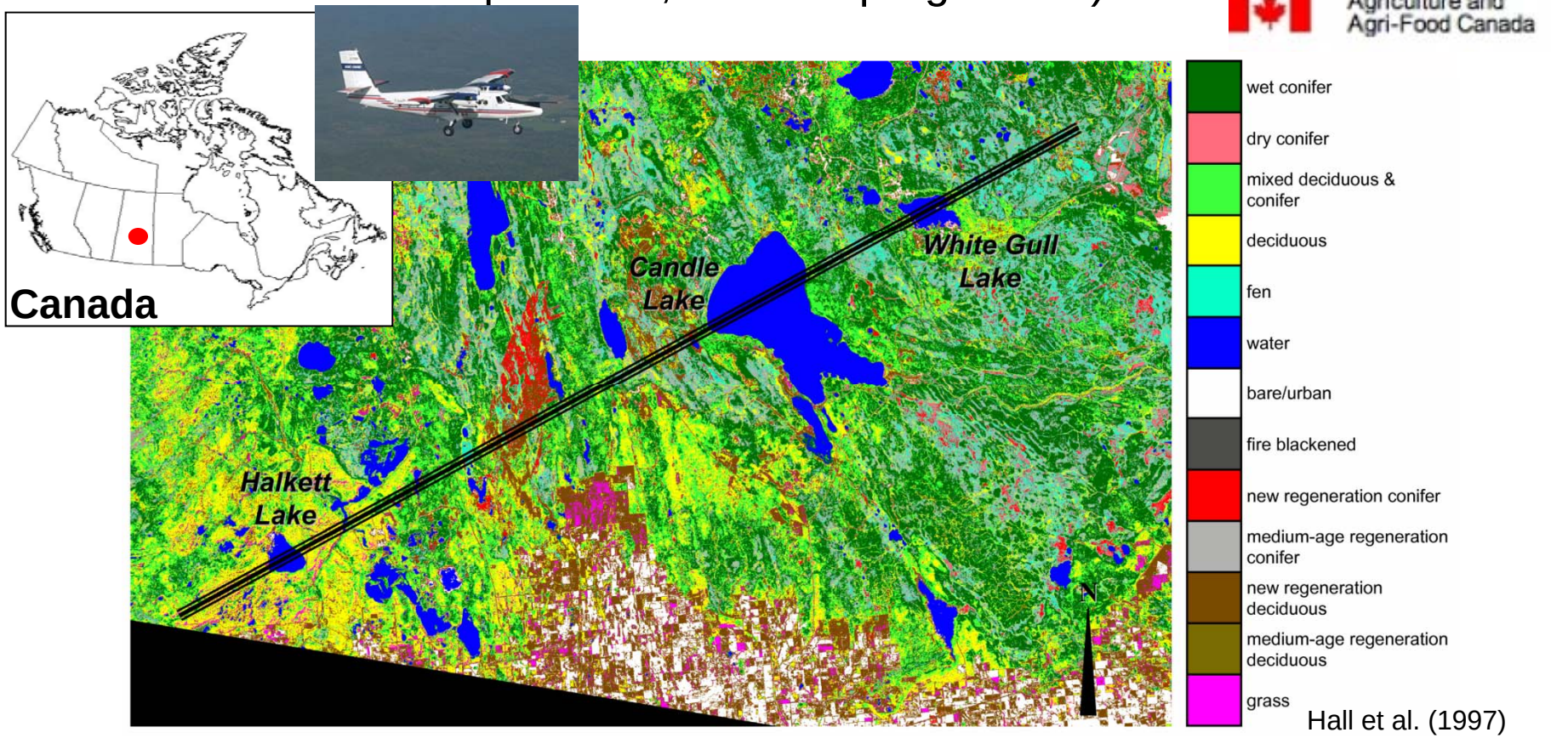


EBRs (monthly basis)
Data: Apr - Aug 2012

aerial photographs: Google (2012)

Experimental data

- Eddy-covariance measurements from TERENO-sites
- Aircraft measurements from Canadian boreal forest („Candle Lake Runs“: BOREAS experiment, BERMS programme)



Hall et al. (1997)

Energy balance closure from aircraft data?

Hypothesis (Mauder et al. 2007):

Airborne measurements capture the total flux:

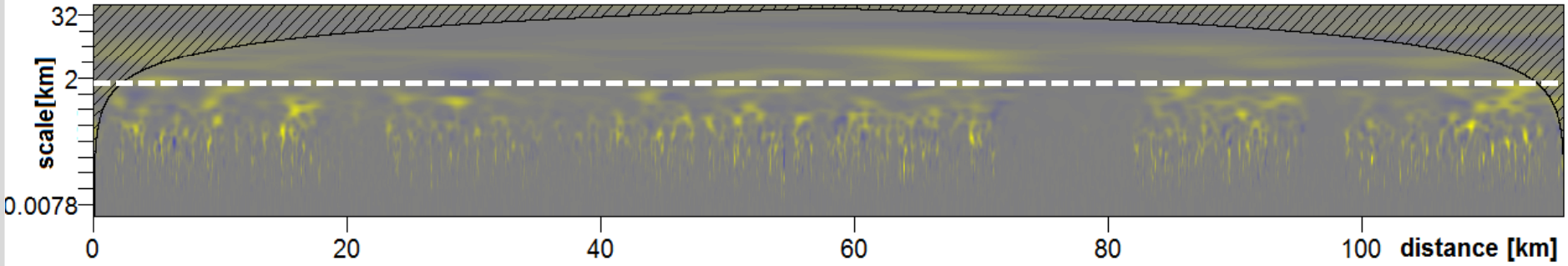
$$F_{total} = F_{small-scale} + F_{meso-scale}$$

$F_{meso\text{-}scale}$ is not captured by eddy-covariance towers.

Method for flux calculation and separation of scales

wavelet transform (Morlet wavelet)

cross-scalogram of w and T



Aircraft-based estimate of *EBR* for the Candle Lake area:

0.88 ± 0.05

Test 1: Parameterization by Huang et al. (2008)

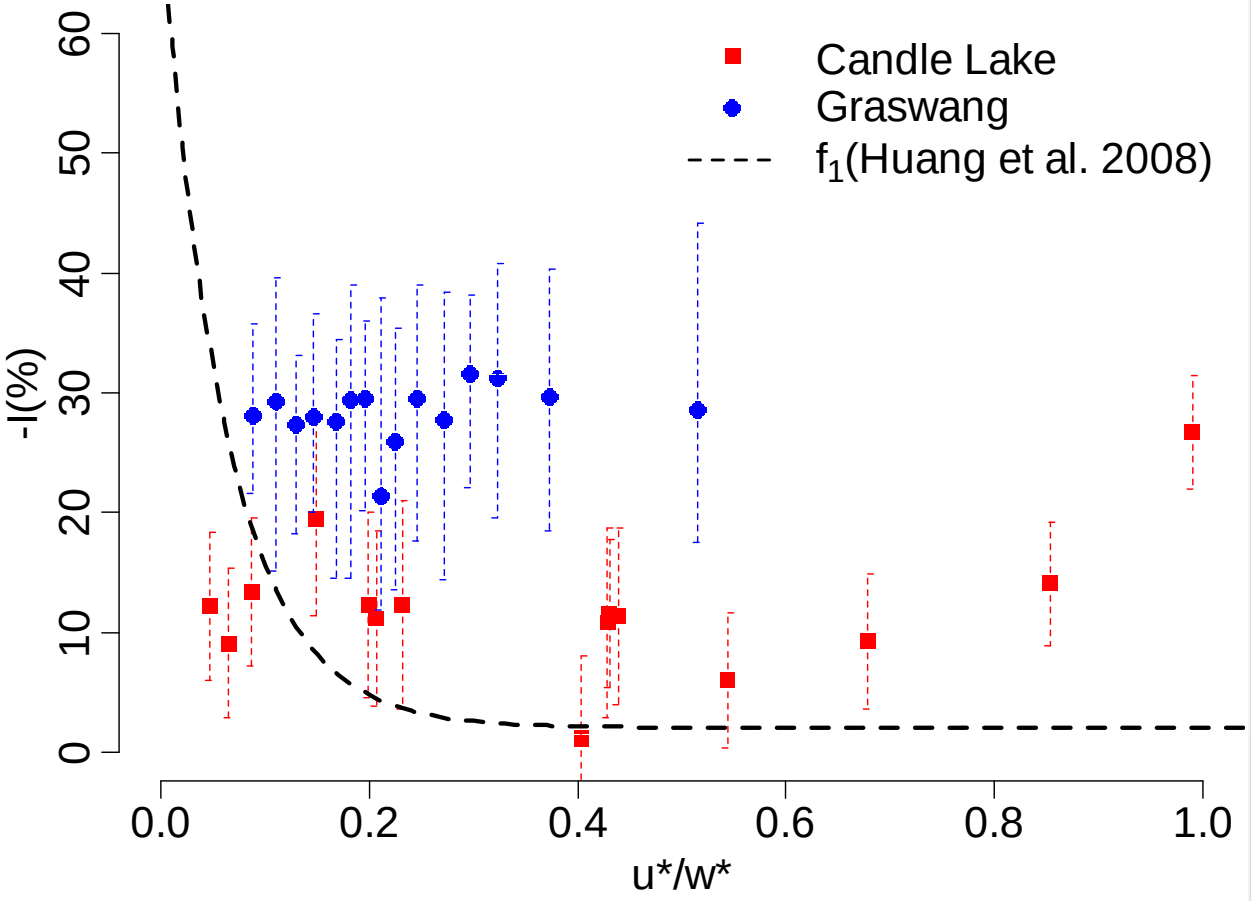
$$I \sim f_1\left(\frac{u_*}{w_*}\right) \times f_2\left(\frac{z}{z_i}\right)$$

tower data:

$$I = \frac{Q_H + Q_E}{-Q_S^* - Q_G} - 1$$

aircraft data:

$$I = \frac{F_{small-scale}}{F_{total}} - 1$$



Test 2: Parameterization by Panin and Bernhofer (2008)

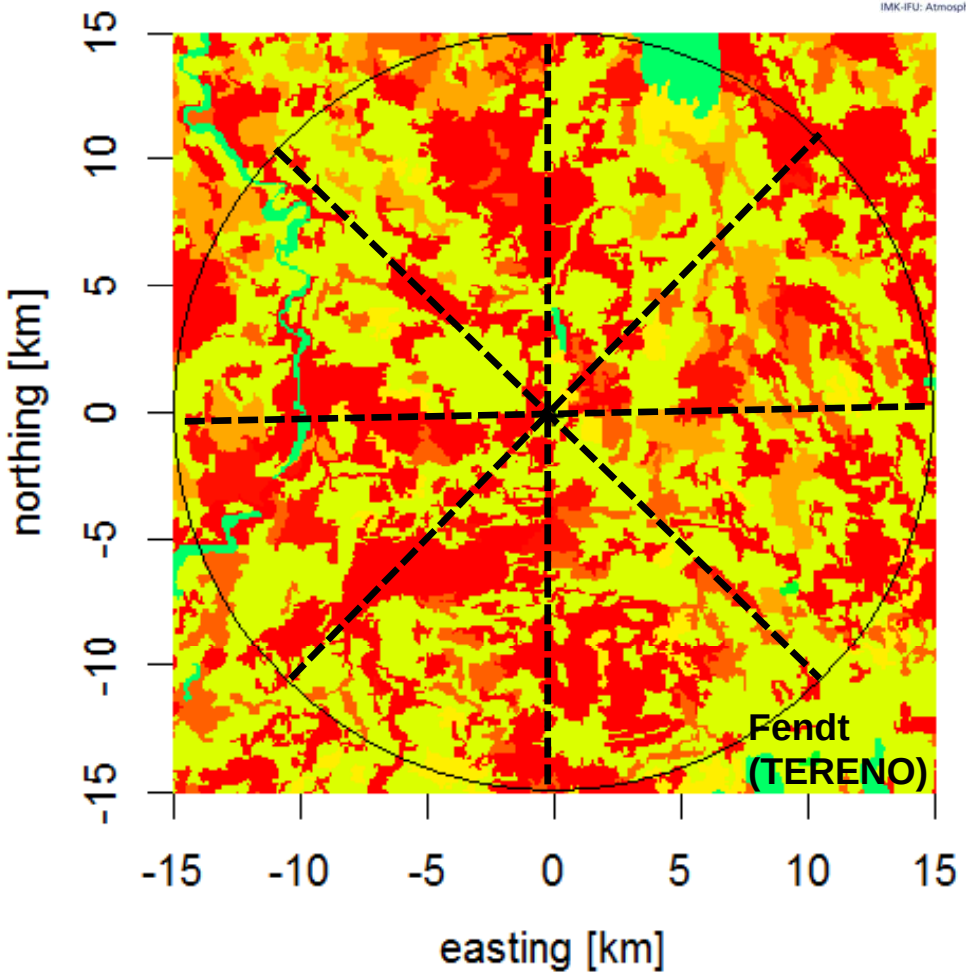
$$k_f \sim \frac{z_{0_{eff}}}{L_{eff}}$$

tower data:

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

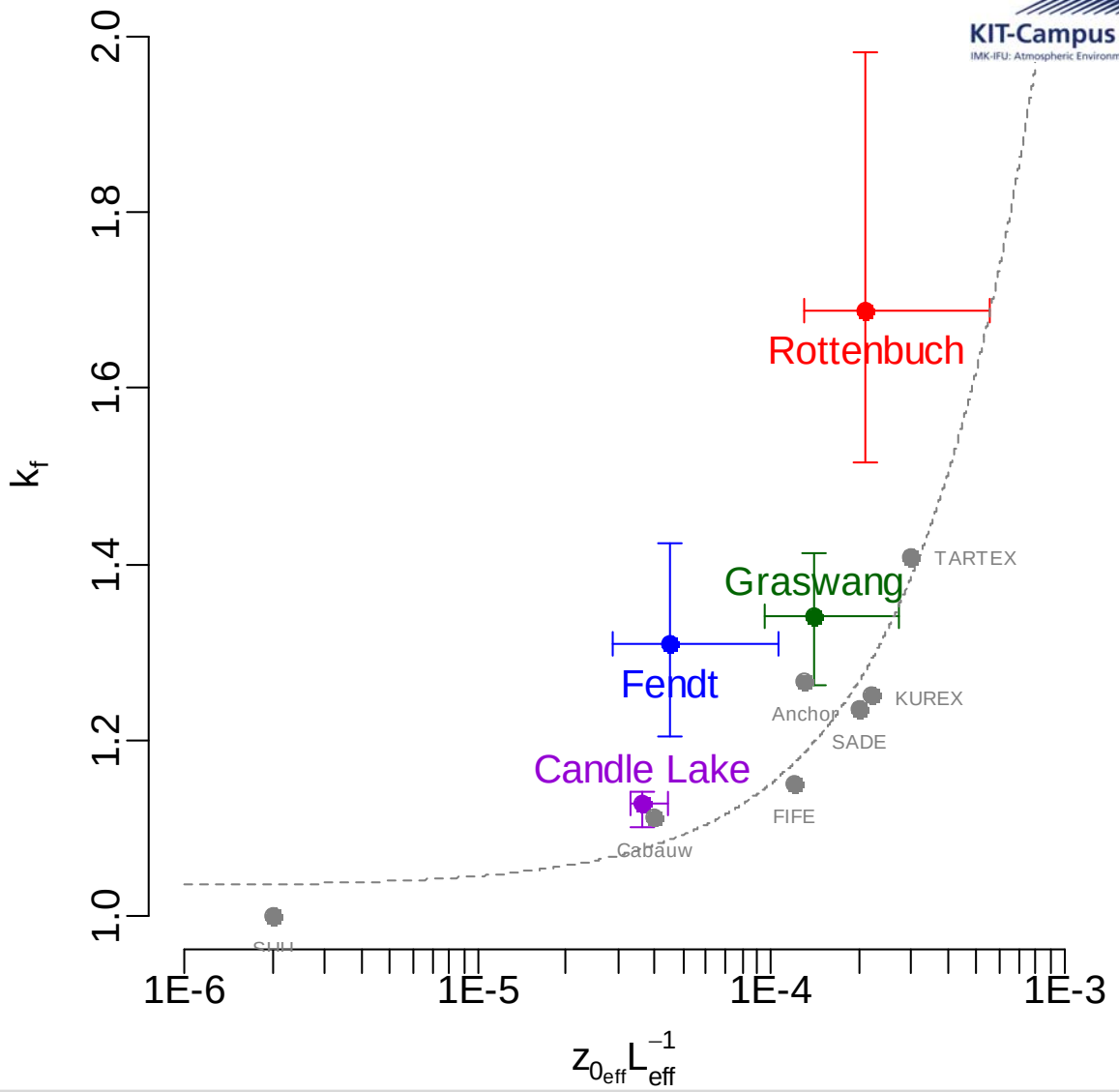
aircraft data:

$$k_f = \frac{F_{total}}{F_{small-scale}}$$



Test 2: Parameterization by Panin and Bernhofer (2008)

$$k_f \sim \frac{z_{0_{eff}}}{L_{eff}}$$



Conclusions

- Are the parameterizations applicable to near-surface measurements? Why (not)?
  - Huang et al (2008): Not for our data.
    - assumes homogeneous terrain
    - the simulated energy balance (virtual towers) is closed near the surface in LES models → insufficient spatial resolution
  - Panin and Bernhofer (2008): Partially.
    - not all relevant surface heterogeneities are represented in a z_0-map
- Second approach (landscape-scale heterogeneities) is promising.