# The Dependence of Energy Budget Components on the surface Characteristics of a shallow pre-Alpine Valley


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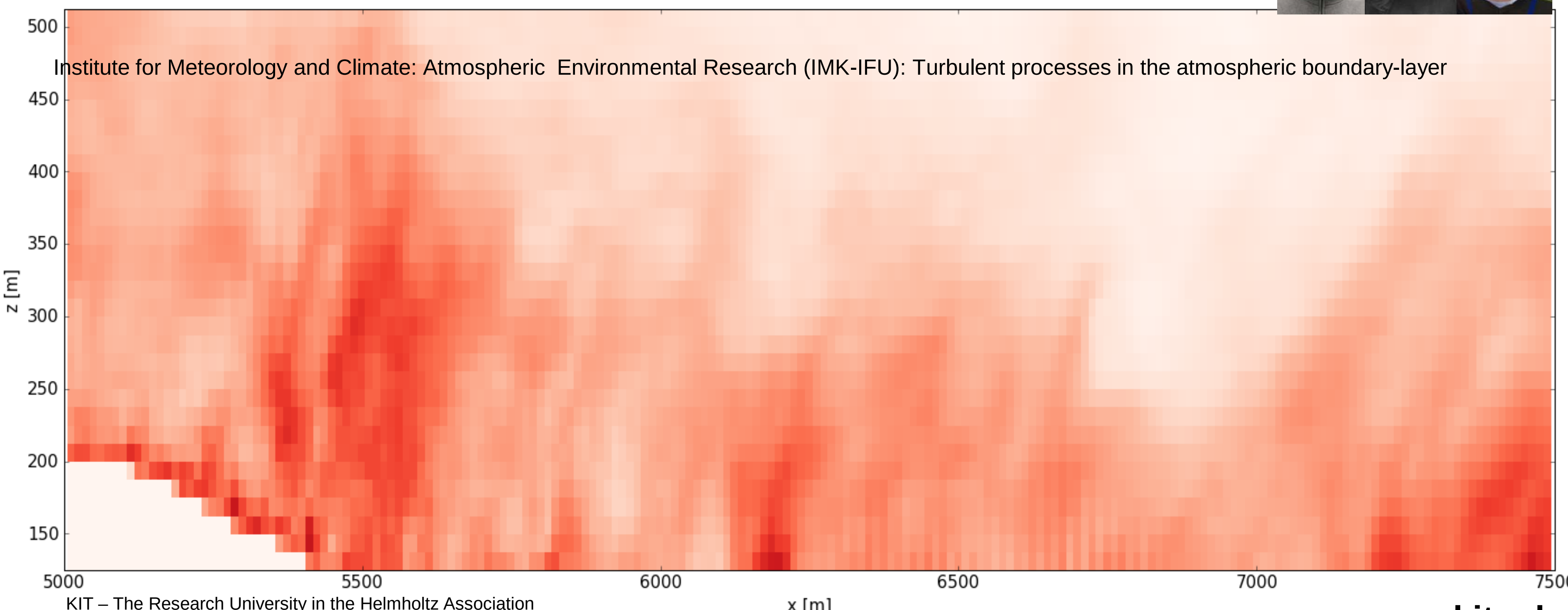
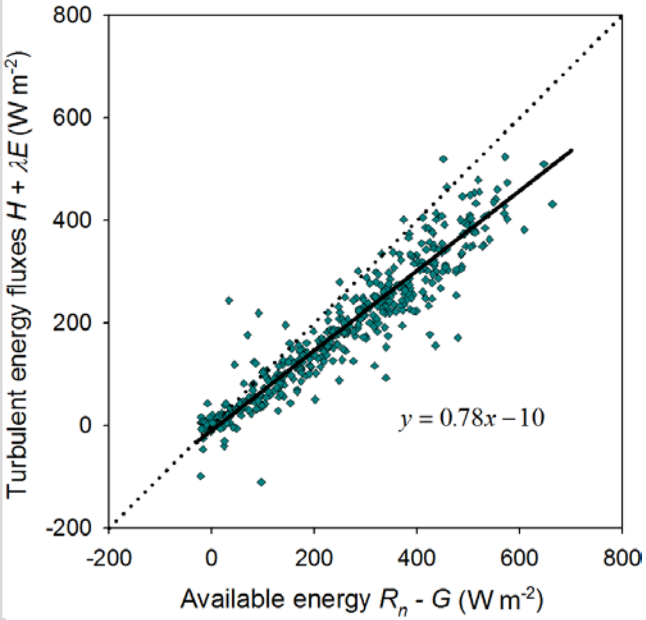
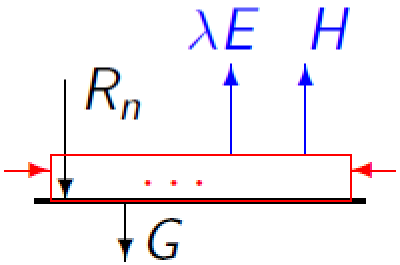
Institute for Meteorology and Climate: Atmospheric Environmental Research (IMK-IFU): Turbulent processes in the atmospheric boundary-layer

# Energy balance closure problem of EC measurements



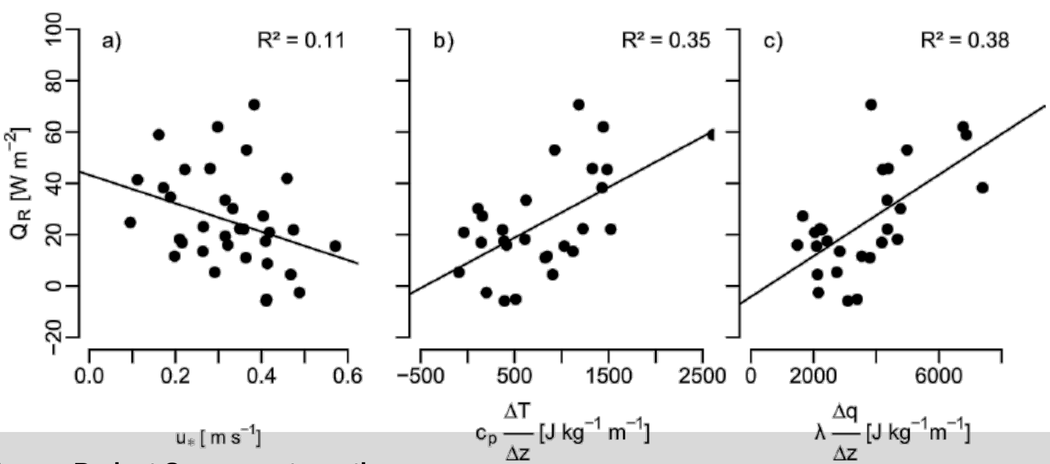

$$R_n - G = \lambda E + H + \Delta$$




- Measurement bias 5-15% [Horst 2015; Frank et al 2012]
- Neglected terms, e.g. storage [Leuning et al 2012]
- Quasi-stationary motions carrying mean flux [Mauder et al 2010 ; Foken 2008]
- Correlators u* and site heterogeneity [Stoy et al 2013]

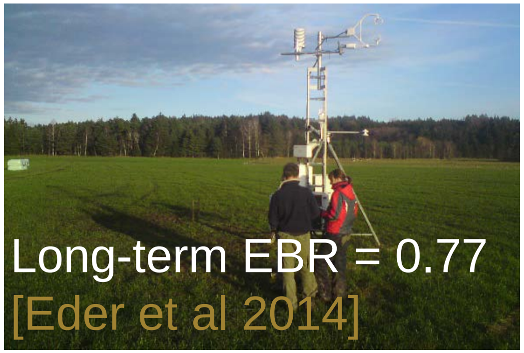
- **Linking of local fluxes with organized boundary-layer structures**
  - Large heterogeneities induce BL motions: penetration to surface?
  - Small: blended but local?

- [Eder et al 2015a] evidence and correlation from measurements
- [Schalkwijk et al 2016] year-long simulated dataset: u*



# Data from measurement site Fendt in the pre-Alps

- German environmental monitoring network TERENO [Zacharias e.a. 2011]
- Intensive campaign ScaleX in summer 2015 and 2016 [Wolf e.a. review]

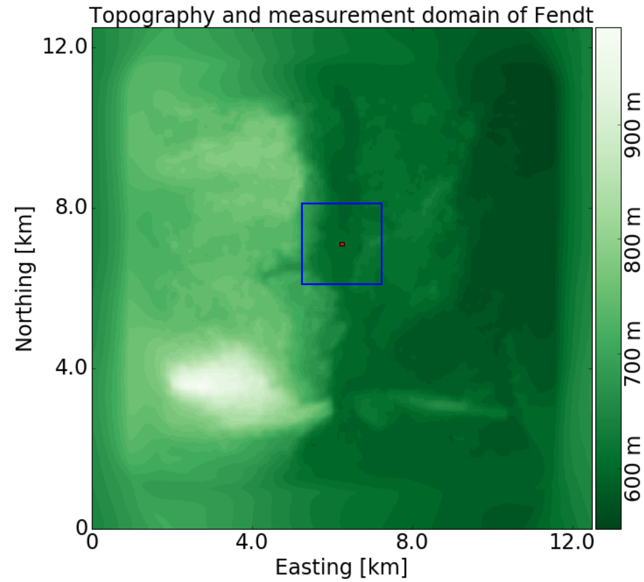


Long-term EBR = 0.77
[Eder et al 2014]

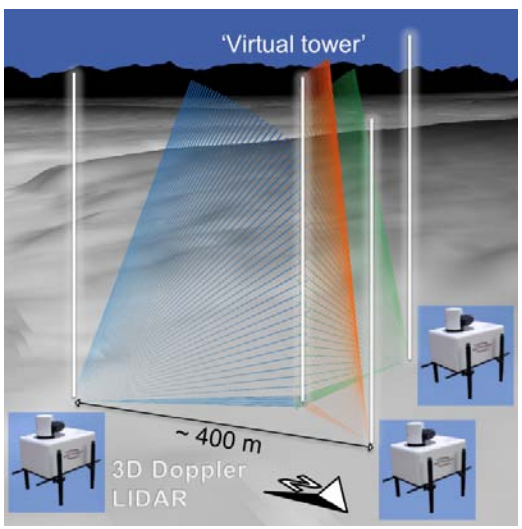
<u>Scales of topography</u>

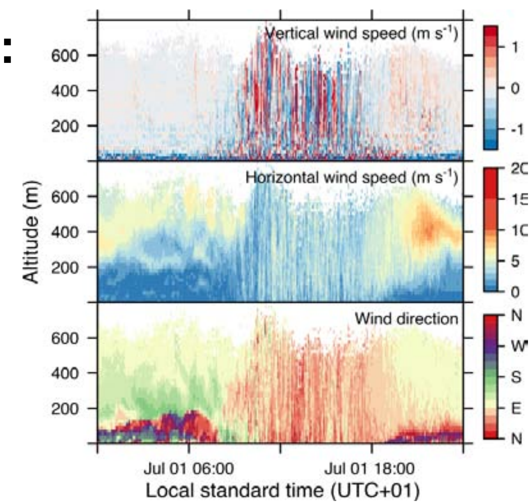
Alps: "Alpine pumping"
$\Delta z$ = 2.5km; $\Delta x$ = 50km

Nearby hill $\Delta z$ = 300m ; $\Delta x$ = 5km
Local slope $\Delta z$ = 150m ; $\Delta x$ = 2km

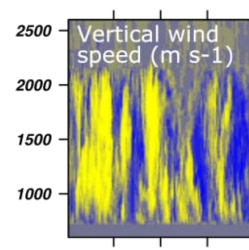



## Coordinated scan modes of Triple Doppler LiDARS:



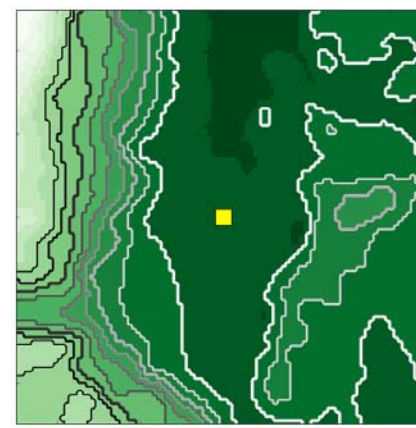




Virtual measurement tower (10 m resolution)



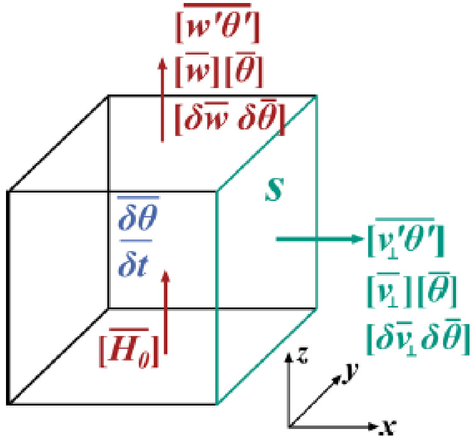

*two hour period*

LES output PALM: [Maronga et al 2015]

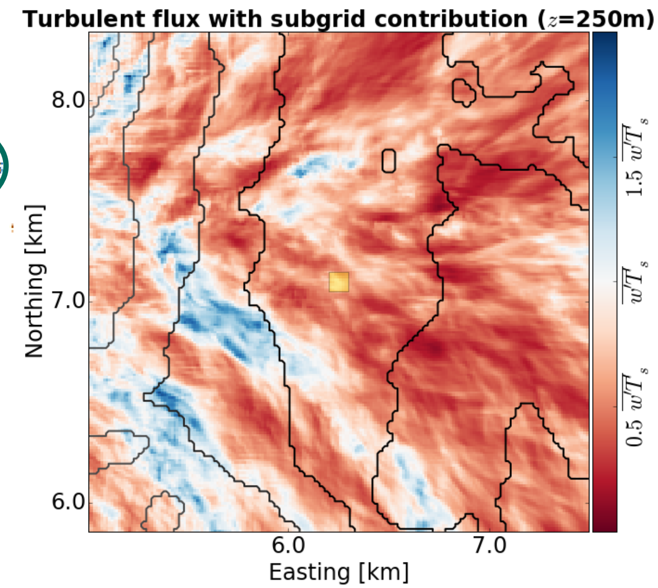


# In complex terrain: a volume approach to determine the simulated surface energy budget

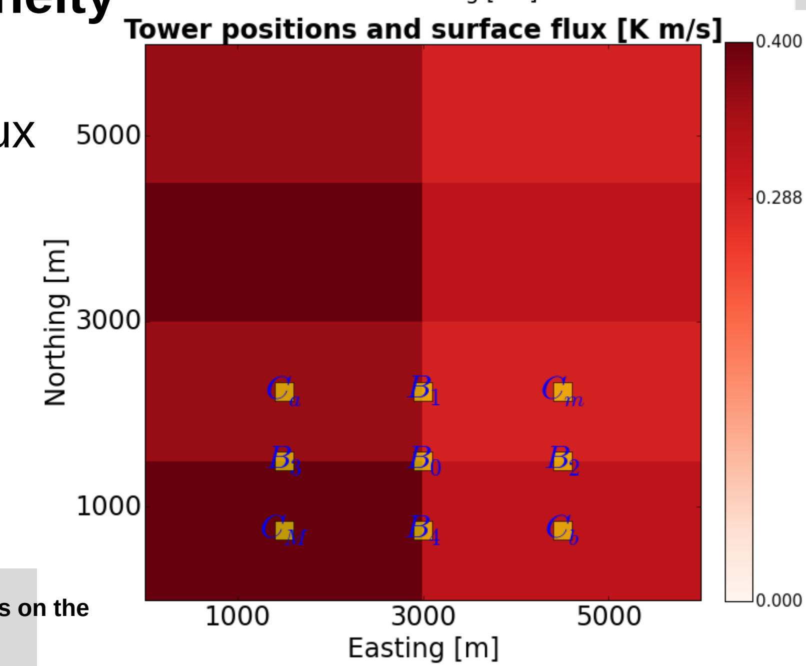
- [Webb et al 1980 ; Lee 2009 ; Eder et al 2015b]




$$[\overline{H_0}] = [\overline{w'\theta'}] + \sum_s [\overline{v'_\perp\theta'}]_s + [\overline{w}][\overline{\theta}] + \sum_s [\overline{\mathbf{v}}_\perp]_s[\overline{\theta}]_s + [\delta\overline{w}\delta\overline{\theta}] + \sum_s [\delta_s\overline{\mathbf{v}}_\perp\delta_s\overline{\theta}]_s + \iiint \frac{\partial\theta}{\partial t}\,\mathrm{d}x\mathrm{d}y\mathrm{d}z$$

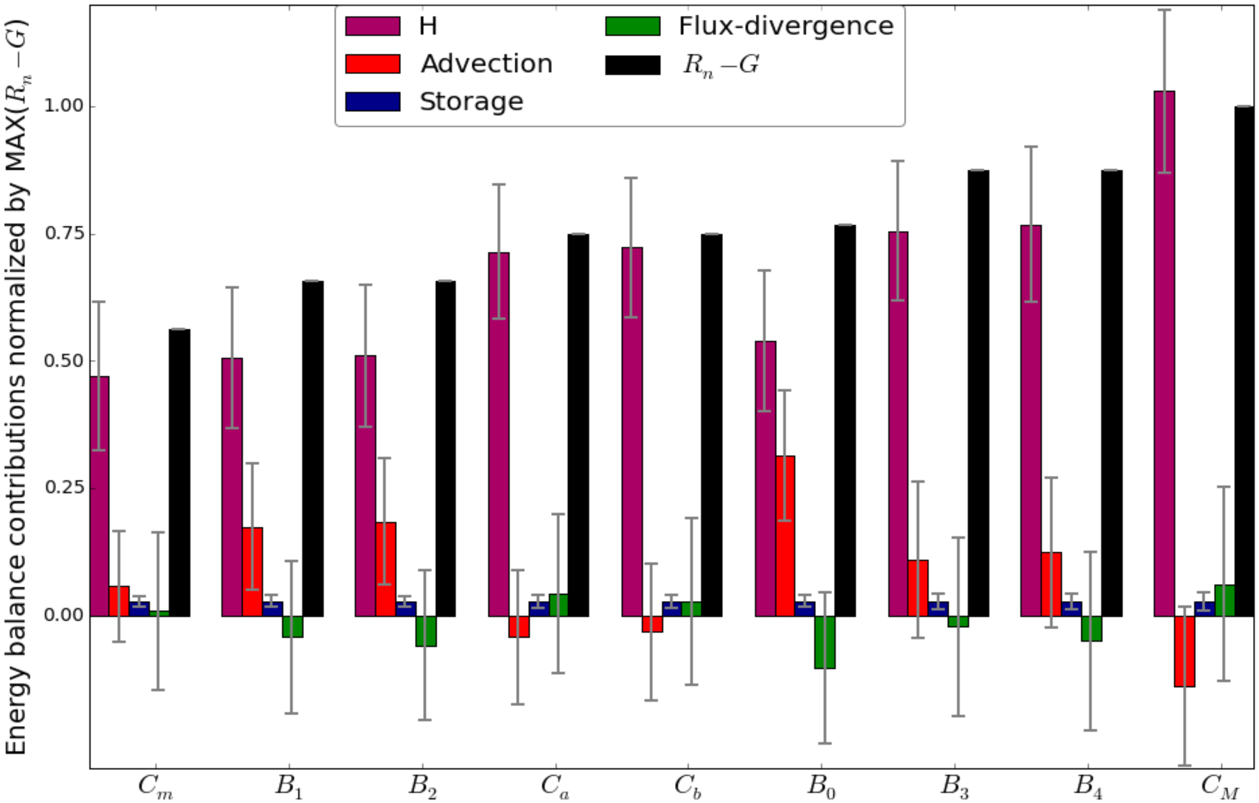



- **Study of idealized surface flux heterogeneity and its influence on the energy budget**
  - Parameter study of variable surface heat flux on tower measurements (318 cases)
  - Main parameters: scales and amplitude
  - Towers at up/downdrafts/borders




- Domain: 6 x 6 x 2.4 km³ periodic in xy
- 10 m grid ; 1 Hz ; 5 x 1hr intervals
- C.v. gridpoints 5 x 5 x 5

# O(km) heterogeneity induces a circulation affecting the energy budget, but the tower position matters




EBR($C_m$)=83%

EBR($B_1$)=76%

EBR($B_2$)=76%

EBR($C_a$)=95%

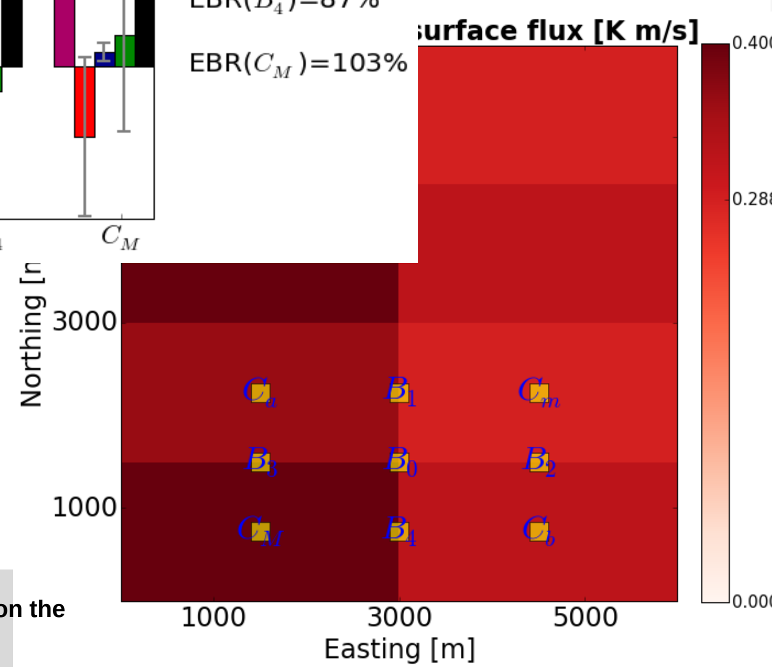
EBR($C_b$)=96%

EBR($B_0$)=69%

EBR($B_3$)=85%

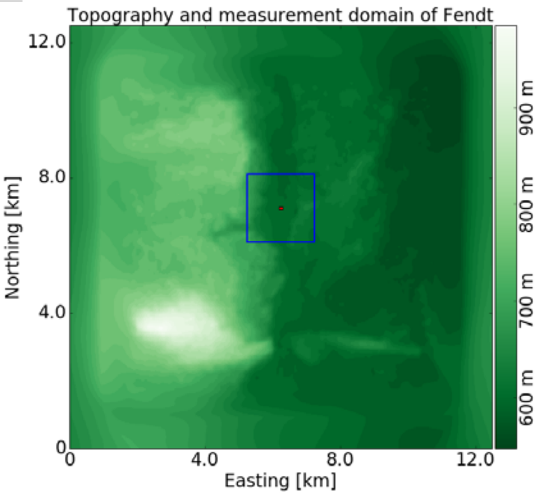
EBR($B_4$)=87%

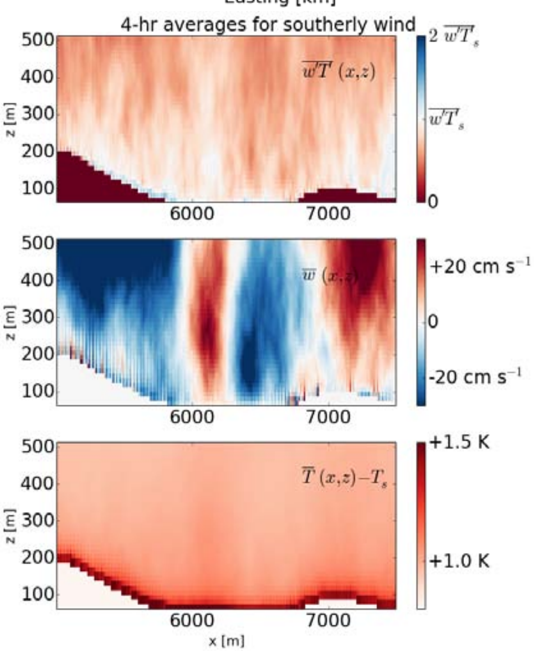
EBR($C_M$)=103%

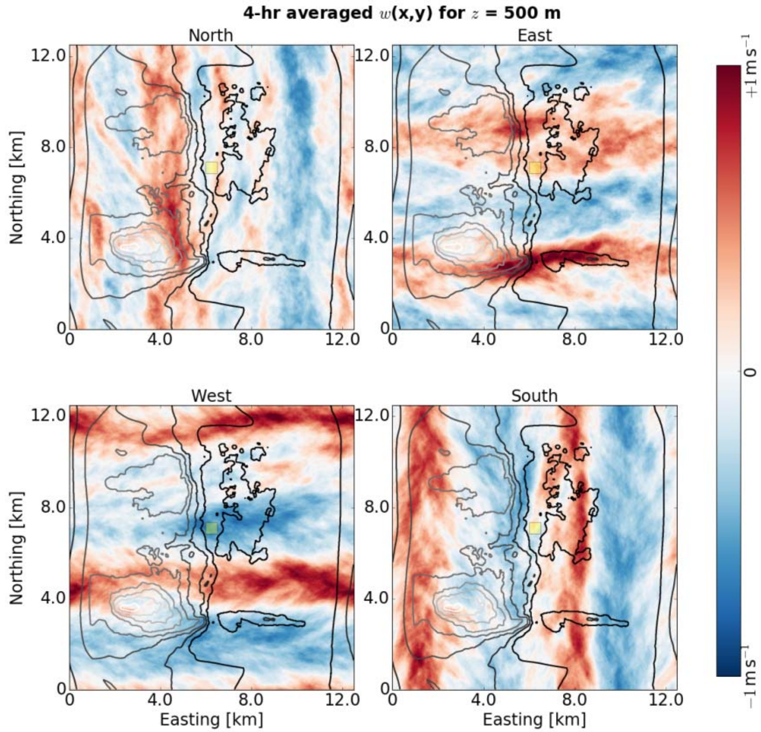


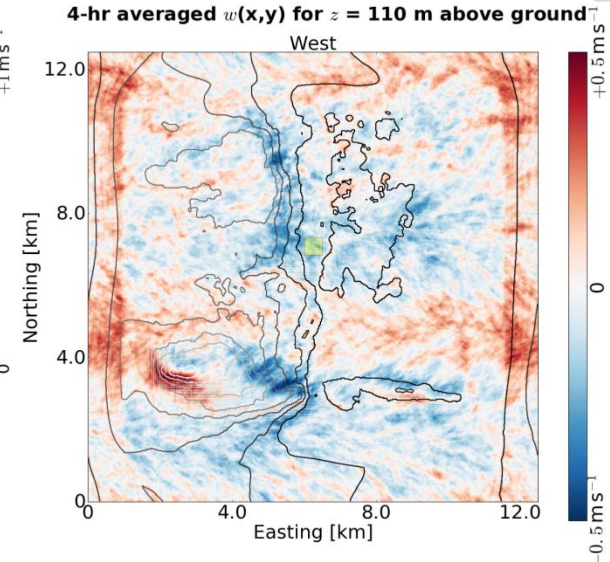

- Heterogeneity of smaller scale O(hm) appears blended at tower height
- Smaller imbalances (ca 10%) and the tower budget appears more uniform

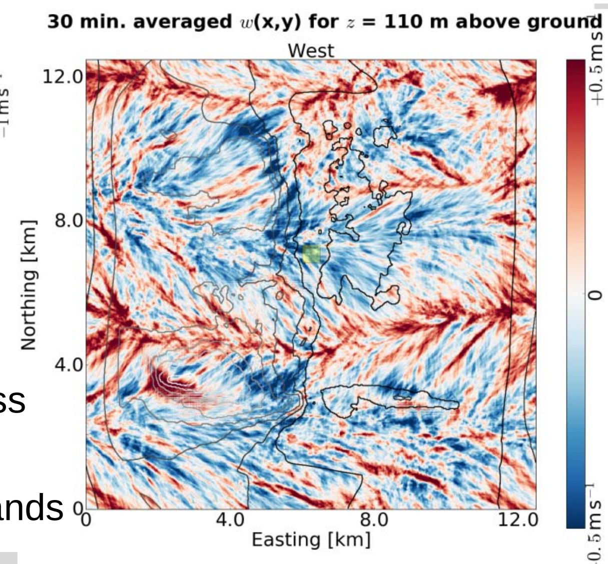
# Variability of turbulent fluxes at scales smaller than the quasi-stationary up- and downdrafts



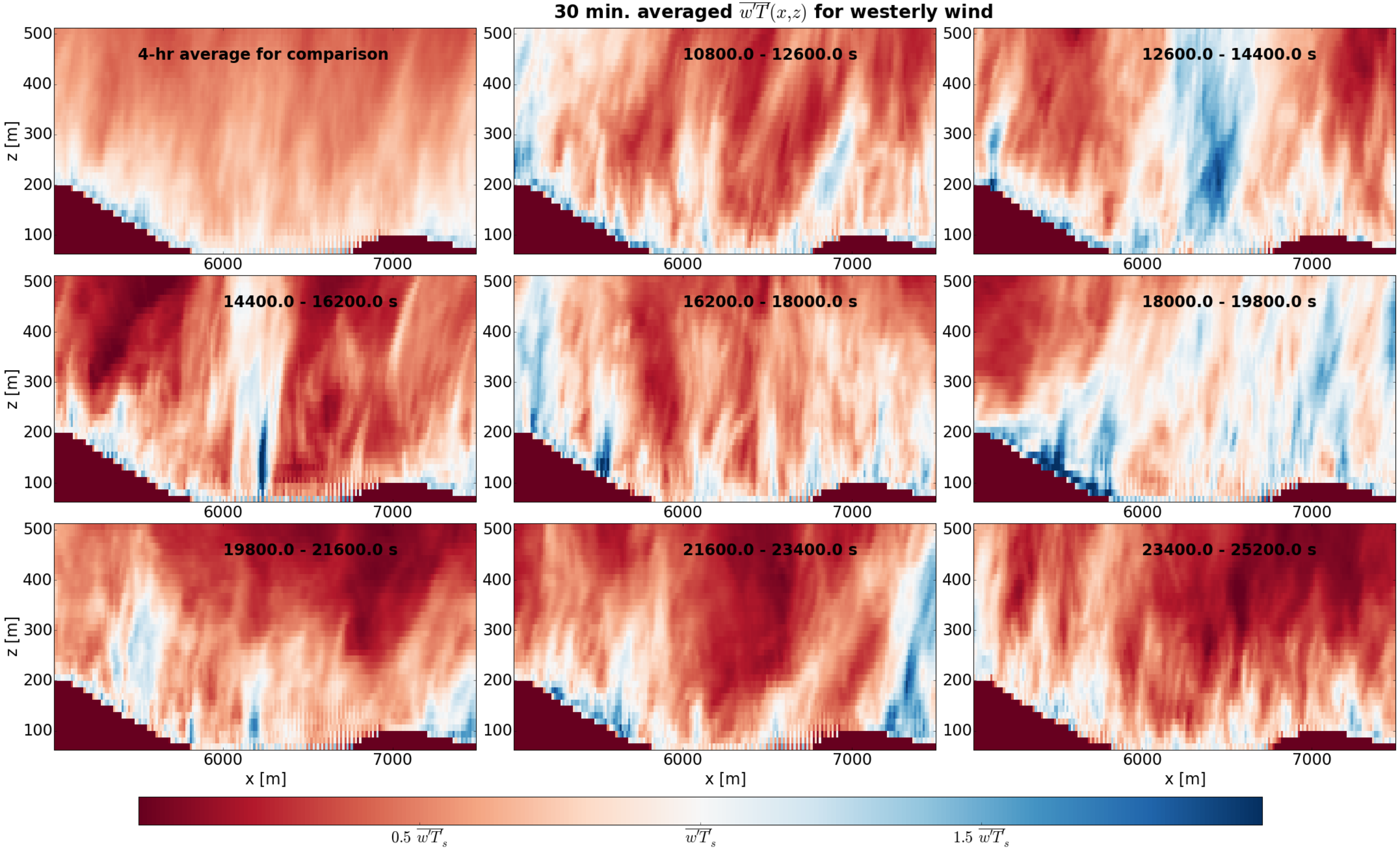




- Preliminary simulations:
- 3 hr spinup; 4 hrs of data ; 12.5m grid
- Initialization from measured profiles
- Heterogeneity in topography and roughness
- Topography: $\Delta z < 20$ gp ; $\Delta z/\Delta x < 10$ %
- Buffer for domain <=> computational demands

# Variability of turbulent fluxes at scales smaller than the quasi-stationary up- and downdrafts

Karlsruhe Institute of Technology



# Conclusions

- Idealized simulations to investigate
  the influence of surface heterogeneity on energy budget
  - Position of tower matters
  - EBR down to 0.7 as in reality (but at $z_m = 50$ m)
  - Flux-divergence has to be considered as well

- Realistic complex terrain from site experiment to investigate
  the influence of boundary-layer structures on turbulent flux
  - **Turbulent flux varies in space and time**
    at scales smaller than the quasi-stationary up- and downdrafts
  - **Local structures in 30 minute averaged turbulent flux fields that penetrate down to the surface**

- Outlook: confirmation at higher resolution