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

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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]

Scales of topography
Alps: “Alpine pumping”
Δz = 2.5km; Δx = 50km
Nearby hill Δz = 300m ; Δx = 5km
Local slope Δz = 150m ; Δx = 2km

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

Coordinated scan modes of Triple Doppler LiDARS:

Virtual measurement tower (10 m resolution)
LES output

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]

**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.

- 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: Δz < 20 gp; Δz/Δx < 10%
- Buffer for domain <=> computational demands
Variability of turbulent fluxes at scales smaller than the quasi-stationary up- and downdrafts

30 min. averaged $\bar{w}T(x,z)$ for westerly wind

4-hr average for comparison

10800.0 - 12600.0 s

12600.0 - 14400.0 s

14400.0 - 16200.0 s

16200.0 - 18000.0 s

18000.0 - 19800.0 s

19800.0 - 21600.0 s

21600.0 - 23400.0 s

23400.0 - 25200.0 s

$0.5 \bar{w}T_s$

$\bar{w}T_s$

$1.5 \bar{w}T_s$
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