8th COPS Workshop and CSIP Meeting, Cambridge, Oct. 26-28, 2009

Numerical Simulation of localized Boundary Layer Circulations affecting the Measurements of the Energy Balance Network during COPS

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presented by THOMAS FOKEN[2]

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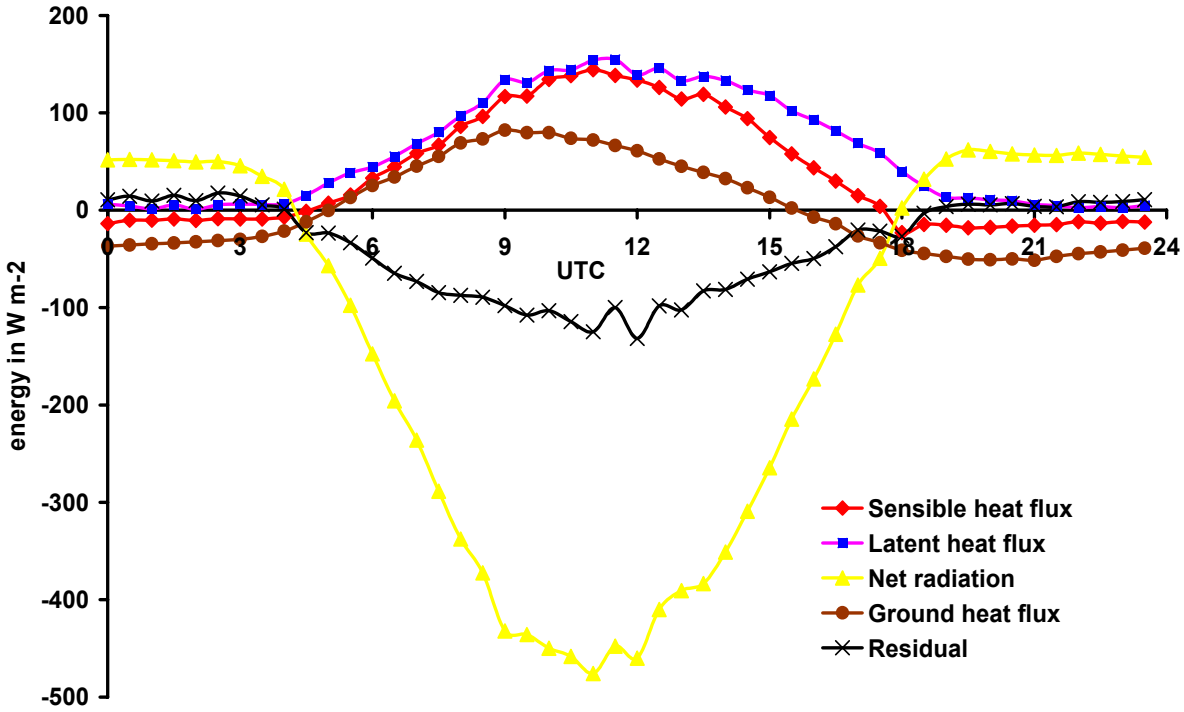
Content

- Energy Balance Closure
- Free Convection from the Ground
- LES Modeling

Energy balance closure problem



Foken and Oncley (1995), Mauder et al. (2006), Oncley et al. (2007), Mauder and Foken (2006), Foken (2008)

The Problem

- **The net radiation is always larger than the sum of the turbulent fluxes (sensible and latent) and the ground heat flux:**

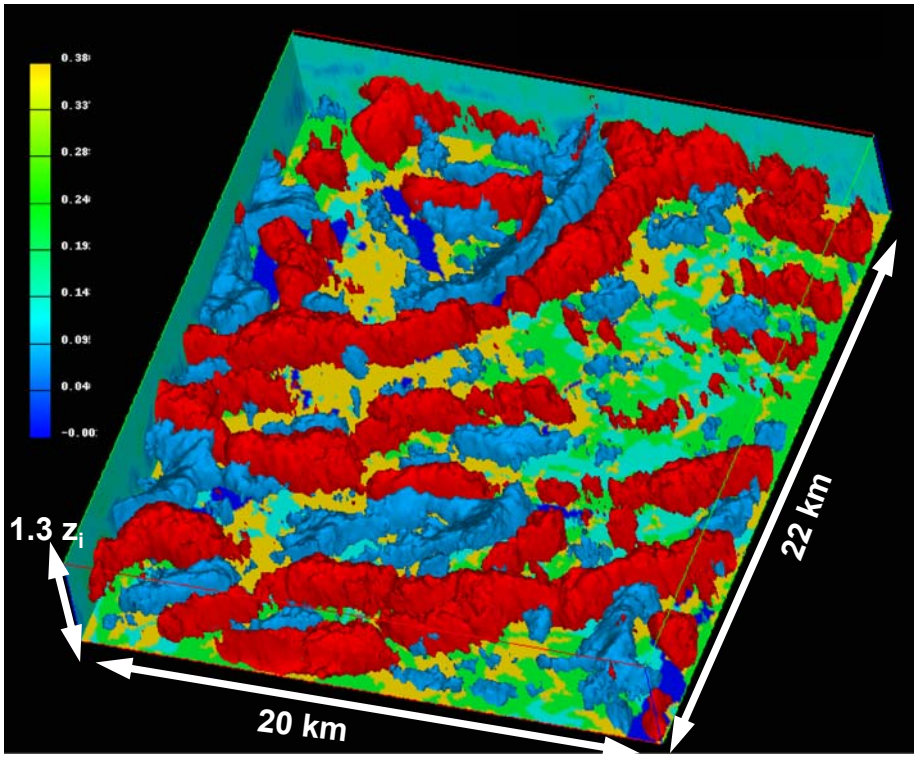
$$Q_S^* \geq Q_G + Q_H + Q_E$$

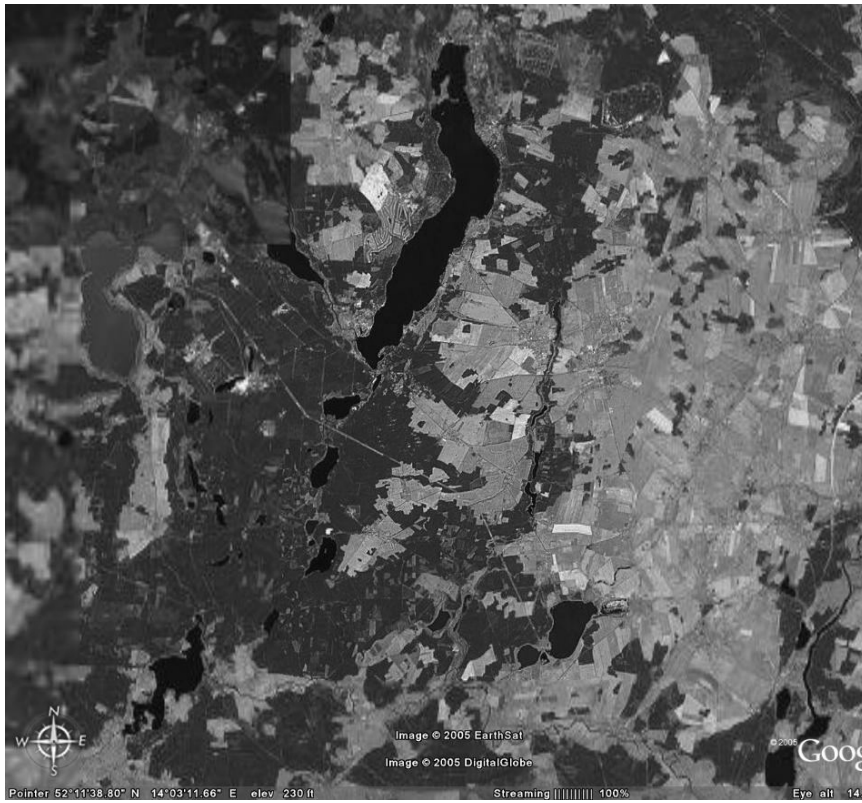
- **Typical residual are:**

$$\frac{Q_G + Q_H + Q_E}{Q_S^*} \cdot 100\% = 70 \ldots 100\%$$

Secondary Circulations found with LES Simulations for the LITFASS-2003 Experiment

2003/05/30, 12 UTC





© Kanda et al. (2004), for LITFASS-2003 Experiment, according to Uhlenbrock et al. (2004)

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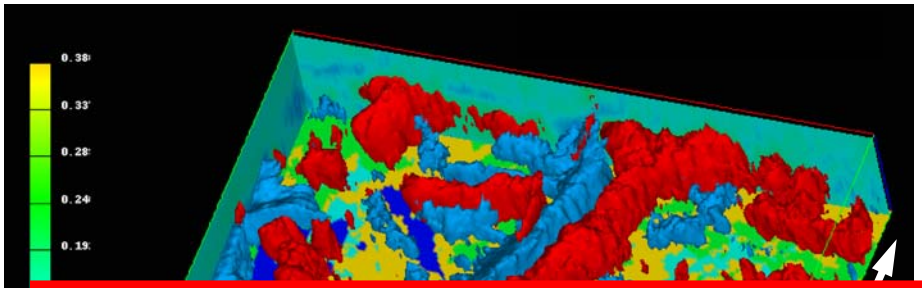
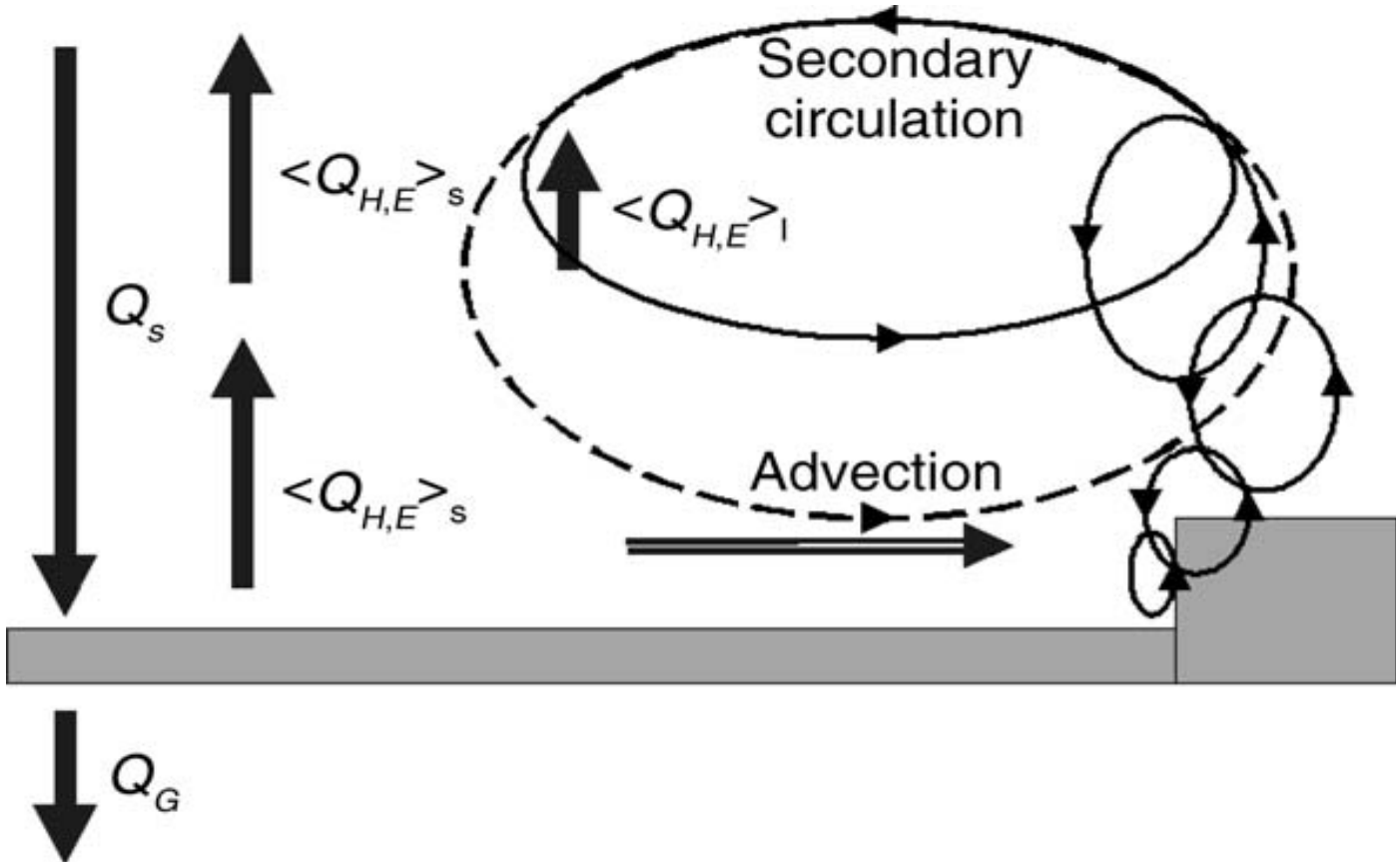


LITFASS-2003 experiment: Special Issue, Boundary-Layer Meteorology **121** (2006) 1 and BAMS **87** (2006), 775-786

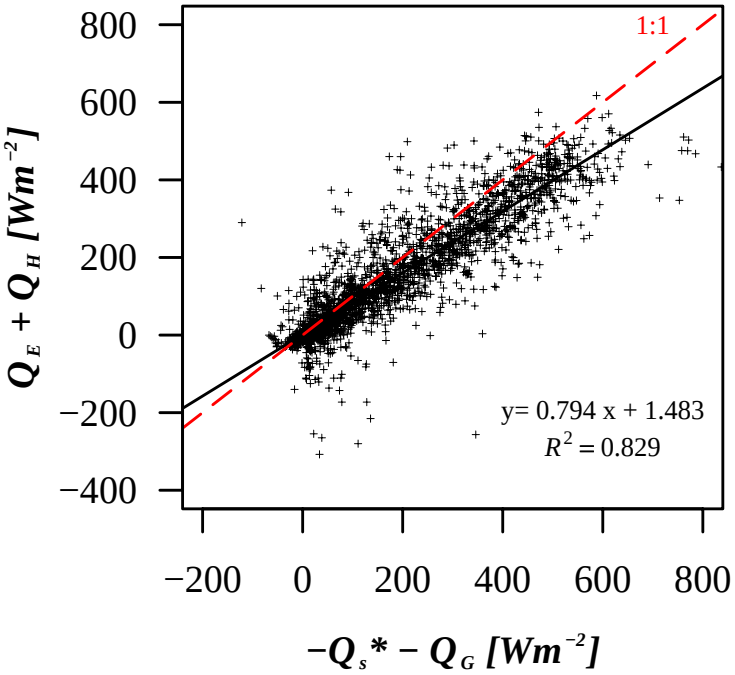
Foken, T; Mauder, M; Liebethal, C; Wimmer, F; Beyrich, F; Leps, J-P; Raasch, S; DeBruin, H; Meijninger, WML; Bange, J:
Energy balance closure for the LITFASS-2003 experiment,
Theoretical and Applied Climatology,
DOI: 10.1007/s00704-009-0216-8 (2009)

© Kanda et al. (2004), for LITFASS-2003 Experiment, according to Uhlenbrock et al. (2004)

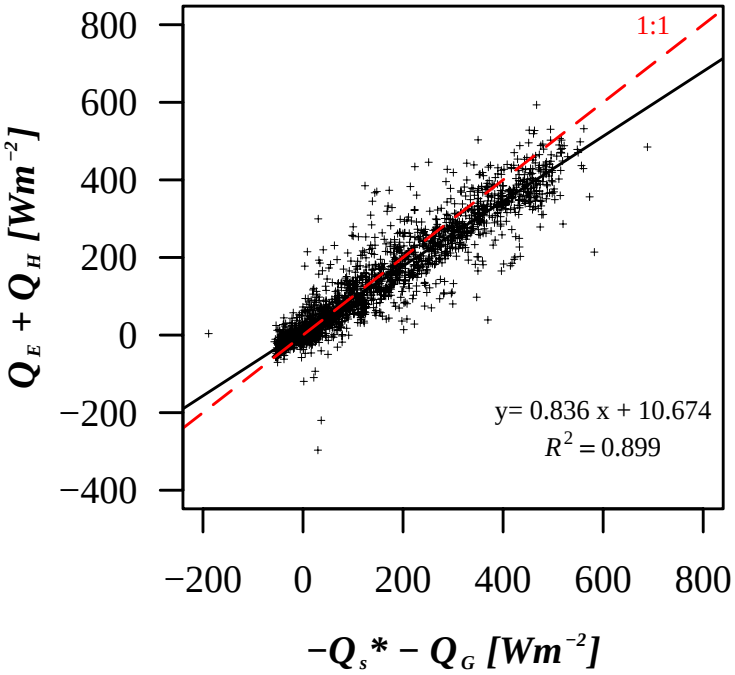
Schematic Overview of the Generation of Secondary Circulations and the Energy Balance Closure



Energy Balance Closure

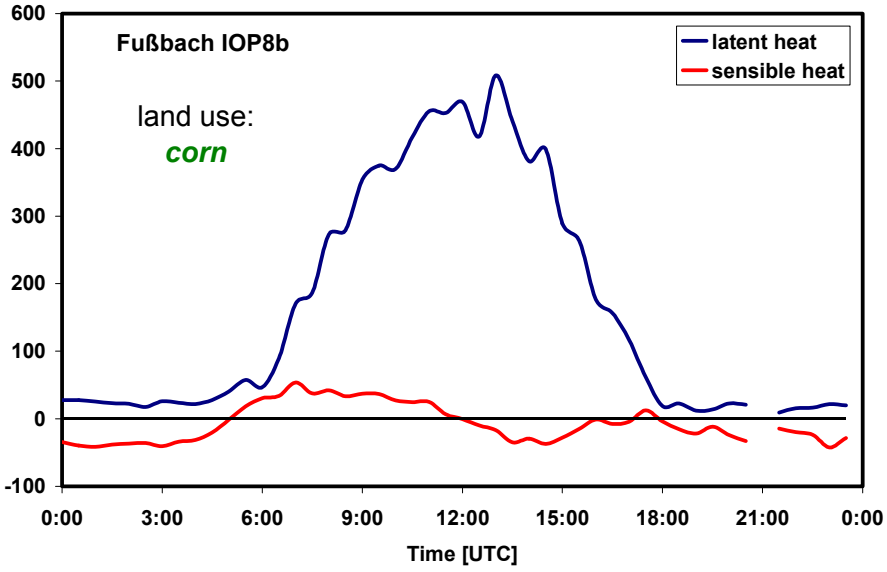


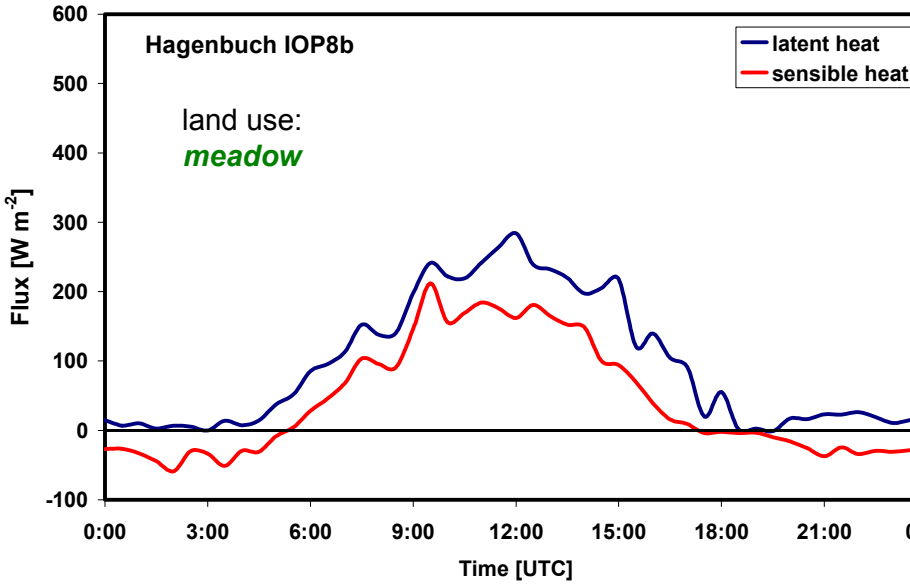
Fußbach (corn)



Hagenbuch (meadow)

Turbulent Fluxes





Fußbach (corn)

Hagenbuch (meadow)

Conclusion 1

- A heterogeneous landscape with typical heterogeneity scales of >> 100 m is a reason for secondary circulations and therefore an unclosed energy balance
- For a landscape, which is homogeneous in scales >> 100 m, the energy balance can be closed. Only for this case experiments and models have equal results.
- The secondary circulations are mainly caused by heterogeneities in the sensible heat flux: The residual is probably more a missing sensible heat flux than a missing latent heat flux.
- Models distribute the residual often according to the Bowen ratio: The models have to low sensible heat flux and to much latent heat flux or they are too cold and too wet.

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Kracher, D; Mengelkamp, H-T; Foken, T: The Residual of the Energy Balance Closure and its Influence on the Results of three SVAT Models, Meteorologische Zeitschrift, **18**, in print (2009)

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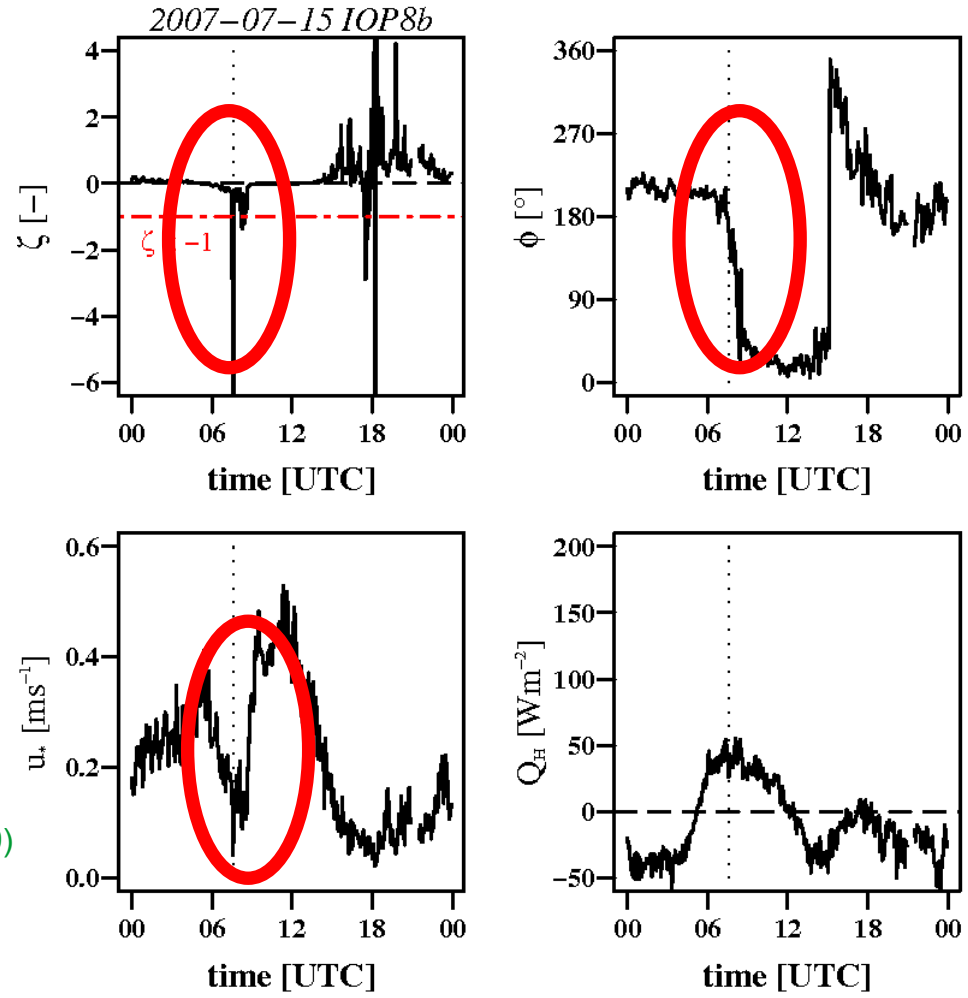
Thermal Heterogeneity

- Free convection in the surface layer (!) is given for

$$\zeta = \frac{z}{L} = -\frac{z \cdot \kappa \cdot g \cdot \left(\overline{w'\theta_v'}\right)_0}{\overline{\theta_v} \cdot u_*^3} < -1$$

- Conditions: Low wind velocity and/or high sensible heat fluxes, increasing height

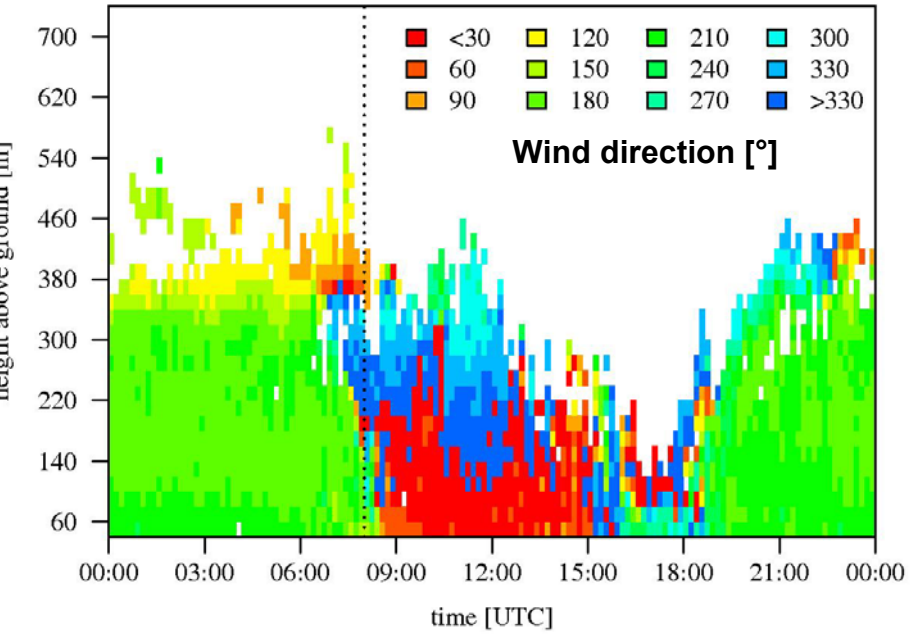
Free Convection found in Surface Flux Measurements

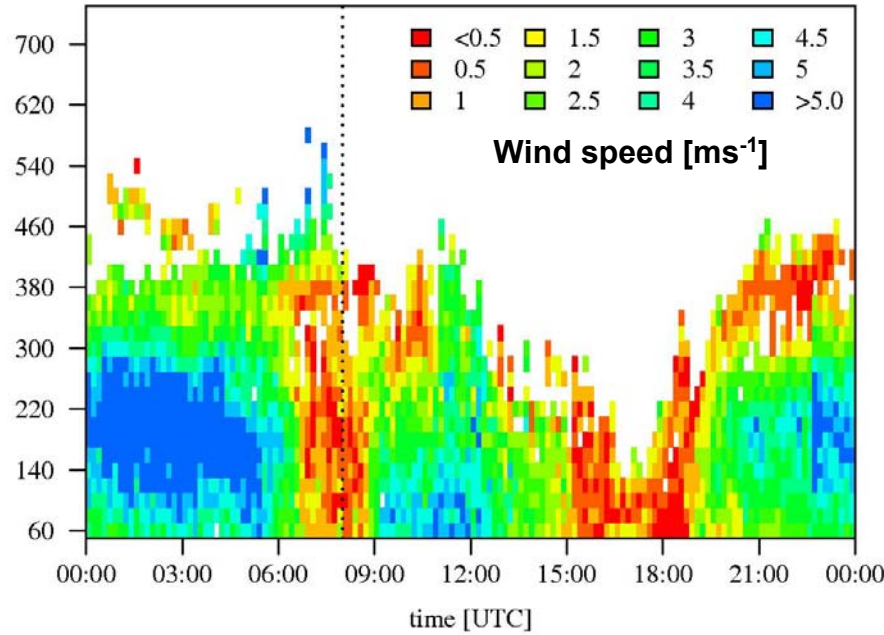


Poster B2

COPS, Kinzig valley

Free Convection found in Surface Flux Measurements



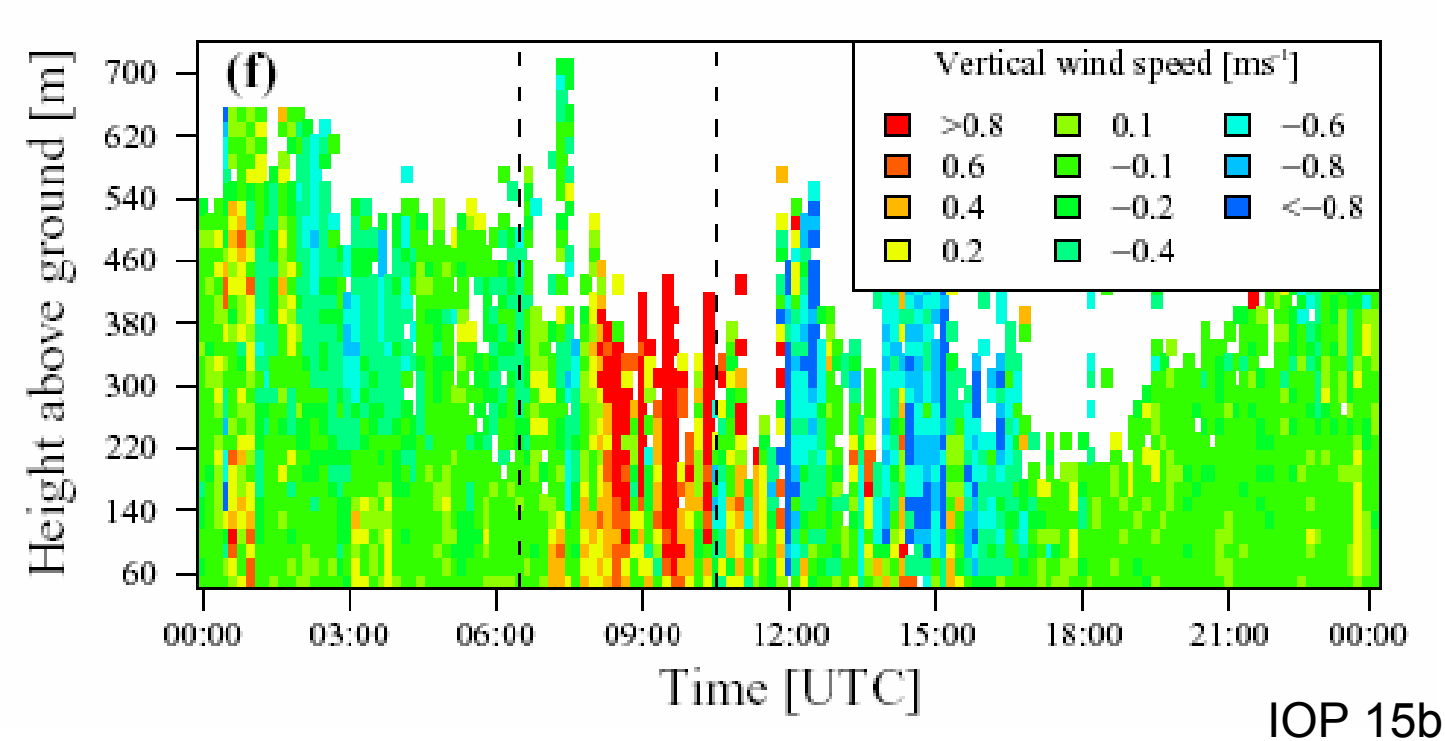


Low wind velocities during the change of the mountain-valley wind system

COPS, Kinzig valley

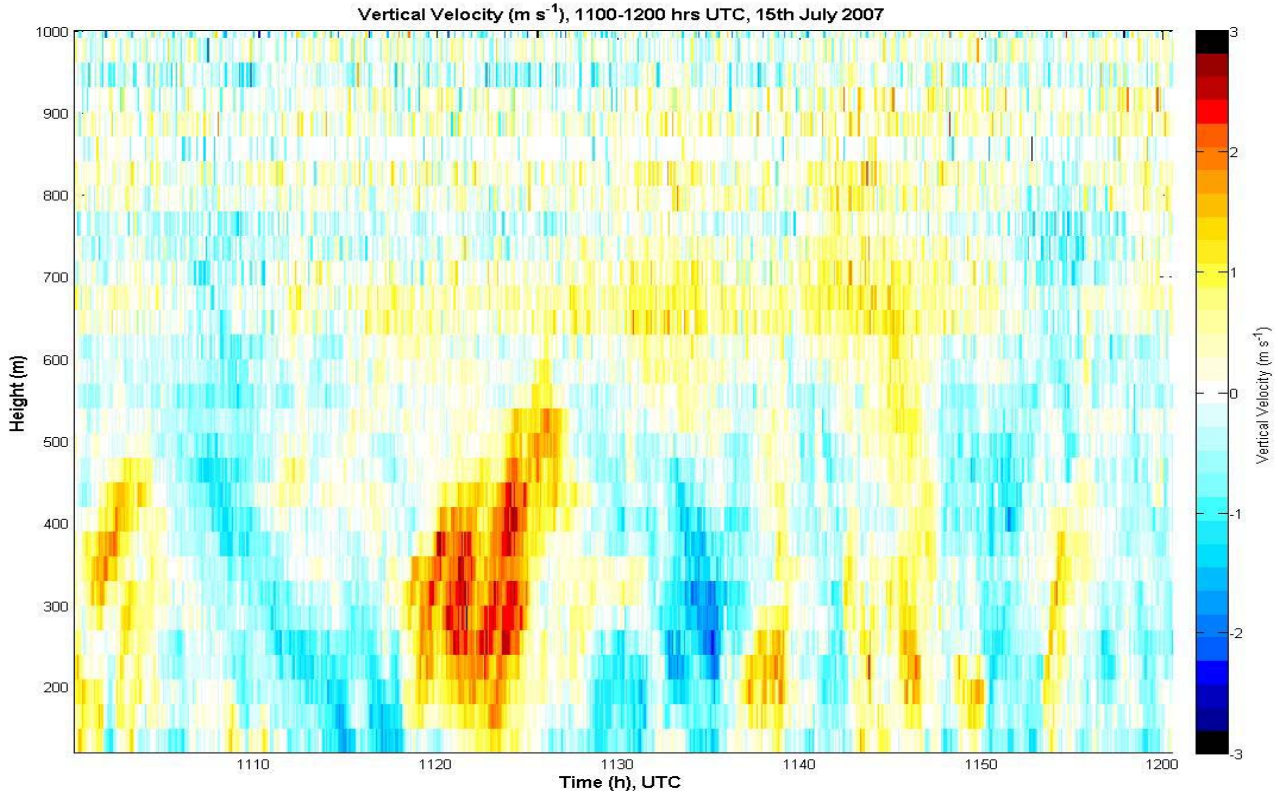
Poster B2

Strong free Convection Events (Vertical Wind measured with Doppler-Sodar)



IOP 15b

Strong free Convection Events (Vertical Wind measured with Doppler-Lidar)

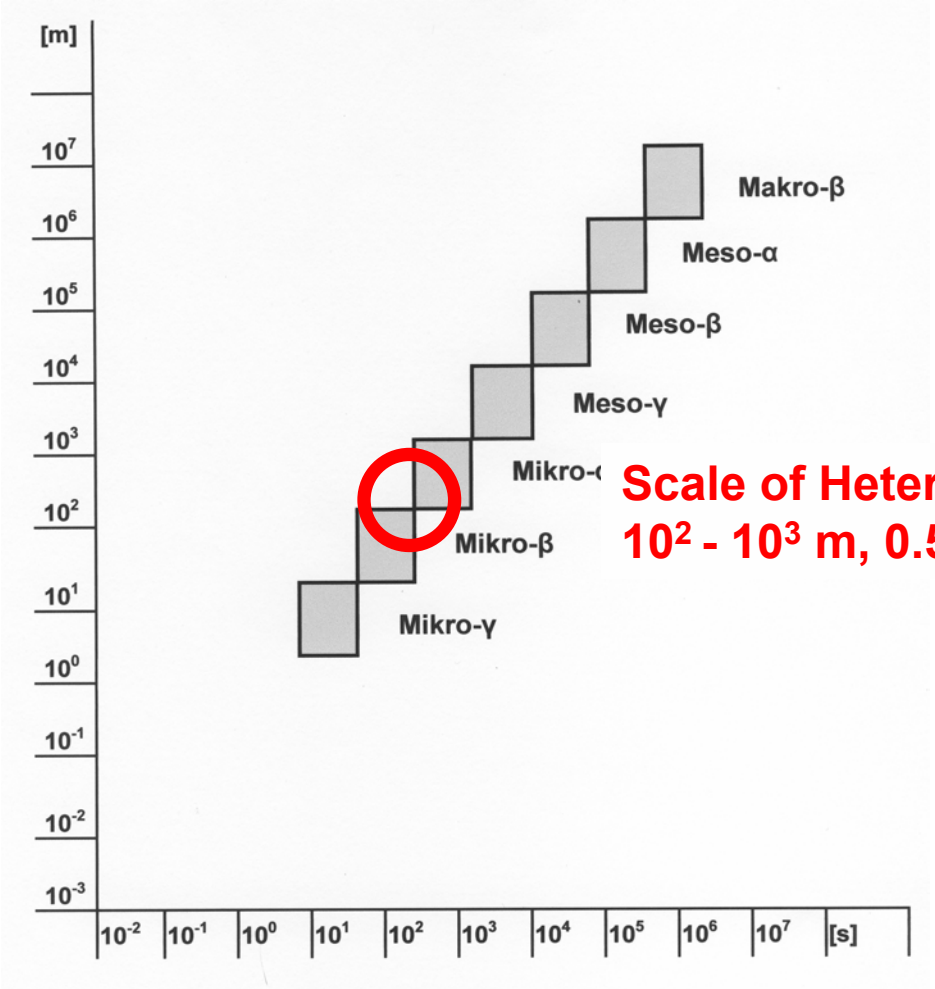


IOP 8b

Conclusion 2

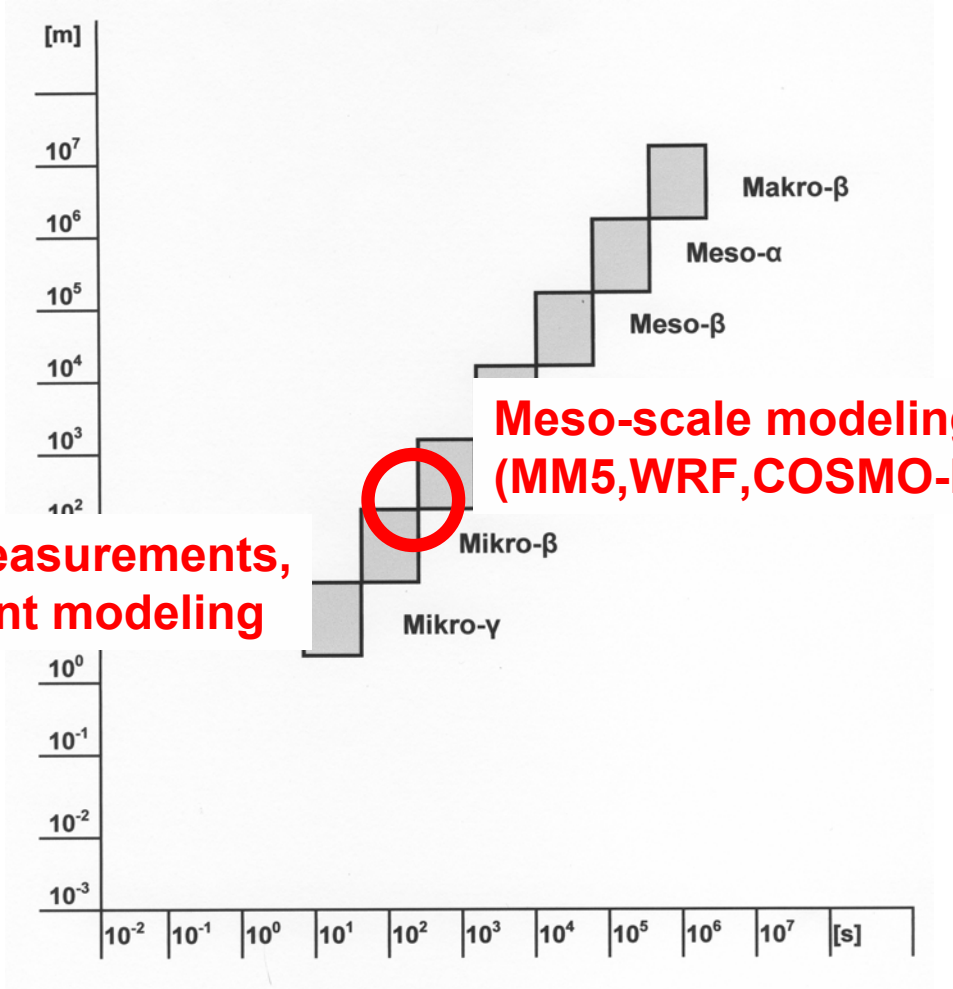
- In a heterogeneous landscape with typical heterogeneity scales of >> 100 m free convection can be generated near the surface
- Reasons are a decrease of the wind velocity (due to local circulation systems) or a heating up of the surface
- Under free convection situations flux measurements have a low data quality, which needs efforts in data quality control

Atmospheric Scales



Scale of Heterogeneities
10^2 - 10^3 m, 0.5 - 10 min.

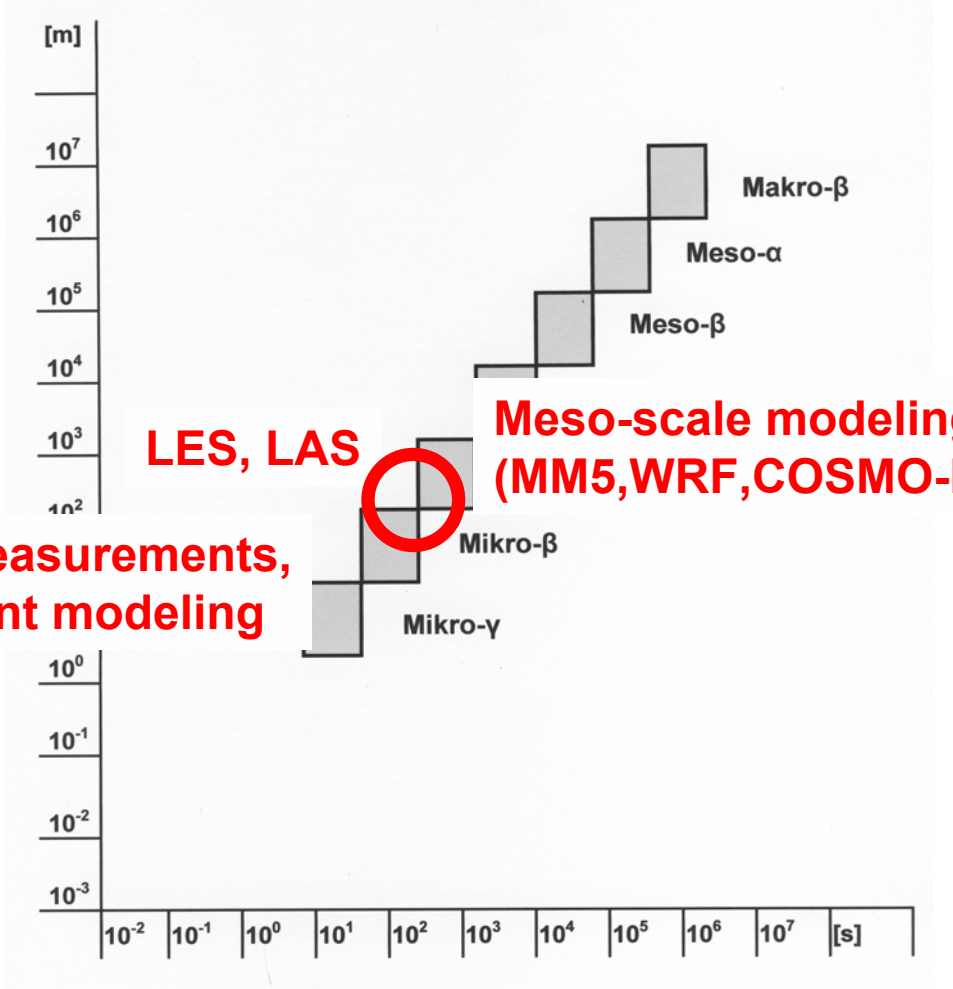
Atmospheric Scales



Meso-scale modeling (MM5,WRF,COSMO-DE)

Flux measurements, Footprint modeling

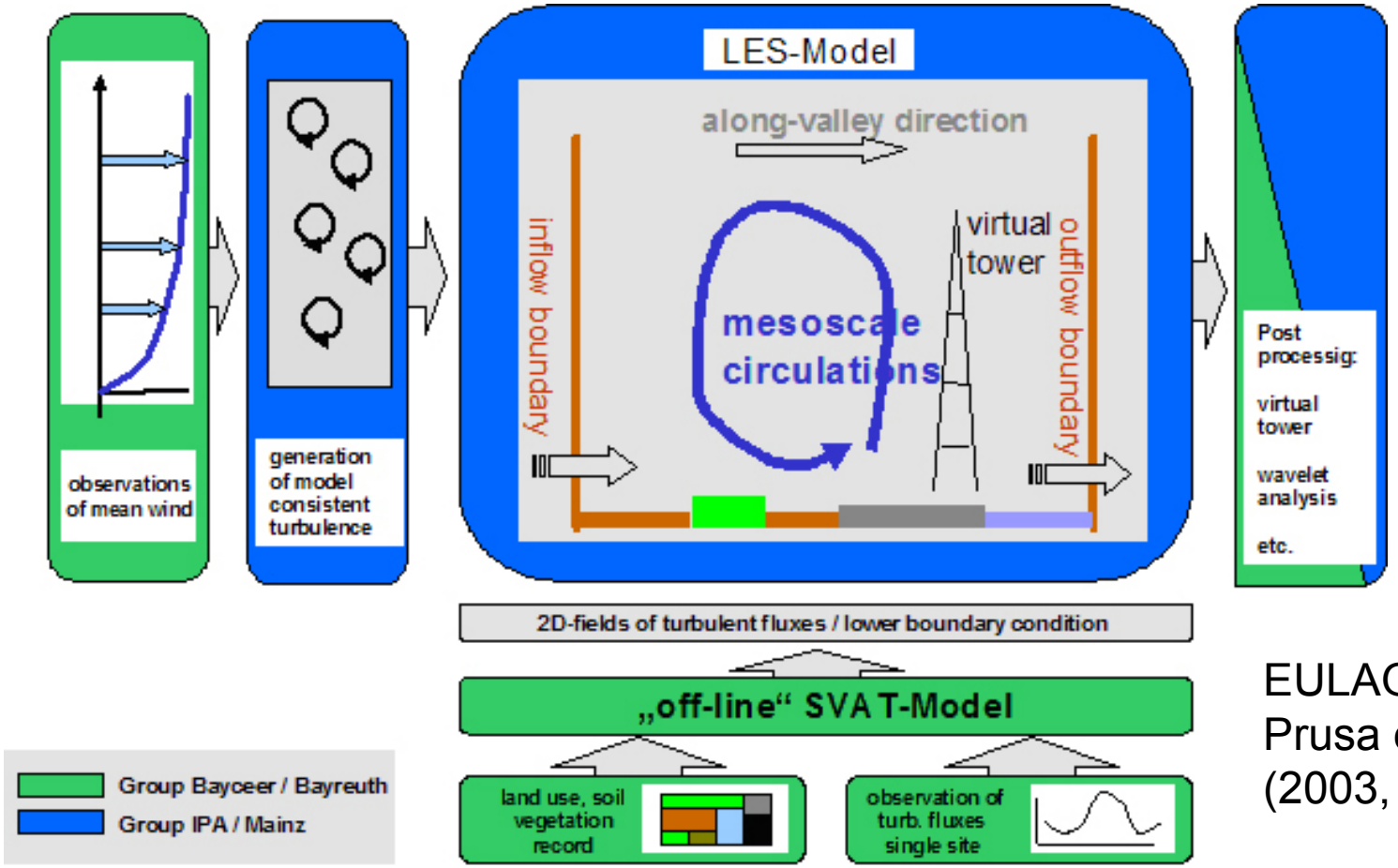
Atmospheric Scales



Conclusion 3

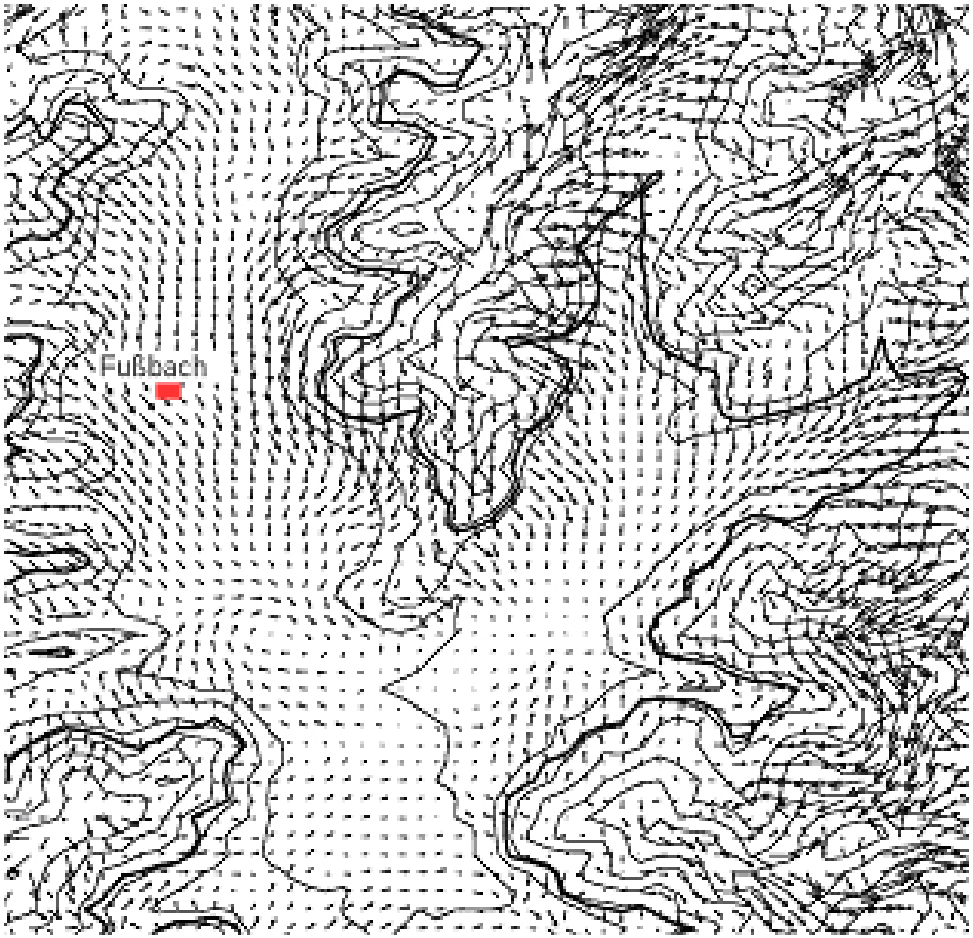
- A heterogeneous landscape with typical heterogeneity scales of >> 100 m can be investigated with LES modeling
- Suitable measuring systems for flux measurements are scintillometers

Application of a LES model

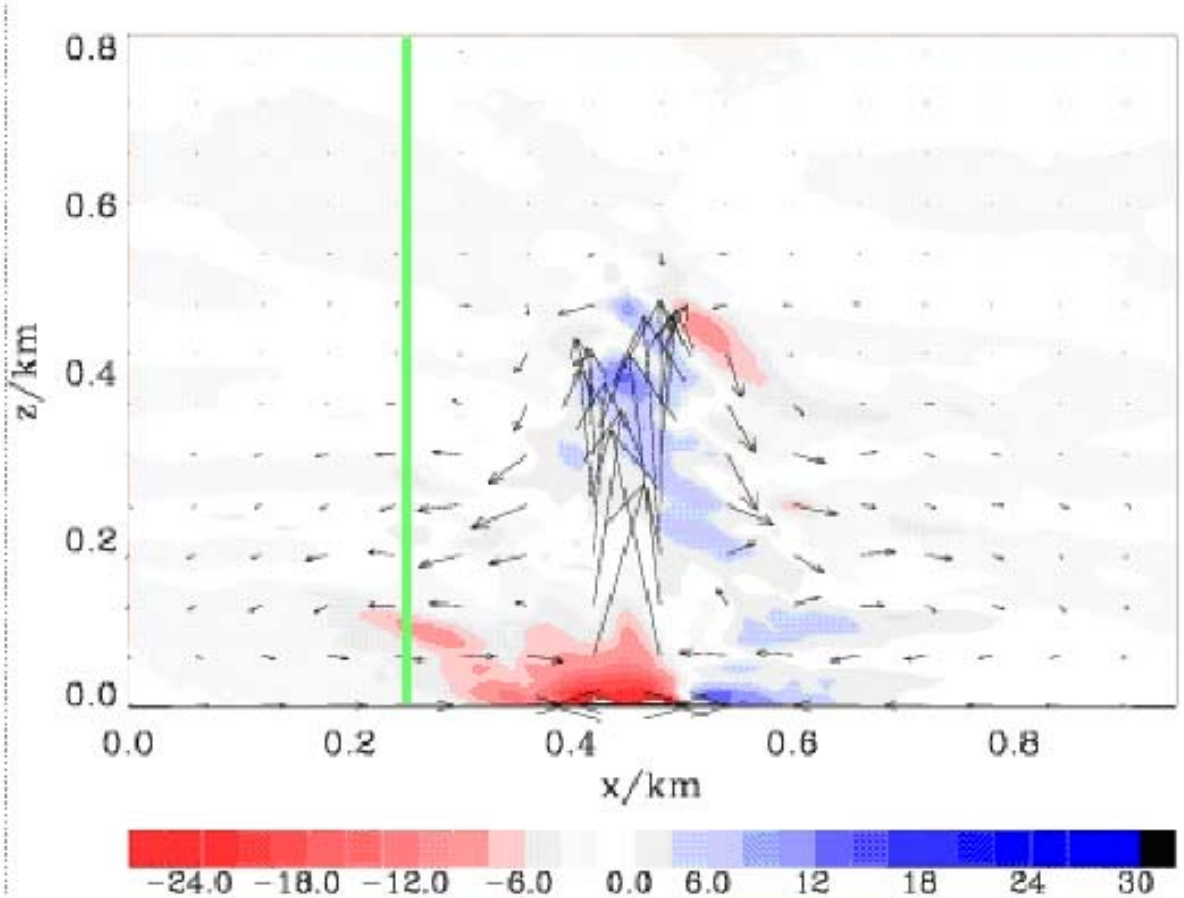


EULAG-model
Prusa et al.
(2003, 2008)

Application of a LES model



Application of a LES model



Conclusion 4

- On the 9th COPS meeting