On the relevance of mesoscale transport for in-situ energy balance measurements

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On the relevance of mesoscale transport for in-situ energy balance measurements

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Scales of atmospheric motion

Reynolds decomposition (1895)
\[ x = x + x', \quad Flux = wq = wq + w'q' \]
Energy balance closure problem

Available energy $R_n - G = \lambda E + H$

- $H$: sensible heat flux, $R_n$: net radiation
- $\lambda E$: latent heat flux, $G$: soil heat flux

Worldwide in-situ measurements show energy balance closure of **84% ± 20%** (Stoy, Mauder et al., AFM, 2013, analysis of 180 FLUXNET sites)

**One possible cause: Mesoscale transport**
Hypothesis: mesoscale transport causes a systematic underestimation of tower flux measurements

Goals:
1. Detect meso-scale structures in the surface layer
2. Evaluate their flux contribution: vertical gradients of $\theta$ and $q$

modified after Mahrt (1998): Flux sampling errors for aircraft and towers, *Journal of Atmospheric and Oceanic Technology*
How large is mesoscale transport in the surface layer?

Candle Lake Runs (BOREAS/BERMS) @ 30 m measurement height

20 flights analyzed
$\Rightarrow$ 5 – 20% mesoscale flux contribution (2 km)

(Mauder et al., 2007, JGR)
How close to the surface can mesoscale structures be found?

DUAL Doppler Lidar (KIT Cube)

RHI Scan (Halo Photonics)

17-04-2013 1030 – 1100 UTC
$U = 3.0 \text{ m/s, } \text{Dir } = 225^\circ$

(Eder et al., JAMC, submitted)
What are potential predictors for the mesoscale flux contribution?

TERENO Energy balance station Selhausen + KIT HATPRO, April and May 2013

\[ \text{Residual} = a_0 + a_1 \cdot \frac{1}{u^*} + a_2 \cdot \lambda \frac{\Delta q}{\Delta z} : \text{multiple } R^2 = 0.60 \]

(Eder et al., JAMC, submitted)
What is the effect of roughness/shear on mesoscale structures near the surface?

Yatir Forest, Israel

Desert:
- ceilometer (boundary layer height)
- mobile flux tower

Forest:
- Doppler lidar (boundary layer height + wind)
- flux tower

Aug/ Sept 2013
What is the effect of roughness/shear on mesoscale structures near the surface?

Desert: EBR = 0.76

Forest: EBR = 1.03

Data from two meteorological towers and one Doppler Lidar: 2013-08-23
Can we use the Bowen ratio to adjust tower fluxes?

Low level flights longer than 100 km

- Polar 5 (AWI)
- Twin Otter (NRC)

Mesoscale latent heat flux larger
Conclusions

• Mesoscale transport can be as large as the energy balance residual in the surface layer.

• Vertical gradients of temperature and humidity explain a larger part of the systematic underestimation of eddy fluxes.

• In the roughness sub-layer, mesoscale structures get broken up by shear - then, the energy balance is closed.

• The mesoscale Bowen ratio is not generally conserved; we often found a larger portion of mesoscale energy exchange in $\lambda E$. 