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

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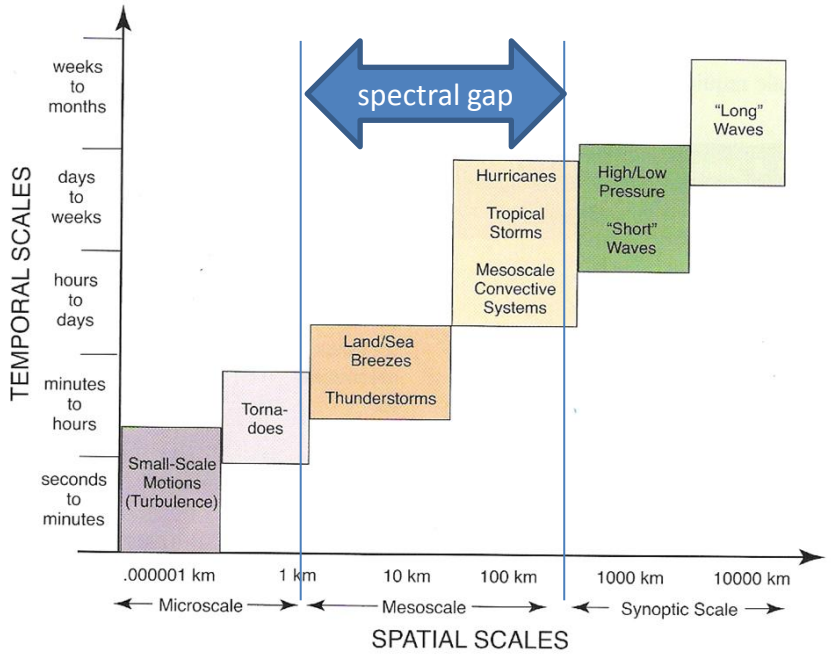
REKLIM Helmholtz-Verbund Regionale Klimaänderungen

Scales of atmospheric motion



(After Orlanski, 1975)

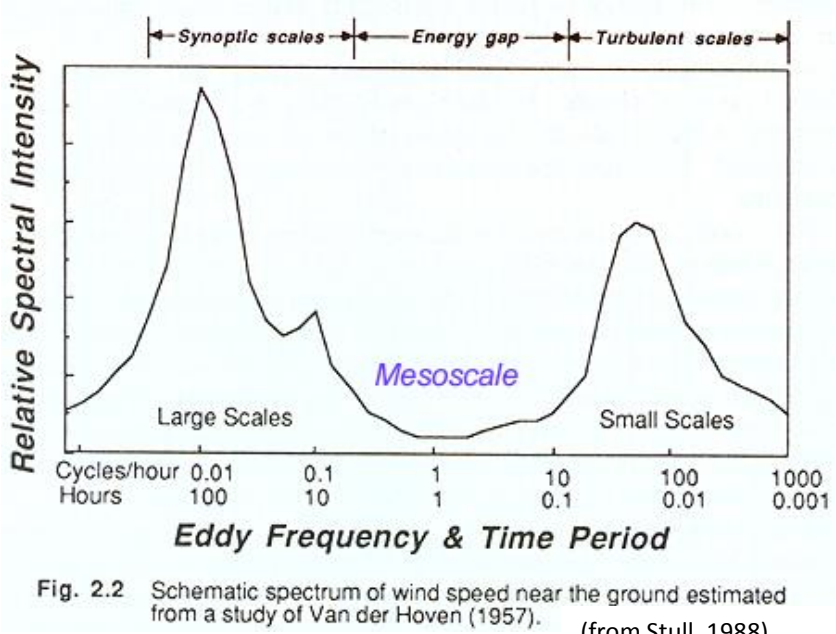


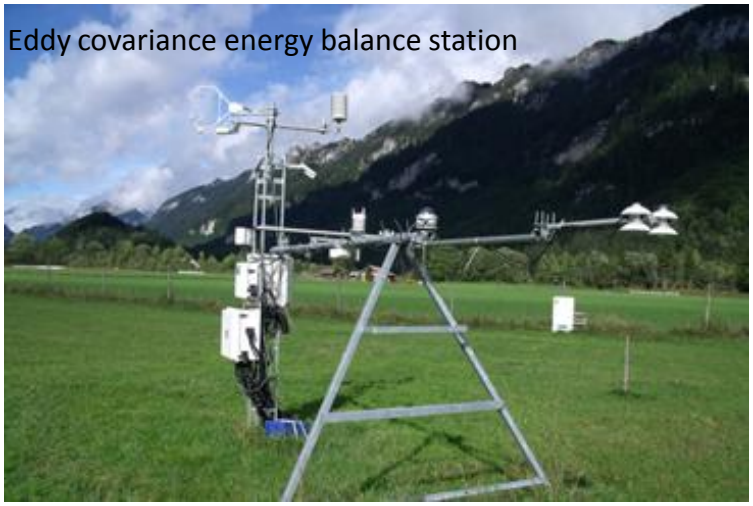
Fig. 2.2 Schematic spectrum of wind speed near the ground estimated from a study of Van der Hoven (1957).

(from Stull, 1988)

Reynolds decomposition (1895)

$$x = \bar{x} + x', \; Flux = \overline{wq} = \overline{\bar{w}\bar{q}} + \overline{w'q'}$$

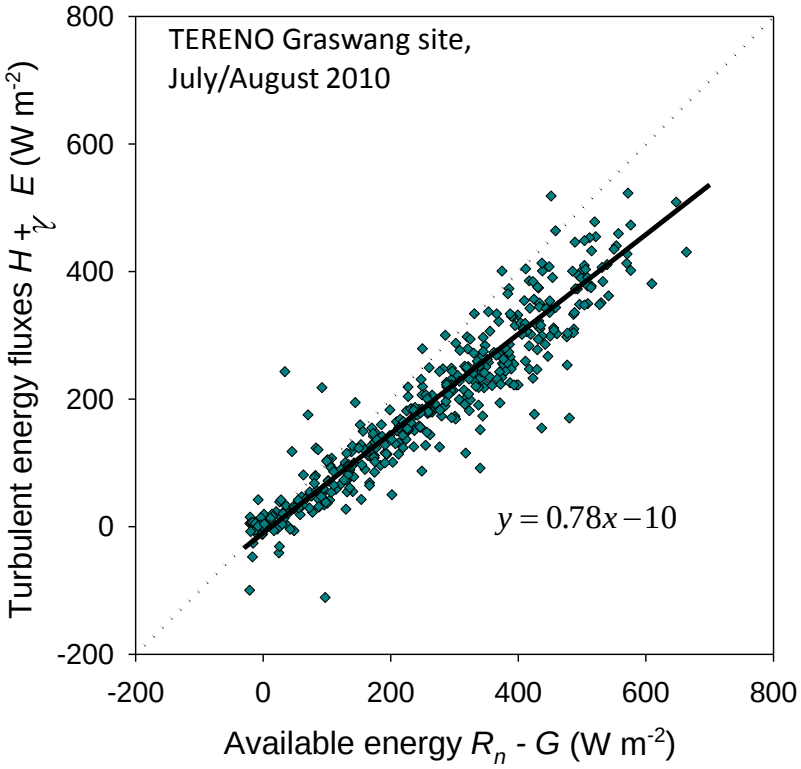
Energy balance closure problem



$R_n - G = \lambda E + H$

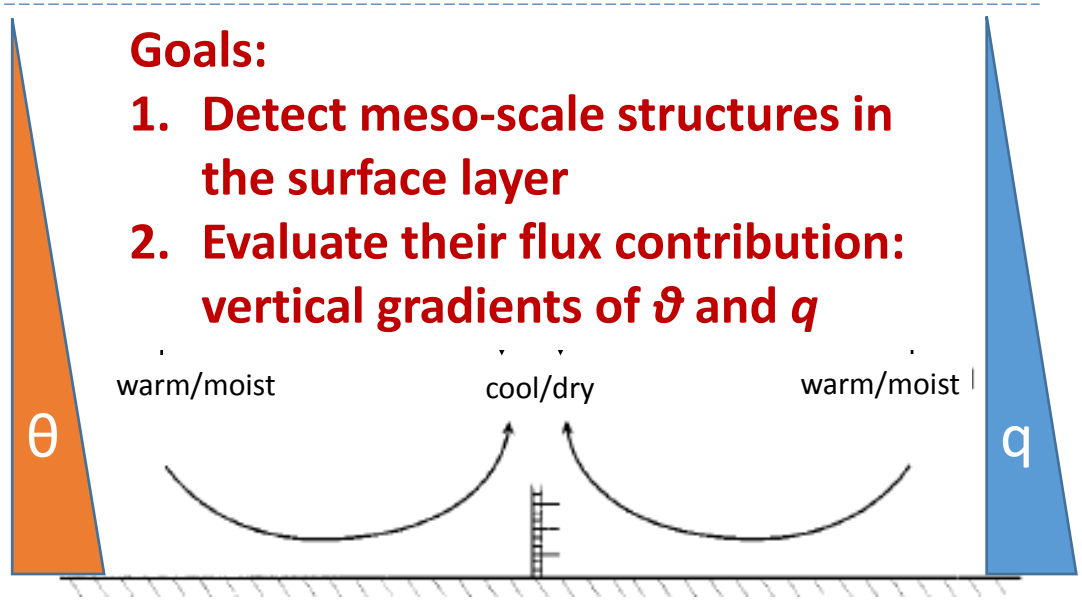
TERENO
Terrestrial Environmental Observatories

H: sensible heat flux, R_n*:* net radiation
λE*:* 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

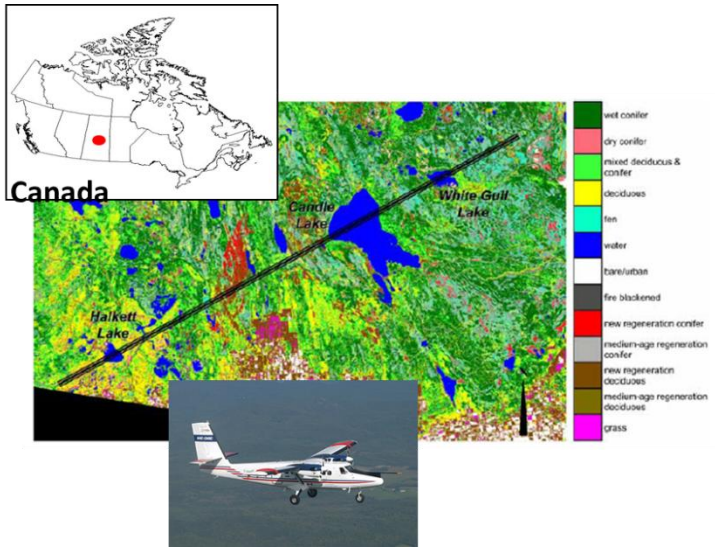
Hypothesis: mesoscale transport causes a systematic underestimation of tower flux measurments



modified after
Mahrt (1998): Flux sampling errors for aircraft and towers, *Journal of Atmospheric and Oceanic Technology*

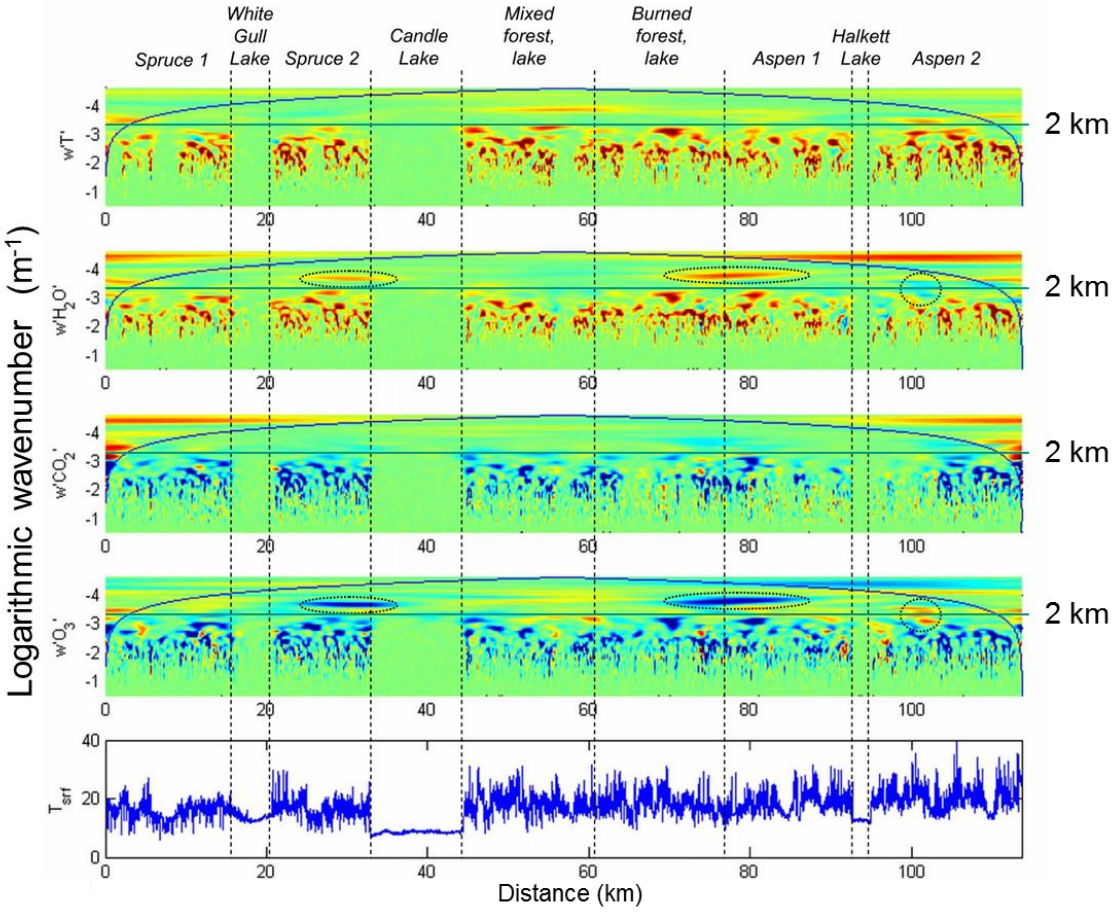
How large is mesoscale transport in the surface layer?

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)



(Mauder et al., JGR, 2007)

HD(CP)²
High definition clouds and precipitation for advancing climate prediction

WindTracer lidar 1

WindTracer lidar 2, HATPRO radiometer

TERENO
Terrestrial Environmental Observatories

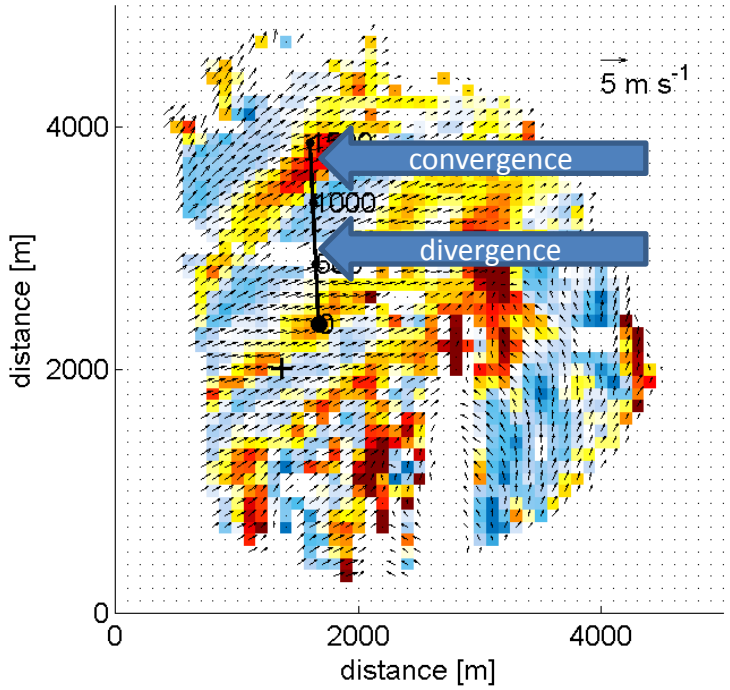
Streamline lidar

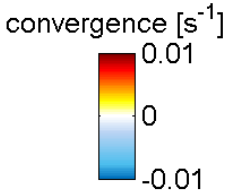
Eddy-covariance station Selhausen

©OpenStreetMap contributors

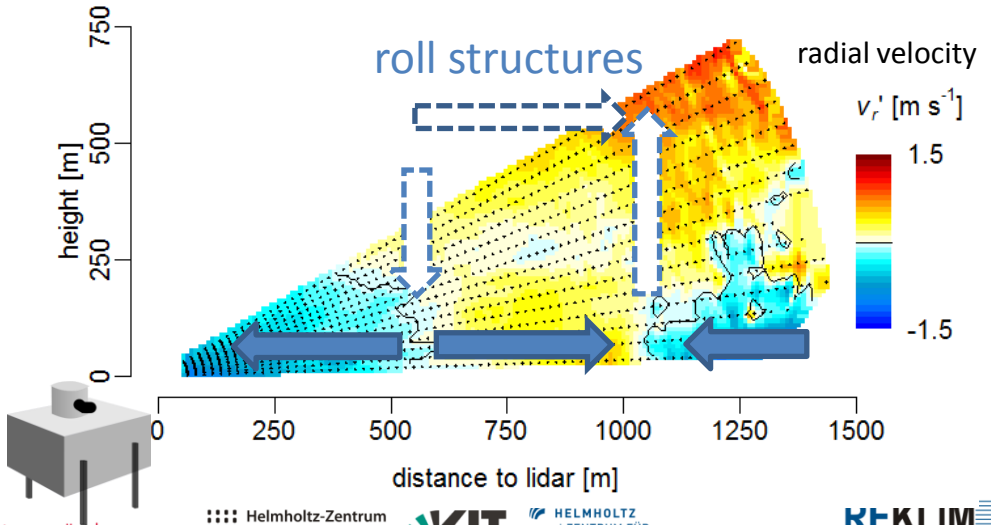
How close to the surface can mesoscale structures be found?

DUAL Doppler Lidar (KIT Cube)





RHI Scan (Halo Photonics)

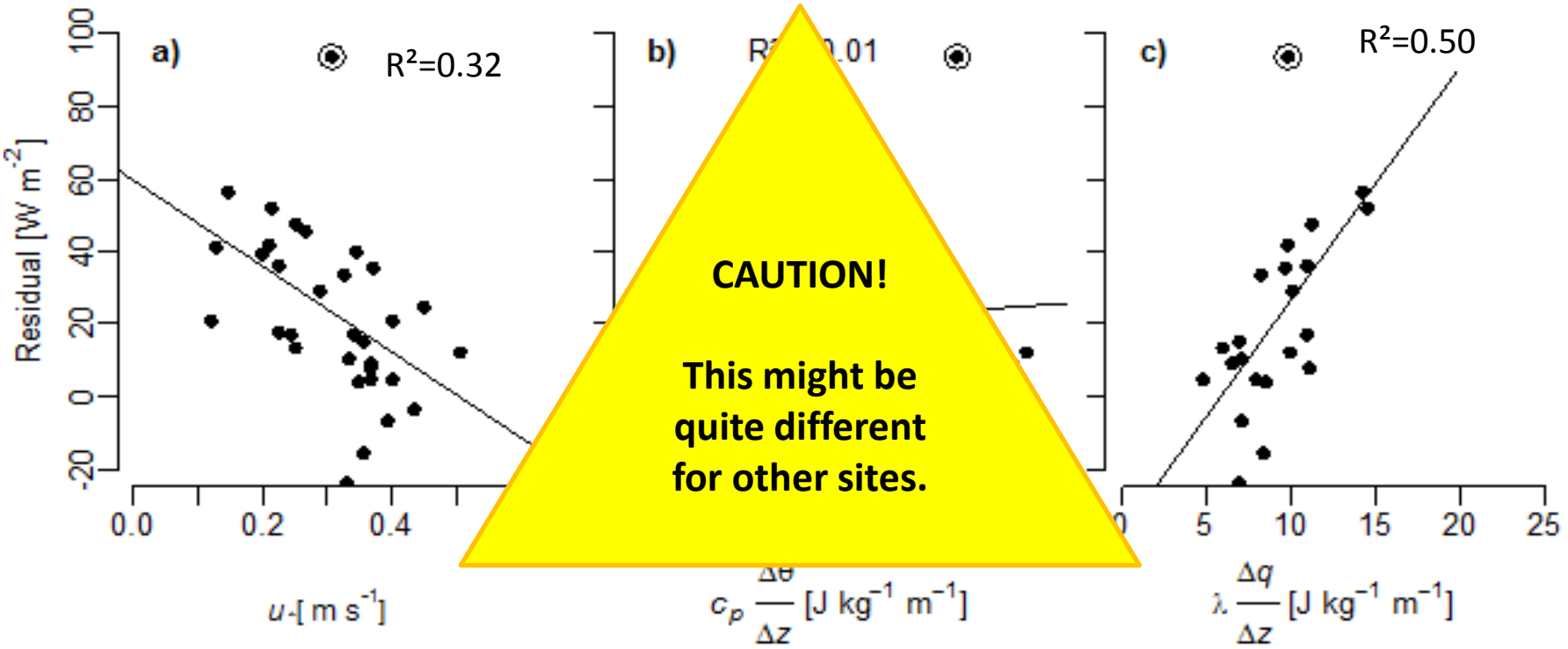


17-04-2013 1030 – 1100 UTC
U = 3.0 m/s, *Dir* = 225°

(Eder et al., JAMC, submitted)

What are potential predictors for the mesoscale flux contribution?

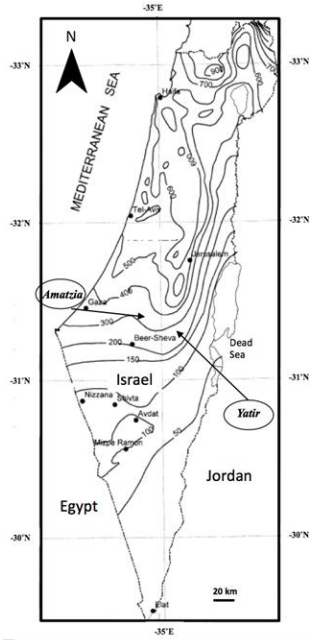
TERENO Energy balance station Selhausen + KIT HATPRO, April and May 2013



$Residual = a_0 + a_1 \cdot 1/u_* + a_2 \cdot \lambda\, \Delta q/\Delta z$: **multiple R^2 = 0.60**

(Eder et al., JAMC, submitted)

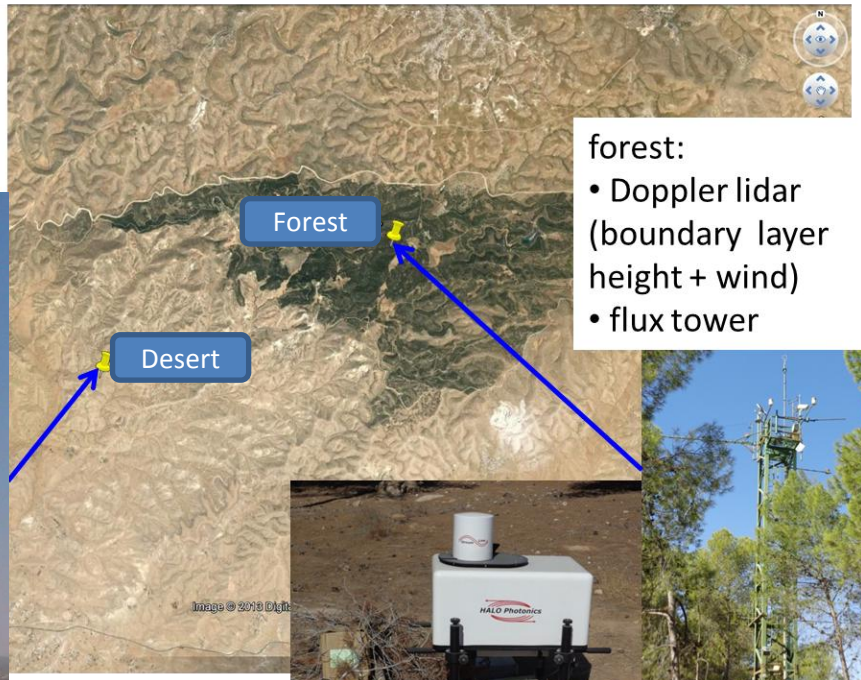
What is the effect of roughness/shear on mesoscale structures near the surface?



Aug/ Sept 2013

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

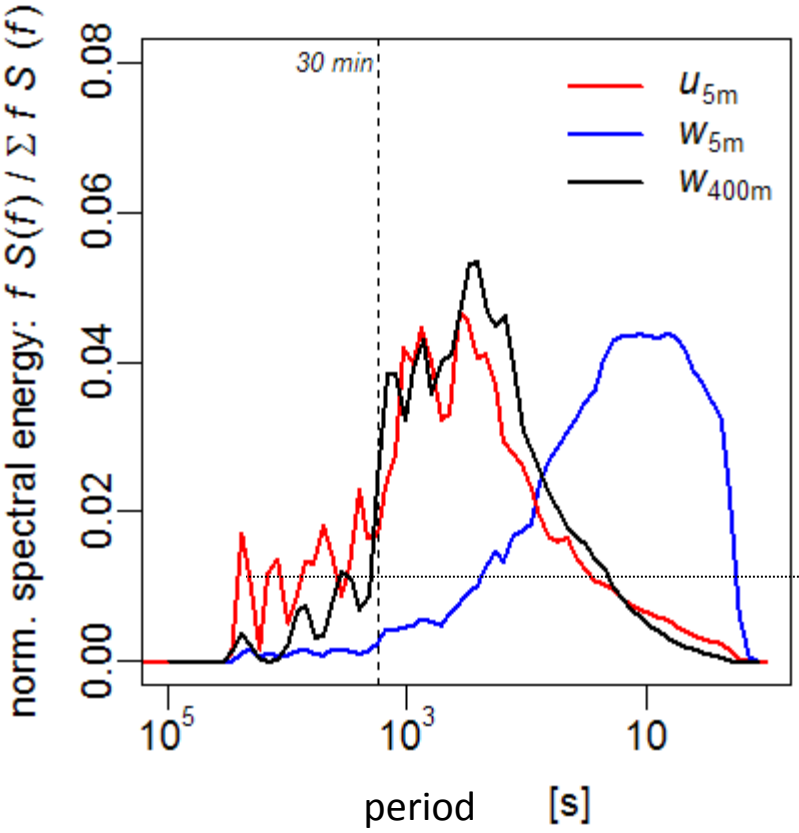
Yatir Forest, Israel



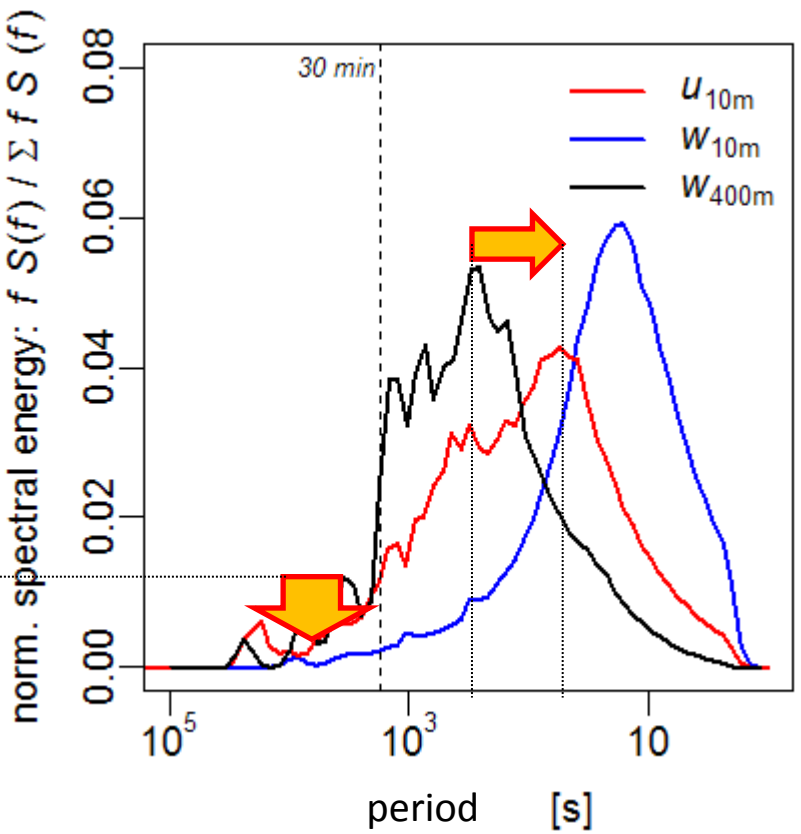
forest:
- Doppler lidar (boundary layer height + wind)
- flux tower

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

Desert: EBR = 0.76



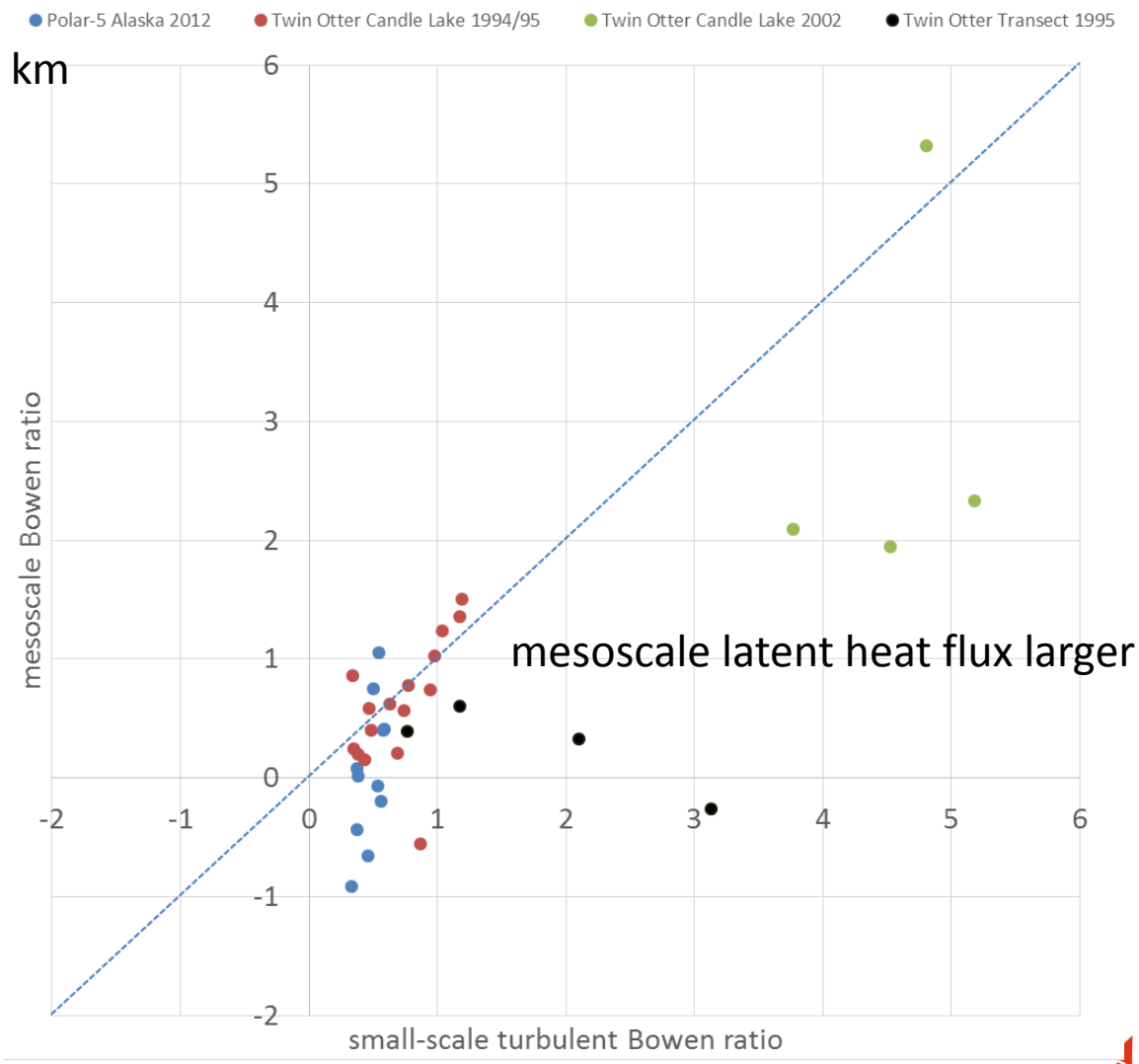
Forest: EBR = 1.03



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



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 λE.