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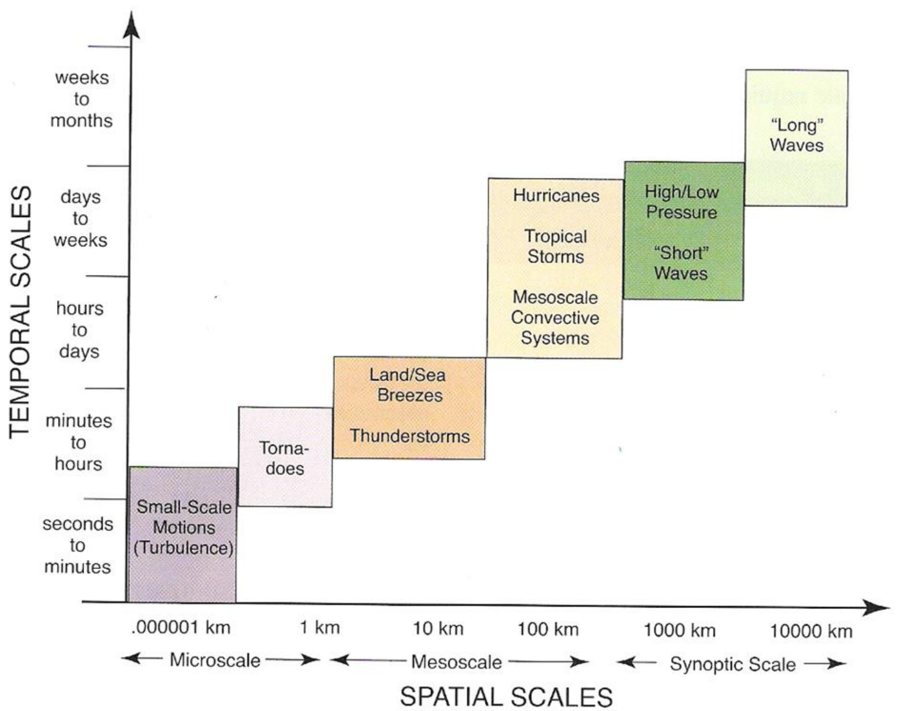
On the relevance of mesoscale transport for in-situ energy balance measurements and its partitioning between sensible and latent heat

Matthias Mauder, Fabian Eder, Hans Peter Schmid, Ray Desjardins, Katja Träumner, Marius Schmidt, Torsten Sachs, Stefan Metzger, Jörg Hartmann, Dan Yakir, Eyal Rotenberg

INSTITUTE OF METEOROLOGY AND CLIMATE RESEARCH, ATMOSPHERIC ENVIRONMENTAL RESEARCH, IMK-IFU,
Transport Processes in the Atmospheric Boundary Layer Group, TABLe

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

Scales of atmospheric motion



(After Orlanski, 1975)

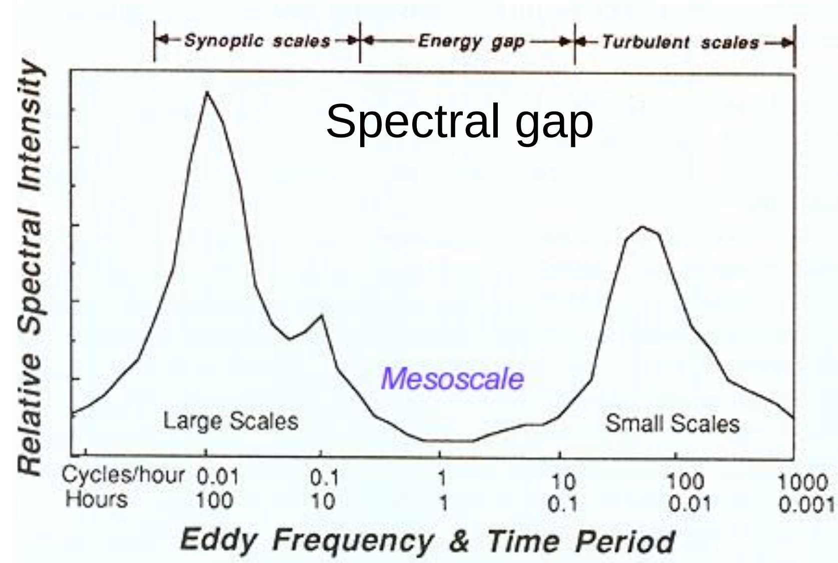


Fig. 2.2 Schematic spectrum of wind speed near the ground estimated from a study of Van der Hoven (1957).

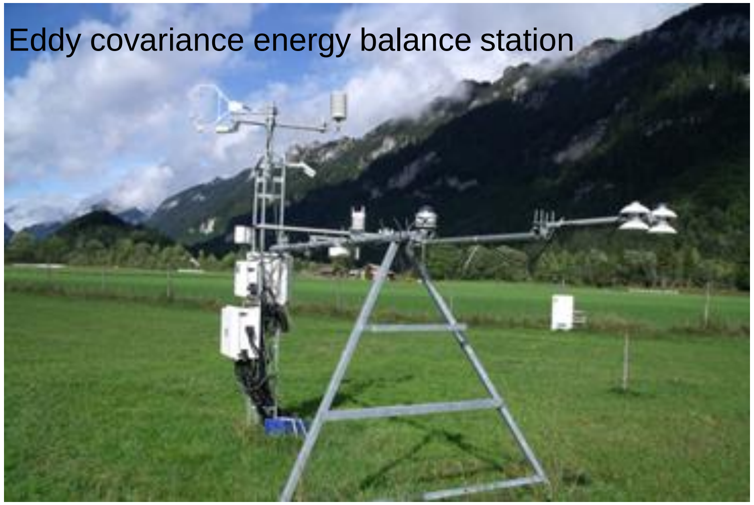
(from Stull, 1988)

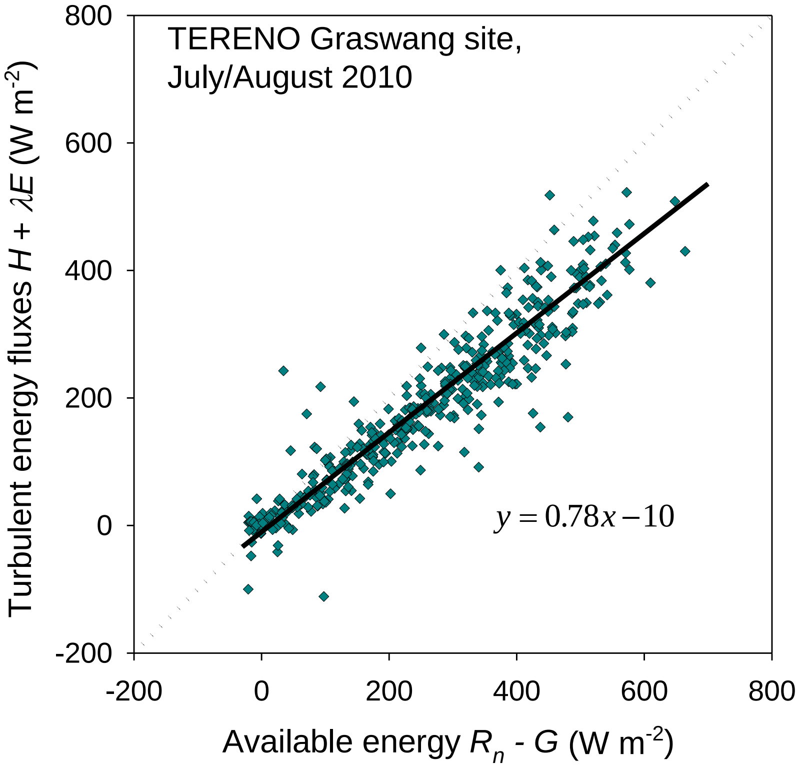
Reynolds decomposition (1895)

$$x = \overline{x} + x', \quad \overline{x'} = 0,$$

$$F = \overline{wq} = \overline{w}\,\overline{q} + \overline{w'q'}$$

The energy balance closure problem





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

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)

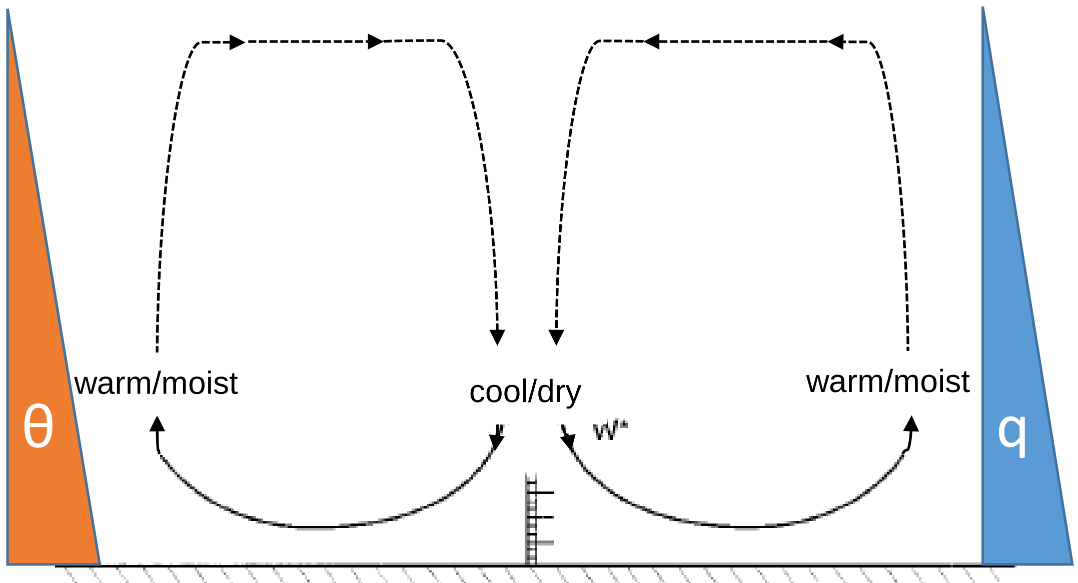
One possible cause: Mesoscale transport

Questions

- How can mesoscale transport cause a systematic underestimation?
- Can mesoscale transport be significant in the surface layer?
- Can mesoscale structures be found at typical eddy tower heights?
- What are potential predictors for mesoscale flux contributions?
- Do mesoscale structures even affect the roughness sub-layer?
- How to adjust tower fluxes for mesoscale transport?

1. How can mesoscale transport cause a systematic underestimation?

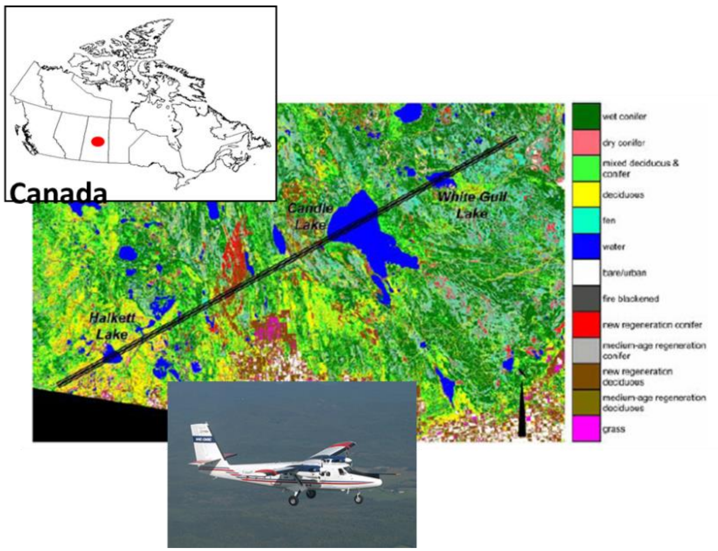
- Mahrt (1998): 'Flux sampling errors for aircraft and towers', JTECH

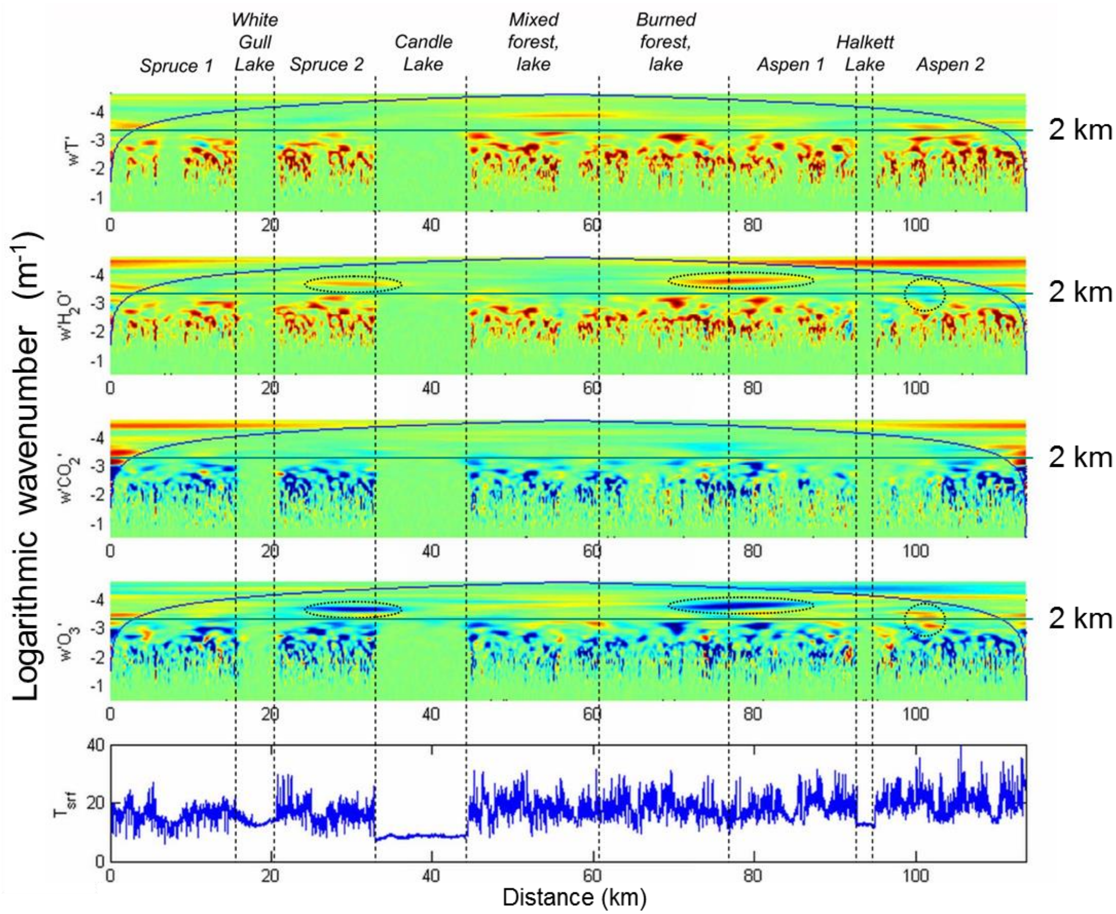


is usually neglected, as would occur with homogeneous flow where $\overline{w} = 0$, in which case the heat flux is $\overline{w'\theta'}$. However, with stationary eddies, $\overline{w'\theta'}$ is an inadequate estimate of the total heat flux so that spatial averaging over the scale of the eddies is required. This can be expressed by decomposing the local time average flow $\overline{w(x)}$ into a spatial average of the time average $[\overline{w}]$, and

2. Can mesoscale transport be significant in the surface layer?

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





20 flights analyzed
=> **5 – 20% mesoscale** flux contribution (2 km)

(Mauder et al., JGR, 2007)

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

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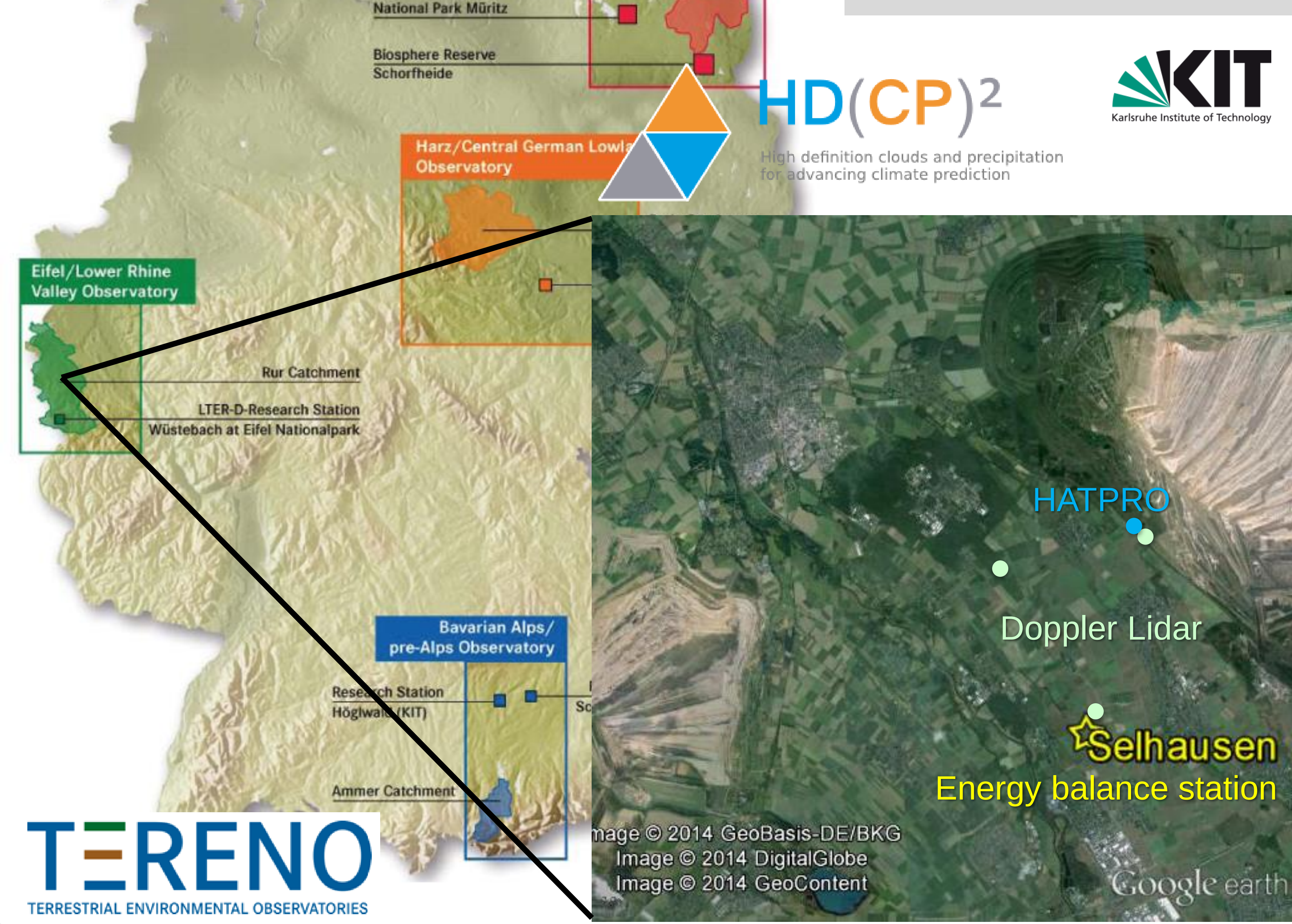

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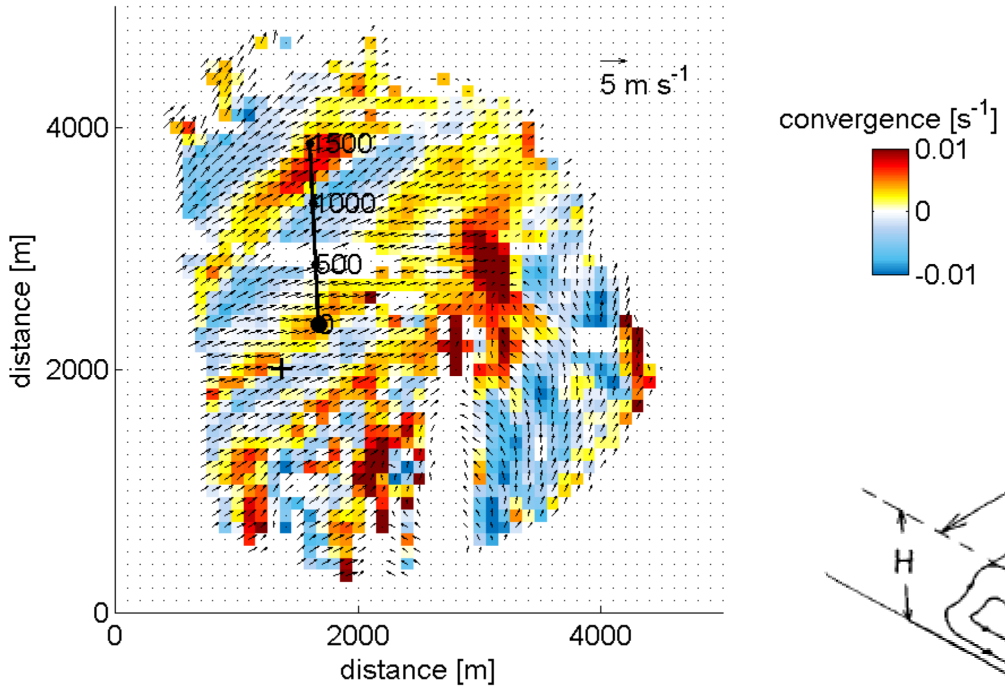
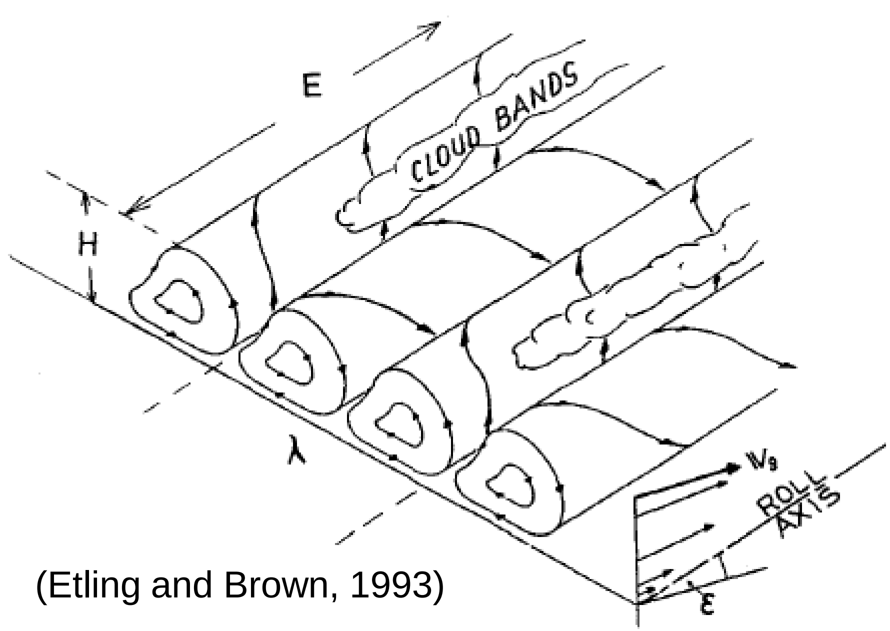
3. How far down towards the surface can mesoscale structures be found?

DUAL Doppler Lidar (KIT Cube)



roll vortices



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

(Eder et al., JAMC, submitted)

(Etling and Brown, 1993)

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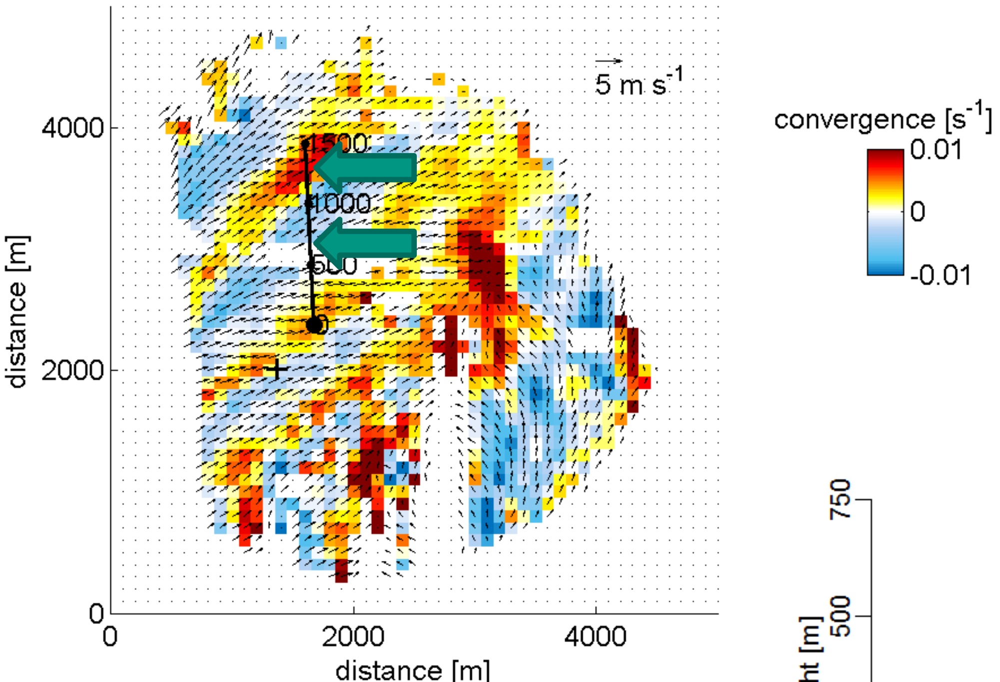
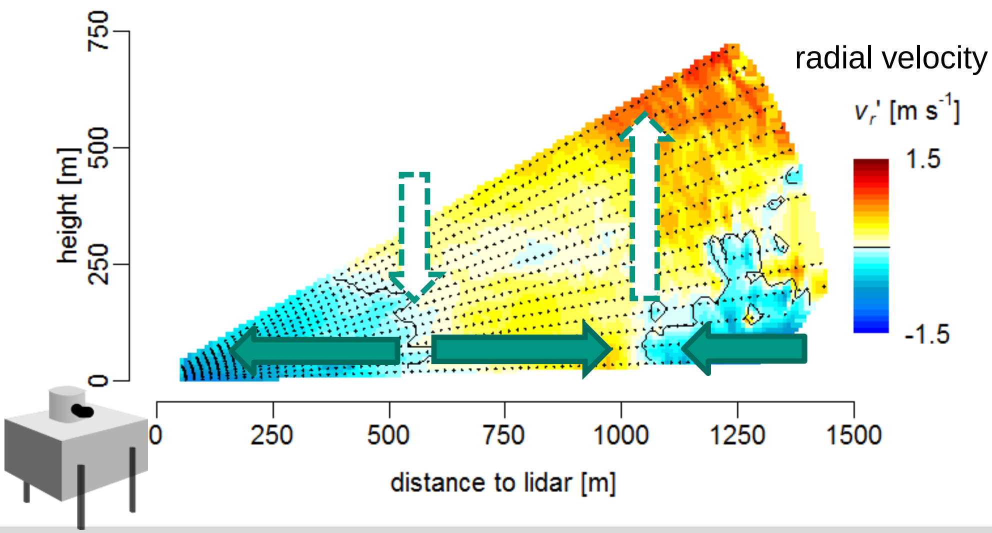
DUAL Doppler Lidar (KIT Cube)



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

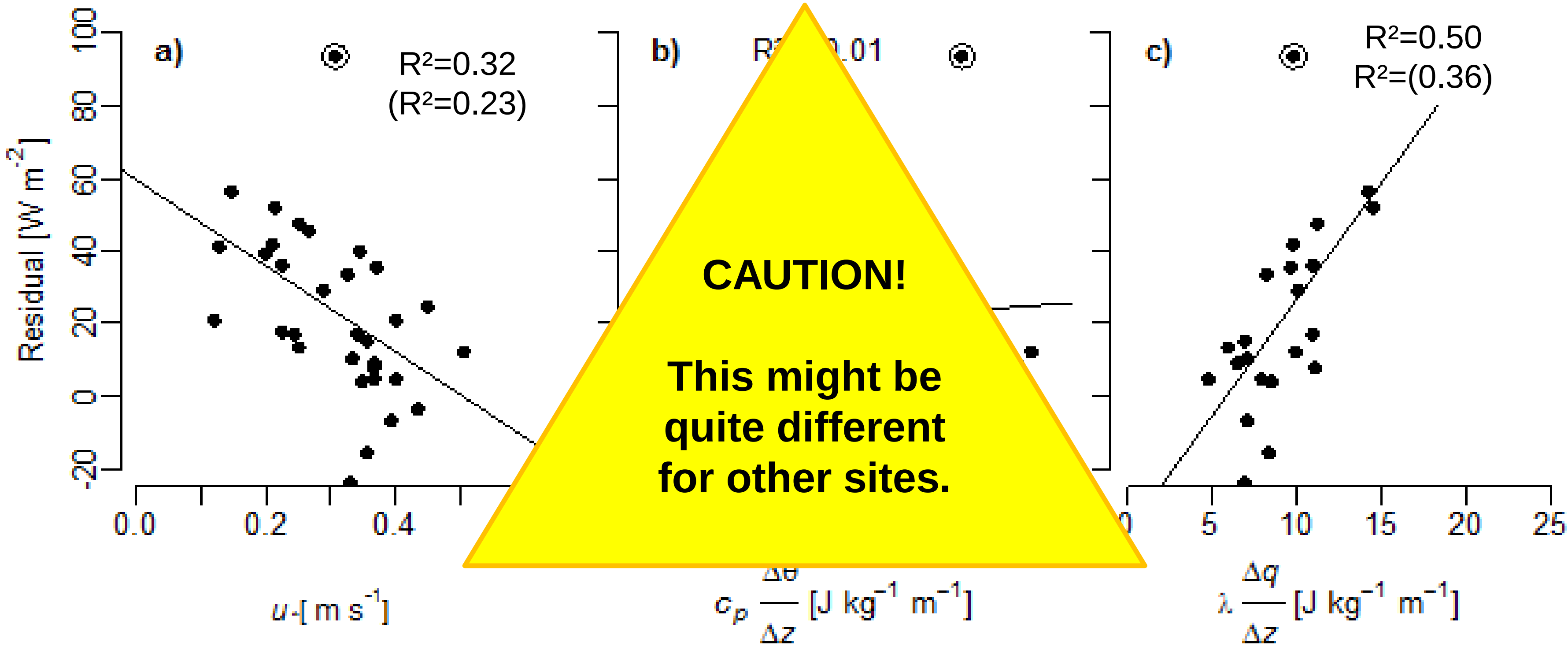
(Eder et al., JAMC, submitted)

RHI Scan (Halo Photonics)



What are potential predictors for the mesoscale flux contribution?

TERENO Energy balance station Selhausen + KIT HATPRO

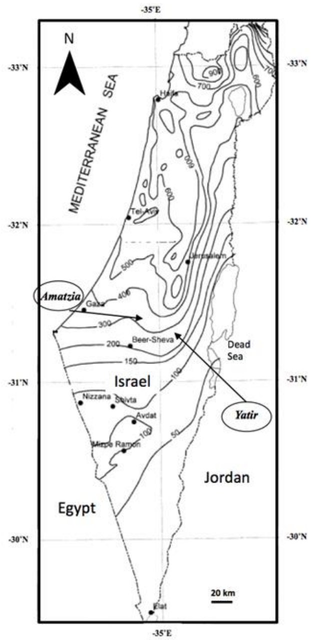


$Residual = a_0 + a_1 \cdot 1/u_* + a_2 \cdot \lambda\ \Delta a/\Delta z$: **multiple R^2 = 0.60 (0.40)**

(Eder et al., JAMC, submitted)

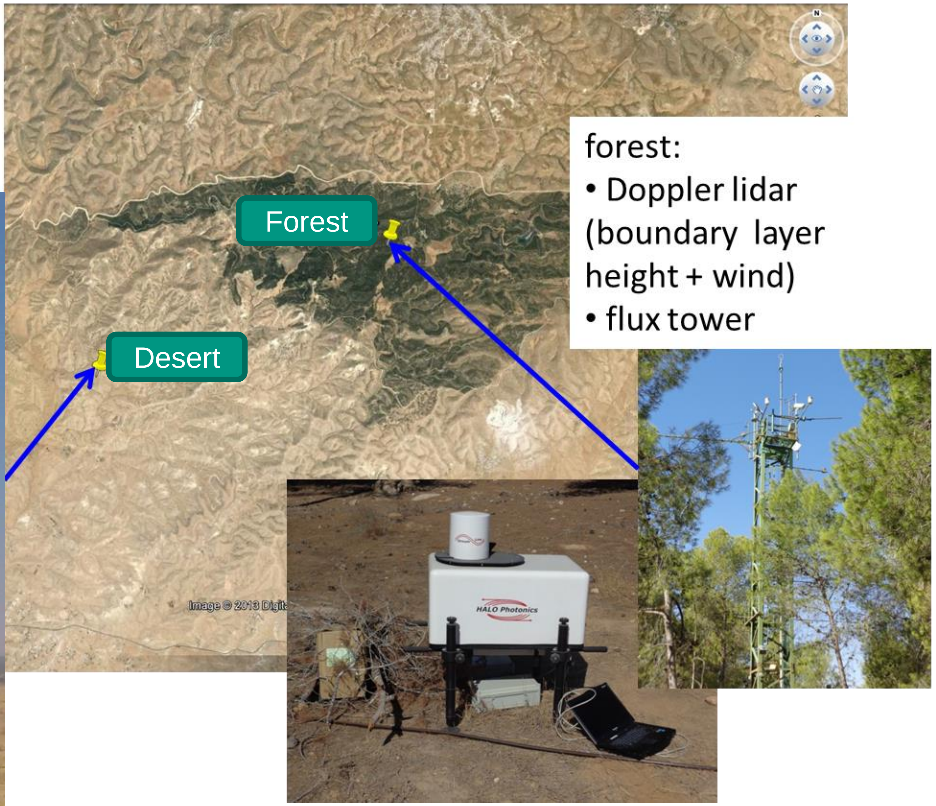
Do mesoscale structures even affect the roughness sub-layer?

Yatir Forest, Israel



Aug/ Sept 2013

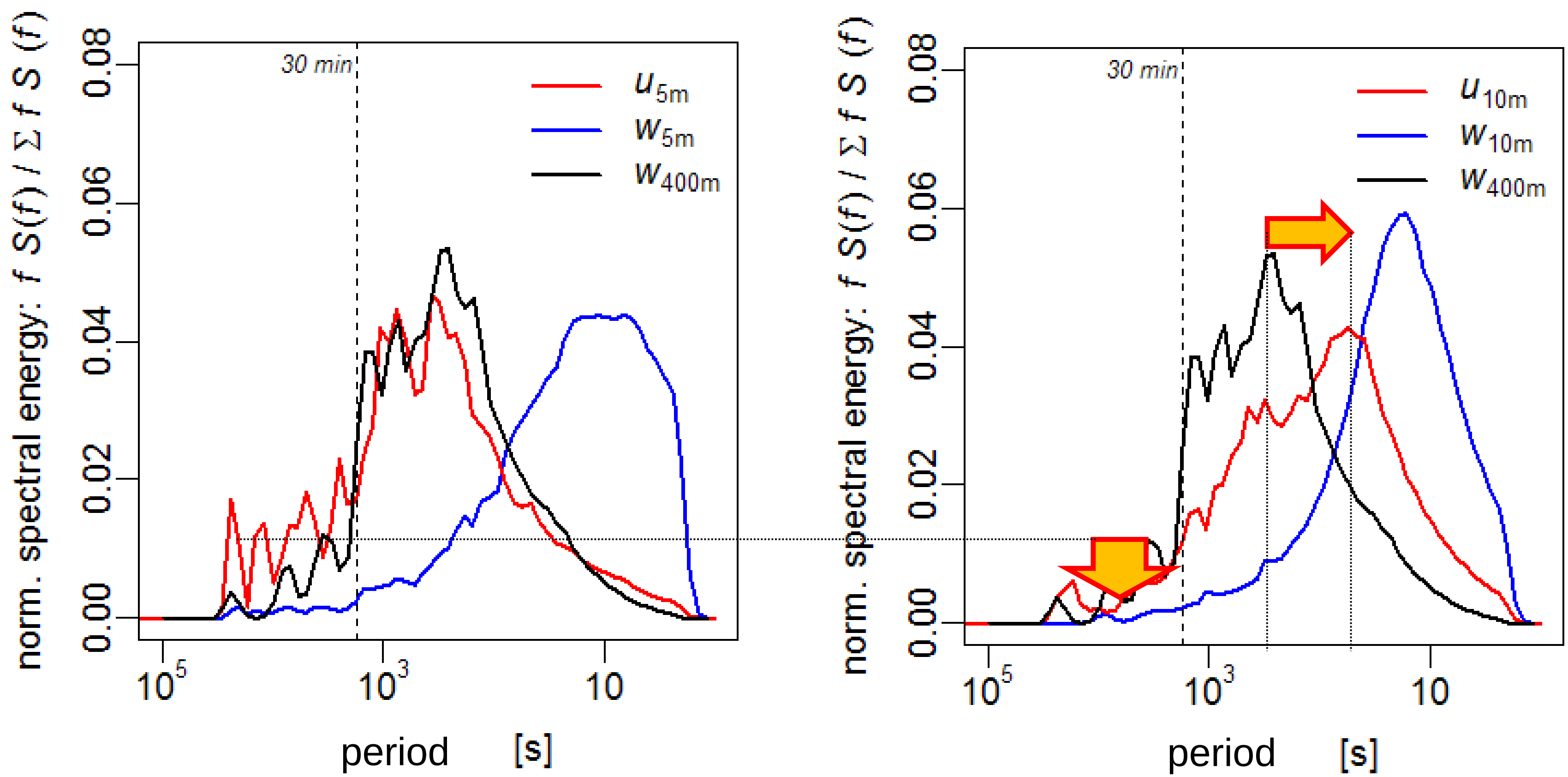
desert:
- ceilometer (boundary layer height)
- mobile flux tower



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

Do mesoscale structures even affect the roughness sub-layer?

Desert: EBR = 0.76 **Forest: EBR = 1.03**



Data from two meteorological towers and one Doppler Lidar: 2013-08-23

How to adjust for tower fluxes for mesoscale transport?

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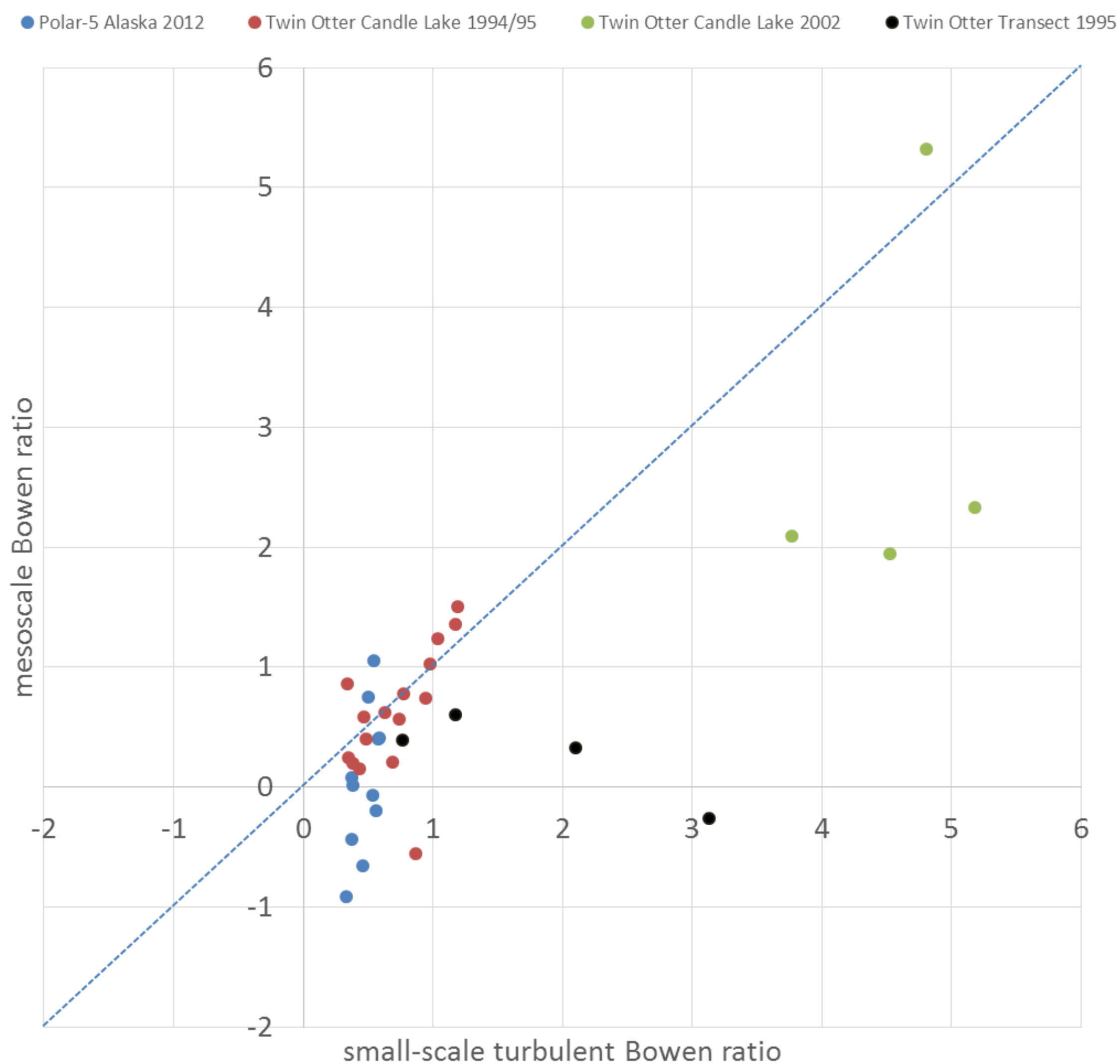
All flight tracks > 100 km



Conclusions

- Mesoscale structures cause a systematic underestimation in the presence of vertical gradients of temperature and humidity in the CBL.
- Mesoscale transport can be as large as the energy balance residual in the surface layer, even at typical eddy tower heights.
- Potential predictors for mesoscale energy flux contributions are u_*, vertical gradients in q and Θ.
- In the roughness sub-layer, mesoscale structures get broken up by shear; 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.