Measuring the turbulent wind vector with a weight-shift Microlight Aircraft

S. Metzger (1,3,4), W. Junkermann (1), F. Neidl (1), K. Butterbach-Bahl (1), H.P. Schmid (1), F. Beyrich (2), X.H. Zheng (3), and T. Foken (4)

(1) Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany (stefan.metzger@imk.fzk.de)

(2) German Meteorological Service, Lindenberg, Germany

(3) Chinese Academy of Sciences, Beijing, China

(4) Bayreuth University, Bayreuth, Germany

overview

- M-IFU application area and setup for fast wind measurement
- from lab- to field calibration
- performance and uncertainty
- outlook

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aerosol / cloud and radiation transfer

- what we got...
  - cruise speed 80 kmh^{-1}
  - payload max 80 kg
  - power max 60 A at 12 VDC
  - high mobility

- and what we need...
  - visual flight
  - wind at ground level < 10 ms^{-1}
  - waterproof shelter for storage
  - runway minimum 200 m

setup for fast wind measurement

- 5 hole probe
  - pascaLine low pressure sensors < 6 hPa
- Omega 50 µm Ni-Cr thermocouple
  - response time < 0.05 s
- Oxford Scientific RT 3000 INS
  - groundspeed σ < 0.05 ms^{-1}
  - attitude angles σ < 0.1°
- Dynamax OP-2 IRGA for H_2O & CO_2
- 4 pole hardware Butterworth filter at 20 Hz
- storage at 10 Hz; spatial resolution ~ 2.6 m

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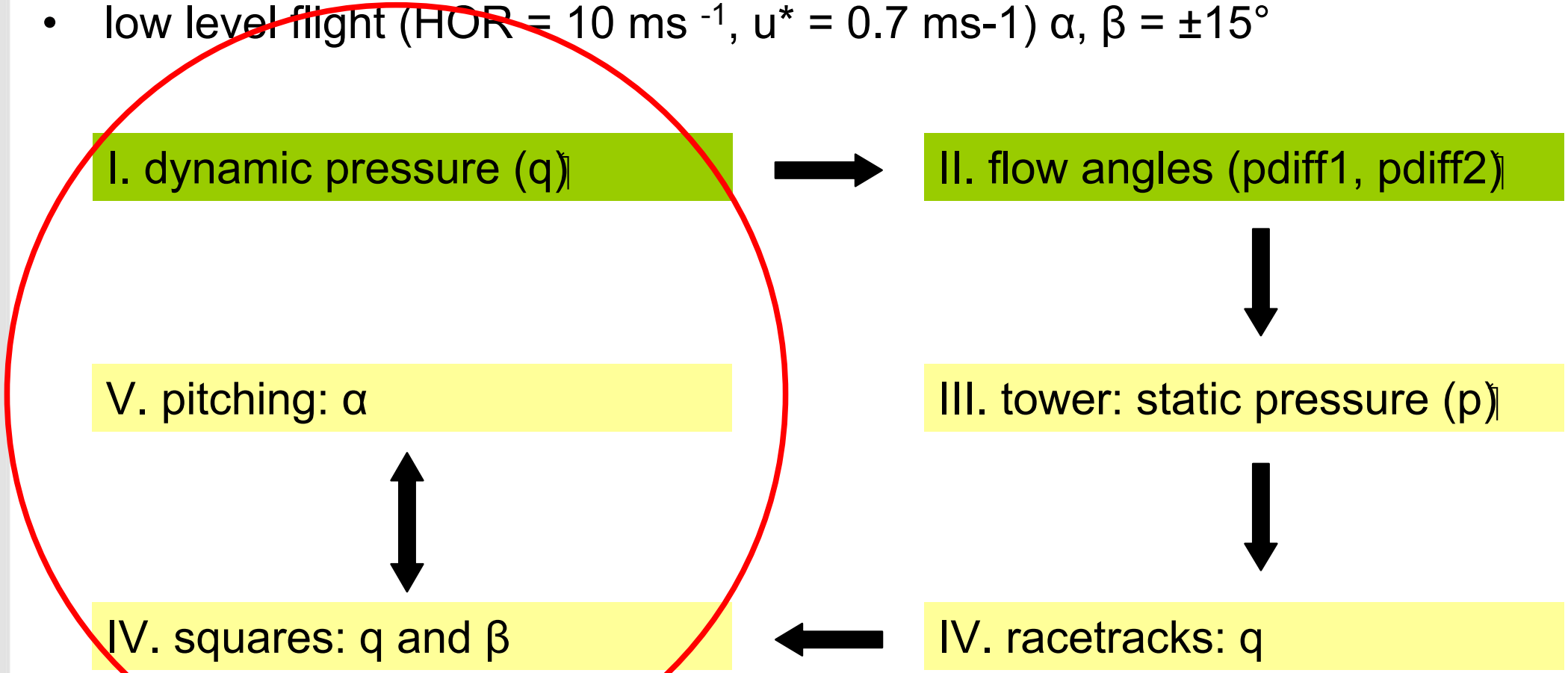
calibration scheme

calibration range for flow angles:

- tan(β) = HOR / TAS
- for TAS = 28 ms^{-1} and HOR = 10 ms^{-1} β = ±20°
- low level flight (HOR = 10 ms^{-1}, u* = 0.7 ms-1) α, β = ±15°

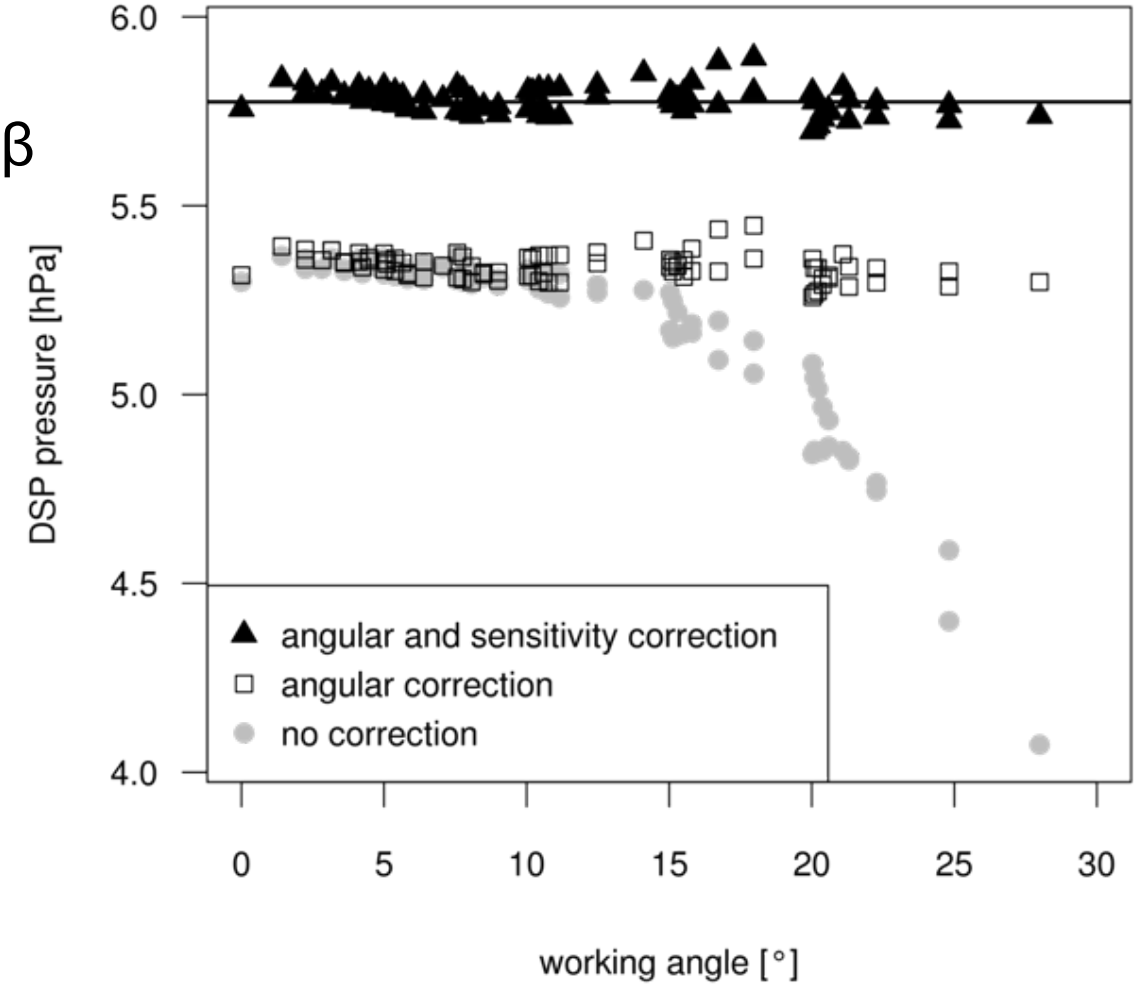


I & II: lab - dynamic pressure and flow angles

- angular correction
  - q port 6° of of half sphere
  - fourth order linear model for q
  - sensitivity for q: Kq11 = 1.080
  - third order linear model for α, β

- uncertainties in residuals
  - $\sigma_q < 0.025$ hPa
  - $\sigma_{\alpha, \beta} < 0.2°$

- outcome
  - q angular independent
  - q recovers input
  - flow angle reference

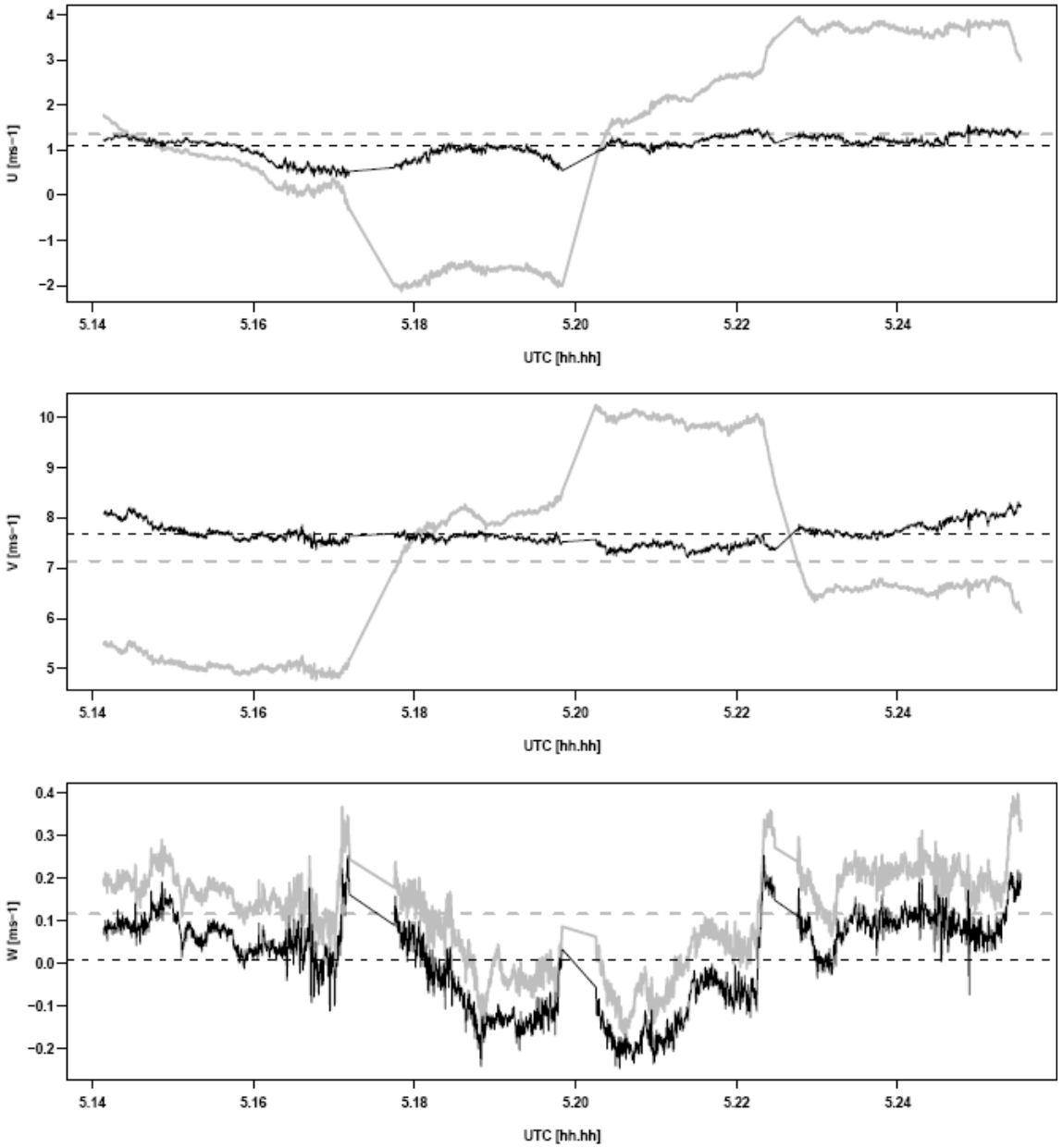


V & VI: field - squares and pitching

- four perpendicular legs
  - cardinal directions
  - calm conditions

- idea
  - q sensitive along-track
  - beta sensitive cross-track

	offset	sensitivity	σ [ms-1]
p	2.12 hPa	-	0.01
q	-	1.09	0.16
α	0.26°	1.09	0.18
β	2.54°	1.21	0.18
T	-	-	0.02
e	-	-	0.01
UVWairc	-	-	0.05
ANGairc	-	-	0.09
uncorrelated Gauss error			**0.32**



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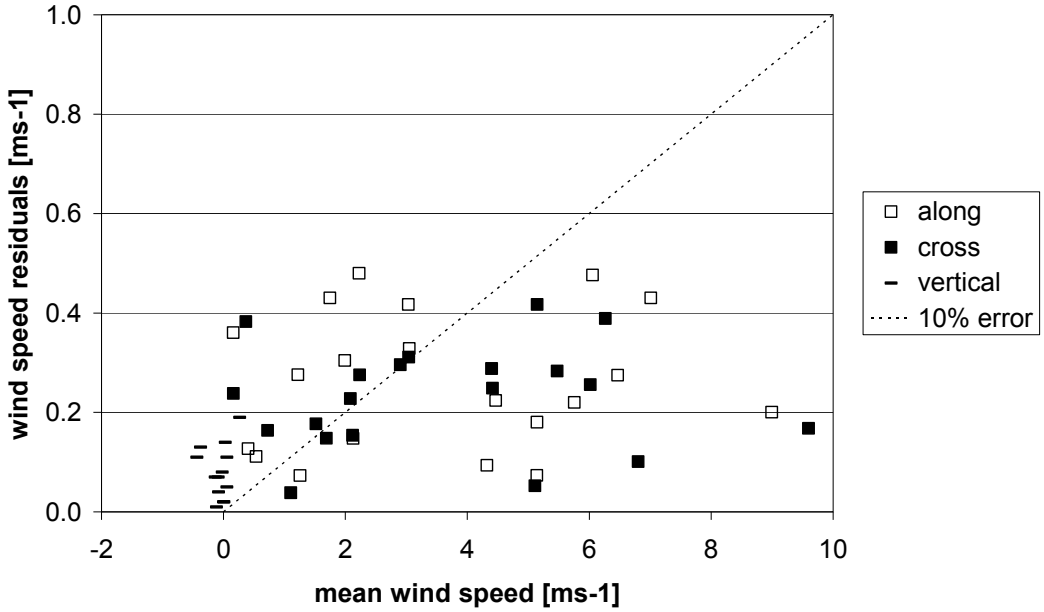
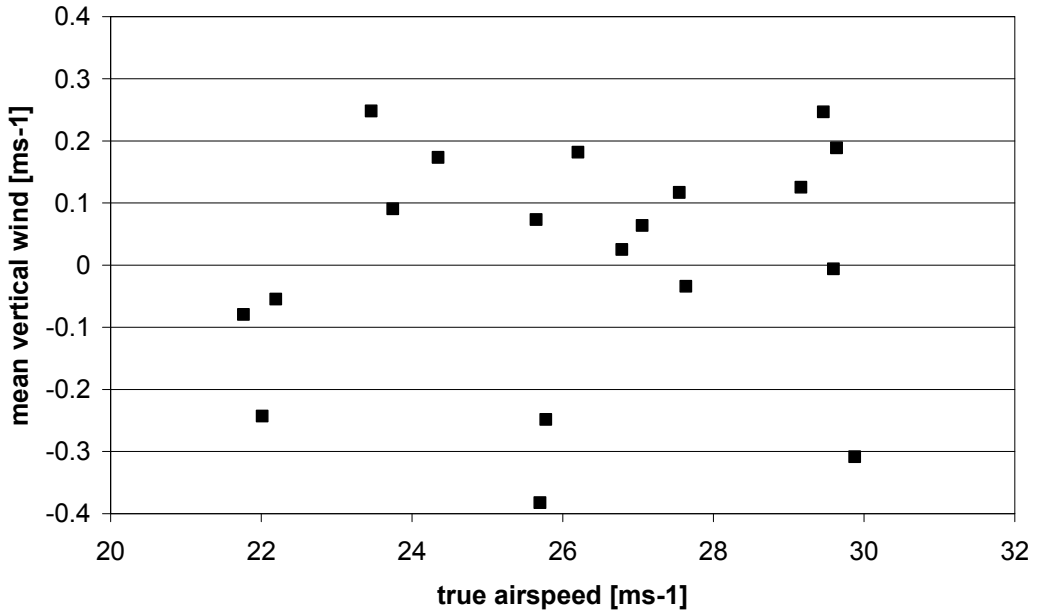
free atmosphere: final wind uncertainty

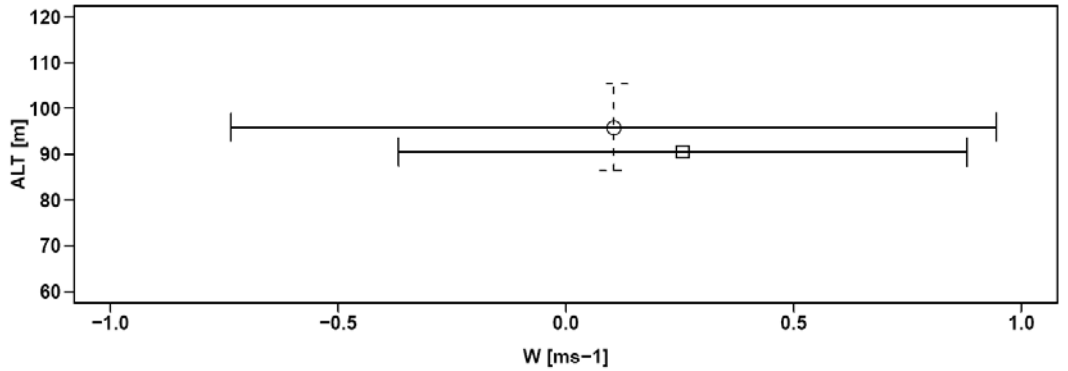
- 20 flights in cardinal directions
- horizontal wind components
  - $\sigma_{UV} = 0.24 \pm 0.12$ ms^{-1}
  - $\sigma_{W} = 0.08 \pm 0.05$ ms^{-1}
- vertical wind
  - independent from TAS
  - $W = 0.02 \pm 0.19$ ms^{-1}

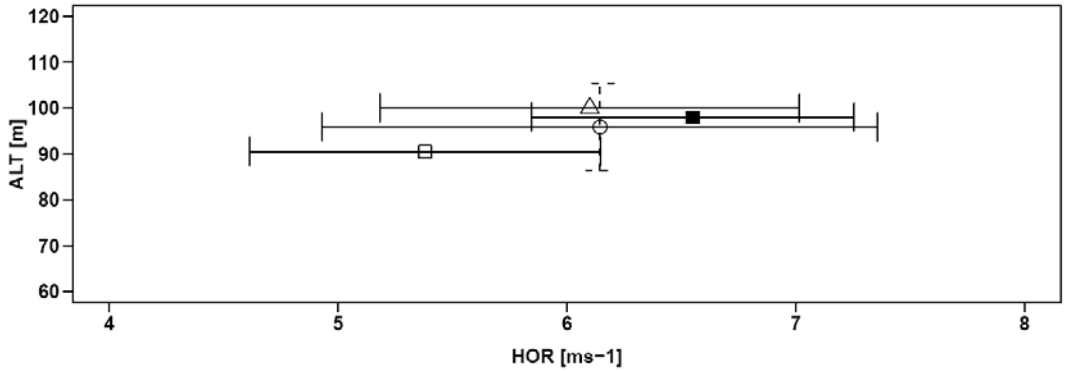


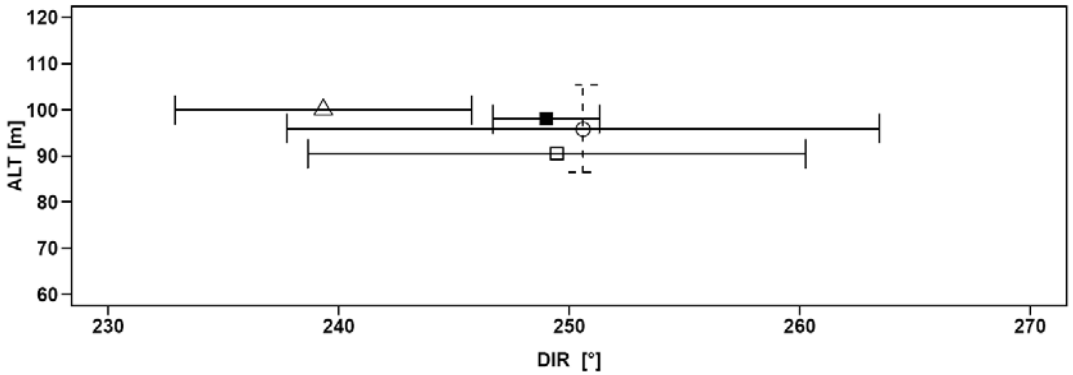


surface layer: ground truth DWD Lindenberg

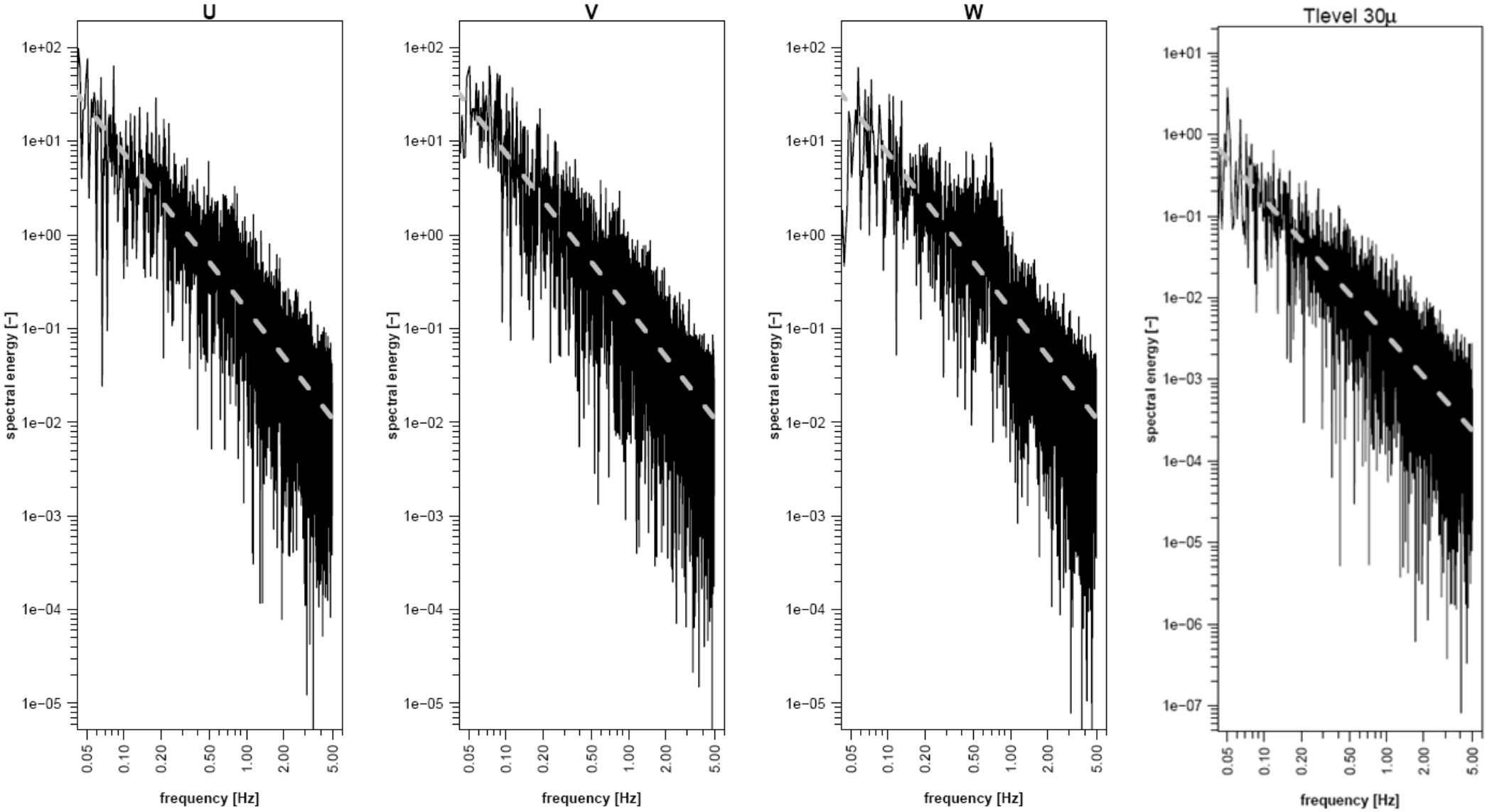
- aircraft (o) compared to
  - SODAR (Δ)
  - tower sonic (□)
  - tower cup and vain (■)
- vertical wind
  - within 0.2 ms^{-1}
- horizontal wind
  - SODAR and tower sonic ambiguous
  - aircraft well centered







frequency response



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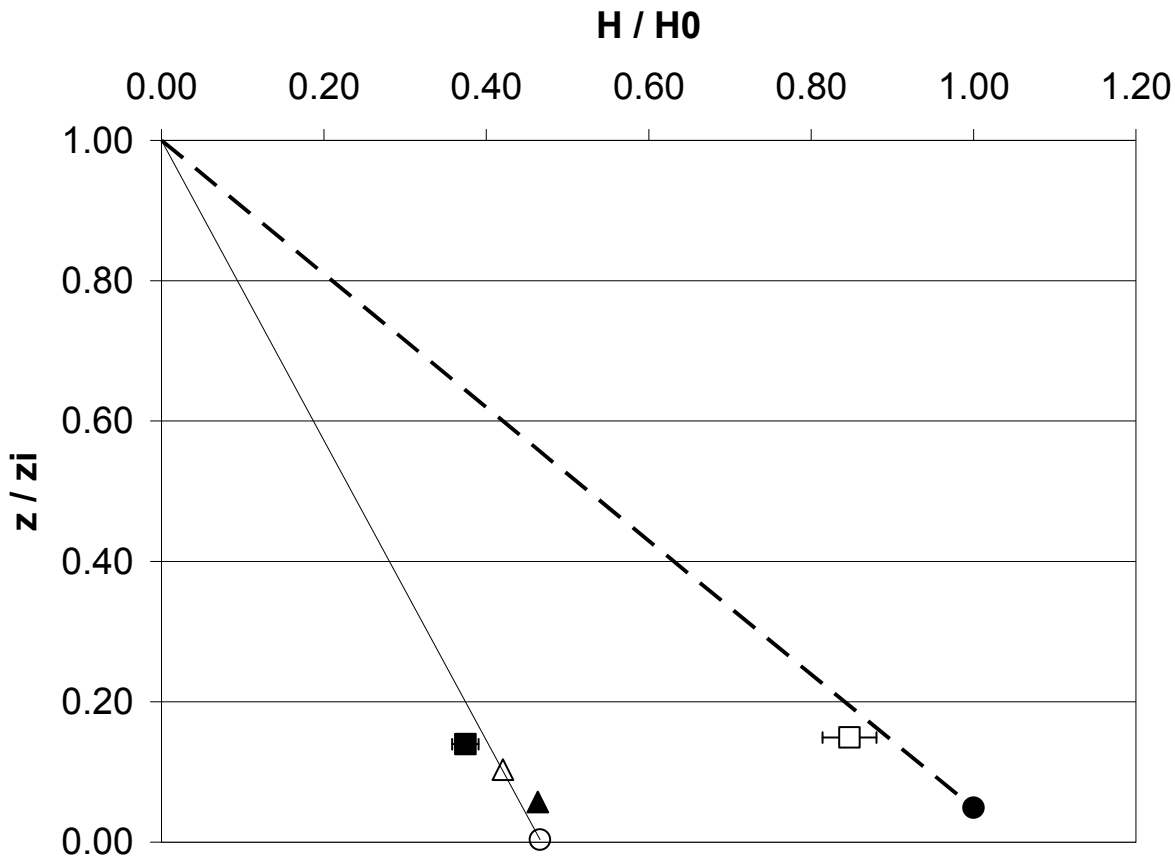
sensible heat: LAS comparison DWD Lindenberg



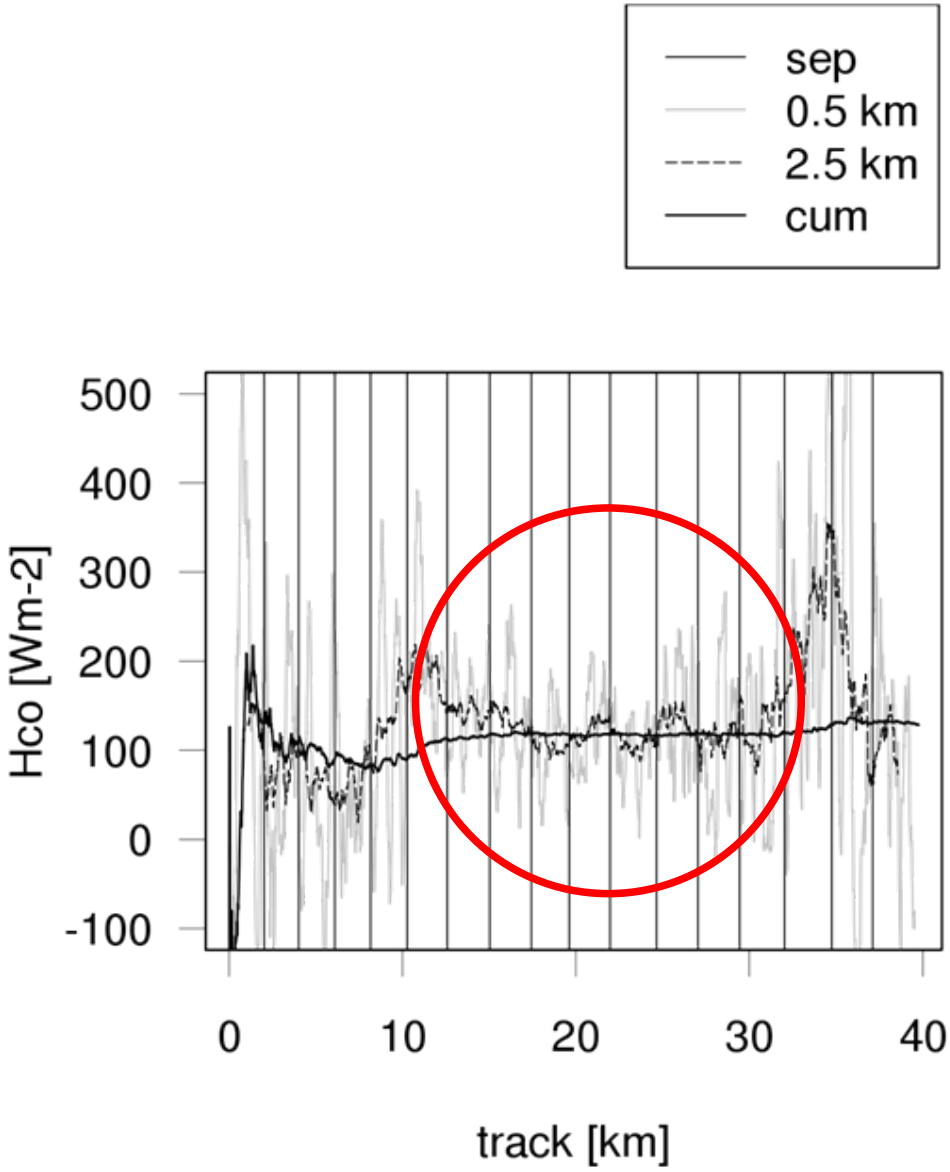
- PBL 875 m
- H_0 45 Wm^{-2}

□ M-IFU leg 2
■ M-IFU leg las
● scintillometer
○ eddy 3m
▲ eddy 50m
△ eddy 90m

- propagation of wind measurement uncertainties
  - 4.3% for leg las (4.7 km)
  - 3.9% for leg 2 (20 km)

spatial resolution: landuse change Inner Mongolia

- altitude < 50 m
- 2 km legs, 1 km inhomogeneity
- resolved during stationary condition



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