



SCREEN CAPTURE
WELCOME

Towards spatio-temporal measurements in the atmospheric boundary layer with a fleet of UAS

EMS Annual Meeting 2022, Bonn

07.09.2022

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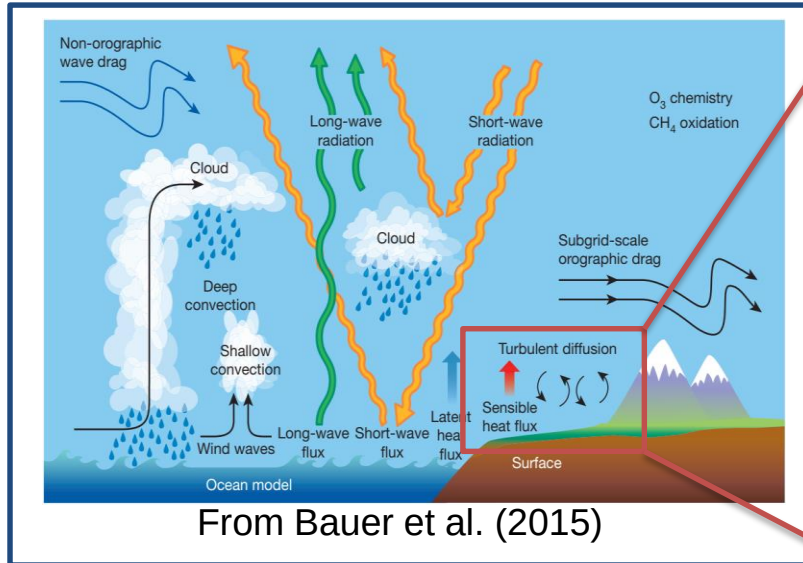


Knowledge for Tomorrow

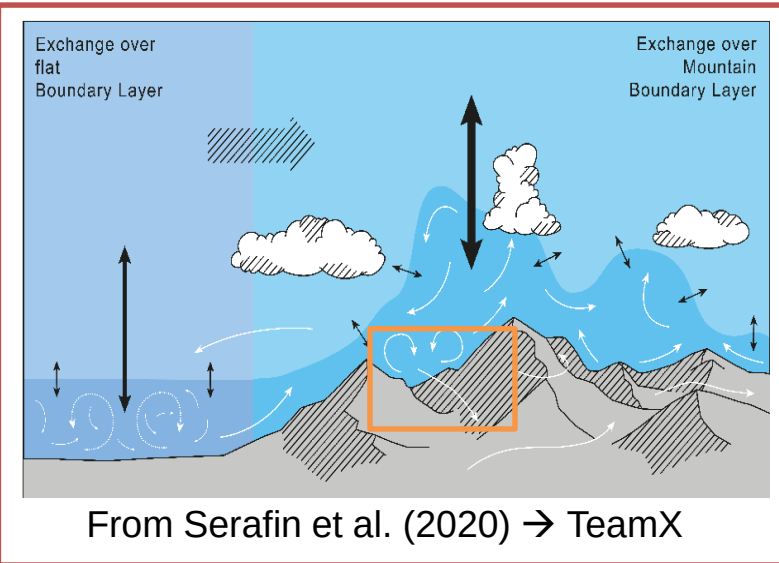


Motivation

Numerical weather prediction



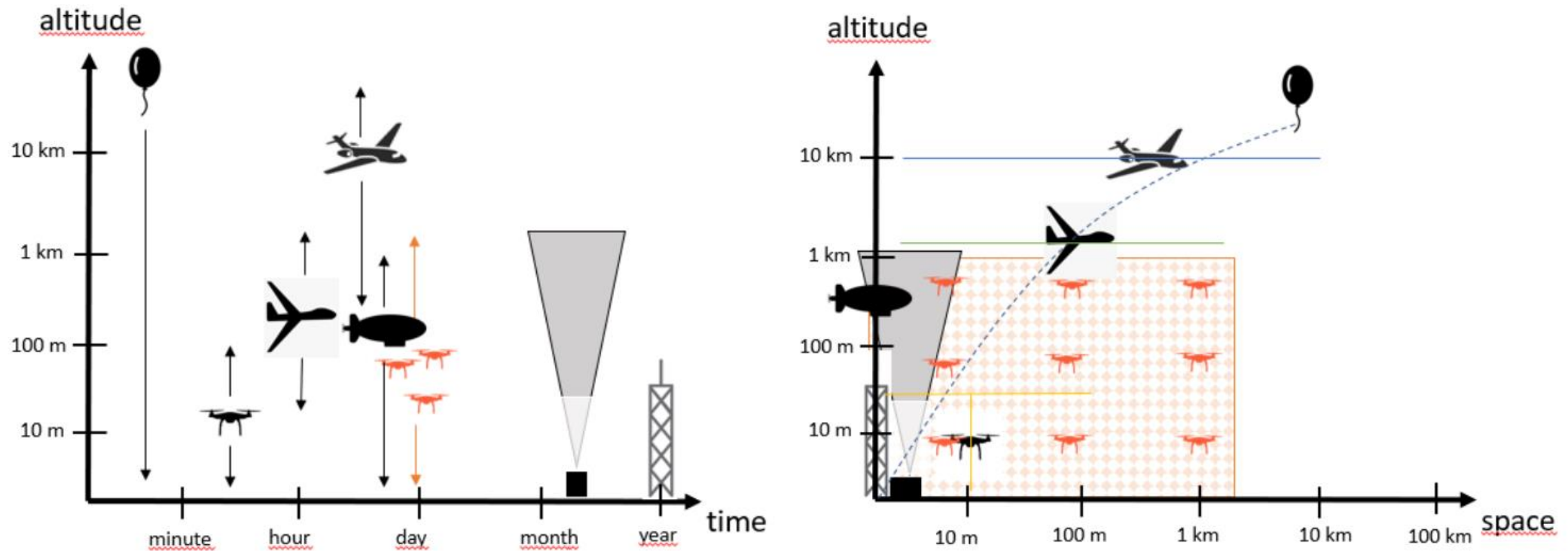
Physical processes in the atm. boundary layer



→ Goal: A better understanding of 3D turbulence in the ABL



Motivation

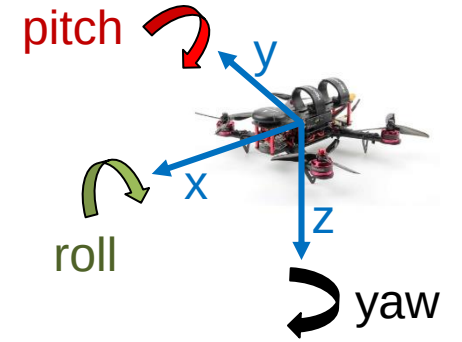


→ Measure where necessary, with *high resolution, simultaneous and in-situ*

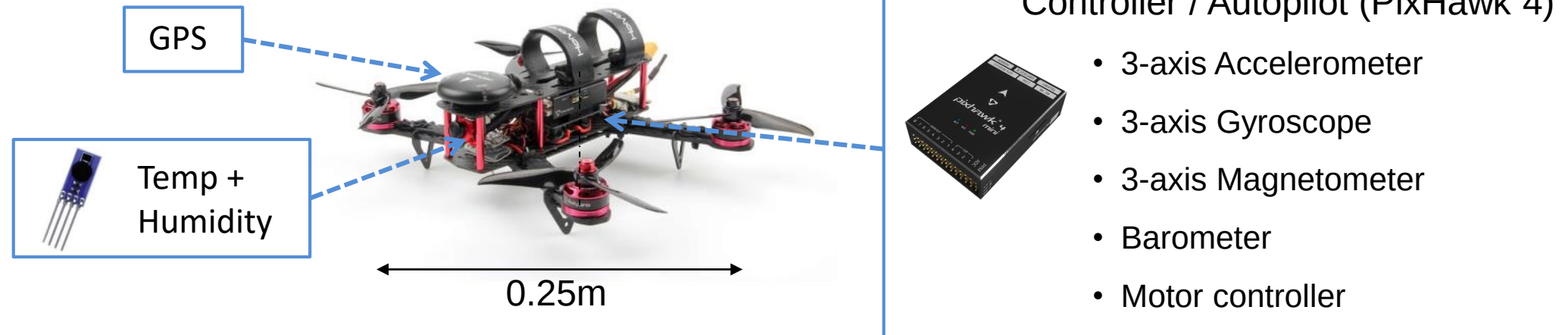


Measurement system

HolyBro QAV250 x 35 → SWUF-3D



Racing-quadrotor



0.65 kg



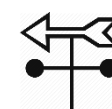
18 m s⁻¹



15 min



Weather vane



- Wind measurement **without** additional sensors
 - based on aerodynamic drag related to **quadrotor motions**

Experiment description – GM Falkenberg (DWD)

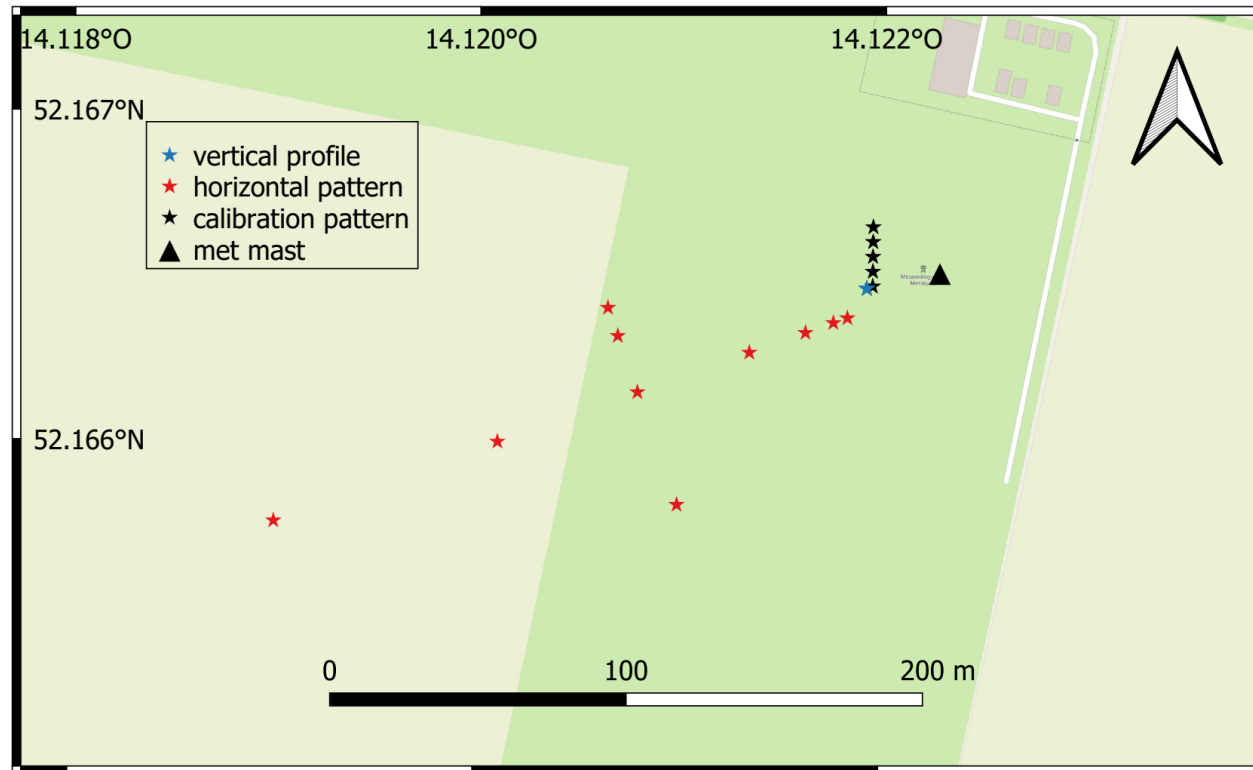


two weeks campaign
(21 June – 02 July 2021)

>1000 single flights

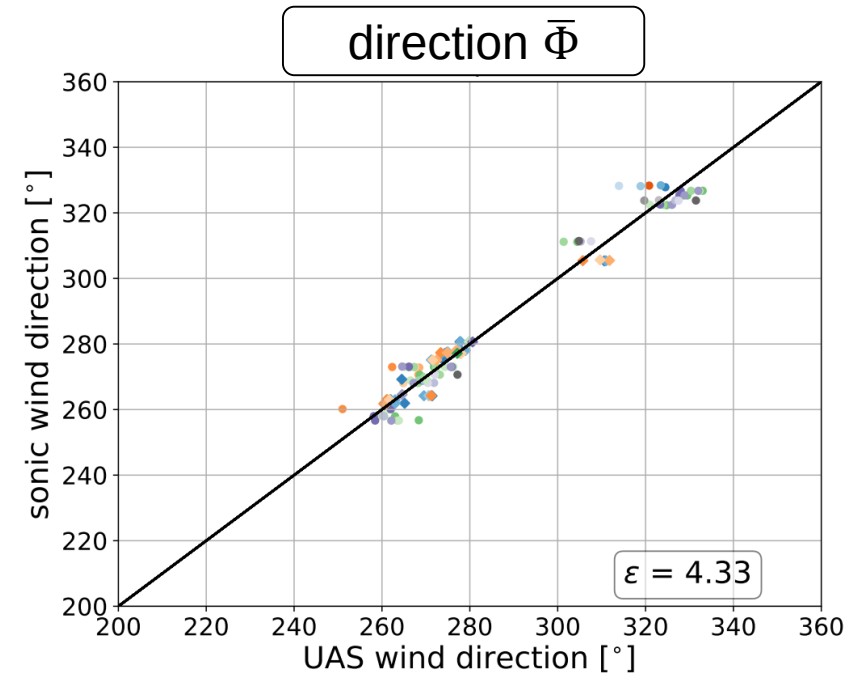
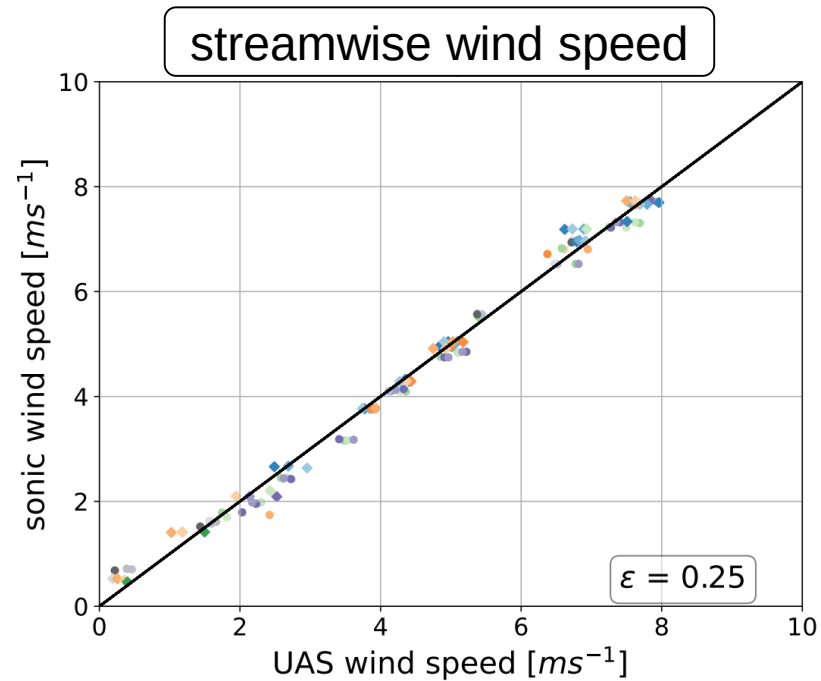
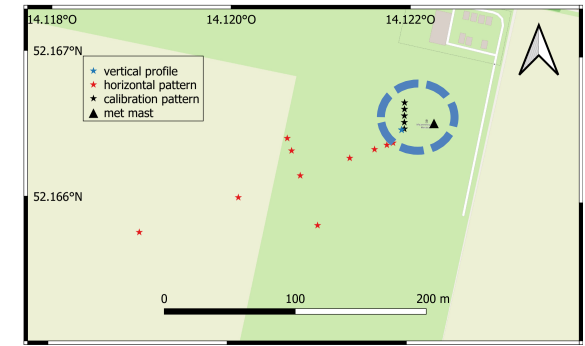
21 UAS
simultaneously

>30 UAS in total



Wildmann, Norman. (2022). Multicopter UAS measurements at GM Falkenberg during FESSTVaL 2021 (Version 0) [Data set]. <http://doi.org/10.25592/uhhfdm.10148>

Calibration against 99-m mast



Wetz et al. 2022,
<https://doi.org/10.1088/1742-6596/2265/2/022086>

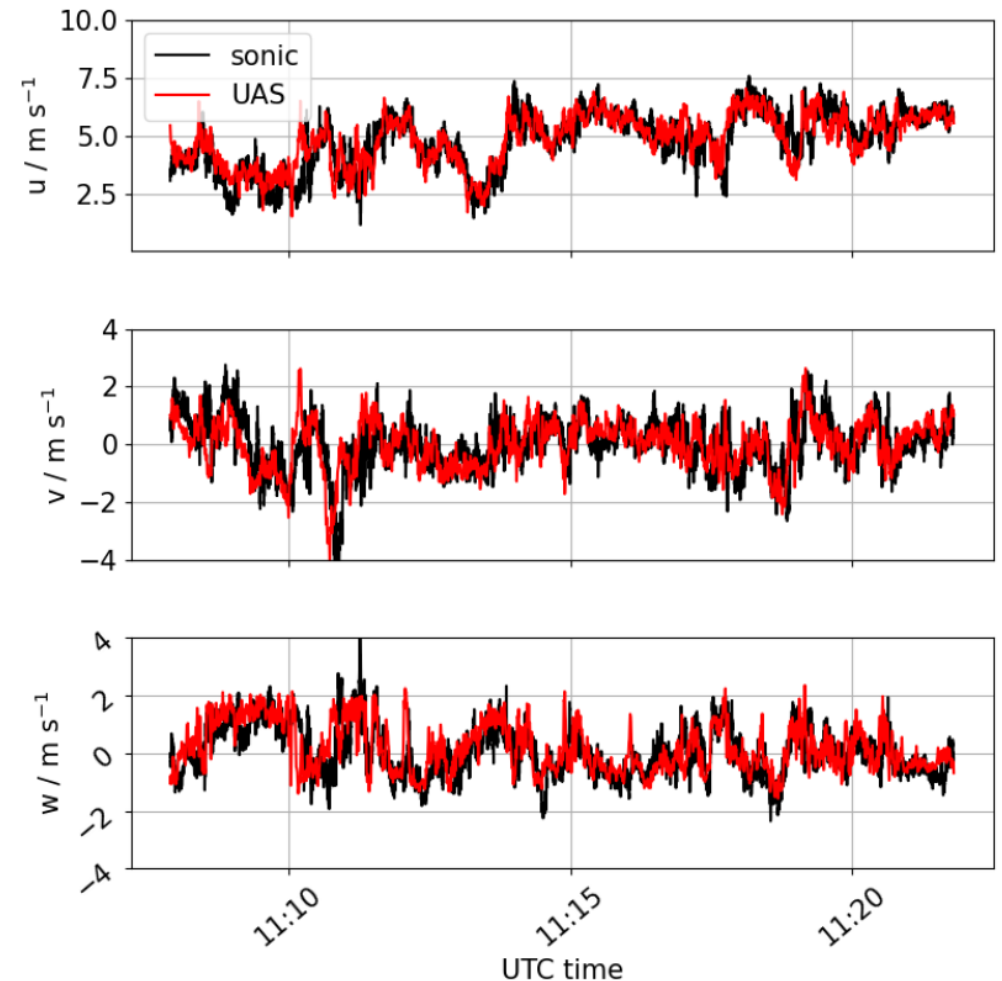
Towards vertical wind and turbulent flux estimation with SWUF-3D



- 2D wind algorithm is extended with **thrust-based** vertical wind estimation

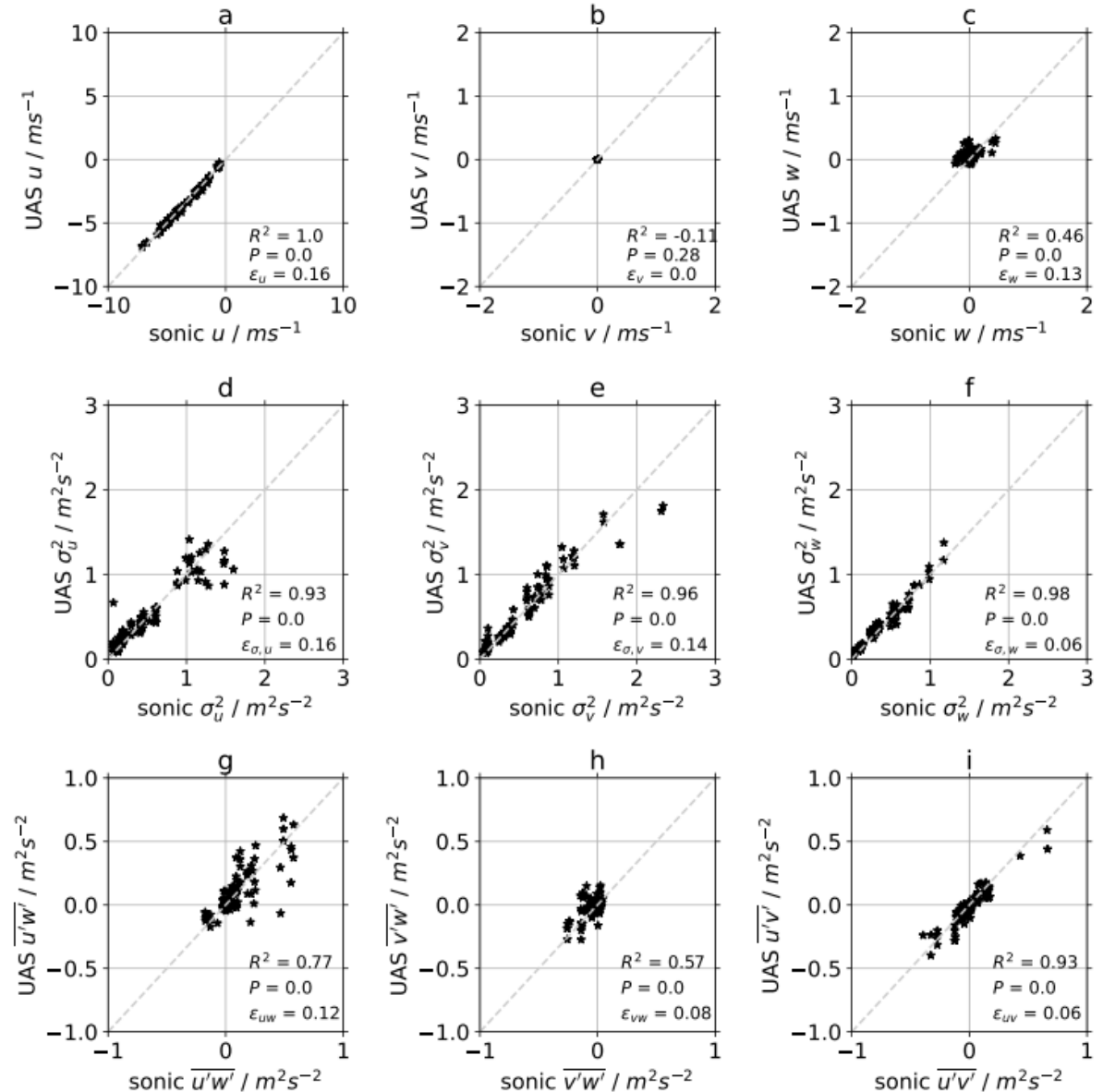
Wildmann, N. and Wetz, T.: Towards vertical wind and turbulent flux estimation with multicopter UAS, EGUsphere [accepted for publication], <https://doi.org/10.5194/egusphere-2022-110>, 2022.

Deutsche unveröffentlichte Patentanmeldung Nr. 10 2022 106 240.6



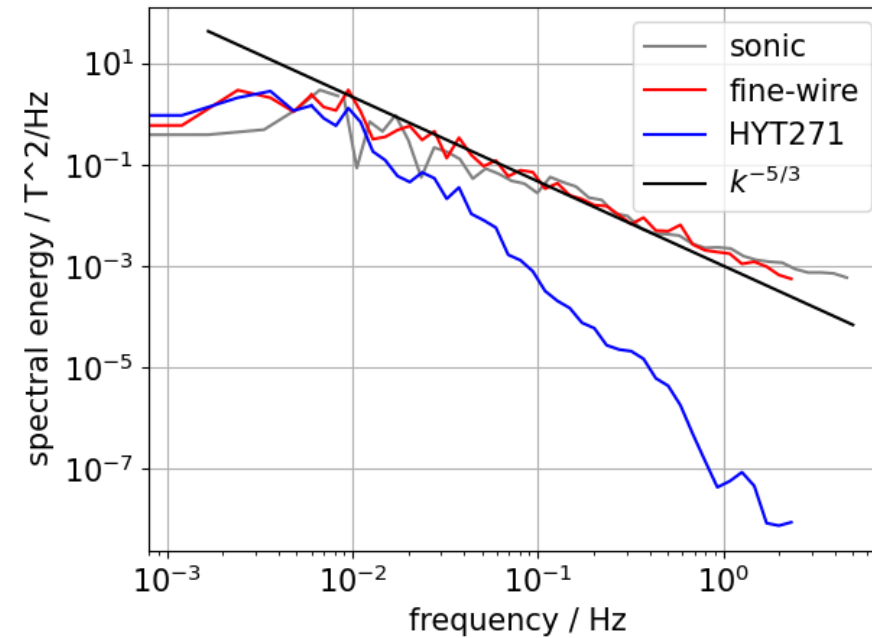
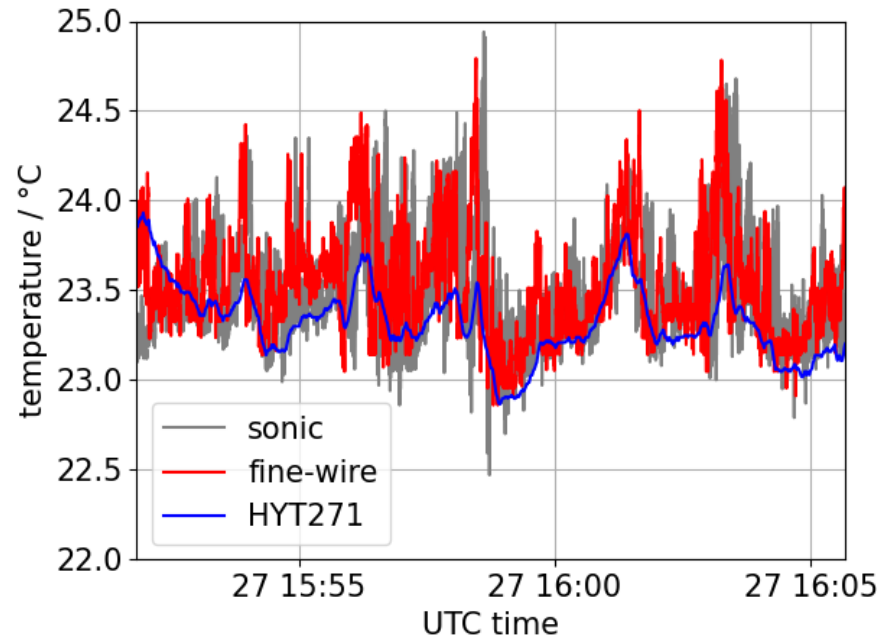
3D wind and turbulence

- Horizontal and vertical wind measurements, rotated into main wind direction.
- Good accuracy of second order statistics.
- Momentum fluxes are calculated and compared to sonic anemometers on the mast.



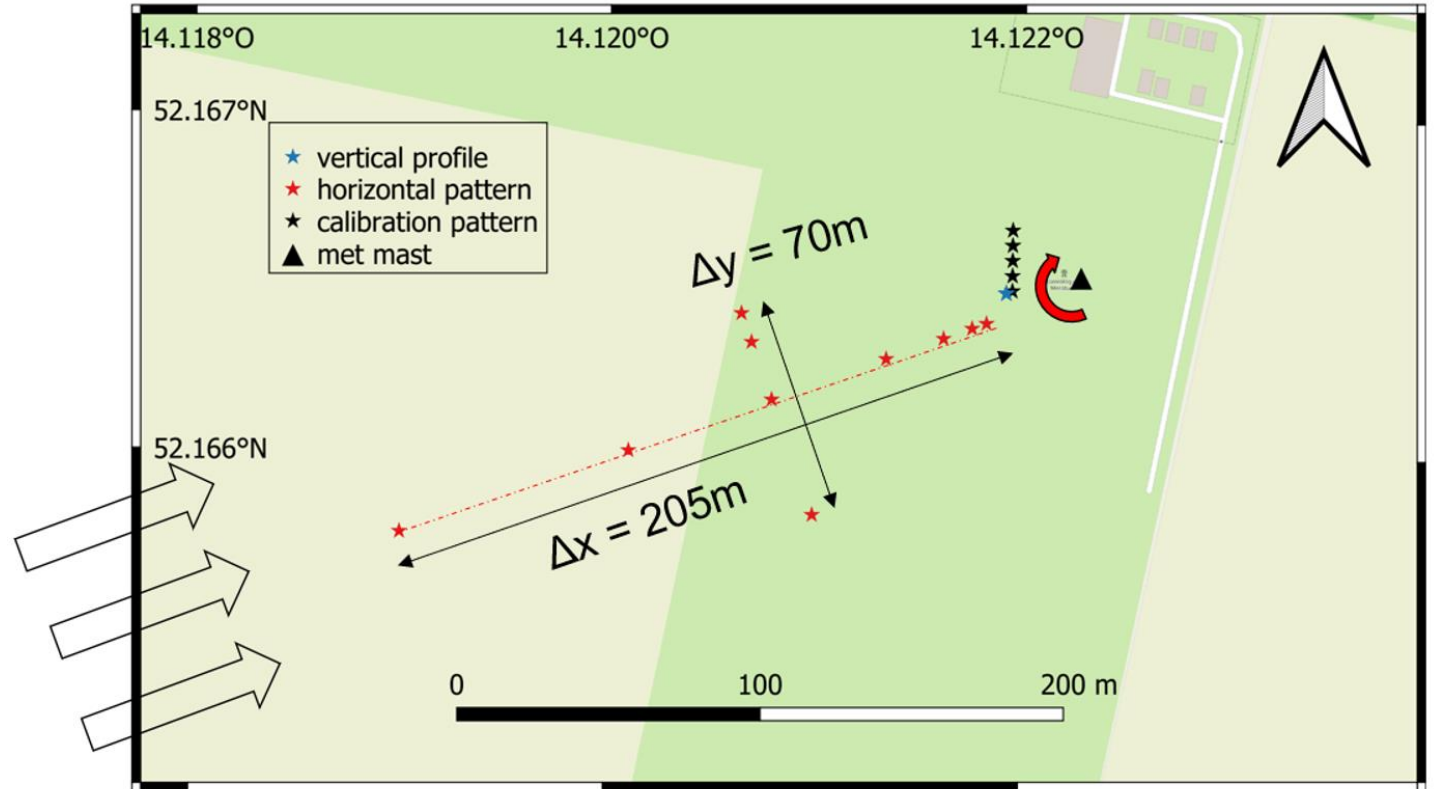
Improved fast-response temperature sensor

- Fine-wire platinum resistance thermometer, compared to slow sensor in flight and sonic anemometer

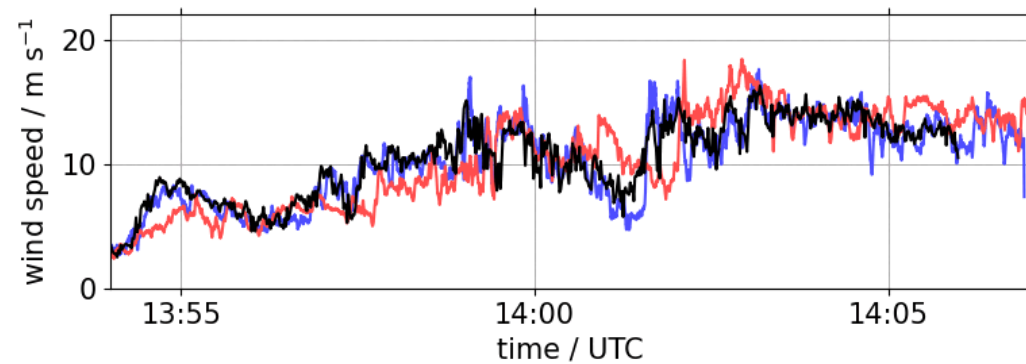
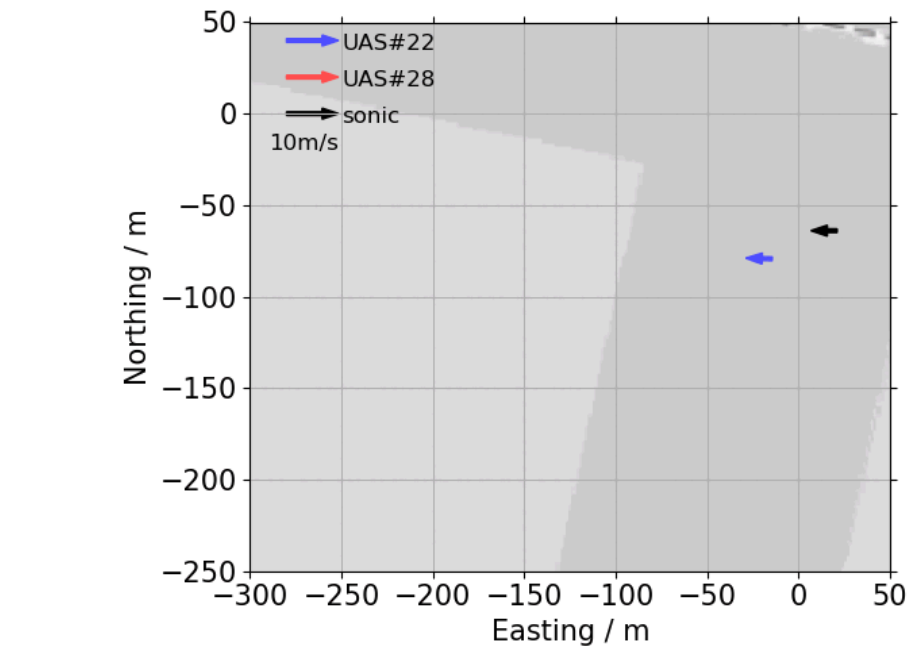


Spatial-temporal measurements

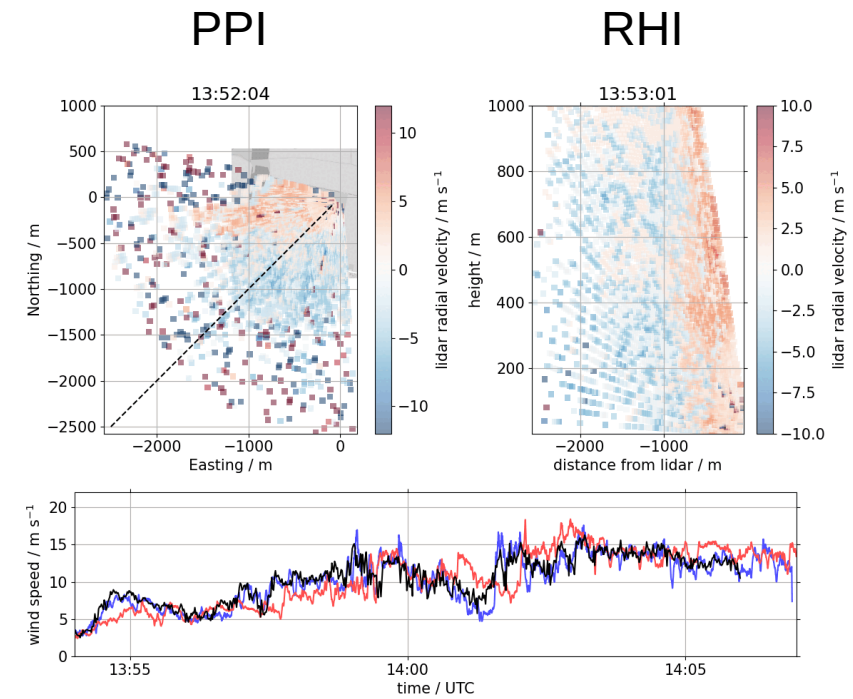
- **Horizontal pattern** adapted to wind direction
- **Streamwise** separation distances 5...205 m
- **Lateral** separation 10...70 m



29.06.2021, Coldpool „Jogi“

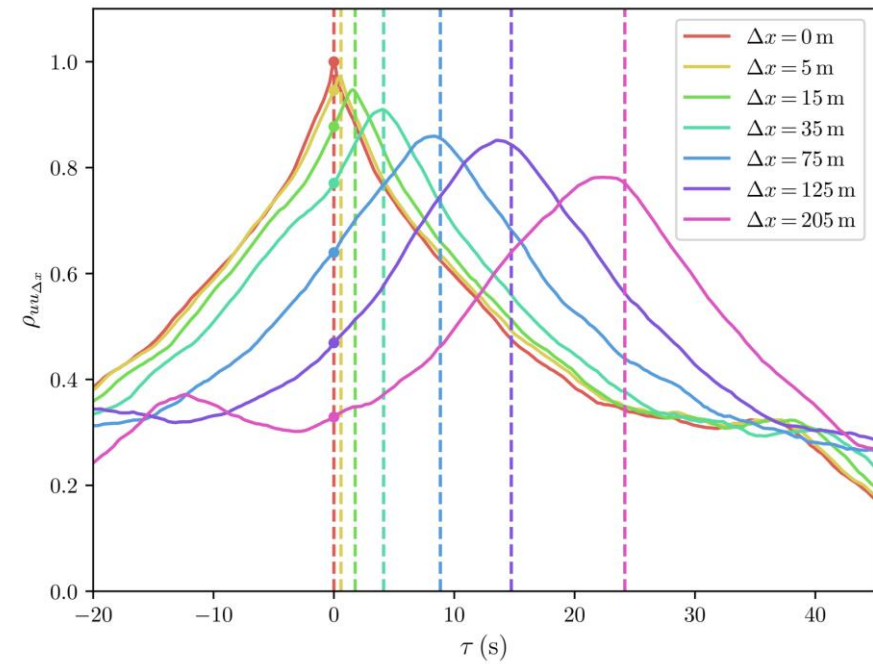
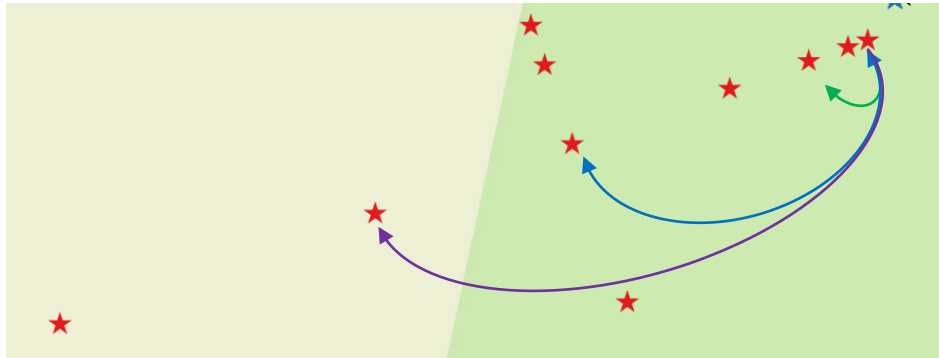


Lidar



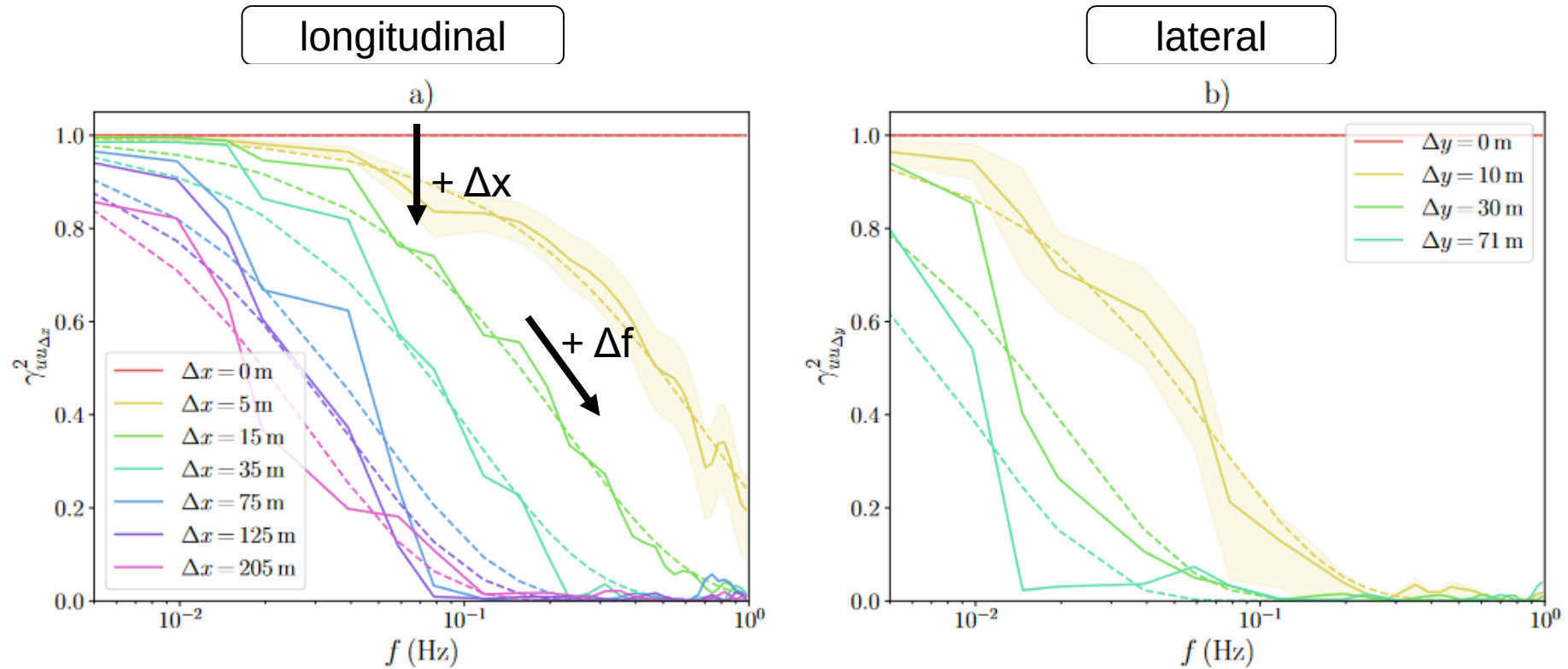
Horizontal spatial cross-correlation

$$\rho_{uu_{\Delta x}}(\tau) = \frac{u'(t)u'_{\Delta x}(t - \tau)}{\sigma_u(t)\sigma_{u_{\Delta x}}(t + \tau)}$$



Horizontal coherence

$$\gamma_{uu_{\Delta x}}^2(f) = \frac{|S_{uu_{\Delta x}}(f)|^2}{S_{uu}(f)S_{u_{\Delta x}u_{\Delta x}}(f)}$$



Wetz, T. and Zink, J. and Bange, J. and Wildmann, N.: Analyses of Spatial Correlation and Coherence in ABL flow with a Fleet of UAS, BLM [submitted], 2022

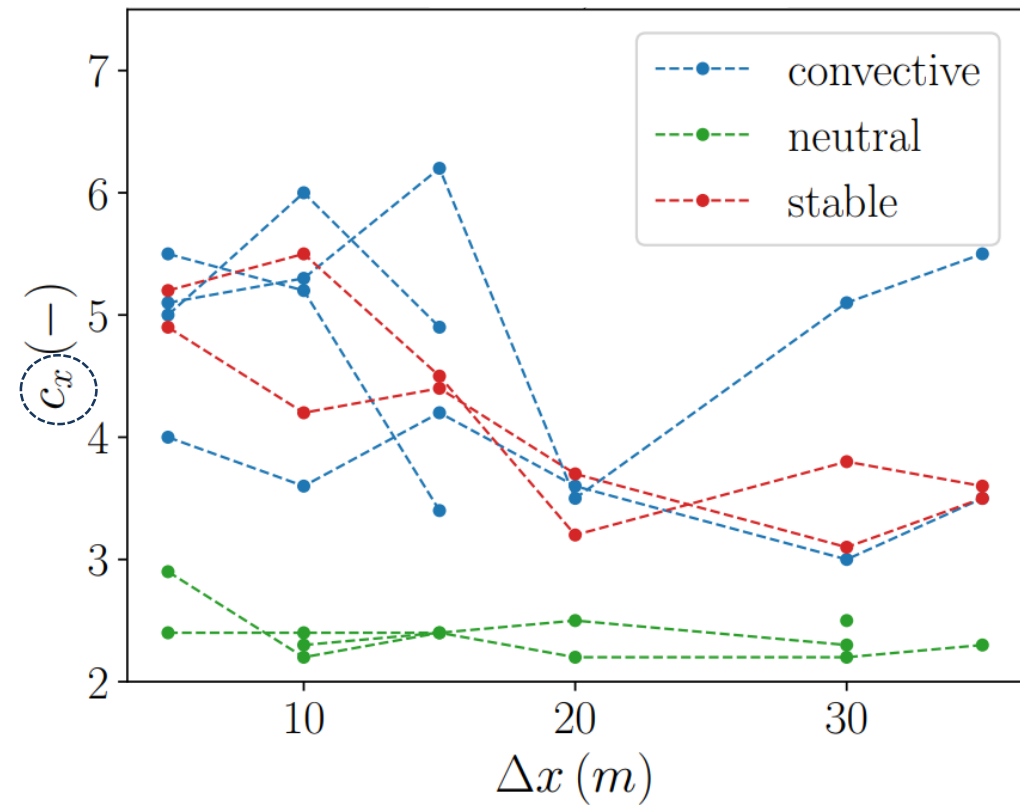
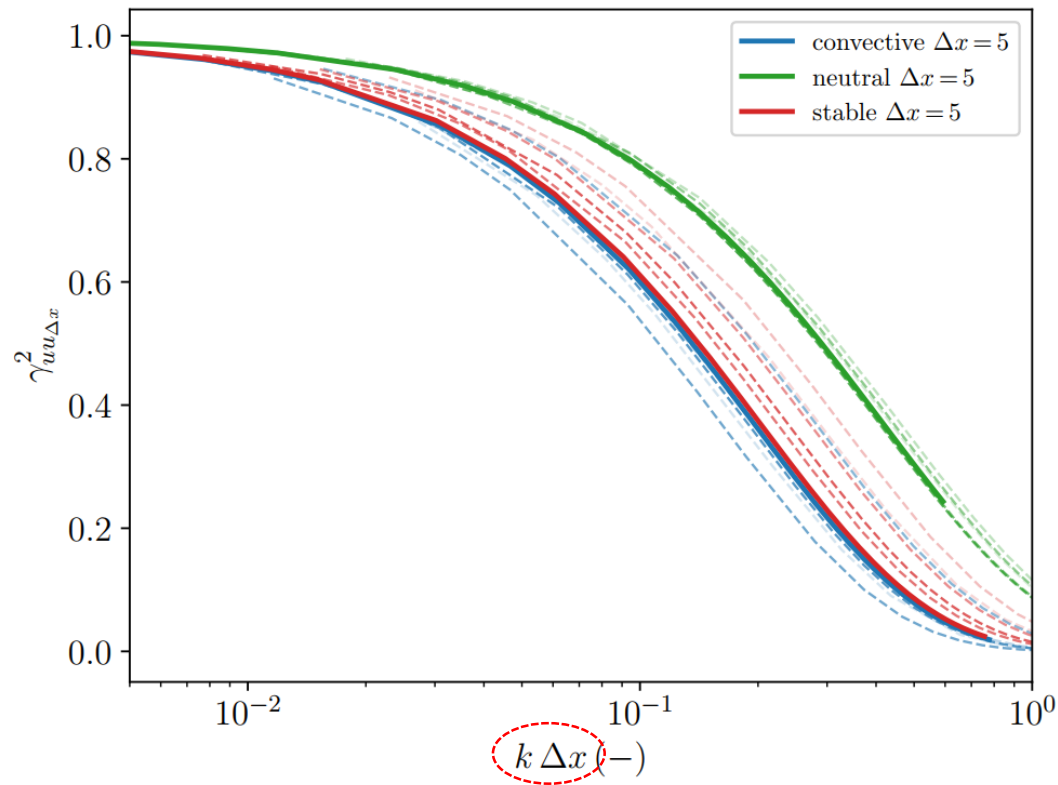


Coherence models

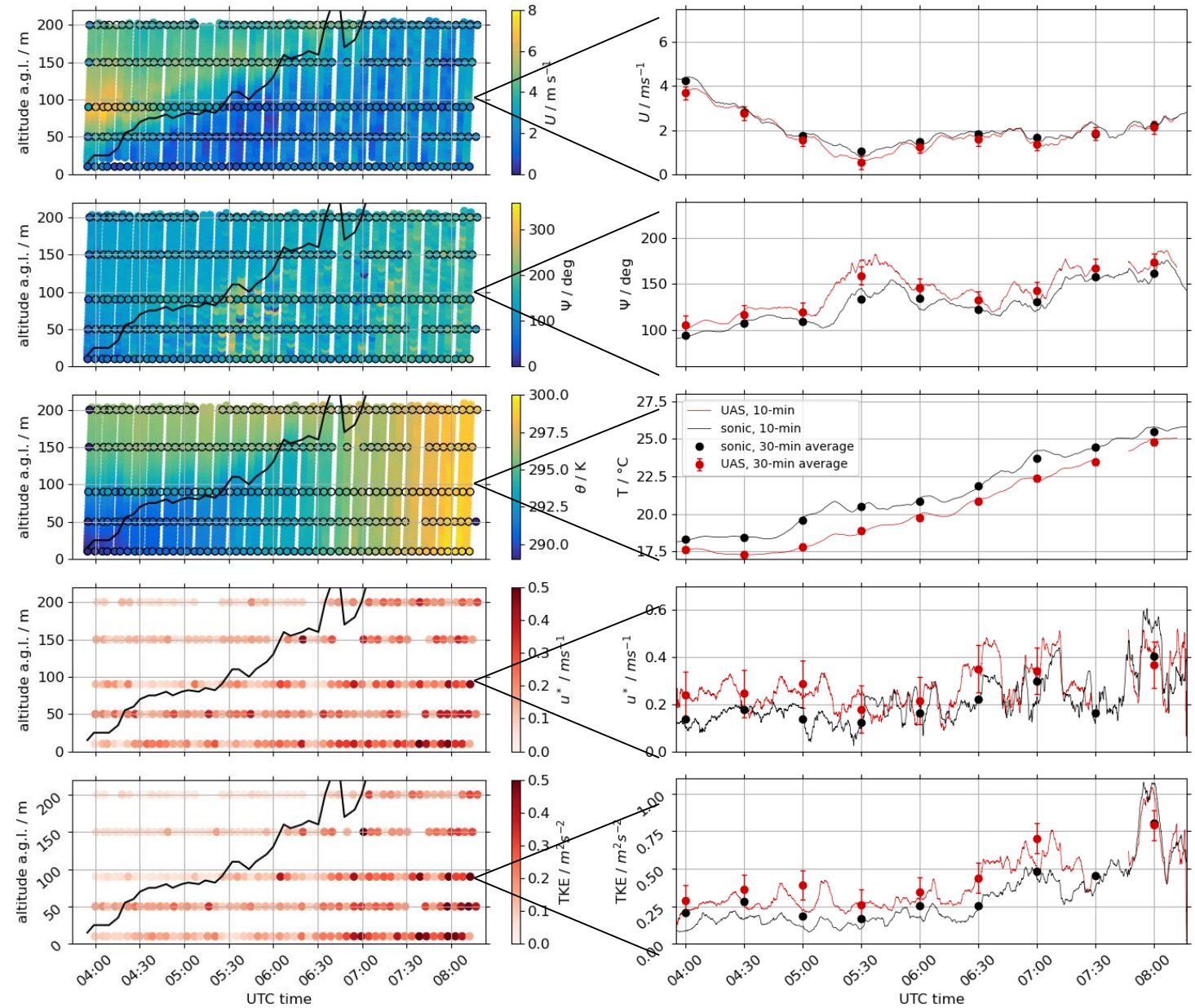
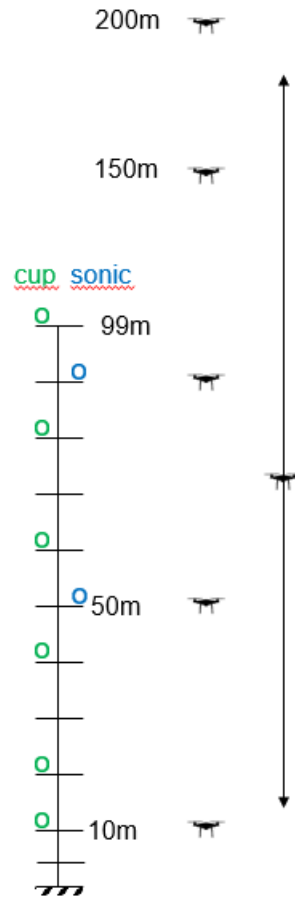
$$\gamma_x^2(f) = e^{-c_x \frac{\Delta x}{u}} f$$

$$k = \frac{f}{\bar{u}}$$

$$\gamma_x^2(f) = e^{-c_x k \Delta x}$$



28.06.2021, Morning transition



Outlook

- Continued work on the FESSTVaL dataset
- Wind turbine wake measurements @ [WiValdi](#)



- Preparation of **TEAMx** campaigns within the **ESTABLIS-UAS** project

ESTABLIS-UAS



Exposing Spatio-Temporal structures of turbulence in the ABL with In-Situ measurements by a fleet of UAS



**Funded by
the European Union**

