Strategies to measure vertical profiles of wind gusts with a Doppler wind lidar within FESSTVaL
(Field Experiment on Sub-Mesoscale Spatio-Temporal Variability in Lindenberg)

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Motivation

- In FESSTVaL (summer 2020) different aspects of sub-mesoscale phenomena in the atmospheric boundary layer will be investigated.
- Our focus is on the precise detection of wind gusts with Doppler lidars.
- A gust retrieval is challenging as the space-time fluctuations are difficult to capture.
- Therefore, we test different configurations (autumn 2019) against a sonic anemometer measurement in 90 m at the Falkenberg weather tower.
- The temporal synchronisation and spatial collocation of three lidar beams (virtual tower) enables a direct determination of the wind vector in an air parcel.

Objective

- desired: 10 min peak wind gust of 3 s duration
- devices: Doppler wind lidars (Halo-Photonics Streamline)
  2 × DWD MO-Lindenberg, 1 × TU Berlin (maybe more)
- reference: Sonic anemometer in 90 m (Metek)

⇒ Comparative measurements at boundary layer field site (GM) Falkenberg (currently realised)

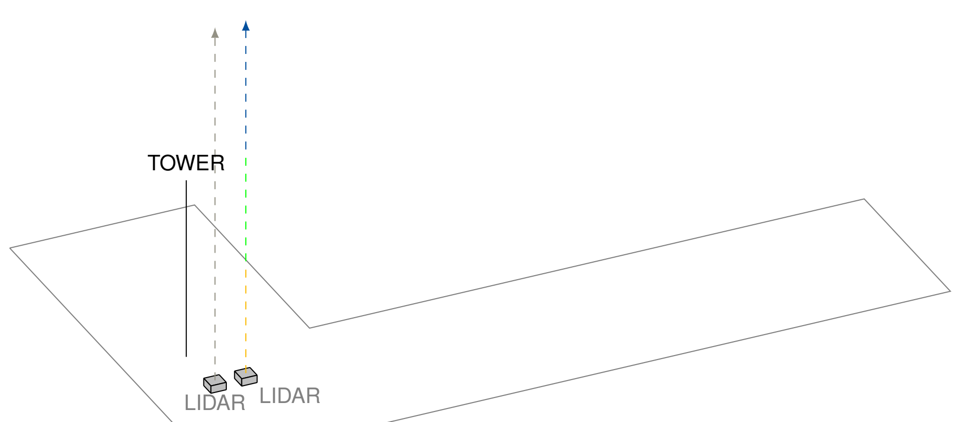

Figure I: Two lidars located next to Falkenberg tower

- reference II: one lidar is measuring only one mode as reference for an operational configuration
- benefits of lidar compared to a weather tower:
  - cheap
  - mobile
  - higher in range

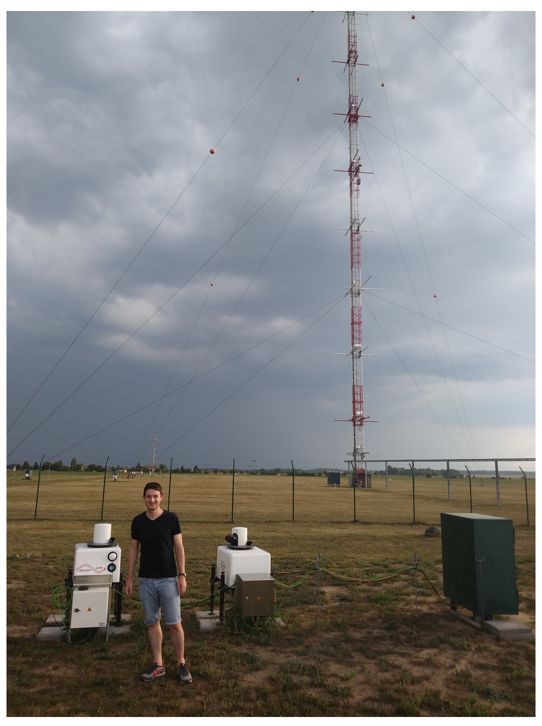

Figure II: GM Falkenberg on August 26, 2019

Method

Connection between measured Doppler velocity d at azimuth θ, elevation α, and wind vector $\vec{v}$

$$\begin{pmatrix}\cos\theta\cos\alpha & \sin\theta\cos\alpha & \sin\alpha\end{pmatrix}\ \vec{v} \ = \ d(\theta,\alpha). \qquad (1)$$

Two ways of retrieving gusts

(A) quick scan that directly measures the gust vector
- Suomi et al. (2017) proposed a method to downscale measured gusts on desired duration. However their used Doppler beam swing is not quick enough with our devices.
- A quick continuous scanning mode (fig. IV) can reach adequate time, but is wearing for device.
- 3 beams (fig. V) can be either quick or more accurate.

(B) slow scan that measures an averaged wind vector
- operational patterns (fig. III and VI) are slower and focus on the mean wind.
- gusts can be obtained by using mean wind information, single beams, and some assumptions (e.g. constant wind direction, constant w, retrieval of 3 consecutive beams).

Reference pattern

- pattern by Smalikho and Banakh (2017)
- useful for mean wind and turbulent kinetic energy

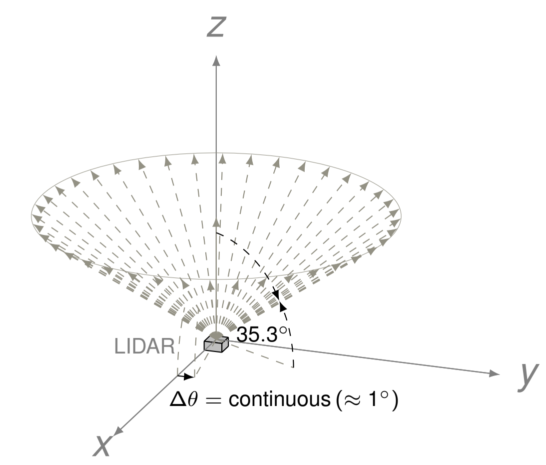

Figure III: Continuous conical scan with permanently changing azimuth, inclined beams, and vertical stare ($t = 72\,s$)

Comparison of lidar patterns

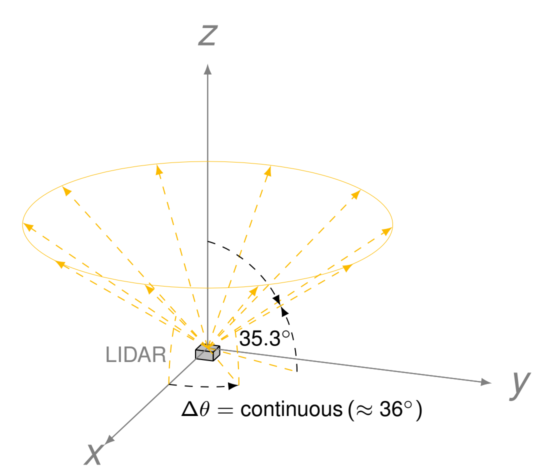

Figure IV: Quick continuous conical scan with permanently changing azimuth, and inclined beams ($t = 3.4\,s$)

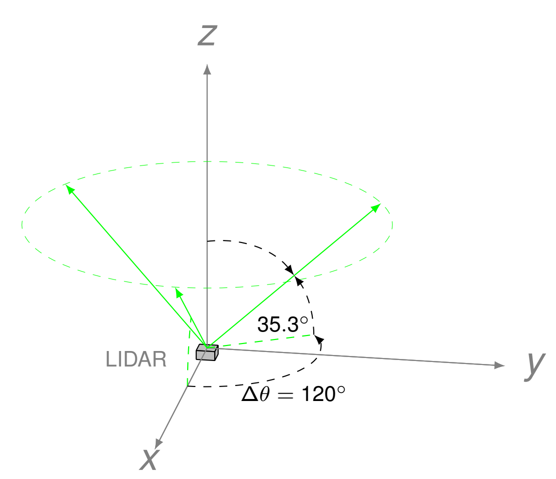

Figure V: Scan with 3 inclined beams ($t = 3.4\,s$, $14\,s$)

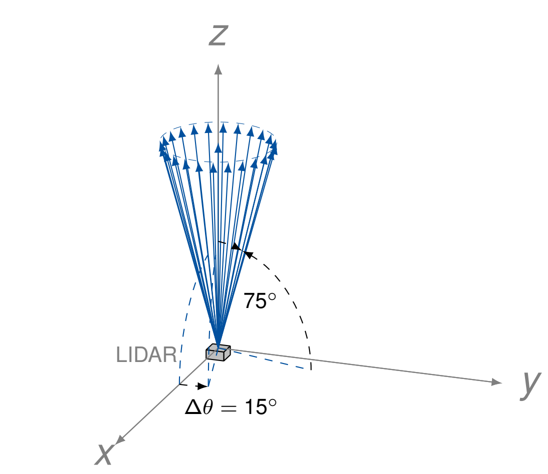

Figure VI: Conical scanning mode with 24 inclined beams, and vertical stare ($t = 120\,s$)

Combining lidars

- 2 lidars side by side (fig. I):

⇒ vertical stare + conical scan with 4 beams ($\alpha = 62°$; $\theta = 0°, 90°, 180°, 270°$; $t = 18\,s$)
Use the vertical stare to receive w and alternating u and v can be calculated from each inclined beam.

- 3 lidars (fig. VII):

⇒ uncoordinated virtual tower: virtual stare + two range height indicator (RHI) scans
overlapping beams empower wind gust retrievals in points; uncoordinated as tests with synchronisation software failed. use the vertical stare to receive w and alternating u and v can be calculated from each inclined beam.

⇒ virtual point measurement: virtual stare + two inclined beams
permanent point measurement from three directions.

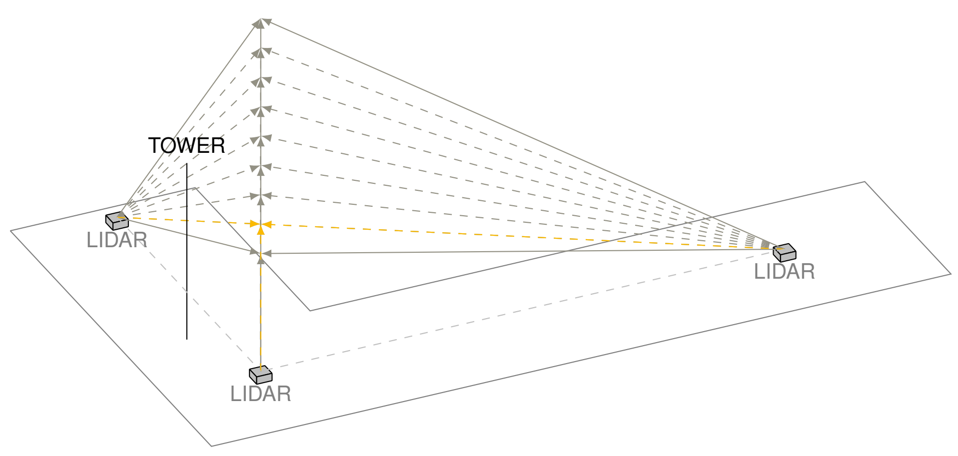

Figure VII: *grey lines:* Uncoordinated virtual tower (one vertical stare + two RHI); *yellow lines:* Virtual point measurement (one vertical stare + two inclined beams).

References

Smalikho, I. N. and V. A. Banakh (2017). "Measurements of wind turbulence parameters by a conically scanning coherent Doppler lidar in the atmospheric boundary layer". In: *Atmospheric Measurement Techniques* 10: 4191-4208. DOI: 10.5194/amt-10-4191-2017.
Suomi, Irene et al. (2017). "Methodology for obtaining wind gusts using Doppler lidar". In: *Quarterly Journal of the Royal Meteorological Society* 143: 2061-2072. DOI: 10.1002/qj.3059.

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