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A novel Airborne Doppler Wind Lidar

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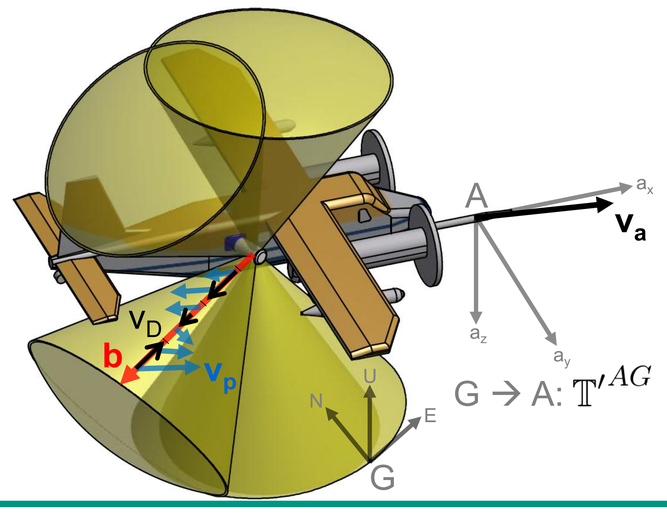
Airborne Doppler Wind Lidar (ADOWL) for Boundary Layer Research



Implementation

- Airborne wind measurements with Doppler Lidar aboard Dornier 128-6 aircraft
- Lidar beam movement using custom-built 2 axis-scanner including aircraft motion compensation

Scientific scope

- Boundary layer & turbulence research
  + moving platform, high spatial coverage
  + flexible and rapid deployment
  + process studies using cross-cutting transects along flow phenomena
  + flexible scanning geometries
- Combined measurements with KITcube

2012 First concept → 2015 System design → Jun 2017 Prototype test flights → Dec 2017 Full system operational → Mid 2018 Measurement campaigns

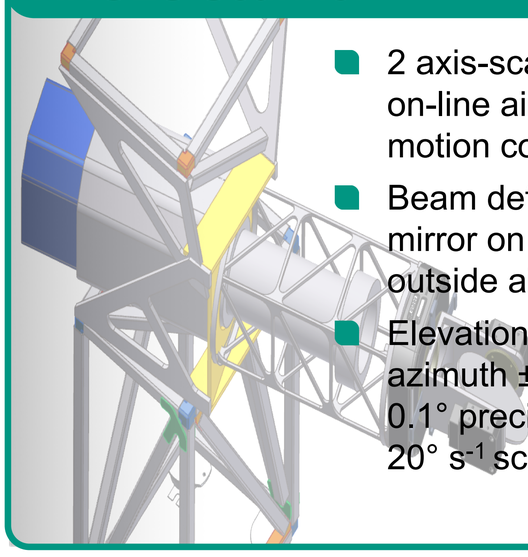
Dornier 128-6 (D-IBUF)

- Fully equipped meteorological research aircraft operated by the Institute of Flight Guidance, TU Braunschweig
- Endurance 4 h @ 65 m s^{-1} operating speed, ceiling < 6000 m, unpressurized
- Nose boom for 100 Hz turbulence measurements, enabling sensible and latent heat flux calculation

Lockheed Martin Doppler Lidar

- Laser: Eye safe Er:YAG @ 1617 nm, range 350 m to 12 km
- Pulse: Length 300 ns, energy 2.7 mJ, repetition freq. 750 Hz
- Data: 120 range gates with customizable 15 - 300 m length, data rate 10 Hz, accuracy 0.5 - 1 m s^{-1}

ARGES Scanner



- 2 axis-scanner with on-line aircraft motion correction
- Beam deflection with mirror on 0.8 m boom outside aircraft
- Elevation ±140°, azimuth ±30° with 0.1° precision and 20° s^{-1} scan rate

ADOWL Simulation

Initial wind field → Aircraft & Lidar beam positions → Simulated Lidar retrieval → Velocity correction → Wind field retrieval

Implementation

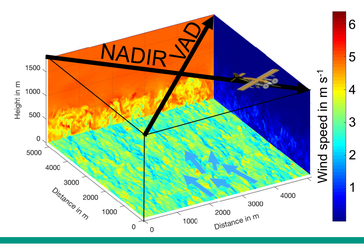
- Simulation of all system components and measurement process chain

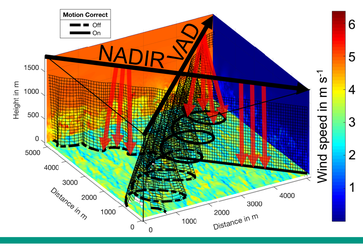
Scientific scope

- System specification
- Optimization of scan strategy and pattern
- Error analysis

Initial wind field
- LES @ 10 m
- Idealized, Lin/Log/Ekman/Shear profiles, spatially in-/homogeneous

Aircraft & Lidar beam positions
- Flexible aircraft path and scan pattern
- Optional motion correction



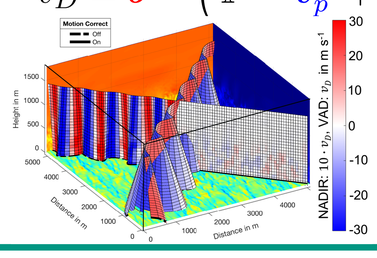


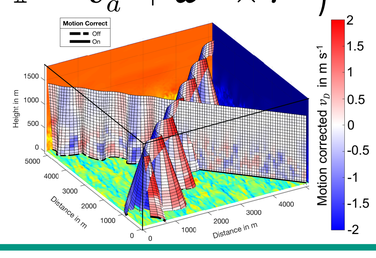
Simulated Lidar retrieval
- Projection of velocities on beam

$$v_D = \boldsymbol{b}^A \cdot \left(\mathbb{T}'^{AG} \boldsymbol{v}_p^G + \mathbb{T}'^{AG} \boldsymbol{v}_a^G + \boldsymbol{\omega}^A \times \boldsymbol{r}^A \right)$$

Doppler speed · Beam direction · Particle velocity · Aircraft velocity · Lidar moment arm

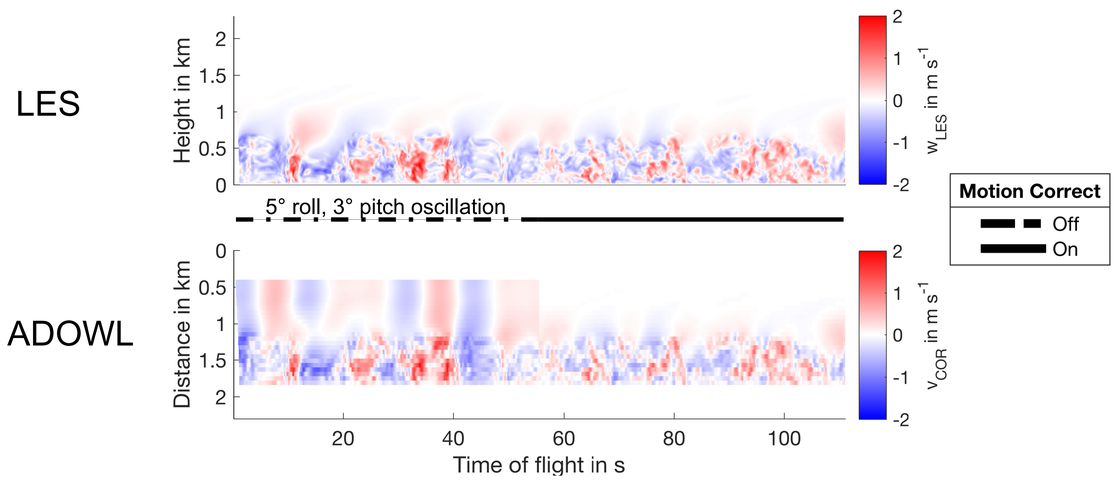
Velocity correction
- For v_D, ideal or with positioning error





Wind field retrieval
- Vertical wind retrieval direct
- Wind profile retrieval through VAD algorithm or singular-value decomposition after spatial and vertical binning to create constant altitude data subsets

Vertical Wind Retrieval – Motion Compensation

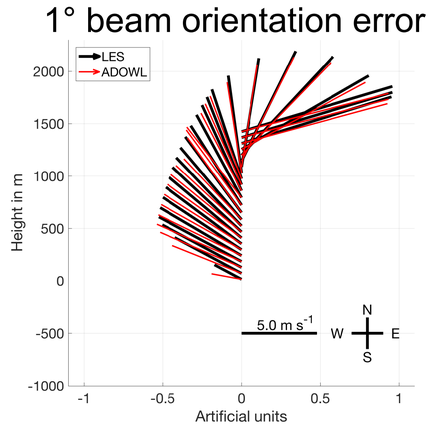


- ~10 m horizontal resolution @ 10 Hz measurement frequency
- ~ 60 m vertical resolution, dependent on range gate length
- Improved results with scanner aircraft motion compensation
- Vertical wind measurements allow for performance evaluation

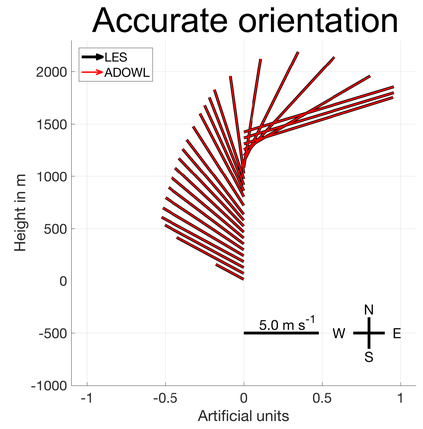
Wind Profile Retrieval – Positioning Accuracy

Idealized wind field - spatially homogeneous, vertically sheared

1° beam orientation error



Accurate orientation



- Vertical wind profiles can be obtained with high temporal (~20 s) and vertical resolution (~100 m)
- Spatial wind profile resolution ~1 km, depending on distance from aircraft and scan speed
- Near the surface, 1° beam orientation error leads to degradation