OPTOkopter - a flying anemometer

OPTOLUTION Messtechnik GmbH offers airborne wind speed measurements services and devices.

Precise airflow measurements are important to understand, predict and simulate flow phenomena. Determining flow velocities is essential for:

- Wind load and construction analysis
- Urban climate analysis and building aerodynamics
- Optimisation of wind farms and wind energy yield
- Micrometeorology and gas dispersal

The OPTOkopter has been developed from scratch and is optimized for measuring flow velocities:

- *Calibrated, high-precision 3D sonic anemometer*
  - True three-dimensional flow velocities
  - Uncertainties: Wind speed ± 1 % ; wind direction ± 0.5 °
  - Sample rate: 16 Hz
- *Optimal aerial platform*
  - Perfectly stable, smooth and agile multirotor
  - Precise compensation of rotor-induced flows and platform motion
  - 40 minutes autonomy with sensor payload, quick battery swap
  - Weight: 5 kg, dimensions: 0.96 m · 0.96 m · 1.46 m
  - Wind speed up to 16 m/s, 7 Bft
  - Centimetre-level 3D positioning with RTK GPS
  - Automatic flight on 3D measurement grids
- *Team*
  - Eleven years of experience in designing and operating multirotors
  - Data evaluation by a team of metrology experts

Exposé

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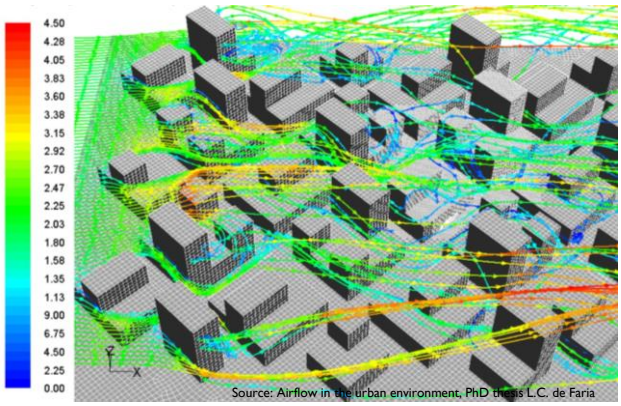
Precise airflow measurements

The wake of wind energy plants influences the energy yield of nearby generators. The robustness of suitable flow simulations should be validated and improved by in-flight measurements. New insights into the aerodynamics of wind farms can be gained.

Example for a measurement plane directly behind a running wind energy plant. Time- and spatially-resolved flow velocities can be captured automatically. A synchronisation with the rotor blade position is possible.



The flow around buildings is important for determining the wind load, building aerodynamics and urban climate. Existing methods mainly rely on simulation. These can be enhanced and validated by using the flow velocity information captured by the OPTOkopter.

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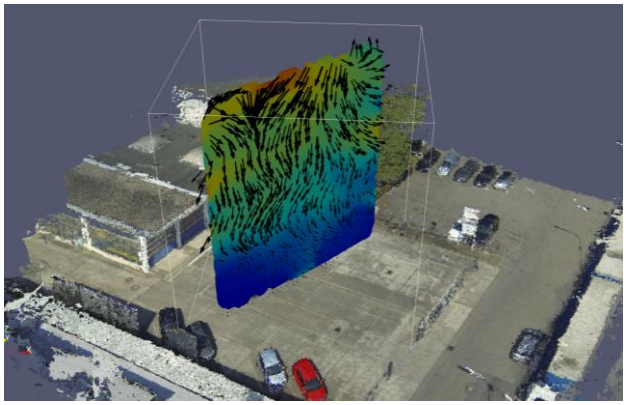
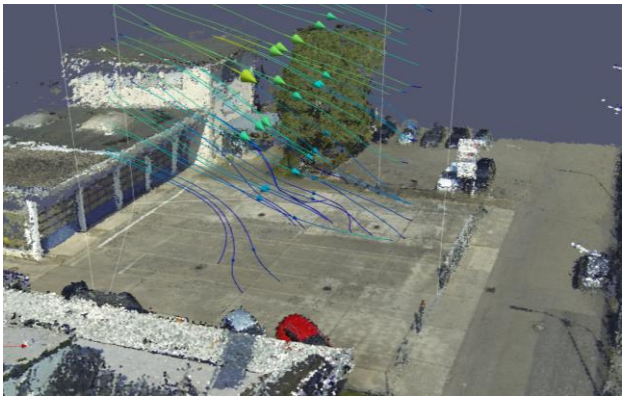
Simultaneous anemometry and mapping (SAM):

Flight path of the OPTOkopter: The surrounding area is mapped in 3D during or before the wind measurement.



Wind speed around buildings: The OPTOkopter measures the three-dimensional wind speed and direction.



Streamlines in the wake of a building: Due to the long endurance and the quick battery swap of the OPTOkopter, longer missions can be completed with minimal ground time.

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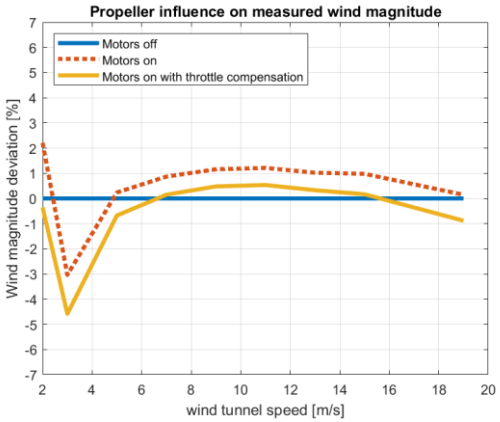
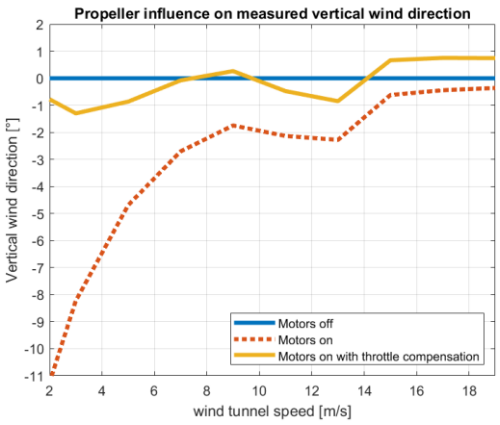
Wind tunnel testing

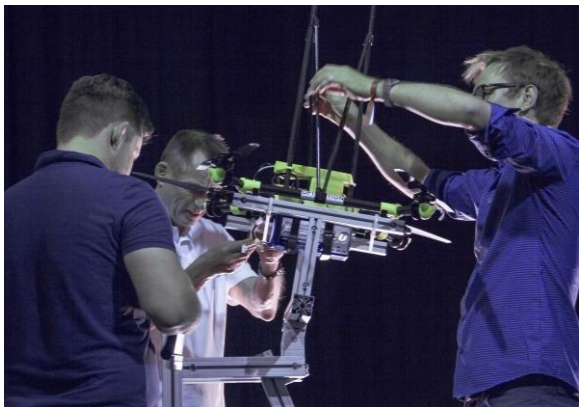
The wind speed measurements of the OPTOkopter have been validated in the low-speed wind tunnel of the University of Dresden, Germany (TU Dresden).
Special attention was paid to the potential influence of the propellers on all three velocity components. Wind speeds between 2 and 19 m/s have been tested with a tethered and a free flying drone. After compensation, the influence of the propellers is mostly below one percent or one degree, respectively.



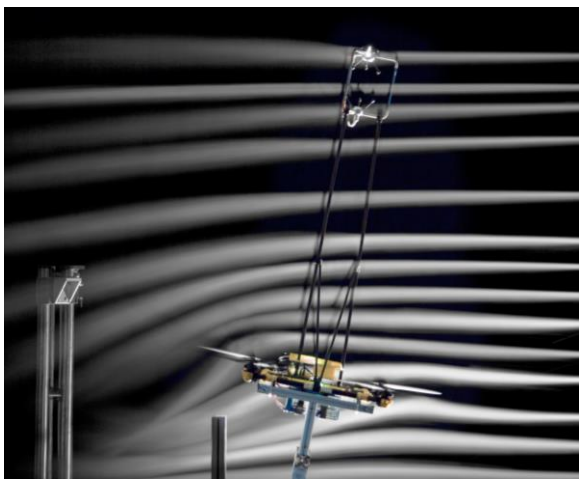
Influence of the propellers on the wind speed measurement. Blue: Motors off. Red: Motors on. Yellow: Motors on, compensation enabled.



Influence of the propellers on the vertical wind direction measurement. Blue: Motors off. Red: Motors on. Yellow: Motors on, compensation enabled.



Stream lines in the wind tunnel (5 m/s).



Stream lines in the wind tunnel (9 m/s).

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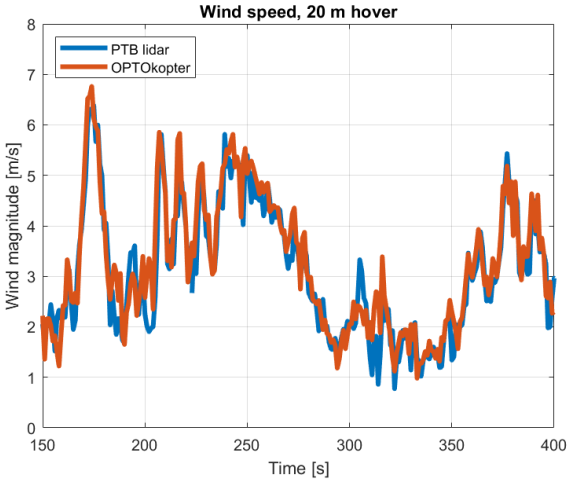
Measurement uncertainties:

The wind measurement of the OPTOkopter has been compared to the measurements of the wind lidar of the Physikalisch-Technische Bundesanstalt (PTB) - Germany's national metrology institute. The high resolution bistatic Doppler lidar is naturally free of any flow-distortion errors and determines the 3D wind vector in a volume of less than 0.0005 m³ at an output frequency of up to 10 Hz.

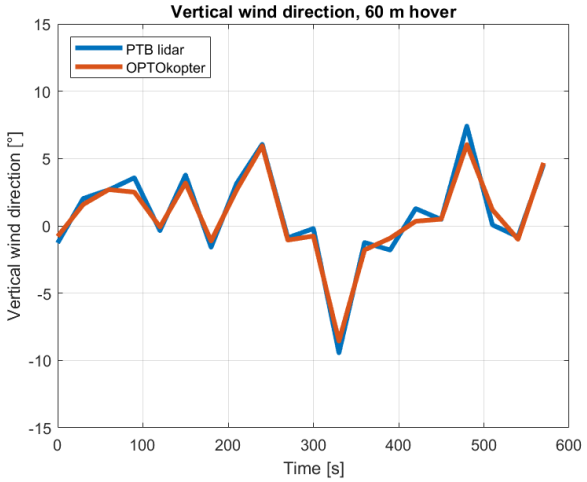
Systematic deviation (n = 7800) of the OPTOkopter and the PTB wind lidar measurement:

Wind speed:	**-0,080 %**
Wind direction, horizontal:	**1 ° (*)**
Wind direction, vertical:	**+0,048 °**

(*) missing PTB wind lidar reference



Wind speed in 20 meters above ground level (time-resolved). Comparison with the PTB wind lidar reference. Due to buildings and trees in close proximity, the flow is very unsteady. However, the deviation from the PTB reference is very small.



Vertical wind direction in 20 meters above ground level (time-resolved). Comparison with the PTB wind lidar reference. The deviation from the reference is smaller than 1°.

More details on the measurement uncertainties and our measurement validation is available on request.

Exposé