Current UAV-assisted Wind Energy Research Projects at the University of Tuebingen with the In-House built MASC Aircraft

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Outline

1. MASC UAV and Sensor System

2. HeliOW

3. WINSENT

4. HeliOW and WINSENT: Measurement Strategies
MASC: Multi-purpose Airborne Sensor Carrier

operated at University of Tübingen

wingspan: 2.7...3.5 m
total weight: < 6 kg
incl. sci. payload: 1.5 kg
cruising speed: 25 m/s
endurance: ≈ 1 hour
electrical engine pusher
autopilot: Uni Stuttgart

Measurements:
- 3D wind vector
- air temperature
- water vapour
- 100 Hz sampling rate
- data link to ground station

Met UAV MASC at the KonTest campaign
Baden-Württemberg, Schnittlingen, 2016
MASCC Sensor System

- complete thermodynamic sensor package:
  - fine wire resistance thermometer
  - capacitive humidity sensors
  - flow probe
  - inertial measurement unit (IMU)
  - GNSS position and velocity

- turbulence measurement up to 30 Hz

- live data observation on ground-station computer

- 100 Hz on-board log to SD-card
HeliOW: Helicopter Operations in Offshore Windparks

Joint Research Project

Involved Partners:
- German Aerospace Centre Braunschweig
- Institute of Aero- and Gas Dynamics Stuttgart
- Technical University of Munich
- Centre for Applied Geoscience of the University of Tübingen

Regulating safety concerns, energie-wende.de
**UAV Measurements**

- High resolution wind data
- Resolving detached blade tip turbulence

**Wake Simulation**

- Near distance wake

**Helicopter Simulation**

- Flight mechanics and trajectories of a helicopter in wake turbulence

- MASC in front of a WEC

- offshore-stiftung.de
Assort current situation

- Evaluate long term weather data over North Sea area
- Obtain and evaluate Pireps/Aireps and interview helicopter pilots

⇒ Correlate with atmospheric conditions and try to identify specific weather phenomena

Hvide Sande (DK), hvidesande.dk

Next Steps

- Finding a substitute WEC at the North Sea shore line (GER/DK)
- Getting flight permissions etc.
- Identify blade tip turbulence

Course deviation inside a WEC wake, Wildmann 2014
WINSENT: **Wind, Science & Engineering Test Site**

**Joint Research Project**

DEM of escarpment at the future test site

**Involved Partners:**

- Center for Solar Energy and Hydrogen Research, Baden-Württemberg
- Stuttgart Wind Energy
- Technical University of Munich
- Karlsruhe Institute of Technology
- Esslingen University of Applied Sciences
- Centre for Applied Geoscience of the University of Tübingen
Superordinate Goals:

- Installation of a wind energy research test site in complex terrain
- Setting up and validate a model chain for simulation of air flow from meso scale down to rotor blade scale
- Installation of two research wind energy converters, including a virtual simulation environment of the complete test site

On Site:
- Reference wind masts
- Lidar measurements
- in-situ UAV measurements in the near wake (once WEC is installed)

Wake simulation Stöttener Berg by IAG Stuttgart, windfors.de
**HeliOW and WINSENT: Measurement Strategies**

**HeliOW**
- Resolving blade tip turbulence in the wake
- Identify region of detached blade tip whirls

⇒ Small(est) scale air flow resolution

**WINSENT**
- Systematic and repeatable mapping of the area
- Wind and turbulence data:
  1. inflow from the **valley**
  2. Along the **escarpment**
  3. Inside the **wake** of the research WEC

⇒ Large scale wind mapping
Flow velocity deficit in hub height (100 m) behind a WEC (ca. 2D) in Grevesmühlen, upper green flight path (s. Fig. to the right)

Grevesmuehlen flight paths behind WECs

Number of flight legs is vital for statistical relevance and detection.
WINSENT: Strategic Starting Point

Starting off with results and recommendations from 'Lidar Complex' and 'KonTest'

e.g. Flight patterns at the future test site behind a WEC

Mean wind flow over the escarpment in Schnittlingen at the future research test site, Wildmann 2016.

→ Improved autopilot allows catching missing information near the surface.
Summary

Both projects require WEC wake measurements

*HeliOW*: strong focus on resolution

*WINSENT*: complementing wind map for test site

Implementation of a fast response 5 hole probe

Multi-equipped UAV

Enhance flight statistics

New autopilot
MASC 3.0?