Proof of concept for wind turbine wake investigations with the RPAS SUMO

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The measurements

The SUMO flights presented in this study were embedded in the joint measurement campaign WINTWEX-W (Kumer et al., 2015) performed in collaboration between NORCOWE and ECN at the ECN test site Wieringermeer in the Netherlands. This campaign was specifically dedicated to the full-scale investigation of structure and dynamics of single turbine wakes and lasted from November 2013 to May 2014. On May 10, 2014 the SUMO system performed 5 flight missions in the vicinity of the 5 NORDX N80 2.5 MW turbines. The racetrack pattern chosen provides for each flight horizontal turbulence transients parallel to the row of wind turbines at two different distances. With a wind from SW of about 12-15 m/s the track positions A and B were located ca. 5 and 1.5 rotor diameter (D) downstream.

SUMO vs. sonic anemometer

In a first step we compared the wind velocity components averaged over the SUMO flight legs, measured at altitudes 80 and 120 m, with the corresponding data from a sonic anemometer at 108 m height on the meteorological mast (left figure). Both data sets represent upstream wind conditions. The black line shows the sonic anemometer measurements in 32 Hz resolution, the gray line denotes a 10 min running mean. The SUMO measurements are given as average values over each straight leg and marked as orange stars. The data shown are for the eight legs of flight 4.

The main results are:
- excellent agreement for the East-West component u
- slight underestimation for the North-South component v, most likely due to the neglectation of the yaw angle deviations in-flight
- slight overestimation in the vertical component w, most likely due to an offset in the angle of attack of the 5 HP

A comparison of the spectral behaviour, between the 100 Hz measurements from the SHP of SUMO and the 32 Hz data from the sonic anemometer is presented in the left figure. The leftmost part of the spectrum shows the instantaneous and averaged energy spectra of the wind velocity components u, v, and w.

The turbulent kinetic energy (TKE) distribution over the flight legs, calculated from the SUMO data for u and v around 1 Hz is most likely induced by aircraft motion triggered by the internal control loops of the autopilot. The obvious lack of energy in the v component for the SUMO data for the lower frequencies requires further investigations.

SUMO spectra for the vertical component are following the -5/3 slope of the inertial subrange also for the highest frequencies, while the sonic data are showing signs of spectral attenuation in this region; potentially a signature of flow distortion by the mast.

SUMO wake measurements

The second step was the analysis of the collected data sets with respect to the wake characterization. The left figure presents the East-West wind component u measurements along the flight track given in UTM coordinates for the positions B (ca. 1.5 rotor diameter downstream) and D (upstream). The overall length of the x-axis presented is 1 km and the ticks are labeled every 100 m. The thin gray lines show the data from the individual legs (10 in the case of B and 4 in the case of D), the colored lines a 10 min running mean. The SUMO data are marked by the orange stars. The panel show from top to bottom: East-West wind component u, North-South wind component v, horizontal wind speed uэфф, and vertical wind speed wэфф.

The main results are:
- excellent agreement for the horizontal components u and wэфф
- slight overestimation in the vertical component wэфф, most likely due to an offset in the angle of attack of the 5 HP
- slight underestimation for the North-South component v, most likely due to the neglection of the yaw angle deviations in-flight
- excellent agreement for the East-West component u

Comparison of wind speed measurements taken by SUMO and the sonic anemometer at 108 m on the meteorological mast during flight # 4. The sonic anemometer data are given by the black lines, the SUMO data are marked by the orange stars. The panel show from top to bottom: East-West wind component u, North-South wind component v, horizontal wind speed uэфф, and vertical wind speed wэфф.

REFERENCES


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