

Answers to the comments of the reviewers for the manuscript

„Airborne measurements for investigating offshore wind farm wakes
and modifications of sea state - benefits and limitations “

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by

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The authors would like to thank the three anonymous reviewers for their detailed comments and suggestions to improve the manuscript. In the following, the comments are provided in italic letters. Each point is answered in normal letters. Changes to the text are indicated by quotation marks. Lines refer to the original manuscript.

Review 1:

Line 51: Too absolute, since LES are often used to validate lower-order models and, in theory, can still be employed despite their high computational cost.

We changed the sentence “At the same time, LES cannot be used for resource assessment due to the large computational costs.” to

“At the same time, the deployment of LES for resource assessment is limited due to the large computational costs.”

Line 91: A brief explanation of the sensor systems would enhance the clarity and interpretability of the presented results.

We added the following information about the sensors:

“The meteorological instrumentation for measuring the high resolution (100 Hz) wind vector, temperature and humidity is installed in the nose boom. For the wind vector, this includes a five-hole probe (Rosemount, USA) and sensors for differential and total pressure (Setra, USA) to determine the airflow angles. The position and orientation of the aircraft are determined with a combination of an inertial measurement unit (IMU, different systems for the Dornier128: iNAV-RQH-1003, iMAR, Germany, and for the CessnaF406: iNAT-RQT-4001, iMAR, Germany) and a Global Navigation Satellite System (GNSS, receiver OEM6, NovAtel, Canada). The wind vector can then be derived by subtracting the air speed vector from the ground speed vector. The temperature is measured by two complementary sensors, one with high accuracy, but slower response time (102DB1AG, Rosemount, USA), one with lower accuracy, but higher response time (102E4AL, Rosemount, USA). Humidity is measured with three different sensors: A capacitive sensor Humicap H233 (Vaisala, Finland), a dew point mirror TP 3-S (Meteolabor, Switzerland), and a fast, but drifting optical sensor (for the Dornier128: Lyman-alpha sensor L-6/HMS-2, Buck Research, USA, and for the CessnaF406: KH-20, Campbell Scientific, USA).

Additional instruments for measuring surface temperature, sea state and solar and terrestrial radiation are installed in the aircraft cabin: an infrared radiation thermometer (KT15.82D in the Dornier128 and KT19.85 in the CessnaF406, Heimann, now Heitronics, Germany), a laser scanner VZ-

1000 (Riegl, Austria, only for the Dornier128), two pyranometers for measuring upward and downward solar irradiance (CMP22, Kipp and Zonen, The Netherlands), and two pyrgeometers for measuring upward and downward terrestrial irradiance (CGR4, Kipp and Zonen, The Netherlands). The radiation sensors are only available for the CessnaF406. More details on the sensors and the accuracies are provided in Lampert et al. (2020) and Lampert et al. (2024).”

Line 113: Why is it suitable to use an already simplified model and the small-angle approximation in this context?

The sentences and the simplified model concerns concern the estimation of the sensitivity of the derived wind speed to a small constant sideslip angle error. As both the sideslip angle and the assumed installation error are small (around 0.3 deg), first order terms dominate and higher order terms are negligible. Furthermore, the use of 30 s median filtering reduces the influence of short-term fluctuations. Hence, the simplified approach is sufficiently accurate for quantifying the magnitude of the systematic error while maintaining a transparent derivation.

We clarified the sentence by writing “The systematic wind speed correction was derived by analytically estimating wind speed perturbation caused by a static installation offset and a small angle-of-sideslip error using a first-order linearisation of the wind derivation equations (see e.g., Bärfuss et al., 2023).”

Line 116: Unit

We corrected the unit of wind speed.

Line 131: How was vertical mixing quantified? How was the airborne campaign designed to capture measurements at multiple altitudes, or were the data obtained from a different sensor?

The results presented here were obtained by in-situ measurements at hub height, plus vertical profiles up to an altitude of 1 km.

We added in Sect. 2: “Based on these in-situ measurements, vertical mixing in the atmospheric boundary layer is identified by fluctuations of the vertical component of the wind speed vector. This allows calculating turbulent kinetic energy, momentum fluxes and heat fluxes.”

Figure 1: Explanation for higher wind speeds on coast?

We added in the text: “For a potential explanation of higher wind speed close to the coast, the reader is referred to Sect. 3.4.”

Line 149: It seems to suggest a comparison regarding data that the SAR is unable to collect.

We agree that the methods are very different, and motivate the comparison in the text:

“Although the methods of airborne in-situ measurements of wakes and satellite borne remote sensing observations based on synthetic aperture radar (SAR) are highly different and sample on other spatial and temporal scales, the quantification of wakes based on the regular SAR overpasses are an important monitoring instrument, which will be compared to almost simultaneous airborne measurements in the following.”

Line 154: Quantification of agreement?

Thanks for the constructive comment. We have added quantitative measures of agreement between the SAR-derived hub-height wind speed and the airborne running-mean wind speed along transects T6–T8. The revised manuscript reports the correlation, the standard deviation of the difference and bias.

“For transects T6–T8, the SAR-derived and airborne wind speeds show an overall agreement with an rms of 0.8 m/s and a correlation coefficient of 0.8. The bias varies between the individual transects (including a change in sign between T6 and T7/T8), indicating that the differences are not systematic across all transects and may depend on local atmospheric boundary-layer conditions. The standard deviation of the SAR and airborne wind-speed differences is about 0.3 m/s.”

Figure 3: At what height were the airborne measurements taken? Was it also at hub height?

We included in the figure caption: “Comparison of airborne wind measurements of D-IBUF at hub height”

Line 217: LaTeX Citation Error

Thank you, we corrected the error.

Line 297: Are the black lines determined analytically or by manual placement?

We changed the text to: “The area influenced by the wind farm is depicted within the manually inserted black lines”