PO.08

ASSESSMENT OF MOTION COMPENSATED TURBULENCE INTENSITY BY A FLOATING LIDAR SYSTEM

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SUMMARY

Floating LiDAR Systems (FLS) have become indispensable tools in the wind energy industry for several reasons. They allow for remote measurements of wind characteristics at varying heights above the sea surface, they are a safer alternative to met masts and they reduce the cost of a project.

TI (Turbulence Intensity) is a key determinant of the performance and longevity of wind turbines. High turbulence intensity can lead to increased wear on turbine components, reduced energy production, and decreased turbine lifespan. Therefore, accurate assessment and prediction of turbulence intensity are crucial for designing and optimizing wind farms.

Floating LiDAR systems measure turbulence intensity. However, the motion of the buoy due to waves and currents can introduce errors or variability in the LiDAR measurements.

A TI motion compensation algorithm was developed in the scope of the MATILDA project[1]. The project aims to quantify the error induced by the buoy motion and provide accurate TI measurements. The algorithm was run though thirteen weeks data from a FLS and then compared against the Fecamp met mast. The results proved to be satisfying and the work was published.

The aim of this work is to further investigate the benefits of the algorithm by applying it to other FLS campaigns and assess its performance on different FLS units. This work presents new results demonstrating the capabilities of the algorithm.

«The bias and slope demonstrate a significant improvement in turbulence intensity measurements across all three buoy campaigns. The mean corrected turbulence intensity matches perfectly the fixed LiDAR TI profile below 8m/s. Mean TI values are reduced by almost by 50% above this value. »

METHODOLOGY

The model-based approach involves estimating atmospheric turbulence intensity using 10-min statistics from a floating LiDAR and the six degrees of freedom time series from an Inertial Measurement Unit (IMU).

The motions are deduced from the combination of the model estimation and the 10-min wind in the LiDAR frame of reference.

In this study, 10-min WindCube v2.1 data and 5Hz motion data from the AKROCEAN buoy were used.

The primary objectives of this research are to assess the performance of the TI correction algorithm in correcting turbulence intensity for floating LiDARS and to investigate its impact on data accuracy.

This research focuses on the analysis of three buoys (A, B and C) campaigns against a fixed LiDAR for ten heights from 62m to 290m. The analysis covered almost all four seasons excluding the winter. The data coverage for each buoy is presented below showing the remaining data points after the data and correction filtering as well as the collocation with the reference LiDAR.

FLS A : February – March (~1.5 months)

FLS B : April – October (~6months)

FLS C : July – September (~2 months)

The coefficient of determination, bias, and linear regression slope between uncorrected and corrected TI against the reference were computed. Mean turbulence profiles across various wind speed bins were evaluated.

Wind speeds above 2/ms were considered for the linear regression and the error metrics computation. Data corresponding to availabilities below 100% and 80% respectively of the reference LiDAR and the FLS were filtered out.

As for the mean TI profile, bins of wind speed of 1m/s ans 2m/s were defined respectively below and above 12m/s. Only bins of minimum 40 data points were considered.

RESULTS

❶ The results demonstrate a significant improvement in turbulence intensity measurements across all three buoy campaigns.
❷ Bias and linear regression slope analyses consistently show enhanced accuracy. The correction deteriorates the coefficient of determination. Figures on the right show an example of uncorrected and corrected scatter (FLS B), linear regression and error metrics at 115m. The TI metrics are expressed in [%].

❸ The accuracy parameters were assessed for all FLSs across all heights. The results show good agreement with the reference.

In order to evaluate the impact of the correction, the difference in bias and slope between the uncorrected and corrected TI, computed earlier, averaged across all heights and three campaigns were computed and stored in the table below.

Bias difference [%] (corr - Uncorr)	Bias difference [%] (corr – Uncorr)/Uncorr	Slope difference (corr - Uncorr)	Slope difference [%] (corr – Uncorr)/Uncorr
-4.234	-95.441	-0.523	-35.358

❹ Based on the binned turbulence intensity profiles (115m and 215m for all the FLSs), it can be seen that the correction reduces the mean TI value per bin of wind speed. The corrected data matches perfectly the fixed LiDAR TI profile below 8m/s. Above this value, even though a gap could be observed between the blue and the green line, the profiles follow the same trend and the TI mean values are reduced by almost by 50% (from black to blue). Similar performance was observed from the remaining altitudes.

It was observed that the model filtered out approximately 35% of the data on average for the three buoys and across all heights. This limitation was already raised in a previous work and was explained by the occurrence of some 10-min samples lacking consistency between IMU and LiDAR measurements and/or not meeting model assumptions.

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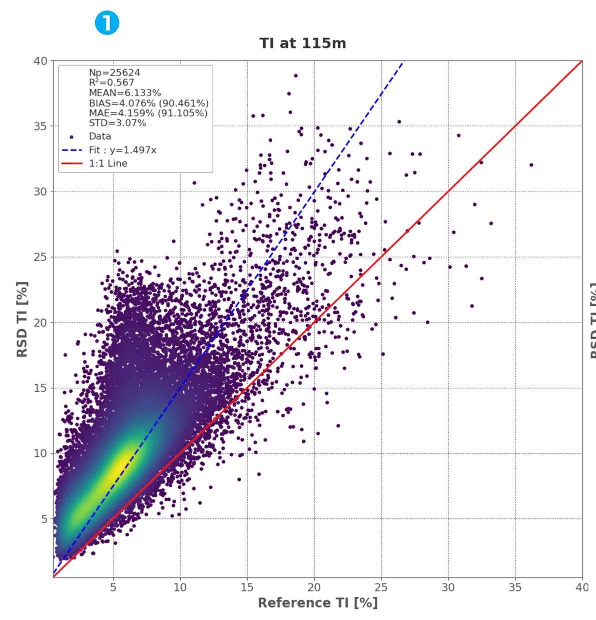

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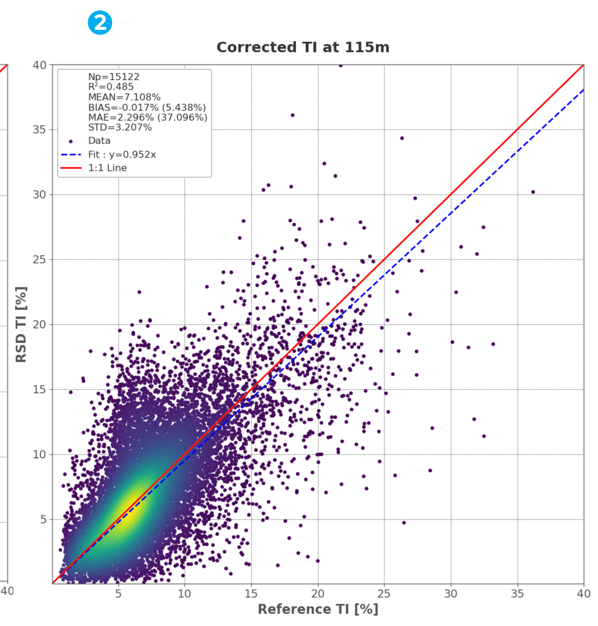

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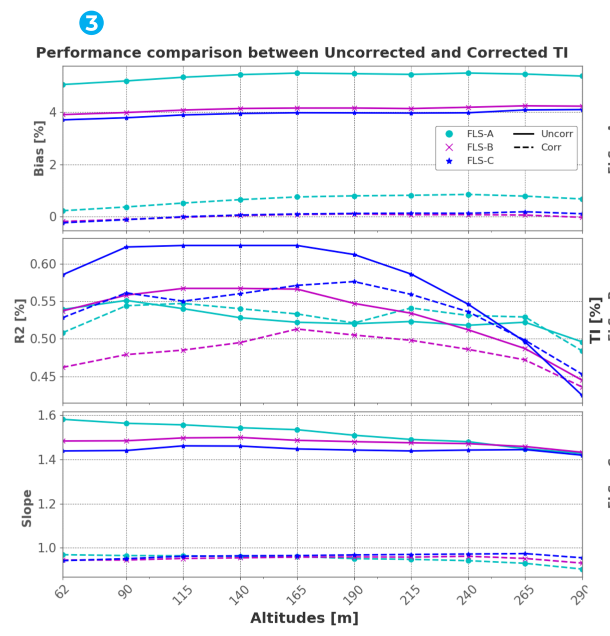

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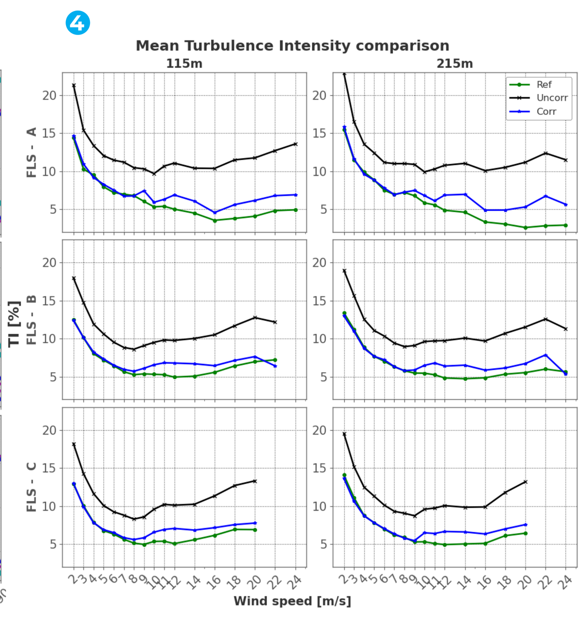

CONCLUSIONS

In conclusion, the TI correction algorithm proposed by AKROCEAN proves to be a valuable tool in correcting turbulence intensity for floating LiDAR measurements.
The correction improves in average (three FLSs and ten heights) both the TI bias and the slope by -4% and -0.5% which represent 95% and 35% less than the uncorrected TI measurements. The study highlights its effectiveness in improving data accuracy.

PERSPECTIVES

Looking ahead, future research should focus on refining the TI correction algorithm to address identified data availability limitations.

To broaden the algorithm's applicability, the next step involves conducting a comparative analysis using FLS data against a met mast following the same methodology.

Furthermore, the application of this comparative analysis could extend to key use cases such as site suitability, load validation, and energy production assessment as presented in the latest DNV recommended practice (RP) [2] . Other error metrics to better evaluate turbulence intensity measurements were introduced.

REFERENCES

[1] Désert, T.; Knapp, G.; Aubrun, S. Quantification and Correction of Wave-Induced Turbulence Intensity Bias for a Floating LiDAR System. Remote Sens. 2021, 13, 2973. https://doi.org/10.3390/rs13152973

[2] DNV-RP-0661 LiDAR-measured turbulence intensity for wind turbines, September 2023