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Time to leverage Nacelle Mounted Lidar for Turbulence Intensity measurement using a new filtering method

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Abstract

Nacelle-Mounted Lidar (NML) is a natural and cost-efficient solution of wind measurement for wind turbines, due to the easy deployment and the accurate wind measurement. Currently, NML are widely uses for multiple applications, such as, Power Performance Testing (PPT)[1,2], Lidar-Assist Control (LAC), turbine load estimations, and offshore floating turbine.

Fig.1 NML installation Photo

Turbulence Intensity (TI) is one of the key parameters for many applications. TI can be used to filter outliers in PPT verification and is the first important measurement for turbine load estimations.

In this study, two measurement campaigns are used to evaluate the NML measurement quality, and a new method has been developed, which can improve the TI accuracy and data availability significantly.

Methods

The overall methodology used can be summarized in 4 steps:

(1) compute LOS wind speed and Standard Deviation (SD) in 10 minutes for 4 beams using 1Hz data. The data availability is computed here to indicate the percentage of valid measurement for 10min period,

$$dRWS_i = \sqrt{\frac{\sum(RWS_i - \overline{RWS_i})^2 * Status_i}{\sum Status_i}}; \qquad \overline{RWS_i} = \frac{\sum(RWS_i * Status_i)}{\sum Status_i};$$

(2) divide SD by LOS mean wind speed to calculate LOS TI for each beam,

$$TI_{LOS} = TI_i = \frac{dWS_i}{\overline{WS_i}} = \frac{dRWS_i}{\overline{RWS_i}};$$

(3) compute TI+ and TI- using the TI from the two upper and lower beams:

$$TI_+ = \frac{TI_0 + TI_1}{2}; \qquad TI_- = \frac{TI_2 + TI_3}{2};$$

(4) compute TI at hub height from TI+ and TI- by a logarithmic interpolation law.

$$TI_{gain} = \frac{TI_+ - TI_-}{ln(H_-) - ln(H_+)}; \qquad TI_{\mathrm{Huser}} = TI_+ + TI_{gain} \cdot (ln(H_+) - ln(H_{user}));$$

A new filtering method is added in Step1 that removes the wind speed outliers for the SD calculation. This filtering method improve significantly the TI measurement.

Measurements: White/Black Box Comparison

The White Box Comparison(WBC) was to compare TI LOS using each Line Of Sight, while the Black Box Comparison (BBC) was to compare TI Hub using all measurement of 4 laser beams at wind turbine hub height.

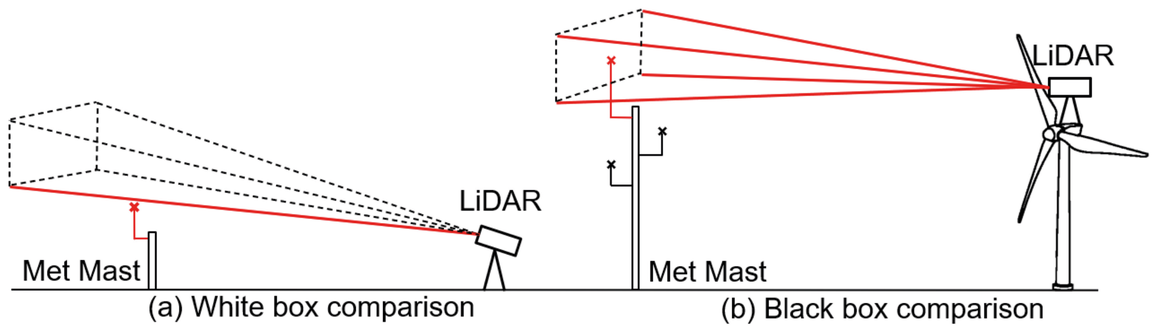

Fig.2 Comparison of Met Mast and NML (left: RWS, middle: TI, right: TKE)

Previous studies of WBC show the correlation coefficient of TI LOS reaches the good value of 0.955 with a slope of 1.03[3].

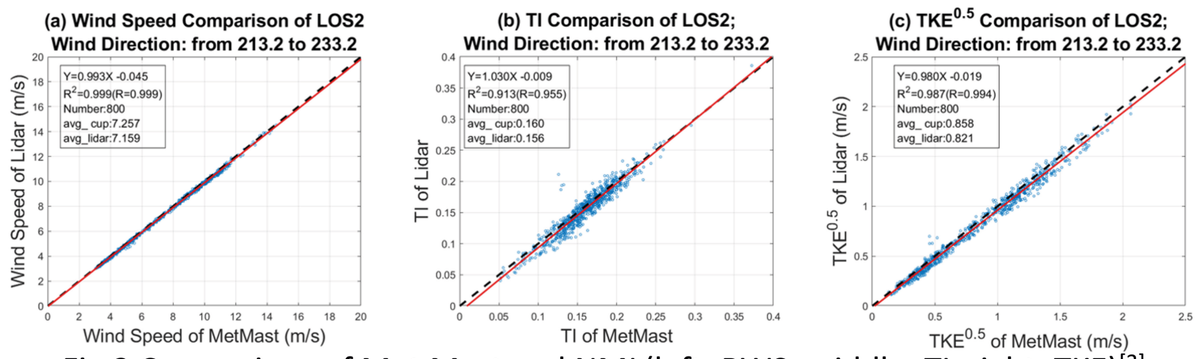

Fig.3 Comparison of Met Mast and NML(left: RWS, middle: TI, right: TKE)[3]

Results of Black Box Comparison

Figure4 and figure5 show the comparison result of BBC: the correlation coefficient is above 0.916, and the slope is 0.951~1.029. TI measurement by NML is very accurate and the bias is smaller than 4.9%.

For TI comparison against Met Mast, the data availability threshold of 80% is used. Hence, a 10-minute TI measurement is used for comparison if at least 80% of measurements are valid. The percentages of available TI in the two campaigns are 83.7% (data number of 4821 is available, 5759 in all) and 71.9% (data number of 3154 is available, 4388 in all) for the measurement period.

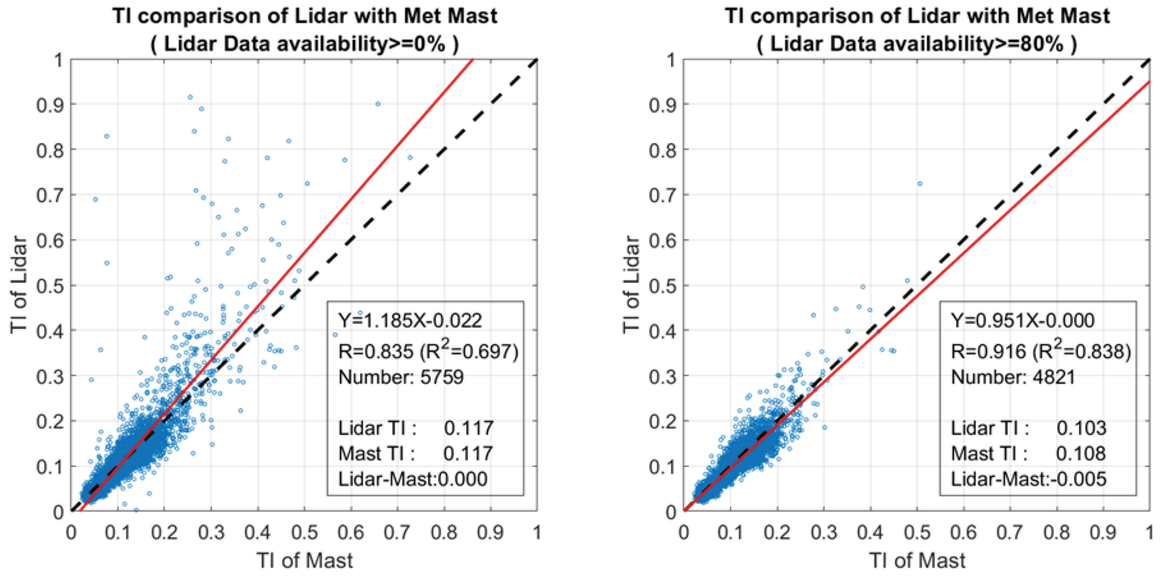

Fig.4 TI comparison in the first measurement campaign for on-nacelle test

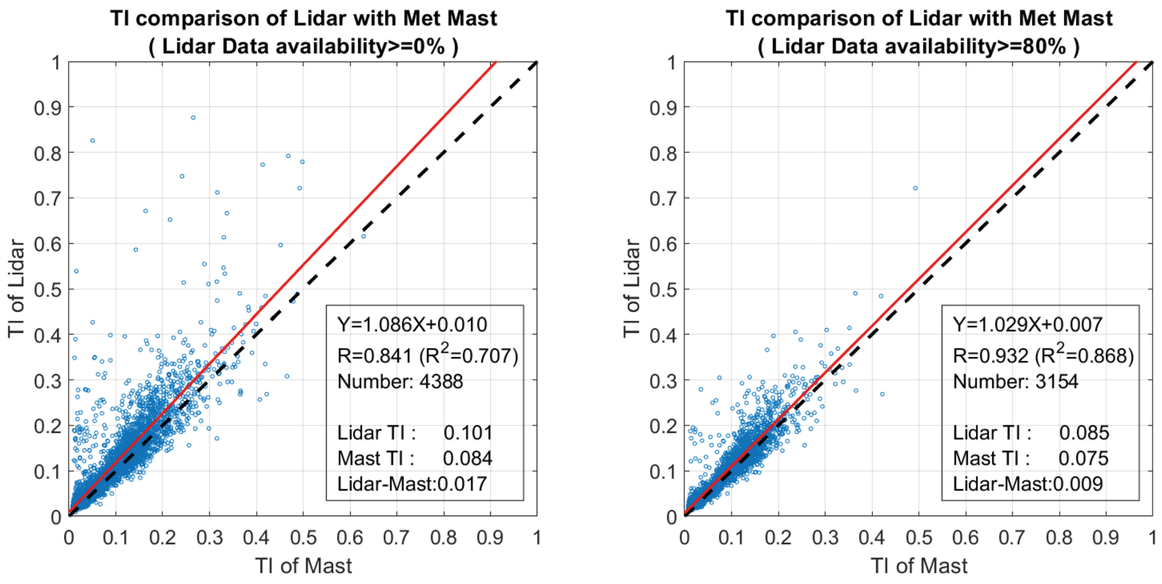

Fig.5 TI comparison in the second measurement campaign for on-nacelle test

Conclusions

This study includes two field measurements, and shows below conclusions:

(1) The global accuracy of TI measurements is high: bias is within 4.9%. The correlation coefficient are 0.916 and 0.932 with slopes of 0.951 and 1.029.

(2) The data coverage percent of valid TI is high. It is 83.7% and 71.9% for the whole duration of the two campaigns.

(3) Here, we would like to highlight the good data coverage of valid TI. TI is very sensitive to wind speed outliers in high frequency data. In the past, the used threshold of data availability was 95%, which could remove 70% to 80% of data from the whole dataset. Now, the data coverage of valid TI reaches the same level as the one for wind speed.

The good measurement accuracy and data coverage of TI shows NML is ready for the industrial applications for TI related direction.

References

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