PO80

Simulating the Impact of Flow Complexity and Sampling Schemes on Ground-Based Lidar Wind Measurements

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ZX Lidars

Turbulence can bias lidar measurements of wind speed by over 4%. High-frequency sampling reduces the impact by as much as factor of 7.

Introduction

Ground-based lidar wind profiling systems execute a conical (velocity-azimuth display, VAD) scan, sampling the wind around a disk at selected heights. To retrieve a 3D wind field from this, a wind field reconstruction algorithm (WFR) must be used to convert a set of line-of-sight (LOS) wind measurements into the desired measure. This process happens under an assumption about the uniformity of the flow responsible for the LOS measurements – allowing for wind speed results to be generated with excellent accuracy in uniform conditions, even with a low number of LOS results

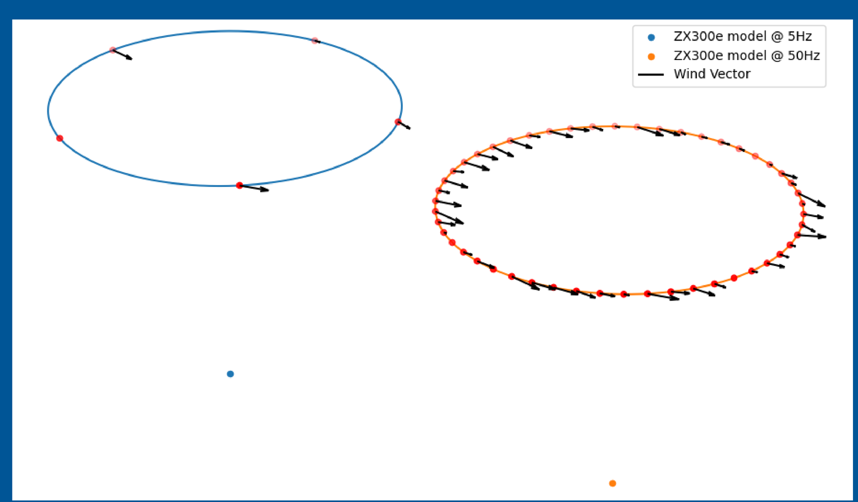
This poster evaluates the impact of complex flow on this process, focusing on turbulence intensity. The goal was to answer two questions:

- How does breaking the assumption of uniform flow via increasing turbulence affect the accuracy of the WFR?
- How does the frequency of LOS samples impact the accuracy of the WFR in turbulent conditions?

- Simulating Lidar Measurements

In order to quantify the impact of turbulence, we turned to simulation – this provided the ability to sample the same turbulent flows with many different lidar models with identical deployments.

TurbSim was used to generate turbulent wind fields with a range of turbulences and seeds.

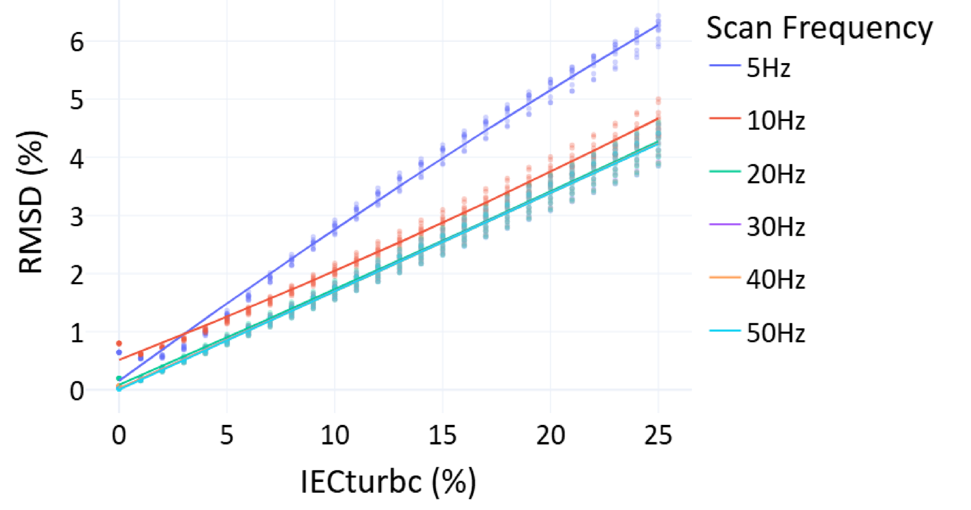


These wind fields were then sampled by a variety of lidar models, at a fixed 1-second scan rate. The model reproduces the geometry of a CW VAD scan, the sensitivity of a focused laser, and the optical-digital conversion of the returning signal.

Tests were run to identify resolutions of turbulence box grids, and discretisation of scan geometry which optimised simulation efficiency and accuracy.

The results were processed by simple implementations of real WFR algorithms used by ZX Lidars. The resulting wind vectors at 1Hz were then compared to 1Hz averages of certain references.

Deviation with respect to average wind speed around VAD scan



The graphs above show the deviation (root mean square deviation) for lidar measurements at different frequencies through a range of turbulences with respect to the average wind speeds at the centre of the scan and around the scan disk. IECturbc is the value of turbulence used to generate the box.

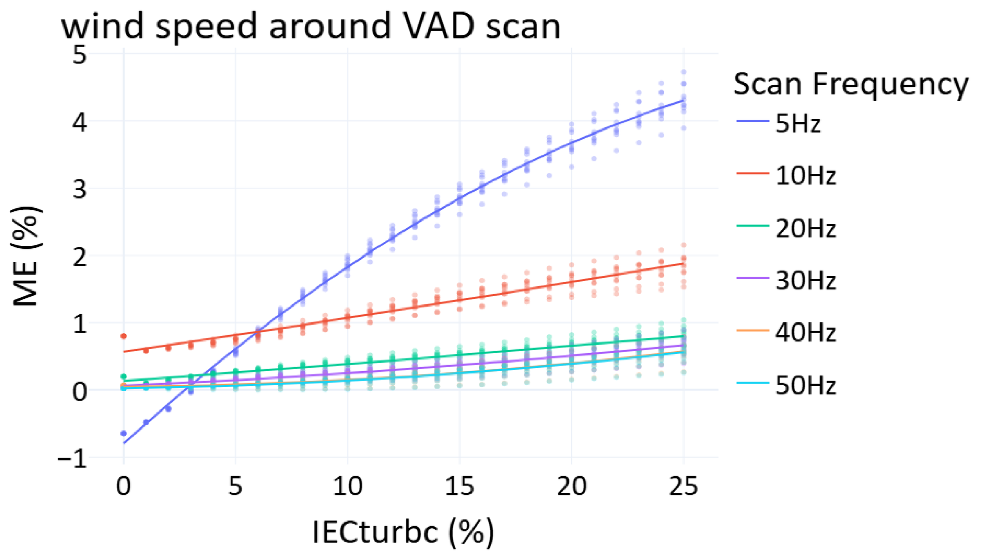
The deviation is approximately linearly related to the turbulence of the simulation. All sampling frequencies greater than 5hz see a 50% reduction in the gradient of the relationship.

The graphs below show the bias (mean error) for the same measurements.

For low frequency sampling, the bias is significant reaching 4.4% at 25% turbulence. In contrast, higher frequencies approach only 0.6% at this turbulence. The relationship is quadratic at high frequency, becoming flatter as frequency increases.

This bias would, unlike the deviation, be preserved when averaging over long periods of time. However, WFR algorithms can be used differently when aggregating multiple scans, reducing bias further.

Bias with respect to average wind speed around VAD scan



The results visualised above are for anisotropic turbulence. This can be shown to both worsen the effects overall and introduce an orientation dependence for lower frequency sampling and sampling regimes which are not axi-symmetric.

Conclusions

The simulation results show a linear relationship between deviation in lidar measurements and TI. The bias result is significantly smaller than the variance, but related quadratically to the TI.

Higher sampling frequency is shown to mitigate these effects. A sampling rate of 5Hz increases the variance compared to standard 50Hz sampling by 50% and the bias by 700%. The impact on the variance is mitigated by sampling at least 20 Hz. The impact on bias is fully mitigated by sampling rates over 40 Hz.