PO72

Simulation and Compensation of Environmental Sensitivities in Lidar Measurements

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Lidar Classification and Calibration uncertainties can be reduced to less than 1% using an SI-traceable, white-box methodology

Summary

Today, lidar uncertainties are derived from field verification campaigns against a met mast reference, and from the lidar type Classification, following the IEC 61400-50-2. The calibration process is very long and the dominant uncertainty in the final budget is the inherited uncertainty from the anemometers. Here we present validation of an alternative approach. The new method uses laboratory calibration of the lidar's radial wind speeds, coupled with a Monte Carlo measurement model. The model is validated through replication of the observed environmental sensitivities, and traceability of the laboratory calibration.

IEC Classification

Measurement uncertainties from remote sensors (RSD) are quantified following the IEC 61400-50-2. Each new RSD model must undergo a rigorous field evaluation of its environmental sensitivities, known as Classification. Environmental sensitivities are a component of an RSDs overall uncertainty budget during measurement campaigns.

WindCube XP Shear Sensitivity

Lidar beams are spread out in space. Their line-of-sight (LOS) measurements are a volume average of the wind velocities within the probe. This volume averaging effect leads to a wind shear sensitivity due to the non-linearity of wind speed profiles, and the shape of the probe's range-weighting function (RWF). In the WindCube XP Classification, a wind shear sensitivity is observed as expected at the lowest measurement heights.

The Measurement Model

The key inputs for the measurement model are the WindCube's laboratory-measured RWF and instrumental noise. These properties are derived using an SI-traceable optoelectronic bench called Simulation of the Atmosphere with Fiber Optics - Multi-Velocity, or SAFO-MV.

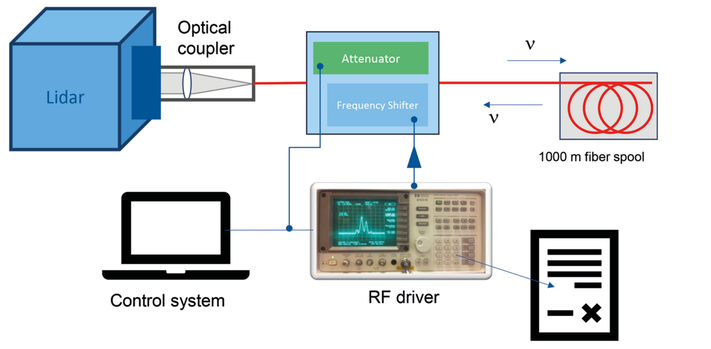


Figure 1: Diagram of SAFO-MV laboratory bench used to derive range-weighting function, instrumental noise, and velocity bias for all beams, CNRs, and velocities

A virtual lidar is configured using the output from the SAFO-MV calibration using MoCaLUM (Monte Carlo Lidar Uncertainty Model) software. This software generates IEC-compliant (KSEC) turbulence boxes with controlled input parameters, sweeping over different conditions to derive the same environmental sensitivities observed in the device Classification.

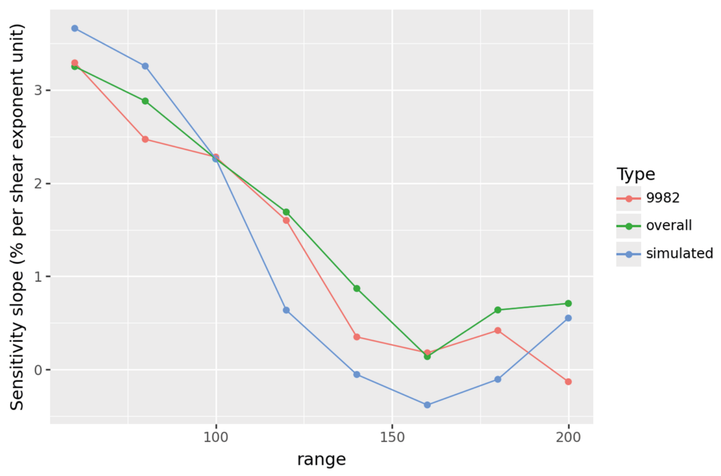


Figure 2: Wind shear sensitivity derived from IEC Classification field campaign and from comparison between virtual lidar and ideal point reference in MoCaLUM

Correcting the Shear Sensitivity

Using the validated measurement model, a correction can be generated and applied to the original Classification to remove the device sensitivity to wind shear.

Type	60	80	100	120	140	160	180	200
Classification	3.2	2.9	2.3	1.7	0.9	0.1	0.6	0.7
Corrected	-0.3	0.3	1.0	1.6	1.0	1.0	1.2	-0.6

Table 1: Wind shear sensitivity from original IEC Classification campaign and using identical data, corrected with MoCaLUM-derived function.

These reduced slopes bring the shear sensitivity below the thresholds of the IEC 61400-50-2, demonstrating that the sensitivity is properly modeled, thus validating the measurement model, and eliminating the Classification uncertainty in a transparent way.

New WindCube Uncertainties

The model validation confirms the SI-Traceability of the new approach. Calibration uncertainties from this methodology are substantially lower than those from existing 50-2 methods, and the calibration period is reduced to about 2 days.

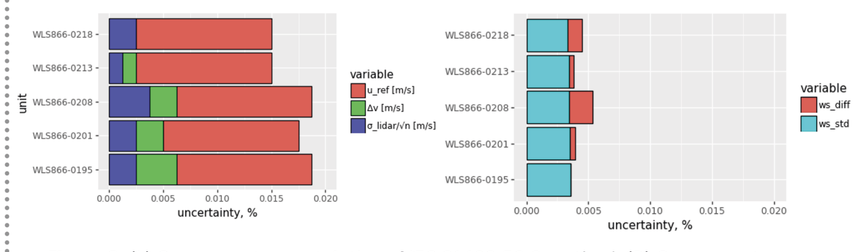


Figure 3: (L) Component uncertainties of IEC 61400-50-2 method. (R) Component uncertainties of Monte Carlo uncertainty method on five WindCube v2.1 systems

Conclusions

- The observed WindCube wind shear sensitivity can be precisely modelled and corrected.
- Validation of the measurement model enables SI-traceable laboratory calibrations using SAFO-MV and MoCaLUM.
- This new method removes the inherit uncertainty of the cup anemometer, reducing the overall lidar uncertainty to less than 1%

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