PO.130

The “Why?”, “What?” and “How?“ of lidar type classification

John Medley, Matt Smith
ZX Lidars

Abstract

In 2018, ZX Lidars completed a project to classify the ZX300 lidar, summarised in DNV/GL’s type classification report [1]. During the project the authors became intimately acquainted with the complicated and time-consuming process described in [2] for type classification of a remote sensor (RS). Here we aim to give a simple guide to the process by answering three questions:

- **Why** is a type classification required?
- **What** does a type classification consist of?
- **How** can and how should a type classification be used?

The answers to these questions are illustrated using the results of DNV/GL’s type classification of the ZX300 lidar. We show that a thorough assessment of measurement uncertainty in an RS measurement campaign can result in significantly lower uncertainties than those achieved through a simple application of the class number.

Why is a type classification required?

Type classification bridges the gap between verification and application of a particular RS device. A verification test assesses the performance of the RS (comparing its measurements with those of a reference sensor traceable to national standards) **under the environmental conditions during the test**.

If the RS were then to be used for a measurement campaign under identical environmental conditions, the uncertainties derived in the verification test would be directly applicable to the new measurement campaign.

In a real world measurement campaign the environmental conditions will vary from the verification test, introducing an extra component to the uncertainty assessment for that campaign. Type classification provides the basis from which this extra uncertainty component can be derived.

What does a type classification consist of?

In a classification test we assess how sensitive the measurement accuracy of a particular remote sensor is to environmental variables (EVs) such as temperature (T), temperature gradient (ΔT), coefficient of wind shear (α) and turbulence intensity (TI). For a type classification, a minimum of 3 such tests are required to try to capture any differences between individual devices and between locations (see [1] for details of the tests and combining test results).

The results are presented in terms of the sensitivities of the measurement accuracy to a range of EVs for each measurement height. These sensitivities are combined to give a class number for each measurement height, from which a **worst-case** standard-uncertainty is derived by dividing the class number by $\sqrt{3}$.

DNV/GL have reported a type classification of the ZX300 lidar in [2]. Class numbers, worst case standard uncertainties and coefficients of sensitivity to selected EVs are shown in Table 1 below.

Table 1: Results of type classification for ZX300 lidar

Meas. height	Class	Worst-case standard uncertainty	Coefficient of sensitivity			
			ΔT	T	TI	α
m	%	%	% / (°C / m)	% / °C	% / unit	% / unit
130	2.2	1.3	-25.4	-0.034	+2.57	-0.95
110	1.9	1.1	-25.4	-0.016	+3.97	+0.48
80	1.8	1.0	-5.7	+0.014	+6.26	+1.40
50	2.0	1.2	3.2	+0.026	+2.17	+1.33
20	2.1	1.2	0.2	-0.018	+3.40	-1.32

References

1. Power performance measurements of electricity producing wind turbines, *IEC 61400-12-1:2017, International Electrotechnical Commission, June 2017*.
2. Type ZX300 lidar: Remote sensing device type-specific classification summary, *GLGH-4275 18 14741 258-R-0003, Rev. D, DNV GL, November 2018.* (Available from ZX Lidars.)
3. Taming uncertainty in wind project financing, *Wind power engineering and development, November 2012.*

How can a type classification be used?

The environmental conditions during application of the RS will differ from those in its verification test. The type classification result can be used to assess the additional uncertainty due to these differences as described below. Here we evaluate the application measurement uncertainty at 110 m, assuming that the verification test uncertainty is 1.5% for the wind speed bin of interest. (Note that uncertainties in the verification test are typically dominated by uncertainties in the reference instrument, typically a cup anemometer.)

1. **Simply**: Direct application of the class number (as a standard uncertainty)

   From Table 1, the standard uncertainty contribution at 110 m is 1.1%. This is combined in quadrature with the verification uncertainty to give an overall uncertainty of:

$$u = \sqrt{1.5^2 + 1.1^2}\ \% = \mathbf{1.86}\ \%$$

2. **Thoroughly**: Using measured differences in EVs

   For an EV, x, with a coefficient of sensitivity, m, a mean value during verification of $\bar{x}_v$ and a mean value during application of $\bar{x}_a$, the contribution to uncertainty due the effects of that EV is (from equation L.6 of [1]):

$$u_x = m.|\bar{x}_v - \bar{x}_a|\ \%$$

   An example uncertainty calculation is shown in Table 2, below, using the coefficients from Table 1. The total classification uncertainty (u_{class}) is calculated by combining the contributions in quadrature.

Table 2: Calculating uncertainty from measured values of EVs

Parameter	M	$\bar{x}_v$	$\bar{x}_a$	u_x
ΔT	-25.4	0.005	-0.005	0.25
T	-0.016	5	15	0.16
TI	+3.97	0.10	0.15	0.20
α	+0.48	0.25	0.10	0.07
u_{class}				0.37

   Combining u_{class} with the verification uncertainty gives an overall value of:

$$u = \sqrt{1.5^2 + 0.37^2}\ \% = \mathbf{1.54}\ \%$$

3. **Pragmatically**: Using a mix of measured and estimated differences in EVs

   If a significant EV cannot be measured during application of the RS, the range of that EV should be estimated (see section L.4.4 of [1]). The maximum absolute difference between this estimated range during application and its mean value during verification is calculated. The standard-uncertainty contribution for the EV is derived by dividing this value by $\sqrt{3}$.

   In the example below, T is measured independently and the mean TI measured by the lidar is used. Estimates are made of the ranges of ΔT and α, and u_{class} is calculated by combining the contributions in quadrature.

Table 3: Calculating uncertainty from measured and estimated values of EVs

Parameter	M	$\bar{x}_v$	x_a	u_x
ΔT	-25.4	0.005	[-0.020, 0.020]	0.37
T	-0.016	5	mean = 15	0.16
TI	+3.97	0.10	mean = 0.17	0.28
α	+0.48	0.25	[-0.05, 0.20]	0.08
u_{class}				0.50

   Combining u_{class} with the verification uncertainty gives an overall value of:

$$u = \sqrt{1.5^2 + 0.50^2}\ \% = \mathbf{1.58}\ \%$$

Conclusions: **How should** a type classification be used?

A pragmatic approach to applying type classification, measuring EVs where possible and estimating sensible ranges where necessary, is recommended to deliver uncertainties significantly smaller than simple use of the class number.

A reduction in wind speed measurement uncertainty of 0.28% could reduce project uncertainty by about 0.15%, which, using the analysis in [3], would improve project value by $1 M / GW.

MEET US AT 1-B40