# Verification of lidars for wind energy applications

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## Abstract

Verification of any equipment requires two things:

1. Assessment of its level of performance, and

2. Conformance of that level of performance with a level required to fulfil the purpose for which the equipment is being verified.

Over the last decade lidars have been adopted by the wind energy industry as an instrument for measuring wind conditions. Lidars can provide:

- Datasets for wind resource assessment, including those acquired by met masts, and various other datasets that fulfil the data requirements of established wind energy assessment procedures developed in relation to the relatively limited capabilities of met masts, and

- New datasets that would not otherwise be available using met masts and which therefore enable investigations of wind conditions that would not otherwise be possible.

Lidar verification challenges arise in relation to both of these scenarios. It is important not to artificially restrict the scope of lidar verification to situations that only correspond to equivalent met mast applications.

In addition, lidar can provide valuable information for the assessment of wind turbine performance post-construction, allowing detailed characterisation of wind conditions to which the assets respond and which they must accommodate.

Guidance on the classification and verification of lidar performance is documented in IEC 61400-12-1 (2nd edition). However, the definition of the level to which this must conform is only now possible as a result of the publication by the IEA of guidance regarding lidar use cases.

The necessary acceptance criteria relative to which lidar performance must be assessed can only be developed with reference to the purpose the measurements are intended to fulfil. This in turn requires the identification of a valid lidar use case to which the certification will relate.

In particular, the data requirements associated with a specific lidar use case allow suitable acceptance criteria to be defined against which the lidar performance can be evaluated. Verification of the lidar with respect to those criteria then indicates its fitness for purpose with respect to that use case.
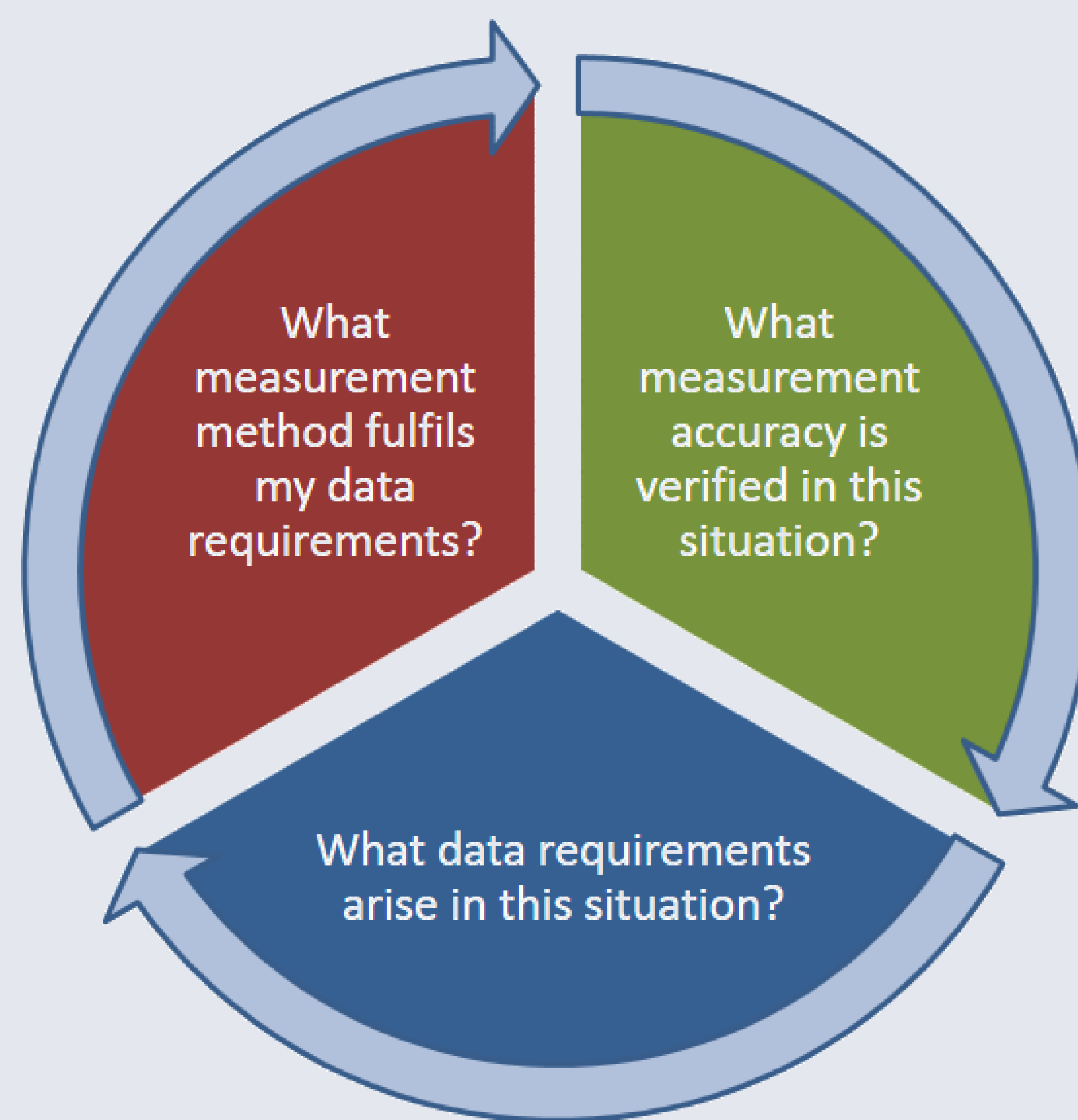
Use cases whose data requirements arise in the course of post-construction performance assessment and optimisation naturally benefit from the confidence in the measurements that can be achieved as a result of following an agreed verification protocol.

## IEA Lidar Use Cases

- Data requirements
- Measurement method
- Data acquisition situation
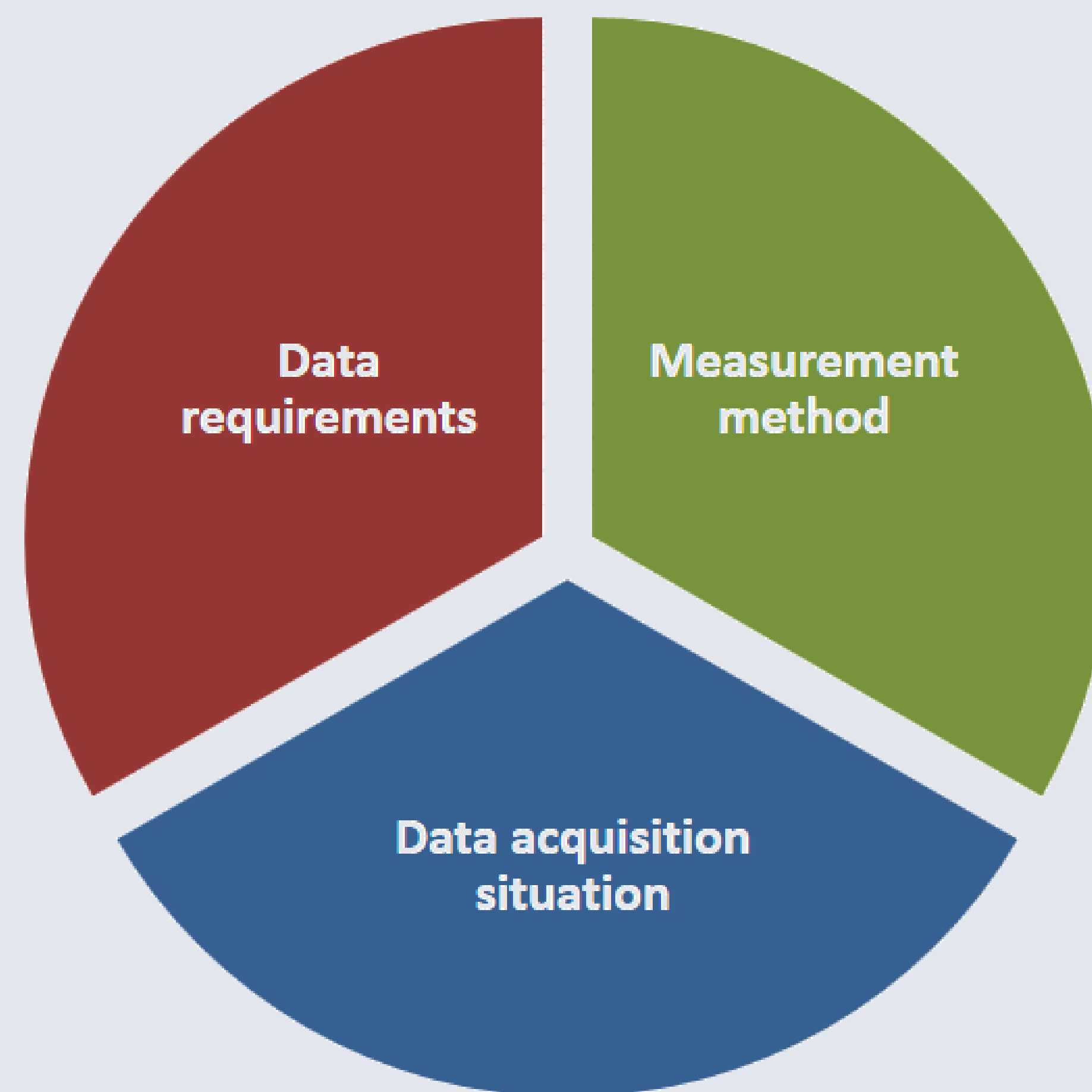
Adequately describing the lidar use case requires us to
- Answer the questions we ought to be asking to ensure we are
- Acquiring appropriate measurements using
- Appropriate and sufficiently well understood tools and techniques

- What measurement method fulfils my data requirements?
- What measurement accuracy is verified in this situation?
- What data requirements arise in this situation?

## Verification procedure

The verification of lidars for wind energy applications is achieved through Site Acceptance Testing (SAT) which replicates the conditions in which the device is to be deployed and the measurements it is required to make.

1. Identify the relevant Lidar Use Case (IEA Wind Task 32). This comprises:

   a) Data Requirements. These arise in relation to desired wind energy project outcomes, and are application specific. The acceptance criteria that must be fulfilled are those that ensure the outcome is achievable.

   b) Measurement Situation: this includes the test site, reference instrument, and lidar device

   c) Measurements method: for example remote mast scan / arc scan, VAD scan, PPI, RHI, etc.

2. Performance assessment

   a) Data synchronisation and filtering criteria are applied for the reference instrument and lidar (e.g. restricting wind direction to a free stream sector, filtering on PiF, PiA, RMSE/HWS, or equivalent)

   b) Data completion criteria must be fulfilled for the results after filtering

   c) Suitable assessment methods must be adopted (for example, for wind speed and direction OLS and binned deviations may be used as illustrated below)

3. Performance verification:

   a) Test results (e.g. wind speed and direction correlations and binned deviations) are compared to the acceptance criteria identified as relevant to the lidar use case.

   b) Conclusions and recommendations are drawn. The results of the verification exercise are valid only for the applications, circumstances and method described by the lidar use case.

**Acceptance criteria**

- Indicate fitness for purpose

- Are application specific

- Are among the data requirements of the use case

- Arise in relation to achieving outcome-driven rather than constraint-driven objectives

- I.e. "what do I want to measure" not "what can I measure"

$y = 0.9948x + 0.1255$
$y = 1.0057x$
$R^2 = 0.9915$
$n = 3233$

Mean Deviation : 0.07 [m/s], 0.7%
Standard Deviation of Deviation : 0.27 [m/s], 2.5%

$y = 1.0049x + -0.1214$
$y = 0.9942x$
$R^2 = 0.9999$
$n = 3233$