An IEA Wind Task 32 Publication

A Review of Guidance for Using Ground-Based Vertically-Profiling Wind Lidar For Wind Resource Assessment

What are the best practices for using wind lidar for wind resource assessments in 2020?

Motivation for this review

Wind lidar is a rapidly maturing field. As a result, it can be hard to know which documents are current, and which are out-of-date. This can be particularly challenging for new lidar users who are just starting out, but can also mean that others might be using guidance or methods that have since been superseded. This document therefore provides a short update on what we consider to be 'best practice' in 2020.

Our goal

Our goal is to document the steps required to collect high-quality, well-documented wind lidar data for use in wind resource assessments on land.

Our use case

We focus on ground-based lidar that use a fixed scan geometry to deliver data that are to be used in the resource assessment phase of a wind farm development on land. These data typically consist of vertically-resolved profiles of wind speed and direction.

A short history of guidance documents

In 2013 IEA Wind Task 32 and Task 11 published recommended practices for ground-based remote sensing for wind resource assessment [1], known as *RP-15*. It was published to satisfy a need from the wind energy community for documented good practice in measurements with active remote sensing devices (RSDs), including lidar and sodar. *RP-15* provided specific guidance as "Recommended Practices" (e.g., *RP-15 RP 1*) and informative notes (e.g. *RP-15 Note 1*) about how to use remote sensing. These covered many different aspects of the remote sensing lifecycle. The document was based on experience and collected the remote sensing community's understanding in 2013. Therefore it was not a standard, but a "recommended practices" document. *RP-15* is available from Task 32's GitHub repository.

In 2016, the Measuring Network of Wind Energy Institutes - MEASNET - published Version 2.0 of a *"Procedure for the evaluation of site-specific wind conditions"* [2]. This procedure provides generic guidance to measuring wind characteristics, and a normative annex on wind measurement using remote sensing devices. It also includes guidance on how to set up measurement campaigns depending on the data required. It is available from www.measnet.com.

In 2017 the International Electrotechnical Committee published a new edition of the IEC 61400-12-1 'Standard for power performance testing of wind turbines' [IEC 61400-12-1 (2017), 3]. The IEC 61400-12-1 standard has traditionally been used as a *de facto* standard for the measurements required for a wind resource assessment. It includes Annex L on the use of remote sensing for wind measurements. As a result, some groups also consider this standard to be applicable to the use case we consider here. The IEC 61400-12-1 (2017) standard can be purchased from the IEC.

What to do in 2020

This review identifies the documents that are applicable at different steps in the lifecycle of a wind lidar deployment. These steps include:

1. Characterising wind lidar
2. Installing wind lidar
3. Operating wind lidar
4. Lidar data analysis
5. Verification of wind lidar.

These steps are recommended to help lidar users gather high-quality, actionable data that meet their stakeholders' needs.

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1 Characterising wind lidar

It is important that the technology used in the lidar is well characterized for future reference. This is covered in *RP-15, RP 1: 'Documentation of RSD characteristics'*.

2 Installing wind lidar

2.1 Training

Users are encouraged to take specialist training on the wind lidar before deploying the device. This is covered in *RP-15, RP 2: 'Training of workers'*.

2.2 Selecting lidar deployment sites

Careful site selection is important to get high-quality data. The user should:

- **Choose a representative location** considering how the lidar data will be used, for example as the sole source of wind speed data; for input to flow models; for model validation; or to confirm shear. This choice should be made with stakeholders. Approaches are given in the MEASNET document [2].
- **Avoid obstructions.** Wind lidar should have a clear sky view. This is described in *RP-15 RP 6 d*. Some lidar devices can deliver accurate data when the beams are partially obstructed.
- **Avoid small-scale wind disturbances** such as mast or tower wakes or other phenomena that might pass through the measurement volume, but are not related to the wind resource that a wind turbine would experience. *RP-15 RP 6 c* recommends avoiding such features. Some wind lidar devices include ignore data processing that can filter out the effects of such small-scale wind disturbances.

Because data processing tools are specific to each device, users should always follow the manufacturer's guidance on how to site their device.

2.3 Deploying wind lidar in complex terrain

Terrain influences the winds above it. This can lead to changes in flow within the lidar's measurement volume. This terrain-induced, measurement-scale flow inhomogeneity is often referred to generally as 'complex flow' that occurs in 'complex terrain'. It is important to note that flow conditions are also influenced by many other factors beside the terrain form. These may include land cover, measurement height, weather, and others [see e.g., 4]

Lidars and cup anemometers use different wind measurement principles. A lidar measurement is based on information from an extended measurement volume, while a cup anemometer uses data from one point. In complex flow, wind lidar and cup anemometers will therefore give somewhat different data.

Cup anemometers are the accepted reference device for the wind energy industry. Therefore, 'transfer methods' have been developed between wind lidar and cup anemometers. These use many different approaches and are often device-specific. The applicability or suitability of these methods is out of scope for this document.

Users may still wonder, "when might the flow be complex enough to need a transfer method?". There is no directly applicable standard because of the range of devices and transfer methods. Therefore, we suggest that it may be appropriate to work with lidar vendors and other experts to assess the need for a transfer method if conditions are complex according to IEC 61400-12-1 (2017).

The use of transfer methods should also be driven by the purpose for which the data is being used. Lidar users should always work with their stakeholders to understand their requirements and their acceptance of different transfer methods. This may also have implications for verification.

An IEA Wind Task 32 working group on the use of wind lidar in complex terrain is carrying out a group study on several different transfer methods. Results are expected in 2021.

2.4 Transport

Suggestions for how to prepare and transport lidar are given in *RP-15, RP 4: 'Reusable protective packaging for RSD transport'* and *RP-15, RP 5: 'Installation of shock detectors on the RSD'*.

2.5 Site preparation

Recommendations for how to prepare a site for a lidar deployment are given in *RP-15 RP 6 a and b*.

2.6 Lidar orientation

It is important to document the lidar's compass orientation. See *RP-15, RP 7: 'Device alignment'*.

2.7 Tilt and roll

It is important to monitor the lidar's tilt and roll with respect to vertical. This may be required for data analysis or to monitor the lidar's stability. Recommended practices are given in *RP-15, RP 8: 'Device levelling'* and *RP-15, RP 9: 'Tilt sensors on the RSD'*.

2.8 Time synchronization

Using data from multiple sources (for example, a wind lidar and a traditional tower) is only possibly if they are time-sychronized. See *RP-15 RP 10*.

2.9 Power supply

Many wind lidar devices will be deployed remotely. Recommendations on how to choose a stand-alone power supply option for such situations are given in *RP-15, RP 11: 'Design of remote power systems'*. Remote power systems that have any kind of on-site fuel require special care and preparation. See *RP-15, RP 12: 'Fuelled remote power systems'*.

2.10 Protection from interference

Like any unattended equipment, care should be taken to protect a ground-based lidar from interfer-

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ence. See *RP-15*, *RP 13: 'Protection from interference'*.

2.11 Safety signs and interlocks

The need for safe operation and signage is covered in *RP-15*, *RP 14: 'safety signs, interlocks and operation'*.

2.12 Function check

It is important to check that the lidar is working properly before being left unattended. A checklist was suggested in *RP-15*, *RP 15: 'Function checklist'*. These checks are still useful, but now might be implemented as part of automated tests by the lidar.

2.13 Stakeholder-driven documentation

An installation report can add value to the final data set that is used in the wind resource assessment by reducing uncertainty. The user should check that the information in the installation report satisfies their stakeholders and considers future needs. Many vendors and third-party engineers provide templates to help collect this data. *RP-15*, *RP 16: 'Installation report'* also suggests a list of things to include in an installation report.

3 Operating wind lidar

3.1 Communications

RP-15 gives recommendations for how to provide remote access to a wind lidar (*RP-15*, *RP 17: 'Remote access to the RSD'*).

3.2 Deployments in cold climates

Wind lidar can be deployed in cold climates. Lidar may be easier to keep operating in icing conditions than cup anemometers, while lidar and met towers could be used together to increase data availability.

There are no existing best practices for lidar deployments in cold climates. Care should be taken to work with lidar suppliers to plan the deployment and obtain any equipment recommended for low temperatures such as heaters, insulating blankets, or protective tents. Users can mitigate the effects of snow by preparing platforms to raise the lidar above the ground, and should use appropriate washer fluid.

IEA Wind Task 32 and Task 19 started a joint effort in 2020 to share and document experience in using wind lidar in cold climates. Results are expected in 2021.

3.3 Servicing and maintenance

Like all wind measurement devices, wind lidar may require maintenance from time to time. Recommendations for how wind lidar users and suppliers can work together to ensure reliability and repeatability are provided in *RP-15*, *RP 23: 'Recommended service intervals'*.

3.4 Operation and maintenance log

Users should log all use and maintenance of the lidar. See *RP-15*, *RP 24: 'Operation and maintenance log'*.

4 Remote sensing data analysis

4.1 Wind speed and vector

It can be helpful to save data wind lidar data at different steps in the internal data processing. Recommendations for what data to store are given in *RP-15*, *RP 25 – 27: ''*.

4.2 Turbulence intensity

Sometimes, lidar users wish to collect turbulence intensity (TI) data as part of a wind resource measurement campaign. These might be used to judge the suitability of a site for a specific wind turbine, or to establish the site class according to a standard. TI data can also be obtained from cups, models, and wind speed data, amongst many other methods.

Because wind lidar measures wind in a volume, there may be differences between the turbulence intensity measured by a wind lidar and that measured by a cup anemometer [see e.g., 5]. As with complex flows (§2.3), deriving turbulence intensity from wind lidar is therefore a device-specific challenge.

There have been efforts to create transfer functions for turbulence intensity, but their applicability and suitability is out of the scope of this document. Users should ask vendors or consultants for guidance.

There are ongoing industry initiatives to explore the use of turbulence data from wind lidar:

- The Consortium for the Advancement for Remote Sensing (CFARS, www.cfars.org) is testing several methods of processing wind lidar data to estimate the turbulence intensity that a cup anemometer would measure. Results are expected in 2020.
- DNV-GL initiated a joint industry project (JIP; see www.dnvgl.com) in 2019 to support acceptance and adoption of wind lidar for wind turbulence measurements. Results are expected from 2021.

4.3 Extreme gusts

Wind resource assessment campaigns sometimes aim to provide the data used to estimate extreme wind gusts. These data are required to assess the suitability of wind turbines for the conditions at a site. Extreme gusts can be measured directly [see IEC 61400-12-1 (2017) 3] or derived from other data.

Wind lidar and cup anemometers use different measurement principles and so extreme gusts measured by wind lidar can differ from those measured by cup anemometers. These differences are also device-specific. Therefore, users should engage with vendors and consultants if they wish to use lidar-derived data to estimate extreme gusts.

5 Verification of remote sensing devices

Verification is the act of quantifying the performance of a device against a reference. Like cup anemometers and other measurement devices used in the development of wind energy facilities, the verifi-

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cation of a wind lidar should be driven by the user's requirements (see *RP-15 Section 1.7 "A note on 'bankability'"*). Verification can therefore take many forms:

- Most lidars are checked by the manufacturer before delivery to customers. This can take the form of a short measurement campaign where the lidar measures winds near a reference anemometer mounted on a tall tower. A comparison of the results shows if the device is performing as expected. This comparison could be carried out according to the IEC 61400-12-1 (2017) standard [3]. Alternatively, the lidar can be placed next to another lidar that is regularly compared to a cup anemometer on a mast. These pre-delivery tests are the same concepts as those offered for cup anemometers.
- Users who want to explore the performance of a lidar device could use the approaches set out in *RP-15 RP 30 – 40*. However, the process described in *RP-15* is unlikely to provide the information needed for an investment decision.
- Users who require more detailed information about the device uncertainty – for example as part of the financing package for a wind energy facility – might require an uncertainty certification according to the IEC 61400-12-1 (2017) standard [3].

These methods may give slightly different uncertainty estimates and the results may be treated differently by different stakeholders. Users should therefore work closely with stakeholders to ensure that they choose a verification approach that gives them an appropriate uncertainty budget.

Verification guidelines for remote sensing devices are being reviewed as part a new IEC wind measurement standard (IEC 61400-50-2), expected 2021.

Summary

Several groups have published guidance about the use of wind lidar for wind resource assessment.

Many of the recommendations made in the 2013 IEA Wind *RP-15* are still applicable in 2020, particularly in relation to general good practice when deploying, operating, and maintaining wind lidar.

Since 2013 the wind energy community has gathered a huge amount of experience in using wind lidar data. Some of this experience has been captured in MEASNET [2] and in the IEC 61400-12-1 standard for power performance measurements [3]. Also, stakeholders may have their own preferences. Therefore a lidar user should always work with their vendors and stakeholders to identify the appropriate solution for their use case. Such collaboration can significantly increase the value of lidar measurements.

Upcoming new IEC standards for resource assessment, instrumentation, and measurements – to be published in the 2020s – may in turn deprecate these documents. Similarly, coordination across the wind lidar community and wind-energy industry initiatives (Task 32, CFARS, DNV-GL, IEC, and others) may lead to convergence on methods.

Your feedback and comments

We welcome constructive feedback about this review and other IEA Wind Task 32 activities. Feedback about this review should be directed to the review's GitHub repository or to the Task 32 Operating agents.

We anticipate revising this document during the years 2021-2023 to reflect feedback and new developments. Check for revisions at http://dx.doi.org/10.5281/zenodo.3862384.

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IEA Wind Task 32 exists to identify and mitigate the barriers to the deployment of wind lidar for wind energy applications.

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