WindCube®
Siting recommendations for the highest quality and performance

Solutions Brief

1. Windcube Overview

WindCube is a Doppler lidar that uses pulsed laser technology to measure ambient wind conditions. The lidar sends invisible, infrared laser pulses into the atmosphere. Four beams are sent successively in four cardinal directions along a 28° scanning cone angle, followed by a fifth, vertical beam. Laser pulses are backscattered by aerosols in the air (dust, water droplets, pollution, etc.) that move at the speed and direction of the wind. The collected backscattered light allows for the calculation of wind speed and direction by measuring and comparing the Doppler-induced laser wavelength shift. Up to 20 different range gates can simultaneously be measured using the laser pulse time of flight allowing for measurement of the wind speed at 20 different heights. A dedicated signal processing algorithm computes wind vector component from the five consecutive line-of-sight measurements.

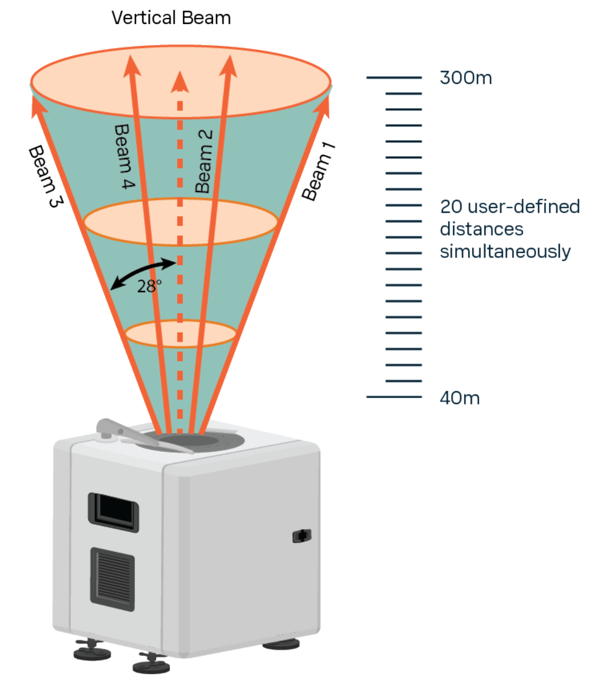


Figure 1: WindCube beam path angles and measurement ranges

2. General Guidelines

These general guidelines are relevant for WindCube deployments in any location regardless of geography. For more details on deployments in moderately complex and very complex terrains, see "In complex terrain" section.

Beam paths

All five beam paths, or lines of sight (LoS), must have a completely clear view to the sky. Figure 1 shows the beam path pattern and the critical angles to be aware of. Each of four radial beams diverges from the lidar window at a half angle of approximately 28°, while these radial beams are positioned at 90° intervals along the circumference of a circle. The fifth, vertical beam aims directly at the zenith.

The User Manual describes how you can ensure there is no blockage of any individual beam by checking carrier-to-noise ratio (CNR) for each line of sight, updated in real time.

Avoid siting WindCube in a location where a change in the natural or built environment could occur and block one or more beams intermittently or permanently. Examples include tree branches that could sway in the wind and disrupt the lidar measurements in certain wind conditions or met tower guy wires that might sag over time and partially obstruct a beam path.

Generally, it is a good practice to place WindCube at a safe distance, which is three times the height of the nearby natural or built object. This is done to avoid any obstacles in the beam path and maintain the most homogeneous flow possible to properly measure wind speed and direction. For deployment near a met mast, please refer to the corresponding section.

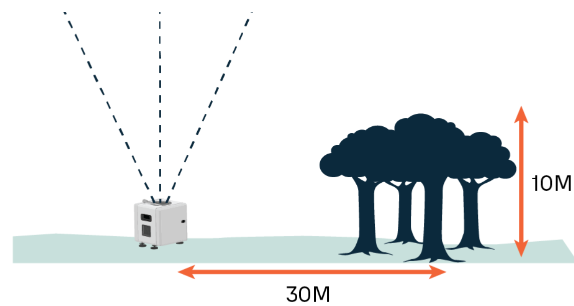
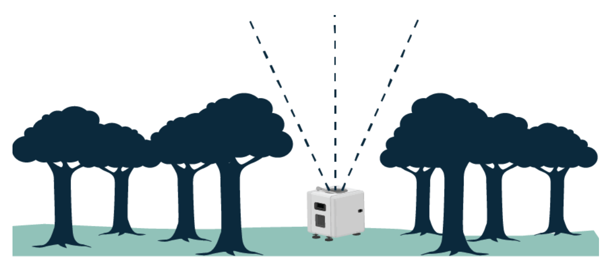


Figure 2a. WindCube deployment adjacent to a nearby obstacle – This graphic is showing the acceptable distance of the lidar to a 10m obstacle



Obstacle Height	Setback distance
5m	15m
10m	30m
15m	45m

It is not recommended for physical objects to be located within the cone of measurement. However, it is possible to successfully deploy a WindCube under certain circumstances in which a fixed object is within the cone. The beams themselves have a very narrow diameter (a few centimeters at origin and narrowing to millimeters at 100m height). It is then possible to orient WindCube to avoid obvious, fixed obstructions between beams. Examples include met tower co-locations within small clearings, in other constrained footprints in urban environments, or near overhead power lines. Still, use extreme caution and diligence when considering deployments of this sort.

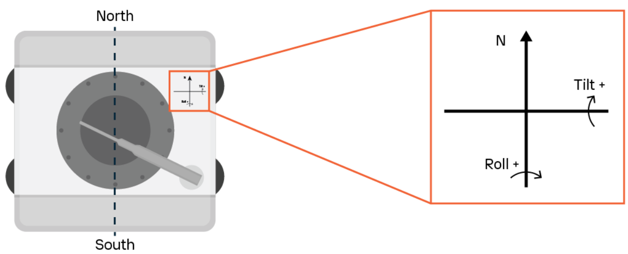


Figure 3: Directional orientation — Directional orientation should be measured from one of two non-door sides of WindCube enclosure.

Orientation

To retrieve wind direction correctly, the lidar should be aligned to magnetic north (the direction that a compass needle points). If the installation site does not allow you to orientate WindCube to the north or if you like to use the true north value (also called "geographic north," i.e., the direction toward the North Pole), you can configure a direction offset (e.g., to avoid beam path blockage or ensure the correct use of the Flow Complexity Recognition (FCR) algorithm).

Lidar orientation should be measured, fine-tuned, and recorded off of one of the non-door sides of a WindCube enclosure with a handheld or laser compass (see Figure 3).

Please refer to the User Manual for specific instructions on programming a direction offset into the WindCube Insights (Windweb) software to account for magnetic declination or other site constraints.

Installation offset

Software update v2.2.1 features a new setting that can be considered in your installation. By default, WindCube's zero-meter vertical reference is its feet. This reference can be changed by configuring an installation offset in the configuration tab of the WindCube Insights — Fleet software (see the screenshot of the software below).

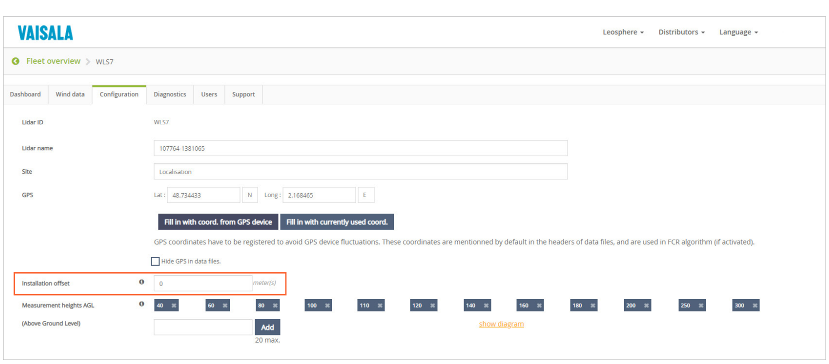


Figure 4: Recording of the Installation offset in WindCube Insights (Windweb) — Use the Installation offset line to configure the necessary offset

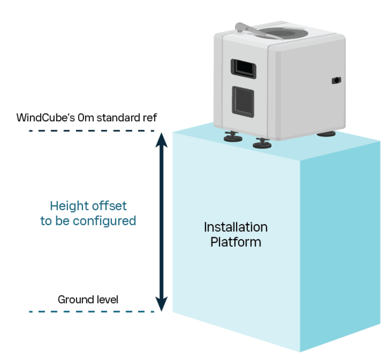


Figure 5: WindCube installed on a platform (schematic) — Installation offset is needed if the lidar

For example, if WindCube is installed at the top of a platform, you must measure its height before configuring measurement heights of the lidar and then configure the installation offset. If you are configuring the lidar to measure at 100m, and it is placed at 2m above the ground level, and if you haven't set the installation offset, the lidar will measure wind speed at 100m + 2m. By setting the installation offset of 2m, WindCube will automatically measure 2m below the desired height.

The minimal distance of measurement height is 40m from the lidar feet and can't be changed. If your lidar is installed at 2m, the minimal distance of measurement will be 42m.

Leveling and maximum accepted tilt/roll

Proper leveling during setup is critical to achieve high quality data during the measurement campaign. It is equally important, however, to install WindCube on a sturdy platform (such as concrete, or a hard platform made of metal) or ground location that is unlikely to shift over time.

During site setup, be sure to check the values on the internal tilt/roll sensors (i.e., inclinometer installed in the optical head of the lidar) via a client PC.

This will ensure the most accurate tilt/roll measurement. The tilt and roll values reported in the software are measured directly from the optical head of the lidar and should be considered very accurate. The window surface of the lidar should not be used as a reference for leveling except in a very coarse manner; make any fine adjustments using the software-reported values. In any case, tilt and roll should be set between 0 and +/- 1°.

Refer to the User Manual for specific instructions on leveling WindCube (feet adjustments and software use).

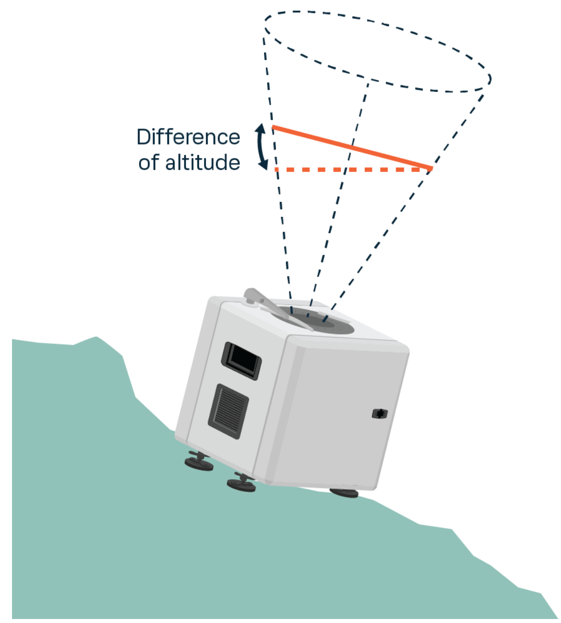


Figure 6: Leveling guidelines — A proper and consistent ground level is mandatory to keep the same altitude on both sides of the scanning cone and record accurate data.

3. Siting guidelines by location

Figure 4: Recording of the Installation offset in WindCube Insights (Windweb) — Use the Installation offset line to configure the necessary offset

Greenfield installations

The benefit of remote sensing devices (RSD) is the possibility to discretely deploy them in nearly any remote greenfield area. In fact, these kinds of installations are very common as future wind farms are often constructed far away from the nearest cities or settlements. In this case or in any other location in general, it is important to ensure a reliable remote power supply and security to the lidar. Hence, we recommend securing the area around the lidar with a fence. More information on security, power supply, and geofencing can be found in the "Special considerations" chapter.

WindCube should be attached to the ground using its fixing ring, a padlock, and chain. Lidar comes with a water tank that we also recommend fixing. It is a good practice to have at least 1x1m space around the lidar to properly manipulate it and have easy access to both doors of the system. Additionally, check the 3G/4G connection to be able to access the lidar data anytime, anywhere.

Figure 8: Example deployment adjacent to a met tower — Example deployment to perform WRA in Laos. The lidar is offset a few meters from outermost guy wire anchor. Beam CNR was closely checked during setup to confirm no guy wire interference. Photo courtesy of Impact Energy Asia Development Limited (IEAD).

Near a met tower

Met masts can be considered as "special obstacles" because of their nature (low impact on wind flow) and use (installed to monitor wind speed). This section supersedes Chapter 2's recommendations on obstacles. If your goal is to compare lidar measurements to mast measurements for validation or calibration, it is best to locate the lidar as close to the met mast as possible to ensure consistency in data analysis. In this scenario, precautions should be taken on lidar orientation so that none of the beams intersect with the tower or guy wires.

WindCube can be installed adjacent to measurement towers. In simple terrain and where space allows, we recommend locating the lidar outside of the guy wire footprint and at a slight offset (or directional rotation) to avoid guy wires as well as the tower itself.

For best performance, locate the lidar and its beam paths to avoid any wakes from the measurement tower or its guy wires. In general, a minimum distance of 5m is acceptable for 80m masts, but if the tower structure is taller, then a larger distance is required. Note this recommendation applies for the measurement heights of the vertical profiling lidar (below 40m lidar can be installed closer to the met mast).

Installation offset can also be used if you need to compare WindCube data to the met mast. You can add an offset so that the zero-meter vertical reference is the same as the one on the met mast (see "Installation offset" section for more details).

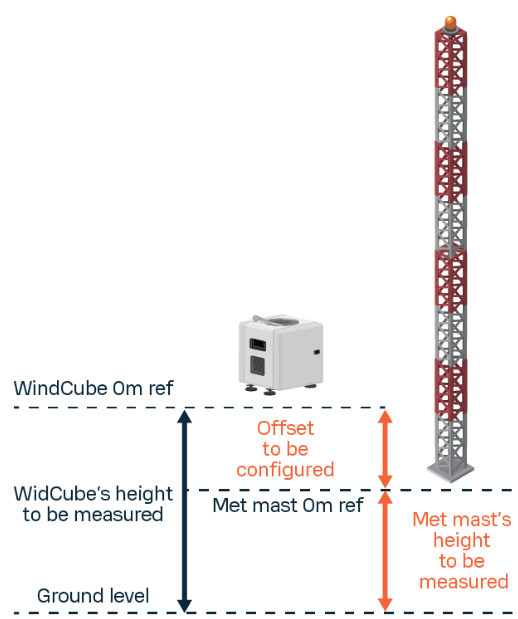


Figure 9: WindCube installed near a met mast (schematic) — Recommendations on how to configure the offset when lidar is co-located with a met mast.

Figure 10: Example deployment within an operating wind farm in China — Photo courtesy of Longyuan Power.

Within an operating wind farm

WindCube units are often used within operating wind farms to measure power curves, for permanent wind monitoring or wind turbine wakes. For Power Performance Testing (PPT) purposes, WindCube should be located approximately 2.5 turbine rotor diameters in the upwind prevailing wind direction relative to the turbine under test and sited with special care next to any nearby met towers. It is possible to place the lidar closer to the turbine but is not recommended due to induction zone effects from the turbine itself.

Wake measurements are also possible with WindCube lidars, although wakes are optimally captured by scanning lidars and/or nacelle-mounted lidars rather than ground-based vertical profilers such as WindCube. WindCube's expanding measurement cone and assumption of horizontal homogeneity in the wind flow both make the absolute characterization of turbulent, heterogenous wake structures difficult to achieve, although a certain level of observation is still feasible.*

* The 2011 Crop/Wind Energy Experiment (CWEX) undertaken by NCAR, University of Colorado, and Iowa State University researchers provides an important example of what is possible to observe with WindCube-based wake measurements.

Figure 11: WindCube Offshore deployed on a buoy — The sunshade helps protect the lidar window against solar radiation, dejection, and splash in offshore deployments. Photo courtesy of Akrocean.

Coastal and offshore locations

WindCube Offshore is designed to withstand the corrosive effects of marine atmospheres and has been reinforced to operate for extended periods in harsh sea conditions (salt water, humidity, and bird presence), hence is suitable for deployment at coastal and offshore sites without special protections. The equipment is adapted for harsh offshore environments such as floating buoys, substations, and vessels.

Consider mounting the sunshade and bird spikes on top of WindCube window where solar radiation, soiling from birds, and wave impacts are a concern. Vaisala supply this hardware upon request.

Carefully consider standard siting rules for offshore installation, especially on small offshore platforms that may also host a measurement tower close to the lidar. It is always better to physically rotate the lidar and apply a direction offset in the software than risk interference with a fixed object and any of the radial lines of sight. Fixed offshore installations on lighthouses, jack-up vessels, or offshore platforms also provide an opportunity to deploy the lidar with a remote power supply solution.

In complex terrain

Remote sensors assume horizontal homogeneity of the wind flow when computing horizontal wind speed and direction across the volume of air that is measured overhead.

Complex topographies introduce variances in which flows become more heterogeneous and complex in nature. This effect can lead to measurement errors typically ranging from zero to 5% bias. There are various methods to mitigate the potential effects of complex terrain-induced bias in the lidar measurements.

To tackle this challenge, Vaisala has developed the WindCube Complex Terrain Ready offering, comprised of different modeling tools and consultation services to help determine the best method based on terrain type.

First, for moderately complex terrain, a simplified CFD model integrated within WindCube, Flow Complexity Recognition (FCR), is enough to provide accurate measurements. FCR is an algorithm that associates the 10-minute average measurement of WindCube with fluid mechanics equations to determine the wind velocity (i.e., wind speed and wind direction) for a given terrain topography. It embeds a 3D wind field model for complex terrain, which has been configured to produce a mass consistent wind field using data from the lidar.

For more complex site, full CFD software is the best post-processing tool. Vaisala works with strategic partners who offer lidar correction services, either to perform the correction or directly obtain the correction factors. All of their CFD correction offerings have been tested and validated for WindCube.

The general process for planning a complex terrain deployment:

1. Determine the potential impacts of terrain-induced flow complexity
2. Deploy WindCube accordingly, respecting specific hardware and software setup recommendations
3. Decide on mitigation efforts to reduce measurement errors

Step 1: Determine the potential impacts of terrain-induced flow complexity

First, review the classifications for terrain complexity. Below we provide simple guidelines to determine when to use FCR data or CFD post-correction:

Terrain situation	Site criteria	Solution
Simple terrain	Slopes of max 5°	WindCube Standard
Moderately complex terrain	Slopes of max 15° (preferably non-forested sites)	WindCube FCR or CFD post-processing
Very complex terrain	Slopes over 15°	CFD post-processing

In addition, for more precise estimation of measurement error, Vaisala developed an advanced experimental Complex Terrain Estimator tool. This Estimator, which utilizes the hypothetical lidar location and surrounding terrain as well as a neural network made from an internal database of lidar-measured accuracies in real-world complex terrain deployments, can provide both insight on expected measurement error and suggest alternative measurement locations within a project area to minimize the error (Touzeau and Mazoyer [Vaisala], 2016). This Estimator can be applied on request by Vaisala experts.

Step 2: Deploy WindCube accordingly

Based on decisions made during Step 1, you may want to optimize the location of WindCube to reduce the initial error induced by heterogeneous flow. For example, locate the lidar further from a ridgeline, or orientate the lidar with two beams roughly parallel to a ridgeline terrain feature rather than aligned exactly to north/south.

Step 3: Decide on mitigation efforts to reduce measurement errors

Based on estimates of potential impacts identified in Step 1, establish a mitigation plan in advance of the lidar deployment. The two leading methods for addressing lidar measurement error in complex terrain are:

a. FCR — An add-on software algorithm that works in real time to generate a resolved “complex terrain” dataset. FCR has been evaluated by numerous third parties over a decade of use and is proven to minimize bias and reduce uncertainty in moderately complex terrain deployments. The modified approach to assumption of follow homogeneity used in FCR is described in Figure 11. Please contact Vaisala for further technical or commercial information on FCR.

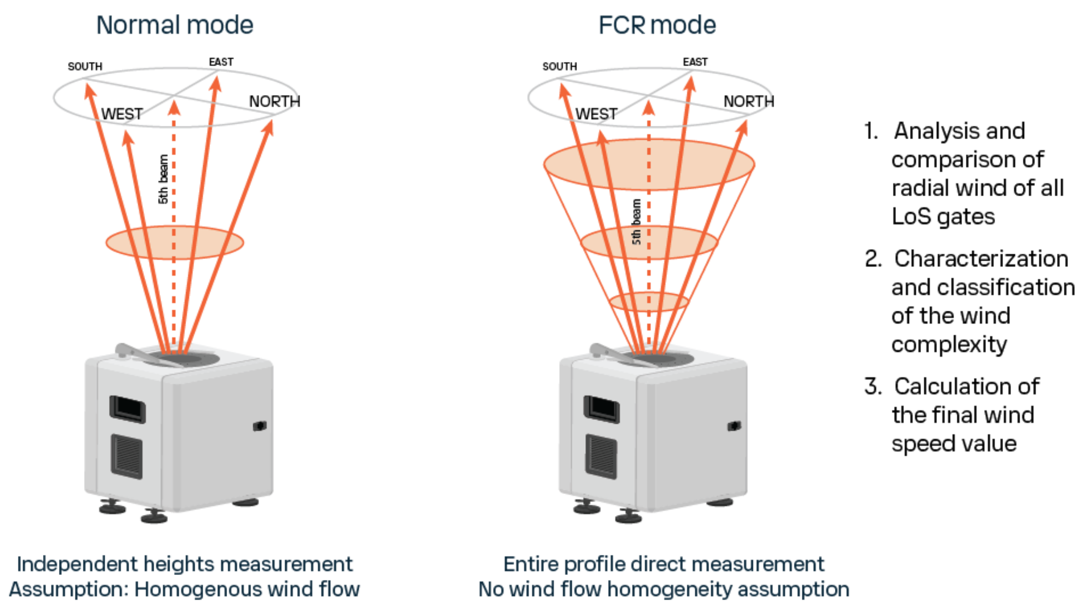


Figure 12: Normal vs. FCR measurement modes

b. CFD post-processing software is also a useful tool for managing terrain-induced measurement error in lidar measurements. Commercial CFD models, including Meteodyn, WindSim, ZephyTOOLS, and service providers such as ArcVera, Deutsche WindGuard, DNV, Fraunhofer IEE, UL, and K2 Management offer lidar correction tools and methods for post-treatment of lidar data that was collected using the “normal mode” algorithm without the FCR mode algorithm. Contact Vaisala to learn more about our strategic partnerships with industry leaders.

NOTE: The wind energy industry strives to minimize measurement uncertainty; however, the tolerance for measurement error may differ, for example, between early-stage qualitative site prospecting and later-stage measurement for quantitative energy assessment purposes.

The industry acceptance of lidars in complex terrain

The use of lidars in complex terrain is becoming a regular practice with standardized application guidelines. Several wind expert groups have reported their recommendation and indicated their acceptance level:

- The German guidelines for WRA, FGW TR6, enable the use of lidar standalone in complex terrain with FCR or CFD post-processing.
- The MEASNET guidelines for WRA require a preliminary short-term correlation with an on-site met mast before deploying the lidar standalone at any location of the wind farm project.
- The IEC 61400-15-1, the upcoming IEC Standard for WRA, is foreseen to enable standalone lidar in complex terrain.
- The CFARS, a large consortium of industry experts, has positively reviewed the correction solutions available for lidars in complex terrain.
- Several consultants now provide guidance on calculating measurement uncertainties in complex terrain after correction.

To learn more, see the WindCube Complex Terrain Ready solutions guide.

Figure 13: Urban WindCube deployment — WindCube v2 deployment at VisionPlus Korea.

In an urban environment or near buildings

For deployments in urban environments or near buildings, follow the same precautions regarding beam blockage, orientation, and leveling as with siting in all other locations. Built landscapes create complex wind flows that may not be homogenous in structure: Take extra care in interpreting volume-averaged data from any vertically profiling remote sensor situated in such an environment. In this kind of environment, FCR or CFD corrections are recommended to improve accuracy (more on FCR and CFD solutions in the "In complex terrain" section).

4. Extreme weather recommendations

Figure 14: WindCube deployment in cold weather conditions — WindCube after a storm in Spain. Courtesy of Barlovento Recursos Naturales.

Cold weather

WindCube lidars have been successfully deployed in the far northern latitudes of the world as well as locations with heavy and persistent winter snowfall (e.g., Nordic countries, North America, Japan, etc.).
Proper precautions are critical for long-term unattended operation with high data recovery.

Temperature

While WindCube reliably operates through temperatures of -30°C onshore or even lower without risk of damage, the device should not be cold soaked (i.e., stored without power connected) at temperatures below -10°C. Cold soaking will not cause damage, but it can expand the initial warmup phase up to several hours as critical components warm up to operating temperature. When possible prior to a cold weather deployment, store and transport the lidar in a heated or semi-heated cabin or bring it into a garage or other indoor storage area the night before to avoid cold temperature extremes.

Snowfall

WindCube lidar does an excellent job of handling light and occasional snowfalls without any special adaptations. If a heavy winter snowpack is anticipated, then the lidar should be placed in an elevated position atop a platform or table, ideally above the expected snowpack height. This will allow for easier winter access if needed and ensure the entire lidar doesn't become buried in snow.

Winter kit, supplied by Vaisala upon request, is designed to safeguard WindCube in harsh winter conditions in the areas subject to heavy snow events. it also ensures continuity of lidar's technical availability.

Hot weather

WindCube is well adapted for hot weather deployments thanks to its efficient design. Daytime high temperatures up to 50°C are within the acceptable limits of operation. Temperatures above 50° may trigger temporary shutdowns of internal components to prevent damage.

To minimize the chances of high-temperature shutdown:

- Make sure both side vents are free of any obstructions
- Elevate the lidar at least 1m off the ground to lessen the effects of ground-level heat absorption and radiation, and to allow for more radiational cooling due to increased winds
- Use additional protection for the lidar such as sunshade to avoid overheating of the system. Vaisala can supply this hardware upon request (see Figures 15 and 16)
- Install a cooling system. In Figure 17, our Brazil-based partner Hobeco has installed the lidar using its own trailer and power pack solution, which is based on off-grid photovoltaic panels. The system has enough energy storage capacity to keep WindCube running for up to five days without solar energy generation and the cooling system helps the lidar withstand most adverse weather conditions
- Consider secure site installations to avoid dust and insects disrupting the lidar performance

Figure 15: Sunshade atop of WindCube unit installed on a trailer in the desert — Sunshade and trailer installations reduce the exposure of the lidar to direct solar radiation.

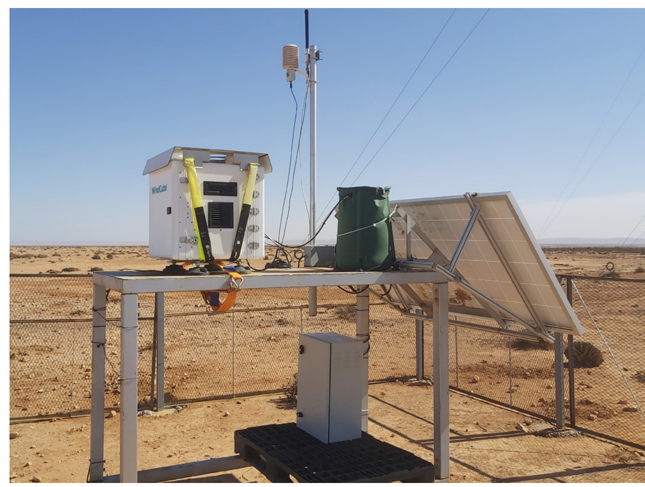


Figure 16: WindCube deployment in Morocco — Lidar is deployed with a sunshade to ensure stable performance in extreme weather conditions such as deserts.

Figure 17: WindCube integrated in a trailer with a cooling system attached to the lidar — Photo courtesy of Hobeco.

5. Special considerations

Power system

A robust power system or grid connection is essential for any WindCube deployment. The optimal solution for power pack operations strongly depends on the local climate, the system relocation, and the desired autonomy.

Vaisala offers lidar power systems appropriate for most regions through several partnerships with power pack providers. In addition to the worldwide established partnerships, WindCube comes with a standard power supply system. The ProCube is a plug-and-play solution powered by two sources of energy: a direct methanol fuel cell and a solar panel. This energy is then stored in batteries. Vaisala can supply the ProCube solution upon request.

WindCube units have been powered over the years and across continents and latitudes by a wide range of technologies. Today, there are several technologies available to suit your project best:

Methanol fuel cell: compact and environmentally friendly power solution

Solar panels: usually used in addition to a power solution mentioned above to increase autonomy

Diesel: In countries where methanol fuel cells are not allowed, you can use other solutions such as diesel, propane, and gasoline which can be offered by our local partners.

Power systems are optimally designed for worst-case load and resource conditions (typically the coldest and darkest times of year), with the highest level of autonomy possible.

If you plan to design your own WindCube power system or source a power system from a third-party vendor, please consult with Vaisala or our local partners. This will allow us to help ensure the system is sized properly for year-round use in the intended location and is fully compatible with the lidar.

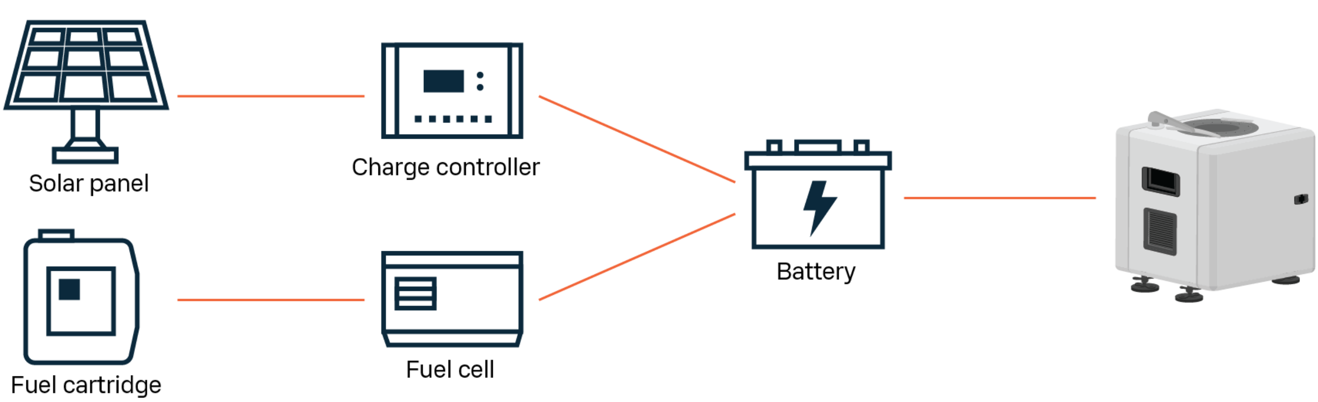


Figure 18: EFOY ProCube remote power supply solution

Considerations for using your own power source

If you plan to design your own WindCube power system or source a power system from a third-party vendor, please consult with Vaisala first. This will allow us to help ensure the system is sized properly for year-round use in the intended location and is fully compatible with the lidar.

Essential steps to consider:

1. Anticipate what power supply you will use during the lidar operation and be fully prepared before the WindCube is delivered, especially if the installation timeline is short. Power supply cables adapted to most countries are available to be delivered with WindCube. They will be selected based on the delivery location. Please precise in your purchase order if a specific cable is needed.
2. Distance to the power supply is important. The WindCube is delivered with a 12m IP67 AC/DC power converter and a 10m IP66 DC/DC power converter. If your power source is located further away, prepare for the deployment in advance.
3. WindCube works on low voltage. For example, a wind turbine delivers high voltage power, so you must use a converter for safe and correct performance of the lidar.
4. The power supply should be stable. Consider using battery backup in the case of an intermittent energy power source (e.g., solar panels, wind turbine).
5. An AC/DC converter works better for long distances.
    a. AC/DC power: wind turbines, electricity grid
    b. DC/DC power: solar panels, fuel cell

Disclaimer: Country regulations vary. Carefully follow local regulations regarding power supply requirements.

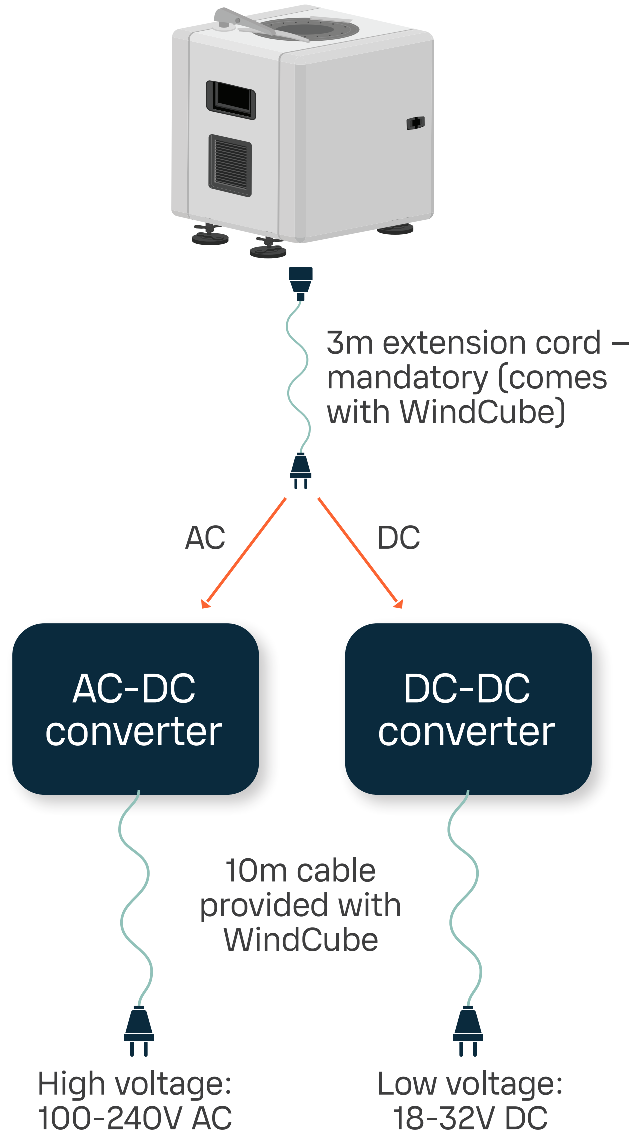


Figure 19: Prepare your site in advance if the power source will be located further than 10m away from the anticipated lidar installation.

Security and safety

Safety

Grounding WindCube and PTH is required for safety and protection against lightning damage. It is recommended to secure the lidar and the water tank to prevent any movement or theft (Figure 20).

Additional solutions, such as geofencing and trailers, are recommended to ensure safety and proper performance of the system.

Geofencing

Vaisala can provide the geofencing solution, which allows users to define an authorized area where WindCube is deployed. In case of the system movement outside of the authorized area, the geofencing system sends alerts to inform the user and help to localize the device. Vaisala can supply a geofencing solution upon request.

Trailer installations

WindCube lidars can also be integrated within a trailer solution, especially in greenfield areas, for additional security and mobility. Some of our clients prefer trailer installations as they provide the possibility to safely integrate a remote power supply solution together with the lidar. Trailers can host additional equipment (e.g., water tank, PC) and act as a protection against extreme weather conditions (cold and hot climates), theft, and animals.

Some of our partners provide their own trailer solutions. In Figure 21, our German partner GWU has built a trailer and power pack design. It contains solar panels, methanol fuel cell, and battery solution to provide electricity to the lidar all year long.

As much as possible, Vaisala can share details about trailer solutions available and facilitate the access to our customers.

In Figure 22, we have another installation example of WindCube powered by an eco-friendly and reliable solar trailer for mild and moderate locations (with options for harsher climates). In this setup, a box trailer design provides extra security and storage for maintenance tools and your lidar transport case. More information on this trailer solution is available upon request through Vaisala Boulder.

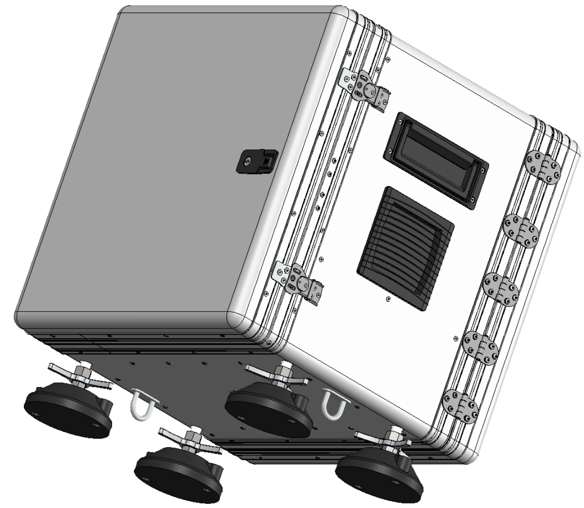


Figure 20: To prevent theft, we recommend chaining WindCube to its anchors

Figure 21: WindCube v2.1 and power supply solution integrated in a trailer — Photo courtesy of GWU.

Figure 22: WindCube deployed with a solar PV + trailer solution to perform WRA in Texas, USA

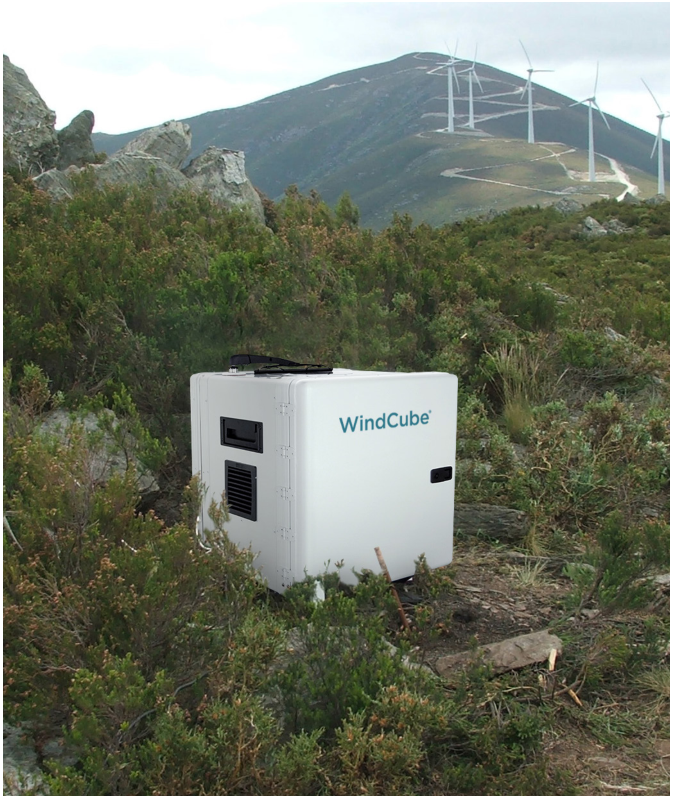
Lidar campaign recommendations

Proper and timely preparation of lidar field deployment is important to ensure a successful wind measurement campaign. Vaisala shares the following (non-exhaustive) list of recommendations.

Vaisala Quick start L1 training	Basis of lidar technology, installation and routine maintenance Includes site-specific recommendations Installation can be performed by Vaisala or by our trained local partner
Benefits from Vaisala's pre-campaign assessment tools that help you with your lidar deployment	Data Availability and Range Estimator Complex Terrain Estimator
Choose lidar location	Take into account distance to obstacles, including met mast
Consider lidar security	Fence installation Vaisala offers geofencing solution
Consider power supply	AC or DC connection Various autonomous power supply solutions, including power packs or trailers supplied by our local partners
Communication: make WindCube data accessible	Local network (LAN) or check for 3G/4G or satellite coverage Prepare an associated SIM card
Special considerations	Winter kit can be supplied by Vaisala for cold climate deployments Installation under tent or in cooling trailer is recommended for hot climates Complex terrain: Activate FCR for moderately complex terrain, or prepare for a full CFD correction in very complex sites
Maintenance plan	Monthly visits Preventive maintenance by Vaisala or by our trained local partner

For additional support

- WindCube User Manual
- WindCube Insights - Fleet software
- Technical expert and scientific support from Vaisala
- Quick start: L1 training (installation, routine maintenance operations, and basic failure diagnostics)
- QR code on your lidar and shipping box to further support you with installation tips and good practices
- Free online refresher course (MOOC) is available for existing clients to update your knowledge on how to manipulate and maintain the lidar as well as extend the L1 training certification for another year



Why Vaisala?

We are innovators, scientists, and discoverers who are helping fundamentally change how the world is powered. Vaisala elevates wind and solar customers around the globe so they can meet the greatest energy challenges of our time. Our pioneering approach reflects our priorities of thoughtful evolution in a time of change and extending our legacy of leadership.

Vaisala is the only company to offer 360° of weather intelligence for smarter renewable energy, nearly anywhere on the planet.
Every solution benefits from our 85+ years of experience, deployments in 170+ countries, and unrivaled thought leadership.

Our innovation story, like the renewable energy story, continues.

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