DOC245967-F

WindCube - Vertical Profiler Lidar

Product Information

WindCube v2.1- 2024/10/28

VAISALA

PUBLISHED BY

Vaisala France
Tech Park, 6A rue René Razel
91 400 Saclay, France
Hotline: +33 9 72 68 11 11
Fax: +33 1 81 69 29 79
Email: helpdesk@vaisala.com.

Visit our Internet pages at https://www.vaisala.com/en/wind-lidars/wind-energy

Table of contents

1. Prior notice

1.1 Prior notice – Introduction

Vaisala is a member of Vaisala Group, where Vaisala OYJ (a stock listed company at Helsinki's Nasdaq) is head of group company. Therefore, Vaisala as mentioned hereafter shall include any of its affiliates (including Vaisala OYJ as its mother company so as any other). For the sake of clarity, any mention to "Vaisala" refers irrespectively to Vaisala Group.

.

1.2 Confidentiality

The present document contains several Vaisala proprietary and restricted information which is released to a business or technical partner or Customer for a strict internal purpose. Its submission is performed under the frame of a strong duty of confidentiality so as any possible Non-Disclosure Provisions in force between the Parties and/or any affiliate of Vaisala Group (hereafter "Vaisala Group").

The disclosure of any information contained in that document is subject to Vaisala prior written approval.

1.3 Applicability with regard to Vaisala Group Terms and conditions

Provision 1.1 of Vaisala Group Terms and Conditions dated April 2021 (the "Vaisala TCs") states that "*Products, services, prices and other relevant information are set out in our quotation or acknowledgement of order. Products and Services, together with associated additional conditions, may be further detailed in Product specific documentation ("Product Information") and/or Service specific documentation ("Service Information") attached to our quotation or acknowledgement of order, or otherwise made available to you*."

For the sake of clarity, the present document shall be construed as the "Product Information" mentioned in that provision. In case of contradiction, the following documents shall supersede in decreasing order of priority:

- The quotation addressed to the Customer;
- Specific Conditions if relevant;
- The WindCube® Product Information (meaning the present documents);
- The WindCube® Technical Support and Service Information;
- Vaisala TCs.

1.4 Specific Conditions

Depending on business needs, Vaisala reserves the right to discuss and accept specific conditions which shall complete and supersede that Product Information (hereafter the “Specific Conditions”). In such a case, such Specific Conditions shall be materialized in a specific document (the “Umbrella Agreement”), which will integrate them so as any document to be attached to the sales contract.

2. Vaisala and Lidar technology

2.1 Vaisala company

Vaisala is the leading provider of ground-based and nacelle-mounted Lidar (Light Detection and Ranging) solutions. The company designs, develops, manufactures, sells and services new turnkey remote-sensing instruments allowing wind measurement and aerosol characterization.

Lidar technology is at the crossroads of several atmospheric environmental applications. Vaisala addresses four different markets:

- wind power
- air quality
- weather and climate
- aviation weather

For the wind industry, Vaisala has a unique product range allowing optimizing wind farm projects value at all stages, from development to operations and maintenance.

Table 1 Vaisala's products

WindCube® Vertical Profiler Lidar	WindCube® Offshore Vertical Profiler Lidar	WindCube® Scan Long Range Scanning Lidar	WindCube® Nacelle Turbine Mounted Lidar
			

Today with thousands of successful deployments, Vaisala has a large experience both offshore and onshore with solutions provided to the wind energy, meteo, airport, ... industries. Our customers and partners in wind industry are developers, turbine manufacturers, operators, owners, consultants, experts, service providers, finance groups and research organizations.

2.2 WindCube, Vertical Profiler Lidar

2.2.1 Lidar general principles

Lidar (Light Detection and Ranging) is a remote sensing technology using laser beams to measure the wind speed and direction.

Based on pulsed Doppler heterodyne laser principle, the Lidar sends a light pulse at high frequency in the atmosphere and observe the signal backscattered by aerosols naturally present in the air.

The time between the pulse and the detection of the backscattered signal is processed by the system thanks to the Doppler effect and provides an accurate measure of the wind speed and direction. This measure is based on a physical constant of high accuracy: light speed.

2.2.2 Advantages of Pulsed Lidar technology

Pulsed Lidars send Laser pulses at a very high frequency: tenths of thousand pulses are sent within 1s.

Light pulses are backscattered by aerosols and, from those received, Doppler shift is analyzed much before next Laser pulse is emitted. This avoids confusing time delays and distances. Therefore, probe distance, or height, only depends on the time it takes for a pulse to be received after it has been emitted.

Several technical advantages arise from Pulsed Lidar technology:

1. Multiple heights are measured simultaneously

- A complete wind profile is measured within the same time in 1s: the shear profile is “frozen” and accurately captured.
- More measurement heights does not impact the duration of measurement: a detailed wind profile is captured with no compromise on temporal resolution and thereby no decrease of accuracy nor data availability.

2. Spatial resolution is constant through the entire wind profile

- Constant probe volume of atmosphere leads to constant accuracy at all heights.
- Probe volume does not increase with measurement height: higher measurement ranges are possible.

3. Measurement is not affected by clouds, fog or high density of dust and sand particles, nor obstacles

- For Pulsed Lidars, only atmospheric conditions at measurement heights matter: measurement accuracy is not affected by light backscattered from other atmospheric layers. At one measurement height, “door is closed” to atmospheric conditions of any other layer.
- Measurement accuracy of Pulsed Lidars is therefore not sensitive to weather conditions or to varying density of aerosol layers. Pulsed Lidars maintain same accuracy under clear sky or presence of fog.

4. Pulsed Lidars directly measure accurately and unambiguously wind direction

- Pulsed Lidars accurately measure direction of each wind speed over the full 0-360° range.
- This ensures an accurate wind rose evaluation for a wind project, which is critical to design a wind farm and evaluate the project finance with the highest accuracy.

5. Pulsed Lidars can use a reasonable number of beams arranged within a flexible pattern

- A vertical beam is possible.

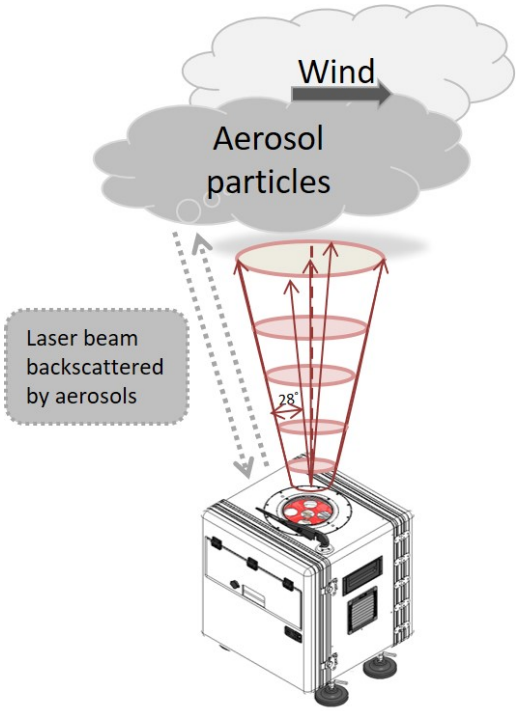
- Vertical beam provides a direct measurement of vertical wind speed, as well as serve advanced wind processing in complex terrain, or advanced techniques for Turbulence Intensity for instance.

6. Data recovery from Pulsed Lidars is not sensitive to wind conditions like shear and turbulence intensity

- Although measurement availability is impacted by very low aerosol density (this is the case for all Lidar types), data recovery of Pulsed Lidars is however not sensitive to wind conditions like shear or turbulence intensity thanks to its large Doppler spectra.
- Data recovery is therefore more stable and not sensitive to wind conditions which reduces the risk to bias the Energy Yield Assessment, and also easier to predict with simulation tools developed by Vaisala.

2.2.3 WindCube measurement principle

WindCube Lidar is used for wind profile measurement from 40 meters to 300 meters. Four beams are sent successively in four cardinal directions along a 28° scanning cone angle, followed by a fifth, vertical beam. Up to 20 different range gates can simultaneously be measured using the laser pulse time of flight. WindCube has been designed for ground-based applications for onshore environments. Offshore environments are also punctually possible but we recommend using our Offshore product version for offshore usage.



2.3 Applications

The WindCube now provides a 300 meters wind profile with 20 independently configurable measurement heights while being easy and quick to deploy or move. Such features allow its use for several applications at all stages of your wind energy project. More than 1000 WindCube Lidars are used globally today for wind resource and wind turbine performance assessment.

2.3.1 Wind resource assessment

Precise and reliable wind resource measurements are critical for developers to increase project value. The profitability of a wind farm directly depends on uncertainty reduction during the wind resource assessment and wind turbine optimization phases. These measurements provide the essential data used to calculate the potential energy yield from a project, which in turns dedicates the terms of the project financing.

Onshore, in standalone or in combination with traditional anemometry, a mobile Lidar collecting continuously 300 meters wind profile data is ideal to better characterize the wind resource and reduce project risk. By providing bankable data to investors and owners, the WindCube can make the difference between project success and failure.

On a wind farm project, uncertainty reduction can mean millions in equity investment savings and a significant increase in the rate of return. This makes the WindCube Lidar is therefore a valuable asset for developers, consultants, wind farm owners and operators.

2.3.2 Power performance testing

In order to assess the performance of a wind turbine, power curve measurements are usually performed. It allows measuring the correlation between the wind speed and the output power of the turbine and to compare this measurement to the contractual power curve.

Lidars are the equipment of choice for such measurement as it measures very accurately and along all the rotor the wind speed and wind direction. The low uncertainty of WindCube wind speed measurement translates directly into a low power curve uncertainty and a low AEP uncertainty.

2.4 Standards, guidelines and current industry practices

Following a long process of validations and proofs, the WindCube is accepted by all experts and various international standards and industrial guidelines already approve its use for different applications and terrains, in standalone or in complement of a met mast. Moreover, the WindCube has achieved full IEC 61400-12-1 Ed.2. compliance with independent third-party classifications.

Below is an overview of the most important existing practices used by WindCube users for bankable projects and contractual performance verifications. The table is summarizing which applications each standard is made for and its status. Of course, there are links between pre and post construction use: for example, IEC 61400-12-1 Ed.2. guidelines for power performance tests are already influencing wind resource assessment practices:

Standard	Application	Status
IEC 61400-15	Wind Resource Assessment	In progress
IEC 61400-12-1 Ed.2.	Power performance testing	Released
IEC 61400-50-2	Wind measurement - ground-mounted remote sensing technology	Released
IEA Wind recommends Lidar use for WRA	Wind Resource Assessment	Released
FGW Technical Guidelines for Wind Turbine PART 6: Determination of Wind Potential and Energy	Wind Resource Assessment	Released
Measnet: evaluation of site-specific wind conditions. Version 2. April 2016	Wind Resource Assessment	Released
DNV GL Stage 3 - Position statement	Wind Resource Assessment	Released
Ecofys position on Lidar use	Wind Resource Assessment	Released

2.4.1 IEC 61400-15 (in progress)

The scope of this forthcoming standard is to define a framework for assessment and reporting of the wind resource, energy yield and site suitability input conditions for both onshore and offshore wind power plants.

The framework will be defined such that applicable national norms are considered and industry best practices are used.

2.4.2 IEC 61400-12-1 Ed.2

IEC standard recommends the use of remote sensors to measure the performances of a wind turbine generator. The WindCube is a fully representative device able to characterize the turbine efficiency at the wind farms. The standard set up some rules in order to perform such analysis mimicking the role of an IEC met mast.

- Hub height wind speed is measured with WindCube and a small met mast (40 meters) allowing monitoring wind speed at low height.
- Measurement of shear and/or veer from multiple range gate of WindCube allows deriving the Rotor Equivalent Wind speed and gets less uncertainty in performances measurement.

- All environmental variables such as Turbulence Intensity can be measured with the WindCube and performances are normalized.

2.4.3 IEA Wind recommends Lidar use for WRA

IEA considers that “The deployment of remote sensing devices may provide wind project developers with useful information that can be used to reduce the costs associated with wind data collection at heights greater than can be achieved using traditional monitoring towers”.

To standardize the use of remote sensors and especially the WindCube, IEA standard describes a set of recommended practices to perform wind resource assessment.

2.4.4 FGW Technical Guidelines for Wind Turbine PART 6: Determination of Wind Potential and Energy Yield. Revision 9 (23/04/2015)

Known as TR6, the German guideline recommends the use of standalone Lidar either in simple or complex terrain for wind resource assessment projects and sets out some rules regarding the measuring range and data availability. According to TR6, measurements need to be performed at 2/3 of the supposed turbine hub-height and register very good availability. It was demonstrated that the WindCube is entirely compliant with those requirements as it measures at high distances (up to 300 meters) and register very good availability for heights under 200 meters.

Based on this evidence, the TR6 guideline agrees that the device can entirely replace a met mast in simple and complex terrains. For the latter, as the wind flow could induce errors in Lidar wind speed reconstruction algorithm, an embedded flow correction model such as FCR (Flow Complexity Recognition) is required and fully validated by TR6.

2.4.5 Measnet: evaluation of site-specific wind conditions. Version 2. April 2016

Measnet standard agrees on the proved technology of remote sensing devices and its growing performance to fully answer wind resource assessment projects expectations regarding costs, risks reduction and bankability: “... remote sensing technique like Lidar and SODAR have reached a stage, where they can be considered as supplement or as alternative to mast measurement in many case”.

In simple terrain, the WindCube can be used in standalone if the device was calibrated against an IEC met mast prior to the campaign. For complex terrains, the standard requires the use of Lidar next to a short met mast (40 meters) and also validates the use of FCR (Flow Complexity Recognition). Following these recommendations, the WindCube answers every type of wind resource assessment analysis from standalone measurement to vertical and horizontal extrapolation.

2.4.6 DNV Stage 3 Position statement

DNV developed a position statement regarding remote sensors devices indicating the amount of validation required in order to rely on data for energy assessment projects.

According to DNV, the WindCube is stage 3 (the highest level) for simple terrain measurements: “a device (here the WindCube) is considered proven for use in the assessment of wind farms sites. The data may be used quantitatively within formal wind speed and energy assessments with only limited or no site-specific validation against conventional anemometry”.

For complex flow, the WindCube is deemed to be stage 2: “Confidence is gained that the device provides robust, continuous and accurate data over the full spectrum of operational conditions. Alternatively, specific conditions where the device does not provide robust data become well understood and can be excluded from analyses”.

2.4.7 Ecofys position on Lidar use

Ecofys recommends the use of Lidar in the following configurations to improve bankability for better financing terms and reduced project risks.

- Standalone Lidar – in simple terrain the Lidar can entirely replace a met mast for wind resource assessment. It can also be used to characterize a site for instance evaluating the wind shear around forests.
- Lidar next to a short met mast – a cost-effective solution to evaluate the wind shear and extrapolate wind speeds at hub height.
- Lidar moved around the site complementing an on-site met mast – this helps to reduce the uncertainty in flow modeling. Also, shorter campaigns spread throughout the year help reducing seasonal effects.

3. WindCube product description

3.1 Specifications

MEASUREMENTS	
Measurement Range[1]	40m to 300m Constant measuring probe (spatial resolution)
Data sampling rate	1 Hz 10.000 measurement pulses accumulated every 0,8 seconds
Measuring distances	20 user defined distances simultaneously
Radial Wind Speed range	-23m/s to +23m/s
Reconstructed Wind Speed range	0m/s to 49m/s
Reconstructed Wind Direction range	0 – 360°
Speed accuracy[2]	0.1 m/s
Speed uncertainty[2]	40 – 80m: 1.4% to 2.6% 80 – 120m: 0.6% to 1.4% 120 – 135m: 0.6% to 0.8%
Direction accuracy[2]	2°
Beam geometry	4 inclined beams at 28° + 1 vertical beam

1) *Height from WindCube feet. Data availability depends on environmental factors such as visibility, type of aerosols and variation of refractive index in the atmosphere*
2) *For 10-min averages, as assessed by several 3rd parties on multiple WindCube devices or in 2020 according to IEC 61400-12-1 Ed.2. Uncertainty figures are Final Accuracy Class divided by √3*

OPERATIONS	
Warranty	5 years standard, extendable once (up to 10 years) after maintenance
Preventive maintenance	5 years cycle (factory or onsite maintenance)

ELECTRICAL	
Input Power Supply **Insulation class: class I (PE connected)**	24,5-27 VDC
Power Supply with the AC-DC converter provided by VAISALA	100-240VAC 50/60 Hz

ELECTRICAL	
Power consumption(1)	45W between -5°C and 30°C (23°F and 86°F) 110W below -5°C (23°F) 55W over +30°C (86°F)

1) Nominal power consumption taken from an initial state of the WindCube at 15°C.

ENVIRONMENTAL	
Temperature range(1)	-30°C to +50°C / -22°F to 113°F (chamber conditions)
Maximum altitude	Maximum operation altitude : 3000m (2000m with provided AC-DC converter)
Operating humidity	0 to 95% RH (non-condensing)
Rain protection	Wiper
Environmental Protection	Designed for installation in many kinds of weather and environmental conditions IP66 and IP67 (Inner sub-assemblies) IP54 (Lidar Casing) Radiation +1000W/m^2 at +45°C
Shock & Vibration	ISTA/FEDEX 6B
LASER Safety Compliance	1M Class / EN 60825-1:2014 + A11:2021
Marine atmosphere (Salt Atmosphere Compliance)	IEC 60068-2-11 (120 hours)
Compliance(2)	CE, FCC, IC

1) Starting the system at low temperature (lower than -20°C) will require to have the WindCube equipped with an adapted protection
2) As verified on WindCube without Geofencing option

TRANSPORTATION	
Size **Dimensions (L x W x H)**	554 x 566 x 554 mm (cube) 608 x 566 x 661 mm (system with feet and wiper)
Weight	59kg (system only) 28kg (shipping case only) 91kg (total with accessories)

SOFTWARE/DATA	
Complex terrain measurements	FCR unlimited license
Data storage	120 GB industrial disk (over 5 years storage of all data)
	WindCube Insights secured cloud-based server
Data file format	.RTD and .STA. (file), UTF-8 Encoding

SOFTWARE/DATA	
Communication	LAN, USB, 3G, or 4G router (router availability depends on the region/ country), Modbus® RTU, Wi-Fi
Time synchronization	GPS, NTP

OUTPUT DATA	REAL TIME DATA (.RTD, 1S)	STATISTICAL DATA (.STA, 1/2/5/10MIN)
Horizontal wind speed	✔	Mean, max, min and standard deviation
Vertical wind speed	✔	Mean and standard deviation
Standard deviation of wind speed values	✔	✔
Direction	✔	Mean
CNR (carrier to noise ratio)	✔	✔
GPS coordinates	One value per day, in header	One value per day, in header
Data availability		✔
Temperature, pressure, humidity (if PTH deployed)		✔

3.2 Hardware description

3.2.1 WindCube components overview

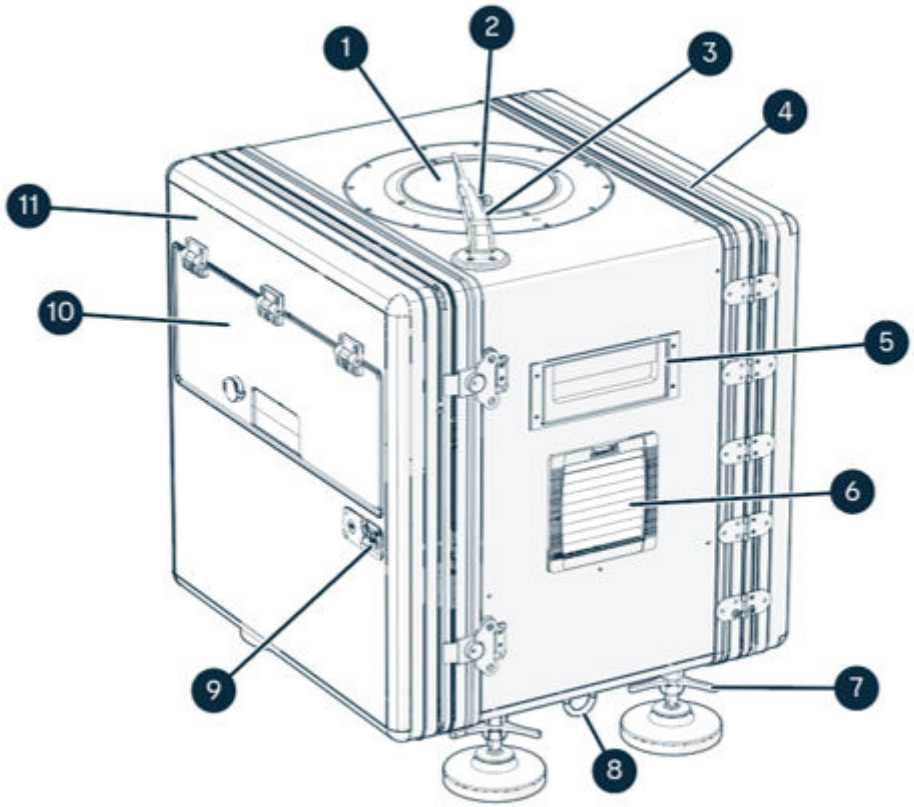


Figure 1 WindCube hardware description

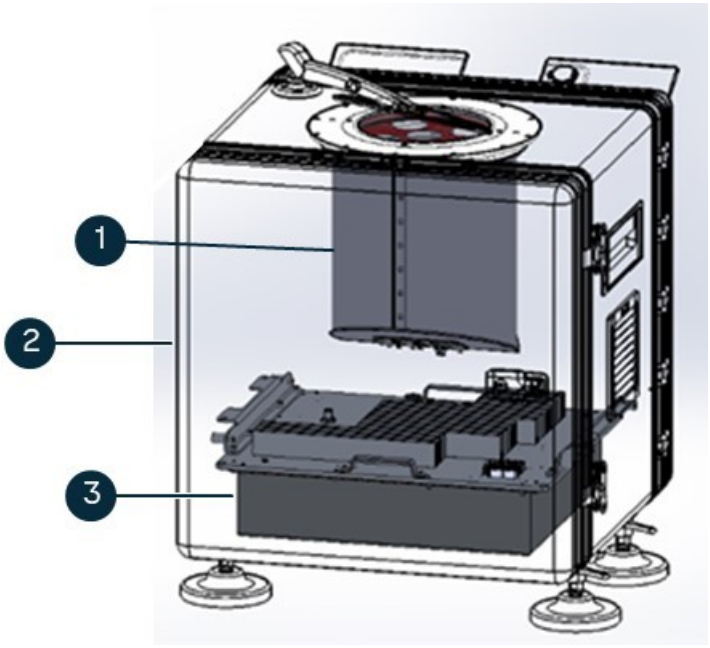
1 Window
2 Wiper blade
3 Wiper arm
4 Rear door
5 Handle
6 Fan vent
7 Fine adjustment feet
8 Fixing ring against theft
9 Door locker
10 Connection trapdoor
11 Front door

3.2.1.1 Architecture

The WindCube V2.1 is made of 4 main modules of components:

- Optical head
- Opto-electronic rack
- Casing
- Accessories

The core elements of the system are the Optical head and the Opto-electronic rack forming the Optical Chain. The two are connected with optical fibers. Regular maintenance is recommended to ensure the high-tech system performance and accuracy.



1 Optical Head
2 Casing
3 Opto-electronic rack

3.2.1.2 Connections

All available connections are at disposal and protected under the trapdoor of the front door.

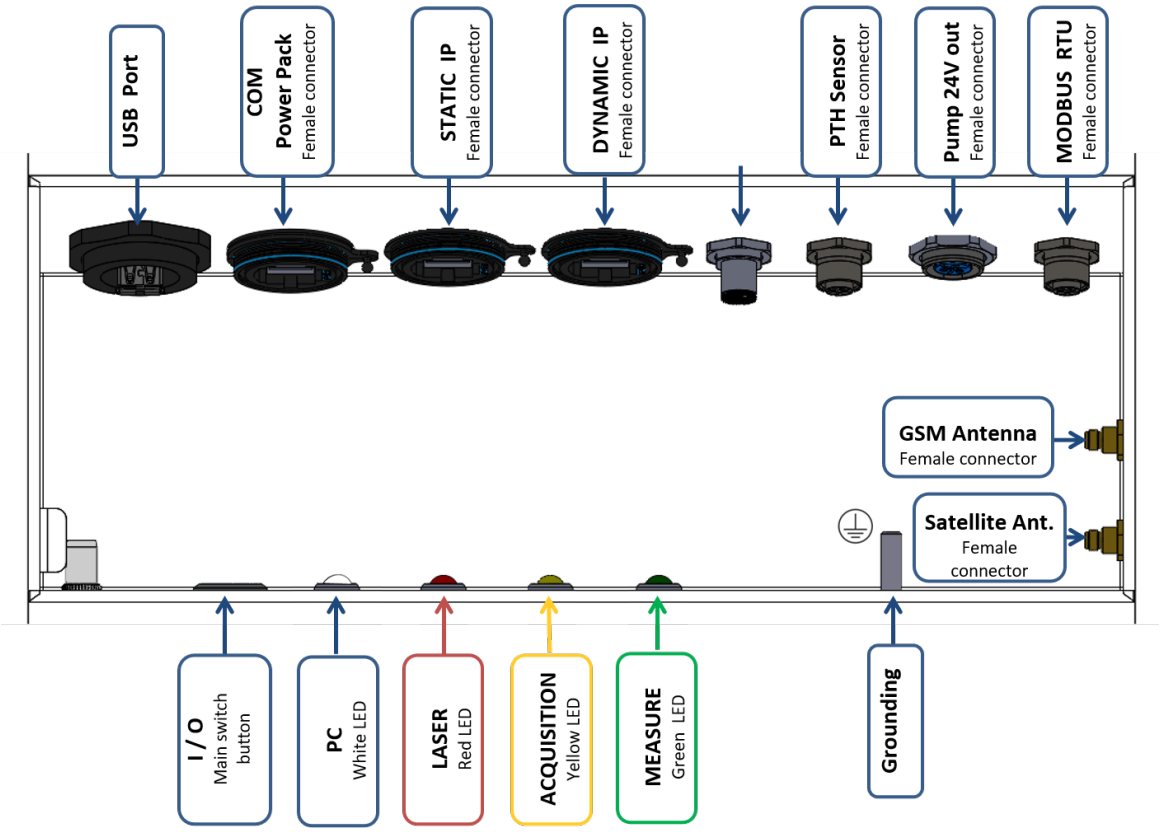


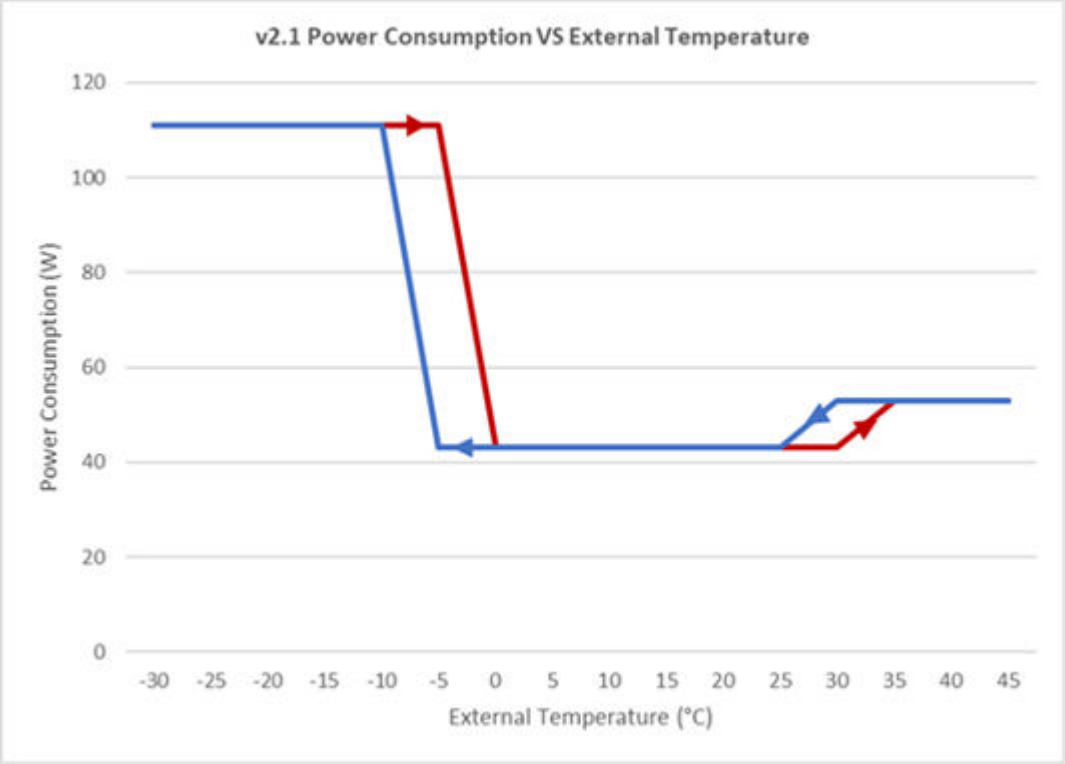
Figure 2 WindCube Lidar connection panel

3.2.2 Power Supply

The system requires an input voltage of 24.5-27V DC. An IP67 transformer is supplied for AC inputs (100-240 V AC / 50-60 Hz) and a DC-DC convertor is supplied for DC input of 18-32V DC.

The chart below describes typical power consumption over a range of ambient operating temperatures.

.



3.2.3 3G and 4G Router

WindCube is equipped with a 3G or 4G router depending on region/country. A 4G router is today available for EMEA countries (Europe, Middle East and Africa), China and US. More regions/countries will be regularly added, therefore please contact Vaisala for more details regarding your specific request for new countries.

A 3G or 4G antenna is also delivered along with the router to ensure complete configuration.

3G or 4G router* Due to specific regulations in some worldwide regions, the nominal operation of the 3G or 4G router delivered by Vaisala may be restricted in some countries. Vaisala has no accurate information on the local regulations regarding the correct functioning of the 3G or 4G router. As such, the company cannot be held liable for any malfunction due to the reasons mentioned above and/or for applicable local specific regulations. Also, as already stipulated in Vaisala General Terms and Conditions, the client warrants that the product received conforms to applicable local regulations especially in terms of Export control.

3.2.4 Packing list

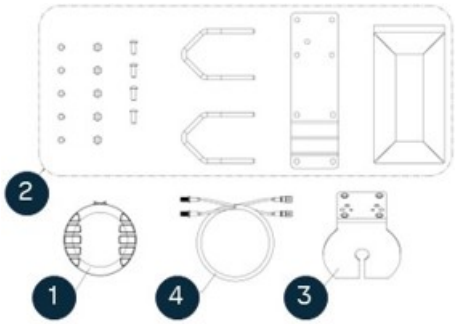
WindCube standard system parts provided to users are:

Figure 3 WindCube system and shipping case

Table 2 Elements in the shipping case

Elements in the shipping case	Description
	External water pump with connector kit Supplied foldable water tank can take up to 50 liters
	IP67 100-240VAC / 25,3VDC Power Converter Total length: 12 m
	IP67 Straight Ethernet cable

Elements in the shipping case	Description
	Grounding cable
	Magnetic compass
	**PTH** probe 1 cable with two M12 connectors (IP67) Pole mounting kit PTH power cable
	IP66 18-32V DC / 26V DC Power Converter Total length: 10 meters

Elements in the shipping case	Description
4G router antenna   	Omni-Directional Antenna 1 Omni-Directional Antenna 2 and 3 Pole mounting kit and Antenna support 4 SMA cable A surface mount double side tape is included.
  	A box containing: **FTP** credentials, USB key, system keys...

NB: Item may differ from photographs.

3.3 Software description

3.3.1 Software overview (WindCube Insights)

The WindCube is accessible through the WindCube Insights software (formerly known as Windweb), available remotely (online mode) or with a direct local connection (offline mode). Offline functionalities are limited compared to the online mode:

Users and rights management

- Flexible and traceable user management based on specific campaign needs
- Individual user's accounts with customizable preferences (eg: language, alerts, email)
- Level of access rights and periods for each Lidar defined by the system administrator (eg: data access, duration, configuration) (online mode only)

Monitor and manage

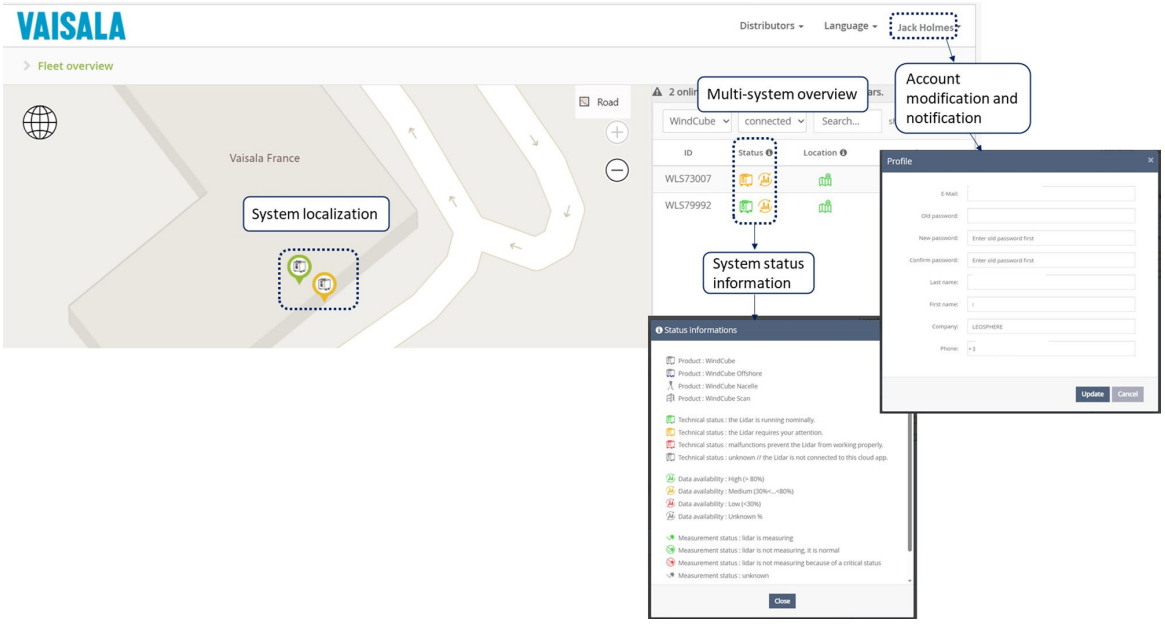
- Comprehensive fleet overview through system status listing and geographical mapping
- Real time monitoring and customized early warning alarms to increase uptime (online mode only)
- Detailed indicators for Lidar system status with proposed actions for easy and fast troubleshooting

Data export and access

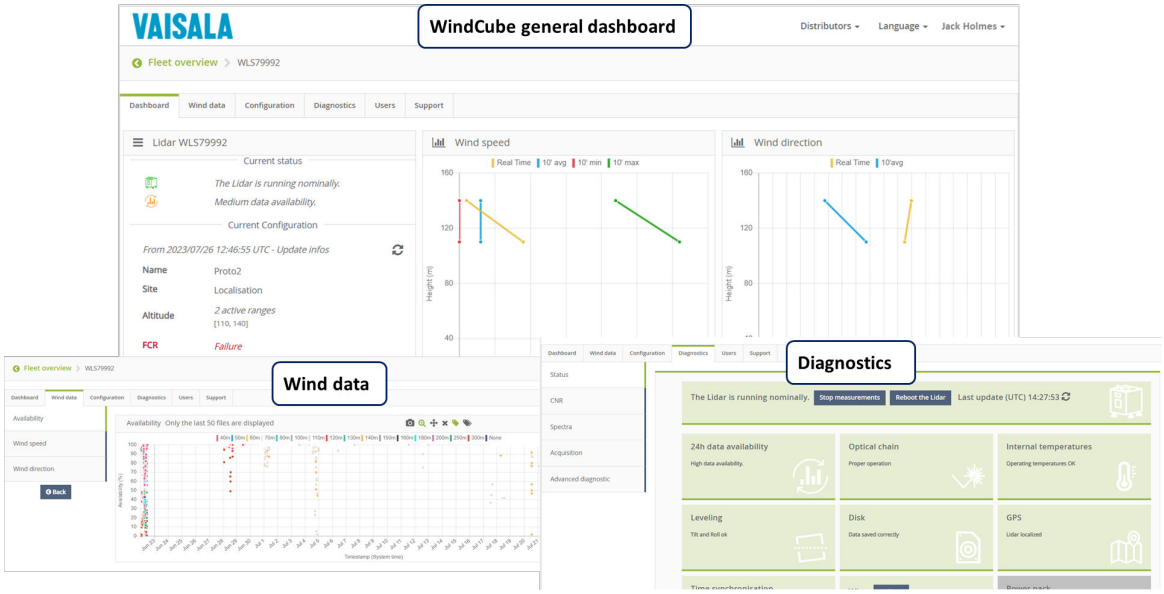
- Long term storage of all data files on a secure, confidential and dedicated server
- Automatic data export to a (S)FTP server and/or email addresses

Real time and archived data access and download from any device worldwide (online mode only). Connecting the system(s) to the internet allows accessing the full functionalities of a cloud-based platform with multi-Lidars, users and campaigns management.

Once connected to the WindCube Insights platform, the fleet overview is displayed thanks to the system status listing and geographical mapping.



WindCube Insights dashboard provides at a glance the system status, configuration, and real time measurements. Potential anomalies can be diagnosed with the detailed status page and troubleshooting suggestions. As well, system alerts can be configured to individual preferences. The data is stored on a secure server with no risk of data loss and the recorded measurements can be accessed and viewed from any desktop.



WindCube Insights includes a system administrator able to authorize a maximum of 10 users on a system. Individual access can be customized with varying levels of permissions, for different periods of time ensuring system and data security in any type of campaign.

3.3.2 Data sample

The system records and stores 1-second continuous data and 10-minute (configurable) averaged data in two different output files.

- 10-minute data is stored in the ".sta" output file.
- 1 second data is available in the ".rtd" output file.

Each altitude measurement is grouped in 18 columns and each line represents averaged data acquired over the past 10 minutes (date and time).

Here .STA data file example:

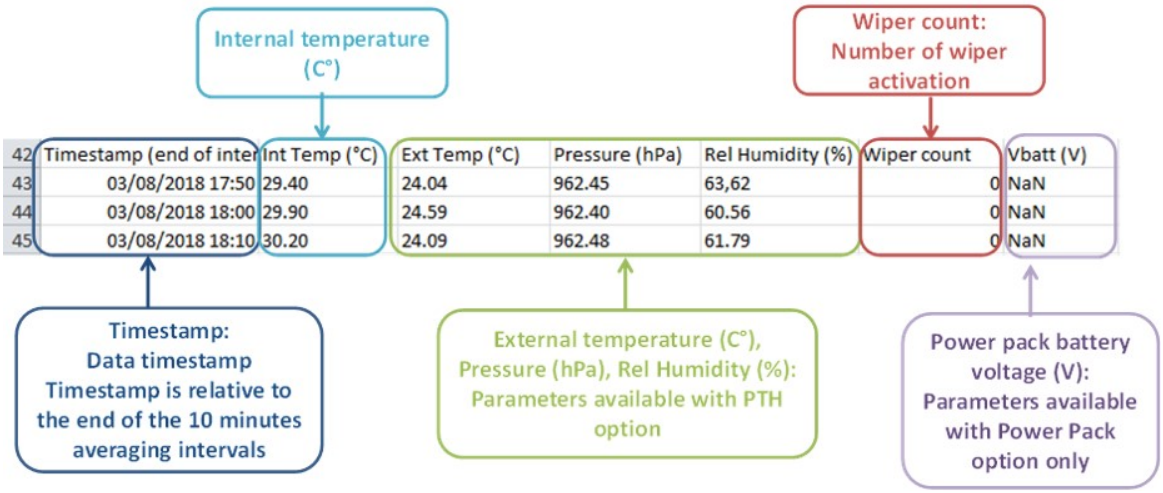
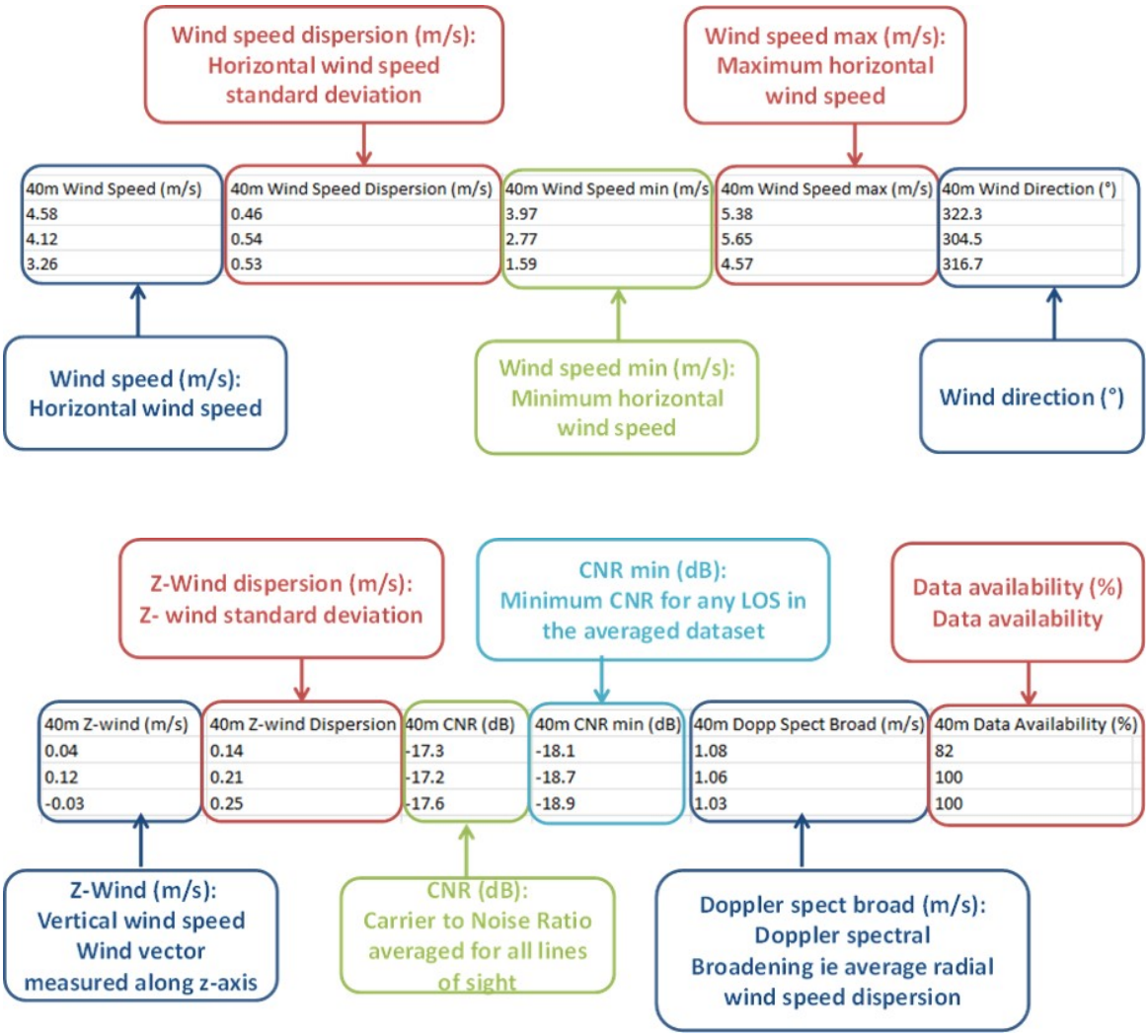


Figure 4 STA data independent of altitude



3.3.3 WindCube measurements in complex terrain with the embedded FCR module

As any remote sensor, standard WindCube wind reconstruction assumes flow homogeneity across the volume of measurement. In complex terrain, this assumption is no longer valid and measurements are inaccurate. To tackle this problem, Vaisala has developed a method allowing capturing flow inhomogeneity and obtaining accurate measurements in complex flow conditions.

Integrated within the WindCube, the FCR is an algorithm which associates the 10 minute average measurement of the WindCube with fluid mechanics equations in order to determine the wind velocity (ie 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 WindCube.

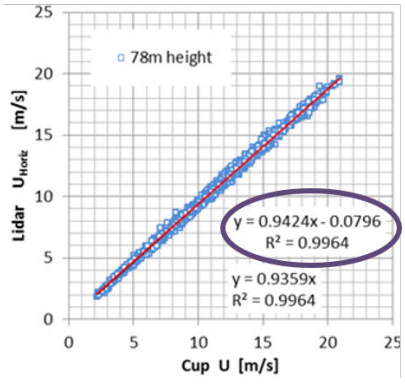
It requires two types of data to be retrieved automatically:

- Site topography: the FCR uses corresponding topographic tiles from the embedded Shuttle Radar Topography Mission (SRTM) or Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) public database based on the configured GPS input. The database contains the terrain elevation at a 100 meter resolution for a 1 km*1 km square, downscaled at a 10 meter resolution.
- Wind measurements: wind speed and wind direction at several heights at a single location as measured by the WindCube standard wind reconstruction.

The FCR approach has achieved broad acceptance. Its performances have been proven on moderately complex terrain and forested terrain. The solution has been tested and validated by independent industry experts around the globe. FCR acceptance is effective: the German TR6 guideline accept its use without mast for moderately complex terrain.

The FCR algorithm relies on a patented technology.

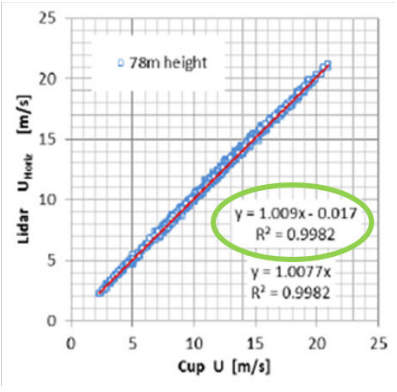
Normal mode



Dimitri Foussekis (CRES):

"At 78m height, wind speed deviations are kept below 0.1%, with a coefficient of determination R^2>0.998. This is an outstanding value approaching results obtained before only in flat terrains."

FCR mode



Among others:

- CRES validation campaign, moderately complex site, Greece, 2010 *(full report available)*
- GL-Garrad Hassan validation campaign, moderately complex site, Canada, 2011
- JUWI validation campaign, moderately complex site, Germany, 2012

- Cowi / DTU validation campaign, moderately complex site, Bosnia, 2013-2014
- Acciona Energia / Barlovento validation campaign, moderately complex site, Spain, 2011
- Evaluation of wind measurement uncertainty of WindCube in complex terrain, Leopshere 2019

In addition, WindCube output data are also compatible with most CFD tools such as Meteodyn, WindSim, ZephyScience or some in-house models from consultants and can be used for post-correction purposes.

3.4 WindCube options

Options may be available for purchase for each LIDAR Systems. As a principle, Warranty of the Options which can be provided with the LIDAR System is working on the exact same conditions as defined for the LIDAR System. Any non-embedded Option shall benefit from a Warranty Period as defined in its quotation. Additional information related to options and services can be found in LIDAR Systems Service Information.

3.4.1 WindCube Power supply solutions

Vaisala has established several partnerships with power supply providers in order to best meet local needs and constraints. Today, there are several technologies available:

- Methanol fuel cell: compact, economic and environmentally friendly power solution
- Diesel: the perfect solution in countries where Methanol fuel cells are not allowed
- Solar panels: usually used in addition to a power solution mentioned above to increase autonomy

Vaisala can support our customers in finding the best solution through our network of partners.

In addition, Vaisala can directly sell, deliver and service a power supply solution for WindCube called EFOY ProCube.

The ProCube is a plug and play, cost-efficient and reliable solution based on methanol fuel cell and solar panels, with remote control and fuel cell level monitoring via WindCube Insights. While checking the fuel cell status and the overall power supply, the following information can be displayed:

- Battery voltage
- Output current from the fuel cell (not the current consumed by the WindCube)
- Operating time
- Operating state
- Operating mode
- Cumulative output energy
- Error status
- Cartridge consumption (in case of problem, a notification will be automatically sent by email)

Figure 5 EFOY ProCube used to autonomously supply power to WindCube

EFOY ProCube is a non-embedded option and comes with a specific warranty of one (1) year or four thousand (4,000) operating hours (first term reached) from date of delivery of that power solution according to the chosen Incoterm (ICC 2020), as stated in its transportation document.

Warranty conditions of the LIDAR System described in the WindCube Technical Support and Service Information document also apply for the specific warranty to the EFOY ProCube. As a result Vaisala shall in no case bear any cost (parts and persons) linked to the commissioning and/or decommissioning of the EFOY ProCube (including travel of employees by any means) in an offshore environment (such as but not limited to EFOY ProCube deployed on oil and gas platforms, offshore wind turbines and/or vessels).

EFOY ProCube is delivered with SFC edited user manual and conditions of use which are to be observed by any of its users.

EFOY ProCube solution can be supplied with our without Solar panels and Batteries to facilitate transport and imports regulations.

3.4.2 Geofencing

WindCube can be packed with features whose purpose is to ensure the safety and the reliability of the system. The Geofencing option allows to:

- Define an authorized area where the WindCube should be
- Localize the WindCube
- Detect the movement of the WindCube if it is moved outside of its authorized area
- Send alerts to inform about the movement of the WindCube outside of its authorized area and localize the system.

Once fitted on the WindCube, the geofencing device can be activated by the purchase of a one-year or five-year license. Activation of the license is done at delivery of the WindCube when license is purchased by customer through Vaisala.

CAUTION! Geofencing* Due to specific regulations in some worldwide regions, the nominal operation of the Geofencing delivered by Vaisala may be restricted in some countries. It is the case in Ireland for instance. Vaisala has no exhaustive information on the local regulations regarding the correct functioning of Geofencing. As such, the company cannot be held liable for any malfunction due to the reasons mentioned above and/or for applicable local specific regulations. Also, as already stipulated in Vaisala General Terms and Conditions, the client warrants that the product received conforms to applicable local regulations especially in terms of Export control.

3.4.3 Satellite communication

The WindCube is equipped with a 4G or 3G router for remote access to the system from any location. If in extreme cases there is no signal reception, the WindCube is compatible with a Satellite communication option available through SmartGrid. Vaisala can facilitate the choice of the right option with SmartGrid.

3.4.4 Winter kit

A winter kit can be supplied as an option to the WindCube. The kit is equipped with active heating elements to prevent the formation of ice or the accumulation of snow on top of the WindCube.

The objective of the kit is to maintain the capability of the WindCube during a harsh snow event and to reduce the time to resume measures after an event.

VAISALA