



Instruction Manual

LAS MkII • Scintillometer

Important User Information

Dear customer, thank you for purchasing a Kipp & Zonen instrument. It is essential that you read this manual completely for a full understanding of the proper and safe installation, use, maintenance and operation of your new LAS MkII Scintillometer.

We understand that no instruction manual is perfect, so should you have any comments regarding this manual we will be pleased to receive them at:

Kipp & Zonen B.V.

Delftechpark 36, 2628 XH Delft, - or
P.O. Box 507, 2600 AM Delft,
The Netherlands

T: +31 (0) 15 2755 210
F: +31 (0) 15 2620 351
support@kippzonen.com
www.kippzonen.com

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Declaration of Conformity



We **Kipp & Zonen B.V.**
Delftechpark 36, 2628 XH Delft
P.O. Box 507, 2600 AM Delft
The Netherlands

Declare under our sole responsibility that the products:

Model **LAS MkII**
Type **Large Aperture Scintillometer**

to which this declaration relates are in conformity with European Harmonised Standards as published in:
Official Journal of the EC, Issue: C288 (30-09-2011)

The compliance of the product has been based on:

Emissions **EN 61326-1:2006**
Immunity **EN 61326-1:2006**

following the provisions of the directives (if applicable):
EMC-directive **2004/108/EC**

Delft, 1st July 2012

B.A.H. Dieterink
President
Kipp & Zonen B.V.

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1. Introduction

Throughout this manual the following symbols are used to indicate to the user important information.



General warning about conditions, other than those caused by high voltage electricity, which may result in physical injury and/or damage to the equipment or cause the equipment to not operate correctly.

Note Useful information for the user

1.1 Product overview

The LAS MkII Large Aperture Scintillometer is an optical instrument with a 150 mm diameter beam that is designed for measuring the path-averaged structure parameter of the refractive index of air (C_n^2) over horizontal path lengths from 250 m to 4.5 km¹. When the supplied 100 mm diameter aperture restrictors are fitted, the path length can be from 100 m to 1 km¹.

LAS MkII uses a transmitter and receiver horizontally separated by several kilometres to measure intensity fluctuations in the air known as scintillations. This is the same effect, but of much smaller amplitude, as the ‘shimmering’ of air over very hot or cold surfaces that causes a mirage.

The scintillations seen by the instrument can be expressed as the structure parameter of the refractive index of air (C_n^2). The light source of the LAS MkII transmitter operates at a near-infrared wavelength of 850 nm. At this wavelength the observed scintillations are primarily caused by turbulent temperature fluctuations.

Therefore, C_n^2 measurements obtained with the LAS MkII can be combined with temporally and spatially coherent meteorological observations of air temperature, wind speed and air pressure to derive the free convection sensible heat flux (H_{free}). An accessory meteorological sensor kit is available for this purpose, which connects to the LAS MKII receiver.

The LAS MkII is self-contained. The system can be locally configured at the receiver with a display and menu keys and has internal digital signal and data processing and data storage. When the data is exported to the included EVATION software package running on a computer the surface sensible heat flux (H) can be calculated.

Compared to traditional point measurement systems, the LAS MkII operates at spatial scales comparable to the grid box size of numerical models and the pixel size of satellite images used in meteorology, hydrology and water management studies. The LAS MkII has important applications in energy balance and water balance studies, because the surface flux of sensible heat is linked to latent heat flux (L_vE) and evapotranspiration (ET). For these measurements a complete LAS MkII ET System is available.

This manual provides information related to the installation, maintenance, calibration, product specifications and applications of the scintillometer.

If any questions should remain, please contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: support@kippzonen.com

Please go to www.kippzonen.com for information about other Kipp & Zonen products, or to check for any updates to this manual or software.

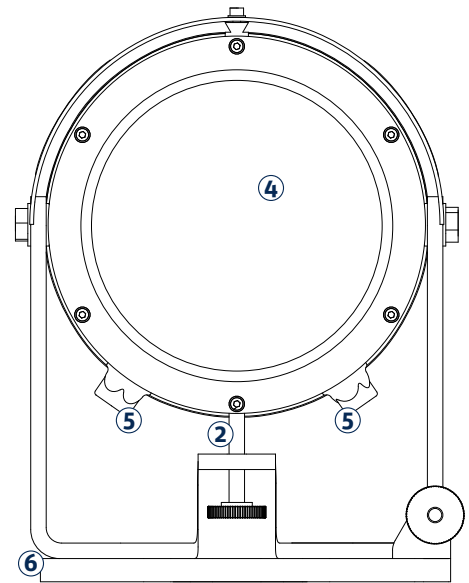
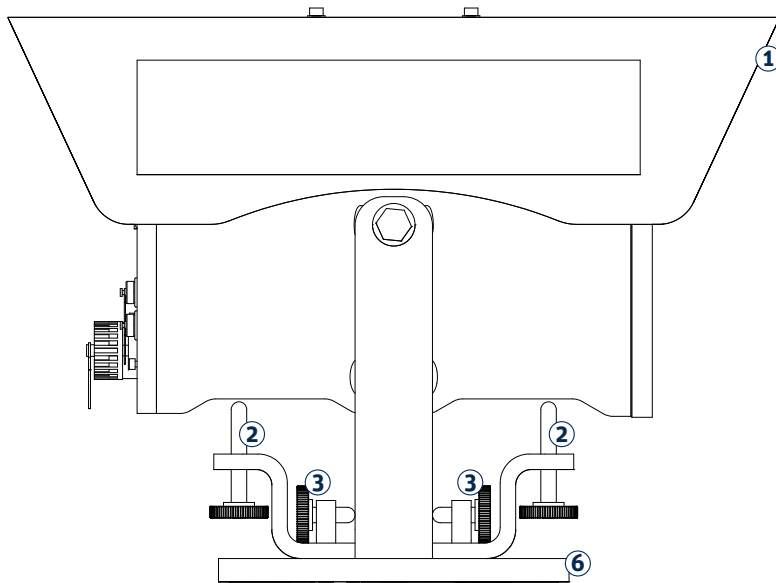
¹The maximum usable path length depends upon the atmospheric conditions, the path lengths given are for ‘clear’ conditions (visibility 10-20 km). In general, it is best to use the scintillometer at full aperture at path lengths down to 250 m, and the aperture restrictors for shorter paths. However, for field-scale measurements at a range of distances up to 1 km it may be convenient to leave the restrictors fitted.

1.2 Key parts of the LAS MkII Scintillometer

1.2.1 Transmitter and receiver

The drawing shows the key common parts of the LAS MkII transmitter and receiver:

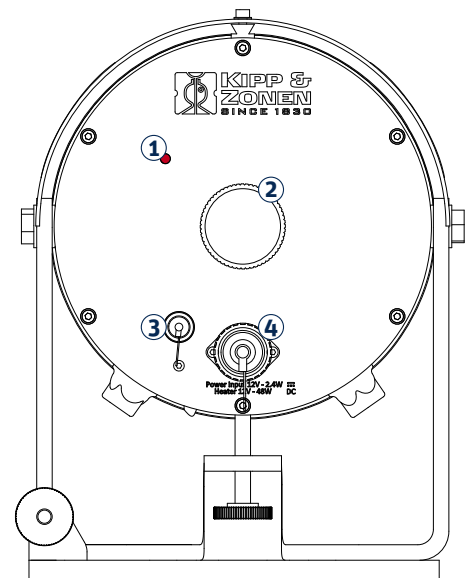
- ① Sun shield fitted to the mounting for the alignment telescope
- ② Tilt (vertical) adjustment screws
- ③ Pan (horizontal) adjustment screws
- ④ Transmitter window, with heater and Fresnel lens behind
- ⑤ Drying cartridges
- ⑥ Baseplate



1.2.2 Transmitter rear panel

The drawing shows the key parts of the LAS MkII transmitter rear panel:

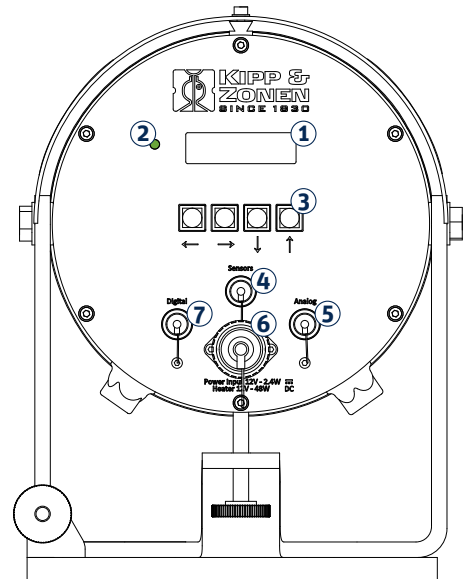
- ① Power indicator (red)
- ② Transmitter power adjustment knob (remove screw-on cover)
- ③ Signal output connector (4-pin)
- ④ Power input connector (12 VDC)



1.2.3 Receiver rear panel

The drawing shows the key parts of the LAS MkII receiver rear panel:

- ① Display
- ② Power and status indicator (green)
- ③ Menu navigation keys
- ④ Meteorological sensor kit connector (8-pin)
- ⑤ Analogue signal connector (4-pin)
- ⑥ Power input connector (12 VDC)
- ⑦ Digital interface connector (8-pin)



2. Installation

Please follow the instructions in this section carefully for the mechanical and electrical installation of the LAS MkII scintillometer.



Do not turn on power to the transmitter or receiver until instructed to do so.



Ensure that fixings and mountings are securely tightened when instructed to do so.

2.1 Included with the product

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport. If there is damage, a claim should be filed with the carrier immediately. In the case of damage and/or the contents are incomplete, contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: support@kippzonen.com

Note The LAS MkII is rugged, but it contains sensitive optical and electronic parts. Please keep the original packaging to safely transport the scintillometer to measurement sites or for other shipments.

The following items are included with the LAS MkII scintillometer:

LAS MkII transmitter with pan and tilt adjuster and baseplate

LAS MkII receiver with pan and tilt adjuster and baseplate

2 × alignment telescope with detachable mounting, adjusted for each transmitter and receiver

2 × sun shield with two fixing screws

2 × 100 mm diameter aperture restrictor with fixing kit, for transmitter and receiver

2 × 10 m cable with 4-pin plug for transmitter signal output and receiver analogue connections

1 × 10 m cable with 8-pin plug for receiver digital communication connections

2 × 10 m cable with 4-pin connector for 12 VDC power input

2 × 3 mm hexagonal Allen keys, for fitting the sun shields

2 × 4 mm hexagonal Allen keys, for fitting the telescopes

1 × CD-ROM containing EVATION software and a pdf file of this LAS MkII instruction manual

8 × spare desiccant packs

2.1.1 The transmitter

The transmitter housing contains a very efficient, eye-safe LED operating at 850 nm wavelength in the near-infrared region. The LED mounting is axially adjustable to position it at the focus of a Fresnel collimating lens. The near-parallel beam is output through a glass window with an aperture diameter of 150 mm. There is a self-regulating heater for the window that can disperse rain, dew, frost and snow. Electronics pulse the LED at 6.5 - 7 kHz and the drive signals can be monitored on the signal output connector.

There is a baseplate with rugged and easy to use pan and tilt adjustment. A mounting rail on the top of the housing is used to fit the alignment telescope or the white heat shield. There are two drying cartridges containing desiccant to keep the transmitter dry internally.

The transmitter is powered by 12 Volts DC.



2.1.2 The receiver

The beam from the transmitter enters the receiver through a glass window with an aperture diameter of 150 mm. There is a self-regulating heater for the window that can disperse rain, dew, frost and snow. A Fresnel lens focusses the 6.5 - 7 kHz pulsed radiation onto a very sensitive large-area photodiode detector with a thin-film optical filter that only transmits radiation in a waveband around 850 nm, blocking ambient light from reaching the detector. The detector and filter assembly are axially adjustable to position the detector at the focus of the lens.

Analogue electronics are tuned to the 6.5 - 7 kHz carrier wave and to the scintillation frequency band of 0.2 Hz to 400 Hz. These signals are rectified and are available at the analogue signal connector. All the remaining electronics are digital. The system can be locally configured at the receiver with a display and menu navigation keys and has internal signal and data processing and storage. It can calculate and log Cn2 measurements and, with the accessory meteorological sensor kit connected, the sensible heat flux (H) can be calculated and stored. External communication is via the digital interface connection.

There is a baseplate with rugged and easy to use pan and tilt adjustment. A mounting rail on the top of the housing is used to fit the alignment telescope or the white heat shield. There are two drying cartridges containing desiccant to keep the receiver dry internally.

The receiver is powered by 12 Volts DC.



2.1.3 Alignment telescopes

Each transmitter and receiver has a telescope, individually adjusted to align with its optical axis, and each telescope is labelled accordingly. These telescopes attach by clamps to mounting rails on the tops of the transmitter and receiver housings and enable alignment of the transmitter and receiver at long path lengths. They are not completely weatherproof and should be removed after alignment and replaced by the sun shields. A 4 mm hexagonal Allen key is supplied for the mounts of each telescope.



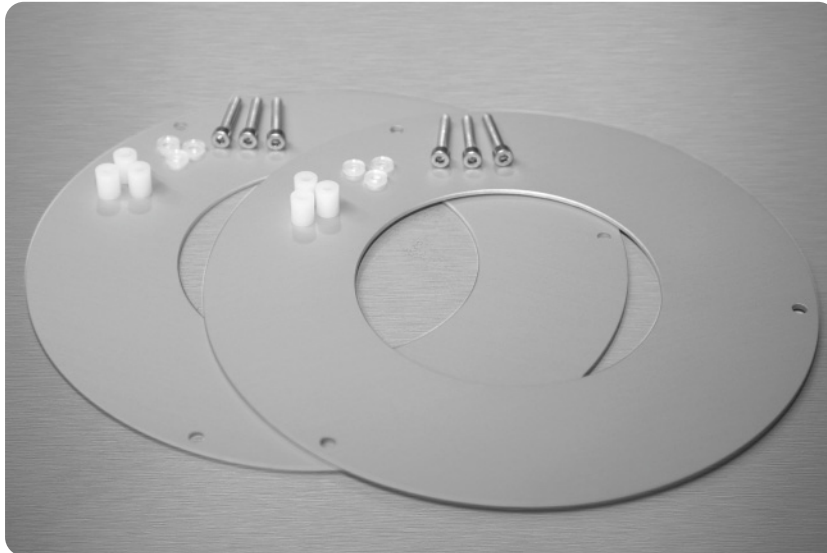
2.1.4 Sun shields

After alignment of the transmitter and receiver the telescopes should be removed and replaced by the sun shields. These are each attached by two screws to mounting rails on the tops of the transmitter and receiver housings. A 3 mm hexagonal Allen key is supplied for the fixing screws of each sun shield.



2.1.5 Aperture restrictors

The full beam aperture of 150 mm enables operation over path lengths from 250m to 4.5 km, depending upon the atmospheric conditions. For shorter path lengths, from 100m to 1 km, restrictors with apertures of 100 mm are fitted in front of the windows of the transmitter and receiver.



2.1.6 Power cables

Two 10 m long cables with 4-pin waterproof plugs are provided for the transmitter and receiver 12 Volt DC power inputs.

2.1.7 Signal cables with 4-pin plugs

Two 10 m long cables with 4-pin waterproof connectors are provided. One for the transmitter signal outputs, the other for the receiver analogue signal connection.

2.1.8 Signal cable with 8-pin plug

One 10 m long cable with an 8-pin waterproof plug is provided for the receiver digital interface connection.



2.1.9 Allen keys

Two 3 mm hexagonal Allen keys are supplied for fitting the transmitter and receiver telescopes and two 4 mm hexagonal Allen keys for fitting the sun shields.

2.1.10 CD-ROM

The supplied CD-ROM contains the EVATION software package and this manual as a pdf file.

2.1.11 Desiccant packs

Eight spare packs of self-indicating silica gel desiccant are supplied for the drying cartridges of the transmitter and receiver.



2.2 tools required

In addition to the items supplied with the LAS MkII scintillometer, the following equipment is required for performing the installation:

- At least two people
- Stable mounting bases for the transmitter and receiver or tripods
- Printed copy of the manual, from the supplied CD-ROM
- Tape measure for determining the installation height
- 2 x radios or mobile 'phones for communication between transmitter and receiver operators
- 2 x sets of mounting bolts and suitable wrenches
- 2 x sources of 12 Volts DC power

2.3 Location and support base

When choosing the location for scintillometer measurements care has to be taken that certain requirements are met.

2.3.1 Path orientation and avoiding direct sunlight

Avoid locating the transmitter and receiver where direct sunlight may be in their views. The Fresnel lenses will focus the light onto the transmitting LED and the receiving optical filter and photodiode and there is a risk of damage due to overheating.

It is recommended to select a path that is approximately parallel to the Earth's surface (i.e. horizontal) and has a north-south orientation to avoid any problems caused at low sun angles. If this is not possible, pick an orientation where some obstruction in the background (buildings, trees) blocks the direct sun.



Direct sunlight close to the optical axes of the transmitter and receiver may permanently damage optical parts.

In order to maximise the footprint of the measurement, it is recommended to select a path between the transmitter and receiver which is perpendicular to the predominant wind direction.



Ensure that the optical path between the transmitter and receiver is free of any obstructions.

2.3.2 Minimum installation height to prevent saturation

When the scintillation intensity rises above a certain limit the theory, on which the scintillation measurement method is based, is no longer valid. When this occurs, the relationship between the measured amount of scintillations (σ_{ln}^2) and the structure parameter of the refractive index of air (C_n^2) fails. This phenomenon is known as saturation.

In order to prevent saturation, C_n^2 must stay below a certain saturation criterion (S_{max}), i.e. the scintillometer can measure well only under weakly scintillating conditions. The dependence of C_n^2 on the optical wavelength (λ), the aperture diameter (D), the measurement height (z_{LAS}) and the path length (L) can be written as follows:

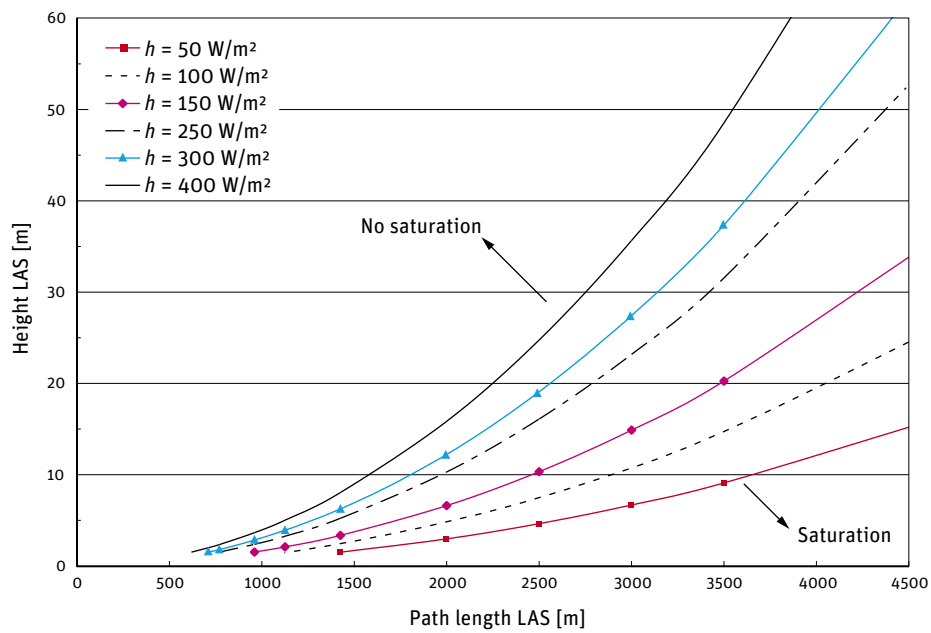
$$C_n^2(\lambda, D, z_{LAS}, L) < S_{max}$$

The path length and the measurement height are the only variables that can be adjusted in order to keep C_n^2 below the saturation criterion. A scintillometer installed at a height close the Earth's surface; will see more scintillations than a scintillometer installed high above the surface. As the path length increases more scintillation will be observed.

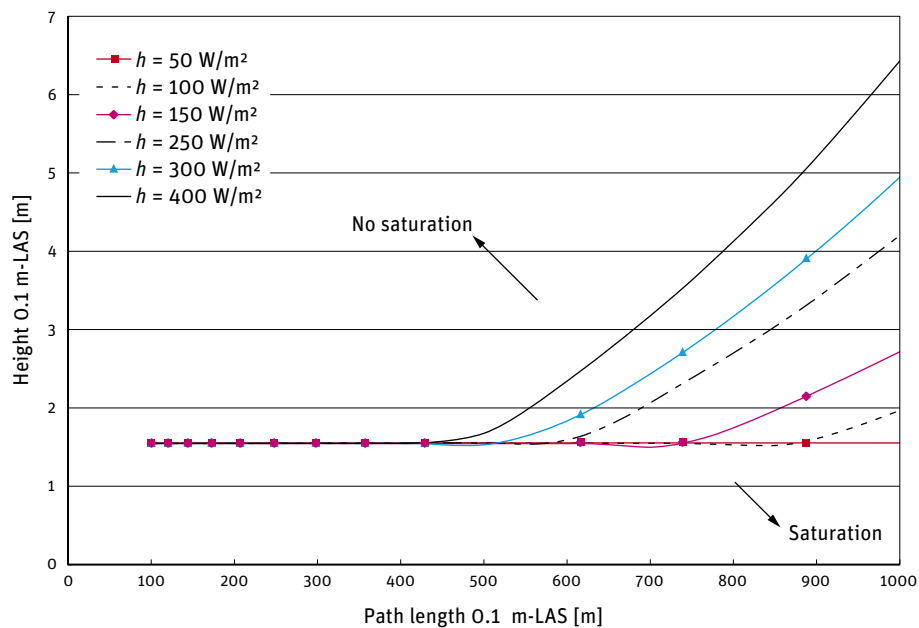
This means that over long distances (several kilometres) the scintillometer must be placed high above the surface in order to prevent saturation. Over shorter distances (several hundred meters) the scintillometer can be installed closer to the surface. Over dry areas the surface sensible heat flux is large, resulting in higher C_n^2 values than over wet surfaces where the sensible heat flux is small.

The graphs below show the minimum height of the LAS MkII for different surface conditions as a function of the path length. The area above the curves in the figure is the so-called non-saturation zone. Below the curves saturation will occur. Based on the user's preferred path length, and the surface conditions of the area of interest, the user must install the LAS MkII scintillometer at a height that lies in the non-saturation zone.

Full 150 mm aperture



Restricted 100 mm aperture



For example, a LAS MkII installed over a relatively wet area ($h \sim 100 \text{ W/m}^2$) and a path length of 3 km must be installed at a height of at least 12 m.



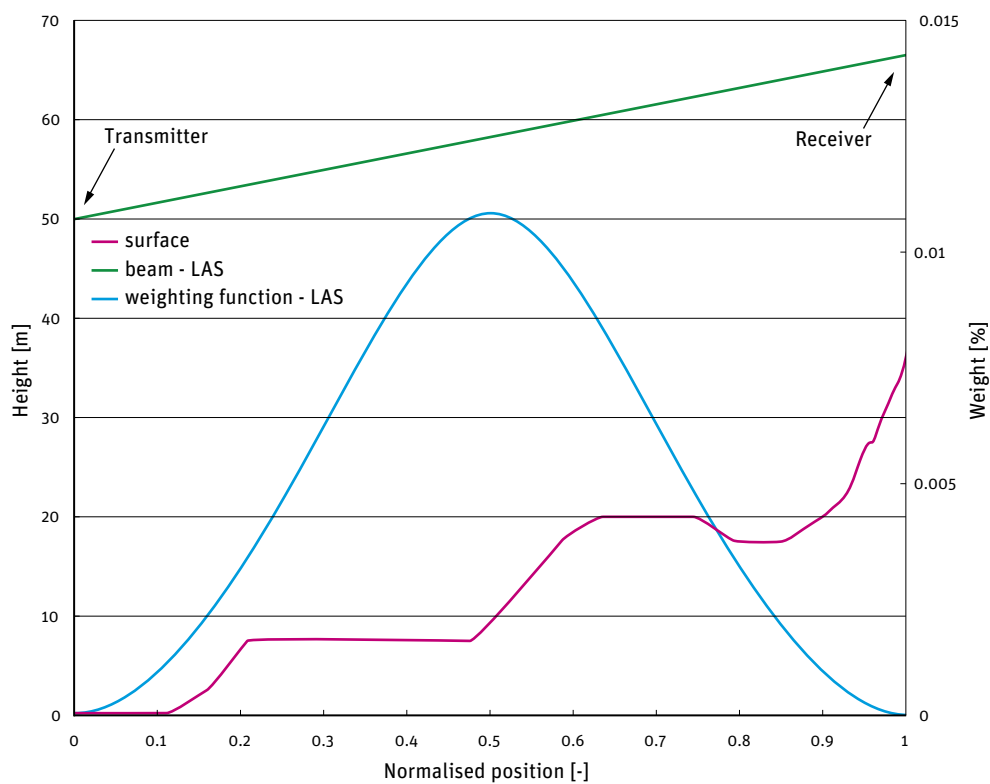
Ensure that the LAS MkII is operating in the 'non-saturation' zone.

2.3.3 Effective beam height

Determine the effective height of beam of the LAS MkII (z_{LAS}) along the path precisely. The surface sensible heat flux (H) derived from the structure parameter data is very sensitive to the height (see Appendix A). When the area is relatively flat and the beam is parallel to the surface the effective height is easy to determine ($z_{transmitter} = z_{receiver} = z_{LAS}$).

The path-weighting function is symmetrical and bell-shaped having a centre maximum and tapering to zero at the transmitter and receiver end. This means that the LAS MkII is most sensitive in the middle of its path. For situations where the area is not flat, or for slanted paths, it is recommend to measure the height of the beam at several points along the path.

The figure below shows how the weighting function must be used in order to estimate the precise height of the beam above the surface for non-flat areas. The effective height calculator in the EVATION software package can be used to find the effective height, as described in Appendix E. For more information see Hartogensis et al, 2003¹.



The graphs above illustrate a LAS MkII path (beam) over a non-flat area. Based on the elevation map (surface) and the LAS path-weighting function, an effective beam height of 46 m was calculated.

¹ Hartogensis, O.K., Watts, C.J., Rodriguez, J.-C. and De Bruin, H.A.R.: 2003, 'Derivation of an Effective Height for Scintillometers: La Poza Experiment in Northwest Mexico', J. Hydro-Meteorol. 4, 915-928.

2.3.4 Operation in the constant flux layer

In order to derive the surface fluxes of sensible heat from the scintillometer measurements (C_n^2) we use the Monin-Obukhov Similarity Theory (MOST) (see Appendix A). MOST is widely used in meteorology and is usually applied to the Surface Layer (SL) and hence is sometimes called the Surface Layer Similarity. The SL is roughly the lowest 10% of the Planetary Boundary Layer (PBL).

The PBL is directly influenced by the earth's surface and its depth varies between roughly 100 m and 2 km. In general the PBL increases during the day, when the Earth's surface is heated by the sun, and decreases again during the night. Within the SL the variation of fluxes (such as the sensible heat flux H and latent heat flux $L_v E$) is negligible with respect to the magnitude of their value at the surface.

Therefore, fluxes measured at a certain elevation in the SL can be considered as being representative of the exchange processes occurring between the Earth's surface and the atmosphere above. The SL can be further divided into the Roughness Sub-layer (RS), influenced by the structure of the roughness elements (e.g. plants, trees, buildings etc.), and the Constant Flux Layer where fluxes are assumed to be horizontally and vertically constant (due to turbulent mixing). This means that measurement techniques that apply MOST for estimating surface fluxes can be applied only in the Constant Flux Layer.

Therefore the LAS MkII must be installed at a height such that it is located above the Roughness Sub-layer and is measuring within the Constant Flux Layer.

The depth of the SL typically varies between 20 m and 100 m. The upper level strongly depends on the diurnal cycle of surface heating and cooling and the presence of clouds. Like the PBL, the SL increases during the day as the surface is heated by the sun and is maximum at sunset (~100 m), before it decreases again due to cooling of the surface at night (~20 m).

The height of the Roughness Sub-layer, and thus the lower level of the Constant Flux Layer, depends strongly upon the size, form and distribution of the roughness elements. Usually, over tall vegetation, the height of the Roughness Sub-layer is taken to be equal to three times the obstacle height (or roughness elements h).

In case the estimated height of the Roughness Sub-layer is below the minimum height to avoid saturation, use a height that ensures the LAS MkII is in the non-saturation zone.



Ensure that the LAS MkII is measuring in the Constant Flux Layer and in the non-saturation zone.

Note More detailed information about the theory of the scintillation technique can be found in Appendix A.

Note A list of symbols and abbreviations can be found in Appendix B.

2.4 Mounting

The LAS MkII can only function properly when the transmitter and receiver are precisely optically aligned. By mounting the scintillometer on a stable support, signal loss and regular re-alignment procedures will be avoided. Vibrations in the mounting structure must be prevented, which can lead to overestimated C_n^2 values. This particularly applies to masts or towers that can bend and vibrate in the wind.



Mount the LAS MkII transmitter and receiver on stable and vibration-free supports.

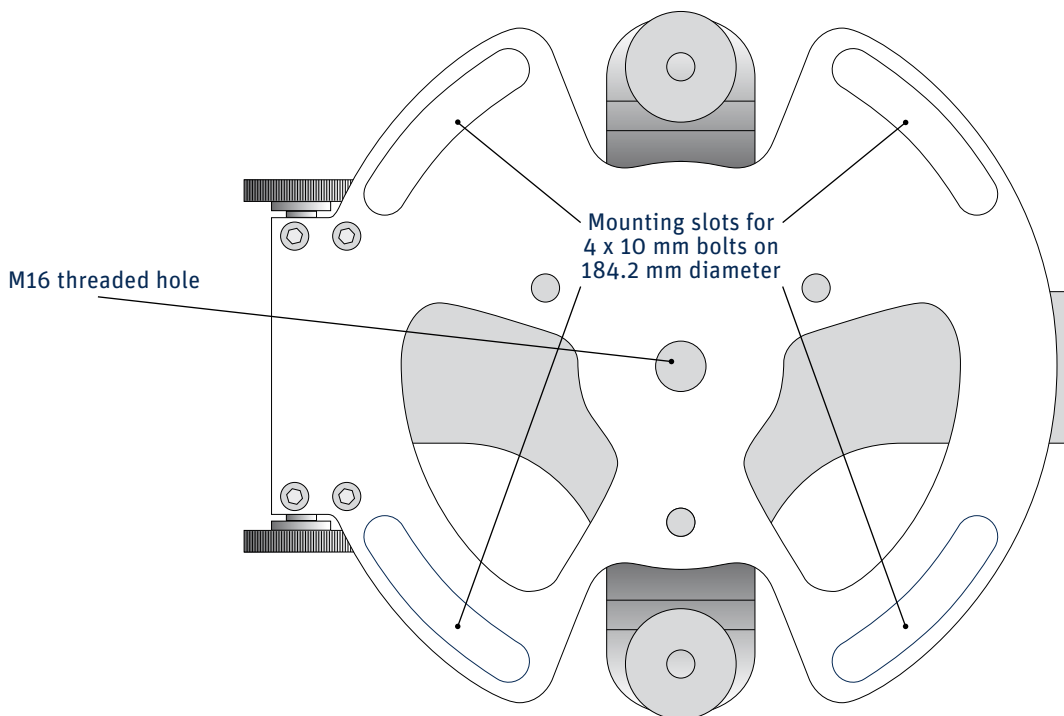
Adjustable tripods are only suitable for short-term measurements. Where they are not on hard surfaces, a board should be used to prevent the tripod legs sinking in and affecting the beam alignment.



If tripods are used, ensure that they cannot easily fall over and possibly damage the transmitter or receiver.

The pan and tilt adjusters of the transmitter and receiver have a baseplate. This has a central M16 thread to fit the mounting bolts of industrial tripods, such as the accessory adjustable heavy-duty tripod package for the LAS MkII.

The baseplate has 4 slots for 10 mm bolts, on 184.2 mm diameter, which can be used for fixing the transmitter and receiver to a customer-supplied support or to the accessory Kipp & Zonen tripod floor stand and/or height extension tube. The bottom view of the baseplate is shown below.



2.5 Electrical and data connections

There are two waterproof connectors located on the rear panel of the transmitter and four on the rear panel of the receiver.

2.5.1 Power connector

The transmitter and receiver are each provided with a 4-pin waterproof plug fitted to a 10 m long cable that is terminated in tinned wires, for 12 Volts DC (nominal) power to the instrument and heater.

Transmitter and receiver power connector and cable

Pin number	Wire colour	Function	Value
1	red	instrument power +	9.6 to 18 VDC
2	orange	heater power +	9.6 to 18 VDC
3	brown	heater return –	0 V
4	black	instrument return –	0 V
shield	thick black	cable screen	housing ground



The LAS MKII transmitter and receiver must be grounded through the shield of the power connector (also connected to pin 4) for protection against lightning and electrical interference.



The LAS MKII transmitter and receiver power inputs should be protected by fuses.
Instrument power +, 1 A normal or slow-blow type. Heater power +, 4 A slow-blow type.

2.5.2 Transmitter signal output connector

The transmitter is provided with a 4-pin plug for signal outputs, fitted to a 10 m long yellow cable that is terminated in tinned wires.

Transmitter signal connector and cable

Pin number	Wire colour	Function	Value
1	red	not connected	
2	blue	6.5 - 7 kHz pulse + 0.5 duty cycle	0 to 8 V
3	green	6.5 - 7 kHz LED pulse + 0.5 duty cycle	0 to 2 V proportional to LED power setting
4	yellow	signal –	0 V
shield	thick black	cable screen	housing ground

2.5.3 Receiver Analogue signal connector

The receiver is provided with a 4-pin plug for analogue signal outputs, fitted to a 10 m long yellow cable that is terminated in tinned wires.

Receiver analogue signal connector and cable

Pin number	Wire colour	Function	Value	Impedance
1	red	Log UC_n^2 signal +	0 to 2 V 10^{-17} to $10^{-12} \text{ m}^{-2/3}$	680 Ω 4700 pF
2	blue	6.5 to 7 kHz AC carrier signal +	0 to 1 V RMS 100 % = 152 mV RMS	120 Ω 4700 pF
3	green	demodulated carrier signal (U_{demod}) +	0 to 2 V 100 % = 606 mV	680 Ω 4700 pF
4	yellow	signal -	0 V	
shield	thick black	cable screen	housing ground	

2.5.4 Receiver digital interface connector

The receiver is provided with an 8-pin waterproof plug for the digital communication interface, fitted to a 10 m long yellow cable that is terminated in tinned wires.

Two communication modes can be selected, RS-232 or 4-wire RS-422 (default). The desired mode can be selected using the LAS MkII configuration menu or by the control software.

Receiver digital interface connector and cable

Pin number	Wire colour	RS-232 function	RS-422 function
1	red	RXD	RXD- (A)
2	blue	CTS	RXD+ (B)
3	green	DSR	do not connect
4	yellow	RTS	TXD+(Z)
5	grey	TXD	TXD- (Y)
6	brown	DTR	do not connect
7	white	DCD	do not connect
8	black	digital ground	digital ground
shield	thick black	cable screen	cable screen



For permanent connection to a computer always use optically or galvanically isolated adapters or converters at the computer serial port to protect against damage caused by lighting.

2.5.5 Receiver meteorological sensor kit connector

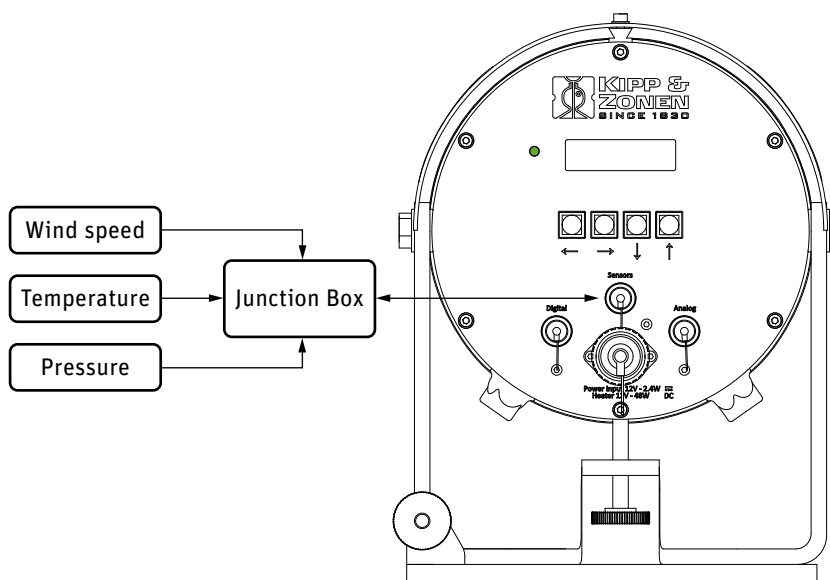


The 8-pin connector marked 'Sensors' must only be used with the accessory meteorological sensor kit. The 12 VDC output must not be used to supply other equipment.

Receiver meteorological sensor kit connector

Pin number	Wire colour	Function	Value
1	red	not connected	
2	blue	not connected	
3	green	not connected	
4	yellow	power supply for sensor kit	12 VDC output do not ground!
5	grey	temperature input	4 to 20 mA
6	brown	air pressure input	4 to 20 mA
7	white	wind speed input	4 to 20 mA
8	black	sensors ground	0 V
shield	thick black	cable screen	housing ground

The accessory meteorological sensor kit is supplied pre-wired with a 10 meter long yellow cable and waterproof connector and will be automatically powered and recognised when plugged into the LAS MkII receiver.



Do not connect a computer to the sensor connector using the digital interface plug and cable. The 12 V power output for the sensors may damage the computer serial port.

2.6 Aperture restrictors for short range applications

In case the LAS MkII is required to operate over short distances the aperture diameter of the transmitter and receiver can be reduced to 100 mm using the supplied restrictors. The LAS MkII can then be used over path lengths from 100 m to 1 km.

To fit the restrictors proceed as follows and shown in the diagram below:

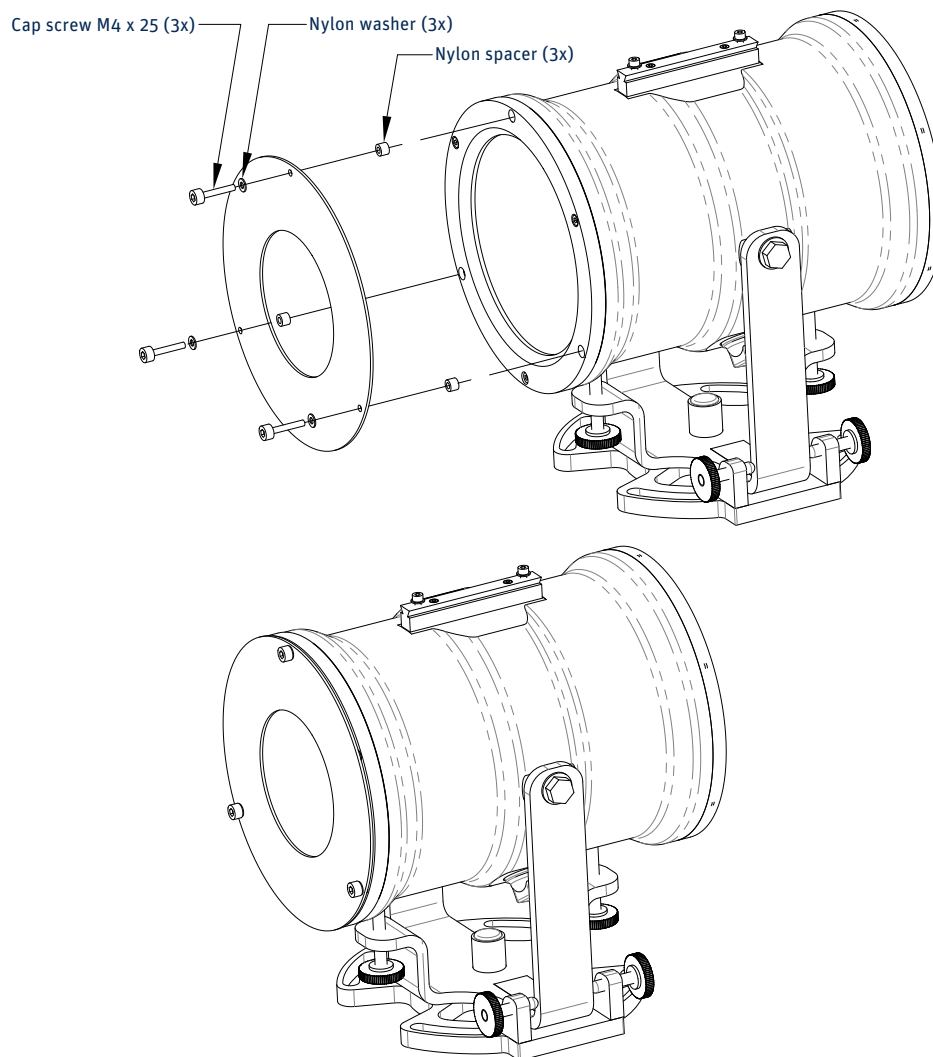
1. Remove 3 of the 6 retaining screws of the transmitter and receiver windows
2. Replace the screws by the nylon spacers
3. Secure the restrictors using the M4 x 25 mm cap-head screws and nylon washers



When using the restrictors, remember to set the aperture values in the LAS MkII configuration menu to 100 mm.



As the beam diameter becomes smaller so does the beam divergence. This means that the alignment of the 100 mm LAS MkII may be more critical than for the full-beam 150 mm LAS MkII. It is recommended to use very stable mounting constructions.

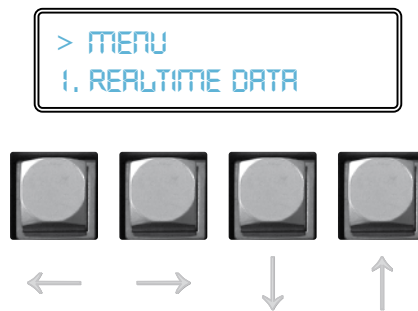


2.7 Using the display and key-pad

The waterproof display and menu navigation keys located on the rear panel of the LAS MkII receiver allow for complete instrument configuration and control without the need for additional computers, cables and software. This section describes the basic procedure for navigating through the menus, changing and confirming settings.

Note The complete menu structure of the LAS MkII scintillometer can be found in Appendix C.

Navigating through the LAS MkII menu structure is very straight-forward using the keys.



The keys are used to scroll through the (sub-) menus or to select or enter a value:

Scroll mode:

Up key	Select next menu item
Down key	Select previous menu item
Left key	Go one menu level back
Right key	Select displayed menu item

Edit mode

Up key	Increment digit
Down key	Decrement digit
Left key	Select previous digit
Right key	Select next digit

Confirm (edit mode)

Display shows	Confirm Entry - Yes
Up or down key	Cycles through options; Yes, No, Quit
Right key	Completes selected action: Yes - confirm changes and go back to menu No - cancel and go back to edit mode Quit - exit edit mode without changes

2. PATH LENGTH
0.00 m

2. PATH LENGTH
1.00 m

2. PATH LENGTH
2.00 m

2. PATH LENGTH
3.00 m

2. PATH LENGTH
4.00 m

CONFIRM ENTRY
YES

CONFIRM ENTRY
NO

CONFIRM ENTRY
QUIT

Press 2x (to move cursor all the way to the right)

To cancel and go back to edit mode

To exit edit mode without changes

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2.8 Configuration for measurement

The table below shows the sub-menus contained within Menu 2, Configuration. These sub-menus require setting up before, or during, installation. To configure the LAS MKII receiver before installation refer to the 'power up receiver' section 2.9.4.

Note The complete menu structure of the LAS MkII scintillometer can be found in Appendix C.

Sub-menu	Sub-menu item	Function	Range	Default
1. Installation	1. Aperture	Set or show effective diameter	0 to 399.9 mm	149 mm
	2. Path Length	Set or show path length	0.0 to 7999.9 m	1184 m
	3. Install Height	Set or show installation height	0.0 to 4999.9 m	1.5 m
	4. Z.Displ.Height	Set or show zero displacement height	0.01 to 9.999 m	0 m
	5. Bowen Ratio	Set or show Bowen Ratio	0.01 to 9.999	2
	6. Signal Gain	Show signal strength and set gain	1x, 2x, 4x	1
	7. Set Defaults	Restore default configuration	0 = No, 1 = Yes	0 = No
	8. << Back	Back to higher menu		
2. Advanced	1. Rel Humidity	Set or show relative humidity	0 to 99.9%	50%
	2. Heat capacity	Set or show heat capacity of air	500.0 to 1999.9	1000
	3. Bowen Ratio	Set or show Bowen Ratio	0.01 to 9.999	2
	4. Empir.Constant	Set or show empirical constant	0 to 9.999	0.48
	5. << Back	Back to higher menu		
3. Sensors	1. Air Temp	Set or show air temperature	-39.9 to 49.9 °C	+17 °C
	2. Air Pressure	Set or show air pressure	0 to 1100 mBar	1012 mBar
	3. Wind speed	Set or show wind speed	0 to 40.0 m/s	2.2 m/s
	4. Device Temp	Set or show receiver temperature	-39.9 to 49.9 °C	N/A
	5. << Back	Back to higher menu		
4. DataLogger	1. Set Date	Set date	yy/mm/dd	ECT
	2. Set Time	Set time	hh:mm:ss	ECT
	3. Wakeup Time	Set or show time start measure & log	hh:mm	99.99=Off
	4. Sleep Time	Set or show time stop measure & log	hh:mm	99.99=Off
	5. Log Interval	Set data average and log interval	0 to 29999 s	600 s
	6. Send Interval	Set send interval of data to computer	0 to 29999 s	0=Off
	7. << Back	Back to higher menu		
5. Interface	1. Set Default	Restore default configuration	Com 1	
	2. BaudRate	Set or show baud rate	1200 to 38400	4800
	3. Parity	Set or show parity	0=none, 1=odd, 2=even	0
	4. Databits	Set or show number of databits	7 or 8	8
	5. Interface Type	Set or show interface type	RS-232-C or RS-422	422
	6. DeviceID	Set device address	0 to 255	255
	7. Restart	Restart the receiver		
	8. << Back	Back to higher menu		

Note The Sensor sub-menu default values are used when the meteorological sensor kit is not connected. These values can be changed by the user, within the ranges shown.

Note If a BaudRate is entered different to those listed, the receiver will select the nearest valid value. Valid interface types are 232 and 422, if another number is entered the port will switch off.

2.8.1 Setting parameters to measure C_n^2

C_n^2 is measured using the following general algorithm:

$$C_n^2 = 1.12 \sigma_{\ln I}^2 D^{7/3} L^{-3}$$

Where; D is the aperture diameter of the LAS MkII, L is the distance between the transmitter and the receiver (the path length) and $\sigma_{\ln I}^2$ the measured variance of the natural logarithm of intensity fluctuations.

The parameters for aperture and path length must be set in the receiver.

Note Set the Aperture to the value stated on the Test and Final Inspection Certificate supplied with the instrument. The typical setting is 149 mm.

2.8.2 Setting parameters to measure sensible heat flux

From C_n^2 data, together with wind speed, temperature, and an estimate of the topology and the displacement height; the surface sensible heat flux (H) can be determined from by solving equations iteratively. See Appendix C for further information.

In addition to the parameters for measurement of C_n^2 the following additional parameters are required to measure surface sensible heat flux (H):

- Installation height
 - Zero Displacement Height
 - Bowen Ratio
 - Temperature
 - Pressure
 - Wind Speed
 - Roughness Length
- } from meteorological sensor kit when connected

The surface sensible heat flux (H) can be calculated by a computer using the supplied EVATION software package, the data from the LAS MkII and meteorological sensor kit and by inputting other parameters, such as the roughness length.

However, for most day-time (unstable) conditions and when the LAS MkII is installed relatively high above the surface ($z_{LAS\ MkII} > 20$ m) the contribution of the friction velocity is relatively small. For these conditions the free convection method can be applied.

Note that the free convection sensible heat flux (H_{free}) calculated by this method is not as accurate as the standard method for H because it does not allow for surface topography (roughness length, etc.).

See Appendix C for further information.

When the meteorological sensor kit is connected the LAS MkII can internally calculate and log the free convection sensible heat flux (H_{free}).

2.8.3 External sensors

When the meteorological sensor kit is connected the correct factory sensitivities and ranges are automatically selected.

When the kit is not connected, fixed values typical of the measurement location can be entered in sub-menu 3 of the configuration menu.

2.8.4 Data Logger

Configure the following data logger settings; date, time, sleep time, wakeup time, log-interval and send interval.

The wakeup time defines the start of the operational mode. When the operational mode is active the LAS is measuring and logging data; the receiver heater is turned on when the temperature of the receiver is below the 'operating temperature' in the heater menu.

The sleep time defines the start of the low power 'sleep' mode, during which there is no measurement and the receiver heater is turned on only when the temperature of the receiver is below the 'standby temperature' in the heater menu.

The log interval defines the interval over which measurements will be averaged and then stored in the internal flash data memory.

The send interval defines the interval at which the current data values will be sent automatically to a computer.

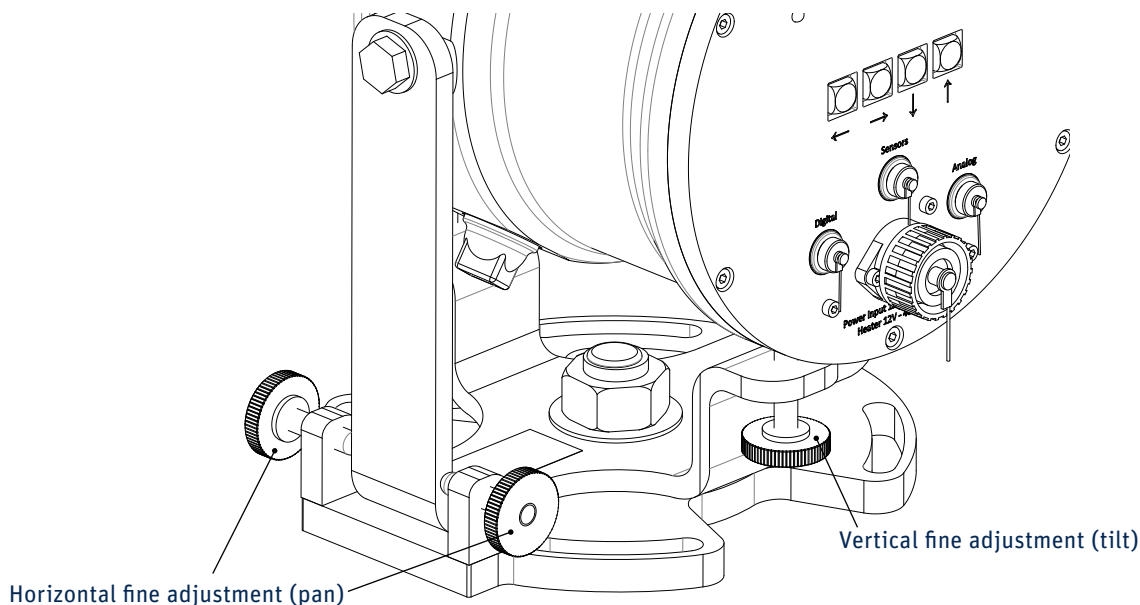
2.8.5 Interface

Configure the following interface settings; baud rate, parity, data bits and interface type.

2.9 Installation and optical alignment

The alignment of the LAS MkII at the measurement site is an iterative process for establishing the optimum signal strength for horizontal line-of-sight transmission. The different steps are summarized below. We recommend practicing the alignment procedure at a short range (~ 250 m) before installation at longer distances.

The transmitter and receiver can be rotated around both vertical and horizontal axes. The coarse horizontal alignment (pan) can be done by rotating the transmitter and receiver before the bolt(s) fixing the baseplate to the supporting structure is (are) tightened. Fine pan adjustment is done with the two horizontal adjustment screws. For the vertical alignment (tilt) two vertical adjustment screws are provided, one at the front and one at the rear.



2.9.1 Preparation for installation

Two people should carry out the alignment, one at the receiver and one at the transmitter. They must be able to communicate either by radio, walkie-talkies or mobile telephones.

Note The final alignment should be carried out under conditions of clear or very clear visibility, i.e. visibility > 10 km.

The table below shows the typical variation in receiver signal strength over a path length of 3000 m for a nominal transmitter power and receiver signal gain setting.

Visibility class	Visibility range	Nominal signal
Very clear	20 to 50 km	175 to 225 %
Clear	10 to 20 km	125 to 175 %
Hazy	4 to 10 km	75 to 125 %

2.9.2 Installing the transmitter and receiver

1. Install the transmitter and receiver of the LAS MkII at their selected positions.
2. The bolts used to fix the baseplates to the tripods or other supporting structures are fastened by hand, so that the transmitter and receiver can still be turned around their vertical axes.
3. Clamp the telescopes to the rails on the tops of the transmitter and receiver using the 4 mm hexagonal Allen keys. Note that the telescopes are factory-aligned for each transmitter and receiver and are marked appropriately with either 'Transmitter' or 'Receiver'.
4. Adjust the transmitter both horizontally (pan) and vertically (tilt) such that the crosshairs of the telescope are centred on the receiver window. Tighten the bolt(s) fixing the baseplate to the supporting structures (further adjustments can be done with the pan fine adjustment screws).
5. Carry out the same procedure for the receiver relative to the transmitter.

2.9.3 Power up transmitter

1. Connect a suitable 12 VDC power supply to the transmitter and switch on the power. The red power indicator on the transmitter rear panel will illuminate.
2. Unscrew the cover of the power adjustment knob and initially set the 10-turn dial (scaled from 0 to 1000) to maximum.

2.9.4 Power up receiver

1. Connect a suitable 12 VDC power supply to the receiver and switch on the power. The green power and status indicator on the rear panel provides information on the operation of the LAS MkII receiver, as in the following table.

Green indicator function	Status
Normal blinking (0.2 sec on 0.8 sec off)	The instrument is operational
Fast blinking (0.2 sec on 0.2 sec off)	A hardware error was detected
Slow blinking	The boot loader is running
Always on	The boot loader is halted, no application is running
Always off	The power is switched off, the instrument has a hardware error, or the supply voltage is too low

2. The display on the rear panel of the receiver will cycle through the following start-up messages (examples are shown):

- The serial number and production document

```
LASRX 12:0001
120-0371500-4
```

- The software release and hardware release

```
SOFTWARE 2.00
HARDWARE 1.2
```

- The communication parameters (interface type, baud rate, data bits, parity)

```
COM1 - RS422
4800/8/N
```

- The successful start-up message

```
START COMPLETED
NO ERRORS
```

Or 'Check 12V Heater' (this is only a warning that the heater is not set, it is not an error)



If a hardware error message occurs, try turning off the power and the restarting the receiver. If the error persists, make a note of the code and contact support@kippzonen.com

3. A configuration error message will be displayed if one or more of the configuration parameters stored in the memory are not correct. The following configuration error messages are defined:

CHECKSUM ERROR
NO CONFIGURATION

SETUP ERROR
NO CONFIGURATION

THE SERIALNUMBER
IS NOT SET

CONFIGURATION
ERROR

THE LOGFILE IS
CLEARED

THE IDLE MODE IS
SET

THE INSTRUMENT
IS IDLE

Note More detailed information about configuration errors and how to clear them is given in Appendix D.

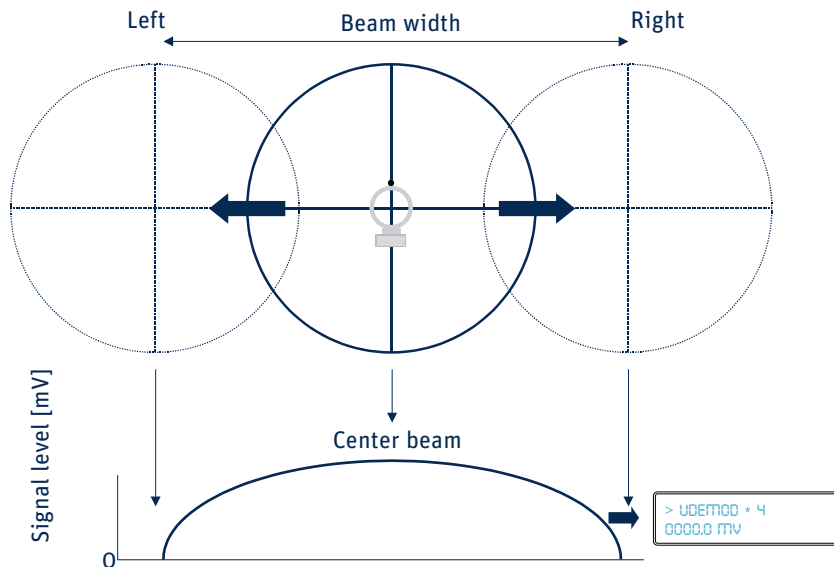
1. At the receiver ensure that the LAS MKII is configured as described in section 2.8, in particular the path length, installation height and aperture (100 mm or 149 mm).
2. At the receiver set the signal gain using the navigation keys as follows:
Main Menu → 2. Configuration → 1. Installation → 6. Signal Gain
Initially set the signal gain to 1 (this is the default value).
3. Return to the main menu and select
Main Menu → 1. View RealTime → 1. Signal Level

2.9.5 Transmitter optical alignment

Note It is very important to follow this procedure carefully because the data is not reliable when the edges of the beam are too close to the receiver or transmitter aperture.

1. The person at the receiver observes the signal level and communicates the values to the person at the transmitter.
2. The person at the transmitter first slowly turns the transmitter horizontally (pan) left and right using the adjustment screws until the maximum signal strength (as given by the person at the receiver) is reached.
3. There should be a 'plateau' region of approximately the same signal strength between the horizontal edges of beam. Find the mid-point of this region, which will be the centre of the beam.
4. The transmitter then needs to be slowly adjusted vertically (tilt) up and down using the adjustment screws to find the mid-point maximum signal strength, as in step 3.
5. The concept of the maximum signal 'plateau' is shown in the figure on the next page.
6. If the receiver signal strength is more than 200 % reduce the transmitter power for a reading of about 100 %. Optimise the horizontal and vertical alignment for the maximum signal strength in the middle of the 'plateau' region. Each time the signal strength is more than 200 % reduce the transmitter power for a reading of about 100 %.

7. Repeat steps 2 to 8 until the best transmitter optical alignment is achieved.
8. Tighten the transmitter adjustment screws, checking that the signal strength has not changed.



2.9.6 Receiver optical alignment

Note It is very important to follow this procedure carefully because the data is not reliable when the edges of the beam are too close to the receiver or transmitter aperture.

1. The person at the receiver observes the signal level and optimises the alignment.
2. First slowly turn the receiver horizontally (pan) left and right using the adjustment screws until the maximum signal strength is reached.
3. As for the transmitter, there should be a 'plateau' region of approximately the same signal strength between the horizontal edges of beam. Find the mid-point of this region, which will be the centre of the beam.
4. The receiver then needs to be slowly adjusted vertically (tilt) up and down using the adjustment screws to find the mid-point maximum signal strength, as in step 3.
5. If the receiver signal strength is more than 200 % reduce the transmitter power for a reading of about 100 %. Optimise the horizontal and vertical alignment for the maximum signal strength in the middle of the 'plateau' region. Each time the signal strength is more than 200 % reduce the transmitter power for a reading of about 100 %.
6. Repeat steps 2 to 5 until the best receiver optical alignment is achieved.
7. Tighten the receiver adjustment screws, checking that the signal strength has not changed.

2.9.7 Finalise optical alignment

1. Adjust the transmitter power to give signal strength of 100 - 120 % and lock the knob with the small black tab. Make a note of the dial setting for future reference.

Note It is possible that at path lengths of 3000 m or greater, and depending upon the visibility, a signal strength of 100 - 120 % is not achievable. The LAS MKII will operate correctly with signal strength of 25 % or more. Do not increase the receiver signal gain, as this also increases the noise and overall measurement performance is not improved.

2. Screw on the cover of the power adjustment knob. Hand-tighten only to avoid damaging the o-ring seal.
3. The optical alignment is now complete. Go back to the View RealTime menu and sub-menu 3 (C_n^2). The LAS MkII should now be measuring and logging data according to the configuration set in section 2.8.

Note It is possible that the transmitter or receiver is not now aligned with the centre of the crosshairs of its telescope. This is due to a difference between the operating path length and the range at which the telescopes were adjusted at the factory. Therefore never rely only on the telescopes during the alignment procedure! If desired, the crosshairs of the telescopes can be adjusted using the instructions provided with them.

4. The telescopes can now be removed and the sun shields fitted to the transmitter and receiver with the fixing screws and the 3 mm hexagonal Allen keys. Store the telescopes carefully for future use.



Never (re-)align the LAS MkII transmitter and receiver using the telescopes only and do not swap the transmitter and receiver telescopes. Always use the optical alignment procedure.



To avoid non-linearity of the detector and overload of the electronics, the signal strength is limited to a maximum of 250 %. Above this the over-range value of 999 % is shown.

3. Accessories

3.1 Meteorological sensor kit

The kit is supplied as a cross-arm with cables connected to a junction box, which has a 10 m long yellow cable fitted with a waterproof connector. The junction box contains an air pressure sensor and has a sintered bronze 'breather' to the ambient air.

Wind speed and air temperature sensors are provided, which must be secured to the cross-arm (the fixing screws are already fitted to the cross-arm) and then connected to the cables.

An aluminium pole, 2 m long, is supplied for supporting the cross-arm and junction box.

The meteorological sensor kit will be automatically powered and recognised when plugged into the LAS MkII receiver.

3.2 CVP 1 LAS MkII power supply

This is a weatherproof heavy-duty AC-DC power supply unit for outdoor use. One each is required for the transmitter and receiver of the LAS MKII.

Wide AC input range, fully protected output 12 VDC at 3.5 A.

Operating temperature range -20 °C to +50 °C.

Pre-wired with 10 m long power output cable and connector for LAS MkII transmitter or receiver, and 5 m long AC power input cable with IEC female plug.

3.3 Transit case

Foam-lined rugged transit case, for safe transport of LAS MkII. One each is required for the transmitter and receiver.

3.4 Adjustable heavy-duty tripod package

Aluminium folding tripod, adjusts up to 3 m height, includes base-frame for hard surfaces and fixing bolts for LAS MkII. Two supplied, one each for transmitter and receiver, in a wood carrying case.

3.5 Tripod floor stand

For easy mounting and levelling of the LAS MkII, height 0.45 m. Very stable and rugged. As used with the Kipp & Zonen Brewer spectrophotometer and 2AP sun tracker. One each is required for the transmitter and receiver.

3.6 Height extension tube

Bolts to the top of the tripod floor stand and extends the mounting height to a total of 1.05 m.

4. Software installation and configuration

The LAS MkII scintillometer can be configured in two ways; using the built-in display and keypad of the receiver or through the included EVATION software package. Configuring the receiver using the display and navigation keys has been described in section 2.8. This section describes the LAS MkII configuration using EVATION.

EVATION allows the LAS MkII user to derive the surface fluxes of sensible heat from recorded scintillometer data and additional meteorological data, such as air temperature (T), air pressure (P), wind speed (u) and Bowen ratio (β).

If a complete LAS MkII ET System is available EVATION can also calculate the latent heat flux (L_vE) and evapotranspiration (ET).

4.1 Installing the EVATION software package

4.1.1 System requirements

The minimum computer hardware requirements for EVATION are a 800 MHz Pentium computer running Windows™ XP or Windows™ 7 (32-bit or 64-bit), 1 GB of RAM, 300 MB of free hard-disk space (excluding LAS MkII data) and a mouse.

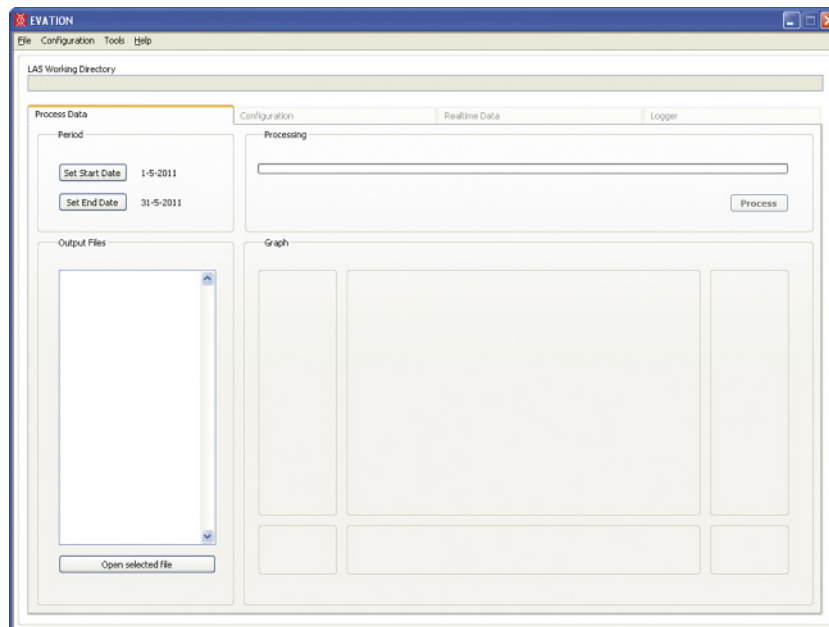
4.1.2 Installation procedure

In order to install the EVATION software package, please select and run the file 'EvationSetup.exe' which is located on the CD-ROM supplied with the instrument. The installer program will guide you through the installation process.

Note 'Administrator' rights on the computer may be required to install the software.

4.1.3 Using EVATION for the first time

When EVATION is started for the first time, the following screen is shown.



Since there is no previous LAS MkII data available, the software must be configured as follows.

4.1.4 Selecting a data folder

EVATION stores all scintillometer data and processing settings in a predefined folder structure.

Folder name	Function
input	All measurement data should be stored here Data retrieved using the LAS MkII digital interface connection is placed here
output	Repository of processed data
config	Configuration setting files are stored in this folder
auxiliary	Any intermediate or temporary data required by EVATION is stored in this folder

The first requirement for working with EVATION is selecting, or creating, a user-defined folder in which the above folder structure is created.

In the main screen select the tab 'File' and then the menu option 'Working directory'.

In case the selected folder is new or empty, in the following screen, click on 'Yes'.



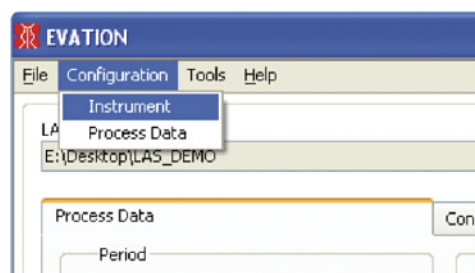
The required folder structure will now be created by EVATION.

4.2 Configuring the EVATION software package

Before EVATION can be used a number of parameters must be configured.

4.2.1 Scintillometer type

In the main screen select the tab 'Configuration' and then the menu option 'Instrument'.



On the next screen, 'LAS Configuration', select 'LAS type'.

This updated version of EVATION will also work with the original Kipp & Zonen LAS, both at full aperture and at restricted aperture (0.1 m), and with the original X-LAS.

For the LAS MkII, select LAS II.



When LAS II is selected, the following options will become available; Communication, Installation and Instrument. For all other LAS types these options are not available.

4.2.2 Communication

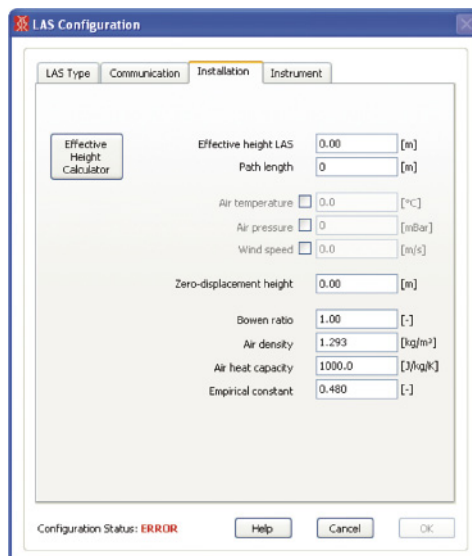
Select the serial communications port of the computer that the LAS MkII is connected to.

Set the baud rate, parity and number of databits to match the LAS MkII receiver settings (the default setting is 4800 bps with no parity and 8 databits).



4.2.3 Installation

Configure the site-specific parameters.

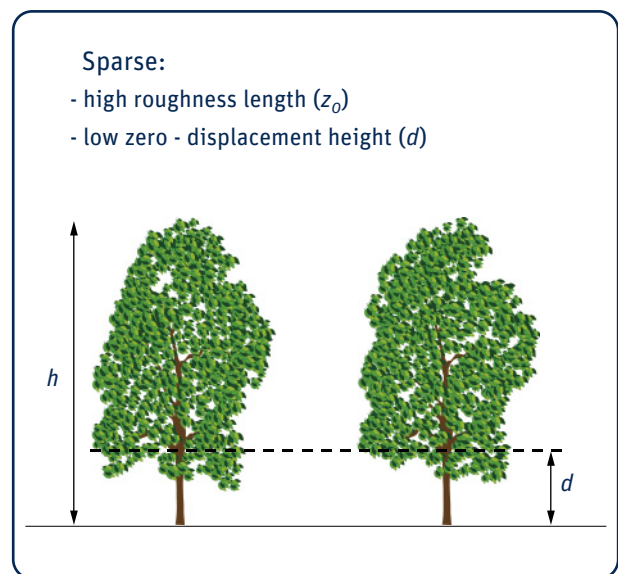
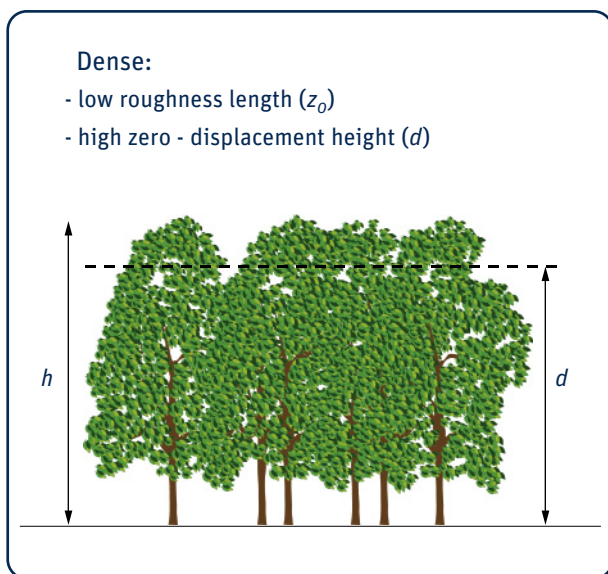


Parameter	Description
Effective height LAS	For an even terrain with minimal changes in elevation along the path, the effective height of the beam is relative to the ground For an uneven terrain use the effective height calculator (see Appendix E)
Path length	The distance between the transmitter and the receiver
Air temperature	When unchecked values from the meteorological sensor kit will be used When checked fixed user values can be entered
Air pressure	
Wind speed	
Zero-displacement height	See description in 4.2.4
Bowen ratio	The ratio between the sensible and latent heat flux, H/L_vE
Air density	Calculated value
Air heat capacity	Can be set to other than the default value if required
Empirical constant	Only change from the default value for advanced applications

4.2.4 Roughness length and zero displacement height

The aerodynamic roughness length or surface roughness (z_o) is an expression for the irregularity of the Earth's surface. It affects the intensity of mechanical turbulence and the fluxes of sensible heat (H), latent heat (L_vE), and momentum, above the surface.

The roughness length depends on the surface, or terrain, characteristics. For example a grassy plain has a smaller roughness length than an area with many trees and buildings. The surface roughness is loosely related to the typical height (h) of closely spaced surface obstacles, often called roughness elements (e.g. waves of water, buildings, vegetation). It depends on the distribution, as well as the height, of the roughness elements - as shown below for trees.



In the table below the eight different terrain classifications are given.

Class	Name	Roughness length m	Landscape features
1	Sea	0.0002	Open water, tidal flat, snow with fetch greater than 3 km
2	Smooth	0.005	Featureless land, ice
3	Open	0.03	Flat terrain with grass or very low vegetation, airport runway
4	Roughly open	0.1	Cultivated area, low crops, obstacles of height h separated by at least $20 h$
5	Rough	0.25	Open landscape, obstacles separated by $\sim 15 h$
6	Very rough	0.5	Landscape with bushes, young dense forest, etc., separated by $\sim 10 h$
7	Closed	1.0	Open spaces comparable with h ; e.g. mature forest, low-rise buildings
8	Chaotic	> 2.0	Irregular distribution of large elements; e.g. city center, large forest with clearings

When the scintillometer is installed over natural landscapes which are mostly heterogeneous over a path length of several kilometers we recommend using the table above for determining a representative roughness length.

If necessary focus on the area in the middle of the path of the scintillometer. In the case where the scintillometer is installed over a relative homogeneous area, such as a dense agricultural field or forest, it is best to apply a simple approximation:

$$z_0 = 0.1 h$$

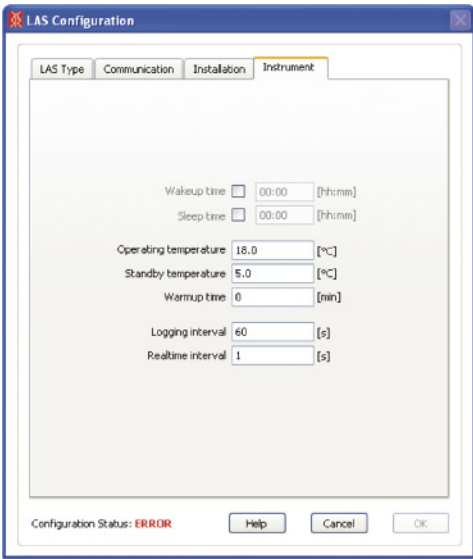
If the area surrounding the scintillometer site consists of roughness elements that are packed very closely together, such as a dense forest or a dense crop, the tops of those elements begin to act like a displaced surface. This is known as the zero-displacement height.

The only proper way to derive the zero-displacement height is from wind profile data; but, there is a simple rule of thumb, using the crop height:

$$d = 0.7 h$$

However, note that this estimate is not very accurate, especially when the crop or forest is not densely packed. When the roughness elements are not closely packed it may be better not to use a zero-displacement height (i.e. $d = 0$).

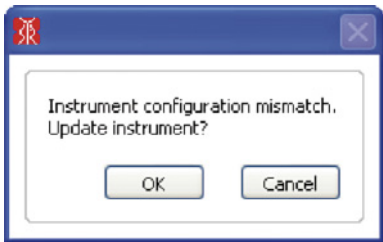
4.2.5 Instrument



Parameter	Description
Wakeup time	The time of day when the receiver begins to measure and store values
Sleep time	The time of day when the receiver stops measuring and storing values
Operating temperature	If the receiver temperature drops below this temperature whilst measuring, the heater is switched on
Standby temperature	If the receiver temperature drops below this temperature whilst sleeping, the heater is switched on
Warmup time	The period of time that the heater is switched on before the wakeup time starts
Logging interval	The interval for averaging data and then storing it in the data logger memory
Realtime interval	The interval at which the LAS receiver automatically transmits data to a computer

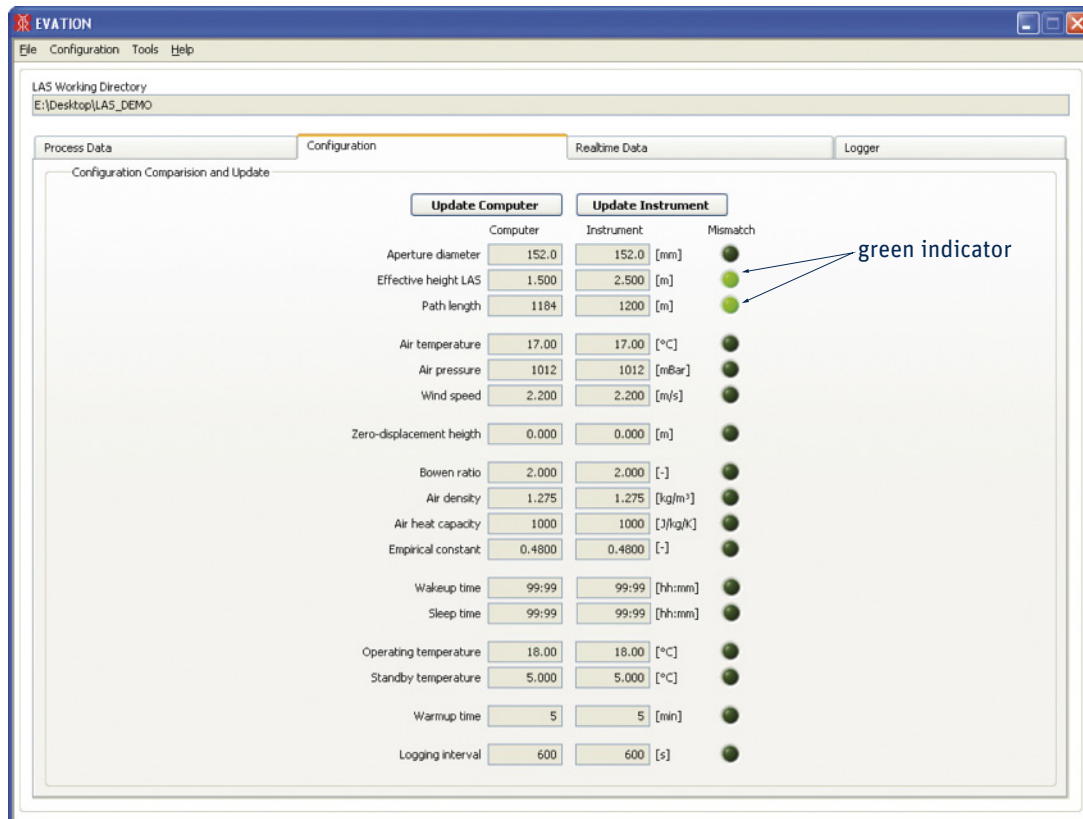
After the configuration parameters have been set, any difference between the LAS MkII receiver settings and the settings in EVATION will be checked at regular intervals by EVATION.

When a difference exists a message will be displayed asking if the configuration of the scintillometer needs to be updated to match the EVATION settings.



If 'OK' is selected, the LAS MkII receiver is updated with the settings in EVATION. If 'Cancel' is selected, no settings in the receiver are changed.

On the main screen the current settings in EVATION and in the LAS MkII receiver are displayed. Any differences between the settings will be indicated by a green indicator next to the parameter.



This screen presents two choices:

‘Update Computer’ : EVATION will be updated with the settings from the LAS MkII receiver.

‘Update Instrument’ : The LAS MkII receiver will be updated with the settings from EVATION.

After pressing an ‘Update button it will change to display ‘Stop Update’. It will remain active and EVATION will continuously check for differences in the settings and will automatically update either EVATION or the LAS MkII, depending on which update button was pressed, if any changes are made at either side. This process will continue until the ‘Stop Update’ button is pressed.

4.2.6 Data processing

In the main screen select the tab ‘Configuration’ and then the menu option ‘Process Data’. In this menu the parameters can be set for processing the scintillometer data. In the case of the LAS MkII many settings are taken from the receiver. For all other types of Kipp & Zonen scintillometer, most of these parameters must be manually entered here.

Process Data Configuration

Installation | Terrain | Algorithm | Input | Output | Program | Notes

Latitude: 50° - 60° North

Effective Height Calculator

Effective height LAS: 1.500 [m]

Height wind speed anemometer: 7.000 [m]

Height temperature/humidity sensor: 7.000 [m]

Height temperature sensor: 7.000 [m]

Depth soil heatflux plates: 0.100 [m]

Real path length: 1104 [m]

Path length LAS according to receiver: 1184 [m]

Minimum signal strength: -10.000 [mV]

Configuration Status: OK

Help Cancel OK

Parameter	Description
Latitude	The latitude of the installation site
Effective height LAS	For even terrain along the scintillometer path, the effective height is the height of the beam relative to the ground For an uneven terrain please use the Effective Height Calculator
Height wind speed anemometer	The height of the anemometer above the surface
Height upper temperature sensor	The height of the upper temperature sensor above the surface
Height lower temperature sensor	The height of the lower temperature sensor above the surface
Depth soil heat flux plates	The depth in the ground of the sensors
Real path length	The direct path length between the transmitter and receiver
Path length according to receiver	The path length set on the receiver
Signal strength	Receiver signal strength in mV

5. Operation and measurement

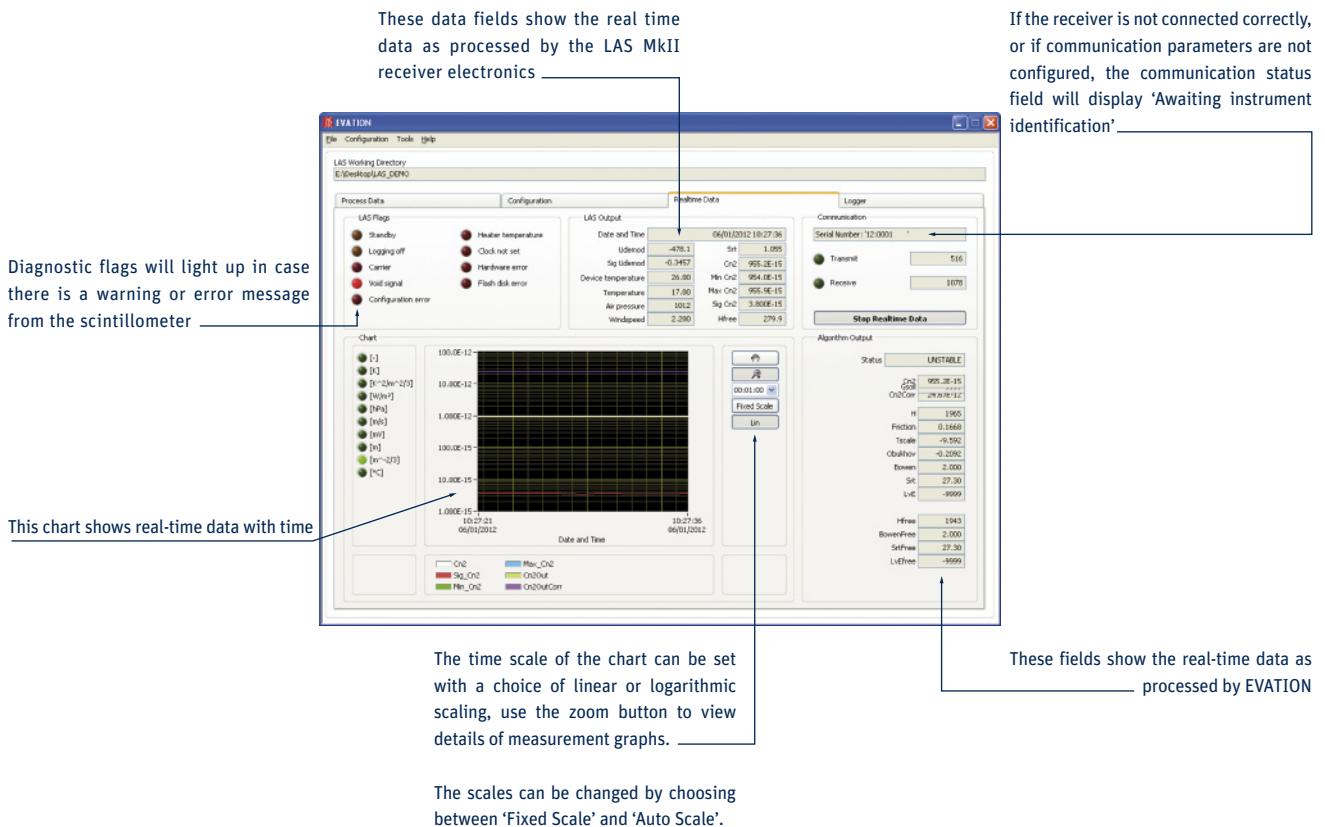
After completing the software installation and configuration the LAS MkII is ready for operation.

5.1 Collecting digital data

The data from the LAS MkII receiver can be obtained using the EVATION software. EVATION has the functionality to collect data from the receiver's internal data logger and the real-time data display.

5.1.1 Real-time data display data using EVATION

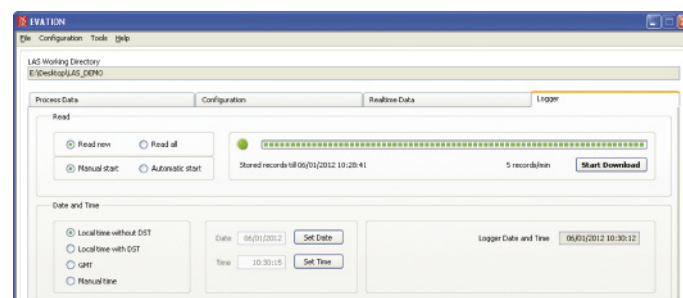
When the LAS MkII receiver is connected to a computer running EVATION, Select the 'Real-time Data' tab from the main screen. A screen similar to the one below will be shown.



Once the 'Show Real-time Data' button is pressed, the graph in the centre of the screen and the data fields will become active.

5.1.2 Downloading data from the internal data logger

Select the tab 'Logger'.



Parameter	Description
Read new	Only new data is downloaded
Read all	All data in the memory is downloaded
Manual start	Download data at the user's request
Automatic start	Download new data records as soon as they are available in the receiver
Start download	Start the data download process
Date and time settings	Four options for setting the LAS MkII internal clock from a computer: Local time without DST Local time with DST Greenwich Mean Time (UTC) Manual time (user defined date and time)
Set Date	Sets the LAS MkII receiver date from the choices above
Set Time	Sets the LAS MkII receiver time from the choices above
Logger date and time	The currently set date and time in the LAS MkII receiver

All downloaded data is automatically placed in the 'Input' folder used by EVATION.

5.1.3 Data logger memory capacity

The LAS MkII receiver is equipped with 32 MB (megabytes) of internal non-volatile flash memory. The storage capacity is 45,312 data records.

One record is written to the final memory after each averaging log interval, as set by the user in the LAS MkII data logger settings.

The formula below can be used to calculate the number of days of logging capacity, depending on the data logger settings:

$$\text{Number of Days} = 45,312 \times \frac{T_{AVG}}{24 \times 3,600} \times \frac{24}{h_{logger}}$$

Where: T_{AVG} is the log interval in seconds

h_{logger} is the hours per day that the data logger is active, the period from wakeup to sleep

Example 1: $T_{AVG} = 300$ s (5 minutes) log interval and $h_{logger} = 24$ h per day logging:

$$\text{Number of Days} = 45,312 \times \frac{300}{24 \times 3,600} \times \frac{24}{24} = 157.3 \text{ days}$$

Example 2: $T_{AVG} = 60$ s (1 minutes) log interval and $h_{logger} = 8$ h per day logging:

$$\text{Number of Days} = 45,312 \times \frac{60}{24 \times 3,600} \times \frac{24}{8} = 94.4 \text{ days}$$

5.2 Data file format

Three types of files are downloaded by EVATION from the LAS MkII internal memory:

- Data files
- Configuration change logs
- Error logs

This section describes the information and format of these file types. The file format is fixed and cannot be changed. The general characteristics of each of the three files are:

Character format	ASCII
Data delimiter	Semi-colon ';'
Number of header rows	2
- Row 1	Label with parameter description
- Row 2	Parameter unit
Date/time format	yyyy/mm/dd hh:mm:ss

In addition the first three columns of each file contain:

1. Date and time
2. Record number
3. Status flag

Note Data processing applications such as Excel® tend to re-format the way date and time stamps are displayed based on local settings, and this may cause misunderstandings of the data.

The data file format is shown below.

	Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Header row 1:	Date/Time	RecordNo	StatusFlags	Udemod	UdemodSig	Cn2	Cn2Sig	Cn2Min	Cn2Max	Srt	Hfree	DeviceTemp	AirTemp	AirPressure	WindSpeed	
Header row 2:	[yyyy/mm/dd hh:mm:ss]	[-]	[-]	[mV]	[mV]	[m ⁻² /3]	[m ⁻² /3]	[m ⁻² /3]	[m ⁻² /3]	[K ² /m ² /3]	[W/m ²]	[°C]	[°C]	[mBar]	[m/s]	
Data row	9-11-2021 23:30	241	69	-9.3	-0.142	1.20E-12	2.85E-14	1.17E-12	1.22E-12	0.814	118	19	18	1013	3	
Data row	9-11-2021 23:31	242	69	-9.3	-0.142	1.20E-12	2.85E-14	1.17E-12	1.22E-12	0.814	118	19	18	1013	3	
Data row	9-11-2021 23:32	243	69	-9.3	-0.142	1.20E-12	2.85E-14	1.17E-12	1.22E-12	0.814	118	19	18	1013	3	
Data row	9-11-2021 23:33	244	69	-9.3	-0.142	1.20E-12	2.85E-14	1.17E-12	1.22E-12	0.814	118	19	18	1013	3	
Data row	9-11-2021 23:34	245	69	-9.3	-0.142	1.20E-12	2.85E-14	1.17E-12	1.22E-12	0.814	118	19	18	1013	3	
Data row....															

The header rows identify the parameter names and units.

The number of data rows depends upon the data logger settings.

5.3 Collecting analogue data

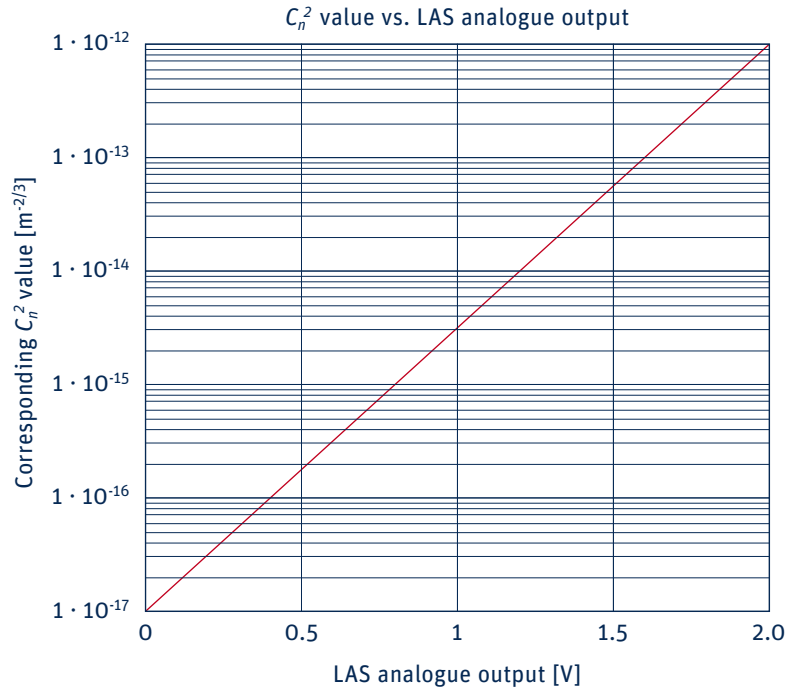
The C_n^2 values can be computed from the output signal ($U_{C_n^2}$) using the following equation:

$$C_n^2 = 10^{(2.5 \cdot U_{C_n^2} - 17)}$$

C_n^2 = structure parameter of the refractive index of air [m^{-2/3}]

$U_{C_n^2}$ = log scaled C_n^2 signal [V]

For example if $U_{C_n^2} = 0.5$ V, then $C_n^2 = 1 \cdot 10^{-16}$ m^{-2/3}



Because of the different averaging intervals of the real-time analogue output signal C_n^2 values (1 second) and the logged interval-averaged $U_{C_n^2}$ values (typically 10 minutes), the latter will not yield the true interval-averaged C_n^2 . Therefore we recommend one of the following two options:

1. Measure the interval averages of $U_{C_n^2}$ and the variance of $U_{C_n^2}$ ($\sigma^2_{U_{C_n^2}}$), and apply the following equation for deriving the correct interval-averaged C_n^2 :

$$C_n^2 = 10^{(2.5 \cdot U_{C_n^2} - 17 + 1.15 \cdot \sigma^2_{U_{C_n^2}})}$$

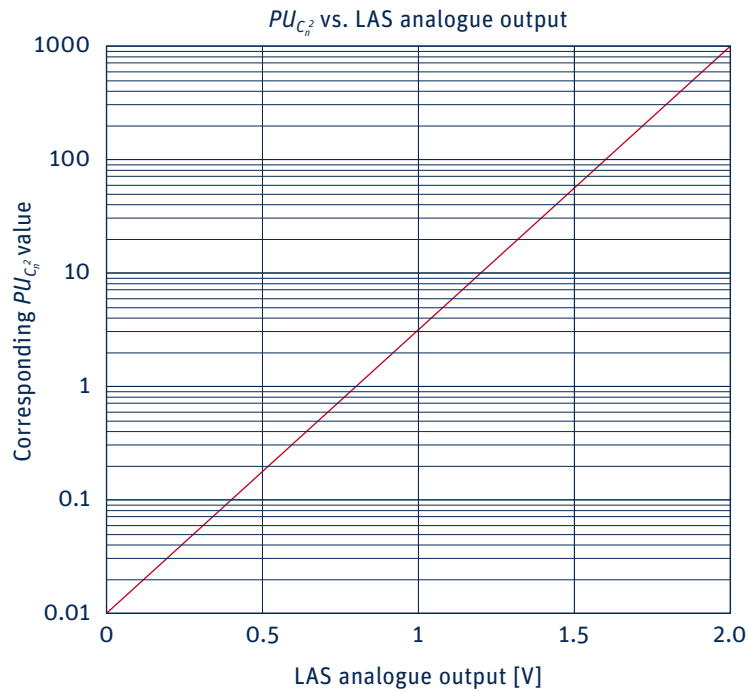
C_n^2 = structure parameter of the refractive index of air [m^{-2/3}]

$U_{C_n^2}$ = log C_n^2 signal [V]

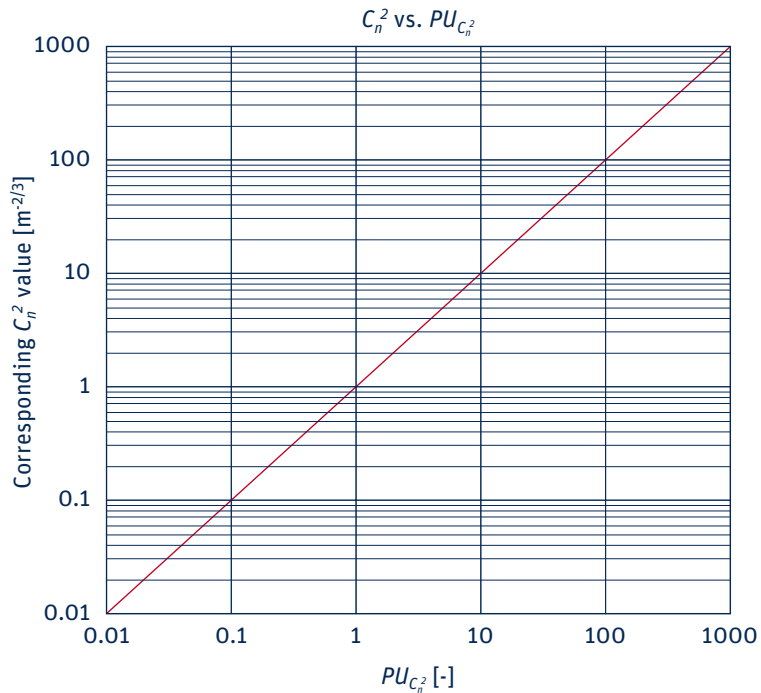
$\sigma^2_{U_{C_n^2}}$ = variance of $U_{C_n^2}$ [V²]

2. Calculate C_n^2 immediately after each measurement cycle (e.g. every 1 second, 1 Hz) and derive the interval-averaged C_n^2 (e.g. 10 minute averages) from the instantaneous C_n^2 values. Because the C_n^2 values are too small to store in most conventional data acquisition systems ($\sim 1 \cdot 10^{-16}$) The following calculation needs to be performed by the data logger:

$$PU_{C_n^2} = \frac{10^{U_{C_n^2} \cdot 2.5}}{100}$$



Afterwards the true C_n^2 values can be derived from $PU_{C_n^2}$ as follows:



5.4 Processing data files

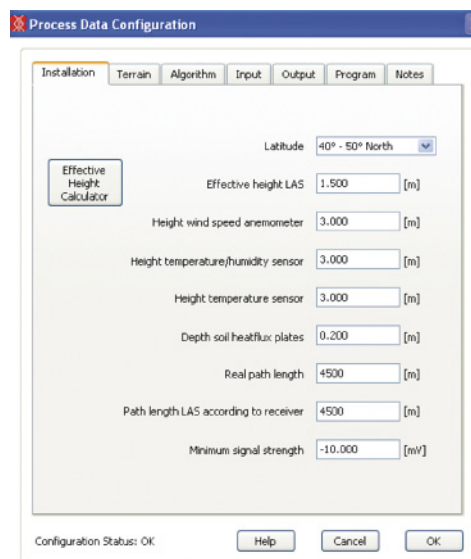
EVATION can process data files retrieved from the LAS MkII receiver data logger, LAS MkII ET Systems and correctly formatted data files from third party data acquisition systems.

5.4.1 Setting input parameters

In order to process the scintillometer data a number of parameters need to be set. Select the 'Process Data' option from the Configuration menu.



On the first page, set all the parameters to match the installation. All parameters need to be filled in. In case certain parameters, such as soil heat flux plates, are not present in the setup they can be ignored during data processing using options in a later step.



In the 'Terrain' tab enter values for roughness length and zero displacement height as described in section 4.2.4.

Leave the setting on the 'Algorithm' tab at the default Generic option.



In the 'Input' tab details on the data files must be selected.

Input	Column	Value/Type
T1	3	17.000 [°C]
T2	0	Unstable
RH	2	50.000 [%]
Pres	4	1012.000 [mBar]
U	6	2.200 [m/s]
W0	0	Bowen ratio
G1	0	0.000 [-]
G2	0	100.000 [W/m²]
Rh	5	500.000 [W/m²]
Cn2	1	PUCn2
Sig_PUCn2	0	
Udemod	7	
Sig_Udemod	0	

If the data files have been generated by the Kipp & Zonen LAS MkII ET System and its COMBILOG data logger, check the 'Standard Input File' box and the default ET System settings will be used.

If LAS MkII has been selected as the scintillometer model in section 4.2.1, the correct file format will be set automatically.

In case a propriety file format is used, please follow the instructions below:

Date and time format

Both the date and time need to be in a single column in the custom data file.

The letters indicating day, month and year, must be capitalised. For hours, minutes and seconds, use lower case letters. Example, use the following setting 'DD-MM-YYYY h:mm'

```
12-11-2010 8:00
12-11-2010 8:30
12-11-2010 9:00
12-11-2010 9:30
12-11-2010 10:00
12-11-2010 10:30
12-11-2010 11:00
```

Header Rows

Indicate the number of rows (usually at the top of the data file) which contain variables, names, units, etc.

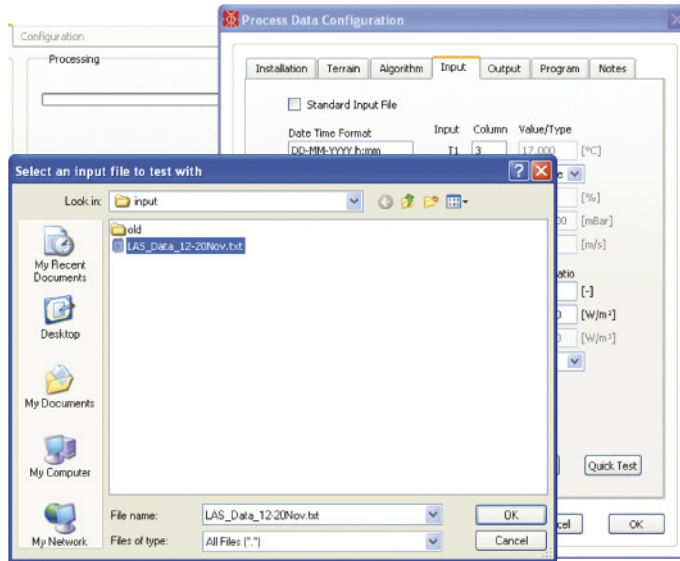
Delimiter

Select the data delimiter; TAB, space, colon, semi-colon or comma.

Input, Columns, Value/Type

This allows selection of which data is present in the columns of the data file. The first column following the column containing the date and time, has index number 1. In case a certain value is not present in the data file enter 0, and a default value can be selected.

To check whether the settings are correct, press the 'Quick Test' button to select a data file to be viewed.



The spread-sheet screen below shows an overview of how the data is read based on the settings. In case the spread sheet is empty, an error has been made in defining the date/time format or an incorrect assignment of column numbers.

Input Data Formatting Test

Date	Time	T1	T2	RH	Pres	U
12-11-2010	0:00:00	4.701E+0	NaN	9.125E+1	8.430E+2	2.228
12-11-2010	0:30:00	3.723E+0	NaN	9.199E+1	8.430E+2	1.492
12-11-2010	1:00:00	2.564E+0	NaN	9.199E+1	8.430E+2	1.766
12-11-2010	1:30:00	1.489E+0	NaN	9.199E+1	8.430E+2	1.891
12-11-2010	2:00:00	1.724E+0	NaN	9.199E+1	8.430E+2	2.144
12-11-2010	2:30:00	-5.430E-1	NaN	9.199E+1	8.440E+2	1.269
12-11-2010	3:00:00	-3.820E-1	NaN	9.199E+1	8.440E+2	1.656
12-11-2010	3:30:00	-1.349E+0	NaN	9.199E+1	8.440E+2	1.251
12-11-2010	4:00:00	-1.950E+0	NaN	9.199E+1	8.440E+2	9.160
12-11-2010	4:30:00	-1.436E+0	NaN	9.199E+1	8.440E+2	5.330
12-11-2010	5:00:00	-2.726E+0	NaN	9.199E+1	8.440E+2	9.210
12-11-2010	5:30:00	-3.102E+0	NaN	9.199E+1	8.450E+2	1.144
12-11-2010	6:00:00	-3.547E+0	NaN	9.199E+1	8.450E+2	9.330
12-11-2010	6:30:00	-4.066E+0	NaN	9.199E+1	8.450E+2	1.530
12-11-2010	7:00:00	-5.598E+0	NaN	9.199E+1	8.460E+2	1.702

Close

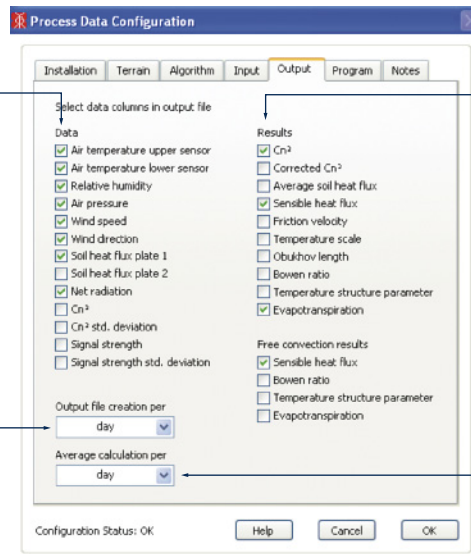
Using the 'Save' button, the configuration for your data files can be saved. This is convenient, especially when processing data files with varying formats or when a fresh installation of EVATION is required. The settings can be restored again using the 'Load' button.

5.4.2 Setting output parameters

In the 'Output' tab, the parameters which need to be included in the output files are chosen. See the image below for more information.

Select the raw data to be included, if present in the original data input file

The processed data can be output as daily, weekly, monthly or yearly files; the time resolution will be the same as the input data



Select which of the processed parameters will be included in the data output file

A second output file is automatically created, which averages the data from 5 minutes to 1 day

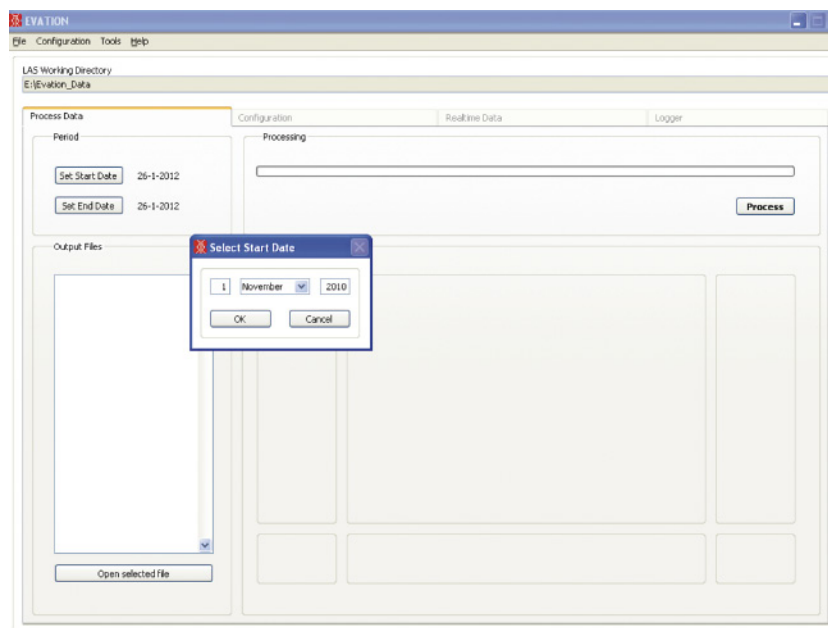
Press 'OK' to complete the process.

5.4.3 Selecting a text viewer

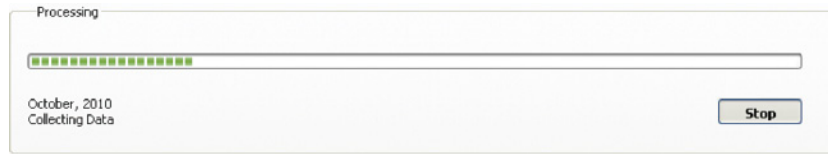
In the 'Program' tab a default viewing program for opening text files can be defined. The default is the Windows Notepad application.

5.4.4 Executing data processing

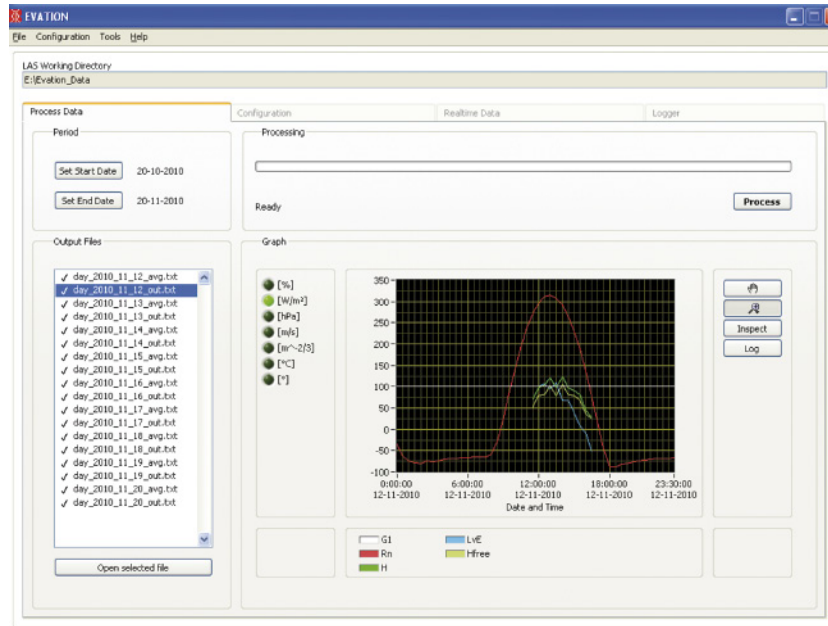
In order to start processing the data; 'Set Start Date' and 'Set End Date' in the EVATION main screen. EVATION will automatically import any data within the data files in the 'Input' folder with a time stamp between the start and end dates.



Press the 'Process' button to start the data processing, the progress bar will indicate the current status.



When the process is finished, an overview is given of the resulting output files. When the files are selected, the graph will show the data contained within them.



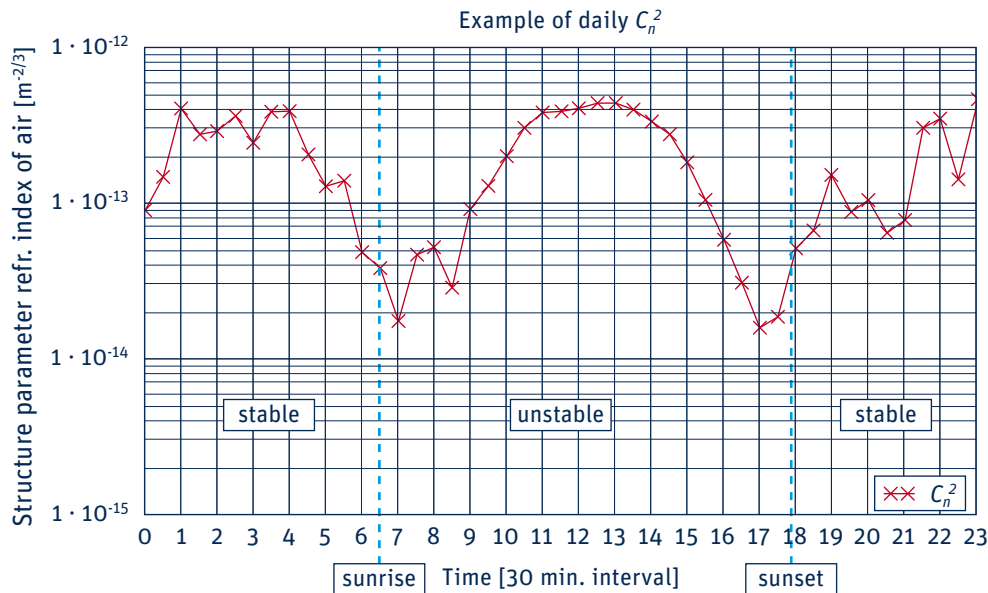
The processed data files are placed in the 'Output' folder.

5.5 Diurnal patterns

This section shows some typical day and night (diurnal) patterns for both C_n^2 and energy fluxes.

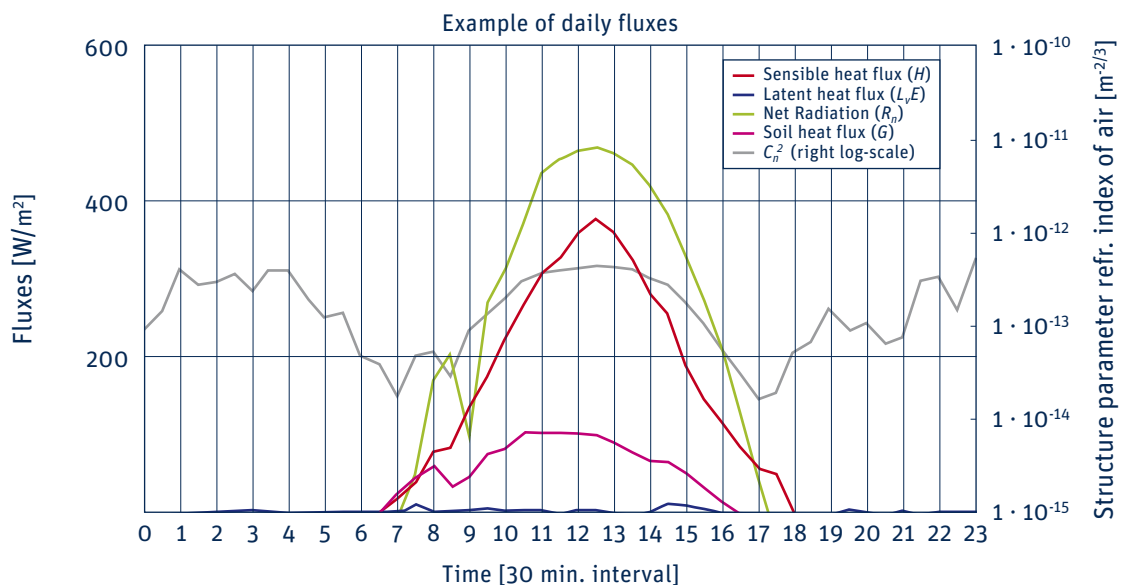
5.5.1 Diurnal C_n^2 patterns

The diurnal pattern of values for C_n^2 differs depending on atmospheric conditions. However, for a typical pattern the most significant features are the two dips in C_n^2 values which occur around sunrise and sunset. These dips indicate the transition between stable and unstable fluxes in the atmosphere.



5.5.2 Diurnal energy flux patterns

As for C_n^2 , in general the energy fluxes also show some typical features, as illustrated below using the same data as in 5.5.1. For completeness the C_n^2 values are shown on the right hand log-axis. Note that at night some of these fluxes may be negative, particularly the net radiation and soil heat flux, as shown in Appendix A.



6. Maintenance and recalibration

6.1 Internal calibration features

The LAS MkII receiver has built-in diagnostics and calibration features to ensure correct operation of the system. These functions can be accessed using the navigation keys and display.

6.1.1 Checking C_n^2 processing

Follow the following steps to check the internal processing of C_n^2 values.

Main Menu → 2. Configuration → 1. Installation → 1. Aperture → set to 152 mm → Confirm Entry: **YES**

Then; 2. Configuration → 1. Installation → 2. Path Length → set to 1184 m → Confirm Entry: **YES**

Enter the Diagnostics menu and set 'Gain' to 10 Hz:

Main Menu → 4. Diagnostics → 1. Gain → set to 010 Hz → Confirm Entry: **YES**

Internally a reference signal is processed with the following characteristics:

Ratio high / low level of pulse	: 2
Scintillation frequency	: 10 Hz

This should yield a C_n^2 value on the display of $1.0 \cdot 10^{-12} \text{ m}^{-2/3} \pm 0.5 \%$.

Note If the result is outside the limits please contact support@kippzonen.com for recalibration.

6.1.2 Electronics offset noise check

The electrical noise of the electronics can be checked as follows:

Main Menu → 2. Configuration → 1. Installation → 1. Aperture → set to 152 mm → Confirm Entry: **YES**

Then; 2. Configuration → 1. Installation → 2. Path Length → set to 1184 m → Confirm Entry: **YES**

Enter the Diagnostics menu and start the 'Offset' test:

Main Menu → 4. Diagnostics → 2. Offset

This procedure disconnects the detector from the input electronics and the C_n^2 measured as the result of electronics noise is displayed. This should be $< 1.0 \cdot 10^{-17} \text{ m}^{-2/3}$.

Note If the result is outside the limits please contact support@kippzonen.com for recalibration.



After either of these check be sure to return the configuration to the correct operational settings for aperture and path length.

6.2 Maintenance and inspection intervals

To ensure that the quality of the measurements is of a high standard, care must be taken with the maintenance of the LAS MkII. Regular cleaning of the transmitter and receiver windows and checking the optical alignment will prevent unnecessary signal attenuation and data loss. Regularly check the desiccant to prevent moisture inside the transmitter and receiver. Periodically check the condition of all cables and connectors.

Inspection / maintenance	Weekly	Monthly	Quarterly
Check signal strength	X		
Clean transmitter and receiver windows	X		
Inspect desiccant cartridges for saturation		X	
Check optical alignment		X	
Check Electrical stability		X	
Check data logger memory capacity		X	
Check cables and connectors			X
Check mountings are secure			X

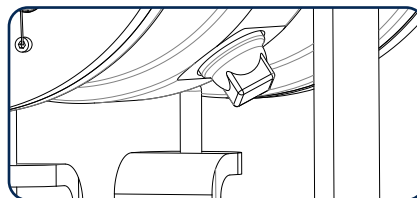


Always keep power connected, and switched on, to the LAS MkII transmitter and receiver when they are placed outside. The power dissipation helps to prevent internal condensation.

6.3 Inspecting and replacing desiccant cartridge

On a regular basis check the desiccant in the drying cartridges. This is a self-indicating silica-gel. When it requires replacement the colour changes from orange to clear.

1. Locate the two desiccant cartridges in the undersides of the transmitter and receiver and inspect the colour of the beads. If they are yellow they do not need replacing. If they are clear and transparent they need replacing with fresh desiccant.



2. To replace the desiccant unscrew the cartridges, if they are tight a 16 mm or 5/8" open-ended wrench / spanner can be used to loosen them, then unscrew by hand.



3. Remove the caps from the ends of the cartridges and safely dispose of the used silica-gel. Refill with fresh desiccant, and refit the end caps to the cartridges.



4. Make sure that the o-ring seals and their seats in the housing are clean, grease with Vaseline if it they are dry. Refit the drying cartridges.

Note Screw in the drying cartridges hand-tight only, to avoid distorting the o-ring seals. Desiccant refill packs are available from Kipp & Zonen. One pack is sufficient for one cartridge refill.

7. Specifications

Note Kipp & Zonen reserves the right to make changes to specifications without prior notice.

7.1 Specifications of LAS MkII transmitter

Parameter	Value
Operating temperature	-20 °C to +50 °C
Humidity	0 to 100 % RH, IP 65
Voltage	12 VDC nominal (9.6 to 18 VDC)
Power	6 W maximum with heater off 54 W maximum with heater on, typical 26 W
Window heater	Self-regulating at approx. +55 °C
Surge protection	For transmitter power, but not for heater
Centre wavelength of transmitting LED	850 nm
Modulation frequency	6.5 to 7 kHz (duty cycle 0.5)
Beam width	Approx. 1 m at 100 m distance
Fresnel lens diameter and focal length	152 mm / 152 mm
Length	266 mm *
Width	229 mm *
Height	297 mm *
Weight	8.5 kg *
* Including pan and tilt assembly, but excluding sun shield or telescope	

7.2 Specifications of LAS MkII receiver

Parameter	Value
Operating temperature	-20 °C to +50 °C
Humidity	0 to 100 % RH, IP 65
Voltage	12 VDC nominal (9.6 to 18 VDC)
Power	3 W maximum with heater off 51 W maximum with heater on, typical 23 W
Window heater	Self-regulating at approx. +55 °C
Surge protection	For transmitter power, but not for heater
Centre wavelength of optical filter for photodiode detector	850 nm
Fresnel lens diameter and focal length	152 mm / 152 mm
Scintillation signal bandwidth	0.2 to 400 Hz
Typical value signal 1 ($U_{C_n^2}$, $\log C_n^2$ signal)	0 to 2 V
Typical value signal 2 (6.5 - 7 kHz carrier)	0 to 1 V, 6.5 to 7 kHz, 0.5 duty cycle
Typical value signal 3 (U_{DEMOD} , signal strength I)	0 to 2 V
C_n^2 turbulent range	10^{-17} to $10^{-12} \text{ m}^{-2/3}$
Noise level of electronics	$< 10^{-17} \text{ m}^{-2/3}$
Length	266 mm *
Width	229 mm *
Height	297 mm *
Weight	8.5 kg *
* Including pan and tilt assembly, but excluding sun shield or telescope	

7.3 Specifications of LAS MkII scintillometer system

Parameter	Value for LAS MkII	Value with restrictors
Nominal aperture	150 mm	100 mm
Minimum path length	250 m	100 m
Maximum path length (depends on atmospheric conditions)	4.5 km	1 km
Minimum height	1.5 m	1.5 m
Maximum height for C_n^2 (or turbulence) measurements	no operational restriction	no operational restriction
Maximum height for H measurements Constant Flux Layer	Approx. 100 m	Approx. 100 m

8. Trouble shooting

The LAS MkII is designed for long periods of operation with little operator maintenance. However, if a problem occurs that cannot be corrected using the standard operating information supplied in the preceding sections of this manual, use the information below to identify and solve the problem.



There are no user-serviceable parts within the LAS Mk II and the transmitter or receiver must not be opened without the agreement and instruction of Kipp & Zonen.

8.1 Communication problems

Most problems with the LAS MkII after a successful installation are related to communication problems between the instrument and a computer, often due to power interruptions or disconnecting cables whilst the EVATION software is running.

If this occurs, check that the port number is still correct. Close the software and turn off the computer. Turn off the power to the LAS MkII receiver and disconnect the digital interface cable.

Reconnect the digital interface cable and turn on the power to the receiver. Wait a few minutes and then turn on the computer. Restart EVATION.

8.2 Receiver status and error messages

Green indicator function	Status
Normal blinking (0.2 sec on 0.8 sec off)	The instrument is operational
Fast blinking (0.2 sec on 0.2 sec off)	A hardware error was detected
Slow blinking	The boot loader is running
Always on	The boot loader is halted, no application is running
Always off	The power is switched off, the instrument has a hardware error, or the supply voltage is too low

If a hardware error message occurs it will be shown on the receiver display, refer to section 2.9.4. Try turning off the power and then restarting the receiver. If the error persists, make a note of the code and contact support@kippzonen.com.

If a configuration error message is displayed, one or more of the configuration parameters stored in the memory are not correct. Check the receiver configuration settings.

If you cannot solve the problem by the steps in the following pages, please contact your Kipp & Zonen representative.

8.3 Receiver has no signal

- Check there is 12 VDC power to the transmitter and receiver
- Check the windows are clean and that there is no internal condensation
- Check optical alignment using the telescopes
- Check for obstacles in the path of the beam
- Check the transmitter pulse and LED pulse are present
- Check the performance of the real-time C_n^2 calculations of the receiver as in section 6.1

If the problem persists contact support@kippzonen.com.

9. Customer support

If you require any support for your Kipp & Zonen product please contact your local representative in the first instance. The information can be found in the 'Contact' section of our website at <http://www.kippzonen.com/?page/74152/Contact.aspx>

Alternatively, you can contact us directly at support@kippzonen.com.

Please include the following information:

- Instrument model
- Instrument serial number
- Details of the fault or problem
- Examples of data and log files
- Computer type and operating system
- Interfaces and power supplies used in the installation
- History of any previous repairs or modifications
- Pictures of the installation and site
- Overview of the local environment conditions

Kipp & Zonen guarantees that your information will not be shared with other organisations.

For details on the service options available please contact support@kippzonen.com.

Appendix A. Theory of the scintillation technique

When an electro-magnetic (EM) beam of radiation propagates through the atmosphere it is distorted by a number of processes. These processes remove energy from the beam and lead to attenuation of the signal. The most serious mechanism that influences the propagation of EM radiation is small fluctuations in the refractive index of the air (n). These refractive index fluctuations lead to intensity fluctuations, which are known as scintillations.

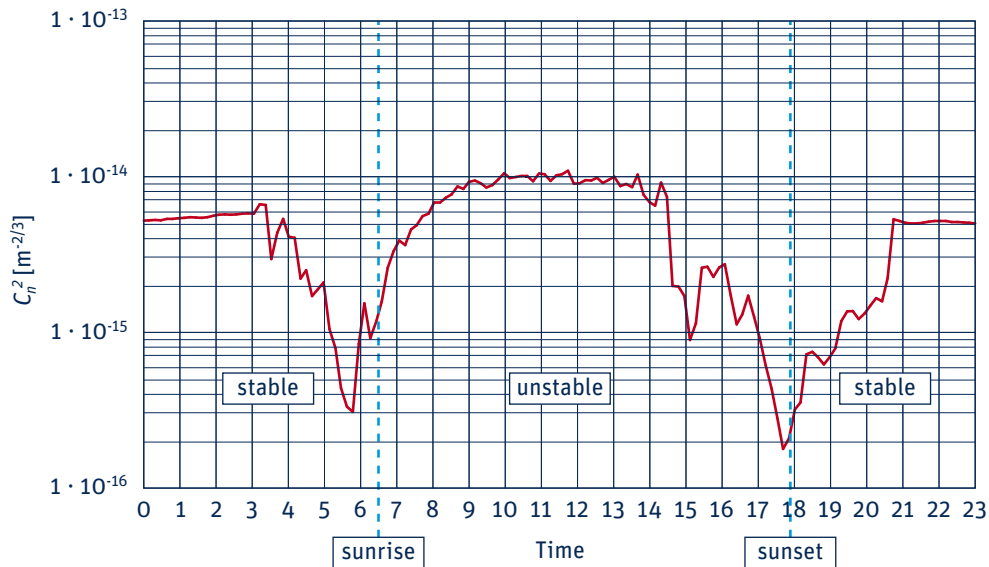
A scintillometer is an instrument that can measure the ‘amount’ of scintillations by transmitting a beam of light over a horizontal path. The scintillations ‘seen’ by the receiving part of the instrument can be expressed as the structure parameter of the refractive index of air (C_n^2), which is a representation of the ‘turbulent strength’ of the atmosphere. The turbulent strength describes the ability of the atmosphere to transport scalars, such as heat, humidity and other species (dust particles, atmospheric gases).

For a Large Aperture Scintillometer, such as the LAS MkII, with equal transmitting and receiving apertures the relationship between the measured variance of the natural logarithm of intensity fluctuations ($\sigma_{\ln I}^2$) and the structure parameter is as follows (Wang et al., 1978):

$$C_n^2 = 1.12 \sigma_{\ln I}^2 D^{7/3} L^{-3}$$

where D is the aperture diameter of the LAS MkII and L the distance between the transmitter and the receiver (i.e. the path length). Typical values of C_n^2 lie between 10^{-13} and $10^{-18} \text{ m}^{-2/3}$.

The graph below shows an example of the diurnal cycle of the structure parameter of the refractive index of air (C_n^2) derived from a LAS MkII on a sunny day with a path length of 4.4 km and an effective height of 40 m.



The C_n^2 values show a distinct drop around 6:00 and 18:00, sunrise and sunset, respectively. Around sunrise the atmosphere changes from stable to unstable conditions and around sunset the atmosphere changes back from unstable to stable conditions.

In the atmosphere fluctuations in temperature (T), humidity (Q), and (to a lesser extent) pressure (P), cause air density fluctuations and with it fluctuations in the refractive index of air (n). Therefore the structure parameter of the refractive index, C_n^2 , can be decomposed into the structure parameters of temperature C_T^2 , humidity C_Q^2 , and the covariant term C_{TQ} as follows (neglecting pressure fluctuations) (Hill et al., 1980):

$$C_n^2 = \frac{A_T^2}{\bar{T}^2} C_T^2 + \frac{2A_T A_Q}{\bar{T} \bar{Q}} C_{TQ} + \frac{A_Q^2}{\bar{Q}^2} C_Q^2$$

A_T and A_Q are functions of the beam wavelength and the mean values of temperature, absolute humidity, and atmospheric pressure and thus represent the relative contribution of each term to C_n^2 . In the visible and near-infrared wavelength region of the EM spectrum A_T and A_Q are defined as follows (Andreas, 1988):

$$A_T = -0.78 \cdot 10^{-6} \left(\frac{P}{T} \right) + 0.126 \cdot 10^{-6} R_v Q$$

$$A_Q = -0.126 \cdot 10^{-6} R_v Q$$

where R_v is the specific gas constant for water vapour ($461.5 \text{ J K}^{-1} \text{ kg}^{-1}$). Typical values for A_T and A_Q , for 'normal atmospheric' conditions ($P = 1 \cdot 10^5 \text{ Pa}$, $T = 288 \text{ K}$ and $Q = 0.012 \text{ kg m}^{-3}$), are $-0.27 \cdot 10^{-3}$ and $-0.70 \cdot 10^{-6}$, respectively. Because A_T is much larger than A_Q the contribution of humidity related scintillations is much smaller than temperature related scintillations, i.e. the near-infrared LAS MkII is primarily sensitive to temperature related scintillations. Therefore a simplified expression can be derived, which makes it possible to derive C_T^2 from C_n^2 as follows (Wesley, 1976):

$$C_n^2 \approx \frac{A_T^2}{T^2} C_T^2 \left(1 + \frac{0.03}{\beta} \right)^2 \quad \text{or} \quad C_n^2 \approx \left(\frac{-0.78 \cdot 10^{-6} P}{T^2} \right)^2 C_T^2 \left(1 + \frac{0.03}{\beta} \right)^2$$

where β is the Bowen ratio, which is a correction term for humidity related scintillations. The Bowen ratio is defined as the ratio between the sensible heat flux (H) and latent heat flux ($L_v E$), i.e. $\beta = H/L_v E$. When the surface conditions are dry H is larger than $L_v E$, resulting in high β values (> 3). This means that the correction term in the latter equation is small. Over wet surfaces β is small (< 0.5), which means that a significant amount of scintillations are caused by humidity fluctuations, resulting in a large correction.

Thus, when the surface conditions are very dry, C_T^2 is directly proportional to C_n^2

$$C_n^2 \approx \frac{A_T^2}{T^2} C_T^2 \quad \text{or} \quad C_n^2 \approx \left(\frac{-0.78 \cdot 10^{-6} P}{T^2} \right)^2 C_T^2$$

when C_T^2 is known, the sensible heat flux (H) can be derived from similarity relationships that have been derived for C_T^2 which are based on the Monin-Obukhov Similarity Theory (MOST) (Wyngaard et al., 1971):

$$\frac{C_T^2 (z_{LAS} - d)^{2/3}}{T_*^2} = f_T \left(\frac{z_{LAS} - d}{L_{MO}} \right) \quad (L_{MO} < 0)$$

where d is the zero-displacement height and $z_{LAS \text{ MkII}}$ is the effective height of the scintillometer beam above the surface (Hartogensis et al., 2003). T_* is a temperature scale defined as:

$$T_* = \frac{-H}{\rho c_p u_*}$$

and L_{MO} is the Obukhov length:

$$L_{MO} = \frac{u_*^2 T}{g k_v T_*}$$

where ρ is the density of air ($\sim 1.2 \text{ kg m}^{-3}$), c_p the specific heat of air at constant pressure ($\sim 1005 \text{ J kg}^{-1} \text{ K}^{-1}$), k_v the von Kármán constant (~ 0.40), g the gravitational acceleration ($\sim 9.81 \text{ m s}^{-2}$) and u_* the friction velocity. The universal stability function f_T is defined as follows for unstable (day-time, $L_{MO} < 0$) conditions:

$$f_T \left(\frac{z_{LAS} - d}{L_{MO}} \right) = c_{T1} \left(1 - c_{T2} \frac{z_{LAS} - d}{L_{MO}} \right)^{-2/3} (L_{MO} < 0)$$

where $c_{T1} = 4.9$ and $c_{T2} = 6.1$,

and for stable (night-time, $L_{MO} > 0$) conditions as:

$$f_T \left(\frac{z_{LAS} - d}{L_{MO}} \right) = c_{T1} \left(1 + c_{T3} \left(\frac{z_{LAS} - d}{L_{MO}} \right)^{2/3} \right) (L_{MO} > 0)$$

where $c_{T3} = 2.2$ (see Andreas, 1988; De Bruin et al., 1993; Wyngaard et al., 1971).

In order to derive H from c_{T2} , the friction velocity (u_*) is required. The friction velocity can be obtained from additional wind speed data (u) and an estimate of the surface roughness (z_0) (Panofsky and Dutton, 1984):

$$u_* = \frac{k_v u}{\ln \left(\frac{z_u - d}{z_0} \right) - \Psi_m \left(\frac{z_u - d}{L_{OM}} \right) + \Psi_m \left(\frac{z_0}{L_{OM}} \right)}$$

where z_u is the height at which the wind speed is measured and Ψ_m is the integrated stability function for momentum defined as (for unstable day-time conditions):

$$\Psi_m \left(\frac{z}{L_{OM}} \right) = 2 \ln \left[\frac{1+x}{2} \right] + \ln \left[\frac{1+x^2}{2} \right] - 2 \arctan(x) + \frac{\pi}{2} (L_{MO} < 0)$$

with:

$$x = \left(1 - 16 \frac{z}{L_{MO}} \right)^{1/4}$$

and for (stable night-time conditions):

$$\Psi_m \left(\frac{z}{L_{OM}} \right) = -5 \frac{z}{L_{OM}} (L_{MO} > 0)$$

In summary, from C_n^2 data together with wind speed, temperature, and an estimate of the surface roughness and the displacement height, the sensible heat flux can be determined from the above equations, which can be solved iteratively.

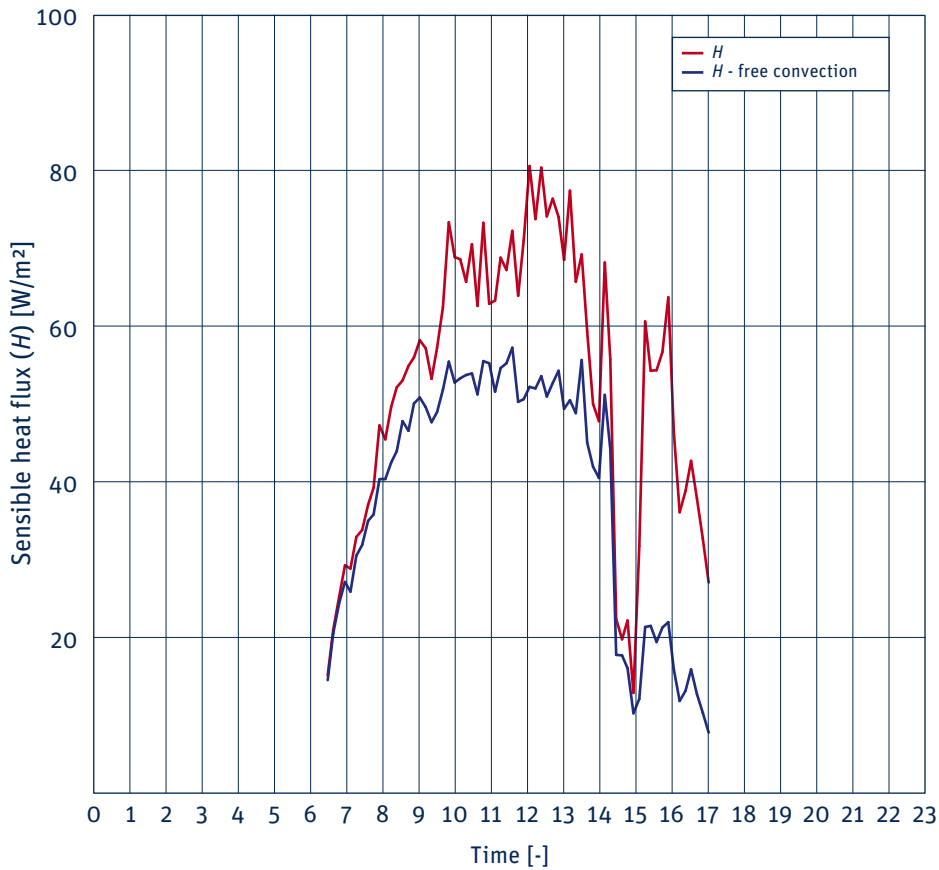
For most day-time (unstable) conditions and when the LAS MkII is installed relatively high above the surface ($z_{LAS\ MkII} > 20\text{ m}$) the contribution of the friction velocity is relatively small. For these conditions the free convection method can be applied:

$$H_{free} = \rho c_p b (z_{LAS} - d) \left(\frac{g}{T} \right)^{1/2} (C_T^2)^{3/4}$$

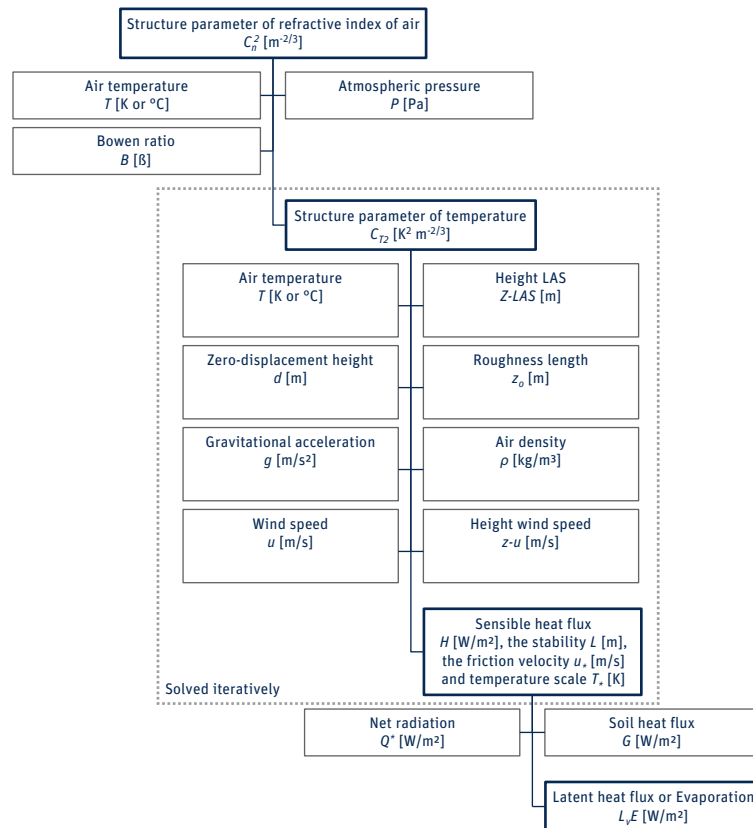
where b is an empirical constant:

$$(b = \sqrt{\left(\frac{1}{c_{T1}} \right)^{3/2} k_v c_{T2}} \approx 0.48)$$

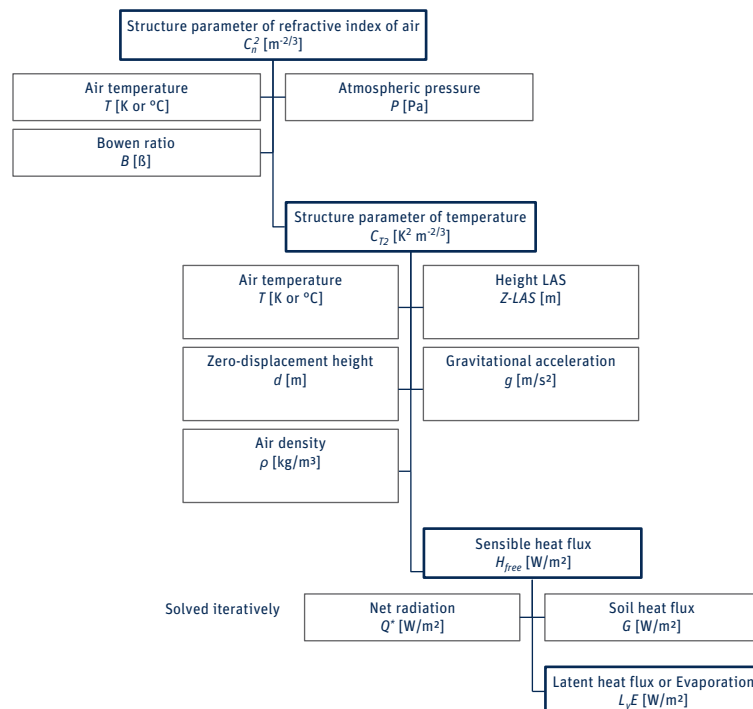
This free convection approach provides a simpler method to determine H (in this case termed ' H_{free} ') directly from C_{T2} without knowing u_* . In practical applications the free convection approach can provide reasonably accurate fluxes under unstable conditions (day-time) when the scintillometer is installed relatively high above the surface ($z_{LAS\ MkII} > 20\text{ m}$), as shown in the figure below.



Summary of the steps to derive surface sensible heat flux, H , from LAS MkII measurements:



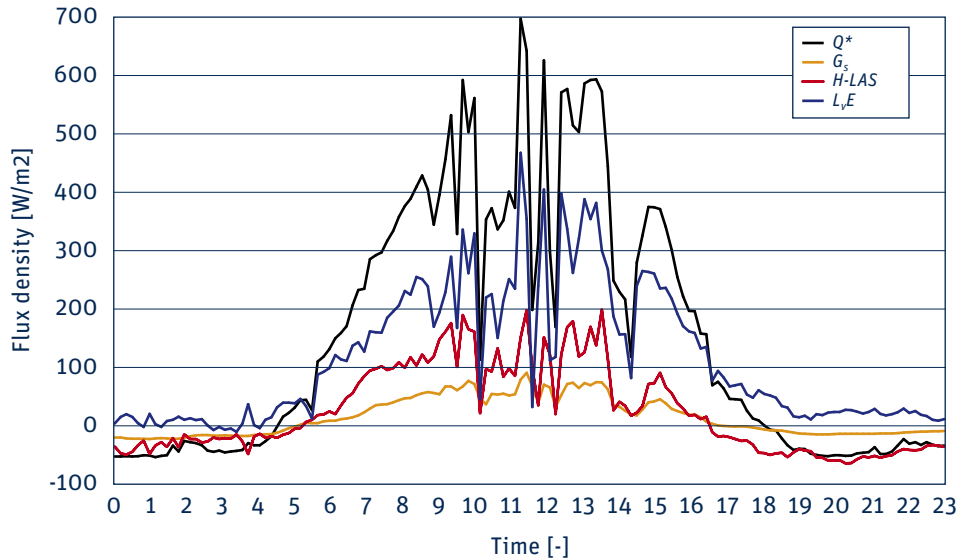
Summary of the steps to derive free convection sensible heat flux, H_{free} , from LAS MkII measurements:



Finally, when additional net radiation (Q^*) and soil heat flux (G_s) data are available, the latent heat flux $L_v E$ (or actual evaporation) can be estimated applying the surface energy balance equation:

$$Q^* = H + L_v E + G_s$$

Below is an example of a time series of net radiation, soil heat flux, sensible heat flux and latent heat flux measurements.



Complete list of required data/information for deriving sensible heat flux (H):

- Mean of C_n^2 (derived from $U_{C_n^2}$)
- Mean of signal strength (or U_{demod})
- Variance of signal strength (or U_{demod})
- Path length (L)
- Average (effective) beam height ($z_{LAS\ MkII}$)
- Zero-displacement height (d)
- Air pressure (P)
- Air temperature (T)
- Wind speed (u)
- Bowen ratio (β)
- Height(s) of cup anemometer(s) (z_u)
- Surface roughness length of source area for LAS MkII and wind speed measurements (z_o)

Additional data required for deriving latent heat flux ($L_v E$):

- Net radiation
- Soil heat flux

Other useful meteorological data:

- Wind direction
- Rainfall

Appendix B. List of symbols and abbreviations

A_T	wavelength dependent constants	[-]
A_Q	wavelength dependent constants	[-]
C_p	heat capacity of air at constant pressure	[~1005 J K ⁻¹ kg ⁻¹]
C_n^2	structure parameter of the refractive index of air ($C_n^2 = 10^{(U_{C_n^2} - 12)}$)	[m ^{-2/3}]
C_T^2	structure parameter of temperature	[K ² m ^{-2/3}]
C_Q^2	structure parameter of humidity	[kg ² m ⁻⁶ m ^{-2/3}]
d	zero-displacement height	[m]
D	effective aperture diameter of receiver	[m]
f_T	universal stability function	[-]
g	gravitational acceleration	[~9.81 m/s ²]
G_s	soil heat flux	[W/m ²]
H	surface sensible heat flux	[W/m ²]
H_{free}	free convection sensible heat flux	[W/m ²]
I	signal strength, or intensity ($I = U_{DEMOD}$)	[V]
L	path length	[m]
L_vE	latent heat flux (or evaporation)	[W/m ²]
L_{MO}	Obukhov length	[m]
Pot	path length setting at transmitter power adjustment knob	[-]
P	air pressure	[Pa]
$PU_{C_n^2}$	scaled C_n^2 ($C_n^2 = PU_{C_n^2} \cdot 10^{-15}$)	[m ^{-2/3}]
Q	absolute humidity	[kg/m ³]
Q^*	net radiation	[W/m ²]
R_d	specific gas constant for dry air	[~287 J K ⁻¹ kg ⁻¹]
R_v	specific gas constant for water vapour	[~461.5 J K ⁻¹ kg ⁻¹]
T	absolute air temperature	[K]
T_*	temperature scale	[K]
u	wind speed	[m/s]
u_*	friction velocity	[m/s]
$U_{C_n^2}$	log C_n^2 signal [V] ($C_n^2 = 10^{(U_{C_n^2} - 12)}$)	[0 to 2 V]
U_{DEMOD}	demodulated signal [V] ($U_{DEMOD} = I$)	[0 to 2 V]
$U_{TH,T}$	thermistor signal transmitter unit	[0 to 8 V]
$Z_{LAS MkII}$	(effective) height of beam/path	[m]
Z_0	aerodynamic (surface) roughness length	[m]
Z_u	height of wind speed measurements	[m]
β	Bowen ratio ($\beta = H/L_vE$)	[-]
κ_v	von Kármán constant	[~0.40]
λ	wavelength of beam radiation	[850 x 10 ⁻⁹ m]
ρ	density of air (at sea level !)	[~1.2 kg/m ³]
σ^2	variance	[-]
$\sigma_{\ln I}^2$	variance of natural logarithm of intensity fluctuations, $\ln(I)$	[-]
$\sigma_{U_{DEMOD}}^2 = \sigma_I^2$	variance of U_{DEMOD} or intensity I	[V ²]
$\sigma_{U_{C_n^2}}^2$	variance of $U_{C_n^2}$	[V ²]
Ψ_m	integrated stability function for momentum	[-]

CFL Constant Flux Layer

In general, in the lowest 10 % of the PBL the surface fluxes are constant with height and this part of the PBL is also known as the Constant Flux Layer of the Surface Layer. Therefore fluxes measured in the SL can be considered as being representative fluxes for the heat and mass exchange processes between the atmosphere and the surface.

LAS Large Aperture Scintillometer

MOST Monin-Obukhov Similarity Theory

A relationship describing the vertical behaviour of non-dimensionalised mean flow and turbulence properties within the Surface Layer as a function of the Monin-Obukhov key parameters.

PBL Planetary Boundary Layer

The PBL is the lowest region of the troposphere, which is directly affected by heating and cooling of the Earth's surface. In general the depth of the PBL varies between 100 to 2000 m. The depth of the PBL increases during the day, when the surface is heated by the sun, and decreases during the night.

RS Roughness Sub-layer

Lowest part of the SL, in which the flow is influenced by individual roughness elements. Consequently, the SL can be divided into the Constant Flux Layer and the Roughness Sub-layer. The height of the Roughness Sub-layer strongly depends upon the height (size and form) of the roughness elements, but also upon the distribution. Usually, over tall vegetation, 3 times the obstacle height is taken as the height of the Roughness Sub-layer.

SL Surface Layer

In general the SL begins at 3 times the vegetation height and has a typical depth of 20 m (at night) to 100 m (during daytime conditions).

Appendix C. LAS MkII menu structure

Below is an overview of the menu structure of the LAS MkII scintillometer.

1. View RealTime		Display real time data	
1.	Signal Level	Display signal level as a percentage	
2.	Udemod	Display demodulator voltage	
3.	C_n^2	Display C_n^2	
4.	C_T^2	Display C_T^2	
5.	H_{free}	Display free convection sensible heat flux, H_{free}	
6.	Saturation	Display saturation indicator	
7.	Device Temp	Display temperature inside the receiver	
8.	Air Temp	Display the air temperature (from the meteorological sensor kit)	
9.	Air Pressure	Display the air pressure (from the meteorological sensor kit)	
10.	Wind Speed	Display wind speed (from the meteorological sensor kit)	
11.	Air Density	Display the calculated air density	
12.	Date	Display date provided by the real time clock	
13.	Time	Display time provided by the real time clock	
14.	«Back	Go one submenu level back	
2. Configuration		Set or show stored configuration in EEPROM	
1. Installation		Set or show basic parameters	
1.	Aperture	Set or show effective lens diameter	(0 to 399.9 mm)
2.	Path Length	Set or show path length	(0 to 7999.9 m)
3.	Install Height	Set or show installation height	(0.0 to 4999.9 m)
4.	Z.Displ.Height	Set or show zero displacement height	(0.0 to 199.99 m)
5.	Bowen Ratio	Set or show Bowen ratio	(0.01 to 9.999)
6.	Signal Gain	Show signal strength and set gain	(1x, 2x, 4x)
7.	Set Defaults	Restore default configuration in EEPROM	(0=No, 1=Yes)
8.	«Back	Go one submenu level back	
2. Advanced		Set or show advanced parameters	
1.	Rel Humidity	Set or show relative humidity	(0.0 to 99.9 %)
2.	Heat capacity	Set or show heat capacity	(500.0 to 1999.9)
3.	Bowen Ratio	Set or show Bowen ratio	(0.01 to 9.999)
4.	Empir.Constant	Set or show empirical constant	(0.0 to 9.999)
5.	«Back	Go one submenu level back	
3. Sensors		Set or show default values, enable or disable sensors	
1.	Air Temp	Set or show default air temperature	(-39.9 to 49.9 °C)
		Enter 99.9 to enable external temperature sensor (ADC input 1)	
2.	Air Pressure	Set or show default air pressure	(650 to 1100 mBar)
		Enter 9999 to enable external pressure sensor (ADC input 2)	
3.	Wind speed	Set or show default wind speed	(0.0 to 40.0 m/sec)
		Enter 999 to enable external wind speed sensor (ADC input 3)	
4.	Device Temp	Set or show temperature inside the receiver	(-39.9 to 49.9 °C)
		Enter 99.99 to enable the temperature sensor inside the receiver	
5.	«Back	Go one submenu level back	

4. Data Logger **Set or show the data logger configuration**

- | | | | |
|----|---------------|--|-----------------------|
| 1. | Set Date | Set Date | (yy/mm/dd) |
| 2. | Set Time | Set Time | (hh:mm:ss) |
| 3. | Wakeup Time | Set or show time to start to measure and log | (hh:mm, 99:99 =Off) |
| 4. | Sleep Time | Set or show time to stop measure and log | (hh:mm, 99:99 =Off) |
| 5. | Log Interval | Set average & log interval of measurements | (0 to 29999 s, 0=Off) |
| 6. | Send Interval | Set interval to send data to a computer | (0 to 29999 s, 0=Off) |
| 7. | «Back | Go one submenu level back | |

5. Interface **Set or show the configuration of digital interface Com 1**

- | | | | |
|----|----------------|--|--------------------------------------|
| 1. | Set Default | Restore default configuration of Com 1 | (0=No, 1=Yes) |
| 2. | BaudRate | Set or show baud rate | (1200, 2400, 9600, 19200, 38400 bps) |
| 3. | Parity | Set or show parity | (0=none, 1=odd, 2=even) |
| 4. | Databits | Set or show number of data bits | (7 or 8) |
| 5. | Interface Type | Set or show digital interface type | (RS-232-C, RS-422, 0=Off) |
| 6. | DeviceID | Set device address | (0 to 255) |
| 7. | Restart | Restart the receiver | (0=No, 1=Yes) |
| 8. | «Back | Go one submenu level back | |

3. Heater **Set or show heater**

- | | | | |
|----|----------------|--|--------------------|
| 1. | Operating Temp | Set or show operating mode switch-on temp. | (0,0 to 49.9 °C) |
| 2. | Standby Temp | Set or show sleep mode switch-on temp. | (-39.9 to 49.9 °C) |
| 3. | Threshold Temp | Set or show threshold temperature | (0.0 to 19.9 °C) |
| 4. | Maximum Temp | Set or show maximum temp. warning | (0.0 to 49.9 °C) |
| 5. | «Back | Go one submenu level back | |

4. Diagnostics **Select diagnostics procedures**

- | | | | |
|----|-----------------|---|-----------------------|
| 1. | Gain | Test gain at specified frequency | (0.5 to 999Hz, 0=Off) |
| 2. | Offset | Test offset | |
| 3. | Analogue Output | Test or set analogue output | (0 to 2500 mV) |
| 4. | Sensor 1 | Show input voltage sensor ADC input 1 | |
| 5. | Sensor 2 | Show input voltage sensor ADC input 2 | |
| 6. | Sensor 3 | Show input voltage sensor ADC input 3 | |
| 7. | Thermistor | Show input voltage receiver temperature | |
| 8. | Heater&Alarm | Set heater and alarm output | (0=OFF, 1=ON) |
| 9. | «Back | Go one submenu level back | |

5. Device *** indicated options are protected by a factory pin code**

- | | | | |
|-----|----------------|--|--------------------------|
| 1. | Enter Pin | Enter PIN code | (pin code) |
| 2. | Coldstart* | Begin cold start procedure | (option) |
| 3. | Set Date | Set date | (yy/mm/dd) |
| 4. | Set Time | Set time | (hh:mm:ss) |
| 5. | Serial Number* | Set or show serial number | (yy:nnnn) |
| 6. | H/W Release* | Set or show hardware release | (0 to 99, e.g. 20=V 2.0) |
| 7. | Lens Diameter* | Set or show nominal lens diameter | (20.0 to 399.9 mm) |
| 8. | Ref. Voltage* | Set or show analogue o/p reference voltage | (80 to 120 %) |
| 9. | Adjust Gain* | Adjust gain at specified frequency | (0 to 999 Hz, 0=Off) |
| 10. | Restart | Restart the device | (0=No, 1=Yes) |
| 11. | «Back | Go one submenu level back | |

«Back **Go to main menu level (0)**

Appendix D. Configuration error messages

A configuration error message will be displayed if one or more of the configuration parameters stored in the memory are not correct. The messages are explained as follows:

Checksum error

The EEPROM-signature was not found. The EEPROM -signature is not set when the EEPROM is empty or when the data stored is lost or corrupted. If this error appears the EEPROM must be reconfigured.

Please **contact support@kippzonen.com**.

Setup error

The setup error is set when the serial number, calibration constants or device setup information is missing. The calibration constants for the external I/O sensors and device setup information are configured by Kipp & Zonen. The device must be reconfigured. When this error appears the firmware will automatically repair the contents of the EEPROM ; calibration constants and device setup parameters are set to default values and the serial number is cleared.

Please **contact support@kippzonen.com**.

The serial number is not set

This error is set when the serial number is cleared. The device must be reconfigured.

Please **contact support@kippzonen.com**.

Configuration error

This error is set when some of the user configuration parameters are missing or set to default values.

Check all parameters (see configuration menu) and reconfigure the device, or upload all configuration parameters via the EVATION software to the receiver.

The log file is cleared

This message is shown if the records stored in the log file are deleted, because the firmware is not able to retrieve valid information from the internal flash data memory.

Idle Mode

When the IDLE MODE is set the instrument will not collect data and the baud rate is set to 115200 baud to make fast data transfer possible.

To enter the idle mode: Press the left and up keys at the same time for at least 30 seconds.

The receiver display will show the message:



THE IDLE MODE IS
SET

When fast data transfer is in progress the instrument's display alternates between the messages:



THE INSTRUMENT
IS TRANSMITTING

and



THE INSTRUMENT
IS IDLE

The receiver will stay in the idle mode whilst communication is in progress and will reset when there is no communication, or when the firmware update or download is completed. To exit the idle mode press any navigation key when the message 'The Instrument Is Idle' is shown.

Note Use the fast data transfer to collect data in the field, or to update the firmware, to prevent a laptop computer battery running down before transfer is completed.

Appendix E. Effective height calculator

The accuracy of the fluxes of sensible heat and evapo-transpiration depend strongly upon the mean height of the LAS MkII optical beam above the surface. In case the area is completely flat the average beam height can be easily derived from the transmitter height and the receiver height.

In case the area is complex it becomes more difficult to determine the effective height of the beam. The EVATION software has a special tool for this purpose; the effective height calculator.

The calculator needs the following input data:

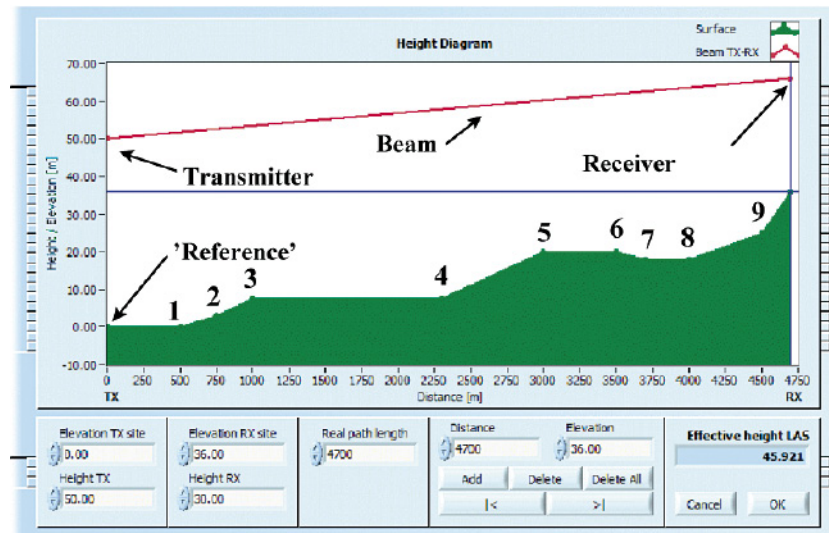
- The elevation of the transmitter site
- The installation height of the transmitter above the ground
- The elevation of the receiver site
- The installation height of the receiver above the ground
- The elevation and position of a number of points along the beam (a cross-section over the optical path)

By entering this information into the effective height calculator the software provides the effective height of the LAS MkII beam, which will be used in the processing of data into fluxes.

Use a table, such as that below, to collect a number of cross-section points. In this case the 'Reference' point is ground level at the transmitter site.

Points in optical path cross-section	Elevation with respect to reference site ground [\pm m]	Horizontal distance from reference site [m]	Installation height of LAS MKII with respect to the site ground [m]
Transmitter site, Tx (Reference)	0	0	50
Intermediate point 1	0	500	
Intermediate point 2	3	750	
Intermediate point 3	7.5	1000	
Intermediate point 4	7.5	2300	
Intermediate point 5	20	3000	
Intermediate point 6	20	3500	
Intermediate point 7	18	3700	
Intermediate point 8	18	4000	
Intermediate point 9	25	4500	
Receiver site, RX	36	4700 (Path Length)	30

The effective height of the LAS beam can then be calculated as shown below.





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SINCE 1830

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HEAD OFFICE

Kipp & Zonen B.V.

Delftechpark 36, 2628 XH Delft
P.O. Box 507, 2600 AM Delft
The Netherlands

T: +31 (0) 15 2755 210

F: +31 (0) 15 2620 351

info@kippzonen.com

SALES OFFICES

Kipp & Zonen France S.A.R.L.

88 Avenue de l'Europe
77184 Emerainville
France

T: +33 (0) 1 64 02 50 28

F: +33 (0) 1 64 02 50 29

kipp.france@kippzonen.com

Kipp & Zonen Asia Pacific Pte. Ltd.

10 Ubi Crescent Lobby E
#02-93 Ubi Techpark
Singapore 408564

T: +65 (0) 6748 4700

F: +65 (0) 6748 6098

kipp.singapore@kippzonen.com

Kipp & Zonen USA Inc.

125 Wilbur Place
Bohemia
NY 11716
United States of America

T: +1 (0) 631 589 2065

F: +1 (0) 631 589 2068

kipp.usa@kippzonen.com

Go to www.kippzonen.com for your local distributor or contact your local sales office

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