KIPP & ZONEN
SINCE 1830

Instruction Manual

LAS MkII • Scintillometer

Applicable to LAS MkII running firmware version 3.0

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:

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Warranty and liability

Kipp & Zonen guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions supplied by Kipp & Zonen.

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EC Declaration of Conformity

CE

Kipp & Zonen B.V.
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The Netherlands

declares under our sole responsibility that the product

LAS MkII Large Aperture Scintillometer

to which this declaration relates is in conformity with European Harmonised Standards as published in Official Journal of the EC, issue: **C321/1 23-10-2012**

The compliance of the product has been based on the following standard
EN 61326-1:2006 [EMC - Emissions]
EN 61326-1:2006 [EMC - Immunity]

following the provisions of the directives
EMC-directive **2004/108/EC**

Delft, 1st October 2014

Dr. F. Kuik - CEO
Kipp & Zonen B.V.

This Declaration of Conformity is compliant with the European Standard EN 45014 *General Criteria for supplier's Declaration of Conformity*. The basis for the criteria has been found in international documentation, particularly in ISO/IEC, Guide 22, 1982, *Information on manufacturer's Declaration of Conformity with standards or other technical specifications*

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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 km[1]. When the supplied 100 mm diameter aperture restrictors are fitted, the path length can be from 100 m to 1 km[1].

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.

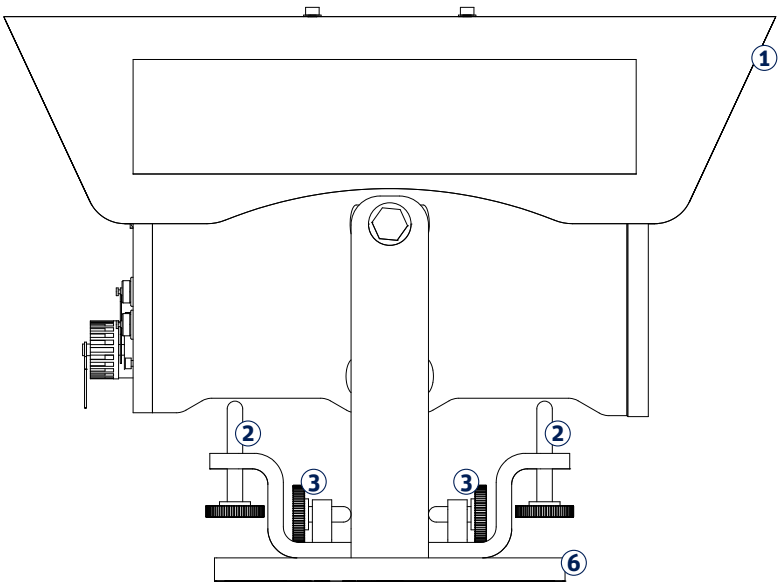
[1]The maximum usable path length depends upon the atmospheric conditions and saturation criterion. The LAS MkII transmitter has sufficient power to reach 6 km with 'clear' atmospheric conditions (visibility 10-20 km), but the user must be careful to check that the LAS is at a sufficiently high height (on a high tower) to avoid saturation (see section 2.3.2), but not outside the Constant Flux layer (see section 2.3.4). In warm regions with high fluxes this is not possible, but in cool high latitudes it may be possible to meet these criteria. In general, it is best to use the scintillometer at full aperture at path lengths down to 500 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.

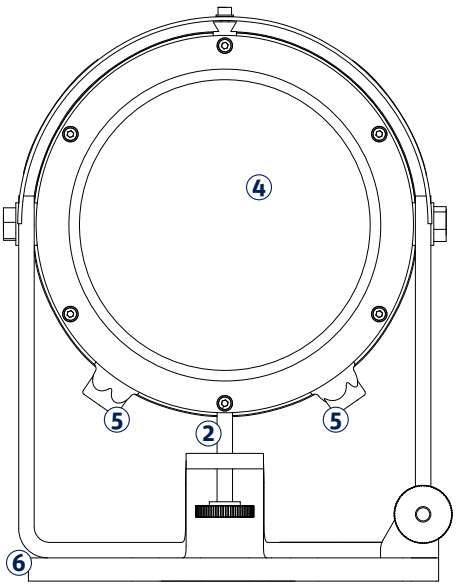
1.2 Key parts of the LAS MkII Scintillometer

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

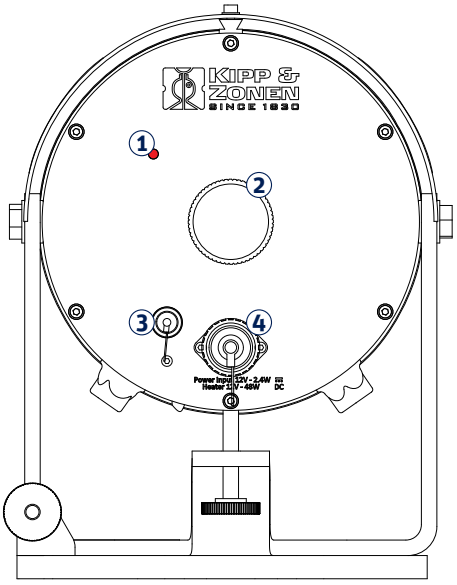




1.2.2 Transmitter rear panel

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

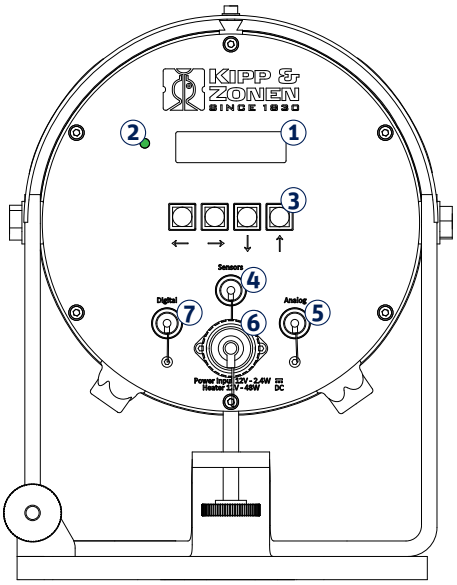
① Power indicator (red)
② Transmitter power adjustment knob (remove screw-on cover)
③ Signal output connector (4-pin)
④ Power input connector (12 VDC)



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 or GPS antenna 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 transport case and 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 x 10 m cable with 8-pin plug and 9-pin D-connector for receiver digital communication connections
2 x 10 m cable with 4-pin connector for 12 VDC power input
2 x 3 mm hexagonal Allen keys, for fitting the sun shields
2 x 4 mm hexagonal Allen keys, for fitting the telescopes
1 x CD-ROM containing EVATION software and a pdf file of this LAS MkII instruction manual
8 x spare desiccant packs
1 x GPS antenna with 2 m cable and 8-pin plug, affixed on aluminium mounting arm
1 x aluminium transport case to hold above parts

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 (factory only adjustment during manufacture). 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 to 7.5 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 to 7.5 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 (factory only adjustment during manufacture).

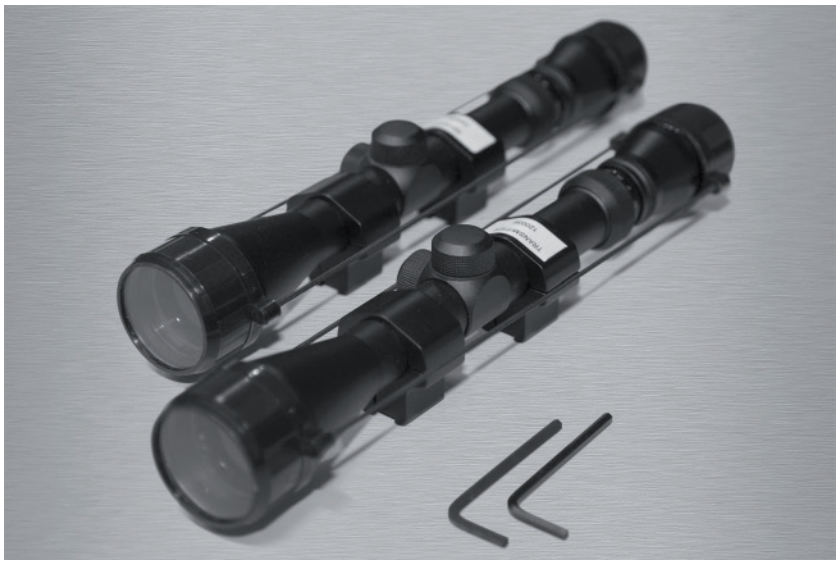
Analogue electronics are tuned to the 6.5 to 7.5 kHz carrier wave and to the scintillation frequency band of 0.1 to 400 Hz. These signals are rectified and are available at the analogue signal connector. All the remaining electronics are digital. The system can be locally configured at the receiver with a display and menu navigation keys and has internal signal and data processing and storage. It can calculate and log C_n^2 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 and GPS antenna. 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

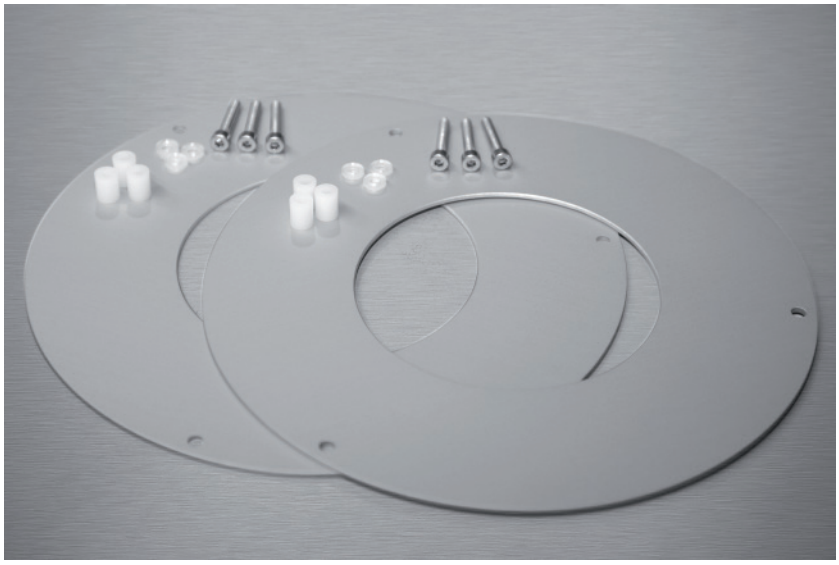
After alignment of the transmitter and receiver the telescopes should be removed and replaced by the sun shields. These are each attached by two screws to mounting rails on the tops of the transmitter and receiver housings. A 3 mm hexagonal Allen key is supplied for the fixing screws of each sun shield.

2.1.5 GPS antenna

In order to synchronise the receiver time to GMT in the field, a GPS antenna mounted on an aluminium arm is fitted to the top of the receiver, under the sun shield (or on top of the sun shield if the user wishes). These are each attached by two 16 mm screws to the mounting rail on the tops of the receiver housings. The GPS antenna is plugged into the Sensor port on the rear of the receiver. When the GPS is connected this is recognised and used as the internal time reference (in GMT) for all data records (and the internal clock will also be updated). If no GPS signal is received by the LAS receiver or no GPS is connected, then the internal data logger will revert to using the internal clock (or if permanently connected to a computer running EVATION software, EVATION can synchronise the LAS to the computer clock).

2.1.6 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 100 to 500 m (1 km maximum), restrictors with apertures of 100 mm are fitted in front of the windows of the transmitter and receiver. Although the restrictors can be used up to 1 km, for path lengths over 500 m it is recommended to operate without restrictors, unless operating in regions with very low heat flux (such as wet, northern latitude and artic regions).



2.1.7 Power cables

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

2.1.8 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.

2.1.9 Signal cable with 8-pin plug

One 10 m long cable with an 8-pin waterproof plug and 9-pin D-connector is provided for the receiver digital interface connection.

2.1.10 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.

2.1.11 DVD-ROM

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

2.1.12 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 ($\sigma_{\ln I}^2$) 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:

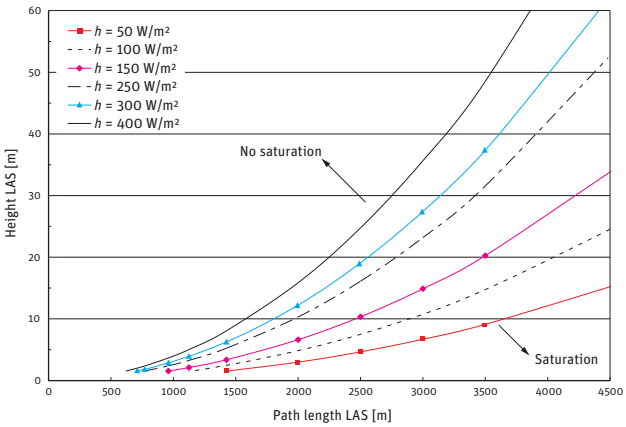
$$C_n^2(\lambda, D, z_{LAS}, L) \prec S_{max}$$

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.

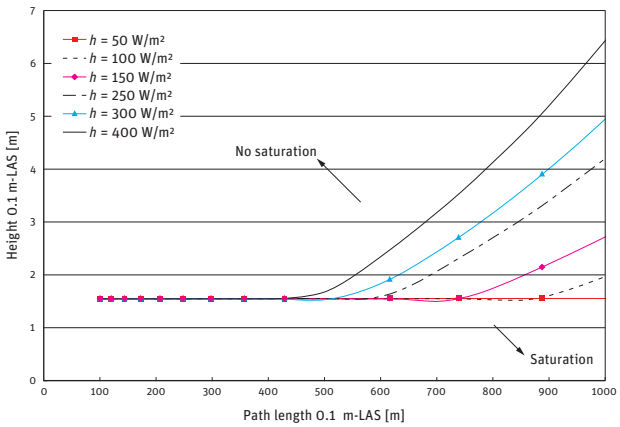
This means that over long distances (several kilometres) the scintillometer must be placed high above the surface in order to prevent saturation. Over shorter distances (several hundred meters) the scintillometer can be installed closer to the surface. Over dry areas the surface sensible heat flux is 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



The minimum installation height of the LAS MkII, as a function of path length and different surface conditions.

For example, a LAS MkII installed over a relatively wet area (h ~ 100 W/m²) and a path length of 3 km must be installed at a height of at least 12 m.

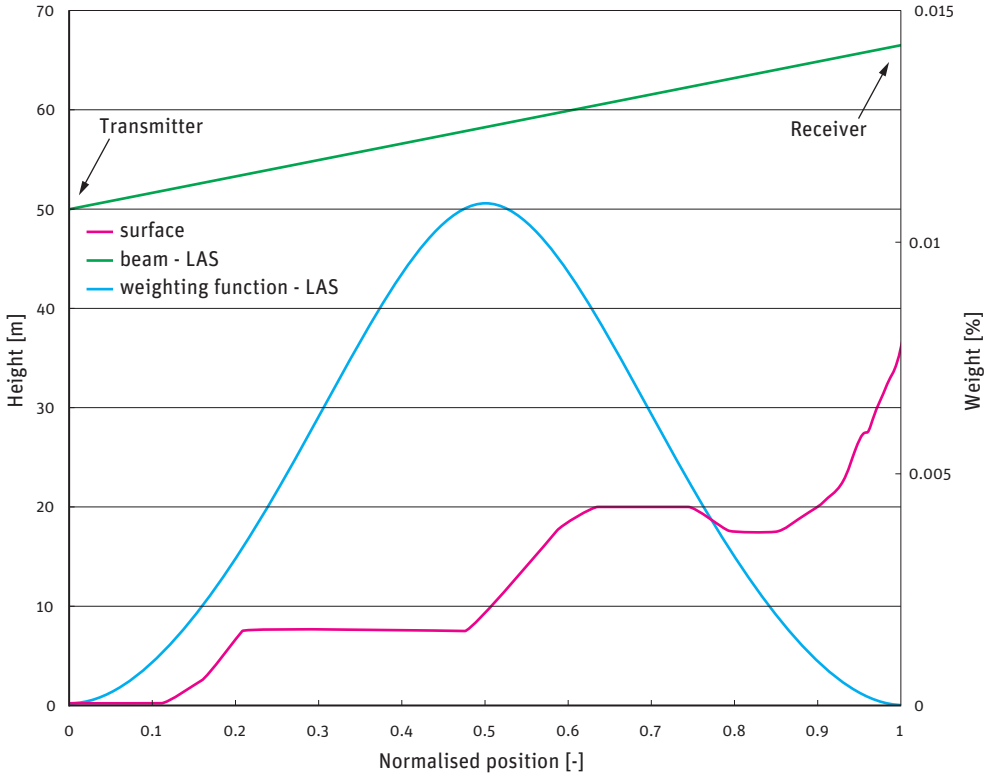
Ensure that the LAS MkII is operating in the 'non-saturation' zone.

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, 2003 [1].



The graphs above illustrate a LAS MkII path (beam) over a non-flat area. Based on the elevation map (surface) and the LAS MkII 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_vE) 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.

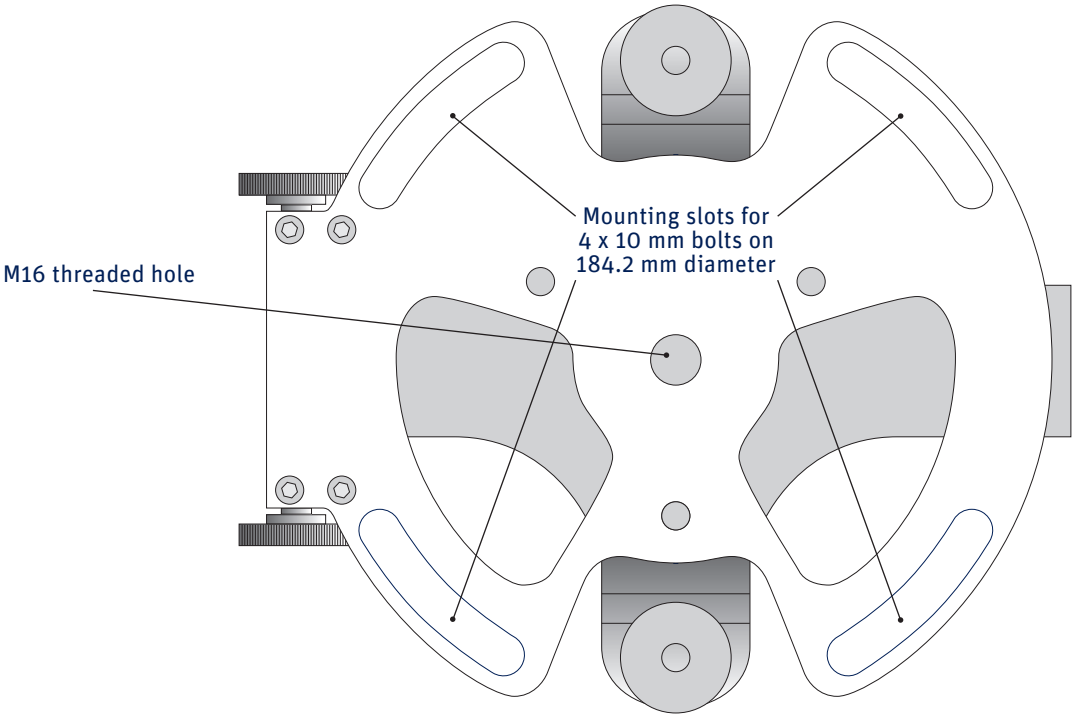
Mount the LAS MkII transmitter and receiver on stable and vibration-free supports.

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. A screw in ground anchor (or dog anchor) in combination with a ratchet cargo strap can be used to tie down the middle of the tripod (and therefore the LAS) to the ground and avoid it being blown over, or knocked over by animals when left unattended for a period.

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 on the next page.



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 +	12 VDC nominal (9.6 to 18 VDC)
2	orange	heater power +	12 VDC nominal (9.6 to 18 VDC)
3	brown	heater return –	0 V
4	black	instrument return –	0 V

The LAS MkII transmitter and receiver must be grounded through pin 4 of the power connector 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.

The wiring to the heater and electronics has been kept separate to allow the user to choose whether to power the heater when power is restricted, such as with solar power, or if the heater is not needed in hot climates. But if there is mist or water vapour condensing on the window of the transmitter or receiver, then the window heater can reduce or stop this (but will not get rid of

any fog of course). The transmitter heater power is controlled proportional to temperature, and the receiver heater can be programmed to come on at a chosen time in the day or all the time, at a programmable temperature. The default for the receiver is to turn on the heater as needed to maintain 18 °C, all day.

2.5.2 Transmitter signal output connector

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

Transmitter signal connector and cable

Pin number	Wire colour	Function	Value
1	red	thermistor output	output thermistor to measure internal temperature of LAS
2	blue	6.5 to 7.5 kHz pulse + 0.5 duty cycle	0 to 8 V
3	green	6.5 to 7.5 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

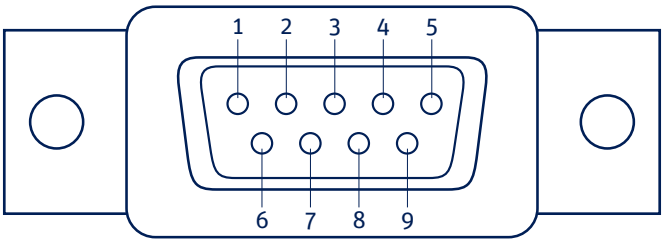
Pin number	Wire colour	Function	Value	Impedance
1	red	Log UC_n^2 signal +	0 to 2.4 V, 10^{-17} to 10^{-11} $m^{-2/3}$	680 Ω, 4700 pF
2	blue	6.5 to 7.5 kHz AC carrier signal +	0 to 1 V RMS, 100 % = 152 mV RMS	120 Ω, 4700 pF
3	green	demodulated carrier signal (U_{demod}) +	0 to 2 V, 100 % = 606 mV	680 Ω, 4700 pF
4	yellow	signal –	0 V	
shield	thick black	cable screen	housing ground	

2.5.4 Receiver digital interface connector without GPS

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 a 9-pin D-connector. This can be connected to a standard serial / com port on a laptop, but if this unavailable an isolated serial to USB converter can be used.

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

Digital interface female 9-pin D-connector layout (solder connections)



Pin number	Wire colour	Function	RS-232 function
1	white	n/c	DCD (Data Carrier Detect)
2	red	connected	RXD (Receive Data)
3	grey	connected	TXD (Transmit Data)
4	brown	n/c	DTR (Data Terminal Ready)
5	black	connected	GND (digital ground)
6	green	n/c	DSR (Data Set Ready)
7	yellow	n/c	RTS (Request to Send)
8	blue	n/c	CTS (Clear to Send)
9	-	n/c	RI (Ring Indicator)
shield	thick black		cable screen

Only pin 2, 3 and 5 of the 9 pin D-connector are connected. The 9-pin D-connector cannot be used for RS-485 as provided, because not all the wires are connected (to use RS-485, open up and rewire the D-connector correctly, as shown below, or replace with the users own connector).

Receiver digital interface connector and cable wiring layout (receiver end) for reference

8-pin, pin number	8 wire cable, wire colour	RS-232 function	RS-422 function	9-pin D-connector, pin number
1	red	RXD	RXD– (A)	2
2	blue	CTS	RXD+ (B)	8
3	green	DSR	do not connect	6
4	yellow	RTS	TXD+(Z)	7
5	grey	TXD	TXD– (Y)	3
6	brown	DTR	do not connect	4
7	white	DCD	do not connect	1
8	black	digital ground	digital ground	5
shield	thick black	cable screen	cable screen	9

For permanent connection to a computer always use optically or galvanicly isolated adapters or converters at the computer serial port to protect the LAS and/or the computer or network against damage caused by lightning.

2.5.5 Receiver digital interface connector with GPS

Pin number	Wire colour	Signal	Direction	Description RS232-C
1	red	RD1	Input	Receive Data 1, arriving data from DCE
2	blue	CTS1	Input	Clear to send 1, to DCE
3	green	N/A	N/A	Do not use
4	yellow	RTS1	Output	Request to Send 1, to DCE
5	grey	TD1	Output	Transmit Data 1, transmitting data to DCE
6	brown	DTR	Output	Data Terminal Ready 1
7	white	GPS, Monitor	Output	Data received from the GPS is available on this pin as output (TD2). This pin can be used to monitor the data transmitted by the GPS This pin is connected with pin 3 of the sensor input connector.
8	black	SG	Ground	Signal ground

2.5.6 Receiver meteorological sensor kit connector

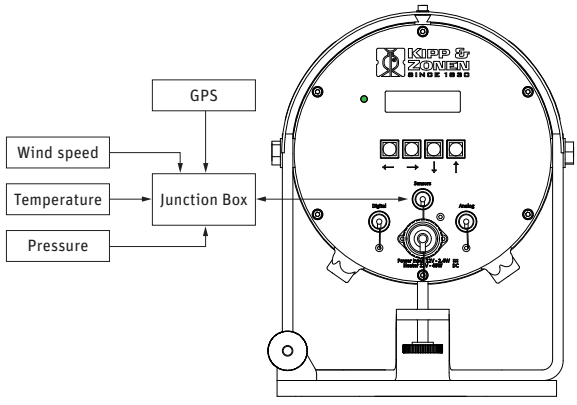
The 8-pin connector marked ‘sensors’ must only be used with the accessory meteorological sensor kit or the supplied GPS antenna. The 12 VDC output must not be used to supply other equipment.

Receiver meteorological sensor kit connector wiring

Pin number	Wire colour	Function	Value
1	red	Power supply for GPS	5 VDC, 200 mA
2	blue	RS232-C Transmit data COM2	
3	green	RS232-C Transmit data COM2	
4	yellow	Power supply for sensor kit	9.6 to 18 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 9.6 to 18 VDC output is 1 to 1 coupled with the 9.6 to 18 VDC power input voltage on the receiver power connector and for this reason is not fused.

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.

If the meteorological sensor kit is not used, then the GPS antenna should be plugged directly into the connector marked ‘sensors’.

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.

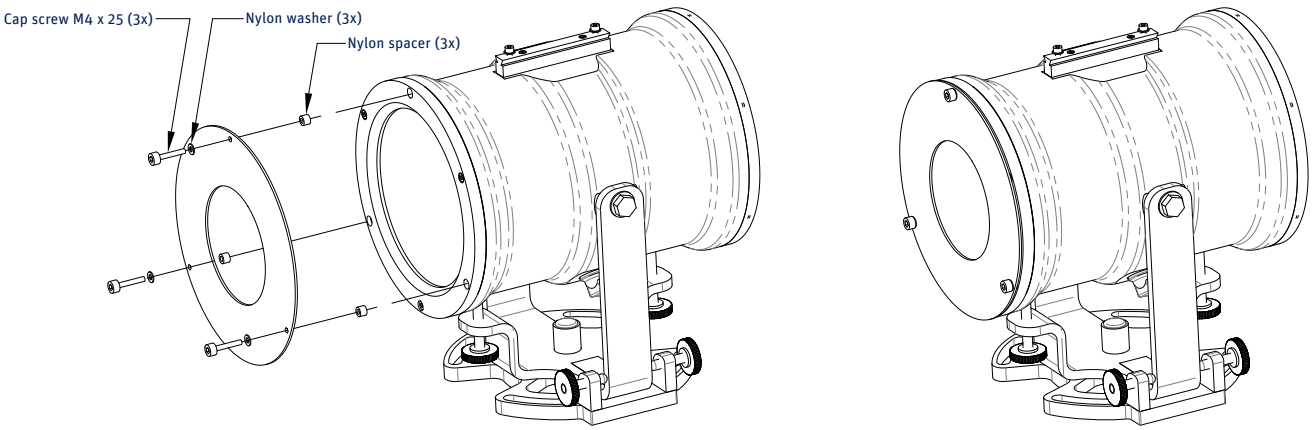
Note If the 100 mm reduction rings are used then this will result in some or more influence by inner scale effects (for more information see 'Exploring Scintillometry in the Stable Atmospheric Surface layer', Chapter 5 and Appendix 5A: Inner scale sensitivity of the LAS, PhD thesis, O. K. Hartogensis).
It is recommended to use the aperture rings when the power level of the transmitter is less than 10 % of the maximum power (dial setting <= 1.00).

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 due to the restrictor, so does the beam width further away. 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

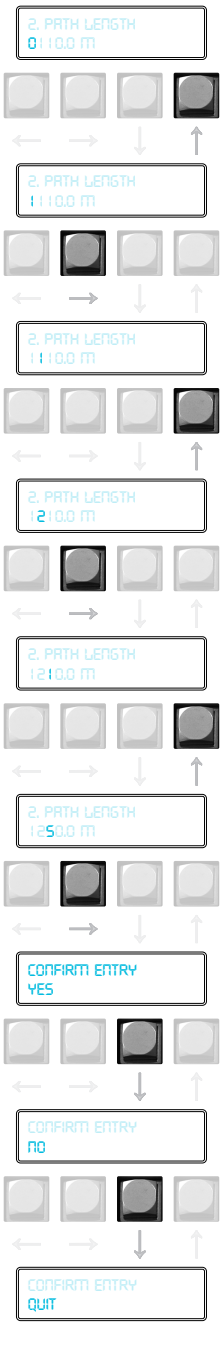
Edit mode

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

For example to change the path length setting from 110.0 m to 1250.0 m the following actions need to be performed:



Press 4x (to increment from 1 to 5)

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

To confirm changes and go back to menu

To cancel and go back to edit mode

To exit edit mode without changes

In order to keep this manual as concise as possible, this process will be shortened in the following way:

Main Menu → 2. Configuration → 1. Installation → 2. Path length → 1250.0 m → Confirm

Note To reduce power consumption and increase life-time, the receiver display is turned off if no keys are pressed for 4 minutes. Pressing any key turns the display on again.

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.

Sub-menu	Sub-menu item	Function	Range	Default
1. Installation	1. Aperture	Set or show effective diameter	0 to 499.9 mm	149 mm
	2. Path length	Set or show path length	0.0 to 19999.9 m	890 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	0.0 to 199.99 m	0 m
	5. Signal gain	Show signal strength and set gain	1x, 2x, 4x, 8x, 16x, 32x, 64x, 128x	1
	6. Set defaults	Restore default configuration	0 = No, 1 = Yes	0 = No
	7. << 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 69.9 °C	+17 °C
	2. Air pressure	Set or show air pressure	600 to 1100 mBar	1012 mBar
	3. Wind speed	Set or show wind speed	0 to 80.0 m/sec	2.2 m/sec
	4. Device temp	Set or show receiver temperature	-39.9 to 69.9 °C	N/A (99.9)
	5. << Back	Back to higher menu		
4. Data Logger	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 COM1	1. Set default	Restore default configuration	COM1	
	2. BaudRate	Set or show baud rate	1200 to 38400	19200
	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	232-C
	6. DeviceID	Set device address	0 to 255	255
	7. Restart	Restart the receiver	0=No, 1=Yes	
	8. << Back	Back to higher menu		
6. Interface COM2	1. Set default	Restore default configuration	COM2 (for GPS)	
	2. BaudRate	Set or show baud rate	1200 to 38400	38400
	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. Restart	Restart the receiver	0=No, 1=Yes	
	6. << 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. The signal gain can also be set in menu 1. Realtime data → 1. Signal level. The Aperture maximum value depends on the effective diameter (see menu Device).

Note If a non-standard BaudRate is entered, 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

} from meteorological sensor kit when connected

- Roughness Length

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 internal 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 COM1

Configure the following interface settings; baud rate, parity, data bits and interface type, for the receiver serial communication with a host (PC).

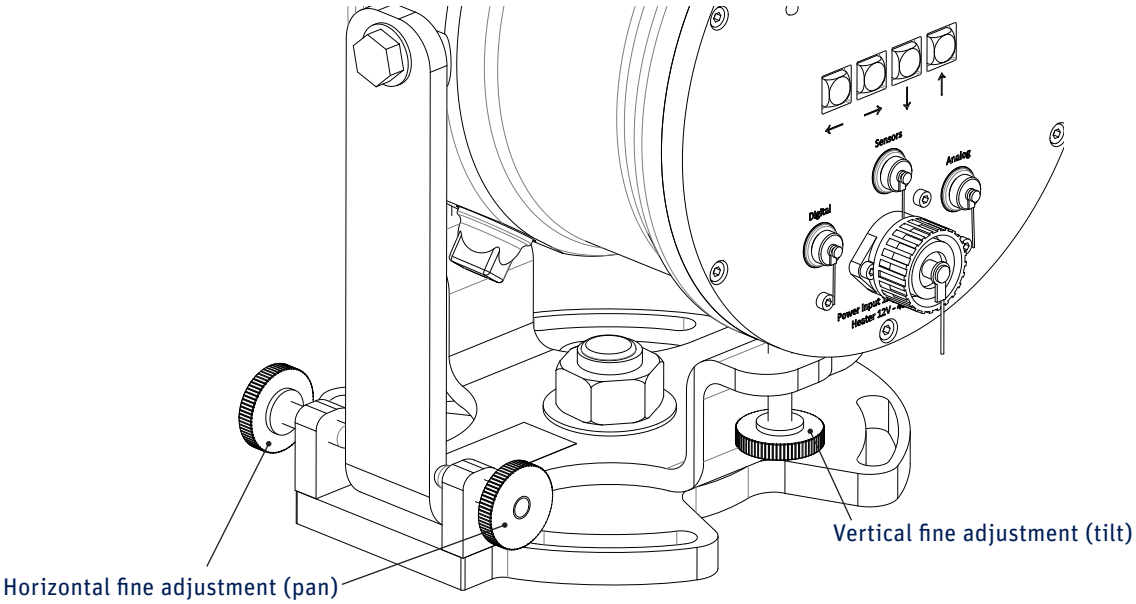
2.8.6 Interface COM2 (for GPS)

Configure the following interface settings; baud rate, parity, and data bits, for the internal communication with the GPS receiver.

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, and low wind (not gusting).

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 just above the receiver window, on the opposing riflescope. 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 the middle of the range i.e. 500 or 5 turns. If the LAS is installed for a long (2 to 4.5 km) path length, then turn the dial 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.

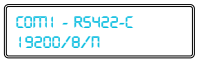
Green indicator function	Status
Normal blinking (0.15 sec on 2.35 sec off)	The instrument is operational
Fast blinking (0.2 sec on 0.2 sec off)	A hardware error was detected
Slow blinking	The boot loader is running
Always on	The boot loader is halted, no application is running
Always off	The power is 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

- The software release and hardware release

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



- The successful start-up message

Or 'Check 12V Heater' (this is only a warning that the heater is not powered, 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:

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

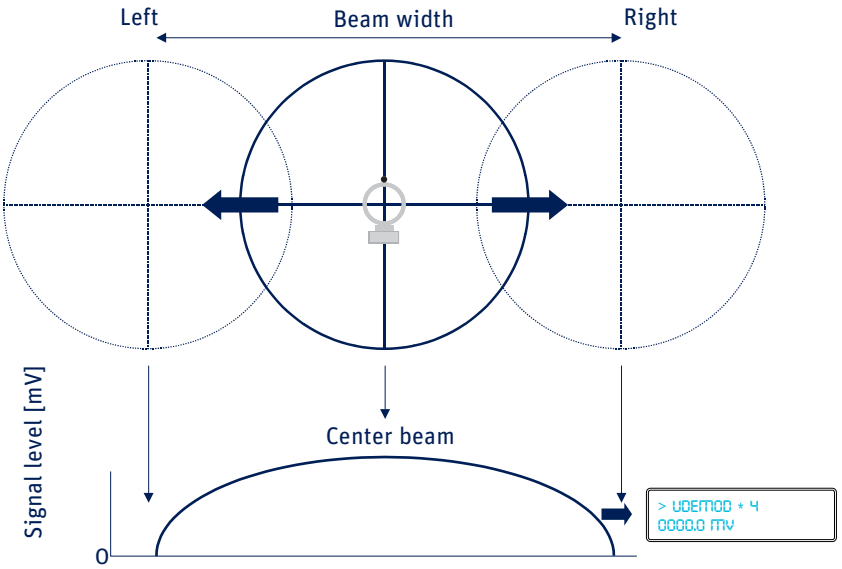
1. At the receiver ensure that the LAS MkII is configured as described in section 2.8, in particular the path length, installation height and aperture (100 mm or 149 mm). If these crucial configuration parameters are not set, C_n^2 and therefore the heat flux will not be calculated correctly.
2. At the 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 to 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. The riflescope can be employed to check the receiver is not tilting while tightening the adjustment screws.

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 perfectly aligned with the centre of the crosshairs of its telescope. This may be due to a difference between the operating path length and the range at which the telescopes were adjusted at the factory or operator experience. 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. For the receiver only, place the GPS mounting bracket with GPS antenna on top of the instrument and place the sun shield on top of the mounting bracket. Use two M4 x 16 hex head screws and washers to fasten on the sun shield and mounting bracket. 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.

Note The meteorological sensor kit makes use of the same port as the GPS antenna. When using this kit, plug the kit into the 8 pin port labelled 'Sensors', and then plug the GPS antenna into an additional 8 pin socket on the junction box which is connected to the GPS inputs and power using the same sensor cable.

3.2 CVP1 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 Double transit case

Foam-lined rugged aluminium transit case, for the safe transport of the LAS MkII. Just one case is required for both the transmitter and receiver and is shipped as standard with the LAS MkII.

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

EVATION runs on Windows™ XP, Windows™ Vista, Windows™ 7 and Windows™ 8.1 with a minimum of 2GB of RAM.

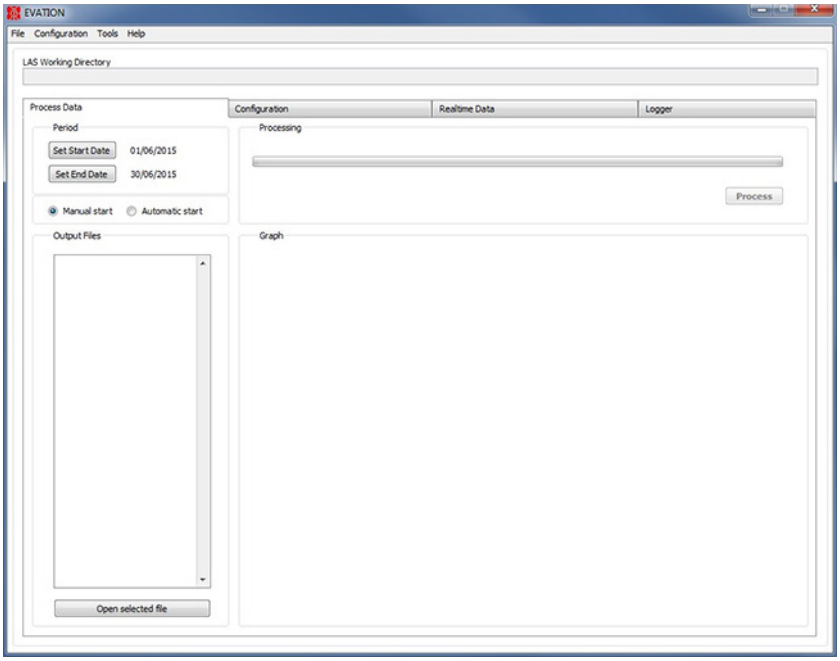
4.1.2 Installation procedure

In order to install the EVATION software package, please select and run the file 'EvationSetup.exe' which is located on the DVD-ROM supplied with the instrument. The installer program will guide you through the installation process. The latest version of EVATION can be found on the Kipp & Zonen website.

Note 'Administrator' rights on the computer are 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.

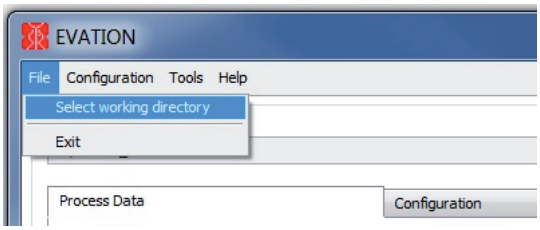
4.1.4 Selecting a data folder

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

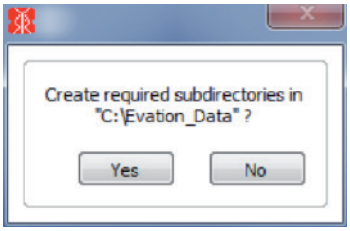
Folder name	Function
input	All measurement data should be stored here. Data retrieved using the LAS MkII digital interface connection is placed here
output	Repository of processed data
config	Configuration setting files are stored in this folder
auxiliary	Any intermediate or temporary data required by 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 choose 'Select working directory' from the 'File'menu. Then select or create a new directory to use as the working directory, and then click on 'Current Folder'.



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. When complete the path to the current working directory will be shown in the 'LAS Working Directory' bar.

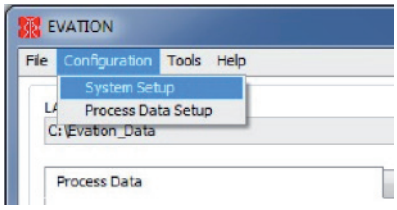
Note If using a different LAS instrument, instrument configuration or other measurement location, then create a new working directory for each configuration. As many working directories as needed can be created.
If you have a working directory which is for post processing with separate sensor data, then the Input directory is filled with separate user data sets. Previously processed LAS MkII output data could be used as an input for this working directory by combining it with additional separate sensor data.

4.2 Configuring the EVATION software package

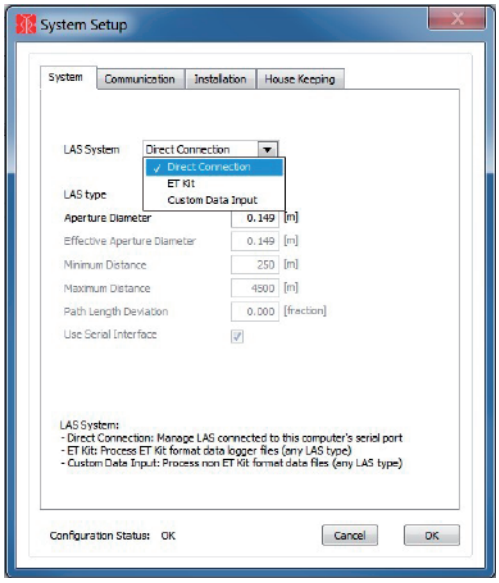
Before EVATION can be used a number of parameters must be configured.

4.2.1 System setup

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



On the next screen, ‘System Setup’, select the ‘System’ tab and then on the ‘LAS System’ drop down menu select ‘Direct Connection’.

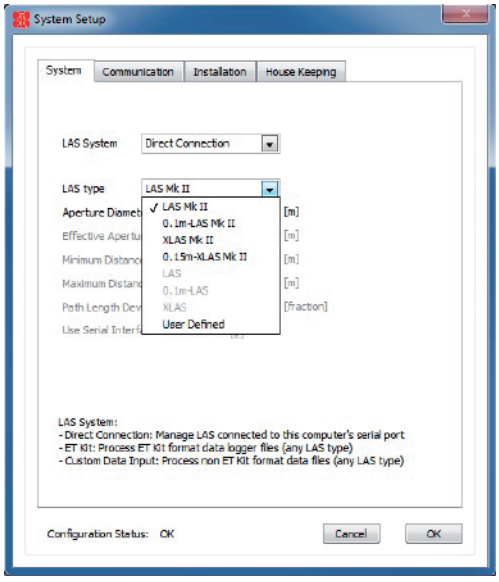


There are 3 options to choose from under the LAS System:

1. ‘Direct Connection’: to manage a LAS instrument connected to the computer’s serial port which is running EVATION.
2. ‘ET Kit’: to process K&Z ET kit format data logger files (of any LAS type).
3. ‘Custom Data Input’: to process non ET kit data files (of any LAS type and with or without other meteorological sensor data).

Then select the ‘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 XLAS and the new XLAS MkII. For the LAS MkII, select ‘LAS Mk II’ from the drop down menu.

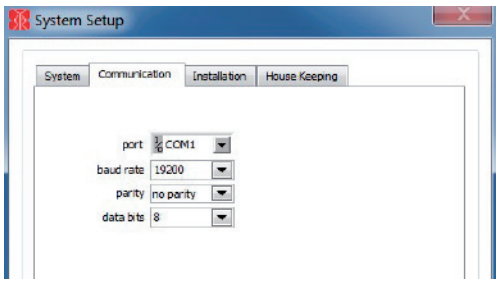


When LAS Mk II, XLAS Mk II or User Defined is selected (along with Direct Connection), the following tab options will become available; Communication, Installation and House Keeping. For all other LAS types these options are not available as they have no digital communication (and in fact the other LAS type choices will be greyed out).

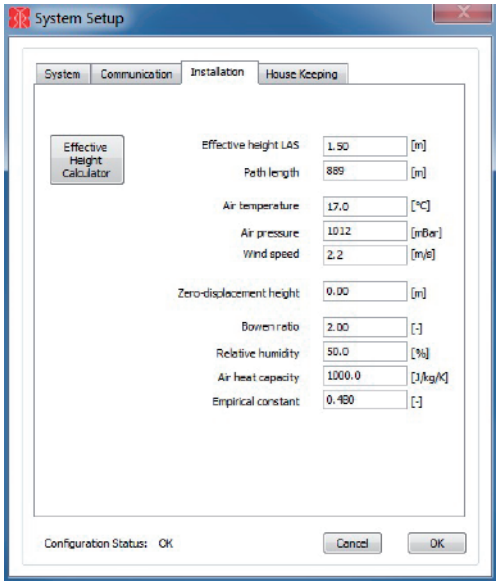
4.2.2 Communication

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 19200 bps with no parity and 8 databits).



4.2.3 Installation



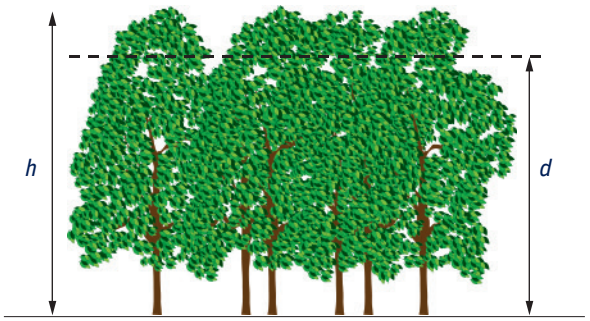
Parameter	Description
Effective height LAS	For an even terrain with minimal changes in elevation along the path, the effective height of the beam is relative to the ground. For an uneven terrain use the effective height calculator (see Appendix E)
Path length	The distance between the transmitter and the receiver
Air temperature Air pressure Wind speed	When unchecked values from the meteorological sensor kit will be used. When checked fixed user values can be entered.
Zero-displacement height	See description in 4.2.4
Bowen ratio	The ratio between the sensible and latent heat flux, H/LvE
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

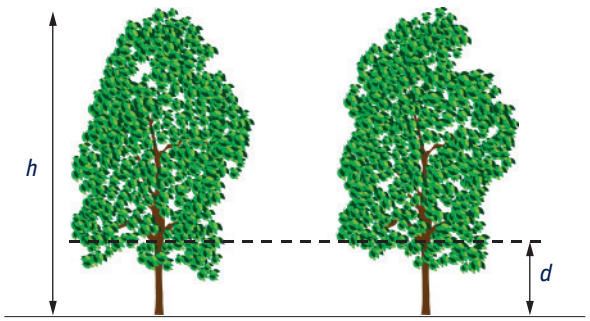
The aerodynamic roughness length or surface roughness (z_0) is an expression for the irregularity of the Earth's surface. It affects the intensity of mechanical turbulence and the fluxes of sensible heat (H), latent heat (L_vE), and momentum, above the surface.

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.

Dense:
- low roughness length (z_0)
- high zero - displacement height (d)



Sparse:
- high roughness length (z_0)
- low zero - displacement height (d)



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 20h
5	Rough	0.25	Open landscape, obstacles separated by ~15h
6	Very rough	0.5	Landscape with bushes, young dense forest, etc., separated by ~10h
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.

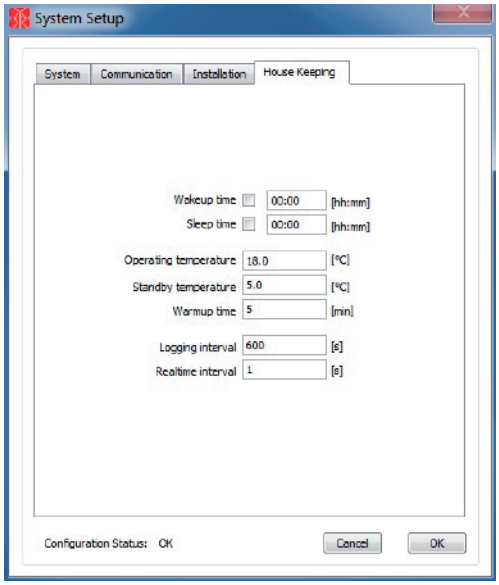
The only proper way to derive the zero-displacement height is from wind profile data; but, there is a simple rule of thumb, using the crop height:

$$d = 0.7\ h$$

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 house keeping

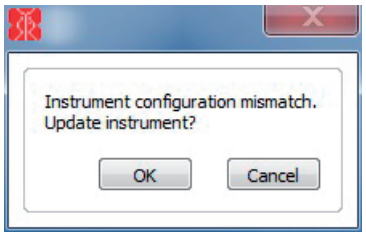
If the 'Wakeup time' and 'Sleep time' are checked then the time entered determines the time that the logger wakes up from standby mode and begins measuring and logging data, and stops measuring so entering standby mode, respectively. This allows you to conserve power or logger memory, by shutting down at night for example, or when data is not required. The 'Warmup time' allows the heater to come on early to warm the up the window, removing condensation, so the instrument is ready for measuring when it starts logging at the 'Wakeup time'.



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 Note: this is labelled as the Send Interval in the LAS Main Menu → 2. Configuration → 1. Installation → 4. Data Logger→ 6. Send Interval option

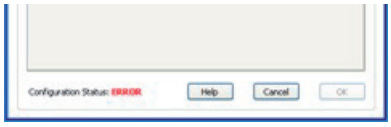
After the configuration parameters have been set, any difference between the LAS MkII receiver settings and the settings in EVATION will be checked at regular intervals by EVATION.

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.

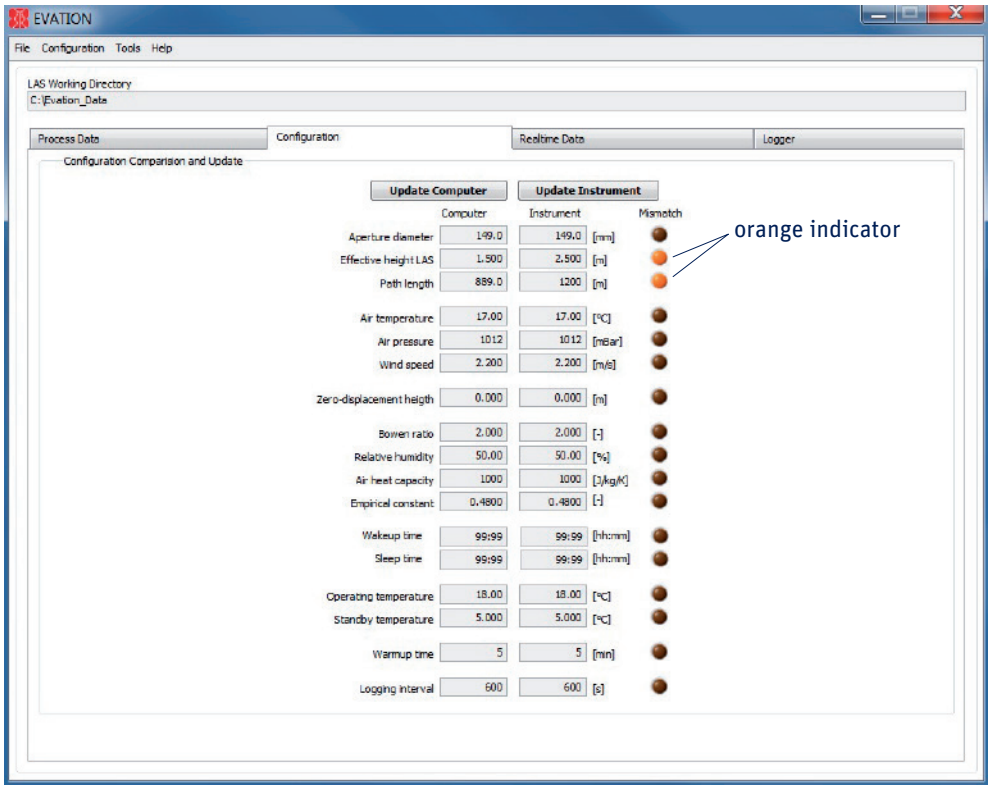


If 'OK' is selected, the LAS MkII receiver is updated with the settings in EVATION. If 'Cancel' is selected, no settings in the receiver are changed.

Note If the following error message is displayed then one of the Configuration parameters is invalid or out of range and needs to be corrected.



On the main screen, under the 'Configuration' tab, the current settings in EVATION and in the LAS MkII receiver are displayed. Any differences between the settings will be indicated by an orange 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.

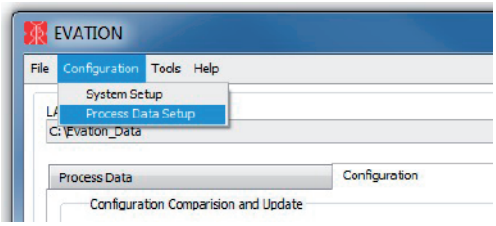
After pressing an 'Update' button it will change to display 'Stop Update' (wait approximately 15 seconds until both columns of values are seen to be updated). It will remain active and EVATION will continuously check for differences in the settings and will automatically update either EVATION or the 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.

A wakeup or sleep time of 99.99 indicates these options are inactive, so the LAS measures and logs continuously.

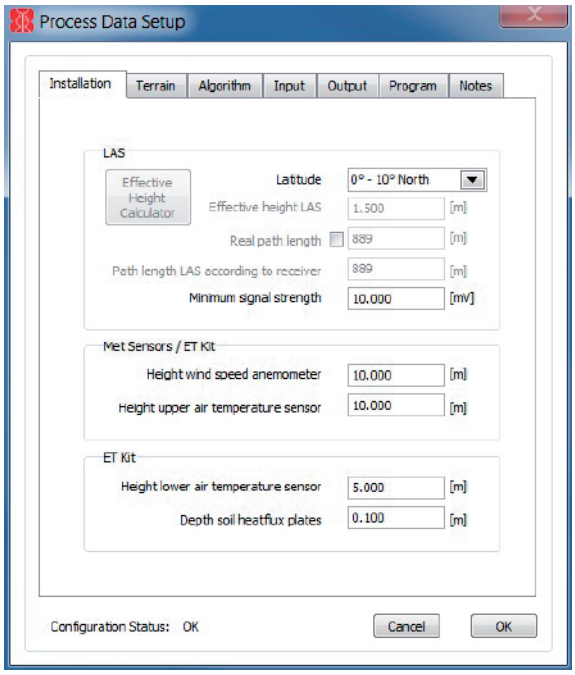
The values onscreen under the Configuration tab cannot be changed by typing in the boxes. The values shown under Computer are taken from the Configuration – System setup settings. The values taken from the instrument can only be changed by entering new values with the keyboard and display on the rear of the instrument, or overwriting using the values in EVATION.

4.2.6 Data processing setup

In the main screen select the menu “Configuration” and then the menu option ‘Process Data Setup’.



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 (as well as in the System Setup).



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
Real path length	The direct path length between the transmitter and receiver (if different from the parameter below)
Path length according to receiver	The path length set on the receiver in the field
Minimum signal strength	Minimum receiver signal strength in mV (below which data will be assumed to be invalid)
Height wind speed anemometer	The height of the anemometer above the surface
Height upper air temperature sensor	The height of the upper air temperature sensor (T1) above the surface
Height lower air temperature sensor	The height of the lower air temperature sensor (T2) above the surface
Depth soil heat flux plates	The depth in the ground of the soil heat flux plate sensors

For more details of processing data files see section 5.4

5 Operation and measurement

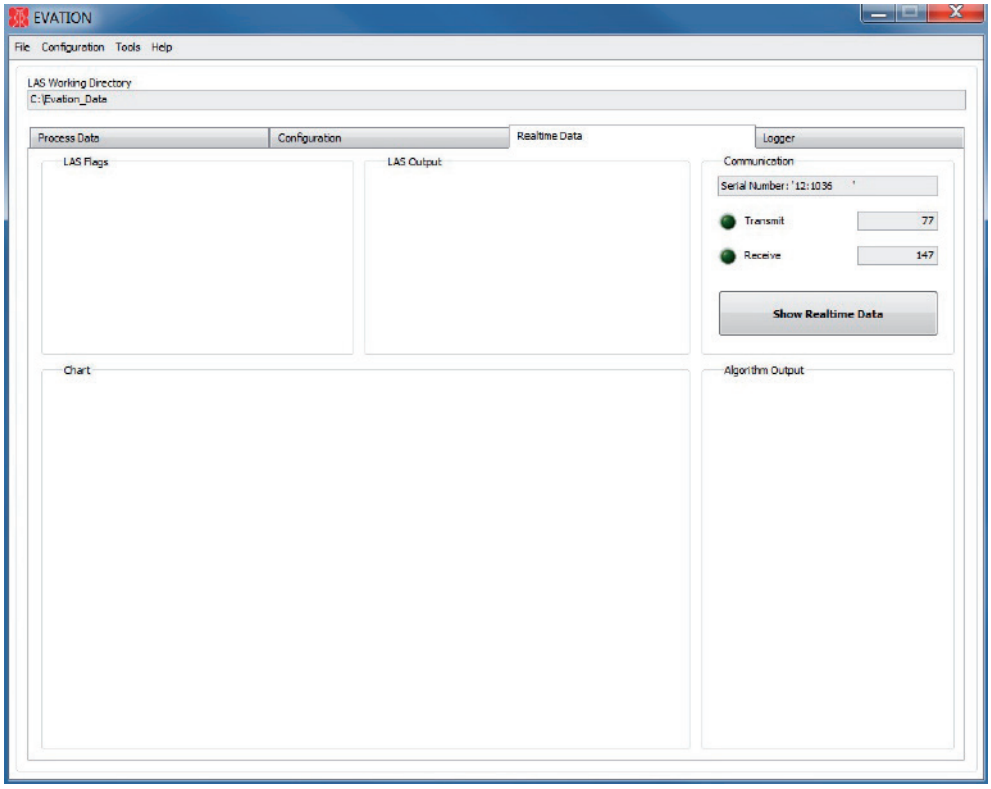
After completing the software installation and configuration the LAS MkII is ready for operation.

5.1 Collecting digital data

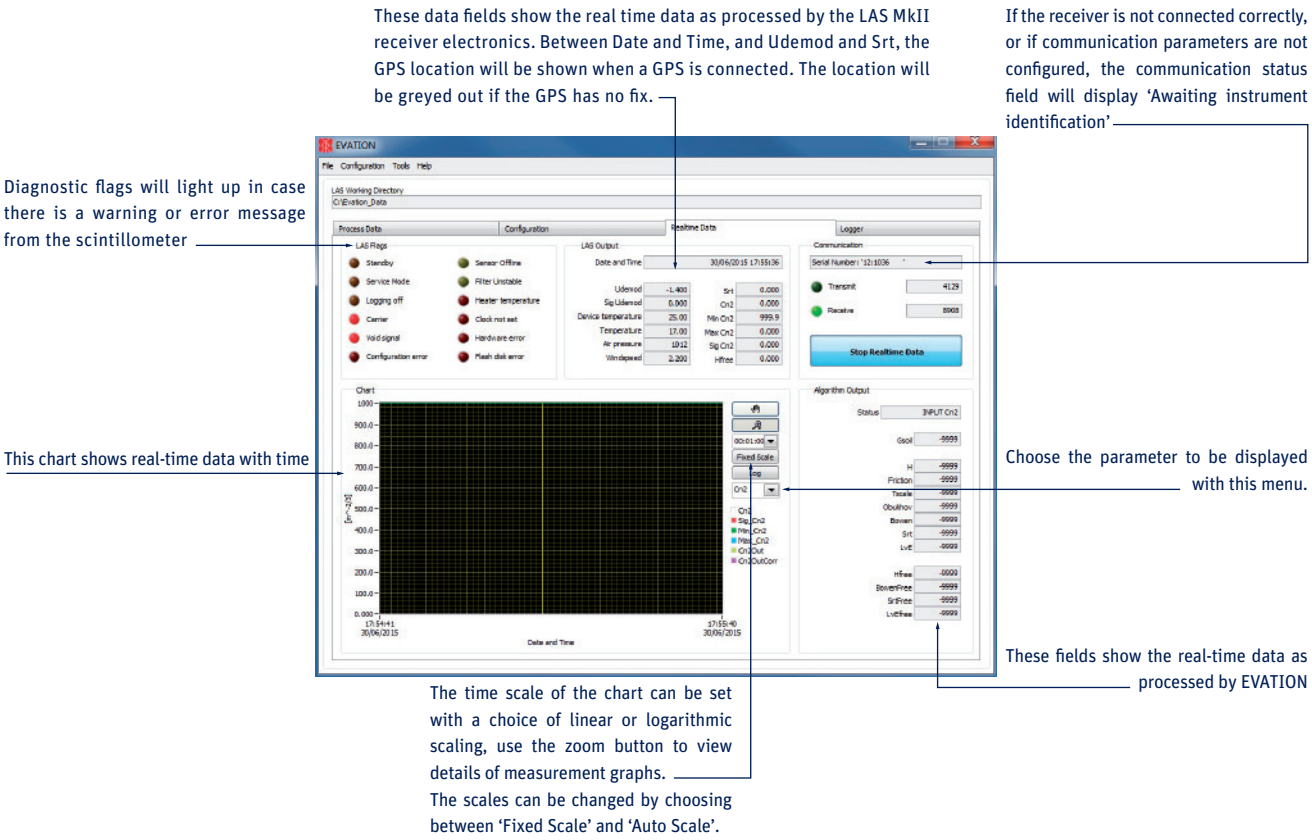
The data from the LAS MkII receiver can be obtained using the EVATION software. EVATION has the functionality to collect data from the receiver's internal data logger and display data in the real-time data view. In addition real-time or downloaded data can be processed into heat flux data.

5.1.1 Real-time display of 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.



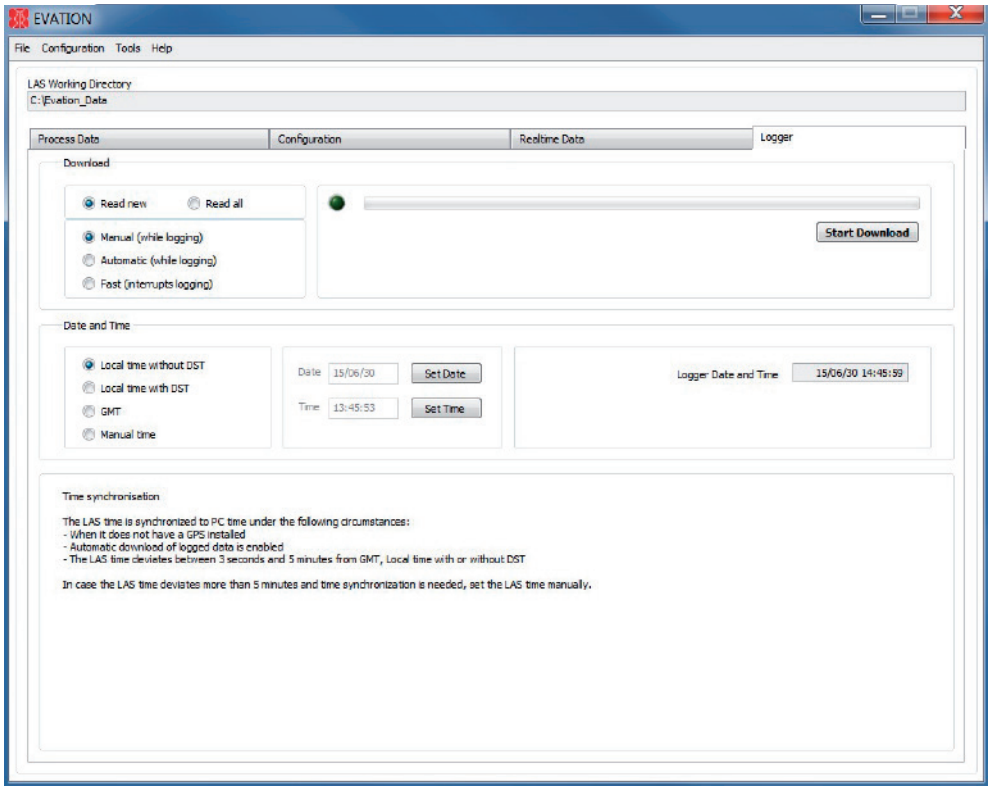
The serial number of the connected LAS should be shown at the top right. If the 'Show Realtime Data' button below this is pressed, the graph in the centre of the screen and the data fields will become active.



Click on 'Stop Realtime Data' at any point to stop updating the screen with new data. At the top left are shown status flags (if the beam is blocked or there is no transmitter the Carrier flag will be on - as above, or if the signal is too low the Void signal will be on). The currently measured values are shown in the upper centre and graphed at lower left, continuously updated at the Realtime interval frequency (this is the interval at which the LAS receiver automatically transmits data to a computer). At the lower right is displayed the output of the data processing algorithm if the Process Data Configuration has been set up and a valid signal is received, otherwise values of -9999 are displayed.

5.1.2 Downloading data from the internal data logger

Select the tab 'Logger'. On this tab data can be downloaded from the LAS internal memory and the instrument time can be configured.



Parameter	Description
Read new	Only new data is downloaded
Read all	All data in the memory is downloaded
Download: Manual	Download data at the user's request at slow speed, while continuing logging / LAS operation
Download: Automatic	Download new data records as soon as they are available in the receiver
Download: Fast	Stops logging and downloads data at the user's request at high speed
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 date from the choices above
Logger date and time	Displays the current date and time in the LAS MkII receiver

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

Note The LAS time will be synchronized to the computer time if the LAS does not have a GPS installed. EVATION detects at which time the LAS runs (local with DST, local without DST or UTC). LAS time will only be synchronized if it deviates less than 5 minutes.

If the LAS has a GPS installed, the LAS time will be synchronized to GMT (UTC) from the GPS. It is not possible to set the LAS to local or custom time with the GPS connected.

5.1.3 Data logger memory capacity

The LAS MkII receiver is equipped with 4 MB 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:

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

5.1.4 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 time stamp is placed at the end of an averaging period (by the LAS internal logger), the same as a regular data logger. So for 10 min average data from 12:00 to 12:10 the time stamp would be YYYY/MM/DD 12:10:00. Data is acquired for the period you choose and then at the end of the period the record is written with the date / time at that moment. EVATION caries on the same format when further processing and averaging data.

The data file format is shown below. The header rows identify the parameter names and units. The number of data rows depends upon the data logger settings and how much time has been spent logging.

Data file format

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11	Column 12	Column 13	Column 14	Column 15
Header row 1	DateTime	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/m²]	[–C]	[–C]	[mBar]	[m/s]
Data row	2015/04/21 08:40:00	1	77	698.400000	0.026480	1.316000E-14	6.733000E-14	7.017000E-15	2.621000E-14	0.014520	225.100000	19.000000	17.000000	1012.000000	2.200000
Data row	2015/04/21 08:50:00	2	64	710.000000	0.027750	1.446000E-14	0.000000	6.285000E-15	3.331000E-14	0.015950	241.500000	18.500000	17.000000	1012.000000	2.200000
Data row	2015/04/21 09:00:00	3	64	716.400000	0.027060	1.375000E-14	0.000000	3.964000E-15	4.656000E-13	0.015170	232.500000	17.500000	17.000000	1012.000000	2.200000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Configuration change log format

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11	Column 12	Column 13	Column 14	Column 15	Column 16	Column 17	Column 18	Column 19
Header row 1	DateTime	RecordNo	StatusFlags	PathLength	InstallHeight	ZeroDisplacement	Diameter	MaxDiameter	BowenRatio	RelativeHumidity	AirHeatCapacity	EmpiricalConstant	WakeupTime	SleepTime	LogInterval	SendInterval	GainError	TimeConstant1	TimeConstant2
Header row 2	[yyyy/mm/dd hh:mm:ss]	[-]	[-]	[m]	[m]	[m]	[m]	[m]	[-]	[%]	[J/kg/K]	[-]	[hh:mm]	[hh:mm]	[s]	[s]	[-]	[s]	[s]
Data row	2015/05/22 10:01:41	12008	0	889.000000	50.000000	0.000000	0.149000	0.149000	2.000000	50.000000	1000.000000	0.480000	99:99	99:99	10	0	0.987000	1.592000	2.500000
Data row	2015/05/22 10:01:57	12010	76	889.000000	50.000000	0.000000	0.149000	0.149000	2.000000	50.000000	1000.000000	0.480000	99:99	99:99	10	1	0.987000	1.592000	2.500000
Data row	2015/05/22 10:19:23	12116	0	889.000000	50.000000	0.000000	0.149000	0.149000	2.000000	50.000000	1000.000000	0.480000	99:99	99:99	10	0	0.987000	1.592000	2.500000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Error log format

	Column 1	Column 2	Column 3	Column 4	Column 5
Header row 1	DateTime	RecordNo	StatusFlags	RecordType	RecordData
Header row 2	[yyyy/mm/dd hh:mm:ss]	[-]	[-]	[-]	[text]
Data row	2000/01/01 00:00:00	123127	512	4	512;057;Record Not Found;^5
Data row	2000/01/01 00:00:00	123128	512	4	512;057;Record Not Found;^4
Data row	2000/01/01 00:00:00	125568	512	4	512;057;Record Not Found;^*
...	...	...	...	...	...

5.1.5 Collecting serial or analogue data

In some situations, or for convenience, the user may wish to use an external data logger instead of or in addition to the internal logger of the LAS MkII. An external data logger can be used to log data from the LAS MkII using either the serial or analogue connection. For accuracy the digital serial output is recommended. See APPENDIX G and 2.5.4 Receiver digital interface connector, for more details on how to collect signals from the LAS serial connector.

Depending on the capability of the external data logger or the situation, the user not be able to make use of the digital communication output of the LAS MkII instrument or data from the internal memory, so the analogue output can be used in combination with an external logger. See APPENDIX H for how to collect signals from the LAS analogue output connector and log this in the appropriate format.

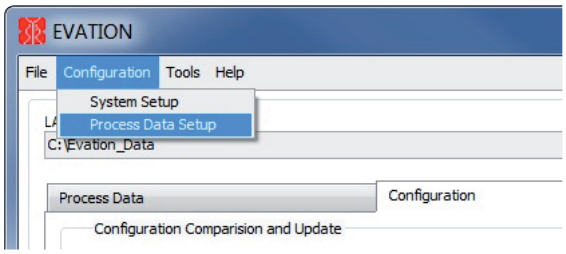
5.1.6 Processing data files

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.

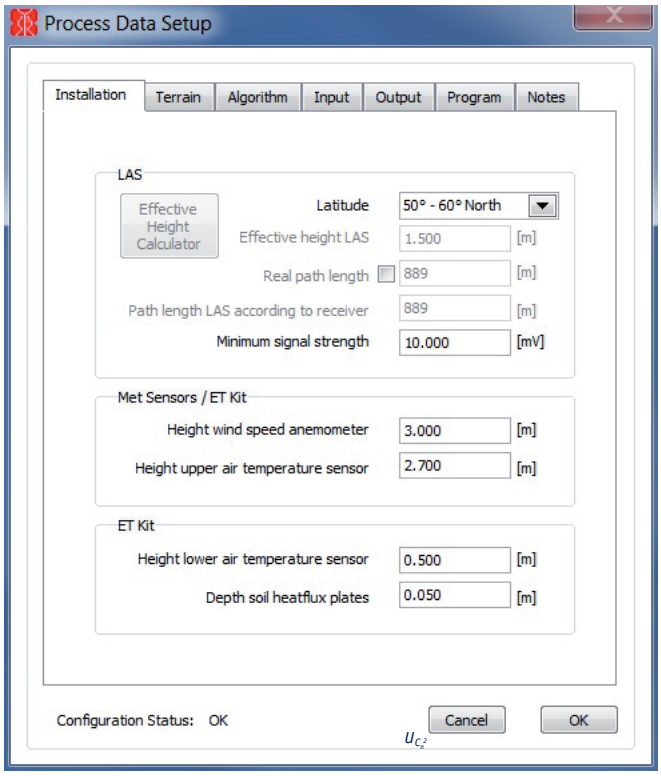
To process data from the LAS MkII manually (offline), data is used which was previously downloaded and stored in the appropriate working directory. The Input directory is filled and kept consistent by downloading from the LAS MkII. But processing can also be done online by selecting ‘Automatic’ on the Logger tab, for continuous operation of a LAS MkII connected to a network via a computer with EVATION.

5.1.7 Setting input parameters

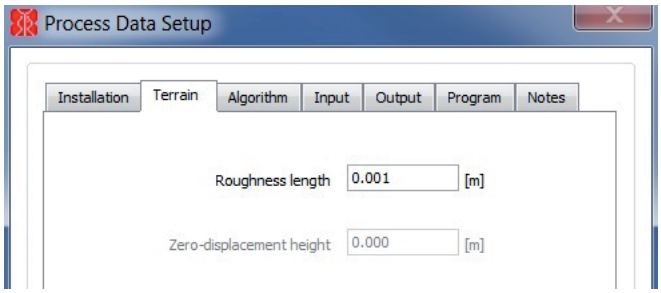
In order to process the scintillometer data a number of parameters need to be set. Select the 'Process Data Setup' option from the Configuration menu.



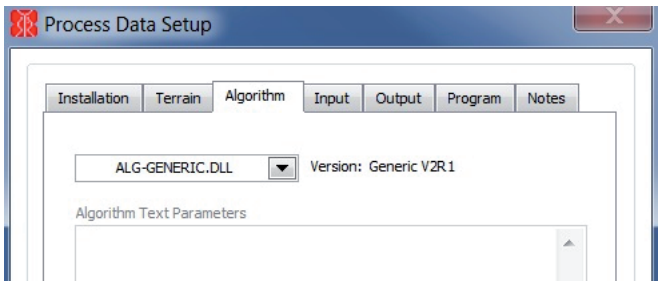
On the first page or tab, set all the parameters to match the installation. All parameters need to be filled in. In case certain parameters, such as soil heat flux plates, are not present in the setup they can be ignored during data processing using options in a later step.



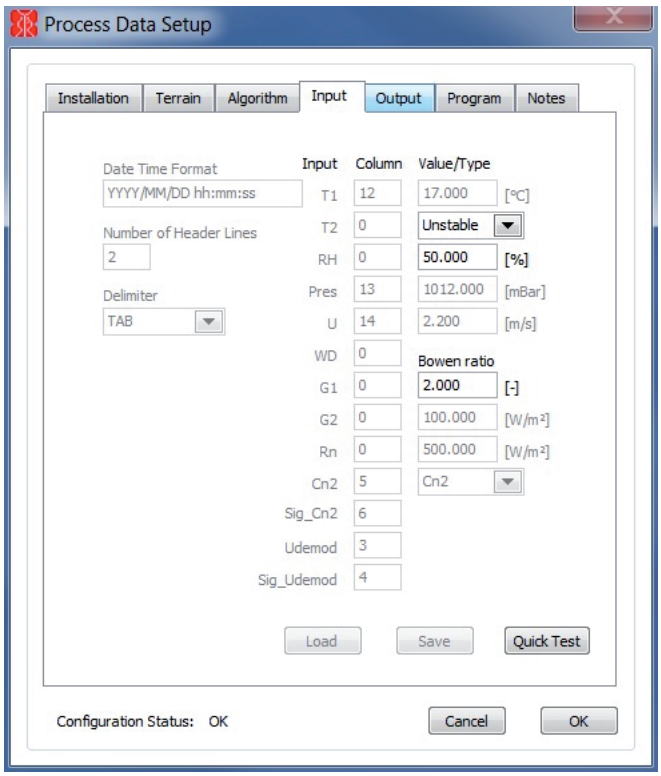
In the 'Terrain' tab enter values for roughness length and zero displacement height as described in section 4.2.4.



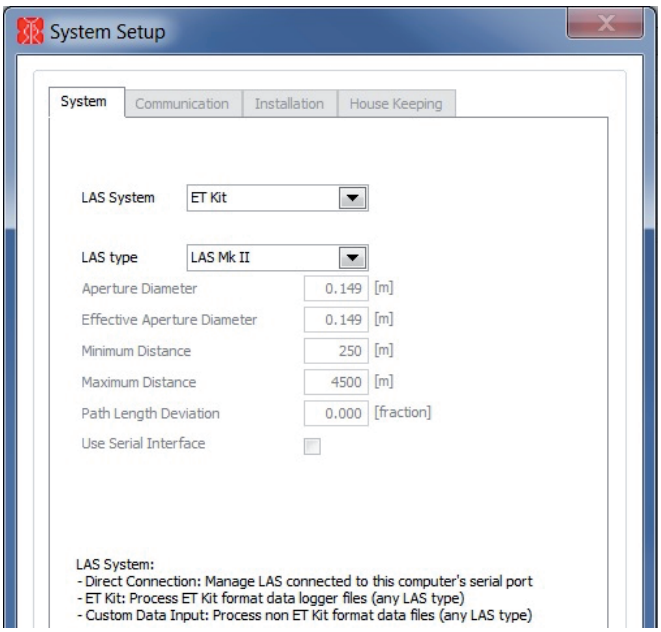
Leave the setting on the ‘Algorithm’ tab at the default generic option.

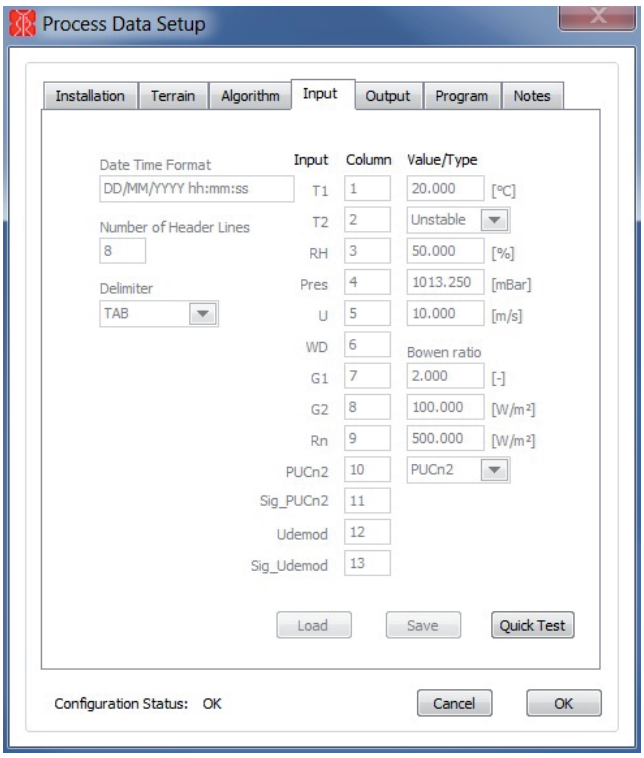


In the ‘Input’ tab details on the data files must be selected.



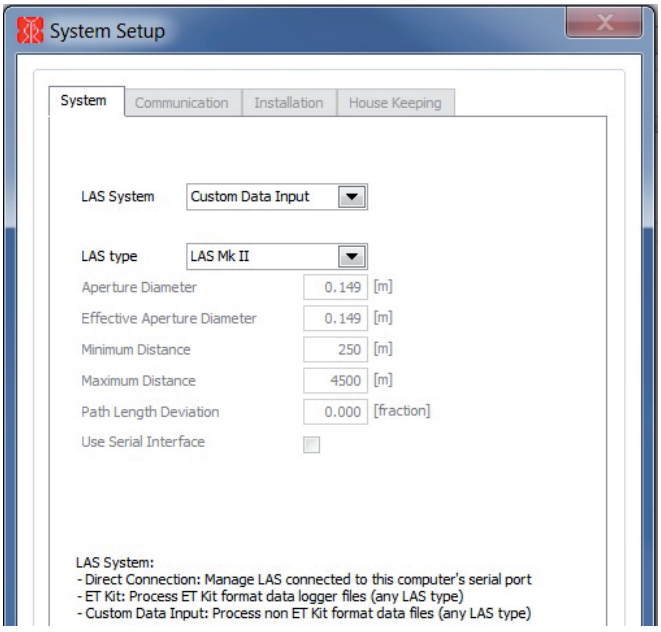
If the data files have been generated by the Kipp & Zonen LAS MkII ET System and its data logger, select the 'ET Kit' from the 'LAS System' choice, (in the System Setup under the Configuration menu) and the default ET System settings will be used.

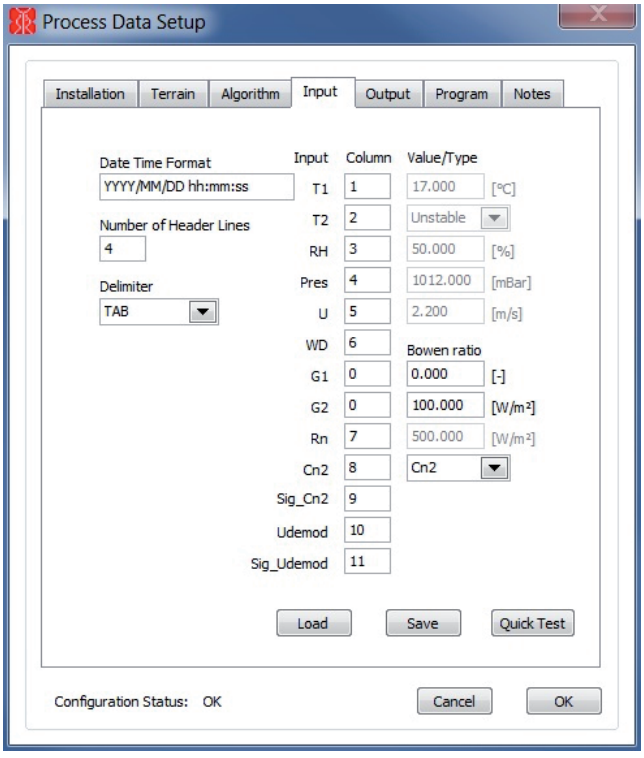




If LAS MkII has been selected as the scintillometer model in section 4.2.1, the correct file format will be set automatically.

In case a propriety or custom file format is used, please select the 'Custom data Input' from the 'LAS System' choice.





All the input variable selection should now be active (not greyed out), allowing the data format to be selected to match the users input data files. Then follow the instructions below:

Date and time format

The typical data and time format used is YYYY/MM/DD hh:mm:ss, but a range of formats can be accepted by EVATION (if selecting the ET kit in the System Setup, then only the above format will be accepted). See APPENDIX I for the date and time format and examples.

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. The total number of columns is 13, plus one for the date / time. Apart from the date and time column, data columns can be in any order and additional data columns can be skipped (to skip over additional sensors that are not needed by EVIATION). In case a certain value is not present in the data file enter 0, and a default value can be selected in the Process data setup screen. Alternatively dummy values (-9999) can be inserted in the 'empty' columns for the specific missing sensor, and then these data columns will be ignored and default values used instead, if required for the calculations.

Note that the TimeDate column holds date and time separated by a space and separators may be '.' or '/' or ':' for date or time. The default value for the soil heat flux is only used if the Bowen ratio is also set to 0 (as well as G1 and G2 set to 0).

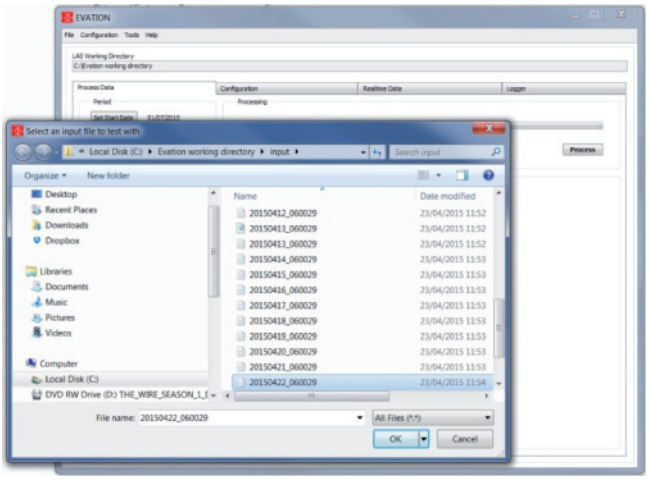
If any of the critical data is missing (LAS C_n^2, T1, Pres, and U), the sensible heat flux cannot be calculated. If both of the soil heat fluxes or the net radiation is missing the latent heat flux cannot be calculated, but a fixed value can be entered for missing variables to allow the calculation.

Wind direction (WD) is not needed for the flux calculations, and Udemod is just used as a check that the signal is in range. T2 is just used along with T1 to see whether the temperature is decreasing with height or increasing with height to switch between the Unstable (day time) and Stable (night time) calculation modes.

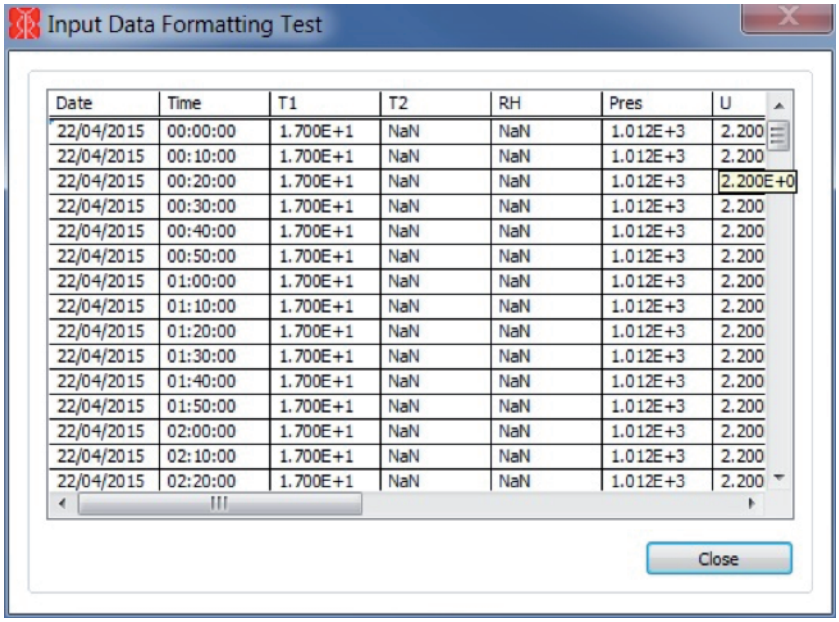
Data variables, example and units:

Column	Name	Variable	Unit	Example	Minimum	Maximum
0	Date Time	Date and Time	YYYY/MM/DD hh:mm:ss	2015/10/10 11:05:24		
1	T1	Upper air temperature sensor	°C	17.000	-39.9 / -30	69.9 / 50
2	T2	Lower air temperature sensor	°C	17.500	-39.9	69.9 / 50
3	RH	Relative humidity	%	50	0	100
4	Pres	Air pressure	mBar / hPA	1012	600	1100
5	U	Wind speed	m/s	2.2	0.01	80 / 50
6	WD	Wind direction	degrees	180	0	360
7	G1	Soil heat flux 1	W/m^2	100	-250	250
8	G2	Soil heat flux 2	W/m^2	100	-250	250
9	Rn	Net radiation	W/m^2	500	-500	1500
10	Cn2	Structure parameter	$m^{-2/3}$	1.0E-14	1.0E-17	1.0E-11
alternative	PUCn2	$C_n^2 \times 10^{15}$	$m^{-2/3}$	10	0.01	1000
alternative	UCn2	LAS MkII analogue output (pin 1) $C_n^2 \times 10^{(2.5 \cdot UCn2-17)}$	V	1.2	0	2.4
11	Sig_Cn2	Standard dev. C_n^2	$m^{-2/3}$	1.0E-18		
12	Udemod	Demodulat or Voltage	mV	660	20 (0)	2000
13	Sig_Udemod	Standard dev. Udemod	mV	0.001		

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. The Quick Test just shows that the data columns can be read in and the column order is correct, but it does not check the validity of the data or if it is in the correct units. 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.



Date	Time	T1	T2	RH	Pres	U
22/04/2015	00:00:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	00:10:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	00:20:00	1.700E+1	NaN	NaN	1.012E+3	2.200E+0
22/04/2015	00:30:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	00:40:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	00:50:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	01:00:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	01:10:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	01:20:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	01:30:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	01:40:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	01:50:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	02:00:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	02:10:00	1.700E+1	NaN	NaN	1.012E+3	2.200
22/04/2015	02:20:00	1.700E+1	NaN	NaN	1.012E+3	2.200

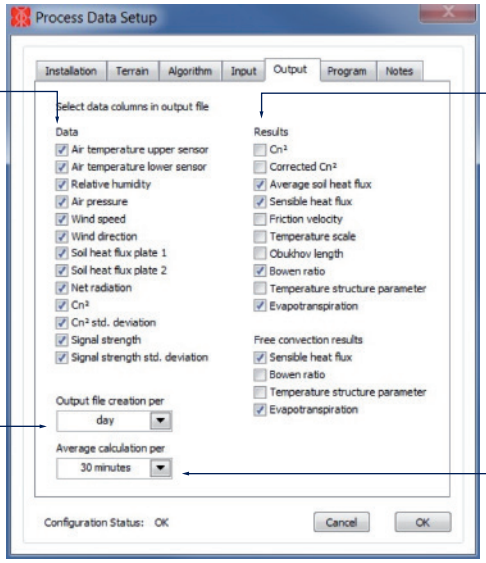
Using the 'Save' button, the configuration for your data files can be saved. This is convenient, especially when processing data files with varying formats or when a fresh installation of EVATION is required. The settings can be restored again using the 'Load' button.

5.1.8 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



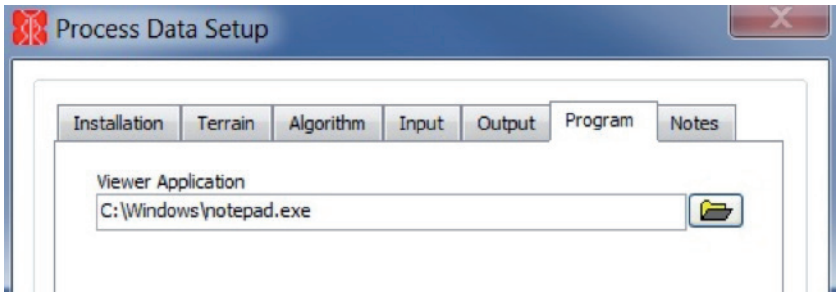
Select which of the processed parameters will be included in the data output file

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

Press 'OK' to complete the process.

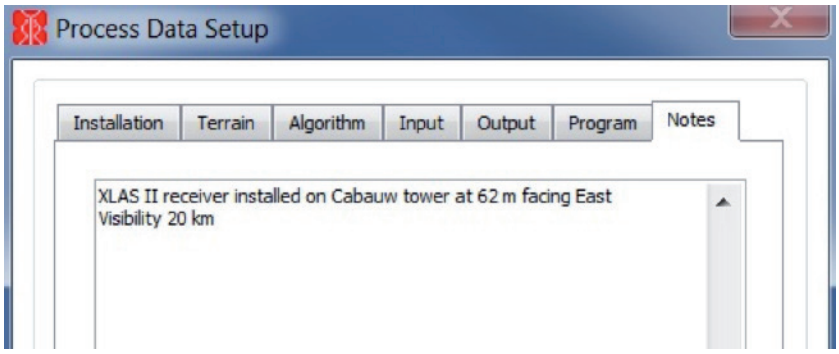
5.1.9 Selecting a text viewer

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



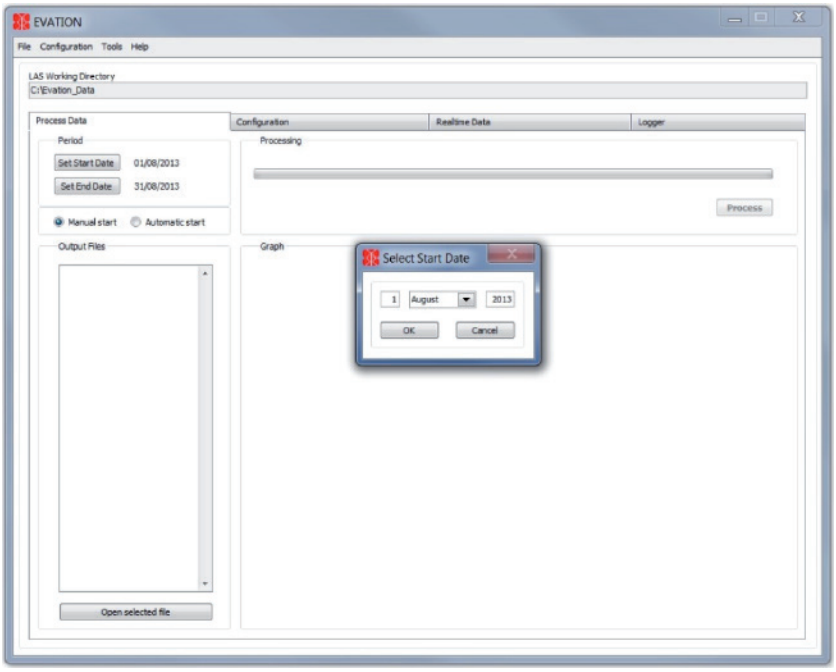
5.1.10 Notes

The last tab, Notes, can be used to make notations about the data, instrument configuration or field setup for this data set, for the users reference.

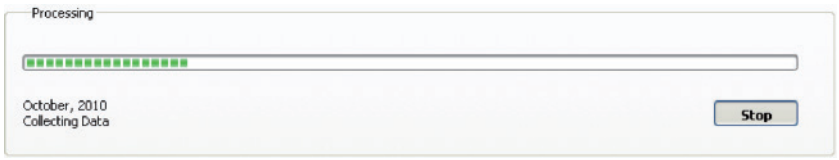


5.1.11 Executing data processing

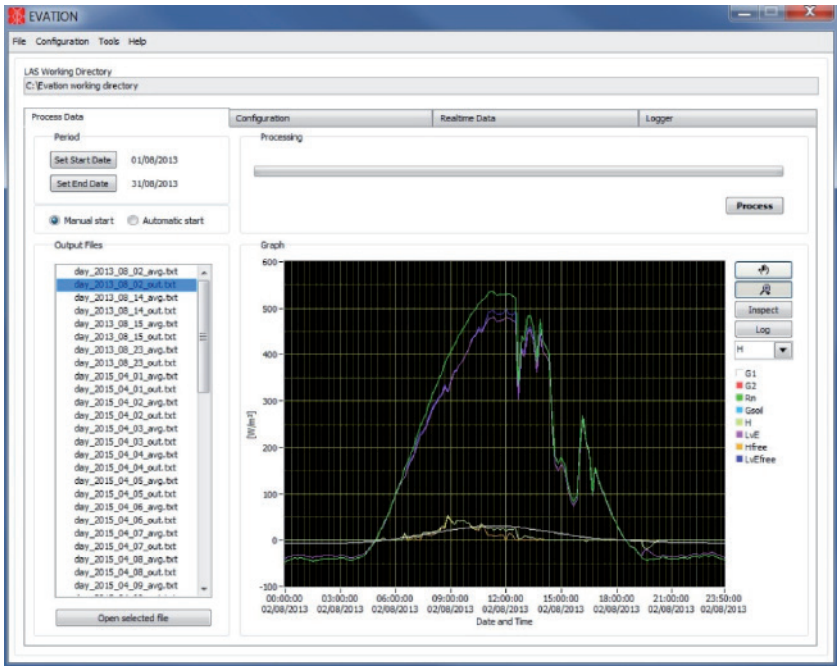
In In order to start processing the data; ‘Set Start Date’ and ‘Set End Date’ in the EVATION main screen. EVATION will automatically import any data within the data files in the ‘Input’ folder with a time stamp between the start and end dates.



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. Two files will be created for each output period, the data in the sample period of the input data (xxxx_out.txt), and the data averaged over a longer sample period than the input data (xxxx_avg.txt) depending on the chosen settings.

As Evation processes data from the LAS MkII (which include the configuration CFG file) any changes in the configuration file will be used to process the data as it goes forward in time.

The ‘Open selected file’ allows you to quickly check the contents of a data file with a chosen program, which is set in the ‘Process data setup’, ‘Program’ tab, under the ‘Viewer Application’ path.

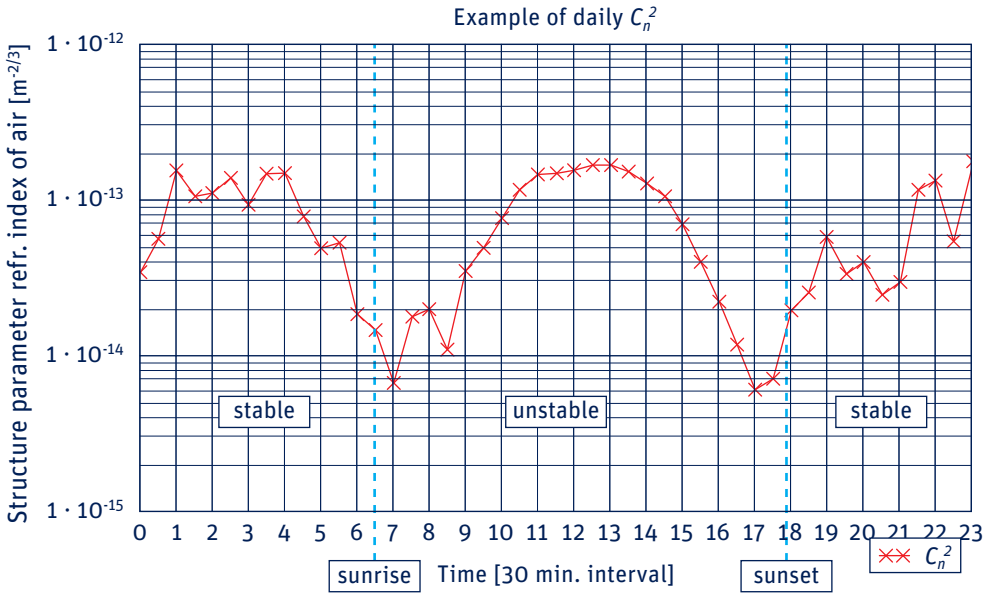
If the status message in the last column of the output file shows an error (such as ‘INPUT Pres’, i.e. the pressure data is invalid, out of range or missing), or a value of -9999 is shown in a data column (often displayed as -1.OOE+04 in Excel), this indicates invalid or out of range data (in the output data file). Check the input file for invalid, out of range or missing input data.

5.2 Diurnal patterns

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

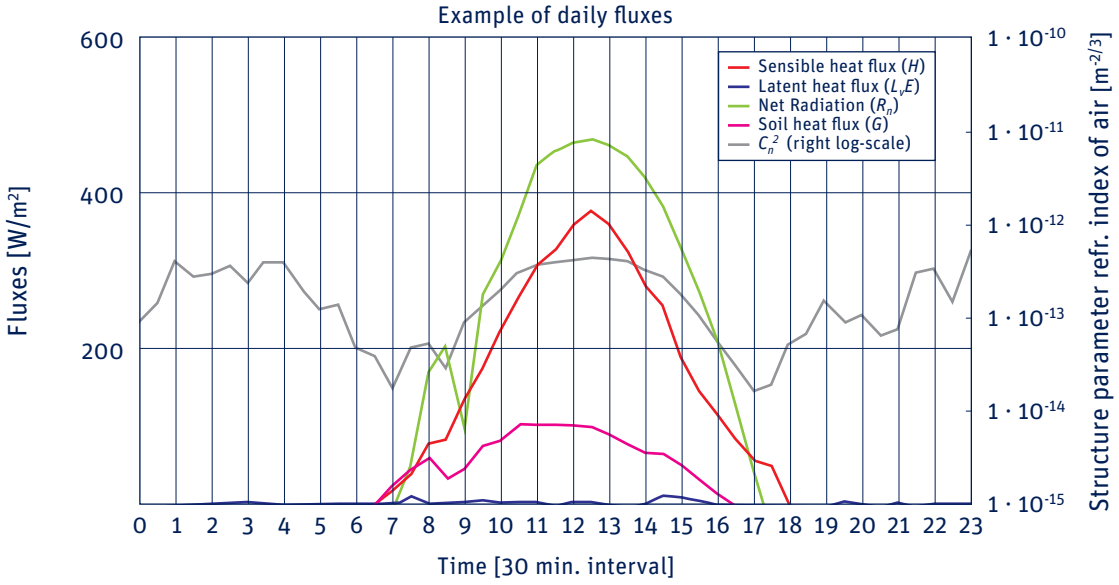
5.2.1 Diurnal C_n^2 patterns

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.



5.2.2 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.



6 Maintenance and internal electronic check

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.

Procedure for firmware version 2.10 and lower:

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**

Procedure for firmware version 3.00 and higher:

Do not alter the aperture and path length settings, as shown above, as this is unnecessary.

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 $1.0 \cdot 10^{-12}$ $m^{-2/3}$ ± 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:

Procedure for firmware version 2.10 and lower:

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**

Procedure for firmware version 3.00 and higher:

Do not alter the aperture and path length settings, as shown above, as this is unnecessary.

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 < $1.0 \cdot 10^{-17}$ $m^{-2/3}$.

This offset depends on the setting of filter1 and the DNL filter (see menu Device). If filter1 is set between 800 and 2500 the recommended value of the DNL filter= 2. If filter1 > 2500 the recommended value is of the DNL filter= 10 and below 800 the recommended value of the DNL filter = 0.

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

6.1.3 Analogue output check

The analogue output can be checked as follows:

1. Connect a digital voltmeter or data logger between the yellow and red wires of the analogue output connector cable (see section 2.5.3 Receiver analogue signal connector).

   Go to:

   Main Menu → 4. Diagnostics → 3. Analog Output

   And enter the value 1000. The measured output should be between 998.25 mV and 1001.75 mV. If not it is recommended to recalibrate the instrument.

2. Connect a digital voltmeter or data logger between the yellow and red wires of the analogue output connector cable. Enter a value of 10 (mV) in the Analog Output menu. The measured output should be between 0 and 34 mV.

After either of these checks be sure to return the configuration to the correct operational settings for aperture, path length and analogue output.

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.

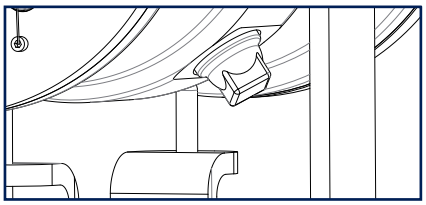
Inspection / maintenance	Weekly	Monthly	Quarterly
Check signal strength	X		
Clean transmitter and receiver windows	X		
Inspect desiccant cartridges for saturation		X	
Check optical alignment		X	
Check electrical stability		X	
Check data logger memory capacity		X	
Check cables and connectors			X
Check 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 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 7.5 kHz (duty cycle 0.5)
Beam width	Approx. 1 m at 100 m distance
Fresnel lens diameter (clear aperture) and focal length	149 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 (clear aperture) and focal length	149 mm / 152 mm
Scintillation signal bandwidth	0.1 to 400 Hz
Typical value signal 1 ($U_{C_n^2}$, log C_n^2 signal)	0 to 2.4 V (2.5 V max)
Typical value signal 2 (6.5 - 7 kHz carrier)	0 to 1 V, 6.5 to 7.5 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^{-11} $m^{-2/3}$
Noise level of electronics	< 10^{-17} $m^{-2/3}$
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

***Note** The transmitter has sufficient power to reach 6 km with clear atmospheric conditions, but the user must be careful to check that the LAS is at a sufficiently high height (on a high tower) to avoid saturation (see section 2.3.2), but not outside the Constant Flux layer (see section 2.3.4). In warm regions with high fluxes this is not possible, but in cool high latitudes it may be possible to meet these criteria.

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 (0.15 sec on 2.35 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**.

8.4 GPS status

The LAS should display firmware version 3.00 at powering on. To check the GPS is obtaining a fix, select menu:

1 RealTime Data → 14 Latitude (or 15 Longitude)

The Display should show the latitude position of the LAS. If the message 'GPS Timed Out' is shown after some time then there is no communication possible with the GPS. If the display shows 'GPS Not Enabled' then the baud rate should be correctly set (see trouble shooting). If the displays shows 'No Location Data' the GPS is enabled and running but does not have a valid fix to locate the instrument.

GPS status messages

Displayed messages in the LAS display under: RealTime Data → 14 Latitude (or 15 Longitude)	Description
XYZ North (or XYZ East) etc. whereby: XYZ = Longitude (or Latitude)	Valid location received (as degrees, minutes and decimal seconds, decimal point separates min and sec, format nnn°nn'.nn(.)nn").
'No Location Data'	No valid location data received from the GPS or Void signal
'GPS Timed Out'	No data received from the GPS (GPS cable not connected, no communication, GPS hardware problems, cable problems or wrong baud rate / parity etc.) The GPS times out after 30 seconds of no communication
'GPS Not Enabled'	The communication port COM2 is not enabled or the baud rate of the GPS is not set (baud rate=0) (See Configuration menu Interface COM2)
'No GPS Board'	GPS interface board is not installed

Troubleshooting GPS communication

1. It is recommended to test the GPS without the cable from the digital output on the LAS to the serial port on the HOST. If the GPS fails, disconnect the cable from the LAS to the HOST and check if the GPS operates without the cable. If the GPS fails again after reinstalling the cable, then there is a conflict between the GPS out signal and the DCD (data carrier detect) signal on the HOST. To solve this problem cut the white wire in the (yellow) cable from the digital output on the LAS to the HOST computer.

2. If there is no communication after some time, check the baud rate of the GPS as described in the user manual.
Select configuration menu: 2 Configuration → 6 Interface COM2 → 2 Baudrate
Enter the baud rate, confirm and, select option: 2 Configuration → 6 Interface COM2 → 5 Restart Device

3. The default baud rate of the GPS is set to 38400 baud by the manufacturer of the GPS, but if the GPS has no valid configuration data then the baud rate defaults to 9600 baud or some other value.

4. If the GPS doesn't work after trying different baud rates, connect a standard 8 wire yellow cable to the sensor output and measure the voltage between the RED and BLACK wire. This should be 5V and measure the voltage between the YELOW and BLACK wire. This should be approximatly 12 V. The voltage depends on the input voltage applied to the LAS on the power input connector.

***Note** Do not short circuit the YELLOW or RED wire with ground (BLACK).

It is possible to monitor the GPS when the GPS is connected to the Sensor Input by monitoring the GPS output on the digital connector to the HOST or PC. Connect the black wire of the digital output to the signal ground of a RS232-C input on your computer and connect the white wire (GPS out) to the RS232-C Receive Data (RD) input on your computer and start a terminal emulation program on your computer. For this you need a special serial data cable.

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 **www.kippzonen.com/contact**

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.

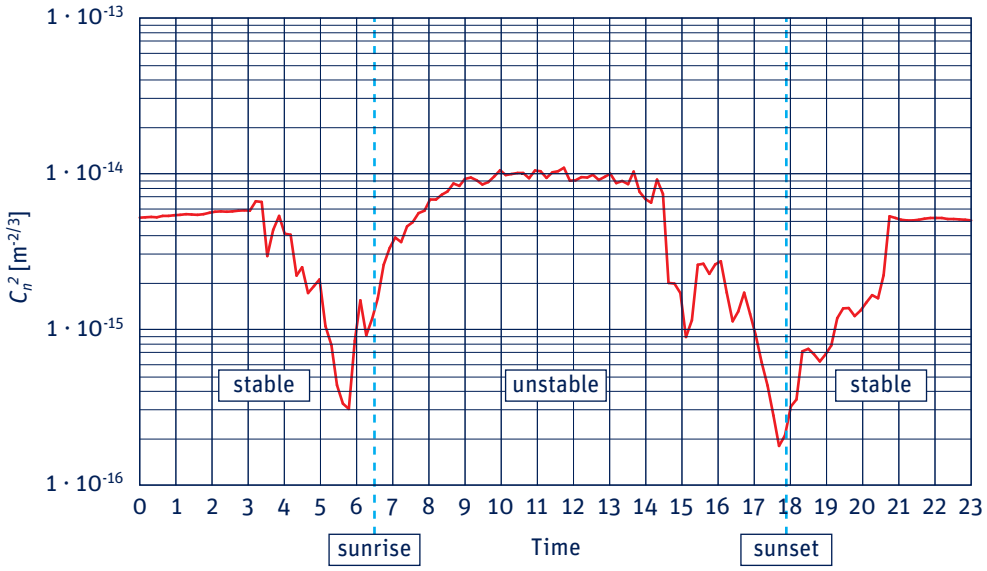
A scintillometer is an instrument that can measure the 'amount' of scintillations by transmitting a beam of light over a horizontal path. The scintillations 'seen' by the receiving part of the instrument can be expressed as the structure parameter of the refractive index of air (C_n^2), which is a representation 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 (σ_{lnI}^2) and the structure parameter is as follows (Wang et al., 1978):

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

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} $m^{-2/3}$.

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):

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

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 J K^{-1} kg^{-1}). Typical values for A_T and A_Q, for 'normal atmospheric' conditions (P = 1·105 Pa, T = 288 K and Q = 0.012 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_vE), i.e. $\beta = H/L_vE$. When the surface conditions are dry H is larger than L_vE, 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} 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 (~1.2 kg m^{-3}), c_p the specific heat of air at constant pressure (~1005 J kg^{-1} K^{-1}), k_v the von Kármán constant (~0.40), g the gravitational acceleration (~9.81 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.

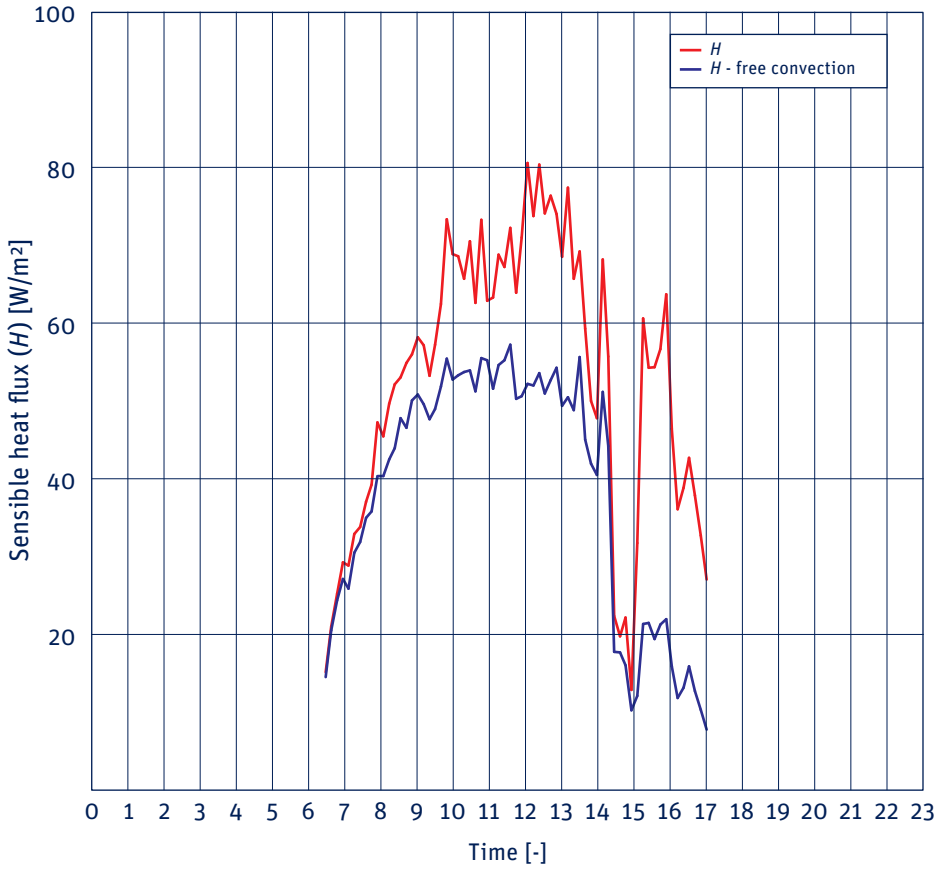
For most day-time (unstable) conditions and when the LAS MkII is installed relatively high above the surface (z_{LAS} MkII > 20 m) the contribution of the friction velocity is relatively small. For these conditions the free convection method can be applied:

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

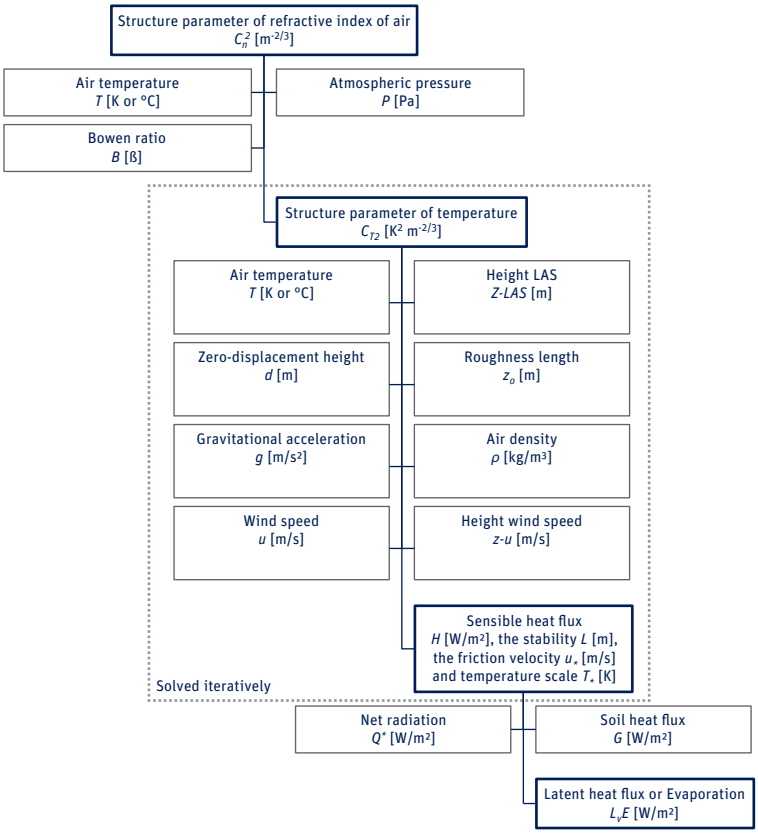
where b is an empirical constant:

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

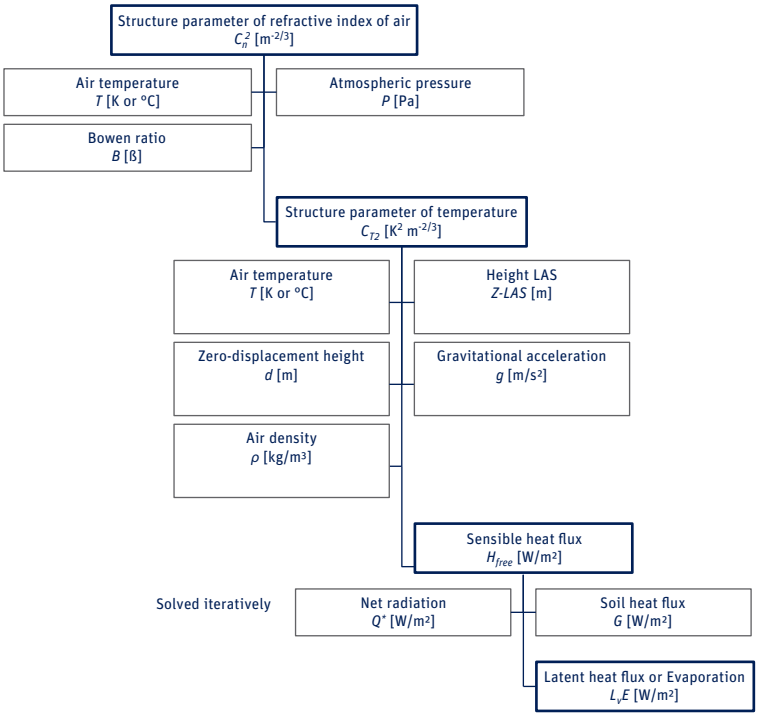
This free convection approach provides a simpler method to determine H (in this case termed 'H_{free}') directly from C_{T2} without knowing u_*. In practical applications the free convection approach can provide reasonably accurate fluxes under unstable conditions (day-time) when the scintillometer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

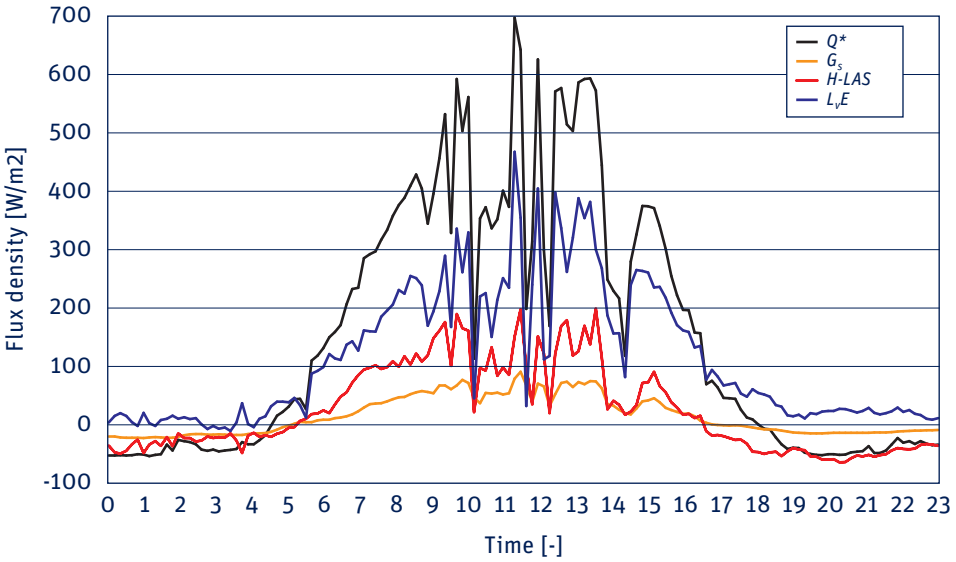


•

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

$$Q^* = H + L_vE + G_s$$

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)

Other useful meteorological data:

- Radiation data (net radiation)
- Soil heat flux data
- Wind direction
- Rainfall
- Humidity

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 ($C_n^2 = 10^{(2.5*U_{C_n^2}-17)}$)	[$m^{-2/3}$]
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] ($C_n^2 = 10^{(2.5*U_{C_n^2}-17)}$)	[0 to 2.4 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 ($\beta = H/LvE$)	[-]
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	[-]
$\sigma^2_{\ln I}$	variance of natural logarithm of intensity fluctuations, ln(I)	[-]
$\sigma^2_{U_{DEMOD}} = \sigma^2_I$	variance of U_{DEMOD} or intensity I	[V^2]
$\sigma^2_{U_{C_n^2}}$	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.	**RealTime Data**	**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 (yy/mm/dd)	Display date provided by the real time clock, or GPS if connected	
	13.	Time (hh:mm:ss)	Display time provided by the real time clock, or GPS if connected	
	14.	Latitude	Display latitude from GPS as degrees, minutes and decimal seconds (ss.ss'' but no sec decimal point displayed), where the minutes are separated from seconds with a decimal point (format: nnn°nn'.nnnn'')	
	15.	Longitude	Display latitude from GPS as degrees, minutes and decimal seconds (ss.ss'' but no sec decimal point displayed), where the minutes are separated from seconds with a decimal point (format: nnn°nn'.nnnn'')	
	16.	«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 Eff. Diameter or 499.9 mm)	
	2.	Path Length	Set or show path length	(0 to 19999.9 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.	Signal Gain	Show signal strength and set gain	(1x, 2x, 4x, 8x, 16x, 32x, 64x, 128x)	
	6.	Set Defaults	Restore default configuration in EEPROM	(0=No, 1=Yes)	
	7.	«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 Enter 99.9 to enable external temperature sensor (ADC input 1)	(-39.9 to 69.9 °C)	
	2.	Air Pressure	Set or show default air pressure Enter 9999 to enable external pressure sensor (ADC input 2)	(600 to 1100 mBar)	
	3.	Wind speed	Set or show default wind speed Enter 999 to enable external wind speed sensor (ADC input 3)	(0.0 to 80.0 m/sec)	
	4.	Device Temp	Set or show temperature inside the receiver Enter 99.99 (default) to enable the temperature sensor inside the receiver	(-39.9 to 69.9 °C)	
	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 COM1	Set or show the configuration of digital interface COM1		
	1.	Set Default	Restore default configuration of COM1	(0=No, 1=Yes)
	2.	BaudRate	Set or show baud rate (default = 19200)	(1200, 2400, 4800, 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	
6.	Interface COM2	Set or show the configuration of digital interface COM2		
	1.	Set Default	Restore default configuration of COM2	(0=No, 1=Yes)
	2.	BaudRate	Set or show baud rate (default = 38400)	(1200, 2400, 4800, 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.	Restart	Restart the receiver	(0=No, 1=Yes)
	6.	«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 69.9 °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 69.9 °C)
	4.	Maximum Temp	Set or show maximum temp. warning	(0.0 to 69.9 °C)
	5.	«Back	Go one submenu level back	
4.	**Diagnostics**	**Select diagnostics procedures**		
	1.	Gain	Test gain at specified frequency	(1 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	(mV)
	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 1 to 4)
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.	Eff. Diameter*	Set or show nominal lens effective diameter (default = 149 mm for LAS MkII)	(20.0 to 499.9 mm)
8.	Ref. Voltage*	Set or show analogue o/p reference voltage	(80 to 120 %)
9.	Dig.Correction*	Correction factor to digital electronics (1)	(0.7 to 1.4)
10.	Set Filter 1*	Electronic filter 1 (default = 1592)	(100 to 59999)
11.	Set Filter 2*	Electronic filter 2 (default = 2500)	(100 to 59999)
12.	DNL Filter*	Dolby Noise Reduction (default = 2), for very short path lengths 10 is recommended	(0 to 99, 0 = off)
13.	Format Flash*	Erase data and format internal flash memory	(0=No, 1=Yes)
14.	Restart	Restart the device	(0=No, 1=Yes)
15.	«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:

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

and

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. Real-time and logged status message and flags

Real-time status messages from the LAS MkII receiver are sent to a computer at the interval set in 'Send Interval' of the data logger menu (referred to as 'Realtime interval' in EVATION). The status messages have associated status flags.

Logged status messages and flags are data stored in the receiver flash memory or in the 'input' records stored by EVATION on the hard disk of a computer.

EVATION can display some parameters in the real-time status messages, but cannot process then to create an 'output' file.

1 Real-time status message format

.STATUS=2;2;3;4 …… 19 <CRLF> where 2 to 19 are the values for the positions in the table.
Example:.STATUS=2;100;1;3;10/04/13;09:19:16;111.8;7.45E-02;4.61E-14;1.90E-16;4.62E-14;4.61E-14;5.87E-02;1.88E+00;-2.0;-40.0;600;0.0;^^A <CRLF>

Position 2 is the total of the number of real-time status flags set as defined in section 2.
For example decimal '9' means that Bit 1 and Bit 4 (binary 1 + 8) are set.
'Average' parameters are taken during the send interval.
16, 17, 18 are either the default values set in the receiver or live from the optional Sensor Kit.

Data Message Type 2		**Data Record**
Position	Field name	Description
0	Record Type	STATUS
1	Record ID	2 (= STATUS Type 2)
2	Device Status Flag(s)	Status flag(s), see section 2 of this appendix
3	First Record number	First used record number in the log file
4	Next available Record nr	First available (free) record number in the log file
5	Date	Transmit date (of the status message)
6	Time	Transmit time (of the status message)
7	Demodulator Voltage	Average demodulated carrier wave signal in mV
8	Sigma Demodulator Voltage	Variance of the demodulated voltage = (VarUdemod)^ ½
9	C_n^2	Structure parameter of refractive index value
10	C_n^2 Dev	Standard deviation of C_n^2 over the send interval period
11	C_n^2 Max	Maximum value of C_n^2 over the send interval period
12	C_n^2 Min	Minimum value of C_n^2 over the send interval period
13	CT	Structure parameter of temperature index value
14	H Free	Sensible heat flux (free convection method)
15	Internal temperature	Average internal temperature of the receiver in °C.
16	External air temperature	Average external temperature in °C (default or live)
17	Average air pressure	Average air pressure in hPa / mBar (default or live)
18	Average wind speed	Average wind speed in m/s (default or live)
19	Checksum	Checksum of the message string

2 Definition of the real-time status flags

Real-time status message flags are set when an internal or external event is raised and cleared after the status message is sent to a computer. They represent the present condition of the instrument and are sent with the status message at the interval set in 'Send Interval' of the Data Logger menu.

These flags appear in the status message, sent to a computer.

Real-time Status Flags		
Binary No.	Name	Description
Bit 1	Void Signal Condition	1= Invalid signal (out of range or not calibrated)
Bit 2	Standby Mode	1= Standby mode, 0= Normal operation
Bit 3	Not Writing Data	1= The log file is closed or log interval is 0
Bit 4	Carrier Fault	1= Carrier wave signal too low, < 20 mV
Bit 5	Temperature Fault	1= Receiver temperature outside operational range
Bit 6	Real Time Clock Error	1= Real time clock error, date and/or time not set
Bit 7	Configuration Changed	x= The configuration has been changed (toggles 0,1)
Bit 8	Configuration Error	1= Invalid configuration or EEPROM error
Bit 9	Hardware Error	1= Hardware error, the error code will be logged
Bit 10	Flash Disk Error	1= Flash disk error, logging data is not possible
Bit 11	Sensor Offline	1= A meteo-sensor is not functioning or not connected
Bit 12	Service Mode	1= Service mode is enabled
Bit 13	Update Firmware Suspended	1= Download firmware request is suspended
Bit 14	Update Firmware in progress	1= Download firmware in progress or not completed
Bit 15	Update Firmware failed	1= Download failed after N retries
Bit 16	Filter unstable	1= Digital filter unstable or the beam was interrupted

3 Logged status message format

Logged status messages are data stored in the receiver flash memory or in the 'input' records stored by EVATION on the hard disk of a computer.

With firmware version 3.00 it is also possible to receive the data records each time when a record is stored in the internal logfile, not just the Status 2 sent data. (Note this feature is not supported by firmware 2.1 or lower).

The difference between a data record and status record, is that a data record is an average over N seconds (whereby N is programmable by changing the log-interval) and a status record is the average over the last second.

.DATA=10;2;3;4 …… 18 <CRLF> where 2 to 18 are the values for the positions in the table.
.DATA=10;80;100;00/01/01;14:52:56;127.1;3.370E-01;1.923E-18;4.698E-20;
2.040E-18;1.845E-18;2.903E-06;6.777E-07;-15.9;42.0;1021;0.0;^^C <CRLF>

Position 2 is the total of the number of logged status flags set as defined in section 4.
For example decimal '9' means that Bit 1 and Bit 4 (binary 1 + 8) are set.
'Average' parameters are taken during the logging interval.
15, 16, 17 are either the default values set in the receiver or live from the optional Sensor Kit.

Status Message Type 10		**Extended Status**
Position	Field name	Description
0	Record Type	DATA
1	Record ID	10 (= DATA Type 1)
2	Logged Status Flag(s)	Status flag(s), see section 4 of this Addendum
3	Record number	Unique number incremented each time a record is stored
4	Date	Date when the record is stored
5	Time	Time when the record is stored
6	Demodulator Voltage	Average demodulated carrier wave signal in mV
7	Sigma Demodulator Voltage	Variance of the demodulated voltage = $(VarU_{demod})^{\wedge}$ ½
8	C_n^2	Structure parameter of refractive index value
9	C_n^2 Dev	Standard deviation of C_n^2 over the send interval period
10	C_n^2 Max	Maximum value of C_n^2 over the send interval period
11	C_n^2 Min	Minimum value of C_n^2 over the send interval period
12	CT	Structure parameter of temperature index value
13	H Free	Sensible heat flux (free convection method)
14	Internal temperature	Average internal temperature of the receiver in °C.
15	External air temperature	Average external temperature in °C (default or live)
16	Average air pressure	Average air pressure in hPa / mBar (default or live)
17	Average wind speed	Average wind speed in m/s (default or live)
18	Checksum	Checksum of the message string

To enable this send the following RS232 command to the LAS
.SET SENDRECORDS =1; <CR-LF>

To change the log interval send the following command to the LAS
Example set log interval to 1 minute (60 seconds)
.SET LOGINTERVAL = 60; <CR-LF>

Two commands can be combined in one line, for example
.SET SENDRECORDS=1; LOGINTERVAL=60; <CR-LF>

The LAS will respond with an .OK; <CR-LF> after every command-line and will send the data records every 60 seconds:

.DATA=10;77;16455;15/01/19;08:26:00;0.0;0.000E+00;0.000E+00;0.000E+00;0.000E+00;9.999E+02;
0.000E+00;0.000E+00;23.0;17.0;1012;2.2;^] <CRLF>
.DATA=10;77;16456;15/01/19;08:27:00;0.0;0.000E+00;0.000E+00;0.000E+00;0.000E+00;9.999E+02;
0.000E+00;0.000E+00;23.0;17.0;1012;2.2;^D <CRLF>
And so on.

Note the ^] and ^D is a check number at the end of each record.

To disable this option, send the following command to the LAS
.SET SENDRECORDS =0; <CR-LF>

This special feature was made so the logger does not have to request or to receive data every second.
If the LAS does not have a GPS for time synchronization, the date and time can be ignored and the date/time of the data-logger used instead.

4 Definition of the logged status flags

These status flags are stored in the instrument data log file. The flags represent the condition of the instrument at the time that the record was written to the log-file (see 'Log Interval' in the Data Logger menu).

The flags appear in the records stored in the flash data memory of the receiver and in the 'input' records stored by EVATION on the hard disk of a computer.

Logged Status Flags		
Binary No.	Name	Description
Bit 1	Void Signal Condition	1= Invalid signal, out of range or not calibrated
Bit 2	Saturation limit	1= Saturation limit detected
Bit 3	Low Carrier	1= Carrier wave signal low warning, < 40 mV
Bit 4	Carrier Fault	1= Carrier wave signal too low, < 20 mV
Bit 5	Heater On	1= Window heater on, if heater is selected in setup
Bit 6	Log Interrupted	1= Set when an incomplete measurement was stored
Bit 7	Configuration Changed	x= The configuration has been changed (toggles 0,1)
Bit 8	Configuration Error	1= Invalid configuration or EEPROM error
Bit 9	Hardware Error	1= Hardware error, the error code will be logged
Bit 10	Record Deleted	1= The record has been, or is selected to be, deleted
Bit 11	Sensor Offline	1= A meteo-sensor not functioning or not connected
Bit 12	Service Mode	1= Service mode is enabled
Bit 13	Not Used	0
Bit 14	Not Used	0
Bit 15	Not Used	0
Bit 16	Filter unstable	1= Digital filter unstable or the beam was interrupted

Appendix F. 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.

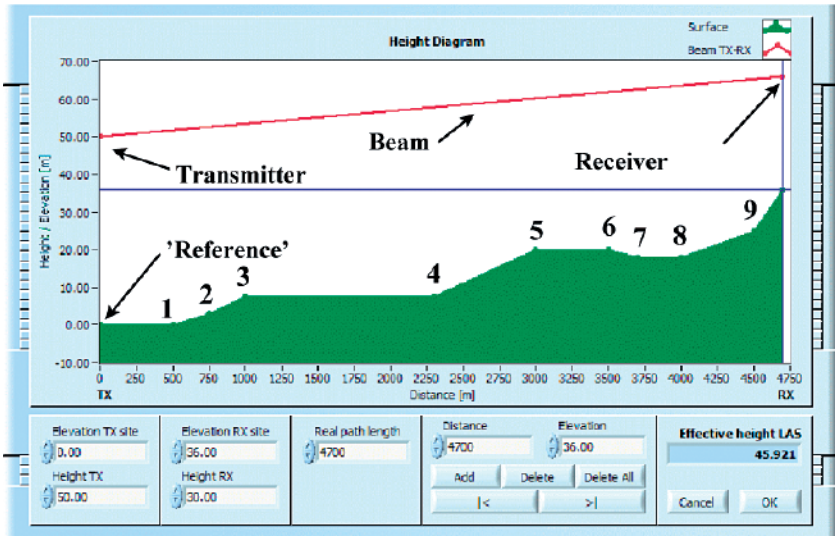
The calculator needs the following input data:
- The elevationof the transmitter site
- The installation height of the transmitter above the ground
- The elevationof the receiver site
- The installation height of the receiver above the ground
- The elevationand position of a number of points along the 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	Elevationwith respect to reference site ground [± 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.



Appendix G. Logging with external data logger using LAS MkII serial output

Logging the digital serial output of the LAS MkII on a data logger

This can be done using the digital communication output on the receiver and the communication cable (a 10m yellow cable with a 8 pin Binder connector on one end and a 9 pin female D-connector on the other, see section 2.1.9 Signal cable with 8-pin plug). This cable is normally used to connect to a PC and communicate with the LAS MkII (download and upload), but it can be used to connect to a data logger, assuming there is serial communication built in or an add on module available. If the serial communication port does not have a 9 pin male D-connector on it, but screw terminals or similar, a spare 10m yellow cable is provided for this (8 pin Binder connector on one end, and bare wires on the other end). See section 2.5.4 Receiver digital interface connector without GPS or 2.5.5 Receiver digital interface connector with GPS, showing the wiring of the receiver digital interface connector.

For RS-232, the LAS should be configured for RS-232 in the menu, and 3 wires should be connected in the 9 pin female D-connector going to the PC or to the screw connections on the data logger serial port:

D-connector pin 3 = RXD, red wire
D-connector pin 2 = TXD, grey wire
D-connector pin 5 = digital ground, black wire

The rest of the wires can be left unconnected, but the wires should be covered so they do not accidentally connect with anything i.e. short out.

For accuracy the digital data from the LAS MkII is recommended, but if a serial connection is not available on your logger, then the analogue output from the LAS can be logged (see APPENDIX H).

Logging data / communication with LAS MkII

The logger does not need to 'poll' the LAS, the LAS can be set to output the message string automatically at any interval from 1 to 29999 seconds (the send interval). As well as the data (carrier wave signal strength and C_n^2) the LAS status, internal temperature, etc., can also be stored on the data logger. The serial data message string received from the LAS contains 19 values.

Status message

The status messages are sent automatically after every N seconds (whereby the interval is set by the command: '.SET SENDINTERVAL= N;'), or after every status request, see command: '.GET STATUS'. There are 2 formats available, a simple or short format and an extended format. The data of a status message is measured over a period of one second. Increasing the send interval does not affect the measurement time. Note the default configuration is status message type 2 (see in APPENDIX E for status message formats). Status messages are not stored in the log file.

EXAMPLE SHORT FORMAT

.STATUS=1;1;1;16;10/01/13;15:32:43;+
.OK

EXAMPLE EXTENDED FORMAT

.STATUS=2;100;1;3;10/04/13;09:19:16;111.8;7.45E-02;4.61E-14;1.90E-16;4.62E-14;4.61E-14;5.87E-02;1.88E+00;
-2.0;-40.0;600;0.0;^^A
.OK;

Status flags:
• The status flags are collected when the data is stored to the log file.

Device Status flags:
• The device status flags are collected when the data is sent to the HOST computer.

The data that that is acquired on a data logger can be imported into EVATION to calculate sensible heat fluxes (H), and also latent heat fluxes depending on additional sensors. The output table of the data logger needs to be configured so that the stored data file is of a suitable format for input into EVATION. See example program below, and also section 5.1.4 and APPENDIX H for details of the file format.

With firmware version 3.00 it is also possible to receive the data records each time when a record is stored in the internal logfile (the LAS internal data logger). (Note this feature is not supported by firmware 2.1 or lower).

The difference between a data record and status record, is that a data record is an average over N seconds (whereby N is programmable by changing the log-interval) and a status record is the average over the last second.

To enable this send the following RS232 command to the LAS

.SET SENDRECORDS =1; <CR-LF>

To change the log interval send the following command to the LAS
Example set log interval to 1 minute (60 seconds)

.SET LOGINTERVAL = 60; <CR-LF>

You can combine the 2 commands in one line, example

.SET SENDRECORDS=1; LOGINTERVAL=60; <CR-LF>

The LAS will respond with an .OK; <CR-LF> after every command-line and will send the data records every 60 seconds:

.DATA=10;77;16455;15/01/19;08:26:00;0.0;0.000E+00;0.000E+00;0.000E+00;0.000E+00;9.999E+02;
0.000E+00;0.000E+00;23.0;17.0;1012;2.2;^] <CRLF>
.DATA=10;77;16456;15/01/19;08:27:00;0.0;0.000E+00;0.000E+00;0.000E+00;0.000E+00;9.999E+02;
0.000E+00;0.000E+00;23.0;17.0;1012;2.2;^D <CRLF>
…and so on.

Note the ^] and ^D is a check number at the end of each record.

The format for the data records is described in detail in APPENDIX E.

To disable this option, send the following command to the LAS

.SET SENDRECORDS =0; <CR-LF>

This special feature was made for data-loggers so the logger does not have to request or to receive data every second. If the LAS does not have a GPS for time synchronization, the date and time can be ignored and the date/time of the data logger used instead.

Example program for logging the LAS MkII serial output and ET kit sensors on a Campbell Scientific CR6 data logger

```
'CR6 Series
'Program Name: LAS2_serial_logging_and_ETkit (tested on CR6)
'Version 1: 21 october 2015,  Author: Keith Wilson

'Program Description:
' The Kipp & Zonen LAS MkII scintillometer data is read by the program via RS232 as
'  a single string and then parsed into its 19 values (including the termination character).
' Data from the LAS is output once a second and all raw data can be stored
'  for future post-processing (this 1 second data rate cannot be changed),
'  or just a 1 and/or 10 minute average is stored.
' The data interval for one of the data tables can be  altered as required
'  (flux measurement stations often use 10 or 30 minute averages).
' LAS MkII Send Interval should be set to 1 on the LAS receiver,
'  so the LAS is pushing data and does not need to be polled.
' The Date and time strings are joined together with a space to match the default
'  format for Evation of: YYY/MM/DD hh:mm:ss
' The default Baud rate of the LAS MkII receiver is 19200, if set different to this
'  the SerialOpen command below will need altering
'
' Data from an  ET kit or weather station is also logged twice per second.
' This data is formated as an input file for the Kipp & Zonen Evation software
' which can be used to process this data into all the flux components.

'Wiring:   (LAS MkII receiver RS-232C digital output via 8 wire serial output yellow cable
'          to CR6 datalogger serial port ComC1)
'   LAS MkII receiver Red wire to CR6 datalogger C1
'   LAS MkII receiver Grey wire to CR6 datalogger C2
'   LAS MkII receiver Black wire to CR6 datalogger G (ground)
'   LAS MkII receiver Cable screen (thick black) to CR6 datalogger G (ground)
'
' For more details see the LAS MkII manual availble on the website www.kippzonen.com
'  and the CR6 manual availble on the website and www.campbellsci.com

'*** Beginning of LAS MkII variables - DIGITAL
Public Term_chr As String
Public STR_LAS_data As String * 240

Public LAS_Parsed(19) As String * 12
Alias LAS_Parsed(1) = Record_Type     'Record Type and Record ID, eg. .STATUS=2
Alias LAS_Parsed(2) = Status_Flags    'Device Status Flag(s)
Alias LAS_Parsed(3) = First_Rec_nr    'First used record number in the log file
Alias LAS_Parsed(4) = Next_Rec_nr     'First available (free) record number in the log file
Alias LAS_Parsed(5) = Date           'Transmit date (of the status message)
Alias LAS_Parsed(6) = Time           'Transmit time (of the status message)
Alias LAS_Parsed(7) = Demod          'Average demodulated carrier wave signal in mV
Alias LAS_Parsed(8) = Sigma_Demod     'Variance of  the demodulated voltage = (VarUdemod)^ ½
```

```
Alias LAS_Parsed(9) = Cn2           'Structure parameter of refractive index value
Alias LAS_Parsed(10) = Cn2_dev      'Standard deviation of Cn² over the send interval period
Alias LAS_Parsed(11) = Cn2_max      'Maximum value of Cn² over the send interval period
Alias LAS_Parsed(12) = Cn2_min      'Minimum value of Cn² over the send interval period
Alias LAS_Parsed(13) = CT           'Structure parameter of temperature index value
Alias LAS_Parsed(14) = Hfree        'Sensible heat flux (free convection method)
Alias LAS_Parsed(15) = IntTemp      'Average internal temperature of the receiver in °C.
Alias LAS_Parsed(16) = AirTemp      'Average external temperature in °C (default or live)
Alias LAS_Parsed(17) = AirPress     'Average air pressure in hPa / mBar (default or live)
Alias LAS_Parsed(18) = Wind_speed   'Average wind speed in m/s (default or live)
Alias LAS_Parsed(19) = MessageChksum  'Checksum of the message string
Public space As String * 1 = " "
Public Date_Time As String * 20     ' Default format for Evation input with ET kit
                                ' YYYY/MM/DD hh:mm:ss
Public PUCn2                    ' Scaled Cn2 , PuCn2 = Cn2*(10^15)

Units Date = YYYY/MM/DD
Units Time = hh mm ss           ' actual format is hh:mm:ss
Units Demod = mV
Units Sigma_Demod = mV
Units Cn2 = m^(-2/3)
Units Cn2_dev = m^(-2/3)
Units Cn2_max = m^(-2/3)
Units Cn2_min = m^(-2/3)
Units CT = K^2 m^(-2/3)
Units Hfree = W/m2
Units IntTemp = Deg C
Units AirTemp = Deg C
Units AirPress = mBar
Units Wind_speed = m/s
Units Date_Time = YYYY/MM/DD hhmmss
Units PUCn2 = m^(-2/3)

'***  ET kit / weather station: Declaration of variables and units for analogue sensors
Public BattV    ' Default Datalogger Battery Voltage measurement
Public PTemp_C  ' Default Wiring Panel Temperature measurement
Public TempH    ' Upper air temperature sensor (at least 2.4 m high or at LAS beam height)
Public TempL    ' Lower air temperature sensor (mounted at 0.5 m above the ground)
Public RH = 50  ' Define constant for relative humidity of 50%, if no humidity sensor is connected.
Public Pres     ' Air pressure
Public Speed    ' Wind speed
Public WD       ' Wind direction
Public HF1      ' First soil heat flux plate, buried just below the surface (less than 50mm below surface)
Public HF2      ' Second soil heat flux plate, buried less than 50mm below surface
Public NR       ' Net radiation sensor (NR Lite2)
```

```
Units BattV=Volts
Units PTemp_C=deg C
Units TempH=deg C
Units TempL=deg C
Units RH=%
Units Pres=mBar
Units Speed=m/s
Units WD=deg
Units HF1=W/m2
Units HF2=W/m2
Units NR=W/m2

'*** Output data tables ***
'DIGITAL Output Table for diagnostic checking (can be removed)
DataTable (LAS2_digital_1sec,True ,-1)
  DataInterval (0,1,Sec,10)
  '  CardOut (0 ,-1)
  '  Sample (1,STR_LAS_data,String)
  Sample (1,Record_Type,String)
  Sample (1,Status_Flags,IEEE4)
  Sample (1,First_Rec_nr,IEEE4)
  Sample (1,Next_Rec_nr,IEEE4)
  Sample (1,Date,String)
  Sample (1,Time,String)
  Sample (1,Demod,IEEE4)
  Sample (1,Sigma_Demod,IEEE4)
  Sample (1,Cn2,IEEE4)
  Sample (1,Cn2_dev,IEEE4)
  Sample (1,Cn2_max,IEEE4)
  Sample (1,Cn2_min,IEEE4)
  Sample (1,CT,IEEE4)
  Sample (1,Hfree,IEEE4)
  Sample (1,IntTemp,IEEE4)
  Sample (1,AirTemp,IEEE4)
  Sample (1,AirPress,IEEE4)
  Sample (1,Wind_speed,IEEE4)
'  Sample (1,MessageChksum,String)
'  Sample (1,Date_Time,String)
EndTable

' 1 minute Output Table
DataTable(LAS2_1min,True,-1)
  DataInterval(0,1,Min,0)
  CardOut(0,-1)
  Sample (1,Date_Time,String)
  Average(1,TempH,FP2,False)
                FieldNames("T1 upper air temp")
```

```
                Average(1,TempL,FP2,False)
                FieldNames("T2 lower air temp")
                Sample(1,RH,FP2)
                FieldNames("RH Relative humidity constant=50%")
                Average(1,Pres,FP2,False)
                FieldNames("Air pressure")
                Average(1,Speed,FP2,False)
                FieldNames("U Wind speed")
                Average(1,WD,FP2,False)
                FieldNames("WD wind direction")
                Average(1,HF1,FP2,False)
                FieldNames("G1 soil heat flux")
                Average(1,HF2,FP2,False)
                FieldNames("G2 soil heat flux")
                Average(1,NR,FP2,False)
                FieldNames("Rn net radiation NR2Lite")
  Average (1,PUCn2,IEEE4,False)
  'StdDev of LAS Cn2
  StdDev(1,PUCn2,IEEE4,False)
  FieldNames("Std_PUCn2_LAS")
  Average(1,Demod,IEEE4,False)
  'StdDev of LAS Demod
  StdDev(1,Demod,IEEE4,False)
  FieldNames("Std_Demod_LAS")
EndTable

' 10 minute Output Table
DataTable(LAS2_10min,True,-1)
  DataInterval(0,10,Min,0)
  CardOut(0,-1)
  Sample (1,Date_Time,String)
  Average(1,TempH,FP2,False)
                FieldNames("T1 upper air temp")
                Average(1,TempL,FP2,False)
                FieldNames("T2 lower air temp")
                Sample(1,RH,FP2)
                FieldNames("RH Relative humidity constant=50%")
                Average(1,Pres,FP2,False)
                FieldNames("Air pressure")
                Average(1,Speed,FP2,False)
                FieldNames("U Wind speed")
                Average(1,WD,FP2,False)
                FieldNames("WD wind direction")
                Average(1,HF1,FP2,False)
                FieldNames("G1 soil heat flux")
                Average(1,HF2,FP2,False)
                FieldNames("G2 soil heat flux")
```

```
            Average(1,NR,FP2,False)
            FieldNames("Rn net radiation NR2Lite")
  Average (1,PUCn2,IEEE4,False)
  'StdDev of LAS Cn2
  StdDev(1,PUCn2,IEEE4,False)
  FieldNames("Std_PUCn2_LAS")
  Average(1,Demod,IEEE4,False)
  'StdDev of LAS Demod
  StdDev(1,Demod,IEEE4,False)
  FieldNames("Std_Demod_LAS")
EndTable
' *************** end OUTPUT *******************


' *************** start PROGRAM *****************
'Main Program
BeginProg
  SerialOpen (COMC1,19200,0,0,240)  'SerialOpen ( ComPort, BaudRate, Format, TXDelay, BufferSize )
  Term_chr = CHR(13)  'LAS MkII TerminationCharacter = Carriage return (CR) = 13

  'Main Scan
  Scan(500,mSec,0,0)
    'Default Datalogger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Default Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,50)
    '  VoltSE( Dest, Reps, Range, SEChan, MeasOff, SettlingTime, fN1, Mult, Offset )
    'Generic 5 Volt Single-Ended Voltage measurement 'TempH' CR6 channel U1
    VoltSe(TempH,1,mV5000,U1,1,0,50,0.0625,-65)
    'Generic 5 Volt Single-Ended Voltage measurement 'TempL' CR6 channel U2
    VoltSe(TempL,1,mV5000,U2,1,0,50,0.0625,-65)
    'Generic 200 mVolt Single-Ended Voltage measurement 'HF1' CR6 channel U3
    VoltSe(HF1,1,mV200,U3,1,0,50,16.05941,0)
    'Generic 200 mVolt Single-Ended Voltage measurement 'HF2' CR6 channel U4
    VoltSe(HF2,1,mV200,U4,1,0,50,16.29461,0)
    'Generic 5 Volt Single-Ended Voltage measurement 'WD' CR6 channel U5,
            ' multiplier =360deg/5000mV
    VoltSe(WD,1,mV5000,U5,1,0,50,0.072,0)
    'Generic 5 Volt Single-Ended Voltage measurement 'Pres' CR6 channel U6
    VoltSe(Pres,1,mV5000,U6,1,0,50,0.18122,175.94)
    'Generic 200 mVolt Differential Voltage measurement 'NR' CR6 channel U7 and 8
    VoltDiff(NR,1,mV200,U7,True,0,50,71.94245,0)
    'Definition; PulseCount( Dest, Reps, PChan, PConfig, POption, Mult, Offset )
    'Generic Pulse Low Level AC measurement 'Speed' CR6 channel U7, [0to70m/s=0to700Hz]
    PulseCount(Speed,1,U10,5,1,0.1,0)
```

```
  'Beginning of LAS MkII DIGITAL measurements
  ' (LAS MkII Send Interval should be set to 1 in LAS receiver so LAS
  '   is pushing data and does not need to be polled)
  If IfTime (0,1,Sec) Then  ' log serial output of LAS MkII (at LAS MkII Send Interval of 1 second),
                    '  and split up data string
    SerialFlush (COMC1)  'The buffer is cleared
    SerialIn (STR_LAS_data,COMC1,100,Term_chr,240)
    'from help: SerialIn ( Dest, ComPort, TimeOut, TerminationChar, MaxNumChars )
    SplitStr (LAS_Parsed(),STR_LAS_data,";",19,5)
    'from help: SplitStr ( SplitResult, SearchString, FilterString, NumSplit, SplitOption )
       Date_Time =  Date & space & Time
                                ' PROCESS DATA  (conversion to PUCn2 for storage in a default format for Evation)
                               PUCn2=Cn2*(10^15)

    'Call Data Tables and Store Data
    CallTable LAS2_digital_1sec   ' Raw 1 second data from LAS digital serial output
  EndIf
  'End of LAS MkII measurements

  IfTime(0,1,Min)
  CallTable LAS2_1min' save 1 min averages
  IfTime(0,10,Min)
  CallTable LAS2_10min' save 10 min averages

 NextScan
EndProg
```

Appendix H. Logging with external data logger using LAS analogue output

This section describes how to collect signals from the LAS analogue output connector and log this in the appropriate format.

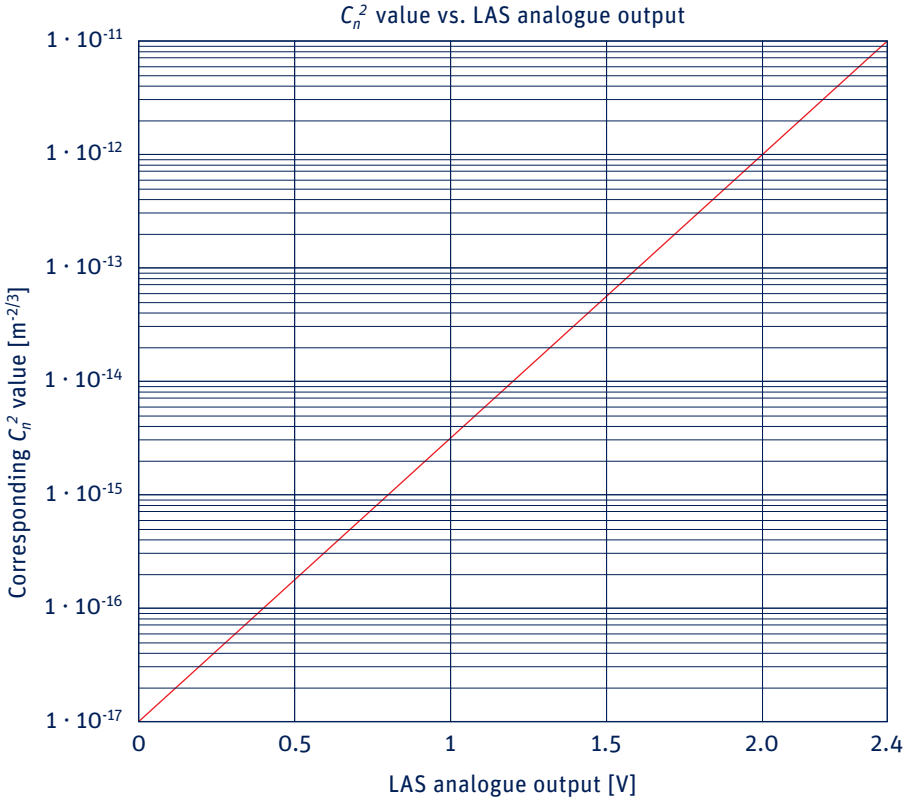
In some situations, or for convenience, the user may not be able to make use of the digital communication output of the LAS MkII instrument or data from the internal memory, so the analogue output can be used in combination with an external logger. For wiring details of the LAS analogue output connector, see section 2.5.3 Receiver analogue signal connector. Usually both the demodulated output (Udemod) and the C_n^2 voltage output (referred to as $U_{C_n^2}$ below), from this connector are logged.

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 $U_{C_n^2}$ = 0.4 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. If the logger is logging at 1 second intervals this is not an issue, but usually longer averaging periods are required. Therefore we recommend one of the following two options:

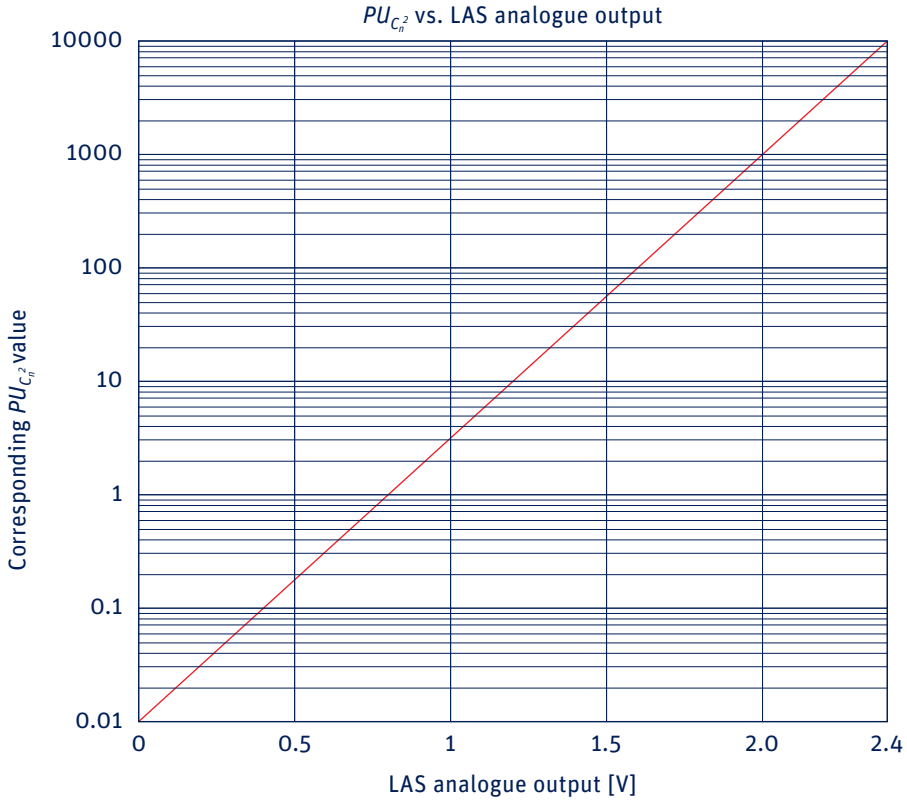
1. Measure the interval averages of $U_{C_n^2}$ and the variance of $U_{C_n^2}$ ($\sigma^2_{U_{C_n^2}}$), and apply the following equation for deriving the correct interval-averaged C_n^2:

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

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 $U_{C_n^2}$	[V^2]

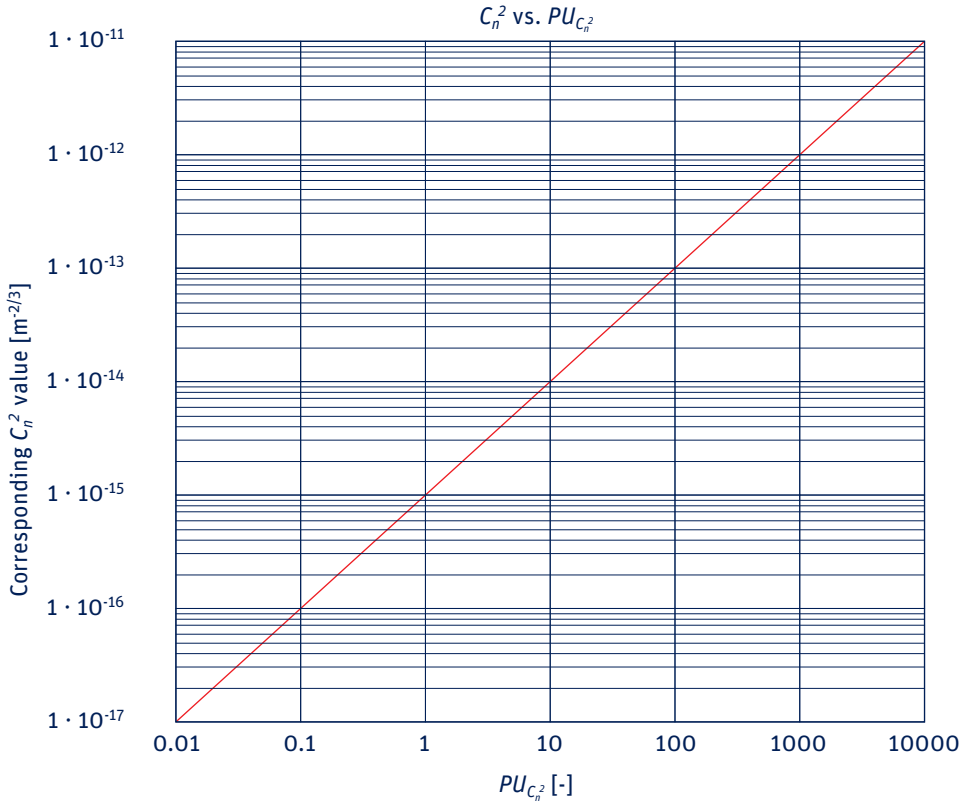
2. Calculate C_n^2 immediately after each measurement cycle (e.g. every 1 second, 1 Hz) and derive the interval-averaged C_n^2 (e.g. 10 minute averages) from the instantaneous C_n^2 values. Because the C_n^2 values are too small to store in most conventional data acquisition systems (~ $1 \cdot 10^{-16}$)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

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



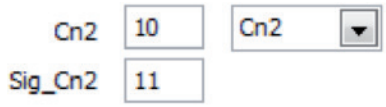
Afterwards the true C_n^2 values can be derived from $PU_{C_n^2}$ as follows:

$$C_n^2 = PU_{C_n^2} \cdot 10^{-15}$$

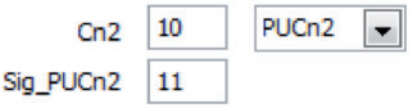


If EVATION is used to import custom data or data from a user's data logger, three options can be chosen in the Process data setup, input tab, for the C_n^2 input:

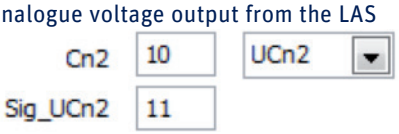
1. Structure parameter of the refractive index of air, C_n^2 (units m$^{-2/3}$)



2. Scaled C_n^2(units m$^{-2/3}$), $PU_{C_n^2} = C_n^2$ x 10^{15} = 0.01*10$^{(Vout*2.5)}$



3. $U_{C_n^2}$ (units V), as C_n^2 in the form of an analogue voltage output from the LAS



As of EVATION V2R4, $U_{C_n^2}$ applies to the LAS MkII format, where 0 < ([$U_{C_n^2}$ LAS MkII] < 2.4 V
LAS MkII C_n^2 ($m^{-2/3}$) = 10^(-17 + ([$U_{C_n^2}$ LAS MkII]*2.5) +1.15* power(Sig_$U_{C_n^2}$;2))

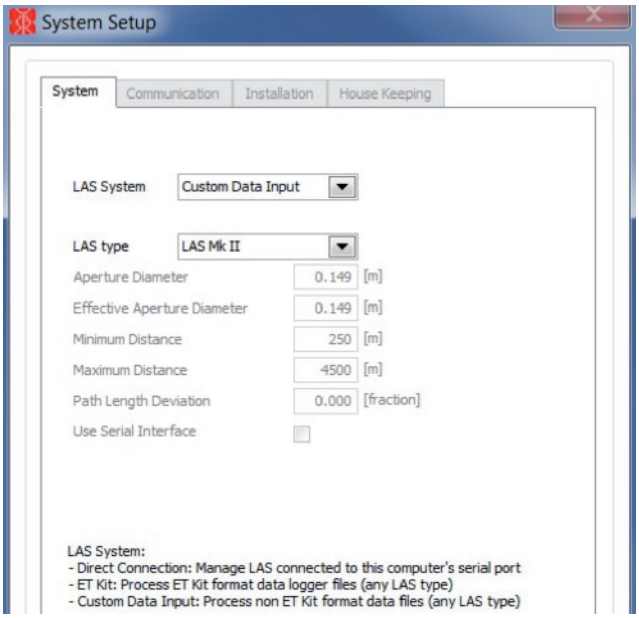
Note For EVATION V2R1 to V2R3, UCn2applied to the LAS MkI format, where -5 V < [$U_{C_n^2}$ LAS MkI] < 0V
LAS MkI C_n^2 ($m^{-2/3}$) = 10^(-12 + [$U_{C_n^2}$ LAS MkI] +1.15* power(Sig_$U_{C_n^2}$;2))

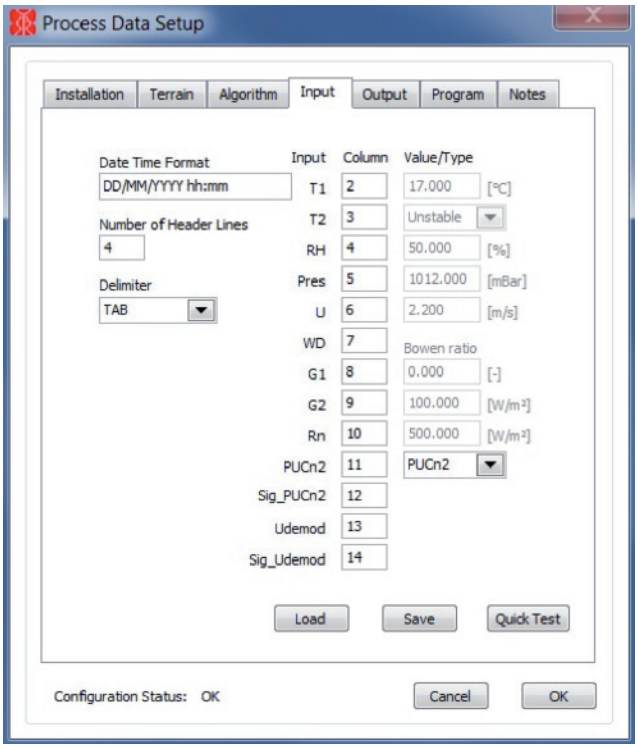
The three options for the C_n^2 input (and its associated standard deviation) detailing the formatting for each option:

Column no.	Description of variable	Variable name	Unit	Format (EVATION input)	Range	Notes
12	Structure parameter of the refractive index of air, C_n^2	Cn2	$m^{-2/3}$	exp	10^{-17} to 10^{-11}	
13	Standard deviation of C_n^2	Sig_Cn2	$m^{-2/3}$	exp		
12	Scaled C_n^2	PUCn2	$m^{-2/3}$	float	0.01 to 10000	Corresponding to 10^{-17} to 10^{-11}
13	Standard deviation of scaled C_n^2	Sig_PUCn2	$m^{-2/3}$	float		
12	$U_{C_n^2}$	UCn2	V	float	0 to 2.4 V (LAS MkII analogue output)	Corresponding to 10^{-17} to 10^{-11}
13	Standard deviation of $U_{C_n^2}$	Sig_UCn2	V	float		

The data logger is probably also logging data from other meteorological sensors as well as the LAS analogue output. See section 5.1.7 ‘Setting input parameters’ for details of formatting the other sensor data correctly.

In EVATION select the ‘Custom data Input’ from the ‘LAS System’ setup (in the System Setup under the Configuration menu) for this custom file format. See the following screenshots showing this choice and the input format to EVATION using an external data logger.





To reproduce the format shown, after the (4) header lines at the start of the file, column 0 would be the data logger date/time stamp, column 1 the record number and then all the ET kit met sensors (columns 2 to 10) followed by the 4 LAS data columns, as shown in the table below.

The data files of a Campbell Scientific data logger should be formatted as follows (columns separated by tabs or ASCII format, tab delimited):

Column no. logger (EVATION input label)	Description of variable	Variable name	Unit	Format (Campbell data logger output)	Format (EVATION input)	Range	Notes
1 (0)	Date and Time (= Begin-Time of interval)	Name/code		DD/MM/YYYY hh:mm:ss	DD/MM/YYYY hh:mm:ss		One string with space between date and time
2 (1)	Record number (logger)			n/n			
3 (2)	Air temperature upper sensor	T1	°C	n,nnn.nnn	float	-30.0 to +55.0	
4 (3)	Air temperature lower sensor	T2	°C	n,nnn.nnn	float	-30.0 to +55.0	
5 (4)	Relative humidity, default value is 50%	RH	%	nnn,nnn.n	float	0.0 to +100.0	Set to default of 50%
6 (5)	Air pressure	P	hPa/mBar	nnn,nnn.n	float	600 to 1050	
7 (6)	Wind speed	U	m/s	nnn.nn	float	0.01 to 50.0	
8 (7)	Wind direction	WD	°	nnn,nnn.n	float	0.0 to 360.0	
9 (8)	Soil heat flux (plate 1)	G1 or HFP1	W/m²	nn,nnn.nn	float	-250.0 to 250.0	
10 (9)	Soil heat flux (plate 2)	G2 or HFP2	W/m²	nn,nnn.nn	float	-250.0 to 250.0	
11 (10)	Net radiation	Q* or Rn	W/m²	nn,nnn.nn	float	-500.0 to 1500.0	
12 (11)	Scaled C_n^2 ($PU_{C_n^2} = C_n^2 \times 10^{15}$)	$PU_{C_n^2}$	$m^{-2/3}$	nn,nnn.nn	float	0.01 to 10000 (0.001 to 1000 in EVATION V2R3 and earlier)	
13 (12)	Standard deviation of scaled C_n^2	Std$PU_{C_n^2}$	$m^{-2/3}$	n,nnn.nnn	float	No range	
14 (13)	Demodulated signal strength	*Udemod*	mV	nn,nnn.nn	float	0 to 2000	
15 (14)	Standard deviation of *Udemod*	StdUdemod	mV	n,nnn.nnn	float	No range	

All the non LAS sensors need to be logged in the data logger and added to the data tables as an average over the sample period (as shown in the above table), just before the 4 outputs for the LAS. If there is no humidity sensor then column 5 would just be a dummy / a constant with value of 50%.

Example program for a CR3000 series Campbell Scientific data logger

```
'CR3000 Series Datalogger, logging Kipp&Zonen LAS MkII analogue output

'  WIRING
'  LAS1_Vout (Cn2) on Channel 1:
'        red = 1H    yellow = 1L
'  LAS1_dem or Udemod on Channel 2:
'        green = 2H    yellow = 2L

'Declare Variables and Units
Public BattV, PTemp_C
Public LAS1_Vout, LAS1_Cn2E15, Udemod

Units LAS1_Vout = V                 '0 to 2.4V = Format for input into EVATION as UCn2
Units LAS1_Cn2E15 = m^(-2/3)        '0.01 to 10000 (x10^-15), equivalent to 10^-17 to 10^-11 = Format for input into EVATION
                                    'as PUCn2 = 0.01*10^(2.5*UCN2)
Units Udemod=mV                     '0.0mV to 2000 mV


'Define Data Table for 1 minute averages

DataTable(AVG01MIN,True,-1)
        DataInterval(0,1,Min,10)
                CardOut(0,-1)  'Ring Mode table (0) (overwrites memory when full) and Size = auto-allocate card memory equally
                'between tables
                'CardOut(0,45000)  ' #records = ~8 records/line x 1440lines/day x 30days
                Average(1,LAS1_Cn2E15,FP2,False)
                StdDev(1,LAS1_Cn2E15,FP2,False)
                FieldNames("SDL1Cn2:StdDev")
                Average(1,Udemod,FP2,False)
                StdDev(1,Udemod,FP2,False)
                FieldNames("SDL1Udemod:StdDev")
EndTable
'Define Data Table for 10 minute averages
DataTable(AVG10MIN,True,-1)
        DataInterval(0,10,Min,10)
                        CardOut(0,-1)
                'CardOut(0,4500)  ' #records = ~8 records/line x 144lines/day x 30days
        Average(1,LAS1_Cn2E15,FP2,False)
        StdDev(1,LAS1_Cn2E15,FP2,False)
        FieldNames("SDL1Cn2:StdDev")
        Average(1,Udemod,FP2,False)
        StdDev(1,Udemod,FP2,False)
        FieldNames("SDL1Udemod:StdDev")
EndTable
```

```
'Define Data Table for 30 minute averages
DataTable(AVG30MIN,True,-1)
	DataInterval(0,30,Min,10)
			CardOut(0,-1)
		'CardOut(0,1500)  ' #records = ~8 records/line x 48lines/day x 30days
	Average(1,LAS1_Cn2E15,FP2,False)
	StdDev(1,LAS1_Cn2E15,FP2,False)
	FieldNames("SDL1Cn2:StdDev")
	Average(1,Udemod,FP2,False)
	StdDev(1,Udemod,FP2,False)
	FieldNames("SDL1Udemod:StdDev")
EndTable

'Main Program
BeginProg
	'Main Scan
	Scan(200,msec,1000,0)	'minimum scan interval is 10 milliseconds
		'Default Datalogger Battery Voltage measurement 'BattV'
		Battery(BattV)
		'Default Wiring Panel Temperature measurement 'PTemp_C'
		PanelTemp(PTemp_C,_50Hz)

'LAS measurements
		VoltDiff(LAS1_Vout,1,mV5000,1,True,0,_50Hz,0.001,0)
		'0,_50Hz = 3 ms settling time and Performs a 20 millisecond integration/ filters 50 Hz noise.
		'Multiplier of 0.001 converts from mV to V for correct format as input into EVATION, and correct conversion to
		'PUCn2 below
		VoltDiff(Udemod,1,mV5000,2,True,0,_50Hz,1,0)

		 ' PROCESS DATA  (conversion to PUCn2)
	LAS1_Cn2E15 = 0.01*10^(LAS1_Vout*2.5)

' OUTPUT DATA
IfTime(0,1,Min)
	CallTable AVG01MIN' save 01-min avg-es
IfTime(0,10,Min)
	CallTable AVG10MIN' save 10-min avg-es
IfTime(0,30,Min)
	CallTable AVG30MIN' save 30-min avg-es

	NextScan
EndProg
```

Notes on the previous CR3000 program

Check that the channel number is correct in the Voltdiff commands.

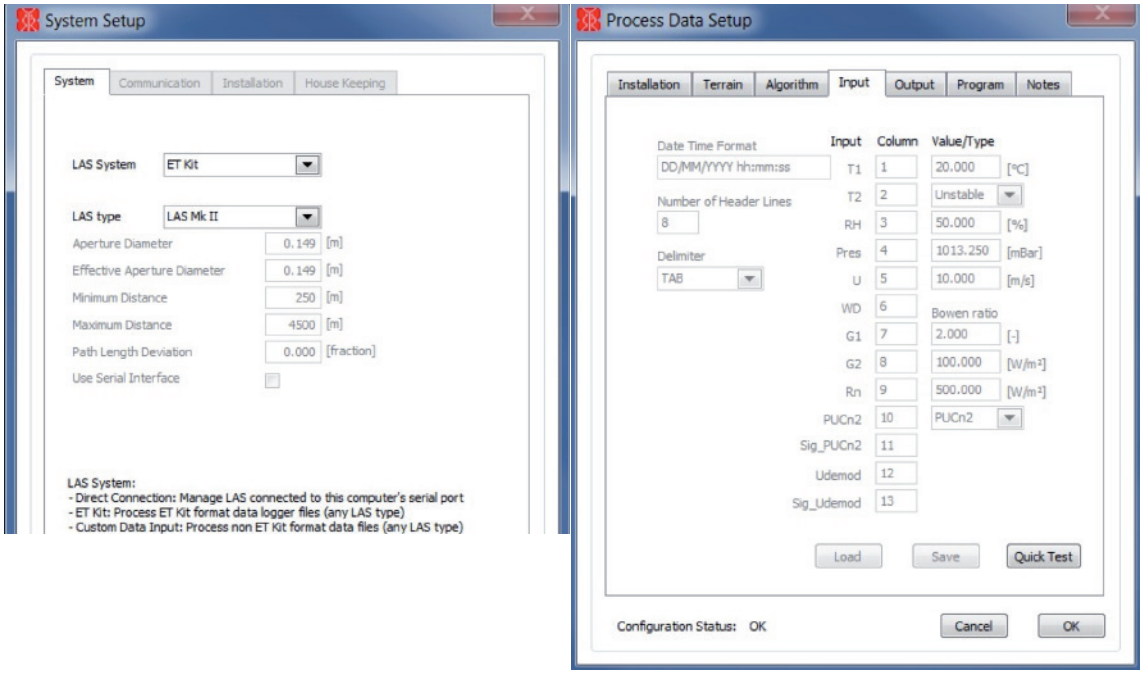
Voltdiff LAS1_Vout has a multiplier of 0.001 to convert it from mV to Volts. Following this is a calculation to convert from UCn2 to PUCn2, which is the format EVATION accepts when selecting ET kit as the system setup.

LAS1_Vout can be added to the data table in addition to LAS1_Cn2E15, if wanted.

There are data tables for 1, 10 and 30 minutes which can be useful for the user, so averaging does not have to be done again to compare against other instruments. These can be commented out as required. The scan interval is short, if this is too large then the logger is only intermittently sampling a continuously varying signal, so a larger error.

COMBILOG data format for input to EVATION:

If the data files have been generated by the Kipp & Zonen LAS MkII ET System and its COMBILOG data logger, select the 'ET Kit' from the 'LAS System' choice, (in the System Setup under the Configuration menu) 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, and all the options will be greyed out as the format is fixed with the ET Kit option.

The data files of a COMBILOG data logger are formatted as follows (columns separated by tabs or ASCII format, tab delimited) to correctly match this Evation input option:

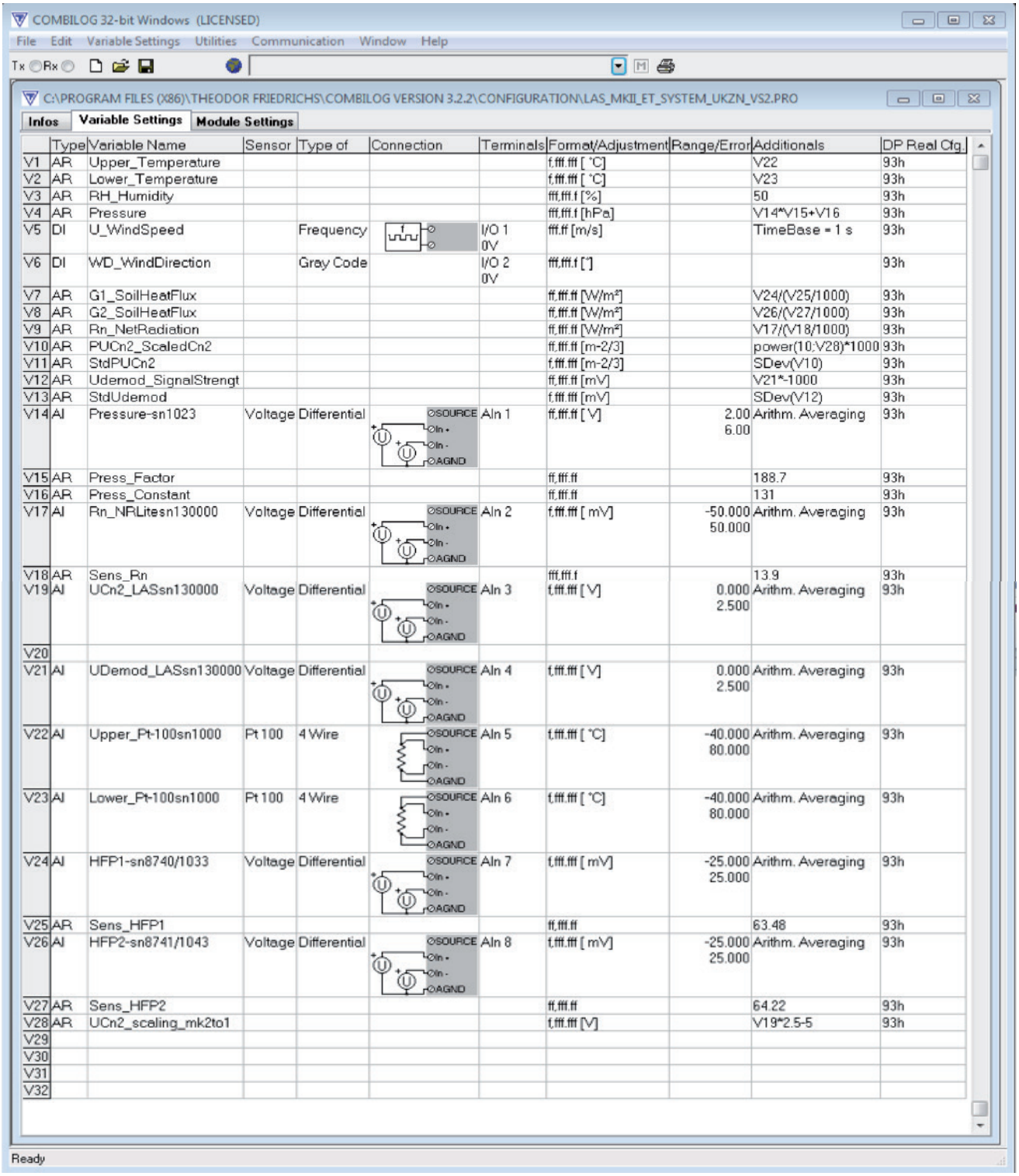
Column no. logger (EVATION input label)	Description of variable	Variable name	Unit	Format (COMBILOG data logger output)	Format (EVATION input)	Range	Notes
1 (-1)	Name/code (from COMBILOG)	Name/code		n/n			
2 (0)	Date and Time (= Begin-Time of interval)			DD/MM/YYYY hh:mm:ss	DD/MM/YYYY hh:mm:ss		One string with space between date and time
3 (1)	Air temperature upper sensor	T1	°C	n,nnn.nnn	float	-30.0 to +55.0	
4 (2)	Air temperature lower sensor	T2	°C	n,nnn.nnn	float	-30.0 to +55.0	
5 (3)	Relative humidity, default value is 50%	RH	%	nnn,nnn.n	float	0.0 to +100.0	Set to default of 50%
6 (4)	Air pressure	P	hPa/mBar	nnn,nnn.n	float	600 to 1050	
7 (5)	Wind speed	U	m/s	nnn.nn	float	0.01 to 50.0	
8 (6)	Wind direction	WD	°	nnn,nnn.n	float	0.0 to 360.0	
9 (7)	Soil heat flux (plate 1)	G1 or HFP1	W/m²	nn,nnn.nn	float	-250.0 to 250.0	
10 (8)	Soil heat flux (plate 2)	G2 or HFP2	W/m²	nn,nnn.nn	float	-250.0 to 250.0	
11 (9)	Net radiation	Q* or Rn	W/m²	nn,nnn.nn	float	-500.0 to 1500.0	
12 (10)	Scaled C_n^2 ($PU_{C_n^2} = C_n^2 \times 10^{15}$)	$PU_{C_n^2}$	$m^{-2/3}$	nn,nnn.nn	float	0.01 to 10000 (0.001 to 1000 in EVATION V2R3 and earlier)	
13 (11)	Standard deviation of scaled C_n^2	Std$PU_{C_n^2}$	$m^{-2/3}$	n,nnn.nnn	float	No range	
14 (12)	Demodulated signal strength	*Udemod*	mV	nn,nnn.nn	float	0 to 2000	
15 (13)	Standard deviation of *Udemod*	StdUdemod	mV	n,nnn.nnn	float	No range	

The number of columns (in this case 15) is constant and independent of the sensor configuration of the LAS MkII ET System. If fewer sensors are used dummy values (-9999) are inserted in the 'empty' columns for the specific missing sensor, and then these data columns will be ignored and default values used instead if required for the calculations.

Note that the TimeDate column holds date and time separated by a space and separators may be '.' or '/' or ':' for date or time.

Note The columns must not be reordered.

Configuration setup screen for Combilog 1022, to use with LAS MkII and ET kit from Theodore Friedrichs:



	Type	Variable Name	Sensor	Type of	Connection	Terminals	Format/Adjustment	Range/Error	Additionals	DP Real Cfg.
V1	AR	Upper_Temperature					f,fff.fff [°C]		V22	93h
V2	AR	Lower_Temperature					f,fff.fff [°C]		V23	93h
V3	AR	RH_Humidity					fff,fff.f [%]		50	93h
V4	AR	Pressure					fff,fff.f [hPa]		V14*V15+V16	93h
V5	DI	U_WindSpeed		Frequency		I/O 1 0V	fff.ff [m/s]		TimeBase = 1 s	93h
V6	DI	WD_WindDirection		Gray Code		I/O 2 0V	fff.fff.f [°]			93h
V7	AR	G1_SoilHeatFlux					ff.fff.ff [W/m²]		V24/(V25/1000)	93h
V8	AR	G2_SoilHeatFlux					ff.fff.ff [W/m²]		V26/(V27/1000)	93h
V9	AR	Rn_NetRadiation					ff.fff.ff [W/m²]		V17/(V18/1000)	93h
V10	AR	PUCn2_ScaledCn2					ff.fff.ff [m-2/3]		power(10;V28)*1000	93h
V11	AR	StdPUCn2					f.fff.fff [m-2/3]		SDev(V10)	93h
V12	AR	Udemod_SignalStrengt					ff.fff.ff [mV]		V21*-1000	93h
V13	AR	StdUdemod					f.fff.fff [mV]		SDev(V12)	93h
V14	AI	Pressure-sn1023	Voltage	Differential	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 1	ff.fff.ff [V]	2.00 6.00	Arithm. Averaging	93h
V15	AR	Press_Factor					ff.fff.ff		188.7	93h
V16	AR	Press_Constant					ff.fff.ff		131	93h
V17	AI	Rn_NRLitesn130000	Voltage	Differential	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 2	f.fff.fff [mV]	-50.000 50.000	Arithm. Averaging	93h
V18	AR	Sens_Rn					fff.fff.f		13.9	93h
V19	AI	UCn2_LASsn130000	Voltage	Differential	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 3	f.fff.fff [V]	0.000 2.500	Arithm. Averaging	93h
V20										
V21	AI	UDemod_LASsn130000	Voltage	Differential	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 4	f.fff.fff [V]	0.000 2.500	Arithm. Averaging	93h
V22	AI	Upper_Pt-100sn1000	Pt 100	4 Wire	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 5	f.fff.fff [°C]	-40.000 80.000	Arithm. Averaging	93h
V23	AI	Lower_Pt-100sn1000	Pt 100	4 Wire	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 6	f.fff.fff [°C]	-40.000 80.000	Arithm. Averaging	93h
V24	AI	HFP1-sn8740/1033	Voltage	Differential	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 7	f.fff.fff [mV]	-25.000 25.000	Arithm. Averaging	93h
V25	AR	Sens_HFP1					ff.fff.ff		63.48	93h
V26	AI	HFP2-sn8741/1043	Voltage	Differential	⊘SOURCE ⊘In + ⊘In - ⊘AGND	AIn 8	f.fff.fff [mV]	-25.000 25.000	Arithm. Averaging	93h
V27	AR	Sens_HFP2					ff.fff.ff		64.22	93h
V28	AR	UCn2_scaling_mk2to1					f.fff.fff [V]		V19*2.5-5	93h
V29										
V30										
V31										
V32										

Note Line 28 above: Convertion to LAS MkI equivalent output = ([LAS MkII V_{out}]*5/2)-5 where 0 < ([LAS MkII V_{out}] < 2.4V
C_n^2 (Units of $m^{-2/3}$) = 10^(([LAS MkI V_{out} in mV]/1000)-12) = 10^(-12 + [LAS MkI V_{out}])
where for LAS MkI: -5 V < [LAS MkI V_{out}] < 0V ($V_{out} = U_{C_n^2}$)

Example of Combilog output data file format:

CombiLog Input File layout specification

The file below (blue) is marked with bold, italic and underlining. This means:

- *Header lines*
- Measurement lines.
- **Variable input data.**
- **Constant input data.**

```
Ident       Friedrichs U3.52 M5.00
Location    KPNAGEL
Serial No   091135
Sample Rate 1s
Store Rate  600s
Name/Code   TimeDate            T1_1   T2_2   RH_1  Pres_1 U_1    WD_1  G1_2  G2_1  Rn_1  PUCn2_1  SigPUCn2_1 Udemod_1 SigUdemod_1
.....
.....
.....
0/1         11/06/2003 04:40:00 18.93  18.83  88.5  1006.3 4.49   247   -1.1  -1.1  16.6  2.91     0.55       -38.62   5.52
0/1         11/06/2003 04:50:00 19.04  18.91  87.2  1006.4 4.47   251   -0.7  -0.7  23.2  2.7      1.01       -41.38   5.52
0/1         11/06/2003 05:00:00 19.05  18.97  87    1006.6 4.46   254   -0.2  -0.2  27.2  1.16     0.57       -41.38   5.52
0/1         .....
```

Note that:

- Fields are separated by <TAB>.
- Note that the TimeDate column holds date and time separated by a space and separators may be '.', '/' or ':' for date or time.
- Lines and fields that are not bold and/or underlined are don't care, but may not be removed.
- The software uses the constant input data fields for looking up specific variable data.
- Columns ***T1_1*** through ***SigUdemod_1*** hold measurement data of a specific sensor. The columns may not be interchanged.
- The line starting with ***Name*** has variable input data fields ***T1_1*** through ***SigUdemod_1***. These fields hold variable input data to allow registration of instrument serial numbers. The software detects changes in these fields and generates a log file with these fields. Serial numbers are handled as strings and therefore may consist of both numbers and characters.

Example of Combilog output data file:

Ident	Friedric V2.41 V4.01														
Location	Delft														
Serial No	100113														
Sample Rate	1s														
Store Rate	600s														
Name	TimeDate	Upper Temperature	Lower Temperature	RH Humidity	Pressure	U WindSpeed	WD WindDirection	G1 SoilHeatFlux	G2 SoilHeatFlux	Rn NetRadiation	PUCn2 ScaledCn2	StdPUCn2	Udemod SignalStrengt	StdUdemod	
Kind		AR	AR	AR	AR	DI	DI	AR	AR	AR	AR	AR	AR	AR	
Unit		°C	°C	%	hPa	m/s	°	W/m²	W/m²	W/m²	m-2/3	m-2/3	mV	mV	
1	17/03/2015 18:00	20.278	20.285	50	1010.9	2.2	110	-19.29	-19.29	312.79	3.29	0.006	660	1	
1	17/03/2015 18:10	23.164	23.176	50	1010.8	2.2	115	-19.29	-19.29	309.6	3.29	0.007	662	1	
1	17/03/2015 18:20	23.166	23.155	50	1010.8	2.2	110	-19.29	-19.29	306.41	3.29	0.009	664	1	
1	17/03/2015 18:30	23.139	23.091	50	1010.9	2.2	120	-19.29	-19.29	303.22	3.29	0.008	666	4	
1	17/03/2015 18:40	23.061	23.005	50	1010.9	2.2	132	-19.29	-19.29	300.03	3.29	0.011	658	4	

Screenshot of live measurement on Combilog:

COMBILOG 32-bit Windows (LICENSED)

File Edit Variable Settings Utilities Communication Window Help

Tx Rx COMBILOG (001) Pietermaritzburg

COMBILOG (001) Pietermaritzburg

Infos | Measure | Variable Settings | Module Settings

	Type	Description	Value	Unit	Set	State
V1	AR	Upper Temperature	23.160	°C		Ok
V2	AR	Lower Temperature	23.161	°C		Ok
V3	AR	RH Humidity	50.0	%		Ok
V4	AR	Pressure	1,010.8	hPa		Ok
V5	DI	U WindSpeed	0.00	m/s		Ok
V6	DI	WD WindDirection	0.0			Error
V7	AR	G1 SoilHeatFlux	-2.57	W/m²		Ok
V8	AR	G2 SoilHeatFlux	-1.49	W/m²		Ok
V9	AR	Rn NetRadiation	2.64	W/m²		Ok
V10	AR	PUCn2 ScaledCn2	3.29	-		Ok
V11	AR	StdPUCn2	0.002	-		Ok
V12	AR	Udemod SignalStrengt	0.00	mV		Ok
V13	AR	StdUdemod	##########	-		Ok
V14	AI	Pressure-sn1023	4.66	V		Ok
V15	AR	Press Factor	188.70			Ok
V16	AR	Press Constant	131.00			Ok
V17	AI	Rn NRLitesn130000	0.037	mV		Ok
V18	AR	Sens Rn	13.9			Ok
V19	AI	UCn2 LASsn130000	1.007	V		Ok
V20						
V21	AI	UDemod LASsn130000	0.000	V		Ok
V22	AI	Upper Pt-100sn1000	23.160	°C		Ok
V23	AI	Lower Pt-100sn1000	23.161	°C		Ok
V24	AI	HFP1-sn8740/1033	-0.163	mV		Ok
V25	AR	Sens HFP1	63.48			Ok
V26	AI	HFP2-sn8741/1043	-0.095	mV		Ok
V27	AR	Sens HFP2	64.22			Ok
V28	AR	UCn2 scaling	-2.483	V		Ok

Note the wind direction sensor was not connected in the table above, the LAS was set to give a 1 V output on the C_n^2 analogue output, and the Udemod is invalid as the mesurement was indoors with no carrier signal received)

Appendix I. Date and time format

The characters listed below can be used to match a date or time field. Any other character will be scanned as is except when it is a regular pattern matching character.

Date-time characteristic	Description
Y	Multiple digit year
YY	2 digit year
YYYY	4 digit year
M	Multiple digit month
MM	2 digit month
D	Multiple digit day of month
DD	2 digit day of month
d	Multiple digit day of year
ddd	3 digit day of year
h	Multiple digit hour
hh	2 digit hour
H	Fractional hour (sets hour, minute and second)
m	Multiple digit minute
mm	2 digit minute
s	Multiple digit second
ss	2 digit second
A	AM/PM

Regular characteristic	Description
. (dot)	Matches any character
?	Matches zero or one instances of the expression proceeding ?
\	Cancels the interpretation of special characters (for example, \? matches a question mark). You can also use the following constructions for the space and non-displayable characters:
\b	backspace
\f	form feed
\n	newline
\s	space
\r	carriage return
\t	tab
\xx	any character, where xx is the hex code using 0 through 9 and upper case A through F
^	If ^ is the first character of regular expression, it anchors the match to the offset in string. The match fails unless regular expression matches that topic of string that begins with the character at offset. If ^ is not the first character, it is treated as a regular character.
[ ]	Encloses alternates. For example, [abc] matches a, b, or c. The following character has special significance when used within the brackets in the following manner.
- (dash)	Indicates a range when used between digits, or lowercase or uppercase letters (for example, [0-5], [a-g], or [L-Q])The following characters have significance only when they are the first character within the brackets.
~	Excludes the set of characters, including non-displayable characters. [~0-9] matches any character other than 0 through 9. gives the space characters and all displayable characters except 0 through 9.

+	Matches the longest number of instances of the expression preceding +; there must be at least one instance to constitute a match.
*	Matches the longest number of instances of the expression preceding * in regular expression, including zero instances.
$	If $ is the last character of regular expression, it anchors the match to the last element of string. The match fails unless regular expression matches up to and including the last character in the string. If $ is not last, it is treated as a regular character.

Notes

• Make sure that no non-separator characters at the end of the date and time strings remain unmatched. These characters will be considered as measurement data.

• Use fixed digit symbols in case date and/or time fields are glued together.

• The last matched character contributing to a date or time field determines the value of that field. For example, in case H is followed by s, the second's time field filled by H will be overwritten by the value matched by s.

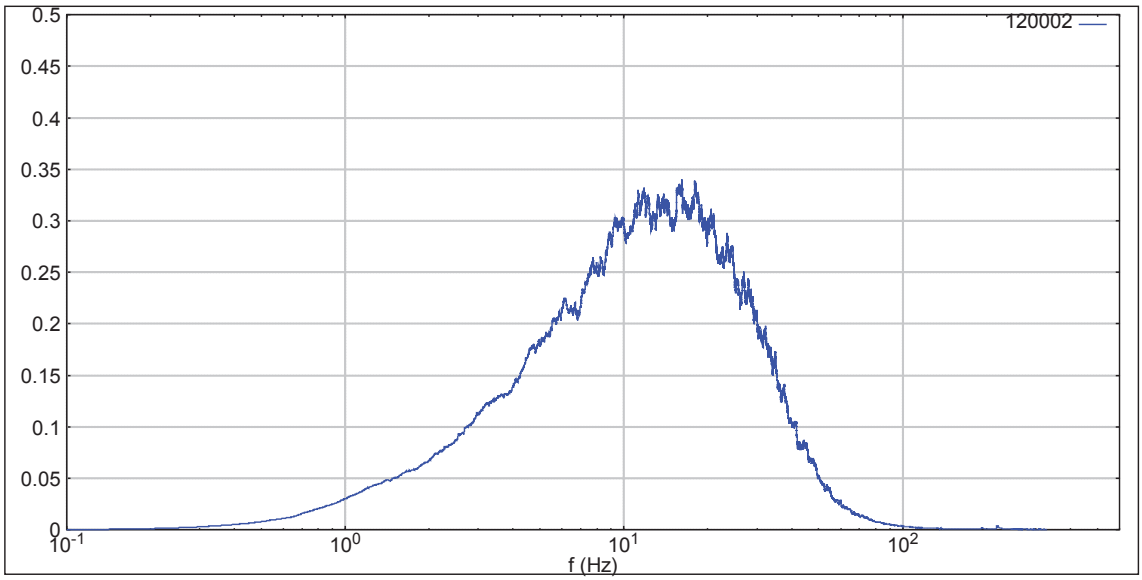
Examples

Date-time string	Suitable patterns
2015139 6.5	"YYYYdddH" or "YYYYddd H"
2015 139 6.5	"YdH" or "Y d H"
2015.00 139.000 6.5	"Y.[0]+d.[0]+H" or "Y.00d000H"
31/10/2015 23:12:10	"D/M/Y h:m:s" or "DMYhms"
31/10/2015 23:12:10.752	"D/M/Y h:m:s.[0-9]+" or "DMYhms.[0-9]+" (no remaining non-separator characters at the end)
31/7/2015 1:05 PM	"D/M/Y h:m A" or "DMYhmA"

Appendix J. Filtering the scintillation frequency spectrum

The LAS MkII measures scintillations from turbulent eddies over a given frequency range.

Below is a measurement of a typical scintillation frequency spectrum:



As can be seen the scintillation spectrum ranges from just above 0.1 Hz to around 100 Hz. With higher cross-wind speeds the scintillation spectrum shifts to the right to higher frequencies. With low cross-wind speeds (calm conditions) the scintillation spectrum shifts to lower frequencies, and a small fraction of the scintillations can be just below 0.1 Hz (note: below around 0.03 Hz unwanted absorption effects will be measured leading to unwanted errors). Any high frequency electronic noise is removed with a filter above 400 Hz, but the precise frequency of this cut-off is not crucial.

In the LAS MkII the high-pass filter (filter 1) determines the low frequency cut-off, and has a default setting of 1592 ms (equivalent to 0.1 Hz). Depending on the users research and measurement conditions, experienced users may want to change the value of this filter. At very short path lengths reducing the frequency of this filter from 0.1 Hz may increase the noise level of the instrument.

Note This should not be confused with the low-pass output filter 2, of which the default is 2500 ms (this has an impact on the response time of the instrument).

Changing High-pass filter (filter 1):
To set the cut-off frequency (-3dB point) to 0.1Hz, set the filter 1 constant to 1592.4 ms.

Use command .SET FILTER1 = 1592; to set the constant to this value in the Communication Interface.

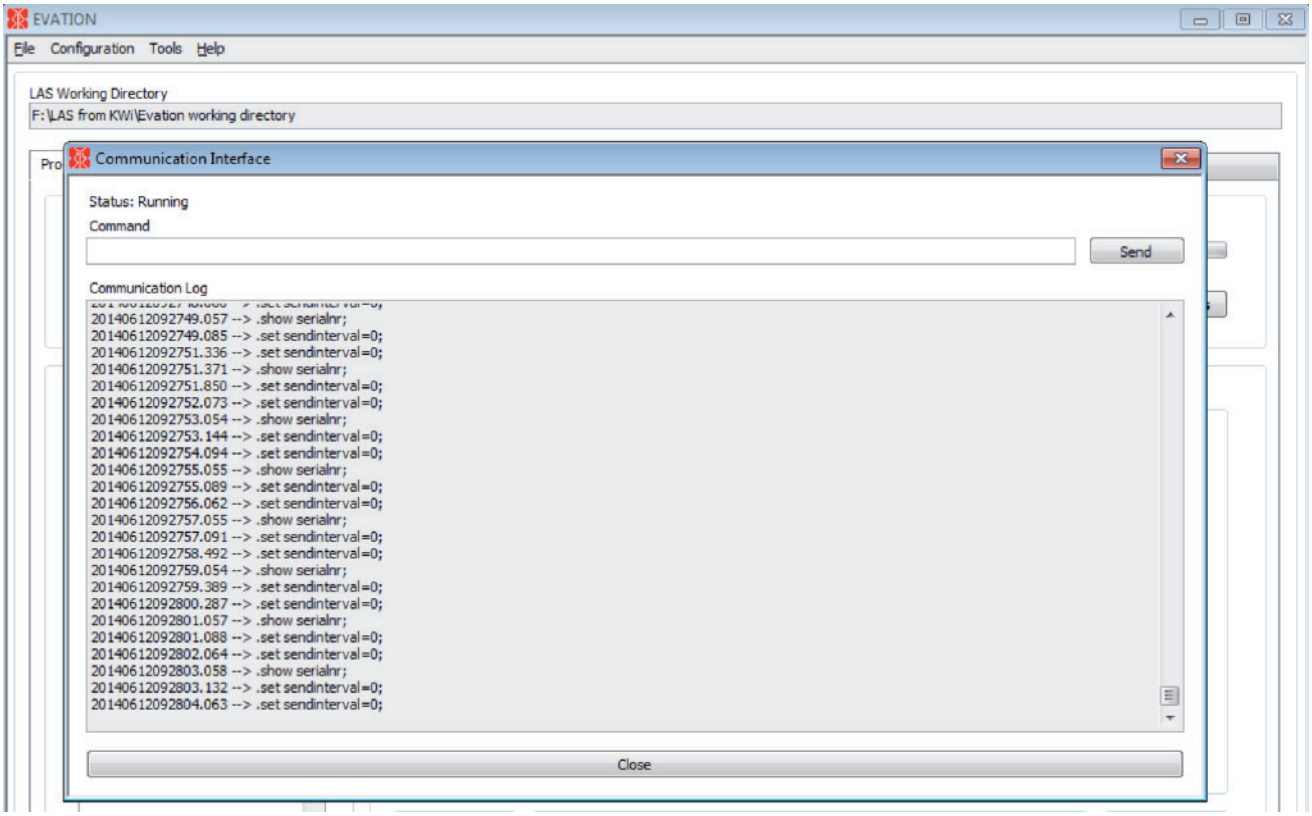
The filter 1 constant in ms is calculated by:
$\tau = 1000 / (2 * 3.14 * \text{frequency})$

For example:

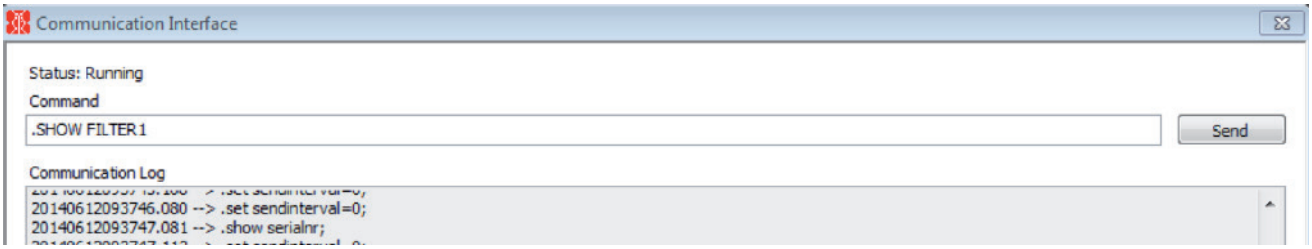
Frequency (Hz)	Equivalent filter 1 constant in ms
0.5	318
0.3	531
0.1	1592
0.03	5308

To change filter 1 in EVATION, click on the menu Tools, and then Communication Monitoring.

A Communication Interface window will pop-up. In the command line at the top commands to the LAS can be typed in, and below can be seen the response from the LAS, i.e. the latest communication messages communicated from the LAS over the serial link.



In the command line type:
.SHOW FILTER1; (as shown below)

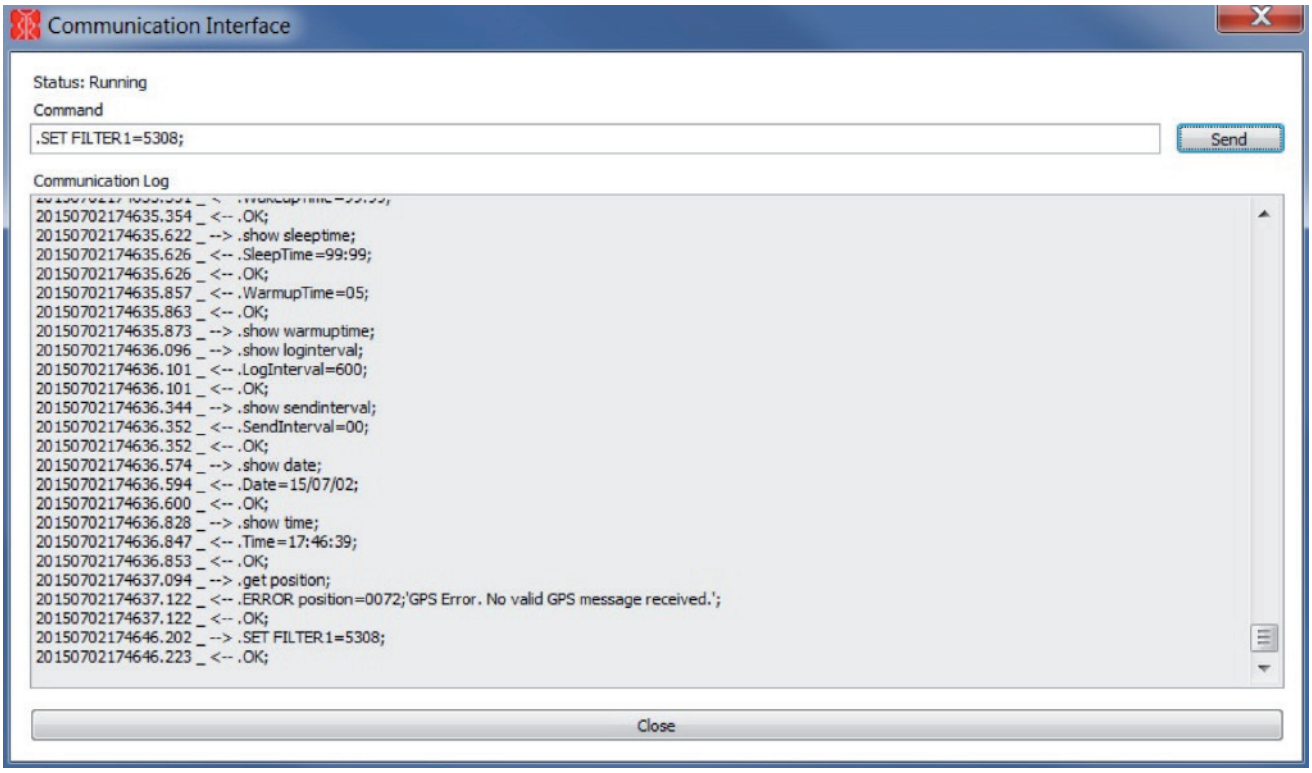


The response in the Communication Log should be:

20150702113413.657 _ --> .Show FILTER1;
20150702113413.670 _ <-- .Filter1=1592;
20150702113413.678 _ <-- .OK;

Showing that filter 1 = 1592 ms, equivalent to 0.1 Hz (the first number string is the date and time during the message, format YYYYMMDDhhmmss.sss).

To change the filter 1 value, in the command line type:
.SET FILTER1=5308;



The response in the Communication Log should be:

20150702114032.378 _ --> .SET FILTER1=5308;
20150702114032.406 _ <-- .OK;

To check this, in the command line type:
.SHOW FILTER1;

And the response in the Communication Log should be:

20150702114302.837 _ --> .SHOW FILTER1;
20150702114302.851 _ <-- .Filter1=5308;
20150702114302.857 _ <-- .OK;

For more information on the high-pass filter and measurement influence see reference, B. Van Kesteren et al., 2015, (Boundary Layer Meteorology, DOI 10.1007/s10546-015-0023-y).

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