User Manual for the

Sunshine Sensor

type ***BF3***

BF3-UM-1.0

Delta-T Devices Ltd

Notices

Copyright

Trademarks

CE Conformity

The BF3 Sunshine Sensor conforms to EU regulations regarding electromagnetic emissions and susceptibility and is CE marked by Delta–T Devices Ltd.

Warnings

To maintain conformance to CE standards, the equipment must be used as described in this manual. Modifications to the equipment may invalidate CE certifications.

Delta-T Devices Ltd reserves the right to change the designs and specifications of its products at any time without prior notice.

Authors

John Wood, Edmund Potter.

User Manual Version: 1.0 May 2002

Delta-T Devices Ltd	**Tel: +44 (0)1638 742922**
128 Low Road, Burwell	**Fax: +44 (0)1638 743155**
CAMBRIDGE CB5 0EJ	**e-mail:** sales@delta-t.co.uk
U.K.	**www:** http://www.delta-t.co.uk

Contents

Introduction

About this Manual

This manual describes the BF3 Sunshine Sensor, and how to use it.

If the BF3 is being used with the SunScan Canopy Analysis system as a reference sensor, you only need to refer to the **Preliminary Checks** and **Use with SunScan** sections in **Getting Started**. Refer to the user documentation supplied with the SunScan system.

Appendix 1 describes the BF3 design and includes a summary of the test results of several experimental trials of the BF3.

The BF3 CDROM contains document files in Acrobat pdf format. These include this manual, an application note on the optical design of the BF3, which may be of interest, and the BF3 Technical Manual.

Description and Functions

What it measures

- The BF3 Sunshine Sensor is one sensor with three output channels:-
    1. Total (global) solar radiation
    2. Diffuse radiation
    3. Sunshine status.
- The Direct beam component of solar radiation can be calculated from the Total minus the Diffuse component.
- You can set up the two radiation outputs to give millivolt signals scaled to the radiation units of your choice:

    For PAR, in $\mu mol.m^{-2}.s^{-1}$

    For Energy, in $W.m^{-2}$,or

    For Illuminance, in klux .

    The Sunshine status output is a logic level that corresponds to sun, or no sun. This can be processed to give sunshine hours duration.
- The Sunshine status threshold corresponds to the WMO value of 120 $W.m^{-2}$ in the direct beam, using an algorithm based on the Total radiation, and the ratio of Total to Diffuse radiation.
- The radiation outputs have a cosine-corrected response.

What it is used for

- SunScan Canopy Analysis System reference
- Canopy Analysis studies, and HemiView reference information
- Meteorological Global Direct and Diffuse solar radiation and Sunshine duration measurements
- Solar Energy monitoring, and solar collector studies
- Architecture and Building design, illumination and heat balance studies of buildings

Advantages of BF3

- It requires no shadow band.
- There are no moving parts.
- It does not need to be adjusted or repositioned to track the sun – a distinct advantage over devices with shadow rings.
- It does not need to be oriented towards North. It will work accurately in any orientation as long as it is mounted horizontally.
- It does not require knowledge of the Latitude or Longitude, and can be used at any Latitude or Longitude.
- It measures sunshine hours as well as Total and Diffuse radiation
- The heated version of the BF3 allows use in condensing and frosty situations.

PC software BF3Read

- The BF3 CDROM contains BF3Read Windows PC software that will read the BF3 output values and status information via the PC RS232 serial port.
- You can use the software to set the BF3 output units to $\mu mol.m^{-2}.s^{-1}$ (PAR), or $W.m^{-2}$ (Energy), or klux (Illuminance).

Use with Data Logger

- The three outputs of the BF3 can be logged with a suitable data logger. The Total and Diffuse radiation millivolt outputs require two analogue channels.
- The sunshine state logic output can be taken to a digital channel, or for some purposes can be connected to an analogue channel in order to give readings of sunshine duration.
- The BF3 is a powered sensor. For power economy, the BF3 can be woken up via a warm-up signal from the data logger.
- The heated version of the BF3 requires a separate heater power supply and cable.

Use with SunScan

- The SunScan system is used for measuring PAR (Photosynthetically Active Radiation) interception by plant canopies, and hence estimating LAI (Leaf Area Index).
- The BF3 can be connected to SunScan probe to provide an instantaneous reference of radiation incident on the canopy. The measurements incident Diffuse and Total PAR above the canopy. This also improves the accuracy of estimating canopy Leaf Area Index (LAI).

Differences from BF1 and BF2

- The BF1 was a very simple sensor consisting of two PAR photodiodes and an adjustable shadow band. It measured Total and Diffuse PAR. It required alignment to true North, and the shadow band required frequent adjustment.
- The BF2 design measured Total and Diffuse PAR without needing any adjustment or North alignment, only horizontal levelling. The BF2 also measured Sunshine state.
- The BF3 uses the same optical design as the BF2, but gives the user a choice of output units for Total and Diffuse radiation, in $\mu mol\ m^{-2}\ s^{-1}$ (PAR) , Wm^{-2} (Energy) , or klux (Illuminance) , as well as Sunshine state.

Construction

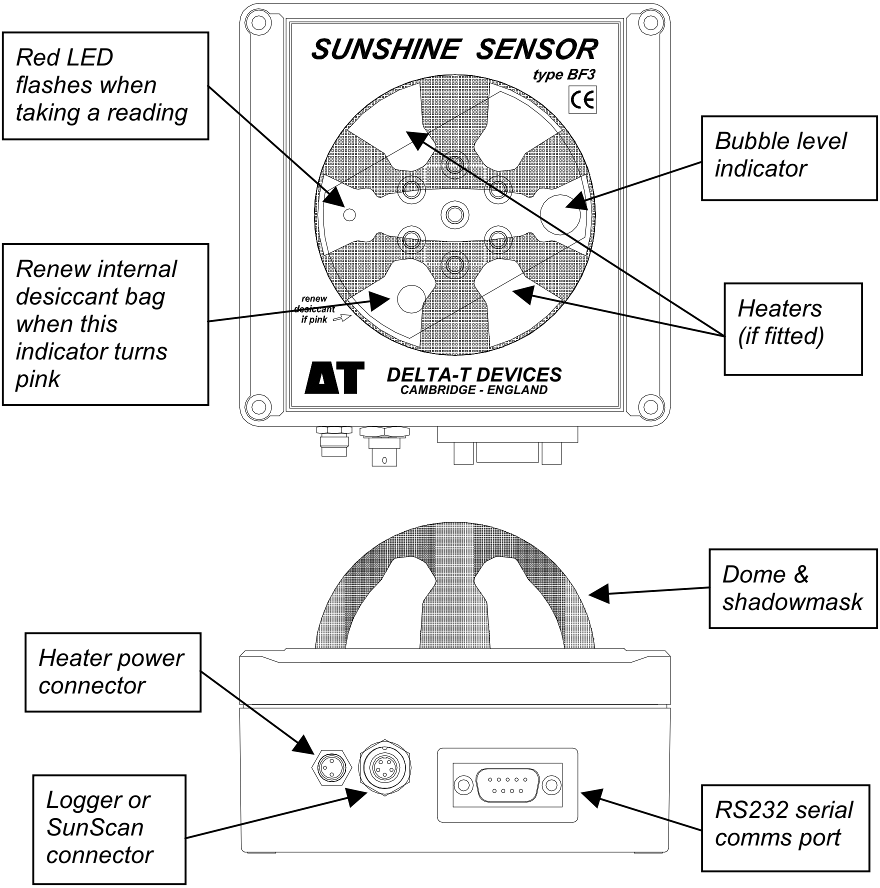
Seven cosine-corrected photodiodes are arranged under a patterned, hemispherical dome, along with a levelling bubble, a desiccant-status indicator, and a red light emitting diode (LED). The LED flashes when the photodiodes are powered up for a reading.

There are two panel mounted sockets for communications, a round 5 pin, blue, analogue socket for connection to SunScan or a logger, and a 9 pin RS232 serial port for connection to a PC.

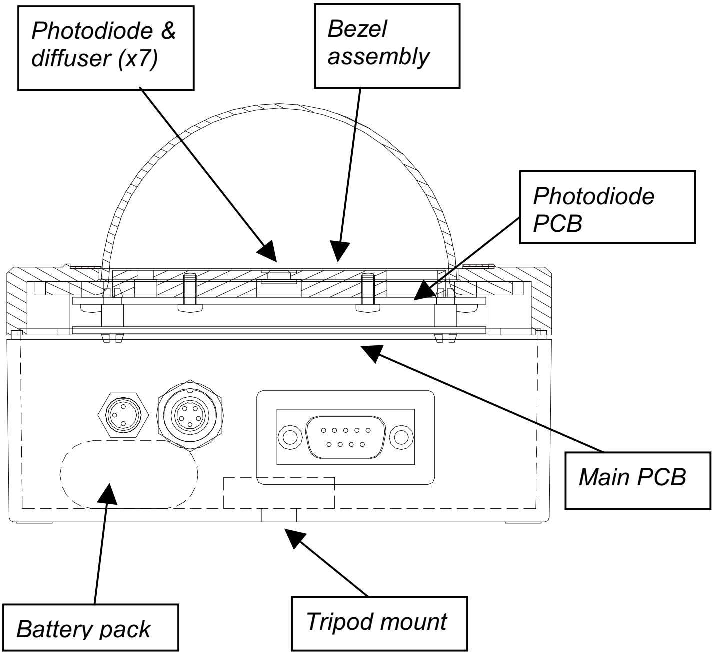
The serial port is provided for checking real time readings, and for changing the output units, using the BF3Read software.

The optional internal heater with a separate power socket is shown. This can be fitted at Delta-T if specified at time of ordering.

A camera tripod-type connector (1/4” BSW thread) is fitted to the base.



Cable connectors and components inside the dome



Section through BF3, showing internal PCBs and battery pack

Accessories

Heater

The BF3 can be fitted with a thermostatically controlled heater option (type BF3H) for protection against frost and condensation. This is recommended for logging applications. The heater option must be specified at time of ordering. It includes a separate cable for connecting the heater to an external 12V battery or battery charger.

Use of the heater stabilises the internal temperature of the BF3 in cold conditions, resulting in greater measurement accuracy.

The heater consists of two cylindrical 9W resistors mounted within the dome and visible from outside.

When power is applied to the heater it works as follows:-

- If the external temperature is above 5°C, the heater provides 2W. This is sufficient to remove condensation and dew.
- Whenever the temperature drops below 5°C the full heater power comes on at 18W, to remove snow or ice.

- The heater switches off if the internal temperature rises above 50°C.

At zero wind speed a BF3 at minus 20°C will become snow and ice and free in 30 minutes once power is applied to the heater.

At 2m.s^{-1} wind speed the dome will remain snow and ice free down to minus 10°C.

***Warning**! The bare heaters can get hot enough to burn your skin when on. Do not operate the heaters with the dome removed.*

Mounting

The BF3 may be mounted on a camera tripod, or more permanently, via an accessory cross-arm type BF3-M with a mounting bracket suitable for connecting to the Delta-T 2 m Weather Station Mast.

Cables

Separate cables are available for connecting the BF3 to the SunScan probe (types BFXL-10, etc), to a data logger (types BFDL-05, etc) and to a heater battery (type BF3H-C). See the Specifications section for full details. The logger cable can also be used to provide the power to the BF3 sensor (but not to its optional heater).

Power Considerations

The BF3 is a powered sensor. There are three possible sources of power:

1. The internal 6V alkaline batteries, if fitted. These are optional.
2. Power from the data logger.
3. Power from the 12V heater supply, if the heater option is fitted.

If more than one of these sources is present, then power is generally taken from the source with the highest voltage, but note that the internal alkaline battery voltage must be exceeded by ~1.2V for this to happen.

If no alkaline batteries are fitted, the power supply must be capable of >5V at 10mA.

You can prevent power being supplied by the data logger by including a resistor in the warm-up line.

Heater

In air temperatures below *5*°C the heater can consume 1.5A at 12V DC so a 40 Ah car battery will only last about one day. For extended datalogging in cold climates, we recommended that you power the heater via a 12 V supply powered from the mains.

Warning! Do not apply AC mains power to the BF3.

Getting Started

- The BF3 is shipped with the internal alkaline batteries installed and connected.
- To check readings you need a SunScan, or PC with BF3Read configuration software installed, or data logger fully programmed and wired up.
- To record or log readings you need a SunScan or a data logger.
- Each requires its own special cable.
- In the field you will need something to mount the BF3 horizontally (on the optional camera tripod, or on a horizontal surface, or on the weather-station mast).

PC software

The BF3Read software runs under Microsoft Windows 95, NT4 or later with a free RS232 port.

If your PC does not have an RS232 serial port, but does have a USB port, USB to Serial adapters are available commercially

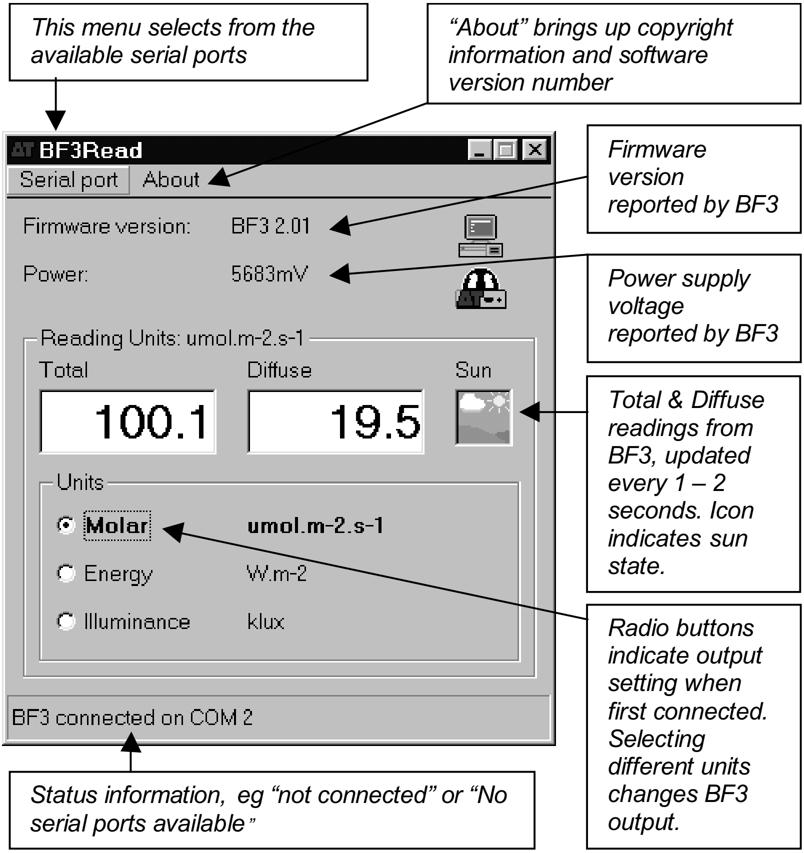
BF3Read Installation

Insert the CDROM the PC drive. On most PCs, installation will start automatically. If it does not, run the file SETUP.EXE in the root folder of the installation disk. See the full installation instructions on the BF3Read CD, and any further information in the ReadMe.txt file on the CD.

On some older machines, you may be asked to reboot after the first part of the installation. Do this, and then run SETUP.EXE again after rebooting.

Connect your BF3

Connect your BF3 to your PC using a “null modem” cable (eg Type **DCT-COM**). Run BF3Read. You will see the display screen below:



Serial port

The Serial port menu indicates which COM ports are available on the PC, with a check mark for the one selected. Once a port is selected, it will be interrogated periodically until a BF3 is found, then the version information will be displayed, and power supply voltage and readings will be updated every few seconds.

About

The about box contains the software version, copyright statements, and contact information for Delta-T. There is also a text summary of Date & Time, BF3 version and units information, which can be copied onto the clipboard, to be used where required. This assists the user to keep an audit record.

BF3Read will also work with BF2 Sunshine sensors, though not allowing change of units.

Preliminary Checks

Battery and Desiccant

- Install the BF3Read software on a PC, and connect the BF3 to the PC RS232 serial port using a “null modem” cable (type DCT-COM). The radiation measurements, units and battery voltage are displayed. Ideally, this should read close to 6 Volts (6000mV). If it reads below 4.5 Volts then the batteries are nearly flat and should be replaced. If the voltage is in between, use your judgement. The battery voltage can also be measured with a voltmeter after undoing the four retaining screws in the lid.
- If the BF3 temperature is likely to exceed 50°C, you are advised to replace the Alkaline batteries with 1.5V Lithium batteries. This is because the capacity of alkaline batteries is poor above 50°C.

WARNING : Do not use 3.6V AA Lithium batteries in the internal battery holder. Only use 1.5 V AA batteries. Delta-T can supply these.

- Check the indicator paper in the dome. It should be blue. If pink, replace the internal bag of desiccant. (To renew the desiccant, see the Maintenance section).
- When you first use the BF3 in the field, check that it is reading in the right units, and that the values seem reasonable.

Check the Dome

The BF3 dome must be clear and unmarked for accurate measurements. It can be cleaned with soapy water or isopropyl alcohol, using a soft clean cloth or paper tissue.

Warning: The dome is acrylic plastic and may be damaged by other solvents

Use with SunScan

Setting up the BF3

Use of the BF3 is similar to the BF1 as described in the SunScan User Manual, but it is simpler to operate. Make sure the BF3 output units are set to the PAR molar units (μmol m^{-2} s^{-1}) using BF3Read.

As a general guide, the above-canopy reference measurements should be made close to, or above, the position of the SunScan probe. Tall canopies will undoubtedly exercise your ingenuity in achieving this!

Using the tripod

The BF3 has a camera tripod mounting screw socket in the base. This is probably the most convenient mounting method to use above low field canopies (up to about 1.8 m high). If you are working with canopies higher than this, it may be convenient to use the cross arm mounting kit which is compatible with the Delta-T Weather Station mast, or devise your own.

Levelling

The BF3 is equipped with a miniature bubble level. The tripod supplied has 3-axis adjustment to facilitate levelling. The sensor is level when the bubble is within the central circle.

It is more important to level the BF3 accurately, than the SunScan probe.

Connecting to SunScan

Use cable types BFXL-10 (or -25, -50) to connect the BF3 directly into the socket on the back of the SunScan Probe.

Run the SunData program on the Psion *Workabout* and select **Menu, Settings, SunScan Probe** and for **Ext Sensor:** choose *BFS*,

The Total and Diffuse readings should then appear on the SunData display. Place the SunScan next to the BF3 and check that the SunScan and BF3 readings are within 10% of each other. If they are not, recalibrate the SunScan using the BF3 as a reference.

For further instructions, see the SunScan User Manual.

Always fit the internal batteries when using the BF3 with SunScan, as SunScan does not provide enough external power to operate the BF3 reliably

Environment and Moisture protection

Avoid putting the BF3, or any SunScan system components at risk when working outdoors. Minimise, as far as practical their exposure to high or rapidly changing temperatures.

Warning! *The BF3 is designed to resist dust and water jets (IP65), but is not hermetically sealed. It will survive rainfall, but may not survive being immersed in water.*

Avoid any situation where it could be flooded. Internal condensation will be avoided if you keep the desiccant fresh. Inspect the desiccant indicator inside the dome. It should be blue.

The BF3 is reasonably robust, but does not have a drop test rating. Do not drop it.

Use with a data logger

The BF3 may be connected to a data logger, with readings being taken continuously. The BF3 updates its output values five times per second.

Diffuse and Total radiation (μmol m^{-2} s^{-1} (PAR) , Wm^{-2} (Energy) , or klux (Illuminance)) and Sunshine status outputs are available for logging.

Use cable type BFDL-05 (or -10, -25, -50) to connect to a data logger.

Data is presented at the analogue and digital outputs of the logger cable within 200 ms of power being applied via the Power + wire.

Where daytime temperatures fall below zero, or inaccuracies due to condensation are undesirable, the use of the heated version (type BF3H) is preferable.

Analogue outputs

The three output units settings all give different output sensitivities, given in the following table:

Output units	**Sensitivity**	**Resolution**	**Full scale output**
Molar μmol.m^{-2}.s^{-1}	1mV = 1 μmol.m^{-2}.s^{-1}	0.6 μmol.m^{-2}.s^{-1}	2500mV = 2500 μmol.m^{-2}.s^{-1}
Energy W.m^{-2}	1mV = 0.5 W.m^{-2}	0.3 W.m^{-2}	2500mV = 1250 W.m^{-2}
Illuminance klux	1mV = 0.100 klux	0.060 klux	2000mV = 200 klux

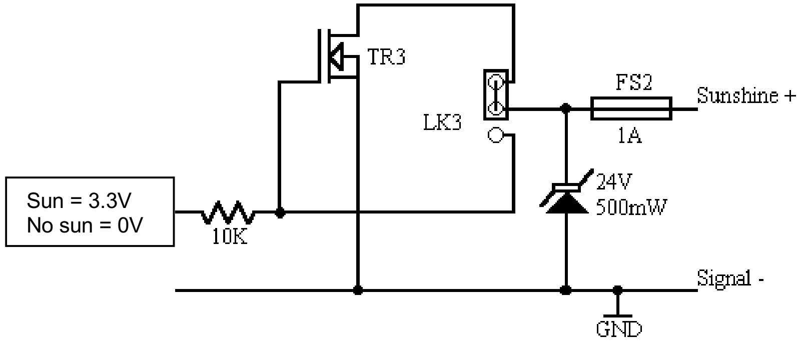
Sunshine Status Output

The sunshine state output is a digital output, i.e. it has only two states, ON and OFF. To accommodate different types of logger input, this can be set by a jumper on the main circuit board to give either:

1. a logic voltage output (no sun = 0V, sun = 3.3V) or
2. a contact closure output (no sun = open circuit, sun = short circuit).

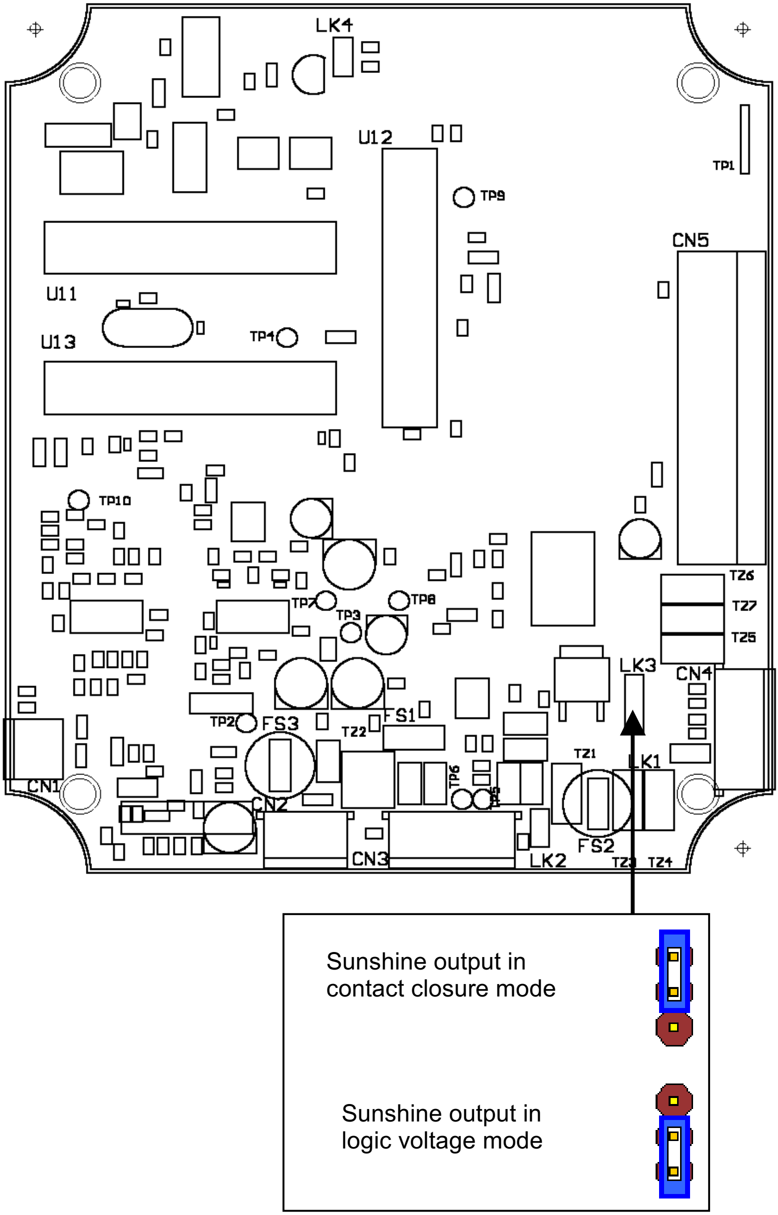
This is shown schematically below. The jumper is LK3 on the BF3 main board.

To set a contact-closure type of output, use the blue jumper socket to connect the centre pin to the top pin.



Circuit diagram of sunshine status output

Location of sunshine output mode jumper LK3



BF3 Sensor Connections

BF3 Power Options

The BF3 is a powered sensor. There are three possible sources of power:

1. The internal 6V alkaline batteries, if fitted. These are optional.
2. Power from the data logger.
3. Power from the 12V heater supply, if the heater option is fitted.

If more than one of these sources is present, then power is generally taken from the source with the highest voltage, but note that the alkaline battery voltage must be exceeded by ~1.2V for this to happen.

If no alkaline batteries are fitted, the power supply must be capable of >5V at 10mA.

You can prevent power being supplied by the data logger by including a resistor in the warm-up line (see below).

BF3 Sensor Wiring

The BF3 sensor is fitted with a 5-pin connector socket. This is used for the output signals, the power and warm-up functions.

Connect the BF3 to the logger with the BFDL-xx logger cables. These are 7-core screened cables, with bare wire ends as standard.

Conductor	**Function**	**Notes**
White	Signal HI	Total radiation output signal
Grey	Signal HI	Diffuse radiation output signal
Yellow	Sun state Output	Sun state output signal. See Note 1.
Green	Signal LO (analog channels)	Total and Diffuse signal return. Common with Power 0V inside the sensor. Note 2
Red	a) Warm-up b) Power V+	See Note 3.
Violet	Power 0V	Power return.
Blue	Not used	Do not connect
Braid	Screen	Connect to logger frame for best electrical interference screening. Not connected to any other conductors.

Note 1:

The Sun state output can be set to a logic HI (~3.3V) level, or an open collector “contact closed” by the jumper LK3 in the BF3. The signal return for these outputs is the Power 0V line when used with digital channels.

Either of these outputs may sometimes be used with analog channels. The implied signal return is then analog channel signal ground.

Note 2:

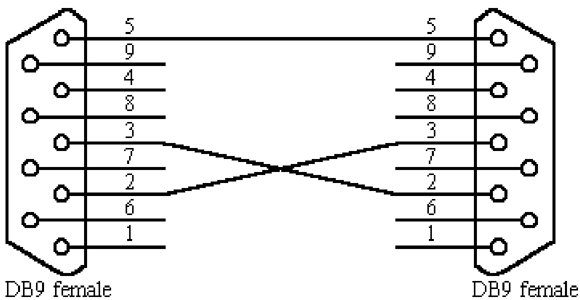
To prevent earth loops causing noisy readings or small voltage offsets, avoid connecting this wire with Power 0V at the logger.

Note 3:

This wire has two functions:
a) Warm-up control. A voltage > ~4V must be applied to enable the BF3 circuit to provide its output signals.
b) Power will be supplied to the BF3 through this wire, if the voltage exceeds the internal battery voltage by ~1.2V, and if no other power source with a higher voltage is available to the BF3.
c) You can prevent power being supplied through this line by including a 10 kΩ resistor in series in it.

BF3 RS232 cable

The minimum requirements for the RS232 cable connecting the BF3 to a PC are shown below:



RS232 cable connections

Any standard null modem cable will also work. Most null modem cables also connect other handshake lines, but these are not used by the BF3.

The DCT-COM cable provided with the BF3 is suitable for this purpose.

DL2e Logger Connections

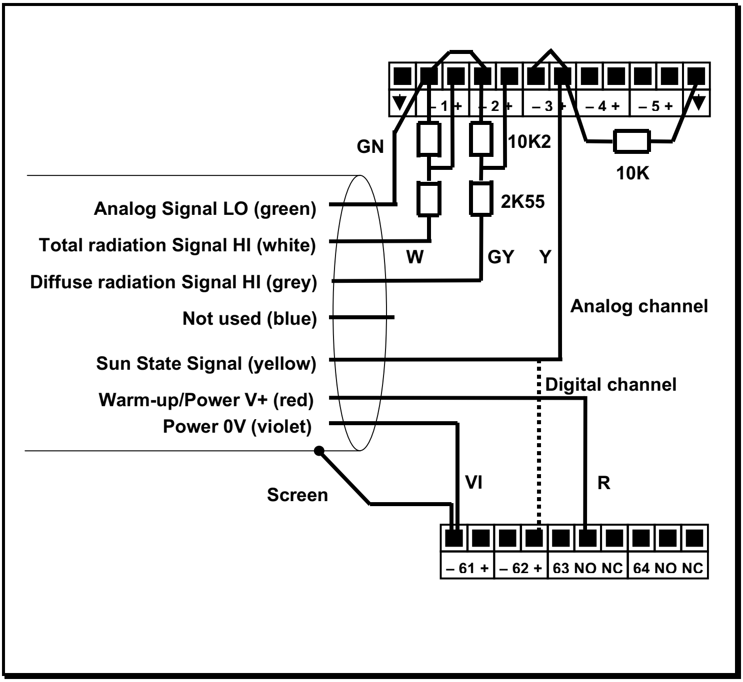
DL2e Logger

Use with LAC1

This diagram shows the wiring connections for the LAC1 analogue input card. For use with other cards, please refer to the DL2e Logger User Manual.

Use the precision resistors provided with BFDL-xx cables to attenuate the BF3 output voltage so it will remain within the DL2e input range.

BF3 Wiring Schematic for DL2e



DL2e wiring connections

Settings

The example shows the BF3 sensor outputs connected to analogue channels 1,2 and 3 in the DL2e logger. The dotted connection shows an alternative connection for the sun state output, using a digital channel.

The BF3 is a powered sensor. All analog outputs should be read using differential channels, for best noise avoidance.

The LAC1 input card of the DL2e logger is used in its 15-channel (differential) mode, with the 15-30 slider set to "15".

Power warm-up for the BF3 sensor is shown routed through relay channel 63. Power from the logger's own battery is connected to terminal 63 using the internal jumper in the DL2e logger. The BF3 will take power from the logger power supply, unless alternative power with a higher voltage is connected (eg via the BF3 Heater option), or if it is blocked with a 10 kΩ resistor in this line (not shown).

The cable screen is connected to channel 61- or 62- terminals for electrical screening purposes. These are the digital earth/frame connections of the DL2e, and are also used for the Power 0V return.

BF3 Special Considerations

Total & Diffuse outputs

The Total & Diffuse analog outputs are shown connected to channels 1 and 2. Note that output attenuators are connected to reduce the maximum voltage seen by the DL2e logger to 2096 mV (its maximum input). The precision resistors for the attenuators are supplied with the connector cables type BFDL-xx.

Sun State output options

The BF3 Sun state output is shown connected to analog channel 3. This is one way of using an analog channel instead of a digital channel. The advantages of this approach are that the need for digital channels is reduced, and the readings are logged as sun hours, rather than simply as the sun state.

Analog channel 3 is configured as a resistance channel (in the 3-wire mode). The precision 10kΩ resistor is provided with the BFDL-xx cable, and is wired as a load resistor. The BF3 sun state output is set to the open-collector mode by its internal jumper LK3.

When the sun is present, the open-collector is effectively "switch closed" to the BF3 ground, the load resistor is thus shorted to ground and will read zero ohms.

With no sun, the open-collector is effectively open circuit, and the resistance reading is 10 kΩ. By means of special DL2e sensor codes (see below) these values can be recorded as sun hours in the logger data.

If you wish to use the BF3 sun state output with a digital channel, simply connect the sun state signal output (yellow) to + input for the required digital channel. Make sure the BF3 internal jumper LK3 is set to the Logic State Voltage output setting. The 10 kΩ resistor is not needed.

DL2e Sensor Codes

When creating your DL2e logger configuration with the LS2e software, you can use the various BF_ sensor codes provided in the LS2e sensor library. Please refer to the *Sensors.txt* file for a full description of each sensor code.

If you have an earlier release of the LS2e software, you can download the latest version from the Delta-T web site. These sensor codes and example configurations are also in the DL2e folder on the BF3Read CDROM.

BFP

Use this code for the Total PAR ($\mu mol.m^{-2}.s^{-1}$) and Diffuse PAR ($\mu mol.m^{-2}.s^{-1}$) outputs from the BF3. Note that it has a conversion factor of 0.8 to allow for the use of the resistor attenuator. (The former BF2 code can still be used).

BFW

Use this code for the Total Energy ($W.m^{-2}$) and Diffuse Energy ($W.m^{-2}$) outputs from the BF3. Note that it has a conversion factor of 0.8 to allow for the use of the resistor attenuator.

BFL

Use this code for the Total Illuminance (klux) and Diffuse Illuminance (klux) outputs from the BF3. Note that it has a conversion factor of 0.8 to allow for the use of the resistor attenuator.

BFD

Select this code for the sun state output with an *analog* channel, using the precision 10kΩ load resistor (as in the diagram above). This will give readings in sun hours per day.

Warning! *You must use this code only with a 24h average period.*

You must start your logging run at the time at which you want your daily total logged (eg midnight, or 9 am).

Warning! *If you occasionally get "noisy" readings reported by the DL2e, change the sensor code Autorange function (A) to Fixed Range (F) in the logger configuration.*

BFH

Similar to BFD, but this will give readings in sun hours per hour.

Warning! *You must use this code only with a 1h average period.*

BFS

Select this code for the sun state output with a *digital* channel. Set the BF3 jumper LK3 to give the Logic State voltage output.

The readings will be simply 1 (for sun) or 0 (for no sun). Subsequent processing of your data file will be needed to translate these readings into sun hours.

Warning! *Do not use this with the "average" function of the logger digital channel – it may not work as you expect.*

Relay warm-up for powered channels

The BF3 sensor needs a warm-up signal in order to enable the circuitry to produce the output signals.

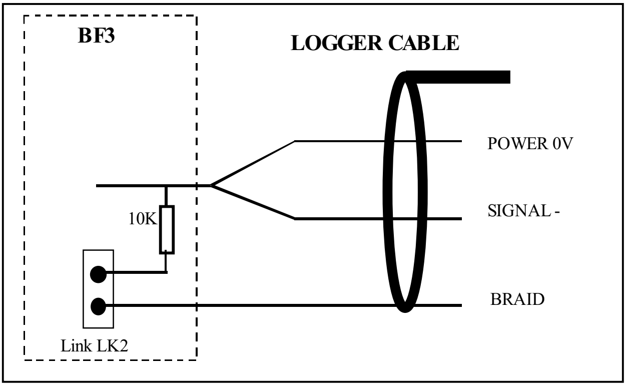
Specify one of the DL2e relay channels 63 or 64, and configure it for the warm-up function with a warm-up time of 1 second.

Use with other Loggers

Refer to your logger User Manual for wiring connection instructions.

The BF3 logger cable screen is normally completely isolated from the BF3 Power 0V return. This is the recommended, factory set, default.

If necessary, it is possible to connect the cable screen to the Power 0V via an internal protection resistor, using a jumper socket on link LK2 on the BF3 main printed circuit board. This resistor should prevent battery supply currents from causing significant offset voltage errors.



Optional link between logger cable braid and ground, normally left open

Connecting the heater

Securely connect the heater cable to your power supply, using the M6 solder lugs provided.

In air temperatures below *5*°C the heater can consume 1.5A at 12V DC so a 40 Ah car battery will only last about one day. For extended datalogging in cold climates, we recommended that you power the heater via a 12 V supply powered from the mains.

Protect the heater power supply from moisture.

Environment and moisture protection

The BF3 is designed to resist dust and water jets (IP65), but is not hermetically sealed. It will survive rainfall, but may not survive being immersed in water.

Internal condensation will be avoided if you keep the desiccant fresh. If the BF3 is being used for long term logging, check the desiccant indicator regularly (every 3 – 6 months). It should be replaced when it turns pink.

The BF3 is reasonably robust, but does not have a drop test rating. Do not drop it.

Technical reference

Specifications

BF3 Accuracy and Resolution

The following accuracy figures give 95% confidence limits, i.e. 95% of individual readings will be within the stated limits under normal climatic conditions.

	Output setting		
	PAR	Energy	Illuminance
Units	$\mu mol.m^{-2}.s^{-1}$	$W.m^{-2}$	klux
Overall accuracy: Total	±10 $\mu mol.m^{-2}.s^{-1}$ ±12%	±5$W.m^{-2}$ ±12%	±0.600 klux ±12%
Overall accuracy: Diffuse	±10 $\mu mol.m^{-2}.s^{-1}$ ±15%	±20$W.m^{-2}$ ±15%	±0.600 klux ±15%
Resolution	0.6 $\mu mol.m^{-2}.s^{-1}$	0.3 $W.m^{-2}$	0.060 klux
Range	0-2500 $\mu mol.m^{-2}.s^{-1}$	0-1250 $W.m^{-2}$	0-200 klux
Analogue output sensitivity	1mV = 1 $\mu mol.m^{-2}.s^{-1}$	1mV = 0.5 $W.m^{-2}$	1mV = 0.100 klux
Analogue output range	0-2500mV	0-2500mV	0-2000 mV

Other specifications

Accuracy : Sunshine hours	±10% compared to the WMO definition
Accuracy : Cosine Correction	±10% of incoming radiation over 0-90° Zenith angle
Accuracy : Azimuth angle	± 5% over 360° rotation
Temperature coefficient	± 0.15 % /°C typical (without thermostat)
Temperature range	-20 to + 50°C with Alkaline batteries -20 to + 70°C with Lithium batteries
Stability	Recalibration recommended every 2 years.
Response time	< 200ms

Spectral Response	400-700nm (see graph)
Latitude capability	-90° to + 90°
Environmental : Sealing	IP65 (shower and dust proof)
Sunshine status : contact closure (CMOS switch) mode	No sun = open circuit Sun = short circuit to ground
Sunshine status : logic state voltage (TTL) mode	No sun = 0V Sun = 3.3V (10K output Impedance)
Internal Battery	4 x 1.5V AA Alkaline batteries
Power requirement	6.5mA, (awake), <30 µA (asleep)
Battery Lifetime	1 year typical
Input Voltage Range – powered from internal battery	3.6 to 15V DC
Input Voltage Range - external power	5 to 15V DC
Logger power supply fuse	100mA , 24V (self resetting)
Fuse trip point, on sunshine status signal, (when in switch-closure mode)	1A, 24V (not self resetting)
Max applied voltage to sunshine status output, in contact closure mode	0 to 24V.
RS232 connector	DB9 panel mounted plug
Signal output & power-in connector	5 pin Mini Triad01 panel mounted plug
Mounting options :	1/4 inch Whitworth camera tripod socket Holes for 4 x M4 bolts at corners of box.
Size & Weight	120mm x 122mm x 95mm, 556g

BF3 Components

Heated version type BF3H

Thermostatically controlled heater version. Requires heater cable type BF3H-C.

Specifications as for BF3 plus the following:	
Heater output below 5 °C	18 W
Heater output from 5-50 °C	1.8 W
Heater output above 50 °C	O W (heater off)
Lowest snow & ice-free temperatures	-20°C at 0 m/s wind speed -10°C at 2 m/s wind speed
Heater : max power	18 W at 12V DC
Heater : max current	1.5A at 12 V
Fuse : max voltage, current	24V, 2A (not self resetting)

Connector	3 pin Hirschmann panel mounted socket
Heater Input Voltage range	7 to 15V DC
Includes heater power supply cable (for external 12V battery)	Type BF3H-C

SunScan SS1 Cables

Types	BFXL-10, BFXL-25, BFXL-50
Length	10 m, 25 m, 50 m
Terminations	5 pin mini Triad plug and socket.

Logger Cables

Types	BFDL-05, BFDL-10, BFDL-25, BFDL-50
Length	5 m, 10 m, 25 m, 50 m
Termination	5 pin mini Triad socket for BF3. Bare wires for logger terminals.

Heater Cable

Type	BF3H-C
Length	5m
Termination	3 pin mini Hirschmann screw in connector at BF3, 6mm solder tags on flying lead to power supply.

Telescopic Tripod

Type	BFT1
Max height	1.73 m
Closed length	0.68 m
Weight	2.5 kg
Screw mount	¼ inch Whitworth socket

Cross Arm for Mast Mount

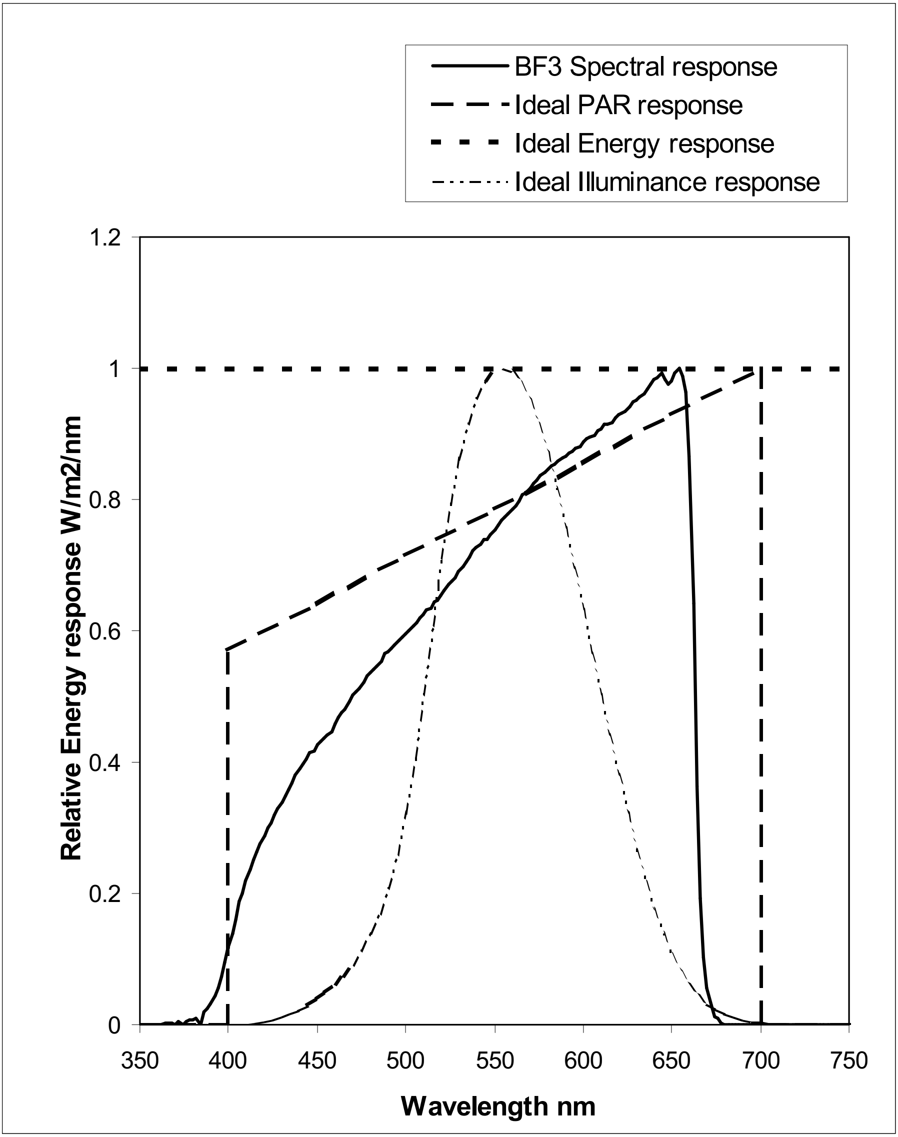
Type	BF3-M
Length, diameter, material	1m long , 1 ¼ inch dia., grey anodised aluminium
Cross arm connector	1 ¼ x 2 inch
Saddle washers	2

Bolt	1 ¼ inch long x ¼ inch BSW stainless steel hex. head
Adjustable Camera Mount	1/4 inch BSW (camera) thread, with ball clamp
Allen key	8mm A/F

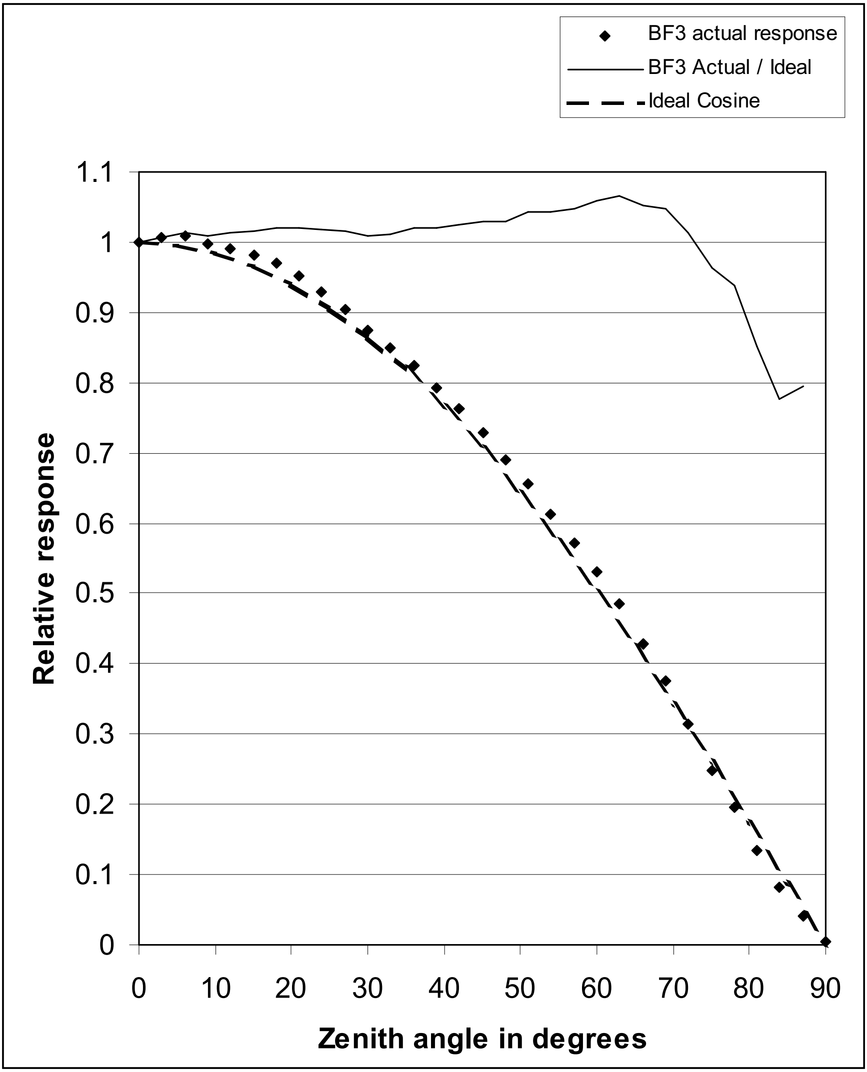
Spares Kit type BF3-SP

Item	**Quantity**
Internal RS232 Cable Assembly	1
Internal Signal Cable Assembly	1
Battery Holder Assembly *(No Batteries Fitted)*	1
Bubble Level Yellow background	1
RH Indicator Paper (disc 11mm diameter)	1
Nylon Spacer 12mm dia x 5mm thick	1
AA Size Alkaline Procell Battery	10
Locking support post, 5mm spacing	4
Desiccant Bag, Activated Clay 60 x 130mm	4
Self Tapping Screw No.4 x ¼ Pozi Pan Hd	4
Fuse 19370K1A	1
Fuse 19370K2A	1
Blue jumpers	4
Molex headers various (1 each 3-, 4-, 6-pin pcb headers)	3
BF3 CDROM	1

BF3 Spectral response



BF3 Cosine response



Routine Maintenance

Batteries

The BF3 is provided with internal batteries, but can also be powered from a logger via the round 5-pin connector. It can also take power from the heater power supply. It will draw power from whatever source has the highest voltage.

Using the internal batteries will prevent any current drain from the logger, and remove any signal errors due to power supply currents in the cable.

The Total & Diffuse radiation and Sunshine Status become active at the 5 pin connector within 200ms of power (>4V) being applied to the Power V+ / Warmup pin. The BF3 will automatically sleep when external power is removed.

The BF3 internal batteries should usually last for about 12 months, depending on logging frequency.

Do not leave the BF3 with exhausted batteries in it, in case they leak.

Desiccant

The dryness of the desiccant pack is indicated by a coloured panel under the dome. Blue indicates dry, pink indicates that renewal is needed.

To regenerate the desiccant.

The desiccant pack can be regenerated by heating. Remove the pack from the BF3 and heat in an oven for a few hours at about 140ºC. Allow it to cool down away from moisture before reinstalling it.

Maintaining the dome

Air pollution and residues in rain and snow can make the dome quite dirty.

A clean dome is essential to maintain the accuracy of the BF.

The dome is acrylic and damaged by many solvents. Clean it when necessary with a damp cloth, moistened with mild detergent, or isopropyl alcohol.

Treatment with a water repellent coating such a “RainX” can reduce the amount of water and dirt on the dome. These are often sold for treatment of car windows or bathroom mirrors.

If the dome cannot be cleaned satisfactorily, a replacement (type BF3-DOM) can be obtained from Delta-T.

Recalibration of BF3

We recommend that BF3s are returned every 2 years to Delta-T for recalibration. A calibration certificate similar to the one below will be provided.

BF3 Calibration Certificate

This is to certify that the Sunshine Sensor type BF3 identified below has been calibrated in accordance with Delta-T Devices Ltd standard production procedures, and conforms to the specifications as detailed.

BF3 Serial Number:	
Date:	
Authorised Signature	

Total PAR Output Setting

Only the Total PAR output accuracy is certified, at 20°C.

The BF3 is calibrated under a uniform light source with a spectrum closely matching the solar spectrum at sea level, against a transfer standard Quantum sensor, which measures the global horizontal PAR irradiance in units of $\mu mol.m^{-2}.s^{-1}$. (PAR is photosynthetically active radiation in the waveband 400-700 nm.)

All other values for diffuse radiation and alternative output settings are calculated relative to this.

The transfer standard, a Delta-T Quantum Sensor type QS, is calibrated by Macam Photometrics Ltd against their reference equipment:

- Xenon Arc Lamp: Spectral Irradiance NPL Certificated
- Photometer: BSI Certificated
- Microvoltmeter: NAMAS Certificated

The absolute accuracy of the Macam calibration is stated as ± 5.0% at 20 °C.

BF3 Accuracy

When correctly calibrated, the expected accuracy is given in the table below. The figures give 95% confidence limits , i.e. 95% of individual readings will be within the stated limits under normal climatic conditions.

	Output setting		
At 20°C	PAR	Energy	Illuminance
Units	**$\mu mol.m^{-2}.s^{-1}$**	$W.m^{-2}$	klux
Overall accuracy: Total	**±10 $\mu mol.m^{-2}.s^{-1}$ ±12%**	±5 $W.m^{-2}$ ±12%	±0.600 klux ±12%
Overall accuracy: Diffuse	±10 $\mu mol.m^{-2}.s^{-1}$ ±15%	±20$W.m^{-2}$ ±15%	±0.600 klux ±15%
Range	0-2500 $\mu mol.m^{-2}.s^{-1}$	0-1250 $W.m^{-2}$	0-200 klux

Delta-T Devices Ltd

128 Low Road, Burwell, CAMBRIDGE CB5 0EJ, U.K.

It is possible to recalibrate the BF3 yourself against a transfer standard sensor, but this is difficult not recommended.

You will need stable sunlight or a stable sunlight simulator. Natural atmospheric turbulence can cause rapid variations in sunlight intensity, which, if greater than the quoted accuracy of the BF3, could make it impossible to recalibrate in sunshine.

For further information on recalibration, refer to the BF3 Technical Manual.

Warranty and Service

Terms and Conditions of Sale

Our Conditions of Sale (ref: COND: 1/00) set out Delta-T's legal obligations on these matters. The following paragraphs summarise Delta-T's position but reference should always be made to the exact terms of our Conditions of Sale, which will prevail over the following explanation.

Delta-T warrants that the goods will be free from defects arising out of the materials used or poor workmanship for a period of **twelve months** from the date of delivery.

Delta-T shall be under no liability in respect of any defect arising from fair wear and tear, and the warranty does not cover damage through misuse or inexpert servicing, or other circumstances beyond our control.

If the buyer experiences problems with the goods they shall notify Delta-T (or Delta-T's local distributor) as soon as they become aware of such problem.

Delta-T may rectify the problem by replacing faulty parts free of charge, or by repairing the goods free of charge at Delta-T's premises in the UK, during the warranty period,

If Delta-T requires that goods under warranty be returned to them from overseas for repair, Delta-T shall not be liable for the cost of carriage or for customs clearance in respect of such goods. However, we much prefer to have such returns discussed with us in advance, and we may, at our discretion, waive these charges.

Delta-T shall not be liable to supply products free of charge or repair any goods where the products or goods in question have been discontinued or have become obsolete, although Delta-T will endeavour to remedy the buyer's problem.

Delta-T shall not be liable to the buyer for any consequential loss, damage or compensation whatsoever (whether caused by the negligence of the Delta-T, our employees or distributors or otherwise) which arise from the supply of the goods and/or services, or their use or resale by the buyer.

Delta-T shall not be liable to the buyer by reason of any delay or failure to perform our obligations in relation to the goods and/or services, if the delay or failure was due to any cause beyond the Delta-T's reasonable control.

Service and Spares

Users in countries that have a Delta-T Distributor or Technical Representative should contact them in the first instance.

Spare parts for our own instruments can be supplied from our works. These can normally be despatched within a few working days of receiving an order.

Spare parts and accessories for sensors or other products not manufactured by Delta-T, may have to be obtained from our supplier, and a certain amount of additional delay is inevitable.

No goods or equipment should be returned to Delta-T without first obtaining the agreement of Delta-T or our distributor.

On receipt at Delta-T, the goods will be inspected and the user informed of the likely cost and delay. We normally expect to complete repairs within a few working days of receiving the equipment. However, if the equipment has to be forwarded to our original supplier for specialist repairs or recalibration, additional delays of a few weeks may be expected.

Technical Support

Technical Support is available on Delta-T products and systems. Users in countries that have a Delta-T Distributor or Technical Representative should contact them in the first instance.

Technical Support questions received by Delta-T will be handled by our Tech Support team. Your initial enquiry will be acknowledged immediately with a "T number" and an estimate of time for a detailed reply (normally a few working days). Make sure to quote our T number subsequently so that we can easily trace any earlier correspondence.

In your enquiry, always quote instrument serial numbers, software version numbers, and the approximate date and source of purchase where these are relevant.

Contact details:

Tech Support Team
Delta-T Devices Ltd
128 Low Road, Burwell, Cambridge CB5 0EJ, U.K.
email: tech.support@delta-t.co.uk
Web site: www.delta-t.co.uk
Tel: +44 (0) 1638 742922
Fax: +44 (0) 1638 743155

Problems

Problem Reports

Always try to isolate the source of the difficulty. This may fall into one of the following areas. It will help considerably if you can mention as many relevant details as possible. In particular:

- A description of the fault, its symptoms, or error messages
- If using SunScan, what components of the SunScan system you are using
- If logging, what logger you are using, details of the logging program and any other devices connected to it.
- Details of any PC you are using
- Software version numbers and hardware serial numbers (see below)

Locating version and serial numbers

The BF3 serial number label is on the underside of the case. The internal software version number is displayed in the About box using BF3Read.

Troubleshooting

BF3 Not Responding

Check cables and connectors

If using the RS232 cable check that you are using a null modem cable, and that it is plugged into the same serial port on your PC that you have selected in the BF3Read software.

If Logging, check the logger cable and compare with your logger wiring connection diagram.

Check also your logger sensor configuration, power warmup relay wiring connection and warmup relay program configuration.

Check battery voltage

The BF3 requires at least 3.6 Volts on its internal battery, or 5 – 15V DC from an external power supply.

Resetting the BF3

If the BF3 still does not respond, its internal microprocessor may be reset by removing and reapplying all power, (including the internal battery) or by shorting pins LK4 on the Main PCB.

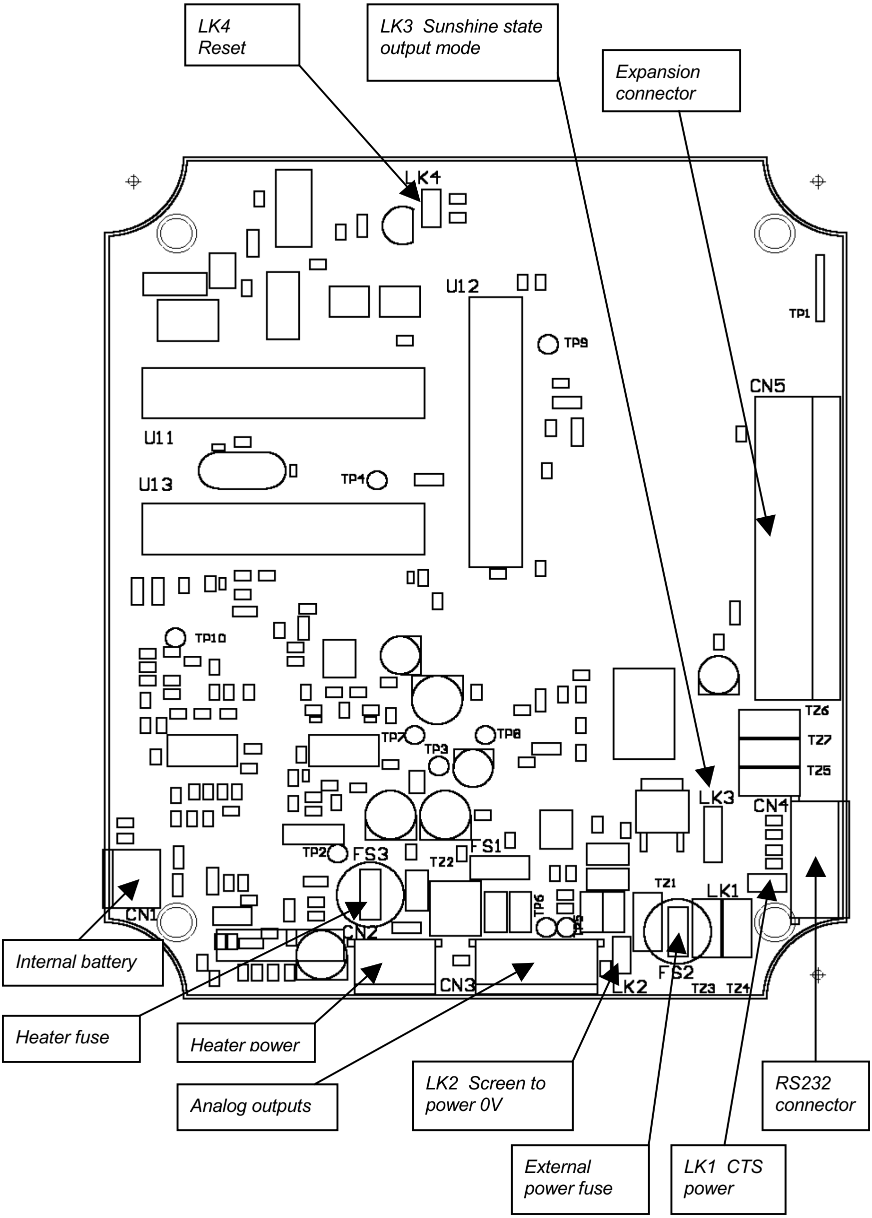
BF3 Technical Manual

The BF3 Technical Reference Manual contains much useful information for Trouble shooting including:

- Circuit board schematics and diagrams.
- Descriptions of how the electronics work
- Test and calibration procedures.
- Wiring diagrams for connectors and cables.
- Specifications for the firmware – i.e. the software in the microprocessors.
- Detailed parts lists.

The Technical manual is available in Adobe Acrobat PDF format on the BF3Read CDROM.

Links and connectors on the BF3 Main PCB



Appendix A: Design and Test Summary

This appendix gives a brief description of how the BF3 design works, and a summary of the results of the test program. More detailed versions of these are available from Delta-T.

Introduction

Measurement of Direct and Diffuse components of solar radiation has many applications - in modelling the interaction of light with crop canopies, studying the energy balance of structures, or as a meteorological indicator. Instruments that make these measurements have generally been expensive and require considerable attention.

One common approach has been to have two sensors, one measuring radiation from the whole sky, the other measuring the whole sky apart from the sun. The shading is generally done using a shade ring, adjusted to match the track of the sun across the sky for that day, or using an occluding disk held on a robot arm. Both of these approaches require accurate alignment to the Earth's axis, and regular adjustment.

Another well established approach is the Campbell-Stokes recorder, which uses a glass sphere to focus the Direct solar beam onto a recording chart causing a burn, which indicates direct beam strength.

Design objectives

The aim of the BF2/3 design was to measure the Direct and Diffuse components of incident solar radiation, and provide a measure of sunshine hours, in a sensor that used no moving parts, and required no specific polar alignment or routine adjustment. The outputs should be compatible with electronic dataloggers, and work at any latitude.

How the design evolved

The prime requirement for this design was to create a system of photodiodes and a shading pattern such that wherever the sun is in the sky:

- at least one photodiode was always exposed to the full solar beam
- at least one was always completely shaded
- both photodiodes receive equal amounts of Diffuse light from the rest of the sky hemisphere.

A basic layout of 7 photodiodes on a hexagonal grid, covered by a patterned hemispherical dome was chosen. The dome pattern was generated by computer, using a specially designed evolutionary algorithm.

Calculation of Outputs

The shadow pattern consists of equal areas of black and clear bands. This means that all of the photodiodes receive 50% of the Diffuse radiation, sampled from all over the sky, and at least one photodiode receives only this radiation. At least one photodiode also receives the full amount of Direct radiation from the sun. Which particular photodiodes these are depends on the position of the sun in the sky, but the fully exposed one is always the photodiode which receives the most radiation, and the fully shaded one the least. All the photodiodes are measured by the electronics, and the maximum and minimum of the seven readings are used. The maximum reading represents the Direct radiation + half of the Diffuse radiation, the minimum reading represents half of the Diffuse radiation. The outputs are calculated as follows:

Diffuse = 2 * MIN
Direct = MAX - MIN
Total = Direct + Diffuse = MAX + MIN
The Total and Diffuse values are used for the instrument output.

Note: This analysis is independent of the spectral characteristics of the individual photodiode sensors, or their spatial response.

Conversion to appropriate units

Molar units ($\mu mol.m^{-2}.s^{-1}$)

The photodiodes used in the BF3 have a spectral response that is close to an Ideal PAR response (see spectral response graph in the Technical Reference section). The BF3 is calibrated using a reference quantum sensor, so calculates its output values in PAR units.

Energy units ($W.m^{-2}$)

The relationship between PAR and Energy measurements under given conditions depends on the spectral content of the light. In practise, the spectral distribution of the Total radiation in most conditions is nearly constant, so a single conversion factor is sufficient to give the Energy Total from the PAR Total, at the stated accuracy of the instrument. However, the spectral distribution of Diffuse light does vary considerable between blue sky and overcast conditions. To take this into account, the BF3 uses the Beam Fraction (Direct / Total) as an estimator of the proportion of blue skylight, and applies a conversion dependent on this value. The actual conversion factors used are:

Energy TOTAL = PAR TOTAL * 0.48
Energy DIFFUSE = PAR DIFFUSE * (0.48 – 0.48 * (Beam Fraction)^4)

These values have been derived from long term measurements against Kipp energy sensors fitted with shade rings, at a number of different sites, over a wide range of conditions.

Illuminance units (lux)

The human eye response curve covers the same spectrum range as PAR. A single conversion factor to lux is used (1 $\mu mol.m^{-2}.s^{-1}$ = 55.7 lux). This has been derived theoretically from a range of different daylight spectra measured with a LiCor spectroradiometer in a range of conditions. The varying spectral distribution of, for example, blue skylight, overcast skylight, or Direct beam sunlight at sunset, only cause a 1% - 2% variation from this, which is well within the specified instrument accuracy.

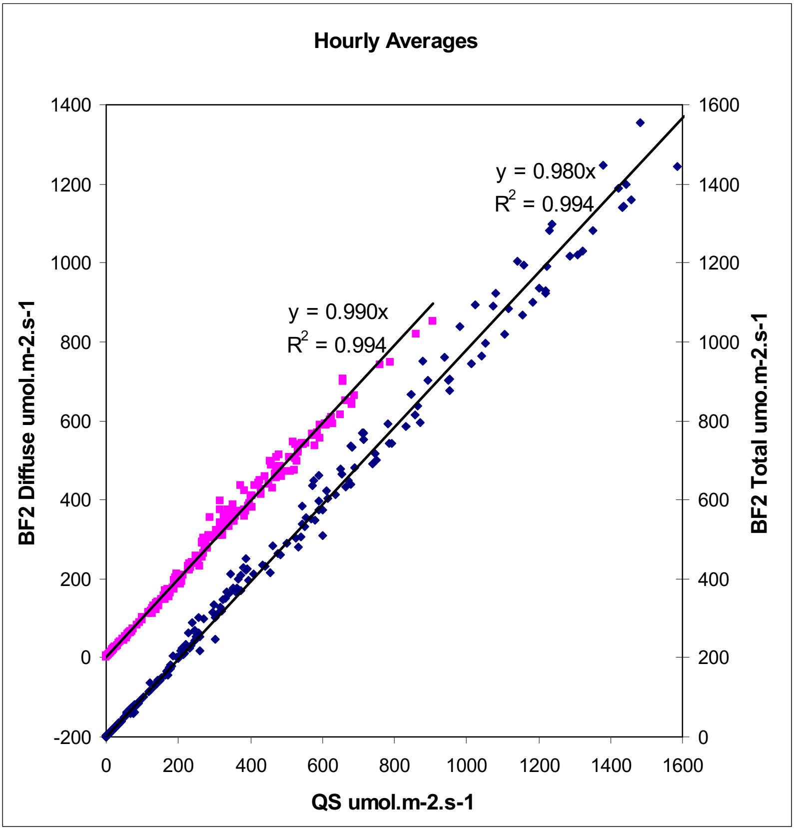
Sunshine state

The WMO definition of sunshine presence is that there is greater than 120 $W.m^{-2}$ in the Direct beam, measured perpendicular to the beam. This cannot be measured directly by a horizontal cosine corrected sensor. The BF3 uses the following algorithm, which has been found to give good results when compared with the WMO definition, and substantially more accurate than measurements using a Campbell-Stokes recorder.

Sunshine presence if Total/Diffuse > 1.25
and Total > 50 $\mu mol.m^{-2}.s^{-1}$

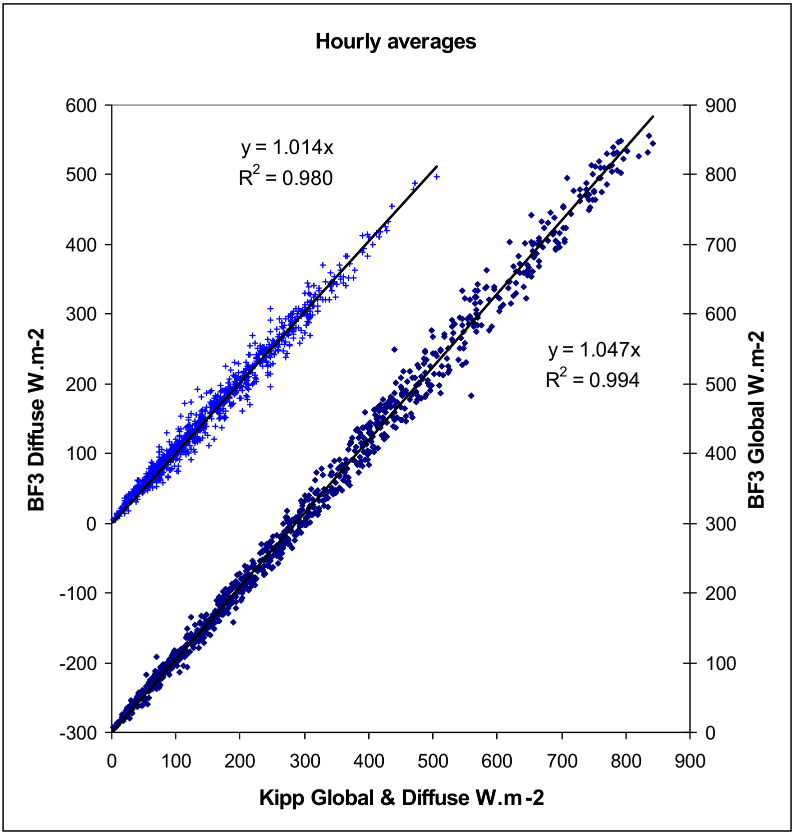
Test results

PAR output



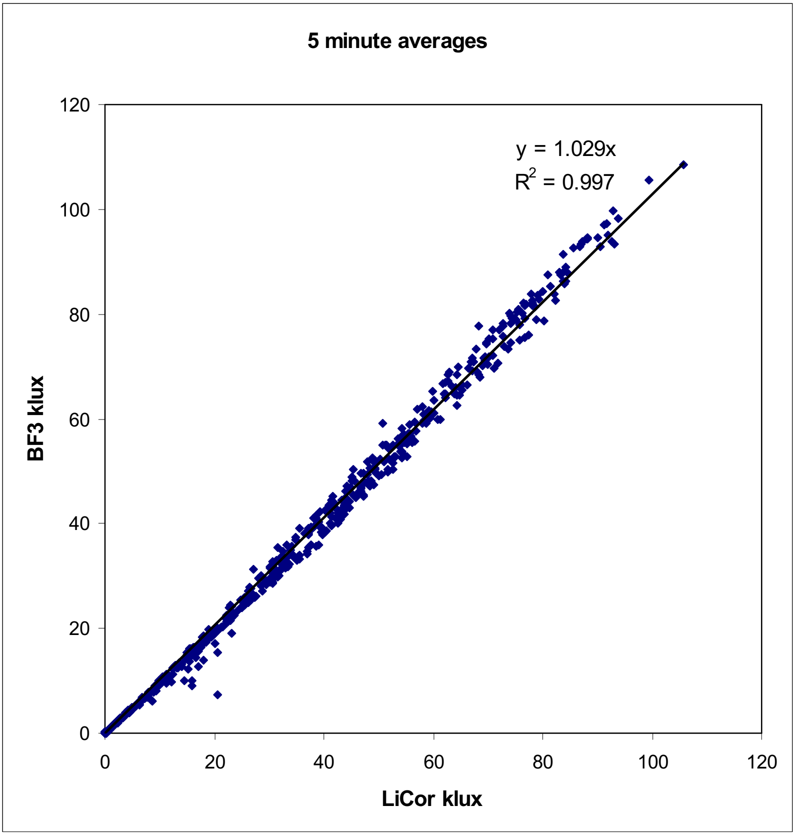
This graph shows a comparison of a BF2 against two Delta-T quantum sensors and a shade ring. Data recorded at Winster, Derbyshire, 20 – 31 May 1999. The graph plots hourly averages of readings every 5 seconds. Note the offset Y-axis to separate the Total and Diffuse plots.

Energy output



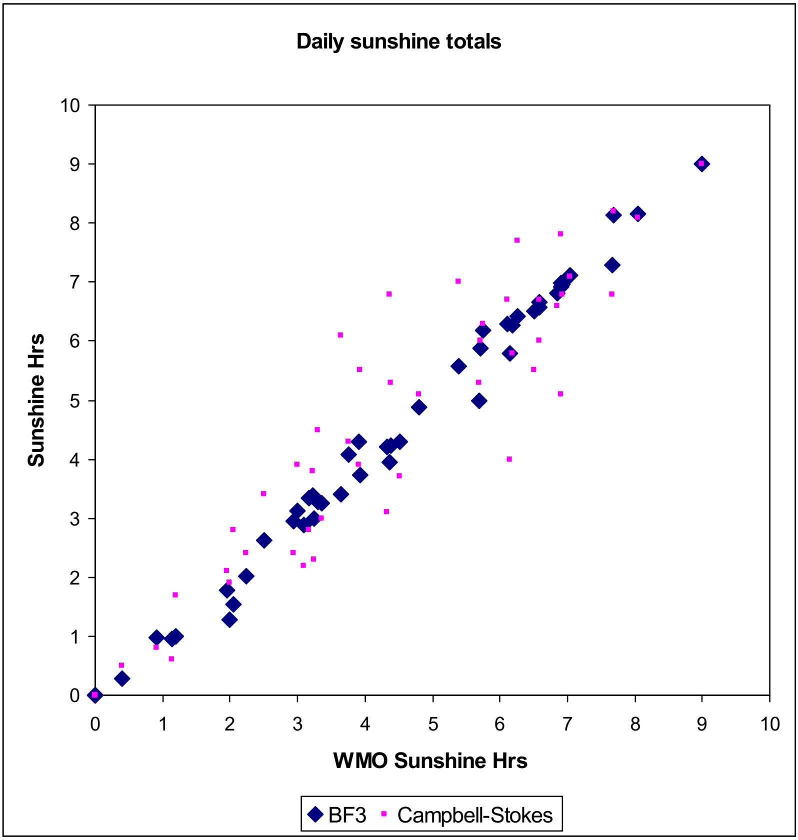
This graph shows BF3 Total and Diffuse outputs compared with two Kipp CM11s and a shade ring. Data recorded at Napier University, Edinburgh between February and July 2001. The graph plots hourly averages of readings every 10 seconds. Note the offset Y-axis to separate the Total and Diffuse plots.

Illuminance output



This graph shows a comparison of a BF3 (Total output) against a LiCor Illuminance sensor. Data recorded at Burwell, Cambridge, UK 16 – 23 Aug 2001. The graph plots 5 minute averages of readings every 5 seconds.

Sunshine state



This graph shows daily sunshine totals measured by a BF3, compared to the WMO definition of 120 W.m-2 in the Direct beam. Data recorded at Napier University, Edinburgh between February and July 2001.Comparable data from an adjacent Campbell-Stokes recorder is also plotted.

Glossary

Azimuth angle– the horizontal angle between the sun, or a light source simulating the sun, and North, increasing in the direction NESW. The BF3 does **not** have to be aligned towards North for correct operation (unlike most other devices).

Beam fraction- the fraction of Total incident radiation in the Direct beam.

Beam Fraction Sensor (BFS) - A device for measuring Direct and Diffuse light above the canopy. Delta-t Type BF1 uses 2 photodiodes and a shading ring. Type BF3 consists of seven PAR sensors and an acrylic dome with stripes. It also measures sunshine hours.

Cosine response - the response of a sensor in which the sensitivity to a ray of light is proportional to the cosine of the angle of incidence of the ray (measured from the perpendicular to the sensor surface).

Diffuse light - light from parts of the sky other than directly from the sun, from scattering in the atmosphere or reflection from clouds.

Direct beam - light coming directly from the sun, with no scattering. Usually treated as if it comes from a point source.

Energy - radiation measured with equal sensitivity to the energy content regardless of wavelength. It is measured in units of $W.m^{-2}$. The normal daylight maximum is a little over 1000 $W.m^{-2}$.

Illuminance - radiation in the visible range (400nm – 700nm) measured with the same spectral sensitivity as the human eye. It is measured in units of lux or klux (=1000 lux). The normal daylight maximum is about 150 klux.

PAR - Photosynthetically Active Radiation is visible light of wavelength 400nm - 700nm, with uniform sensitivity to the number of photons received, regardless of their wavelength. It is measured in units of $\mu mol.m^{-2}.s^{-1}$ (micromoles per square metre per second) or formerly μE (micro-Einstein). The normal daylight maximum is a little over 2000 $\mu mol.m^{-2}.s^{-1}$.

SunData software- the software used to drive the SunScan probe and calculate and store the results. There are two versions, one which runs in the Psion *Workabout*, the other in an IBM compatible PC. They are functionally very similar.

SunScan probe - the long light sensitive wand and handle used for light readings within the canopy.

Sunshine – the threshold for *bright* sunshine, defined by the WMO, is 120 $W\ m^{-2}$ of Direct beam solar radiation, measured perpendicular to the direction of the beam. It is defined this way in order to ensure historical continuity with Campbell-Stokes recorders.

Total radiation - the sum of Direct beam and the Diffuse light.

Zenith angle - the angle between the centre of the sun and the point directly overhead.

Index