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User Manual for the

# *Sunshine Sensor*

type **BF5**



BF5-UM-1.0

**AT**

*Delta-T Devices Ltd*

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

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# Introduction

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## About this Manual

This manual describes the BF5 Sunshine Sensor, and how to use it.

**SunScan Users:** If using the BF5 with the SunScan Canopy Analysis system refer to the **Preliminary Checks** on page 17 and **Use with SunScan** on page 17.

See also the SunScan documents on the [Software and Manuals CD](#).

Appendix 1 describes the BF5 design and includes a summary of the test results of several experimental trials of its predecessors, the BF3 & BF2.

See also:

[BF5 Quick Start Guide](#)

[BF3 Optical Design v2](#)

[BF3 Evaluation](#)

These are also on the [Software and Manuals CD](#).

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## Description and Functions

### What it measures

- The BF5 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  $\mu\text{mol.m}^{-2}.\text{s}^{-1}$
  - For Energy, in  $\text{W.m}^{-2}$ , 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 World Meteorology Office (WMO) value of  $120 \text{ W.m}^{-2}$  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 BF5

- 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
- A heater allows use in condensing and frosty situations.

## SunRead software

SunRead runs on a PC running Windows XP, Vista and 7.

### *About Sunread*

- Reads the BF5 output values and status information via the PC RS232 serial port.
- Sets the BF5 output units, to  $\mu\text{mol.m}^{-2}.\text{s}^{-1}$  (PAR), or  $\text{W.m}^{-2}$  (Energy), or klux (Illuminance) as required.
- Logs data directly to PC.

## Use with a data logger

- The three outputs of the BF5 can be logged with a suitable data logger. The Total and Diffuse radiation millivolt outputs require two analogue channels. The use of a data logger with differential sensor inputs (rather than single-ended) is recommended.

- 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 BF5 is a powered sensor. For power economy, the BF5 can be woken up via a warm-up signal from the data logger.
- The internal heater requires a separate power supply. This should be completely isolated from all other BF5 ground connections.

## Use with SunScan

- The SunScan system is used for measuring PAR (Photosynthetically Active Radiation) interception by plant canopies, and hence estimating Leaf Area Index (LAI).
- The BF5 can be connected to SunScan probe to provide an instantaneous reference of solar radiation incident on the canopy. The measurements give the incident Diffuse and Total PAR above the canopy. This also improves the accuracy of estimating canopy LAI.

## Differences from BF1, BF2 and BF3

- 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 used the same optical design as the BF2, but gave the user a choice of output units for Total and Diffuse radiation, in  $\mu\text{mol m}^{-2} \text{s}^{-1}$  (PAR) ,  $\text{Wm}^{-2}$  (Energy) , or klux (Illuminance) , as well as Sunshine state.

The BF5 has the same performance and specifications as the BF3, but with an improved electronic and mechanical design.

- The power consumption is improved:- the external power requirement reduced from 6.5 to 2 mA, the number of internal AA batteries reduced from four to two, and their typical lifetime increased from 6 to 12 months.
- The accuracy of the analogue outputs has been improved, with the output offset reduced to 3mV.
- There are now no internal jumpers or fuses.
- The design also includes a heater and more rugged and weather-proof cabling connectors and extension cables which are now interchangeable with the SPN1 Sunshine Pyranometer.

---

## 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:

- An 8 pin, M12 male analogue socket for connection to SunScan or to a data logger.  
This can also connect to a logger warm-up power supply for the BF5 sensor and to a separate power supply for the heater.
- A 5-pin M12 male connector serial port for connection to a PC or to the SunScan radio link option.

The serial port is provided for checking real time readings, for changing the output units, and for logging data directly to the PC.

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

## Heater

The BF5 is fitted with a thermostatically controlled heater for protection against frost and condensation. Its use is recommended for logging applications. It requires a separate external 12V DC power supply.

Use of the heater stabilises the internal temperature of the BF5 in cold conditions, keeping the dome free of frost and resulting in greater measurement accuracy.

The heater consists of two 15W resistors fixed to the shadow-mask.

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

- If the external temperature is above 5°C, the heater provides 2W, reducing to zero above 35°C.  
This is sufficient to remove condensation and dew.
- Whenever the temperature drops below 5°C the heater is increased, to full power below 0°C - to remove snow or ice.

At zero wind speed a BF5 at minus 20°C will become snow and ice free in 30 minutes once power is applied to the heater.

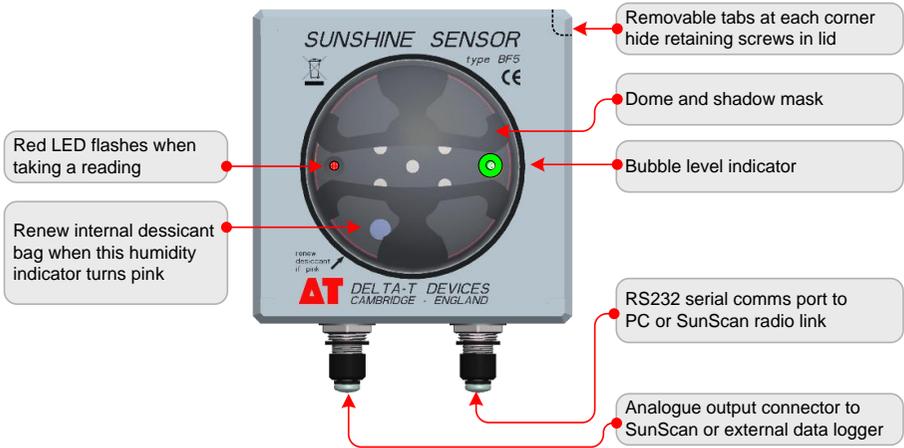
At 2m.s<sup>-1</sup> wind speed the dome will remain snow and ice free down to minus 10°C.

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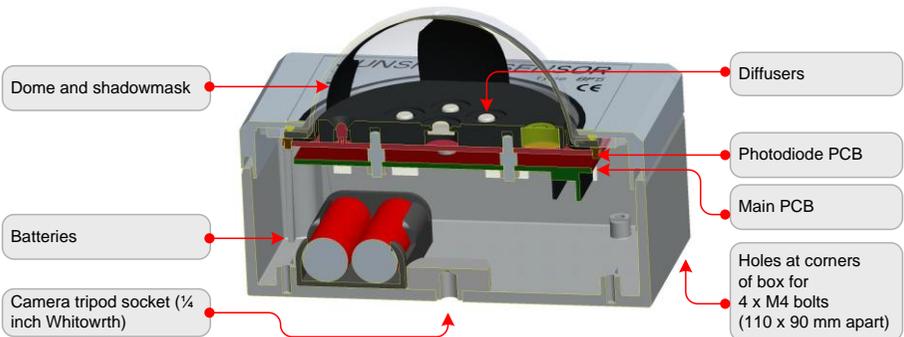
**Warning:** *The bare heaters can get hot enough to burn your skin when on. Do not operate the heaters with the dome removed.*

**Warning:** *Ensure the heater ground is isolated from all other BF5 ground connections. If possible use a data logger with differential sensor inputs. See also page 21*

---



### Cable connectors and components inside the dome



### Section through BF5, showing internal PCBs and battery pack

# Accessories

## Mounting

Mount the BF5 to a camera tripod if using it close to, or above low field canopies (i.e. up to about 1.8m. A standard camera tripod socket is mounted in the base of the BF5 for this purpose (¼ inch Whitworth x 8mm).

Above this height the **BF5-M** (1m x 32mm) cross-arm adaptor may be useful.

It includes a Manfrotto type 482 camera adaptor and a KeeKlamp type 45-86 connector. This is compatible with the Delta-T M2 weather station mast and with many building scaffolding systems.



## Cables

	CABLE OPTIONS		BF5 end
RS232 cable	9-way serial female	1.5 m <b>SP-BF-RS01</b>	5-way M12 female
RS232 extension cable	5-way M12 male	10 m <b>SP-BF-RS10</b>	5-way M12 female
SunScan cable	5-way male	5 m <b>BF5-SS1-05</b>	8-way M12 female
Logger cable	Flying leads	5 m <b>SP-BF/w-05</b>	8-way M12 female
Logger extension cable	8-way M12 male	5 m 10 m 25 m <b>EXT/8w-5</b> <b>EXT/8w-10</b> <b>EXT/8w-25</b>	8-way M12 female

Separate cables and extension cables are available for connecting the BF5 to a PC, to SunScan and to a data logger, as shown in the diagram above.

The logger cable can also be used to connect external power to the BF5 sensor (e.g logger warmup power) and, separately, to connect power to the BF5 heater.

For full details see **BF5 - SunScan Cable** on page 31.

See also the **BF5 Quick Start Guide**.

# Power Considerations



Optional  
Internal  
3V alkaline  
batteries

Battery power



SP-BF/w-05

Mains-powered power supply  
7-15V DC, 1.5A max at 12V,  
outputs isolated from mains



Heater power

(To enable analogue outputs connect the separate logger warmup line - see below)



SP-BF/w-05

**Warm up control:**  
>3V required for BF5 to provide its output signals, if power is provided elsewhere and/or  
**External sensor power:**  
5-15V @ 2mA recommended to power sensor via warm-up line



Power via logger warmup.

Analogue outputs enabled.  
No heater.



SP-BF-RS01

BF5 power from PC's RS232 serial port (draws up to 2mA from the RS232 DTR line if no other power available)

Note: some laptops may not provide enough current

Power from PC

The BF5 is a powered sensor. There are four possible sources of power:

1. The internal 3V alkaline batteries, if fitted. These are optional.
2. Power from the data logger. This only needs to be applied when the logger takes a reading. The BF5's Total, Diffuse and Sun analogue outputs are valid 100ms after power is applied, and are then updated every 250ms. These analogue outputs are only enabled when there is a voltage present on the data logger power input (via DL-Power).
3. Power from a 12V heater supply.

4. Power from the PC's serial port (but not some laptops). The BF5 draws power from the PC DTR signal. Most computer serial ports will provide enough power for the BF5 sensor electronics (but not its heater).

If more than one of these sources is present, then power is generally taken from the source with the highest voltage.

If no alkaline batteries are fitted, the power supply must be capable of >5V at 2mA.

To prevent power being drawn from the data logger include a 10k resistor in the logger power cable. This is OK as long as power is available from elsewhere, e.g. from the heater supply

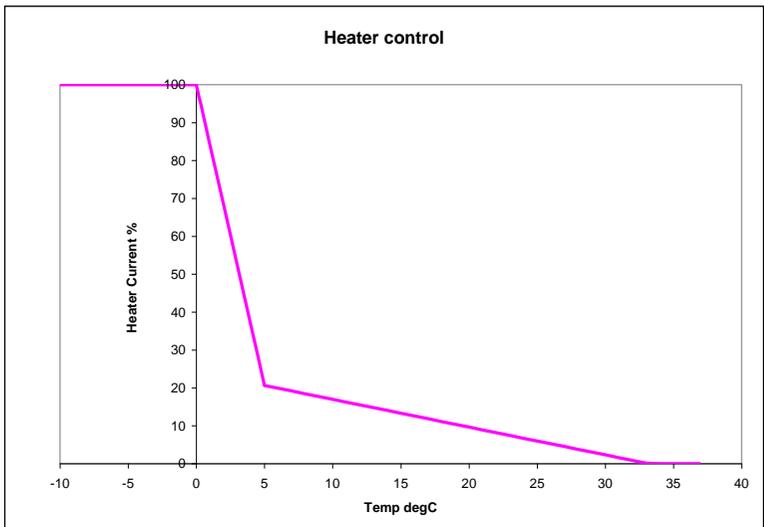
See also the [BF5 Quick Start Guide](#).

## Heater

The BF5 is fitted with an internal thermostatically controlled heater for protection against frost and condensation. The heater is mounted on the shadow mask, which will transfer heat around the inside of the dome and the top of the enclosure.

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

- The heater current is controlled by a 4Hz pulse-width modulated switch.
- If the external temperature is below 0°C, the heater provides the full power available (up to 20W at 15V).
- Above 0°C, the power reduces smoothly to 20% at 5°C, and then down to nothing at 33°C.



At zero wind speed the dome will remain snow and ice-free down to minus 20°C.

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

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 data logging in cold climates, we recommended that you power the heater via a 12V DC output supply which is itself powered from the mains.

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**Warning!** *Do not apply AC mains power to the BF5.*

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**Warning** *Ensure the heater ground is isolated from all other BF5 ground connections.*

*If possible use a data logger with differential sensor inputs.*

*See also page 21*

---

# Getting Started

The BF5 is shipped with the internal alkaline batteries installed and connected.

To check readings, record or log readings use either:

- a Windows PC running SunRead, or
- an external data logger fully programmed and wired up, or
- a SunScan system.

Each require their own special cable(s) - see page 11

See also [BF5 Quick Start Guide](#)

In the field you need something on which to mount the BF5 horizontally.

- Use a camera tripod, e.g. type [BFT1](#), or
- Bolt onto a suitable horizontal surface using the four M4 bolt holes in the base of the BF5 plastic housing, or
- Use the [BF5-M](#) cross arm. This is compatible with the Delta-T 2m weather station mast and with many builder's scaffolding systems.

See also the [BF5 Quick Start Guide](#).

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## PC software

The [SunRead](#) software runs under Microsoft Windows 98 or later, with a free RS232 port or USB-Serial adapter.

### SunRead Installation

You need [SunRead](#) version 1.5 (or later).

This is provided on the [Software and Manuals CD](#) version 3 (or later).

On most PCs, the CD will start automatically when inserted.

If it does not, run the file SETUP.EXE in the root folder

On the Contents Page scroll down to Software and click on **Install SunRead software**

Follow the links to install the software.

Note also the [SunRead Release Notes](#) information in the ReadMe.txt file on the CD.

## Connect your BF5

Connect your BF5 to your PC using a cable **SP-BF-RS01**  
Run **SunRead**. You will see the display screen below:

The screenshot shows the SunRead software window with the following callout boxes:

- Selects from the available serial ports**: Points to the 'Serial port' menu.
- Sets up data logging, either to PC or built-in logger (if fitted)**: Points to the 'Logging' menu.
- Software version numbers**: Points to the 'About' menu.
- Firmware version reported by BF5**: Points to the 'Firmware version' field.
- Battery voltage if batteries are fitted, otherwise external power supply voltage**: Points to the 'Power' field.
- Logging status, if internal logger is installed**: Points to the 'Status' field.
- Total & Diffuse readings, updated every 2s. Icon indicates sunshine state.**: Points to the 'Total' and 'Diffuse' reading boxes.
- Indicates BF5 output units. Selecting different units changes BF5 analogue output scaling**: Points to the 'Units' section.
- Status information, eg "not connected" or BF5 serial number**: Points to the bottom status bar.

The SunRead interface displays the following information:

- Serial port**: Logging About
- Firmware version**: BF5 v1.0h Apr 30 2009
- Power**: 7553mV
- Status**: Ready
- Reading Units**: umol.m-2.s-1
- Total**: 459.0
- Diffuse**: 164.1
- Sun**: [Sun icon]
- Units**:
  - Molar (umol.m-2.s-1)
  - Energy (W.m-2)
  - Illuminance (klux)
- Bottom status bar**: BF5\_A999 connected on COM 1

### 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 BF5 is found, then the version information will be displayed, and power supply voltage and readings will be updated every few seconds.

## Logging

This menu enables you to log readings directly to the PC.

## 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, BF5 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.

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*SunRead will also work with BF2 and BF3 Sunshine sensors*

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# Preliminary Checks

## Battery and Desiccant

- Install the SunRead software on a PC, and connect the BF5 to the PC RS232 serial port using BF5 serial cable type **SP-BF-RS01**.  
The radiation measurements, units and battery voltage are displayed. Ideally, this should read close to 3 Volts (3000mV).  
If below 1.5 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 BF5 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.

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*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.*

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- Check the indicator paper in the dome.  
It should be blue. If pink, replace the internal bag of desiccant.  
To renew the desiccant, see Page 35.
- When you first use the BF5 in the field, check that it is reading in the right engineering units, and that the values seem reasonable.

## Check the Dome

The BF5 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.

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

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# Use with SunScan

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## Setting up the BF5

The BF5 is simple to operate. Make sure the BF5 output units are set to the PAR molar units ( $\mu\text{mol m}^{-2} \text{s}^{-1}$ ) using **SunRead**.

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 BF5 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 type **BF5-M** which is compatible with the Delta-T Weather Station mast, and with many building scaffolding systems - or devise your own.

### Levelling

The BF5 is equipped with a miniature bubble level. The tripod supplied type **BFT1** has 3-axis adjustment to facilitate levelling. The sensor is level when the bubble is within the central circle.

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*It is more important to level the BF5 accurately than the SunScan probe.*

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## Connecting to SunScan

Options:

- Use cable type **BF5-SS1-05** with optional extension cables type **EXT/8w-x** (where x = 5, 10 or 25m) to connect the BF5 directly into the socket on the back of the SunScan Probe.  
Or use the **BF5-RL4** to **SS1-RL4** Sunscan radio link

If you are just checking to see that the BF5 is working, or measuring Leaf Area Index, it is OK to use the radio link.

- Place the SunScan next to the BF5
- Run the **SunData** program on the PDA and press **Read**.  
The Incident and Transmitted radiation readings should then appear on the SunData display.
- Check that the “Transmitted” (i.e. SunScan) and “Incident” (BF5) readings are within 10% of each other.  
(Note: 10% corresponds to a Leaf Area Index error of 0.1 – which is normally an acceptable precision for LAI measurements)

Note: the radio link can be up 3 seconds behind – this could give inaccurate readings in a turbulent atmosphere. So if using the BF5 to calibrate SunScan it is better to use the cable **BF5-SS1-05**.

If SunScan and BF5 disagree by more than 10% it may be appropriate to recalibrate the SunScan using the BF5 as a reference.

For further instructions, see the **SunScan User Manual**.

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*Recalibration of the BF5 itself in the field is not recommended.*

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*Always fit the internal batteries when using the BF5 with SunScan, as SunScan does not provide enough external power to operate the BF5 reliably*

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## **Environment and Moisture protection**

Avoid putting the BF5, or any SunScan system components at risk when working outdoors. Minimise, as far as practical, their exposure to high or rapidly changing temperatures.

The BF5 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. Inspect the desiccant indicator inside the dome. It should be blue.

The BF5 is reasonably robust, but does not have a drop test rating. Do not drop it.

# Use with a data logger

The BF5 may be connected to an external data logger with readings being taken continuously. The BF5 updates its output values four times per second.

A logger with differential sensor inputs (rather than single-ended) is recommended.

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

Use cable type **SP-BF/w05** to connect to a data logger.

This can be extended using cable type **EXT/8w-x** (where x = 5, 10 or 25m) up to a maximum of 100 m.

Data is presented at the analogue and digital outputs of the logger cable within 100 ms of power being applied via the Power + wire.

Where daytime temperatures fall below zero, or inaccuracies due to condensation are undesirable, make provision to provide power to the heater (via cable type **SP-BF/w05**).

The heater power supply must be isolated, not sharing any earth return with the BF5 sensor outputs.

## Effect of engineering units on sensitivity and resolution

The choice of output units has an effect on output sensitivities, as shown in the following table:

Output units	Sensitivity	Resolution	Full scale output
Molar $\mu\text{mol.m}^{-2}.\text{s}^{-1}$	1mV = 1 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$	0.6 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$	2500mV = 2500 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$
Energy $\text{W.m}^{-2}$	1mV = 0.5 $\text{W.m}^{-2}$	0.3 $\text{W.m}^{-2}$	2500mV = 1250 $\text{W.m}^{-2}$
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. It uses a contact closure output (no sun = open circuit, sun = short circuit).

## Analogue outputs

Connect the BF5 to a data logger via the 8-pole M12 waterproof connector using cable type **SP-BF/w-05**.

See also **Cables** on page 11.

Additional weatherproof extension cables with M12 connectors at each end are also available (type **EXT/8w-x** where x = 5, 10 or 25m).



BF5 analogue output connector pin-out  
(looking into the cable at M12 connector end)

Signal Name	Pin No	SP-BF/w-05 Cable	Cable Notes
Total	1 ----	White	Total output
Diffuse	2 	Brown	Diffuse output
SigGND	3 	Green	Signal ground (connected to DL-Gnd internally)
Sun	4 	Yellow	Contact closure on sunshine
DL-Gnd	5 	Grey	Datalogger power ground
DL-Power	6 	Pink	Datalogger power supply 5 - 15V 2mA
Htr-	7 	Blue	Heater ground
Htr+	8 	Red	Heater power supply, 12V 1.5A max
<b>Screen</b>		<b>Screen</b>	Cable screen and BF5 ground plane

The Total, Diffuse and Sun outputs are active 100ms after a voltage is applied to the data logger power cable, and then updated every 250ms.

The Total and Diffuse outputs have a range of 0V – 2.5V, with an internal resistance of 100Ω. There is also some protection on these outputs if they are taken outside their normal range. These outputs should be measured by a high impedance voltage input channel, with SigGND taken to the negative input of the channel.

The sun output is switched by a FET (transistor) to ground. When there is no sun, this output is open-circuit. When there is sun, it is connected to ground. Any voltage applied to this output should be between 0V and 15V, with a maximum current capacity of 500mA (0.5A). If this output is used to switch more than a few milliamps, you should ensure that the current flows back through the DL-Gnd cable, and not the SigGND, otherwise there may be voltage errors in the Total and Diffuse measurements.

The DL-Power and DL-Ground connections provide power to the sensor circuitry (but not the heater), and enable the analogue output signals.

The Htr+ and Htr- cables provide power to the BF5 heater. If this power supply is separate from the data logger power, it should be a fully isolated supply to ensure that no current flows between the data logger power supply negative terminal and the heater power supply negative terminal.

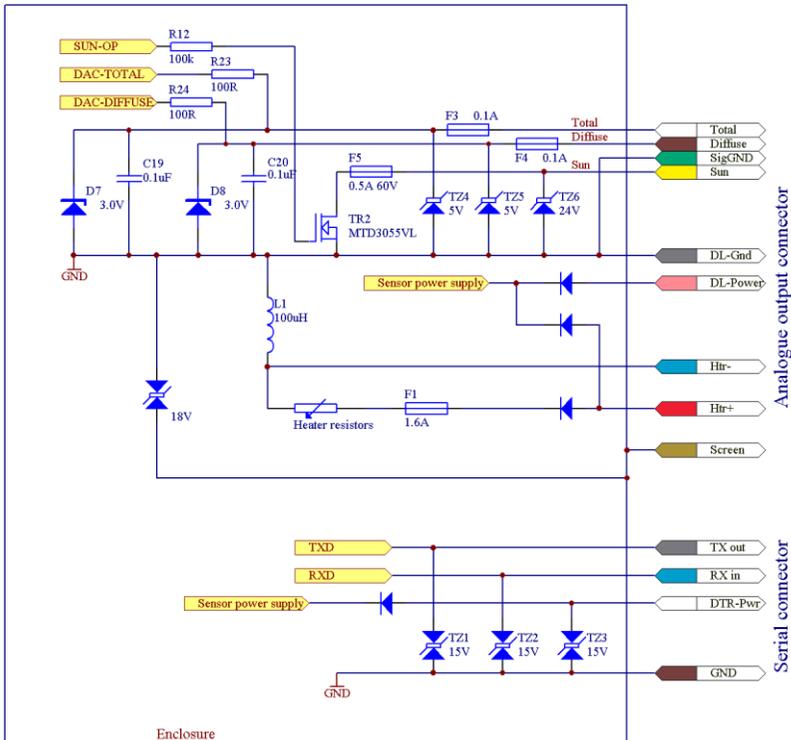
**Note**

The various grounds (Htr-, DL-Gnd, Signal Gnd) are all connected at the BF5, so if the heater is in use, then the Signal Gnd must be able to float relative to the two power grounds at the logger end.

**Use a data logger with differential sensor inputs to avoid potential errors caused by an incorrectly wired heater earth return.**

Alternately, if you have to use a single-ended logger, the requirement is that either the logger or the heater PSU must be able to float relative to the other, and there must be no connection between signal and power grounds or BF5 enclosure anywhere except inside the BF5.

## Simplified output schematic



This schematic shows a simplified version of the output circuitry, protection components and grounding details.

The Total and Diffuse outputs are protected from electrostatic discharge (ESD) by the transient voltage suppressors TZ4-6, and from low voltage misconnection by the zener clamps D7 & D8, and resettable fuses F3 & F4 (the fuses reset when the fault is removed). The Sun output has similar protection against ESD and overcurrent.

The heater circuit is protected against reverse connection and overcurrent. Htr- is connected to the main sensor ground by an inductor, to protect it from any noise in the heater circuit.

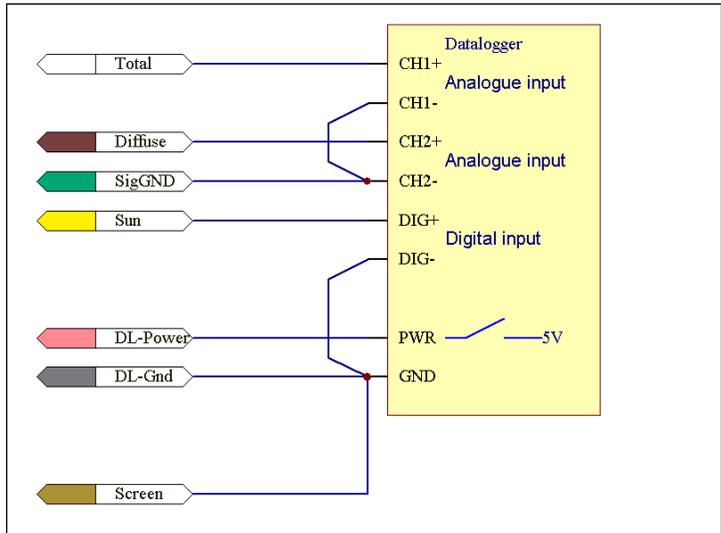
The serial port lines have basic ESD protection.

## Suggested power supply connections

For use with a data logger, the DL-Power line has to be at 5V or more to enable the analogue outputs. The power required can be taken either from the DL-Power line, or the heater supply. For most logging situations, one of the following two connections is recommended.

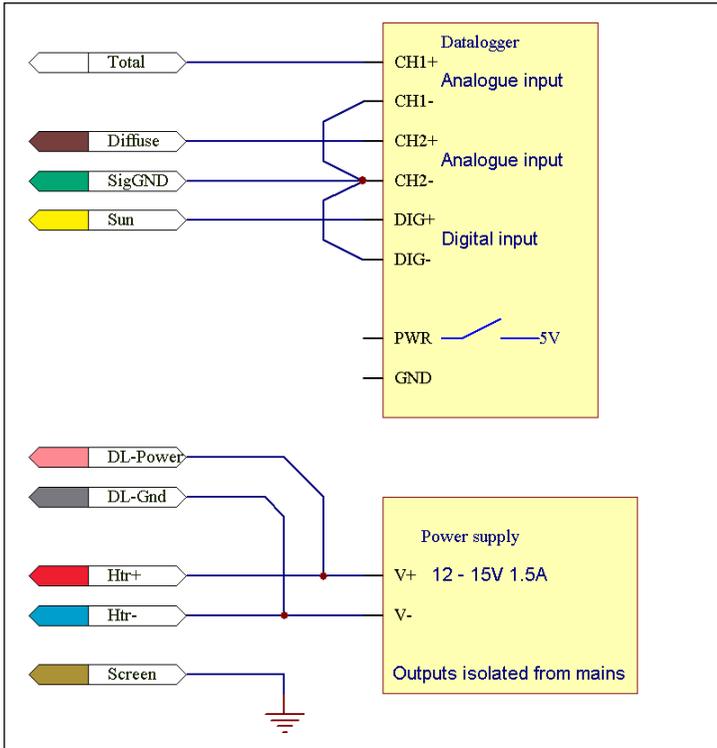
### 1 **No heater, BF5 powered by logger warmup**

This connection would be appropriate for an isolated, battery powered logger such as the Delta-T **GP1**. The BF5 heater is left disconnected. The logger must power up the BF5 at least 100ms before the reading is taken.



## 2 Heater power available, BF5 permanently enabled

This connection would be appropriate to an installation with permanent mains power available. The BF5 heater is powered up, and the BF5 analogue outputs are permanently enabled for logging.



### Note

The key point is that the various grounds (Htr-, DL-Gnd, Signal Gnd) are connected at the BF5, so if the heater is in use, then the Signal Gnd must be able to float relative to the two power grounds at the logger end.

This is achieved easily with a differential input.

For a single-ended logger, the requirement is that either the logger or the heater PSU must be able to float relative to the other, and there must be no connection between signal and power grounds or BF5 enclosure anywhere except inside the BF5.

## Suggested Sun output connections

There are several possible ways of connecting up the BF5 Sun output, depending on the capabilities of your data logger. The Sun output is open circuit when there is no sun, and connected to ground when there is sun.

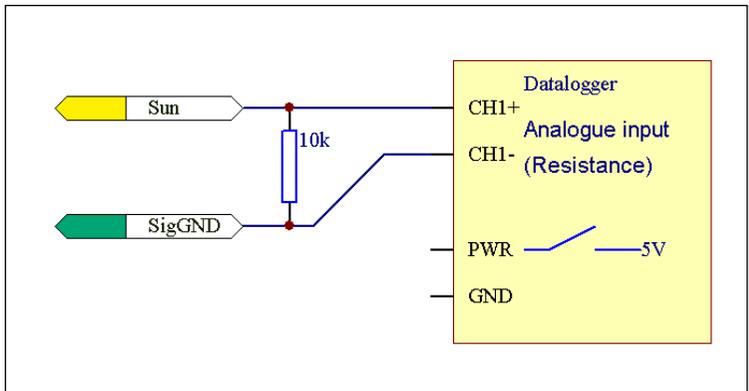
### 1 **Logger digital input**

In general this will be the simplest connection if your logger has a digital input. Connect as shown in the previous two diagrams. The logger digital input is usually referenced to logger ground, so you should take care only to connect this to SigGND if the logger is not supplying power for the BF5. Otherwise, power supply currents may flow through the SigGND cable, which may cause voltage offsets on the Total and Diffuse readings with long cable lengths.

### 2 **Logger resistance input**

If the logger has no digital inputs, but can measure resistance, then the Sun output can be measured with a 10k resistor connected in parallel. This will be measured as 10k with no sun, and 0k with sun present. Disable any autoranging on the input.

Note : The following scheme is for illustration only. Refer to your own logger user manual for the correct wiring instructions, which may be different.

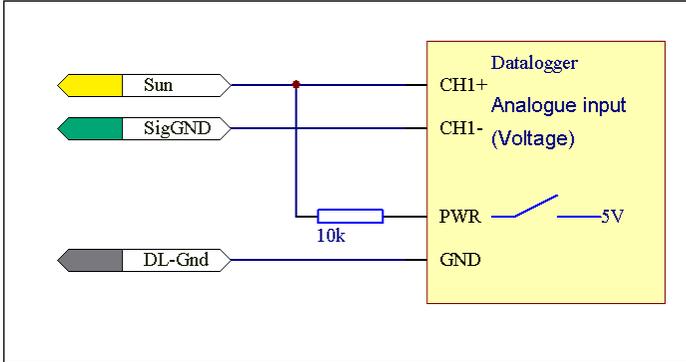


### 3 **Logger voltage input with pull-up resistor**

Alternatively, if a stable voltage is available in the logger, you can use a 10k pull-up resistor, and measure the Sun output with a voltage channel.

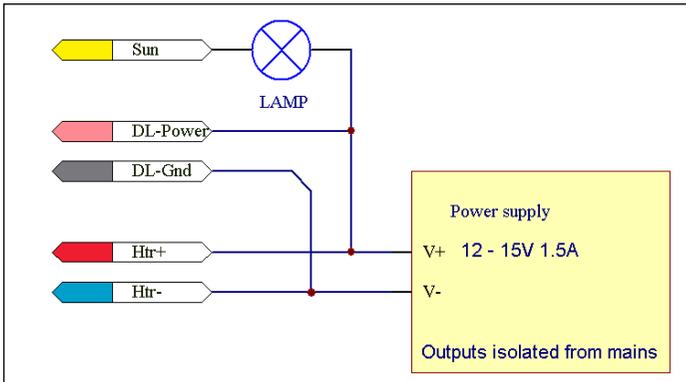
Sun present = 0 V, no sun = 5 V.

Note: Your logger must be able to read the voltage going into the resistor. If it is too high, use a potential divider.



### 4 **Switching an external load**

If for any reason you want to use the Sun output to switch a high current load, you should make sure that the current return path is through the DL-Gnd wire, and not the SigGND wire, otherwise you may see large offset voltages on your Total and Diffuse readings.



## Ground and screen connections

### *Ground connections*

There are three different ground connectors in the BF5 analogue output cable (and another one in the serial cable), so it is possible to create offsets in the readings if these are used without care, especially with long cables. You also need to think about how the data logger ground is connected internally.

Some key principles to remember are:

- Ensure that no return currents flow in the SigGND wire. This should only go to the –ve terminal of a differential voltage input channel.
- Ensure that the current returns for the DL-Pwr wire and the Sun wire are through the DL-Gnd wire.
- Ensure that the current return for the Heater current (Htr+) is through the Htr- wire.
- If you use a logger and a separate power supply, then one of them must be able to float relative to the other, or they must share a common ground connection.

### *Earthing and screen connections*

The braided screen of the 8-core analogue cable type **SP-BF/w-05** is connected to the BF5 electronics internally. The screen is connected to the sensor ground by an 18V transient suppressor - to minimise the possibility of high voltages relative to the internal circuitry if there are nearby lightning strikes.

In general the screen (black wire) should be connected to local earth near the logger. The BF5 may also be connected to earth at its mounting point. If there is a lightning strike nearby, there may be large transient voltages induced between earth points, and in the sensor cabling. Some of this may also appear on the signal wires. Because of this, the logger should either be free to float relative to local ground, or should have some form of transient protection on its inputs to avoid damage.

The 5-core serial cable type **SP-BF-RS01** is screened. The screen is connected to the 5-pole M12 connector shell but not to the DB9 shell.

The 5-core serial extension cable type **SP-BF-RS10** is also screened. The screen connects the M12 connector shells at both ends.

# Delta-T data logger connections

## GP1 logger

See the **BF5 Quick Start Guide** for a description of how to connect to and use a GP1 logger.

## DL2e logger

See BF5-DL2e wiring connections in the online sensor library of the Ls2Win PC software SR7(service release 7) on the **Delta-T Software and Manuals CD**.

Note: If upgrading from an earlier service release of Ls2Win you will need to reinstall the sensor library. This is described in the online *Ls2Win Release Notes* installed with Ls2Win and which can be found from the **Start** menu under **Programs, Ls2Win, Documents**.

## DL6 logger

The **DL6** logger is not suitable for use with the BF5. The input voltage range is insufficient and we provide no SPN1 sensor types or program for it.

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*Warning: Do not attempt to attach a BF5 to a DL6 via the 8 pole M12 connector on the DL6. It may damage the sensor.*

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# Technical reference

## Specifications

### BF5 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	$\mu\text{mol.m}^{-2}.\text{s}^{-1}$	$\text{W.m}^{-2}$	klux
Overall accuracy: Total	$\pm 10 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ $\pm 12\%$	$\pm 5\text{W.m}^{-2}$ $\pm 12\%$	$\pm 0.600$ klux $\pm 12\%$
Overall accuracy: Diffuse	$\pm 10 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ $\pm 15\%$	$\pm 20\text{W.m}^{-2}$ $\pm 15\%$	$\pm 0.600$ klux $\pm 15\%$
Resolution	$0.6 \mu\text{mol.m}^{-2}.\text{s}^{-1}$	$0.3 \text{W.m}^{-2}$	0.060 klux
Range	0-2500 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$	0-1250 $\text{W.m}^{-2}$	0-200 klux
Analogue output sensitivity	1mV = $1 \mu\text{mol.m}^{-2}.\text{s}^{-1}$	1mV = $0.5 \text{W.m}^{-2}$	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
Temperature range	-20 to + 50°C with Alkaline batteries -20 to + 70°C with Lithium batteries
Stability	Recalibration recommended every 2 years.
Response time	< 250ms
Spectral Response	400-700nm (see graph)
Latitude capability	-90° to + 90°
Environmental : Sealing	IP65 ( shower and dust proof)
Sunshine status : contact closure	No sun = open circuit Sun = short circuit to ground
Internal Battery	2 x 1.5V AA Alkaline batteries
Power requirement	2mA, (awake ), <30µA (asleep)
Battery Lifetime	1 year typical
Input Voltage Range – powered from internal battery	1.4 to 3.6V DC
Input Voltage Range - external power	5 to 15V DC
Fuse trip point, on sunshine status signal, (when in switch-closure mode)	0.5A, 30V (self resetting)
Max applied voltage to sunshine status output, in contact closure mode	0 to 24V.
RS232 connector	5-pin M12
Signal output & power-in connector	8 pin M12
Mounting options:	Camera tripod socket (¼inch Whitworth) Holes for 4 x M4 bolts at corners of box.
Size & Weight	120mm x 122mm x 95mm, 635g
Heater output below 0°C	15 W
Heater output above 5°C	2W reducing to 0W at 35°C
Lowest snow & ice-free temperatures	-20°C at 0 m/s wind speed -10°C at 2 m/s wind speed
Heater : max power	15 W at 12V DC
Heater : max current	1.5A at 15V
Fuse : max voltage, current	24V, 1.6A (self resetting)
Heater Input Voltage range	12 to 15V DC

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# BF5 Components Specifications

## BF5 - SunScan Cable

Type	<b>BF5-SS1-05</b>
Length	5 m
Terminations	8-pin M12 female to 5-pin mini Triad male

## BF5 Logger Cable

Type	<b>SP-BF/w-05</b>
Length	5 m
Termination	8-pin M12 male connector to combined power and signal cable to bare wires for logger terminals and/ or heater power supply.

## BF5 Analogue Extension Cables

Can be used to extend both BF5-Sunscan cable and BF5-Logger Cables

Type	<b>EXT/8w-05</b>
Length	5 m
Termination	8-pin M12 female combined power and signal cable to 8-way M12 male for logger terminals and/ or heater power supply.

Type	<b>EXT/8w-10</b>
Length	10 m
Termination	8-pin M12 female combined power and signal cable to 8-way M12 male for logger terminals and/ or heater power supply.

Type	<b>EXT/8w-25</b>
Length	25 m
Termination	8-pin M12 female combined power and signal cable to 8-way M12 male for logger terminals and/ or heater power supply.

## RS232 Serial Cable

Types	<b>SP-BF-RS01</b>
Length	1.5 m
Termination	5-way M12 female to 9-way D-sub connector female.

## Serial Extension Cable

Types	<b>SP-BF-RS10</b>
Length	10 m
Termination	5-way M12 female to 5-way M12 male.

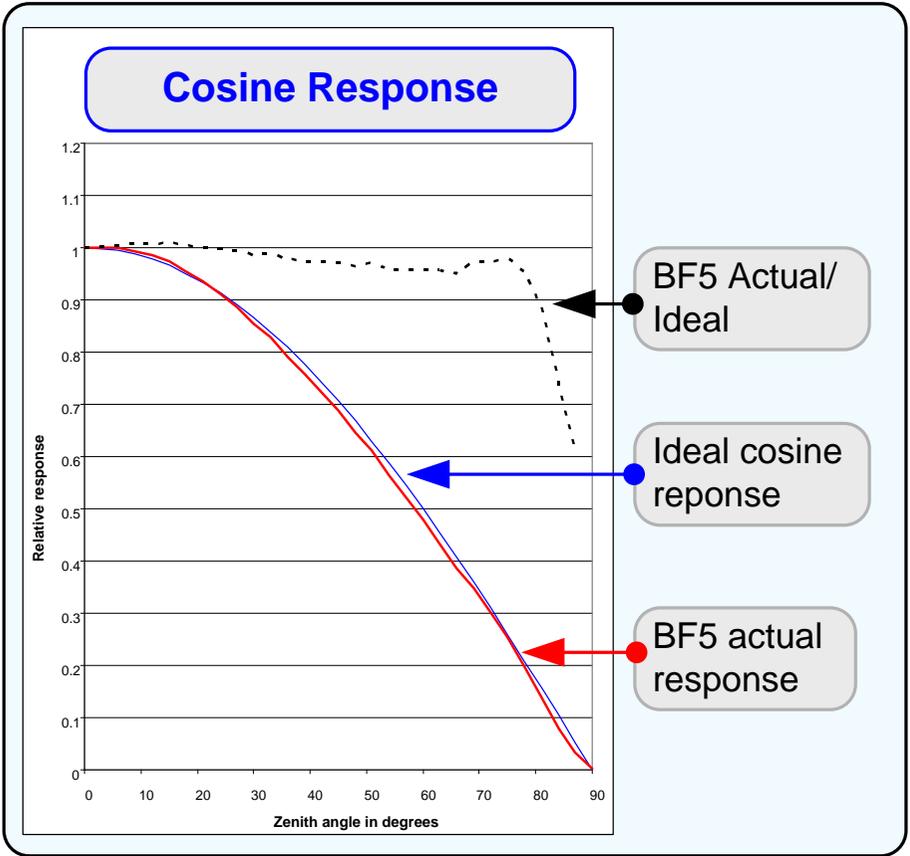
## Telescopic Tripod

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

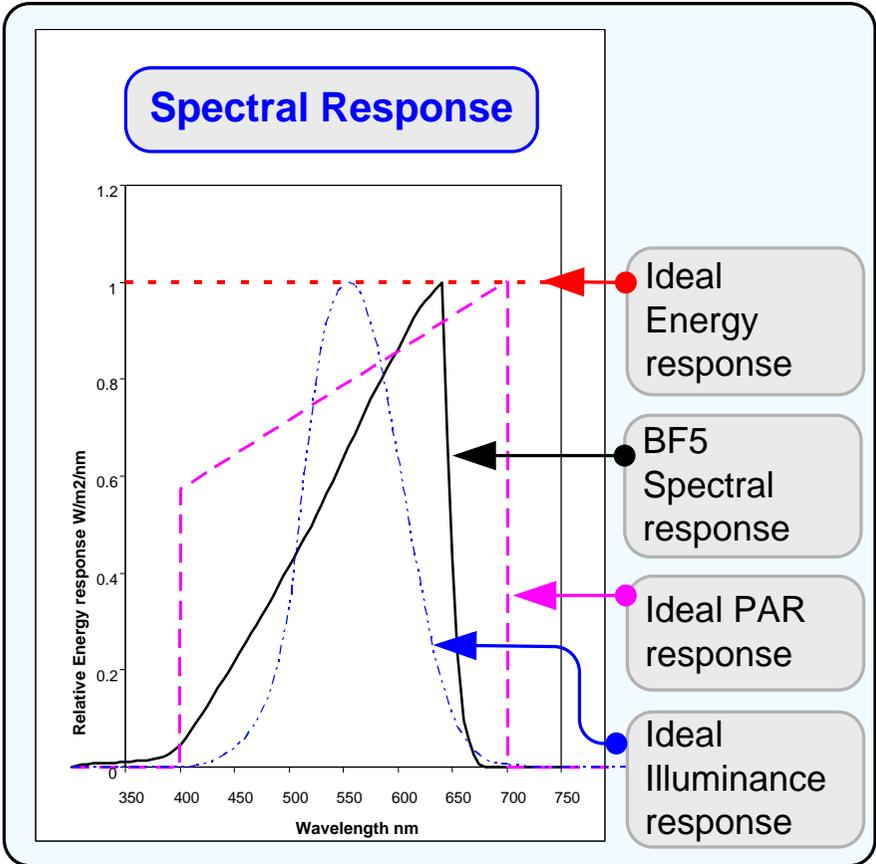
## Cross Arm for Mast Mount

Type	<b>BF5-M</b>
Length, diameter, material	1m long , 1 ¼ inch dia., grey anodised aluminium
Cross arm connector	1 ¼ x 2 inch, KeeKlamp type 45-86
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

# Cosine response



# Spectral response



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# **Routine Maintenance**

## **Batteries**

The BF5 is provided with internal batteries, but can also be powered from an external data logger via the round 5-pin connector. It can also take power from the heater power supply and from the RS232 serial cable. It will draw power from whatever source has the highest voltage.

Using the internal batteries will prevent any current drain from an external 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 8 pin analog connector within 100ms of power (>4V) being applied to the DL-Power warm-up pin. The BF5 will automatically sleep when external power is removed.

The BF5 internal batteries should usually last for about 12 months, depending on logging frequency.

Do not leave the BF5 with exhausted batteries in it; they may 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 BF5 and heat in an oven for a few hours at about 140°C. 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 BF5.

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 as "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 BF5-DOM) can be obtained from Delta-T.

# Recalibration of BF5

We recommend that BF5s are returned every 2 years to Delta-T for recalibration. A calibration certificate similar to the one below will be provided.

## BF5 Calibration Certificate

This is to certify that the Sunshine Sensor type BF5 identified below has been calibrated in accordance with Delta-T Devices Ltd standard production procedures, and conforms to the specifications as detailed.

BF5 Serial Number:	
Date:	
Authorised Signature	

### Total PAR Output Setting

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

The BF5 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  $\mu\text{mol.m}^{-2}.\text{s}^{-1}$ . (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 Certified
- Photometer: BSI Certified
- Microvoltmeter: NAMAS Certified

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

### BF5 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	$\mu\text{mol.m}^{-2}.\text{s}^{-1}$	$\text{W.m}^{-2}$	klux
Overall accuracy:	$\pm 10 \mu\text{mol.m}^{-2}.\text{s}^{-1}$	$\pm 5 \text{W.m}^{-2}$	$\pm 0.600 \text{klux}$
Total	$\pm 12\%$	$\pm 12\%$	$\pm 12\%$
Overall accuracy:	$\pm 10 \mu\text{mol.m}^{-2}.\text{s}^{-1}$	$\pm 20 \text{W.m}^{-2}$	$\pm 0.600 \text{klux}$
Diffuse	$\pm 15\%$	$\pm 15\%$	$\pm 15\%$
Range	0-2500 $\mu\text{mol.m}^{-2}.\text{s}^{-1}$	0-1250 $\text{W.m}^{-2}$	0-200 klux

## Delta-T Devices Ltd

130 Low Road, Burwell, CAMBRIDGE CB25 0EJ, U.K.

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*It is possible to recalibrate the BF5 yourself against a transfer standard sensor, but this is difficult and 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 BF5, could make it impossible to recalibrate in sunshine.*

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# Warranty and Service

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## 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 inexperienced 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.

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## 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.

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## 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

130 Low Road, Burwell, Cambridge CB25 0EJ, U.K.

email for technical support: [tech.support@delta-t.co.uk](mailto:tech.support@delta-t.co.uk)

email for repairs: [repairs@delta-t.co.uk](mailto:repairs@delta-t.co.uk)

web: [www.delta-t.co.uk](http://www.delta-t.co.uk)

Tel: +44 (0) 1638 742922

Fax: +44 (0) 1638 743155

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# 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 BF5 serial number label is on the underside of the case. The internal software version number is displayed in the **About** box using **SunRead**.

---

# Troubleshooting

## BF5 Not Responding

### *Check cables and connectors*

If using a PC check that you are using the **SP-BF-RS01** serial cable (5 pin M12 to DB9), and that it is plugged into the same serial port on your PC that you have selected in the SunRead software.

If using an external logger, check the logger cable and compare it with the logger wiring connection diagram.

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

### *Check battery voltage*

The BF5 requires at least 1.4 Volts on its internal battery, or 5-15V DC from an external power supply.

### *Resetting the BF5*

If the BF5 still does not respond, its internal microprocessor may be reset by removing and reapplying all power (including the internal battery).

# Appendix A: Design and Test Summary

This appendix gives a brief description of how the BF5 design works, and a summary of the results of the test program. More detailed versions of these are available from Delta-T and on the [Software and Manuals CD](#).

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## 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 BF2/3/5 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:

$$\text{Diffuse} = 2 * \text{MIN}$$

$$\text{Direct} = \text{MAX} - \text{MIN}$$

$$\text{Total} = \text{Direct} + \text{Diffuse} = \text{MAX} + \text{MIN}$$

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

The photodiodes used in the BF5 have a spectral response that is close to an Ideal PAR response (see spectral response graph in the Technical Reference section). The BF5 is calibrated using a reference quantum sensor, so calculates its output values in PAR units.

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

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 BF5 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:

$$\text{Energy TOTAL} = \text{PAR TOTAL} * 0.48$$

$$\text{Energy DIFFUSE} = \text{PAR DIFFUSE} * (0.48 - 0.48 * (\text{Beam Fraction})^4)$$

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 ( $1 \mu\text{mol.m}^{-2}.\text{s}^{-1} = 55.7 \text{ lux}$ ). 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.

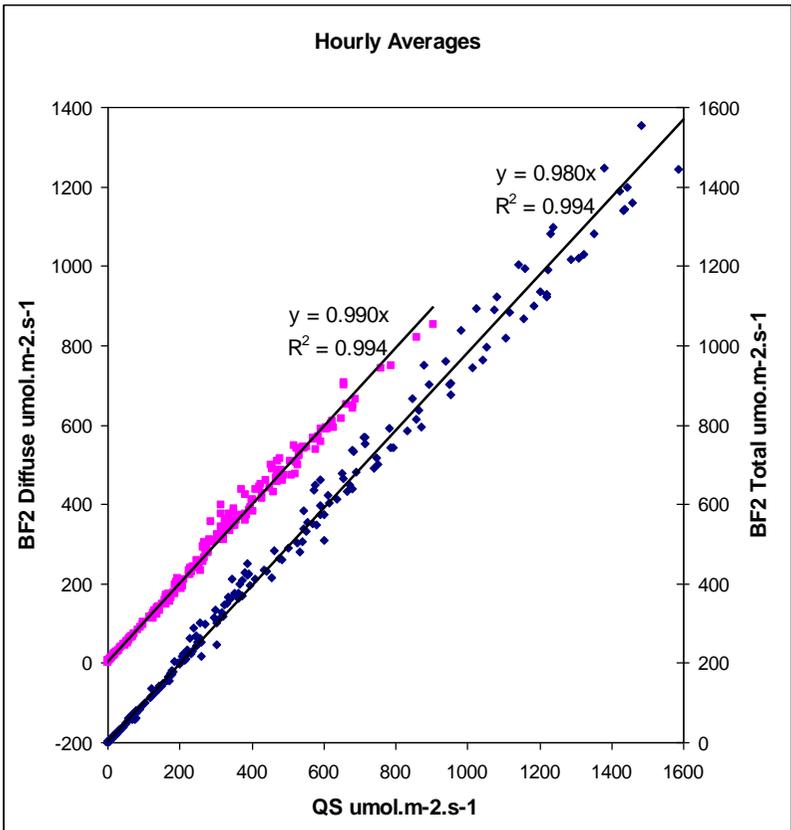
# Sunshine state

The WMO definition of sunshine presence is that there is greater than  $120 \text{ W.m}^{-2}$  in the Direct beam, measured perpendicular to the beam. This cannot be measured directly by a horizontal cosine corrected sensor. The BF5 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  $\text{Total/Diffuse} > 1.25$   
and  $\text{Total} > 50 \mu\text{mol.m}^{-2}.\text{s}^{-1}$

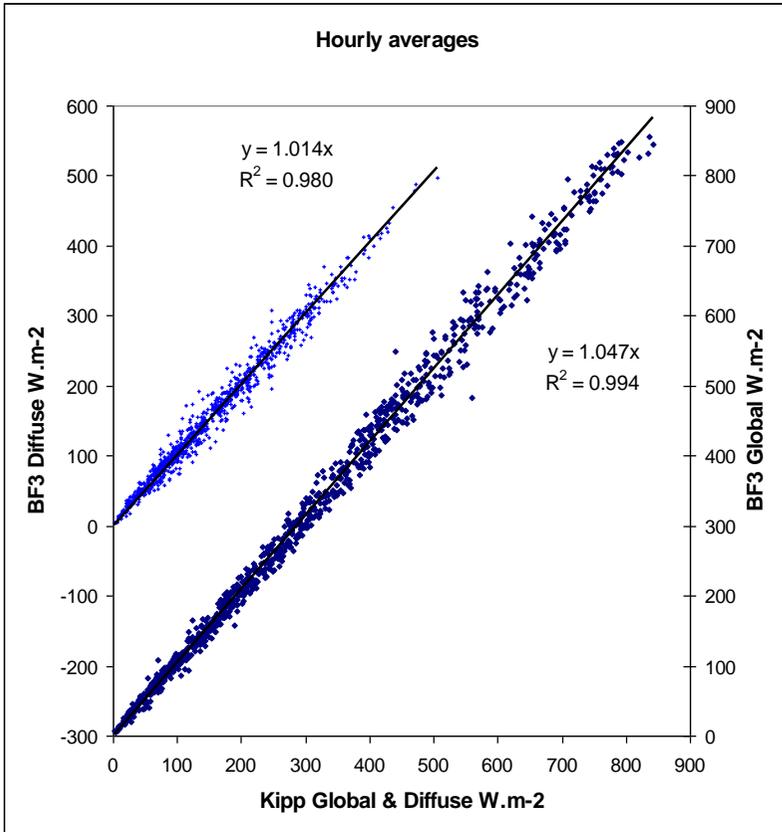
## Test results

### PAR output



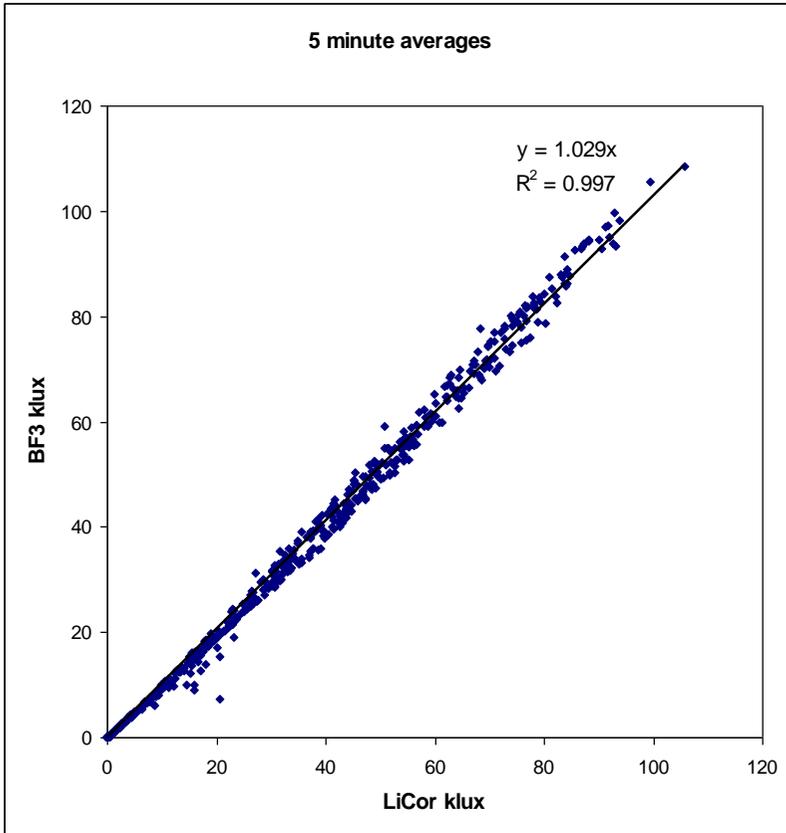
This graph shows a comparison of a BF2 against two Delta-T quantum sensors and a shade ring. Data recorded at Winster, Derbyshire, 20 – 31 May 1999. The graph plots hourly averages of readings every 5 seconds. Note the offset Y-axis to separate the Total and Diffuse plots.

# Energy output



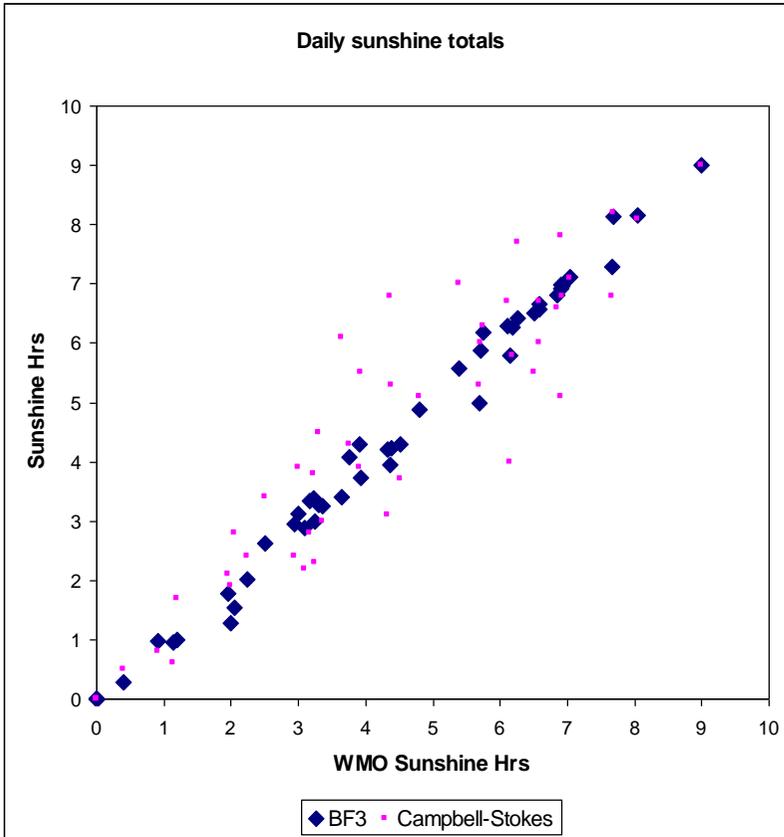
This graph shows BF3 Total and Diffuse outputs compared with two Kipp CM11s and a shade ring. Data recorded at Napier University, Edinburgh between February and July 2001. The graph plots hourly averages of readings every 10 seconds. Note the offset Y-axis to separate the Total and Diffuse plots.

## 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<sup>-2</sup> 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 BF5 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. Types BF3 and BF5 consist of seven PAR sensors and an acrylic dome with stripes. They also measure 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  $\mu E$  (micro-Einstein). The normal daylight maximum is a little over  $2000 \mu mol.m^{-2}.s^{-1}$ .

**SunData** - the software used to drive the SunScan probe and calculate and store the results. It runs on a PDA running Windows Mobile 5 or later.

**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.

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