

# INSTRUCTION MANUAL



## **SR11 Pyranometer**

6/17



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# Safety

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**DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.**

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at [www.campbellsci.com](http://www.campbellsci.com) or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

## General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

## Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

## Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

## Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

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# SR11 Pyranometer

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## 1. Introduction

The SR11 is an ISO-first-class pyranometer that monitors solar radiation for the full solar spectrum range. It produces a millivolt signal that can be measured directly by a Campbell Scientific datalogger. The SR11 can provide solar radiation measurements for many meteorological applications. This pyranometer is manufactured by Hukseflux.

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**NOTE**

This manual provides information only for CRBasic dataloggers. It is also compatible with many of our retired Edlog dataloggers. For Edlog datalogger support, contact Campbell Scientific.

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## 2. Precautions

- READ AND UNDERSTAND the [Safety](#) section at the front of this manual.
- Although the SR11 is rugged, it is also a highly precise scientific instrument and should be handled as such.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, contact Campbell Scientific.

## 3. Initial Inspection

- Upon receipt of the SR11, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the correct product and cable length are received.
- See Section [3.1](#), *Ships With (p. 1)*, to ensure that all of your parts are included.

### 3.1 Ships With

- (1) Sun screen from original manufacturer
- (1) Calibration certificate (see Section [3.2](#), *Calibration Certificate (p. 1)*)
- (1) 2.5 mm hex key for clamping and removal of sun screen
- (1) *ResourceDVD*
- (2) Screws (pn 7313),
- (2) Washers (pn 6561)
- (2) Lock-washers (pn 2143)

### 3.2 Calibration Certificate

Included with the sensor is a calibration certificate with the sensor calibration constant and serial number. Cross-check this serial number against the serial

number on your SR11 to ensure that the given calibration constant corresponds to your sensor.

## 4. Overview

The SR11 pyranometer is designed for continuous outdoor use. Due to its flat spectral sensitivity from 285 to 3000 nm, it can be used in natural sunlight, under plant canopies, in greenhouses or buildings, and inverted to measure reflected solar radiation. Two SR11s can be used in combination to measure albedo. The SR11 can also be used to measure most types of artificial light (Xenon lamps, Halogen lamps, etc.).

The SR11 pyranometer consists of a thermopile sensor, housing, two domes, and cable. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation and converts it to heat. The resultant temperature difference is converted to a voltage by the copper-constantan thermopile. The thermopile is encapsulated in the housing in such a way that it has a field of view of 180 degrees and the angular characteristics needed to fulfill the cosine response requirements.

## 5. Specifications

### Features:

- Compatible with the following CRBasic dataloggers: CR300 series, CR6, CR800 series, CR1000, CR3000, CR5000, and CR9000(X)
- Measures reflected solar radiation when inverted
- Provides measurements in direct sunlight, under plant canopies, under cloud cover, and in artificial light
- Includes bubble level and leveling screws eliminating need for a separate leveling base, simplifying installation
- Acceptable for providing the solar radiation data used in stability estimations
- Double glass dome

### Overall classification according to ISO 9060 / WMO:

First class pyranometer

### Response time for 95% response:

18 s

### Zero offset (response to 200 W m<sup>-2</sup> net thermal radiation):

5 W m<sup>-2</sup> unventilated

### Zero offset (response to 5 K/h change in ambient temperature):

< 4 W m<sup>-2</sup>

### Non-stability:

< ±1% change per year

### Non-linearity:

< ±1% (100 to 1000 W m<sup>-2</sup>)

### Directional response for beam radiation:

±20 W m<sup>-2</sup>

### Spectral selectivity:

< ±5% (350 to 1500 nm)

### Temperature response:

< ±2% (-10 to 40 °C)

### Tilt response:

< ±2% (0 to 90 ° at 1000 W m<sup>-2</sup>)

|  |   |
|--|---|
| <b>Sensitivity (nominal):</b>  | 15 $\mu\text{V}/(\text{W m}^{-2})$                  |
| <b>Expected voltage output:</b>  | –0.1 to 50 mV in natural sunlight                   |
| <b>Operating temperature range:</b>                                    | –40 to 80 °C  |
| <b>Sensor resistance range:</b>  | Between 40 and 60 $\Omega$                          |
| <b>Measurement range:</b>  | 0 to 3000 $\text{W m}^{-2}$                         |
| <b>Cable replacement:</b>  | Cable can be replaced by the user                   |
| <b>Spectral range (20% transmission points):</b>                       | 285 to 3000 nm                                      |
| <b>Leveling:</b>   | Bubble level and adjustable feet                    |
| <b>Directional response composition (nominal at 60° zenith angle):</b> | azimuth error: < 1%<br>zenith error: remaining part |
| <b>Dome diameter (FIGURE 5-1):</b>                                     | 5 cm (2.0 in)                                       |
| <b>Height (FIGURE 5-1):</b>  | 9 cm (3.5 in)                                       |
| <b>Body diameter (FIGURE 5-1):</b>                                     | 13.6 cm (5.4 in)                                    |
| <b>Weight with 5 m cable:</b>  | 0.75 kg (01.65 lb)                                  |

<sup>1</sup>*Guide to Meteorological Instruments and Methods of Observation*, fifth edition, WMO, Geneva and ISO9060

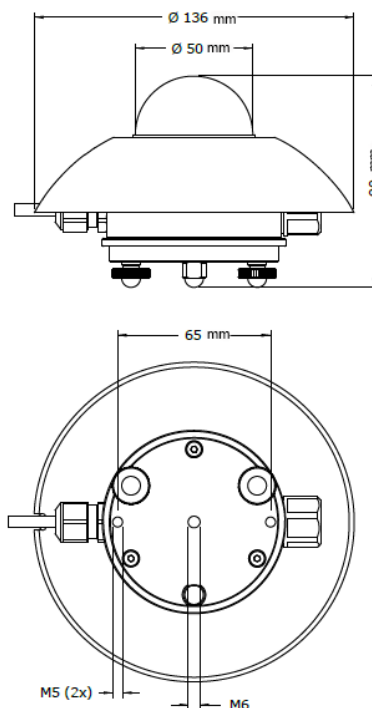


FIGURE 5-1. SR11 dimensions

## 6. Installation

### 6.1 Siting Considerations

The SR11 is usually installed horizontally, but can also be installed at any angle including an inverted position. In all cases, it will measure the flux that is incident on the surface that is parallel to the sensor surface.

Site the SR11 to allow easy access for maintenance while ideally avoiding any obstructions above the plane of the sensing element. Mount the SR11 such that no shadow or reflection will not be cast on it at any time. If this is not possible, try to choose a site where any obstruction over the azimuth range between earliest sunrise and latest sunset has an elevation not exceeding 5°. Diffuse solar radiation is less influenced by obstructions near the horizon. For instance, an obstruction with an elevation of 5° over the whole azimuth range of 360° decreases the downward diffuse solar radiation by only 0.8%.

The sensor should be mounted with the cable pointing towards the nearest magnetic pole. For example, in the northern hemisphere, point the cable toward the North Pole.

### 6.2 Mounting

The following mounting procedure is for mounting the sensor horizontally using a CM225 Solar Sensor Mounting Stand. Alternatively, the sensor can be mounted at an angle by using a CM255 or CM255LS adjustable-angle mount, or mounted near the end cap of the NexTracker torque tube by using a CM265 Adjustable Solar Sensor Mounting Kit (see the [015ARM](#), [CM225](#), [CM255](#), [CM255LS](#), and [CS265 Solar Radiation Sensor Mounts Manual](#)).

#### 6.2.1 Required Tools

Tools required for installation on a tripod or tower:

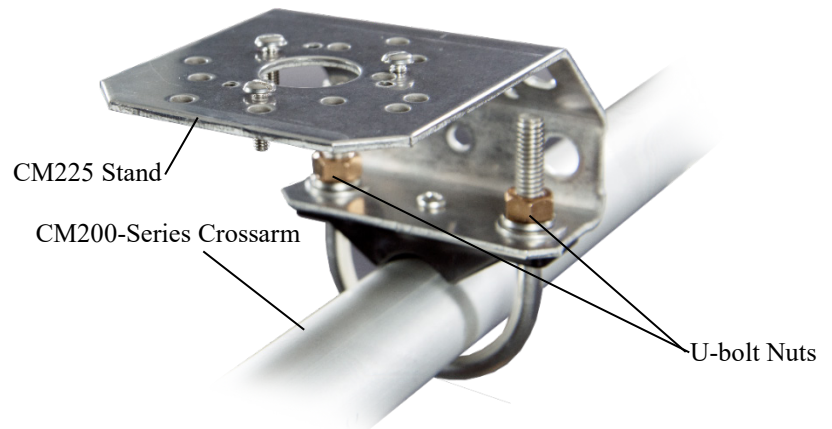
- Small and medium Phillips screwdrivers
- 5/16 inch, 1/2 inch open end wrenches
- 5/32 inch Allen wrench
- Tape measure
- UV-resistant wire ties
- Side-cut pliers
- Compass
- Step ladder

## 6.2.2 CM225 Mounting Procedure

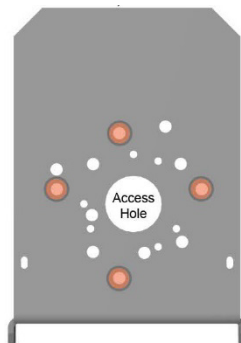
### CAUTION

The CM225 should never be mounted directly to a vertical pipe. Instead, the CM225 should be mounted to a crossarm. This avoids reflections from the vertical pipe onto the sensor.

1. Mount the crossarm to the tripod or tower.
2. Place the CM225's U-bolt in the bottom holes and secure the CM225 to the crossarm by tightening the U-bolt nuts.

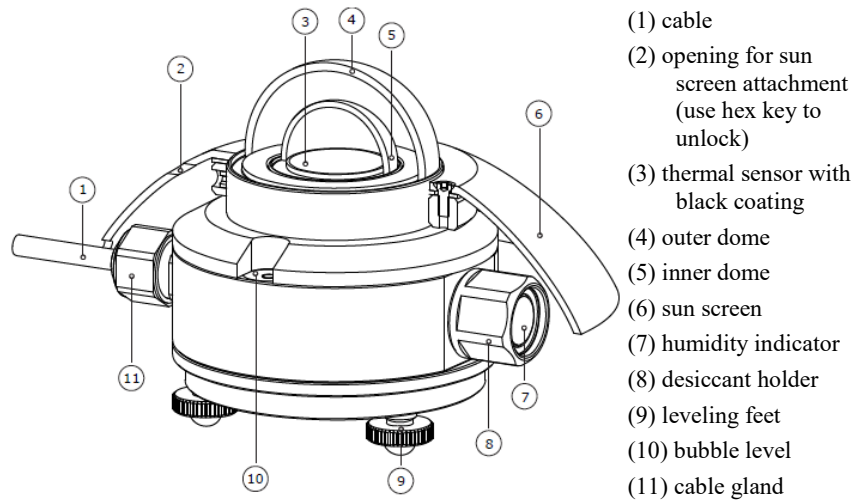


3. Loosely mount the pyranometer on the mounting stand. Do not fully tighten the two mounting screws.

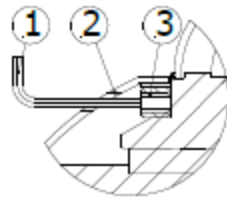


CM225 mounting holes used for the SR11 are indicated in orange.

4. Turn the leveling feet (9) as required to bring the bubble of the bubble level (10) within the ring.



5. Tighten the mounting screws to secure the assembly in its final position. Check that the pyranometer is still correctly leveled and adjust as necessary.
6. Use the hex key (1) to secure the white plastic sun screen (2) by tightening the set screw (3).



7. Route the sensor cable along the underside of the crossarm to the tripod/tower, and to the instrument enclosure.
8. Secure the cable to the crossarm and mast using cable ties

## 6.3 Wiring

A schematic diagram of the SR11 is shown in [FIGURE 6-1](#).

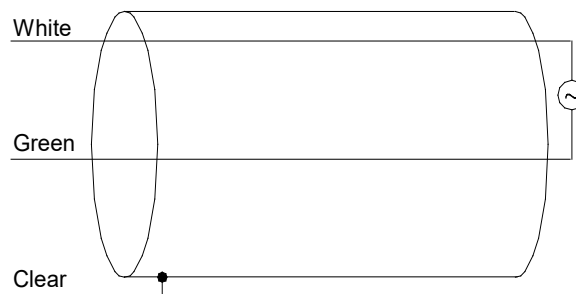


FIGURE 6-1. SR11 schematic

Connections to Campbell Scientific dataloggers are given in TABLE 6-1. The pyranometer can be measured using either differential or single-ended analog channels. A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement. If a differential channel is not available, a single-ended measurement can be used.

**TABLE 6-1. Wire Color, Function, and Datalogger Connection**

| Wire Color   | Wire Function    | Differential Connection Terminal  | Single-Ended Connection Terminal   |
|--|------------------|---|--|
| White  | Signal High      | U configured for differential input <sup>1</sup> , <b>DIFF H</b> (differential high, analog-voltage input)                | U configured for single-ended analog input <sup>1</sup> , <b>SE</b> (single-ended, analog-voltage input) |
| Green  | Signal Reference | U configured for differential input <sup>1, 2</sup> , <b>DIFF L</b> (differential low, analog-voltage input) <sup>2</sup> | <b>AG</b> or $\perp$ (analog ground)   |
| Clear  | Shield           | <b>AG</b> or $\perp$ (analog ground)  | <b>AG</b> or $\perp$ (analog ground)   |
| <sup>1</sup> U channels are automatically configured by the measurement instruction.<br><sup>2</sup> Jumper to <b>AG</b> or $\perp$ with a user-supplied wire. |                  |   |  |

## 6.4 Programming

Programming basics are provided in the following section. A complete program example can be found in Appendix A, *Example Program* (p. A-1).

Solar radiation can be reported as an average flux density ( $\text{W m}^{-2}$ ) or daily total flux density ( $\text{MJ m}^{-2}$ ). The appropriate multipliers are listed in TABLE 6-2. Programming examples are given for both average and daily total solar radiation.

The SR11 outputs a low-level voltage ranging from 0 to a maximum of up to 35 mV, in natural light, depending on the calibration factor and radiation level.

The SR11 is measured using either the differential voltage instruction (**VoltDiff**) or a single-ended voltage instruction (**VoltSE**). A differential voltage measurement is recommended because it has better noise rejection than a single-ended measurement. If a differential channel is not available, a single-ended measurement can be used. The acceptability of a single-ended measurement can be determined by simply comparing the results of single-ended and differential measurements made under the same conditions.

### 6.4.1 Input Range

The output voltage of the SR11 is usually  $-0.1$  to  $50$  mV per  $1000 \text{ W m}^{-2}$ . When estimating the maximum likely value of sensor output, a maximum value of solar radiation of  $1100 \text{ W m}^{-2}$  can be used for field measurements on a horizontal surface.

Select the input range as follows:

1. Estimate the maximum expected input voltage by multiplying the maximum expected irradiance ( $\text{W m}^{-2}$ ) by the calibration factor ( $\mu\text{V/W m}^{-2}$ ). Divide the answer by 1000 to give the maximum in millivolt units.
2. Select the smallest input range, which is greater than the maximum expected input voltage. With some dataloggers, an autorange option can be used if measurement time is not critical.

The parameter code for the input range also specifies the measurement integration time. The slow or 60 Hz rejection integration gives a more noise-free reading. A fast integration takes less power and allows for faster throughput.

## 6.4.2 Multiplier

The multiplier converts the millivolt reading to engineering units. The calibration supplied by the manufacturer gives the output of the sensor (c) as microvolts ( $\text{V} \times 10^{-6}$ ) per  $\text{W m}^{-2}$ . As the datalogger voltage measurement instructions give a default output in mV, the following equation should be used to calculate the multiplier (m) to give the readings in  $\text{W m}^{-2}$ :

$$M = 1000/c$$

Other units can be used by adjusting the multiplier as shown in TABLE 6-2.

| TABLE 6-2. Multipliers Required for Flux Density and Total Fluxes   |                                      |                   |
|---|--------------------------------------|-------------------|
| Units   | Multipliers                          | Output Processing |
| $\text{W m}^{-2}$   | M                                    | Average           |
| $\text{MJ m}^{-2}$  | $M \cdot t \cdot 0.000001$           | Total             |
| $\text{kJ m}^{-2}$  | $M \cdot t \cdot 0.001$              | Total             |
| $\text{cal cm}^{-2}$  | $M \cdot t \cdot 0.0239 \cdot 0.001$ | Total             |
| $\text{cal cm}^{-2} \text{ min}^{-1}$   | $M \cdot 1.434 \cdot 0.001$          | Average           |
| M = calibration factor in $\text{W m}^{-2}/\text{mV}$<br>t = datalogger program execution interval in seconds |                                      |                   |

## 6.4.3 Offset

The offset will normally be fixed at zero as the sensor should output no significant signal in dark conditions. In practice, because of the nature of thermopile detector sensors, there will be some offset in dark conditions; sometimes this offset can give negative light readings. This offset varies with several factors (for example, rate of change of sensor temperature), so it cannot be removed with a fixed offset.

## 6.4.4 Output Format Considerations

In CRBasic, store the data in the IEEE4 format.



## 7. Maintenance and Troubleshooting

**NOTE**

All factory repairs and recalibrations require a returned material authorization (RMA) number and completion of the “Declaration of Hazardous Material and Decontamination” form. Refer to the [Assistance](#) page at the beginning of this manual for more information.

### 7.1 Maintenance

At regular intervals, physically inspect the pyranometer to ensure that:

- Dome is free of dirt, condensation, and ice (Section [7.1.1](#), *Cleaning Domes* (p. 9)).
- Desiccant indicator is blue (Section [7.1.2](#), *Changing the Desiccant* (p. 9)).
- Mounting is secure and level.
- Pyranometer is level (if mounted horizontally).
- Cables and cable gland are in good condition.

#### 7.1.1 Cleaning Domes

Clean the outer dome at regular intervals (daily if possible, but at least every two weeks). Remove any accumulated dust, condensation, or ice from the dome and pyranometer body using a soft cloth dampened with water or alcohol.

#### 7.1.2 Changing the Desiccant

A desiccant-filled drying cartridge prevents dew from forming on the inner sides of the domes; Campbell Scientific pn 27052 is the replacement desiccant for this cartridge.

Replace the desiccant if the desiccant indicator is pink instead of blue (FIGURE [7-1](#)). Refill packs of desiccant are shipped with the pyranometer and can be purchased from Campbell Scientific.

When changing the desiccant, coat the rubber of the cartridge with silicone grease or petroleum jelly.

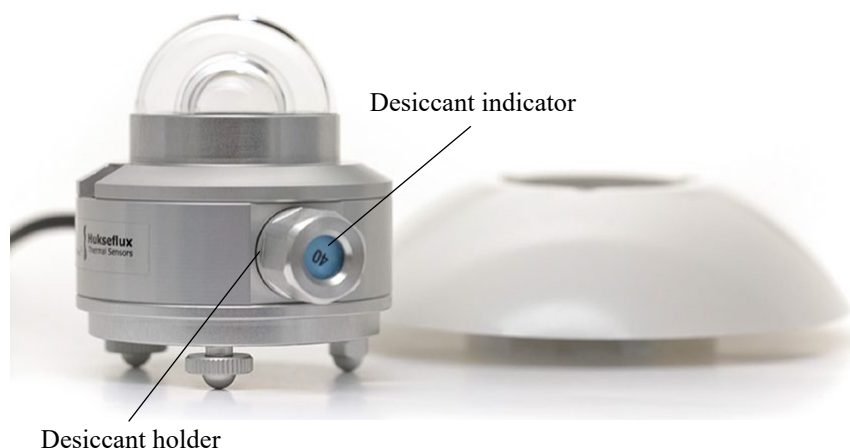


FIGURE 7-1. Desiccant indicator and holder

### 7.1.3 Check Sensor Output

Regularly, check the data returned from the sensor as it will show the first indication of a fault. Look for any patterns and events that deviate from what is normal or expected. However, several expected phenomena can cause strange measurements. In particular, on clear, windless nights, the outer dome temperature of horizontally placed pyranometers can fall as low as the dew point temperature of the air, due to infrared radiation exchange with the cold sky. (The effective sky temperature can be 30 °C lower than the ground temperature, which results in an infrared emission of  $-150 \text{ W} \cdot \text{m}^{-2}$ .) If this happens, dew, glazed frost, or hoar frost can be precipitated on the top of the outer dome and can stay there for several hours in the morning. An ice cap on the dome is a strong diffuser and can increase the pyranometer signal by up to 50% in the first hours after sunrise.

## 7.2 Recalibration

The calibration of the pyranometer may drift with time and exposure to radiation. Recalibration every two years is recommended. The sensor should be returned to Campbell Scientific for recalibration (see [Assistance](#) page).

## 7.3 Troubleshooting

Symptom: NAN, -9999, or radiation values around 0

1. Check that the sensor is wired to the differential channel specified by the measurement instruction.
2. Verify that the range code is correct for the datalogger type.
3. Use a multimeter at the 200  $\Omega$  range to check the electrical resistance of the sensor between the green (–) and white (+) wire. Measure the sensor resistance first with one polarity, then reverse the polarity. Take the average value. The typical resistance of the wiring is 0.1  $\Omega/\text{m}$ . Typical resistance should be the typical sensor resistance of 40 to 60  $\Omega$  plus 1.5  $\Omega$  for the total resistance of two wires (back and forth) of each 5 m. If the resistance is very low, there may be a short circuit (check the wiring). Resistances somewhat lower than expected could be due to water ingress

into the sensor or enclosure connectors. If the resistance is infinite, there is a broken connection (check the wiring).

4. Ensure that the sensor reacts to light by having the multimeter at its most sensitive DC voltage range, typically  $100 \times 10^{-3}$  Vdc range or lower. With the sensor located 4 inches below a 100 W light bulb, the voltage should be greater than 2 mV. No voltage indicates a problem with the sensor.

Symptom: sensor signal is unrealistically high or low

1. Verify that the correct calibration factor has been properly entered into the datalogger program. Please note that each sensor has its own individual calibration factor.
2. Visit the installation site and ensure that it is still free from obstructions.
3. Check the condition of the sensor cable.
4. Ensure that the dome is clean.
5. Check sensor mounting, verifying that it is still level and at the proper orientation.

Symptom: sensor signal shows unexpected variations

1. Check for the presence of electromagnetic radiation (radar, radio etc.)
2. Check the condition and the connection of the sensor shield wire.
3. Check the condition of the sensor cable.

Symptom: internal condensation on outer dome

1. Replace desiccant (Section [7.1.2](#), *Changing the Desiccant (p. 9)*).

Symptom: internal condensation on inner dome

1. Return to Campbell Scientific for a factory repair (see [Assistance](#) page).



# Appendix A. Example Program

The following program measures the SR11 every 10 seconds and converts the mV output to  $\text{W m}^{-2}$  and  $\text{MJ m}^{-2}$ . A sensor calibration of  $15.02 \mu\text{V per W m}^{-2}$  is used for the example programs. Both programs output an hourly average flux ( $\text{W m}^{-2}$ ), and a daily total flux density ( $\text{MJ m}^{-2}$ ).

## CRBasic Example A-1. CR1000 Program Measuring the SR11

```
'CR1000

'Declare Variables and Units
Public Solar_Wm2
Public Solar_MJ

Units Solar_Wm2=W/m²
Units Solar_MJ=MJ/m²

'Hourly Data Table
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Average(1,Solar_Wm2,IEEE4,False)
EndTable

'Daily Data Table
DataTable(Table2,True,-1)
  DataInterval(0,1440,Min,10)
  Totalize(1,Solar_MJ,IEEE4,False)
EndTable

'Main Program
BeginProg
  Scan(10,Sec,1,0)

  'SR11 Pyranometer measurement in Wm-2:

  'The Multiplier (M) for this example is based upon a sensor calibration (c) of
  '15.02 µV/Wm-2, and will be different for each sensor.
  'Multiplier (M) = 1000/c = 66.577896.
  VoltDiff(Solar_Wm2,1,mV25,1,True,0,_60Hz,66.577896,0) 'use the 50 mV range
                                                         'for the CR3000, CR5000
                                                         'and CR9000

  'Calculate units in MJ, where MJ = m * t * 0.000001. m = Solar_Wm2 from above,
  'and t = 10 (scan interval)

  Solar_MJ=Solar_Wm2*0.00001

  'Call Data Tables and Store Data
  CallTable(Table1)
  CallTable(Table2)
NextScan
EndProg
```





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